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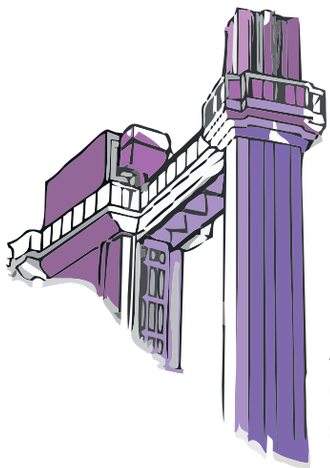

XIV IPC
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Palaeobotany and Palynology: towards new frontiers

Salvador (Brazil) 2016

XIV International Palynological Congress
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Asociación Latinoamericana de Paleobotánica y Palinología

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Salvador, October 2016

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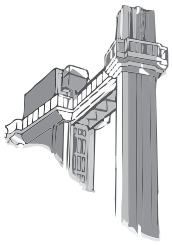

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GENERAL SESSIONS (ABSTRACTS)

Presentation

Bem-vindo a todos!

At last, the Portuguese accent will sound among palynologists and paleobotanists around the world. But, it is different! It is a new Portuguese: the Brazilian language is mixed with African and Indian sounds. In this edition of the *International Palynological Congress (IPC)* and the *International Organisation of Palaeobotany Conference (IOPC)*, in the first major metropolis in the Southern Hemisphere from the colonial times and the largest black city outside Africa, Salvador welcomes researchers and students with the sound of its *berimbaus* and songs to the orishas, asking them to grant blessings to all during their stay in the city and to provide good technical and scientific integration.

The IPC/IOPC logo shows one of the city's main sights, which is of great historical importance: the Lacerda Elevator. This was the first urban elevator in the world, built to connect the two cities (Lower Town and the Upper Town) within the city of Salvador. It still runs perfectly. Its choice as the Congress logo references the theme of the event—"***Palaeobotany and Palynology: towards new frontiers***"—representing the role played by paleobotany and palynology, which primarily links new areas of knowledge. In addition, it is a way to mark the presence of the two events together in a new land: Salvador, which has the Lacerda Elevator as one of its main symbols.

Even when encountering an unprecedented crisis in Brazil, members of the Organizing Committee never reconsidered hosting this congress, which required a high level of organization in the scientific community.

Most of the members of the Organizing Committee are part of the newest Brazilian research team in palynology, which is located in the State of Bahia and originated with guidance of Professor Therezinha Sant'Anna Melhem (Instituto de Botânica, São Paulo).

Accordingly, the development of palynology and paleobotany is overcoming obstacles and realizing goals on a daily basis, and new generations take advantage of previous advances and paths to explore further.

The realization of this event in Brazil is an old dream of Brazilian palynologists and paleobotanists. The dream was realized in the hands of the new generation. The IFPS and IOP showed great confidence in the technical and scientific competence of the Bahia team in allowing the possibility for congresses to be organized by new people. IFPS and IOP will always be remembered for their vote of confidence!

Be welcomed and greeted with ***axé***!

INVITED PAPERS

Palynology in Brazil: the past, present, and future

Ortrud Monika Barth

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Introduction

For almost 90 years, investigation of the quality of Brazilian coal required knowledge of its formation and quality in ancient times. The varied spore morphology of Lycopodophyta and ferns (Pteridophyta) has become an essential tool to distinguish between different sedimentary depositional layers. The exploration of both Brazilian oil and the depositional layers demanded a deep understanding of spore morphology. Research has been extended from the Paleozoic to the Mesozoic, from ferns to angiosperms.

There were two major problems to overcome in Brazil. First, it was necessary to improve not only the technical equipment to collect samples but also the laboratory equipment, mainly stereo and photonic microscopes. Next, a better concentration of microfossils, pollen grains, and spores, along with a better resolution of its morphological structures, could be obtained.

The great and basic works of palynology appeared outside of Brazil. The wonderful and detailed descriptions, illustrations and drawings of Wodehouse (1935) (the photomicrograph was still in development and the author was considering good optical resolution) still enchant palynologists. Erdtman (1943) and his brother developed the method of acetolysis, a technique of artificial fossilization applicable to both preserved and living material, culminating in the publication of 1952. Structural details of the sporoderm of hundreds of species were presented through schematic drawings, which remain the basis of pollen morphology. In parallel, Erdtman (1920) and Faegri & Iversen (1954) laid the groundwork for modern studies in palynology, mainly during the Quaternary Period.

Since the 1940s, great progress has been made in the development and commercial launch of powerful microscopes with resolution to the molecular level. In parallel, the photomicrograph transformed from black and white and color to digital and is currently launching the 3D digital phase with image rotation. This transformation enabled a better definition of the morphological structures of spores, pollen grains, and palynomorphs, primarily with respect to the apertures and ornamentation of sporoderms.

The beginning of palynology in Brazil

Rocha (1927) was the pioneer in palynological research on Brazilian coal, followed much later by Sommer (1953). Barth (1972) has conducted a literature review on palynology studies conducted in Brazil organized by chronological, morphological and ecological topics.

Even before the introduction of the acetolysis method for the preparation of pollen and spores, several groups of scientists began to conduct palynological research in Brazil, ranging from the Paleozoic Era to the present. Sommer (1953) and Trindade (1954) study Paleozoic megaspores. Palynomorphs of the Mesozoic and Tertiary primarily include the reports of Petrobrás. Later, for the Quaternary, a brief study of a sambaqui was conducted by Loureiro-Fernandes and Guimarães (1964), although no further studies were conducted. Pioneer was also a sediment analysis obtained in the Baixada Santista, São Paulo State, by Absy (1975). Currently, laboratories in several Brazilian states conduct research in paleopalynology and Quaternary palynology (see the list below).

Dozens of published articles constitute a catalog on the pollen morphology of the vegetation in a reservation of São Paulo, including detailed studies on sporoderm structures (Salgado-Labouriau 1961) and in the State of Santa Catarina (Veloso & Barth 1962), which, although sporadic, are up to date. These two works (catalogs), which present nothing but schematic drawings of pollen morphology, initially suffered from the poor quality of the photomicrographs. Salgado-Labouriau (1973), using schematic drawings and descriptions of pollen grains, includes a great number of pollen grains of the Brazilian "Cerrado" vegetation. The advent of both good-resolution photonic microscopes and electron microscopy, primarily scanning electron microscopy, has led to the production of articles (Barth 1965) without the requirement of demanding schematic drawings of pollen grains. Today, an extensive bibliography covers many botanical taxa and their pollen and spores morphology.

Research in melissopalynology was started with a series of publications by Santos (1961) that comprises the morphology of pollen grains of Brazilian bee plants, especially in the State of São Paulo. He applies the knowledge gained by those publications in the characterization of honey samples of *Apis* bees. Barth (1969) has continued to develop this line of research, expanding it to studies of propolis, royal jelly, pollen loads and, most recently, the products of Meliponini, which are native stingless bees (Barth & Freitas 2015).

Pioneer studies in aeropalynology were executed by Lima *et al.* (1942) beginning in the 1940s. This group of physicians inquired into the occurrence of respiratory allergies in the Brazilian population and discussed the evidence (or lack thereof) of the occurrence of pollinosis in Brazil, mainly in the Southern region. Lima and Guimarães (1958) and Mendes *et al*. (1958) have conducted atmospheric pollen counts in the city of São Paulo. Later, Barth (1978) did the same for the city of Rio de Janeiro.

Once palynology in Brazil established (I) the preparation techniques of various materials for research (samples) in palynological studies (basic and applied), (II) the accessibility of microscopes with high-resolution capacity and (III) the reproduction of images with good definition to the digital level, the discipline was implemented in numerous governmental and private institutions, universities and research institutions throughout Brazil.

Through knowledge acquired of pollen and spore morphology, applied palynology developed rapidly, both in the field of beekeeping / melissopalynology and in Quaternary palynology. Strong research groups emerged that developed methodologies applicable to samples from tropical and subtropical regions of Brazil.

Recently, the "Associação Latinoamericana de Paleobotânica e Palinologia" (Latin-American Association of Palaeobotany and Palynology, ALPP, Boletínes 13/2009, 14/2013 and 15/2015) conducted a survey of Latin American palynology laboratories, including in Brazil (see the following list of major palynology laboratories currently operating in Brazil). These are laboratories that operate in almost all forms of palynology, and detailed information describes their research projects, palynotheca and teaching activities in human-resources training.

No regular meetings of Brazilian palynologists have occurred in Brazil. The first such event was held at the "Instituto de Geosciências, Universidade de São Paulo" (Institute of Geosciences, University of São Paulo) in the 1970s and was titled the First Meeting of Paleobotanists and Palynologists – RPP, (actually, The Brazilian Symposium of Paleobotany and Palynology). The most recent such event was held in Rio de Janeiro in 2013. Local meetings, sometimes linked to botanical societies, became frequent, covering all palynological specialties.

Below is appended a chronological framework based on dates for the start of research lines in palynology and their authors, who pioneered palynology in Brazil. These groups began their work around 1970, and few continue their research activities today. Many new groups have been formed based on the relationships among most of the currently active palynology laboratories, which will be presented later.

Starting palynology in Brazil: 1942-1969 **Chronology**
1942 – A. Oliveira Lima (and contributors) – Numerical studies on the incidence of pollen grains in the capitals of the Brazilian states. These studies represent the beginning of research in aeropalynology aimed at medical practice related to cases of respiratory allergies and suspected pollinosis.
1947 – Luis Gouveia Labouriau – Studies on the symmetry and structure of pollen grains.
1949 – José Correia Gomes Junior – Study of pollen morphology both in Bignoniaceae and in caatinga plants.
1953 –Friedrich Wilhelm Sommer – Studies on megaspores from the Paleozoic.
1959 – Rubens Braga – Palynological notes of plants in the State of Paraná.
1958 – Álvaro Xavier Moreira – Started to conduct morphological studies of Asteraceae pollen grains using acetolysis after Prof. G. Erdtman's 1956 visit to the Museu Nacional do Rio de Janeiro.
1961 – Clóvis Ferraz de Oliveira Santos – Started studies in melissopalynology in the State of São Paulo.
1961 – Maria Léa Salgado-Labouriau (and contributors) – Began her studies with "Palinologia de plants do Cerrado" (palynology of plants of the "Cerrado"). The same year, she started studies of pollen grain morphology of plants in the "Parque Estadual das Fontes do Ipiranga, São Paulo." This research continues.
1962 – Ortrud Monika Barth (and contributors) – Started studies of the pollen grain morphology of trees in the State of Santa Catarina. This research continues.
1962 – Margarida Maria Barros de Miranda – Started studies of pollen grain morphology of Mimosaceae, initiating the palynological studies in Northeastern Brazil.

1963 – Normélia C. Vasconcellos – Started studies of the pollen grain morphology of Amazonian plants.
1969 – Ortrud Monika Barth (and contributors) – Started studies of pollen grain morphology in melissopalynology. This research continues.

Brazilian palynology laboratories that maintain a staff are set forth below. Their activities are described in the Boletín de la Associación Latinoamericana de Palinologia y Paleobotánica (ALPP) 13 (2009), 14 (2014) and 15 (2015). In addition, there are several palynothecae (pollen libraries) located in Brazilian institutions that contain collections of slides of pollen grains and palynomorphs. See Gonçalves-Esteves *et al.* (2014) for a complete list.

Active Brazilian Laboratories of Palynology in 2016	
States	**Laboratories**
Rio Grande do Sul	Laboratory of Palynology, Departamento de Botânica, Instituto de Biociências, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul. *Head: Maria Luisa Lorscheitter*
	Laboratory of the Life and the Earth – LAVIGÆA, Universidade do Vale do Rio dos Sinos, UNISINOS, Rio Grande do Sul. *Head: Tânia Lindner Dutra*
	Laboratory of Palynology Marleni Marques Toigo, Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Porto Alegre. *Head: Paulo Alves de Souza*
	Laboratory of Palynology, Universidade Luterana do Brasil Canoas, Centro de Ciências Naturais e Exatas, Canoas. *Head: Andreia Cardoso Pacheco Evaldt*
	Collection of Paleobotany, Departament of Paleontology and Stratigrafy, Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Porto Alegre. *Heads: Roberto Iannuzzi & Daiana Rockenbach Boardman*
	Sector of Botany and Paleobotany, Museu de Ciências Naturais da UNIVATES, Lajeado. *Head: André Jasper*
São Paulo	Laboratory of Palynology and Paleobotany Prof. Dr. Murilo Rodolfo de Lima, Universidade Guarulhos, Guarulhos *Head: Maria Judite Garcia*
	Core Research of Palynology, Centro de Pesquisa em Plantas Vasculares, Instituto de Botânica de São Paulo. *Head: Cynthia Fernandes Pinto da Luz*
	Laboratory of Palyno-Ecology, Departament of Biology, Faculdade de Filosofia, Ciências e Letras, Ribeirão Preto, Universidade de São Paulo. *Head: Cláudia Inês da Silva*
	Palynotheca of the Laboratory of Paleoecology and Ecology of Landscape, Universidade Federal de São Paulo, Campus Diadema (UNIFESP). *Head: Ana Luisa Vietti Bitencourt*
	Collection of Macrophytofossils and Palynological Slides, Museu de Paleontologia e Estratigrafia "Paulo Milton Barbosa Landim", Universidade Estadual Paulista (UNESP Rio Claro), São Paulo. *Head: Rosemarie Rohn*

Active Brazilian Laboratories of Palynology in 2016	
States	**Laboratories**
Rio de Janeiro	Laboratory of Palynology Álvaro Xavier Moreira, Universidade Federal do Rio de Janeiro – Museu Nacional, Rio de Janeiro. *Head: Prof. Vânia Gonçalves Lourenço Esteves*
	Laboratory of Palynology Monika Barth, Departament of Geology, Instituto de Geociências da Universidade Federal do Rio de Janeiro. *Head: Prof. Ortrud Monika Barth*
	Laboratory of Vegetal Paleoecology, Sector of Paleobotany and Paleopalynology, Departament of Geology and Paleontology, Universidade Federal do Rio de Janeiro - Museu Nacional, Rio de Janeiro. *Head: Marcelo de Araújo Carvalho*
	Laboratory of Palynology, Manages of Bioestratigrafy and Paleoecology (BPA/CENPES/ PETROBRAS), Rio de Janeiro. *Head: Cecília Cunha Lana*
Minas Gerais	Palynological Sudies, Laboratory of Bryophytes, Department of Botany, Universidade Federal de Juiz de Fora, Minas Gerais. *Head: Andréa Pereira Luizi Ponzo*
Mato Grosso	Laboratory of Palynology, Universidade Federal de Mato Grosso, Campus Cuiabá. *Head: Silane Aparecida Ferreira da Silva Caminha*
Bahia	Laboratory of Plant Micromorphology, Universidade Estadual de Feira de Santana, Feira de Santana. *Head: Prof. Francisco Assis Ribeiro dos Santos*
Pará	Laboratory of Palynology, Departamento de Botânica, Museu Paraense Emílio Goeldi, Belém, Pará. *Head: Léa Maria Medeiros Carreira*
Amazonas	Laboratory of Palynology, Department of Botany, Instituto Nacional de Pesquisas da Amazônica (INPA), Manaus. *Head: Maria Lúcia Absy*

The prospects for palynology in Brazil

According to Barth (1972) as mentioned above, palynology in Brazil is comprehensive in all its forms, but progress has been slow. The causes of this situation are varied. Public and/or private institutions need to plan and invest financial resources in palynology. As a science and/or an interdisciplinary specialty, palynology is considered a complement to more traditional topics.

The development and application of complex techniques in palynology, from the classic acetolysis to tridimensional and molecular studies comprising proteins and genomes of pollen grains and spores, fungi and algae, hybridization and genetic enhancement, physiology and preservation, shows that through its interaction with various branches of science, palynology has become increasingly interdisciplinary.

Pollen morphology related to botanical taxonomy should remain the basis for investigations that have different purposes. Illustrative works (books) of reference with a good level of reproduction are missing and can gather scattered publications in numerous scientific journals. Based on Brazil's large size, such works should refer to vegetation types in well-defined geographical areas. They are essential for pollen studies related to the environment.

Physiology and pollen genetic deserve attention and should be a future research target. For example, the hybridization of species, which generates individuals resistant to pests, chemicals, and diseases, should be studied. This area is currently not well explored and could be considered innovative in the future.

Aeropalynology currently comprises a good knowledge of anemophilous plant species and their pollen morphology and should develop molecular investigations when supposedly allergic reactions are assigned to these species.

Paleopalynology and Quaternary palynology continue their current objectives, primarily in collaboration with geology, and rely heavily on financial investments. Forensic palynology, through the knowledge of pollen morphology and ecology / environment, will respond to more casual questions.

It is expected that there will be a considerable increase in melissopalynological research. In this branch of study, the pollen morphology of bee plant species is well developed. However, interpretations of that research are often incomplete or even misleading. Because of the commercial demand for bee products, both native and introduced, quality requirements increase. It is necessary to have good oversight.

Because of the great diversity of our flora, to maintain the accuracy of results in applied palynology, a more detailed knowledge of pollen morphology will continue to be the best foundation and deserves continuous support, access to modern technology, and the training and retention of human resources.

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The history of Brazilian paleobotany

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The Portuguese Royal Family in Brazil

The transfer and establishment of the Portuguese Crown in Brazil (1808-1821) and the colony's elevation to the position of the *United Reign of Portugal*, *Brazil and Algarve* (1815-1822), paved the way for many *scientist-travelers* (naturalists, botanists, mineralogists) to explore the country. That notwithstanding, because of Brazil's inaccessibility attributable to the physical dangers of long sea voyages and the scientific community's lack of unanimity in appreciating the work of scientist-travelers, this task was usually performed by younger naturalists or naval officers or adventurers. Therefore, the naturalists who came to Brazil were those who braved the difficulties and undertook these hazardous journeys. For example, Auguste de Saint Hilaire, a French naturalist / botanist, visited Brazil during 1816 and 1822. He was highly impressed and fascinated by the tropical forests around Rio de Janeiro and narrated the beauty and diversity of species within them. He collected many Brazilian medicinal plants for his studies. To provide another example, in 1817, the *Scientific Mission of Natural History* or *Austrian Mission* funded visits by scientists in various specialties (zoologists Johann Baptist von Spix and Johann Nattere and botanists Carl Friedrich Philipp von Martius, Johann Sebastian Mikan and Johann Emmanuel Pohl), along with artists, a lithographer, a taxidermist and a photographer accompanying the Archduchess of Austria, Lady Maria Leopoldina, daughter of King Francis I, who had just married Prince Dom Pedro de Alcântara de Bragança e Bourbon through a power of attorney.

After their arrival in Rio de Janeiro, *Von Spix*, *Von Martius* and the painter *Ender* moved away from the Austrian group and travelled to the basin of the Paraíba do Sul. During 1817 to 1820, they covered thousands of kilometers across the country, visiting Ouro Preto and Diamantina in Minas Gerais Province, where they learned about diamond exploitation. Later, they went to the provinces of Bahia, Pernambuco, Piauí, Maranhão, Pará and Amazonas and crossed Caatinga vegetation in the Northeast of Brazil and the Amazon Forest, contracting several diseases. Nevertheless, they profited from their time by collecting and describing animals and plants. They discovered the giant meteorite of Bedengó in Bahia and the fossil fishes of the Santana Formation of Araripe Basin. The monumental *Flora Brasiliensis* (1840-1906), elaborated by *von Martius*, *August Wilhelm Eichler* and *Ignatz Urban*, was also the result of this travel. It was sponsored by three monarchs—the emperor of Brazil, the king of Bavaria and the emperor of Austria—with the support of 65 specialists from several countries. It is noteworthy that Lady Leopoldina's strength and determination, much more than could have been expected from either the archduchess of the Austria house or the princess of the Bragança house or from the empress of Brazil, stood out as a leader on projects to boost development of science, culture and other activities, strongly supporting the formation of the Brazilian society. Given that the "*Father of Paleobotany*", Adolphe Brongniart, published his first identifications of European and Indian fossil plants in 1822, the year when Brazil obtained its independence from Portugal, it is possible to assume with confidence that, during colonial times, no mention of fossil plants was made.

Independence from the Portuguese domain and the Empire of Brazil (1822- 1889)

During the period of the Empire, as in the period of the *United Reign of Portugal*, *Brazil and Algarve*, naturalistic research in Brazil was led by *European Scientist-Travelers* (mainly British, French and German), with the incipient participation of Brazilian researchers. Until the opening of the Ouro Preto School of Mines in 1876, geological investigations were conducted almost exclusively by foreign scientists, some of whom settled in Brazil (Mendes and Petri, 1971).

It is worth explaining that there was only one period of Brazilian Empire (1822-1889), which is historically divided into the *First Reign* (1822-1831, Dom Pedro I), an interval of regencial government (1831-1840) and the *Second Reign* (1840-1889, Dom Pedro II).

● *First Brazilian Reign (1822-1831)*

The European Naturalist-Explorers

Friederich Sellow (a disciple of Carl Ludwig Willdenow, Georges Cuvier, Jean-Baptiste Lamarck and Alexander Von Humboldt) left Berlin for Brazil in 1824 as part of the *Langsdorff Expedition* (a Russian

expedition organized and headed by *Baron Georg H. von Langsdorff*, a German naturalized Russian). Sponsored by the young Empire of Brazil, with sizeable credit and customs advantages, the expedition aimed to make scientific discoveries, conduct geographical research, gather statistics and study the trade of unknown products. From 1824 to 1829, *Sellow* traveled more than sixteen thousand kilometers throughout Brazil, from Minas Gerais to Rio Grande do Sul and Uruguay, making records of its nature and society and providing the most complete inventory of *Brazilian First Reign*. As a botanist, he was probably the first to examine Jacuí coal samples and to describe a fossiliferous sequence between São Gabriel and Caiguaté (RS), with teeth and skulls of fish and *silicified dicots*. He sent paleontological samples to the National Museum of Rio de Janeiro. To the Berlin Natural History Museum he sent 12,000 plants, 5,000 birds, 110,000 insects and 2,000 geological samples. *Sellow* remained here until 1831 and died tragically by drowning in the River Doce (MG). Unfortunately, he had no time to describe what he had collected.

Charles Darwin (1809-1882) was certainly the most distinguished *Scientist-Traveler* who passed through Brazil during the First Reign. He left England in December 1831 to participate as a naturalist on the ship HMS "Beagle". He arrived in Salvador (BA), in February 1832 and was astonished by his first sight of the tropical forest and fauna. Later, Darwin went to Rio de Janeiro, where he went on small tours, visiting Tijuca Forest, Botanical Garden, Gávea, Corcovado and the Imperial Museum (now the National Museum). He collected insects and observed and studied their behaviors around the city, sending dozens of insects to Professor Henslow for further studies. These materials provided information helpful to the posterior formulation of the *Theory of Evolution by Natural Selection*. Nevertheless, Darwin observed nothing in terms of paleobotany.

Brazilian naturalists during the First Reign (1822-1831)

The first geological information of scientific value in Brazil was obtained by the *Andradas Brothers* (José Bonifácio and Martim Francisco de Andrada e Silva), who reported on Brazilian diamonds. Their research was published in 1792 by the *Societé d'Histoire Naturelle Bulletin of Paris* (Mendes and Petri, 1971).

José Bonifácio de Andrada e Silva (1763-1838, Figure 1A), named the "Patriarch of Independence", was a Brazilian geologist and a strongly influential political statesman during the First Reign (the Dom Pedro I government). He was a renowned scientist and was considered the first geologist from the American continent. However, he did not observe anything pertaining to paleobotany.

The Regencial Period (1831-1840) is an interval between the end of the *First Reign* of Dom Pedro I and the beginning of the *Second Reign* that occurred during the childhood of then-future Emperor Dom Pedro II.

In 1836, exactly 180 years ago, Franz Unger (1800-1870, Figure 1B), an Austrian botanist and paleontologist, first reported a Brazilian phytofossil, *Psaronius brasiliensis* Unger, a stem of an arborescent fern, in the work of Von Martius entitled *Historia Naturalis Plantarum*. At that time, Unger described the stem based only on a fragment of the surrounding layer of adventitious roots. In 1817 and 1820, this first phytofossil specimen was collected by Von Martius from the Pedra de Fogo Formation, Permian of the Parnaíba Basin, between Oeiras and Sao Goncalo do Amarante in Piaui. In 1872, during the Second Reign, Adolphe Brongniart (1801-1876) described the anatomical details of *Psaronius brasiliensis* based on other specimens collected either between 1817 and 1820 by C. F. Von Martius or in 1826 by F. Sellow and deposited in the Imperial Museum of Rio de Janeiro.

● *The Second Brazilian Reign (1840-1889)*

The Second Reign was a time of great cultural progress and huge importance to Brazil with the growth and consolidation of the Brazilian nation both as an independent country and as an important member of the American nations. Profound changes were observed in the social situation, such as the gradual liberation of black slaves and the encouragement of immigration from Europe to supplement the Brazilian workforce.

In 1853, the exploitation of coal began in Rio Grande do Sul State with the opening of the Arroio dos Ratos mine (Mendes and Petri, 1971).

Studies of Brazilian Paleobotanical Material: Scientists from European Museums and North America in the Nineteenth Century

From 1863 to 1864, Nathaniel Plant, an English naturalist, analyzed the coal reserves of Rio Grande do Sul, including its fossils. In Part III of Plant (1869), William Carruthers (1830-1922, Figure 1C) identified and described *the first phytofossils regarding Glossopteris Flora of Brazil* found in shales associated with the coals: *Flemingites pedroanus* Carruthers [specific epithet in honor of Dom Pedro II, Emperor of Brazil, now designated as *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistikow, Hill, 1979]; *Odontopteris*

plantiana Carruthers [now *Botrychiopsis plantiana* (Carruthers) Archangelsky and Arrondo 1971]; and *Noeggerathia obovata* Carruthers [now *Gangamopteris obovata* (Carruthers) White, 1908]. This was a pioneering contribution to the inception of Brazilian Gondwanan paleobotany. Carruthers was a British naturalist specializing in geology and botany. In 1859, he was appointed assistant of the Department of Botany of the British Museum of Natural History. It is said that Carruthers combined his two passions (geology and botany) through the study of paleobotany, in which he specialized in *Lepidodendron* and *Calamites* genera, the Lycopodiaceae family and the anatomy of fossilized stems.

Among the *scientist-travelers* of the Second Reign, in addition to the Europeans, many North American researchers became interested in Brazilian paleontological studies.

Louis and Elizabeth Agassiz traveled to Brazil during 1865 and 1866. Agassiz dated as Cretaceous the fossil fish from Ceará State collected by George Gardner in 1841. Accompanying the Agassizes in 1865, Charles Frederic Hartt came to Brazil with an expedition that was to study freshwater fauna and the possibilities of an ice age in Northern Brazil. He returned to Brazil twice, once in 1867 and again in 1870, to do research on the geology of the Brazilian coast. Hartt was accompanied by researchers such as Orville Adelbert Derby and others.

During the second half of the nineteenth century, under the command of Dom Pedro II, Brazil made progress in the scientific field. During that period, the emperor's support of scientific events and publications vouched for any project carried out by Brazilian scientists. Since 1870, the National Museum of Rio de Janeiro and the Pará Museum of Natural History and Ethnography (now Museum Emílio Goeldi) have stood out as producing centers of ethnographical and natural sciences. Until that time, Brazilian scientific productions were still incipient, but grounded in Positivism and Darwinism, which, incorporated by the intellectual elites and Brazilian politicians, allowed Brazil to approach the *European Scientificism* context.

At the end of the Second Reign (1870-1889), some North American geologists and paleontologists were installed in Brazil by invitation of the Brazilian government (1874-1915); others received phytofossils in Europe.

In 1874, Charles Frederic Hartt (1840-1878, Figure 1D) was invited by the Brazilian Government to organize the *Imperial Geology Commission* with the goal of preparing a geological map of Brazil based on geological, mineralogical and paleontological (mainly paleobotanical) data, obtaining collections. He had among his assistants Orville A. Derby.

Orville Adelbert Derby (1851-1915, Figure 1E) was also a North American geologist, a naturalized Brazilian who dedicated his life entirely to Brazil's geology, earning the title of *Father of Brazilian Geology*. C. F. Hartt, Derby's professor of geology and geography at Cornell University, invited him to accompany him on a trip to Brazil in the summer of 1870. During the first trip of the Morgan Expedition, Derby was in the State of Pernambuco, collecting fossils from the Maria Farinha Formation. In the summer of 1871, on the second trip of the Expedition, Derby returned to Brazil to explore the valley of the Amazon River. At that time, he collected Carboniferous brachiopods in the limestone of the Itaituba Formation in the Tapajós River, which became the study object for his doctorate in 1874.

Invited by the provincial government, O. Derby organized the *Geographical and Geological Commission of São Paulo Province* from 1886 to 1904. It is currently designated the *Geological Institute* of the Department of Environment of the State of São Paulo.

In Piracicaba Region, State of São Paulo, Derby collected silicified stems of lycophytes from the Corumbataí Formation, Permian of the Paraná Basin. He sent them to Dr. B. Renault in Paris. Based on morphological study of the cortical surface and the anatomy of the inner portion of the stem, he erected the genus and species *Lycopodiopsis derbyi* Renault.

The taxonomy of the Permian gymnosperm woods of Paraná Basin began in the late nineteenth century with the description of *Dadoxylon pedroi*, identified by Zeiller in the coal layers of the Rio Bonito Formation exposed in the Valley of the Jaguarão in Rio Grande do Sul State.

René Zeiller (1847-1915, Figure 1F) considerably expanded knowledge of the Flora of Glossopteris in Southern Brazil and Africa and described new forms from the Lower Gondwanas of India. He examined a collection of phytofossiliferous samples from the Arroio dos Ratos mine belonging to Princess Isabel and explained that because of her generosity, some of those samples were donated to the École de Mines de Paris. In 1898, Zeiller re-examined the specimens described by B. Renault and recombined as *Lepidodendron derbyi* (Renault) Zeiller, which was endorsed by Arber (1905).

The first Republic of the United States of Brazil (1890-1930)

In Brazil, the method of large-scale producing generated by the *Industrial Revolution* began to significantly develop very late, that is, only in the late nineteenth and early twentieth centuries. It fell to the São Paulo coffee growers, with fortunes originating from coffee exports, to initiate investments in

the industrial sector. Therefore, it became necessary to intensify coal mining as a source of energy for that sector.

During the first three decades of the twentieth century, renowned European and American paleobotanists continued to describe Brazilian plant fossils sent to them by geologists who lived here.

H. Solms-Laubach (1842-1915, Figure 1G) was a German botanist who studied Permian fossil woods from the Parnaíba Basin, identifying them in 1904 as *Psaronius brasiliensis* (Unger) Brongniart. He also described petrifactions of Permian ferns similar to the *Psaronius* from Corumbataí Formation in the northeast area of the Paraná Basin as *Tietea singularis* Solms-Laubach in 1913, differentiated by the absence of well-organized and defined meristeles in the central portion of the stem that are typical of *Psaronius*. These forms have recently been restudied by Tavares *et al.* (2011). Chahud and Petri (2015) have also recorded the species *T. singularis* in the formation immediately below Corumbataí, *i.e.*, in the Tatuí Formation (meaning the Rio Bonito **+** Palermo formations in the southern part of the basin).

In 1905, E. A. Newell Arber made a careful and analytical summary of what had become known so far about Glossopteris flora in his *Catalogue of the Fossil Plants*. In this important work, Arber referred to Brazilian fossils deposited in the British Museum and other European museums, quoting from the works of Unger (1836) and Solms-Laubach (1904) (see Arber, 1905 and references therein mentioned below) on *Psaronius brasiliensis*; fossils described by Carruthers (1869) and its restudy by Zeiller (1895). He referred also to Plant (1870) studies registering *Lepidodendron* in association with *Glossopteris* in Candiota and Jaguarão coals in Rio Grande do Sul. He cited Hartt's (1870) records on *Asterophyllites (Calamocladus)* in the south of Bahia and the work of Liais (1872) on the occurrence of *Sphenopteris* and calamitaleans in Candiota and Jaguarão coals. He recorded Derby's (1888) observation that trunks of *Dadoxylon*-type conifers and the stems and leaves of *Lepidodendron* and *Psaronius* fragments occurred in the province of São Paulo. He emphasized that Renault (1890) had described a new species of lycophyte stem as *Lycopodiopsis derbyi* of Piracicaba (SP) associated with fern trunk (*Psaronius*) and *Cordaites* leaves. Arber also reported his agreement with Zeiller (1898) that the genus *Lycopodiopsis* Renault would be a true *Lepidodendron* and highlighted that Hettner (1891) had recorded the presence of Glossopteris flora in the coal area of Jacuí river called Arroio dos Ratos, located in Rio Grande do Sul. He also observed that Zeiller (1895) examined Hettner's specimens in the Berlin Museum and among them identified *Gangamopteris cyclopteroides* var. *attenuata.* Arber also stressed that Zeiller was the first to recognize that Brazil had a remarkable combination of elements of the Glossopteris flora [*Gangamopteris cyclopteroides* Feistm. and *Neuropteridium validum* (Carr.) Feistm.] with common Euramerian plants in the Upper Carboniferous such as *Lepidophloios laricinus* Sternberg.

Charles David White, or simply David White (1862-1935, Figure 1H), was a North American geologist. After briefly mentioning the *Flora of the Brazilian Coal Measures* (*Science*, 1905), White produced the first comprehensive monograph on the Permian plants from Southern Brazil, which is one of the most important and complete descriptions of fossils of the Glossopteris flora from the coal layers of Brazil (Santa Catarina and Rio Grande do Sul), as described in Part III of (the not least important) Israel Charles White's *Final Report* for the *Coal-Stone Research Committee of Brazil* (1980), in which the famous *White Column* of the stratigraphic sequence of the Paraná Basin has been described.

G. Lundqvist (1919) recorded a new *Glossopteris* taphoflora from the Permian of Rio Grande do Sul and Paraná states. In that work, he accepted White's proposal (1908) to consider *G. cyclopteroides* Feistmantel as synonymous with *G. obovata* (Carr.) White. He also described the fructification *Arberia brasiliensis* Lundqvist.

The Brazilian naturalists-scientists of the first three decades of the twentieth century (1907-1929)

This is the first phase of development of Brazilian geopaleontological activities in the twentieth century.

Under the leadership of Orville Derby, the Geological and Mineralogical Service of Brazil (SGMB, Portuguese acronym) was established in 1907. Its primary purpose was to advance Brazil's interests (i.e., the interests of its government and industry) in the pursuit of the country's mineral resources and coal. The first group of paleontologists arose in this context, interrupting the delivery of fossils for study abroad.

In 1910, Derby's disciple Matias Gonçalves de Oliveira Roxo (1885-1954, the first Brazilian paleontologist) began his research in SGMB. Roxo 1938 (apud Dolianiti 1972 published the first Brazilian textbook on paleophytology (Paleofitologia). The young people attracted to the paleontological sciences included Elias Dolianiti (1911-1985), who became the first Brazilian paleobotanist and began his research around 1945 (discussed below).

Edward Wilber Berry (1875-1945, Figure 1I) was an American botanist whose research focused on paleobotany. From 1911 to 1930, Berry produced important works on the American Mesozoic and Cenozoic paleofloras. However, he also conducted important taxonomic studies identifying Cenozoic fossil

leaves from Central and South America (from the Caribbean to Patagonia), providing paleoclimatic and paleophytogeographic interpretations.

Berry's publications, especially by The Johns Hopkins University, continue to provide the foundation for many Paleogene and Neogene paleobotanical studies. Berry published on various Tertiary phytofossiliferous occurrences in Brazil: in 1924, he co-authored a work with Charles Arthur Hollick on the flora of Bahia Pliocene (Alagoinhas and Marau); in 1933, he published a work on petrified wood (Jacaranda tertiaria Berry) of Bahia Pliocene; in 1935, he published a work on Brazil's Tertiary plants in general; and in 1937, he published a work on Acre Pliocene leaves (Cruzeiro do Sul municipality).

Carlotta Joaquina Maury (1874-1938, Figure 1J) was an American paleontologist who was an expert in invertebrate paleozoology. She began working for the Geological and Mineralogical Survey of Brazil in 1918. In 1930, her paper *"O Cretaceo da Parahyba do Norte"* of the *Geological and Mineralogical Service of Brazil*, *Monograph 8*, described two coconut fruits of the Gramame Formation (Maastrichtian) from João Pessoa (state of Paraíba). Those fruits were named *Palmocarpon luisi* (in honor of President Washington Luis). According to Maury, they came from a *Palmae flora*, which covered the Northeastern coastal region during that time, similar to *Palmocarpon cretacea*, Maastrichtian of the Netherlands. In 1936, in her work entitled *"O Cretáceo de Sergipe"* in the Riachuelo Formation, Maury recorded the presence of *Lithothaminium*. Maury (1937) simultaneously with Berry (1937) worked on the identification of the Acre Pliocene leaves (Cruzeiro do Sul municipality). Those identifications were *evaluated* by Duarte (1970), who proposed *synonyms* for the identified species.

The second and third Republic of the United States of Brazil

Brazilian paleobotany during the Vargas Dictatorship - Vargas Age (1930-1945)

During the *Vargas Age* (1930-1945), or *New State*, the *National Department of Mineral_Production* (DNPM, Portuguese acronym) was formed and the SGMB was changed to the *Division of Geology and Mineralogy* (DGM). The division was included in the newly formed DNPM. The *Section of Paleontology* was placed within the division to house the collections formed by the SGMB. In addition, the Conselho *Nacional de Petróleo* (CNP) and the *Companhia Siderurgica Nacional* (CSN), the largest steel industry in Latin America, were formed. The plant is located in the city of Volta Redonda (RJ), its blast furnaces consuming a huge quantity of coal of the Santa Catarina mines and promoting its most intense study.

During World War II (1939-1945), a co-operation agreement between the *DNPM* and the *U.S. Geological Survey* was signed and lasted approximately 20 years. At that time, several North-American paleontologists and geologists came to Brazil, among them *Charles Brian Read*.

Charles Brian Read (1907-1979) was a brilliant North American geologist and paleobotanist. His paleobotanical studies included morphology and plant anatomy, floristics and biostratigraphy. In the late 1930s and early 1940s, Read studied and published on the Devonian to Permian floras of South America in Peru, Argentina and Brazil (especially the Paraná Basin) with the macrofloral successions. Read's primary work on Brazilian phytofossils was presented in 1941 as Monograph 12 DNPM / DGM entitled *Plantas fósseis do Neo-Paleozoico do Paraná e Santa Catarina*, *Brasil.*

Carl Rudolf Florin (1894-1965, Figure 1K) was a prestigious Swedish botanist and paleobotanist during the first half of the twentieth century. His studies covered observations on floras worldwide since the middle Paleozoic. One of Florin's best-known papers is "*The distribution of Conifer and Taxad genera in Time and Space*". His works and evolutionary interpretations were based on the *Teloma Theory of Zimmerman.* In 1940, Florin described *Paranocladus dusenyi* and *P (?) fallax* based on specimens from the area of Figueira or Cambuí (PR), today recognized as the Triunfo Member of the Rio Bonito Formation, Cisuralian (Asselian/ Sakmarian) of the Paraná Basin.

During the Vargas Age, some Brazilian researchers devoted to the study of living angiosperm logs anatomy conducted investigations of Paleozoic and Cretaceous woods.

Dr. Fernando Romano Milanez was an anatomist of living logs and director of the Botanical Garden of Rio de Janeiro. He oriented paleobotanist Diana Mussa in her first work within the specialty. In 1935, he described a petrifaction of Cretaceous angiosperm from Piauí designating *Lecythioxylon brasiliense.* In 1950, in collaboration with *Elias Dolianiti*, he conducted a study on a new Lower Permian gymnospermic trunk.

Dr. Calvino Manieri, an anatomist of living woods and director of the Wood Section of the Institute for Technological Research of São Paulo State during 1944 and 1946, greatly contributed to the study of the anatomy of Paleozoic *Dadoxylons*.

Euzébio Paulo de Oliveira (1883- 1939, Figure 1L) was an engineer of the Commission of Coal Mines of Brazil in 1907. In 1935, Euzébio de Oliveira and Luiz Flores Moraes Rego noted the presence of typically Euro-American plants (*Sphenopteris*) in the Pennsylvanian of Parnaíba Basin, i.e., in the northwestern region

of the Gondwanan Continent. In 1936, he described *Dadoxylon derbyi* Oliveira. In turn, Moraes Rego (1935) (*apud* Dolianiti 1972) has suggested a possible correlation among the sediments of the Poti, Piauí and Pedra de Fogo formations (Parnaíba Basin) and the formations of the Tubarão and Passa Dois groups (Paraná Basin) based on the presence of *Psaronius* in the northeast and *Pecopteris* and *Tietea* in the south.

Fourth Republic of the United States of Brazil (1946-1964)

With the fall of dictator Getúlio Vargas in 1945 began a new period of Brazilian republican history known as the *Fourth Republic of the United States of Brazil* (1946-1964).

Brazil's rapid industrialization during the presidency of Juscelino Kubitschek (1956-1960) led to national demand for geology experts in both public institutions and private enterprises. Thus, in 1957 the Geologists Formation Program (CAGE) was initiated within the Ministry of Education and Culture.

The first group of Brazil-trained geologists (1957-1960) resulted from the opening of four geology programs: the Universidade Federal de Pernambuco (UFPE); the Ouro Preto School of Mines; the Universidade de São Paulo (USP) and the Universidade Federal do Rio Grande do Sul (UFRGS). All these programs were initiated by Brazil's federal government.

In 1944, Elias Dolianiti (1911-1985, Figure 1M), a DNPM naturalist, traveled to the coal region of Santa Catarina, collecting approximately 3,000 fossil specimens of Glossopteris flora. He became a great specialist of that flora in Brazil, registering several species from the Rio Grande do Sul to Paraná, especially those collected in the State of Santa Catarina between 1946 and 1956. He also studied fossil plants from the Fonseca Tertiary Basin, Minas Gerais, from 1946 to 1950 and reviewed the flora of Teresina (Parnaíba Basin) in 1954.

In 1955, Dolianiti identified fossil fruits from the Maria Farinha Formation, Paleocene of the Pernambuco Basin as *Nipa pernambucensis*, collected between Olinda and Paulista. They are considered a small-sized palm with big fruit, coming from the Eastern Hemisphere.

In response to a request from the National Research Council (CNPq), Dolianiti accompanied Prof. Richard Kräusel (1890-1966) from the University of Frankfurt, Germany, in his field work to the Paraná Basin, resulting in an excellent work on gymnosperm woods of the Brazilian Paleozoic (Kräusel and Dolianiti, 1958) and Early Devonian fossils of the Picos Formation in the Parnaíba Basin (Kräusel and Dolianiti, 1957, apud Dolianiti 1972).

In the 1960s and 1970s, Dolianiti gave continuity to his research on the Brazilian Paleozoic and Mesozoic floras. He led scholars and actively participated in fieldwork. In the 1980s, Dolianiti began to investigate the flora of Cerquilho (São Paulo State) with José Henrique Millan.

In 1972, during the International Symposium on Carboniferous and Permian Systems in South America, Dolianiti expounded on the presence of two Carboniferous and Permian floristic regions in Brazil that previously had been observed by several authors, one in the northern area of the country (Parnaíba Basin), which was floristically Euro-American, and another, which was Gondwanan, in the southern area (Paraná Basin).

Elias Dolianiti had a profound knowledge of Brazilian paleobotany and despite the difficulties of doing research during the time published more than 30 scientific papers on fossil plants of Brazil's sedimentary basins. All those papers are known and appreciated by experts. The certainty, clarity and accuracy demonstrated in Dolianiti's works brought him deserved national and international recognition as an authority on Gondwanan flora. In our view, he undoubtedly deserves the title of *Father of Brazilian Paleobotany*.

Reinhard Maack (1892-1969, Figure 1N) was a German geologist who moved to Brazil in 1926 and spent most of his life in the State of Paraná. Maack published numerous works on southern geology and scientifically trained many young people in Paraná. He was a student of the Permian lycophytes of Paraná Basin. Following his studies on the geology of Southern Africa, Maack moved to Brazil, making significant correlations between the Kaokoveld region in Namibia and Gondwanan strata of Southern Brazil, greatly contributing to the knowledge of the *Theory of Continental Drift* and *the Gondwana supercontinent*. In 1949, Maack became a naturalized *Brazilian.*

Octavio Barbosa (1907-1997, Figure 1O) was a geologist. Starting in the beginning of the 1930s, he worked in the old SGMB. Barbosa published more than 200 papers on geology and mineral prospecting. From 1952 to 1958, he published works on paleobotany, defining the age of the Gondwana floras of Paraná Basin and observing the *Parataxopitys americana* Barbosa, a fossil wood of the Irati Formation (Kungurian of Paraná Basin). He was the first researcher to detect the taphoflora of Monte Mor, State of São Paulo, registering it as a Pennsylvanian flora prior to the Glossopteris flora.

Friedrich Wilhelm Sommer (1907-1994), an Austrian naturalized Brazilian, worked at DGM/ DNPM, in Rio de Janeiro. Despite being more inclined toward micropaleontology, Sommer made some incursions

into the field of paleobotany. His most outstanding works include studies on algal fossils of Spongiophytales, Tasmanales and Protosalviniales of the Parnaíba and Paraná Basins and studies on Pennsylvanian and Permian megaspores of the Paraná Basin.

Lelia Duarte [1930? -2013] was an extremely productive paleobotanist dedicated to research on Brazilian Mesozoic and Cenozoic fossil plants. She worked in the Paleontology Section of the DGM/DNPM from 1956 to 1984(?). She conducted numerous field studies and participated intensely in scientific events. During her time at the DGM/DNPM, she collected and deposited important phytofossil specimens in the DGM/DNPM collection of paleobotany. From 1985, Duarte worked at the Universidade do Estado do Rio de Janeiro. Her contribution to Brazilian paleobotany was wide and involved phytofossils from different Brazilian sedimentary basins.

From 1956 to 1961, Duarte studied Melastomataceae, Styracaceae, Annonaceae leaves and a Bombacaceae flower in the Tertiary Fonseca Basin. In 1985a, she erected two new species of ferns from this basin: *Anemia debiis* Duarte and *Asplenium ferruginii* Duarte.

In 1965, Duarte began her studies on the Early Cretaceous floras of Araripe Basin and in 1985b, presented as its components *Brachyphyllum obesum* Heer, *B. castilhoi* Duarte, *Podozamites lanceolatus* (L & H) Sch, *Nymphaeites choffati* (Sap) Teixeira and *Choffatia francheti* Sap. In 1993, her studies were concentrated on Araucariaceae of the Santana Formation, mainly the Crato Member. Simultaneously, she presented the floristic elements from the Areado Formation of the São Francisco River Basin (1985c).

Collaborating with Adelia Maria Salviano Japiassú**,** Duarte conducted an extensive and complete survey of the plant record throughout Brazil (as known through 1971) from the Triassic to the Holocene.

Lelia Duarte defended her doctoral thesis at the Universidade de São Paulo (1972) on the Miocene Amazon flora of the Pirabas Formation occurring in the state of Pará. She concluded that it is a tropical flora composed exclusively of angiosperms with high diversity of species, composed of 20 species belonging to 19 genera and 18 families, among which only one species belongs to monocots. The rest are distributed among the Archychlamidae with 15 families and 16 genera and Sympetalae, with two species in two genera of two distinct families.

An important contribution to the knowledge of the Cenozoic flora of southeastern Brazil, was made by Duarte and Rezende-Pimentel (1985), who described the flora of the Peripheral Depression of São Paulo, in Vargem Grande do Sul, where they identified leaf fossils of Celastraceae, Myrtaceae, Melastomataceae and Symplocaceae.

In the 1980s, Duarte and Mandarin-de-Lacerda also conducted important studies of the Paleogene flora of Taubaté Basin.

Duarte, along with her collaborators, also contributed significantly to the Quaternary paleobotany of Umbuzeiro (State of Paraiba) and Morro do Chapéu (State of Bahia).

Diana Mussa (1932-2007, Figure 1P) had a deep knowledge of plant anatomy, biostratigraphy and geology, devoting herself to Brazil's largest study of Permian macrofloras in the fossil woods of the Paraná Basin. Her doctoral thesis entitled "*Lignitafofloras Permianas da Bacia do Paraná*, *Brasil (Estados de São Paulo e Santa Catarina)"* was defended at USP (1982).

In the early 1980s, *Diana Mussa* worked as a researcher at the DNPM and was recruited by the National Museum (MN/UFRJ) in 1983. She conducted research, advised students and taught various subjects both in the Department of Geology and Paleontology of the National Museum (DGP-MN / UFRJ) and in the Institute of Geosciences (IGEO / UFRJ). In 1993, following a public contest, she was appointed as Associate Professor of Paleobotany at the National Museum / UFRJ.

Mussa's scientific production, which included approximately 50 high-level papers, involves mainly Paleozoic, Mesozoic and Cenozoic woods studies; however, it also includes phytofossiliferous impressions from the Devonian to the Cretaceous. Based on paleoanatomy, she made ontogenetic interpretations, paleoclimatic, taphonomic and phylogenetic lineages of fossil plants.

Mussa worked with phytofossils from almost all of Brazil's continental sedimentary basins: Acre, Parnaíba, Lima Campos, Potiguar, Sergipe-Alagoas, Jatoba, and Itaboraí, with special attention to Gondwanan phytofossils of the Paraná Basin. She described approximately 30 genera of fossil plants. She left an important collection, with more than one thousand slides of fossil woods. She trained many graduate students. With a beautiful career, despite the fact that she was published only in Portuguese, Mussa is internationally recognized as Brazil's most important paleoxylologist and the world authority on Devonian floras.

Richard Kräusel (1890-1966), from the University of Frankfurt – Germany, produced not only the previously mentioned works in partnership with Dolianiti but also an important monograph on revision of the petrified genus *Lycopodiopsis* and other Permian lycophytes of the Paraná Basin, reviewing all previous information and adding observations based on new material (Kräusel, 1961).

Sergio Mezzalira (1920-2009, Figure 1Q), working at DGM/DNPM in Rio de Janeiro from 1942 to 1946, produced scientific field works in the State of São Paulo, locating for the first time an occurrence of Corumbataí Formation fossil plants in Rio Claro. He moved to the Geographical and Geological Institute (now the Geological Institute, IG) of São Paulo in 1946 and started cataloging the fossil collection. Although Mezzalira was an expert on the bivalves and crustaceans of the Passa Dois and Bauru groups, he also often studied Permian, Mesozoic and Cenozoic phytofossils. From 1953 to 1960, he developed a mapping project on the contact between the Corumbataí and Irati formations in the areas of São Carlos, Rio Claro, Piracicaba, Araras and Casa Branca, locating and collecting many fossils. He recorded new occurrences of lycophytes in Piracicaba, glossopterids in Tatuí and the fructification *Plumsteadiella* in the Tubarão Group. He described Cenozoic phytofossils from the Rio Claro Formation in Vargem Grande do Sul (SP), erecting a new fossil species of Melastomataceae, *Tibouchina izildaisabelae* Mezzalira.

Fifth Republic: Military dictatorship (1964-1985)

During the *Military Dictatorship*, more precisely in the period from 1968 to 1972, several post-graduate courses began to emerge in Brazil's geology schools, encouraged by CAPES. These courses included strengthened expertise in paleontology (mainly in the UFRGS, USP and UFRJ), including paleobotany. Foreign researchers such as Sergio Archangelsky from Argentina, Denise Pons from France and John Rigby from Australia were specially invited to encourage the study of paleobotany among graduate students of Rio Grande do Sul and São Paulo.

Many Brazilian paleobotanists of "generation 1968-1980" were trained in important paleobotanical centers abroad. Carlos A. Bortoluzzi trained between 1972 and 1973, Mary Bernardes-de-Oliveira performed a *sandwich stage* (between master and doctorate) in 1973-1974, and Margot Guerra-Sommer trained between 1980 and 1981. All three of these paleobotanists did this training at the *Laboratoire de Paléobotanique M. Le Prof. Édouard Boureau*, *Université Paris VI*, *France.* Oscar Rösler was trained between 1975 and 1976 at the *University of London*, *England*, by *Prof. William Gilbert Chaloner*.

The graduate students specializing in paleobotany in Rio Grande do Sul at that time (1968-1980) included the following:

Dr. Carlos Alfredo Bortoluzzi, who primarily studied the coal deposits of Santa Catarina and the Dicroidium flora of the Triassic Santa Maria Formation, Rio Grande do Sul.

Dr. Miriam Cazzulo-Klepzig (Figure 1R), who works at UFRGS studying Permian taphoflora from the Itararé Group to the Rio do Rasto Formation (Passa Dois Group) as a palynologist. She also studies macrofloras from a taxonomic, paleoclimatic, paleoecological and faciological point of view, and has published more than 40 works since 1979.

Dr. Margot Guerra-Sommer (Figure 1S), has been a professor at UFRGS since 1974. She structured the paleobotanist sector and implemented paleobotanical research in the IGEO/UFRGS post-graduate program. As a paleobotanist, Guerra-Sommer performs dendrological and paleoclimatic determinations of Paleozoic and Mesozoic taphofloristic associations of supersequences Gondwana I and Gondwana II of the Paraná Basin and the Lower Cretaceous of the Araripe Basin. She analyzes them from a taxonomic, taphonomic, paleoecological, paleoclimatic, relative and absolute (radiometry) dating point of view. In addition, she studies paleophytoatmospheric indicators of cuticular structure type of the Glossopteris flora and of *charcoal* and palynofacies studies and organochemistry of Quaternary sediments for paleoenvironmental, paleoclimatic and paleoecological interpretations. She has been endeavoring to train new paleobotanists.

Dr. Tania Lindner Dutra (Figure 1T) began her paleobotanical studies in 1974 and wrote a brilliant doctoral thesis on the Cretaceous-Tertiary floras of Antarctica (1997). As a lecturer at the University of Vale dos Sinos in Rio Grande do Sul, Dr. Dutra is practically the only Brazilian paleobotanist to develop studies on the Mesozoic and Cenozoic floras of the Antarctic Peninsula and their paleoecological, paleogeographic and biostratigraphic implications. She studies the Araucaria Forest of meridional Brazil, Southern South America and Australia, correlating it with the Paleogene floras of Antarctica. She also develops studies on Mesozoic floras of Southern Brazil. She has trained other paleobotanists.

Dr. José Henrique Millan represents the paleobotanists of the *"generation from 1968_to 1980*", in Universidade Federal do Rio de Janeiro (UFRJ). He received his doctorate from the USP (1970) with a thesis on the Pennsylvanian pre-Glossopteris flora of the Itararé Group, Paraná Basin, in Monte Mor (São Paulo State). Millan's thesis is a very comprehensive study of the components of that taphoflora that records the first occurrence of conifers and *Ginkgophyllum* in the Paraná Basin. Dr. Millan worked at the National Museum of Rio de Janeiro. In addition to becoming an expert of Gondwanan platyspermic seeds of Paraná Basin, he studied the Pennsylvanian taphofloristic occurrences in Itapeva and the Early Cisuralian in Cerquilho (São Paulo State), both of the Itararé Group. He can be considered the great student of the interglacial Itararé

Group floras in the state of São Paulo, although he has also studied the flora of the Rio Bonito Formation in Santa Catarina.

In the Geosciences Institute of the Universidade de São Paulo there were two Paleobotanists of the *"generation from 1968 to 1980":* Oscar Rösler and Mary Elizabeth Cerruti Bernardes-de-Oliveira.

Dr. Oscar Rösler (Figure 1U) is a paleobotanist from the State of Paraná. His thesis at USP (1972) was on the Early Permian flora of the Triunfo Member, in the lower portion of the Rio Bonito Formation in São João de Triunfo and Cambuí, in the State of Paraná. His thesis describes three new species of sphenophytes—*Sphenophyllum brasiliensis*, *Annularia occidentalis* and *A. readi*—associated with fern remains, glossopterids, lycophyta, etc. He created many collections of Carboniferous and Permian phytofossils throughout the Paraná Basin, which were deposited in the Scientific Collection of IGc / USP and located many new fossil outcrops.

Dr. Rösler became an important student of paleofloristic Lower Gondwana succession of the Paraná Basin and in 1978 proposed a paleofloristic succession scheme for the Gondwana I sequence (Itararé, Guatá and Passa Dois groups). He has authored more than 50 papers on the floras of the Tubarão and Passa Dois groups. He has supervised several master's degrees and doctorates in paleobotany at USP.

In 1978, with Dr. M.R. de Lima and Dr. M.E. Bernardes-de-Oliveira, Rösler started meetings of paleobotanists and palynologists (RPPs) at IGc / USP. These meetings or events have come to constitute a stimulus and integration tool for paleobotany students from all over the country and subsequently, beyond the limits of USP, gave rise to the Brazilian paleobotany symposia.

As Dr. O. Rosler foresaw in 1980, in an evaluation of the 2nd RPP: "*The symposium was successful and will certainly stimulate the realization of future events of this kind*, *because it has been shown that they stimulate scientific production in this area*, *and they constitute unique opportunities for discussing specific topics of direct interest to our paleobotanical community."*

Dr. Mary E. C. Bernardes-de-Oliveira's (Figure 1V) doctoral thesis at USP (1977) was on Glossopteris flora of the Late Cisuralian Siderópolis Member, upper portion of the Rio Bonito Formation, in the State of Santa Catarina. As a professor at IGc / USP since 1968, she operates in paleobotanical research, with many publications in the late Paleozoic Tubarão Group, Paraná Basin - Glossopteris flora. In the Early Cretaceous Crato flora of the Araripe Basin, along with North American (David Dilcher) and European (Barbara Mohr, L. Kunzmann, C. Coiffard, Denise Pons, etc) researchers, Bernardes-de-Oliveira has developed studies on ferns, gymnosperms, basal angiosperms and magnoliids (*e.g.*, new genera and species: *Ruffordia goeppertii*, *Welwitschiostrobus murili*, *Duartenia araripensis*, *Pseudofrenelopsis capillata Hexagyne philippiana*, *Schenkeriphyllum glanduliferum*, *Friedsellowia gracifolia*, *Jaguariba wiersemana*, *Spixiarum kipea*, *Cariria orbiculiconiformis*, *Pluricarpellatia peltata*, *Novaolindia dubia*, *Endressinia brasiliana*, among others). In the Paleogene and Neogene basins, she has developed studies on the paleobotany of the Continental Rift of Southeast Brazil basins: Taubaté and São Paulo *(Bauhinia aff. B. divaricata*, *Leandra sp.*, *among others);* the Aiuruoca Basin (*Nectandra*, *Annona*, *Caesalpinia veraechinataformis*, *Machaerium aiuruoquense Machaerium paleogenum*, among others) and the Peripheral Depression of São Paulo State-Rio Claro Formation (*e.g.*, *Ocotea fittipaldii*, *Typha meli*, *Aspidosperma duartei*, among others). Her publications are co-authored with her students and several Brazilian, South American, European, Indian and North American researchers.

Sixth Republic (1985 to the present)

During the Sixth Republic (1985 to the present), - *"Generation 1968-1980"* has attracted a new generation of Brazilian paleobotanists. This new *"Generation 1990-2016"* began to emerge in the 1990s and has been forming and developing to the present with great boldness, innovation and training. In addition to working with prints, this generation works with petrifactions and cuticles, phytofossils and charcoals. The new "*Generation 1990-2016*" works not only with revisions of taxonomy in impressions but also with paleoanatomy, phytostratigraphy, paleoecology, phytofacies, taphonomy, paleoclimate, paleophytogeography (using new study techniques), etc.

"Generation 1990-2016" in meridional Brazil

Dr. Roberto Iannuzzi (Figure 1W), who is a professor at IGeo-UFRGS, develops paleobotanical studies with paleophytogeographic, phytostratigraphic and paleoecological interpretations of both Carboniferous Rhacopteris flora and Permian Glossopteris flora. He began his paleobotanical studies with Dr. O. Rösler, analyzing Mississipian floras of Bolivia and Argentina in the form of impressions. Later, he also studied Permian floral impressions of the Terezina and Rio do Rasto formations in Santa Catarina and Paraná. He examined the *Dicroidium* Triassic flora of Rio Grande do Sul and its biostratigraphic implications with Dr. Guerra-Sommer. After studying some Permian filicophytes, sphenophytes and ginkgophytes of the

Paraná Basin, he began to analyze, especially with Dr. O. Rösler, South American paleophytogeography and biostratigraphy to observe the floristic migration and translatitudinal displacement of the continent during the late Paleozoic.

With his team and other collaborating researchers, Iannuzzi conducted herbivory analyses and an insect-plant interaction in Glossopteris leaves in the Paraná basin and the Bolivian Altiplano. He was the first to record the presence of herbivory in *Botrychiopsis* leaves in Western Gondwana. Without abandoning his studies on the Mississipian, he extended those studies to the Permian plants (*Asterotheca*, *Pecopteris* and *Glossopteris*) and drew (together with palynologist Dr. Paulo Alves de Souza) an overview of the floristic succession of Permian of the Paraná Basin in 2005.

Along with detailed taxonomic studies of glossopterids, sphenophytes, platyspermic seeds and pecopterids of the Late Paleozoic of Rio Grande do Sul, together with his students, Iannuzzi has performed taxonomic revaluations of the genera *Gangamopteris* and *Rubidgea*, *Cordaicarpus*, fructifications of Pteridosperms and described new species of *Phyllotheca*. In addition, he has re-evaluated the Poti flora (late Visean) and reinterpreted *Kegelidium lamegoi* Dolianiti of Parnaíba Basin. With Dr. Mercedes Di Pasquo and others, he developed new palynological information about the Poti Formation. He has also studied the Quaternary flora of Catalan (GO). At that time, Iannuzzi was also devoted to the study of the Cisuralian postglacial paleofloristic succession of Rio Grande do Sul. He has observed the genus *Paulophyton* in the Carboniferous of Paracas, Peru. With his team, Iannuzzi is studying the taxonomy, biostratigraphy and phytogeography of the Devonian paleoflora of the Paraná Basin.

Dr. André Jasper (Figure 1X) is a professor at UNIVATES in the State of Rio Grande do Sul. In paleobotany, he operates in the areas of plant paleo-wildfires through the analysis and microscopic study of charcoals, Gondwana paleofloras and paleoecology.

Dr. Jasper began his paleobotanical studies in 1999 with the arborescent cormophitic lycophytes of the Rio Bonito Formation. He also studied the *Botrychiopsis* and their biostratigraphic implications in the Paraná Basin. He has been devoted to studies on the evidence of Permian and Triassic paleo-wildfires and their relations with levels of atmospheric oxygen, observing the paleoecology of coal-related layers in Paraná Basin. He looks for paleobotanical evidence of paleo-wildfires in Permian and other geological periods not only in Brazil but also in other Gondwanan countries. The Permian woods of Tocantins State and *charcoal*s from various stratigraphic levels (Permian, Campanian, Barremian) of the Paraná, Parnaíba, Roraima basins and other Gondwanan countries such as India and Africa are studied with many collaborators and students. Along with co-authors, he registered the presence of *Lycopodites* in the Lower Permian of the Paraná Basin.

Dr. Jasper is the Brazilian coordinator for the Second International Scientific Cooperation Project Brazil-India of CNPq.

Dr. Isabela Degani-Schmidt (Figure 1Y) is dedicated to the study of the epidermal cuticles of fossil leaves, wood anatomy, charcoal structures and dispersed organic matter through observation with optical, scanning electron and fluorescence microscopies for the paleoenvironmental paleoecological and paleoclimatic interpretation of Permian bogs. She develops works, co-authored with Dr. Guerra-Sommer and others, on Ginkgophyte logs of the Rio Grande do Sul Triassic; the effects of volcanic ash on the Permian peatland; changes in the number of stomata in the Permian leaf epidermis of glossopterids of the Paraná Basin and its paleoclimatic and paleoecological relations; Albian/Cenomanian conifer logs of the Parnaíba Basin and Cisuralian *Agathoxylon*-type wood of the Paraná Basin; radiometric dating of Permian tonsteins in Southern Brazil; and correlations of solenoid complex woods level of the Irati Formation (Brazil) and the Upper Barakar (India).

It is noteworthy that the paleobotany school of Rio Grande do Sul, which began under the strong leadership of Dr. Margot Guerra-Sommer, increased by Drs. Tania Dutra, Roberto Iannuzzi and Andre Jasper, has stimulated the emergence of a strong group that is generating or spreading researchers to other parts of the country, including Dr. Robson Tadeu Bolzon of the University Federal do Paraná, Dr. Etienne Fabbrin Pires of the Universidade Federal do Tocantins, Dr. Juliane Marques de Souza of the Universidade Federal de Roraima, Dr. Carlos E. Vieira of the Universidade do Vale dos Sinos, and Dr. Nelsa Cardoso of the Pontifícia Universidade Católica do Rio Grande do Sul. Other researchers include Dr. Daiana Boardman, Dr. Graciela Tybusch, Dr. G.A. Roesler, etc., of the Universidade Federal do Rio Grande do Sul.

The new "generation 1990-2016" in Rio de Janeiro

Dr. Sheila Merlotti, one of the paleoxylologists still active in the area, grew up under the guidance of Dr. Diana Mussa.

Dr. Sheila Merlotti's doctoral thesis is from UFRJ (1994) and is entitled "*Lignitafoflora do município de Pouso Redondo*, *SC*, *Formação Rio Bonito*, *Supergrupo Tubarão*, *Bacia do Paraná*, *Brasil: considerações*

taxonômicas, *filogenéticas*, *tafonômicas*, *paleoecológicas e bioestratigráficas"*. Since that time, Dr. Merlotti has developed works on Permian gymnospermic logs of Rio Bonito Formation and Parnaíba Basin. She is an associate professor at the Universidade Federal de Santa Catarina.

The paleobotany of Rio de Janeiro almost became cruelly ostracized after the death and / or retirement of its brilliant researchers. A new impetus for the specialty has arisen from the hiring of Dr. Luciana Witovisk Gussella by the MN/UFRJ.

Dr. Luciana Witovisk Gussella (Figure 1Z) has a Ph.D. in Geosciences from UFRJ (2012) and is analyzing preserved logs for permineralization and carbonification and analyzing Antarctic Cretaceous leaves. She works in the field of paleobotany, especially Cretaceous logs from the Larsen Basin, James Ross Island, in Antarctica. She is currently professor of paleobotany in the Department of Geology and Paleontology of the National Museum - UFRJ. She is also directing undergraduate research in Taubaté Basin (São Paulo) and the Sub-Basin Center Tucano (Bahia).

The new "generation 1990-2016", trained at the Universidade de São Paulo

Under the guidance of Dr. Oscar Rösler, important Brazilian paleobotanists have trained at the Universidade de São Paulo and now work (or once worked) at other Brazilian universities. They include the following:

Dr. Fernando Cilento Fittipaldi (1951-2013, Figure 1XX), who under the guidance of Dr. Rösler began his master's studies of the cuticular characterization of *Glossopteris communis* Feistm., from Rio Bonito Formation, Paraná Basin. He introduced cuticular studies to Brazilian paleobotany with techniques for epidermal cuticle recovery.

Later, while preparing his doctorate, Fittipaldi devoted himself to the study of plant fossils of the Itaquaquecetuba Formation (São Paulo Cenozoic Basin), analyzing foliar or reproductive structures compressions of *Luehea divaricatiformis*, *Schizolobium inaequilaterum*, *Myrcia* cf. *rostrataformis*, *Psidium paulense*, *Byrsonima bullata*, *Serjania itaquaquecetubensis* and *Serjania lancifolia*. In addition, he proposed eight new species of angiosperms (*Ocotea pulchelliformis*, *Piptadenia tertiaria*, *Cassia rosleri*, *Sophora giuliettiae*, *Machaerium piranii*, *Bertolonia coimbrai*, *Tocoyena riccominii* e *Echinodorus rossiae*), a new fern species (*Lindsaea pradoi*) and a new bryophyte species (*Isotachis simonesi*).

Dr. Rosemarie Rohn Davies (Figure 1YY) is a professor at the Universidade Estadual Paulista (UNESP), in Rio Claro (SP). She works brilliantly in paleobotany, especially in the Permian of the Paraná and Parnaíba basins. Under the guidance of Dr. Rösler in 1994, she contributed greatly to the knowledge of the late Permian Glossopteris Flora of the Rio do Rasto and Teresina formations in the State of Paraná and Northern Santa Catarina, describing sphenophytes, pteridophylles and glossopterids. She also studied the pre-Glossopteris flora of the Itararé Group in Salto de Itu (SP) and proto-glossopterids (mainly sphenophytes) from Capivari and Cerquilho (SP). Recently, she has been dedicated to the study of the petrified logs *Tietea* and *Psaronius* of the Corumbataí Formation and Calamitaceae, Maratiales, along with the gymnosperms of the Parnaíba Basin. Among the paleobotanists guided by Dr. Rohn Davies, Dr. Tatiane Tavares Marinho Vieira, now at the Universidade Federal do Tocantins, and Dr. Rodrigo Neregato stand out.

Dr. Fresia Riccardi-Branco (Figure 1ZZ) is a lecturer at the Universidade Estadual de Campinas (Unicamp). In 1998 she studied for her doctorate the Gondwanan Taphoflora of the Triunfo Member of the Rio Bonito Formation (Asselian/Sakmarian) in the municipality of Figueira, State of Paraná, continuing with studies on the Late Paleozoic of the floras of Triunfo Member, lower portion of the Rio Bonito Formation, in the region of Cambuí, PR under the guidance of Dr. Rösler.

She conducts research in phytotaphonomy, Phanerozoic floras of South America and new methods of paleontological analysis.

In partnership with Dr. Bernardes-de-Oliveira, Dr. Riccardi-Branco studied the paleofloristic composition and succession in Itararé Group, of the State of São Paulo.

She conducts studies of the bryophytes and lycophytes of Corumbataí and Teresina formations, in the State of São Paulo, develops multidisciplinary studies in Quaternary paleoenvironmental reconstruction in Brazil, and develops paleofloristic studies in Araripe Basin. She also studied the Paleogene floras of Fonseca and Gandarela and has observed the characteristics of plant remains accumulations in the sub-basin of the Rio Preto and their distribution model in the area of Itanhaém, SP. She conducts paleophytogeographic and lignitaphofloristic studies in the Paraná and Parnaíba basins. She also develops a Quaternary paleoenvironmental analysis of the Cerrado / Atlantic Forest ecotone in the municipality of Mogi Guaçu (SP). She has also used data from multiple sources for paleobotanical analysis in the Carboniferous-Permian area of the Paraná Basin. Important paleobotanists guided by Dr. Riccardi-Branco include Dr. Jean Carlo Mari Fanton, Dr. Rafael de Souza Faria and Dr. Isabel Cortez Christiano de Souza.

Figure 1. Brazilian Paleobotanists, from early times to now. A- José Bonifácio de Andrada e Silva; B- Franz Unger; C- William Carruthers; D- Charles Frederic Hartt; E- Orville Adelbert Derby F- René Zeiller; G- H. Solms-Laubach; H- Charles David White; I- Edward Wilber Berry; J- Carlotta Joaquina Maury; K- Carl Rudolf Florin; L- Euzébio Paulo de Oliveira; M- Elias Dolianiti; N- Reinhard Maack; O- Otavio Barbosa; P- Diana Mussa; Q- Sergio Mezzalira; R- Miriam Cazzulo-Klepzig; S- Margot Guerra-Sommer; T- Tânia Lindner Dutra; U- Oscar Rösler; V- Mary E. C. Bernardes-de-Oliveira; W- Roberto Iannuzzi; X- André Jasper; Y- Isabela Degani-Schmidt; Z- Luciana Witovisk Gussella; XX- Fernando Cilento Fittipaldi; YY- Rosemarie Rohn Davies; ZZ- Fresia Riccardi-Branco.

The new "generation 1990-2016" formed at the Universidade de São Paulo under the guidance of Dr. Mary E. C. Bernardes-de-Oliveira includes the following scholars who work (or who have worked) at other Brazilian universities or other institutions: M.Sc. Sandra Eiko Mune (2005), who has published works mainly on the interglacial Pennsylvanian taphoflora of Monte Mor; M.Sc. Maria Aparecida dos Santos (2007), who has published works on Jaguariúna taphoflora; Dr. Paula Andrea Sucerquia Rendon (2007, 2013), who has published works on conifers (Cheirolepidiaceae) of Early Cretaceous Crato flora and works at the Universidade Federal de Pernambuco; M.Sc. Maria Cristina de Castro Fernandes (2011), who has published on platyspermic seeds of the upper part of the Itararé Group of Paraná Basin and Fabaceae of Aiuruoca Basin; M.Sc Carlos Humberto Biagolini (2012) and M.Sc. Alexandra G. Caramês (2012), who have reported on new taxonomic elements of taphoflora of Itaquaquecetuba Formation (São Paulo Basin); M.Sc. Elaine Priscila Gomes Estevam Biemann (2012), who has published on Welwitschiaceae of the Crato Formation and works at the Universidade Nove de Julho (UNINOVE); M.Sc. Fabiola Fabricio Braz (2012), who has published on Nymphaeaceae leaves and their insect damage; M.Sc. Amanda Hoelzel Mendes (2014), who has published on Gangamopterids from the Itararé Group in Cerquilho (SP) and M. Sc. Karoline Gonçalves Pereira (2014), who is preparing to publish on the Paleogene Myrtaceae of the Entrecórregos Formation. All these scholars' research articles have been co-authored with Dr. Bernardes-de-Oliveira and her collaborators.

Nevertheless, it is noteworthy that the IGc/ USP, the birthplace of many Brazilian paleobotanists and a stimulation and meeting center for Brazilian paleobotanists and palynologists that has hosted eight paleobotanists and palynologists national meetings (RPPs), is in need of new blood, *i.e.*, new recruits who specialize in paleobotany. Its huge paleobotanical material collection for study includes Neopaleozoic phytofossil collections of the Paraná Basin and Mesozoic phytofossil collections from the Araripe Basin and the Cenozoic basins in Southeastern Brazil, including Aiuruoca, Taubaté, São Paulo and Peripheral Depression of São Paulo. All this material awaits study by researchers.

We need to remember that at the Universidade Federal de Pernambuco and the Universidade Regional do Cariri, new groups of paleobotanists are being trained under the leadership of Drs. Alcina Barreto, Paula Sucerquia and Flaviana Jorge de Lima, whose primary focus of study is the Mesozoic floras of the northeastern parts of Brazil.

Final considerations

As seen from the foregoing account, the Brazilian paleobotany was and is, for the most part, conducted by geologists dedicated to this science or developed within geological institutions. Consequently, it has resulted in a paleobotanical approach for geological purposes: paleoclimatic, paleophytogeographic, phytostratigraphic interpretations or dating. Brazilian biologists turning to paleobotany through the influence or requirement of the "geological environment" are developing a paleobotany with a geological vision or purpose. Therefore, *our paleobotany needs more researchers from the biological area* or who are more concerned with phylogeny, evolution, biochemistry, etc.

It is necessary to remember that because of Brazil's huge land mass, the almost complete and abundant record over geologic time from the Silurian to the Holocene in large continental basins, and its proportionally small number of experts in this area, a great deal of paleobotanical material remains to be studied.

Overall, Brazilian paleobotanical studies, although significant, require more precise taxonomic identification of taphofloristic occurrences (whether known or unknown) and analysis of phytofossiliferous material under all types of preservation: impressions, petrified wood, compressions or charcoal, and epidermal cuticles of leaves.

This material should be analyzed through methods including simple observations in stereo-optical microscopy and the use of infrared light, scanning electron microscopy and transmitted light and tomography microscopy to extract the maximum information. It requires in-depth taphonomic and biostratigraphic studies with paleoecological and paleophytogeographic interpretations. However, phylogenetic and evolutionary interpretations are also required so that the long and complete story of Brazil's rich plant diversity, which so enthralled the first naturalists who were here, can be better known, completed and explained.

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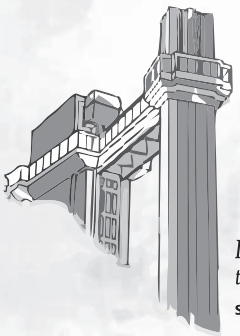
SYMPOSIUM SESSIONS (ABSTRACTS)



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Palaeobotany and Palynology: towards new frontiers

Salvador (Brazil) 2016

ADVANCES IN LONG TERRESTRIAL POLLEN RECORDS THROUGH INTERNATIONAL COOPERATION IN SCIENTIFIC DRILLING

Timme H. Donders & Laura Sadori

Cenozoic terrestrial climate change and the demise of forests on Wilkes Land, East Antarctica

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The question whether Cenozoic climate was warm enough to support a substantial vegetation cover on the Antarctic continent is of great significance to the ongoing controversial debate on the dynamic behaviour of Antarctic land ice during the transition from a greenhouse to an icehouse world. Here we present palynological results from an Eocene to Miocene sediment record provided by the Integrated Ocean Drilling Program Expedition 318 to the Wilkes Land margin (East Antarctica). We used red fluorescence to quantitatively identify reworked and *in situ* palynomorphs. The palynological record shows a change from a diverse early Eocene paratropical rainforest (54–51 Ma) to a cooler temperate rainforest dominated by the southern beech (*Nothofagus*) at ca. 51 million years ago (Ma) The early Oligocene assemblages (33.9-23 Ma) indicate further cooling and are characterised by cool temperate *Podocarpus-Nothofagus* forests with *Dacrydium* and *Lagarostrobos* (both common in southern forests of New Zealand and Tasmania today). A decline in *Dacrydium* and *Lagarostrobos* (Huon Pine) and absence of Proteaceae indicate climate cooling during the late Oligocene (~25-23 Ma). A strong cooling after the Oligocene-Miocene transition and subsequent establishment of a lowland tundra shrub during the Miocene is indicated by a sharp decline in tree ferns and disappearances of "unambiguous" forest indicators along with an increase in bryophytes. A return of some temperate woody plants can be recorded for the Middle Miocene Climate Optimum (17-15 Ma). Our pollen record suggests that temperatures at Wilkes Land were higher than in the Ross Sea region (i.e. Andrill, Cape Roberts) and the Wilkes Land margins were possibly one of the last refugia for temperate forest taxa on Antarctica during the Late Oligocene and Miocene.

***Keywords*:** Antarctica, Paleogene, Neogene, pollen, vegetation

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The history of glacial forest biodiversity from Europe's oldest lake

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The vegetation record of the Quaternary in Europe is characterized by successive loss of tree species due to the repeated migration across E-W oriented mountain chains during glacial-interglacial cycles. Relative to central Europe, tree diversity in refugia in the Mediterranean remained high for much of the Quaternary, although the precise relation between (regional) extinctions, climate variability and local edaphic factors is not known. Lake Ohrid, located at the Albanian/Macedonian border at 693 m asl, is the deepest, largest and oldest tectonic lake in Europe and formed between 1.2 and 1.9 Ma ago. Lake Ohrid is a biodiversity hotspot and a likely glacial forest refugium, containing a continuous sediment infill of glacial-interglacial vegetation cycles since its establishment. Within the International Continental Scientific Drilling Program (ICDP), the lake was drilled in 2013 and a 569-m long sediment core was collected. The DEEP site is analysed integrally by a team of palynologists. Here we investigate the botanical extirpation events that are documented in the palynological record and assess the relation between the tree cover and glacial-interglacial climate variability and local palynological richness. The record is dated independently through tephrastratigraphy and complementary tuning of biogeochemical proxy data to orbital parameters, and there is a good correspondence between forested / non-forested periods at Ohrid and glacial / interglacial cycles of the Mediterranean marine isotope stratigraphy, suggesting a regionally relevant vegetation and climate record. The base of the record contains occurrences of typical 'Tertiary elements' that currently occur in SE United States and SE Asia, such as *Taxodium* and *Liquidambar* and subsequent surprisingly young last occurrences of *Tsuga*, *Cedrus*, *Pterocarya*, *Carya* and possibly *Engelhardia*. While the some stratigraphic positions still need confirmation, reworking levels are minimal and, hence, with confirmed identifications a unique continuous terrestrial biodiversity record becomes available. The Quaternary biodiversity loss is clear and likely related to the strength and structure of the glacial phases. Rarefied palynological richness of tree taxa (i.e. corrected for variable count sums) shows relatively low variability. After the transition toward a more seasonally dry 'Mediterranean'-type climate during marine isotope stage 9 (i.e., ~ 300 ka BP) cumulative richness per zone, both in glacial and interglacial stages, actually increased, pointing to the refuge character of the site where, in glacial conditions, vegetation belts were compressed but tree diversity apparently remained largely intact.

***Keywords*:** Ohrid, biodiversity, relict tree species, ICDP, Quaternary

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New palynological data for the period between 190 ka and 110 ka from the oldest European lake

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Lake Ohrid (Albania / FYROM) is located in the north-eastern Mediterranean region at 693 m a.s.l., in a graben formed during the last phases of Alpine orogenesis. The lake is the oldest continuously existing lake in Europe. It was declared a UNESCO World Heritage Site in 1997 as it hosts over 210 endemic species that make it one of the largest water-reserves in the world.
Its sediments were retrieved in the frame of the project SCOPSCO (Scientific Collaboration On Past Speciation Conditions in Lake Ohrid) and the drilling was financed by the ICDP (International Continental Scientific Drilling Program). In April 2013, 6 parallel cores have been collected from the depocenter of the lake and a composite sequence 569 m long (DEEP), spanning at least the last 1.2 million years was obtained. The pollen diagram of the top 200 m of the sediment record has revealed that Lake Ohrid can be considered a valuable archive of biodiversity, and in particular of floristic, vegetation and climate changes that occurred over the millennia in the Mediterranean region. The record shows a progressive change from cooler and wetter to warmer and drier conditions during both interglacial and glacial periods. We present the pollen results of sediments ascribed to marine isotope stage 6 (MIS6) and the high-resolution of marine isotope substage 5e (MIS5e) corresponding respectively to the alpine Riss glaciation and to the last interglacial, the Eemian. Only few detailed pollen studies are available on MIS5e and this is due to the difficulty in finding so old materials in terrestrial records. The long glacial phase could be divided in two parts. The limit between the two open formations is marked by a change from a grassland-dominated environment (Poaceae and Cyperaceae) to a steppe-dominated (*Artemisia*) one. Dry conditions are also indicated by a decrease of *Quercus robur* type

and an increase of *Q. cerris* type together with *Juniperus* type and *Hippophaë* percentages. The second part of MIS6 appears to be the driest phase of the diagram. The interglacial Eemian is characterized by mesophilous communities prevailing on montane ones. Forests are mainly characterized by expansion of *Q. cerris* type and *Q. robur* type together with *Abies* and *Pinus*. The palynological results support the notion that Lake Ohrid has been a refugium area for both temperate and montane trees during glacial periods.

***Keywords*:** Lake Ohrid (Macedonia/Albania), pollen analysis, climate change, MIS6, MIS5e0

Impacts of climate on the vegetation history in eastern Anatolia (Turkey): New high-resolution pollen record from Lake Van

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Promoted by the potential of the sedimentary sequence for reconstructing the paleoecological and paleoclimate development of the Near East, a deep drilling operation was carried out in 2010 supported by the International Continental Scientific Drilling Program (ICDP). Lake Van, located on the eastern Anatolia high plateau in Turkey, provides a key position within a sensitive semi-arid region among the Black Sea, the Caspian Sea, and the Mediterranean Sea. Therefore, the long continuous sedimentary archive of Lake Van adds significantly to the picture of long-term glacial-interglacial variability and high-frequency (millennial-to-centennial scale) oscillations during the last 600 ka. A unique multi-proxy study, derived from pollen and microscopic charcoal data, stable oxygen isotopes from bulk sediment samples and X-ray fluorescence (XRF) measurements, provides the opportunity to examine different paleoenvironmental indicators, e.g., vegetation communities, erosion processes, melt water supply, evaporation rates, and moisture availability in the catchment area. The results show an alternation between forest periods and open steppe vegetation, a reflection of major climatic shifts from interglacial to glacial stages. During interglacials, high local and regional moisture level is documented by dense temperate arboreal vegetation. Here, an ecological succession is represented by (I) *Pistacia* cf. *atlantica* expanding early indicating summer dryness and mild winter conditions, (II) a temperate oak steppe-forest (deciduous *Quercus* and *Ulmus*) indicating warm/humid climate conditions with enhanced evaporation; followed by (III) *Carpinus betulus* phase (esp. during the last interglacial, MIS 5e) suggesting increased wet/cool conditions with reduced evaporation rate, and finally (IV) a period of *Pinus*-dominated steppe-forest documenting the onset of colder/drier environment. During glacials, moisture deficiency and lower winter temperature would have led to significant reductions in the density of tree & shrub communities. The increasing expansion of open desert-steppe vegetation (e.g., *Artemisia*, Chenopodiaceae) favors physical erosion and enhanced local terrigenous input. However, we are able to recognized pronounced temperate tree oscillations (Dansgaard-Oeschger like events) during glacial periods (e.g., MIS 4-2 and MIS 6). Furthermore, our robust chronological framework allows us to correlate the complete stratigraphical Lake Van record with long-term southern European terrestrial sequences, marine records, and ice-core archives to evaluate regional response to global climate changes of the Northern Hemisphere.

***Keywords*:** Lake Van, pollen record, glacial/interglacial cycles, paleoclimate

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Human-environment relationships in the Strymon Valley (Northern Greece). Coupling palynological and geomorphological approach in a long terrestrial record

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Our research presented in this oral communication has been conducted in the southern part of lower Strymon Valley in Northern Greece (around 100 km long and 15 to 20 km wide), which consists of more than 30 m of fluvio-lacustrine deposits for the Holocene period. A long terrestrial core (24.50 m deep), located into a favorable regional context to pollen records, between the Tenaghi-Philippon former marsh from less than 50 km and the Ohrid lake from 250 km was carried out recently. Furthermore, this core drilling takes place close to marine reference data for the Mediterranean Basin, 100km from the M2 and 150 km from the SL152. From an archaeological perspective, this area has the advantage of being situated at the outlet of a north–south axis that has repeatedly played a crucial role in the population dynamics of the Balkans and in exchanges between the Aegean world and southeast Europe. Consequently, this considerable sediment archives for the last 7 millennia and the archaeological knowledge reveal a significant potential for high resolution palaeoenvironmental studies. The reconstruction of environmental changes is based on a core with 17 consistent AMS. After multi-proxy geomorphological analysis (size particle analysis, LOI, Carbonate content, electric resistivity and magnetic susceptibility) we present in this work the pollen and non-pollen palynomorphs data. Palaeobotanical proxy gives an overview of a Rapid Climate Change episodes in the Eastern Mediterranean and Balkans regions such as the 4.2 ka cal BP event and thereafter a comprehensive view of anthropogenic impacts, on the vegetation cover. This case study highlights the interest to combine geomorphological data to palynological evidence in a rich archaeological context. It point out this necessity to assess the effects of specific farming and herding practices on the dynamics of mosaic landscapes in Mediterranean areas with greater precision and to discuss the question of human society-environment-climate interactions that do not always have the same periodicities from the Neolithic on.

***Keywords*:** Holocene, Greece, multiproxy analysis, human-environment relationships, 4200 cal BP event

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Colônia deep drilling project: long-term climate cycles in the Tropical rainforest

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The Colônia structure (23°52»S, 46°42'20»W 900m asl) is located near the city of São Paulo, in the Brazilian Atlantic rainforest, 4000 km south of the Amazon basin. The site is exceptional because it is located in the wet tropics of the Southern Hemisphere, a poorly explored region of the planet. It comprises a circular rim of ~3 km diameter and a sediment infilled basin. Thus, the drilling project will provide valuable new information to understand the climate, biological, and geomicrobiological evolution of this unique system. Numerous studies during the last decades did not allow to define the origin of the structure. Seismic surveys showed that the total infill could be ~500 m and it has been interpreted as comprising peat in the upper layer and lacustrine sediments from 9 m depth down to a layer composed of fine sediment until the rock basement. The geophysical information is complemented with core data showing a good preservation of bio and geochemical indicators allowing a continuous reconstruction of rainforest diversity and distribution. Based on these data it has been estimated that the site could contain a record covering the past 5 Ma and thus demonstrating the enormous promise of the Colônia structure for an ICDP drilling campaign. Additionally, our project will allow the potential identification of aquifers within this deep structure, an issue of major societal relevance considering its location close to one of the largest megacities (~20 M people) of the world and, thus, responding to one of the goals of the new ICDP science plan. Here we propose an integrated study of the Colônia structure to obtain cores from the peatbog and lacustrine sequences as well as the crater structure. This will provide ideal material to gather information on (1) environmental, climatic, and limnological change over several glacial-interglacial cycles during the past ~5 Ma; (2) the age and origin of the structure ; (3) the environmental and climatic context shaping the evolutionary history of floral elements; (4) long-term changes in the microbiome, as well as microbial processes occurring at depth in the peatbog and lacustrine sediment sections.

***Keywords*:** Atlantic forest, Southern Hemisphere, 5 million years, Plio-Pleistocene transition, Tropics

The climate in the Balkans during the last 500000 years inferred from Lake Ohrid (Macedonia/Albania) pollen data

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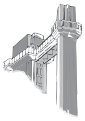
Lake Ohrid, a lake shared by the Republics of Albania and Macedonia, is one of the deepest and oldest tectonic lake in Europe. Its location at middle altitudes in a rift basin (693 m) surrounded by high mountain ranges, provides an excellent opportunity to study the impact of past climate changes on mid- to high-altitude forests. The location of Lake Ohrid at the confluence of temperate and Mediterranean climate influences makes it an exceptional site for recovering climate changes over the glacial-interglacial periods. Given its high potential for palaeoenvironmental studies, Lake Ohrid has been the subject of numerous investigations including a deep drilling carried out in 2013 within the framework of the Scientific Collaboration on Past Speciation Conditions (SCOPSCO) project. The DEEP site sediment sequence covers the entire lake history. An age model was established for the last 640 kyr, of which the last 500 kyr or 12 marine isotope stages have been integrally analysed at a millennial-scale resolution by a team of palynologists from several European laboratories. The so far existing DEEP pollen sequence records the major vegetation and climate changes. Results show that there is a general good correspondence between forested/non-forested periods and glacial–interglacial cycles of the marine isotope stratigraphy, suggesting a regionally relevant vegetation and climate record. Our aim is to obtain robust and precise quantitative estimates of the climate from the DEEP pollen record. The goal of this study is three fold: (1) to explore climate change on the Balkan Peninsula at the confluence of temperate and Mediterranean climate influences, (2) to identify the major patterns of climate change during the last 500 kyr in this region with a focus on the seasonality of the reconstructed climate parameters, and (3) to reconstruct the climatic change during the glacial and interglacial periods to better understand the variability of these glacial–interglacial cycles in south Europe. We also aim to produce a robust climate reconstruction based on a multi-method approach to better assess the error of the climate reconstruction. We use the Modern Analogues Technique (MAT), the Non-Metric Multidimensional Scaling/Generalized Additive Model method (NMDS/GAM), the Weighted Averaging-Partial Least Squares regression (WA/PLS), and the Probability Density Functions (PDF). The originality of our approach is also to integrate all the errors calculated by each method in an "optimal" temperature and precipitation reconstruction.

Keywords**:** Lake Ohrid (Macedonia/Albania), climate reconstruction, multi-method, ICDP, Quaternary



AN UPWARD OUTLOOK ON THE EVOLUTION OF PLANT FORM: EVO-DEVO APPROACHES INTEGRATING FOSSILS AND LIVING PLANTS

Kelly K. S. Matsunaga & Alexandru M. F. Tomescu

On the general evolutionary trends of female organs in land plants

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Since the occurrence of heterospory, enhanced nutrition supply and protection for seeds as well as their dispersal mechanisms are the major raceways in the evolution of female organs in land plants. Nutrition is of the major concern for the survival of the plants, and insurance of plenty of nutrition is a major advantage for plants during their survival competition. This is first exemplified in the distinction between megaspore and ovule, the latter remains on and derives further nutrition from the sporophyte after meiosis, and such extended nutritional bond is well exemplified in viviparity, namely, germination of seeds on the sporophytes. Protection of megasporangia or ovules is one of the major trends of land plant evolution, and plants demonstrate great variations in this term. First, ovules as megasporangia are protected by the integument (angio-megasporangium), which is frequently taken as an aggregation of surrounding sterilized peer sporangia. Second, the ovules are protected by various laminar structures derived from former branches. The different extent of seed protection and enclosure (angio-spermy) by such laminar structures and the spatial relationships between these laminar structures and the ovules define and distinguish various fossil or extant plant groups. These protective laminar structures have different appearances in different gymnosperms including the so-called seed ferns, giving rise to various morphologies of the fruits. Third, further protection occurs as pre-pollination ovule-closing (angio-ovuly). This feature distinguishes most angiosperms from gymnosperms, and is directly hinged with the great diversity and ecological success of angiosperms in the current ecosystem. Fourth, fruits derived from structures enclosing ovules are further covered by additional lateral appendages (angio-carpy). This is a level of plant evolution that not all angiosperms have reached. As the nutritional and protecting relationships evolve, different fruit types emerge in various groups throughout times, and, correspondingly, various fruit morphologies and dispersal mechanisms evolve. The coupling evolution between animals and fruits plays a crucial role in the diversification of angiosperms.

***Keywords*:** land plant, evolution, reproductive organ, protection.

Primordia, procambium, and polar transport – exploring the role of auxin in the evolution of tracheophyte body plans

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The hormone auxin has fundamental roles in plant morphogenesis. These are best documented in seed plants, where auxin is required for establishing longitudinal embryonic polarity, development of leaf primordia and phyllotaxis, maintaining apical dominance, patterning vascular tissues, and gravitropic responses. Auxin signaling mechanisms are present in all embryophyte lineages and likely inherited from charophyte ancestors. However, the extent to which auxin-associated developmental mechanisms documented in seed plants can be generalized across all tracheophytes is poorly understood. Here we review current knowledge on the roles of auxin in the development of seed-free tracheophyte body plans. There is mounting circumstantial evidence from extant and fossil plants that some auxin-associated developmental patterns may be shared among all tracheophytes: (1) presence of basipetal polar auxin transport (PAT) in shoots of *Selaginella*, rachises of filicalean and hydropteridalean ferns, and the vascular cambium of fossil lycopsids, sphenopsids, and lignophytes; (2)

auxin-associated apical dominance in ferns; (3) inhibition of root growth by auxin transport inhibitors in the fern *Ceratopteris*; (4) root branching promoted by auxin in *Selaginella*; (5) auxin regulation of root initiation and vascular tissue differentiation in filicalean ferns. While these general processes appear to be shared by all tracheophytes, other features suggest fundamental differences between the roles of auxin in the development of lycophyte body plans as compared to seed plants: (1) presence of acropetal PAT in non-root homologs – *Selaginella* rhizophores and isoetalean rhizomorphs; (2) decoupling of phyllotaxis and stelar architecture in *Lycopodium*; (3) unlike in seed plants, auxin inhibitors do not disrupt leaf primordia formation in *Selaginella*; (4) among fossil isoetaleans, rootlets (leaf homologs) exhibit helical taxis along rhizomorphs in which PAT is acropetal, suggesting different mechanisms regulate primordium initiation and phyllotaxis. Together, these observations indicate that while auxin has shared fundamental roles in the development of tracheophyte body plans, different auxin-related processes underlie lycophyte organogenesis, and auxin-related developmental controls across seed-free lineages have yet to be elucidated. Progress in these directions must come from studies of both extant and fossil plants. Because auxin is a key factor controlling the patterning of vascular tissues, which have very high preservation potential, clues to developmental mechanisms are recorded in fossils. Such anatomical fingerprints will provide insights into plant development at deep nodes of plant phylogeny, improving our understanding of features like leaf traces in *Asteroxylon* and the ring-meristem of rhizomorphs, and can be used to test hypotheses posed by studies of extant plants.

Keywords**:** auxin, development, lycophyte, *Asteroxylon*, rhizomorph

Experiments on lycopodium to test the hypothesis that leaf trace formation in lycophytes is under the same broad auxin controls as seed plants. This contributes towards testing the plausibility of the hypothesis that the leaf traces of asteroxylon are related to disruption in auxin production by leaf primordia

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Developmental modularity and hierarchy in the evolution of *Equisetum* reproductive morphology

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The origin and homologies of the *Equisetum* strobilus and sporangiophore have been debated for well over a century. The paradigm underlying these debates has been the traditional perspective that views the plant shoot as an alternation of nodes and internodes, with sporangiophores attached at nodes. The fossil record has been called upon to assemble transformational series explaining the evolution of the sporangiophore and strobilus. However, a number of fossil sphenopsids historically excluded from these discussions exhibit intriguing reproductive morphologies that suggest attachment of sporangiophores along internodes, challenging the traditional view of the sporangiophore as an appendage attached at a node. Such morphologies, illustrated by plants such as *Cruciaetheca* and *Peltotheca*, have rekindled debates that revolve around the evolution of the *Equisetum* strobilus, but lack of mechanistic explanations has led these discussions to a stalemate. To circumvent this, we propose a shift of focus from the node-internode view to another traditional perspective that emphasizes the phytomer as modular growth unit of the shoot. This perspective frees the debate of constraints associated with homology assumptions on the nature of the sporangiophore and inspires a mechanism-based hypothesis for the evolution of the strobilus, with implications for the homology of the sporangiophore. This hypothesis, supported by data from developmental anatomy and growth regulation mechanisms, teratological forms, and the fossil record, rests on two tenets: (i) growth of the equisetalean shoot arises from the combined activity of the apical meristem, which lays down the phytomer pattern, and intercalary meristems responsible for internode elongation within each phytomer; and (ii) plant meristems are equicompetent and shared genetic switches can turn on reproductive growth programs in the intercalary meristem where they lead to production of sporangiophore whorls that exhibit a basipetal maturation pattern. Within this framework, hierarchical expression of three regulatory modules responsible for (1) the (reversible) transition to reproductive growth, (2) determinacy of apical growth, and (3) node-internode differentiation within phytomers, produces the reproductive morphologies illustrated by *Cruciaetheca* (module 1 only), *Peltotheca* (modules 1 and 2), and *Equisetum* (all three modules). This model has implications that are testable by studies of the fossil record, phylogeny, and development, for directionality in the evolution of reproductive morphology (*Cruciaetheca*-*Peltotheca*-*Equisetum*) and for the

homology of the *Equisetum* stobilus. Furthermore, this model implies that sporangiophore development is independent of node-internode identity, suggesting that the sporangiophore represents the expression of a deeply ancestral euphyllophyte developmental module that pre-dates the evolution of leaves.

***Keywords*:** development, Equisetales, evolution, phytomer, strobilus.

An upward outlook reveals that heterospory evolved more than once in the Isoetalean lineage

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In a recent paper Dunn *et al.* 2012 reconstructed the ligulate, cormose-based, lycopsid plant *Winslowia tuscumbiana* except for the microsporophylls and microspores. Because conventional wisdom, based priamrily on the top-down phylogeny of extant *Isoetes*, suggests that cormose, ligulate lycopsids are heterosporous, it was assumed that this was a heterosporous plant that produced *Triletes* type megaspores. And the microsporophylls and microspores were yet to be recovered. *Winslowia* was recovered from a monospecific Serphukovian salt marsh assemblage in a limestone quarry in Tuscumbia, Alabama. Monospecificity of the marsh was suggested by the presence of only *Winslowia* organs in the assemblage. However despite the presence of only one set of plant organs, the presence of *Potoniesporites* prepollen suggested extrabasinal palynological influence in the assemblage. But we hypothesized that the major component of the microspore flora of the strata should be the microspore produced by *Winslowia*. Since *Winslowia* is a Mississippian lycopsid,we further hypothesized that the microspore should be the spore genus *Lycospora*, acknowledging that *Lycospora* was also produced by other Serpukhovian lycopsids. Ten palynology samples were processed into 24mm by 50mm strew slides and on one of the slides all of the microspores were counted and identified. Analysis of the other nine were by transect. However, our hypotheses were not supported. The first slide contained 6248 spores and *Lycospora* only comprised a plurality at 34.8% with *Cyclogranisporites* at 29.7% and *Granulatisporites* at 19.1%. Twenty-four additional spore genera were identified, but together only comprised 16.4% of the sample. Therefore, our hypothesis must be revised and we considered three possible alternatives. One alternative hypothesis would be that *Winslowia* was not heterosporous, but rather homosporous. A second alternative hypothesis would be that *Winslowia* might be dioecious with microspore producing plants spatially separated, and a third possibility would be that the production of microspores and megaspores is temporally segregated. Alternatives one and two are highly unlikely, leaving the alternative hypothesis that *Winslowia* was not heterosporous, but rather homosporous as the most parsimonious option. However, that would imply that the conventional wisdom suggesting that heterospory in the ligulate lycosids evolved only once is incorrect. In addition, the interpretation of the over 400µm in diameter, triletes-type spores are megaspores is also incorrect, and that, at least in part, some of these are isospores.

***Keywords*:** Cormose, Isoetalean, Ligulate, Lycopsid, *Winslowia*

New insights into the development of cambial variants in Pteridosperms

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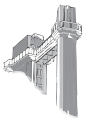
The stem anatomy of pteridosperms presents a wide variety of secondary vascular patterns, many of which are result of atypical cambial growth (i.e. cambial variants). Their origin and development has been subject of different interpretations since the late nineteenth century. In this contribution, we reinterpret the secondary growth patterns of seed fern families characterized by the presence of cambial variants. We classified the vascular patterns of pteridosperms in the following categories: 1. compound vascular

cylinder, constituted by vascular segments surrounded by cortical tissues (Medullosaceae, *Amosioxylon*), 2. secondary vascular cylinder divided in wedges by large parenchymatous rays (Corystospermaceae), 3. presence of centripetal secondary xylem and phloem (Corystospermaceae), 4. two vascular systems (Medullosaceae, Corystospermaceae, *Eoguptioxylon*), 5. successive cycles of centrifugal secondary xylem and phloem (Corystospermaceae). By comparison with the stem anatomy and cambial growth of living plants, we could elucidate the types of cambial variants involved in each vascular pattern. The compound vascular cylinder is determined previous to the earliest stages of secondary growth. The interfascicular cambium does not develop, while each primary vascular bundle is surrounded completely by one ring of fascicular cambium. This kind of cambial variant was called *multiple cambia*, since each ring of fascicular cambium function simultaneously and independently from each other. The secondary vascular cylinder divided in wedges is a result of *differential activity* of the interfascicular cambium, which only produces parenchyma and sclerenchyma cells. On its behalf, the centripetal secondary vascular tissues are developed by an additional cambium named *inverse* due to it generates xylem and phloem towards the pith. In the case of two vascular systems, their origin in *Eoguptioxylon* and Medullosaceae is different from those characterizing the Corystospermaceae. In the former, the two vascular systems are already existent in the primary vascular cylinder; the medullar system has numerous scattered vascular bundles with irregular secondary growth and the peripheral system possess ordered vascular bundles with a uniform secondary growth. In Corystospermaceae, the development of two vascular systems only begins with the secondary growth, considering that the primary vascular cilinder is unique. Finally, the successive cycles of centrifugal secondary xylem and phloem are produced by "successive cambia". Unlike the "multiple cambia", the successive cambia are not active at the same time. Conversely, after functioning for one or more years the first cambial ring cease their activity. Subsequently, a second cambial ring is developed from the innermost cortical parenchyma cells or wood parenchyma.

Keywords**:** ontogeny, cambium, Medullosaceae, Corystospermaceae



ATMOSPHERIC CHANGE AS A DRIVER OF PLANT MACROEVOLUTION

Jennifer McElwain & Kevin Boyce

At the mercy of O_2 and CO_2 – A novel approach on plant evolution

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The fossil record and models of atmospheric O_2 and CO_2 over the last 500 million years suggest that many major shifts in ecological dominance between the three major reproductive grades (i.e. monilophytes, gymnosperms and angiosperms) coincided with dramatic changes in Earth's atmospheric composition. Photosynthetic efficiency, which is a decisive factor in the ecological success of plants, is governed by the relative abundance of O_2 and CO_2, and sub-ambient O_2 levels have been shown to negatively impact plant reproduction and photosynthesis. However, the traditional view largely overlooks a potential role of O_2 and/or O_2:CO_2 ratio as drivers of plant evolution. Our aim was to investigate how fluctuations in O_2 and CO_2 may have influenced the timing of speciation, extinction and diversification events in the evolutionary history of land plants. In this context, we designed and carried out a number of highly novel 'miniworld' experiments. Plants belonging to all three major reproductive grades were grown under different O_2 and CO_2 concentrations and their fitness was assessed using physiological and anatomical methods. Our results reveal that the contrasting responses of angiosperms, gymnosperms and ferns are a legacy of differences in atmospheric composition at the time of radiation and clearly hint a role for O_2:CO_2 ratio in shaping patterns in plant evolution. Using deep time modelling we demonstrate that past changes in the O_2:CO_2 ratio resulted in shifts in the relative competitiveness of the three major plant groups, which seem to be in agreement with group-level richness changes observed in the fossil record. Furthermore, the innate physiological traits and differential response of each plant group to variations of the O_2:CO_2 ratio allow us to predict future ecological shifts in the composition of plant communities as a result of rising CO_2.

Keywords: Plant evolution, plant groups, plant-atmosphere interactions, O_2:CO_2 ratio, physiological convergence/divergence

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CO_2 decline and the rise of the angiosperms

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The angiosperms occupy almost every habitat type on Earth and comprise nearly 90% of extant plant species. Yet this rise to dominance is a relatively recent (geological) phenomenon with a variety of palaeobotanical evidence suggesting a likely first occurrence in the Early Cretaceous followed by a relatively rapid increase in diversity. Both proxy data and predictions from long-term carbon cycle models indicate that the angiosperm diversification was accompanied by a decline in atmospheric CO_2. This observation raises the intriguing possibility that declining atmospheric CO_2 concentration could have given angiosperms a competitive advantage when compared to other plant groups. Here we set out to test this idea by growing a six species (*Ranunculus acris* and *Polypodium vulgare*, chosen to represent Cretaceous understorey angiosperms and pteridophytes respectively. *Liquidambar styraciflua* and *Laurus nobilis* represented canopy angiosperms and *Ginkgo biloba* and *Metasequoia glyptostroboides* canopy gymnosperms) in controlled conditions across a CO_2 gradient (2000, 1200, 800 and 400 ppm) to simulate Cretaceous CO_2 decline. Using this experimental framework we will discuss the comparative ability of these species to acclimate physiologically, morphologically and biochemically. Analysis reveals shows that angiosperms have a greater capacity for acclimation suggesting that declining CO_2 could have acted as a trigger for the angiosperm rise to dominance in both the understorey and canopy, but perhaps more markedly in the understorey.

Keywords: Angiosperm, CO_2, ecophysiology, stomata, acclimation

Assessing the role of atmospheric oxygen in plant evolution

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Atmospheric oxygen has changed dramatically through earth history, ranging from 0% before the evolution of photosynthesis over 2.4 billion years ago to an estimated high of ~30% during peak glaciation of the late Carboniferous to early Permian. Much of the Triassic and Jurassic are characterised by atmospheric O_2 levels below present levels, rising again to O2 highs in the Cretaceous. Robust quantitative palaeo-O_2 proxies have yet to be developed and mass balance models which assess the carbon, sulphur and phosphorous cycles to estimate palaeo-atmospheric oxygen evolution remain hampered by significant uncertainties and error ranges. Despite these uncertainties, there is a general consensus that the Palaeozoic, Mesozoic and Cenozoic are characterised by distinctly different O_2 atmospheres. Atmospheric oxygen is vital for aerobic respiration of all eukaryotic cells, as O_2 is used as the final electron acceptor in respiration: the aerobic metabolism of glucose to generate ATP. In plants, respiration fuels growth, development, repair and reproduction. It is generally considered that O_2 concentrations above 2% fulfil most respiratory requirements of plants, however few experiments to date have grown plants in realistic and large scale palaeo-atmospheric chambers and most have focused on highly derived model angiosperms with little palaeobotanical or deep-time relevance. This presentation will be an overview of recent results from ERC grant OXYEVOL which aimed to investigate the role of atmospheric oxygen in plant macroevolution and macroecology. Results of leaf phenotypic and anatomical traits, as well as carbon isotopic and plant reproductive responses to both suboxic (<16%) and superoxic atmospheric O_2 (> 24.5%) will be presented. The role of oxygen in evolutionary selection will be assessed and the influence of atmospheric oxygen change on the performance of palaeo-CO_2 proxies will also be discussed.

***Keywords*:** atmospheric oxygen, stable carbon isotopes, vein density, stomatal density, leaf phenotype

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Growing plants in palaeo-atmospheres: effects on plant carbon isotopes and stomatal function

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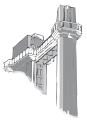
Plant evolution on land has resulted in many strategic adaptations to enable their survival. Tracking these adaptations over time can deepen our understanding of plant evolution and responses during critical changes in Earths past climates such as CO_2 induced global warming events. Plant stable carbon isotopes ($\delta^{13}C_p$) and stomatal function of C3 plants can be easily influenced by environmental factors and can therefore be used to give ecophysiological insight into fossil plants and the atmosphere they grew in. Plant stomatal function is controlled by stomatal aperture and/or density and is influenced by both atmospheric oxygen (O_2) and carbon dioxide (CO_2) concentration. Any such changes may cause changes in $\delta^{13}C_p$ also. Variation in stomatal function may have been a key factor influencing the evolutionary pattern observed in the fossil record. In order to investigate how fluctuating atmospheric O_2 and CO_2 may have influenced plant isotopic composition and stomatal function throughout plant evolution, representative species from the four major vascular plant divisions (lycophytes, ferns, gymnosperms and angiosperms) were grown in walk-in plant growth chambers for six months under ambient (21 % O_2 and 400 ppm CO_2), super elevated CO_2 (1900 ppm CO_2) and low O_2 conditions (16% O_2). Carbon isotopic composition was analysed for all species and stomatal responses to light were measured using a portable Infra-Red Gas Analyser. With the exception of one gymnosperm species, results show a significant disruption of physiological stomatal function in the high CO_2 treatment, with the low O_2 treatment showing no effect. Isotopic analysis shows that $\delta^{13}C_p$ has a species-specific response to O_2:CO_2 ratios, but with an overall trend towards increased discrimination. Although the experiment included a highly depleted $\delta^{13}C_a$, these results affirm the potential to interpret past O_2 and CO_2 levels from fossil $\delta^{13}C_p$. These results also demonstrate how super elevated CO_2 can impair stomatal function, but leave questions unanswered in regard to the role of O_2.

***Keywords*:** palaeo-atmospheres, stable carbon isotopes, stomatal function, plant evolution, growth chambers



ECOPHYSIOLOGICAL SIGNALS OF FOSSIL LEAVES AS INDICATORS OF ENVIRONMENTAL, CLIMATIC AND ATMOSPHERIC CHANGE IN DEEP TIME

Anita Roth-Nebelsick, Lutz Kunzmann,
Johanna Kovar-Eder & Karolin Moraweck

Paleoclimate and Paleoecology of Diverse Early Paleocene Fossil Flora from the San Juan Basin, New Mexico, USA

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Earliest Paleocene fossil floras from across North America have been characterized as being low diversity and dominated by long lived, cosmopolitan, mire adapted species. These patterns in floral composition and diversity have been hypothesized to be a response to the Cretaceous-Paleogene (K-Pg) mass extinction. However, this hypothesis is derived from studies in the Northern Great Plains of North America, and relatively little is known about floras from southern basins. This lack of data from southern North America limits regional comparisons of floral diversity, composition, and plant community response to the K-Pg boundary. The San Juan Basin (SJB), located in northwestern New Mexico, contains a nearly complete record of earliest Paleocene deposits, making it an ideal location to fill this gap in the record. Here we describe the composition and diversity of the earliest Paleocene floras in the SJB and use leaf physiognomic methods to reconstruct paleoclimate. We then compare the SJB floral and paleoclimate records to those from the Northern Great Plains. Fossil leaves were collected from the earliest Paleocene Ojo Alamo Sandstone in the SJB. The Ojo Alamo Sandstone corresponds with polarity chron C29r and was deposited ~66.0-65.7 Ma. Fifteen leaf localities were collected, with census collections made at 5 of the sites. The Ojo Alamo flora is dominated by dicot angiosperms in number of morphotypes and specimen abundance. Monocot angiosperms, ferns, equisetum, and conifers occur as accessory taxa at most localities. There are considerable differences in floral composition between localities indicating both lateral heterogeneity and a facies effect on species composition. The Ojo Alamo floras are relatively diverse (site average = 18 morphotypes, total = 51 morphotypes). Importantly, these floras are significantly more diverse than previously studied locations further north with a large proportion of morphotypes endemic to the SJB. Using Digital Leaf Physiognomy, mean annual temperature and mean annual precipitation for the earliest Paleocene in the SJB was 24.9 (±4.0) °C and 159.8 (+128.5, -71.2) cm/yr, respectively, which is warmer and wetter than climate reconstructions from further north. Leaf mass per area estimates indicate the Ojo Alamo flora was dominated by deciduous species, with some evergreen taxa also present. These results indicate that a diverse and largely endemic plant community existed in the SJB within <~300 kyr of the K-Pg boundary. Further, the comparison of regional floral diversity show a large north-south gradient in diversity suggesting variable responses to the K-Pg mass extinction across North America.

***Keywords*:** Cretaceous-Paleogene Boundary, Paleocene, paleoclimate, paleoecology, leaf physiognomy

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A leaf gas-exchange model for reconstructing paleo-CO_2: ground-truthing and fossil applications

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There is a pressing need for reconstructing atmospheric CO_2 concentrations in the past, both for understanding Earth system behavior over geologic time and for honing predictions of future climate. This need is especially acute for the pre-Cretaceous, where presently only one quantitative paleo-CO_2 proxy has been broadly applied (the pedogenic carbonate proxy). Recently, a new CO_2 proxy was proposed that is based on the behavior of gas exchange in leaves (Franks *et al.*, 2014, *Geophysical Research Letters*, 41: 4685-4694); the three required inputs are stomatal density, stomatal size, and leaf $d^{13}C$. In principle, the proxy can be applied to any species with stomatal-bearing leaves, thus opening up much of the paleobotanical record for CO_2 inference. Despite its considerable promise, confidence in the new proxy would be strengthened if it could be verified in more extant species. Here we present CO_2 estimates based on measurements from 23 species of field-grown plants in Connecticut and Panama (the latter were sampled from a canopy crane), and 10 species grown in controlled chambers at lower (400-500 ppm) and higher (700-1000 ppm) CO_2 concentration. The majority of the CO_2 estimates are close to their targets, even when using very general (vs. species-specific) inputs for scalars such as the ratio between operational to maximum stomatal conductance and the ratio between guard cell width to length. A minority of species are off-target (usually falsely high), even when using species-specific scalars. Overall, the model appears robust for most of our tested species. With this information in hand, we applied the proxy to several key intervals in Earth history: the aftermath of the end-Cretaceous mass extinction during the fern spike, a tropical-looking forest from the early Paleocene in Colorado where CO_2 can be estimated with independent proxies, a middle Eocene fossil forest from the Canadian high arctic, and a middle Miocene tropical rainforest from Panama. The proxy, when applied judiciously, shows great potential for enriching our understanding of the geologic history of atmospheric CO_2.

Keywords**:** Carbon dioxide, paleoclimate, end-Cretaceous, Paleocene, Miocene

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Precipitation and leaf size in modern day Australian and Fijian tropical forests provides insights into Australian Eocene and Miocene climates

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Leaf size varies with annual precipitation in both regional and global datasets, but this relationship appears to be confounded in some regions by: (1) leaf life span (dominance by deciduous vs. evergreen woody dicots), (2) soil fertility, and (3) the seasonality of precipitation. The variation of leaf traits along climate gradients is used in palaeobotanical climate proxies such as Leaf Area Analysis (LAA), which is based on a correlation between mean leaf-area of woody species in modern western hemisphere forests, and mean annual precipitation (MAP). Northern Australia and adjoining island areas, including Fiji, have a monsoonal climate where wet season precipitation is > 75–85% of annual precipitation. These areas also share a common tropical dry forest flora rich in deciduous tree taxa in contrast to the regional dominance by broadleaf evergreen taxa in ever-wet forests and sclerophyllous woodlands and savannahs. In this report, 101 Australian and 9 Fijian sites from tropical seasonally-dry to humid forest sites (MAP 47–438 cm/yr; mean annual temperature 17.6–28.4°C) were examined to assess whether these forests in Oceania show the same relationship as the original LAA calibration and whether seasonality affects leaf area. Only tropical sites were included to minimize confounding effects of temperature. Our data show that: (1) Australian and Fijian tropical seasonally-dry deciduous to humid evergreen forests show the same relationship between mean leaf area and annual precipitation as the original western hemisphere LAA calibration and they show a more precise correlation than either that dataset, a 'global' calibration or other regional datasets; (2) the wettest evergreen forests (MAP ≥ 200 cm/yr, Dry 3 months ≥ 15 cm) display fewer large-leafed species than expected from the western hemisphere calibration; and (3) precipitation seasonality affects leaf-size precipitation relationships. New estimates of MAP are provided for Australian Eocene and Miocene macrofloras, demonstrating MAP 56–232 cm/yr but with large errors, with interior sites with low MAP, likely reflecting seasonally dry climates.

Keywords**:** leaf physiognomy, monsoon, precipitation, Eocene, Miocene.

Vegetation, climate and atmospheric change prior to the Eocene-Oligocene transition: the terrestrial perspective from northern central Europe

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Cenozoic basins in northern central Europe, Germany: Weißelster, Czech Republic: Cheb, Sokolov and North Bohemian, have an extensive megafossil record of Paleogene and Neogene vegetation including across the Eocene-Oligocene transition (EOT) and the late Oligocene warming. Herein we focus gradual changes between the late Bartonian and the EOT, a time interval of gradual global cooling. Results of investigations of new fossil floras from the Weißelster Basin are summarized and placed in context of the modern lithostratigraphic concept for central Germany. Previously published floras from this basin that come from unambiguous lithostratigraphic positions are revisited. Czech floras are included for comparison. Based on these distinct plant fossil associations paleoclimatic parameters are reconstructed (CLAMP, Coexistence Approach), and paleoatmospheric pCO_2 is estimated using either the Stomata Density approach or the Mechanistic Gas Exchange approach. Results show a gradual change in the composition of megafossil associations prior to the EOT, i.e. in riparian forests associations. Several consecutive floristic stages can be recognized based on disappearance of typical 'subtropical' species, immigration of thermophilous evergreen and deciduous species and by the persistence of warm-temperate elements in the Oligocene. The latter were able to withstand significant climatic changes during the EOT. A massive immigration of broad-leaved deciduous elements prior to the EOT occurs in the North Bohemian Roudníky flora but has not been recognized in the Weißelster Basin. For most of the middle to late Eocene sites a moderate seasonal 'subtropical' to warm temperate climate is reconstructed. Temperature changes corresponding to the gradual cooling trend in the marine realm could not be quantified due to several reasons, e.g., taphonomic biases, low diversity of the fossil associations etc. The inverse relationship between stomatal density and pCO_2 from a unique stratigraphic sequence of fossil leaves of *Eotrigonobalanus furcinervis* (Fagaceae) was used to derive pCO_2 records. Atmospheric pCO_2 decreased continuously from the late middle to late Eocene, reaching a relatively stable low value before the end of the Eocene. Similar trends were documented in an overlapping stratigraphic sequence of *Platanus neptuni* (Platanaceae) leaves to which the Mechanistic Gas Exchange Approach was applied. These investigations of floristic changes and changes in paleoatmospheric composition derived from the megafossil plant record in northern central Europe reveal similar trends in the middle to late Eocene and may coincide with the global cooling trend postulated from the marine isotope record.

***Keywords*:** Paleogene, vegetation dynamics, paleoclimate changes, paleoatmospheric composition, central Europe

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Adaptations of fossil leaves to paleoclimatic and paleoenvironmental change during the Paleogene

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Within the project "Ecophysiological signals of plant fossils as indicators of climatic and atmospheric change during the Paleogene" we study the response of Paleogene vegetation to climate changes and evolve new techniques tracing these changes based on leaf traits. During the Paleogene major shifts in temperature, humidity and CO_2 occurred, which should be reflected by distinct changes of different morphological and anatomical traits and their corresponding leaf functions. For this purpose we recorded anatomical, morphological and morphometric data of certain fossil taxa from Europe with a long stratigraphic record, which grew under various environmental conditions (coastal and riparian habitats, volcanic sites, hinterland floras). We try to couple micro- and macromorphological leaf traits of long lived fossil plants (1) to get insights into changes of anatomical and morphometric leaf traits through time under given paleoclimatic and paleoatmospheric conditions and (2) in different paleoenvironments assuming a correlation between habitat and leaf morphology and leaf anatomy. First results were derived from leaves of the extinct Platanaceae *Platanus neptuni*, representing an important thermophilous element of subtropical to temperate vegetation in Europe within the late Eocene up to the upper Miocene, which grows under various paleoenvironmental conditions and *Rhodomyrtophyllum reticulosum*, an evergreen subtropical species within the middle to late Eocene, forming mass occurences in fluvial plant taphocoenosis. The data reveal dependencies between anatomical traits (stomata density, stomata index, pore length, trichome density) and morphometric traits (leaf area, leaf length, leaf width) with paleoclimate data and mirror differences in sedimentary facies types. The derived leaf trait data and paleoclimate data have been used to reconstruct paleoatmospheric conditions using the gas exchange model. Alongside these taxon-based approaches we also established a method to obtain the leaf type composition of fossil plant assemblages (e.g. lobe shapes, margins, primary and secondary venation). The existence and frequency of leaf types could be used as a fingerprint to determine paleoecological and paleoclimatic conditions. The contribution will focus on possibilities, innovative methods and combinations thereof using leaves of fossil plants as tools for reconstructing ancient paleoclimatic conditions and, other way around, the response of vegetation on paleoclimatic changes.

***Keywords*:** Paleogene, leaf traits, stomatal density, paleoclimate, paleoenvironment

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Rapid leaf character response to climate variability in *Vitis*: Implications for leaf physiognomic paleoclimate reconstructions

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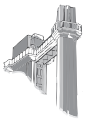
The size and shape (physiognomy) of woody, dicotyledonous angiosperm leaves are correlated to climate. These relationships have been used to develop paleoclimate proxies. Many plant communities, particularly in Northern Hemisphere temperate regions, have an inverse correlation between temperature and the degree of leaf dissection and the presence of teeth, as well as tooth size and abundance. One of the underlying assumptions of leaf physiognomic-paleoclimate proxies is that leaf traits can plastically respond to climate such that that leaves reliably track changes in temperature and precipitation. Additionally, it is also assumed that leaf traits allometrically scale as a leaf matures through the growing season, such that juvenile and mature leaves have similar leaf traits. However, little work has been done to determine how quickly leaves plastically respond to changes in climate or whether all leaves on a plant respond in the same way. We used Digital Leaf Physiognomy (DiLP) to measure leaf characters of multiple *Vitis* species from two growing seasons with different temperatures and precipitation. The same vines were sampled each year in order to compare leaf shape on a vine-by-vine and leaf-by-leaf basis. We found three primary results: (1) there were predictable significant differences in leaf characters in leaves of different developmental stages along the vine, (2) there were significant differences in leaf characters in leaves of the same developmental stage between the growing seasons, and (3) when averaged by plant there were significant differences in leaf characters between the growing seasons. Differences in leaf traits through leaf development have significant implications for paleoclimate reconstructions as it suggests that sampling leaves are different stages in their heteroblastic development could confound leaf trait-climate relationships, which in turn could bias paleoclimate reconstructions. Interestingly, these results are similar to analyses of variability in the lobing of the same leaves between growing seasons. Together these findings indicate that at least some leaf traits, and in particular leaf lobing and leaf teeth, can plastically respond to differences in climate in as little as a single growing season.

***Keywords*:** leaf physiognomy, paleoclimate, climate change, leaf development



ECOLOGICAL INSIGHTS FROM PALYNOLOGICAL AND MACROFOSSIL ANALYSIS OF QUATERNARY DEPOSITS

Simon Brewer, Thomas Giesecke, Petr Kuneš & Sonia L. Fontana

Forest composition changes through time in western Mediterranean during the last 7500 years

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The Mediterranean basin is located in a transition zone between tropical and temperate areas. It is characterized by a Mediterranean climate with dry/warm summers and mild/wet winters. In France, the Mediterranean area represents only 15% of the national territory. It sheltered around 68% of the French vascular plant diversity and is one of the regions with the highest forest cover (43.4%). Besides its inherent value for biodiversity conservation, the Mediterranean forest also has a high economic value. Conservation of vegetal biodiversity is now considered a prior socio-economic task for politics and is a challenging issue for scientists. In the recent past, the French Mediterranean forests underwent the strong impact of human activities and almost disappeared during the 19th century. However, disentangling the influence of present climate change from human activities on these very disturbed environments must be considered in a long time perspective. In that sense, high resolution pollen analyses are undertaken on a core from the Palavasian lagoon system (Herault, southern France) to provide key information for scenarios simulating the near future changes of the forested cover. The pollen sequence is used to investigate the factors triggering forest successional pathway in the French Mediterranean during the last 7500 years. Five successive phases of vegetation dynamic are depicted along the sequence. The thorough comparison of the pollen data with climatic, archaeological and historical archives addresses consistent hypothesis for causes possibly responsible for the main observed changes. Indeed the long term aridification trend depicted since the second half of the Holocene in the western Mediterranean, the multi-decadal arid events and the anthropogenic cycles of deforestation and reforestation shaped the present day Mediterranean forested landscapes in southern France.

***Keywords*:** Mediterranean forest, Holocene, Human impact, arid events, deforestation/reforestation cycles

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From natural to human-made landscapes and ecosystems: a case study from Eastern Mediterranean

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Elaia, the harbour city for ancient Pergamon (western Turkey), was investigated using geoarchaeological methods. The rise and fall of Elaia were closely linked to the flourishing period of Pergamon, which ruled wide parts of today's western Turkey in Hellenistic times. In the framework of this research, the palynological analysis of a 9 m sediment core, Ela-70, retrieved from the enclosed harbour of the city, was carried out to reconstruct the vegetation and environmental history of the wider Gulf of Elaia region. An age-depth model, based on 11 calibrated radiocarbon ages, starting from 7.5 ka BP, provides the basis for the high resolution study of sediments from the Hellenistic period, as well as before and after. The palynological record from a sediment core from the long since silted-up basin of the harbour of Elaia, provides insight into the vegetation dynamics and the long-term human impacts on terrestrial and lagoon ecosystems of the Bay of Elaia since prehistorical times. Around 7500 years ago, the landscape was covered with open oak forests, which later experienced several phases of deforestation alternating between natural forest recovery phases. At about 850 BC, the intensification of the land-

use is evidenced by the appearance of olive groves, agriculture, arboriculture, increased pasture pressure, and soil erosion. The strongest impact is documented during the phase when Elaia's harbour was in full operation. The phase of very intensive land-use and possibly over-use of the ecosystems lasted for more than 1500 years. This seems to have led to a change of the climax plant communities from open oak forests to an even more open vegetation and pine forest. Based on palynological data from the sediment core Elaia, we argue that large areas of modern pine forests in western and southern Turkey very likely represent human-made landscapes.

Keywords**:** palynology, non-pollen palynomorphs, harbour, Turkey

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Palaeo-megafires cause canopy replacement in the SE Australian highlands

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Perceptions of fires in the Australian environment are often dominated by notions of their destructive powers that lead to deforestation and degradation of diverse and "pristine" habitats. These notions have been exacerbated over the last two decades by mega-fire events associated with a series of prolonged droughts in which vast areas of forest were lost. How often have mega-fires occurred in the past and what are the causes and consequences of palaeo-megafires in the Australian landscape? Records of ancient macroscopic charcoal and pollen morphotypes show that fires have been an important factor in SE Australian *Eucalyptus* forest dynamics on Quaternary timescales. To investigate the influence of palaeo-megafires on *Eucalyptus* morphotypes, we used a regime shift detection method to model changes in a high-resolution palaeoecological temporal series from Bega Swamp in the SE Australian highlands over the past 16000 years. The record shows major changes in *Eucalyptus* forest types at 9500 and 5000 cal yr BP, which lagged the charcoal inferred fire-frequency peaks by around 100 years. Innovative modeling approaches suggest rapid transformation of past plant communities in the face of major environmental change.

Keywords**:** Australia, Palaeo-Megafire, charcoal, canopy replacement, regime shift

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Mid- and Late Holocene vegetation dynamics and fire history in the boreal forest zone of European Russia: a case study from the south-eastern part of Meshchera Lowlands

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The new results from paleoecological studies of vegetation and fire history over the last 8500 years in the south-eastern part of the Meshchera Lowlands based on pollen, plant macrofossils, testate amoebae and charcoal records from peat sequences are presented. Changes in woody coverage were reconstructed using the Best Modern Analog technique which allowed us to assess responses of vegetation to fire disturbance in the past. The obtained results showed that most of the changes in the regional vegetation during the Mid- and Late Holocene were mainly influenced by the climate and fire regime. Since 8500 cal yr BP, the vegetation history represented a series of consecutive phases of birch, birch-pine and pine-broadleaf forests with participation of spruce after 2500 cal yr BP. The maximal abundance of broadleaf tree species was detected for the period of 4700-2000 cal yr BP. Since 1400 cal yr BP, vegetation dynamics were strongly influenced by human activity. High fire frequencies were reconstructed for the periods of 8500-5000 cal yr BP and 3000-2000 cal yr BP, when the fire return period varied from 70 to 200 years. The fire frequency reduced in the last two millennia, while the fire return period increased to 200-500 years. This work was supported by the Russian Foundation for Basic Research, projects 15-05-00550.

Keywords**:** pollen, plant macrofossil, testate amoebae, fire frequency, woody coverage

Disturbance and topography determine time lag of forest-steppe ecotone response to the Holocene climate change

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Forest-steppe ecotone was hypothesized to be sensitive to climate drying; however, our pollen evidence from 18 sites within the forest-steppe ecotone in northern China indicate that there are time-lags of up to 2000 years for the replacement of forest by steppe as a response to climate drying during the mid- to late-Holocene. The resilience of forest to climate drying in the forest-steppe ecotone was related to disturbance. Fire was suggested as a triggering disturbance that acted to reduce the resilience of forests to drought and prevent rapid forest recovery under subsequent climatic amelioration. No simple anti-correlation between fire and Pacific monsoon intensity suggested by previous studies was found, highlighting vegetation as a critical factor for fire occurrence through the accumulation of fuel in the forest-steppe ecotone, where vegetation growth is strongly constrained by precipitation. With climate drying, pine forest replaced broadleaved forest, leading to more intensive fire. Consequently, pine forest was gradually replaced by steppe and fire intensity declined. The duration of this process extended from ~4 cal ka BP to ~2 cal ka BP. When the forest-steppe ecotone moved across mountains, topographic factors cannot be ignored. Altitude range was suggested to be the most important topographical factor. Large altitude range permits different vegetation coexisting at local scale. Climate change might drive altitudinal movement of vegetation at local scale, which did not change pollen assemblages in lake sediment. Besides replacement of forest by steppe, we found also savannification of forest indicated by pollen concentration, which is also part of resilience of forest to drought. The savannification can also lead to time-lag of replacement of forest by steppe interpreted by pollen assemblages. In summary, the time-lag of replacement of forest by steppe was either caused by vegetation resilience, or by undetected changes in pollen percentage diagrams. Disturbance reduced vegetation resilience, but did not lead to prompt evolution of vegetation due to feedback between disturbance and vegetation evolution. It is implied that the current prediction of fast recession of forest in the forest-steppe ecotone to climate drying should be reevaluated.

***Keywords*:** Holocene, pollen analysis, forest-steppe ecotone, fire, altitude

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Exploring vegetational and agricultural dynamics during the Neolithic (7000-4200 BC) on the Swiss Plateau by using annually layered sedimentary time series

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Annually layered lake sediments (also called varves) are rare. For the Swiss Plateau, we present two new sites with varved sediments that cover the period of first increasing human impact during the Neolithic (7000-4200 BC). The two small lakes are Burgäschisee (465 m a.s.l., 21 ha) and Moossee (521 m a.s.l., 31 ha). For both lakes, Neolithic pile dwellings from the Cortaillod Culture (3900-3500 BC) are known. One settlement at Burgäschisee ("Burgäschi Ost") is part of the UNESCO World Heritage (Prehistoric Pile Dwellings around the Alps). Mostly, the Neolithic landnam phases were rather short-lived (less than 20 years). However, the high precision of the varve chronology together with an 8-year resolution sampling allows identifying these short-term settlement phases. Cultural indicators such as Cerealia-t. (t.= type), *Plantago lanceolata*-t., *Linum usitatissimum*-t., *Papaver rhoeas*-t. and others, light-loving shrubs such as *Corylus avellana* and *Juniperus* (indicator for more openness of the landscape), macroscopic charcoal (indicator for local fires), green algae such as *Tetraedron minimum*, *Coelastrum* and *Botryococcus* as well as cyanobacteria such as *Anabaena* and *Aphanizomenon* (indicator for eutrophication) point to several local occupation periods during different cultural phases. Our results show that some cultural phases were present at both lakes (e.g. Cortaillod Culture), while other occupation phases were more prominent at only one of the two lakes (e.g. Horgen Culture (3500-2750 BC) at Burgäschisee, Corded Ware Culture (2750-2400 BC) at Moossee). Sometimes, no local archaeological evidence has been found so far, even though our results indicate local human presence (e.g. Horgen Culture at both lakes). Our high resolution

analysis suggests shifts from crop farming with more cereals to small meadows with probably more cattle farming during the Horgen Culture. We use our data to thoroughly check the Central European succession theory by analyzing post-disturbance patterns at subdecadal to millennial time scales. Afforestation usually starts with shrubs (e.g. *Corylus avellana*) and tree *Betula* as a pioneer tree. The climax forest was a mixed beech forest with mainly *Fagus sylvatica* and other deciduous together with *Abies alba*. We show an analysis of early human impact and vegetation responses with a precision and resolution that has never been reached before in Central Europe. The new data provide ample evidence of strong vegetation reorganizations and marked fire regime shifts in response to human impact.

***Keywords*:** Annually laminated sediment, archaeology, land use, multiproxy, high resolution

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New data on analysis of extant plants to enable better implementation of molecular paleoecology

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A growing area of interesting is the use of biogeochemical methods to interpret paleoecology of ancient sediments to supplement the micro to macrofossil record. Although our understanding of the relationships of molecular fossils to our understanding of sedimentology and paleoecology has grown, there still remain large gaps in our knowledge of living systems, diagenesis and fossil biomarkers. Combined, these gaps prevent full reconstruction of paleovegetation and paleoclimate. Recently, we analyzed several different living collections and share the following preliminary results: 1) Using hydrous pyrolysis to artificially mature specimens, at higher temperatures, triterpenoids (angiosperm biomarkers) appear to preferentially disappear compared to diterpenes (conifer biomarkers). 2) Concentrations of n-alkanes and terpenoid compounds from living herbaceous plants vary, as do the concentrations in different organs, but not in a consistent way. 3) Analysis of a larger diversity of living species representing many fern lineages indicates that there are no universal biomarkers for the clade, but that some subgroups might be identifiable. 4) Herbs and woody plants may have significantly different concentrations of alkanes and bulk triterpenoids. Together, this information will help to constrain paleoecological interpretations made from plant biomarkers preserved in the geologic record and will hopefully provide clues about early plant evolution and the rise of angiosperms.

***Keywords*:** biogeochemistry, paleoecology, paleoclimate, n-alkanes, biomarkers

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How resistant are pollen-based climate signals to the influence of humans?

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Settlement of any region by large numbers of people, such as the European settlement of North America, is a known cause of significant floral change. A spike in *Ambrosia* pollen often accompanies such large anthropogenic disturbances, which occurs as this weed opportunistically colonizes disturbed areas. Anthropogenic driven changes to flora are reflected in the pollen records of lakes, bogs, and nearby repositories, and this man-made change in the pollen spectra has long been suspected of overprinting natural parameters such as climate. The goal of this study was to investigate the efficacy of pollen-based climate reconstructions from three man-made lakes with varying levels of human disturbance. The three lakes (Bray Area, Pine Forest, and Frisco) located in and around the city of Rolla (Missouri, USA) were manually cored and evaluated for palynology, geochemistry, mineralogy, and sedimentology. Pollen data were used to create Modern Analogue Technique (MAT) climate reconstructions (January and July median temperature and annual precipitation). The reconstructed climate parameters were compared to historical climate data supplied by the U.S. National Oceanic and Atmospheric Administration. Root mean square error (RMSE) was calculated between the reconstructed parameters and the historical data. For this comparison, time chronologies were established for each lake and the average rate of sedimentation was calculated.

This information was used to determine the time lapse between pollen samples. The median value for historical climate data from the interval of time represented by a pollen sample was used for comparison with the climate reconstructions. Results from the pollen data corresponded with historical events, while reconstructed climate parameters closely approximated historical values (RMSE 0.9°-1.6°C for temperature, and 150-160 cm precipitation for annual rainfall). This study has shown that anthropogenic impact on the flora of a small city like Rolla may be insufficient to overprint the regional climate signal.

***Keywords*:** Holocene, pollen analysis, Missouri, precipitation, climatic changes

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Did dry grassland expand into the present-day humid east China during LGM?-a pollen perspective

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It remains unknown the vegetation pattern covered the widespread low plain in east China during the Last Glacial Maximum (LGM) mainly to due to the loess-related sediment archive unfavorable for pollen analysis in this area. Fortunately, a LGM alluvial sequence (23-16ka) was occasionally recovered. Pollen results show that herbaceous taxa are surprisingly abundant dominated by *Artemisia* and Poaceae (about 70% in average percentage) which are characteristic taxa in grassland in northern China. In addition, *Aster*-type, *Echinops*-type, *Taraxcum*-type, Apiaceae and *Thalictrum* are also common in low percentage. Arboreal taxa such as *Quercus*, *Pinus*, and *Alnus* are limited. The pollen flora suggests grassland or grassland with sparse trees distributed in the lowland under a dry and cold continental climate during LGM in sharp contrast to the present-day warm-humid broadleaved forest in the study area. The expansion of grassland southward into SW China is probably attributed to the strengthening winter monsoon during the glacial period. Furthermore, the spread of loess into the south China support the grassland migration. The study will put insight into climate modeling and loess south-limit during LGM. The study is funded by the National Natural Science Foundation of China (No.41371207).

***Keywords*:** LGM, Grassland, Pollen analysis, Loess expansion, east China

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Pollen indicated the Holocene alpine timberline evolution in the subtropical-temperate transition in Central China

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Sensitivity of alpine timberline to climate change requires test from palaeoecological evidence that remains rather short in lower latitudes. Taibai Mountain, situated in the subtropical-temperate transition, is the only alpine mountain in south of 35°N to show timberline evolution in eastern China mainland. We report postglacial alpine timberline evolution in Mt. Tabai by investigating three C14-dated high resolution sediment sequences from below modern forestline situated at 3080 m a.s.l., within timberline ecotone situated 3410 m a.s.l. and above treeline situated at 3556 m a.s.l., respectively. AMS^{14}C dating, high-resolution pollen, TOC, TN and particle size were undertaken. The results show that between 5850-4200 cal. yr BP, *Picea*/*Abies* and *Larix* had fluctuated sharply and were extremely unstable, indicating Foye Chi was located in the upper limit of the timberline, thus timberline was inferred about 3400 m a.s.l.. During 4200-1000 cal. yr BP, timberline had moved up at 3500 m a.s.l. confirmed by the increasing pollen concentration of *Picea*/*Abies* and *Larix* around Sangongdian Swamp. From 1000 cal. yr BP onwards, timberline moved to lower elevations. Timberline position indicated by the elevation of both forestline and treeline well captured that winter rather than summer temperature determined the position of alpine timberline in Mt. Taibai. Our study implies that pollen evidence can well capture the dynamics and sensitivity of alpine timberline.

***Keywords*:** Alpine timberline, mid-Holocene, lacustrine sediment, pollen, Taibai Mountain

Holocene Fire history in the humid forest of Northwestern Patagonia, Argentina

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Fire is recognized as a critical agent in the earth system. A strong interaction between climate variability and regional fire regimes exists in Patagonia, with human influences having a more localized impact. In Northern Patagonian rainforest disturbed sites, the cane *Chusquea culeou* is the dominant understory species, contributing to burning biomass. Pollen and charcoal records of El Laguito del Morro lake (41°31'54.0" S, 71°48'25.2" W) allowed us to identify five palynological zones showing major changes in the rain forest structure an its relation to changes in fires frequency and severity during the last 14000 cal. Yr B.P. Charred grass fragments were identified under SEM as *Chusquea culeou* foliar epidermis. In Zone 1 (14000 – 8300 cal yr BP) *N.dombeyi*-type pollen increased from 65 % to 95% whereas rainforest elements, Cupressaceae and shrubland/steppe types were lower than 10%. Poaceae, probably *Chusquea culeou*, reached 15%. Charcoal values (woody and charred grass) were high. This period was characterized by open *Nothofagus* forest with frequent fires. In Zone 2 (8300 - 5300 cal yr BP) *N.dombeyi*-type, remained high while Cupressaceae and shrubland/steppe types decreased to the lowest values of the entire record. This period was characterized by a closed low diversity *Nothofagus* forest. Concentration of woody and grass charcoal declined suggesting less fires and an increase in moisture. In zone 3 (5300 - 3800 cal yr BP) Cupressaceae increased sharply while Poaceae and shrubland/steppe types were in low percentages. Charcoal concentrations were initially low and gradually increased pointing the early expansion of mixed *Nothofagus-Austrocedrus* forest. In zone 4 (3800 – 1200 cal yr BP) *N.dombeyi*-type remained at *ca* 80% and Cupressaceae declined while Shrubland and steppe types increased. The mixed forest was established. Woody and grass charcoal concentrations increased towards 1200 cal yr BP. The highest concentration of woody charcoal of the entire sequence was recorded at 1500 cal. yr BP indicating high fire frequencies. In zone 5 (1200 cal yr BP to present) the expansion and establishment of scrub "matorral" occurred. Rainforest and steppe herbs also became more abundant while Cupressaceae decreased. Grass charcoal increased but woody charcoal steadily declined suggesting more frequent and less severe fires. Our results at El Laguito del Morro indicate that forest vegetation dynamics was mostly determined by low severity and high fire frequencies along most part of the Holocene period. First evidences of the role of *Chusquea culeou* burning events in long term forest dynamics are shown. It is a contribution to grants ANPCyT PICT 2012/528, 2012/ 471 and CONICET PIP 112-201201-00212

***Keywords*:** Patagonia, rainforest, fire history, charcoal, Holocene

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Rapid vegetation turnover rates during the Pleistocene-Holocene transition

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The Northern Hemisphere is currently warming at the rate, which is unprecedented during the Holocene. Associated with this rapid warming are the accelerated biotic turnover and extinction rates, and fundamental ecosystem reorganizations. The previous time in the geological history with comparable warming rates was during the Pleistocene-Holocene transition (PHT) about 15,000 to 11,000 years ago. Here, we explore the vegetation and biotic turnover rates during the PHT by focusing on the Baltic region in the southeastern sector of the Scandinavian Ice Sheet, where an exceptionally dense network on microfossil and macrofossil data that reflect the biotic turnover history is available. We further use a composite chironomid—based summer temperature reconstruction compiled specifically for our study region to calculate the PHT rate of temperature change patterns. Our results show that the fastest biotic turnover in the terrestrial and lacustrine communities occurred during the Younger Dryas-Holocene shift at 11,700 years ago, when the rate of warming was 0.17°C/decade, thus slightly lower than the current Northern Hemisphere warming of 0.2°C/decade. This shift is also marked by regional extinctions, including disappearance of many arctic-alpine plant taxa, such as *Dryas octopetala* and *Salix polaris*, along with mammal species, such as mammoth and reindeer, from the region. An even faster rate of temperature change occurred at the onset of the Younger

Dryas, 12,800 years ago. However, the biotic turnover was relatively low during this period. In addition to the rate of temperature change, the potential of crossing critical threshold values may be an important factor explaining the differences in biotic turnover responses.

***Keywords*:** vegetation turnover, local extinctions, rate of climate change, late glacial

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Pollen, Landscape Reconstruction Algorithm and lake sediment geochemistry combined to refine interpretations of nature and chronology of Roman Iron Age terrestrial ecosystem changes

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Sediments of small Lake Ilsø situated in the Illerup/Alken Enge Valley, Denmark, were studied to investigate past landscape development with special focus on the period of the presumedly ritual post battle Roman Iron Age (0 – 400 CE) deposition of human bodies documented in the valley. A detailed pollen record from Ilsø and a number of other records from Jutland were combined using the Landscape Reconstruction Algorithm (LRA) to reconstruct local vegetational changes through the last 2800 years. These methods were supplemented by studies of catchment-related geochemistry of the Ilsø lake sediments. Geochemical indicators of landscape change seem to respond faster than pollen assemblages to ecosystem changes and allow direct links to the timing of the body deposition based on archaeological data. The results show a vigorous reforestation event slightly preceded by a strong decrease in erosion levels by the beginning of Common Era, contemporaneous with the deposition of human skeletons at Alken Enge. Comparison with a pollen record 10 km away and with those from other sites reveals that this reforestation occurs unusually early and vigorously, and this development is unparalleled in a Danish context. We conclude that the strong landscape changes at the beginning of the Roman Iron Age and the dense forest cover for the next hundreds of years comprise a striking example of ritual controls on local land-use.

***Keywords*:** Pollen analysis, Landscape Reconstruction Algorithm, palaeolimnology, geochemistry, erosion rates

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Paleoecology of the Pampa plain, southeastern South America: long term records of shallow lakes as a basis to elucidate their functioning during the Holocene

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Palaeolimnological studies based on multi-proxy analysis constitute the best tool to reconstruct the evolution of aquatic systems as well as evaluating their responses to natural and anthropogenic effects. Additionally, multi-site studies help to detect common trends that respond to intrinsic as well as to extrinsic factors. For more than a decade the authors have been investigating shallow lake records from the Pampa plain in Argentina (33°-39°S; 57°-66°W) with the main goal of elucidating their evolutionary history during the Holocene. Here, we review published palaeoecological evidence for the middle and late-Holocene, and present new results for the early-Holocene. Pollen, non-pollen palynomorphs (NPPs), and plant macrofossil remains and associated fauna were analyzed from five shallow lakes located in the southeastern Pampa plain. Regarding their modern functioning, these lakes present two alternative states of equilibrium. Some of them are turbid lakes due to the high amount of algae, while others are clear macrophyte-dominated lakes. Long-term records indicated that during the Holocene, the shallow lakes of the Pampa plain underwent different states related to light penetration, nutrient load, sediment suspension and water depth. These lakes were active since the early

Holocene as clear and brackish lakes, dominated by charophytes and some submerged macrophytes. During the middle Holocene and the beginning of the late Holocene, lakes remained clear but the presence of resting structures of algae and invertebrates suggest very shallow conditions and reduced size, with alternating periods of droughts and floods. Since ca. 2000 yr BP, the increase in nutrients favored a rise in biodiversity such as the number of submerged macrophytes, remaining in a clear water regime. From ca. 700 yr BP to the present, lakes became predominately turbid alternating with clear phases as indicated by the increased in phytoplankton. Integrating long-term multiproxy data from multiple-sites offers the opportunity to elucidate ecological processes that operate on the timescale of centuries to millennia. The theory of alternative stable states provides a good tool to interpret the dynamics of these systems on much longer time scales than ecology can offer. In turn, as feedback to the ecological theory, palaeoecological data explain the rates of change of these aquatic ecosystems, the state of resilience and permanence, as well as possible ecological thresholds.

Keywords**:** multi-proxy, multi-sites, alternative stable states, palaeoecology, ecology

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Postglacial changes in European landscape diversity

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The collection of pollen diagrams in the European Pollen Database (EPD) makes it possible to study changes in vegetation composition through time and space. Pollen diversity and richness is related to landscape diversity and the regional plant species richness. However, due to the multiplicity of contributing authors the nomenclature of pollen types is complex as it includes many synonyms as well as identifications to different morphological and hence taxonomic levels. Both hamper the comparisons of pollen type diversity and richness between pollen diagrams. To overcome this problem, we reviewed the nomenclature of pollen types in the EPD by identifying synonyms and amalgamating them. Moreover, we constructed a hierarchical system of the pollen types on the basis of pollen morphology rather than phylogenetic relatedness of the parent plants. Using this harmonized database, we compute pollen type diversity and richness and map these variables through time across Europe. Our reconstructions show how the Lateglacial and early Holocene spread of forests as well as the spread of agriculture and medieval deforestation determined patterns of landscape diversity throughout Europe. We investigate pollen type richness at individual sites along a latitudinal gradient as well as using large regional groups of sites. Both analysis indicate that current diversity gradients emerged gradually during the early Holocene and were later impacted by land use change.

Keywords**:** Europe, pollen diversity, richness, land-use, postglacial

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Pollen based tropical mountain forest in Northeast Brazil: characterization and dynamic

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Although the Northeast Brazil is mainly characterized by a semi-arid climate that corresponds to the driest area of Brazil, a sub-humid climate persists in small mountainous areas close to the coast. Such very local climatic conditions enable the development of a highly diversified mountainous rainforest surrounded by a xeric shrubland and thorn forest. Because such rainforests are characterized by small areas with specific

vegetation and microclimatic conditions, their potentials to sustain tropical biodiversity are generally underestimated within the future scenarios of climate change. In order to characterize the different communities and distributions of these rainforests we analyzed the present-day pollen rain in soil samples along an altitudinal gradient that we compared with botanical data from different mountainous area from Northeast Brazil. We identified several ecological successions characterized by significant changes in rainforest assemblages whose distribution depends on water availability. To test their potential to sustain future tropical biodiversity we compared our calibration of pollen rain with fossil pollen data. Despite the high sensitivity of rainforest to climatic variability evidenced by our study, the rainforest persisted and responded to past climate changes by recruiting key species among its highly diverse stock. Our results illustrate long-time perspective on ecological processes response to climatic changes of mountainous rainforests from Northeast Brazil. Conservation of such microhabitats in the context of future climate change represents therefore a crucial interest in policing the tropical biodiversity.

Keywords**:** paleoecology, Northeast Brazil, tropical rainforest

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Post-glacial disturbance dynamics revealed from pollen records

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Disturbance plays an important factor in maintaining ecosystems' diversity and shaping their long-term development. During the past millenia nature encountered different disturbance regimes moderated to various extent by human impact, but also by climatic events. Research focused in the long-term perspective (Q-time) mainly on the effect of humans, but studies also emphasize natural disturbances such as windthrows, herbivory (including insect outbreaks) or fire, many of which could be a direct effect of climatic events. Pollen provides a valuable information on long-term (millenial) vegetation and environmental change. Ecological indices (e.g. Ellenberg values) represent a valuable tool to describe important environmental factors of vegetation. Newly acquired indicator values assign affinity of plants to disturbance frequency (DF) and severity (DS) for central-European species. The same region provides a high-quality database of sedimentary pollen, which we link to plant taxa with disturbance indices in order to detect postglacial disturbance dynamics. In the dated pollen sequences each counted pollen was assigned a plant taxon weighted by its present-day frequency in vegetation attributed by the disturbance index. This process was repeated 100 times and finally a mean disturbance index was calculated for the whole pollen assemblage dated to a certain time. Generalized additive model was then fit to all pollen assemblages to show main trend at the timescale. Overall, disturbance reaches its minimum between 5000–1 BC. DF gradually decreases during the Late Glacial and starts decreasing sharply around 9000 BC, then after 1 AD sharply increases again. DS continuously decreases between 13000–5000 BC and increases again after 1 AD. Regionally, DF shows the highest amplitude in Šumava mountains, which afforested only in the postglacial, whereas Carpathians were partly forested already during the Late Glacial and DF increases due to climatic cooling. DF reaches the highest values in two lowland regions, which corresponds to the highest human impact. DS resembles regionally similar trends, but surprisingly in some cases does not reach higher values at present, in one example even lower. Disturbance played surprisingly more important role before the arrival of agriculture (5500 BC), and after that only lowlands remained frequently and severely disturbed. Interpretation of pollen records through ecological indices proves to be an important approach and enriches information given by already existing disturbance proxies (charcoal, erosion, deforestation, etc.).

Keywords**:** pollen analysis, Holocene, disturbance frequency, disturbance intensity, central Europe

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Processes and patterns of vegetation change during the Holocene at the forest-steppe ecotone in northern Patagonia, Argentina

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Northern Patagonia is characterized by unique landscape with the presence of *Araucaria araucana* and *Austrocedrus chilensis*. Climate change, volcanic eruptions, earthquakes, fires and human activities have controlled

the recent environmental history of the region. Strong climate gradients determine the vegetation distribution which is most distinct at the forest-steppe boundary. This investigation looks at the vegetation composition along climate gradients in space as well as through time in order to gain insights into the dynamics of the ecotone and past climate change studying the vegetation internal processes and responses to disturbance events. The study focuses on the forest-steppe ecotone in the eastern side of the Andean Cordillera in Argentina, at around 39 degrees south. Pollen and charcoal are analysed from sediment cores in two sites across the forest-steppe ecotone. Lake Torta (39°06'S, 71°21'W; 1090masl) is located on the humid side of the forest-steppe ecotone in a mixed forest of *Nothofagus obliqua* and *Nothofagus antarctica* with *Araucaria araucana*. Lake Tonkol (39°08'S; 71°14'W; 1060masl) is placed 30km towards the east in a drier landscape characterized by a mixed forest of *Araucaria araucana* and *Nothofagus antarctica* with *Austrocedrus chilensis*. The 10m sediment cores recovered at both sites span the complete Holocene period. Sediments are intercalated with numerous tephra layers of varying thickness (up to 70cm tick). Pollen data indicates that the forest-steppe ecotone has gradually shifted towards the east over the Holocene. Changes in species abundances occurred rapidly during the first few hundred years. Afterwards, vegetation changed gradually from open *Austrocedrus* woodland to *Araucaria* woodland and then, to a more dense forest dominated by *Nothofagus*. The increase in *Nothofagus obliqua* pollen towards the top of the sequences is consistent with a more humid second half of the Holocene. Individual tephra layers are not associated with sudden vegetation change. However, maximum values of *Araucaria* pollen were encountered at times with a low frequency of tephras, suggesting that the tree benefits from reduced disturbance frequency. Evidence of human activities can be recognized in the pollen diagram through the presence of introduced pollen taxa associated to cattle-based activities since European contact. Clearance of natural vegetation for timber and plantations of exotic trees occurred during the last ca. 100 years.

***Keywords*:** Holocene, vegetation history, forest-steppe ecotone, northern Patagonia, Argentina

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Impact of agro-pastoralism on the biodiversity of the alpine landscapes of the Central Alps since the last 6,000 years

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Agro-pastoral activities in the past have shaped the current cultural landscape in the European Alps. In the Swiss Alps, millenium-scale traditions of land-use are acknowledged to still play an important role on grassland biodiversity. We present the reconstruction of human impact on the environment of the Lower Engadine Valley and the Silvretta Massif (Switzerland) since the last 6000 years, based on pollen, NPP and charcoal data from four peat bogs. Settlers from the Late Neolithic Period most probably used fire to open the forested landscapes of the Central Alps, and in order to establish pasture and cultivated fields. High-altitude meadows were also used for pastoral activities since that time and until present day. Thanks to diversity indices, we show that such anthropogenic use of land resources promoted a higher diversity among plant taxa. However, during the last centuries, diversity seems to decrease due to the progressive abandonment of agro-pastoral activities in the region. We suggest promoting past farming traditions as an important and effective lever to maintain high diversity in these particular landscapes.

***Keywords*:** fire activity, agro-pastoralism, cultural landscape, biodiversity

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Centennial and millennial-scale hydroclimate changes in Northwestern Patagonia since 16,000 yr bp

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We examine hydroclimate changes at centennial/millennial timescales since 16,000 yr BP in northwestern Patagonia based on the pollen and charcoal record from Lago El Salto, a small closed-basin lake located

in the Chilean Lake District (41°38'48.02"S, 73° 5'48.42"W). We observe cold/wet conditions between 14,500-16,000 yr BP, followed by further cooling with increased precipitation until 13,000 yr BP, enhanced precipitation seasonality and/or variability between 11,600-13,000 yr BP, and an extended warm-and-dry interval between 7500-11,300 yr BP with peak paleofire activity. Colder-and-wetter than present conditions and muted paleofire activity prevail between 5300-7600 yr BP, followed by alternating cold/wet and centennial-scale warm/dry phases starting at 5300 yr BP with three conspicuous megadroughts since 2500 yr BP. The most recent megadrought occurred during the Medieval Climate Anomaly. We identify a cold reversal that spans the Antarctic Cold Reversal (ACR) and the Younger Dryas (YD) chrons with stronger-than-present westerly influence during the former and enhanced variability during the latter. These results extend the northern limit of strong cooling and increase in precipitation during the ACR and the southern limit of influence of strong hydrologic variations during the YD in terrestrial environments, suggesting an overlap in the spheres of influence of processes originating from southern and northern polar latitudes. An extended warm southern westerly wind (SWW)-minimum interval is evident between 7600-11,300 yr BP, followed by a rapid shift to cool-moist conditions between 5300-7600 yr BP brought by a mid-Holocene SWW maximum. Since then we observe centennial-scale hydroclimate variability, which has driven biodiversity and fire-regime shifts of evergreen temperate rainforests.

Keywords: Northwestern Patagonia, southern westerly winds, centennial/millennial-scale climate variability, Holocene, Antarctic Cold Reversal

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Environmental records in Middle Holocene sediments from Eastern Romania: palynological data in correlation with archaeozoology

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This paper provides a palaeo-environmental reconstruction of a local vegetation and landscape character to the Eastern Romania. Integrated results of pollen and non-pollen palynomorphs, allowed us to propose an evolving paleo-landscape scenario in this area for the last 6500 years BP. Palynological records suggest that grasslands were a major feature of this area during Middle Holocene. Our results attest the overall presence of steppe taxa like *Artemisia*, *Plantago*, Poaceae, Chenopodiaceae, Caryophyllaceae. Palynological data reveal also the presence of *Quercus* forests with *Tilia*, *Ulmus*, *Carpinus*, *Fagus*, *Fraxinus*, *Corylus*. Pollen of plants related to human activities (*Rumex* type, *Polygonum aviculare* type, *Artemisia*) and Cerealia type reflect agricultural activity. In addition to archaeobotanical material, several archaeozoological samples discovered in Chalcolithic settlements (e.g. Hoiseşti, Costești, Poduri-*Dealul Ghindaru*) have been analysed, confirming these results. Thus, domestic animals such cattle (*Bos taurus*) and sheep/goat (*Ovis aries*/*Capra hircus*) have been identifed in a relative hight percentages assuming the use of a large open spaces for grazing. The wild animal species, such as red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*), prove the forest exploitation. All these data show that Chalcolithic communities played an important role in ecosystems, through the coexistence of different activities regarding exploitation of plants and animals: traditional agriculture practices, grazing, gathering, hunting. Palaeobotanical researches emphasized a productive environment, with sustenance strategies based on cereals cultivation. Non-pollen palynomorphs data and archaeozoological records attests that land has been used for extensive grazing by cattle and sheep-goat. Acknowledgement: This work was supported by grant GI-2015-01 from Alexandru Ioan Cuza University of Iași (Romania).

Keywords: Eastern Romania, palynology, gathering, grazing, forest exploitation

Vegetation dynamics of El Kala Wet Complex (North East of Algeria): palynological and macrofossil analyses in alder-bog Ain Khiar

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El Kala is a wet complex which is located in North-East of Algeria, estimated with 76438 ha of area consists of a mosaic ecosystems: 73% forest, 9% agriculture areas, 7% lakes and 11% marshes and riparian forest dominated by *Alnus*. Alder-bogs are fragile areas, being last refuges of endangered species. Ain Khiar bog is a part of El Kala wet complex, estimated at 170 ha, considered as a rare biodiversity refuge area. For the richness of Ain Khiar peatland is protected by RAMSAR convention from 2003. The study of one pollen sequence (260 cm) allows the reconstruction of the regional vegetation history. Pollen diagram shows a local input of *Alnus*, Juncaceae, Cyperaceae, and Nymphaceae. Regional vegetation is characterized by a scattered *Quercus* forest. *Myrtus* and Ericaceae matorral is also present, which is a certain prove of degraded oak forest. The herbaceous cover (Poaceae, Fabaceae, Apiaceae) dominates the whole sequence. Macrofossil data confirm pollen results, both providing changes in this ecosystem.

***Keywords*:** Algeria, El Kala wet complex, Alder Ain Khiar, pollen analysis, macrofossil

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Ecosystem changes in the central Russian Plain during the middle Holocene: reconstruction from palaeofloristic data

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Present-day plant communities in the study area are extremely varied. Within the Upper Volga lowland and adjacent uplands both the southernmost taiga forests and the northernmost broad-leaved forests in the entire Russian Plain occur, along with various mire, meadow and riverine phytocenoses. Based on the palynological and macrofossil data on peat and lake sediments, and Early Man sites in the region, three consecutive fossil floras (FF), covering the warmest middle part of the Holocene (9-5.4 cal. kyr BP), are established. For each FF a diagram attributing every species to the plant communities where it occurs in the present conditions (so-called ecological-cenotic spectrum – ECS) is compiled. Comparison of ECSs shows a general similarity of the phytocenotic composition of vegetation in the research area during the middle Holocene, with changes only in the proportion of plant species characteristic of various forest and mire communities. The ECS of FF1 and FF2 are the closest to each other, while FF3 differs from both of them by a higher proportion of plant species growing in spruce forests. To better detect changes in the ecosystems during the middle Holocene, a geographical analysis of the modern ranges of plant species comprising FF1-3 has been done. By identifying the region where all the species of a FF occur at the present time, it is possible to determine the closest modern landscape and climatic analogue to the past environment at the site. The region-analogue for FF1 is located on the western end of the Smolensk-Moscow Upland, where the modern vegetation combines a broad variety of pine, mixed broad-leaved/coniferous and broad-leaved forests, including those with participation of hornbeam, as well as different types of mires. Vegetation composition within region-analogue of FF2 at the lower reaches of the Neman River is similar to that of FF1. It is represented by spruce forests with participation of *Quercus robur* and *Carpinus betulus*, and by mixed deciduous forests. The region-analogue of FF3 includes the middle Zapadnaya Dvina and the upper Lovat' River basins. Within this area, various kinds of spruce forests occur, along with pine, birch and aspen communities with participation of broad-leaved trees. Comparison of the climatic conditions in the regions-analogues with the modern climate of the study area indicates substantial warming in the middle Holocene expressed in higher winter temperatures and longer frostless period.

***Keywords*:** Middle Holocene, central Russian Plain, fossil floras, vegetation composition, modern analogues

Effects of changing UV-B radiation on past terrestrial ecosystems

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UV-B radiation changes can be viewed as a driver for change or disturbance in ecosystems. Increased exposure to ultraviolet radiation (UV-B wave-length = 280-315 nm) is known to have a specific effects on human health, crops, terrestrial ecosystems and biogeochemical cycles. The impact of increased exposure to UV-B is well studied in plants with evidence to indicate DNA damage, mutagenesis, reduction in aboveground biomass and height and a decrease in overall fitness including reproductive fitness. The impact of past changes in incoming UV-B flux could therefore have had significant impact on all aspects of ecosystem functioning and fitness from genes to biomes. To determine biotic responses to increased UV-B flux through time a detailed measure of UV-B radiation is required. Recent work has demonstrated that an extremely promising method for reconstructing UV-B flux through time is the examination of the aromatic compounds p-coumaric acid and ferulic acid in the walls of pollen and spores and in the cuticles of leaves (Blokker *et al.* 2005; 2006; Rozema *et al.* 2009; Willis *et al.* 2011). Preliminary work has shown that p-coumaric acid can be measured on modern and fossil pollen from *Pinus sylvestris* in Europe.We now build on these preliminary results to determine systematically the spatial and temporal variability of UV-B that can be obtained using aromatic compounds in fossil pollen and cuticles of leaves/needles contained in organic sedimentary sequences. In the presented project we have combined long-term data, field-studies and modelling to develop a suite of new palaeoecological techniques and long-term model systems to address key hypotheses associated to effects of changing UV-B radiation on terrestrial ecosystems, with a special focus on *Pinus sylvestris*. To evaluate whether there is any relationship between increased concentration of UV-B flux and reproductive fitness (as measured in the the production of *Pinus sylvestris* pollen) we have calculated annual pollen concentration of *Pinus sylvestris* from 12 sites for the past six years in areas with different climate and incoming UV-B radiation (Beckmann *et al.* 2014). Based on the relationship between present day pollen concentrations of *Pinus sylvestris* and the observed UV-B radiation we report the first results from this study to determine the relative impact of this climatic variable on pollen productivity. Informed by these results the next step in this project will be to investigate the impact that different past changes in UV-B radiation have had on the vegetation dynamics at the selected sites.

***Keywords*:** pollen, aromatic compounds, UV-B flux, ecosystem, Holocene

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Postglacial vegetation dynamics and climate in north-western Patagonia, Argentina

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Studies on past climate change help anticipating possible future changes with climate warming over the next century. The transition from the Last Glacial Maximum (LGM) to the Holocene is a period of particular interest to examine possible biotic responses to rapid and abrupt changes in climate because they can provide good analogues for future changes. The objective of my research is to reveal the spatial and temporal patterns of the most important climatic changes that occurred since the LGM at different sites along the Patagonian Andes, based on past vegetation changes. However, climate change is not the only factor influencing the dynamics of vegetation. Changes in vegetation observed in the fossil record may be attributed to a range of environmental factors (volcanic eruptions, fire, human activities, and climate) and ecological processes (migration, expansion, succession, competition). The Andean Cordillera of southern South America is a critical region that allows us to evaluate the role of different factors which influence

changes in vegetation because (1) it presents a range of vegetation types along climatic gradients; (2) it has been influenced by intensive volcanic eruptions through the Quaternary period, and (3) by the occurrence of frequent fires. Therefore, we first analyse the effect of fire and volcanic eruptions on the composition and structure of the vegetation, before reconstructing the climatic changes. Here, we present a late-Quaternary sedimentary record of changes in vegetation, volcanic activity and fire, from Mallín Piedra Pintada (39°6'16.00"S; 71°4'39.31"W), a site located at the forest-steppe ecotone in an open *Austrocedrus chilensis* woodland. The 8m long sediment core recovered is intercalated with numerous tephra layers of varying thickness (up to 30cm tick). The vegetation around the site is today an open woodland with *Nothofagus* species, *Austrocedrus chilensis* and steppe elements. The occurrence of *Araucaria araucana* pollen indicates that also this species was already present in the region. The woodland composition shows stability with gradual change in species abundance, indicating that volcanic eruptions have no significantly affected the vegetation. Fires with different frequency and intensity have continuously modelled the local vegetation through time. Human impact on the landscape is significant during the last ca. 100 years, associated to the establishment of European settlements in the area.

***Keywords*:** pollen and charcoal analyses, Holocene vegetation history, fire regime, climate change, north Patagonia Argentina

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Late Holocene vegetation dynamics and disturbance regimen in north Patagonia

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Despite several investigations on the long-term vegetation dynamic of the eastern side of the Andes, our knowledge is still limited, especially in northern Patagonia where the forest near the steppe ecotone is particularly divers. The distribution of the vegetation in this area responds to a west-to-east precipitation gradient, documenting that climate is the main control on the regional-scale variability in vegetation composition. However, natural and anthropogenic disturbances amplify or override the effects of climate on vegetation composition. Therefore, understanding the regional drivers, such as fire, volcanic eruptions and human activity and differentiating them from climate is important for climate reconstructions and nature conservation efforts. The aims of this project are to (i) reconstruct the late Holocene environmental history, (ii) identify the principal local and regional drivers of vegetation changes, (iii) compare the effect of disturbance events between sites at different altitudinal positions, and (iv) examine the fire-climate interaction across time. To answer these questions, we collected sediment cores from two lakes: Lake Bruja (40°14'S, 71°30´W; 1069m) and Lake Avutarda (40°23'S, 71°25´W; 1610m). Lake Bruja is situated about 150 m above a wide valley which is used for summer pasture of cows and horses that roam the forest around the lake, which is dominated by *Nothofagus dombeyi* and *Nothofagus obliqua*. Coring stopped after 130 cm due to a thick tephra deposition and the base of the core was dated to 3600 years ago. Lake Avutarda is located near the treeline of *Nothofagus pumilio*. Here a 110 cm long core was obtained and the bottom dated to 2800 years ago. Pollen and charcoal analysis, lithological description and estimation of organic matter content by loss on ignition were carried out on both cores. Preliminary results show frequent deposits of tephra, derived from volcanoes, mostly located in Chile. We are comparing the impact of these tephra depositions as well as fire events between the two sites. This work will contribute to an understanding of the importance of disturbance for the vegetation composition and help reconstruct changes in Holocene climate near the forest steppe ecotone in Patagonia.

***Keywords*:** Holocene, disturbance, vegetation, Northern Patagonia, climate.

Orbital-scale vegetation fluctuations in western Japan based on pollen records from Japan Sea during the last glacial-interglacial cycle

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Regional climate and vegetation in Japan are strongly affected by changes in the Japan Sea environment and the East Asian monsoon. We are studying those vegetation responses to ocean and atmosphere climate changes based on pollen records from Japan Sea and other marine and terrestrial sites around the Japanese archipelago. In this presentation, orbital-scale vegetation fluctuations will be discussed based on new pollen records from the U1427 sediment core, which was drilled by Integrated Ocean Drilling Program (IODP) Expedition 346 in the northern coast of western Japan, and the KR07-12 pc-07 sediment core from the south central part of Japan Sea. Pollen record from the U1427 site indicates that pinaceous conifer pollen such as *Tsuga* and *Pinus* show relatively high percentages in samples from 7-10m, 25m, and 47m. In contrast, temperate conifer pollen of *Cryptomeria japonica*, which is an endemic species in Japan, becomes dominant in samples from 10-20m, and 28-33m. In addition, deciduous broadleaved tree pollen such as *Quercus* subgenus *Lepidobalanus* increase in samples from 3m, 23m, and 47m. Based on comparisons with pollen records around the Japanese archipelago, pinaceous conifers dominated periods in the U1427 sediment core are correlated with MIS 2, 4, and 6, respectively. In addition, *Cryptomeria japonica* dominated periods are corresponded to MIS 3 and 5. During MIS 5, *Cryptomeria* pollen increased during 5e/5d, 5c/5b, and 5a/4 transitions in marine and terrestrial pollen records. Pollen record from the KR07-12 pc-07 site indicates that temperate conifer pollen of *Cryptomeria japonica* and *Sciadopitys verticillata* show high percentages in samples from 150-250cm, and 300-650cm. Pinaceous conifer pollen such as *Picea* and *Pinus* increase associated with herbaceaous pollen of *Artemisia* from 100cm, 230cm, and 800cm. Although total pollen concentrations are low, *Pinus* pollen becomes dominant in surface samples. Compared with dark and light layers in the Japan Sea sediment which reflects the millennial-scale climate variability in East Asia, total & *Cryptomeria* pollen concentrations in dark layers show relatively high amount, whereas concentrations in light layers are quite low. Those fluctuations in the pollen concentrations from the KR07-12 pc-07 site are closely correlated with lightness of the sediment. It suggests that pollen input from the Japanese archipelago increased during periods when dark layers formed, likely influenced by the millennial-scale fluctuations in Tsushima warm current of Japan Sea and the East Asian monsoon.

***Keywords*:** last interglacial, pollen analysis, Japan Sea, vegetation fluctuations, Tsushima warm current

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Human disturbances on natural grasslands of Buenos Aires, Argentina: environmental implication of land-use practices

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Grasslands of the central eastern part of Argentina are one of the most productive agricultural land in the world. Land-use activities around the city of Buenos Aires begins at the end of the sixteenths century with the establishment of the first European settlements. At this time, the original inhabitants had a hunting and gathering lifestyle. The province of Buenos Aires was gradually turned into agricultural land during the seventeenths century, as European settlers established dominance over the territory, displacing the indigenous peoples. During the colonization period, farming activities were largely limited to livestock, while the cultivation of crops became important towards the nineteenths century. During this process the natural vegetation was largely destroyed or modified. This study analyses the impact of human activities on natural-grassland ecosystems and assess the environmental quality by looking at changes in vegetation and aquatic

biota trough the fossil record. Pollen and macrofossil remains, including plant and aquatic invertebrates are analysed from a lake sediment record recovered from Laguna Corina (38°14'11.2S; 59°27'38.7W), located in San Cayetano, southeast Buenos Aires province. Native people seem to have had little or no impact on the environment prior to the arrival of European settlers. Subsequently, the expansion of weeds, both native *Ambrosia* and exotic *Rumex* and *Plantago*, evidence the use of the land for cattle grazing. Afterwards, the appearance of cultivated pollen indicates the initial practice of agriculture. The presence of *Pinus* and *Eucalyptus* pollen reflects small patches of exotic tree plantations for shelter. The intensity of disturbance increased with the improvement of agricultural skill and machinery together with population expansion. These changes in land-use also affect the aquatic community and as a consequence, the diversity and abundance of aquatic biota decreased towards the top of the sediment record, at an alarming rate. Only few remains of aquatic taxa are represented in the recent samples: *Nitella* oospores (Characeae), *Daphnia* ephippia (Cladocera), *Plumatella* statoblasts (Bryozoa), some chironimid head capsules and ostracod valves poorly calcified. Water eutrophication occurs due to increased nutrient-input from the surrounding fields. The influence of climate change on changes in the environments is evaluated.

***Keywords*:** human impact, vegetation history, grassland, aquatic biota, Argentina

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Paleovegetation and climatic conditions in a refugium of temperate plants in central Japan in the Last Glacial Maximum

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Paleovegetation and climatic conditions in the Last Glacial Maximum (LGM; ca. 24.4 and 20.1 ka) were reconstructed based on plant macrofossils and pollen assemblages deposited in a sandy channel outcropped in the Hanamuro River, Ibaraki Prefecture, central Japan. The plant macrofossil assemblages were composed of 31 arboreal and 76 herbaceous taxa. Occurrence of plants with various habitat preferences exhibited the distribution of highly diverse vegetation types depending on geomorphology and humidity conditions in and around the drainage of the Hanamuro River. Rich aquatic and wetland flora indicates an expansion of backmarsh mosaics along the river channel in the bottom of the valley. Wetland forests composed of *Picea* sect. *Picea* assignable to *Picea koyamae* and riparian forests dominated by *Alnus inokumae* are well represented in the macrofossil assemblages. Pinaceous conifers were dominant in mesic or dry places with *Betula* and the other deciduous broadleaved trees. Occurrence of macrofossils and pollen indicates that *Abies veitchii* was distributed in mesic place, *Larix kaempferi* and *Picea jezoensis* var. *hondoensis* were on the upper slopes, and *Pinus koraiensis* was dominant on the plateau. Dominant *Selaginella remotifolia* and the other drought-intolerant understory herbs indicate closed canopy of mesic coniferous forests, while many kinds of meadow and/or ruderal plants were indicative of open vegetation along the river and slopes. Annual mean temperature of the fossil site based on occurrence of *Selaginella remotifolia* was 8.1 °C, which is observed in the present cool temperate zone where deciduous broad-leaved trees are dominant. This indicates that the distribution limit of subarctic conifers shifted to warmer temperature condition than the present. The overlapping distribution of temperate and subarctic plants occurred widely in the lowlands in the distribution ranges of temperate trees, south of around 38° N in Japan. In the LGM, with lower precipitation, dryness was an important environmental factor that controlled plant distribution along with temperature. Water stress confined temperate broad-leaved trees into the humid valley bottom and released conifers from competition against them to promote expansion to warmer regions. Macrofossil evidences indicate the persistence of temperate plants in their inland and/or northern refugia in humid places during the LGM.

***Keywords*:** Last Glacial Maximum; coniferous forest; plant macrofossils; paleoclimate; pollen analysis

Vegetation and climate change during the last glacial termination in the modern forest-steppe ecotone, central Patagonia (~46°S)

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Little is known about the vegetation that developed along the eastern margin of the Patagonian Ice Sheet (PIS) during the last glacial termination (termination 1 = T1, ~11-18 ka, ka= 1000 cal yr BP) in central Patagonia (45°- 48°S), as well as the local timing, structure and rates of climate changes over this transition, arguably the largest and fastest of all climate changes on Earth during the Cenozoic. The southern westerly winds (SWW) constitute the sole source of precipitation to the central Patagonian Andes, where a formidable west–to-east decline in precipitation drives a strong zonation of vegetation units ranging from North Patagonian rainforests in the pacific coast to the Patagonian Steppe in the extra Andean plains to the east. Here we present a pollen record from Lago Unco (45°34'29.4"S; 71°43'7.6"W, 756 masl), a small closed-basin lake located in the modern forest-steppe ecotone in direct association with moraines deposited by the Coyhaique/Balmaceda piedmont glacier lobe during the youngest advance of the last glacial maximum (LGM). The record starts with very low pollen concentrations between 16.5-17.7 ka consisting of herbs and shrubs characteristic of cold high-Andean environments and the Patagonian steppe (Poaceae, Asteraceae subfamily Asteroidae, Ericaceae and Apiaceae). A sustained rise in *Nothofagus* ensued (11-16.5 ka), accompanied by the hygrophilous cold-resistant conifer *Fitzroya/Pilgerodendron*, the herb *Gunnera*, the pteridophytes *Blechnum* and *Lycopodium magellanicum*, along with traces of the tree *Drimys winteri*. Because these moisture-dependent taxa are absent in the Patagonian Steppe, we interpret colder and hyperhumid conditions relative to the present along the eastern Andean slopes during T1, implying stronger-than-present SWW influence. The presence of cold-resistant hygrophilous taxa so early during T1 (the earliest in any published record in the region) suggests that these taxa thrived near the eastern margin of the PIS during the LGM and may have been a source for the postglacial dispersal and colonization of trees currently dominant in rainforests along the pacific coast of central Patagonia. We observe the appearance (14.5 ka) and subsequent increase (11.5-12.8 ka) of the conifer *Podocarpus nubigena* at times of maximum abundance of *Nothofagus* (~45%) attesting for the proximity of humid forests. The slight increase of littoral macrophytes (Cyperaceae) between 11.3-10.9 ka reflect a lower water level of Lago Unco probably due to warm/dry conditions linked to lower SWW intensity. We will compare these results with palynological data from contemporary sites (Lago Edita, L. Churrasco, L. Mellizas) located ~20 km upwind.

***Keywords*:** central Patagonia, last glacial termination, southern westerly winds, forest-steppe ecotone

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Deglacial and postglacial hydroclimate changes in Central Andean Patagonia revealed by Lago Mellizas record (45°S)

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We report pollen and charcoal records from lake sediments obtained from closed-basin lake Lago Mellizas (45°32'35.83"S, 71°48'49.08"W, 760 m.a.s.l.) to reconstruct the evolution of the southern westerly winds during the last 14,000 years. Lago Mellizas is located near the climate-modulated forest-steppe ecotone in the Aysén sector of Central Chilean Patagonia. In this region the southern westerly winds (SWW) are the only source of precipitation and is sensitive and ideal for reconstructing past climate changes because its strategic position within the wind belt. This is facilitated by the marked west-east precipitation gradient across the Patagonian Andes that induces a zonation of the regional vegetation which can be used for inferring past changes in precipitation regimes based on fossil pollen records. The Lago Mellizas pollen record shows dominance of *Nothofagus*, along with hygrophilous and cold resistant conifers, herbs and shrubs characteristic of cold high-Andean environments and the Patagonian steppe, and littoral macrophytes between 11.9-14 ka (ka=1000 cal yr BP). Because moisture-dependent taxa are absent in the modern forest-steppe ecotone, we interpret cold and wetter climate conditions, implying stronger-than-present SWW

influence in central Patagonia. An abrupt decline of hygrophilous conifers, herbs and shrubs, along with increase of *Nothofagus* at 11.9 ka suggest increase of forest cover. Macroscopic charcoal accumulation rates (CHAR) exhibit discrete maxima at 12, 10-9.9, 9.5-9.4 and 8.9 ka, suggesting local fires and dry intervals. We interpret the increase of forest cover and the occurrence of local fires as warmer and drier climate conditions, implying weaker than present SWW influence. *Nothofagus* reaches maximum abundance at 9.5 ka and remains dominant with little change through the Holocene, suggesting uninterrupted persistence of deciduous forest in this area. The disappearance of littoral macrophytes between ~8-2.5ka, suggest increase of lake levels as a result of relatively humid conditions, except for centennial-scale dry intervals as indicated by discrete maxima of CHAR at 7100, 5000-4800, 3350-3250, and 1550 ka, implying weaker than present SWW influence. We note a sustained decline of forest during the 20th century, along with increases of herbs and non-native plants (*Pinus*, *Rumex*, *Plantago)*, we interpret as a forest opening as a consequence of the strong impact over the landscape by the Chilean-European settlers. The increase of littoral macrophytes during the last 100 yr suggest lake-level lowering in response to decreased precipitation. Acknowledgments Fondecyt 1121141, Fondap 15110009, and ICM grants P02-51 and NC120066.

Keywords**:** Southern Westerly winds, Central Patagonia, Climate change, *Nothofagus* forests

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Beyond Palynology and Prehistoric Lake Villages in Austria

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The two medium-sized, central European Lakes Attersee and Mondsee in Upper Austria are UNESCO world heritage locations and are key sites for the understanding of socio-economical and ecological change during the Neolithic and Bronze Age Periods (5500-800 BC) in the pre-Alps of Austria. Systematic investigation of sedimentary archives of both natural and anthropogenic origin was conducted in order to develop a better understanding of the landscape transformation processes, as well as to trace possible subsistence patterns in the palaeoenvironmental record. Within an interdisciplinary research programme (2015-2018) between palynology, archaeology, geology, sedimentology, archaeobotany, dendrochronology, and GIS-analyses a row of prehistoric lake dwellings and their surrounding flora and vegetation are studied in order to understand past agricultural sustainability, livestock husbandry systems, climatic alterations, as well as the use of natural forests and subsequent diversity cycles and regeneration processes. First results on regional aspects of past plant diversity changes rely on a partly yearly laminated lake marl core from the deepest (> 60 m) parts of Lake Mondsee, whereas onsite palynological studies are presented from the lake dwelling site of Abtsdorf on the western littoral of Lake Attersee. Palynological results obtained within the cultural layers of the lake dwelling village Abtsdorf I allowed insight into the vegetation dynamics under anthropogenic influence and on the development of the cultural landscape during the Early Bronze Age. They indicate an opening of the landscape triggered by activities related to the occupation phase of the lacustrine site. Pollen types such as from *Cerealia* or *Linum usitatissimum* give evidence for important local crop cultivation. Changes in certain arboreal taxa might be linked to subsistence strategies such as leaf-hay foddering connected to agricultural practices like coppicing. The main focus was hereby to provide a set of basic data on environmental and geomorphological aspects in order to understand the formation process of the cultural layers at this prehistoric site of Abtsdorf I.

Keywords**:** Holocene, Palaeoecology, Austrian Pre-Alps, cultural landscapes, environmental history

EOCENE PALAEOFLORAS: NEW INSIGHTS INTO A WARM FORESTED ANCIENT EARTH

David R. Greenwood & Tammo Reichgelt

The Ellesmere Island flora: a diverse assemblage of early Eocene flora from the Canadian Arctic

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The early Eocene experienced the warmest temperatures of the Cenozoic era. Lush forests grew as far north as 82°N during this globally warm period. These forests were home to a thermophilic fauna (e.g., alligators, turtles, and a diverse mammalian fauna). Cold month temperatures at these latitudes were often ≥5°C, with mean annual temperature estimates of ≥12°C and mean annual precipitation estimates often exceeding 150 cm/yr. These early Eocene forests provide an excellent opportunity for reconstructing polar climates and environments from an ancient greenhouse world. The Lower Eocene sediments of the Margaret and Mount Moore Formations on Ellesmere Island contain a rich fossil flora of a mixed hardwood broadleaf deciduous forest, including leaves, seeds and fruits. Although this fossil flora was discovered over a century ago by early polar expeditionary teams, detailed descriptions of the dicot angiosperm fossil leaves have not been completed. Recent work has also improved the age constraints of these floras. Presented here is a survey of leaf morphotypes and descriptions of the fossil flora from multiple early Eocene localities from Ellesmere Island, Nunavut, Canada. These descriptions will form the first framework establishing a polar flora from the Canadian Arctic Archipelago. Dicot angiosperms dominate this fossil flora and >45 leaf morphotypes have been identified. We have identified morphotypes belonging to Betulaceae, Cercidiphyllaceae, Fagaceae, Juglandaceae, Ulmaceae, and Trochodendraceae; as well as representatives of key temperate genera such as *Aesculus*, *Carya* and *Juglans*. The conifer *Metasequoia*, *Equisetum*, and a fern tentatively identified as *Osmunda* have also been found. The sediments associated with this fossil flora are crevasse-splay, over-bank, and floodplain mudstones, siltstones, and sandstones from a prograding fluvio-deltaic system. Many of the fossil leaves are damaged or fragmentary, though whole, undamaged leaves are common, suggesting that the leaves were transported a short distance from their original trees. The diversity of this fossil megaflora collection supports earlier studies based on pollen analysis suggesting that the fossil forests of the Canadian Arctic during the early Eocene were at least as diverse, if not more than, as modern mid-latitude temperate forests. Additionally, the diversity of this fossil flora is similar to contemporaneous floras documented from the northern Great Plains of the United States (e.g., floras in the Bighorn and Williston Basins), suggesting that the equatorial-polar diversity gradient of today was greatly reduced during the early Eocene.

***Keywords*:** Eocene, Arctic, megaflora, leaf morphotype, floral diversity

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Fossil coryphoid palms from the Paleogene of western Canada

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Palms (Arecaceae) are iconic plant fossils, providing evidence of warm climates in the geological past in geographical areas that today support temperate, boreal or even polar climates. The palm fossil record can also be used to date nodes in phylogenies, but such analyses rely upon accurate taxonomic and temporal data for fossil palms. *Sabal*-type or coryphoid (i.e., subfamily Coryphoideae) palmate and costapalmate fossil palm fronds are well known from Paleocene to Eocene sites in the U.S.A., including Colorado, Mississippi, Montana, Washington, and as far north as interior south-central Alaska (~62° N). Palms are poorly known, however, from the Canadian Paleocene and Eocene despite early reports of *'Sabal'* or *Sabalites campbelli* (Newberry) Lesquereux from exposures around Vancouver in the late 19th century. No palm megafossils

have hitherto been reported from Canadian Paleocene localities. In addition, a single megafossil species (*Uhlia allenbyensis* Erwin & Stockey) is known from the Princeton Chert from anatomically preserved root, rachis, stem, and leaf pieces that show a mixture of features from the extant genera *Brahea–Raphidophylllum–Serenoa* in the Tribe Trachycarpeae. Here, palms from the Eocene Huntingdon Formation from Vancouver in British Columbia Canada, and previously unreported palms from the late Paleocene Genesee megaflora (Paskapoo Formation) of Alberta (~53° N), are described and illustrated for the first time. These fossil palm fronds are fan palms (Coryphoideae), but demonstrate the presence of two form genera (*Amesoneuron* H.R. Göppert emend. Read and Hickey and *Sabalites* Saporta emend. Read and Hickey), reflecting the limited diagnostic information of leaf fragments, and match known records of *Sabalites* from Washington and Alaska (Kupreanof Island at ~57° N, Cook Inlet at ~59° N, and interior south-central Alaska at ~62° N). The coryphoid fossil palms from British Columbia and Washington are interpreted as members of the Trachycarpeae and not *Sabal* (Sabaleae); thus, their age and geographic location is consistent with the early to middle Eocene initial diversification of the Trachycarpeae in North America into non-tropical environments. The Paleocene coryphoid leaves, however, cannot be placed into a Tribe and so do not contribute to our understanding of Trachycarpeae or Sabaleae diversification. However, the Paleocene palm leaves from interior south-central Alaska are much smaller (~50 cm) than most living Coryphoideae, and at >15 cm across the Alberta leaves are tiny, comparable in size only to living *Serenoa repens*. The diminutive leaf size of these Paleocene costapalmate palms appears to document palms growing at their northern limits.

Keywords**:** palms, Arecaceae, Paleogene, leaf fossils, Canada

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Palynological investigation and hydrocarbon source rock evaluation of the Kopili Formation of the Litang valley, Meghalaya, India

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The palynofacies distribution and Rock Eval in Kopili shale from the Litang valley, Meghalaya have been carried out for reconstruction of the source potential of hydrocarbon. The present palynotaxa are mainly composed of Dinoflagellate cysts viz. *Operculodinium centrocarpum*, *Operculodinium major*, *Polysphaeridium zoharyi*, *Polysphaeridium subtile*, *Diphyes colligerum* etc. The source rock potential of Kopili shale recorded the different types of organic matters such as charcoal, partly biodegraded terrestrial organic matter, amorphous, black debris, spore and pollens (dinoflagellates). Based on the palynofossils investigations, the sediments were deposited under a shallow marine environment having inner shelf relatively deeper and open marine influence and absence of brackish water environment. Rock-Eval and TOC analysis of the Kopili shale indicates that all the samples have poor organic richness (TOC < 0.5%) and poor hydrocarbon generation potential (S_2< 0.5 mgHC/g rock). The type of kerogen is predominantly of type III and type IV. The T_{max} and productive index (PI) values support the findings of visual kerogen analysis. Most of the samples are in the mature stage. A few of them are immature and post-mature. The amorphous organic matter is more dominant than other organic matter. From the Van-Krevelen diagram almost all the samples are in mature stage. The source rock potential for the Kopili shale of this valley appears to be poor potential of hydrocarbon.

Keywords**:** Kopili shales, Rock Eval, dinoflagellate cyst, hydrocarbon, Litang valley

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Diversity of plant-insect interactions in the Middle Eocene Climatic Optimum from Anglesea, Southeastern Australia

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Insect diversity through deep time can be determined from leaf damage types. Insect diversity was recognized to be significantly higher in South America compared to North America during the Eocene, but little has been recorded from contemporaneous Australian floras. This study utilizes the Christophel Collection housed in the Melbourne Museum, Australia. Christophel extensively sampled the Anglesea brown-coal measures, Eastern

View Formation from the 1970s to 1990s. Mummified leaves and compression material were collected from six discrete clay lenses within the coal overburden, over two sites: "Site I" and "Site II"; the two sites are laterally equivalent. A diverse tropical flora has been described, including 6 conifer species (Podocarpaceae), 3 cycad species and 19 angiosperm species: *Gymnostoma*; Lauraceae I, II, III and IV; *Brachychiton*, *Myrtaceaephyllum*; *Banksieaephyllum*, Lobed Proteaceae; Serrate I, II, III; *Austrodiospyros cryptostoma*, 3-veined microphyll, *Quintinia*; Notophyll I, II and Acrodromous Notophyll. Palynology of the clay lenses permitted placement in the Middle *Nothofagidites asperus* Zone, of probable late middle Eocene age. Climate calculations using LMA gave 17°C MAT, corresponding to the Middle Eocene Climatic Optimum, a warm period during the overriding Cenozoic cooling trend. Previously recorded leaf mines came from Site I. New preliminary studies of the Christophel Collection show 78 leaf Damage Types (DT), some previously un-described, belonging to 8 Functional Feeding Groups (FFG) including: 12 hole feeding; 7 margin-feeding; 9 skeletonization; 7 surface-feeding; 4 piercing-and-sucking; 2 oviposition; 13 mining and 24 galling. Comparisons between the sites indicate Site I is richer in galling, dominated by mature-insect feeding, such as margin- and hole-feeding and lacking oviposition; where as Site II has a greater intensity and diversity of damage. Smaller leaf size, higher percentage of serrate margin leaves and flora dominated by Lauraceae at Site I may indicate plant strategies to avoid insect damage but may be overprinted by a cooler climate. *Myrtaceaephyllum* was only recorded from Site II, and had a higher occurrence of surface, mining and skeletonization feeding, evidence that these leaves were a favorable host for insect larvae. The majority of internal foliage feeding damage featured a reaction rim, suggesting that the leaves were attached to the parent plant at the time of feeding, however, many margin-feeding traces lacked a reaction rim, suggesting feeding after excision. High diversity and inter-dependent plant-insect relationships reflect evolution of complex foodwebs in these tropical, high-latitude terrestrial ecosystems during the Eocene greenhouse climate.

***Keywords*:** Fossil leaf damage, foodwebs, plant-insect interactions, Middle Eocene Climatic Optimum, SE Australia

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Eocene Fagaceae from South China and the implications on phytogeography and paleoclimate

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Cenozoic is an important geologic era for the evolution of angiosperms, especially the Eocene with warm and wet climate is crucial for the diversification and establishment of modern floras. The fossil record suggest that Fagaceae has been widely distributed in the northern hemisphere, especially in East Asia, since the Eocene with well-developed families and genera of modern flora. In China, floras from the northeastern, eastern and southwestern areas were well studied, however, there is no corresponding report on Fagaceae fossils from the lowest latitude of South China. In this study, 25 species distributed in 5 genera (including *Berryophyllum*, *Castaneophyllum*, *Castanopsis*, *Lithocarpus* and *Quercus*) of the new materials of Eocene Fagaceae fossils recovered from South China in the recent years are investigated and described in detail. The present fossils of the above genera discovered from South China indicate that the genera have been distributed in the lowest latitude of subtropical to tropical regions at least in the Eocene. Among these Fagaceae fossils, *Berryophyllum* and *Castaneophyllum* fossils recovered from the Eocene of Hainan Island are the lowest distributed fossil record so far. The present *Castanopsis* fossils were not only the earliest fossil record in China but also the world's lowest latitude appearance for this genus. The *Lithocarpus* fossils herein have similar implications comparing to *Castanopsis* that they have the lowest distribution latitudes in the world and are the earliest record in China. The present *Quercus* fossils suggest that the differentiation of the two subgenera within the genus and the diversity evolution of the subg. *Cyclobalanopsis* already started as early as the Eocene in South China. The modern Fagaceae is tropical to subtropical distribution. According to the five genera of Fagaceae fossils discussed above and the living environment of their nearest living relatives, we speculate that the climate of the tropical to subtropical of South China is warm and wet during the Eocene, which is adaptable for the growing of Fagaceae, especially that the tropical elements, *Quercus* subg. *Cyclobalanopsis*, are well-developed and highly differentiated during that time.

***Keywords*:** South China, Eocene, Fagaceae, phytogeography, paleoclimate

The Eocene steppe of the NE Tibetan Plateau (China)

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The Eocene is well represented in the sedimentary record of the NE Tibetan Plateau (China). These sediments contain a wealth and variety of sporomorphs that permit us a glimpse into the paleovegetation of the playa and lake environments that occurred there at the time. Here we report on a palynological study of sedimentary successions in the Xining and Tarim basins. In particular we focus on the species diversity and abundance of the Ephedraceae and Nitrariaceae. Both taxa predominated during the relatively humid, warm climatic conditions that characterized the Eocene in the NE Tibetan Plateau. The Ephedraceae were very diverse and abundant, with *Ephedra distachya* type being the most common form. This pollen type is characterized by pseudosulci and favoured by wind transport. We hypothesize that the development of this pollen morphology in Asia may be related to the intensification of the Asian monsoon. Nitrariaceae were also abundant and diverse in both sedimentary basins and, notably, occurred in the coastal sediments of the Paratethys Sea. This sea reached its easternmost extent in the Tarim Basin until c. 37 Ma. The occurrence of this taxon in the Eocene coastal deposits is in agreement with the proposition that Nitrariaceae, nowadays mostly a coastal plant, originated along the coasts of the Paratethys Sea. After the Eocene Ephedraceae and Nitrariaceae dwindled, with Poaceae, Asteraceae, Chenopodiaceae taking over as predominant taxa and Ephedraceae and Nitrariaceae forming the minority in the palynological records.

***Key* words:** *Nitraria*, *Ephedra*, Paratethys, Asian monsoon.

From Gondwana into the tropics

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Temporal and spatial succession of paleofloras in southern South America has been linked to climatic changes and the transition from a "greenhouse" to an "icehouse" during the Cenozoic, and to the contraction of the climatic belt toward boreal latitudes. The high global temperatures of the early Eocene provoked the expansion of the tropical and subtropical climatic belts toward high latitudes, exerting a selective pressure on temperate taxa and explain the current distribution between tropical and temperate taxa. Recently, Hinojosa and collaborators suggest that lineages of Gondwana origin expanded into the tropics as species tracked mesothermal climates, and dispersal towards current tropical zones has been possible because species have tracked ancestral climatic niches from high or mid-latitudes towards lower latitudes, driven by both climatic and tectonic changes. We evaluate this into the tropic hypothesis comparing phylogenetic climate reconstruction of selected taxa with paleoclimatic reconstruction of the Early Eocene Ligorio Marquez Formation (LMF) using both coexistence approach and leaf physiognomy analysis, in the micro and macroflora. LMF is a continental clastic succession of fluvial channels, flood plains, and marsh deposits located in the border of Argentina and Chile (46° S). The fossils plants, including pollen and leaf remains, are diverse, highlighting the local presence of *Nothofagus* and *Gunnera. Financial support*: FONDECYT # 1150690 and IMEB PO5-002; PFB-23.

***Keywords*:** Early Eocene, Paleoclimate, Niche Reconstruction, Ligorio Marquez Formation

Eocene Esmeraldas Flora from Colombia and their implications for understanding the impact of global climate change

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An important step in the evolution of our modern glacial climate state occurred during the middle Eocene to early Oligocene, when the global temperature cooled, and the first Antarctica ice sheet appeared. This dramatic climate change caused a significant global turnover in marine and terrestrial biotas, however, more evidence from tropical regions is still needed to document these changes. The macroflora from the Esmeraldas Formation of Colombia provide plant fossil evidence to understand some of the biotic changes that could have occurred in tropical regions. The Esmeraldas Flora has been collected from two localities and has more than five hundred specimens of compressions and impressions of leaves mostly, but also seeds, fruits and seldom flowers. Detailed stratigraphic data show that the Flora was deposited in floodplains of braided and meandering rivers. The age of the Esmeraldas Formation ranges from late Early Eocene to Late Eocene, however, isotopic analyses of δ13C of rock samples collected along the entire Formation are being analyzed in this study as a chronostratigraphic tool to provide better age estimates for the localities where fossil material was collected. Here, we present preliminary results of paleoclimatic analysis of leaf fossil material from the Esmeraldas Formation that so far are suggesting drier conditions during deposition compared to those from the present. Leaf cuticle analyses that include anatomical features and isotopic values δ13C are also being performed to provide estimates of atmospheric CO_2 concentration for the Esmeraldas Formation. Finally, we propose preliminary taxonomic affinities of some fossil leaves, flowers, fruits and seeds, that suggest the presence of plant groups like Fabaceae, Myrtaceae, Myrsinaceae, Malvaceae and Solanaceae. In conclusion, the Esmeraldas Flora exhibit a great diversity, a predominance of microphyll leaf sizes and a great preservation of cuticles and dry fruits, that in general are so far suggesting that the Esmeraldas Flora might have represented a dry ecosystem.

***Keywords*:** Eocene, leaf macrofossils, Colombia, paleoclimate, Esmeraldas Formation

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Does the Río Turbio Formation preserve evidence of an extinct biome?

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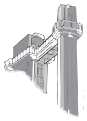
The Rio Turbio Formation (RTF) was accumulated in the Austral Basin, Patagonia, during the early Middle Eocene to the Late Eocene. The RTF preserved a unique paleoflora known as the "Mixed Paleoflora (MP)", a flora that by the middle Eocene occupied most of temperate South America. The MP lived under a unique combination of climatic parameters including a temperate region with a relatively warm winter, high annual precipitation, little seasonal variation, representing a climate that has not a modern analogue. The MP had a mixture of angiosperms and gymnosperms that combined Neotropical elements, cold-temperate elements from Gondwana—sub-Antarctic in origin—and in situ Chaco forests. Is the MP a biome with no modern analog? In order to answer this question, we studied 22 palynological samples from nine sections of the Eocene in Patagonia. We compared the palynological assemblages with most of the extant biomes temperate South America. We used the pollen data from the Latin American Pollen Database and perform a similarity analysis using the Chao's similarity index. Preliminary results show that the MP of the upper member of the RTF have a greater similarity to the extant Valdivian Forest. In contrast, The MP of the lower member of the RTF is not similar to any extant biome. We aim to expand the analysis to include additional Gondwanan Eocene floras of Brazil, Chile, Bolivia, Australia and New Zealand.

***Keywords*:** paleopalynology, Mixed Paleoflora, Latin American Pollen Database, Patagonia, Eocene.



EVOLUTION OF BIODIVERSITY HOTSPOTS

Tao Su & Torsten Utescher

Palynological evidences for evolutionary history of biodiversity hotspots in Yunnan, SW China

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Yunnan Province in SW China is an essential part of the "Mountains of Southwest China (Geo-)Biodiversity Hotspot". It is located adjacent to the southeast of the Tibetan Plateau with a complicated topography, diverse climate conditions, and high plant diversity. Its relief ranges from 1,000 to 7,000 m a.s.l. covering tropical, sub-tropical temperate and alpine vegetation types including over 18,000 plants representing almost 52% of all Chinese species. The geological history of Yunnan has been strongly affected by the uplift of the Tibetan Plateau in the Cenozoic. The Late Cenozoic is considered as a crucial period in the development of local vegetation. During that time, there were severe environmental changes occurred both on the lands and in the oceans, such as the global climate variations, the enhanced Neotectonic movement, the development and spread of C4 grasses, the aridification of the interiors of continents, the expansion of open landscapes, and the development and evolution of the East Asian monsoon, etc. Palynological data are reviewed to partially brings insight into the possible evolutionary history of biodiversity hotspots in Yunnan. The Late Cenozoic pollen datum from Qujing Basin is a good exsample in demonstrating the developing process of local vegetations with environment changes. The original oak forest shows a variation of retreat, expanse and retreat again, which is considered to be in correspondence with the uplift of Qinghai-Tibet Plateau and the worldwide climate cooling at ca. 3.4 Ma and 2.5 Ma respectively. The high-resolution pollen study of the lake sediment in Heqing Basin displays that the increase or decrease of vertical vegetational belts and the changes in the components of vegetational belts were controlled by the tectonic uplift of mountains and the climatic changes since 2.78 Ma B.P. The excavation of Palaeolithic sites in Yunnan also gives us chances to reconstruct the local vegetation and its climate background for the early human beings. The site at Xiangbidong is the first Palaeolithic cave relic in the province, which is located in the Hengduan Mountains with complex landforms and diverse natural landscapes. Pollen study reveals vegetation and environment changes in close relationship with the development of monsoon, and possiblly human activities as well.

***Keywords*:** Geo-biodiversity, vegetation changes, palaeoenvironment, Late Cenozoic, Yunnan

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Pliocene environmental evolution of the Hengduan Mountains (biodiversity hotspots), SW China: evidence from geochemical data

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The Pliocene is a key period to understand past climatic changes, because the environment in this period is quite comparable to today. We employ geochemical data from the strata of Dali basin (2.8 - 3.6 Ma) situated at the southeastern margin of the Qinghai-Tibetan Plateau to explore the paleoenvironmental changes in the Pliocene of the Hengduan Mountains. We measured the values of $\delta^{13}C$ and $\delta^{18}O$ on bulk carbonates, $\delta^{13}Corg$ on bulk organic matter, as well as total organic carbon (TOC) to answer the following questions: 1) How did the paleoenvironment evolve during the Middle to Late Pliocene (2.8 - 3.6 Ma) ? 2) What were the main driving factors contributing to palaeoenvironmental changes? The main results are listed as follows:

1) $\delta^{13}C$ positively correlate with $\delta^{18}O$ ($r = 0.76$, $p<0.01$); 2) The mean value of $\delta^{18}O$ is -11.3047 in ZoneI (3.5-3.28Ma), -11.6955 in ZoneII (3.28-2.98Ma), -11.128 in ZoneIII (2.98-2.82Ma), mean value of $\delta^{13}C$ is – 1.2802 in ZoneI, -1.4001 in ZoneII, -1.1474 in ZoneIII; 3) δ^{13}Corg values range between -28.71 ‰ –- -22 ‰; 4) TOC is 0.5199 in ZoneI, 0.3661 in ZoneII, 0.4123 in ZoneIII, TOC negatively correlate with δ^{13}Corg ($r = -0.194$, $p<0.01$). According to the results above, we summary that: 1) Dali basin had a closed-lake configuration; 2) The values of both $\delta^{13}C$ and $\delta^{18}O$ show precipitation/evaporation (P/E) in low latitude lakes first increasing (3.6 – 3.1 Ma) and then decreasing (3.1 - 2.8 Ma). In Yunnan, the major source of rainfall is driven by monsoon, which possibly indicating the intensification of monsoon increased firstly and then decreased there; 3) δ^{13}Corg values reflect the sign of C_4 plants did not appear in this area, we hypothesize the lack of high temperature and long day sunshine, also possible the dense forest presented in this area; 4) The TOC and δ^{13}Corg values may reflect the plant community structure with different lake levels, and primary productivity/recycling ratio. At last, the spectrum analysis revealed the main driving factors to environmental evolution in Hengduan Mountains that the $\delta^{13}C$ and $\delta^{18}O$ values followed both the obliquity (33 kyr) and precession (19 kyr) cycles. Comparing to our $\delta^{18}O$ data with previously published data, we found that the trend of $\delta^{18}O$ values in area coincides with the trend of the global benthic foraminifers $\delta^{18}O$ (LR04) during 3.5 -2.8 Ma, suggesting that other factors contributing to paleoenvironmental changes in Dali might be the global temperature, sea-lever, or ice-volume.

Keywords**:** Pliocene, geochemistry, Yunnan, palaeoenvironmental changes, orbital cycles

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Miocene Maguan flora and its climate, implications for the evolution of South China biodiversity hotspot

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South China has long been known as a biodiversity hotspot; however, the evolutionary history of the hotspot is still less well known. Recently, a late Miocene paleoflora was discovered from the South China hotspots at Maguan basin, southeastern Yunnan province, China. The paleoflora contains diverse flower, fruit and leaf fossils in excellent preservation, and is thus of significance to reveal the evolution of South China biodiversity hotspot. So far, 35 taxa are identificated including 2 conifers and 33 angiosperms. The species composition shows that the flora is a subtropical evergreen broadleaved forest dominated by Fagaceae and Lauraceae. The understory taxa includes *Myrsine* and *Camellia.* Beside, common taxa *Ailanthus*, *Carpinus*, *Cedrelosperum*, *Craigia*, *Ulmus*, *Calocedrus* and *Sequoia* are identified. The rich diversity of Leguminosae including *Abizia*, *Bauhinia*, *Cercis*, *Cladrastis*, *Dalbergia*, *Mucuna*, *Pterolobium* and *Podocarpium* suggests that it was a biodiversity center for Leguminosae during that period. Abundant winged fruits, *e.g. Craigia*, *Cedrelosperum*, *Craigia*, *Engelhardia*, *Pterolobium*, *Pterocarya* and *Ulmus* indicate that wind dispersal was well represented in Maguan flora and sufficient winds were present. In addition, *Cedrelospermum*, *Deviacer*, and *Podocarpium* constitute three extinct genera found in the flora, and *Sequoia* represents a regional extirpated genus in the flora. The discovery of *Pterolobium maguanensis* is the first fossil in the genus, and *Cedrelospermum asiaticum* constitutes the first fossil record of the genus in Asia. A preliminary paleoclimate was reconstructed based on the Coexistence Approach (CA). The Mean Annual Temperature (MAT) was calculated to be 18.6-21.9°C, indicating a warmer temperature than today (16.8°C). The Mean Annual Precipitation (MAP) was calculated to be 1095-1597 mm, indicating a similar precipitation with today (1344.8 mm). The driest month precipitation (MPDRY) represents 9.4% to 10.7% of the wettest month precipitation (MPWET), indicating that seasonality was present, but not as strong as today (13.8%). The extinction of *Cedrelospermum*, *Deviacer*, *Podocarpium* and *Sequoia* from South China as well as Asia is possibly related to the general cold temperature and increased seasonality of precipitation after the late Miocene.

Key words**:** biodiversity hotspot, climate, extinction, late Miocene, South China

Some angiosperm fossils from the Oligocene in South China and their geological significance

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Some angiosperm fossils were collected from the Ningming Formation of the Oligocene in Ningming, Guangxi, South China. Of them, there are two *Buxus* species. They have good cuticles and are respectively identified as *Buxus ningmingensis* sp. nov. and *Buxus preaustro-yunnanensis* sp. nov. based on gross morphology and microstructure. Comparing with related extant and the known fossil species, the occurrence of the two species implies that South China may represent one of the centers for early diversification of the *Buxus* genus. Other angiosperm species are described on their leaf architecture and fruit macrostructures. A total of 13 species which belong to 6 families and 11 genera have been identified. Together with other plant fossil records, it can be inferred that the major members in the Oligocene flora are Lauraceae, Fagaceae, Leguminosae and Arecaceae. The plant fossil assemblage shows that the Oligocene Ningming flora is mainly composed of evergreen broad-leaved trees and lives under a tropical or subtropical climatic condition. These plant fossils can provide a new insight into the plant systematic and evolution. Furthermore, the Oligocene fossil plants from Ningming will greatly help us to understand the paleoclimatic evolution and paleoenvironmental changes during the Paleogene. The presence of the flora indicates a warm-humid tropical or subtropical paleoclimate during the Oligocene in Guangxi, southern China.

***Keywords*:** Oligocene, angiosperm, cuticular structures, paleoclimate, South China

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The palaeoelevation and palaeoclimate during the latest Eocene in eastern Tibet: evidence from plant fossil record

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The uplift of the Qinghai-Tibetan Plateau as well as its influence on the palaeoenvironment and biodiversity have been interesting and pivotal topic for a long time. Plant fossils are importance evidence for the palaeoenvironmental changes in geological times; however, the Cenozoic floras in Tibet is far from fully investigated until now, because of the logistical inconvenience and dramatically tectonic activities. Recently, we found plenty of well preserved plant fossils from an elevation of about 4000 m in Kajun village, Mangkang County, eastern Tibet. According to the Argon-Argon dating of volcanic rocks in the fossil-bearing stratum, the age of the flora is about 35.5±0.3 Ma. The flora is rich in species, with four genera of gymnosperms, i.e., *Abies*, *Chamaecyparis*, *Pinus*, and *Tsuga*, and 36 morphotypes of angiosperms, e.g., *Betula*, *Elaeagnus*, *Lindera*, *Quercus*, *Tsuga*, *Viburnum*, and *Vitex*. Among them, ring-cupped oak (*Quercus* subgenus *Cyclobalanopsis*) is the most abundant, followed by *Betula*, indicating a temperate evergreen and deciduous broadleaf forest. Palaeoclimate reconstruction using Climate-Leaf Analysis Multivariate Program (CLAMP) shows that mean annual temperature (MAT) was 13.6 C, and growing season precipitation was 152.8 cm. Palaeoelevation

reconstruction with atmosphere enthalpy was about 2600±900 m for the flora, this is also supported by the spatial coexistence of taxa in the flora even the paleoclimate background is considered. Our results indicate a warmer and wetter climate in the southeastern part of the Qinghai-Tibetan Plateau during the latest Eocene; moreover, this part had already been high at that time. This work is supported by National Natural Science Foundation of China (No. 31470325, U1502231), and the Foundation of the State Key Laboratory of Paleobiology and Stratigraphy, Nanjing Institute of Geology and Paleontology, CAS (No. 143107). This work is a contribution to NECLIME (Neogene Climate Evolution in Eurasia).

***Keywords*:** Fossil, Eocene, flora, CLAMP, uplift, Qinghai-Tibetan Plateau

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Late Miocene occurrence of the genus *Oleandra* (Oleandraceae s.s.) from SW China and implications for its evolutionary history

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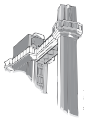
China possesses the most diverse lycophytes and ferns in the world, with ca. 2270 species and 178 genera belonging to 40 families. Of which, Yunnan is a world famous biodiversity hotspot, and take the first place for the diversity of lycophytes and ferns with about 1365 species. Especially, there are ca. 414 species of ferns endemic to China (taking 30.33% of the total of Yunnan) and 181 species endemic to Yunnan (taking 43.72% of the total of Chinese endemics in Yunnan). However, the origin and the evolution of the higher diversity of Chinese ferns in the geological prospect, with emphasis on ferns of Yunnan, are little known. The monogeneric family Oleandraceae is more natural and distinctive in morphology among the derived ferns, but its origin and evolution is still remaining unknown due to its absence in fossil records. Here we recognized a new fossil species of *Oleandra* cav. from the upper Miocene of Yunnan, SW China. It represents the first fossil occurrence of the genus *Oleandra* (Oleandraceae). *Oleandra bangmaii* sp. n. is characterized by a simple fertile frond with an entire and cartilaginous margin. The venation system is unique by a prominent midrib plus parallel, closely spaced secondary free veins. Sori borne dorsally, with round kidney-shaped indusia. This only fossil occurrence so far probably supports that this genus was probably spread out of Asia to the pantropical regions of the world. This new founding together with other evidence implies the crown of eupolypods I has been diversified and the epiphytism was much common in the late Miocene (11.6-5.3 Ma) forests of Yunnan before the Quaternary glaciation.

***Keywords*:** Miocene, fern, *Oleandra*, Yunnan, frond morphology



IAWA SYMPOSIUM: THE HYDRAULIC ARCHITECTURE OF PLANTS THROUGH TIME

Jonathan P. Wilson, Anne-Laure Decombeix & Lisa D. Boucher

Systematic and functional diversity of Famennian (Late Devonian) archaeopterids from Anti-Atlas, Morocco

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Archaeopteris (Archaeopteridales) formed widely-distributed forests in the Late Devonian and was the first arborescent genus showing a dense conifer-like wood. Nineteen species of *Callixylon* (a form-genus for anatomically preserved roots, stems and branches of *Archaeopteris*) have been described based on wood characters. Specific distinctions are mostly based on the structure and dimensions of the rays. It is believed that the success of *Archaeopteris* is partly associated with its well-developed wood which played a significant role in both water conduction and mechanical support. This study focuses on a collection of anatomically preserved specimens representing several species of *Callixylon* from the Famennian locality of Mader el Mrakib in Anti-Atlas (south-eastern Morocco). The affinities of two specimens showing sclerotic nests in the pith are examined using qualitative and quantitative data obtained from light microscopy and image analysis. The hydraulic properties of the Moroccan species are investigated using Wilson's mathematical model calculating the hydraulic conductivity of single tracheids. This model is based on anatomical data such as tracheid length and diameter, pit morphology and density. Conductivity is quantified using an analogy between hydraulic properties of conductive tissues of a plant and electric properties of an electronic circuit. Putting some virtual tracheids together, an extension of this model to the tissue scale that takes rays into account is proposed. The two Moroccan specimens with sclerotic nests are interpreted as representing a new species of *Callixylon* within Orlova and Jurina's '*erianum*' group. Their hydraulic properties are evaluated and compared to those of the other species of *Callixylon* occurring at Mader el Mrakib, accounting for the functional diversity of the genus. This approach contributes to a better understanding of the relationships between the anatomical, systematic and functional diversity of *Archaeopteris.*

***Keywords*:** Devonian, trees, wood, hydraulic properties, model

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Preliminary investigation on the paleoflora of Bantak Petrified Forest Park, Tak Province, Northern Thailand

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Some of the longest petrified trunks in the world (ranging from 22 to 69 meters in length) are found in the Petrified Forest Park (PFP), Bantak District, Tak Province in northwestern Thailand. Numerous fossilized trees, of smaller size, have also been found scattered throughout the forest park. Only two taxa, however, were described, on the basis of the seven largest logs. To provide more information on the PFP paleoflora, we collected 34 samples from 13 selected sites and investigated a selection of 14 samples from the 13 sites. The petrified trees belong to 4 dicotyledonous wood taxa: *Pahudioxylon; Koompassioxylon*; cf. *Pterygota* and *incertae sedis*. The wood features, including indistinct growth rings, diffuse porous wood, vessels commonly solitary and occasionally in short radial multiples, simple perforation plates and alternate intervessel pits, are common characters found in tropical

hardwood species. The fossils are embedded in unsorted well-rounded gravel deposits (Pleistocene); some are exposed on hills and along dry streambeds Riverine trees were possibly up-rooted, downed, transported over a short distance by water and eventually buried in what is today the PFP. The PFP modern vegetation is represented by dry dipterocarp forest. The fossil trees suggest a somewhat wetter and much taller forest, as their dimensions imply that original trees towered up to more than 80 meters. This is consistent with our determination of *Koompassioxylon*, related to *Koompassia*, among the tallest Southeast Asian trees today.

***Keywords*:** petrified wood, *Pahudioxylon*, *Koompassioxylon*, Pleistocene

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Modern hydraulic architecture at the Cretaceous-Paleocene Boundary of India

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We review the wood anatomy and botanical affinities of the Deccan Trap woods from Central India – dated as latest Cretaceous (Maastrichtian) to early Paleocene (Danian). There are at least 80 wood types, most collected from five distinct and productive localities. We recently examined thin sections of the holotypes of over 40 species. It appears that this species rich, for the Cretaceous, assemblage harbours many first records of angiosperm orders, families or even genera and that its spectrum of hydraulically important functional traits is very modern, and comparable to that of extant dry tropical forest ecosystems. This runs counter to earlier global analyses of fossil wood, dominated by assemblages of higher latitude from both the Northern and Southern Hemispheres. These higher latitude Cretaceous and Paleocene woods have higher incidences of so-called "primitive" hydraulic attributes such as scalariform vessel perforations and lower incidences of vessel-associated axial parenchyma. The paleolatitude of the Deccan woods was close to the equator. Apparently, latitudinal differences in wood anatomical functional traits were as great or greater at the KPB as they are today. The absence of distinct growth rings in most Deccan Woods suggests a climate with minimal seasonality, contrasting with monsoonal seasonality of today.

***Keywords*:** Cretaceous, Paleocene, wood anatomy, secondary xylem, Deccan Traps

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Hydraulic variability among Late Paleozoic plants: convergence, coordination, and conundrums

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Functional properties of plant organs, including xylem and stomata, can be determined by the application of mathematical and biophysical models derived from the properties of water transport and gas exchange. We employed a series of models and statistical analyses of stem, branch, and leaf xylem and coupled these analyses with biophysical models of gas exchange through leaves to test the hypothesis that Late Paleozoic plants occupied a limited range of ecological function with respect to water transport and transpiration. Leaf and stem measurements focused on four key Late Paleozoic taxa, including seed-free vascular plants and seed plants: the pteridosperm Medullosa, the stem group gymnosperm Cordaites, the equisetophyte Sphenophyllum, and the Gondwanan pteridosperm Glossopteris. Results provide additional support for functional convergence among plants containing pycnoxylic wood, with biseriate and multiseriate xylem from Cordaites matching hydraulic properties of extant conifers and Glossopteris closely resembling cold-tolerant plants. Plants containing manoxylic wood, including Medullosa and Sphenophyllum, exhibit structural and hydraulic properties that closely resemble early angiosperm vessels, with wide tracheids and narrow cell walls featuring abundant pits. When integrated with measurements that inform leaf hydraulic properties, including mesophyll path length, vein length per area, and maximal theoretical stomatal conductance, Late Paleozoic plants contain coordinated adaptations between leaf and stem hydraulics. Cordaites plants contain dense mesophyll with relatively long path lengths between veins and stomata and stomatal conductance comparable with extant gymnosperms and

drought-adapted angiosperms. Thin medullosan foliage effectively shortens the path length between veins and leaves, and medullosan leaf morphotypes appear to occupy distinct ecophysiological zones throughout the peak glacial-interglacial cycles in the Pennsylvanian period. Hydraulic bottlenecks in Glossopteris and low air-seeding safety margins in Sphenophyllum form two end-members of a safety-efficiency spectrum. Further exploration of the hydraulic variability among Late Paleozoic seed-free vascular plants and seed plants will illuminate the evolutionary history of plant function.

Keywords**:** xylem, cavitation-embolism, water transport, pteridosperm, sphenopsid

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Functional secondary xylem in context: characters and assemblages during the Cretaceous

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The development of secondary xylem increases the longevity of functional vascular tissue, allowing for plant structures with greater height (e.g. tree forms), potentially faster growth and recovery (i.e. new tissue from cambia), unique growth forms (e.g. lianas), and response to environmental stimuli (e.g. reaction wood). From modern comparative genomics, it appears that the functional domains of genes in the xylem transcriptome are relatively conserved in vascular plants, with evidence for greater divergence in the angiosperms. This rapid diversification implies that the angiosperm xylem transcriptome was more sensitive to selection or other evolutionary forces. Furthermore, the variation seen in secondary xylem suggests that there are a suite of traits under complex selective pressures and trade-offs. By the end of the Cretaceous, gymnosperms and angiosperms were the plants with secondary growth that dominated floras to a varying degree based on scale; global trends were largely related to paleolatitude whereas local trends were based on environmental differences. General trends in xylem characters through time and global location of representative taxa and their relation to climatic variations have been previously studied. A more detailed subset of data focusing on the co-occurrences of taxa with secondary growth at the landscape level addresses the setting at which secondary xylem and selective pressures operated. The objective of this study was to examine the secondary xylem of gymnosperms and angiosperms from Cretaceous in situ assemblages in an effort to link anatomical traits to their composition, abundance and local distribution along the landscape. New data from the Late Cretaceous Fruitland, Kirtland, and Menefee floras of North America will be compared with available global assemblage data at similar scale. By examining specimen data in this way, we relate the co-occurrence of traits within different taxa to their local distributions. Because of trait constraints, and other indirect features contributing to fitness, these traits will be considered in the context of other characters and their relative importance through time and place as well as whole-plant function. The results support selective pressure on hydraulic traits within the secondary xylem in gymnosperms and angiosperms. Additionally, the initial spread of smaller angiosperm populations would have had an influence on microevolutionary dynamics, and may have played a significant role in the diversification of secondary xylem in angiosperms. After the Cretaceous, greater phylogenetic variation and environmental pressures may have overcome thresholds providing angiosperms a competitive advantage in a greater range of environments.

Keywords**:** secondary xylem, wood assemblages, functional evolution, Cretaceous

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Fossil wood from the early Cenozoic volcanic rocks in Fildes Peninsula, King George Island, Antarctic Peninsula: Conifer dominant forest

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Despite the well-known abundant occurrences, the fossil wood of King George Island in Antarctic Peninsula have been relatively little investigated, based only on pebbly loose blocks from the outcrops, i.e. ex-situ

materials. During the 2014/2015 Summer Expedition on King George Island, in-situ fossil wood trunk and stems from volcanic rocks were collected near Suffield Point of Fildes Peninsula. The collected trunk was noted by several researchers before, but no anatomical study has yet to be performed. The host rock of fossil wood is a volcano-sedimentary deposit, and belongs to the Fildes Formation which is the early Cenozoic (Eocene) in age. Thin section slides have been prepared for anatomical observations. Nine specimens are identified as coniferous woods. These coniferous wood specimens, except three poorly preserved ones, show *Metapodocarpoxylon*-, *Phyllocladoxylon*- or *Agathoxylon*-like anatomies. The tenth specimen is identified as a dicotyledonous wood, with diffuse-porous to semi-ring porous vessel arrangement. These results increase the wood floral diversity documented for the early Cenozoic King George Island, and suggest that conifers largely prevailed over angiosperms in this Eocene forest. This conifer dominance, as here documented by wood flora, fits well with early Eocene vegetation reconstructed by wood, leaf or pollen analysis from in the other parts of Antarctic Peninsula. The conifer element of this study is also comparable to that of the extant high-altitude volcano vegetation elements in Valdivia (Chile) area, described as the Valdivian Model by Poole *et al.* (2001). We expect that further study of in-situ floras will yield more information for understanding of the palaeoflora and palaeoenvironment in Antarctic Peninsula during the early Cenozoic.

***Keywords*:** Fossil wood, early Cenozoic, Fildes Peninsula, Antarctic Peninsula, conifer forest

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Seeking for climatic indicators in wood anatomical characters of dry and seasonally wet forests from Panamá

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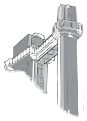
One of the great challenges of modern wood research is to understand the relationship between climate and wood anatomical trait variation in order to obtain reliable predictive models. Only a few extensive studies have been conducted linking wood anatomy and climate. However, what we know today about the ecological tendencies of the secondary xylem is based on the combination of extensive studies and regional approaches. Tropical dry forests have been reduced to less than 0.1% of their original extension in the Pacific Coast of Central America due mainly to human activities. In Panamá, those forests have been scarcely studied, much less in terms of wood anatomy. We tested six localities in Panamá, including five from dry forests (Sarigua, Las Tablas, Coronado, Achotines, and Divisa) and one from seasonally wet forest (Barro Colorado Island) to see if there were significant differences in their continuous wood anatomical trait in relation to Mean Annual Precipitation (MAP) and Mean Annual Temperature (MAT). 28 species belonging to 18 different families were studied**.** We find no significant differences between localities of dry forests, as we can expect since the precipitation rates varies little. However, vessels and fibres traits were not different between dry forests and Barro Colorado Island (BCI), with nearly 1000 mm of difference in MAP. Only traits related to ray length showed significant differences. Rays are shorter in dry forests than in seasonally wet forests and we observed the lowest values of ray sizes in Sarigua and Las Tablas, which are the studied localities with the lowest MAP. Additionally, we find significant correlation between ray characters and the 2 climatic variables (MAT and MAP). Mechanical significance of rays has been explored very recently but the main functions are to radial-transport water between the phloem and the xylem and storage of water, sugar and other nutrients. It is complex to interpret ray variation in size and proportions because it is driven by multiple factors. Additionally, we build the first reference collection of woods of dry tropical forests from Panamá. The references slides are part of the collection of Jodrell Laboratory in Kew Gardens and the Center of Tropical Archaeology and Paleoecology (CTPA) in the Smithsonian Tropical Research Institute. We developed an illustrated guide to woods from Panamá, which is the first reference for tropical woods. Finally, this work will enable us to better know our tropical dry forests and will seek for analogues to be applied in further analysis with fossil assemblages of the region.

***Keywords*:** Dry forests, Barro Colorado Island, wood anatomy, MAP, MAT.



LONG-TERM VEGETATION, CLIMATE, FIRE DYNAMICS AND HUMAN IMPACT IN TROPICAL AND SUBTROPICAL ECOSYSTEMS

Hermann Behling, Kamaleddin Alizadeh,
Paula A. Rodríguez-Zorro & Siria Biagioni

Paleoecological reconstruction from the Mid Holocene (5500 years B.P.) in Palm Swamp Communities (*Mauritia flexuosa* l. f.) on the Amazon Region (Colombia)

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A palynological analysis was carried out in a palm swamp community located in the Colombian Amazon, was conducted a reconstruction of changes in vegetation and climate of the last 5500 years B.P. In the palynological diagram it was possible to distinguish three (3) zones associated with stages of vegetation succession; initial: dominated by the pollen representation of the pioneers elements (*Cecropia*, *Litachne*, *Echinocloa*) and swamp (Amaranthaceae, *Mauritia*, *Mauritiella*) who dominated in wetter epochs that actual, intermediate: dominated by elements of the floodplain (*Bactris*, Mimosaceae, Malpighiaceae) and late: represented by forest land (*Attalea*, *Geonoma*, *Iriartea*). In the Zone I (4870 to 3915 years Cal B.P.) there was a bucket with a water mirror (*Botryococcus*, *Pseudoschizaea*), on the banks set a swamp formed by Amaranthaceae and *Cecropia*. Sub Zone II-A (3915 to 2900 years Cal B.P.) increased representation of floodplain vegetation dominated by a mixed palmar (*Bactris*, *Memora* and *Symphonia globulifera*), in the forest land dominated the mixed palmar (*Attalea* and *Acalypha*) and began the representation of palm swamp communities (*Mauritia flexuosa*). Sub Zone II-B (2900 to 2035 years Cal B.P.) dominated the representation of the forest land elements, mixed palmar of *Attalea Geonoma*, *Pouteria* and *Iriartea deltoidea*. Zone III-A (2035 to 1330 years Cal B.P.) the extent and depth of the bucket was recovered, (*Botryococcus*, *Pseudoschizaea*, *Litachne pauciflora* and *Mauritia flexuosa*), it decreased the mixed palmar of the forest land especially for the disappearance of the representation of *Attalea*. Sub Zone III-B (1330 years Cal B.P. to present), decreases the representativeness of forest land palmar, the palm swamp (*Mauritia flexuosa*) increased its representation with elements of swamp, the representation of floodplain forest as forest land was very low. Changes in plant succession are related to moisture (rain and flow) at local and regional level.

***Keywords*:** Amazon Basin, Palm swamp, Paleopalynology, Plant succession

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Changes in the distribution and floristic composition of the Atlantic forest through time using fossil pollen records

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To characterize changes in the spatial distribution of the Atlantic forest, we focused on three different forest physiognomies, evergreen, semi-deciduous, and *Araucaria*, during the last 17,000 years and we provide a list of indicator taxa for each class retrieved from the original published datasets. A review of published fossil pollen records allowed us to classify regional behaviors in three main areas of distribution, north of 15°S, between 15 and 23°S and south of 23°S latitude that correspond to three climatic geographical barriers. Statistical probability density function method was used to illustrate changes in forest physiognomies throughout the three distribution areas. We show that the three modern barriers also functioned through the past. Asynchronous patterns of forest physiognomies are linked to an antiphasing pattern of monsoon precipitation between the northern and central area, while in the southern area is linked to frequency and intensity of the polar advection in the subtropics. Our results attest to strong climate forcing on forest

distribution between the late glacial and the interglacial period. They call into question the common reference to the last glacial maximum as a major (and sometimes as the only) driver of forest-related vicariance and genetic diversity patterns, but suggest that instead, orbital cycles were the main drivers of the successive expansion/contraction of the Atlantic forest throughout the Quaternary.

***Keywords*:** Atlantic forest, insolation cycle, probability density function, climate change, Brazil

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An extended palynological record from Bromfield Swamp and its contribution to refinement of late Quaternary vegetation and environments on the Atherton Tableland, NE Australia

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Palynological records from accumulated sediments within volcanic craters on the Atherton Tableland of northeastern Australia have provided a history of rainforest and rainforest-savannah dynamics covering in excess of the last 200ka. Despite the number of records sites investigated (seven), a detailed regional picture of patterns of vegetation change and associated environmental factors has been difficult to generate due to factors like different record age ranges, variable site characteristics and coring problems. Only one record, Lake Euramoo, has provided detailed coverage of the diverse rainforest assemblages of the whole of the Holocene and impact of European settlement in the Anthropocene, while Lynch's Crater alone provides continuous coverage of vegetation and environments for MIS2 to beyond MIS3 and importantly includes the time of arrival of Indigenous people on the Australian continent, around 50-60ka, and subsequent decline of moist rainforest with increased burning about 40ka. The opportunity to provide a more spatial assessment of late Quaternary vegetation has been made possible recently by extension of a pre-existing Holocene record from Bromfield Swamp to 37ka. A number of significant results are emerging. As in at Lynch's Crater, there is a fourfold division in dryland pollen assemblages with a basal representation of moist rainforest to 32ka, a total dominance of dry sclerophyll vegetation (32-14ka), a transition to rainforest (14-9ka) and then dominance of current complex rainforest to present. The climate influence over these and several additional marked changes is clearly demonstrated by detailed geochemical and sedimentological proxies. These also indicate centennial to millennial-scale cyclicity, possibly related to ENSO variability as recorded in Lynch's sediments, to which dryland vegetation appears not to have been responsive. Throughout the record, there is evidence that conditions were drier than at Lynch's Crater indicating the maintenance of the present rainfall gradient across the Tableland. Extreme conditions are identified between 32 and 27ka with the local development of salt marsh but the demise of moist rainforest prior to this time was probably equally a result of increased burning associated with the impact of people as it was a drying climate. However, the lack of correspondence between macro- and microcharcoal values, probably resulting from charcoal alteration within largely inorganic sediments, makes inferences about past burning in places problematic. In relation to the current complex rainforest phase, this record, in combination with others, provides an excellent picture of differential responses of many taxa to regional and global environmental triggers.

***Keywords*:** Late Quaternary, humid tropics, northeastern Australia, multi-proxy analysis, vegetation dynamics

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Holocene history of climate, vegetation and anthropogenic disturbance from core monsoon zone of central India as reflected in lacustrine sediments of Lonar Crater, Maharashtra

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To infer Holocene changes in monsoon activity, sediments of Lonar Crater Lake have been studied within the Indian-German research collaboration project HIMPAC (Himalaya: Modern and Past Climates). The lacustrine sequence of Lonar Lake provides one of very few comprehensive and well dated records of vegetation changes in the context of climate fluctuations and human activity during the last ca. 10,000 years in India. Lonar Crater is situated on the Deccan Plateau of Buldhana District. The climate is driven by Indian summer monsoon (ISM) circulation. The modern tree or shrub savannah of this area is assumed to be sensitive to changes in annual precipitation and length of the rainy season. Under modern climate conditions the potential natural landcover of southern India is traditionally characterized as tropical deciduous forest, which has been transformed to savanna, due to long-term anthropogenic pressure. Results of pollen analysis and n-alkane stable carbon isotope measurements in the Holocene sediment sequence from Lonar Lake shed a new light on the Holocene evolution of vegetation of central India. Closed moist-deciduous forest featuring C3-grass undergrowth formed the vegetation in the Lonar region between 8.8 and 5.1 kyr BP suggesting enhanced rainfall in the today semi-arid area. After 5.0 kyr BP, evergreen woody elements (e.g., *Syzygium*, *Olea*, *Schleichera*) widely disappear from the pollen record, while pollen of dry deciduous and xeric trees and shrubs (e.g., *Tectona*, *Azadirachta*, *Acacia*) contemporaneously increases. Moreover, stable carbon isotope ratios proof the establishment of C4-grasses, which suggest the appearance of savanna vegetation. The rapid change in the functional vegetation type reflects the mid- to late Holocene decrease in ISM activity, which is observed throughout the ISM realm. While archaeological evidence suggests that the cultural shift from hunting-gathering to sedentary agriculture on the Deccan appeared earliest at 4.5 kyr BP, and becomes evident in the Lonar Lake pollen record not before 1.2 kyr BP, human activity can be ruled out as initial cause for the change in the vegetation type, highlighting the importance of climate changes for the establishment of grass-lands in central India.

***Keywords*:** Lonar Lake, modern pollen, Holocene, Savannah, Indian summer monsoon

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Holocene vegetation dynamics and fire history of tropical peatlands in Central Sumatra, Indonesia

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Tropical peatlands, large portion of which are found on the island of Sumatra, Indonesia, provide important ecological functions including carbon storage, biodiversity source and water regulation. These functions are threatened mostly by land transformation following the rapid increase of Indonesian population. In addition, warming climate also contributes to the threat by an increasing frequency of severe droughts and wildfires. Thus, the understanding of the interaction between ecosystem and fire in the past is necessary in order to preserve and manage the important functions as well as to create the future projection of peatlands. Holocene palaeoecological records of two peatlands in Jambi Province, Air Hitam and Sungai Buluh, derived from 60 samples analyzed for pollen and spore, CN content and fire regime, have been compared in order to assess the long-term ecosystem-fire interaction in Central Sumatra. The two sites display different patterns in vegetation dynamics and fire regime. Nevertheless, it appears that the occurrence of fire hardly affected the carbon storage function at both sites in the past.

***Keywords*:** palaeoecology, tropical peat, past vegetation, fire, Sumatra

Vegetation history and climate variability since 1.3kaBP reconstructed from high-resolution multiproxy analysis of mountainous peat sediment, Southeast China

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Climate change during the last two millennia is one of the most important focuses of the "Past Global Changes" (PAGES) initiative. In this study, vegetation history and climate variability since 1.3kaBP was reconstructed from high-resolution multiproxy analysis of mountainous peat sediment from the central part of a swamp in Jiangxi Province, China. ^{210}Pb, ^{137}Cs and AMS^{14}C dating were used to build the age framework on the basis of Bacon model. Pollen, Humification degree (HD), Loss-on ignition (LOI), XRF scan elements and grain-size distribution were analyzed. During 637-800 AD, the vegetation combination consists of upland herbs taxa and scattered evergreen *Quercus (Quercus* E*)*. However, the pollen concentration was very low, and plant genera were seldom. Since harsh environment is not conducive to pollen storage, vegetation condition reconstructed by pollen information cannot reflect real climate change. During the Medieval Warm Period (MWP, 800-1250 AD), vegetation is abundant through the entire period, *Quercus* E is the building group of the forest, *Pinus* and *Castanopsis* are sporadic. Upland herbs grew up vigorously in the lower part of forest. Peat began to accumulate in the basin high terrain, where wetland herbs grew vigorous. The climate during MWP was characterized by warm and wet, inside there were obvious secondary fluctuations. Dramatic vegetation changes were recorded during the Little Ice Age (LIA,1340–1870 AD). The vegetation community was primarily dominated by Castanopsis, upland land herbs thrive; wetland herbs were sparse with great fluctuations depending on changes in the humidity. Overall, during LIA, temperature pattern was featured by "four cold period and three warm period", and humidity condition was experienced a process from drought to wet. Periodic analysis of the moisture proxy (PCA 1) and temperature indicator (E/D: evergreen/deciduous tree pollen) shows cyclic fluctuations of ~150 years in the temperature and precipitation, which is corresponded to historical document records. Solar activity should be the fundamental force that drove the same-phase variation of the temperature and precipitation in this region.

***Keywords*:** Medieval Warm Period, Little Ice Age, peat, pollen, vegetation and climate

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A mid-Holocene look into the Roraima Savannas, a record from Serra do Tepequém of the northern Brazilian table mountains

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Past forest-savanna dynamics in the northern savanna regions of South America are very good indicators to detect past climate changes. A decrease on the representation of savanna taxa like Poaceae and Cyperaceae, the increase on forest vegetation besides the expansion of the palm *Mauritia flexuosa*, suggest a change from dry to wetter conditions in several palaeoecological studies. We have chosen Serra do Tepequém at the Roraima Savannas in northern Brazil to analyze past forest-savanna dynamics, including *Mauritia flexuosa* palm and the fire regime as indicators of drier or wetter conditions. Records of pollen, spores, microcharcoal and loss on ignition analyses, indicate two different phases of vegetation and fire dynamics, reflecting a change to wetter conditions. The first period from ca. 7550 to 6350 cal BP is showing a dry phase with a reduced wet season. Savanna vegetation with small forest patches dominated at that time with very frequent regional fires. For the second period from ca. 6350 to 4670 cal BP *Mauritia flexuosa* and forest expanded with new forest species, pointing to a change to wetter conditions. In addition, savanna vegetation and regional fires were reduced. A first slight increase of *Mauritia flexuosa* palm is already recorded at ca. 6600 cal BP, pointing to a wetter environment. Our study shows that the early increase on *Mauritia flexuosa* had an antagonist development compared with the increase on fire and savanna expansion found in other regions in northern South America.

***Keywords*:** *Mauritia*, Mid-Holocene, fire, forest-savanna mosaics, Amazon

Holocene vegetation dynamics of submontane rainforests following volcanic deposition in the Kerinci Seblat National Park, Sumatra (Indonesia)

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Volcanic processes play an important role in the history of vegetation in Indonesia, affecting in various and complex ways tropical rainforest plants. While the short-term effects of volcanic eruptions on the vegetation and subsequent pioneer recolonization are well studied, less attention has been given to slow trends in plant succession, rate of change and recovery, in particularly in Sumatra. When ashes are produced by eruptions they accumulate in screes on the tops of volcanoes. Subsequent re-deposition of these barren materials in the montane valleys can be very slow and impede for long time the return to the vegetation composition and structure before the event occurred. We present the palynological and macro-charcoal results of a 491 cm long sediment core from the margin of the small marshy lake, Danau Njalau (2.275073°S, 101.556131°E, 1040 m asl). The site is located in a remote mountain valley in the Kerinci Seblat National Park, a hotspot of biodiversity and a protected area, surrounded by seven active volcanoes. Sediment composition and AMS radiocarbon dating indicate that the soil at the site was affected by accumulation of sedimentary volcanic material for ca. 600 years. Palynological analysis reveals that in this phase (4700-4100 cal yr BP) the vegetation was dominated by taxa adapted to cope with high acidic soils, in particular *Casuarina* and *Myrica*. Interestingly, it took 900 years to recover to primary forest after volcanic deposition in the soil ended. This suggests that species composition was largely affected by the presence of volcanic material in the soil layer where trees have their roots. Once the peaty organic soil accumulated above such a layer, species of *Casuarina* and *Myrica* could no longer outcompete against other rainforests species, and rapidly decreased. The local fire regime reconstructed using macro-charcoal analysis indicates that average fire return interval was ca. 400 years for the past 4700 years. Phases of increased fire frequency could not be linked to either any of the vegetation phases or regional climatic changes, suggesting fire occurrences were stochastic events. Our results overall suggest that volcanism have acted as one important driver of changes in the rainforests of the Kerinci Seblat National Park. Of a particular ecological interest is the finding that volcanic eruption can have an important effect on vegetation composition in this area even centuries after the event actually occurred.

***Keywords*:** volcanic deposition, Kerinci Seblat National Park, Holocene, palynological analysis

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ENSO influence during the Middle and Late Holocene on coastal vegetation dynamics of southern Mexico

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Climate in the Caribbean region is basically defined by changes in precipitation patterns originated from the ITCZ migration. However, ENSO variability and intensity seems to be a major tropical climate change driver in the long term perspective. In this context the Yucatan Peninsula has experienced changes in precipitation patterns during the Holocene and, although it has been registered mainly through non-biological proxies, the vegetation response and correspondence with major climate change drivers is not well understood. Recognizing the relationship between atmospheric processes and ecosystems dynamics is fundamental to withstand climate change threats. In this sense, mangroves and coastal ecosystems are ideal for long-term climate and ecological reconstructions, because of their relatively simple structural composition and sensitivity to changes on local and regional climate. A 8 m sediment core was obtained in the Rio Hondo Delta (Southern Yucatan Peninsula, México) allows climate and ecological reconstruction in order to understand the last 7k years of vegetation dynamics and response to increasing ENSO activity since the middle to late Holocene. Geochemical proxies present high runoff variability since the last 4k years as a reflection of increasing regional ENSO activity, vegetation dynamics during early to mid-

Holocene barely responds to ENSO activity, although more high resolution pollen analysis is needed to discard this hypothesis. Core chronology control gave evidence of hiatus existence and/or dramatic sedimentation change event.

Keywords**:** *Holocene*, *ENSO*, *ITCZ*, *mangrove systems*, *pollen analysis*

Palaeoecological Evidence of Initial Human Colonization of Islands in the Indian Ocean (Diego Garcia, Seychelles and Madagascar)

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A recent research program "Crossing the Green Sea: Early maritime mobility, trans-oceanic contact, and remote island colonisation in the tropical Indian Ocean" sort to understand the timing and nature of anthropogenic modifications to islands in the Indian Ocean through the analysis of palaeoecological and archaeological records from Diego Garcia, Seychelles and Madagascar. Estimates of the period in which people first colonized Madagascar have varied considerably, ranging from as early as 4300 BP to as late as 1100 BP. The timing and nature of human impacts on the remote islands of Diego Garcia and the Seychelles are somewhat later, beginning from 750 BP and 300 BP, respectively. The results show that while these islands have experienced different timing of human colonization, the nature and pace of anthropogenic ecological transformation is unprecedented in the palaeoecological records. These records support a late and rapid colonization model for Madagascar via a near-coastal route from SE Asia.

Keywords**:** Palaeoecology, Charcoal, Human Impact, Diego Garcia, Seychelles, Madagascar.

Vegetation and environmental dynamics in Brazilian ecosystems during the late Quaternary

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Palaeoecological studies based on pollen analysis in different Brazilian ecosystems provide inside on past vegetation dynamics and biodiversity changes. Several examples on past vegetation and plant diversity changes will be given. Long pollen record from eastern Amazonia, covering several glacial and interglacial periods, document marked changes between Amazon rain forest and savanna vegetation. The Amazon rain forest must have been markedly reduced during glacial periods. There is evidence of lower pollen and spore diversity reflecting lower plant diversity during periods of dry climatic conditions and high diversity during wetter ones. Pollen records from the southeastern Brazilian Atlantic lowland show the replacement of savanna (cerrado) by semi-deciduous forests during the Holocene. Plant diversity increased markedly. Palaeoecological data from the SE Brazilian Atlantic mountain forest and high elevation grassland (campos de altitude) region show that drier climatic conditions and a higher fire frequency during the early Holocene caused an expansion of the high elevation grassland and a reduction of the local biodiversity. Studies from the *Araucaria* forest region in southern Brazil document that the former grasslands (campos) on the southern highland have been replaced since the late Holocene. Drier climatic conditions during glacial and early Holocene times and the marked increase of fire frequency, probably of anthropogenic origin, during the early Holocene, caused a decrease of plant biodiversity.

Late Pleistocene forest dynamics from the eastern Andean flank of Ecuador

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Changes in climate, and the impact of humans, have been shown to drive changes in Neotropical vegetation through the late Quaternary. However, prior to the last glacial maximum (c. 21,000 years ago) few late Quaternary records exist. This paucity of late Pleistocene Andean sedimentary archives is at least in part due to the dynamic environment of this extremely tectonically and volcanically active region. Here we present a multiproxy analysis of a cliff section containing interbedded volcanic tephra layers and organic sediments from the eastern flank of the Ecuadorian Andes within the present day cloud forest (0°36'2.8"S, 77°50'48.8"W, 2010 m altitude). The "Vinillos" section was exposed by a road cut, is 3.25 m high of which 2.15 m represent organic sediments. Radiocarbon dating of pollen residues from the top and bottom of the section indicated that the sediments were deposited between 45,200 and 41,900 years ago. Analysis of pollen, non-pollen palynomorphs (NPP), charcoal, sediment organic content and wood macro fossils provide evidence of the depositional environment, vegetation assemblage and fire regime of a glacial montane forest. Three distinct vegetation assemblages with different dominant taxa have been identified from the fossil pollen: *i*) Poaceae – Asteraceae, *ii*) Melastomataceae – *Weinmannia* – *Ilex*, and *iii*) *Alnus* – *Hedyosmum*. The pollen zones identified relate with statistical significance to zones obtained independently from the NPP assemblage data. Increases in organic content at the top and bottom of the section are linked to an increased abundance of algal and aquatic zoological remains indicating deposition occurred in a lake or bog type environment. While the presence of the coprophilous fungi *Sporormiella* sp. in these parts of the section, suggests the presence of glacial fauna within the montane forest. Large wood macro fossil remains (>30 cm) preserved beneath the largest tephra layers indicate rapid burial of the forest during catastrophic volcanic events. Charcoal is present in low abundance throughout the section and increases in proximity to the tephra layers suggesting that volcanism was the major source of fire. Changes in the vegetation community seen through the palynomorph assemblage suggest that volcanic activity and millennial scale climate variability were the primary drivers of vegetation turnover within this glacial montane forest.

***Keywords*:** palaeoecology, multiproxy, Ecuador, Pleistocene, Andean flank

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Late Quaternary environmental dynamics on Mt. Kilimanjaro - comparing the wet northern with the dry southern slopes

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Tropical mountain forests characterized by high species richness represent great ecological importance as sources of water and other ecosystem services for millions of people living in the tropics. However, in context of combined impacts of global warming and the conversion of natural to human-modified landscapes, understanding of long term vegetation dynamic in Tropical mountain forests in urgently needed to assess future landscape dynamics. Here we used pollen analyses of palaeosoil profiles from montane forests of Mt. Kilimanjaro to reconstruct past vegetation dynamics. Our results show changes in altitudinal vegetation belt and species composition according to different climate conditions. Comparison between different sites, located on the drier northern slopes and the wetter southern slopes allow to characterized ecosystem dynamics and their reaction on environmental changes, especially regarding precipitation and temperature. These results will contribute to a better understanding of modern and future ecosystem dynamics and to maintain and manage the high biodiversity in the East African biodiversity hot spots by governmental and non-governmental agencies.

***Keywords*:** paleoecology, Kilimanjaro, East Africa, tropical forest, climatic changes

Uncoupling humans from climate during the Late Holocene in the southern Brazilian highlands: Testing a predictive model of forest distribution with stable carbon isotopes

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Uncoupling the causal relationships among humans, climate, and vegetation is one of the most provocative topics in archaeology, geography and climate science, with implications for understanding past human impacts on landscapes and its legacy for modern conservation. One such debate revolves around the replacement of grasslands by the abrupt expansion of the economically important Araucaria forest circa AD 1000 as recorded in pollen cores in the southern Brazilian highlands. This vegetation transition coincides with both the dramatic onset of wetter climatic conditions and more intensive occupation by the southern proto-Jê. In this study we apply an interdisciplinary methodology using independently established analyses to test the hypothesis that arboreal vegetation expanded beyond the spatial limits of natural succession due to anthropogenic factors by using a combination of δ13C and phytolith analyses from soil profile transects. In relatively undisturbed locations a distinct vegetation pattern defines the maximum natural forest distribution under present climatic conditions in which forest is limited to river courses and south facing slopes, whereas north facing slopes and plateaus are characterised by grassland vegetation. Interestingly, it appears that the pattern does not hold in areas of extensive modern or archaeological activity, suggesting anthropogenic factors enabled forest expansion beyond its natural limits, enabling the isolation of human from climate induced forest expansion. We modelled the potential maximum natural forest distribution in GIS and tested it with soil profile transects in two areas: (1) an area with high density of archaeological sites and historically attested continuous forest distribution in Campo Belo do Sul, Santa Catarina, Brazil, and (2) a control area devoid of archaeology and covered by a mosaic of Araucaria forest and natural grasslands, in the region of Lages, Santa Catarina. Stable isotope analysis of the soil profiles demonstrates a transition from C4 to C3 in the first area, indicating forest expansion at the expense of grasslands in locations where Araucaria would not naturally be expected to occur (hilltops and north facing slopes). No such change was observed in the control area. Our results give further support to the hypothesis of anthropogenic impact on modern Araucaria forest distribution.

***Keywords*:** Late Holocene, *Araucaria angustifolia*, forest expansion, stable isotopes

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Pollen, spore and charcoal aid to the reconstruction of monsoon variability in the Makassar Strait, Indonesia for the past 26 ka.

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The tropical rainforests of Indonesia are regarded as important hotspots of biodiversity due to their unique biogeographic history and sensitivity towards perturbations such as climate variability and human activities. One of the open questions which need resolving is the understanding of the effects of high latitude climate forcing on the precipitation variability over the Indonesian archipelago. This is of a particular relevance, as such an understanding provides aid to the accuracy of climate model predictions in the tropical pacific, currently one of the area in the world with the largest uncertainties. The marine sediment core SO-217 18515-3 was recovered from the southern Makassar Strait, off southern Sulawesi (3°37,791'S, 119°21,601' E, 688 m water depth) in 2011. Using terrigenous flux, sea surface salinity and temperature proxy data, such as X-ray fluorescence scanning, Mg/Ca paleothermometry and stable oxygen isotope measurements, changes in monsoon variability and surface hydrography for the past 26 ka are reconstructed from the core. However, the interpretation of the results is complicated due to local changes in sea-level during the

deglaciation. Although those changes where of a smaller entity in the Makassar strait as compared to the shallower Sunda and Sahul shelves, decoupling the effect of sea-level/run-off changes (i.e. proximity of land to the coring site) from the precipitation signal is necessary in order to confirm the monsoon reconstruction. We present the preliminary results from pollen, spore and charcoal analysis of the core SO-217 18515-3. The vegetation composition in Sulawesi changes following mostly changes in rainfall distribution over the year. Thus relative changes in the abundance of ecological groups of pollen taxa belonging to trees/forest or grassland in general reflects wetter vs. dries conditions. On the other hands mangroves pollen has been widely used in Indonesia and elsewhere as indicators of sea-level changes. We use the concentrations of pollen from mangroves as a proxy for changes in the proximity of land to the coring site. Finally, charcoal particle concentrations, in particular those morphologically produced by grasses, are used as proxy for biomass burning and increase in droughts over land, thus adding an extra variable to the reconstructed climatic conditions from geochemical proxy data of core SO-217 18515-3. Altogether, our results show the potential of applying pollen, spore and charcoal proxies to marine core records to disentangle the signal of climatic variability from local scale changes of sea-level, thus contributing to the understanding of climatic response to global-scale climate changes in the important archipelago of Indonesia.

Keywords**:** pollen and spores, charcoal, monsoon, precipitation, Indonesia

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Agricultural and Climatic History from Calakmul Empire: a 3600-year record

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During the Late Classic the Maya Culture had structured a highly engineered environment that facilitated and sustained big urban populations, these cities were used as routes of communication between the Maya empires. Much has been learned in the last 30 years about the factors controlling Maya Lowland society by studying tropical ecology (ecosystem services), archaeology (material culture and social structure) and history (lineages of agents). Our understandings, however, do not yet match our much more comprehensive data picture of the Maya land use. High-resolution pollen and geochemistry data from territory of Calakmul, reveal changes in vegetation and soil during the last 3600 years. Two cores Chumpich and Silvituc show strong agricultural activity (Zea mays pollen) during the Early Classic, the deforestation record included all the Late-Classic period (4th and 8th century). The geochemistry and pollen record shows the occurrence of several droughts during century 4th to 9th. The pollen data shows high decrease of tropical forest during the Classic Period, but this diminution is not similar during the droughts of 6th and 9th century. The land use change and climate change had an important effect to the geochemistry of soil. Calcium, Titanium, Iron, Strontium and Chromium indicate changes on rainfall, runoff and erosion. The upper part of records shows the influence of Little Ice Age (LIA) and the modern human impact over the Calakmul region. These high-resolution records from Chumpich and Silvituc lakes show correspondence with several previous records from the different zones of Yucatan Peninsula, and contribute with new knowledge related with agricultural land use. During the Pre-classic and Classic period the extensive agriculture had an effect over landscape, but no necessarily how some authors suggest, the data show that the ecological response of the ecosystems to transformation was effective. The present work contributes with new data to comprehension of resilience of Yucatan Peninsula ecosystems as well as to the major comprehension of land use performed by the Maya culture.

Keywords**:** Pollen analysis, geochemistry data, Maya Culture, climate change, deforestation.

Late Quaternary Environment Reconstruction based on Pollen and Organic-Walled Dinoflagellate Cysts of Marine Sediment in Southeastern South America

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To reconstruct the vegetation dynamics and changes in the marine environment in southeastern South America during the last glacial and Holocene period, marine sediment cores GeoB 2107-3 and GeoB 6211-2 located in the South Atlantic Ocean off southern Brazil have been studied by pollen, spores and dinoflagellate cysts. These proxies are very good indicators for the reconstruction of past vegetation changes and the physical water conditions, respectively. The aim is to understand the interactions between land and ocean changes and to understand how climate change as well as changes with the sea-surface currents, sea-surface temperature and salinity in the study region. The results show that during glacial times, grassland was the dominant vegetation in southern Brazil, indicating cold and dry climate. Small areas of Atlantic rain forest and Araucaria forest occurred in southern Brazil. Dinoflagellate cysts data indicate that the sub-polar Malvinas Current had a markedly stronger influence during that time, particular during the last glacial maximum period. During the Holocene period, the expansion of trees and tree ferns indicate humid and warm climatic conditions. This occurred together with the increase of the sea-surface temperature of the South Atlantic Ocean in the study region. The expansion of the Araucaria forest occurred only during the late Holocene.

***Keywords*:** Late Quaternary, South Atlantic Ocean, dinoflagellate cysts, vegetation dynamcis, marine environmental change

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Climate and cultural implications of vegetation dynamics in the middle elevations of tropical Mexico

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During the last decades environmental reconstruction of the Maya lowlands have proliferated. However, little is know about the environmental dynamics at Maya midlands, a region that probably played a critical role at providing refugia for natural and human populations during hardship environmental transitions. Here we report the paleoecological analysis of a 9,500-year-old sediment core from Lake Ocotalito (920 m asl), southeastern Mexico. We used pollen, charcoal, and geochemical evidence to identify vegetation compositional change in the Lacandon Forest in relation to potential climatic and human influences. Our geochemical results used to infer the climatic context suggest high moisture ability during early Holocene, which favored the establishment of dense tropical forest. Between 8,200 and 6,500 BP, a major transition toward dry and high seasonality occurred and, according to the palynological record, was dominated by elements of cloud forest. Typically more seasonal conditions may exceed horizontal precipitation in mountain areas and limit the plants evapotranspiration, promoting the cloud forest. Up to this point climatic were main driver of vegetation changes. However, human activities were important from 6,500 to top of record (2,000 BP), simplifying the landscape and together with climatic instability, reducing strongly the forest cover. The Comparison between modern and fossil pollen samples, suggest high analogy between modern vegetation of the Lacandon Forest and forests previously established from 8,200 to 6,500 BP. These show that modern forest recovery processes is according to the composition of previous forest to intense human activity (cloud forest). In the regional context, different to Maya lowlands, the position of Lacandon forest in the middle elevations may have provided the forest resilience during environmental difficult and thus ensuring their recuperation when climatic conditions were favorable. Also, our results strong support that the Lacandon Forest we know today is no a novel ecosystem and even less the legacy of ancient human impact, it is the result of critical changes in the climatic system with the human activity as a secondary amplifier of vegetation changes.

***Keywords*:** Disturbance, Holocene, human legacy, Lacandon Forest, modern analogues

Pre-Columbian human land use versus climate change: understanding *Araucaria* forest expansion during the Late Holocene in southern Brazil

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We present palaeoecological results from an interdisciplinary project, which seeks to understand the relationship between late Holocene expansion of *Araucaria* forest, climate change, and land use by the pre-Columbian (pre-1492) Jê culture in southern Brazil. Previous palaeoecologial studies in the southern highlands of Brazil (Iriarte & Behling 2007) have shown a significant expansion of *Araucaria* (monkey-puzzle) forest at around 1,000 yr BP (cal yrs before present). This expansion was attributed by the authors to an increase in precipitation. Nevertheless, further archaeological evidence has shown that this forest expansion coincides with an increase in built landscapes, such as mound and enclosures and pit houses, created by the local Jê people. It is known that *Araucaria* pine nuts were an essential part of the diet and culture of this indigenous group, raising the possibility that the Jê culture may also have played a role in the expansion of *Araucaria* forest. Here we present new palaeoecological data from three bog cores collected amongst archaeological locations, two in habitation sites (27°42'32.52"S, 50°46'12.78"W & 27°50'31.42"S, 51°10'22.48"W) and one in a funerary mound-and-enclosure complex (27°40'15.48"S, 50°44'34.56"W), built by the Jê group. We reconstruct vegetation and fire history, land use and past agricultural practices at the sites, based upon fossil pollen, charcoal and geochemical analysis of the sediments. We integrate this information with the local archaeological data, as well as independent palaeoclimatic data (speleothems), to understand the relationship between human land use, climate change, and vegetation dynamics over the last 6,000 years. Our results show an initial local expansion of *Araucaria* forest at the expense of 'campos' grasslands ca. 4,000 yr BP, but with a later expansion to peak abundance at ca. 1,000 yr BP. The latter occurs at all sites, concomitant with the major expansion of the Jê culture around 1000 yr BP, although it was followed by a sharp decline in *Araucaria* at the funerary site. New high resolution oxygen isotope data from the Botuverá speleothem site in Santa Catarina (Cruz, unpublished data) confirm that the initial *Araucaria* expansion at 4,000 yr BP was likely driven by increasing precipitation, but the lack of significant climate change over the past 3,000 years suggests that the Jê culture was largely responsible for the subsequent expansion of this economically important species ca. 1,000 yr BP. These findings demonstrate that humans played a much greater role in the biogeographic history of this iconic tree species than previously assumed.

***Keywords*:** Late Holocene, indigenous, Araucaria, human land use, pollen, southern Brazil

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Lake Bambili, Cameroon: 90 000 years of montane forest history in central Africa

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Mountains of Central Africa are particularly suitable for paleoenvironmental and paleoclimatic studies because they host a large number of sites favorable to the preservation of sedimentary archives. Moreover, they are true "hot spots" of biodiversity that harbor environments known to be extremely sensitive to climate change. Lake Bambili (Cameroon) yields an exceptional pollen series which documents for the first time the history of the Equatorial montane forests and their vulnerability facing climate change over the last 90 000 years with a resolution of decades to centuries. Here we discuss several aspects such as the evaluation of plant diversity, of biome distribution and of up and down movements of the upper treeline in relation to climate and CO_2 changes. Quantitative reconstructions of relevant climate parameters are addressed via

inverse modeling approach and model simulations. This research is funded by the French ANR (IFORA et C3A project), the Belgium BELSPO (AFRIFORD project) and the IGFAGCR Belmont Forum (VULPES project) in close collaboration with IRD and IRAD in Cameroon.

***Keywords*:** Pollen analysis, biomes, climate reconstructions, equatorial montane forests

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Long-term vegetation, climate, fire and human impact trends in a Neotropical wetland: Holocene dynamics of the Orinoco Delta (Venezuela)

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Tropical wetlands are ecosystems characterised by the occurrence of a more or less extended flooded period. Their unique environments support a wide array of ecological and socio-economic values appreciated from local to global scales. It has been proposed that coastal wetlands could be highly threatened by the ongoing and future climatic change, including projected sea-level changes as an additional forcing factor compared to more inland locations. Nevertheless, for much of the tropical wetlands there are still more uncertainties than available knowledge. This is particularly acute when the targeted goal refers to the study of the wetlands communities' dynamics in the long-term (> 50 years), and the most influential drivers involved. This long-term view will help us to understand the responses to projected drivers by analysing the communities' responses in the past. Here we present the first Holocene palaeoecological study carried in the Orinoco Delta, in NE Venezuela. Several sedimentary archives were retrieved performing a transect along the river course in the swampy location called Caño del Tigre, in Delta Amacuro state. This study area is characterised nowadays by daily tidal variation of up to 1 m despite its distance to the open sea (c. 60 km). The record presented here, PATAM18_A12 (9° 30' N - 62° 41' W, 13 m bsl), contains sediments from the last 6000 years and is located in a river-shore swamp dominated by the palm *Mauritia flexuosa*. This palm is very abundant in the region, which is its northernmost distribution limit, and forms both extensive monospecific and mixed vegetation communities along the river courses. Current human occupation is almost restricted to small settlements of the Warao indigenous culture, being its survival quite related to this and other palm species present in the zone. The multi-proxy approach includes different palaeoecological analyses such as radiocarbon dating, pollen and non-pollen palynomorphs (NPP), charcoal particles, rock-magnetism and XRD. In this sense, we aim to disentangle the effect of several environmental drivers and the anthropogenic effect on the evolution of this unique landscape until its present shape. Preliminary results show a continuous presence of charcoal particles, indicative of fires occurrence, with a different effect on the local vegetation, suggesting a potential role for extra-local sources of sediments being deposited. These results would provide information about the sensitivity or resilience in facing external stressors and will be valuable tools for managing the future of this ecosystem.

***Keywords*:** charcoal, indigenous, *Mauritia flexuosa*, pollen, tides.

Synopsis of the desertification process in a semi-arid region of Ceará State, Brazil

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The semi-arid region of northeastern Brazil is covered by the Caatinga, a deciduous, xerophytic, seasonally dry tropical forest. It is today a very degraded vegetation type due to historical land use and strong interannual climate variability. Anthropogenic activities were present since the occupation of the territory by early Portuguese settlers and further by small scale farming and logging followed by livestock and more recently by "Sequeiro" farming. After the drastic decrease of livestock production at the end of the 19 century, farmers were forced to revert to this subsistence farming with a land rotation system (nomadic farming) that relies on fire for vegetation clearing during the dry season. With the increase in human population density and the partitioning of the large landlord farms, the interval between each land use

cycle has been decreasing. This type of land use has increased the size of degraded areas and the intensity of degradation and desertification. Considering the climatic prognosis to northeast of Brazil with reductions in precipitation and increases in evapotranspiration, the desertification process can be intensified and in that case increasing even more socioeconomic problems. The species of the Caatinga are well adapted to a hot and dry climate characterized by an average rainfall of less than 800 mm concentrated in three successive months, but severe droughts lasting few years are frequent and water resources rare. Many dams have been built since the 50s. Here to evaluate the impact of the successive climatic droughts and of the human pressure on a semi-arid landscape we analyzed the sediments deposited in one of the largest and oldest dams. The Acaraú-Mirim dam is 109 years old and lies in the northwestern part of the Ceará State. Pollen, charcoal, ^{210}Pb radioactivity and XRF analyses of a 97cm sediment core are used to reconstruct the history of land use and diversity loss during the last century in an area under a degradation/desertification process. Besides the pronounced climatic variability that characterizes semi-arid regions, we also intend to investigate the impacts of future global warming in this semi-arid region.

***Keywords*:** Land use, semi-arid climate, fire, degradation process, Caatinga

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Quaternary mangrove vegetation dynamics along northern latitudinal limits in south China: an overview

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Understanding Quaternary mangrove vegetation dynamics along northern latitudinal limits helps trace their biogeography and evolution history. However, few studies assess such a unique mangrove vegetation dynamics based on palaeoecological data. Here palynololgical studies are reviewed to synthesis Quaternary mangrove vegetation dynamics since the last decades along the latitudinal limits in south China. Many sedimentary records from south China show mangroves deeper than the present lower limit of mangrove habitat at mean sea-level, indicating sea-level rising over time. In early Quaternary, the tropical warm condition is indicated by pollen records of key tropical mangrove species (such as *Sonneratia*, *Rhizohpra*, *Nypa*) along the coasts of South China Sea, suggesting tropical mangroves expanded beyond current latitudinal limits (e. g., Wang and Zhang, 1998; Zheng and Li, 2000; Huang and Zhang, 2002). High sea level stands during the warm period maintained the vegetation succession and the structure of mangrove ecosystem. However, sea-level dropped sharply as a result of subsequent glaciations in late Pleistocene, especially the Last Glacial Maximum (LGM); the mangroves and their sedimentation settings failed to keep up with the pace of seawater lowering and lost intertidal habitats. Therefore, the Quaternary glaciations, especially LGM, played a significant role in shaping the current distribution range of tropical mangrove in southern China (Mao and Foong, 2013).

***Keywords*:** Quaternary, mangrove, vegetation dynamics, south China

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600 cal yr BP of Araucaria Forest and Grassland dynamics in the Serra da Bocaina National Park, Southeastern Brazil

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The Serra da Bocaina National Park, with an area of 104.000,00 km^2 is located at the border of the states of São Paulo and Rio de Janeiro in southeastern Brazil. The region is one of the first areas occupied by European during the Brazilian colonization. The original vegetation was composed by Montane Atlantic Forest, Araucaria Forest and High Elevation Grasslands. However, more or less 400 years of land use changed the landscape, ecosystems and species composition. The immigrants prepared the land basically putting fire and cutting all the vegetation, first for coffee plantation and afterward for cattle. Nowadays, there are also some exotic species such as *Pinus* spp. and *Eucalyptus* spp.. The National Park embraces a large gradient of elevation, from the

sea level to more than 2.000 m. As a result of several geomorphological domains, it presents different reliefs, microclimates, hydrography, soils, ecosystems and landscapes, as well as ecologic refugees, endemic and endangered species; increasing the importance of the area for conservation. To study past vegetation dynamics and how humans changed the vegetation, a sediment core from a swamp was cored in a contact area between Araucaria Forest and Grassland, near São José do Barreiro, São Paulo State at 1.539 m elevation (S 22°44'02.0"/ W 044°38'39.4"). The 228 cm-long record represents the last 600 cal yr BP. From 228 to 76 cm the sediment core is sandy with silt and mostly greyish. The uppermost part of the sediment (76-0 cm) is characterized by the presence of roots and organic material, with a reddish and yellowish brown colour. The record provides important information on mountain vegetation dynamics, human impacts and climate change. The tree pollen types found are characteristics of the Upper Montane Araucaria Forest, such as *Podocarpus*, *Weinmannia*, *Alchornea*, *Myrsine* and *Myrtaceae:* However, *Araucaria* pollen is very low represented. Most of this tree pollen types describes secondary vegetation. In addition, the quite abundance of Poaceae and Cyperaceae indicate human activities. The pollen record with taxa of Araucaria Forest, Atlantic Forest and Grassland are discussed in the light of the past, current and future scenarios enabling the planning of strategic actions of management for conservation the ecosystems and their biodiversity.

Keywords**:** Pollen analysis, Araucaria Forest, Grassland, Protected Area, Holocene

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The early and late Holocene vegetation and climate reconstruction at Acarabixi lake in the upper Rio Negro, Brazil

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Located at the northwestern part of the Amazon basin, Rio Negro River is the largest black-water river in the world, with a mean annual discharge of 28.000 m^3/s. Its alluvial flood plains and anabranching channel systems contain the largest black-water inundation forest of the world, growing along waters with high humic acids concentration and low quantities of suspended matter. Recent vegetation and geomorphologic studies at the Rio Negro River describe that the Igapó vegetation is mainly related to Holocene deposits. Therefore, we have used a 300 cm sediment core from Acarabixi Lake, located at the upper Rio Negro River. Our aim is to detect changes in early and late Holocene vegetation assemblages and their relationship with the River dynamics using geochemistry and pollen and spores analyses. Our first results based on geochemistry (organic carbon (TOC), $\delta^{13}C$ and $\delta^{15}N$) show different phases and pulses of sedimentation during the early and late Holocene. For the early Holocene (ca. 10580 and 10530 cal yr BP) an extreme event with high sedimentation rates ca. 1.95 cm/yr occurred. Mean values on carbon flux were 493 g/cm^2/year. After that period, the lake had mean carbon flux values of 37 g/cm^2/year until ca. 9740 cal yr BP. Around 9550 to 8500 cal yr BP the carbon accumulation rate dropped with mean values of 8 g/cm^2/year reflecting a low proportion of autochthonous organic matter. Between 8500 and 1520 cal yr BP was found a hiatus in sedimentation. For the late Holocene mean carbon flux values were 18.5 g/cm^2/year. Pollen and spores analysis is still in process.

Keywords**:** Rio Negro, Holocene, carbon, Igapó, Amazon

Inconsistency between vegetation history of Amazonia and reconstructed climate of Younger Dryas-Holocene transition

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The Younger Dryas-Holocene transition (YD-HT) at ca. 13-10 ka (cal kilo yr BP) is characterized by increasing global temperature and atmospheric CO_2. Although studies suggest that during this period, Amazon basin was extremely dry, the response of the world largest continuous rainforest to this specific climatic condition is not quantitatively assessed. Here we analyzed 8 well-dated palynological records from 5 different lowland ecosystems located in Amazonia and surroundings. Our results demonstrate that, despite the suggested

YD-HT's drought, the percentages and influx of arboreal pollen grains increased almost in all records between 13 and 10 ka and these values were comparable with their peers during the wetter late Holocene. We discussed here three different possible scenarios for this finding. Because the aridity and the parallel increase of temperature and atmospheric CO_2 are common features of the modern and the YD-HT's climate, our study can offer new insight into the future of Amazon rainforest.

Keywords: Younger Dryas, Holocene, global temperature, atmospheric CO_2, Forest expansion

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Paleoenviromental variability in the Pampas region, southeastern South America during the last millennium based on palynological analyses

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Palynological analysis from Laguna Chasicó (LCh) (38°37'S; 63°05'W) has provided information on the paleoenvironmental history of the last 1000 years of the southwestern semi-arid Pampas region. LCh (20 m b.s.l.), the lowest water body of South America, is located in the Pampa grasslands-xerophytic woodland ecotone. During the last ~110 years the area has experienced several flood and drought events which are reflected in highly variable lake water depth and size, and salinity as a consequence of changes in precipitation related to climatic variability. Continuous three cores were recovered from the deepest part of the lake (~14 m) for past environmental studies. The deepest core (143 cm) was selected for high-resolution palynological study. Forty bottom surface pollen samples from both LCh and its only tributary Arroyo Chasicó provided information for the understanding and interpretation of the fossil palynological record. The age model covers a period from ~AD 1100 to the present. It is based on ^{14}C dating (at 43 and 125 cm depth) and the first appearances and changes of exotic pollen trees introduced in the area since the early 20th century which are related to historical data. Changes in grassland/xerophytic woodland pollen ratios and shifts of the local halophytic taxa suggest variations in lake size and salinity. The reconstruction provided evidence of alternating wet and dry phases at century-scale and a lake size similar to the present and low salinity from AD 1100 to near the early 20th century. Subsequent abrupt increase in halophytic and xerophytic taxa from AD 1920 to AD 1977 indicates the driest period and extremely low lake level when LCh reduced its area to ~31 km^2 and salt content was ~100 g/L in the 1960s. The uppermost recent decrease in halophytic taxa and fluctuating increases in grassland taxa represent a wet period, high water level and a decrease in salinity after AD 1977, coeval with a general increase in precipitation across the Pampas which led to a fast water level rise in 1980 when LCh reached 100 km^2 and salt content decreased up to ~20 g/L. The inundation peak in AD 1983 coincided with one of the strongest "El Niño" events of the 20th century. The main human impact on vegetation is indicated by the increase in weeds and exotic trees from ~AD 1970 onwards. This paleoenvironmental reconstruction provides a new high-resolution record of the climatic variability in the Pampas during the last millennium.

Keywords: palynological analysis, climatic variability, last millennium, Pampas region, Argentina.

Riparian woody vegetation history in the *campos* region of Uruguay during two time windows: late Pleistocene and late Holocene

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We present a detailed palynological record of a 163-cm-long sediment core from Laguna Formosa (LF) (31°48'S-54°28'W) situated in the northeastern *campos* region of Uruguay. Based on seven AMS radiocarbon dates and the presence of a sedimentary hiatus, the record represents two periods: late Pleistocene (from 14,570 to 13,500 cal. years BP) and late Holocene (from 3280 cal. years BP to the present). At ca. 14,570 cal. years BP hydrophilous trees and shrubs were recorded, mainly represented by *Salix chilensis*, *Celtis* and *Cephalanthus glabratus*, which reflected the development of riparian hydrophilous shrublands on the littoral

of freshwater bodies. After ca. 14,310 cal. years BP the shrubland diversity gradually increased, indicated by the occurrence of new taxa such as *Phyllanthus sellowianus*, *Lithraea*, and *Schinus*. The development of hydrophilous shrublands probably promoted the fixation of the freshwater bodies' margins, maintaining calmer and clearer water conditions and leading to the development of submerged plants. This is the first evidence of woody riparian vegetation development along the rivers for northern *campos* during the late glacial period, being the vegetation constituted not only by isolated individuals. The climate must have been relatively wet and not so cool to allow such a vegetation development. At *ca.* 3280 cal. years BP riparian forests consisted of both hydrophilous and mesophilous woody taxa. Since ca. 2270 cal. years BP woody vegetation gradually increased, accompanied by the incorporation of other taxa (e.g. *Allophylus edulis*, *Erythrina crista-galli* and *Daphnopsis racemosa*) by ca. 940 cal. years BP. The riparian forests changed their abundance and diversity during the late Holocene until achieving a composition similar to the current one at ca. 540 cal. years BP. The increased woody vegetation since ca. 2270 cal. years BP and the evidence of more frequent and intense flooding events in the study area between 1200 and 1800 cal. years BP could be related to higher precipitation over La Plata Drainage Basin. Grasslands and bunchgrasses were regionally dominant throughout the recorded late Pleistocene and late Holocene period. It is interesting to point out that the riparian woody vegetation composition is totally different for both time windows treated here, and the modern composition emerged only after ca. 540 cal. years BP. In addition, we recorded *Inga*, *Trema*, *Alchornea* and even *Araucaria* pollen during the late Holocene, representing trees that currently no longer develop in the study area, thus suggesting plant migrations from southern Brazil and northeastern Uruguay.

***Keywords*:** palynology, late Pleistocene, late Holocene, woody vegetation, plant migrations

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Past 2000 years vegetation changes in the mid-latitude Andes under an ENSO perspective

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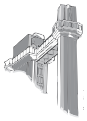
Mountain ecosystems are characterized by hosting a unique biota that lives under a steep environmental gradient such as precipitation, temperature and topography. These ecosystems are potentially vulnerable to the effects of climate change. The Andes Cordillera and foothills in central Chile (30°-35°S) is one of the areas in the world experiencing decline in rainfall and increasing temperatures that negatively affect the Andean communities. However, the rainy years associated to the warm phase of El Niño Southern Oscillation (ENSO) seems to alleviate the water stress in the region. A 2000-year pollen record obtained from a high altitude lake at the Andes in central Chile (Laguna Chepical, 32°16'S; 70°30'W, 3050m asl) was used to reconstruct past vegetation changes and ENSO related climate implications. We used Poaceae as indicator of moisture availability related to winter precipitation, and its relative abundance values were correlated (running correlation) with annually reconstructed Southern Oscillation Index (SOI) for the past 2000 years. Between AD 1 and AD 900, Poaceae and SOI do not show correlation (R=~0.0) possibly due to chronologic and resolution issues. However in general terms, high frequency of Poaceae suggests wetter than today conditions since AD 1, consistent to negative long-term trend of SOI (El Niño-like mean conditions) between AD 1 and AD 400. Later, the expansion of the littoral taxa *Arenaria/Stellaria* indicates lake-level fluctuations, and suggests an incremental trend in temperature during summer months associated to high climate seasonality (i.e. wet/cold winters and dry/warm summers) and/or annual variability coherent with high amplitude of SOI between AD 400 and AD 900. In contrast, long-term trend for the past millennia shows the highest negative correlation between Poaceae and SOI (R= -0.8). Between AD 1000 and AD 1400, negative trend of SOI is associated to relative high Poaceae frequency. This suggests that during the Medieval Climate Anomaly chronozone in central Chile was wetter than today, similar to El Niño-like mean condition. Conversely, minimum values of Poaceae and positive SOI between AD 1400 and AD 1850 suggest the Little Ice Age as a period more La Niña-like mean condition. Even so, an isolated wet pulse during 17th century is overlapping with neoglacial advances in the Subtropical Andes, indicating regional-scale synchrony. Finally, the recent global warming, positive phase of SOI and human-related disturbances have caused severe changes in plant communities, such as upward shift of vegetation, and the reduction of arboreal taxa by land-use changes.

***Keywords*:** Andes cordillera, mountain vegetation, ENSO, precipitation, land-use changes



MOUNTAINS UPLIFT AND ITS IMPACT ON BIODIVERSITY

Zhou Zhekun & Huang Yongjiang

An integrative assessment of plant diversification and biogeographic processes in the Eastern Himalayan biodiversity hotspot

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Mountain ranges surrounding the Qinghai-Tibetan Plateau (QTP) harbor exceptional diversity. Despite increasing interest from biogeographers, the timing, tempo, and mode of their biotic assembly remains poorly understood. In this contribution, we informed the biogeographic histories of 18 clades of vascular plants and compared dynamics of the Hengduan Mountains with the Himalayas and temperate East Asia to account for the remarkable diversity of the Hengduan flora. For all regions, species accumulation by each process is seemingly exponential (log-linear) following initiation until about the last 8 Ma. During this earlier "constant" phase, assembly in both the Hengduan Mountains and Himalayas-QTP is dominated by colonization, but the rate of increase in *in situ* speciation is faster than for colonization. By contrast, in temperate/boreal East Asia the dominant process is *in situ* speciation, but the rates of increase in both processes are roughly equal. Following the constant phase, the assembly dynamics of the Hengduan Mountains and Himalayas diverge considerably, with relatively little change in temperate/boreal East Asia. In the Hengduan Mountains, the cumulative number of *in situ* speciation events overtakes that of colonization around 8 Ma. In the Himalayas-QTP, *in situ* speciation never overtakes colonization. *In situ* speciation has contributed about twice as much to the assembly of the Hengduan Mountains flora as it has to the Himalayas-QTP flora, especially since the late Miocene. The rate of *in situ* speciation for the Hengduan Mountains region, in events per resident lineage per Ma, increased almost twofold over the past 10 Ma, while for the Himalayas-QTP, it remained more or less constant. Our analysis supports an uplift-driven diversification for Hengduan Mountains and is the first to make quantitative inferences about the relative contributions of *in situ* lineage diversification and colonization to the assembly of one flora.

***Keywords*:** mountain radiation, Himalayas, Neogene, dispersal; biogeography

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Middle Miocene Climatic Optimum Flora from Yunnan, Southwest China

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The Miocene flora located in Wenshan Basin, southeast Yunnan Province, is situated in the karstic region of south China. This site is of particular interest because it has been dated to the Miocene Climatic Optimum (15–16.6 Ma) by paleomagnetism. Plants are exceptionally diverse: more than 100 morphotypes have been recognized, 60 of which were identified and include vegetative and propagative organs of pteridophytes, gymnosperms and angiosperms. Species composition of the flora reveals a subtropical forest with differentiated habitats. Evergreen broadleaved taxa form the main body of the flora dominated by evergreen Fagaceae such as *Quercus sect. Cyclobalanopsis*, *Castanopsis* and *Lithocarpus*. Common taxa in evergreen broadleaved forest today such as *Cinammomum*, *Phoebe*, *Lindera*, *Paleocarya*, *Mahonia*, *Exbucklandia*, *Polyspora*, *Itea*, *Styrax* and *Symplocos* were also identified. Unlike the extant subtropical forests in south China, deciduous taxa such as *Quercus miovarabilis*, *Zelkova*, *Carpinus*, *Acer*, *Rosa*, *Ailanthus*, *Cornus* and *Fraxinus* mixed in the flora were found. This may be due to altitude differentiation. A lot of calciphilous taxa such as *Burretiodendron*, *Bauhinia*, *Ficus microerecta*, *Ziziphus*, *Berchemia*, *Craigia*, *Dalbergia* and *Fraxinus* indicate that the karstic limestone environment influenced the species composition. Meanwhile, *Coriaria*

and *Mallotus*, reflecting an open environment, and the riparian *Salix* and *Syzygium* reveal the wide range of habitats in the Wenshan flora. Interlayer plants such as the lianas *Holboellia*, *Iodes* and epiphyte fern *Gonioplebium* suggest a comparatively complex community structure. In this locality, *Pinus massoniana* was found, demonstrating that this flora displays close affinity with the Sino-Japan Flora rather than the Sino-Himalaya Flora. Other conifers, the once widely-distributed *Calocedrus* and now extirpated *Sequoia* were also found, the massive recession of their distribution could be due to the intensification of the seasonality. The palaeoclimate was reconstructed based on the Coexistence Approach and shows that Wenshan experienced a subtropical to tropical environment during the Miocene Climatic Optimum. The Mean Annual Temperature (MAT) was calculated 15.6–21.9°C, indicating a similar temperature to today (17.9°C). However the temperature during the warmest month was higher (MWMT, 25.0–28.1°C, 23.2°C today). The seasonality in temperature was more pronounced (MWMT=27.3–27.8°C compared to MCMT=10.6–13.4°C). The Mean Annual Precipitation (MAP) was 1096–1597 mm, indicating a wetter climate than today (1069 mm). The driest month precipitation (MPDRY) represents 8.8 to 10.6% of the wettest month precipitation (MPWET), indicating that seasonality was already present, but not as strong as today.

***Keywords*:** Miocene, Climatic Optimum, flora, Southwest China, palaeoclimate

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Palaeoenvironmental change and its impact on plant diversity: evidence from Yunnan, southwestern China

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The environmental change and its impact on plant diversity is becoming a hot topic in recent decades. Yunnan, situated in southwestern China and bordered by the Qinghai-Tibetan Plateau, is a topographically complex area with large altitude and climate gradients. It has long been renowned for high plant diversity. Understanding how this diversity arose is a focus in various research areas, such as botany, palaeobotany, molecular phylogenetics and environmental biology. Impacted by the uplift of the Qinghai-Tibetan Plateau, Yunnan has experienced surface uplift, topographic deformation, temperature decline, monsoon intensification and aridification since the early Miocene. On one hand, these environmental changes have promoted the diversification and flourishing of numerous plant groups, such as *Incarvillea* and *Pedicularis*; and the complex landscape featuring huge mountains and deep valleys has created various climatic conditions that may allow plant species with different climatic tolerances to coexist in a limited geographical area. On the other hand, the climatic fluctuations may have resulted in a number of species extinctions. These include the severe aridification associated with the intensification of the Asian monsoon, particularly during the dry season, that may have influenced seed germination and young leaf development, and thus led to the disappearance of several woody genera from Yunnan, such as *Cedrus*, *Metasequoia* and *Sequoia*. To conclude, the pronounced environmental changes mainly as a result of the uplift of the Qinghai-Tibetan Plateau have drove numerous differentiations as well as some extinctions of plants during the Neogene and Quaternary, and eventually led to the establishment of modern plant diversity in Yunnan.

***Keywords*:** Palaeoenvironment, palaeoclimate, biodiversity, monsoon climate, Yunnan

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Uplifting mountain and increasing seasonality, *Quercus schottkyana* replaces the *Q. delavayi* complex as the dominant tree species in evergreen broadleaf forests

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Quercus schottkyana is a dominant species in evergreen broadleaf forests in central Yunnan Province, China. The *Quercus delavayi* complex, comprised of two fossil species and one modern oak, has been widely

distributed in China since the late Miocene. Modern species of *Q. delavayi* complex is distributed evergreen broadleaf forests in central Yunnan as associated species in general and fossil species, *Q. predelavayi* and *Q. tenuipilosa*, are widely found from Neogene strata. Leaf shape, size and venation of *Q. schottkyana* and of the *Q. delayayi* complex are similar but differ in trichome structure. *Q. schottkyana* has a single trichome which forms unicellular trichome bases and the *Q*. *delavayi* complex has multicellular trichome bases which can be well preserved in fossils. Many fossils of the *Q. delavayi* complex have been reported from Neogene strata in Yunnan. This indicates that the dominant species of evergreen broadleaf forests in the Neogene was *Q. delavayi* but *Q. schottkyana* has become the new dominant since the Quaternary. This replacement can be explained by seed traits of *Q. schottkyana* and an increase in seasonality. Oak seeds are recalcitrant and germinate as soon as they are mature. Our previous research shows that, in Yunnan, seasonality is increasing and precipitation has become more concentrated in the wet season since the late Miocene. Within *Quercus* subg *Cyclobalanopsis*, *Q. schottkyana* seeds have the greatest ability to tolerate desiccation thereby allowing greater adaptability to a seasonal climate. Therefore, as seasonality increases *Q. schottkyana* has become the dominant species in these forests. This hypothesis is supported by molecular analysis which shows that oaks with multicellular trichome bases (*Q. delavayi* complex) originated earlier than *Q. schottkyana*.

***Keywords*:** Mountain uplift, monsoon, *Quercus*, evergreen broad-leaf forest, Neogene

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Process of Plio-Pleistocene plant extinction in Japan influenced by mountain uplift, sea level and climate changes

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The extinction of major elements in the Neogene flora and an expansion of plants dominant in modern cool-temperate and subalpine forests represent Plio-Pleistocene floral changes in Japan. The floral change was stepwise, and the events were concentrated in transition periods of climatic fluctuation and/or in a downward shift of the glacial climate. These events in central Japan are characterized by the last occurrence of exotic taxa in the late Pliocene (ca. 3.3 – 2.5 Ma) and late Quaternary (1.2, 0.9, 0.5 Ma, and in the Late Pleistocene). The last occurrences are generally recorded in warm stages followed by significantly colder stages. Their extinction is thus attributed to extirpation of refugia during the cold stages in and around the sedimentary basin. Increased dryness and coldness provided by winter monsoon that developed in a stepwise manner would have altered the climate regime and the ability of plants to grow and establish populations. Mountain uplifts became active after the late Pliocene and may have promoted plant extinction by constituting barriers of migration. It is because the decreasing winter temperatures in higher altitudes would have hindered migration to the north and inland over mountain ranges, even as exotic taxa surviving in southern sedimentary basins had the potential to expand their distribution under improving climatic conditions. Along with mountainous areas surrounding the basins, the landform of the lowland plains in the sedimentary basins was also changed by tectonic movement and sea level changes, which increased in magnitude during the later stages of the Quaternary. This change influenced directly on habitats of wetland plants such as *Metasequoia* and *Glyptostrobus* and thermophilous plants which were distributed in the lowest altitude in basins. Pronounced sea level changes after the late Early Pleistocene also transformed alluvial plains. During interglacial stages, basins and coastal plains were submerged during marine transgressions that reached near mountain bases and diminished habitat of wetland plants. Furthermore, alluvial plains that lost water after sea levels decreased became drier uplands with steep and narrow valleys at the lowest sea level stands in glacial stages. Such drastic environmental changes in the lowlands possibly influenced the regeneration and growth of *Metasequoia* and *Glyptostrobus*, which dominated wetland vegetation before the late Early Pleistocene. The occurrence of these taxa during the Early Pleistocene glacial stages indicates their cold tolerance; therefore, their extinction is ascribed mainly to geomorphological changes of habitats in lowland plains.

***Keywords*:** climate changes, plant macrofossil, Plio-Pleistocene, mountain uplift, sea level changes

NEW FRONTIERS AND CLASSIC STUDIES IN PALAEOZOIC PALYNOLOGY AND PALYNOSTRATIGRAPHY (CIMP-SPONSORED SYMPOSIUM)

John Marshall, Sa'id Al-Hajri & Charles Wellman

The significance of radio-isotopic ages in calibrating Gondwanan Permian palynozones

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Radio-isotopic ages tied to endemic Gondwanan fossil assemblages are rare, complicating correlation to the International Time Scale, which is calibrated using fossils not present in Gondwanan biotas. The recent procurement of many new radiometric dates from Permian successions of the main Karoo Basin, South Africa and the basins of eastern Australia provided the opportunity to precisely correlate these strata using radio-isotopic ages, rather than relying on age estimates using palynology. Permian palynological assemblages from South Africa have been correlated with Australian palynozones in the past, but floristic provincialism has hindered correlations between these two Gondwanan landmasses. Radio-isotopic ages for Permian rocks in Australia and South Africa were used as chronometric tiepoints between stratigraphic units, which also allowed for a comparison of the age ranges of key palynomorphs in both countries. When these strata are correlated using radio-isotopic ages, some of the results are quite different to correlations made on the basis of palynofloral similarity. Radio-isotopic ages for both Australia and the main Karoo Basin of South Africa demonstrate that key marker palynomorph taxa all appear diachronously in the two countries, or they are absent in one of the countries. Differing palaeoenvironments, changing stratigraphic terminology and incomplete stratigraphic records are evaluated as potential factors influencing diachronous palynomorph ranges. The ranges of Permian pollen species are strongly tied to palaeolatitude, with floral distributions primarily affected by temperature, precipitation and seasonality. The resulting spatio-temporal variation in floras across Gondwana hinders global biostratigraphic correlations. Both South Africa and Australia have excellent long-ranging Permo-Triassic terrestrial sedimentary successions, but the diachronous ranges of palynomorphs must be considered when correlating South African rocks to other global sections by means of the Australian spore-pollen zonation. The well-refined Permian palynozonation of western and eastern Australia is the current standard biostratigraphic classification for the Southern Hemisphere, but intra-Gondwanan floristic provincialism means that several stratigraphically useful palynomorph taxa are rare or absent elsewhere in Gondwana. The wealth of new radiometric dates from both Australia and South Africa provides the opportunity to more confidently link spore-pollen zones to the International Geologic Timescale, enhancing their potential for correlation of Permian lithological successions across Gondwana and providing crucial age controls for fossil fuel exploration.

***Keywords*:** Karoo, Australia, palynology, Permian, Gondwana

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Palynological analysis of the Middle Devonian of northern Spain: hunting for the Kačák event

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Northern Spain contains one of the most complete Devonian sequences in Western Europe chronicling widely varying depositional environments in a Peri-Gondwana setting. We describe palynomorph assemblages from the Eifelian and Givetian age (393-382 Ma) Huergas, Naranco and Gustalapiedra formations from Asturias, Castilla y León and Palencia provinces, respectively. These laterally equivalent formations represent a transect

from shallow nearshore marine, across the shelf, to deep offshore shelf deposits and are comprised of large sandstone bodies interspersed with black shales, sandwiched between the thick limestone sequences which make up the rest of the Devonian succession. These anomalous units also exhibit a progression in character, with the terrestrial clastic influence diminishing as one travels eastwards, away from the former coastline and towards deeper water. Samples have been collected from 30 exposures including four logged sections and have yielded rich assemblages of land-derived spores and marine palynomorphs (acritarchs, chitinozoans and occasional scolecodonts). The palynological assemblages have been quantitatively analysed in order to assess the changing palaeoecology of the area and the possible effect of the Kačák event. This is a widely occurring anoxic event that occurs around the Eifelian/Givetian boundary and is associated with extinctions and faunal turnover in the marine realm of New York state and Central Europe, amongst other localities. Despite this the effect of the event on terrestrial floras is little known and it is not well characterized in the Iberian peninsula, though it is believed to be represented in a shale member of the Gustalapiedra formation, correlating to the upper part of the Huergas and Naranco formations. We aim to identify the Kačák event in northern Spain and document its effect on both the marine phytoplankton and terrestrial biota.

***Keywords*:** Middle Devonian, palaeoecology, Spain, Kačák Event, Gondwana

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Cryptospores and the Canalization of Plant Sporogenesis

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The Cambro-Ordovician record of cryptospores tracks the evolution of spore characters as the land plant sporophyte evolved in response to natural selection in subaerial habitats. This process effectively ended by Darriwilian time (Middle Ordovician) as indicated by the first occurrence of geometrically regular cryptospore tetrads (*Cryptotetras* Strother, Traverse & Vecoli, *Tetrahedraletes* Strother & Traverse) and dyads (*Dyadospora* Strother & Traverse, *Didymospora* Strother, Traverse & Vecoli) found in the Hanadir Shale Member of the Qasim Formation in Saudi Arabia. The Hanadir Shale cryptospore assemblage marks a major evolutionary step in plant evolution, because it demonstrates that normal plant sporogenesis, as marked by simultaneous nuclear division and coordinated cytokinesis during meiosis, had evolved by this time. All cryptospore-bearing deposits prior to this time are dominated by taxa that do not demonstrate such regularized development. The earliest Cambrian cryptospores are characterized by spore formation that decoupled nuclear division and spore-wall formation (cytokinesis). This condition of serial karyokinesis coupled with latent cytokinesis resulted in the production of spore packets that can contain different numbers of wall-enclosed spore-bodies. In addition, the Late Cambrian taxon, *Agamachetes* Taylor & Strother was characterized by a form of endosporic development in which pairs of spore dyads, representing the final round of spore wall formation, occurred within a prior wall. Some Cambrian and Dapingian cryptospores do show geometric regularity, in the positioning of the sporocytes into serial rows or palmelloid packets. Such cryptospores were not produced in unilocular sporangia, as in true land plants; but, instead, were likely generated by sporocytes that began as embedded cells that were not surrounded by a nutritive jacket of cells or any sort of proto-archegonial tissue. Some of these older cryptospores, then, may be representing evolutionary dead-ends that were evolving in response to natural selection in subaerial habitats, but which were not stem group embryophytes. All this changed with the geometrically regular spores found in the Hanadir Shale, which have retained sporoderm characteristics compatible with bryophytic sporogenesis. Thus, the geometrically regular cryptospores recorded in the Hanadir assemblage appear to be tracking, not the origin of embryophytes, but, rather, the canalization of an embryophytic-style sporogenesis. It could well be, as predicted long ago by Bower, that the plant sporangium evolved in advance of embryonic development in land plants. The fossil record now supports a specific sequence – spore, sporangium, then vegetative sporophyte – as the order in which plants evolved toward complex multicellularity in the sporophyte.

***Keywords*:** origin of land plants, meiosis, Ordovician, paleopalynology, fossil charophyte

Palynostratigraphic study of the Finnmark Platform, Norway - Establishing a palynozonation for the Mississippian successions of the Barents Sea

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During late Palaeozoic time, the Finnmark Platform, offshore northern Norway, was located on the northern margin of the Euramerican Supercontinent. This area was part of an E-W orientated intra-cratonic basin that received mainly continental siliciclastic sediments derived from braided rivers, swamps and large prograding fans. These sediments constitute the Billefjorden Group. Dating and reliable correlation tools are essential in every aspect of geological mapping and palaeogeographic reconstructions. Palynology has proved to be the only applicable tool for dating the Billefjorden Group in the Barents Sea. A biozonal scheme for the Mississippian succession is therefore needed and is currently being developed. Palynological results from the Finnmark Platform are presented here. Detailed palynological analysis has been performed on three shallow stratigraphic cores (7127/10-U-2; 7127/10-U-3; 7029/3-U-1) and two exploration wells (7128/4-1; 7128/6-1). A preliminary palynozonation has been established and a tentative correlation with the western European biozonal scheme is presented. These indicate that the cored sediments are Visean to possibly early Serpukhovian in age. However, more work is needed in order to fully understand the qualitative and quantitative distribution of many palynomorph taxa present (e.g., *Cyrtospora cristifera*, *Knoxisporites triradiatus*, *Murospora aurita*, *Raistrickia nigra*), not only on the Finnmark Platform, but also through the entire Barents Sea.

***Keywords*:** Palynology, Visean, Miospore, Barents Sea, Norway

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Palynology and palaeogeography of the middle Přídolí from Saudi Arabia

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A distinctive, rich and diverse marginal marine palynological assemblage from the Tawil Formation occurs in several wells from northwestern and eastern Saudi Arabia. The composition of this assemblage strongly indicates a middle Přídolí age. The assemblage contains abundant miospores, chitinozoans, acritarchs, tasmanites, freshwater algae, scolecodonts, eurypterid cuticle and other organic remains. Many taxa from this assemblage are of taxonomic interest and useful for regional and intercontinental correlation. The palaeogeographic distribution of this assemblage is also discussed: acritarchs, chitinozoans and miospores encountered in the studied samples correlate well with similar palynological suites from various Algerian, Libyan, and Ibero-Armorican localities (i.e. Ibarmaghian regions). This corresponds to what is considered a transgressive mid-Přídolí event in the Algerian Sahara, with non-marine intervals bracketing this brief marine sea level rise. This event is likely to have extended into all of north Gondwana including Arabia and relates to S50 Maximum Flooding Surface from the sequence stratigraphic framework defined in the Neftex Geodynamic Earth Model.

***Keywords*:** Přídolí, Saudi Arabia, miospores, chitinozoans, acritarchs

The palynostratigraphy of the Mississippian Berwath Formation in northern Saudi Arabia

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Mississippian sediments are not exposed in Saudi Arabia and therefore our understanding of this succession is dependent on subsurface data. A stratigraphic test well (667-44) drilled in northern Saudi Arabia, produced *ca.* 1,500 ft of continuous conventional core, part of which extends through the Mississippian (Tournaisian to Serpukhovian) succession and continues into the Pennsylvanian. The cored section provides a potential biostratigraphic and lithostratigraphic reference section for Mississippian rocks in the region. The Mississippian succession in northern Saudi Arabia comprises, at the base, a series of early-middle Tournaisian red clastic sediments of the uppermost part of the Jubah Formation followed by late Tournaisian to early Visean dark grey mudstones of the lower Berwath Formation. These organic-rich, high gamma mudstones, are marginal marine for the most part, but show a marine maximum at the top, marked by a gamma ray peak. This horizon is characterized by an influx of prasinophyte algae marking the base of the upper Berwath Formation. The unit is consistently more silt- and sand-prone, reflected by lower gamma ray response, but is still a shallow marine. Sedimentological evidence indicates fluvial distributary channel, bay, lagoon and tidal palaeo-environments, with tidal bundle features and heterolithic bioturbated sands and muds. The youngest upper Berwath Formation strata encountered are of late Serpukhovian age. The Mississippian Berwath Formation is unconformably overlain by the Pennsylvanian Juwayl Formation of glaciogenic origin. This study is based on a high-resolution palynostratigraphic investigation undertaken as part of a joint study between Saudi Aramco and the Commission Internationale de la Microflore du Paléozoique (CIMP). Previous attempts to date and correlate Saudi assemblages mainly utilized the zonal scheme erected in Libya, but with unsatisfactory results due to the infrequent occurrence of several of the zonal index species. The Berwath Formation section in Well 667-44 spans the whole of the Libyan RT Biozone and parts of the overlying MJ and underlying SG biozones, but determination of zonal boundaries remains tenuous for reasons outlined. Many miospore taxa previously recorded in open nomenclature from Saudi Arabia have been formally described by other authors investigating the Mississippian palynostratigraphy of the Amazonas Basin, northern Brazil. The bizonation erected by these authors is inapplicable in Saudi Arabia, and therefore a new zonal scheme is presented.

***Keywords*:** Saudi Arabia, Mississippian, biostratigraphy

The significance of *Verrucisporites* megaspores in the Mid and Late Devonian of Saudi Arabia

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In 2007 Marshall *et al*., erected a new species of *Verrucisporites*, (*V. yabrinensis*) from the Mid Devonian of Saudi Arabia. This was subsequently synonymised (2013) into *V. ellesmerensis* by Bruer and Steemans. In 2012 Xu *et al*., had placed *Longhuashanispora reticuloides* into *Verrucisporites* with the new specific epithet of *V. lui*. Xu *et al*., also placed *Verrucisporites yabrinensis* in synonymy with *V. lui*. In 2015 Berry and Marshall recognised the significance of *Verrucisporites* from Svalbard as the *in situ* megaspore of the equatorially distributed lycopod tree *Protolepidodendropsis*, the microspore being *Cymbosporites magnificus*. Recognition this link between the various species of both *Verrucisporites* and *Cymbosporites* enables us to better understand the significance of the megaspore in Saudi Arabia. It occurs (Breuer and Steemans, 2013) in the *catillus* and *langii-concinna* zones of latest Givetian to Frasnian age. Here it co-ranges with

the *Cymbosporites catillus* morphon which, from comparison with the Svalbard co-association, can now be postulated as the related microspore. This gives a key Gondwanan data point for plotting the global spread of lycopod forests during the Mid and Late Devonian. *Verrucisporites lui* occurs in Xinjiang in northernmost China, in addition to the type locality in Yunnan, South China. *Cymbosporites* is also abundant and diverse in both these areas. In Xinjiang *Cymbosporites* is the dominant microspore and present within rooted coals demonstrating that it was a peat forming plant within an ever wet equatorial climate. The Saudi Arabian occurrence of *Verrucisporites* with the ?related *Cymbosporites* shows the presence of similar lycopods but in a somewhat drier climate than Svalbard and South China. It shows the migration of the group along the northern margin of Gondwana. Both spores can be found in long sections in Bolivia showing that the parent plant also moves south into the higher palaeolatitudes of western Gondwana.

***Keywords*:** Devonian, megaspore, lycopod, Saudi Arabia, China

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The Ballagan Formation, the CM spore zone and the Tournaisian of Scotland

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The TW:eed project has been a multi-disciplinary investigation of the earliest known terrestrial tetrapods from the earliest Carboniferous, within the faunally impoverished interval known as Romer's Gap. This investigation has included the tetrapods themselves, their phylogenetic relationships, habitat, palaeoclimate and age. Significant new tetrapod discoveries have been made in the 500 m thick Ballagan Formation at Burnmouth in the Scottish Borders. This section has been logged in detail and comprehensively sampled for palynology. At the base of the section there are very simple palynological assemblages dominated by *Retusotriletes incohatus* with *Plicatispora scolecophora* and typical of the earliest Carboniferous VI spore zone. These have only rarely been reported from Ballagan Formation sections. This is then followed by the inceptions of *Cristatisporites hibernicus* and then *Claytonispora distincta* at 50m and 71m respectively. At 104m there are the closely spaced inceptions of *Neoraistrickia cymosa* and *Grandispora upensis*. The palynological assemblages then become dominated by *Anaplanisporites delicatus*, the *in situ* spore of the creeping lycopod *Oxroadia*. Further inceptions include *Spelaeotriletes balteatus* (291m) and then *Raistrickia clavata* (338m). The latter is coincident with a significant tetrapod bed and another peak in abundance of *Anaplanisporites delicatus*. These zonal indices do not have contiguous ranges but are sporadic and their occurrence probably relates to humidity events within the sequence. The inception of the zonal indices are in the same order as recognized in the early to mid Tournaisian zonation as defined from clastic sediments in southern Ireland. However, in Scotland the Ballagan Formation has been included entirely within the CM spore zone of late Tournaisian age as defined by the inception of *Schopfites claviger*. This spore occurs from 50 m in the Burnmouth section. If *Schopfites claviger* did have a late Tournaisian inception then all these other early and mid Tournaisian spores would be present in all assemblages throughout the sequence. The implication is that the Ballagan Formation represents most of Tournaisian time which is very significant for understanding earliest Carboniferous tetrapod diversification. In reality, the occurrence of *Schopfites claviger* and related species may be controlled by seasonality variations in the somewhat unstable environments of the Ballagan Formation.

***Keywords*:** Early Carboniferous, Tournaisian, Scotland, spores, CM zone

Occurrence and significance of minute palynomorphs of marine and non-marine origin in the Middle Ordovician from Saudi Arabia

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Abundant and well-preserved palynomorph assemblages occur in core samples across the transition between the Sajir Member of the Saq Formation and the Hanadir Member of the Qasim Formation in central Saudi Arabia. Organic-walled microfossil assemblages include cryptospores, acritarchs, chitinozoans, cuticle-like fragments and other problematic forms together with more or less abundant amorphous organic matter. The Hanadir Member of the Qasim Formation is biostratigraphically well-constrained by the presence of chitinozoans of the successive *formosa* and *pissotensis* zones of early to late Darriwilian age. The biostratigraphic age of the Sajir Member is considered to span through the Dapingian-Darriwilian boundary although definitive age evidence is lacking. In this paper we describe previously unreported assemblages of small microfossils of the picoplanktonic and ultraplanktonic size classes, which are key components of the palynological assemblages. Among these small microfossils are unornamented sphaeromorphs, which occur in either isolated or irregular clusters. Others are small acritarchs or prasinophycean phycomata, of 5 to 15 µm in total diameter, which display complex morphologies especially when observed under SEM, and which represent a unique assemblage with no described counterparts in other Middle Ordovician successions. The smallest elements that we encountered in this study were stained nanospheres of 500 nm to 1µm in diameter, which occur embedded within organic-rich mats. These minute forms had not been detected before, because in standard palynological preparations, particles less than 10 to 15 µm in diameter are usually discarded by sieving and/or are not generally reported in palynological publications. We discuss the depositional distribution and paleobiological significance of these small palynomorphs in terms of marine eukaryotic and prokaryotic (e.g., cyanobacteria) ultraplankton, as well as the possible connection of their remains to those of terrestrial or freshwater biota.

***Keywords*:** Minute palynomorphs, Middle Ordovician, Saudi Arabia

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Tournaisian (Early Carboniferous) Palynology of the West Mains Farm Borehole, UK

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As part of the study of the tetrapod world in the Scottish Borders during the earliest Carboniferous, a fully cored 500 m science borehole was drilled through most of the Tournaisian Ballagan Formation. Both miospores and megaspores have been studied throughout the section and give new insight into the recovery of the terrestrial vegetation following the End Devonian Mass Extinction event. The persistent assemblage throughout the section is from the CM spore biozone, as typified by *Schopfites claviger* and *Auroraspora macra*. However, quantitative counts of the miospores shows that other spores became dominant and tell us much about how terrestrial vegetation was re-established. These spores include *Anapiculatisporites delicatus* (from the creeping lycopod *Oxroadia*) and *Prolycospora claytonii* that is presumed to come from an arborescent lycopod. These lycopods successively recolonised the Ballagan environment – a pattern that is mirrored in the megaspore distribution. The quantitative counts also reveal a changing pattern of *Schopfites/Auroraspora* that represent drier climatic conditions, whereas the lycopods support a

progressively more humid environment. These changes in the dominant spore assemblage are also matched by a changing environment as shown by the distribution of key facies, such as different types of palaeosol and cementstones.

***Keywords*:** Tournaisian, palynology, Scottish Borders, environmental changes, borehole

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Late Devonian acritarchs and prasinophycean phycomata from the Caima PH-2 core-drill, Amazonas Basin, northern Brazil: taxonomy and biostratigraphy

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Located in the Tapajós River area of the Amazonas Basin, northern Brazil, Caima PH-2 is a fully cored shallow drill that has been investigated successively for organic geochemistry, miospores, chitinozoans, and marine organic-walled microphytoplankton (acritarchs and prasinophycean phycomata). The section studied concerns the Barreirinha Formation, of early Frasnian through late Famennian (pre-Strunian) age, in the lower part of the Curuá Group. This formation is divided in ascending stratigraphic order into the Abacaxis, Urubu, and Urariá members. Long-lasting anoxia spanning the entire Frasnian–early Famennian interval (with transgressive peaks in the Frasnian) originated a thick, radioactive black shale succession making up the Abacaxis Member. The palynological investigation of 375 samples from a 137 m thick shaly-silty section revealed rich and highly diversified assemblages of marine and terrestrial palynomorphs. Due to sustained marine conditions in a continuously subsiding basin, acritarchs and prasinophycean phycomata are exceptionally diversified. Over 200 species have been identified, of which 31 are new. This work results from a joint PETROBRAS/U.B.O. project, aimed to conduct a detailed systematic study of Paleozoic acritarchs and prasinophytes from northern Brazil, to establish regional palynozones, and to calibrate their biostratigraphy after chitinozoans and miospores. The Frasnian–late Famennian interval of Caima PH-2 comprises three major acritarch/prasinophyte zones (further subdivided into subzones), as follows: the *Duvernaysphaera cruciforme* nov. sp.–*Leiofusa bisubulata* (Dc-Lb) Interval Zone, of early (but not earliest)–early late Frasnian age; the *Maranhites insulatus–Puteoscortum williereae* (Mi-Pw) Interval Zone, of late Frasnian–middle Famennian age; and the *Polyedryxium tapajosense* nov. sp. (Pta) Total Range Zone, of late (but not latest) Famennian age. Many morphological groups are represented, and their evolution and distribution are discussed. Higher diversity than previously recorded is noted, e.g., within the *Umbellasphaeridium saharicum* plexus. An overrepresentation of *Maranhites* spp. characterizes the late Frasnian–middle Famennian. The above-mentioned Caima PH-2 zones can be correlated with coeval successions of the Paraná and Parnaíba basins in Brazil, as well as with Bolivian biozones. The main marine palynoevents recognized in this study are undoubtedly synchronous with those noted outside Western Gondwana, e.g., in North Africa, North America, and Western Europe. But to the contrary of the latter, Brazilian Devonian acritarchs and prasinophytes remained highly diversified until the latest Famennian (Strunian), as seen in other Amazonas and Parnaíba basin wells. We also discuss the palynological signal of acritarchs and prasinophytes from the late Famennian *Protosalvinia (Foerstia)* Zone, in the upper part of Caima PH-2.

***Keywords*:** Acritarchs, prasinophytes, Late Devonian, Amazonas Basin, Brazil.

A review of Silurian dispersed spore assemblages from the Arabian Plate: biostratigraphy and palaeogeography

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Establishing a global Silurian dispersed spore biostratigraphy has been plagued by a number of long-standing problems: (i) spores are absent or rare in global stratotypes for the Ordovician-Silurian and Silurian-Devonian boundaries that are located in marine facies; (ii) spore endemicity is high on the dispersed Silurian continents hampering intercontinental correlation. Silurian spores from the Arabian Plate have been described from the Qalibah and Tawil formations. The Ordovician-Silurian boundary is difficult to locate due to the complicated stratigraphy (with downcutting, glacial tillite infill etc.) and extensive palynomorph reworking associated with the Hirnantian glaciation. However, rich Llandovery and Wenlock-Ludlow spore assemblages have been described from the marine deposits of the Qalibah Formation: Qusaiba Member and Sharawra Member, respectively. Spores are currently poorly documented from the continental deposits from the lower part of the Tawil Formation, but sparse assemblages recovered from cuttings samples indicate a probable Ludlow age. However, rich and well preserved mid Pridoli spore assemblages are now known from marginal marine deposits from a marine intercalation higher in the Tawil Formation. The exact location of the Silurian-Devonian boundary within the Tawil Formationa has yet to be pinpointed. The Silurian spore assemblages from the Arabian Plate show significant differences to those from beyond Gondwana highlighting the extent of palaeophytogeographical differentiation and hence problems of intercontinental correlation for Silurian spores. Statistical analysis of these differences, using coefficient of similarity (CS), will be reported in this presentation.

***Keywords*:** Silurian, dispersed spores, early land plants, biostratigraphy, palaeogeography

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A preliminary study on acritarch assemblages from the Tremadocian in the Xiangshuidong section, Songzi, Hubei Province

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A new IGCP program "The onset of the Great Ordovician Biodiversification Event" has been accepted as IGCP653 which focus on the triggers of the GOBE. As the primary producers during the Paleozoic, acritarchs are very important in the GOBE. The Xiangshuidong section located along the provincial road at Xiangshuidong village of Songzi, Hubei Province and well-exposed a continuous sequence from the upper Cambrian to the Upper Ordovician Pagoda Formation. The Early-Middle Ordovician rocks from the Xiangshuidong section are subdivided into the Nantsinkuan, Fenhsiang, Hunghuayuan, Zitai, Kuniutan and Pagoda formations in ascending stratigraphic order. A moderately preserved and diverse acritarch assemblages were recognized in the Nantsinkuan, Fenhsiang, Hunghuayuan, Zitai formations from the Xiangshuidong section. The Nantsinkuan and Fenhsiang formations are represent the sediments of the Tremadocian (Lower Ordovician). The acritarch assemblage analysed from the Nantsinkuan Formation containing 28 species assigned to 16 genera, is dominated by *Cymatiogalea*, *Polygonium* and *Aryballomorpha*. The acritarch assemblage consisting of 32 species attributed to 23 genera was recorded from the Fenhsiang Formation is dominated by *Lophosphaeridium*, *Polygonium*, *Cymatiogalea*/*Stelliferidium* and *Peteinosphaeridium*.

***Keywords*:** Early Ordovician, acritarchs, Nantsinkuan Formation, Fenhsiang Formation, South China

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Preliminary correlation of Palynomorph Darkness Index (PDI) with Vitrinite Reflectance and other indicators of organic maturity

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Palynomorph Darkness Index (PDI) is a fully quantitative method for assessing the darkness of palynomorphs in transmitted light using standard palynological microscopes and digital cameras. It provides a rapid and inexpensive means of estimating thermal maturity that can be deployed during routine palynostratigraphic

investigations. Results are presented from Saudi Aramco Well 667-44, a cored stratigraphic borehole drilled in Northern Saudi Arabia that penetrated the Carboniferous Berwath formation. A detailed investigation of the thermal maturity of this section has been completed as part of a joint study between Saudi Aramco and C.I.M.P. PDI results from this section are mainly from simple trilete miospores (*Punctatisporites* spp. and *Waltzispora* spp.) with more limited data from (*Tasmanites* spp.) and acritarchs (*Veryhachium* spp.). The stratigraphic interval investigated is *ca.* 600 m thick and covers the critical maturity range of submature into the uppermost part of the oil window. This study has comprised determination of PDI calibrated against vitrinite reflectance (R_{oran}). Additional PDI data obtained from well and outcrop samples of various ages from Europe, North America and North Africa considerably extend the organic maturity range covered. A preliminary correlation of PDI with vitrinite reflectance is presented and correlation with other maturity indicators including SCI discussed.

Keywords**:** palynostratigraphy, miospores, prasinophytes, acritarchs

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Palynology and organic geochemistry of an Early to Middle Devonian succession from borehole TCB X-1001 – Tacobo, Tarija Basin, southern Bolivia

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Palynological, palynofacies and organic geochemical analyzes have been performed on an Early to Middle Devonian clastic marine sedimentary succession of the borehole TCB X-1001 – Tacobo, in the Foothills, Tarija Basin (southern Bolivia), located between the Subandean and the Chaco-Plains. The Foothills is considered one of the areas of the country boasting best exploration potential for gas and oil. The studied section ranges, from the upper to the lower part, between 4520 m and 5780 m in depth, mainly encompassing shallow marine deposits of the Los Monos, Huamampampa and Icla formations. The Los Monos Formation, considered the main source beds for oil and gas in the area, is mostly composed of dark grey to black shales. The Huamampampa Formation is characterized by grey to greenish grey fine-grained sandstones intercalated with light grey siltstones and sandy-siltstone beds. The Icla Formation consists of alternations of dark grey shales, thin-bed sandstones and gray siltstones. Eighteen from the twenty-three cutting samples available for this study were productive, yielding variable abundance, diversity and preservation of organic-walled phytoplankton and miospores. The relative abundance of marine and terrestrial palynomorphs fluctuates throughout the section with an increasing trend of terrestrial palynomorphs transpiring towards the younger beds. *Archaeozonotriletes variabilis*, *Chelinospora timanica*, *Convolutispora subtilis*, *Cristatisporites triangulatus*, *Geminospora lemurata*, *Cymbosporites cyathus*, *Dibolisporites uncatus*, *Dibolisporites farraginis*, *Grandispora libyensis*, *Grandispora permulta*, *Grandispora verrucosa*, *Samarisporites eximius*, *Verrucosisporites premnus*, cf. *Chelinospora ligurata*, *Arkonites bilixus*, *Crucidia carminense*, *Maranhites mosesii*, *Stellinium comptum* and *Polyedryxium talus* are among the most relevant taxa of the Los Monos Formation. The Huamampampa Formation comprises *Acinosporites acanthomammillatus*, *Acinosporites eumammillatus*, *Polyedryxium* sp. cf. *condensum* and *Umbellasphaeridium deflandrei*. The Icla Formation contains *Bimerga bensonii*, *Cordobesia* cf. *uruguayensis*, *Duvernaysphaera angelae*, *Dibolisporites echinaceus*, *Emphanisporites annulatus*, *Acinosporites*, sp. and *Grandispora* sp. Based on the miospores and the organic-walled phytoplankton of the studied section, the Los Monos, Huamampampa and Icla formations are interpreted to be Givetian, Eifelian and Pragian? - Emsian in age, respectively. The palynofacies analysis evidences a strong predominance of AOM (amorphous organic matter) in the majority of the samples. Considering TOC, RockEval pyrolysis, HI and Tmax data, all the source rocks in the Los Monos, Huamampampa and Icla formations present poor to regular quality with a mixed III/IV kerogen type. Although the shale intervals in the Los Monos Formation reached initial to advance oil window maturity; similar lithology from the Huamampampa and Icla Formations have reached a thermal evolution from advance oil to condensate window.

Keywords**:** palynomorphs, biostratigraphy, hydrocarbon potential, Devonian, Bolivia

Silurian palynomorphs from the Precordillera basin, western Argentina: biostratigraphy and diversity trends

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The Silurian succession of the Precordillera, western Argentina, constitutes a typical foreland basin deposit. The middle-upper Silurian to Lower Devonian (Wenlock to Lochkovian) is represented in the Los Espejos Formation. It is composed of siliciclastic, mainly fine-grained shelf deposits with a gradual upward thickening and coarsening and evidences of subaerial exposures in its upper part. Its thickness diminishes from north to south and the younger levels are only present in the northern outcrops. In this contribution, the organic-walled phytoplankton and the miospores from two sections of the Los Espejos Formation, Quebrada Ancha and Cerro La Chilca, are presented. A total of 21 productive samples, in which marine palynomorphs exhibit a clear predominance in almost all the samples in both sections, were obtained. The only productive samples that evidence a predominance of miospores over marine phytoplankton are the two uppermost ones of the Quebrada Ancha section and the uppermost sample of Cerro La Chilca section. *Fimbriaglomerella divisa*, *Leiofusa bernesga*, *Melikeriopalla polygonia*, *Muraticavea wenlockia*, *Oppilatala ramusculosa*, *Ozotobrachion palidodigitatus*, *Pterospermella martini* and *Schismatosphaeridium perforatum* were among the most relevant phytoplankton species recorded in the Quebrada Ancha section. The phytoplankton species support, for the whole section, a Gorstian?-Ludfordian to Pridoli age based on the miospores. *Chelinospora poecilomorpha* var. *verucata* Morphon, *Stellatispora inframurinata* var. *inframurinata*, *Chelinospora* cf. *hemiesferica* in Richardson *et al.* (2001), *Synorisporites tripapillatus*, *Brochotriletes foveolatus*, *Leonispora argovejae* and *Amicosporites streelii* are the more biostratigraphically relevant miospores species recorded in this section. The Cerro La Chilca section contains a phytoplankton assemblage composed of species such as *Schismatosphaeridium algerense*, *Fimbriaglomerella divisa* and *Ozotobrachion palidodigitatus*. The stratigraphic range of the phytoplankton species support a Homerian?-Ludfordian age based on miospores such as the hilate cryptospore *Hispanaediscus lamontii* and the trilete spores *Chelinospora* cf. *cantabrica* and C*helinospora sanpetrensis*. The lower part of the Los Espejos Formation displays the highest phytoplankton diversity and the better preserved palynomorphs of the whole formation in both sections. This peak of diversity corresponds to the early Ludfordian and could consequently indicate a particularly favorable environmental condition for this time interval. The diversity tends to diminish towards the upper part of the formation in agreement with the transition to storm-dominated shelf and shoreface environments and subaerial exposures that probably prevent the preservation of palynomorphs.

***Keywords*:** organic-walled phytoplankton, miospores, Silurian, biostratigraphy, diversity

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A biostratigraphic and paleoenvironmental approach to Late Ordovician (Sandbian) palynomorphs of Sweden: the oldest evidence of land plants in Baltica

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A detailed palynological study throughout the Late Ordovician (Sandbian) Kinnekulle K-bentonites in Motala, Östergötland province, south-central Sweden, has been carried out. Twenty one palynological samples drawn from the Borenshult-1 drillcore provided an abundant, diverse and well-preserved palynological assemblage dominated by marine organic-walled phytoplankton. The studied interval of 4.9 m is comprised within 40.1 m and 35.2 m of depth. This interval, dominated by mudstones, includes the Kinnekulle K-Bentonite represented by two layers of which the thickest one reaches up to 1,65m. These ash beds, derived from two volcanic events that occurred in the Iapetus Ocean, southwest of Baltica are recognized as being the product of one of the largest eruptions of the Phanerozoic. Isotopic (U-Pb) dating indicates 453.4±4.2 Ma age for the Kinnekulle K-Bentonite, thus providing an independent age control for the palynological assemblage and a precise timing for the inception of land plants in Baltica. The marine organic-walled microphytoplankton is represented by genera such as *Baltisphaeridium*, *Excultibrachium*, *Ordovicidium*, *Orthosphaeridium*, *Lophosphaeridium*, *Michrystridium*, *Multiplicisphaeridium*, *Buedingiisphaeridium*, *Gyalorhethium*, *Nexosarium*, *Hoegklintia*, *Aremoricanium*, *Rhopaliophora*, *Peteinosphaeridium*, *Polyancistrodorus*, *Caelatosphaera*, *Veryhachium*, *Dorsennidium*, *Stellechinatum*, *Estiastra*, *Navifusa*, *Eupoikilofusa* and *Nanocyclopia*, with a marked predomi

nance of acanthomorphitic acritarchs. Among the most relevant taxa, *Ordovicidium elegantulum*, *Baltisphaeridium perclarum*, *Aremoricanium rigaudae*, *Navifusa ancepsipuncta*, *Hoegklintia* cf. *corallina* and *Nexosarium* sp. have been recorded in Upper Ordovician strata from Baltica. The fact that such taxa have also been recorded from Laurentia and Gondwana, renders them potentially useful for biostratigraphic long-distance intercontinental correlations. The assemblage also contains chitinozoan, scolecodonts and zooclasts. The studied assemblage is characterized by the occurrence of large-sized species of *Baltisphaeridium*, *Ordovicidium*, *Orthosphaeridium* and *Hoegklintia*. Such fact has also been observed in other Late Ordovician marine assemblages from Baltica and, furthermore, in paleoplates such as Avalonia, Laurentia, Gondwana and the Tarim block. Significantly, sparse terrestrial palynomorphs represented by cryptospores have also been recorded in the section. They are represented by low-diversity dyads and tetrads such as *Dyadospora murusatenuata*, *Psedudodyadospora petasus*, *Tetrahedraletes grayae* and *Tetraplanarisporites laevigatus*; that is, a similar but slightly more diverse assemblage than the one identified from Röstånga, southern Sweden in younger (Katian) deposits. So far, this cryptospore assemblage recorded from Sandbian strata constitutes the oldest record of land plants in Baltica. A palynofacies analysis and the evaluation of fluctuations in palynomorph diversity and abundance throughout the studied section allow the interpretation of the relationship between the palynomorph distribution and depositional paleoenvironments.

***Keywords*:** Sandbian, organic-walled phytoplankton, cryptospores, Baltica, paleoenvironments

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A new record of the *messaoudensis-trifidum* acritarch assemblage (Late Tremadocian-Floian) in the Cordillera Oriental, Central Andean Basin, northwestern Argentina

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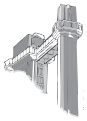
Lower and Upper Ordovician sedimentary rocks crop out in the Caspalá area, Sierra de Zenta (Jujuy Province), on the eastern margin of the Cordillera Oriental. Even though the Lower Ordovician stratigraphic units have not been well defined in the area so far, they are considered as equivalent to the Santa Victoria Group. This group comprises the Santa Rosita and Acoite formations of late Cambrian-Tremadocian and Floian ages, respectively. The group reaches more than 3000 m of thickness in the Sierra de Zenta and is composed of alternating sandy and shaly packages indicating prograding coastal system successions. The Lower Ordovician marine deposits are interpreted as wave-dominated delta lobes with intervals of subaerial exposure. The overlying glacial deposits of the Caspalá Formation (Katian?-Hirnantian) present an erosive contact with the Lower Ordovician Acoite Formation. Eighteen samples from a section that spans the Tremadocian - Floian boundary, in the Caspalá area, were taken for palynological analysis and fourteen of them proved productive. The studied samples yield organic-walled phytoplankton and chitinozoans. The organic-walled phytoplankton assemblages are low in diversity and abundance and moderately to badly preserved. Levels of the Santa Rosita Formation in this area are considered as late Tremadocian. They contain *Stelliferidium trifidum*, *Eisenackidium orientalis*, *Polygonium* spp. and *Michrystridium* spp. and correspond to the *Euconochitina paschaensis* chitinozoan assemblage recorded in the Sierra de Zenta. In spite of the scarcity and low preservation of the phytoplankton, the identification of *Stelliferidium trifidum*, which is one of the index species of the *messaoudensis-trifidum* acritarch assemblage, favors the recognition of this typical peri-Gondwanan assemblage in the studied area. The overlying Floian Acoite Formation yields a more diverse acritarch assemblage that corresponds to the *Lagenochitina* sp. A chitinozoan assemblage. It is composed of *Acanthodiacrodium costatum*, *Arbusculidium filamentosum*, *Coryphidium bohemicum*, *Coryphidium* sp., *Cymatiogalea cuvillieri*, *Cymatiogalea velifera*, *Dactylofusa velifera brevis*, *Eisenackidium orientalis*, *Stellechinatum* cf. *brachyscolum*, *Striatotheca* spp., *Veryhachium lairdii* group, *Leiofusa* sp., *Michrystridium* spp. and *Polygonium* spp. Most of these taxa were previously recorded, in different localities, from the *messaoudensis-trifidum* assemblages and with first occurrences in the late Tremadocian. *A. filamentosum*, a recognized marker of the beginning of the Floian of the *messaoudensis-trifidum* assemblage, first appears in the same level of *Eremochitina brevis*, which is typically associated with *Lagenochitina* sp. A, and is the index species of the late middle Floian in North Gondwana. These new data contribute to the better knowledge of the biostratigraphically relevant *messaoudensis-trifidum* assemblage in western Gondwana.

***Keywords*:** organic-walled phytoplankton, chitinozoan, Lower Ordovician, biostratigraphy, Argentina



NEW INSIGHTS ON ASSOCIATED PALEOZOIC TO CENOZOIC FLORAS AND PALYNOFLORAS FROM GONDWANA

Mercedes di Pasquo, Roberto Iannuzzi & Paulo A. Souza

Fern diversity and comparative analysis of Cretaceous formations in Argentina

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The fossil record is relevant for biological reconstructions helping to understand the evolutionary processes of the biota worldwide. Fern spores and macrofossils have been widely recorded in different basins around the world. Previous studies indicate that the fern flora was highly diverse during the early and mid-Cretaceous and underwent a considerable decline in species number by the end of this period when the angiosperms became dominant. The goal of this work is to analyze the Cretaceous fern distribution and diversity in Argentina based on published spore and macrofossil records. A total number of 38 formations were considered in this study. They belong to seven basins distributed throughout the country (Salta Group, San Luis, Neuquén, Chubut River Area, San Jorge, Deseado Massif, and Austral). Presence-absence of species was included in a distribution chart. A cluster analysis was performed to detect associations between paleofloristic locations and the Jaccard index was used as a similarity measurement. The diversity comparative analysis results show that the Kachaike Formation is the most diverse for the Lower Cretaceous and the Monte Chico Formation for the Upper Cretaceous. The Order Schizaeales (including Lygodiaceae, Anemiaceae, and Schizaeaceae) contains the higher number of species followed by the Marsileales (Marsileaceae). The Lower Cretaceous concentrates about 68% of the fern diversity while the Upper Cretaceous the remaining 32%. The cluster analysis for the Lower Cretaceous determined that the higher similarity index on fern composition is between the Mulichinco (late Valanginian) and La Amarga (Barremian-Aptian) formations from the Neuquén Basin, with 38% of species in common. For the Upper Cretaceous, the Allen (Campanian) and Jagüel (Maastrichtian) formations also from the Neuquén Basin share around 35% of the species. The higher diversity of fern spores during the Lower Cretaceous previously documented in other regions is confirmed in this work. The most diverse cretaceous fossil association in terms of ferns belong to the Austral Basin located in southernmost Argentina. This may be due to different causes: patagonian basins have been most widely studied than the northern ones or perhaps they have better lithologies for fossil preservation. Our results constitute a good contribution to understand the Cretaceous paleoclimatic and paleocologic conditions in this part of southern south America.

***Keywords*:** Ferns, diversity, Cretaceous, Argentina

First platyspermic seeds in the Jejenes Formation, Quebrada Grande, western Argentina dated with palynology and $^{206}Pb/^{238}U$ volcanic zircons

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Platyspermic seeds and palynomorphs are found together in a tuffaceous deposit of the Jejenes Formation (Bashkirian) at Quebrada Grande, Paganzo Basin, Precordillera Argentina. The Jejenes Formation represents the glacial to postglacial fill of a palaeovalley carved in the Eastern Precordillera. The tuffaceous level bearing

these fossils yielded first-cycle volcanic zircons that were analysed by SHRIMP. An absolute age of 321.3±5.3 Ma confirms a Bashkirian age. The platyspermic seeds *Cordaicarpus cesariae* and *Cordaicarpus famatinensis* were recorded for the first time in this location associated to undertermined stems of lycophytes and gymnosperms. It is known that platyspermic seeds are related to cordaiteans and primitive coniferaleans gymnosperms globally known since the Serpukhovian (late Mississippian). In Argentina and Bolivia they are mainly documented in Bashkirian assemblages of the NBG Zone from western Argentina and Bolivia. This age is confirmed herein by the novel isotopic calibration. Palynoassemblages are characterized by poorly preserved trilete spores and monosaccate pollen grains along with a high amount of terrestrial phytoclasts. Main species indicating the SubZone A of *Raistrickia densa-Convolutispora muriornata* Zone (DMa SZ) are *Vallatisporites ciliaris*, *Cristatisporites rollerii*, *C. stellatus*, *C. chacoparanensis*, *C. inconstans* and monosaccate pollen grains such as *Circumplicatipollis plicatus*. Below the DMa SZ it is defined the *Reticulatisporites magnidictyus-Verrucosisporites quassigobbetti* (MQ) Interval Zone in the Cortaderas Formation akin to the late Visean – early Serpukhovian. The absence of monosaccate pollen grains in this zone and the presence of sparse records in northern Bolivia supports an age not older than late Serpukhovian for their inception in the DMa SZ of western Argentina. The sedimentary succession at Quebrada Grande includes five stages. This tuffaceous and fossiliferous deposit is part of the Upper Stage III, which is interpreted as the main interglacial transgression that occurred after the Serpukhovian-Bashkirian glacial event here documented as Stages I and II, and recorded elsewhere in Paganzo Basin. The palynofacies analysis of the productive samples in Stage IV (turbidites deposits) yielded palynomorphs with degraded walls due to pyritization that support the interpretation of marine settings linked to the transgressive event. A new local glacial event (Stage V) is recorded in the upper section of the area with the presence of erratic boulders and dropstones with Precambrian affinity suggesting a possible ice advance and subsequent retreat from Sierras Pampeanas located to the East.

***Keywords*:** Platyspermic seed, palynology, Bashkirian, Jejenes Formation, Argentina

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Palynostratigraphy of the Yaurichambi and Copacabana formations in the Manuripi X-1 core, Madre de Dios Basin, northern Bolivia: First constraints from U-Pb dating of volcanic ash

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The interval between 1140 and 850 m depth in the Manuripi X-1 Mobile-Oxy core was examined for palynology. The Yaurichambi Formation (ca. 40 m) is composed of sandstones with minor interbedded mudstones separated from the underlying latest-Visean/early Serpukhovian Toregua Formation (*Mag* Zone Melo and Loboziak) by a regional erosional surface. Its upper contact with the Copacabana Formation occurs at the first appearance of carbonate beds, which is mainly composed of fossiliferous carbonates, evaporites, cherts, sandstones, shales and tuffs. From the Yaurichambi Formation one (1132 m depth) of six samples (1140-1090 m depth) and eight (1081m, 1080m, 1058m, 1046m, 1043m, 1042m, 1041m, 948m depth) of eleven samples (1085-850 m depth) of the Copacabana Formation were productive. The first assemblage yielded poorly preserved acritarchs (*Maranhites*, *Polyedryxium embudum*, *Pterospermella pernambucensis*) and less frequent spores (*Punctatisporites*, *Calamospora*). Instead of Pennsylvanian, they indicate recycling of underlying Devonian and Mississippian deposits associated to the erosive unconformity of the Serpukhovian glaci-regressive event. This paleotopography, covered by Bashkirian transgressive sedimentation, is also documented in the base of other Bashkirian units of South America, like in the Pando X-1 core where reworked palynomorphs were also identified directly over the unconformity. The palynofacies of eight samples of the Copacabana Formation are characterized by fairly well- to rather poorly-preserved palynomorphs (indigenous monosaccate pollen grains, spores and *Botryococcus*) with evidence of pyrite affecting their walls in some levels. Reworked palynomorphs (*Retispora lepidophyta*, *Gorgonisphaeridium discissum*) from Devonian deposits are also recognized in low abundance. Amorphous organic matter, terrestrial components (tracheids, cuticles), and others (resins, brown and black particles) are variably recorded in different levels. These features suggest an input of terrestrial organic matter incoming into a restricted warm-water marine

palaeoenvironment under semi arid conditions. Indigenous species with biostratigraphic meaning are the spores *Lundbladispora braziliensis*, *Reticulatisporites passaspectus*, *Convolutispora muriornata*, *Brevitriletes levis*, the monosaccate pollen grains *Costatacyclus crenatus*, *Caheniasaccites flavatus*, and species of *Cannanoropollis*, *Plicatipollenites*, *Potonieisporites* and few striated pollen grains (e.g. *Meristocorpus* sp., *Protohaploxypinus* sp.). This assemblage shares many species with the Bashkirian palynofloras in the Pando X-1 and the Macharetí Group in southern Bolivia, as well as with other Bashkirian to Cisuralian (Permian) palynofloras in South America. Calcareous foraminifera, fusulinids and conodonts demonstrate a Bashkirian through Middle Moscovian age for this interval. Supportive new evidence comes from an ash bed found at the depth of 882.4-883.2 m in the Manuripi core, which has yielded an age of 316.0 ± 0.4 Ma ($^{206}Pb/^{238}U$ CA-ID-TIMS method). The combined results establish a robust Bashkirian age.

***Keywords*:** Palynostratigraphy, radiometric age, Yaurichambi and Copacabana formations, Madre de Dios Basin, Bolivia

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Comparison of Lopingian palynological associations from Eastern (India) and Western (South America) Gondwana: taphonomic and climatic implications

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Despite paleolatitudinal similarities (~ 30º-45ºS latitudes) between Eastern (India) and Western Gondwana (South America) during the Lopingian, the proximity of India to the Paleotethys Ocean and the continentality of meridional basins in South America resulted in differences in paleoclimatic conditions between them. India witnessed a warm/cold humid coastal environment favouring extensive coal formation, while greater parts of Western Gondwana witnessed an arid climate. In the Western Gondwana viz. South Africa (Central Karoo Basin), south Brazil and Uruguay and some parts of Argentine, the Lopingian red bed lithologies are mostly devoid of palynomorphs. Palynoassemblages characteristic of the *Lueckisporites virkkiae* Zone have been reported from the Brazilian Rio do Rasto Formation (Serrinha Member). Albeit, the red beds from the upper part of Rio do Rasto Formation contain excellent macroflora which are morphographically very similar to the Indian equivalent, Raniganj Formation suggesting that they made part of the same evolutive stage despite the climatic differences. Guadalupian-Lopingian assemblages were also recorded from the Tunas Formation, in Claromecó Basin, Argentina, which were in part compared to the *Lueckisporites virkkiae* of the Paraná Basin. However, both records from Brazil and Argentina differ from the Lopingian Indian ones by the absence of many of the species characteristic of Lopingian, therefore comparisons are limited. On the other hand, the Indian Lopingian palynoassemblages show gross similarities with that of the La Veteada Formation, of the NW Argentinean Paganzo Basin where the associations are characterized by the dominance of striate bisaccates such as *Striatopodocarpites* and *Protohaploxypinus* in association with other stratigraphically significant forms (*Goubinispora*, *Corisaccites*, *Guttulapollenites*, *Lunatisporites*, *Lueckisporites Weylandites* and *Marsupipollenites*). We believe these differences are due to (i) the lack of a continuous record of Late Permian age in most part of the South American basins; (ii) palynoassemblages were deposited but they were not well preserved since their earliest taphonomic phases, once most part of the deposits were subjected to oxidizing conditions. Therefore, these similarities between palynocomposition and macrofloras of both Gondwana areas suggest that although a more or less similar *Glossopteris* paleoflora thrived throughout the entire Gondwana province during the Permian, climatic and taphonomic factors exerted a profound impact on preservation.

***Keywords*:** Palynology, Eastern Gondwana, Western Gondwana, India (Raniganj Formation), Lopingian

Reconstructing *Glossopteris*

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Almost 200 years after the discovery and description of *Glossopteris*, a fossil gymnosperm distributed extensively across India and the southern continents, remarkably few whole-plant reconstructions are available for this genus. *Glossopteris* achieved iconic status through its use to support early concepts of continental drift and its major contribution to the economic Permian coal reserves of the Southern Hemisphere continents. However, the precise palaeogeographic limits of this plant group remain poorly constrained, its stratigraphic range is disputed, and its growth habit has been interpreted from rhizomatous to arborescent. Associations of normally detached organs are now providing a clearer image of the architecture and growth habits of glossopterids. These organ associations also provide data that feed into the character sets employed for phylogenetic analyses. Greatest controversy surrounds interpretation of the architecture of glossopterid ovuliferous organs. The many morphogenera established for these fossils are undergoing Gondwana-wide systematic revision but fundamental questions of organ homology between glossopterids and other groups will need to be answered by further careful anatomical investigations of three-dimensionally preserved, permineralized fossils.

***Keywords*:** Glossopterids, Permian, Gondwana, fructifications, whole-plant reconstructions.

Floristic and climatic changes in Chilean Patagonia inferred from new palynological results

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Geography and topology of Patagonia offer a wide array of altitudes, wind exposures and precipitation rates conducting to a variety of floras, showing both endemism and affinities to other floras of South and North America, Oceania and New Zealand. Its past location in Gondwanaland adjacent to present South America, Antarctica, Africa and Falkland islands, and the climatic changes that have occurred during their separation made Patagonia a key place to observe dispersion and vicariance processes that resulted in present floras based on paleobotanical approach. Paleobotanical and palynological studies are better documented in Antarctica and the Argentine side of Patagonia, but are recently increasing in Chile. We conducted palynological analyses on the material collected during the collaborative research between Chile and Japan that started in 1974, particularly on calcium-carbonate concretions containing rich permineralized plant remains. We report here well-preserved palynofloras identified from this material which further document paleovegetation of Patagonia. The material was collected from Late Cretaceous (Maastrichtian) to Miocene localities belonging to the Quiriquina and Curanilahue formations of the Bío-Bío Region (VIII), the Cucao Strata of the Los Lagos Region (X), and the Chorillo Chico, Cerro Dorotea, Leña Dura, Brush Lake and Filaret formations of the Magallanes Region (XII). Most of them provided a diversity of palynomorphs, and we could describe for the first time palynofloras from the Cerro Dorotea (late Paleocene), Brush Lake and Filaret (Miocene) formations of the Austral Basin. We also focused on the distribution of *Nothofagidites* pollen whose diversity from the Maastrichtian Chorillo Chico Formation reflects the continental connection with Antarctica and their floristic similarities, and we then followed its later expansion towards Central Patagonia through the Cenozoic era. Compositions of our palyno-assemblages and their comparison with megafloral remains from the same material and with well-documented palynofloras from Argentina permit to affine the floristic and climatic changes in the Chilean side of Patagonia.

***Keywords*:** Chilean Patagonia, Maastrichtian, Cenozoic, palynology, *Nothofagidites*.

First palynological information of the upper Teresina Formation (Guadalupian) bearing *Krauselcladus* remains, Santa Catarina, Brazil

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The well-known Canoinhas outcrop bearing conifer *Krauselcladus canoinhensis* Yoshida from the upper Teresina Formation (probably early Guadalupian in age), located at the homonymous municipality, in Santa Catarina, South Brazil, was the first time investigated for palynology. This conifer is represented by distinct branch orders densely covered by decurrent, linear and lobed leaves which cuticles were usually preserved, and it has been recovered into a single fine sandstone (greenish grey) massive bed found in the basal portion of the exposed section in that outcrop. A sample of the rock from the same bed that contains the *K. canoinhensis* remains was processed for palynology after the standard methodology (HCl, HF). The organic residue obtained was sieved with a 25 µm mesh, and several slides mounted with jelly glycerin. The productive residue yielded amorphous organic matter and abundant palynomorphs, mainly bisaccate striated and non-striated pollen grains, and subordinated monolete and trilete spores. Some specimens are pyritized. The frequent species identified that are well represented in the *Lueckisporites virkkiae* Zone (mid Cisuralian-Guadalupian), belong to the genera *Striatopodocarpites* (*S. cancellatus*, *S. pantii*) and *Lunatisporites* (*L. variesectus*, *L. pellucidus*), and others less abundant to scarce in this sample, such as *Lueckisporites virkkiae*, *Marsupipollenites striatus*, *Vittatina saccata*, *Vitreisporites pallidus*, *Protohaploxypinus limpidus*, *Chordasporites australiensis*, *Pteruchipollenites indarraensis*, *Alisporites australis*, *Limitisporites rectus*, and the spores, *Cristatisporites* sp., *Laevigatosporites vulgaris*, *Lundbladispora braziliensis*, *Polypodiisporites mutabilis*, *Polypodiites secoensis*. This result differs substantially from those obtained in core samples from the Teresina Formation, where the spores were predominant within the palynological associations. The present association reflects better taxa (i.e. bisacate pollen grains) representing forests mainly of conifers (among other gymnosperms), and pteridophytes from humid understory places whilst glossopterids and lycophytes derived from not so distant lowlands. It is quite likely that this predominance of pollen grains here is directly related to the sedimentation process that allowed the input of massive amount of conifer remains in the water body, which would have promoted the carrying and the preservation of associated sporomorphs. In this sense, some of the dominant grains in the association have a high probability of belonging to *K. canoinhensis*, mainly because they are known to be linked to the conifer clade. Also, the presence of pyrite in palynomorphs and AOM suggest anoxic bottom waters in a shallow aquatic paleoenvironment, which would have facilitated the fossilization of plants remains and sporomorphs.

***Keywords*:** Palynomorphs, conifer *Krauselcladus*, Teresina Formation, Paraná Basin, Guadalupian.

Reavaluation of plant assemblage from the early Permian Faxinal Coalfield, southern Brazil

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The paleobotanical content of Faxinal Coalfield is characterized by the occurrence of a single plant assemblage preserved at *tonstein* level interbedded in the main coal seam. Differently, the palynomorphs have been recovered from up to five levels through the section that crops out. Stratigraphically, the Faxinal Coalfield is positioned in the middle-to-upper portion of Rio Bonito Formation, Guatá Group, from the eastern rim of Paraná Basin. Radiometric dating (i.e. 291 ± 1.3 Ma) was obtained from the fossil plant-bearing *tonstein* level suggesting a latest Sakmarian age for this deposit. Paleobotanical data from this *tonstein* bed was originally reported as an abundant compressed macroflora, predominantly composed of glossopterids. The relative abundance of the taxa in this association revealed 78% of *Glossopteris*-type leaves, composed of three species derived from epidermal pattern (cuticular features): *G. papillosa* Guerra-Sommer, *G. brasiliensis* Guerra-Sommer, *G. similis-intermittens* Guerra-Sommer. Secondarily, occurs 17.6% of

Cordaites-type cordaitalean leaves (=*Rufloria gondwanensis* Guerra-Sommer), 2% of ovulate structures of glossopterids (=*Plumsteadia sennes* Rigby), 1.4% of pteridophyte fronds (=*Sphenopteris* cf. *S. ischanovensis* Zalesky) and 1% of *Cordaicarpus*-type seeds (=*Platycardia* sp.). The main objective of this contribution is to review the specimens attributed to glossopterids from the analysis of the original and additional materials. As a result of our study, it was possible to identify c.a. six species among the *Glossopteris*-type leaves on basis of external morphological (morphographic) characteristics, namely: *G. indica* Schimper, *G. communis* Feistmantel, *G. occidentalis* White emend. Tybusch et Iannuzzi, *G. leptoneura* Bunbury, *Glossopteris* sp. 1 and sp. 2. Among the ovulate structures we have identified a new species of *Plumstedia* and a new genus unknown until now throughout the Gondwana. The Faxinal Coalfield plant assemblage is included in the *Glossopteris*–*Rhodeopteridium* Association Zone, the uppermost unit within the phytostratigraphic zonation proposed for the Lower Permian of southern Brazilian Paraná Basin. In terms of palynological assemblages, guide-species of the *Protohaploxypinus goraiensis* Subzone, the lower portion of the *Vittatina costabilis* Zone, are recorded. Also, this can be considered the first record of *Plumstedia* in floral succession and thus the earliest record of these kind of structures in the Paraná Basin. In the plant assemblages positioned stratigraphically below are only the occurrence of *Ottokaria*- and *Arberia*-type structures. Thus, it is presented here, for the first time, a radiometric dating based-age for the appearance of *Plumstedia* all over the Gondwana.

***Keywords*:** Ovulate fructifications, Glossopterid leaves, Faxinal Coalfield, Early Permian, Paraná Basin.

Patterns in palynological diversity in the Upper Paleozoic of South America

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This work analyzes palynological changes in terms of diversity trends and processes of generic appearance and disappearance throughout the Late Carboniferous and Permian of some basins in Western Gondwana (South America). The database is a bibliographic compilation and includes 135 genera from the Paraná, Parnaíba and Amazonas basins in Brazil and the Paraná Basin in Uruguay. Previous studies of palynoflora diversity were performed with data restricted to Permian strata and using the PAST software program. In this study, a larger database, a longer time interval and other statistical analysis were employed. Taxa diversity per interval was estimated as the number of taxa present on each interval. Per-capita appearance and disappearance rates of taxa were estimated following Foote equations using the R package Paleotree. In order to minimize the effects of differences in the number of units of analysis per unit of time, related to the sampling effort, a random subsampling was conducted using the same number of units of analysis for each time interval. The results obtained are consistent with previous results and show that most appearances occur at the beginning of the Permian and there is a peak in diversity at the end of the Cisuralian. On the other hand, an increase in disappearances is observed through the Gaudalupian and the Lopingian. When pollen grains and spores are analyzed separately, it is possible to observe that even though having a general similar behavior, there are some differences between these groups. In particular, the decrease in diversity during the middle and late Permian seems to be explained mainly by the disappearance of a large amount of spore genera. Despite the bias that may exist in this kind of analysis, the results obtained so far indicate that it is valid to assume an association between diversity patterns and climate changes proposed for the Upper Paleozoic in Western Gondwana.Then, the *climatic amelioration* in the lower Permian would be associated with an increase in the number of sporomorphs genera and the beginning of the more arid phase would be related to a decrease in diversity. Furthermore, taphomic effects such as the increasing of weathering under terrestrial and arid conditions can hinder the access to the records, once most part of the upper Permian sections is barren or devoided of well preserved palynoassociations.

***Keywords*:** Permian, diversity, palynology, Brazil, Uruguay

Reinterpreted fertile marattialean leaves of the Permian Rio do Rasto Formation, Paraná Basin, Brazil, and paleophytogeographic considerations

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An intricate difficulty in Paleobotany is the assessment of the natural relationships between plant fossils presenting different types of fossilization. The present study focuses on Permian marattialean foliage of the Paraná and Parnaíba Basins, respectively in the southern and central-northeasten Brazil. In the first basin, the fertile leaves with pecopterid bauplan are preserved as compressions or impressions, being usually classified as *Asterotheca*. The sterile pinnae and pinnules, a priori related either to ferns or to pteridosperms, are included in *Pecopteris*. Some exceptionally petrified specimens of this genus were found in the Kungurian-Roadian Corumbataí Formation in the northeastern region of the Paraná Basin. This formation and the lateral equivalents, interpreted as an interior epeiric sea, also bear silica-permineralized marattialean stems, mainly *Tietea* and rarely *Psaronius*. About 25 years ago, very curious impressions of fertile pinnae and pinnules were collected (by R.Rohn and colleagues) in some continental red beds of the Wordian-Wuchiapingian Rio do Rasto Formation, in the eastern Paraná Basin. Some specimens have normal pecopterid distal parts, but the fertile regions expose only the synangia (each with four sporangia), not the foliar limbs. One of the pinnules shows bizarre hook-like structures that firstly were not recognized as belonging to the leaf, nor to be analogous to badly preserved curved "projections" at the margins of another specimens. Vieira & Iannuzzi (2000, Rev.UnG, v.5) included some of these fossils in *Asterotheca*, others in *Pecopteris*, but these fossils continued enigmatic. Several years later, paleobotanical investigations in the Lower (?) Permian Motuca Formation in southern Parnaíba Basin promoted the collection of three-dimensionally petrified pinnae and pinnules, as well as *Tietea*, *Psaronius* and other fossils. The sterile leaves correspond to *Pecopteris*, but the fertile ones, namely *Buritiranopteris costata* Tavares, Rohn, Röβler and Noll, 2014, are characterized by a thick leaf lamina with extraordinary deep incised margins and respectively long, narrow downturned lobes that completely enclose each synangium. This tight sporangia protection, interpreted as a xeromorphic response to relative aridity, thus finally gives the clue to understand the strange hook-like structures or projections observed in the Paraná Basin. Therefore, the paleogeographic range of the *Buritiranopteris*-like plants can be extended to the Paraná Basin. These leaves and *Tietea*, both restricted to West Gondwana, probably were long lasting genera with close taxonomic relationship that dispersed from the tropics to the south in compass with warming, aridization and northward continental drift during the Permian.

***Keywords*:** Ferns, pecopterids, West Gondwana, Upper Paleozoic

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The record of plant-insect interactions at the Permian La Golondrina Formation, Santa Cruz, Argentina

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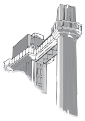
A total of 2549 fossil plant organs from the La Golondrina Formation (Permian, Santa Cruz province, Argentina) were tallied in order to assess the diversity, frequency and composition of insect damage. The typical *Glossopteris* flora found at the La Golondrina Formation is characterized by several species of glossopterids, ferns and sphenophytes, and to a lesser degree, lycophytes, coniferophytes and cordaitales. Although no evidence of arthropod bodies were found at the basin yet, their past presence is recorded through various types of plant-insect interactions, involving oviposition, external feeding, piercing and sucking, galling, and a potential mine structure. Whenever possible, the interactions were identified and assigned to a previously described damage type (DT); however, some were found different enough to eventually be considered as new DTs. Results showed that at least 171 organs (all of them plant leaves) suffered from some type of insect damage. Oviposition is the predominant interaction (35%), closely followed by generalized external feeding (margin feeding + hole feeding + surface feeding + skeletonization,

34%), piercing and sucking (17%) and galling (11%). The potential presence of a mine is suggested by an interaction on a *Glossopteris conspicua* var *patagonica* Archangelsky leaf, where several loops with a central circle repeat contiguously along the margin. If its presence is confirmed, this would represent the first mention for the Paleozoic and the earliest evidence of this type of damage. Herbivory occurred almost exclusively on glossopterid foliage, as expected. Far from the glossopterids as a preferential target (92% vs. 5%), the sphenophytes (*Sphenophyllum* spp.) and ferns displayed low levels of herbivory, whereas the other plant groups were barely attacked. Among glossopterid leaves, it was common to find more than one type of damage type on the same organ (i.e., oviposition and margin feeding), proving the leaves were exploited for multiple purposes. Qualitatively speaking, the diversity, frequency and composition of the plant-insect interactions at the La Golondrina Formation are similar to those described for other Permian paleofloras in South Africa, Brazil, and Australia. Important patterns, such as seed-plants preferentially targeted over other plant groups and predominance of oviposition over the rest of DTs, replicate in most of these well-studied southern floras.

***Keywords*:** *Glossopteris* flora, damage types, Patagonia, Gondwana, insect herbivory.



NON-POLLEN PALYNOMORPHS AS INDICATORS OF ENVIRONMENTAL AND ANTHROPOGENIC PROCESSES IN PALAEOECOLOGY: FRONTIERS AND ADVANCES IN METHODODOLOGY AND INTERPRETATIONS

Encarni Montoya, Lyudmila Shumilovskikh,
Renée Enevold & Jean Nicolas Haas

Finding even more anthropogenic indicators in mildly prepared sediment samples

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NPPs in anthropogenic soils and archaeological samples are often numerous in types as well as in abundance. Preparing these soil samples with methods based on acid digestion holds the potential of severe bias leaving the NPP assemblages devoid of acid vulnerable NPPs. In many cases it might be worth the effort to prepare the NPP samples with as mild a preparation method as possible. We have mildly prepared NPP samples from a small forest hollow, Tårup Lund, Denmark. From the recovered NPP assemblages we attempt identifying anthropogenic indicators by comparing to the environmental information derived from sediment, pollen and macrofossil analyses. The sediment from the forest hollow encompasses environmental information from the last 6000 years, including a period of locally intense pastoral and/or agricultural activity during the Iron Age.

***Keywords*:** NPP diversity, forest hollow, anthropogenic indicators, pastoral/agricultural activity

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The contribution of non-pollen palynomorphs to the environmental reconstruction for the archaeological site of Veksa, NW-Russia

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The site of Veksa, Oblast Vologda, in northwestern Russia is characterized by archaeological layers, comprising all periods from the Mesolithic through to the Medieval period, including pile dwelling-like

structures from the Late Neolithic. Today, the settlement remains extend along a river bank. However, silty and layered sediments rich in organic matter point to rather lacustrine environments in the past. Next to the multi-proxy reconstructions of both the on-site conditionds during the phases of occupation and the evolution of the local environment over the millenia, palynological studies of a near-site sediment profile and two on-site archaeological stratigraphies aim at fathoming the onset and further development of agriculture and animal husbandry in this area. The first palynological results display several phases of increased disturbance regime within the vegetation in the course of the Holocene. A clear attribution to human agency, however, is problematic because unambiguous anthropogenic indicators are missing or, respectively, emerge only in the recent past, as in the case of cereal pollen grains. In the face of this, the NPP assume a special role in distinguishing between artificial and natural disturbances of the local environment. In the deposits investigated up to now, more than 150 different NPP-types could be destinguised, many of which are of unknown origin, and the analyses are still proceeding. The near-site record displays four main phases of different NPP-compositions.The oldest stage is characterized by a relatively diverse fungal frequency, including ascospores of *Sordaria*-type, *Cercophora*-type and *Sporomiella*-type, which may refer to the presence of animals providing dung as substrate. Furthermore, the greatest abundance of chlamydospores of *Glomus* is restricted to this stage, which is also marked by high frequencys of Poaceae and ruderal herbs. The following phase is distinguished by the presence of cyanobacteria and rotifer eggs accompanied by a distinct reduction in pollen indicators from open land. The next stage shows a huge increse in both green algae (*Pediastrum* and *Botryococcus*) and diverse cysts of unknown origin, coincidenting with elevated degree of pollen analiticaly recorded environmental disturbanes.The youngest period is characterized by the lowest proportion of NPP-types, whereas first traces of agriculture occur. Based on both these examples and the inclusion of data from the on-siteprofiles, this contribution will discuss whether the NPP record in combination with pollen reflects anthropogenic interferences or natural effects such as variations of the water table, changes in water quality or changes between a lake and a river system, respectively.

***Keywords*:** Fungi, cyanobacteria, green algae, pollen, environmental disturbances

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Modern and fossil Non-Pollen Palynomorphs (NPPs) of the Great Basin, Nevada, USA

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In Europe Non-Pollen Palynomorphs (NPPs) have been widely studied since the 1970s while in the United States only a few very common types are included in palaeoecological analyses. It has been largely demonstrated that NPPs can be used as crucial indicators of climate or human induced environmental change to support and enhance pollen records. In this study we present the results from modern and fossil samples collected eastern central Nevada (USA). To the best of our knowledge this is the first study of modern and fossil NPPs from the Great Basin. The modern surface samples are represented by soil and sediment specimens collected in 2015. The fossil NPPs have been counted on the same slides previously analyzed for pollen from a sediment core recovered in 2010. Eight thousand years of vegetation history in the Great Basin have been reconstructed from this core through a palynological approach without including NPP analysis. Sixty-four NPPs from both modern and fossil samples were identified. Unknown NPPs (33) were named using a code. Even if the origin of several NPPs remained uncertain, they provided essential ecological information. PLN01, a NPP found at the marsh edges of the modern samples (likely algal origin), appears in the core immediately before and after the driest period in the area (around 3100 and 2100 cal yr BP) confirming shrinking of the wetland during a severe drought between 2800 and 1850 cal yr BP as shown by pollen records. Several known NPPs were detected in the modern and fossil samples. The trend of the algal spores, represented by *Spyrogira* sp., Zygnemataceae and three unknown algal spore types, is consistent with the trend of the aquatic plants mainly represented by Cyperaceae pollen. The abundance of aquatic plants is also consistent with the presence of *Gaeumannomyces* known as a Cyperaceae parasite (*Carex* genus in particular). The comparison between modern and fossil samples provided crucial information that validate the environmental changes that occurred in Great Basin in the last 8000 years.

***Keywords*:** Non-Pollen Palynomorphs, Pollen analysis, Great Basin, Meadow, Drought.

The spore morphology of myxomycetes used in identification from Çanakkale (Turkey)

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Myxomycetes popularly known as “plasmodial slime moulds” or “true slime moulds” are a group of fungus like organisms that found especially abundant in most terrestrial ecosystems. In their life cycle, there are two different trophic stages, one consisting of uninucleate amoebae, and the other consisting multinucleate structure, called plasmodium. Under favourable conditions plasmodium gives rise to one or more fruiting bodies including spores and these fruiting bodies vary in size from microscopic to quite large. These spores are wind-dispersed in most species and this is considered important for this organism to colonise new areas. Therefore, they are also a potential source of aeroallergenic spores in the outdoor air like pollen grains but they haven’t investigated widely yet. Spores range in size from slightly 5µm to 15 µm. Nearly all of them appear to be globose and most of them are ornamented. These ornamentation can range from almost smooth to punctate, distinctly warted, spiny or reticulate. These are taxonomically significant details used in identification of myxomycetes but only spore morphology does not allow species to identify. Also spore shape, diameter of spores and colour of spore mass are very important for identification. For example spore colour in mass can be classified as either dark (in Stemonitales and Physarales) or light to brightly coloured (all of the other orders). Because of the taxonomic importance of spore morphology, we aimed to compare the spore size, shape, ornamentations and colours of myxomycetes through 38 taxa belonging 17 genera which were collected and identified from excursions around Canakkale province and to expose the differences between taxonomical groups.

***Keywords*:** Myxomycetes, spore morphology, Canakkale, identification.

Late Glacial and Early Holocene riparian woodland dynamics in two East-Central European river valleys in the light of multi-proxy studies

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The presented study is focused on the Younger Dryas and Early Holocene spread of woodlands on the floodplains and the lowest terraces of two big Eastern-Central (EC) European river valleys: Dniester (south-western Ukraine) and San (south-eastern Poland) rivers. The special attention is paid to the period in which elm (*Ulmus*) was a prominent constituent of woodlands. Moreover, we examined the influence of the local woodlands on oxbow lakes’ transformations. Two profiles collected from two palaeo-oxbow lakes, being densely dated using ^{14}C AMS method, were subjected to analyses of pollen, non-pollen palynomorphs (NPPs), plant macrofossils, molluscs, Chironomidae and Cladocera. *Pinus* and *Betula* were major constituents of woodlands during the Younger Dryas and at the threshold of the Holocene at both sites. The site from the Dniester river valley recorded that the colonisation of elm started at least ca. 11,800 cal. BP, which is surprisingly early (>2%; late Younger Dryas, i.e. earlier than in the northern area of the Romanian Carpathians). The expansion of elm accelerated ca. 11,150 cal. BP, and the optimum of this taxon occurrence in local woodlands lasted until ca. 10,390 cal. BP. The reconstruction of the mean July temperature (T_{Jul}) inferred from Chironomidae for the elm optimum displayed the mean temperatures even ca. 2°C higher than nowadays reaching ca. 18.5–20.7°C. About 11,200–10,950 cal. BP the highest sedimentation rate (2.4 mm/yr) in the profile was recognized, probably due to the *Nymphaea* expansion (mainly manifested by HdV-

127). The oxbow lake in the San river valley was cut off ca. 11,600 cal. BP, however until ca. 11,470 cal. BP it was still under the strong influence of fluvial activity of the river, proved by very high sedimentation rate (12 mm/yr), simultaneous to the prominent accumulation of Glomeromycota and coprophilous fungi. From ca. 11,470 cal. BP *Betula* was present in the area of the lowest terraces and floodplains, but it retreated ca. 11,390–11,330 cal. BP (probably flood event). The expansion of elm started there ca. 11,130 cal. BP and this process was gradual, contrary to the site from the Dniester river valley. During the optimum of *Ulmus* T_{Jul} was assessed on the basis of Chironomidae at between ca. 17.5 and 20°C. Together with the spread of *Quercus*, *Corylus* and *Fraxinus* dated at ca. 10,700 cal. BP *Gleotrichia* (HdV-146) became abundant in the oxbow lake in the San river valley. Funded by National Science Centre (Poland) – grant UMO-2012/07/B/ST10/04345.

***Keywords*:** Younger Dryas, Preboreal chronozone, *Ulmus*, Ukraine, non-pollen palynomorphs (NPPs)

Occurrence of Non-Pollen Palynomorphs from Holocene sediments of Lower Bengal basin, India with environment of deposition

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The distribution pattern of the Non-Pollen Palynomorphs i.e. NPPs like algal and fungal remains in time and space is highly significant in understanding the depositional environment of geologically ancient sediments. The present study aims to understand the biosphere-eco-climatic changes of the environment of Lower Bengal basin, India since late Quaternary by considering the occurrence of NPPs. These samples are collected from freshly excavated lithosections, primarily, containing peat and peaty clay layers at Kumirmari (KUI), Dakshin Harishpur (DHI), Taldi (TI) and Canning (CNI) in Lower Bengal basin. *Gleotrichia natans*, a fresh water algae along with diverse isolated fungal spores are recovered from the Grey clay with sand layer at Kumirmari deposited during 1970±80 yr. B.P., Grey clay with sand layer at Daksin Harishpur deposited during 590±70 yr. B.P. and Silty clay layer at Taldi and Canning deposited during c. 2000 yr. B.P. Isolated fungal spores viz. *Inapertisporites* sp., *Cladosporium* sp., *Monoporisporites* sp., *Diporisporites* sp., *Fusiformisporites* sp., *Dyadosporonites* sp., *Multicellaesporites* sp., *Frasnacritetrus* sp., *Pluricellaesporites* and *Meliola spinksii* occur in the Peaty clay layer at Kumirmari and Dakshin Harishpur deposited c. 3000 yr. B.P and Grey clay with sand layer at Taldi and Canning deposited c. 6000 yr. B.P. The leaves with epiphyllous fungal colonies and ascomata of *Meliola spinksii* and *Callimothallus* sp. are reported from Greyish silty layer at Kumirmari (KUI) deposited during c. 4450 – c. 3000 Yr. B.P., Peaty clay layer at Dakshin Harishpur (DHI) deposited during 4450±170 – c. 3500 Yr. B.P. and Peat layer at Taldi and Canning deposited during 9271±41 – 7687±38 yr. B.P. along with the occurrence of mega plant remains viz. stems of *Sonneratia apetala*, *Phoenix paludosa*, *Pandanus* sp., *Heritiera fomes* and fragmented leaves of *Heritiera fomes* and *Aegiceras corniculatum*. On the basis of abundance and occurrence of environment indicator taxa, three phases of depositional environment during 9271±41 – 590±70 yr. B.P. have been explored in the chronologically dated sediments. The abundance of *Meliola spinksii* and *Callimothallus* sp. suggest warm, humid , brackish water palaeoecological condition with high rate of precipitation during 9271±41 – 7687±38 yr. B.P. in the study area followed by warm, humid and swampy condition supported by the occurrence of large number of various isolated fungal spores during c. 3000 – c. 6000 yr. B.P. followed by humid, fresh water palaeoecological condition during c. 2000- 590±70 yr. B.P. in this area indicated by the presence of *Gleotrichia natans*, a fresh water algae.

***Keywords*:** Non-Pollen Palynomorphs, Holocene, Lower Bengal basin, depositional environment

Non-pollen palynomorphs from ombrotrophic bogs in N Poland as indicators of palaeoenvironmental changes: a multi-proxy approach

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Ombrotrophic bogs are the source of information about past environmental changes. Using analysis of pollen, testate amoebae (TA) and plant macrofossils, supported by radiocarbon (AMS ^{14}C) dating we can reconstruct peatland development, its hydrological changes and local forest succession. Such palaeoenvironmental reconstructions have already been done for three *Sphagnum* bogs located in N Poland along the east-west continentality gradient: Mechacz Wielki, Gązwa and Kusowskie Bagno. These reconstructions were carried out on the profiles dated back to 2000, 6000 and 4000 cal. yr BP, respectively. In this study, we present the results of the analysis of non-pollen palynomorphs (NPPs) that was conducted on these profiles. The main goal was to extract the indicative value of different NPP types, by combining the obtained results with available qualitative and quantitative reconstructions. Within each sample, we compared the NPP data with the depth to the water table (DWT) and pH (both derived from TA analysis) to identify the NPP types which were the most susceptible for changes of the water table level and pH. Moreover, we checked the relationships between NPPs and local vegetation to find out if there are some correlations between the presence of particular plant and NPP taxa. The preliminary results (based mainly on the profile from Gązwa bog) reveal that NPP data are in agreement with the results of other biotic proxy analyses. HdV-10, HdV-90 were typical of periods with high DWT values (dry conditions), whereas HdV-13, HdV-30 and HdV-37 were characteristic of periods with low DWT values (wet conditions). NPP types that show some affinity to higher pH are HdV-29, HdV-77A and HdV-96A, whereas lower pH on the bog promoted the appearance of HdV-35 in the past. Research is funded by the National Science Centre, grant no. UMO-2014/13/B/ST10/02091.

***Keywords*:** non-pollen palynomorphs, *Sphagnum* bogs, palaeoenvironmental studies, Holocene, N Poland

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Pollen attacked by fungi: additional nutrient source in Holocene ombrotrophic bogs

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Experienced Quaternary palynologists working with peat bogs are familiar with the occurrence of a special non-pollen palynomorphs type – fungal hyphae growth inside pollen grains. This paper presents the records of pollen attacked by dark-coloured fungal hyphae found in the Holocene peat sediments from several raised bogs in northern Germany and discusses their nature. In modern mycology, laboratory experiments and field observations demonstrate that saprotrophic and ectomycorrhizal fungi effectively use pollen cytoplasm and suggest pollen produced by wind-pollinated trees as a crucial nutrient source for fungi and their plant hosts in nutrient-limited environments. However, the role of such interactions is still underestimated or neglected in ecology and palaeoecology. Here, we consider pollen attacked by fungi in palynological records from Holocene raised peat bogs as nutrient source for ecosystems in the past. The attacks occurred through the pollen germination areas by a variety of saprotrophic, ericoid mycorrhizal, ectomycorrhizal or dark septate endophyte fungi. Large amounts of attacked pollen in phases rich in *Calluna vulgaris* pollen highlight the importance of Ericaceae shrubs, hosting ericoid mycorrhizal fungi and forming hotspots of decomposition in nutrient-deficit bogs. Applying estimations of pollen rain from literature, and based on own observed pollen infection rates we estimate the annual release of nitrogen, phosphate and potassium from pollen, and highlight their significance in pushing the ecosystem nutrient cycle in early spring time, when several species release their pollen. We highlight the significant

role of anthropogenic changes in pollen deposition for pre-industrial bogs and hypothesize about the consequences of the pollen-based interrelation between wind-pollinated plants and their mycorrhizal fungi in palaeoecology and evolution.

Keywords**:** non-pollen palynomorphs, palaeoecology, fungi, decomposition, anemophily

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Atlas of modern dinoflagellate cyst distribution in the Black Sea Corridor

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Amongst the Non-Pollen Palynomorphs now routinely used for palaeoenvironmental reconstructions, organic-walled dinoflagellate cysts (dinocysts) have been highly valuable for assessing past and current marine conditions, as well as been excellent biostratigraphic indicators. Global modern distribution has documented the strong influence of sea-surface conditions (temperature, salinity, productivity, sea-ice cover) in species occurrence and abundance. These relationships have been further used to quantitatively assess past marine conditions. Although we have now a relatively strong knowledge of dinocyst ecology in most oceans, there are still some parts of the world that are understudied. We present here the first compilation of recent distribution of dinocysts from 185 surface samples collected in the Black Sea Corridor (BSC) which is a series of marine basins extending over 3,880 km from the Aegean to the Aral Sea (including Marmara, Black, Azov and Caspian Seas). Recent anthropogenic activities have here deeply influenced marine ecosystems and biodiversity and by studying both modern and past distributions of this important phytoplankton group, we can provide a baseline of land-sea linkages. A large diversity of 71 taxa has been identified, and their taxonomy has been revised in accord with new studies and/or biomolecular data. Several species show distinct morphotypes that are being related to specific sea-surface conditions in low salinity seas. Maps of distribution and statistical analysis show the strong influence of annual and seasonal sea-surface salinity, as well as temperature, to a lesser degree. The most common taxon, *Lingulodinium machaerophorum*, dominates most of the assemblages except in the Caspian Sea, where *Impagidinium caspienense* is the dominant species. Species associated with marine conditions are well distributed in Marmara and the Black Sea, such as *Operculodinium centrocarpum*, *Spiniferites mirabilis* and *S. ramosus.* In contrast, *Spiniferites cruciformis*, which was first described from early Holocene sediments from the Black Sea, today occurs in low abundance in the northern Black Sea, and in the Caspian and Aral Seas. A few taxa in the low salinity Black Sea, e.g. *Achomosphaera andalousiensis*, may be modern relicts of more widespread Mio-Pliocene distributions. In addition, based on late Quaternary records, we can estimate when species have entered these seas, either due to climatic conditions or anthropogenic activities. This modern database will also provide a baseline for future quantitative reconstructions of past salinity.

Keywords**:** Dinoflagellate cysts, Marmara, Black Sea, Caspian Sea, endemism

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Pollen, dinoflagellate cysts and other non–pollen palynomorphs recorded in the Lake Ladoga postglacial-glacial-preglacial sediment record

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The German-Russian project investigates the Late Quaternary climatic and environmental history along a Northern Eurasian transect. Lake Ladoga, the largest lake in Europe was cored in 2014. The 22.7 m lake sediments were studed for pollen and non-pollen palynomorphs (dinoflagellate cysts, algae remains, fungi spores, plant tissue fragments). The lowermost sediments (PZ 1) containing few pollen and cannot be used for environmental reconstructions. Pollen concentration is much higher in PZ 2. *Betula* and *Alnus* dominate the zone but *Pinus* and broad-leaved taxa are also common. Pollen concentration is also

high in PZ 3 dominated by *Betula* and *Alnus* but *Pinus*, *Picea*, and broad-leaved taxa are also numerous. Pollen assemblages indicate that the sediments of PZs 2 and 3 were formed during an interglacial with climate conditions more favorable compared to the Holocene ones. The sediments also contain numerous fresh water *Pediastrum* and *Botryococcus* as well as cysts of marine dinoflagellates and brackish water acritarchs (prasinophytes *Cymatiosphaera* and *Micrhystridium*). Dinocyst assemblages are poor in species, presented mostly by *Spiniferites ramosus*s and *Lingulodinium machaerophorum*. Very short processes of the latter species indicate rather low salinity. The dinoflagellate cysts suggest that Lake Ladoga was a part of brackish-water corridor between the Baltic and the White Seas during the Last Interglacial. Pollen concentration is extremely low in PZ 4 dominated mostly by pollen of herbs. We assume that the PZ 3 pollen assemblages were accumulated during the lateglacial when an extensive periglacial Baltic Ice Lake was extended along the southeastern margin of the Scandinavian Ice Sheet having Lake Ladoga as its north-eastern bay. Pollen concentration is slightly higher in PZ 5 dominated mostly by pollen of herbs, *Betula*, *Alnus*, and *Pinus* but is characterized by rather significant *Picea* increase pointing to more favorable climate conditions. The potential Younger Dryas (PZ 6) sediments are characterized by high percentages of herb pollen (mainly *Artemisia* and *Chenopodiaceae*) indicating the dry and cold climate. *Betula*, *Pinus*, and *Alnus* predominate among the arboreal pollen suggesting the tundra-steppe vegetation in the lake catchment. Pollen concentration is drastically increased in PZ 7. The revealed early Holocene pollen assemblages are characterized by increased *Pinus* and Polypodiaceae contents, while Poaceae, Cyperaceae, and, especially *Artemisia* and Chenopodiaceae gradually disappeared from the spectra. PZ 8 is characterized by further increase in *Pinus* and *Alnus* pollen contents as well as by significant peak in *Picea* percentages.

***Keywords*:** Late Quaternary, Lake Ladoga, pollen, non-pollen palynomorphs

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Non-pollen palynomorphs, plant macrofossils and associated fauna as complementary indicators of the trophic status of shallow lakes from southern South America

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Different fossil groups reflect different aspects of the system strengthening palaeoenvironmental interpretations. In lacustrine sediments the analysis of non-pollen palynomorphs (NPP), plant macrofossils and associated fauna are complementary to the pollen analysis. NPP comprehend mycelium and spores of fungi, cyanobacteria and clorophycean algae remains (cenobia, zygospores, colonies, akinetes, heterocysts and sheaths), cysts of dinoflagellates, testate rhizopod (thecamoebian), invertebrates remains (exoskeleton fragments, resting eggs, rotifer loricas, microturbellarian oocystes, gemmula and spicules of freshwater sponges, spines of leaves, among others). Plant macrofossils and associated fauna include seeds, fruits, spores, leaves, buds, bud-scales, flowers, tissue fragments, fragments of invertebrates and resting eggs. All these represent planktonic, benthic and plant communities of obligate aquatic organisms, as well as those living in the lakeshore area. We present results of the analysis of these fossils from eight shallow lakes located in Pampa plain (33°-39°S; 57°- 66°O), Argentina. Pollen, NPP and plant macrofossils and associated fauna analyzed in lacustrine sediment sequences revealed the ocurrence of alternating macrophyte-dominated clear and phytoplankton-dominated turbid phases during the Holocene. At the beginning of the Holocene the abundance of *Chara* (gyrogonites) indicated that these lakes were clear and shallow. During the middle Holocene the presence of *Chara* (gyrogonites and oospores) and high amount of *Peridinium* cyst, denote that these lakes were clear and brakish. This condition persisted until ca. 2000 yrBP, when others macrophytes appeared (*Tolypela* oospores, *Myriophyllum* mericarps, *Zanichellia and Ruppia* fruits, *Potamogeton* seeds and *Ceratophyllum* spines), indicating a more diverse community due to a higher nutrient level. Towards *ca*. 700-500 cal yrBP the lakes turned to a turbid phase dominated by phytoplankton species like *Pediastrum*, *Scenedesmus*, *Tetraedron* (cenobia) and *Gloetrichia* (sheats) and became eutrophic. Cladocera (zooplankton) increased their abundance denoted by the occurrence of resting eggs (ephippia) of *Daphnia*, *Ceriodaphnia*, *Simocephalus and Bosmina*. The existence of turbid phase indicators as well as the presence of *Nitella* (oospores) and the others macrophytes indicate clear phases alternating with the general turbid state.

In this multi-proxy analysis, NPP, and plant macrofossils and associated fauna in conjunction with pollen, provided an adjusted interpretation of the evolution of lakes. Also, it contributes to a better understanding of the complex network of interactions of these ecosystems, helping unravel the potential causes of the observed patterns.

***Keywords*:** macrofossils, microfossils, Pampa plain, trophic status, shallow lake

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Late Quaternary non-pollen palynomorphs from the cloud forest of Ecuador

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The application of non-pollen palynomorphs (NPPs) as a palaeoenvironmental indicator has proven to be a useful proxy in aiding with the reconstruction of Quaternary environments and in establishing historical trends of human impact on the landscape. NPP analysis was developed as a palaeoecological proxy primarily in northern European peat bogs during the 1970's but its application to the Neotropics has been limited (< 20 studies) and its usefulness restricted by a lack of autecological information for many morphotypes. To date analysis of NPPs within the Andes has been confined to Venezuela and Colombia, here for the first time we present records of late glacial, late Holocene and modern NPP assemblages from the cloud forest of Ecuador (1200–3600masl). The eastern Andean cloud forest is situated within the tropical Andean biodiversity hotspot and consists of a narrow band of montane forest separating the lowland Amazonian rainforest from the high altitude grassland of the Andes. During this study we recorded 73 NPP morphotypes (55 fungal, 10 algal and 8 zoological remains) from modern habitats (moss polsters, surface soil and lake sediment), a pre-Columbian to present-day variably disturbed lake environment (Lake Huila sediment core) and a glacial (~42kya) pre-human arrival swamp environment (Vinillos open cliff section). Historical land clearance by humans and disturbance by volcanic episodes has led to shifts in the vegetation recorded in the palynological record. Here we assess how these changes to the ecosystem and vegetation assemblage are represented in the NPP record and present 21 new NPP morphotypes. We identify individual morphotypes that are found in modern and fossil records suggesting broad ecological tolerances of some types (*Cercophora*, *Coniochaeta*, HdV.123), while others are restricted to narrow ranges (*Gelasinospora*, Gaeumannomyces, HdV.201). The indicator value of specific known NPP types such as *Sporormiella* allows us to establish the arrival of cattle farming at Lake Huila and infer the potential presence of Pleistocene mega fauna at Vinillos, while an increase in *Glomus* correlates with increased erosion after the removal of forest around Lake Huila. In order to develop NPPs as an independent but complimentary proxy to pollen further work is required to establish modern altitudinal and environmental gradients of NPP assemblages and to better understand the autecology of common morphotypes, especially within mega diverse ecosystems.

***Keywords*:** non-pollen palynomorphs, cloud forest, palaeoecology, Ecuador, Andean flank

400 years of small lake functioning and forest succession registered by one of the oldest Holocene landslide depressions in the Beskid Makowski Mountains (Western Carpathians, S Poland)

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Lakes and fens originating in landslide depressions in several areas of the Western Carpathians are the only source of information about past vegetation changes. Being basins of relatively small area, they are very sensitive to local environmental changes which are then recorded in lacustrine and peat deposits. The main aim of this study is to reconstruct, on the basis of high-resolution sampling, the vegetation changes in the vicinity of one of such lakes and its transformations during the first four centuries after the landslide event (dated back to the Preboreal oscillation). The analysed landslide depression is located at the southern slope of the Mt. Koskowa Góra (Bogdanówka stream valley) in the Beskid Makowski range (675 m. a.s.l.; a northern part of the Western Carpathians). Pollen, non-pollen palynomorphs (NPPs), plant macrofossils, cladocerans (Cladocera), midges (Chironomidae), the ratio of the total organic carbon to the nitrogen (TOC/N) and $\delta^{13}C$ from organic matter were applied for the reconstruction. Between ca. 11,230 and 11,145 cal. BP pine (*Pinus sylvestris*) dominated in the local forests. Additional components were birch (*Betula*), spruce (*Picea abies*) and poplar/aspen (*Populus*) with an addition of *Larix* and *Pinus cembra*. In that period elm (*Ulmus*) manifested its presence by low pollen percentage curve (up to 1%), indicating very tentatively its local sparse occurrence. From ca. 11,145 cal. BP elm started to spread (pollen: ca. 2%) and from ca. 11,090 cal. BP it begun to be an important constituent of the local forest (pollen: >10%), at least until ca. 10,820 cal. BP. During the period of ca. 11,230–10,820 cal. BP the lake was strongly silted (sediment accumulation rate: 2.3 mm/yr) which was reflected in the high abundance of the terrestrial fungi such as coprophilous fungi, Glomeromycota and HdV-572. Among algae only *Spirogyra* appeared regularly in this period. The small share of TOC and TN in the sediments may reflect low algae productivity, whereas TOC/N with a combination of $\delta^{13}C$ reveals the prominent contribution of terrestrial plants to the accumulation of organic matter. The scarce and irregular presence of midge remains, apart from indicating siltation, may reflect seasonal fluctuations of the water table or even desiccation of the lake. Among aquatic taxa *Callitriche*, *Lemna* and *Potamogeton* (*P. natans*, *P. obtusifolius* and *P. friesii*) were the most frequent, which highlights the shallow character of the then water body. The research is funded by National Science Centre (Poland) – grant UMO-2012/07/B/ST10/04345.

***Keywords*:** pollen, non-pollen palynomorphs (NPPs), plant macrofossils, Central Europe, *Ulmus*

Deciphering the relations between non-pollen palynomorphs and the environment – surface samples from three *Sphagnum* bogs (N Poland)

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Studies on non-pollen palynomorphs (NPPs) can be dated back to the 1970's. However, despite the increasing interest in their indicative value, most of research explores palaeorecords. In this study we tried to find links between NPPs and their deposition environment analysing 90 surface samples collected from Baltic bogs in the east-west continentality gradient in N Poland (Mechacz Wielki, Gązwa, Kusowskie Bagno, respectively).

Within each sample we combined the presence of NPPs with modern peatland vegetation, the pollen content, water level and pH. The surface samples represent all possible bog microforms – hummocks, hollows, pools, lawns, forests with *Sphagnum* patches and drainage ditches, varying in terms of the vegetation cover. Some of the samples were collected close to the dung of animals crossing the mire (hares, wolfs, roe deers, elks and wild boars). The preliminary results, despite the low frequency of NPPs in most of the samples, show that there are differences in the taxa composition between the samples obtained directly from the open bog surface and the adjacent bog forests. Similarly, the NPP spectra from samples that were collected near the dung also varies. They recorded higher *Sporormiella* values and greater pollen diversity. In the Gązwa bog, the past drainage ditch overgrown by *Sphagnum fallax* proved to be the habitat characterised by the greatest abundance of testate amoebae (recorded during independent analyses of testate amoebae and NPPs from palynological samples) and pollen richness. Research is funded by the National Science Centre, grant no. UMO-2014/13/B/ST10/02091.

Keywords**:** non-pollen palynomorphs, pollen, testate amoebae, *Sphagnum* bogs, surface samples

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Characterization of phytoliths in *Syagrus* species (Arecaceae) as subsidy to the taxonomy of the genus

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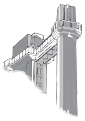
The Arecaceae is pantropical and has about 200 genera and 2.000 species distribuited in five subfamilies, among which Arecoideae takes the larger amount of species. In Arecoideae, *Syagrus* is one of the genus, with a great morphological variation between species, of which 21 of them are referred to the Northeast of Brazil. The Arecaceae family has a high production of phytoliths most frequently found in the aerial part of the plant and formed by absorbing the mineral particles by the plant roots and deposited in their cells throughout their lives. These corpuscles silica, in addition to constitute as excellent fossil elements have relevant taxonomic significance pattern for the family, may separate or delimit palms groups. They were then analyzed botryophora *Syagrus species*, *S. microphylla* and *S. petraea* to characterize the morphological types of existing phytoliths in order to create a primary database characteristic for the genre and taking into account the identification of species and geographic region occurrence. For morphological analysis of phytoliths specimens of these species were collected in the Herbarium Alexandre Leal Costa, Institute of Biology of the Federal University of Bahia, for calcination, extraction and carbonization in oven at 500 °C. The results obtained were observed sizes from small to medium, elongated and globular types along with rough ornamentation or projections in the form of thorn. The morphological type Globular equinado was the most common among the types of phytoliths observed in the three species analyzed.

Keywords**:** Arecaceae, phytoliths, *Syagrus*, calcination, Globular echinate



OLIGOCENE PLANT ASSEMBLAGES – CHANGE FROM THE OLD TO MODERN WORLD VEGETATION

Johanna Eder, Steve Manchester & Zlatko Kvacek

An Oligocene flora from Yunnan, SW China and its paleoclimatic implications

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The Oligocene is an important period for establish of modern vegetation, however, Oligocene floras are rare in China especially in southwestern China where harbors extremely high plant diversity today. In this contribution, we report the first confirmed Oligocene macrofossil flora from Lühe town, center of Yunnan. The age of the Lühe flora was a little younger than 32-33 Myr based on U-Pb dating with the tuff from the lower part of the same strata. More than 30 morpho-types have been recognized so far, 20 of which were identified to species or generic level. The Betulaceae and Fagaceae are dominant families with mixed evergreen and deciduous genera. Deciduous genera include *Betula*, *Carpinus*, *Ostrya*, *Liquidabar*, *Paleocarya*, etc. Evergreen elements include genera such as *Quercus*, *Castanopsis* and *Lithocarpus*. This flora differs extant subtropical forests in southwest China by having abundant deciduous taxa and relic conifers, such as *Sequoia*, *Cryptomeria*, *Taxodium*, *Glyptostrobus* and *Metasequoia*. Interestingly, plenty of fin-winged fruits such as *Carpinus*, *Palaeocarya*, *Acer*, *Fraxinus*, *Dalbergia*, *Ostrya* and *Paliurus* were discovered suggesting a more open environment. Palaeoclimatic reconstruction based on different quantitative methods suggest a similar temperature to today but a much more humid winter than today (3DRY; 205.7 mm, today 26.3mm).

***Keywords*:** Early Oligocene, megafossil, paleoclimate, southwestern China, Yunnan

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Oligocene floras of western North America: Forest responses to a cooling world

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Paleofloras of western North America provided evidence first recognized by Chaney, MacGinitie, and Wolfe to show rapid and significant cooling during the Eocene-Oligocene transition. Floras of latest Eocene age range from broadleaved evergreen and paratropical rain forests of the Pacific coast lowlands to temperate forests of higher elevation regions in the continental interior. Late Eocene upland floras provided sources of temperate taxa that dispersed or evolved to form forests of new composition in cooler climates during the Oligocene. Oligocene floras of the Pacific coast (e.g., Bridge Creek and Lyons floras of Oregon) show strong similarity to the deciduous hardwood forests of eastern Asia and eastern North America but less resemblance to modern west coast forests, whereas interior floras of the southern Rocky Mountains and Rio Grande Rift (e.g., Antero, Creede, Hermosa, and Hillsboro floras of Colorado and New Mexico) "modernized" within that region during the Oligocene and developed strong affinities to the region's modern flora. The early Oligocene Bridge Creek flora (31.8-33.6 Ma) is well documented and represents one of the best examples of the type of vegetation that became widespread at low elevations in mid-latitudes of the Northern Hemisphere following cooling during the Eocene-Oligocene transition. The flora contains >125 species and indicates a temperate broad-leaved deciduous forest similar to the modern Mixed Mesophytic forest with a predominance of Cupressaceae, Pinaceae, Platanaceae, Ulmaceae, Fagaceae, Betulaceae, Juglandaceae, Rosaceae, and Sapindaceae. By contrast, Oligocene floras of the southern Rocky Mountains contain a strong coniferous component and are cool temperate, indicating moderately high elevations (1800-2400 m). The transitional Eocene-Oligocene Antero flora (33.76 Ma) contrasts with the nearby latest Eocene Florissant flora (34.07 Ma) by having a significant

reduction in warm temperate angiosperm hardwoods and an increasing abundance of Pinaceae, implying response to Eocene-Oligocene cooling. The late Oligocene Creede flora (26.8 Ma) represents a cool temperate montane Mixed Coniferous Forest dominated by Pinaceae mixed with dryland angiosperm shrubs (particularly Rosaceae) and having strong similarities to the modern Rocky Mountain flora. The early Oligocene Hermosa and Hillsboro floras (28.1-33.6 Ma) of the Rio Grande Rift indicate a subalpine forest growing in cold temperate conditions at very high elevation (2800-3000 m) and are dominated almost totally by bristlecone pine (*Pinus* subsection Balfourianae), a group whose entire evolutionary history is endemic to western North American. Collectively, these floras provide evidence for dynamic climate and elevation history of western North America during the latest Eocene through the Oligocene.

Key words**:** Eocene-Oligocene climate change, Bridge Creek flora, Antero flora, Creede flora, Hermosa and Hillsboro floras

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Early Oligocene plant diversity along the Upper Rhine Graben (Germany)

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Following the ETM the early Oligocene is a period characterised by distinct changes in the terrestrial flora. In Europe the plant record is well studied from North Bohemia (Chech Republic) and Saxony (Germany) while otherwise it is rather spotty. Along the Upper Rhine Graben only the flora from Flörsheim near Mainz (Germany) was known so far. About 100 km further south the flora from Rauenberg (Baden-Württemberg, Germany) has not yet been described. The fossiliferous strata, well-bedded clay- to siltstones of marine origin belong to the Bodenheim Formation. Nannoplankton indicates NP 23 (Rupelian, Oligocene). These sediments not only document rich marine life by nannoplankton, foraminifera, molluscs, fish, turtles, algae, etc. but also provide insight in the terrestrial biota. Plants, mainly carbonised leaves, insects and even bird remains are preserved. Thus, Rauenberg turned out to be a fossil site of extremely high organismic diversity both marine and terrestrial. Leaves are mainly entire-margined or minutely toothed, so that species diversity is assessable mainly by cuticular studies. More than 65 species (23 families) have been identified so far, many of them by single or few specimens only. New species of ? *Berchemia*, *Dicotylophyllum* (4), *Distylium*, *Laurophyllum*, *Oleinites*, *Phyllites*, *Trachelospermum*, and *Oleinites* have been determined. Remarkable are leaves and articulate axes of yet unclear affinity with possibly ? salt glands. The presence and diversity of *Pinus*, palms and *Myrica* may indicate a forest community that possibly developed on sandy soils near the coast (coastal pine forests). Possibly *Daphnogene cinnamomifolia* and/or *Laurophyllum pseudoprinceps* and *Tetraclinis salicornioides* were also part of this community. *Platanus neptuni* may have grown along streams and on river banks. Along with the robustness of its foliage, this may explain its dominance in this flora. *Carya* and *Populus germanica* may also have been elements of riparian habitats. The majority of the Lauraceae, *Ceratozamia*, *Craigia*, *Distylium*, *Engelhardia*, *Hydrangea*, *Sloanea*, *Symplocos*, *Trachelospermum*, and others may represent mesophytic forests. Taxa with presumably wider ecological tolerance as *Craigia*, *Myrica*, *Betula*, *Engelhardia*, may have flourished in diverse environments. The pollen record from the Bodenheim Formation in the Mainz Basin indicates a higher diversity of deciduous taxa than the macro record. Nevertheless, the diversity of probably evergreen taxa surmounts that of deciduous ones. Both macro and pollen record lack evidence of nearby swampy environments. The monograph of the flora and a survey of the Rauenberg fossil Lagerstätte are in preparation.

Keywords**:** Early Oligocene, leaf flora, cuticles, new species, Germany

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Earliest fossil fruits of *Stephania* (Menispermaceae) at the low latitudes of East Asia

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The genus *Stephania* Loureiro contains about 60 species of predominantly herbaceous or woody vines that are naturally distributed in tropical and subtropical Asia and Africa, a few in Oceania. The fossil presences,

however, indicate a broader distribution for the genus during the geological time, including records from the middle to late Paleocene of Colombia, early Miocene of Kenya and the late Pleistocene of Nepal. Here, we report two well-preserved mummified fossil endocarps of *Stephania* from the Oligocene of Nanning Basin of Guangxi Province, southern China (22°52′50″N, 108°25′2″E). Comparing to impression materials, the mummified fossils can provide us a far more detailed source of information that are extraordinarily important for understanding the composition, structure and biotic evolution of the floras once grew there. The specimens show endocarps usually bony or woody, horseshoe shaped; outline of endocarp obovoid to obovoid-rotund; length 7.1 mm or 8.3 mm, width 6.1 mm or 7.0 mm; with a keel running along the dorsal surface; only one lateral crest on each side of the endocarp; 25 or 26 grooves presented at the ridge of the dorsal side and separated by the radially aligned ribs; locule cast apically positioned within the outline of the endocarp, and rimmed by the lateral crest with approximately equal limbs; endocarp with a tiny perforation in the condylar area, near the base, length 1.3 mm or 2 mm, wide 0.8 mm or 1.3 mm. These characters are comparable to dispersed extant genus *Stephania*. There are different hypotheses about the origin place of this genus. Herrera *et al.* (2011) suggested that the *Stephania* may (1) dispersal via Laurasia; (2) transpacific spread between South America and Australasia and (3) exchange via Antarctica. Based on the fossil records mentioned before and the specimens found from the Oligocene of southern China, we adopt the first dispersal route as available. The *Stephania* may originate from neotropical locations, with subsequent spread to Europe where it appears in Eocene (in press), followed by Asia, where it is first recorded from the Oligocene. Overall, the specimens described here are the first fossil records of *Stephania* endocarps in China and, moreover, they are the most ancient ones reported from eastern Asia. This finding enhances our knowledge of the taxonomic and morphological diversity of the *Stephania* and it provides new evidence for the research of the origin and phytogeographic history of this genus.

***Keywords*:** *Stephania*, endocarps, Oligocene, Nanning Basin, East Asia

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Investigations in taxonomy and leaf anatomy of late Oligocene plant assemblages in the volcanic Seven Mountains area near Bonn, Germany

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A reinvestigation of historical fossil plant collections made in the 19th century at Orsberg and Stößchen (Rhineland-Palatinate, late Oligocene) and published by C.O. Weber and P. Wessel (1851–1855) as well as other material collected later from these sites resulted in new interpretations on both fossil floras. Previous morphological and anatomical investigations of foliage were partly revised (Winterscheid and Kvaček 2014, Palaeontographica B. 291: 1-83). The floras of Troisdorf-Altenrath, Siegburg-Stallberg and Hennef-Söven belong stratigraphically to the siliciclastic facies of the Underlying Strata of the Seven Mountains (Siebengebirge), which is interpreted as a marginal facies of the Cologne (Köln) formation in the southern Lower Rhine Embayment. Chronostratigraphically they are assigned also to the late Oligocene (Chattian) on account of the correlation with the fauna recovered in the contemporary site at Rott. These coarse-grained to silt and clayey deposits originated in coastal and slope-wash areas within fluviatile environments of variable deposition energy. Fine-grained leaf bearing layers accumulated in temporarily flooded levees. Remains of *Taxodium dubium*, *Eotrigonobalanus furcinervis*, *Populus germanica* and *Daphnogene cinnamomifolia* dominated among the recovered fossil species. General aspects of this plant assemblage correspond, together with sedimentary settings, to the riparian forest vegetation with mesophytic elements (Winterscheid and Kvaček, in press). The flora of the Fossillagerstätte Rott in the same volcanic area near Bonn is being examined and systematically and taxonomically revised. In the first part of this work (Winterscheid *et al.*, Palaeontographica B, submitted) the geological setting of the sites and treatments of representatives of the Bryidae, Polypodiidae and Pinidae are given. Angiosperms and environmental evaluation the flora of Rott and other adjacent sites are being prepared for the next continuation of our study to be published in Palaeontographica B. The research is supported by the Grantová Agentura of the Czech Republic (GAČR), Project No 14-23108S.

***Keywords*:** Macroflora, late Oligocene, Rhineland, Germany.

Oligocene floras in Japan and Far East Asia - a review

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Oligocene refers to the time prior to the formation of the Sea of Japan and when the Japanese Islands were assumed to be located toward the edge of the middle latitude of the Eurasian Continent. A brief review for the Oligocene plant fossil assemblages, which are sporadically distributed throughout Japan, was conducted to determine the floristic changes in this region. Most of these assemblages, though still need further taxonomic works, have been misinterpreted as belonging to the Neogene period due to their similarity to those from the Miocene or younger periods. The early Oligocene or possibly the late Eocene–early Oligocene assemblages have been identified from the Wakamatsuzawa Formation of Kitami, northeast Hokkaido, and the Kobe Group in Hyogo, west Honshu. In contrast to the middle (to late) Eocene assemblages showing subtropical to tropical aspects with various archaic elements, these assemblages consist of temperate elements closely related to their extant representatives in Japan and Far East Asia. A cooler temperate forest consisting of various species of conifers and deciduous angiosperms is suggested from the Wakamatsuzawa flora, while the Kobe flora is characterized by a warm temperate forest dominated by oaks (deciduous/evergreen) and lauraceous species together with various deciduous elements and some palms and Musa species. Both these assemblages yield so-called "lobed-oaks," which are characteristic to the late Eocene–Oligocene of Far East Asia; some of them also yield extinct genera, like *Macclintockia* and *Palaeocarya*. A late early to late Oligocene successions recorded in coal-bearing coastal deposits in the Ainoura and Sasebo groups (northwest Kyushu) and shallow marine deposits in the Hioki Group (western end of Honshu) show more modernized aspects with some "Paleogene elements" like *Acer arcticum*, *Alnus prenepalensis*, *Taxodium dubium*, and so on. All of them comprise temperate floristic elements similar to extant forest vegetation in Japan and Far East Asia, with signs of climate warming toward the upper part. Floristic changes throughout the Oligocene seem to be in parallel with the trend of global climate; however, in contrast to the assemblages identified at the middle latitude in Central Europe, which retain some tropical/subtropical elements, Oligocene assemblages in Japan and Far East Asia are characterized by a paucity of these elements. On the contrary, some elements like "lobed-oaks," which assumed to be related to extant representatives in western Asia and Europe, and possibly North America, have expanded and diversified from Far East Asia during the later periods.

***Keywords*:** modernization of flora, northern middle latitude, Japan, Far East Asia, Oligocene

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Oligocene wood from the Czech Republic: a review

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Fossil wood is quite abundant in the Oligocene of the Czech Republic. There are many historical finds, but new fossil woods are also discovered and described, e.g., three types of conifers (two stem woods and one root wood of Cupressaceae s.l.) and six types of angiosperms (families Lauraceae, Betulaceae, Ulmaceae, Malvaceae, Sapotaceae and one problematic sample) from the volcanoclastic sediments of Doupovské hory and České středohoří Mts. (Koutecký and Sakala 2015, Acta Mus. Nat. Pragae, Ser. B Hist. Nat. 71, 377–398). Our presentation summarizes the fossil wood record from the Oligocene of the Czech Republic relative to its stratigraphic position. It is mainly focused on the Tertiary of north-western Bohemia, but new anatomical observations and unpublished results from the Master Thesis in progress by S. Venclová from southern Bohemia and Master Thesis by I. Továrková (2011) from Moravia are also included. This research is supported by grants GA14-23108S and PRVOUK P44.

***Keywords*:** fossil wood, systematic palaeobotany, stratigraphy, Oligocene, Czech Republic

Biogeographic and climatic implications of the Oligocene carpoflora of Belén, Peru

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In the 1920s, E.W. Berry published an assemblage of 33 species of permineralized fruits and seeds from the vicinity of a former railway stop known as Belén in the Petroleum rich area near Talara, in northwest coastal Peru. This flora is the only Paleogene carpoflora known from South America. Prior estimates of the age of the Belén flora ranged from early Eocene to Oligocene, but marine diatoms from the same horizon indicate an early Oligocene age. The Belén flora provides insight into the vegetation and paleoclimate that occurred in this region prior to the uplift the Andes in western Peru. Newly recovered specimens, studied in conjunction with the original material, provide the basis for updating the taxonomic composition of the flora. Some identifications have been revised and new taxa have been recognized, leading to a current inventory of 38 species in 34 genera. Extant families identified with confidence include Palmae, Heliconiaceae, Annonaceae, Euphorbiaceae, Humiriaceae, Icacinaceae, Leeaceae, Vitaceae, and Rutaceae. Prior identifications of Anacardiaceae and Myristiaceae are rejected, including "*Anacardium*" *peruviensis* Berry which had cashew-shaped seeds but spiny fruits unlike anything in extant Anacardiaceae and "*Virola" tertiaria*, which lacks ruminate endosperm and appears instead to represent the seed of *Gnetum*. Prior determinations of Boraginaceae, Cucurbitaceae, Malvaceae, Rubiaceae, and Sapindaceae remain unsubstantiated. Securely identified genera provide insights into the Oligocene vegetation and paleoclimate of this region. These include *Ampelocissus*, *Cissus*, *Duckesia*, *Leea*, *Pyrenacantha*, and *Vantanea*, which are ecologically out-of-place relative to the arid vegetation native today in this part of Peru. In addition to Neotropical elements, the flora includes some exotic genera that are now confined to the Old World tropics, like *Leea* and *Pyrenacantha*.

***Keywords*:** Tertiary, Paleogene, Oligocene, fruits, seeds

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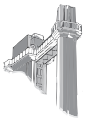

PALAEOBOTANY AND PALYNOLOGY COLLECTIONS: FROM MUSEUMS TO ONLINE DATABASES

Cláudia Inês da Silva, Angel Montero, Antonio Mauro Saraiva & Geraldo Aquino

Study of macroscopic plant remains from Holocene sediments of Lower Bengal basin, India for biostratigraphic zonations and environment of deposition

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The macroscopic plant remains recovered from the Holocene sediment of India and outside have been analyzed in considerable details to utilize the evidences in reconstruction of the palaeoenvironmental change. This investigation in Lower Bengal basin, India has explored a considerably rich and diverse mega plant remains in the form of well preserved isolated and in situ tree trunks of *Heritiera fomes* occasionally with root system, isolated stems of *Sonneratia apetala*, monocot stem of *Pandanus sp.* and *Phoenix paludosa* with scar of aerial roots, part of leaf rachis of *Nypa fruticans*, and large number of fragmented leaves of *Heritiera fomes* and *Aegiceras corniculatum*. All these plant remains are recovered from various depths between 1.5 to 8 m of the measured sections and chronologically dated Grey clay with sand and Peaty clay layer sediments (c. 11,000 to 590±70 Yr. BP) of Lower Bengal basin at Kumirmari (KUI), Dakshin Harishpur (DHI), Taldi (TI) and Canning (CNI) and these are analyzed to understand the biosphere-eco-climatic changes of the environment of this area in chronological sequence. Local Mega Plant Remains Assemblage Zones are proposed for each section of the study area. Correlation of the local zones of C^{14} dated sediments has revealed five Regional (LBb; Lower Bengal basin) Mega Plant (MP) Remains Assemblage Zones viz. assemblage zone

LBb. MP – I *Heritiera fomes* (stem) – *Heritiera fomes* (fragmented leaves) – *Nypa fruticans* (fragmented parts of leaf rachis), LBb. MP – II *Sonneratia apetala* (stem) – *Aegiceras corniculatum* (fragmented leaves), LBb. MP –III *Pandanus* sp. (stem) – *Phoenix paludosa* (stem) – *Heritiera fomes* (stem) – *Heritiera fomes* (fragmented leaves), LBb. MP – III *Pandanus* sp. (stem) – *Phoenix paludosa* (stem) – *Heritiera fomes* (stem) – *Heritiera fomes* (fragmented leaves), LBb. MP – IV *Sonneratia apetala* (stem) – *Aegiceras corniculatum* (fragmented leaves) and LBb. MP – V *Pandanus* sp. (stem) – *Phoenix paludosa* (stem) – *Heritiera fomes* (stem) – *Heritiera fomes* (fragmented leaves). The environmental phases of deposition of the Holocene sediments of Lower Bengal basin as revealed from the Regional Mega Plant Remains Assemblage Zones are (1) brackish water swampy mangrove with influence of fresh water during c. 11, 000 – c. 10, 000 yr. B.P., (2) swampy mangrove to tidal mangrove during 9271±41 – 7687±38 yr. B.P., (3) brackish water mixed fresh water *Heritiera* forest during c. 6, 000 – c. 5, 000 yr. B.P., (4) swampy mangrove to tidal mangrove during 4450±170 – c. 3500 yr. B.P. followed by (5) brackish water mixed fresh water *Heritiera* forest during c. 3000 - 590±70 yr. B.P.

***Keywords*:** Macroscopic plant remains, Holocene, Mangrove, Lower Bengal basin, environmental phases of deposition

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Analysis of pollen stratigraphy from Holocene sediments with environment of deposition in Lower Bengal basin, India

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The coastal development and the history of the mangrove communities through palynological description of chronologically dated Holocene sediments were enunciated time to time by several workers throughout the world. The present study deals with a rich assemblage of spores and pollen recovered through analysis of samples collected at close intervals of one profile each from Kumirmari (KUI), Dakshin Harishpur (DHI) and Taldi (TDI) and Canning (CNI). The samples are from known depth and C^{14} dated. The results have been plotted to understand the trend of biosphere-eco-climate and phytogeographical changes since late Holocene (9271±41 to c. 2, 000 yr. B.P.) in Lower Bengal basin, India. The natural vegetation in the study area dominated by common non-littoral species is very much disturbed due to biotic pressure viz. human settlement and their arable and pastoral activities. Species of Poaceae, Cyperaceae, Acanthaceae, Euphorbiaceae, Asteraceae, Verbenaceae etc. of natural tropical forest still survive. Six regional pollen assemblage zones have been established form the pollen diagrams viz. (I) *Heritiera* – *Nypa fruticans* – *Bruguiera* – *Excoecaria* - Fern Assemblage zone, (II) *Sonneratia* – *Xylocarpus* – *Bruguiera* – *Heritiera* – Fern Assemblage zone, (III) *Phoenix* – *Heritiera* – *Xylocarpus* – Poaceae – Fern Assemblage zone, (IV) *Sonneratia* – *Avicennia* – *Ceriops* – *Bruguiera* – *Heritiera* – Fern Assemblage zone, (V) *Heritiera* – *Excoecaria* – *Phoenix* – *Bruguiera* – Asteraceae – Malvaceae – Fern Assemblage zone and (VI) *Heritiera* – *Acrostichum* – *Suaeda* – *Typha* – Poaceae – Fern Assemblage zone. These regional pollen assemblage zones reveal six environmental phases of deposition. These are (a) Mixed brackish water and fresh water tidal mangrove with regular inundation (c. 11, 000 – c. 10,000 yr. B.P.), (b) Tidal mangrove with regular inundation (9271±41 - 7687±38 yr. B.P.), (c) Mangrove upland with high frequency of *Phoenix* (7687±38 – c. 6000 yr. B.P.), (d) Swampy mangrove vegetation (c. 3000 – c. 2500 yr. B.P), (e) Brackish water mixed fresh water *Heritiera* forest with initiation of non-littoral taxa (c. 2500 – c. 2200 yr. B.P.) and (f) Supra-tidal fresh water swamp with abundance of *Acrostichum aureum* (c. 2200 – 1970±80 yr. B.P). The environmental succession depicted from the pollen assemblage zones during c. 11, 000 – 1970±80 yr. B.P suggests regression of sea after c. 6000 yr. B.P from Taldi and Canning area and after c. 2000 yr. B.P. from Kumirmari and Dakshin Harishpur area causing seaward extension of mangrove vegetation and progradation of delta in the area of investigation.

***Keywords*:** Palynological study, Holocene, Lower Bengal basin, Mangrove, regression of sea

How online databases strengthen Forensic Palynology and Forensic Botany

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Palynological and botanical knowledge have been erratically applied in Brazilian crime scene investigation, even though Brazil is recognized for its mega-diverse flora. It is generally agreed that the main problem concern absence of botanists and palynologists in police boards. The background shared among the majority of forensic experts do not able them to act in substitution of researches who were submitted to long and complex training. Therefore, forensic experts should work as bridges connecting these two spheres: Criminalistics and Basic Science. That means forensic experts should be able to conduct preliminary studies and, when necessary, refer its results to specialists. New technologies made it possible to store online large quantity of plant data. Having a species name, it is easy to search for its habitat, habit, region of occurrence, traits, if it is native or exotic, rare or frequent, cultivated, ruderal or invader, if toxic or edible. However, big amounts of data and quality data must go hand in hand. Searching information based on a dated species name is only one of the problems. Nowadays we watch the enormous effort of numerous public researchers in making available online the institutional plant collections. Data from fresh and herbaria plants and pollen of all Brazilian species are in progress. The result, a complete species list with comprehensive descriptions and photographs, will drastically change the way forensic experts face Botany and Palynology. In most cases, forensic experts have no idea about the species name or even Family of the collected plants in crime scene. Actually, they work mainly with plant parts (leaves, pollen, seeds). In the near future, having a single database uniting "Flora of Brazil 2020", "Specieslink" and "Rede de Catálogos Polínicos", forensic experts can use keywords or select features to narrow down the matches of plant collected and, in many cases, successfully reach a name. This undoubtedly reduce time and fund needed for investigations and preserves the requisites of custody chain. Moreover, be able to easily link all the plant parts commonly found in suspects clothes, as pollen and seeds, to the crime scene vegetation, based on an official database gives confidence to forensic analysis, modernizes Law Enforcement and strengthens evidence to be presented in court.

***Keywords*:** Forensic Palynology, Collections, Online database.

The online Pollen and Spores Image database at the University of Göttingen, Germany

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The Department of Palynology and Climate Dynamics at the University of Göttingen in Germany has a long-term tradition in pollen and spore analysis. As building up proper reference collections is a must for conducting palynological analyses on fossil and modern materials, for decades researchers and students working in Göttingen have contributed to the palynological collection. Currently the collection available in the departments includes about 6000 specimens collected and processed for pollen and spore from different locations around the world, including Central Europe and the Mediterranean, Mongolia, Indonesia, Africa, Galapagos, Ecuador and Brazil. However as extended and useful as that is, this collection has been so far only available on request (exchange slides) or to guests coming to visit the department in Göttingen. In order to make such a valuable tool available to all professionals and amateurs of pollen and spores, we developed a platform for storage and sharing of pollen and spore images online. A beta test version of the database is now available at: http://gdvh.uni-goettingen.de/. To maximize the participation of as many users as possible and at the same time ensure quality control of the data, the database includes a peer review process. Each images goes to a registered reviewer and needs to be approved before publication (internally and online). Additionally, the database is built with an integrated morphological description tool, which allows for queries and filtering of pollen and spore taxa based on selected features. Other selected key

features include an integrated tool to modified (e.g. cut, rotate etc.) images, video tutorials and help online tool, different access levels (from private, to available only to registered users, to online). The database is currently being tested and new data are inserted regularly from the collection at the University of Göttingen. Users from elsewhere are welcome to try and contribute to the collection.

***Keywords*:** pollen and spores, online image database, University of Göttingen

Biodiversity informatics applied to pollinators at the BioComp

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Biodiversity informatics (BI) is a recent transdisciplinary area, which is concerned with the application of computing tools and techniques to biodiversity for research, extension and education purposes. From a data life cycle perspective, BI has an important role on many phases, including data acquisition, digitization, integration, and analysis. The Research Center on Biodiversity and Computing, BioComp., has been working on all those phases, with a special emphasis on the application of BI to issues related to pollinators and pollination. As far as data acquisition is concerned, we have worked on a number of tools to automatize that task, with many potential advantages such as standardization, scaling up data acquisition (frequency and location wise), no need to further (error prone) digitization, among others. Examples are pollinator flight activity monitoring, pollinator behaviour (with sound and video) online recording. Digitization of pollinator occurrence data has also been tackled with the development of a tool named Biodiversity Data Digitizer, BDD. It allows digitizing data such as biological collection data following an international data standard, Darwin Core. It has been the kernel of other digitizing efforts following more specific protocols, such as those adopted at the FAO/UNEP global pollinator project for pollinator population monitoring and pollinator-plant interaction. Data integration from different, distributed sources is very important to create a larger online database that can be accessed by anyone, anywhere, allowing for analyses that are more comprehensive. We have worked on the Pollinators Thematic Network, PTN, of the InterAmerican Biodiversity Information Network, IABIN-PTN that involved digitizing and integrating pollinator collection data from 14 collections from 11 Latin American countries. We have also worked on the development of data analysis tools, like openModeller, which is a framework for species distribution modelling. We have been very much involved on international efforts on data quality in biodiversity, not only developing tools, but especially on the proposition of a conceptual basis to allow a common understanding, standardization, and efforts sharing. Additionally we have developed many case studies on specific questions about pollinators, usually involving distribution modelling. Recently we joined the group that proposed and is implementing the Online Polen Catalog Network, RCPol. We understand that it is critical for the pollinators, for the environment and for our own survival that data may turn into sound decisions. Biodiversity informatics has an important role to accomplish that goal.

***Keywords*:** computing, databases, instrumentation, modelling, pollinators, pollination, pollen

Online Pollen Catalogue Network (RCPol): basis for multidisciplinary studies

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The need of a pollen database to help on the identification of plant species was the reason to start the construction of RCPol (Online Pollen Catalogues Network). Designed in 2009 and created in 2013 RCPol's main objective is to promote interaction between researchers and the integration of data from their pollen collections, herbaria and bee collections. RCPol's coordinators and collaborators intend to facilitate the search for information on Angiosperms species, their flowers, their pollen and the interaction between

these plants and bees. Soon it will be released the interactive species identification key that was developed in collaboration with 'Escola Politécnica' of USP (Universidade de São Paulo) and researchers of several Brazilian Institutions and others countries in America and Europe. This key was developed to identify species through the morphological description of its flowers and pollen grains. The database will be available in the Online Pollen Catalogue Network website (www.rcpol.org.br). The network also allows access to plant species webpages that describe the main characteristics of the species, and to the specimen data at the collection. At moment in the RCPol's Melissopalynology and Palynoecology database there are more than 500 plant species inserted. Other two pollen database are under construction: Palynotaxonomy and Paleopalynology. Both will be available in December 2016. Currently we already have eight pollen collections taking part of the network, and fifteen others are expected to join in the next two years. Palynology has been a complementary science, supporting studies on pollinator's management and conservation, especially bees, in natural ecosystems and agroecosystems. At the beginning, our focus was to identify the plant species used in the bees' diet (Melissopalynology and Palynoeology database), but over time we extended to other areas of Palynology such as: Palynotaxonomy, Copropalynology, Forensic palynology, Geopalynology and Paleopalynology. With the spread of the use of pollen as a natural marker and given the small number of researchers working on Palynology and the few Pollen Collections in Brazil in relation to the existing botanical diversity, RCPol wants to encourage the integration of the Pollen Collections.

***Keywords*:** pollen database, pollen collection, melissopalynology, paleopalynology, palynotaxonomy

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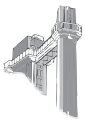

PALAEOWILDFIRES AND THEIR IMPACT ON THE EVOLUTION OF TERRESTRIAL ECOSYSTEMS AND ORGANISMS

André Jasper & Dieter Uhl

Charred plant remains from Early Cretaceous (Aptian) fissure fills in the Sauerland area (Northrhine-Westphalia, W-Germany) and their palaeoenvironmental implications

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Fissure fills containing charred plant and animal remains have been known for decades from the Sauerland area in W-Germany, especially the Brilon-Nehden region and the Warstein region. In both regions, which are only a few km apart, massive Devonian limestones occur, which underwent karstic erosion already during the middle Paleozoic. Due to this erosion fissures are present in both regions and they were (at least partly) filled with sediments during the Early Cretaceous (Aptian). Here we compare the charcoal contents of two different fissure fills in the Warstein and Brilon-Nehden regions. The fissure fill from the long known locality Brilon-Nehden is well known for the occurrence of dinosaur remains, i.e. *Iguanodon*. Charred plant remains from this locality have previously been described by various authors in regional journals and have thus been overlooked in recent global compilations of Cretaceous evidence for wildfires. The charcoal from this fissure fill is dominated by wood remains, with only subordinate occurrence of charred ferns and conifer needless. The fissure fill from the locality Kallenhardt in the Warstein region has so far not been described in the scientific literature. In this locality charred remains of ferns, especially *Gleichenia chaloneri*, are dominating the assemblage with only subordinate occurrence of wood, conifer and bryophyte remains. At Kallenhardt, but not at Brilon-Nehden, most wood and conifer remains shown signs of pre-charring decay or at least massive infestation by fungi and/or other microorganisms. Taxonomically, both fissure fills show remarkable similarities but frequencies and preservation of individual taxa are significantly different. Based on the abundance patterns, as well as the preservation of certain taxa, it is suggested that the charcoal from Brilon-Nehden originate from a crown-fire, whereas the charcoal from Kallenhardt probably originate from a ground-fire.

***Keywords*:** Early Cretaceous, wildfire, charcoal, ground-fire, crown-fire

Fires in the mire: Repeated fire events in Early Permian 'peat forming' vegetation of India

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Macro-charcoal, as direct evidence of palaeo-wildfires, is a common constituent throughout Early Permian coal seams from different areas of Gondwana. Also the presence of high inertinites contents in such deposits is well known and has just recently been related to a pyrogenic origin. With the aim to confirm that connection, samples of coal were randomly taken from three levels of the Coal Seam VI Top of the Dhanpuri Coal Mine (Barakar Formation, Sohagpur Coalfield, Madhya Pradesh, India). Those samples were analyzed in laboratory to define the presence of both, macro-charocal and inertinites. For the macro-charcoal analyses, the samples were extracted with the aid of forceps and needles and subsequently mounted on standard stubs with adhesive tabs for anatomical analysis under a Scanning Electron Microscope (SEM). For maceral and reflectance analyses, samples from each studied level were submitted to standard preparation for optical analyses, following ISO 7403-3/1984 and ISO 7405/5-1984 methods. In a comparative analysis, it was possible to confirm the continuous presence of macro-charcoal together with inertinites within this particular seam, demonstrating that inertinites have a pyrogenic origin. That data also show that fires occurred repeatedly in the source vegetation of the seam. Additionally, the macro-charcoal remains provided an anatomical assessment of the diversity and taxonomic composition of the vegetation which experienced wildfires and contributed to the formation of peat/coal, that was dominated by gymnosperms, with a minor component of pteridophytes. The results also support previous studies which suggest a pyrogenic origin for the high inertinite contents of many Permian coals within Gondwana.

Keywords**:** charcoal; coal; intertinite; palaeo-wildfire; Permian.

Fire dynamics under monsoonal climate in Yunnan, SW China: Past, present and future

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Climate change is likely to alter wildfire regimes, but the significance of climate- driven factors in regional fire regimes over extended temporal scales is poorly understood. Comparison of the reconstructed fire dynamics from charcoals in sediments with modern active fire dataset can provide clues about the drivers of wildfire activities, and help us validate models of fire activity for both the past and the future. Microscopic charcoals from Miocene sediments in Wenshan Basin (Yunnan, Southwestern China), were used to reconstruct fire dynamics in deep time. Palaeoclimate was reconstructed quantitatively using pollen samples in sequence from the sediments. The relationship between regional climatic parameters and the ratio of charcoals during the Miocene was explored, and compared throughout different time periods. Our results indicate that the temperature in the dry season was the main factor controlling the frequency of fire in Wenshan during the Miocene. These results were compared with modern active fire dataset of Yunnan Province from NASA Earth observations. The relationships between active fire data and present climate were analyzed using Maximum entropy model (Maxent) to provide insights into how climatic factors affect wildfire frequency and distribution. Maxent results are consistent with the results from fossil sediment analysis, that dry season temperature is the main driver of fire activity. Our findings suggest a significant fire-temperature relationship under the monsoonal climate since the Neogene. Furthermore, models for the

last-glacial maximum suggest that the LGM had lower levels of fire activity than present, which increased during the Holocene prior to reaching present levels. Models also predict increases in fire activity across most of Yunnan in the future. This study indicates that, temperature is the main factor contributing to the wildfire frequency. The predicted increase of wildfire under the global climate change with the higher temperature in future could have a great impact on the biodiversity.

***Keywords*:** charcoal, Miocene, wildfire, southwestern China, climate

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Dinosaurs and wildfires - The Late Cretaceous (Cenomanian) Bahariya Formation of Egypt

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The Late Cretaceous (Cenomanian) Bahariya Formation of Egypt has an outstanding reputation for its wealth of vertebrate remains, including a variety of iconic dinosaurs, like the carnivorous *Spinosaurus* and *Carcharodontosaurus*, as well as the herbivorous *Aegyptosaurus*. The profile of the upper part of the formation at Gabal El Dist, located in the north of the Bahariya Oasis, can be subdivided in four different lithofacies, representing fluvial floodplain and/or near-shore deposits. Here 5-6 distinct charcoal bearing horizons could be identified during field work. All charcoal investigated so far in detail is of gymnospermous origin, pointing to a considerable proportion of this plant group within ecosystems that experienced fires. Exceptional amongst the charcoal records are fragments that preserve evidence for the occurrence of wood decaying microorganisms during deposition of the Cenomanian Bahariya Formation in Egypt. This evidence consists of direct evidence in form of fungal hyphae, as well as indirect evidence in form of peculiar erosional cavities within cell walls probably produced during decomposition of the wood by so far unidentified microorganisms. Our data present evidence that the landscapes in which the Bahariya dinosaurs roamed, repeatedly experienced wildfires, adding additional proof that the Late Cretaceous was a fiery world on a global scale.

***Keywords*:** Late Cretaceous, Cenomanian, Bahariya Formation, Egypt, palaeo-wildfire

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Interaction between vegetation dynamics and wild fire during the past 1270-year inferred from Pangu peat profile of Daxing'an Mountain, northeast China

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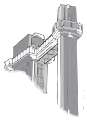
Daxing'an Mountain is known as a high incidence area of fire in China. However, little is known about past fire occurrence and dynamics in the region. To explore the fire history and the interactions between fire, vegetation and climate change, a 93cm peat profile at Pangu (PG) in the north of Daxing'an Mountain was sampled for pollen, *Sphagnum* spore, total organic carbon (TOC) and charcoal analysis. Vegetation history, climate change and fire episodes were reconstructed for the past 1270 years. Our study shows that coniferous and broad-leaved mixed forest dominated by *Larix*, *Pinus* and *Betula* has been distributed in the region for a long time. These dominant species have biological characteristics of adaptation to fire. Three periods of fire frequency with different climates are detected over the past 1270 years: MWP (warm and dry), early LIA (AD 1300-1500) and late LIA (AD 1700-1900) (cold and dry). Occurrence of more intensive fire activities is consistent with dry climate. Few fires have been identified in middle LIA (AD 1500-1700) due to the cold and wet climate. Our results therefore suggest that the occurrence of fire in the region was determined by both the biomass and climate, i.e. the more biomass accumulation and the drier the climate, the more frequent fire occurrence. Dominant species have been developed continuously for the past 1270 years in this region, which implies that vegetation regeneration was not hampered by fire

***Keywords*:** pollen, charcoal, fire, *Sphagnum*, Daxing'an Mountain



PHANEROZOIC PALYNOLOGY OF AMAZONIA

Carina Hoorn & Rodolfo Dino

Vegetation across the Middle Miocene Climatic Optimum in Western Amazonia

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During the Miocene, western Amazonia experienced major changes in its geography and biodiversity as a response to Andean uplift and climatic change. Fluvial drainages were split into west and east branches with the west discharging into a vast system of lakes, megalakes and floodplains. The area was connected to the Orinoco basin and episodically underwent a marine advance from the Caribbean. Climate during the Miocene evolved in continuation to the long term Cenozoic cooling trend but was punctuated by a warming of ~2°C during the Middle Miocene. To better understand the evolution of the western Amazon forest during this time, we studied the palynology of the Solimões Formation (NW Brazil) using core 1-AS-105-AM (4.25° S, 69.9° W). Samples yielded a rich and well preserved assemblage of palynomorphs. Ages were established following graphic correlation of biostratigraphic data from the studied core with a pollen zonation from the nearby Colombian Llanos. The results indicate age ranges from 18.7 to 10.7 Ma (late Early to earliest-Late Miocene). The pollen associations found are typical of Amazonian humid forests throughout the entire period, except for two short phases where marine incursions were detected. There is a negligible effect of these marine phases on vegetation. There is significant increase in diversity at ca. 16 Ma, independent of lithofacies, of up to 46% that is coupled with a significant compositional change. Overall, the forest changes its composition by the addition of new species rather than their removal and coincides with the Middle Miocene Climatic Optimum. Altogether, the results bring more detail to the environmental history of western Amazonia, furthering into the Miocene period the long climate-diversification relationship that had already been largely reported for most of the Cenozoic in Neotropical biomes.

Keywords: Amazonia, pollen, diversity, Miocene, warming

A tropical palynoflora in the K-Pg Vilacapujio section, southwestern Bolivia

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Palynological productive samples from El Molino Formation were collected at the Vilcapujio locality, Eastern Cordillera, SW Bolivia. The present study is part of a multi-proxy approach (gathering palynomorphs and vertebrates), which will play a pivotal role for better understanding the settlement of early Cenozoic ecosystems in South America. The studied unit is mainly composed of marls and mudstones, with subordinated limestones and sandstones. Several depositional environments are recognized throughout the concerned interval: outer shelf, oolite barriers, inner shelf, mouthbar deposits, supratidal to intertidal zones, and continental domain. The El Molino Fm. yields an abundant palynoflora dominated in all assemblages by freshwater chlorophycean algae, but a few brackish/marine peridinioid dinocysts were also identified. The statistical results indicate percentages of 80% of algae of the total, at the base of the section represented by: *Botryococcus*, *Pediastrum*, *Ovoidites*, *Lecaniella*, and *Scenedesmus.* The terrestrial association is characterized by tropical to subtropical key species such as *Buttinia andreevi* Boltenhagen, *Crassitricolporites brasiliensis* Herngreen (a thick wall taxon endemic from northern South America), *Aquilapollenites* sp., *Zlivisporis blanensis* Pacltova, and abundant granulate periporate species similar to *Psilastephanoporites brasiliensis* Regali, Uesugui, Silva-Santos. *Ephedripites* (2-3%) is the most represented gymnosperm. Going up in the section the key taxa disappear and monocolpate palmae-type pollen increase in abundance (*Retimonocolpites*, *Longapertites*, and *Arecipites*) with percentages of nearly 30%. Large amounts of water ferns (spores and

massulae) characterize the uppermost part of the section mainly represented by *Gabonisporis vigourouxii* Boltenhagen and *Azolla boliviensis* Vajda and McLoughlin*.* Cretaceous Bolivian palynofloras are included in the Palmae Province on the criteria outlined by Herngreen, which probably reflect warm, ever-wet conditions. The co-occurrence of the key palynomorphs (*B. adreevi*, *C. brasiliensis*, and *G. vigourouxii*) and of the sawfish *Pucapristis* cf. *branisi* Schaeffer, which all become extinct at the K-Pg boundary, corroborates the Maastrichtian age for the El Molino Fm. at Vilcapujio. The depositional environment was probably lagoonal with some marine influence, as indicated by the mixed character of the palynomorph-vertebrate association recovered. Two younger vertebrate faunas from the same section, Danian and Thanetian in age are under study (Santa Lucia and Cayara formations). The unexpected palynomorph diversity of this K-Pg locality, their exceptional preservation, and the co-occurrence of vertebrate-bearing levels in the same section, will provide relevant information on the evolution of floras and faunas during the crucial period of the K-Pg boundary in this region.

***Keywords*:** El Molino Fm., Palmae Province, Tropical palynoflora, Eastern Cordillera Bolivia, Vertebrates

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Palynology of the Ramon and Solimões Formations, Acre Basin, Brazil

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The Paleogene and Neogene sequences of the Acre Basin are recorded in the Ramon and Solimões Formations. Geophysics, lithology and palynology provide data about those units indicating that Ramon was deposited in shallow marine environments with Paleocene to Eocene ages and that Solimões was deposited in continental environments with Eocene (?) to Pliocene ages. Herein I present palynological data of the well 2CDST0001 drilled in the Acre Basin in the 60ths by Petrobrás, with a total depth of 2650 m. Ten samples of the first 1815 m were studied in order to improve the biostratigraphy information of the deposits. Moreover, I compare those results with previous palynological research of the Neogene Solimões Basin. In addition, samples from four outcrops were collected along the Acre River near the border with Peru and Bolivia and are now revised. Preliminary results of the sample collected at 1808, 9 meters of Ramon Formation shows peak of dinoflagelate cysts (78%), corroborating the previous marine environment interpretation. Forty-eight spores and pollen morphotypes were described, some of them were: *Rhoipites guianensis*, *Echitriccolporites* sp., *Bombacacidites nacimentoensis*, *Monoporopollenites annulatus* and *Crotontricolpites* sp. also confirming the Early Tertiary age. In the Solimões Formation part of the well 25 morphotypes were found, mainly in the sample collected at 617, 56 m. Some of them were: *Fenestrites* sp., *Byttneripollis ruedae*, *Cingulatisporites laevigatus*, *Pteridaceoisporis gemmatus*. All of them recoded for the first time in the Upper Miocene/Pliocene of the Solimões Basin. Forams and dinocysts also were observed in the Acre section. Outcrops samples show the presence of *Grimsdalea magnaclavata* and Asteraceae (*Fenestrites* sp.), suggesting a Late Miocene and Pliocene age to some sections. In conclusion, the Upper Miocene and Pliocene of the Solimões Formation in Acre Basin is deeper than in Solimoes Basin. Outcrops in Acre could be considered as having the same age of outcrops in the Solimões Basin. (CNPq/Processo 476020/2013-1)

***Keywords*:** pollen analysis, biostratigraphy, Amazonia basins, Neogene, Acre

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What is the age and the provenance of the Amazon River sediments in the Atlantic Ocean (Foz do Amazonas Basin, Brazil)?

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The Foz do Amazonas Basin (FAB) is situated along the Brazilian Equatorial Margin and was formed during the break-up of Africa and South America followed by the formation of the Equatorial Atlantic Ocean. The sedimentary record in this basin comprises a Mesozoic pre-rift and rift sequence, followed by a Mesozoic and Cenozoic post-rift sequence. The Amazon submarine fan forms the final part of the sedimentary succession, and represents the seaward extend of the Amazon River. The shelf-end of the FAB was extensively explored by the oil industry during the '70s and '80s, while more recently the deep water-end of the basin was explored. Our study was based on an analysis of Neogene samples from deep water BP3, which was drilled in 2004 by a consortium of oil companies. The age of the Amazon River has been a topic of substantial debate and has implications for the understanding of biotic and abiotic interactions in the entire drainage basin. Our aim was to reassess the age and provenance of the Amazon River sediments at sea by means of a multiproxy approach and establish age versus provenance, and paleoaltitudes in the drainage basin. We used geochemical analysis to determine the Sm/Nd ratio in the sediments, and sporomorphs to differentiate between tropical lowland and Andean vegetation in the source area. In addition, specific sporomorph taxa also provided an estimate of paleoaltitudes in the Andes during the Neogene. Our results confirm the late Miocene onset of the transcontinental Amazon River and provide indications for a high Andes. This study was carried out in the context of the CLIMAMAZON program, a Brazilian and European facility for the study of the Amazon drainage basin.

***Keywords*:** Neogene, provenance, paleoaltitude, Andes, Amazon River

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New palynostrigraphic data of the Formação Solimões, Neogene, applying Unitary Association Method

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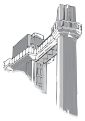
The palynology of the Solimões Formation in the Solimões Basin offers important information about the paleoenvironment and development of the Amazon forest that now covers its vast extension. A few paleogeographic models have been proposed for Neogene evolution of the basin under the influence of the Andean orogeny. In all of them the age established for the end of the deposition is Late Miocene. New biostratigraphic data have been presented in the last five years providing more elements for dating sedimentary rocks from wells and outcrops. Here we present the palynostratigrafic analysis of 17 samples from the well 1AS-37-AM, from the drilling project *Carvão do Alto Solimões* (CPRM). The age established for the samples is Middle/Late Miocene by the presence of *Ladakhipollenites*? *caribbiensis*, *Cichoreacidites longispinosus*, *Fenestrites spinosus* and *Paleosantalaceaepites cingulatus*, characteristic of the biozone T-16 *Fenestrites spinosus* (12.7 a 7.1 M.a.) *sensu* Jaramillo *et al.* (2011). We compared these results with previous studies of four other wells in the same area using the Unitary Association Method (UAM) for quantitative biostratigraphy. UAM is a method to define concurrent range zones of taxa in a set of stratigraphic sections. These wells have their age well determined by biostratigraphic markers ranging from Early Miocene to Pliocene. In order to refine these intervals, we used the program PAST to analyze the superposition and coexistence relations of 230 species. Six unitary associations were established that provide new insights in the history and development of the Solimões Basin.

***Keywords*:** Palynology, biostratigraphy, Miocene, Pliocene, Amazonia, statistics



PLANT ORIGINS AND THE PRIMARY DIVERSIFICATION OF THE TERRESTRIAL FLORA

Paul K. Strother & Wilson A. Taylor

Dispersed spore assemblages from the classic Lower Devonian plant-bearing deposits of New Brunswick, eastern Canada

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Early land plant fossils from the Lower Devonian deposits exposed along the Restigouche River in northern New Brunswick, eastern Canada were among the first reported. Subsequent work on these fossiliferous horizons has been critical in developing our understanding of the biology of Lower Devonian plants and the palaeoecology of the early terrestrial ecosystems they inhabited. However, placing the plants in a stratigraphical context was hampered because the stratigraphy of the deposits was unclear and they were poorly age-constrained. Furthermore, palaeoecological interpretation of the plant communities was limited because they lacked sedimentological context. Recent work on the stratigraphy, sedimentology and palaeoecology of these deposits, coupled with analysis of their dispersed spore/pollen assemblages (this work), now enables the plant communities to be considered within a rigid stratigraphical/biostratigraphical framework and their palaeoecology of be analysed. Rich assemblages of well preserved spores have been recovered from throughout the Lower Devonian sequence. These belong to the PE, AS and DE Spore Assemblage Biozones, indicating that the sequence covers the late Pragian-latest Emsian interval. Analysis of dispersed spore/plant megafossil distribution, with respect to facies, suggests that clonal plant growth in monotypic stands was an important feature of early land plant communities.

***Keywords*:** Lower Devonian; Canada; early land plants; dispersed spores.

Cryptospores from the Cambrian of Laurentia

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New genera of cryptospores are reviewed: *Adinosporus* Strother, *Vidalgea* Strother, and *Spissuspora* Strother. Together with the late Cambrian *Agamachetes* Taylor & Strother, these microfossils characterize an evolutionary flora in transition from charophytic algae to the embryophytes. This microfloral assemblage is quite extensive in time and space – it is found around the southern margin of Laurentia from eastern Tennessee to Wisconsin. Stratigraphically it ranges from Cambrian Stage 4 to the Jiangshanian (ca. 510 Ma to 490 Ma). Cambrian cryptospores occur in packets of spores or spore dyads – often preserved within enclosing walls. Not all appear to have formed in unilocular sporangia, as, in some cases, adjacent packets retain the geometric relations of the generative sporocytes. In other cases spore masses occur in close association with membranous tissues. The overall topology of spore formation in these forms indicates that karyokinesis, cytokinesis and spore wall formation were essentially decoupled from each other at this time. Both *Adinosporus* and *Vidalgea* are essentially multilaminate and this condition helps to link these problematic forms with spores of embryophytes. Sporogenesis during this time appears to reflect endoreduplication of DNA (as seen in *Coleochaete* Bréb. today) in combination with spore wall formation as seen in embryophytes. The Cambrian cryptospore microflora can be interpreted as documenting an early stage in evolution of the plant sporophyte (as envisioned by Bower just over 100 years ago) in which meiosis was not yet canalized into a modern form of plant sporogenesis. If spore characters were the first to evolve in a temporally extended scenario of sporophyte evolution, then the long-held assumption that tetrahedral

tetrads mark the origin of land plants may be in need of a paradigm shift in favor of a much later origin to the land plants, perhaps matching more closely the stratigraphic record of plant mesofossils in the Silurian.

***Keywords*:** origin of land plants, plant sporogenesis, meiosis, antithetic theory, paleopalynology, Rogersville Shale, Bright Angel Shale

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Sporoderm ultrastructure of Cambrian cryptospores from eastern Laurentia

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The classic Thorn Hill section in eastern Tennessee contains sediments of Cambrian age that were deposited in an inner clastic belt around the Laurentian margin. A recent palynological investigation of shale units from the Rome Formation (Series 2, Stage 4) and the Conasauga Group (Series 3) reveals abundant cryptospores, which have been placed into three genera (*Adinosporus*, *Vidalgea* and *Spissuspora*) described on the basis of white light morphology (all erected in Strother, 2016). We have now examined several species of *Adinosporus* and *Vidalgea* using transmission electron microscopy. All of these forms present problems taxonomically because they exhibit great variability in terms of the number and arrangement of spore bodies, all of which are clustered together into packets. *Adinosporus voluminosus* possesses a multilaminated wall that consists of four discrete laminae, each of which is about 60 nm in thickness. This structure is also apparent in the wall of a second species, *A. bullatus*. This species is characterized by dark-colored bulbils, visible under the light microscope, that contain electron-dense granular inclusions embedded within laminated walls, so these structures do not simply represent applied sculpture. *A. voluminosus* is present in the Rome Fm., long considered to be of lower Cambrian age. Thus, multilaminar walls are characteristic of the oldest described fossil cryptospores to date, consistent with their proposed plesiomorphic position with respect to the spores of land plants.

***Keywords*:** origin of land plants, *Adinosporus*, *Vidalgea*, Rogersville Shale, paleopalynology

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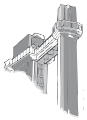

POLLEN-BASED HOLOCENE LAND-COVER RECONSTRUCTIONS FOR CLIMATE MODELLING – PAGES LANDCOVER6K

Marie-José Gaillard, Sonia Fontana, Ralph Fyfe, Konrad Gajewski, Ulrika Herschuh, Anupama Krishnamurthy, Anne-Marie Lézine, Rob Marchant, Jack Williams & Qinghai Xu

Pollen productivity estimates and regional vegetation estimates in west Siberian Arctic tundra, a work in progress

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Pollen-based reconstructions of land-cover by using the landscape reconstruction algorithm (LRA) have been produced for several years in the most populated areas of the world. This is not the case in the Arctic tundra, partly because of the lack of pollen productivity estimates (PPE) of the tundra vegetation, partly because the area is virtually uninhabited and hence not in a significant role when the focus is on land-use change and its role in the anthropogenic climate forcing. Reindeer (*Rangifer tarandus*) is the dominant large herbivore affecting the vegetation of the northern Eurasian tundra. It has been observed throughout the

Arctic, and especially in Fennoscandia and northern Russia, that human-animal impact, e.g. concentrated grazing and trampling by semi-domesticated reindeer herds have changed the vegetation at large by creating graminoid dominated green patches, which have persisted over the centuries in some places. To be able to model the effects that the growing size of the reindeer herds has had on the vegetation since the beginning of the domestication about 1500 years ago, a set of PPEs from the Arctic tundra will be needed. Current work aims to produce the relative pollen productivity estimates for the most common taxa in tundra. The research area is located on the south side of the Yuribey River in the Central Yamal Peninsula, western Siberia, Russia. Vegetation in the area is grass and sedge dominated dwarf shrubs tundra, *Betula nana* and *Salix* sp. growing in the moist areas. A series of 46 surface pollen samples with the percentage cover of the vegetation estimated around them were collected during two summer field seasons in 2013 (30 samples) and 2014 (16 samples). The vegetation data for the distance weighted plant abundance will be combined from field observations and ground truthed very high resolution WorldView-2 satellite data. With the current set of data, the pollen productivity estimates are obtainable to Poaceae, Cyperaceae, *Salix*, *Betula nana*, *Rubus chamaemorus*, Artemisia, and to some of the Ericaceous species. The pollen records from 3 lakes in the area will be used for the LRA REVEALS estimates of regional vegetation changes.

***Keywords*:** PPE, REVEALS, vegetation, modeling, Arctic, tundra

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Holocene global land-cover and land-use change for climate modelling studies: the PAGES LandCover6k initiative and its first achievements

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The envisioned product from the PAGES LandCover6k initiative (2015-2020) is quantified empirical data on past anthropogenic land-cover and land-use change that are relevant and useful for climate modelling within international programs (e.g. CMIP, PMIP). Land-use change is one of many climate forcings and quantification of its impact on climate is still debated. Among the effects of land-use change (deforestation) on climate, the global biogeochemical effect, i.e. the influence on the exchange of CO_2 between land and atmosphere, is the most studied and best known. The biogeophysical effects are less studied, especially at the regional spatial scale at which they will be most significant. Moreover, the net effect of a) changes in the albedo and evapotranspiration (biogeophysical effects) and b) biogeochemical and biogeophysical processes together are difficult to quantify and still a matter of debate. LandCover6k infers land-cover and land-use quantitative data from fossil pollen, and from historical archives and archaeological data. The working group is divided into three activities, i) pollen-based reconstructions of past land cover using the Sugita's REVEALS model, and mapping of pollen-based land-cover change using spatial statistics, ii) upscaling of historical and archaeological data into maps of major land-use categories linked to quantified attributes useful for climate modellers, and iii) Anthropogenic Land-Cover Change (ALCC) modelling. The results of activities i) and ii) are used to revise existing ALCCs, the HYDE database and the Kaplan *et al.*'s KK scenarios (activity iii). Estimating pollen productivity (PPE) of major plant taxa is an essential part of activity i) because PPEs are required for REVEALS applications. PPEs are available for part of the northern hemisphere's major plant taxa, but are still missing for large parts of Asia and for the tropics. Climate modellers will use the LandCover6k products as such (i and ii), and/or the revised HYDE and KK ALCCs (iii). The LandCover6k working group focuses on regions of the world where humans have had a significant impact on land cover through deforestation and diverse agricultural practices, i.e. the Americas, Western and Eastern Africa, Europe, and Asia. In Asia, the emphasis has been placed so far on China, India and Japan. Examples of LandCover6k products in progress will be presented.

***Keywords*:** Global land-cover and land-use change, Holocene, pollen, REVEALS, LandCover6k

Holocene land cover changes in the Mediterranean basin

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The lands surrounding the Mediterranean Sea are the product of a distinctive climate and natural environment and have been transformed by human agency over many millennia. The precise timing of changes in the Mediterranean, and the processes that caused these changes, are important for a range of reasons. These include land cover-climate feedback mechanisms, sustainability of human-environment relationships, and identification of biodiversity hotspots. Long-term perspectives, drawing on pollen analytical data, have the potential to address many of these issues. Indeed existing research has already begun to identify major changes between mid-Holocene pollen assemblages and the present day, although this work does not identify when key transformations take place. The spread of agriculture from the eastern extent of the Mediterranean to the north-west Europe, and subsequent major phases of civilisation (e.g. the 'Romanisation' of the landscape around two millennia ago) is likely to have had profound effects on land cover. This paper focuses on the use of a large number (~180) of publically-available, dated, pollen records (taken from the European Pollen Database). Each sequence is re-sampled into 200-yr long, contiguous, time windows for the period 11,000-present. Not every time interval is present at every site. Samples are assigned to key land cover types (defined by distinctive pollen assemblages) using cluster analysis. Clusters of distinct anthropogenic land cover types are evident within the data, and are apparent by 5000 cal BP. The development of distinctive 'anthromes' (anthropogenic biomes) within the Mediterranean basin is discussed. Comparison with archaeological settlement evidence is in progress to understand the importance of human land use systems on driving changes in mid- and late-Holocene land cover.

***Keywords*:** Holocene, Mediterranean, land cover, pollen analysis, agriculture

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Pollen-based REVEALS quantitative reconstructions of Holocene plant abundance in temperate China

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China is one of the regions of the world where agricultural civilizations already flourished several millennia ago. However, the impact of human activity on past vegetation is still not fully understood. As a contribution to the PAGES LandCover6k initiative, this study aims to achieve a first attempt at pollen-based reconstructions of regional land-cover in northern and temperate China over the Holocene using the REVEALS model (Sugita, 2007). This model corrects major biases caused by inter-taxonomic differences in pollen productivity and characteristics of pollen dispersal and deposition. The spatial scale of reconstruction of the model is ca. 100 km x 100 km. The aims of this study are to i) calculate pollen productivity estimates (PPEs) for major plant taxa in cultural landscapes of temperate China, ii) provide REVEALS estimates of regional plant abundance for individual plant taxa and map the regional plant cover in time (over the Holocene) in northern and temperate China, and iii) quantify regional landscape openness in order to estimate Holocene anthropogenic land-cover changes in the study region. Pollen productivity of plant taxa (PPEs)is a key parameter required for the application of the REVEALS model. PPEs can be estimated from data sets of surface pollen assemblages and related vegetation cover. PPEs are available for some herbs and trees from earlier studies in steppes and meadows of northern China, and forests of temperate NW China. In this study, we have calculated PPEs for herbs and trees characteristic of traditional agricultural landscapes of temperate China. The study was performed in the low mountain ranges of the Shandong province located in central-eastern China. We obtained PPEs for seven trees (*Pinus*, *Platycladus*, *Quercus*, *Ulmus*, *Robinia*, *Castanea*, *Juglans*), 10 herbs (Poaceae, Cyperaceae, Caryophyllaceae, Chenopodiaceae, Cruciferae, *Artemisia*,

Aster type, Tubuliflorae SubF. Cichorioidae, *Galium*, *Humulus*), and one shrub (*Vitex*). All available PPEs were then combined into PPE data sets for REVEALS model applications. We applied the model using fossil pollen records from 70 lake and bog sites located in six of the eight vegetation zones of northern and temperate China. We find that, as in other parts of the northern hemisphere, herbs are underrepresented in pollen assemblages compared to their actual cover and, therefore, anthropogenic deforestation is underestimated, while REVEALS estimates of landscape openness provide a more realistic reconstruction of the past cover of human-induced open land. Sugita S. 2007. *The Holocene* 17 (2), 229–241.

***Keywords*:** Temperate China, pollen productivity estimates, REVEALS model, pollen-based estimates of vegetation cover, Holocene

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Pollen productivity estimates for dominant plant taxa in southeastern Inner Mongolian grassland of China

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A primary goal of pollen analysis is to reconstruct past plant abundances. Establishing a quantitative relationship between modern pollen and vegetation has been a focus although there are still many uncertainties due to many factors affecting pollen productivity and distribution. Pollen productivity estimates (PPE) is an important parameter for the reconstruction of past plant abundances, and Extended R-value (ERV) model is a commonly accepted reliable method over the past decade for calculating the PPE and Relevant Source Area of Pollen (RSAP). This paper analyzes pollen data using surface sediment samples of 8 lakes in southeastern Inner Mongolia Plateau in forest-grassland ecotone and vegetation data around the lakes in 8 directions within the basin. Pollen Productivity Estimates (PPE) of four dominant plant taxa in temperate grassland and the RSAP of lakes in different sizes were simulated with pollen data of 8 lake surface sediment samples and its vegetation data in Inner Mongolia of China. The PPE estimated by ERV model using lake surface sediment samples were: Poaceae 1, *Artemisia* 14.3-16.8, Asteraceae 0.5, Cyperaceae 0.1; The RSAP of different size of lakes were: 1200 m for lake water radius is 250 m, 1900 m for lake water radius 550 m, and 2700 m for lake water radius 850 m. The factors such as lake size, vegetation survey method, relationship between the number of sites and the number of taxa might account for uncertainties in the results of PPE. In this paper, the results simulated with data of 8 lakes and 4 small lakes were stable, while the result calculated with data of 4 large lakes has large outliers by analyzing the standard deviation of results and comparing with other research. The PPE and RSAP results of this paper were applied to the reconstruction of regional land cover changes of the forest-grassland ecotone.

***Keywords*:** Inner Mongolian grassland, ERV model, pollen productivity estimates (PPE), relevant source area of pollen (RSAP)

Quantitative reconstruction of past vegetation in the forest-steppe ecotone region of northern China: calibration and validation of a pollen-vegetation model using modern samples

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Relative pollen productivity (RPP) and relevant source area of pollen (RSAP) are very important parameters in quantitative vegetation reconstructions. $RPP_{Poaceae}$ and RSAP are estimated from the forest–steppe ecotone in the north of Shanxi, China, using 3 ERV sub-models with ERV-Analysis.v1.2.3 programme. Pollen sampling was performed at 18 random sampling sites. The pollen analysis results show that *Artemisia*, Asteraceae, Poaceae, *Pinus*, *Picea*, *Quercus*, *Betula* and *Hippophae* dominate the pollen assemblages with more than 80%

proportion. The RSAP is about 600m based on 3 ERV sub-models with Prentice's distance-weighting method and the background pollen loading is about 50%. The results of $RPP_{Poaceae}$ suggest that the values of *Pinus* and *Hippophae* are more than10, followed by *Picea* and *Betula*, which are about 5, *Artemisia* is only about 3-4, which is much lower than that in the steppe area. The $RPP_{Poaceae}$ of *Quercus* is about 0.5, which is much lower than that in the northeast of China and in Europe. After that we quantitatively reconstruct the vegetation proportion with LOVE model and MAT method, and the results show that the correlation coefficient between observed values and reconstructed values is more than 0.5, but the correlation coefficient getting from LOVE model is higher, indicating that the LOVE model is more robust in this study, and have potential use for quantitative reconstruction of paleo-vegetation in the forest–steppe ecotone in northern China.

Keywords**:** RSAP; RPP; Forest–steppe ecotone; Relationship between vegetation and pollen; Potential use

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Palynological perspective of the historical context of wetland from La Paz Valley and their surroundings

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We realized a vegetation construction using palynological methods in wetlands of the central Andes near La Paz, Bolivia (≥4000m). In this work, we present the profile analysis conducted in the wetland near Charquini Glacier, Murillo Province (4700 m a.s.l.). The calibration of current analog shows that the wetland is lower anthropised, dominated by cushions plants as *Oxychloe andina*. On the wetlands surface soil dominate palymorphs: highly related to the current vegetation species (peat bog/ "bofedales"), grassland -surrounding vegetations-, and extralocal species from low altitude vegetation as Yungas. Extralocal pollen suggests low vegetation cover, this facilitated the pollen deposition transported by air currents. The sediment profile reached 4 m deep; ^{14}C dating is older than 3.3 m correspond to 4980 cal yr BP (years after the present), here it was registered a higher Poaceae pollen percentage suggesting a humid period, this condition that maintains stable with some fluctuations between 995 and 586 yr cal BP. The most dramatic decrease of Poaceae was registered, at 280 yr cal BP. This pattern is similar with Tuni Condoriri wetland, this reduction can be interpreted as lower effect of the little ice age during the second half of 17 th century (1650 year). After this event it was register an Asteraceae increase suggesting mayor temperature, with higher point during the last 50 years. During 900 – 1400 AD (1100-600 yr BP) it was registered Chenopodiaceae pollen percentages associated with *Chenopodium quinoa* crops, this was probably cultivated by human during the last Tiwanacota period. This data are in agreement with other studies in Tiquimani.

Keywords**:** Reconstruction, palynology, Charquini, Poaceae/Asteraceae, Quinoa

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Altitudinal changes of surface pollen and vegetation on the north slope of the Middle Tianshan Mountains, China

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In order to provide information on vegetation patterns and altitudinal distributions of pollen assemblage in surface soil layers as well as their complicated relationships in a dryland mountain-basin system in northwestern China and then provide a more realistic basis for paleovegetational reconstruction, we

investigated 86 vegetation quadrats and analyzed 80 soil samples from the surface soil layers along an altitudinal transect on the north slope of the Middle Tianshan Mountains from alpine cushion vegetation at 3,510 m asl near glacier to desert vegetation at 460 m asl in Gurbantunggut Basin. According to surface pollen assemblages and the results of Detrended Correspondence Analysis (DCA), the transect can be divided into six major altitudinal pollen zones as alpine cushion vegetation, alpine and subalpine meadows, montane *Picea* forest, forest-steppe ecotone, *Artemisia* desert and typical desert, which basically reflect the characteristics of mountainous vegetation patterns on the north slope of the Middle Tianshan Mountains. However, *Picea* pollen exists out of the spruce forest, Chenopodiaceae and *Artemisia* pollen appeared above the elevation of 1,300 m, indicating that most of them might be introduced from lower elevation by upslope winds. Airborne pollen researches from three regions at different elevations further suggest that a high-frequency northwest anabatic wind has a remarkable influence on the transportation and dispersion of surface pollen in the area.

***Keywords*:** altitudinal transect; vegetation zone; pollen assemblage; *Picea* forest; Middle Tianshan Mountains

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Human induced land-cover changes in western Norway

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Anthropogenic land cover changes over the last c. 10 000 years are shown for western Norway using pollen-based land cover estimates obtained through the Landscape Reconstruction Algorithm, LRA (Sugita 2007, The Holocene 17, 229–257) combined with archaeological records. Pollen data from lakes, bogs and small peat deposits mainly sampled in relation to archaeological excavations are combined for regional reconstruction of land cover change. The pollen samples are grouped into 500-year time windows from c. 10 000 cal BP to c. 1000 cal BP, covering the prehistoric time from the Mesolithic to the end of the Viking Age. For vegetation reconstructions with the REVEALS model pollen data from several sites within a radius of 30 km in each region is used. The effects of human impact on the land-cover through time are assessed by comparing local vegetation reconstructions (REVEALS/LOVE) with archaeological data through ordinations. 22 mainly anemophilous taxa were used. For these taxa clear relationships exist between the LRA-estimated forest cover based on surface samples and modern vegetation, using pollen productivity estimates for plant taxa derived from the region combined with available estimates from elsewhere in northern Europe (Hjelle *et al.* 2015, J Quat Sci 30, 312–324). Archaeological data from existing databases and from reports at the University Museum of Bergen were compiled within a radius of 2500 m of each pollen site where local vegetation cover is estimated using the LOVE model. The LOVE-estimated forest cover shows spatial variations through time which improves the understanding of the human forced changes at the regional level. Along the coast opening-up of the vegetation took place in the vicinity of hunter-fisher sites in the Mesolithic and Early/Middle Neolithic, followed by forest regeneration after abandonment. More marked openings of the forest in all regions took place after c. 4000 cal BP, especially after 3500 cal BP, concurrent with an increase in finds of house remains and prehistoric fields reflecting farming communities. Regional variations are observed with periods of reforestation followed by new forest clearings. Although existing along the coast in the Mesolithic, open heathlands increased stepwise from c. 2500 cal BP, associated with the increase in number of farms and exploitation of heathlands for grazing as part of the management system. This study shows the potential of combining local scale reconstructions and archeological data to identify causes of pollen-based land cover changes on a regional scale through time.

***Keywords*:** Pollen, archaeology, Landscape Reconstruction Algorithm, land-cover changes, Norway

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The end of the African Humid period in Equatorial Mountain forests: biodiversity, climate, land use and land cover changes

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High-resolution pollen, charcoals and organic matter analyses of the last 4ka at lake Bambili allow discussing the end of the Holocene Humid Period in the Equatorial montane forests of Cameroon. Environmental (Biome, Diversity and Land cover) and climate reconstructions show two major events (1) a forest collapse occurred at 3.3ka. It was immediately followed by the increase in xerophytic biomes, which culminates during the last millennium. Increase in dryness was accompanied by intense burning events in particular between 3.3ka and 2.7ka, then after 1.2ka; (2) the drastic reduction of the scores of all forest biomes (except the wettest type of rain forests) during the last millennium remains the major event of this period. It occurred both in altitude (mountain forest) and in the lowlands (seasonal rainforest and tropical dry forest). Vegetation cover reconstruction using REVEALS algorithms will be developed for the first time in Equatorial Africa from a set of about 40 modern pollen samples and plant inventories, based on pollen productivity estimates of the major forest trees with the aims to accurately quantify the amplitude of the environmental changes and the forest vulnerability facing climate and anthropogenic stresses. This research is funded by the French ANR (IFORA et C3A project), the Belgium BELSPO (AFRIFORD project) and the IGFAGCR Belmont Forum (VULPES project) in close collaboration with IRD and IRAD in Cameroon.

***Keywords*:** Pollen, Charcoal, Organic Matter, Biomes, Land cover and Climate reconstructions, Equatorial montane forests, Africa

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Pollen productivity estimates in Japan: use of flower traps for major Pinaceae trees and direct harvesting of flowers for several herbaceous plants

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The Landscape Reconstruction Algorithm (LRA; Sugita 2007a,b) – a quantitative method for reconstruction of the past changes in vegetation – requires pollen productivity estimate (PPE) as one of the critical parameters. Although the Extended R-value model approach and its variants have provided PPEs in Europe and elsewhere, those estimates are potentially biased by the selection of pollen dispersal function and sampling schemes of field data. To avoid those biases, this study uses other approaches for PPEs of a set of the major Pinaceae species and several herbaceous plants in Japan, specifically using Saito's method with flower traps (Saito 1983, 2012) for the former and a direct harvest method for the latter. PPEs of pinaceous conifers, especially subarctic taxa, are critical for quantitative reconstruction of vegetation during the Last Glacial Maximum and those of herbaceous taxa, including several species in Poaceae and Asteraceae, for estimating the past changes in land use in Japan. Ten to sixteen flower traps 50 cm x 50 cm in opening were set up in each of nearly monospecific stands of *Pinus koraiensis*, *Picea glehnii*, *Picea jezoensis* var. *hondoensis* and *Abies sachalinensis*. In order to use the flower trap method we collect male flowers (microsporangium) just before flowering, fix those with Carnoy solution (Ethanol : Acetic acid =3:1), and measure the number of anther per male flower (*An*) and the number of pollen grains per anther (*Pn*). Then, the number of pollen grains per male flower (*PFn*) is obtained as *An* x *Pn*. The number of male flowers per unit area (*Fn*) is estimated using the flower trap data. The PPEs of individual species per unit area are estimated as *PFn* x *Fn*. The direct harvest method for herbaceous taxa follows the same procedure in general; however, we take into account the phenology of each species when estimates of the number of male flowers are obtained by harvesting flowers per unit area. Thus far, PPEs of the following taxa (all in grains·ha^{-1}·yr^{-1}) are obtained: 7.6 x10^{12} (2015) for *Pinus koraiensis*, 7.8 x10^{11} for *Avena*

fatua, 7.1 x10^{12} for *Miscathus sinensis*, 4.4 x10^{12}, and *Sorghum halepense*, in Poaceae, and 8.7 x10^{12} for *Artemisia princeps.* These estimates appear comparable and consistent with those previously obtained for the same taxa and genera in Japan and elsewhere; thus, relative PPEs based on those values will be applicable for the LRA-based reconstruction of vegetation and land cover in Japan.

***Keywords*:** Landscape Reconstruction Algorithm, pollen productivity estimate, flower trap method, the direct harvest method, *Pinus koraiensis*

The last hundred years of land use history in the southern part of Valdai Hills (European Russia): reconstruction by pollen and historical data

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The last hundred years of land use history in the southern part of Valdai Hills (European Russia) were reconstructed on the base of high resolution pollen data from the peat monolith taken from the Central Forest State Reserve supplementing with historical records derived from maps of the General Land Survey of XVIII and XIX centuries and satellite images. According to created age-model, provided by dating using radio-nuclides ^{210}Pb and ^{137}Cs, pollen data of the peat monolith allow us to reconstruct vegetation dynamics and human induced changes during the last hundred years with near annual time resolution. The obtained data showed significant variations in the pollen values of main tree species (spruce, pine and birch) that are associated with both changes in pollen productivity of these tree species in different years, and with forest successions after clear cutting. Despite the location of the studied peatland in the center of the forest area and rather far away from possible fields and hayfields, the pollen values of plants – anthropogenic indicators (*Secale serale*, *Centaurea cyanus*, *Plantage major/media*, *Urtica*, *Rumex*, etc) are relatively high in the period since the beginning of the 20th century to 1970th, especially in the peat horizon formed after the Second World War. In the late 1970th – early 1980th of the pollen of cereals gradually disappeared from the assemblages, the quantity of pollen of other anthropogenic indicators are also significantly reduced, which reflects the overall processes of the agriculture decline in the forest zone of former USSR. The studies of micro-charcoal concentration in peat samples revealed an increase in the proportion of micro-charcoal remains in the peat layer that had accumulated during the War. The highest concentrations micro-charcoal particles were observed in samples of peat, accumulated the 1960th to the 1990th, and probably reflects the use of brown coal as fuel in the region. During the last twenty years the industry and agriculture in the territories adjacent to the Reserve fell into decay that was reflected in compositions of pollen assemblages.
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***Keywords*:** Holocene, pollen analysis, peatland, land use history, European Russia

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New PPEs for key Mediterranean taxa

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Global climate projections show that the Mediterranean is one among the most sensitive regions to the future climate change, especially concerning moisture availability (IPCC, 2014). During the last decade, Mediterranean climate modelling has been developed in order to address this issue at a regional scale (Lionello *et al.*, 2006). Reliable estimates of past land cover are critical for assessing potential effects of anthropogenic land- cover changes on past earth surface-climate feedbacks. Pollen-based reconstructions of past land cover, inferred from the 'Regional Estimates of VEgetation Abundance from Large Sites' model (REVEALS, Sugita,2007), have a great potential to serve to evaluate vegetation-climate interactions over long time periods. Pollen Productivity Estimates (PPE) are important parameters in current pollen

dispersal and deposition models used to reconstruct past vegetation. While PPE have already been obtained for several northern European taxa (from Broström *et al.*, 2008; Mazier *et al.*, 2012), PPE for Mediterranean taxa have never been investigated before. This study presents the first attempt to quantify PPE for dominant mediteranean taxa in the Montpellier area (southern France). These PPE were calculated using Extended R-Value models (e.g. Prentice & Parsons, 1983; Sugita,1993), modern pollen data from moss pollsters and related distance-weighted vegetation data from twenty four sites randomly located. They will then be used to infer past land-cover in the Mediterranean area. This study is part of the PAGES working group LandCover 6k (http://www.pages-igbp.org/ini/wg/landcover6k/intro).

***Keywords*:** Meditteranean, Pollen productivity estimates, Pollen dispersal, Modelisation, Quantification.

Relative Pollen Productivity and Relevant Source Area of Pollen in Changbai Mountains and Taiyue Mountains of China

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The relationship between pollen and vegetation is affected by many factors. Relative pollen production (RPP) and relevant source area of pollen (RSAP) are the most important factors to correct the relationship. Therefore, the pollen production of plants from one region and its pollen source area must be determined to interpret pollen assemblages and recover paleovegetation and paleoclimate correctly. This paper estimated the RPPs for 14 pollen types from Changbai Mountains and 11 pollen types from Taiyue Mountains, as well as RSAP of study areas using the ERV model based on detailed vegetation survey from 36 points in Changbai Mountains and 30 points in Taiyue Mountains. Results show that RSAP of Changbai Mountains is about 800 m, whereas that of Taiyue Mountains is about 450 m. Wind speed and pollen fall speed have little influence on the RSAP. With Quercus as a reference taxon (RPP = 1), among 14 pollen types in Changbai Mountains, RPPs of *Pinus*, *etc.* is relatively high; RPPs of Chenopodiaceaeetc. etc. is moderate; and RPPs of Cyperaceae etc. is relatively low. Among 11 pollen types in Taiyue Mountains, RPPs of *Pinus*, *Betula* etc. is relatively high; RPPs of Ranunculaceae etc. is moderate; and RPP of Cyperaceaeis relatively low. Vegetation composition, regional climatic characteristics and other reasons could make the RPP of same pollen type remarkably different in various areas. Hence, estimated RPPs in one area should not be directly applied to another area.

***Keywords*:** Changbai Mountains, Taiyue Mountains, ERV model, Relative pollen productivity Relative source area of pollen

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Potentiality of past vegetation land cover reconstruction in forest - high Andean steppe ecotone of Southern Patagonia, Argentina - First results

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High-altitude climatic treelines are sensitive biomonitors of past and recent climate change and variability. Many authors have demonstrated that high elevation treeline responses can act as an “early-warning” of climate

change impacts through structural, positional and compositional changes. Southern Hemisphere temperature reconstructions show extreme warm periods between 850-650 cal yr BP (and since 1950), with an extreme cold period between 550-250 cal yr BP. These oscillations are expected to have influenced the upper treeline of the forest and the forest - high Andean steppe in Southern Patagonia. These variations last for more than a hundred years, long enough to have a sustained effect on several tree cohort life cycle attributes that could be register in the palaeoecological high altitude records. Past vegetation dynamics have been qualitatively or semi-quantitatively reconstructed largely by pollen and charcoal records from peatbogs and lakes since middle twentieth century. There are not yet reported Holocene reconstructions of past vegetation land cover for South American ecosystems. The main limiting factor to apply this technique is the lack of information about two main parameters, the sedimentation velocity and the Relative pollen productivity estimates from the main pollen types. Southern Patagonia high Andean steppe communities adjacent to treeline present a high plant diversity and include peatbog, prairie and dwarf shrub patches. In contrast, the upper *Nothofagus* forests are composed by monospecific closed canopy stands with a low understory vegetation diversity. We present a first approach to understand pollen-vegetation relationships by comparing modern pollen samples coupled with vegetation surveys around each sampling point. We highlight the main pollen types associated to modern communities by ordination analysis and correlate modern forest land cover at different concentric radii with *Nothofagus* pollen percentages from modern pollen samples. The ordination analysis suggests that pollen assemblages from the high Andean steppes differ from treeline forest assemblages although pollen samples were arranged close to one another. Thus, past changes on Southern Patagonia treeline position could be detected palynologically from peat-bog sediments. The correlation analysis show an r = 0.8 between forest land cover at 1500 meters concentric radii (oriented according to the prevailing wind direction) and *Nothofagus* pollen percentages. These first results will help us to focus future research to apply Multiple Scenario Approach to reconstruct past treeline communities land cover at different periods during the last 1500 years and compare the vegetation changes to those expected in the context of current global warming.

Keywords**:** past land cover reconstruction, *Nothofagus* forest- high Andean steppe ecotone dynamics, surface pollen samples, pollen-vegetation relationship.

Comparison of relative pollen productivity from forest steppe, typical steppe and desert steppe in Inner Mongolia

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Relative pollen productivity (RPP) is a ratio of the absolute pollen productivity to the reference taxon (e.g. Artemisia). RPP is the important parameter to the quantitative reconstruction of paleovegetation in landscape. In order to compare RPPs of different area, we conducted vegetation survey and pollen collection in Hulunbuir, Xilinhot and Sonid Left Banner. Five common pollen taxa including Artemisia, Compositae, Gramineae, Cyperaceae and Chenopodiaceae were chosen. These taxa widely distributed in these tree areas, The results showed that the order of fall speed from large to small is Gramineae (0.032 m/s), Cyperaceae (0.027 m/s), Chenopodiaceae (0.027 m/s), Artemisia (0.021 m/s) and Compositae (0.019 m/s). RPPChenopodiaceae is the largest and RPPGramineae is the smallest. RPPs of the same pollen taxa are different in three areas. For example, in Hulunbuir forest steppe, when RPPArtemisia is 1.00, RPPCompositae is 0.33, RPPGramineae is 0.44, RPPChenopodiaceae is 4.78 and RPPCyperaceae is 1.21; But in Xilinhot typical steppe, when RPPArtemisia is 1.00, RPPCompositae is 4.72, RPPGramineae is 0.01, RPPChenopodiaceae is 2.05 and RPPCyperaceae is 1.31 x 10-4; However, in Sonid Left Banner desert steppe, when RPPArtemisia is 1.00, RPPCompositae is 6.72, RPPGramineae is 2.15, RPPChenopodiaceae is 36.25 and RPPCyperaceae is 0.41. The main reason for the difference of RPPs in different areas is likely the species diversity in different vegetation types. We found that relevant Source Areas of Pollens (RSAPs) in all the three areas are less than 20 m. Our study suggests that vegetation should be distinguished from forest steppe or steppe by pollen assemblage and then select the appropriate RPPs when using RPPs to reconstruct paleovegetation, which will result in an accurate vegetation reconstruction.

Keywords**:** relative pollen productivity (RPP), fall speed, relevant source areas of pollen (RSAP), steppe, Inner Mongolia

REVEALS-based reconstruction of the past regional vegetation in Tango peninsula, Japan: Use of pollen productivity estimates independent of dispersal models

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Pollen-based reconstruction has often been intuitive rather than quantitative. The Landscape Reconstruction Algorithm (LRA) has provided an objective framework of quantitative reconstruction of the past vegetation and land cover. Although the LRA-based approach has proved to be effective in northern Europe and elsewhere, a further improvement is possible. The LRA requires reliable sets of parameters and a robust pollen dispersal function that help reduce biases caused by intertaxonomic differences in pollen productivity and dispersal. One of the critical parameters is pollen productivity estimate (PPE). Recent studies have suggested that PPEs obtained with the Extended R-value model approach and its variants, which are now commonly applied, can potentially be biased by the selection of pollen dispersal models. In this study, we quantify the past changes in regional vegetation in Tango Peninsula of Kyoto Prefecture, Japan, using the REVEALS model – the first step of LRA – with pollen productivity estimates that are measured by a "flower trap" method for major tree taxa. This method provides PPEs independent of pollen dispersal model. Fossil pollen records from two lakes and five bogs in the area are used for vegetation reconstruction. First, the modern vegetation composition of the region, which is calculated from a vegetation map distributed by Japanese Ministry of the Environment with GIS, is compared with the pollen-based estimates from surface sediment samples at individual sites. The REVEALS results are much closer to the GIS-based vegetation composition than the pollen percentages alone, indicating the usefulness of the PPEs independent of dispersal models. However, pollen percentages and the REVEALS results of *Quercus* subgenus *Lepidobalanus* (deciduous oaks) are rather low, comparing with the mapped area of "deciduous oak forests". We suspect that the "deciduous oak forests" category includes many other broadleaved tree taxa, making the actual composition of deciduous oaks smaller than indicated in the map. Second, we reconstruct the regional vegetation composition over the past 7000 years at every 500 years; the REVEALS results suggest that *Cryptomeria* trees were much less abundant and *Pinus* and deciduous broadleaved trees more abundant than pollen percentages alone would suggest. Comparing with PPEs obtained in northern Europe, the variation of PPEs in Japan is relatively small among taxa: 2.3 in average of 12 taxa against Poaceae. With PPEs independent of dispersal models the REVEALS model provides realistic estimates of the regional vegetation history in our study area of Japan.

***Keywords*:** pollen analysis, quantitative vegetation reconstruction, pollen productivity estimate, the Landscape Reconstruction Algorithm, the REVEALS model

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Holocene land-use/land-cover changes based on pollen and paleoecological records from archaeological sites around Lake Biwa, Japan

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Past land-cover change related to human land-use during the Holocene is an important issue for ecology, archaeology, history, and paleoclimatology. For reconstruction of the past land-use/land-cover changes during the Holocene, collaboration with archaeologists and archaeological data can be fruitful for paleoecology. In this presentation, we introduce paleoecological data from archaeological sites around Lake Biwa, western Japan, in addition to our present status of collaborative works with archaeological data. We checked 2236 reports of excavation in Shiga prefecture stored in Lake Biwa Museum. Paleoecological data were included in 200 archeological sites and pollen data were included

at 61 archaeological sites. Age code was added to each layer for the paleoecological data. Pollen sites were mainly located in the lowland area of the southern part of Lake Biwa, because of developing activity and condition of pollen preservation. Paleoecological data for the older period (e.g. the early Holocene) were limited in this region. Based on the pollen records from the archaeological sites around Lake Biwa, deciduous broad-leaved forests mainly composed by *Quercus* subgenus *Lepidobalanus* were dominant during Initial Jomon period. After Middle Jomon period, dominant forests around Lake Biwa changed to evergreen broad-leaved forests composed by *Quercus* subgenus *Cyclobalanopsis*. Especially in Late Jomon period, *Cryptomeria japonica* increased with the evergreen forests. Two steps of land-cover changes were recognized around the region during the last 2,500 years affected by human activities. In the first step, secondary forests composed by *Pinus* and rice paddies increased after Yayoi period, although *Quercus* subgenus *Cyclobalanopsis* and *Cryptomeria japonica* were still abundant. In the second step, rapid increases of secondary forests and rice paddies were occurred after Kamakura period, while *Cryptomeria japonica* decreased. In addition, differences in those land-cover changes were recognized between the inland and the highland areas in the southern part of the region. Increases of secondary forests composed by *Pinus* in the lowland area occurred earlier than that in the highland area after Yayoi period. Land-use changes such as human subsistence and settlement around Lake Biwa will be also discussed based on archaeological data compared with those land-cover changes.

***Keywords*:** archaeological site, pollen record, paleoecological data, land-use/land-cover, Lake Biwa

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Human impacts on vegetation during the late Holocene in the Chugoku Mountains, western Japan

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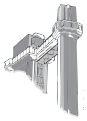
Japanese forests have been heavily impacted by human activities. The increase in *Pinus* pollen during late Holocene was observed in almost all pollen records in Japan, as a result of human impacts (Tsukada, 1988). However, the direct cause of vegetation change can vary according to local human activities. For example, late Holocene vegetation change in the northern Kyoto Basin was closely tied to the pottery industry and fuel wood collection (Sasaki and Takahara 2011). The Chugoku Mountains, which lies on the western part of Honshu Island, is known as iron production area since the seventh century. To elucidate impacts of ancient manufacture on vegetation, sediment samples from two sites, at Akana site and Hiruzen site in the Chugoku Mountains, were analyzed for pollen and charcoal. Pollen record from the Akana site shows that *Cryptomeria* forest with *Pinus* and *Quercus* subgenus *Lepidobalanus* (deciduous oaks) had been developed at ca. 2000 cal yr BP. In the Medieval (ca. 700 cal yr BP), *Cryptomeria* pollen decreased markedly, and *Pinus*, *Quercus* subgenus *Lepidobalanus*, Poaceae and *Artemisia* pollen were increased indicating open landscape. At Hiruzen site, pollen record suggests that secondary forest dominated by deciduous oaks had been developed at ca. 2000 cal yr BP. At ca. 1000 cal yr BP, *Pinus*, Poaceae and *Artemisia* pollen increased coincidentally with an increase of charcoal particles. It suggests that open landscape was established by fire disturbance. Many iron-smelting sites, which worked in sixth to eighteenth century, were excavated in the Chugoku Mountains. Based on comparing pollen and charcoal records with archaeological and historical records, it is suggested that decrease of forest resource at two sites were caused by manufactures, which consume a large amount of wood such as iron working. Also, in the lower part of sediments, which correspond to the early Holocene, charcoal concentrations are rather high comparing with the late Holocene, suggesting that frequent fire disturbances during the early Holocene.

***Keywords*:** Holocene, pollen analysis, charcoal analysis, human impact, Iron working



TERRESTRIAL RESPONSE OF THE TRIASSIC – JURASSIC BOUNDARY EVENTS: EVIDENCE FROM PALAEOBOTANY AND PALYNOLOGY

Yongdong Wang, Mihai Popa, Vivi Vajda, Stephen McLouglian, Majka Babacka & Mike Pole

Interactions and associations in a Jurassic geothermal landscape from Patagonia, Argentina

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Herein, we describe diverse examples of interactions and associations between plants, fungi, bacteria, animals and protists in a Jurassic geothermal landscape in southern Patagonia (Santa Cruz, Argentina). Fossils are preserved as silicifications in cherts deposited in La Matilde and Chon-Aike formations of the Bahia Laura Group in north-central Santa Cruz, Patagonia, Argentina. Interactions include parasitism represented by fungus-infected plant organs, and pollen and spores showing a variety of host reaction responses. The presence of galls and other decay scars in a wood specimen infected with actinomycetes and fungi also reveals parasitic interactions. Mutualism has also been recorded, being characterized by young plant roots infected by arbuscule-forming fungi. Various other interactions are recorded as diverse decay patterns left by fungal decomposers and xylophagous insects on wood. Interactions are also deduced from the contents of a diversity of coprolites present, which indicate a range of animals specializing in single components and others on a variety of elements. Associations include different forms of epiphytism by fungi, cyanobacteria and protists on plant stems. Furthermore, associated with cyanobacteria filaments are epiphytic algae that occur tightly packed at their bases. Altogether, this new survey of the interactions and associations provides an unusually rich source of information about ecological dynamics in a Jurassic landscape. Represented are a range of roles for fungal, animal, plant, bacteria and protist components of the community comparable to those developed by extant counterparts in modern environments. In addition, it shows that formation of endomycorrhizae probably was a common form of coping with unusually extreme parameters in the geothermal systems. Our survey also suggests that a number of animals occupied different trophic positions in the community, mutually influencing one another by acting as specific and generalist consumers. It also shows that the associations between different biotic components responded to mutual influences triggered by living in the same environment (or niche superposition) or to more specifically driven mechanisms, in ways that affected all parts involved. This report provides a promising starting point for the reconstruction of the structure and functions of the Jurassic geothermal landscapes in Patagonia. As such, it represents a unique window into the past about biotic interactions and associations in Jurassic terrestrial ecosystems.

Keywords**:** biological interactions, Jurassic, geothermal ecosystems, fossil microorganisms, ecosystem structure and function

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The missing root of *Ginkgo* wood evolution

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The maidenhair tree or *Ginkgo* is often described as a "living fossil". It is one of the very few extant plant group that can be traced back in deep time to the Jurassic, at about 170 Myr ago. Since *Ginkgo apodes* Zhou and Zheng, the "missing link" in *Ginkgo* evolution, has been described from North-Eastern China, the genus has a quite complete fossil record lineage, documenting different organs including leaf, pollen, reproductive structures, long and dwarf shoots. Such a complete record lineage is of great interest for phylogenetical studies and to decipher the potential role of developmental heterochronies in the evolution of Ginkgoales. A tree is made of wood. Wood ecophysiology is recognized as a first order factor in plant evolution. Unfortunately, the fossil wood record for *Ginkgo* is very scanty, with no established data predating the Late Cretaceous, i.e. ca. 100 Myr. Some woods older than the Cretaceous with supposed and putative relationship link to the Ginkgoales were described as a variety of taxa, such as *Baieroxylon* Greguss, *Palaeogingkoxylon* Feng, Wang *et* Roessler, *Primoginkgoxylon* Süß, *Progingkoxylon* Zheng et Zhang and *Protogingkoxylon* Zheng *et* Zhang *ex* Khudaiberdyev. These fossil records predating the Cretaceous are supposedly linked to the Ginkgoales; however, there is no evidence of direct and certain systematic relationship with *Ginkgo*. Such relationships is hypothesized for isolated secondary xylem pieces mostly on the basis of the occurrence of tracheid bunches, with their tips bent alongside the rays (intrusive tracheids), according to a Greguss' statement. However, assigning Palaeozoic, Triassic or Jurassic woods to Ginkgoales represents a challenging task, because there is no consensus with regards to Palaeozoic Ginkgophytes systematics or wood anatomy; and the use of a single xylological feature (intrusive tracheids) is risky, while several other features (e.g. araucarian radial pitting) are strongly departing from modern *Ginkgo* wood anatomy. To sum up, *Ginkgo* wood anatomy before the Cenomanian is a matter of hypothesis. We report a new Mid-Late Jurassic fossil wood from North-Eastern China. While the leaf and reproductive structures of northeastern China based *Ginkgo apodes* filled a 100 Myr gap in the fossil record of *Ginkgo* leaf and sexual organs, the present fossil wood, at 153-159 Myr ago, roughly a little younger than *Ginkgo yimaensis*, however, represents the oldest known *Ginkgo* species. It thus documents earliest *Ginkgo* wood anatomy and establishes what could be called the missing "root" for *Ginkgo* wood evolution.

***Keywords*:** Ginkgoales, fossil wood, *Ginkgoxylon*, Middle Jurassic, Western Liaoning

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Vegetation changes and terrestrial ecosystem variations across the Triassic-Jurassic transitions in the Sichuan Basin, China: progresses and perspectives

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The terrestrial Triassic and Jurassic sequences are continuously cropped out in the Sichuan Basin, China yielding diverse fossil biota. The Upper Triassic deposits are represented by the Xujiahe Formation with abundant and diverse fossil, including plants, spore-pollen, bivalves, conchostracans and ostrocodes, indicating Norian to Rhaetian age. The Lower Jurassic sequences Zhenzhuchong and Ziliujing Formations consist of shell limestones, purple red mudstone and limestones with sandstone or variegated bed. The former formation is the basal part of the sequence (ca. corresponding to the Hettangian). The Triassic/Jurassic boundary is defined in between the Upper Jurassic Xujiahe Formation and the base of Lower Jurassic Zhenzhuchong Formation. The fossil vegetation in the Xujiahe Formation include four plant communities, such as coastal hydrophyte community, marsh humid hygrophyte community, bank & plain hygrophyte to Mesophyte shrub, arborescent forest community, and the mesophyte and xerophyte upland forest community. However, the Early Jurassic floras of the Sichuan Basin are featured by the dominance of ferns and cycads, the rise of the Dicksoniaceae, the decrease of pteridophytes and the occurrence of ginkgophytes and conifers. It is noteworthy that some arid and hot elements (*Brachyphyllum* and *Pagiophyllum*) have been described from this flora showing important climate significances. Our recent survey demonstrates that the Late Triassic climate is fluctuated with some temperature decreasing events in the general background of warm and humid climate conditions, based on fossil wood and palynological evidences. The climate in the Early Jurassic shows close succession relationship with the Late Triassic Xujiahe Period in northeastern Sichuan regions. It prevailed by hot and humid conditions and the temperature increase while the humidity decrease compared with than that of Late Triassic. Palaeobotanical and geochemical data also show the wide fire activities recorded across the Triassic and Jurassic transitions in the Sichuan basin.

***Keywords*:** vegetation change, terrestrial ecosystem, Triassic-Jurassic boundary, Sichuan Basin, palaeoclimate

Proliferation of cyanobacterial mats as a response to the end-Triassic event – evidence from Sweden

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Wrinkle structures are microbially produced sedimentary structures (MISS) formed by cyanobacteria and are rare in the Phanerozoic record. We document the first wrinkle structures in the Mesozoic succession of Sweden, and one of the first global occurrences in earliest Jurassic successions. The Swedish wrinkle structures are of *Kinneyia*-type and developed in the shallow subtidal or lower intertidal zone, i.e., in a deeper environment compared to where modern mats develop. Palynostratigraphy indicates a late Hettangian (earliest Jurassic) age of the deposits, i.e., relatively soon after the Late Triassic mass extinction event. Since perpetually wet, and thus soft, microbial mats are susceptible to grazing. The presence of wrinkle structures may be explained by lower bioturbation and grazing associated with the mass extinction. The palynological analyses of fine-grained sandstones hosting the wrinkle structures further show that the local terrestrial environment consisted of a wetland hosting ferns, cypress and the extinct conifer family Cheirolepidaceae. The finding of wrinkle structures is significant as the presence of microbial mats in the shallow subtidal zone, (in a deeper setting compared to where modern epibenthic microbial mats grow) suggests decreased benthic biodiversity and suppressed grazing in shallow marine environments in the early aftermath of the end-Triassic mass extinction event.

Keywords: Jurassic, Sweden, Cyanobacteria, palynology, mass extinction

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Palynofloral and palaeoenvironmental variations across the Triassic-Jurassic transition in the northeastern Sichuan Basin, China

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The end-Triassic mass extinction is one of the five largest extinctions in the Phanerozoic, but the terrestrial records of floral turnover across the Triassic-Jurassic boundary are relatively scarce in East Asia. In this study, a detailed investigation of well-preserved palynomorphs of Late Triassic-Early Jurassic terrestrial deposit in Xuanhan region of northeastern Sichuan Basin, China, has been conducted to reconstruct the palaeoclimate and palaeoecosystem variations. The palynoflora in the Xujiahe and Zhenzhuchong Formations shows a high diversity of spores and pollen grains, including 148 species of 67 genera. Three assemblages were recognized in ascending order: the *Dictyophyllidites-Cycadopites-Annulispora*, *Pinuspollenites-Chasmatosporites-Quadraeculina*, and the *Cyathidites-Classopollis* zones. These three zones indicate different geological ages: Norian-Rhaetian (Late Triassic), Triassic-Jurassic transitional period, and Hettangian to Pliensbachian (Early Jurassic). Palaeovegetation reconstruction shows a predominance of fern floras, followed by gymnosperms represented by conifers during the Late Triassic; at the latest Late Triassic, conifers and cycadophytes/ginkgophytes increased, whereas ferns decreased; at the earliest Early Jurassic, ferns were the most abundant, represented by the Cyatheaceae/Dicksoniaceae; conifers were less abundant, the Cheirolepidiaceae began to develop; during the Early Jurassic, conifers became thriving, represented by the Cheirolepidiaceae, among fern plants, Cyatheaceae/Dicksoniaceae displaced the Dipteridaceae. The Sporomorph EcoGroup model analysis suggests several climate variations of the Late Triassic-Early Jurassic time in Xuanhan region, including a warm and humid climate generally prevailed during the Late Triassic period interrupted by a relatively cooler and drier period (Member 2 of the Xujiahe Formation); it was cool and dry during the late Late Triassic; at the beginning the Early Jurassic, it became warm and humid; later during the Early Jurassic, it has a cooling and drying trend upward. The palynofacies analysis indicates a general fluvial-deltaic and peat mire sedimentary environment during the Late Triassic-early Jurassic in Xuanhan region, four palynofacies assemblage zones are recognized, reflecting two distinct distal- proximal sedimentary cycles. Besides, the Xujiahe and Zhenzhuchong Formations are gas prone. Plant community analysis reveals a major change across the T-J boundary in Xuanhan region, from conifer dominated forest of the latest Late Triassic to predominately understory and ground cover vegetation of the earliest Early

Jurassic. This may be affected by the wildfire activity across the T-J boundary in the Sichuan Basin. This study reveals the terrestrial ecosystem variations across the Triassic/Jurassic boundary in the Sichuan Basin, and thus provides important evidence for understanding the response of terrestrial vegetation to regional and global environmental changes across the Triassic/Jurassic transition.

***Keywords*:** Sichuan Basin, Triassic-Jurassic, palynoflora, palaeoclimate, palaeoenvironment

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Diversity variation and tempo-spatial distribution of the Dipteridaceae ferns in the Mesozoic of China

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The extant family Dipteridaceae is a remarkable leptosporangiate fern because it includes only one genus with a restricted distribution to tropical regions. The fossil record of this family has been widely reported from Mesozoic strata in Eurasia, America, Australia and Greenland. In China, numerous fossils of the Dipteridaceae have been documented, in total, about 74 species of 6 genera. Geographically, they are distributed both in the Southern and Northern Floristic Provinces, and were particularly well developed in the Southern Floristic Province during the Late Triassic and the Early Jurassic intervals. Fossil diversity of Dipteridaceae varies in the different episodes of the Mesozoic in China. It is shown that Dipteridaceae has undergone a diversity development process and a distinct turnover during the Mesozoic. They appear to have diversified in the warm and humid Late Triassic–Early Jurassic, but declined sharply as aridity developed in the Middle Jurassic, and became extinct at the end of the Early Cretaceous. The diversity variation and tempo-spatial distribution pattern is suggested to be linked with paleoclimatic variations during the Mesozoic.

***Keywords*:** Dipteridaceae, Mesozoic, fossil records, tempo-spatial distribution, diversity variation, China

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Fossil plant cuticles as proxy for volcanic SO_2 emmissions at the Triassic-Jurassic boundary

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Flood basalt volcanism has been implicated in several episodes of mass extinctions and environmental degradation in the geological past, through global warming caused by highly elevated CO_2 concentrations. The Triassic-Jurassic boundary (Tr-J), coinciding with CAMP volcanism, is one such event. Recently attention has turned to additional volcanic products as aggrevating factors in these events, in particular sulfur dioxide (SO_2). To understand the mechanisms behind mass extinction events, it is important to distinguish between the driving agents, but it has so far proven difficult to recognize the presence of SO_2 in the geological record. In an effort to address this, two studies have recently explored the possibility of detecting SO_2 in the past, one through studying fossil leaf shape across the Tr-J and another through investigating the effects of SO_2 on the cuticle structure of modern analouges of Mesozoic plants. Here, we present new data showing that fossil plant cuticles may indicate the presence of SO_2 at the Tr-J. Plant cuticles are highly resistant polymeric structures, which often persist as fragments in sediments, even when macrofossils are not available, and therefore have large potential as proxies. We show that damaged cuticle structures from the Tr-J are consistent with modern cuticle SO_2-caused damage and with leaf-shape changes across Tr-J, thus identifying cuticle structure changes as a useful proxy for past SO_2 emmisions.

***Keywords*:** Fossil plant cuticles; SO_2 proxy; flood basalt volcanism; Triassic-Jurassic boundary; end-Triassic mass extinction

THE MESOZOIC PLANT FOSSIL CUTICLES: COMPARATIVE ANATOMY, FINE STRUCTURES AND THEIR SIGNIFICANCES FOR EVOLUTION AND PALAEOENVIRONMENTAL CHANGE

Gaëtan Guignard, Yongdong Wang, Mihai Popa,
Majka Babacka & Georgina Del Fueyo

Plant fossil cuticles and Ultrastructure, a short review

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Plant cuticle covers plant epidermis of many leaves and non-lignified axes, and this organic mould is very precious for fossil studies. Cuticle studies increased significantly from the XIXth century, for instance the term "cuticule" is used in French by Zeiller in the late century, even associated with an extraction method from the sediment to get a clean material observable with the microscope, and he also provides in the plates transversal sections showing stomata. In this period, he reports about "cuticules" material worldwide, including Brazil, Russia, Argentina, Vietnam, China, India. In fact, as this very thin layer can resist almost intact despite millions years in the sediment, a large variety of methods are used to extract useful data, among them transmission electron microscopy TEM allows fruitful interpretations with ultrathin sections of 60-70 nanometers. These very fine detailed studies began in the years 1985-90 with Archangelsky and Taylor, since then a good number of results were achieved enhancing diverse interpretations on various plant groups. In this short review, after summarizing some methods, three among the various aspects of cuticle statistical studies will be detailed in Ultrastructure and also partly in recent EDS elemental analysis: Taxonomy, Palaeoenvironment and Evolution.

Keywords**:** fossil plant cuticles, ultrastructure and EDS analyses, Taxonomy, Palaeoenvironment, Evolution

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Reconstructing paleoatmospheric CO_2 levels based on fossil *Ginkgoites* from the Upper Triassic and Middle Jurassic in Northwest China

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Fossil Ginkgophyta are one of the most widely used indicators for estimating the paleoatmospheric CO_2 levels during the Triassic to present day. There are quite a few CO_2 estimates for the Triassic to Jurassic interval; however, the data from China are still limited. In this study, two fossil *Ginkgoites* species, *Ginkgoites magnifolius* Du Toit and *Ginkgoites obrutschewii* (Seward) Seward are described based on recent collections from the Upper Triassic and Middle Jurassic in Huating County, Gansu Province, Northwest China. The fossil leaf morphology and epidermal structure was studied and the stomatal parameters were analyzed for the reconstruction of paleoatmospheric CO_2 concentrations. The paleoatmospheric CO_2 concentration during the Late Triassic of China is estimated for the first time based on fossil material from Gansu. Our fossils yield paleo-CO_2 values of 1962 ppmv in the Late Triassic and 1320 ppmv in the Middle Jurassic. Compared with previous estimates of atmospheric CO_2 concentration based on stomatal parameter of fossil *Ginkgo/Ginkgoites* from Northwest China, the change of Jurassic paleo-CO_2 levels accord with the trend of CO_2 concentration proposed by GEOCARB III and Crustal Production models. The results demonstrate that the paleo-CO_2 of the Late Triassic was higher than that of the Early to Middle Jurassic; but an increasing trend of paleo-CO_2 could be detected from the Early to the Middle Jurassic. However, GEOCARBSULF model indicates a decreasing trend during this interval. Therefore, the present data provide an independent check for the paleo-CO_2 values estimation based on isotopic analysis.

Keywords**:** *Ginkgoites*, stomatal parameters,·CO_2 concentration, Triassic, Jurassic

Cuticle ultrastructure of *Pseudofrenelopsis gansuensis*: further taxonomical implications for Cheirolepidiaceae

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The application of transmission electron microscopy (TEM) in palaeobotany began in the late the 1980s. Recently two species of Cheirolepidiaceae, *Pseudofrenelopsis dalatzensis* and *Suturovagia intermedia* have been studied. The result shows that the proportions of cuticle proper and cuticular layer in the epidermal cell cuticular membranes, the wavy, the polylamellate and the granular layers in cuticle proper differ among cheirolepidiaceous conifers. A new study on *Pseudofrenelopsis gansuensis* from the Lower Cretaceous of Wangqing, Jilin Province, China is conducted in detail with scanning and transmission electron microscopy. In total, nine ultrastructural features are recognized, which are helpful in distinction cuticles of ordinary epidermal cells, subsidiary cells and guard cells of the stomatal apparatus, and hypodermal cells as well. As a result, a three dimensional reconstruction of the cuticle ultrastructue is made. It is the second species of this genus (the third species of family Cheirolepidiaceae) of which the cuticle ultrustructure is studied statistically with 30 measurements and the confidence interval values estimated. A close comparison of cuticle ultrastructure characters (including statistical data) among Cheirolepidiaceae and other fossil conifers provides further evidence for their taxonomic significance: thirteen of them appear to be of value in specific separation, and fourteen useful in generic and three in family determination.

***Keywords*:** Cheirolepidiaceae, *Pseudofrenelops*, cuticle ultrastructures, Cretaceous, China

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Conifers from the Jurassic Daohugou Flora in Northern China and their biogeographic implications

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The Jurassic Daohugou biota in northern China represents exceptionally preserved fossil ecosystems and it has revolutionized our understanding of animal and plant evolution. The discoveries of feathered dinosaurs, early mammals, pterosaur and a mass of excellent insects in these strata are some of the most notable findings, but the deposits have also yielded a host of plant remains that provide the evidence of an array of biogeographic diversity of Mesozoic plants. According to the preliminary study on the plant fossils collected from the Daohugou biota, this flora contains at least 64 plant taxa that belong to algae, bryophytes, lycopsida, horsetails, ferns, seed ferns, bennettites, czekanowskiales, ginkgoaleans, conifers, early angiosperms and gymnosperms of unknown systematic affinity. In this flora, conifers are the most diversified and well-preserved plants. These conifer materials consist of impressions and compressions represented by well-preserved leafy twigs and branches as well as ovulate cones and pollen cones. Based on the macromorphology and microstructures of epidermal features and bract-scale complexes, we have identified about 13 genera and 20 species of conifer taxa. These conifers were classified in the Pinaceae, Cupressaceae, Taxaceae, Podocarpaceae, Araucariaceae, Cheirolepidiaceae, and conifers of unknown classification position. Taxa assigned to be Pinaceae include 4 species of *Pityocladus*, 1 species of *Pityospermum* and 2 species of *Schizolepis*. Cupressaceae consists of *Austrohamia* (*Yanliaoia* ?), which is the most abundant taxa in the flora, and represented by vegetative shoots associated with pollen and seed cones as well as well-preserved bract-scale complexes and seeds. Vegetative shoots with ovules of *Amentotaxus* and *Taxus*, and some leafy shoots assigned to Taxaceae, are described here, the specimens of *Amentotaxus* and *Taxus* may represent the earliest records of these two genera. Fossils of Podocarpaceae are composed of leafy branches, identified by its morphological and microstructural features, and Araucariaceae are present as seed cones and some seed scales. There is only one genus assigned to Cheirolepidiaceae, preserved as leafy shoots and identified as *Frenelopsis* sp. Besides, there are also some leafy branches of conifers, which include 3 species of *Elatocladus*, 1 species of *Brachyphyllum* and 1 species of *Podozamites*. The abundance of conifers in the Daohugou Flora and the earliest occurrence of some genera, suggests that northern China may be the center of distribution and differentiation of conifers in the Middle to Late Jurassic

***Keywords*:** Jurassic, conifers, fossil, Daohugou Flora, biogeographical history, northern China

New Southern Hemisphere stomatal proxy-based pCO_2 record across the Cretaceous-Paleogene boundary supports global pCO_2 trends

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Reliable high-resolution reconstructions of atmospheric carbon dioxide concentrations (pCO_2) are required to resolve the relationship between biotic mass extinctions and changes in paleo-pCO_2, for constraining the pre- and post-extinction atmospheres and potential inter-hemispheric differences. Here we estimate pCO_2 based on fossil Lauraceae leaf cuticle specimens deriving from two localities covering the latest Cretaceous to the late Paleocene, including a new Cretaceous–Paleogene boundary (K–Pg) locality, in New Zealand. We use two independent methods of stomatal density-based pCO_2 reconstructions; transfer functions calibrated using herbarium material and the stomatal ratio method, producing three calibration sets. Our results indicate pCO_2 of at least ca. 540–660 ppm during the latest Cretaceous and across the K–Pg, falling precipitously to ca. 360–420 ppm during the earliest Paleocene, and further to ca. 310–320 ppm in the late Paleocene. A 'spike' of extremely high pCO_2 at the K–Pg could not be confirmed, perhaps due to low sample resolution, but our results are nonetheless consistent with previously published pCO_2 records from the Northern Hemisphere, and show that stomatal density worldwide was responding to significant changes in pCO_2 across the K–Pg.

Keywords**:** Carbon dioxide; stomatal proxy; K–Pg boundary; mass extinction; Lauraceae

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Chemical preservation states of Mesozoic gymnosperms leaves (Santa Cruz and Mendoza, Argentina). A chemometric approach

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The cuticle has numerous functions of essential importance for plant life and provides a broad set of information, including many biochemical investigations in both fossil and extant gymnosperms and angiosperms. In this contribution, two gymnosperm fossil taxa were chemically compared using semi-quantitative Fourier transform infrared (FTIR) spectroscopy. These derived IR-data were then interpreted by principal component analysis (PCA) while a complementary anatomical study was performed using scanning electron microscopy (SEM). The material consists of very well preserved coalified gymnosperm leaves from the Mesozoic of Argentina belonging to *Squamastrobus tigrensis* Archangelsky & Del Fueyo (Coniferales, Lower Cretaceous, Santa Cruz) and to *Jonhstonia coriacea* Walkom (Corystospermales, Middle to Upper Triassic, Mendoza). The resulting multivariate model shows differences in grouping of dataas a function of functional groups (chemical structures), which are related to a variety of preserved features in both taxa cuticles. Furthermore, *Squamastrobus tigrensis* and *Jonhstonia coriacea* fossil plants do not completely conform to any of the three most commonly known, general states of coalified-preserved plant fossils that are mainly defined according to chemical criteria; *i.e*., compressions, fossilized cuticles, and cuticle-free coalified layers. Results also indicate that a number of different physico-geochemical conditions proceeding along a multidimensional continuum, resulted in different preservations states which can occur in nature. In fact, specimens of *S. tigrensis* and *J. coriacea* can be considered as in-between stages of the wide spectrum of organic matter transformations. It is a contribution to grants ANPCyTPICT 2012/528 and CONICET PIP 112-201201-00212.

Keywords**:** spectrochemistry, preservation, compressions, Cretaceous, Triassic.

UNDERSTANDING CLIMATE VARIABILITY IN A WARMER THAN PRESENT PLIOCENE WORLD

Ulrich Salzmann, Matthew Pound & Stijn De Schepper

Late Pliocene/early Pleistocene environments of northeastern Siberia inferred from Lake El'gygytgyn pollen record

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The Arctic is known to play a crucial role within the global climate system. Therefore, the development of possible scenarios of future climate changes is a major scientific challenge. However, reliable projections are hampered by the complexity of the underlying natural variability and feedback mechanisms. An important prerequisite for the improvement of the climate projections is a better understanding of the long-term Arctic history. Continuous high-resolution sequences penetrating the entire Quaternary and further into the Pliocene are is highly desired. Such a record has now become available from Lake El´gygytgyn located in northeastern Siberia. The lake lies within a meteorite impact crater located 100 km to the north of the Arctic Circle in Chukotka Peninsula, northeastern Russia (67°30' N, 172°05' E). The crater was created nearly 3.6 Myr ago in volcanic target rocks. The impact formed an 18 km wide hole in the ground that then filled with water. The modern lake is 170 m deep and has a roughly circular shape with a diameter of 12 km. The ICDP drilling projectf has completed three holes in the lake penetrating about 318 m thick lake sediments. The cores offer unique opportunities for paleoclimate research, allowing the time-continuous reconstruction of environmental history of the terrestrial Arctic. Our studies show that Lake El´gygytgyn sediments are an excellent archive of vegetation and climate changes since ca 3.55 Myr BP. Pollen assemblages can be subdivided into zones well reflecting the main paleoenvironmental fluctuations in the region. Climate conditions were the warmest 3.5-3.35 Myr BP. Conifeous forests dominated the vegetation in nowadays treeless tundra area. After 3.4 Myr BP dark coniferous taxa gradually disappeared from the vegetation. The very pronounced environmental changes are revealed 3.35-3.275 Myr BP when treeless tundra and steppe like habitats dominated the area. Large amounts of coprophilous fungi spores point to a permanent presence of numerous grazing herds around the lake. The dry and cold climate conditions were similar to the Late Pleistocene ones. The treeless environments also revealed at the beginning of the Pleistocene, ca 2.6 Myr BP. The early Pleistocene pollen assemblages reflecting alternation of treeless intervals with cold and dry climate and warmer intervals when larch forests with stone pine were also common in the region. Very dry environmental conditions are revealed after ca 2.175 Myr BP. High amounts of *Botryococcus* point to a shallow water conditions ca 2.55, 2.45, and ca 2.175 Myr BP.

***Keywords*:** Pliocene, pollen, Arctic Russia, vegetation and climate changes

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Early Pliocene mid-latitudinal climate variability and vegetation response – a case study on Zanclean strata of the Lower Rhine Basin

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The rich palaeobotanical record recovered from lacustrine to paludal strata of the earlier Zanclean of the Lower Rhine Basin (LRB, Rotton Fm., NW Germany) allows for studying climate variability at the onset of the Pliocene and the response of vegetation. The studied sediments were deposited during the global sea-level high-stand postdating the Me-2 third-order sequence boundary. According to the available sequence-stratigraphical concept the succession represents a time-span of about 500 kyr. Quantitative climate reconstructions based on the palaeobotanical record (Coexistence Approach) indicate that the early Pliocene climate of the LRB was even warmer compared to the Piacenzian for which a significantly raised

atmospheric CO_2 level of around 400 ppmv is assumed. Based on the analysis of macroflora, a Cfa Koeppen-type climate existed in the warmer phases of the Zanclean, with temperatures being higher than present by up to ca. 5 °C, and with mean annual precipitation exceeding the modern level by ca. 500 mm (modern climate: Cfb Koeppen-type with MAT at 9 °C, CMT at 0 °C, and MAP at 700 mm). Palaeoclimate analysis based on pollen flora allows for reconstructing climate variability at shorter-term scales. Temperature variability is most evident in CMT while climate phases with mild winters had a lower seasonality. Data on precipitation in the warmest and wettest months indicate time shifts of the wet season. Unlike in the Miocene, warmer climate phases of the Zanclean were connected to dryer conditions (less precipitation in the warm season). The observed regional climate dynamics most probably can be related to varying intensity of the NAC. The identification of third order oxygen isotope events in the continental climate record also testifies a close correlation with marine archives. At the same time, the continental strata distinctly reflect signals of the biosphere and thus allows for studying changes of vegetation and biodiversity. At the level of plant functional types, ecospectra reconstructed for the palynofloras display hierarchical cyclicities and biodiversity changes in response to climate variability. E.g. broadleaved evergreen functional types sensitively reflect these changes. Peaking in the late Tortonian the diversity of these components had significantly declined throughout the Messinian. In the warm phases of the Zanclean, broadleaved evergreen functional types attained again higher proportions, but were completely absent from in the cool parts of the climate cycles. Thus, our data point to repeated conversions of the ecosystems existing in the early Pliocene LRB.

Keywords**:** early Pliocene, palaeobotanical record, Lower Rhine Basin, climate dynamics, palaeo-biodiversity

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Climate variability and long-term cooling in Arctic Norway during the Pliocene (ODP Site 642, Norwegian Sea)

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We present the first Pliocene (5.05–3.14 Ma) high-resolution reconstruction of vegetation and climate change in northern Norway based on terrestrial palynomorphs in the marine sediments of ODP Hole 642B, Norwegian Sea (67°N). Pliocene vegetation alternated between cool temperate forests during warmer-than-present intervals and boreal forest similar to today during cooler intervals. The northern boundary of the deciduous to mixed forest zone was displaced by at least 4–8° latitude towards the north and warmest month temperatures were 8–14°C higher than present during warm phases. In three distinct warm climatic intervals (5.05–4.31 Ma, 3.85–3.47 Ma and 3.29–3.18 Ma), diverse cool temperate deciduous to mixed forests predominated in the lowlands of the Scandinavian mountains. These forests consisted of thermophilic taxa such as *Carpinus*, *Carya*, *Quercus*, *Sciadopitys* and *Tsuga* and more boreal elements (e.g. *Alnus*, *Betula*, Cupressaceae, *Juniperus*, *Picea* and *Pinus*) which became predominant at higher elevations. Clear cooling events around 4.31 Ma and 3.47–3.3 Ma, immediately prior to Marine Isotope Stage M2 are characterised by boreal forests and open, low alpine environments at high altitudes. This is evident from the decrease in thermophilic conifers, the predominance of *Pinus* pollen and relative high abundances of Asteraceae and Ericaceae pollen and *Lycopodium* spores. Peatlands expanded at the expense of herb field communities at higher altitudes. After c. 3.29 Ma, in the mid-Pliocene Warm Period, a highly variable climate is indicated by repeated expansion of forests and peatlands during warmer and cooler periods, respectively. These vegetation changes are mirrored by changes in sea surface temperatures (alkenone) and also dinoflagellate cyst assemblage shifts reveal a variable influence of warm waters via the North Atlantic Current.

Keywords**:** Pliocene, pollen and spores, vegetation, climate, Norway

The tropical rain belt of western South America during early Pliocene

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A phenomenon of tropical climate that vividly displays the meeting point of the two hemispheres is the intertropical convergence zone (ITCZ). It is a region encircling the earth where the trade winds meet, characterized by pronounced cloud formation and high levels of precipitation. The latitudinal position of the ITCZ shifts seasonally, but also over longer timescales. While much is known about present ITCZ dynamics, major long-term shifts in the geological past, especially during Pliocene, are still controversially discussed. During Pliocene, the progressive closure of the Central American Seaway (CAS) between 4.7 and 4.2 Ma triggered a major reorganization of ocean and atmospheric circulation, influencing also the ITCZ position. While numerical modelling predicts a cooling of the eastern equatorial Pacific (EEP) surface water directly after CAS closure resulting in a northward ITCZ shift, paleoceanographic data indicate a later EEP cold tongue development and a southwards ITCZ movement. The vegetation in Ecuador strongly depends on precipitation from the southernmost ITCZ extension. A southern ITCZ position and a weak zonal temperature gradient in the Pacific (El-Niño like conditions) enhance precipitation over Ecuador. Our aim is to determine the latitudinal position of the ITCZ over western South America during Pliocene, thereby resolving the contradiction between numerical modelling results and paleoceanographic data indicating shifts in opposite directions. Vegetation and hydrology changes in western Ecuador are investigated using marine palynological techniques. 40 samples from ODP Site 1239 were analyzed focusing on the time window from 4.7 to 4.2 Ma. Pollen types were grouped according to ecosystem or habitat type which they are most characteristic for. The record comprises representatives from páramo, upper montane forest, lower montane forest (LMF) and lowland rainforest (LR). At 4.2 Ma, a strong increase in páramo vegetation is indicated. However, more samples need to be analyzed to confirm this observation. Between 4.7 and 4.2 Ma, the relative abundance of LR pollen and spores increases while that from LMF decreases. The number of spores compared to the number of pollen is generally high throughout this period. Grass pollen is low in abundance which indicates the lack of open habitats and substantiates a broad rainforest coverage. In our preliminary interpretation these findings are an effect of more rainfall. We, therefore, corroborate the hypothesis of a southward ITCZ shift in line with paleoceanographic results.

***Keywords*:** intertropical convergence zone, Pliocene, eastern equatorial Pacific, CAS closure, paleoclimatology

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A terrestrial Pliocene-Pleistocene temperature record from North-Western Europe

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The Mid-Pliocene Warm Period (MPWP) (*ca* 3.3 to 3.0 Ma) serves as an appropriate analogue to our current climate for two main reasons. Firstly, atmospheric CO_2 levels are similar (400-450 ppmv) to present day levels. Secondly, continental configurations during the Pliocene were largely similar to the present day. The MPWP is especially interesting regarding future climate predictions as global temperatures were roughly 2–3 °C warmer than present, indicating that current climate may not yet be in equilibrium. Reconstructions of MPWP sea surface temperatures (SSTs) indicate SSTs were warmer than present, particularly at high latitudes (ΔSST=2–6°C). However, continental temperatures for this interval remain poorly constrained due to a lack of trustworthy proxies, and scarcity of terrestrial sedimentary archives. Here we analysed both marine and terrestrial organic microfossils, as well as branched GDGTs (brGDGTs) in a sediment core from the Netherlands to reconstruct coastal conditions, regional vegetation cover, and continental mean air temperatures (MAT) during the Early Pliocene to mid-Pleistocene. BrGDGTs are membrane lipids of organisms living predominantly in soils whose relative distributions relate with the temperature and pH of the soil in which they are biosynthesized. BrGDGTs can be delivered to coastal marine sediments by fluvially transported soil material. Due to the coastal position of the sample site, land-sea climate correlations can be studied by the marine/terrestrial palynomorph ratio as well as through comparison of marine and terrestrial biomarker based paleo

thermometer indices (*i.e.* U^{k}_{37}, TEX_{86}, and long chain diol index (LDI). The multiproxy record can be divided into four main events: two small 'glacial' events, the MPWP, and the onset of Northern Hemisphere glaciation marking the onset of the Pleistocene, the latter being characterized by unstable and fluctuating temperatures, forest decline and clear progradation of the delta front. The glacial periods have been tentatively assigned according to recently published framework for Pliocene glaciations, the first being the 4 Ma glacial, and the second being the MIS M2 glacial, occurring roughly at 3.4 Ma. Notably, reconstructed SSTs do not correspond to the terrestrial temperature record; TEX_{86}-based SSTs show stable and unchanging conditions. Therefore, we propose that the SST may be affected by an influx of warm North Atlantic waters, caused by the initiation of the modern Nordic Seas circulation, which was in turn influenced by an input of cool Pacific waters through the Bering Strait at 4.5 Ma. Evidence is reflected in the palynology of the core.

***Keywords*:** Pliocene, branched GDGTs, palynomorphs, NW Europe, climate changes

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Challenges in quantifying and understanding Pliocene warming

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Comparing simulations of key warm periods in Earth history with contemporaneous geological proxy data is a useful approach for evaluating the ability of climate models to simulate warm, high-CO_2 climates that are unprecedented in the more recent past. Here we present a global data set of confidence-assessed, proxy-based surface air temperature estimates and biome reconstructions to assess the ability of eight models to simulate warm climates of the Pliocene epoch. The Late Pliocene, 3.6–2.6 million years ago, is an accessible geological interval to understand climate processes of a warmer world. We show that model-predicted terrestrial and sea surface temperatures reveal a substantial cold bias in the Northern Hemisphere high latitudes. Particularly strong data–model mismatches in mean annual surface air temperatures (up to 18° C) exist in northern Russia. Our model sensitivity tests identify insufficient temporal constraints hampering the accurate configuration of model boundary conditions as an important factor impacting on data– model discrepancies. Our studies demonstrate the value of understanding climate variability on orbital timescales, whereby the unique spatial and temporal signatures of individual interglacials or glacial-interglacial cycles highlight sensitive regions. In an effort to better understand Pliocene climate variability over glacial-interglacial timescales, we invite all interested scientists to join our new PAGES working group PlioVar (http://www.pages-igbp.org/ini/wg/pliovar/intro).

***Keywords*:** Pliocene, data-model comparison, Piacenzian, climate change

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Ocean–vegetation interactions in the late Pliocene Nordic Seas region

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We present a high-resolution reconstruction of the variability of the Norwegian Atlantic Current (NwAC) and vegetation in northern Norway during late Pliocene. The reconstruction is based on dinoflagellate cyst and pollen assemblage changes in the sediments of ODP Site 642 (Norwegian Sea) in the time interval from 3.32 to 3.14 Ma. The records cover the PRISM interval (Pliocene Research, Interpretation and Synoptic Mapping, 3.264–3.025 Ma) within the late Pliocene which has been intensely studied because of its similarities to projections of future global warming. The dinoflagellate cyst assemblages are dominated by cysts of *Filisphaera filifera*, *Habibacysta tectata*, *Protoceratium reticulatum*, and *Spiniferites/Achomosphaera*. Other abundant species include *Bitectatodinium* sp. A, *Lingulodinium machaerophorum*, *Nematosphaeropsis labyrinthus*, *Pyxidinopsis*

braboi, and round brown cysts. The cysts of *P. reticulatum* are considered a tracer for North Atlantic water in the Nordic Seas and are dominant in most parts of the record, indicating the inflow of warm Atlantic waters via the NwAC. A decrease in the relative abundance of cysts of *P. reticulatum* together with an increase in the cysts of *H. tectata* at two occasions suggests cooler surface water conditions and a weakened NwAC. These changes in the influence of warm Atlantic waters correlate well with vegetation changes in northern Norway. High abundances of *Pinus* and other conifer pollen (*Abies*, Cupressaceae, *Juniperus* type, *Picea*, *Sciadopitys*, *Taxus* and *Tsuga*), reflecting cool temperate climatic conditions in northern Norway, coincide with high percentages of the cysts of *P. reticulatum* and thus warmer sea surface conditions. In turn, lower abundances of *Pinus* and other conifer pollen together with higher proportions of *Sphagnum* spores co-occur to higher percentages cold water dinoflagellate cysts such as *F. filifera* and *H. tectata*.

***Keywords*:** dinoflagellate cysts, Norwegian Atlantic Current, multi-proxy, vegetation, late Pliocene

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Rock Glacier Ice: A completely new palynological proxy for the reconstruction of Holocene climate and environments

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The interdisciplinary study of an ice and debris core from the 40 m thick active rock glacier Lazaun in the southern Ötztal Alps (South Tyrol, Italy) revealed unexpectedly rock glacier sediments and ice to be excellent palynological proxies. Radiocarbon dated plant macrofossils preserved in the ice fraction of this rock glacier indicated the start of the rock glacier formation around 10'300 cal. BP resulting in two superimposed, active rock glacier lobes, the upper one persisting until today. The inferred age-depth model clarifies very stable deposition of snow, ice and rock debris during the entire Holocene, with the exception of a mid-Holocene drought event. This multi-centennial drought period around 4000 cal. BP and was probably related to reduced snow accumulation and a prevailing warm climate, probably closely related to a general, short-term Mediterranean/Central European climatic reorganization. The palaeoecological study of the ice/debris samples and the quantification of pollen, cryptogam spores, non-pollen palynomorphs, micro-charcoal particles as well as plant and animal macrofossils allowed tracing the former climatically and anthropogenically induced vegetation and environmental changes at alpine altitudes (above 2600 m a.s.l). However, micro-cracks allowing the downward percolation of younger microfossil assemblages (< 150 µm) within the ice-debris sediments below the drought related layer dated to 4000 cal. BP must be implied, probably related to melt-water penetrating the frozen body of the rock glacier along a network of small channels. This result is important in terms of understanding physical and climate related, within-ice processes leading to mid- to long-term pollen downward transport, even if macrofossils (> 150 µm) imbedded within the ice-matrix were not affected by such vertical transport phenomena.

***Keywords*:** Rock Glaciers, European Alps, Holocene, Climatic Change, Palaeoecological Proxies.

100 YEARS AFTER LENNART VON POST: ADVANCES, ACHIEVEMENTS AND THE FUTURE OF QUATERNARY PALYNOLOGY

Jean Nicolas Haas

Can we derive critical pollen values for the past tree line positon? Data from annual pollen trapping across tree line in western Norway

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Monitoring of the modern pollen production of local sub-alpine and alpine vegetation has been performed using pollen traps situated along an elevational transect crossing the *Pinus sylvestris* and *Betula pubescens* elevational limits and continuing into the mid- and high-alpine vegetation in western Norway. The aim of the study is to monitor annual variation in the pollen production and hence the representation of common taxa found at or near the tree-line, that can be used to derive critical pollen values that can be used to infer the presence of these taxa in the past, and to reconstruct past changes in tree-line positions. Nine modified Tauber pollen traps has been positioned in the vegetation from 663 to 1347 m a.s.l. and sampled from 2004 to today. Additionally, three sub-aquatic traps were located in a small lake at 800 m.a.s.l. just above the present-day *Betula pubescens* tree-line. The results display large variations in pollen percentages and pollen accumulation rates (PAR) from year to year, as well as great differences between the traps placed in the vegetation and in the lake suggesting further pollen trapping is needed to get a solid long-term average. The vegetation traps follow the vegetation distribution better and, as expected, give a more local signal than the lake traps. The present day vegetation near the pollen traps have been studied in detail based on aerial photos and field registrations to get quantitative and qualitative data on the pollen–vegetation relationship within the pollen source area. It will be important to test if different vegetation types can be characterised by their pollen rain composition, to identify under- and over-represented taxa, and to test the match between modern pollen rain and fossil pollen assemblages, as well as to know how closely the tree line position can be identified.

***Keywords*:** monitoring, pollen accumulation rates, pollen traps, concentrations, tree-line ecotone

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Palynology on Human Mummies

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In the last decades more and more palynological research has been conducted on human mummies, which provide essential insight into the life circumstances of ancient bodies, and became a new frontier in palynology. Main focus of these studies is attached to conservation techniques, dietary reconstructions, determination of seasonality of death but also to environmental reconstructions, all of them strongly influenced by recent advantages in forensic palynology. Here we show more than 25 years of investigations on the Neolithic Glacier Mummy "Ötzi" which reveal a great deal of information about the living and environment of Neolithic man in the Alps. His artefacts disclose a skilled person, well adapted to the alpine environment. Since the discovery of an arrowhead in his left shoulder, a strong evidence for a violent death is on hand, but still several questions are unanswered about his demise and deposition in 3200 m asl in the Alps 5300 years ago. In particular, the results concerning the seasonality of death as well as the taphonomic interpretation of the find assemblage give reason to controversial discussions. Furthermore, besides the dispute about the Iceman's personal fate, a discussion about his social status has emerged. Primarily, four hypotheses are suggested to explain the find in its entirety. The speculations vary from a hunter/worrier to a shaman, a miner or a shepherd. Neither of these proposals is accepted or corroborated by archaeological findings,

but on the basis of palynological studies conducted in the vicinity of the discovery site the assumption that the Iceman was involved in an early form of seasonal transhumance has gained general acceptance. Recent results from archaeological field studies and from coprolite analyses on dung pellets from his discovery site cause doubts on the existence of such a transhumance during Ötzi's lifetime and the shepherd hypothesis is no longer maintainable.

***Keywords*:** palaeo-forensics – Neolithic Iceman – Alps – transhumance – land use changes

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European vegetation change in space and time – how far have we come?

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At the 16th Scandinavian meeting of natural scientists in 1916 Lennart von Post presented several pollen diagrams along a vegetation gradient. He thus demonstrated not only that percentage pollen diagrams are useful, but also that several sites together allow insights into changes in space and time. In his lecture, von Post also showed that general shifts in vegetation composition had occurred regionally so that pollen analysis may be used as a dating tool. With the development of radiocarbon dating pollen diagrams could be independently dated, which makes it possible to evaluate the earlier assumptions of synchronous changes and study the dynamics in space and time. Pollen diagrams collected in continental and global databases provide important research tools to study continental scale vegetation dynamics. For Europe we constructed interpolated maps of pollen deposition for the last 15,000 years for the most abundant pollen taxa at 500 year intervals. Together with insights from the spatial distribution of genetic markers in extend plant populations these maps provide a new understanding of postglacial vegetation history. Particularly the two taxa *Fagus* and *Picea* that von Post used to demonstrate the regionally synchronous change in forest composition stand out as anomalies from the general pattern of postglacial European vegetation change. The postglacial histories of *Fagus* and *Picea* have been the focus of model simulations, recent and ancient DNA studies as well as extensive palaeoecological research, however, the reasons for their late expansion are still heavily debated. Their time of expansion has proven asynchronous in Scandinavia, while it clearly characterizes the Late Holocene. Other changes in European vegetation history have however proven synchronous and assist in establishing age models still today.

***Keywords*:** Europe, pollen database, interpolation, postglacial spread of trees, Lennart von Post

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Colluvial sediments, hiatuses and environmental contaminants in pollen archives and their potential for palaeoecological reconstructions

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Lakes and raised peat bogs are regarded as classical objects of pollen analysis. Their occurrence is however limited to particular ecosystems and depends on specific climatic parameters. Investigating the vegetation history of landscapes which do not offer such favorable framework for pollen conservation is therefore complicated, though not impossible. Germany's extensive basins with fertile soils have constituted preferred settlement areas since the Neolithic and as such form objects of particular archaeological interest. They are a prominent example for landscapes lacking suitable archives for the reconstruction of vegetation history which had already been concluded by Firbas in 1952. He remarked that unfortunately, the richness of prehistoric finds was met with a deficiency of bogs and of lakes. This is the reason why many of these archeologically significant regions hardly play any role in traditional studies on vegetation history. Compounding the situation in these landscapes is the fact that the millennia-spanning settlement history has influenced the genesis of archives to a considerable degree – which is why they have been regarded as unsuitable for analysis until a few decades ago. Thanks to state-of-the-art dating methods and geochemical analysis, however, it is exactly these anthropogenic markers, in the form of colluvial sediments, hiatuses or heavy metal contamination, which reveal essential information about the development of a wide variety of landscapes including the role of man. We use examples from different regions to highlight the potential

of 'disturbed' deposits for the environmental reconstruction of landscapes where human activities have been a dominant factor. The interlinking of precisely dated cultural layers and palynological results is a key instrument of the analysis. The archives are often the only evidence for large-scale environmental changes in many relevant settlement areas. Investigations of pollen spectra in combination with inputs of heavy metals and minerogenic material washed into fens allow to pinpointing ancient mining districts and their local impact on the landscape.

***Keywords*:** pollen-analyses, pollen archives, colluvial sediments, geochemistry

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German Uplands in a new light - reinvestigating prehistoric landscapes of Hesse, Germany

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Pollen analysis is considered a standard practice in archaeological research today. Whereas rather undisturbed archives like lakes and raised peat bogs in remote areas were preferred for investigations of vegetation history, archaeological research has shifted the focus on prehistoric settlement areas and cultural landscapes with less suitable deposits. Great progress in dating methods, pedological and geochemical analysis allows to investigate small mires and wetlands in agriculturally used areas as well as colluvial sediments from archaeological sites, like ditches, pits and wells. However, intensified field surveys and the use of remote sensing technologies, such as satellite imagery, LiDAR-Scanning etc, suggest that supposedly peripheral regions in fact were far more occupied than expected. The Central and East Hesse Uplands (Taunus and Rhön Mountains) reach heights up to 950 m and are largely forested. They frame remarkable prehistoric cultural landscapes like the extensive basin Wetterau. The exploration of low mountain ranges (300-500 m a. s. l.) is well-known for the Iron Age (~800-1 BC) but might have taken place earlier in the Late Bronze Age (~1200-800 BC) as various archaeological sites comprising burial mounds, fortified hilltops and depots indicate. Due to poor preservation of many sites the settlement structure and the extent of land use remains uncertain. The analysis of peat bogs has a long tradition in vegetation history of Germany's Central Uplands, but often did not focus on local human activities. Thus, the reinvestigation of presumed "well-known" pollen archives including the application of modern dating techniques and high resolution analysis may provide new insights to anthropogenic environmental changes. Combined results from peat bogs and different local deposits in the surroundings of archaeological sites will lead to a better understanding of prehistoric land use and resource management at low to mid-mountain ranges.

***Keywords*:** low mountain ranges, cultural landscapes, pollen archives, resources

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Agriculture and husbandry in western Norway – the potential found in different deposits

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Six sites representing early farming contexts from different areas in Hordaland, Norway, are used to study local variations in resource exploitation within a region where general vegetation development is known based on lake sediment studies. All six sites were investigated as part of rescue excavation projects undertaken by the University Museum of Bergen. The sites represent early farming settlements and cultivation areas in different geographical settings, from the western coast to the inner fjord areas, giving rise to differences in continentality and oceanity. The main aim of the study is to investigate the first sign of human impact on a local scale, the vegetation prior to farming, and how different land-use practices changed the following vegetation development. The sites were examined with emphasis on pollen, NPP and macrofossil data. The time periods covered by the sites spans the period BC 7050 to AD 400 which in Norway covers the Mesolithic to the Late Roman Iron Age. Samples for pollen and macrofossil analysis were collected from soil profiles in close proximity

to a variety of archaeological structures. In addition, macrofossil samples from house structures were collected for analysis when possible. The study showed differences between the geographical areas regarding emphasis on husbandry compared to agriculture, and that the availability of easily managed, good quality soil seems important. In most places the earliest clearing of vegetation is not recorded, but where this early period is available, animal husbandry seems to have started in the Middle Neolithic. Full scale agriculture was practised from the Late Neolithic or the Early Bronze Age at the latest. House remains were found at just a few sites, and where found, there is evidence of long term and/or recurring occupancy (up to 3000 years) which may testify to the agricultural suitability of a site. The study demonstrates the importance of analysing samples from soil profiles and archaeological contexts when investigating local changes in farming practices, as well as the importance of combining pollen analysis, macrofossil analysis, NPPs and numerical methods.

***Keywords*:** agriculture, Late Neolithic, macrofossils, pollen

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New insights into development of agriculture along the coast of Norway based on past land cover changes

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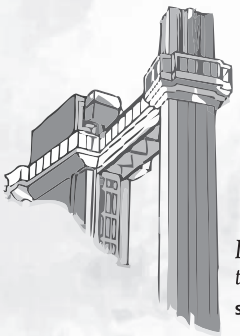
A breakthrough of agriculture in Norway took place c. 4300 cal BP, but it is still questioned what happened c. 6000 cal BP and when, why and where the first farmers arrived. Vegetation development along the western coast from Vest-Agder in the south, to Rogaland and Hordaland in the north, has been central in this discussion. To be able to evaluate the development along the coast consequently and as objective as possible, the regional vegetation cover was reconstructed using REVEALS within the Landscape Reconstruction Algorithm, LRA. A grid of coordinate points was set out systematically at every 20 km in both north-south and east-west directions; pollen sites located within a distance of 20 km of each of the coordinate points were automatically selected. Pollen data from 69 sites were analyzed in 500-year intervals, a minimum of two sites was set as criteria for performing REVEALS, and altogether 32 coordinate points gave REVEALS estimates. Pollen productivity estimates, a key input parameter to the method, were based on a combination of locally derived estimates and estimates from elsewhere in Europe. REVEALS-estimated cover indicates open areas along the coast also in the Mesolithic (prior to 6000 cal BP). A combination of landscape openness and presence of *Plantago lanceolata*, an anthropogenic indicator, is therefore used in the interpretation. The vegetation has generally been more open along the coast in the south than in the north. Introduction of agriculture and animal husbandry may have caused forest clearance along the whole coast from 5200–5700 cal BP, but the impact seems to have been stronger and probably also started earlier, in the southern part of the coast than in the north. In south-western Rogaland extensive areas covered by heathlands existed c. 3000 cal BP, whereas the main heathland expansion took place c. 1000 years later in northern Hordaland, supporting earlier studies. *Plantago lanceolata* has probably been growing in natural openings in south western Norway through the entire Holocene. The first scattered finds must therefore be treated critically in the evaluation of introduction of agriculture.

***Keywords*:** Pollen, Regional vegetation cover, REVEALS, introduction of agriculture, Norway

GENERAL SESSIONS (ABSTRACTS)



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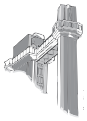

AIRBORNE POLLEN

Claudia Barbieri Ferreira Mendonça

Global Warming and airborne pollen concentrations in the Eastern Alps

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Airborne pollen records sampled over 35 years (1981-2015) were evaluated from two pollen-monitoring stations in the Central Eastern Alps. This long-term observations of airborne pollen allow a statistically evaluation of the start of the flowering period, the main flowering period, pollen release and productivity. A further aspect of the quantitative studies of atmospheric pollen is the possible relationship with the observed increase in the prevalence of pollen allergy in the human population in many parts of the world. The sampling and measuring of the atmospheric pollen was done with Hirst-type continuous volumetric pollen sampler, in the valley bottom (Innsbruck) with a Lanzoni pollentrap and in the subalpine region (Obergurgl) with a Burkard pollentrap. The two monitoring sites are 100 km apart from each other and differ in altitude: the subalpine site Obergurgl (2000 m asl.) and Innsbruck in the valley bottom (620 m asl.). During the years 1981-2015 the monthly mean temperatures show for both sites a temperature increase of about 1, 5° C. The monthly concentrations of airborne pollen increase from 1981 to 1992. In the years 1993-2005 the monthly concentrations of airborne pollen are up to 30 % higher. After 2004 the values are at the same level or even lower than before 1994. This tripartite pattern is reflected also in many single pollen taxa and is in contrast to the hypothesis that higher yearly average temperature leads to a higher pollen concentration in the air.

***Keywords*:** aerobiology, airborne pollen, pollen monitoring, pollen concentration, Alpine region

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Occurrence of pollen grains and spores in exogenous thaw lakes in King George Island, Antarctic Peninsula

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The oceanic and atmospheric circulation that occurs in Antarctic makes this region of great importance for atmospheric transport studies and local and continental climatology. Antarctica is situated in a secluded position of other continents. It has low diversity of vertebrates, less anthropogenic interference compared with other continents and only three species of angiosperms. Recent studies indicate the presence of particulate materials of mineral origin, aerosols, gases, bacteria, fungi. Few studies have reported the presence of exogenous mainland pollen grains, and South America and Australia are the main emitting source. The aim of this study was identify the pollen grainsand its concentration in thaw lakes from the Fildes Peninsula, located at King George Island, and associating with the plant source of palynomorphs. The processing of the samples consisted of decantation of particles in the bottom of the bottles followed by splitting into sub samples and subsequent centrifugation. The remaining material was sieved over a mesh of 6mm. Mounts the blades were made and later identified the present palinomorphs. Three spores were identified (Pityrogramma, Bryophyte and Gleicheniaceae) and 12 different pollen grains belonging to: Meliaceae, Urticaceae, Ranunculaceae (Ranunculus sp.), Leguminosae-Mimosoideae (3), Rubiaceae, Asteraceae (2), Apocynaceae, Ruscaceae and Cyperaceae. Most of the families belong to pantropical regions. Studies have indicated migratory birds, humans and atmospheric transport as possible introductory routes on the continent. The palynomorphs are small / medium, amb circular or subtriangular, and ornamented. The pollen of Cyperaceae, Urticaceae and Asteraceae (the latter with caveate exine) usually have anemophilous pollination, a result that could corroborate the studies of atmospheric teleconnections to the

mainland. The collection points with lower contribution of human population were the most abundant of palynomorphs. The birds are spread throughout the area.Therefore, prevented the observation of a pattern relating the pollen quantity with the quantity and quality of migratory birds. Because of the wide variation in pollen morphology and peculiarities of the study area (e.g. historical factor) was not possible to conclude the introduction manner of the palynomorphs at the area. No surviving families on the continent were identified. The results showed that defrost lakes represent an efficient matrix for holding palynological studies. However, ineffective for correlation between flowering period and deposition rate. Analyses in snow matrix, firn, ice and air associated with mathematical models that identify the atmospheric trajectories could provide greater accuracy in studies of atmospheric teleconnections and may contribute to the studies of aerosols in the region.

Keywords**:** palynomorphs; exogenous; Antarctica.

Reducing Pollen Dispersal using Forest Windbreaks

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The adoption of biofuel grasses with wind-blown pollen has created concern about the movement of unwanted genes or transgenes into native plant populations, weedy species, identity-preserved crops, or seed production. In response, farmers and other stakeholders are looking for practical methods to mitigate pollen dispersal and gene flow. The goal of this project was to measure the ability of a forest windbreak to mitigate downwind pollen fluxes from switchgrass (*Panicum virgatum* L.), a North American grass that has become a biofuels feedstock. Switchgrass fields were established in two identical plots where one had a forest windbreak and the other was in an open (control) site. Switchgrass reproduction, pollen dispersal, wind speed, and wind direction were measured over two years. Daily release of switchgrass pollen peaked at 11:00-13:30 during a flowering period that lasted about 44 days. Based on morphological traits and pollen capture data, the best estimate for switchgrass pollen source strength was 141 x 10^9 pollen/season/hectare for fields planted at commercial densities. The forest windbreak consistently decreased downwind switchgrass pollen concentrations by 333-20,000 fold compared to the control plot which had a 58-77 fold decrease due to downwind distance alone. These results suggest that forest windbreaks could be used to mitigate wind-blown pollen dispersal and gene flow in switchgrass and other grasses grown as dedicated biofuels feedstocks.

Keywords**:** gene flow, *Panicum virgatum*, pollen source strength, switchgrass, windbreak

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Spatial differences on airborne pollen concentration in Montevideo City, Uruguay

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Airborne pollen is mainly monitored in cities with the aim to determine pollens representing a risk to allergic patients. Sites to install samplers are chosen based on such factors as availability and accessibility and, at certain height, it can be safely assumed the sampled air is representative of the whole city. However, spatial heterogeneity affects the pollen cloud and can be especially relevant for allergic individuals exposed to allergenic pollen types or concentrations. In order to evaluate that spatial heterogeneity in Montevideo, airborne pollen was sampled in two areas with different urbanization level and local vegetation cover during a calendar year a more “open” and a closely built area – old town. Grass vegetation cover was estimated from satellite images in concentric rings up to 2.5 km around each airborne pollen sampling point. Likewise, the

number of trees of selected species was estimated from SIG information. Total pollen index was almost double in the open area than the old town; however, the relative contribution of woody and non-woody pollen was similar in both locations (ca. 41% and 59%, respectively). All selected taxa, except *Platanus*, *Ambrosia* and Urticaceae, recorded higher total pollen concentrations on the "open" site. Regarding main pollen periods, Poaceae, Cupressaceae, *Fraxinus* and *Ambrosia* pollen grains were recorded over longer periods on the "open" area. On the other hand, *Platanus* and Urticaceae pollen were recorded more days on the old town. The differences observed between both sites are partially explained by differences in local vegetation cover and urbanization levels. In old town, its higher urbanization and almost peninsular location over the Rio de la Plata estuary could be limiting pollen dispersion from extra-local and regional sources and could explain lower total concentrations and the shorter pollination periods recorded for many taxa. In addition, wind direction and speed relationship with pollen concentrations, as well as similarities between daily pollen concentrations of some taxa, suggest that extra-local and regional vegetation have also a strong influence on local pollen values across the city. Our results indicate that airborne pollen is different in areas with different local vegetation and urbanization level in Montevideo city and therefore aerobiological information from one point must be used taking this into account when assessing and informing allergic patients.

***Keywords*:** airborne pollen, spatial variability, Montevideo, Uruguay.

Application of pollen grains and spores as atmospheric transport biomarkers between South America and Antarctica

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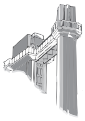
This study shows the feasibility of using pollen grains and spores as atmospheric transport biomarkers between South America and Antarctica. For this, snow samples collected in 2005 on the Joinville Island were used, dated by glaciochemical methods, as well as water samples from 10 lakes defrosting and a sediment testimony lacustrine collected in 2013 on King George Island. Samples were collected as follow: a) rates obtained on the wall of three trenches and 2 m deep, located at Joinville Island; b) water samples from 10 defrost lakes at King George Island and c) 29 cm deep lacustrine sediment profile, also obtained at King George Island. Snow analysis was performed through adaptations from the standard methods of palynology and traditional methods to rescue palinomorphs were used in sediment samples. The preparation as well as analysis of morphology of the pollen ornamentation was made at Professor Álvaro Xavier Moreira of Palynology Laboratory of the National University Federal of Rio de Janeiro Museum. The record for snow samples consisted of a total eight pollen and one type of spore of the following taxa: Cyperaceae sp., Dennstaedtiaceae, (Gentianaceae) *Schultesia*, (Passifloraceae) *Passiflora passiflora* (2), (Rubiaceae) *Oreopolus glacialis*, unidentified pollen grain, *Blechnum* sp. spores and vegetable fibers with remarkable vessel elements. The pollen record of water samples from defrost lakes revealed the occurrence of 9 up pollen grains: Asteraceae (2), Apocynaceae, Cyperaceae, Gleicheniaceae, Mimosoideae (2), Rubiaceae, Ruscaceae. The lacustrine sediments profile showed 14 identified palinomorphs: *Antulsporites verrucatus* (2), *Baculatisporites comaumensis* (2), *Cyathidites australis* (10). Samples of snow and water contained pollen and spores besides other palinomorph elements. The palinomorph elements identified in the sediment were taxonomically different from those found in other samples. Biogeography of species represented reveals the occurrence of pollen transport having the region of the Andes as the source term. The use of HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) platform allowed evaluating the possible trajectories of air masses that reached the point of collection and associating the biogeography of the species represented in the samples with trajectories of air masses, which corroborates the identification of the source term region. The statistic analysis data from pollen morphology combined with the climatology will be realized through new sampling in the region.

***Keywords*:** Antarctica; palynology; Biomarkers; teleconnection



CENOZOIC PALYNOLOGY AND BOTANY

Silane Aparecida F. da Silva-Caminha
& Paulo Eduardo de Oliveira

Long-term eutrophication responding to change in climate-ecosystem in Poyang Lake, China

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Poyang Lake is the largest fresh-water lake in China within the Yangtze River catchment, with an area of 4300km^2 and an catchment area of 160000 km^2, existing in a mesotrophic state and a trend toward eutrophication since the 19th century. Aiming at understanding long-term lake trophic evolution, we used lake sediment records and climate-hydrology-forced ecosystem model to do data-modelling comparisons to understand climate-aquatic biomass-nutrient interaction during the last 1000 years. Based on principles and structures of Lotka-Volterra dynamic model, this paper firstly built a competition system between phytoplankton algae and higher aquatic plant of the lake primary producers. Then a predator-prey system was constructed between top-level predator of fish and the primary producers in the lake ecosystem. Finally, based on relations between climate-lake water and the biomes, Lotka-Volterra competitive and/or predatory systems were established with delay functions and feedback controls. Four experiments of different periods, from the modern time to the past 1000 years respectively, were designed to perform the numerical simulations. The result showed an asymmetrical process of biomass changes. The water increases lead to a slow rate of biomass changes while the water decreases make a fast rate of biomass changes, quantizing the water-controlled negative-feedback. The boundary conditions were controlled by precipitations in the Poyang catchment. When the precipitation decreased 19%, the lake areas correspondingly decreased 33% and water heights decreased 7%, leading to the lake biomass oscillating and declining during 50~60 years. When the extreme drought climate lasted more than 50 years, the biome growth stopped and the lake ecosystem froze. The result can be evidenced by sedimentary pollen data during Little Ice Age when psammophytes and xerophytes were dominant instead of aquatic and palustral plants. It is suggested that the lake ecosystem would be long-term oscillated and finally collapsed under a last-drought climate, because the changes in the boundary conditions significantly exceeded the capacity of the ecosystem. Comparison of simulated aquatic plant biomass and aquatic pollen concentration revealed 60.6% of the same variance. Similarly, comparisons of modeled primary biomass and δ13C showed 61.9% of the same variance, suggesting reliable simulations. The simulations revealed different processes in nutrient change of the past 300 years. Contribution partitions from hydrology and aquatic biomass accounted for 79.1% and 20.9% of this time, respectively. The synchronous changes between hydrology-forced and ecosystem-feedback nutrient during the past 300 yrs occupied 62.5% of the time, suggesting climatic-hydrological factors played a major role in the process of nutrient evolution.

***Keywords*:** Past 1000 years, eutrophication, climate-ecosystem, modelling, Poyang Lake

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Climate and Carbon Cycle Dynamics in the Eocene-Oligocene boundary based on palynological analyses from Mississippi, Gulf Coast Plain

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The Eocene-Oligocene transition (E/OT: ~34 Ma) is the largest climate transition of the past 65 million years. In less than 0.5 Ma, deep-ocean benthic foraminiferal oxygen isotope ratios ($\delta^{18}O$) record a large (>1‰) positive step-change, corresponding to a deep-water cooling and massive increase in the terrestrial cryosphere, as Antarctic ice sheets grew to a continental extent. This coincided with a long-term transition

from high to low-pCO_2 levels, and from a greenhouse to icehouse climate state. Recent coccolith-dominated high-resolution bulk carbonate isotopic records from the eastern Equatorial Pacific show a pronounced negative shift in both $\delta^{18}O$ and $\delta^{13}C$ between ~35.5 and 34.5 Ma, prior to the E/OT. Here we present new data from this pre-cursor interval, through into the E/OT, from continuously cored continental shelf section on the US Gulf Coast. Composed of ~137m (15-152m deep) Yazoo Formation clays, these yield high quality microfossil, and palynomorph preservation. More than one hundred palynological slides provided a ~28kyr resolution biostratigraphy, including a number of potentially useful palynomorph bioevents and palaeoenvironmental reconstruction. The Eocene-Oligocene boundary was placed at 87ft within the core. The species richness between ~35.5 and 34.5 Ma initially has a sharp increase but then suddenly decreases. This behavior can be interpreted as a response to the environmental change. If the species are analysed separately, those from restricted to inner neritic environments (e.g. *Homotryblium floripes*, *Homotryblium oceanicum*) tend to disappear across the cited range, while those from outer neritic to oceanic environments (e.g. *Pentadinium laticinctum*) tend to peak in abundance, which may indicate a relative transgression during the pre-cursor shift. This is in accordance with the negative long-term oxygen isotope shift. The system tract model proposed here is characterized by a transgressive system tract at 491-399ft and a high stand system tract at 399-51ft. A maximum (399ft) and a minor (251ft) flooding surface were detected inside the core, which is supported by previously published sequence stratigraphy models. The next step of this project aims to generate a new high resolution fine-fraction (<20μm) bulk carbonate stable isotope records through the latest Eocene and the Eocene/Oligocene transition. This would provide a further stratigraphic and palaeoclimatic framework for the interpretation of the palynological data. This work was supported by CNPq, National Council for Scientific and Technological Development (Brazil).

Keywords**:** palynomorphs, palaeoclimate change, Eocene-Oligocene transition, Gulf Coast Plain

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A fossil *Quercus* (sect. *Heterobalanus*) male flower with in situ pollen from the late Pliocene of southwest China

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Extant *Quercus* sect. *Heterobalanus* (Oerst.) Menits is concentrated in the eastern Himalaya areas, especially in the Hengduan Mountains in China, though this group contains about 11 species distributed from Chiang Maim in Thailand to southwest China, Burma, India, Bhutan, Nepal and Afghanistan. The fossil record of this section is dated back to the Miocene, however very few fossils of male flowers with in situ pollen have been documented so far. Here we present new fossil record of *Quercus* (sect. *Heterobalanus*) male flower from the late Pliocene of southwest China, and we found well preserved anthers with in situ pollen clump. Both fossil male flower and in situ pollen grains are comparative to the extant species from *Quercus* sect. *Heterobalanus*. Our finding betters the understanding of the biogeographical history of this section.

Keywords**:** *Quercus*, fossil male flower, pollen in situ, Pliocene, southwest China

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The new fossil record of *Mesocyparis* (Cupressaceae) from the Paleocene of Heilongjiang, China and its phytogeography

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Mesocyparis McIver & Basinger 1987 (Cupressaceae) is an extinct genus which occurred in both eastern Asia and western North America from the Late Cretaceous to Paleocene. Recently, we discovered new fossil materials of *Mesocyparis* in the upper part of the Paleocene Wuyun Formation, at Wuyun coalmine (49°14′N, 129°28′E) in Jiayin County, Heilongjiang province. Together with other species in this genus, the Wuyun cypress macrofossil specimens give a case study in revealing the early connection and differentiation

of conifer taxa which lived in eastern Asia and western North America. The materials in this study are compressions. Seed cones of the specimen borne in opposite pairs, ovate, 4.4-5.2 mm long, 4.0-5.1 mm wide; bracts 4, woody, decussate, obovate to ovate; umbo leaflike, erect, at the top of scale, apex acuminate. Fertile shoots flattened, leaves decussate and dimorphic – facial and lateral leaves morphologically different; the facial leaves triangular to rhombic, 0.9-2.7 mm long, 0.7-1.2 mm wide, thickened along the midrib; lateral leaves folded, falcate to triangular, 1.2-2.2 mm long, 0.4-0.8 mm wide, apex acute. Branching pinnate, flattened, branchlets plagiotropic, borne in opposite pairs, forming flat frond-like sprays. After detailed comparison with other living and extant members in Cupressoideae, we found the character combinations of Wuyun specimens correspond with the extant genus *Mesocyparis*. Furthermore, the significant difference between our Wuyun fossils and other 4 species in this genus made us to name Wuyun fossils *Mesocyparis sinica* sp. nov. as a new species. The morphological evolution of *Mesocyparis* from Late Cretaceous to Paleocene are expressed on: arrangement of seed cones changed from decurrent to opposite, and the size of scales changed from basal pair commonly slightly narrower than distal pair to approximately equal in size. Separately, the changes of different species in western North America are more variable than those in Eastern Asia. Moreover, plot all sites of this genus on respective paleogeographic maps, we may infer that *Mesocyparis* probably originated at high latitudes in western North America, and spread via the land conjunction of western North America and northeast Asia entered into eastern Asia at the end of Cretaceous, before diffusing to the Heilongjiang/ Amur region by the Paleocene.

***Keywords*:** Eastern Asia, Western North America, *Mesocyparis*, morphological character

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Global vegetation distribution and terrestrial climate evolution at the Eocene-Oligocene transition

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The Eocene – Oligocene transition (EOT; ca. 34–33.5 Ma) is widely considered to be the biggest step in Cenozoic climate evolution. Geochemical marine records show both surface and bottom water cooling, associated with the expansion of Antarctic glaciers and a reduction in the atmospheric CO_2 concentration. However, the global response of the terrestrial biosphere to the EOT is less well understood and not uniform when comparing different regions. We present new global vegetation and terrestrial climate reconstructions of the Priabonian (late Eocene; 38–33.9 Ma) and Rupelian (early Oligocene; 33.9–28.45 Ma) by synthesising 215 pollen and spore localities. Using presence/absence data of pollen and spores with multivariate statistics has allowed the reconstruction of palaeo-biomes without relying on modern analogues. The reconstructed palaeo-biomes do not show the equator-ward shift at the EOT, which would be expected from a global cooling. Reconstructions of mean annual temperature, cold month mean temperature and warm month mean temperature do not show a global cooling of terrestrial climate across the EOT. Our new reconstructions differ from previous global syntheses by being based on an internally consistent statistically defined classification of palaeo-biomes and our terrestrial based climate reconstructions are in stark contrast to some marine based climate estimates. Our results raise new questions on the nature and extent of terrestrial global climate change at the EOT.

***Keywords*:** Eocene-Oligocene transition, palynology, global vegetation, climate, biomes.

Palynological and geochemical studies of the Miocene successions of the Indo-Myanmar Range, North-East India

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The Indo-Myanmar Range (IMR) has formed as a result of the subduction of the North-Eastern plate of India and the Myanmar plate. The Miocene successions of IMR are represented by the Surma Group in the form of molasses. The Surma shales from Manipur, Nagaland and Mizoram have yielded a variety of pteridophytic spores, fungal remains, gymnospermous and angiospermous pollen along with a number of reworked Permian palynomorphs. An analysis of the palynoflora indicates that the pteridophytic spores dominate over gymnospermous and angiospermous pollen. The fungal remains are also well distributed in these regions. The *Striatriletes* spp., reworked palynomorphs and fungal remains are very common in these areas. Dinoflagellate cysts and microforaminiferal linings are present in the Upper Bhuban succession of Mizoram. These microbiota are not recovered from Surma shale of Manipur and Nagaland. Their presence in Mizoram indicates shallow marine conditions. However, a warm and humid freshwater depositional environment is inferred for the Upper Bhuban Formation of Surma Group in both from Nagaland and Manipur regions based on *Striatriletes* spp. and fungal remains. The common occurrence of *Striatriletes* spp. indicates tropical and subtropical climate in these regions. The reworked taxa are represented by *Primuspollenites* spp., *Scheuringpollenites* spp., *Plicatipollenites* spp. The high frequency of reworked palynomorphs in the assemblage suggests that the materials of the Bhuban Formation preserving palynomorphs were mainly derived from the Gondwana succession or from the earlier deposited successions of the Himalayan foothills. An attempted has been made for analysis of organic geochemistry by using Rock Eval analysis. The organic matter content is predominantly of Type-III and Type IV in these shales. The T_{max} are mainly made up of immature and mature temperature. These shales of IMR appear to be poor to moderate for gaseous hydrocarbon as potential source rock. XRD result suggests that these sediments were deposited in a basin, where condition may fluctuate from anoxic to oxic environment. This study also reveals that the sediments have attained the late stage of diagenesis (telogenesis) that accompanies or follows uplift of previously buried sediments by mountain-building activities.

***Keywords*:** Palynomorphs, Surma Group, Hydrocarbon, XRD, Indo-Myanmar Range

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Oceanic environments, vegetation and climate from the Middle to Late Miocene Brassington Formation, UK

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The Brassington Formation is the most extensive Miocene sedimentary succession onshore in the UK. Because of its unique position at the margin of NW Europe, the pollen, spores, fungal remains and macrofossils from this lithostratigraphical unit provide evidence on the development of environments and vegetation affected by North Atlantic currents and hypothesized atmospheric circulation changes that accompanied the Middle to Late Miocene climatic cooling. Palynostratigraphy suggests that the uppermost Kenslow Member of the Brassington Formation is not coeval. Previously, all occurrences of the Kenslow Member were assumed to be contemporary. This new dating of the Brassington Formation now means that a sequence of fossiliferous horizons is present, rather than one. Multiple palaeobotanical horizons has allowed the development of a new vegetation and climate record for the Atlantic margins of northwest Europe. To develop this new archive of Middle to Late Miocene palaeoenvironment and palaeoclimatic data we have taken fresh palynological samples and applied geochemical analysis to the exceptionally preserved fossil wood. For the first time the fossil fungal remains are documented and utilized to better understand the palaeoenvironment. From the fresh palynological analysis, the oldest pollen assemblage is from the more southern Bees Nest Pit, which

represents a subtropical conifer-dominated forest of late Seravallian age (c. 12 Ma). A younger assemblage was observed from the more northern Kenslow Top Pit and indicates that a subtropical mixed forest was present during the early Tortonian (11.6–9 Ma).

***Keywords*:** Miocene, pollen and spores, fungi, wood, climate.

First record of Podocarpoid fossil wood in South China

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As the second largest family within the conifers, the modern Podocarpaceae largely comprises evergreen trees and shrubs belonging to 194 species within 19 genera. This family is mainly distributed in tropical and subtropical regions. Although modern Podocarpaceae are widespread mostly in the Southern Hemisphere, there are numerous reports of Cenozoic megafossils and palynomorphs attributable to this family from the Northern Hemisphere. In this study, we report a new species of fossil wood of *Podocarpoxylon* from the late Eocene of Nadu Formation in Baise Basin of the Guangxi Province, South China (23° 52' 14.84'' N, 106° 34' 49.27'' E). This fossil wood is characterized by distinct growth rings, circular to oval tracheids in cross section, 1-2-seriate opposite pits on radial tracheid walls, uniseriate (rarely biseriate) rays, smooth end walls of ray parenchyma cells, and the absence of resin ducts, suggesting its affinity to Podocarpaceae. The new species is distinctive from other Cenozoic woods ascribed to this family by the combination of distinctive growth rings, the absence of axial parenchyma, the occurrence of bordered pits on tangential tracheid walls, and the occurrence of 3-4 cuppressoid or taxodioid pits on cross-fields. This represents the first record of podocarpoid fossil wood in South China and provides the first robust physical evidence for the early dispersal and diversification of Podocarpaceae in eastern Asia as well as for a warm and wet seasonal climate in this region, and the presence of clear growth rings also suggest a seasonal climate during the late Eocene.

***Keywords*:** Baise Basin, late Eocene, Podocarpaceae, *Podocarpoxylon*, South China

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Anatomical characters for intrageneric classification of genus *Pinus*

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Genus *Pinus* (Pinaceae) appeared in the Early Cretaceous at the latest and many fossil cones of the genus are reported from the ages thereafter. Several external characters are known to be useful for classification in the section and subsection level, but there is no comprehensive study on anatomical characters of cones which could be used for inferring phylogenetic position of a fossil cone within the genus. In this study, we explored such anatomical characters by comparing cone scale anatomies of extant *Pinus* species including those of the section *Quinquefoliae* (3 species), *Trifoliae* (9 spp.) and *Pinus* (9 spp.). In the section *Trifoliae*, vascular bundles are oblong to reniform with planar primary xylem in a cross section; distinct rays are observed in the secondary xylem; epithelial cells of resin canals are sclerified in some species, but cells encircling a resin canal are not sclerified. In the section *Quinquefoliae*, vascular bundles are oblong to reniform with planar primary xylem in a cross section; distinct rays are observed in the secondary xylem; epithelial cells of resin canals, as well as cells encircling a resin canal, are not sclerified; there are many resin canals thicker than vascular bundles; several rows of resin canals are present abaxially to a row of vascular bundles. In the subsection *Pinus* of the section *Pinus*, vascular bundles are round in a cross section; primary xylems are round to oval in a cross section; rays of the secondary xylem are developed in some species, but not distinct in species of *P. thunbergii* clade; epithelial cells and cells encircling a resin

canal are well-sclerified. However, *P. pinaster* of the subsection *Pinaster* shares cone scale characters with the section *Trifoliae*. These results suggest that following characters are plesiomorphic in the genus *Pinus*: oblong to reniform vascular bundles; planar primary xylem; secondary xylem with distinct rays; not-sclerified epithelial cells; not-sclerified cells encircling a resin canal. On the other hand, the subsection *Pinus* could be characterized by round vascular bundles and double concentric rows of sclerified cells encircling the hollow of a resin canal. Abaxial resin canals arranged in several rows are also reported in the section *Parrya* which constitutes the subgenus *Strobus* with the section *Quinquefoliae*. Therefore, this character would be a synapomorphy of the subgenus *Strobus*.

Keywords**:** *Pinus*, Pinaceae, anatomical characters, cone scale

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Lower Eocene to middle Miocene Tehuacán-Cuicatlán vegetation, south-central Mexico

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The Tehuacán-Cuicatlán Valley located in southeastern Puebla and norheastern Oaxaca (south-central Mexico) is a megadiverse area with a great number of endemic plants belonging to families such as: Agavaceae, Asteraceae, Cactaceae, Fabaceae and Scrophullariaceae. The semiarid conditions at the valley are due to the orographic shadow of the "Sierra Madre Oriental". The most important Cenozoic units exposed in this area are the Mequitongo Formation (lower Eocene) and the Tehuacán Formation (late Oligocene to middle Miocene). The comparison of the palynological associations from both units give evidence of different plant communities developed during lower Eocene, contrasting with those registered from the middle Miocene. More humid temperate to tropical conditions during Ypresian led to the development of *Pinus*, *Pinus-Quercus*, deciduous, and cloud forests. Besides, gallery and tropical deciduous forests were suggested as local vegetation. Although *Pinus-Quercus* and cloud forests were also recognized in the middle Miocene regional vegetation, some elements from cloud forest, for instance the *Momipites* group were more diverse during the lower Eocene. Middle Miocene semiarid local conditions were inferred by lithological evidences (presence of evaporites) and the increase in the diversity of tropical deciduous forest taxa: Fabaceae, Cactaceae and Burseraceae. Furthermore, vegetation as chaparral and xerophytic shrublands were also registered in the palynological assemblages from the middle Miocene Tehuacan Formation. This contribution is part of PAPIIT-DGAPA IN114914 project.

Keywords**:** Tehuacán-Cuicatlán Valley, Miocene vegetation, Eocene Mequitongo Formation, Tehuacán Formation, Cenozoic flora.

Palynostratigraphy and Cenozoic spores, pollen and dinocysts zonation for Middle Magdalena Valley, Colombia (NW South America)

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Despite palynology has a wide use in Colombia, South America, there is currently very little holistic published information about Middle Magdalena Valley (MMV), Colombia, which allows the geologist to assess the exploration (age, environments and correlation) in this basin. This study presents the results of an advanced palynological investigations carried out on two surface sections and 19 exploratory and appraisals wells drilled in the eastern border of MMV. The wells have penetrated thick non marine sands and

shales sequences which reflect fluvial and lacustrine deposition and marine marginal and oceanic deposits. Petronorte have been conducted a petroleum exploration program in the MMV from 2013 to 2016, with Paleosedes assisting biostratigraphy, an account of this program have stated that the upper part Paleogene and Neogene rocks penetrated are non-marine origin. Cretaceous and Early Paleocene are marginal marine and oceanic depositional sequences. The total spore-pollen and dinocysts zonation of these sediments have been established as results of study of more than 1000 well samples and more than 95.000 feet of thickness of sediments drilled. Early and late Cretaceous, Paleocene, Eocene Oligocene and Miocene subsurface floral units have been recognized and palynologically defined. The MMV floras are related to the Africa and South America floral province. 30 Meso-Cenozoic zones were recognized and a Middle Albian to Middle Miocene ages were assigned to both the studied intervals and the litostratigraphical units penetrated. This paper is focused to the palynostratigraphy from Cenozoic of the MMV as follow: Paleogene Zones P-1A Interval (IZ) *Echimonocolpites protofranciscoi - Buttinia andreevi*, Earliest Daniense (66-65.5 Ma), IZ P-1B *Spinizonocolpites baculatus*, Early Daniense (65.5-61.9 Ma), Partial range Zone (PRZ) P-02 *Zlivisporis blanensis*, Late Daniense (61.9-61.6 Ma), Association Zone P-3A *Bombacacidites annae-Gemmamonocolpites macrogemmatus*, Selandian (61.6-59.2 Ma); Range total Zone (RTZ) P-3B *Foveotricolpites perforatus*, Thanetian (59.2-56.1 Ma); IZ P-04 *Longapertites proxapertitoides/ Polypodiisporites pachyexinatus*, Early Ypresian (56.1-55.7 Ma); IZ P-05 *Striatopollis catatumbus*, Late Ypresian (55.7-48.6±0.8 Ma); RPZ P-06 *Spinizonocolpites grandis*, Lutetian and Bartonian (48.61±0.61-38 Ma); RPZ P-07 *Echitriporites trianguliformis orbicularis*, Priabonian (38-33.9 Ma), RPZ P-08 *Retibrevitricolpites triangulatus*, Early Rupelian (33.9-32.1 Ma); RPZ P-09 *Retitrescolpites magnus*, Late Rupelian (32.1-30.9 Ma); RPZ P-10 *Verrutricolporites rotundiporus* and/or *Magnastriatites grandiosus/Mauritiidites franciscoi Acme*, Latest Rupelian to Earliest Chatian (30.9-26.8 Ma), RPZ P-11 *Cicatricosisporites dorogensis*, Late Chatian (26.8-23.03 Ma), and IZ N-12 *Malvacipollis spinulosa*, Aquitanian (23.03- 17.7 Ma). The spore-pollen proposed zonation is related to those of Colombia (Eastern Llanos), Venezuela and northern Brazil.

***Keywords*:** Palynostratigraphy, Colombia, Paleogene, Neogene, on-site biostratigraphy

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A Late Early Pliocene Marine Incursion in the Madre de Dios Basin, Peruvian Amazon

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The Neogene evolution of the Amazonian landscape is highly debated especially the number and existence of marine incursion in Western Amazonia. Combined biostratigraphical and sedimentological analysis carried out in the Pebas-Nauta Formations, Madre de Dios Basin (Sub-Andean zone and foredeep depozone) yield enough evidence to suggest for the first time an episode of marine influence in the late Early Pliocene. This holistic contribution is a collaborative project of the IRD advanced Amazonian research program and doctoral thesis sponsor. The results from 15 surface productive samples of four stratigraphic sections SE-NW oriented in the Madre de Dios basin, and from base to top surface-ordered sand and shale samples, are as follows: **Puerto Maldonado** (MD-325/MD-51), **Santa Rosa** (MD-208/MD-13), **Inambari** (MD-204C), and **Pongo de Coñeq** (**Section 1**: MD 244/MD-246). The 13/15 analyzed samples have revealed autigenic pyrite, *Miliammina*, *Bathysiphon*, *Trochammina* and *Haplophragmoides* facies, which suggest marginal marine sedimentation and oligohaline - lower mesohaline (about 2-16 ppt) environment, common in salt marshes and most mangroves. All samples show the same palynofacies containing abundant cuticles among the phytoclasts and palynomorphs dominated by Poaceae and pteridophytes spores (*Cyathidites*, *Laevigatosporites*, *Polypodiisporites*, *Equisetum*), fungi spores, and bryophytes. Additionally, some samples revealed specific features such as: MD-325/MD-51 present crabs (ichnofacies), *Oedogonium* algae, *Tetraploa* and *Potamomyces* (fungi) and some proximate dinoflagellate morphotypes related to estuarine tidal type environment. MD-13/MD-208 contains *Oedogonium* algae, *Tetraploa* and *Potamomyces* (fungi) and pyrite in the spore-pollen. MD-244/MD-246 yielded *Deltoidospora* aff. *adriensis* and *Potamomyces.* MD-204C

yielded *Verrucatotriletes*, *Deltoidospora*, *Pteridaceae* and algae (*Pediastrum*, *Oedogonium*) and angiosperms (*Cecropia* and *Poaceae*). *Deltoidospora adriensis* suggests a mangrove swamp with anoxic bottom. The recovered marker species in these sections (*e.g. Cyatheacidites annulatus*, *Cingulatisporites laevigatus*, *Nijssenosporites fossulatus*, *Grimsdalea magnaclavata* and *Bombacacidites baculatus*) indicate (7.15-3.4 Ma) age for studied outcrops, and the first record of chironomidae and species of *Potamomyces* and *Tetraploa* in MD-51/MD-325, MD-13/MD-208, MD-244/MD-246 outcrops, support a Neogene age. However, the presence of *Alnipollenites-Echitricolporites* association (*Alnipollenites verus* and *Echitricolporites mcneillyi* in MD13/208 and *Alnipollenites* forms (Pliocene-Pleistocene), in MD-51/MD-325 and MD-204C, as well as a dating in MD-204C (biotite Ar/Ar 3.45 Ma) indicate a late Early Pliocene. The holistic analysis of the sections allowed us to document a marine incursion into a Neogene cycle. Reworked palynomorphs due to erosion of the Andean range and the influence of its mountainous flora (*Clavainaperturites microclavatus*, *Cecropia*, *Podocarpus*), are also evinced in almost all samples.

***Keywords*:** Late Early Pliocene, palynology, benthic foraminifers, Southern Peruvian Amazon basin, Marine incursion

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Using phytolith to track vegetation changes during the MMCO of the Santa Cruz Formation, Patagonia (Argentina)

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The Santa Cruz Formation (SCF) of coastal Patagonia (17.5-16.8 Ma) represents the southernmost sedimentary record in the world spanning the onset of the middle Miocene climatic optimum (MMCO). The SCF has yielded one of the most species rich and well-preserved Cenozoic vertebrate assemblages on Earth, which has helped demonstrate that the MMCO was a time of unusual faunal diversity in high-latitude South America. The SCF also contains paleobotanical evidence in the form of leaf and wood macrofossils, and, above all, well preserved phytolith assemblages from the same strata as the vertebrate fossils. This combination of fossil records allows us to compare, for the first time, detailed records of past faunal and floral diversity and ecology, vegetation composition and structure, and local climate through the middle Miocene global warming event in South America. Uniquely, variation in paleovegetation and paleofauna communities can be studied both in time and space, as several, well-dated stratigraphic levels of the SCF are traceable laterally along the Atlantic coast of Southern Patagonia for tens of kilometers. Thanks to a collaborative grant awarded to our international team, we have been able to gather floristic, faunal, and isotopic data form the SCF that are comparable and complimentary. Here, we present preliminary results from phytolith analysis of the main stratigraphic section, recording vegetation change during the early part of the MMCO. We analyze variation in phytolith assemblage composition (i.e. Δ% of different plant functional types) through time, and interpret it in the light of the current climatic hypothesis derived from isotopic and faunal data from the SCF.

***Keywords*:** phytoliths, MMCO, Santa Cruz, vegetation, climate.

Paleofloristic reconstruction based on the palynological assemblages recovered from lacustrine Villa Alegria (Puebla) and Cerro Prieto (Oaxaca) of the Tehuacan-Cuicatlan Valley, Mexico

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A reconstruction of the Pliocene-Pleistocene paleoflora and a biostratigraphic correlation between rocks from the lacustrine Villa Alegría (Puebla) and the travertine Cerro Prieto (Oaxaca) localities in the megadiverse Tehuacan-Cuicatlan Valley were made. A total of 94 samples from eight sections outcrop travertine were collected and were processed for standards methods. Paleopalynological assemblages registered 4,957 pollen grains and spores of 212 taxa. By means of multivariate analyses we confirm the presence of regional cloud forest, pine-oak forest, as well as gallery forest along watercourses. Additionally, the presence of the tropical deciduous forest and chaparral are reported, with some floristic elements now present in the desert scrub, suggesting semiarid conditions. Biostratigraphic Villa Alegría correlations showed two biozones based in the abundance of *Alnus* sp. and *Fraxinus* sp. On the other hand, correlation among Cerro Prieto sections showed one important biozone based in *Pinus* sp. Finally, correlation between Villa Alegría and Cerro Prieto showed one abundance biozone based in *Fraxinus* sp.

***Keywords*:** Pliocene-Pleistocene, travertine, paleoflora, correlation, abundance biozones.

New Contribution to the palynology of the São Paulo Basin, Paleogene of the State of São Paulo, Brazil

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Many palynological studies have been carried out in the southeastern brazilian cenozoic rift basins to determine climate change and to reconstruct local and regional paleofloras during the Paleogene and Neogene. At the São Paulo Basin, these studies are clustered at the northwestern, northern and northeastern areas and there is still a lack of data from the southern region. The current study is based on the analysis of 16 palynological samples obtained from four adjacent geotechnical drill holes made in the municipality of São Bernardo do Campo, at the southern area of São Paulo Basin. These samples were chemically treated according to standard methods used for Paleogene and Neogene sediments. The slides were mounted in entellan mounting medium and analyzed in light microscopy. The identified palynomorphs show the occurrence of algal spores (*Catinipollis geiseltalensis* Krutzch 1966, *Mougeotia*-like, *Spirogyra*-like), bryophytic and pteridophytic spores such as trilete grains (*Deltoidospora*, *Cicatricosisporites*), monoletes (*Laevigatosporites ovatus* Wilson & Webster 1946, *Gleichenidites*, *Verrucatosporites*) and *Azolla* massulae. There are also gymnosperm pollen (*Dacrydiumites florinii* Cookson & Pike 1953, *Podocarpidites*, *Ephedripites*) and angiosperm pollen such as *Corsinipollenites*, *Ulmoideipites krempii* Anderson 1960, *Arecipites*, *Monoporopollenites annulatus* Jaramillo & Dilcher 2001. This palynoflora suggests a lake or a flooded area as the depositional environment due to the dominance of algae and other palynomorphs typically found in aquatic vegetation (*e.g.* Onagraceae). There is relative abundance of pollen grains of gymnosperms, which are anemophilous. The occurrence and abundance of this gymnosperm record is a broadly observed feature at the southeastern brazilian cenozoic rift basins, especially in sediments from upper Eocene to Oligocene. Associated to the gymnospermous taxa, the observed abundance of *Azolla* massulae suggests a colder climate, related to the period of the formation of the Antarctic Ice Sheet and the opening of the Drake Passage.

***Keywords*:** São Paulo Basin, Tertiary, palynoflora, paleoclimate

Palynological records from the late Pliocene section of the ODP Site 798B, East Sea: climate and paleoceanographic implications

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The palynological study from the selected intervals (Section 798B-31X, 286.4-296.73 mbsf) of core drilled in ODP Leg 128, Site 798B on Oki Ridge in the Yamato Basin, East Sea, provide a consistent pollen stratigraphy and a solid basis for Asian monsoon climate history during the late Pliocene. The palynological assemblages are composed of terrestrial-derived pollen and marine dinoflagellates. Six local pollen assemblage zones (LPAZ) and seven LPA subzones are suggested. Each LPAZ reflects its paleoenvironmental history such as paleoclimate changes, but paleoceanographical setting is not reconstructed yet here. The palynological assemblages are characterized by the predominance of arboreal pollen throughout the interval. Of the palynomorphs, the conifers including *Pinus* and Taxaceae-Cephalotaxaceae-Cupressaceae, together with the cool-temperate representatives of *Fagus* and *Quercus* (*Lepidobalanus*) are dominant. Pollen analyses allow recognition of well-known episodes of climate evolution (development of major Northern Hemisphere glaciation and of mixed conifer-deciduous forest at 2.5-2.3 Ma), as well as now insights into climate dynamics such as occurrences of short, warm excursions and of unstable periods.

***Keywords*:** pollen, dinocyst, late Pliocene, East Sea, IODP

Paleoclimatic studies based on fossil wood from the Río Leona Formation (Miocene), Santa Cruz, Argentinean Patagonia

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Secondary xylem (wood) is a plant tissue that is greatly influenced by external climatic factors like temperature and water availability. Because of this, there are some anatomical characters of fossil wood that enable to do inferences about the climate condition prevailing in the place where the plant lived. Fossil woods are used to estimate the temperature and humidity during the Miocene of Santa Cruz province, Argentina. The studied material comes from the Río Leona Formation and consists of numerous permineralized wood fragments assigned to two conifers and twelve dicots. Petrographic slides and acetate peels were made. To calculate the mean annual temperature (MAT) and the mean annual precipitation (MAP) the equations proposed by Wiemann *et al.* (1998 and 1999) and the method of coexistence approach (CA) were used. The 17 equations proposed by Wiemann *et al.* for MAT estimation gave very different values between -1.63°C and 28°C, showing that these equation are questionable for this case. The CA seems to be a more reliable method, giving a MAT between 8.7 and 11.6°C. Wiemann *et al.* MAP equation gave an unlikely result (5780 mm), instead the CA method gave a MAP between 824 and 2260 mm. Carlquist's vulnerability and mesomorphy indexes were also calculated, with values of 0.5 and 246.77 respectively. Mean sensibility index varies between 0.08 and 0.54. Based on these results, it can be concluded that the zone had a temperate humid climate, with enough water availability and a marked seasonality influenced by temperature. The variation in the mean sensibility index results shows that the annual growth was not constant and adverse climatic conditions or other factors could have affected it.

***Keywords*:** paleoclimate, Miocene, fossil wood, Patagonia.

Preliminary study of sedimentary organic matter of the Neogene, Solimões Basin, North Brazil

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Palynofacies patterns were used to detect paleoenvironmental changes in 78 sediment samples of one well (1-AS-46-AM) drilled through the Solimões Formation. The formation consists of mudstones interpreted as fluvial/lacustrine system. Samples were prepared using the standard method of palynological preparation. The three main categories of particulate organic matter (POM), viz., amorphous organic matter (AOM), phytoclasts and palynomorphs were counted and identified. The organic constituents in the studied samples have been grouped into: autochthonous particles (algae); opaques phytoclasts; non-opaque non-biostructured phytoclasts and cuticles (Nop-NBio); structureless particles (AOM, pseudoamorphous and resin) and sporomorphs. The stratigraphic distribution of the groups was used to infer the paleoenvironmental changes. The proximity of the source is the main factor that reflects of dominance of No-NBio with average of 80% of the total POM. The section was subdivided into three intervals, according of palynofacies assemblage observed in the section. The first interval (85.17-200.17 m) is characterized for high amounts of Nop-NBio (almost 83%); however two episodic events of increase of autochthones, structureless particles and sporomorphs were recorded. The first event at 192.46 m, the autochthones, structureless particles and sporomorphs were predominant, being the autochthones the most abundant category. The second event was longer (141.91-122.32 m) and is coincident with abundance variations of autochthones, structureless particles and sporomorphs. Nop-NBio was replaced mainly by sporomorphs, especially between 134.26 and 135.19 m, when the Nop-NBio shows the lowest abundance in the whole section. The phytoclast input is continuous indicating a fluvial setting. However, the two episodic events have indicated lacustrine conditions. The second interval (57.59 - 85.17 m) is characterized for a gradual decreased of Nop-NBio and raised of opaque phytoclasts and sporomorphs which could reflect a subaerial exposure or at most shallow lakes. However, in the top of this interval (57.59 - 79.57 m), the Nop-NBio increased again, replacing opaques phytoclasts and sporomorphs. The third interval (41.73 - 55.10) started with Nop-NBio prevailing upon the others POM constituents. However, the significant change occurred at 41.73 m, in which Nop-NBio is replaced for structureless particles. This change has showed again the influence of lacustrine environment in a fluvial system.

***Keywords*:** Palynofacies analysis, paleoenvironments, Miocene, Pliocene, Amazonia

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Oligocene taphoflora of Tremembé Formation, Taubaté Basin in Quiririm (SP): palaeoclimatic and palaeoecological inferences based on leaf damage caused by other organisms

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Tremembé Formation, a lithostratigraphic unit of Taubaté Basin, consists of grayish to black argillaceous, papyraceous and bituminous shales, smectite clays and pebbly mudstones. It contains a very rich and diversified fossil faunal and floral record, the latter being among the most important Cenozoic paleofloras of Southeastern Brazil. Macrofossils preserved as impressions and/or compressions were collected from levels of papyraceous shales outcropping in the upper portion of the formation. The taphoflora of Quiririm (Municipality of Taubaté, State of São Paulo) presents a floristic composition constituted by an assemblage of, in general, algae, monilophyta, gymnosperm and angiosperm foliar taxa, probably deposited near the margin of a lake. The taphonomy suggests gradual deposition in a reducing environment, inferred from the horizontal arrangement of phytofossils on the bedding surface and their chaotic direction. Foliar morphographic analysis indicates that during the Late Oligocene the annual average temperature was between 25° - 30°C, forming a tropical / humid or seasonal subtropical biome on the valley and on the slopes of the Paraiba do Sul River graben. Paleoenvironment has been reconstructed based on the inferences

drawn from plant associations corroborated with palynological and vertebrate paleofaunal data.The leaf damages caused by the entomological fauna were recognized as holes, perforations and suctions marks, marginal feeding marks, galls and leaf mining, that confirm the wide diversity of insect taxa already detected in the paleoentomofaunal record and those caused by fungal organisms. Galls are the most abundant type of damage noticed and were caused by insects belonging to Lepidoptera, Coleoptera, Hymenoptera and Diptera, whose registers are observed in this and/or other outcroppings of the formation. Leaf minings indicate the abundant presence of moths (Lepidoptera) in the paleofauna. The leaf minings observed in *Xylopia*, typical in present day Nepticulidae, suggest an old interaction between these taxa resulting from putative coevolution. An intense and diversified herbivory and parasitic activity is indicated by the types of leaf damages. This fact associated to a diversified flora and foliar morphographic data is suggestive of a warm and more humid climate for the study area. [CNPq - 304978/2013-2, MECBO; CNPq-306609/2012-6, MJG; CNPq-.300578/2015-6, PSK].

Keywords**:** Angiosperms, entomogenic foliar damages, paleoecological and paleoclimatic interpretations, Late Oligocene, Taubaté Basin

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Novel Pleistocene record of plant remains in terrace sediments of Teles Pires River, northern Mato Grosso, Brazil

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As the result of paleontological rescue developed under the Research, Monitoring and Paleontological Heritage Rescue Programme of the Teles Pires hydroelectric plant, a large amount of samples including concretions and mudstones blocks containing plant fossils were recovered. The fossiliferous deposits lie in the current fluvial bed and terraces (levees) of the Teles Pires River, in the area destined for the future reservoir. Initially, we are investigating only the fossil from pelitic deposits, which are represented by unlithified sediments, situated on the banks of the river channel, deposited in the adjacent floodplains, and accumulated by gravitational processes (landslides) and suspension (floods and marginal lakes). Fossil remains preserved with the original organic matter are rare, but we obtained (AMS) ^{14}C ages of cal. 19,230 +/- 80 years BP, that is, late Pleistocene, in the base of the main phytofossiliferous outcrop. For this contribution, 74 specimens of fossil leaves, preserved in the form of impressions and compressions were selected. We based the analysis and description of the different morphological aspects of the remains on criteria established by the "Manual of Leaf Architecture". The venation patterns observed in the specimens constituted one of the main parameters for the segregation in morphotypes, as well as for taxonomic determination. The samples analyzed were described in detail and, whenever possible, identified with the aid of the work "Flora Pleistocênica do Paleolago Cemitério, Catalão, GO: taxonomia e fitofisionomia" and "Estudo de Impacto Ambiental da UHE Teles Pires (Volume 3)", but also on the information available in the "rede speciesLink" and "INCT- Herbário Virtual da Flora e dos Fungos". To implement the taxonomic study of the material, the specimens were separated into 16 distinct angiosperm morphotypes, which are largely included in the dicotyledonous clade, while a few are associated with the monocots. As a preliminary result, we identified specimens of Fabaceae and Myristicaceae families, and at generic level, two morphotypes classified as *Bauhinia* sp. and *Virola* sp. The remaining material are still under analysis, but will probably match the living taxa, many of which are currently present in the area, given the recent age of the analyzed deposits.

Keywords**:** Fossil flora, Teles Pires River, Amazon Rainforest, late Pleistocene.

Fossil woods from Cape Wiman (Paleocene), Seymour (Marambio) Island, Antarctica

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Fossil woods collected at the locality of Cape Wiman, in the northeastern part of the Seymour (Marambio) Island were anatomically studied in detail. The fossil wood bearing sediments of Paleocene age, were formerly considered a stratigraphic unit (Wiman Formation) but according to more recent studies, these strata are part of the Cross Valley Formation. The collection consists of more than 40 samples. All the samples are charcoaled and permineralized with carbonates and preservation is often poor. Samples were thin sectioned and observed at SEM. The assemblage is dominated by conifers. Among the conifers, about half of the woods are assigned to the Araucariaceae (*Agathoxylon* spp.), accompanied by Podocarpaceae (*Phyllocladoxylon* and probable *Podocarpoxylon*). Angiosperms are not very well preserved, but the samples apparently correspond to the same taxonomic unit, probably *Eucryphaceoxylon eucryphioides*, which has scalariform perforation plates, mostly uniseriate rays and predominantly solitary small vessels. Diversity of the fossil woods is similar to previous studies of the Cross Valley Formation found in other localities of the same island. These composition reinforces the hypothesis that the Paleocene forest canopy were dominated by the Araucariaceae in the area and were later replaced by the Podocarpaceae in the Eocene (La Meseta Formation).

***Keywords*:** Wood anatomy, Western Antarctica, Cross Valley Formation.

Palynology Of Sinu-San Jacinto Basin (Colombian Caribbean). A Marine Eocene Record

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Caribbean Colombian is key area in oil and gas exploration. The presence of numerous oil seeps have proved an active petroleum system. The Agencia Nacional de Hidrocarburos–ANH is drilling stratigraphic wells in order to understand the geological evolution of this region. The Piedra Blanca-1 stratigraphic well is composed by a 2467,3' (~752 m) thick siliciclastic sequence of black-gray mudrocks interbeded with thin sandstone turbiditic beds. In the mudrocks 111 samples were prepared for micropaleontologic analysis. Pollen, spores, dinoflagellates, calcareous nanofossils and foraminifera were recovered. The palynological preliminary study allow to identify: *Bombacacidites gonzalezii*, *Bombacacidites simplireticulatus*, *Bombacacidites nacimientoensis*, *Bombacacidites psilatus*, *Brevitricolporites microechinatus*, *Ctenolophonidites costatus*, *Cyclusphaera scabrata*, *Foveotriporites hammenii*, *Gemmamonocolpites amicus*, *Gemmamonocolpites barbatus*, *Gemmamonocolpites dispersus*, *Grimsdalea minor*, *Mauritiidites franciscoi var. minutus*, *Mauritiidites franciscoi var. franciscoi*, *Proxapertites humbertoides*, *Spinizonocolpites baculatus*, *Spirosyncolpites spiralis*, *Laevigatosporites granulatus*, *Polypodiaceoisporites? Fossulatus;* Dinoflagellates: *Polysphaeridium subtile*, *Nematospheropsis* sp1, *Spiniferites* sp. This assemblage suggest the T05 (*S. catatumbus*) Early Eocene palinozone described for the llanos basin in Colombia. In the same beds were found calcareous nanofossils: *Chiasmolithus* spp., *Helicosphaera* cf. *bramlettei*, *Helicosphaera lophota*, *Sphenolithus radians*, *Reticulofenestra reticulata*, *Reticulofenestra bisecta* s.s, *Reticulofenestra dictyoda* indicators of NP14?-NP20 zones (Matini, 1971) and Foraminifera: *Parasubbotina varianta*, *Globorotaloides quadrocameratus*, *Globoturborotalita bassriverensis*, *Acarinina punctocarinata* and *Subbotina crociapertura* typical of E1-E11 zones (Berggren and Pearson, 2005). This assemblage allow to indicate an early-middle Eocene age and contributes to the intercalibration of marine and terrestrial microfossils in the Caribbean area. The high content of terrestrial organic matter and in less proportion lowland pollen and spores suggest important deltaic input to the basin. The relative abundance of continental and marine microfossils allow to indicate relative changes in the sea level.

***Keywords*:** Palynology, Eocene, Colombia, Caribbean, marine microfossils

Miocene palynology in the Colombian Caribbean (Los Pájaros-1 well): record of sea level fluctuations

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Colombian Caribbean basins have a Late Cretaceous to recent sedimentary record. Micropaleontologic studies are mainly focused on marine sequences. In contrast there are few paleoecological and paleoenvironmental studies using pollen and spores palynology. Los Pájaros stratigraphic well was recently drilled in this region by National Hydrocarbon Agency (ANH). It is composed by a 1344' (410 m) sequence of green-gray mudrocks, sandstones and conglomerates. Some coal levels are distributed along the sequence. The mudrocks have an abundant and good preserved assemblage of terrestrial and marine palynomorphs: *Clavainaperturites microclavatus*, *Crassiectoapertites colombianus*, *Crassoretitriletes vanraadshooveni*, *Echiperiporites akanthos*, *Echiperiporites stellae*, *Echiticolporites spinosus*, *Fenestrites spinosus*, *Grimsdalea magnaclavata*, *Malvacipolloides maristellae*, *Multimarginites vaderhammenii*, *Nijsenosporites fossulatus*, *Perfotricolpites digitatus*, *Zonocostites ramonae*, *Tuberculodinium vancampoae.* This assemblage is typical of T14 (*G. magnaclavata*) and T15 (*V. vanraadshooveni*) Langhian-Serravallian biozones described for the llanos basin of eastern Colombia. Some beds contain benthonic foraminifera, which suggest low energy marine enviroments. The presence of *Darwinula* (Ostracoda) suggest fresh or brackish water enviroments. The assemblage show important variations in terrestrial lowland pollen, spores, mangrove vegetation and marine palynomorphs (dinoflagellates, foraminifera lining and scolecodonts). These relative variations reveal changes in the coast line as consequence of climatic and /or tectonic events occurred during early-middle Miocene in the area.

***Keywords*:** Palynology, Caribbean, Miocene, Mangrooves

Palynology of oil, formation water and core from Lower Pliocene Productive Series at the western flank of the South Caspian Basin

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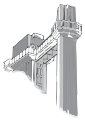
Plant residues are unique material for reconstruction of conditions of oil-bearing deposit formation. The Binagady oil field, situated in the central part of Absheron Peninsula (the western flank of the South Caspian Basin), was investigated for identifying the age as well as migration pathways of oil. Oil, formation water and core were sampled from Podkirmaky Suite at depth of 725-730 m. Podkirmaky Suite belongs to the lower part of Productive Series of Early Pliocene age (Zanclean) (5.3-3.6 Mybp). Extraction of plant micro-residues from rocks and formation water was conducted using the standard method of maceration. Previously oil was diluted with kerosene and filtrated through membranous (planctonic) ultra-filters with pore diameters 3-5 micrometers. The largest amount of pollen was discovered in formation water and core samples, represented by shale. Complexes extracted from hydrocarbons contain spores and pollen of plants, microphytic algae, fungi spores, plant tissue residues. Spores and pollen of geophytes inherent for this stratigraphycal unit dominate in plant micro-residues extracted from rocks, formation water and oil. Spores and pollen complexes from core and formation water are represented by *Taxodium*, *Ginkgo*, *Larix*, *Juglans*, *Quercus*, *Myrica*, *Pterocarya*, *Polypodiaceae.* Pollen of Conifers (*Pinus*, *Tsuga)* and herbs (*Chenopodiaceae)* are common for all three types of samples. Difference of pollen complexes is in large diversity of spores extracted from core (*Cyathea*, *Lycopodium*, *Osmunda*, *Schizaea*, *Polypodiaceae*) and their single presence in formation water (*Polypodiaceae*) and oil (*Osmunda)*. In complexes from oil spores and pollen typical for country rocks constitute 1/3 of total amount (spores and microphytic algae constitute 2/3). Formation water is characterized by spores and pollen of country rocks as well as Oligocene-Miocene dinoflagellates (*Wetzeliella*). In core spores of Cretaceous are present together with Early Pliocene spores and pollen forms.

While solving issues related to oil migration, the most interesting part of complex is spores, pollen and other plant micro-residues delivered by hydrocarbons and water from underlying oil-bearing deposits during migration process. In this case the ancient spores of unclear classification in Early Pliocene oil and dinoflagellates of Oligocene-Miocene age may be considered as the evidences of vertical migration.

***Keywords*:** pollen analysis, Oligocene, Miocene, dinoflagellates, South Caspian basin.



FORENSIC PALYNOLOGY

Leticia Povilauskas

Forensic Palynology: Contributions to the investigation of a homicide in South America

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The Palynology is a discipline within Botany dedicated to the study of pollen grains and spores. This discipline can be applied in different fields, as well as the oil and hydrocarbons, ecology, taxonomy and systematics of plants, and the legal and forensic area, among others. In the forensic area, the Palynology serves to provide useful information on the circumstances in which a crime, a murder occurred. The objective of this contribution is to publicize the activities developed on the basis of Forensic Palynology in a case of homicide occurred in South America; and pose a research protocol involving some considerations to take into account the crime scene and develop palynological analysis on samples obtained. In some countries, in recent years we has been concerned to extend support tools and study for judges, prosecutors and authorities, putting at their disposal element analysis study as forensic palynology. A collection and transportation of unsuitable samples and / or accidental contamination of forensic samples will produce inaccurate results. This can not only lead to misinformation but can be used to discard invalid data resulting evidence in a court. In this case study, a sample of the topsoil (0-2 cm) and sediments attached to clothing, shoes and hair of the victim at the scene was made. In the laboratory, under the light microscope, a total of 300-400 palinomorphs per sample were counted, the percentage counts were overturned tables and graphical charts. The types and amounts of pollen grains per sample were compared between different samples collected from the crime scene and surroundings. At this stage, prevailing statistical analyzes were performed to evaluate the data obtained from sampling and knowledge of where the murder occurred, which is very useful in the investigation of a crime such as the one presented in this paper, and today is in vogue.

***Keywords*:** Forensic Palynology, homicide, palinomorphs, South America.

Palynological Investigation of Mummified Human Remains

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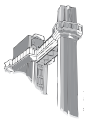
Pollen analysis was applied to a mummified homicide victim in Nebraska, USA. Control samples from outside of the corpse provide an idea of the normal ambient pollen of the crime scene. From inside of the decedent, samples from the sacrum well as a section of intestine were analysed. Another internal control sample of powder was recovered from the area inferior to the diaphragm. Finally, pollen was washed from the victim's hair. The intestine was rehydrated and microfossils were recovered from the inside of the section. The control samples were dominated by wind pollinated, environmental pollen types, as ragweed (*Ambrosia* type and

related genera), goosefoot/pigweed (*Chenopodium*/*Amaranthus*), maize (*Zea mays*) and grass (Poaceae), among others. The internal intestine sample was dominated by dietary pollen types as *Brassica* type (broccoli and related plants). The sacrum sample was also dominated by dietary pollen types, as *Brassica* type and prickly-pear cactus (*Platyopuntia*), with some environmental pollen types, for instance, maize, goosefoot/pigweed, grass and oak (*Quercus*). The pollen from the diaphragm was dominated by environmental pollen, as ragweed, goosefoot/pigweed, grass, oak, among others. The intestinal section method, proven important in archaeological investigations of mummies, can be directly transferred to forensic investigations.

***Keywords*:** forensic, mummy, intestine, Nebraska, pollen, method.



MELISSOPALYNOLOGY

Ortrud Monika Barth Schatzmayr & Paulino Pereira Oliveira

Palynology reveals behavior of *Melipona quadrifasciata* in a urban forest of Rio de Janeiro city, Brazil

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Rio de Janeiro city exhibits one of the largest urban forests in the world. A continuous covering of trees, shrubs and lowland vegetation is typical of the Atlantic forest. Nevertheless introduced exotic plant species are not uncommon. Besides birds and bats, the native Meliponini bees are significant pollinators. Its preferences are species specific. Reforestation activities and conservationism need knowledge about pollination and seed production of the native trees and shrubs adapted to the soil conditions. The present study used pollen loads of *Melipona quadrifasciata anthidioides* Lepeletier 1836, collected monthly from July 2014 to August 2015, in order to identify the visited plants during one year. Four localities were chosen to apiaries installation. The apiary of point 1 was established inside the Tijuca National Park, next to the visitor center. The point 2 in the lowland area of this Park, the point 3 in the Atlantic forest side and the point 4 also on the Atlantic side at higher altitude. Each monthly collection was composed of pollen loads obtained from bees coming into its nest in the morning. The pollen loads were mixed and cleaned using ethanol, washed, homogenized in equal volumes of water and glycerin and observed with 400x magnification. Evaluation of more than 500 pollen grains counted per sample follows the rule of monofloral patches when more than 90% of the pollen grains belong to a unique plant species or 60% when no accessory pollen type (15-45%) was present. Following the monthly sequence of the collection, point 1 presented monofloral pollen batches of *Myrcia*, *Eucalyptus*, *Solanum* and Melastomataceae pollen grains. Point 2 showed *Myrcia* and *Eucalyptus* monofloral pollen batches, point 3 that of *Myrcia*, *Eucalyptus*, *Solanum*, *Anadenanthera colubrina* and *Mimosa caesalpiniaefolia*, and point 4 that of *Myrcia*, *Eucalyptus*, *Anadenanthera colubrina* and *Melastomataceae*. Bifloral batches were composed of two of these taxa. In conclusion, nevertheless the Atlantic forest is very rich in tree and shrub species, the native bee *Melipona quadrifasciata* is loyal to one plant flowering species while producing pollen. This behavior proves the best efficiency in pollination, in sequence seed production and, finally, the installation and perpetuation of our forests.

***Keywords*:** pollen analysis, Meliponini, pollination, urban forest, Rio de Janeiro

The South American Honey Monitoring (SAHM) project

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Honey produced in South American (SA) countries constitutes a large proportion of the honey consumed in Europe and USA. In addition, the Neotropics inhabits about 5000 known native bee species serving the neotropical diverse flora and widespread agriculture by pollination. However, very little is known about the diversity of the plants visited by these various bee species and the diversity of the natural/artificial chemicals in produced honeys. This study aims to investigate and use biological and chemical diversity reflected in SA honeys to: 1) trace temporal, spatial and zoological dynamics of this diversity, 2) study the effect of short-term climatic anomalies (e.g. ENSO) and anthropogenic forces on this diversity, 3) introduce new sources for commercially, medically and cosmetically important products and 4) provide a base for future molecular biodiversity studies. Our results will serve nature conservation, rural development, resource management, food security and certification, world honey market, medicine and cosmetic industry.

***Keywords*:** Melissopalynology, Physiochemical analysis, climate change

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Botanical origin and physico-chemical properties of honey in the Chaco region (Argentine)

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The vegetation of Chaco region extends over 800 000 km^2 in one of the few areas in the world where the transition between tropics and the temperate belt occurs as semiarid forests and woodlands. In the Province of Chaco, which is within the Chaco region, beekeeping is growing. A total of 189 samples of honey were collected from 2005 to 2008 in different ecosystem complexes (landscapes) belonging to both Dry and Humid ecoregions. Honeys were studied in order to: - detect the main sources of nectar exploited by honeybees by means of melissopalynological analysis and, - establish their physico-chemical properties as color, free acidity, humidity, electrical conductivity, pH, hydroxymetylfurfural and diastase activity. Data were analyzed statically. Quantitative analyses indicated the floral origin of honey (Groups II and III). From qualitative analysis a total of 122 pollen types were identified, mostly from native plants. The families most important were Anacardiaceae, Arecaceae, Asteraceae, Capparaceae, Fabaceae, Myrtaceae, Nyctaginaceae and Rhamnaceae. A total of 17 pollen types characterized the monofloral honeys; excepting those of *Prosopis alba* and *Schinopsis balansae* which are harvested in dry and humid Chaco, a correspondence between floral origin and the two ecoregions was found. Monofloral honey of *Cynophalla retusa*, *Schinopsis balansae*, *Trithrinax schizophylla*, *Tessaria integrifolia*, *Ziziphus mistol* and multifloral with predominance of *Prosopis* and *Pisonia zapallo* were indicative of dry Chaco. *Copernicia alba* and *Eugenia uniflora* characterized the humid Chaco and, in areas where agriculture is practiced, were common the honeys from *Helianthus annuus* and *Baccharis-Eupatorium* which also contained pollen from a variety of aquatic herbs. Monofloral honeys from *Sagittaria montevidensis*, *Heimia salicifolia*, *Gleditsia amorphoides*, *Pisonia zapallo*, *Prosopis nigra* and *Bulnesia sarmientoi* were found only once. In general, physico-chemical properties adjust to normal

parameters according to the international specifications for commerce. Color and electrical conductivity were related with botanical origin of honey. Light amber color was predominant in honey samples. The high representation of pollen from native species supports the origin of these honeys from Chaco vegetation and shows a huge potential for the production of monofloral honeys.

***Keywords*:** Chaco, pollen, honey, physic-chemical properties.

How to distinguish between propolis and geopropolis – Palynological studies of South Brazilian samples

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Resin of plants, bee wax, glandular secretions of the worker bees and pollen grains are the main compounds of propolis elaborated by honey bees (*Apis mellifera L.*). Similar compounds are found in geopropolis elaborated by stingless bees, but in addition it contains soil, mud, clay, earth or sand. The present study intends to distinguish between propolis and geopropolis using pollen analysis of 12 samples obtained in the Southern Brazilian macro-region. Samples processing followed the standard melissopalynological methodology when all structural components were recovered after alcoholic extraction and before acetolysis treatment. A strong contribution of Asteraceae and *Eucalyptus* pollen grain characterized the eight propolis samples proceeding from the States of Paraná, Santa Catarina and Rio Grande do Sul. Geopropolis samples of *Tetragonisca angustula* contained mainly *Cecropia* pollen grains and that of *Melipona quadrifasciata* and *Melipona mondury* showed a predominance of Melastomataceae pollen grains. In addition to pollen grains, propolis samples showed trichomes and tissue fragments frequently. By the other hand, strong values of fungi spores, amorphous organic matter, sand or clay and remainder of plants resin characterized the geopropolis samples. As a conclusion, the structured elements recognized in propolis and geopropolis sediments, beside pollen grains, are decisive to distinguish between these two products of apicultural activities.

***Keywords*:** propolis, geopropolis, pollen grains, structural elements

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Pollen diversity in honeys of *Apis mellifera* L. Produced in a region of the semiarid of Bahia, Brazil

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Bee flora consists of useful plants for bees and is composed by nectariferous or polliniferous plant species. It´s identification is important for the knowledge and maintenance of the local flora, as well as to determine the botanical and geographical origin of the honey. In order to determine the botanical origin of honeys produced by *Apis mellifera* L. on apiarian Lagoa Rasa, Caetité - Ba, it was carried out the pollen analyzes of six honey samples collected monthly from January to December 2015. The samples (10g of honey) were dissolved in distilled water (20mL) and subsequently acetolized, following a count (1000 pollen grains) to determine the relative frequencies and occurrence. Were identified 43 pollen types, belonging to 13 families, 23 genera and 20 species (average of 7 pollen types per sample). Of these, four types were unidentified. The families Convolvulaceae, Euphorbiaceae, Leguminosae and Myrtaceae stood out for the large number of species visited by *A. mellifera*. The pollen types *Chamaecrista* sp. (54.8%), *Mimosa tenuiflora/verrucosa* (94.2%) and *Mitracarpus scabrellus* (88.2%) were classified as predominant pollen (P) in samples related to December, October, and August, respectively, being classified accordingly frequency of occurrence as very frequent or infrequent. The samples from August and October were considered monofloral honey from *M. tenuiflora/verrucosa* and *M. scabrellus*, once these pollen types have a frequency of more than 70% and are important nectar sources. *Chamaecrista* sp., *Copaifera* sp., *Mimosa adenophylla*, *M. ursina*, *Myrcia*

laruotteana, *Myrcia* sp.1 and Myrtaceae sp. were classified as secondary pollen (S). The pollen types *M. ursina*, *M. adenophylla* and *Chamaecrista* sp. reached, together, 77,8% of representativeness in sample from February, classifying this honey as mixed from these types. In sample from November, 97,4% of the pollen spectra where relative to four different pollen types of Myrtaceae. *Centratherum puctatum*, *Croton heliotropiifolius*, *Mimosa adenophylla*, *Mimosa caesalpiniifolia*, *Mimosa tenuiflora/verrucosa* and *Schinus terebinthifolius* were reached between 50 and 66% of frequency between samples, classified as very frequent. Water scarcity in some months decreases the floral resources, and consequently honey production becomes insufficient for storing large quantities. The pollen diversity found in the samples shows a variety of bee plants present in the vicinity of the apiary, important for the production of honey. Our analysis shows that the Caetité region have the potential to produce mixed (with few pollen types mainly contributing to production), monofloral or heterofloral honey, all of them presenting pollen types characteristic of the Brazilian northeast.

***Keywords*:** Melissopalynology, Northeast, bee, pollen grains, mixed honey

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Botanical origin and geographic differentiation of bee-pollen production from the Colombian East Andes

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In the Colombian East Andes (~2000-3000 masl), specifically at the Altiplano Cundiboyacense and Norte-Gutiérrez regions, beekeepers have gotten specialized in pollen production with substantial harvests all year round. Despite this productive advantage, knowledge about plants used by honeybees as pollen resources is still limited. Hence, the aim of this work was to identify the botanical origin of bee-pollen from these regions, as well as examine the geographic differentiation between them, based on their pollen spectra. The Altiplano Cundiboyacense and Norte-Gutiérrez region are located next to each other in the west flank of the Colombian East Andes, in the departments of Cundinamarca and Boyacá. In the Altiplano Cundiboyacense the study was circumscribed to the four distinguished sub-regions: Sabana de Bogotá, Fúquene, Márquez and Tundama. A total of 86 bee-pollen samples (250 g each) were collected between the years 2008 and 2010 from the five study areas. Five grams from each sample were mixed with alcohol 70% and 0.1 g of this mixture were taken and acetolysed. Two mounting slides per sample were observed under the microscope for pollen type identification and at least 500 pollen grains were counted per sample. With this data was determined the frequency and abundance classes of pollen types for each study area. Geographical differences between pollen samples were examined with a correspondence analysis. A total of 126 pollen types were found, belonging to 57 botanical families. Asteraceae (18) and Fabaceae (11) were the families with the largest number of pollen types. Major pollen types correspond to the exotic species *Hypochaeris radicata*, Brassicaceae Type, *Eucalyptus globulus*, *Trifolium repens* and *Trifolium pretense*, with occasional yields from native species like *Gaiadendron punctatum*, *Morella parvifolia*, *Quercus humboldtii* and *Weinmannia.* Significant differences were found between the pollen spectra of the five study areas and the major regions (Altiplano Cundiboyacense and Norte-Gutierrez). Differences were mainly associated to variations in pollen abundance and frequency of native plant species. This result highlights the potential for commercializing bee pollen from the Colombian Eastern Andes with geographical origin differentiation, as well as the importance for beekeeping in promoting the conservation of the natural ecosystems from the region.

***Keywords*:** Altiplano Cundiboyacense, *Apis mellifera*, Beekeeping, Denomination of Origin, Mellissopalynology.

Comparative nectar preferences by *Melipona quadrifasciata anthidioides* Lepeletier 1836 and *Scaptotrigona postica* Latreille 1807 in two remaining native forest at São Paulo state, Brazil, through palynology

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Honey samples were taken monthly over a full year (April 2015 to March 2016) from food pots, from two different sampling locations, in an effort to more broadly understand the trophic resources utilized by *Melipona quadrifasciata anthidioides* (Mq) and *Scaptotrigona postica* (Sp). The flora in the two sites is part of the Atlantic Rainforest and of the "Cerrado" (savanna, woodland) domains, with remaining native vegetation. The first (Parque Estadual das Fontes do Ipiranga - PEFI) was surrounded by *Eucalyptus* plantations and ornamental plants and, the second (Reserva Biológica de Mogi Guaçu - Fazenda Campininha) had *Pinus* and *Eucalyptus* plantations with varied agricultural crops (niger, orange, maize, eggplant, sorghum), an orchard with fruit-bearing plants (guava, jaboticaba) and an experimental grove with Brazilwood trees (*Caesalpinia echinata* Lam.). Two colonies of each stingless bee species were selected in each site and the honey samples were analysed with melissopalynological methodology by counting 300 pollen grains per sample in order to calculate the relative frequencies. The similarity between the samples was made using a principal component analysis to examine the influence of quantitative and qualitative data on the ordination of the pollen types. A total of 67 pollen types (45 in Mq and 61 in Sp) were identified in 45 samples, of which 56 genera and 35 families were recognized. The following families showed the highest pollen richness in Mq honeys: Fabaceae (7), Asteraceae (3), Myrtaceae (3), Sapindaceae (3), Dilleniaceae (2) and Malvaceae (2). In the Sp honeys were Fabaceae (13), Asteraceae (5), Euphorbiaceae (4), Myrtaceae (4), Sapindaceae (3), Dilleniaceae (2), Lauraceae (2), Moraceae (2) and Solanaceae (2). In Mq honeys the most frequent nectariferous pollen types (>45%) were *Anadenanthera*, *Cordia*, *Dalbergia*, *Eucalyptus*, *Mimosa scabrella*, *Sida*, *Serjania* and *Vernonia*. In Sp honeys were *Anadenanthera*, *Bidens*, *Cordia*, *Eucalyptus*, *Protium*, *Tapirira* and *Schefflera*. There was a distinct usage of floral sources in each one of stingless bee species when the two principle annual harvest periods were compared (March to August and September to February) given that the honey samples formed two main groups of similarity. Although the majority of the pollen types showed low percentage values, the results demonstrated that the stingless bees have taken advantage of the nectariferous sources available in the forest, as well as in the "Capoeira" (brushwood, secondary forest), "ruderal" (field) vegetation and cultivated plants, probably implying its importance as pollinators of the native flora and of the exotic species.

***Keywords*:** Atlantic Rainforest, Cerrado, nectar sources, pollen analysis, stingless bee

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Pollen diversity in honey produced by *Tetragonisca angustula* Latreille in a semiarid region of Bahia State, Brazil

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The pollen grains founded in honey are considered "contamination" once it plays no role in honey production. During the process of nectar collection the bee comes into close contact with the anthers and some of the pollen falls into the nectar.Based on this idea it´s possible to analyze the pollen content of honey to determine the bee flora. The samples (11) were collected at Fazenda Palmeira, in the municipality of Caetité - Bahia. For the pollen sample processing (4g honey per sample) it was used the conventional method of acetolysis after dissolution in distilled water (8ml). It was performed a count of at least 1000 pollen grains per sample. The identification of pollen types was based on reference collection of the Laboratory of Palynological Studies (LAEP), thesis, books (catalogs) and scientific papers. The pollen types were classified according to their frequency in the sample (predominant pollen, secondary pollen, important minor pollen, minor pollenand trace pollen) and among the samples (very frequent, frequent, infrequent and rare). Of the identified

pollen types stands out S*chinus terebinthifolius* (Anacardiaceae), rated as predominant pollen (>45%) in three samples; and secondary pollen (10 – 45%) in five samples. Among families with a larger number of pollen types we can mention *Leguminosae* with 15 types, being *Mimosa* as the most representative genus with six distinct species. The pollen types that were considered most representative and classified as very frequent was *Anadenanthera colubrina*, *Cecropia* sp., *Celtis* sp., *Delonix regia*, Melastomataceae sp. and *Trichogonia* sp..Two samples were considered as monofloral of *Schinus terebinthifolius* which are over than 90% of representativeness, once that pollen type is considered over-represented; the others samples were considered heterofloral. The analysis of honey samples produced by *Tetragonisca angustula* it is important for indicate which plant species are part of the important flora for this specie at Fazenda Palmeira, located in Caetité. Thus, this study contributes to the conservation of the environment in question, since it emphasizes the importance of local plant species for beekeeping. Financial support: FAPESB, CNPq.

***Keywords*:** Melissopalynology, ecotone, pollen grain.

Pollen content of bee pollen loads from an area of semiarid

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Apis mellifera L. is considered a generalist species, it has an intense foraging activity, ability to adapt to susceptible environments and compete with other species (native ones). The composition of bee pollen varies according to region, season and rainfall, indicating the variations of the local flora. This study aimed to analyze the pollen collected by bees in order to identify the most used plants by *A. mellifera* and recognize the main pollen source throughout the studied months for bee pollen production. The study was conducted in an area predominantly abreast of cerrado and caatinga, considered Ecotone, located near of Caetité city, Bahia. The pollen pellets were treated by acetolysis, and then was performed a counting of 1000 pollen grains in order to identify the pollen types present in each sample. Were collected six samples (01-06): november (01-02) and december 2015 (03), january (04) and februrary 2016 (05-06 respectively). Sixty two pollen types, belonging to 16 families were identified. Among the families that stood out in number of pollen types is quoted Leguminosae (17 types) and Myrtaceae (18 types).The genera *Mimosa* and *Myrcia*, respectively, were the most diverse in the samples. *Byrsonima brevifolia* and *Eucalyptus* sp. were the only ones present in all samples. The pollen types related to Myrtaceae were the most representative in samples one (*Eucalyptus* and *Myrcia*) and three (*Myrcia*), with 34,3% and 54,5% respectively. *Evolvulus* sp. reached 71,7% in sample two; in four and five the main source of pollen belongs to Leguminosae (85% and 98,7%). *M. caesalpiniifolia* were "probably" the most important pollen source in these samples (46,2% and 64,1%). In sample six were observed two main pollen types, *Byrsonima brevifolia* (45%) and *M. caesalpiniifolia* (45%). In spite of the presented data, it is necessary mention the importance of compare the pollen grains sizes and volumes, once this characteristic influences the nutritional potential of each pollen grain to bees. For example, in samples four and five, when comparing this feature regarding *Chamaecrista* and *M. caesalpiniifolia*, *Chamaecrista* contributes with more nutritional content once its volume is approximately 9,2x bigger than the volume of *M caesalpiniifolia.* This study demonstrates the great diversity of pollen types found in the samples, reflex of the amount of botanical species present in the study area, especially the pollen types mentioned above. Also point to the importance regarding the real nutritional value of the pollen grains related to their size and volume. (FAPESB – CNPq)

***Keywords*:** Pollen grains, Semiarid, Palynology, Bee pollen, *Apis mellifera*.

Temporal variation of *Elaeis guineensis* L. in samples of bee pollen monofloral of Arecaceae in the municipality of Nilo Peçanha, Bahia, Brazil

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The family Arecaceae consists of 252 genus and 2.600 species approximately, but in the Brazil its occurrence is estimated in 38 genera with about 270 species. It considered the third most important family in terms of economic importance and, among the species, highlight for *E. guineensis* that plays a key role in the economy of the municipality of the Bahia, mainly with the production of bee pollen monofloral, since it has as characteristic present flowering throughout the year. Based on this feature, the goal is to verify a temporal variation of *E*. *guineensis* in relation at flowering throughout the study period in the municipality of Nilo Peçanha, Bahia, Brazil. Eighteen samples of bee pollen monofloral of Arecaceae were analyzed during the period of 2013-2014. These samples were chemically treated by acetolysis, for each sample, five permanent slides mounted with glycerine jelly, and analyzed in an optical microscope. A minimum of 500 pollen grains was count for each sample, and the botanical identification carried out with the aid of specialized literature and for comparison with a pollen library of Laboratório de Micromorfologia Vegetal. Despite the classification of samples as monofloral of Arecaceae by beekeepers, the pollen spectrum was comprised of 36 pollen types belonging to 20 botanical families. The family Arecaceae was present in all the samples, but the types belonging to families Cyperaceae and Fabaceae were present in 94% of the samples. The pollen type *E*. *guineensis* was present in eight samples with percentages above 30% and, among these samples only had values above 90%. Already the pollen type *Mimosa pudica* was present in four samples with values above 90%, showing the apicultural potential on this bee pollen type. Regarding the temporal variation of the type *E. guineensis*, it is possible to identify the months of December/2013 to May/2014 were the periods with the highest rate, since months of June to October/2014 were represented for the type *M*. *pudica*. This variation of *E. guineensis* occurred due to its continuous flowering throughout the year. Furthermore, factors such as temperature and rainfall influence both in the production of the resource by the plant and in the activity of foraging bees. Based on these results, we can conclude that the temporal variation within of the samples directly influences in their classification, so, carry pollen studies are necessary to confirm this classification in monofloral and multifloral. Financial support: Capes, CNPq.

***Keywords*:** Apiculture, Arecaceae, monofloral, pollen spectrum.

Palynological analysis of Northern Spain propolis

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Palynological analysis of seventeen propolis samples from bees (*Apis mellifera* L.) from different areas in Northern Spain has been carried out for the present work. Such samples were gathered using polyethylene mesh for food use which placed in Langstroth beehive from end of April to middle of November 2011. The methodology followed for the analysis of the samples was the method of Barth (1998), with some modifications. The results obtained reveal the diversity of pollen types identified: around one hundred pollen types were identified belonging to thirty six plants families, being the most significant ones Asteraceae and Ericaceae with 71% and 80%, respectively. The pollen types identified in bigger quantities belong to *Calluna vulgaris*, *Centaurea calcitrapa*, *Cytisus scoparius*, *Chenopodium album*, *Erica arborea*, *E. australis*, *Helianthus annuus*, *Polygonum persicaria*, *Thymus* sp. y *Salix* sp.

Keywords: propolis, pollen, Spain, Ericaceae, Asteraceae

An overview on Melissopalynology in Brazil through researches presented in the Brazilian Botanical Congress

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We present an overview of pollen analysis of bee products in Brazil, through analyzing abstracts published in editions of the Brazilian Botanical Congress (55th-64th). The research has included abstracts available on the website of the Botanical Society of Brazil, regarding the events held between 2003 and 2015. We have searched for abstracts presenting one of the following keywords: "melissopalynology", "bee" or "honey". After a thorough reading, we found 59 abstracts focused on pollen analysis of bee products. Abstracts from Northeastern Brazil corresponded to 68% of the findings, followed by those ones from Southern (21%) and Northern (11%) regions. The Bahia State stood out with 58% of the abstracts analyzed, followed by Maranhão (11%), Amazonas (9%), Minas Gerais (6%), São Paulo (5%), Rio de Janeiro (5%), Rio Grande do Sul, Amapá and Pará (2% each). The bee species whose products have been studied under a melissopalynological view are: *Apis mellifera* L., 1758 (42%), *Melipona (Michmelia) scutellaris* Latreille, 1811 (14%), *Tetragonisca angustula* (Latreille, 1811) (8%), *Melipona (Melikerria) compressipes* (Fabricius, 1804) (3%), *Cephalotrigona femorata* (Smith, 1854) (3%), *Scaptotrigona tubiba* (Smith, 1863) (3%) and *Melipona (Melipona) quadrifasciata* Lepeletier, 1836 (2%); this information was lacking for 24% of the abstracts. Erdtman›s acetolysis, revised in 1960, was the most employed method in honey processing (87%), whereas 13% of the abstracts analyzed non-acetolyzed bee products (European method). Honey was the main bee product palynologically investigated (91%), followed by similar products bee products (9%), such as bee pollen and propolis. The most frequent families cited in the abstracts in order of frequency were: Fabaceae, Myrtaceae, Asteraceae, Anacardiacae, Rubiaceae, Arecaceae, Malvaceae, Euphorbiaceae, Lamiaceae and Leguminosae. At about 73% of the researches were funded by any Brazilian agencies (*e.g.* CAPES, CNPq, FAPESB, FAPESP). Our results suggest that pollen analysis of bee products are still scarce in Brazil. However, we conclude that the Northeastern region, especially Bahia State, stands out in the Brazilian Melissopalynology because of its increasing number of researches focused on pollen analysis of bee products. Furthermore, Bahia figures as one of the main honey producers in Brazil, which might foster melissopalynological studies. Additional studies are desirable in order to providing a broader view of the pollen spectra of Brazilian bee products, especially those from stingless bee species.

***Keywords*:** bee products, honey, pollen analysis, pollen grains, state-of-the-art

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Pollen in Honey of *Melipona scutellaris* L. (Hymenoptera: Apidae) in an Atlantic Rainforest area in the state of Bahia, Brazil

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Uruçu (*Melipona scutellaris* L.) is an example of native stingless bee typical of Brazil's Northeastern region. It stands outs due to its high quality honey and for being responsible for 40 to 90% of the pollination of native species. A total of 37 honey samples were analyzed, collected between Jul/2012 and Jun/2014 in a meliponary located in the municipality of Entre Rios, state of Bahia, Brazil. Honey samples were diluted in distilled water, then in alcohol and then were acetolyzed. Climate information (precipitation and temperature) for the area was obtained during the same period of time. We found 102 pollen types, of which 71 were identified as belonging to 36 plant families. Fabaceae was the most representative family with 15 types, followed by Myrtaceae with seven types. Myrtaceae was highly expressive due to the high distribution frequency and dominance of the *Eucalyptus* type. The *Miconia* type (Melastomataceae), highly polliniferous, also stood out in our analysis with a high distribution frequency and dominance in some of the sampled months. The precipitation index of the second year of study (Aug/2013 to Jun/2014) was much superior to the first year (Jul/2012 to Jun/2013), being proportional to the increase of pollen diversity in the same period.

***Keywords*:** Melissopalynology, bee products, native plants, precipitation index.

The pollen spectrum of the propolis of *Apis mellifera* L. (Apidae) from the Atlantic Rainforest of Bahia, Brazil

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Propolis produced by honeybees (*Apis mellifera* L.) over a period of 24 months, in an Atlantic Forest area in the municipality of Entre Rios (Bahia, Brazil), was analyzed palynologically. Climate data (precipitation and temperature) for the area was obtained during the same time period. Fifteen samples of propolis were chemically treated in order to concentrate the pollen grains present. A total of 115 pollen types were found, of which 92 were identified as belonging to 40 plant families and 71 genera. The study recorded the occurrence of pollen types related to resiniferous plant species (i.e., *Cecropia*, *Maytenus*, *Phyllanthus*, *Protium heptaphyllum*, *Schinus terebinthifolius*, *Spondias tuberosa*, *Symphonia globulifera* and *Tapirira guianensis*). However, the greatest percentage found was for the *Eucalyptus* type (60%), which was present in a sample from January 2014. The maximum recorded temperature was 33 °C during January 2014, while the minimum was 18.4 °C during September 2012. The maximum recorded rainfall volume in the region was 190 mm^3 in April 2013, while the minimum was 21 mm^3 in January 2014.

***Keywords*:** Bee products, melissopalynology, rainfall, resinous plants.

Pollen analysis towards botanical origin and heavy metal content of honeys from the state of Bahia, Brazil

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Honey is a food produced and consumed in almost every country in the world because its high nutritional and energy value. Its composition is a complex mix of carbohydrates, proteins, amino acids, organic acids, vitamins, and minerals. The minerals are a content part of the environment, and thus it can be absorbed by plants and incorporated into the honey *via* nectar. Heavy metals are examples of toxic minerals to human health and can be found in some honey bee. Therefore, this study aimed to characterize the botanical origin and the heavy metal content (cadmium, chrome and lead) of five honey samples from the state of Bahia. The methodology used to identify the botanical origin of the honey was the standard melissopalynology methods with acetolysis. To establish the frequency classes of pollen types in each honey sample, at least, 500 pollen grains were counted. The concentrations of heavy metals were determined by atomic absorption spectrometry after microwave digestion. The samples were statistically treated using pollen similarity analysis (Jaccard index) in order to group them based on their pollen spectrum. Sixty-four pollen types were identified, fourteen belonging to the family Fabaceae, the most prevalent among the samples. *Myrcia* sp.1 was the most representative pollen type in the study, followed by *Chamaecrista nictitans* e *Tapirira*. Based on the similarity pollen the samples came together in two groups: (1) samples of cities Palmeiras and São Felipe, and (2) samples from cities Feira de Santana, Barra do Choça and Ilhéus. Regarding the content of heavy metals, only lead was detected in all the samples, ranging to 1.4 – 5.5 ppm. Chromium was present only in samples of Feira de Santana (2.4 ppm) and Barra do Choça (3.5 ppm), and cadmium only in latter (0.6 ppm). Comparing the results with the literature, it is clear that only the chromium levels were higher than the maximum levels detected in honey. However, considering Brazilian laws, all metals studied here were detected with higher levels than the maximum allowed in honey. Financial support: CAPES, CNPq.

***Keywords*:** food contaminants; honey bee; *Apis melifera*; atomic absorption spectrometry

Influence of the pollen type *Mimosa* in the samples of pollen pots of *Melipona asilvai* produced in the biome Caatinga

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Melipona asilvai Moure is an endemic species to Brazilian semiarid region, and it is an important pollinator for plants from the caatinga, with great potential for meliponiculture. Pollen analysis of bee products is an effective tool to recognize the bee flora of a region, and thus to determinate its apicultural potential. This method based on the identification of pollen grains by comparison of morphological similarities with pollen grains from plant species that contributed as floral resource for bees. It is also possible to provide information on the frequency of species by counting the amount of pollen grains. In this work it was conduced a palynological investigation of 24 stingless bee pollen. The samples were collected from April 2012 to March 2014 in an area of caatinga, Bahia, Brazil. The aim is to infer the flora visited by bees (*M. asilvai*) to evaluate the participation of species of the genus *Mimosa* as a source of resources used by these bees. The samples were submmited the usual laboratory processing techniques (acetolysis). At least, a total of 500 pollen grains was counted for sample, and the identification carried out with the aid of specialized literature and for comparison with a pollen library of Laboratório de Micromorfologia Vegetal (LAMIV-UEFS). Based on the analysis, the pollen spectrum is constituted for 48 pollen types belonging to 22 botanical families. The family with highest diversity of pollen types was Fabaceae with 14 types. Pollen types from the genus *Mimosa* showed high representativity in the spectrum, as it were found in all samples with high frequency in some of them. The pollen type *M. tenuiflora* showed frequency of occurrence in 91.5% of the samples and had great contribution in the sample set. The other pollen types identified for the genus *Mimosa* and their frequency of occurrence were *M. arenosa* (66.7%), *M. quadrivalvis* (29.2%), *M. misera* (8.3%) and *M. pudica* (50%). Besides those pollen types mentioned, other pollen types contributed in the formation of the pollen spectrum, like *Angelonia* (Plantaginaceae) in three samples and *Chamaecrista racemosa* (Fabaceae) in a sample. Other pollen types that were found only as very common (<50%) in the sample set were Melastomataceae, *Solanum paniculatum* (Solanaceae), *Borreria verticillata* (Rubiaceae) and *Myrcia* (Myrtaceae). However, despite the variety of registered floral sources, it was possible to diagnose the floral preferences of these bees by *Mimosa* indicating the important role of its species as a resource for the bees. Financial support: CAPES, CNPq.

***Keywords*:** pollen analysis; source resource, Fabaceae, stingless bee

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Euclides Neto Colony, Bahia, Brazil honeys: Botanical aspects and colour

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Palynological and colour analysis of honey is of great importance in the quality control of the product, as it becomes possible to certify its origin and detect tampering. The present work had as objective the determination of botanical and colour of *Apis mellifera* L. honey from Euclides Neto Colony, in Mata de São João, Bahia, Brazil (12°31'48"S; 38°17'56"W). It also aimed to relate their floral origin with the colour, providing value to this regional and sustainable product. Palynological and colorimetric analyses were carried out with eight samples of production in February-March/2013 April/2014. For palynological analysis, the samples were submitted to standard procedures of melissopalynlogy, with acetolysis pollen. Some pollen types were identified from pollinic catalogues and palynotheca at the Palynological Studies Laboratory, at the Department of Exact and Earth Sciences II, of the University of the State of Bahia. For colour analysis, we used the colorimeter, HANNA HI 96785. The palynological analysis of the samples showed 44 pollen types of which 35 had their botanical affinities identified. The pollen types *Eucalpytus* sp (Myrtaceae) and *Mimosa caesalpiniifolia* (Fabaceae) occurred as predominant and secondary pollen respectively. Other types were classified as minor pollen and/or trace pollen. The pollen types *Tapirira guianensis* (Anacardiaceae), *Mimosa pudica*/*sensitive* (Fabaceae) and *Eucalyptus* sp type (Myrtaceae) appeared in all samples, while the types *Cocos nucifera* (Arecaceae), *Cecropia* sp (Cecropiaceae) and *Myrcia* (Myrtaceae), were registered in 87.5% of the samples. Pollen types with limited registration, i.e., in only one sample, were: *Gochnatia*

sp (February/13) and *Byrsonima* sp (March/13). Six samples were classified as *Eucalyptus* sp. monofloral honey (predominant pollen: 79.3% to 97.8%) and two samples as *Eucalyptus* sp. (predominant pollen: 55.2% and 65.9%) and *Mimosa caesalpiniifolia* (secondary pollen: 15% and 20.7%) bifloral. Honey colour analysis revealed variation in colour spectrum: 85 to 150 mm Pfund, which made it possible to classify them as: amber (five), light amber (two) and dark amber (one). When it was related to botanical origin with the colour, it was noticed that for all the samples analyzed of light amber and amber, *Eucalyptus* sp. type was predominant and as the dark amber, *Mimosa caesalpiniifolia* and *Eucalyptus* sp. types were registered.

***Keywords*:** Melissopalynology, bee flora, colour, *Apis mellifera*

Antimicrobial effect of the ethanolic extracts of the *Apis mellifera* L. bee pollen from residual fragments of the Atlantic Forest in Alagoinhas, Bahia, Brazil

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The bee pollen has been used in the natural food segment, as a supplement to the human diet, probably for the richness in bioactive compounds. The aim of the present study, conducted in a remaining area of the Atlantic Forest, in the municipality of Alagoinhas - Bahia- Brazil, was to analyze the botanical composition and the antimicrobial potential of ethanolic extracts of *Apis mellifera* bee pollen obtained from January to December of 2014. For palynological analysis, the samples were submitted to standard procedures of melissopalynlogy, with acetolysis. Three grams of bee pollen were macerated and resuspended in 15 ml of 70% alcohol, in a water bath at 70^0 C for 30minutes and centrifuged at 7.000 g for 30 minutes. The antimicrobial test was conducted by disk diffusion method using *Bacillus subtilus* (ATCC 6633), *Staphylococcus aureus* (ATCC 6538), *Micrococcus luteus* (ATCC 10240), *Escherichia coli* (ATCC 94863), *Pseudomonas aeruginosa* (ATCC 15442) grown on Mueller-Hinton agar. 10 µL of the extracts were used at concentrations of 200, 100 and 50 mg/mL. 10 µL Chloramphenicol at 1 mg/ml were used as positive control, while 10 µL of 70% alcohol solution were used as negative control. The samples and controls were added to a 6.0 mm paper discs. From the pollen analysis was possible to register the presence of 48 pollen types belonging to twenty botanical families. In the antimicrobial analysis after 24 h of incubation it was observed that only extracts collected in September and December were able to inhibit the microbial growth. For December, at concentrations of 100 and 200 mg / mL of pollen, the inhibition halo displayed around the discs on plates containing *Escherichia coli* accounted for 33.33% and 60.47% to the chloramphenicol, respectively. For the same month, at the concentration of 200 mg/ml, in the plate containing *M. lutteus*, *S. aureus* and *B. subtilis* the halo exhibited 65.13%, 57.14% and 62.38%, respectively. In this sample the predominant pollen type was *Piper divericatum* with 38.3% record. For the pollen obtained at September used in the highest concentration, only *B subtilis* was inhibited at 34.78% of the cloranfenicol and the pollen type *Mimosa pudica/sensitiva* predominated in the sample with 75.3% frequency. Due to the floristic diversity of the study area, these results may be related to the presence of diverse bioactive products found in different pollen types during the year.

***Keywords*:** Antimicrobials, Bee Pollen, Extracts, Botanical Composition

Antioxidant action of the ethanolic extracts of *Apis mellifera* L. bee pollen from residual fragments of the Atlantic Forest in Alagoinhas/BA/Brazil

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The bee pollen is obtained from the agglutination of pollen grains from various plant sources, harvested by bees, which are mixed with nectar and salivary secretions. This survey was conducted in a remaining area of the Atlantic Forest, in the o municipality of Alagoinhas - Bahia - Brazil. The aim was to analyze the botanical composition of corbicular pollen *Apis mellifera* collected monthly from January to December 2014 to evaluate its antioxidant potential from different ethanol extracts. For palynological analysis, the samples were submitted to standard procedures of melissopalynlogy with acetolysis. The extracts were obtained from 3 grams of bee pollen macerated and resuspended in 15 ml 70% alcohol. The extraction was performed in water bath at 70^0 C for 30 minutes. The suspension was centrifuged at 7.000 x g for 30 minutes and the supernatant was stored at -20°C until the analysis. The evaluation of the phenolic compounds was performed by Folin-Ciocalteu spectrophotometric method. To evaluate the antioxidant activity the kidnapping methodology of DPPH (1,1-diphenyl-2-picrilidrazil) was used. The results are set forth in mgGAE/g extracts. From the pollen analysis was possible to register the presence of 48 pollen types belonging to twenty botanical families.The assessment of the data showed that the content of phenols and the DPPH radical kidnapping activity varied throughout the year, with the following values: 61; 66.5; 62; 32; 30; 48; 164; 57; 49; 81; 59 and 62 mgGAE/g for the contents of total phenols, and 87.7; 71.1; 92.3; 87.7; 68.8; 95.15; 89.45; 84.5; 82.3; 74; 85.5; 84.3 % for the scavenging activity. These values correspond to the data obtained between the months of January to December 2014. Of these, the greatest value for the content of total phenols was observed in July, 164 mgGAE/g extracts. April and May, showed the lowest values, 32 and 30 mgGAE / g extracts, respectively. For these samples the predominant pollen types were: *Eucalyptus* (April), *Mimosa caesalpiniifolia* (May) and *Mimosa pudica/sensitiva* (July) with frequency of 92.69%, 82.77% and 77.27% respectively.There was no correlation between the period with increased antioxidant activity of bee pollen extracts, and the period of highest scavenging activity of DPPH. Thus, it can be suggested that the lack of correlation between antioxidant activity and phenol content is due to different compositions of the extracts, as well as the presence of non-phenolic compounds with antioxidant activity or the presence of products of bee own metabolism.

***Keywords*:** Antioxidant; Bee Pollen; Phenol; Extracts; Botanical Composition

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Pollen analysis of honey samples of *Apis mellifera* L. produced in the municipality of Antônio Gonçalves, Bahia, Brazil: preliminary data

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Honey production is an activity that is growing every year in the Itapicuru's Northern Territory, including the municipality of Antônio Gonçalves, State of Bahia, Brazil. Aiming to increase the knowledge about the regional bee flora and classify botanical families with melliferous potential, the honey samples produced in two apiaries ("Area D" and "Caldeirão do Mulato") from Antônio Gonçalves and commercialized by Beekeeper Cooperative of Campo Formoso (COOAPICAF), had their pollen spectra analyzed. Four samples were collected during the periods October 2014 (sample I), August and December 2015 (sample II, samples III and IV, respectively). The pollen analysis was performed using the method of acetolysis. The honey samples were analyzed qualitatively, by counting at least 1000 pollen grains per sample, to establish the classes of pollen frequency of each pollen type registered. The pollen grains present in the samples had their specific botanical affinity whenever possible, based on the pollen reference collection of Palynological Studies Laboratory of UNEB - *Campus* VII and specialized references. On preliminary data, it was registered the occurrence of 69 pollen types in total of the samples. The most frequent pollen types were: Amaranthaceae (*Alternanthera*); Arecaceae (*Syagrus*); Asteraceae (*Eremanthus*); Fabaceae (*Mimosa pudica-sensitiva*, *M. quadrivalvis*, *M. tenuiflora*); Malvaceae (*Herissantia*); Rubiaceae (*Borreria*).

Less frequent pollen types (> 25-50%) were: Anacardiaceae, Euphorbiaceae, Cecropiaceae, Lamiaceae, Myrtaceae, and Poaceae. The *Mimosa pudica-sensitiva* pollen type stands out by being present in the four samples (> 75-100%), while *Borreria* and *Eremanthus* types belong to the accessory pollen class (16-45%), represented 22% and 17%, respectively, of pollen types present in honey samples. The diversity of pollen types found so far, contributes to the recognition of plant species of the region used by bees *Apis mellifera* L. in the production of their products.

***Keywords*:** Pollen type, floral origin, *Apis*, Honey

Pollen spectrum of *Melipona scutellaris* Latreille, 1811 honey from an Atlantic Forest fragment bordering Salvador city, Brazil

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Melipona scutellaris Latreille, 1811 (Hymenoptera, Apidae, Meliponini) stingless bees can be found in Bahia state and are known for their fidelity with the floral resource of food. However, the extinction reports of this species can be directly related with the destruction of the local flora. Wishing to know and to preserve the flora used by these stingless bees, the study aimed to identify the pollen types in *M. scutellaris* honey in a fragment of a forest area bordering Salvador city, Bahia state, Brazil. Samples were collected from operculate honey pots in random colonies during 12 months then sent to the Palynology Laboratory of the Research Team Insecta at Federal University of Reconcavo of Bahia in Cruz das Almas. The samples were analysed using the methods adapted from Jones Jr. and Bryant (2004), and Erdtman (1960), with the samples displaced between slide and coverslip. For each sample/slide pollen grains were counted and identified, where possible, up to 1000. A total of 42 pollen types between 17 families were identified, however for 6 types identification of the pollen type was not possible. The Fabaceae family had the highest diversity of pollen types with 30.56% of the total followed by Asteraceae, Euphorbiaceae, and Myrtaceae each with 8.33% of pollen types. The pollen types classified as dominant were *Mimosa caesalpiniifolia*, *Miconia*, *Solanum*, and *Tapirira*, and as accessory the pollen type were species of *M. caesalpiniifolia*, *Myrcia*, *Psidium*, *Protium*, and *Solanum*. The most frequently identified pollen types in the samples were *M. caesalpiniifolia* (100%), *Miconia* (88.89%), and *Solanum* (77.78%). The Pollen spectrum of the honey studied was diverse, which can be classified as polyfloral honeys. The results indicate the important contribution of Fabaceae species in honey composition produced by *M. scutellaris* from the samples analysed. (CAPES; SEMA/FAPESB)

***Keywords*:** Stingless bees, melissopalynology, pollen types, polyfloral honeys, Fabaceae

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Palynological assessment of Ecuadorian stingless bee honeys from Esmeraldas and Manabí provinces

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Pollen spectra of floral nectar resources visited by honey bees reveal the botanical origin of honey. A specialized interpretation is need of honeys obtained from tropical plants, frequently presenting a low number of pollen grains when compared with honeys proceeding from colder countries. Ecuadorian Meliponini honeys from Esmeraldas and Manabí provinces were selected for this study. Honey samples were prepared following the European technique without the use of acetolysis. At least 300 pollen grains were counted. The nectarless anemophilous pollen grains were excluded from the counting. Therefore pollen grains from nectariferous plants were responsible for 100% of the honey production. There are under and over-represented plant

species in the pollen spectra and a correction was need in order to evaluate the real origin of a honey sample. Monofloral honeys are assigned to particular honeys whose pollen spectra contain over 45% of a nectariferous plant taxon. No correction factors are available at the moment. The large experience of a palynologist in tropical vegetation and melissopalynology may empirically determine the botanical origin of an under-represented honey. Considering Ecuadorian honey samples of stingless bees (Meliponini) in our study, the most under represented plants belong to species of the Bombacaceae (Malvaceae) family. As there are no specific correction factors related to tropical environments, it is desirable that in future these factors could be established in order to get a more accurate assessment of these honeys.

Keywords**:** melissopalynology, Ecuadorian honeys, under-represented pollen, Bombacaceae

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Bee, palynology and maintenance of ecosystem services

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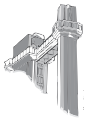
Pollen analysis either of larval food provided by females to immature forms in solitary bees or of pollen stored by bees or brought to the colony by foragers may provide information on the trophic niche breadth of a species, as well as its resource overlap with another one, helping us to better understand the way they interact with plants. For this reason, Palynology has become a complementary science, supporting studies on bee and plant interaction in natural ecosystems, urban areas and agroecosystems. In the last decade, there was an increase in the studies on bee diet with focus on conservation, besides the certification of bee products. Both groups from the Bee Laboratory of IB-USP (Universidade de São Paulo) and the Bee Laboratory of UFC (Universidade Federal do Ceará) have been studying bees in several regions with different types of vegetation in Brazil. Among them is worth mentioning the Atlantic Forest, the "Cerrado" (Brazilian Savannas), the Amazon Forest, the "Caatinga", the Hygrophilous Forest and the Semideciduous Forest. In several studies we found that generalist bee species may exhibit a temporal selectivity. On the other hand, more specialist bee species may present a more generalist behavior, depending on the environment conditions and availability of floral resources. We also found that when resource availability decreases, bees can increase their foraging area, reducing their reproductive activities or even leaving their nests, as occur in the Caatinga. Pollen analysis became an important tool in studies about bee diet. Many protocols have been developed combining palynological and ecological methods to better understand the interactions between bees and plants, opening new paths of management and conservation of bees.

Keywords**:** bee-plant interaction, biodiversity, conservation, melissopalynology, pollen analysis



MESOZOIC PALYNOLOGY AND BOTANY

Georgina Del Fueyo

A new permineralized *Araucaria* species from the Early Cretaceous of Chubut Province, Argentina

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The conifer family Araucariaceae is characterized by a relatively small extant diversity, especially compared with its rich, diverse and worldwide distribution in the fossil record. Most of the Mesozoic record of Araucariaceae is confined to the type genus *Araucaria*, while *Agathis* and *Wollemia* records are less abundant. Extant *Araucaria* is divided into four sections: *Eutacta*, *Bunya* and *Intermedia* have distribution confined to Australasia, while section *Araucaria* (i.e., *A. araucana* and *A. angustifolia*) is distributed in southern South America. Previously described anatomically preserved cones from Argentina are restricted to *Araucaria mirabilis*, from the Middle Jurassic of Patagonia. Here we describe a new permineralized seed cone from the Lower Cretaceous Cerro Barcino Formation (Chubut Province, Patagonia, Argentina). The cone is characterized by a broad central axis, composed of parenchymatous and isodiametric sclerenchymatic cells that are more abundant towards the periphery of the axis. The parenchymatous pith is surrounded by a ring of isolated, endarch vascular strands. A series of resin canals occur on the outside of the stele, these are highly variable in shape and morphology. Numerous fan-shaped bract/scale complexes are helically arranged around the central axis, each bearing a single, anatropous, central ovule completely covered by tissues of the ovuliferous scale. Megagametophyte and integuments were observed in some seeds. This bract/scale complex morphology is characteristic of araucarian conifers. The new cones from Patagonia are characterized by a bract/scale complex with highly reduced lateral wings; a feature that can be considered as an intermediary stage in the evolution of the South American section of the genus *Araucaria*, where extant species are characterized by the absence of lateral wings on their bract/scale complexes. This new species shows a possible intermediate stage in the evolution of the genus *Araucaria* in South America, while its phylogenetic position and importance is investigated on the base of a total evidence analyses.

***Keywords*:** Cretaceous, Patagonia, *Araucaria*, permineralized seed cone, evolution

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Peltaspermales from the Jurassic of Cañadón Asfalto Basin, Chubut Province, Argentina

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The Cañadón Asfalto Basin in Chubut province (Patagonia, Argentina) bears one of the richest Gondwanan Mesozoic biotas. While this formation is famous for its never-ending dinosaur discoveries, it also possesses a rich record of Jurassic floras, with localities from the Early, Middle, and Late Jurassic. The Early to Middle Jurassic "Pomelo" locality at the Cañadon Asfalto Formation bears a rich compressed taphoflora including Equisetales, Filicales, Bennetitales, Araucariaceae, Cupressaceae, Cheirolepidiaceae, and Pteridospermales, the later being the subject of this contribution. The pteridospermous vegetative remains are characterized by bipinnate to tripinnatifid, imparipinnately arranged fronds with intercalary pinnules (zwischerfiedern) on the rachis. Pinnules are up to 6-mm. long and 3-mm. wide with entire or serrate margins. Deeply lobed pinnules occur on larger fronds. Pinnule venation is simple, consisting of a mid-vein that almost reaches the pinnule apex and alternately arranged secondary veins emerging at *c.* 45°. Cuticular preservation allows us to describe enlightening epidermal characters. The fronds are amphistomatic and have partially sunken,

monocyclic stomatal apparatus with subsidiary cells usually bearing cutinized lappets overarching the stomatal pore. The epidermal cells are either papillate or non-papillate, polygonal, and measure *c.* 50 µm wide. These features are consistent with a well-known peltaspermalean pteridosperm genus, *Lepidopteris*, whose biochron is considered to be from Late Permian until the Late Triassic. The pteridospermous material from "Pomelo" is *c.* 25 Ma. younger than the previously known stratigraphic record of *Lepidopteris*. Three additional lines of evidence support the presence of this lineage in the Jurassic of Patagonia. First, peltate discs matching the basic structure of *Peltaspermum* (the ovuliferous organ of *Lepidopteris*) were found intimately associated to the vegetative remains. Second, *Antevsia*-like pollen organs (the pollen-bearing organ of *Lepidopteris*) were also found at "Pomelo". Finally, *Cycadopites*-type pollen, which is considered the pollen type of this Peltaspermalean assemblage (*i.e. Lepidopteris-Peltaspermum-Antevsia*), has also been found at the Cañadon Asfalto Formation. Considering these four lines of evidence, we think there is a strong case for the presence of a relictual peltasperm in the Jurassic of Patagonia. With more fieldwork at "Pomelo", we hope to find these pteridospermous organs in organic connection, thus enabling us to develop a whole-plant reconstruction for this Jurassic peltasperm, an important step towards incorporating it into a phylogenetic framework aiming to resolve the phylogenetic relations of Mesozoic pteridosperms.

***Keywords*:** Jurassic, Pteridosperms, Peltaspermales, Cañadon Asfalto Basin, *Lepidopteris*

Vegetation dynamics of riparian plant communities in the Norian on the western margin of Pangea (Chinle Formation, Petrified Forest National Park, Arizona, SW USA)

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The Chinle Formation in SW North America hosts a remarkable Norian terrestrial ecosystem with rich floral remains and vertebrate fossils. Our new palynological data indicate that a floral turnover occurred in the middle of Chinle Formation around 215.5 Ma ago. The floral turnover is associated with an ongoing climate change towards more arid climate and severe environmental perturbation. The analysis of the plant communities revealed that this turnover was followed by a complete reorganization of the riparian vegetation driven by the tectonic regime of the hinterland, fluvial styles and gradual transition towards more arid climate. The newly formed riparian community hosted Cupressaceae-Araucariaceae related plants suggested by the presence of *Araucariacites australis*, *Inaperturopollenites* sp. and *Perinopollenites elatoides* in the pollen record in this interval. The presence of trees with similar stature to modern day Araucariaceae and Cupressaceae was allowed by the more stable overbank settings proposed for the upper part of Sonsela Member based on the sedimentological observations. The frequent flooding events and crevassing in the lower Sonsela Member according to the sedimentology didn't support the presence of these trees in the proximity of the stream; they colonized probably more stable environments further from the stream. The migration of these plants closer to the stream might be connected to the increase in aridity and drop of groundwater table after the turnover which eliminated the presence of plants with shallow penetrating roots in the floodplain. Besides the re-organization of riparian communities the rapid loss in the sporomorph diversity and significant increase in the ratio of *Klausipollenites gouldii*, aberrant *Klauispollenites gouldii* morphotypes, the increase in *Patinasporites* spp. and *Froelichsporites traversei* are also indicators of environmental stress, possibly more arid climate and the perturbation of the global carbon cycle and increased pCO_2. Comparison of the vegetation turnover with definitely younger assemblages from the Chinle Formation in New Mexico showed the same turnover patterns suggesting two distinct drier periods implying climatic oscillations in the upper Norian of the American SW. The climate induced floral turnover contributed to the extinctions and turnover in the vertebrate fauna because the contraction of the previously inhabited wetland areas and different food sources provided by new plants. The floral and faunal turnover are all temporally close to the Manicouagan impact event suggesting that severe environmental perturbations took place and affected the Chinle ecosystem.

***Keywords*:** Chinle, Norian, palynology, vegetation, climate

Cretaceous monocots from Northern Gondwana

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The Lower Cretaceous angiosperm macrofossil record already contains members of the major angiosperm groups i.e. ANITA (*Pluricarpellatia*, *Scutifolium*), Magnoliids (e.g. *Archaeanthus*, *Endressinia*, *Araripia*) and Eudicots (*Sapindopsis*). However, Monocots that constitute about one-fourth of living angiosperm are very scarce in the Cretaceous, being known only from charcoalified flowers, possibly *Acaciaephyllum* and some other fossils. Their fossil record remains scarce until the Turonian, but includes already several taxa of Araceae. After the Turonian Arecaceae and Pandanaceae are also present. Despite recent findings from the Upper Cretaceous, these fossils are restricted to a few (sub)families, e.g. Orontioideae (Araceae) and Coryphoideae (Arecaceae). Furthermore, most of these fossils come from the Northern mid-latitudes. In an ongoing revision of an Upper Cretaceous flora from Northeastern Africa, we discovered a very diverse assemblage of Monocots containing nine taxa, of which five belong to the Araceae. This assemblage is also very different from Northern assemblages, being more similar to Eocene assemblages from Northern mid-latitudes. These findings highlight the hitherto poorly known Cretaceous history of low-latitude vegetation and its relationships to the emergence of tropical rainforest clades.

***Keywords*:** Cretaceous, monocots, Norther Gondwana

Jurassic Angiosperms and their implications for Angiosperm Evolution

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All known gymnosperms are woody, and angiosperms are thought derived from gymnosperms. It is not surprising that ancestral angiosperms are thought woody, like *Magnolia* or *Amborella*. However, this thinking has never been confirmed by fossil evidence yet. In contrast to woody ones, herbaceous plants lack secondary growth, and this habit so far is restricted to angiosperms among seed plants. So finding an herbaceous seed plant in the Jurassic means that most likely you get an angiosperm, and the previous woody-ancestor-thinking may be flawed. Most monocots are herbaceous, and their elements demonstrate greater molecular distances between each other than angiosperms in other groups. Such greater distances among them is at odd with their assumed relatively derived position in the current angiosperm tree. This conflict can be reconciled in two ways, 1) monocots do have a greater evolving speed, 2) monocots have a longer undetected history before the Cretaceous. Recent palaeobotanical progress seems to favor the latter. First, pollen grains hard to distinguish from those of angiosperms have been found in the Triassic, and a perfect flower with all parts connected and hard to distinguish from its extant peers has been found in the Middle Jurassic. At least these two discoveries, not mention others, make herbaceous angiosperms in the Jurassic theoretically conceivable. Confirming this inference, here we present an herbaceous angiosperm preserved in whole, named as *Juraherba bodae*, recovered from a worldwide famous fossil Lagerstätten of the Middle Jurassic at Daohugou Village, Inner Mongolia, China. Isotopic dating and biostratigraphy by various authors independently converge to the same conclusion that the minimal age for the fossiliferous layer is at least 164 million years old. Although the plant is small, only 38 mm tall, but it is a complete plant individual, including physically connected hairy root, stem, numerous leaves, and four fructifications. The angiospermous affinity of *Juraherba* is suggested by its herbaceous habit and further confirmed by its ovules/seeds enclosed in more or less fleshy fructifications. The *Juraherba* marks two records in the current fossil world, namely, the earliest record of herbaceous seed plants as well as of herbaceous angiosperm. The new combination of information on fossil plants and molecular data demands a refresh look at the evolutionary theories of angiosperms, which most time were based only on the information of extant angiosperms and Cretaceous fossil record.

***Keywords*:** seed plant, Jurassic, herbaceous, whole plant, angiosperm.

Diversity of conifer woods and cycadophytes from the Early Cretaceous Kirkwood Formation, South Africa, and palaeoenvironmental implications.

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The Kirkwood Formation, Uitenhage Group, outcrops in the Algoa and Gamtoos Basins, Eastern Cape of South Africa, and has been known since 1845. Discoveries of dinosaurs, a variety of invertebrate fossils and plants have been made over the years. The plants comprise ferns, cycads, cycadeoids and conifers. The large trunks exposed along the Bezuidenhouts River, among other sites, are poorly preserved but the charcoal fragments preserved in a 1m thick stratified parabreccia are much better preserved. Silicified charcoal from Shamwari Game Reserve is also well preserved. Three genera are known from this formation but have not been described, *Agathoxylon*, *Brachyoxylon* and *Protocircoporoxylon*. A new example of the genus, *Taxaceoxylon* is now added to the list. The cycadophytes include the cycad *Pseudoctenis* and bennettitalean *Zamites* which are re-assessed here and updated. Based on these woods from a number of other sites worldwide it is possible to reconstruct the past environment. *Agathoxylon* is the most common wood in Gondwana and occurred in all climate zones. *Brachyoxylo*n ranges from the Early Jurassic to Early Cretaceous but is more common in summer wet environments, as is *Protocircoporoxylon* but its time range is limited to the Early Cretaceous. *Podocarpoxylon* has a long time range but did not occur in summer wet regions. *Taxaceoxylon* was restricted to warm temperate and winter wet environments. These woods in particular and the rest of the flora in general imply a diversity of microhabitats rather than a long time range and rapidly fluctuating climate.

***Keywords*:** Early Cretaceous, South Africa, Coniferales, Cycadales, Bennettitales

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Palynology of the São Carlos Formation (Bauru Group, Upper Cretaceous), Brazil: chronostratigraphic and paleoenvironmental interpretations

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The Bauru Group is well known as fossiliferous mainly by its animal fossils (vertebrates and invertebrates). However, it is relatively poor in fossils of plant origin, including palynomorphs. The São Carlos Formation – proposed in 2002 by the group including three first authors of this paper as a pelitic unit overlying basalts of the Serra Geral Formation – does contain a rich palynoflora, whence palynological analyses have facilitated precise chronostratigraphic and paleoenvironmental interpretations. Samples of fine siliciclastic rocks (shales and siltstones) were collected along a creek in the Nossa Senhora de Fátima Farm, situated 16 km NNW of São Carlos city (central São Paulo state, Brazil). Among 30 samples prepared for palynology, 17 proved richly palyniferous. The following palynomorph types were identified: 20 pteridophyte spore taxa, 13 gymnosperm pollen taxa and 41 angiosperm pollen taxa. In general, both angiosperm pollen and ephedroid pollen grains (*Equisetosporites*, *Gnetaceaepollenites* and *Steevesipollenites*) are predominant. The latter, occurring in an assemblage with subordinate content of *Classopollis* grains, suggest a paleoclimate tending toward aridity during deposition of the São Carlos Formation. Some strata relatively rich in pteridophyte spores are suggestive of contribution from lakeside vegetation. The permanent presence of freshwater is attested by the conspicuous presence of microalgal remains (*Botryococcu*s, *Pediastrum*, *Staurastrum* and prasinophyte phycomata), recognizable via fluorescence microscopy. Significant amounts of microalgal remains in some samples suggest episodic blooms, probably induced by eutrophication of the paleolake. Concerning the age, the presence of *Anacolosidites* sp. A, combined with the absence of *Steevesipollenites nativensis*, indicate a late Santonian dating (ca. 84 Ma). Other associated index-palynomorphs – e.g., *Confossia vulgaris*, *Cretacaeiporites polygonalis*, *Foveotricolpites tienabaensis*, *Gabonisporis vigourouxii*, *Hexaporotricolpites emelianovi*, *Psilastephanoporites brasiliensis*, *Retitricolporites belmontensis*, *Victorisporis roberti* and *Zlivisporis blanensis* – are compatible with this chronostratigraphic determination. The late Santonian age is also reinforced by common occurrence of carbonized sclereids (cells of sclerenchyma of higher plants), which were produced by "the Great Santonian Paleowildfire", whose records are well known in coeval strata of the offshore Campos and Santos basins.

***Keywords*:** Palynostratigraphy, Paleoecology, Paraná Basin, Santonian, Brazil

Exploring the early radiation of Cornales: New evidence from Upper Cretaceous fruits

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While core eudicots appear in the fossil record by the mid-Cretaceous, the most diverse lineage, the asterids (>80,000 living species), does not appear until the Late Cretaceous. The earliest diverging order, Cornales, originated sometime during the Late Cretaceous and radiated rapidly into five major clades: 1) Cornaceae - Alangiaceae, 2) Nyssaceae –Mastixiaceae - Davidiaceae, 3) Curtisiaceae - Grubbiaceae, 4 Hydrangeaceae - Loasaceae, 5) Hydrostachyaceae. This rapid diversification has made it difficult to resolve phylogenetic relationships among the major lineages and to understand early evolutionary patterns within the order. Cornalean fossils, particularly those of fruits, from the Late Cretaceous can greatly improve our understanding of their initial diversification. The Cretaceous record of Cornales until recently was limited to fruits from the Coniacian of Japan and the latest Maastrichtian of Europe. Since cornalean fruits are systematically informative and critical to our understanding of the diversification of the order, we have initiated a research program to recover, characterize, and analyze Late Cretaceous cornalean fruits from around the world to test previous evolutionary hypotheses based on molecular and morphological data and divergence-time estimations. Seven different permineralized cornalean fossil fruit types have been recovered from Coniacian, Santonian, Campanian, and Maastrichtian sediments from North America and Japan. Two of these represented by endocarps, some with mesocarp still attached, have been recovered from the Coniacian of western North America. These fruits are synchronous with the earliest record of Cornales from Honshu, Japan, and indicate that Cornales were already diverse and geographically widespread by the Coniacian (Late Cretaceous). A new genus of Santonian cornalean fruits from the Tomamae area of Hokkaido, Japan shows a mosaic of characters resembling Davidiaceae, Curtisiaceae, and Cornaceae. By far the highest diversity of fossil cornalean fruits is known from the Campanian. These include two taxa from North America with a mosaic of characters representing Cornaceae, Davidiaceae, and Nyssaceae, and a third type assignable to *Cornus piggae*, representing the earliest described *Cornus* fossil to date, providing a sound minimum clade age date for Cornaceae. One fossil endocarp from the Maastrichtian of North Dakota represents the oldest fossil assignable to Curtisiaceae, and the first fossil record of the family in North America. A non-metric multidimensional scaling (NMDS) morphospace analysis was implemented to explore evolutionary patterns in cornalean fruits, and to complement hypotheses based on phylogenetic relationships. These Late Cretaceous fossils greatly enhance our understanding of the initial diversification of Cornales.

***Keywords*:** Asterids, Cornales, Cretaceous, Fruits, Morphospace

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Triassic palynofloral changes at Tulong, southern Xizang, China: responses to the evolution of eastern Tethys

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Triassic is an important period for the evolution of eastern Tethys. This tectonic event certainly brought great palaeoenvironmental changes and then led to profound impacts on terrestrial floras. Palynological analysis from Tulong, southern Xizang reveals a distinct palynofloral change from early Olenekian lycopod-dominated to late Olenekian gymnosperm-dominated, implying an obvious palaeoenvironmental transfer from humid to arid conditions. Considering the earlier palynofloral turnover recorded in eastern Tethys rather than in central Europe in the western and the sedimentary evolution evidence in this area, the abrupt transfer may be related to the continental rifting in the northern margin of Gondwanaland or the extension of Tethys as an epeiric sea during this time. In Late Triassic, the local palynoflora at Tulong, southern Xizang shows close affinity to the Onslow playnofloras and is distinct from the palynoflora at Lhasa Block. The latter belongs to the North Tethys palynofloras in having unique key taxa *Rhaetipollis* and *Riccisporites*. According to global phytogeographic records, these Onslow and North Tethys palynofloras distribute in low latitude of the southern and northern hemisphere respectively, indicating that the southern Xizang block and Lhasa block were far apart from each other. In other words, the Tethys Ocean between these two blocks had formed a broad ocean across the equator in Late Triassic.

***Keywords*:** Triassic, Tethys evolution, palynofloral change, phytogeography, southern Xizang

Late Jurassic to Early Cretaceous Dinoflagellate Cysts from the Eastern Gulf of Mexico: Facilitating future exploration and development activities in the basin

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The Late Jurassic to Early Cretaceous deposits of the Eastern Gulf of Mexico (EGoM) are one of the world's major hydrocarbon reserves. However, there is a distinct lack of published studies on dinoflagellate cysts from these strata. This research aims to fill that data gap and produce a higher resolution dinoflagellate cyst biostratigraphy using data collected from three wells around the EGoM. The Gulf of Mexico is a structurally complex area in terms of its tectonic setting. This unusual basin therefore requires a well age-constrained biostratigraphy to be established to further link strata and structures around the EGoM basin. There are rich assemblages of well preserved palynomorphs in these deposits that are dominated by dinoflagellate cysts. 175 samples have been analysed using a light microscope to collect the palynofacies data, as well as to systematically describe each dinoflagellate species and collate quantitative data concerning their occurrence/abundance. These data have been analysed to produce a working biostratigraphy of the EGoM. Further analysis of the palynodebris and palynomorphs has unveiled information concerning the depositional environments. The data was interpreted using a Tyson Ternary Kerogen Plot (AOM – phytoclasts - palynomorphs) and compared to a Ternary Liptinite – Vitrinite – Inertinite Kerogen Plot to indicate hydrocarbon source potential of the surrounding rocks. Both Ternary plots were then compared to the Palynomorph Darkness Index (PDI; Goodhue & Clayton 2010) values for each sample to infer the temperature to which each of the samples had been subjected, and as such the thermal maturity of the wells. This is the first time a PDI value has been calculated using dinoflagellates (*Sentusidinium explanatum*) as the palynomorph subject. Development of a robust biostratigraphic model for the EGoM basin will greatly facilitate upcoming exploration and development activities in this basin and ensure future energy security.

***Keywords*:** Dinoflagellate, Mesozoic, PDI, Gulf of Mexico, Biostratigraphy

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Pollen and spores of the Glen Rose Formation (early Albian, Texas) and their significance for correlation of the Potomac Group

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Although the middle Albian terrestrial palynoflora of the lower Fredericksburg Group in the US Gulf Coastal Plain (southern Oklahoma) has been described in detail, the pollen and spores of the underlying Glen Rose Formation (upper Trinity Group) are poorly known. Because this unit is well dated by ammonites, it is a potentially important reference point for correlation of continental sequences such as the classic Potomac Group and for dating events in the radiation and dispersal of angiosperms. Samples from the Glen Rose at Barker Branch and Cedar Brake Camp on the Paluxy River (north central Texas), which can be assigned to the late early Albian *Douvilleiceras mammillatum* zone, are dominated by *Classopollis* and *Exesipollenites*, but angiosperm pollen is the next most common terrestrial element, and several index spore species for Zone II in the Potomac Group are present. Among the angiosperms, monosulcates of the *Clavatipollenites* and *Retimonocolpites* types are most common and diverse, but there are also several tricolpate species. Stratigraphically important angiosperms include members of the *Clavatipollenites rotundus* group (*Retimonocolpites dividuus* of many authors) and reticulate tricolpates, which are similar or identical to types that appear in upper Zone I of the Potomac Group and the well-dated earliest Albian of England and Portugal. However, there are also tricolpates with striate-reticulate sculpture, a pollen type that is not known from upper Zone I but appears in the later early Albian of Portugal. This assemblage contrasts with floras from Potomac Zone II and the lower Fredericksburg Group, where tricolpates equaled and soon exceeded monosulcate angiosperms in species diversity. These results confirm arguments based on the Portuguese section that there is a significant hiatus between Zones I and II in the Potomac Group, and that

this gap includes the later part of the early Albian. The dominance of *Classopollis* and *Exesipollenites* and the occurrence of isolated Northern Gondwanan elements such as *Sergipea* and *Tucanopollis* may mean that Texas lay in a transition zone between Southern Laurasia and the hotter and drier Northern Gondwana province, but broader regional studies are needed to disentangle geographic and climatic effects from effects of the lagoonal local environment.

***Keywords*:** palynology, Cretaceous, Albian, Texas, angiosperms

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Re-evaluation on the systematic position of the Mesozoic fern genus *Coniopteris* based on morphological characters, phylogenetics and molecular dating

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Coniopteris genus was established by Brongniart in 1849, after revised by Saporta and Scrimper respectively, and gradually restricted to Mesozoic fossil ferns only. *Conipoteris* became a widely known cosmopolitan fossil genus consisting of more than 60 described species and reported in nearly all Mesozoic floras, yet mostly from Northern Hemisphere. From the Early Jurassic to the beginning of Cretaceous, *Coniopteris*is typically characterized by considerable sterile-fertile frond dimorphism, as well as dimorphic basal pinnules, sporangia typically wedge shaped, and by the cuplike indusia in most forms, often possessing two flaps. Species diversity of *Coniopteris* is significant for further understanding Mesozoic paleophytogeography and paleoclimatology, while its character evolution and systematic position are both unsolved mysteries. *Coniopteris* has been placed in the tree fern family Dicksoniaceae based on their cuplike indusium since its establishment, while the cup-like indusium is not synapomorphic and now considered plesiomorphic characters for ferns from our current understanding of fern phylogeny. Another controversy is that extant Dicksoniaceae are tropical tree ferns with erect and arborescent trunk habit, meanwhile the mesozoic *Coniopteris* are mostly smaller and shorter herbaceous plants. And also observes that Dicksoniaceae are nowdays subtropically dispersed and founds also in the fossil record of Antarctica.The third controversy is that most *Coniopteris* species have vertical annules, which is the common synapomorphy for polypods, while the extant tree ferns all have the oblique annuals. Here we consider all these phylogenetic and morphological data to re-evaluate the relationship between *Coniopteris* and its modern close relatives (tree ferns and polypodiaceous ferns), and to explore its phylogenetic position, the possibility exists that the Mesozoic ferns genus *Coniopteris* may be more associated with polypod against tree ferns.

***Keywords*:** *Coniopteris*, tree ferns, fern phylogeny, polypods, morphological evolution

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A new permineralized fertile leaf of Schizaeaceae from the Late Cretaceous of Livingston Island, Antarctica

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Diversity and morphology of Cretaceous ferns in Antarctica have been well documented recently based on newly found permineralized materials such as from the Cerro Negro Formation (Aptian) of Livingston Island (e.g. Vera, 2013). Here we report a new fern fertile leaf attributable to the Schizaeaceae *s.l.* It was found on the surface of a silicified soil rock collected from Livingston Island of Antarctica. Several fossil-containing rocks were found isolated on exposed ground surface near Williams Point during a field research by INACH in 2011. The materials were probably derived from the Willams Point Bed dated as Cenomanian - Early Campanian. The rocks also contain a variety of permineralized plant organs such as leaf fragments, conifer wood, root systems, and reproductive organs. Some root systems consist of a vertical main axis and diverging rootlets with fine root hairs, suggesting that plant remains are preserved *in situ*. The fossil is about 2 cm long and 1 cm wide, and is composed of five globose structures each of which has one basal slender axis

concurrent alternatingly to one main axis ca. 0.5 mm thick. Twenty-one serial sections were prepared by the cellulose acetate peel technique using HF. A 3D reconstruction was rendered using AMYRA. Reconstructed ramification pattern of the axis reveals a distal part of a compound fern frond consisting of a main axis distally diverging two alternate laterals and one ultimate axis. Each of the branching axes terminates the globose structure, which is a circination of a pinnately lobed lamina, 2.2-3.8 mm in diameter. The ultimate segment is narrow, ca. 1 mm wide and up to 3 mm long, adaxially bearing 8-10 sporangia alternately arranged in two rows along each side of the segment midrib, constituting a "sorophore" (Wistrom *et al.* 2002). No indusium was observed. The sporangium is pyriform 0.35-0.45 x 0.44 x 0.53 mm, with a terminal complete annulus consisting of 17-25 thick-walled cells, and attached to the segment by a very short basi-lateral stipe. The sporangium contains numerous, rather poorly preserved tetraheadral spores 31.7-45.2 μm in diameter. SEM images show flat and less-ornamented surface. The sporangium morphology suggests Schizaeaceous affinity of the fossil. Within four extant genera of the family, the fossil is most comparable to *Lygodium* based on the presence of the sorophore and sporangium morphology. However, the fossil differs from *Lygodium* in the absence of indusium and less-ornamented spore. The phylogeny of the family has been proposed based on molecular and fossil data (e.g. Wistrom *et al.* 2002), but still lacking sufficient fossil information. Permineralized fertile fronds of schizaeaceous affinity have been reported from the Late Cretaceous of the Northern Hemisphere. *Schizaeopteris* (Turonian - Coniacian, Japan) and *Paralygodium* (Coniacian - Eocene, Japan and Canada). *Schizaeopteris* is anatomically comparable to *Anemia* and differs from the present fossil in leaf architecture and sporangium/spore morphology. *Paralygodium* most resembles the antarctic fossil in having the sorophore, but differs in having wider lamina that is basically palmate. In considering a diverse fertile-leaf morphology expressed by extant *Lygodium*, the Antarctic fossil could be designated as a new species of *Paralygodium*. However, until the morphological variation of Mesozoic Schizaeaceae is more clearly understood, the fossil would better be designated as a new morphogenus of the family representing a species group once inhabited in Antarctica. The new fossil adds further evidence of Cretaceous worldwide diversity of Schizaeaceae and early diversification that occurred close to the *Lygodium* clade. This work was supported by INACH and by KAKENHI to HN (18405013, 24570112).

***Keywords*:** Antarctica, Cretaceous, fertile leaf, permineralized, Schizaeaceae

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Variation and time-spatial distribution of new records of Ginkgoales, Czekanowskiales and Caytoniales in the Jurassic of southern Mexico

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The fossil record of Mesozoic flora shows a high diversity, and the Ginkgoales, Czekanowskiales and Caytoniales are important components of this diversity. Although the place and time of origin of the Ginkgoales, Czekanowskiales and Caytoniales are still a matter of controversy, the diversity achieved in the Jurassic was outstanding. The fossil record of Ginkgoales-Czekanowskiales-Caytoniales is widely distributed in Eurasia where several studies have been carried out, but there are few reports of this flora in North America and Gondwana. We recently initiated a long term palaeobotanic study of the Jurassic stratigraphic record of Mexican Mesoamerica that has already yielded findings of this flora in several localities. The purpose of this contribution is to analyze the time-space and palaeoclimate context in which the Ginkgoales, Caytoniales and Czekanowskiales settled in southern Mexico during the Jurassic. To carry out this analysis, we have worked with the palaeobotanic, stratigraphic, geographic and palaeoclimatic information of the following genera: *Ginkgo*, *Ginkgoites*, *Nehvizdyella*, *Eretmophyllum*, *Ginkgoitocladus*, *Karkenia*, *Sphenobaiera*, *Ginkgoidium*, *Czekanowskia* and *Sagenopteris*. The results of this analysis allow us to argue that the presence of the flora Ginkgoales-Czekanowskiales-Caytoniales in southern Mexico (tectonoestratigraphic Mixteco Terrane) was favored by the interaction of tectonic events and paleoclimate during the Toarcian/Callovian. On one hand, the tectonic events allowed the origin of a contrasting landscape between plains and mountainous areas near the coast of the paleo-Pacific. On the other hand, lowland and swampy areas nearby the coast were predominantly warm and humid with signs of drought while the continental areas had wetter climates. Then, based on these palaeogeographic and palaeoclimatic conditions, we distinguished variations in diversity throughout the Torcian/Callovian. It is remarkable the presence of only *Nehvizdyella* in the Rosario Formation (Toarcian), increasing to nine genera (*Ginkgo*, *Ginkgoites*, *Nehvizdyella*, *Eretmophyllum*, *Ginkgoitocladus*, *Sphenobaiera*, *Ginkgoidium*,

Czekanowskia, and *Sagenopteris*) in the Bajocian/Bathonian Zorrillo-Taberna Indiferenciadas Formation of fluvial to floodplain/coastal wetlands environment, and only two genera, *Karkenia* and *Sagenopteris*, in the Tecomazuchil Formation (Callovian), a continental region under humid conditions. The implications of our results reveal an increase in the diversity of Jurassic flora of Mexico and North America. However, it is still necessary to continue the analysis in the light of new geological, geographical and palaeobotanical data.

Keywords**:** North America, Palaeobotany, Palaeoclimate, Palaeogeography, Jurassic.

The Oxfordian (Upper Jurassic) palynology of northwest Colorado and Utah, USA

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There is a dearth of published information on the Jurassic palynology of the onshore contiguous USA. In an attempt to remedy this situation, 30 samples from several outcrops of the Oxfordian in northwest Colorado and Utah were collected and prepared. The majority of these samples produced abundant and well-preserved palynofloras. Both terrestrially-derived and indigenous marine palynomorphs are present in varying proportions. The former are dominantly long-ranging pollen and spore taxa. However many of the dinoflagellate cysts are biostratigraphically and palaeogeographically significant. These forms include chorate cysts, *Endoscrinium galeritum*, *Gonyaulacysta dentata*, *Gonyaulacysta eisenackii*, *Gonyaulacysta jurassica*, *Mendicodinium groenlandicum*, *Pareodinia* spp., *Scriniodinium crystallinum*, *Trichodinium scarburgense* and *Wanaea* spp. *Gonyaulacysta dentata* and *Wanaea* spp. are highly characteristic of the Callovian–Oxfordian transition in Europe. The entire dinoflagellate cyst flora is of European aspect. No characteristically Tethyan forms were observed, and the presence of *Gonyaulacysta dentata* is indicative of a Boreal provenance. This situation is entirely consistent with the palaeogeographical setting of the shoreward (closed) extremity of the Western Interior Seaway which was open to the north.

Keywords**:** biostratigraphy, dinoflagellate cysts, Jurassic, palaeogeography, USA

Generic and specific problems and concepts in Molteno and Gondwana palaeobotany

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A perspective is provided of the "Palaeodeme" concept for describing fossil species and the application to the study of plants from the Molteno Formation as followed by John Anderson and Heidi Anderson over the years from 1970 to the present. A single organ palaeodeme is defined as a collection of specimens judged to represent a single breeding population, showing normal distribution of variation for selected diagnostic characters and derived from a single fossil assemblage from a discrete lithological unit. A similar concept for palynomorphs had been published by Hughes from Cambridge as the "Biorecord". At present we still have similar problems in palaeobotany and a novice researcher could well be asking the same question I once asked 45 years ago. How does one define the genus *Dicroidium* – as one or as six genera? How does one communicate with researchers from the various Gondwana continents if the same definitions are not used? At present leaves of identical morphology that I refer to as *Dicroidium elongatum*, are placed by palaeobotanists from Argentina as *Xylopteris elongatum*. One may ask "Is it of concern?" In solving problems of distribution, phylogeny, palaeoecology etc of genera and species, it is of great importance to use the same uniform taxonomy and nomenclature. Even a simple question such as "What is the first and last appearance of a genus?" would lead to different results. According to present literature, *Umkomasia*, the female fruit of *Dicroidium* first appeared in the Upper Permian of India according to Chandra *et al.* as reported some eight years ago and the last record is from the Lower Cretaceous of Mongolia as recently reported by Shi *et. al*. However, these fruits have been incorrectly classified and are not *Umkomasia*. My conclusions are based on having collected and described (with John Anderson) more *Umkomasia* than any other researchers. Furthermore these were not made in isolation but in comprehensive collections from specific horizons (including the type locality) with the whole associated flora documented. We can expect

many more *Umkomasia* will be obtained from the Gondwana Triassic but rather unlikely from the Permian or the Cretaceous. It is possible that genuine *Umkomasia* may be found outside of the Gondwana Triassic but first we must agree on what it really is. At present the genus *Umkomasia*, originally based on a good collection of fossils with the affiliated organs *Pteruchus* (male) and *Dicroidium* (leaf) is becoming a 'basket genus' for fruit with somewhat similar cupule morphology found anywhere in the world.

***Keywords*:** Gondwana, Triassic, *Dicroidium*, *Umkomasia*, Palaeodeme

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A tristichous moss from the Lower Cretaceous (Valanginian) of Vancouver Island, British Columbia, Canada

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The Early Cretaceous (ca. 136 Ma) Apple Bay flora of Vancouver Island is preserved anatomically by calcium carbonate permineralization, in concretions that host an allochthonous fossil assemblage deposited in nearshore marine sediments. The Apple Bay flora has yielded representatives of most major groups of tracheophytes (lycopodialean and selaginellalean lycopsids, sphenopsids, ten fern families, and several types of gymnosperms), as well as fungi (ascomycetes and basidiomycetes) and a lichen. A wide variety of bryophytes are also present. These make the Apple Bay flora one of the most diverse fossil bryophyte floras worldwide and have broadened significantly the range of biodiversity covered by the generally sparse fossil record of the group. Notable here are polytrichaceous and leucobryaceous mosses, as well as a several types of tricostate mosses, at least some of which have hypnanaean affinities (Tricostaceae). Another bryophyte type identified at Apple Bay has gametophytes characterized by weakly triquetrous stems bearing tristichous, helically arranged, imbricate, and evenly keeled leaves. The leaves are erect and closely spaced, with slightly recurved margins in the upper half. The lamina is unistratose, but can be bistratose near the costa. The strong costa is attenuate and exhibits some differentiation between thicker-walled epidermal cells and thinner-walled internal cells. In the extant flora, select species of some genera or entire genera exhibiting tristichous helical phyllotaxis are known in several moss families, including the Meesiaceae, Seligeriaceae, Polytrichaceae, Bartramiaceae, Catoscopiaceae, Grimmiaceae, Pottiaceae, Fontinalaceae, Amphidiaceae, and Ditrichaceae. Of these, the Apple Bay tristichous moss compares well with *Seligeria tristicha* (Brid.) Bruch & Schimp. (Seligeriaceae), *Anoectangium* Schwägr. and *Triquetrella* C. Müll. (Pottiaceae), *Tristichum mirabile* (C. Müll.) Herz. (Ditrichaceae), and *Plagiopus oederianus* H. Crum et L.E. Anderson (Bartramiaceae). A complete description of this moss type and anatomical comparisons with the extant moss species of above families, will allow for more precise taxonomic circumscription of this Apple Bay fossil.

***Keywords*:** bryophyte, Canada, Cretaceous, moss, permineralized.

Resolving the Bajocian radiation of dinoflagellates: new records from the Middle Jurassic of Europe

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Dinoflagellates underwent a major radiation during the Bajocian (Middle Jurassic, 170–168 Ma). The group emerged during the Middle Triassic, but diversity remained low until the Early–Middle Jurassic. Nearly 100 dinoflagellate cyst species appeared through the Bajocian, making it a major phase of diversification. However, Bajocian dinoflagellate cysts have received relatively little study; here we present the results of a high resolution palynological and chemostratigraphical study of the Bajocian of SW Germany and southern England, with supporting data from Scotland. We show that the Late Aalenian–Early Bajocian saw a major

phase of archaeopyle experimentation within gonyaulacoid dinoflagellates, during which multi-plate precingular, single-plate precingular and epicystal archaeopyles were first developed; this was accompanied by the appearance of ca. 15 new dinoflagellate cyst species. The genus *Dissiliodinium* was extremely abundant during the Early Bajocian, which may have been linked to an increase in ocean fertility and bioproductivity, as indicated by a positive shift in our carbon isotope records and the onset of biosiliceous sedimentation in the Tethys. Previous work has linked climate change to enhanced weathering in the mid-latitudes as the cause of this increase in nutrient supply. *Dissiliodinium* declined in abundance in the latest Early Bajocian as other cyst-forming dinoflagellates radiated dramatically, with the appearance of ca. 60 new dinoflagellate cyst species by the earliest Bathonian. The family Gonyaulaceae expanded through this interval to become the dominant family of cyst-forming dinoflagellates and many of these genera would become key components of Middle–Late Jurassic dinoflagellate cyst floras (e.g. *Ctenidodinium*, *Gonyaulacysta*, *Meiourogonyaulax*). Our stratigraphical data suggests that the Bajocian radiation of dinoflagellate cyst taxa through Europe was strongly influenced by third-order sea level cycles, with first appearances correlating with transgressive episodes. It is also notable however, that coccolithophores diversified at this time, and in the Late Bajocian, the first planktonic foraminifera appeared. Moreover, other groups of pelagic organisms, including ammonites and fishes were radiating at this time, pointing to major innovations in pelagic ecosystems as a whole, with connecting links provided by mesozooplankton. Given these wider-scale changes, the Bajocian radiation was ecologically driven, and forms part of the Mesozoic Marine Revolution.

Keywords**:** dinoflagellates, plankton, evolution, Bajocian, Jurassic

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Stems and leaves of fossil cycads: morphological, anatomical and ultrastructural characters

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Extant cycads represent one of the last remnants of antique floras, and their evolutionary history extends back to the mid-Permian. This group was able to survive through several environmental changes and major extinction events across the Paleozoic, Mesozoic, and Cenozoic. Despite this, they have not suffered considerable changes in the morphology and anatomy of their vegetative organs. For those reasons, the features commonly used in systematics to segregate the living genera are few or with subtle differences. Certain characters in living Cycadales are considered as to drought, fire, volcanism and grazing adaptations, developed as ancestral conditions strengthened by the changes occurred in the environments where cycads lived. Therefore, some characters present in leaves and stems suggest a plesiomorphic condition, or homoplasy with respect to other groups of plants (e.g. Pteridosperms, Bennettitales). For these reasons, in several cases the assignment of fossils remains based on livings forms is relatively easy; however, in other occasions doubts arise because of the plasticity of vegetative organs to environmental changes. In this study we describe and compare the cuticle ultrastructure in cycadalean leaves of nine fossil and fourteen extant species. The goal of this research is to increase the knowledge on the morpho-anatomical characters of cycads, with new descriptions and analyses of their leaf cuticles that could help resolving the unclear systematic position of some fossil taxa. Results obtained from a cladistics analysis carried out with the addition of the new data provides different interpretations in the relationships of the Cycadales and their evolution.

Keywords**:** Cycadales, systematics, anatomy, wood, cuticles.

A statistical approach to vegetation community structure in the Lower Cretaceous lacustrine environment of Western Africa

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Despite the difficulties and uncertainties in assessing palynomorph paleobotanical affinities in pre-Quaternary sediments, quantitative spore-pollen data have a great potential in providing information on the vegetation community structure and climatic conditions. This study documents the application of a method based on different statistical approaches for the elaboration of several wells data from the Lower Cretaceous of Western Africa. It documents how the integration and application of quantitative palynology within a multidisciplinary-regional study is critical in petroleum basin analysis. The method is based on the use of cluster analysis in tandem with an ordination analysis, which tries to arrange the samples along linear axes representing environmental gradients. Firstly, quantitative data are analyzed using the TacsWorks software and the Fuzzy C-means (FCM) clustering module. In the FCM analysis the number of clusters is defined by the user. The groups obtained are not just taxonomic, for example Cheirolepidiaceous gymnosperms are found in every group. This implies that certain parents plants occurred in more than one sub-environment and palynomorphs are not divided by simple presence-absence among the sub-environments but typically vary in abundance. Bias of the quantitative composition of palynomorph assemblages due to differential transport has also been considered in clusters interpretation. Palynomorph clusters are then transferred into plant groups on the basis of published data about botanical-ecological affinities. To check the consistency of the established groups a Correspondence Analysis (CA) is performed in some key-wells, by plotting the abundances of plant families in each sample. Three plant associations are produced by the CA and are distributed along the first axis; they consist of: 1) Gnetophyta; 2) Auraucariaceae, Pteridophyta, Schizaceae, Gleicheniidaceae and Cycadaceae; 3) Cheirolepidiaceae and Pteridospermales. This ordination seems to suggest a climate-controlled grouping with Gnetophyta characteristic of an arid climate and the moisture-loving group 2 developing under wetter conditions. The isolation, along the first axis, of the third group dominated by Cheirolepidiaceae (*Classopollis* parent plants) and Pteridospermales (*Alisporites-Vitreisporites* parent plants) could be indicative of bias due to wind-transported pollen grains. Despite data interpretation is further complicated in Lower Cretaceous by the radiation of first angiosperms and by the uncertainties about their modes of growth, the application of this statistical approach allows to differentiate the main plant communities colonizing the lacustrine landscape and their distribution.

***Keywords*:** Lower Cretaceous, palynology, Western Africa, Correspondence Analysis, Fuzzy C-means

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Recent advances into whole-plant reconstruction of Corystospermaceae: new evidences from Middle Triassic of Argentina

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Reassembling the parts of a fossil plant is a key process to understanding plant evolution, particularly into totally extinct groups. Seed ferns comprise many examples of complex reconstructions, since they are a heterogeneous assemblage lacking extant close relatives. Among them, the family Corystospermaceae has been subject of different whole-plant hypotheses. Corystosperms probably originated in the paleotropics during the Permian, and became the dominant elements of Triassic Gondwanan communities. The family was restored on the basis of *Dicroidium* bifurcating leaves, *Rhexoxylon* trunks, *Pteruchus* pollen organs and *Umkomasia* ovulate organs. At first, plants with *Rhexoxylon* stems were interpreted as lianas due to their unique vascular anatomy. Afterwards, more and larger specimens were discovered; including several one-

meter high trunks in life position, enabling to interpret that they were self-supporting plants with a tree habit. Two kinds of whole-plant concepts have been proposed for arborescent Corystospermaceae: one with a palm-like habit (i.e. unbranched stem with an apical crown of evergreen leaves) and other with a conifer-like habit (i.e. profusely branched stem with deciduous leaves). There has been much discussion about these two contrasting hypotheses, since a plant family showing both types of architecture is not currently known. In this contribution, we present new reconstructions based on fossil plants coming from the Middle Triassic of Western Argentina (Sorocayense Group, San Juan province), and reanalyze the current evidence, in order to enlighten corystosperm habit dilemma. We reconstructed two arborescent Corystospermaceae from Sorocayense Group, one from Barreal Formation (including *Tranquiloxylon* sp. trunks, *Zuberia zuberi* leaves, *Pteruchus barrealensis* pollen organs and *Umkomasia speciosa* ovulate organs), and other from Cortaderita Formation (comprising *Rhexoxylon cortaderitaense* trunks, *Z. feistmantelii* leaves, *Pteruchus* sp. pollen organs, *U. macleani* ovulate organs). These reconstructions, along with new observations and reinterpretations, allow us to develop a third hypothesis for the whole-plant concept of corystosperms. This model is characterized as a sympodial tree, with a scarcely and irregularly branched stem, orthotropic first-order branches, bipinnate leaves helicoidally borne in the branches, and adventitious an buttress roots. Although branched, the type of architecture proposed here is very different from the habit of ginkgos and conifers, but it is more similar to that present in some eudicots.

***Keywords*:** Triassic, seed fern, reconstruction, *Zuberia*, *Rhexoxylon*

Palynology and palynofacies analysis of Lower Cretaceous successions, southern Iraq

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A diverse and well-preserved non-marine and marine palynomorph assemblage was recovered from the Lower Cretaceous Yamama, Ratawi and Zubair formations in southern Iraq. A distinctive monospecific assemblage of the dinocyst *Subtilisphaera* in the Ru-19 Well, in addition to its frequent occurrence in other wells in the Zubair Formation, reflects an ecologically stressed, marginal-marine environment. This assemblage constitutes the first record of the *Subtilisphaera* ecozone in Iraq and Arabian realm and indeed only the second one east of Morocco. The palynofacies composition of the studied rock units has been related to previous organic geochemical analyses. Each rock unit has its own palynofacies characteristics and in general, samples dominated by amorphous kerogen have the highest total organic carbon (TOC) and hydrogen index (HI), as is the case for some samples from the studied Yamama Formation and samples belonging to palynofacies PF2 from the Zubair Formation. Samples that are mostly retrieved from the Zubair Formation, containing abundant phytoclasts, have the lowest TOC and HI values.

***Keywords*:** Palynology, Palynofacies, Cretaceous, Iraq.

Palynology and palynofacies analysis of the Cretaceous succession from the Faghur Hj5-1 Well, north Western Desert, Egypt

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Optical analyses of palynological (kerogen) preparations of 18 cutting samples collected from the Faghur Hj5-1 Well, north Western Desert, Egypt show three different palynological assemblages belonging to three different rock units. In the dominant non-marine of those succession, dinocyst occurrences at the basal sector suggests an initial marine context to the Alam El Bueib Formation. To the Abu Roash Formation, the presence of the ecozone of *Pediastrum* and allied algae, proposed in previous works, is a good datum

for the Cretaceous time period in the north Western Desert of Egypt. The palynofacies composition also shows distinct assemblages and depositional environments. The Alam El Bueib samples are composed of mixed kerogen assemblages of marine and non-marine organic facies. The upper part of the Kharita/lower Bahariya interval is mostly barren, may be due to lithofacies that are mostly sandy ones. The overlying Abu Roash Formation contains a homogenous kerogen, mainly composed of granular fluorescing amorphous organic matter and algae, accompanied by rare palynomorphs. The main objective of this study is to use palynological data in an attempt to assess the kerogen type of the studied formations in the north Western Desert. These data, in addition, also allow for the reconstruction of the depositional environment.

***Keywords*:** Palynology, Palynofacies, Cretaceous, north Western Desert, Egypt.

Reinvestigating *Viracarpon*, an enigmatic fossil monocot from the Deccan cherts of India, using X-ray micro-computed tomography

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The Deccan Intertrappean Beds of India host a rich and well-studied fossil flora, known from over 50 localities in western, central, and southeastern India. Plant fossils are permineralized in cherts, which formed during intervals between major basalt eruptions of the Deccan volcanic province during the Late Cretaceous to early Paleocene (Maastrichtian-Danian), at a time when the Indian subcontinent was geographically isolated and situated in the southern hemisphere tropics. The flora, in which angiosperms dominate, includes several monocotyledonous taxa for which systematic affinities remain elusive. One such fossil is *Viracarpon*, which comprises infructescences known from five localities in central India. Five species of *Viracarpon* have been described since this extinct genus was first documented over a century ago. However, opinions differ on the interpretation of morphology, whether all described species represent distinct taxa, and on family-level affinities. In the present study we reinvestigate the morphology of *Viracarpon*, aided by X-ray micro-computed tomography (μCT), in an effort to resolve its morphology and taxonomic affinities. In all species fruits are sessile and have a compact arrangement on the axis, forming alternating vertical rows. The axis contains scattered vascular bundles, supporting monocot affinities. At least two species can be distinguished, *Viracarpon hexaspermum* and *Viracarpon elongatum* (=*Shuklanthus superbum*). The inflorescence axis in *V. hexaspermum* is more robust, 5–6mm wide and up to 3.5cm long, with 8–12 vertical rows of fruits (~5mm wide). In contrast, the axis of *V. elongatum* is 1.5–2mm wide, up to 6.8cm long, and bears 5–6 rows of fruits (~2mm wide). The gynoecium is apocarpous, consisting of six carpels partially fused at the base and surrounding a thick central axis. There is one seed per carpel, and in *V. hexaspermum* there is a sclerified cap on the distal end of each seed. The perianth is composed of six elements positioned opposite the locules that are either free from (*V. elongatum*) or partially fused to the ovary (*V. hexaspermum*). μCT scans reveal that, at least in *V. hexaspermum*, the central axis of the gynoecium is expanded distally, forming six radiating ridges fused to the top of each ovary and the surface of the perianth, consistent with the reconstruction of Chitaley (1954). Affinities with several angiosperm families have been proposed for *Viracarpon* and include Araceae, Cyclanthaceae, Moraceae, and Pandanaceae. Preliminary comparisons reveal no perfect match with any extant families, but high character overlap with the Arecaceae and Pandanaceae.

***Keywords*:** India, monocot, fossil, Cretaceous, *Viracarpon*

Asyncronic oldest record of *Nothofagus* leaves in Antarctica and Patagonia

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Intensive paleontological studies carried out in Patagonia and Antarctica, have produced during the last three years a remarkable collection of new fossil records and localities. Fieldwork in a fossiliferous locality at Rip Point, Stansbury Peninsula, Nelson Island, South Shetland Islands, Antarctica, resulted in the discovery of plant-bearing beds containing *Nothofagus* leaf imprints, associated with ferns and angiosperm remains. The average size of the leaves is over 15 cm long, representing in at least three different morphotypes in rocks assigned to the Lower Campanian (~80 Mya). On the other hand, the recent new record of *Nothofagus* leaves at Las Chinas Valley, at the north of Cerro Castillo, Ultima Esperanza Province, Chilean Patagonia, in beds assigned to the Lower Maastrichtian (~68 Mya) represents the oldest record of the taxon in South America. At least two morphotypes, associated with a complex assemblage of angio and gymnosperms have dominated a continental forest in an alluvial fan, close to the coast. The asynchronic presence of *Nothofagus* could be interpreted as a direct evidence of land discontinuity between the northern tip of the Antarctic Peninsula and the southern of South America during the Campanian that prevented the dispersion of the genus from Antarctica to Patagonia. The biogeographical barrier apparently disappeared during the Lower Maastrichtian, avoiding the colonization. The event could be linked with the global record of cooling events that provoked glacioeustacy and the fall in the sea levels. The biology of *Nothofagus* support the idea that a landbridge is needed to disperse because its anemochory and anemophily dispersal syndromes. Nothofagus is considered a key genus of the modern sub Antarctic forests of New Caledonia, Queensland, New Zealand, Chile and Argentina. Its oldest record in Antarctica endorse the hypothesis of the Antarctic Peninsula center of diversification, and fits with the newest molecular phylogenies for the taxon.

***Keywords*:** Cretaceous, Nothofagus, Patagonia, Antarctica, Imprints.

Late Cretaceous continental paleoclimate from Cerro Guido – Las Chinas complex, Patagonia, Chile

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Previous paleobotanical studies at Cerro Guido – Las Chinas complex, Chilean Patagonia, have recorded a floristic change during the Campanian/Maastrichtian interval. The oldest plant-bearing beds are dominated by the Sterculiaceae family indicating warm conditions, which later, in the younger Lower-Upper Maastrichtian beds were replaced by a *Nothofagus* dominated forest, which is in turn an indicator of temperate like climate. The finding of a shift towards colder conditions is correlated with a marked decrease in global temperatures inferred from CO_2 levels during the Maastrichtian period. Some of these cooling events have been proposed as part of the evidence sustaining a Patagonian – Antartic landbridge hypothesis, which would have permitted a biotic exchange between the two continents. Late cretaceous paleoclimate estimates inferred from leaf macrofossils in southern South America are scarce, however, recent campaigns in Patagonia have increased considerably the fossil material available for these approximation, which would be the first of its kind. We have collected approximately 600 fossil leaves from the Cerro Guido – Las Chinas complex in Chilean Patagonia, which were used to estimate paleotemperature (mean annual temperature/

MAT) and paleoprecipitation (mean annual precipitation/MAP) in which these fossil floras have developed, using both uni- and multivariate methods. These paleoclimatic conditions together with floristic systematic is discussed in the context of Patagonian-Antarctic floral evolution models and geological – climatic main events occurring in this period.

***Keywords*:** Cretaceous, Patagonia, Paleoclimate, Paleotemperature, Paleoprecipitation.

New interpretation of *Tritaenia linkii*

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The narrow leaves of *Tritaenia linkii* from the German Wealden were originally described as a conifer, subsequently reinterpreted as a ginkgophyte, later classified as a conifer again. Studies based on sterile foliage probably cannot resolve this issue. Due to this, bulk maceration of a large amount of material was performed. Coal claystone with its leaves and other material forming monodominated taphocoenoses provided a number of associated organs: besides leaves, there were shoots, ovuliferous structures and male structures containing pollen. Based on the monodomination, it is assumed that all the material comes from one fossil plant - *Tritaenia linkii* (Roemer) Maegdefrau et Rudolf. Its leaves are variable in length, and in number of veins per leaf. The leaves are hypostomatic, with very thick cuticle, bearing stomata in two to five stomatal bands; external surface shows papillae, forming star-like structures. *Sulcatocladus robustus* Watson et Harrison is a name for shoots always associated with leaves of *T. linkii*. The shoots are covered with helically arranged leaf bases, each subtending one or two types of scars. Ovuliferous organs representing ovate seeds of *Allicospermum* type are born on simple pedicelate collars. Seeds consisting of two membranes interpreted here as sarcotesta and sclerotesta are filled with numerous resin bodies forming large bulging structures, sometimes prominent on the seed surface. Male reproductive structures form micro-strobili, consisting of helically arranged bracts subtending male organs containing monosulcate pollen. The pollen is smooth, broadly elongate, monocolpate of *Cycadopites* type. Ovuliferous organs associated with *Tritaenia linkii* resemble the organs described as female reproductive structures of Ginkgoales. Similar construction of seeds (*Allicospermum* type) and characteristic collar argue for ginkgoalean origin of the structure. Monosulcate pollen of *Cycadopites* type found *in situ* underpins this assumption. Coniferous origin of the *Tritaenia* plant which is the most common interpretation of the leaves is supported only by the shape of leaves similar to *Sciadopitys*, and shoots covered by large persistent leaf cushions. Palaeoecology of *Tritaenia* plant is reconstructed using palynology and stable carbon isotopes indicating coastal-estuarine environment.

***Keywords*:** Early Cretaceous, Ginkgoales, reproductive structures.

Asteroid impacts on Earth – purveyor of death or life? New results relating to the vegetation response to the Cretaceous-Paleogene boundary

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New palynological results from Cretaceous-Paleogene (K-Pg) boundary succession from New Zealand and South America provide some new insights into the vegetation response to one of the major events in Earth's history, the K-Pg event. This extinction event covers a crucial interval of abrupt change that greatly influenced the physical characteristics of Earth's biosphere. These perturbations in the environment imposed dramatic changes on the biota with global extinctions of c. 75% at species level. The K–Pg event had a demonstrable extra-terrestrial cause, attributed to an asteroid impact in Yucatan peninsula 66 million years ago. The global darkness experienced in the aftermath of the impact due to the dispersal of vast amounts of vaporized target rocks, was probably the prime killing mechanism for the photosynthetic biota. This is evident in the global plant record by a sudden mass-kill of the terrestrial flora and phytoplankton and the cessation of photosynthesis resulted in a collapse of the entire food chain, where the marine top predators, the mosasaurs and the

plesiosaurs went extinct. Similarly in the terrestrial realm this was mirrored in the demise of the dinosaurs. Undisrupted sedimentary successions spanning the K-Pg boundary with the diagnostic iridium-rich boundary clay preserved, that also include terrestrial fossils such as pollen and spores, are only well exposed in New Zealand (including the sub-Antarctic Campbell Island), and central parts of North America including the US and Canada. New palynological results from New Zealand show that the extinction within plants was moderate compared to North America but that a major mass-kill is evident also from New Zealand with reorganization of the ecosystems. Interestingly, Araucariaceae shows a major decrease across the New Zealand K-Pg boundary, where araucaria (although not extinct) is replaced by podocarps which increase in abundance after the event. This shift still needs an explanation. New results from Bolivia (where no iridium-enriched boundary clay has yet been identified) show that the terrestrial ecosystems suffered a major loss, comparable to that of North American terrestrial ecosystems. New results from Torotoro, Bolivia revealing aridification during the Late Maastrichtian is evident in evaporites and stromatolites within the Late Cretaceous successions of the Potosi Basin. These arid conditions during the end of the Cretaceous might have contributed to the negative stress in central South American, tropical ecosystems in the aftermath of the Chicxulub impact. Interestingly, the evolution of new species following the asteroid impact accelerated with the appearance of diverse vegetation and mammal fauna. Asteroid impacts, such as the Chicxulub impact evidently brings death and destruction but extra-terrestrial bodies may also provide new life on Earth by providing new niches for life and new habitats such as crater lakes, porous rocks and hydrothermal systems.

***Keywords*:** Cretaceous-Paleogene, mass extinction, palynology, Chicxulub, asteroid

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Cuticular analysis of conifers from the Keuper (Triassic) of Franconia, southern Germany

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The Keuper deposits (upper Middle–Upper Triassic) from the Germanic Basin have yielded rich plant assemblages that have been known and studied for well over 200 years (e.g., by Sternberg, Brongniart, and Schimper). Whereas most of this material is preserved in the form of impressions or more-or-less altered compressions, very rarely also cuticle-bearing remains occur in these assemblages. Cuticular analysis has proven a helpful tool in taxonomic, systematic, and palaeoecological studies of fossil plants. We here present the results of cuticular analyses of conifer material from three localities in the Carnian (Upper Triassic) Keuper deposits of Franconia, southern Germany. For the first time, cuticle micromorphology of well-known taxa, such as *Voltzia coburgensis*, *Widdringtonites keuperianus*, and several species of *Elatocladus*, is documented and described in greater detail. Furthermore, the deposits contain isolated conifer cone scales and a broad array of dispersed gymnosperm cuticles; of special interest are some cuticle fragments that show features typical of macrofossil taxa that have so far been known from considerably younger (latest Triassic or Jurassic) deposits, such as Czekanowskiales and Cheirolepidiaceae. Altogether, this study shows that the Keuper (Carnian) of Franconia contains a rich archive of well-preserved conifer specimens (including isolated reproductive structures) and dispersed cuticles that is much more diverse than previously recognized. The early Mesozoic was a crucial phase in conifer evolution, yet our knowledge of the biology and systematic affinities of many Triassic conifers is still very incomplete. We anticipate that future detailed studies of these classic Keuper deposits may make an important contribution towards a more complete understanding of the biology and systematic affinities of Late Triassic conifers.

***Keywords*:** Triassic, conifers, cuticular analysis, Keuper, Carnian.

Jurassic terrestrial palynology of Yorkshire, UK

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Quantitative analysis of the distribution of dispersed spores and pollen (sporomorphs) has been used to assess temporal vegetation change through the Jurassic (Toarcian-Bathonian) of Yorkshire, UK. Different stages possess relatively distinct sporomorph and palynofacies assemblages, which potentially reflect a dynamic history regarding the nature of parent vegetation. Samples for palynology were taken across the carbon isotope excursion that marks the Early Toarcian mass extinction event to further understand the terrestrial consequences of this global warming episode. Individual and sample-based rarefaction demonstrates that Bathonian samples are more diverse than Aalenian and Bajocian samples. Temporal variations in assemblages are a result of long-term depositional and possible climatic fluctuations through the Jurassic. Ordinations of sporomorph data using non-metric multidimensional scaling (NMDS) demonstrate that short-term variations between samples are largely governed by taphonomic biases as a result of slight changes in depositional processes, which give rise to highly variable catchment areas that supply deposits with sporomorphs. Long-term compositional changes are apparent in sporomorph assemblages regardless of lithology/local depositional environments, suggesting that long-term variations are more substantial than short-term variations and possibly include genuine regional changes in parent vegetation. Sporomorph assemblages from the Yorkshire coast are compared with coeval regional deposits to further understand local floral provinces. High compositional similarity is apparent between samples from Yorkshire, the North Sea and southern Sweden. Comparisons of the dispersed sporomorph and plant megafossil records indicate that both fossil assemblages reflect different aspects of the palaeoflora due to a multitude of taphonomic and ecological factors.

***Keywords*:** Jurassic, palynology, spores and pollen, vegetation, Yorkshire

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New plant-fossil sites in the Victoria Group (Permian–Jurassic) in the far North of Victoria Land, East Antarctica

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Antarctic fossil deposits play a key role for understanding the biology and ecology of plant life in past high-latitude ecosystems. Of special importance are the silicified peat deposits from the Permian (Skaar Ridge) and the Triassic (Fremouw Peak) of the Queen Alexandra Range, central Transantarctic Mountains. These deposits preserve plants and plant parts in intricate cellular detail, and in association with a broad array of fungal and other microbial remains. In addition to these classic localities, blocks of silicified peat occur also in equivalent strata in other regions of the Transantarctic Mountains, e.g., the Allan Hills in south Victoria Land or Timber Peak in north Victoria Land. So far, however, these additional occurrences have turned out poorly preserved or completely barren of identifiable plant remains. We here present the surprising results of palaeontological field work carried out during the 11. German Antarctic North Victoria Land Expedition (GANOVEX XI, 2015/2016) in the Helliwell Hills, a remote outcrop region in the central Rennick Glacier area. All sedimentary deposits in this area have so far collectively been assigned to the Permian Takrouna Formation of the Victoria Group. We documented and sampled several sections in the northern Helliwell Hills in detail for the first time. Finds of typical Triassic plant compressions (*Heidiphyllum* and *Dicroidium* leaves, *Lepacyclotes* sporophylls) and fossil wood (*Kykloxylon*) indicate that at least part of those sections belong to an unknown Triassic sedimentary unit. The most exciting palaeontological discovery is the occurrence of abundant blocks of silicified peat: some bedding planes on these blocks show impressions of small seed-fern fronds (cf. *Dicroidium odontopteroides*) and conifer leaves (*Heidiphyllum*); others contain accumulations of gymnosperm wood, and a few, particularly large blocks show abundant sections of uncompressed and apparently well-preserved fern rhizomes. We are eagerly awaiting the results of the first detailed screening and preparation of this promising new plant-fossil resource. Altogether, the little-known mountain ranges in the far north of Victoria Land seem to hold a great potential for future palaeontological discoveries.

***Keywords*:** Triassic, Antarctica, permineralization, silicified peat, *Dicroidium*

Palynology and biostratigraphic characterization of Pojuca Formation – Recôncavo Basin

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Any knowledge achieved about the geological history of the Recôncavo Basin contributes effectively for understanding the geology of the entire Northeastern Brazil. Besides the several researches concerning the richness of ostracods in the basin, there are few studies focused on biostratigraphical aspects, which are especially important for understanding the geological evolution of a basin. This paper presents results of the palynological analyses carried out on core samples from the 9FBA-65-BA and 9FBA-79-BA wells, drilled by the Petromis Company, in the Recôncavo Basin. They include one hundred seventy-three samples, with well preserved and diverse palynological assemblages. The identified palynoflora suggest a predominantly continental paleoenvironment, composed by a fluvial deltaic-lacustrine system in a hot and arid climate. Comparisons with overseas palynofloras support the hypothesis that this assemblage belongs to the pre-Albian *Dicheiropolis/Afropollis* (ex W.A.S.A) Phytogeographical Province. Fifty six palynomorphs species have been identified and partially illustrated. The identification of the *Dicheiropollis etruscus* and *Vitreisporites pallidus* species allows inserting these strata in the *Vitreisporites pallidus* Biozone, which is considered as Aratu local stage, corresponding to late Hauterivian/early Barremian in age.

Keywords**:** Cretaceous, Recôncavo basin, Pojuca Formation, palynology.

New record and a taxonomic review of the fossil wood genus *Ginkgoxylon* (Ginkgoaceae)

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In contrast to the abundant ginkgoalean leaf fossils recorded from both the Northern and Southern Hemispheres, ginkgoalean wood fossils are rare. *Ginkgo*-like woods, described under the generic names of *Ginkgo* L. or *Ginkgoxylon* Saporta emend. Süss, have mainly been reported from the Upper Jurassic to the Pleistocene of the Northern Hemisphere. They have been described from the Upper Jurassic of Vietnam and India, Lower Cretaceous of China, Upper Cretaceous of Uzbekistan, France and the Czech Republic, Oligocene-Miocene of India, Eocene and Miocene of the United States, Miocene of Greece, Pliocene of France, and Pleistocene of Vietnam. In Russia, a fossil wood, with features very similar to those of modern *Ginkgo*, was described from the Upper Cretaceous (Maastrichtian) of Zeya-Bureya Basin, Russian Far East. This is the first ***univocal record*** of ginkgoalean wood fossil from Russia. Morphogenus *Ginkgoxylon* was validly published independently at different times by Saporta (1884), Andreánszky (1952), and Khudajberdyev (1962). Süss (2003) emended Saportas's diagnosis of *Ginkgoxylon*, but a type was not designated. Later, Bamford and Philippe (2008) proposed *Ginkgoxylon gruetii* as neotype for this generic name. Kräusel (1919), Greguss (1961), Scott *et al.* (1962), Khudajberdyev (1971), Zhang *et al.* (2000), Süss (2003), and Afonin (2016) reviewed fossil woods with characteristics of *Ginkgo*, including those assigned to *Ginkgoxylon*. According to the above-mentioned reviews, the following species can be attributed to *Ginkgoxylon*: *G. amurense* Afonin from the Upper Cretaceous of Russia, *G. asiae-mediae* Chudajberdyev from the Upper Cretaceous of Uzbekistan, *G. beckii* (Scott *et al.*) Zhang *et al.* from the Miocene of the United States, *G. bonesii* (Scott *et al.*) Zhang *et al.* from the Eocene of the United States, *G. chinense* Zhang *et al.* from the Lower Cretaceous of China, *G. diversicellulatum* Süss from the Miocene of Greece, *G. dixitii* Biradar et Mahabale from the Upper Jurassic and the Oligocene-Miocene of India, *G. gruetii* Pons et Vozenin-Serra from the Upper Cretaceous of France, *G. lesboense* Süss from the Miocene of Greece and *G. quangnamense* Serra from the Upper Jurassic and the Pleistocene of Vietnam. The research was supported by the Grants Council for state aid of Russian young scientists (project no. MK-2993.2015.4).

Keywords**:** *Ginkgoxylon*, *Ginkgo*, fossil wood, Mesozoic-Cenozoic, Northern Hemisphere.

Gymnosperm and angiosperm woods from the Cretaceous (Aptian-Maastrichtian) of Russian Far East

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Fossil woods are common in the Cretaceous strata of Russian Far East. The fossil woods studied come from the Rarytkin Formation (Maastrichtian) of Chukotka Peninsula, the Kedrovka (Albian) and the Penzhina (Turonian-Coniacian) formations of Kamchatka Peninsula, the Tsagayan (Maastrichtian) and the Sitogo (Albian) formations of the Amur River area, the Lipovtsy (Aptian) and the Galenki (Albian) formations of the Southern Primorye Region and the Bykov Formation (Late Cenomanian-Early Campanian) of Sakhalin Island. Diverse gymnosperm and angiosperm fossil wood taxa were described from these formations: *Cercidiphylloxylon*, *Piceoxylon*, *Sequoioxylon* and *Taxodioxylon* from the Rarytkin Formation; *Cedrus*, *Keteleerioxylon*, *Taxaceoxylon*, *Protocedroxylon*, *Protocupressinoxylon* and *Xenoxylon* from the Kedrovka Formation; *Keteleerioxylon*, *Piceoxylon* and *Taxodioxylon* from the Penzhina Formation; *Ginkgoxylon*, *Hamamelidoxylon*, *Piceoxylon*, *Pinuxylon*, *Platanoxylon*, *Sequoioxylon*, *Taxodioxylon* and *Xenoxylon* from the Tsagayan Formation; *Protocedroxylon* and *Xenoxylon* from the Sitogo Formation; *Protopiceoxylon*, *Protocedroxylon*, *Thylloxylon* and *Xenoxylon* from the Lipovtsy Formation; *Palaeopiceoxylon*, *Protocedroxylon*, *Taxodioxylon*, *Sequoioxylon* and *Xenoxylon* from the Galenki Formation; *Magnoliaceoxylon*, *Paraphyllanthoxylon*, *Sequoioxylon* and *Taxodioxylon* from the Bykov Formation. Fossil wood of *Cedrus*, *Cercidiphylloxylon*, *Ginkgoxylon*, *Hamamelidoxylon*, *Magnoliaceoxylon*, *Platanoxylon*, *Paraphyllanthoxylon* and *Thylloxylon* were described from the Cretaceous deposits of Russia for the first time. Therefore, the investigation of the Cretaceous woods of Russian Far East will improve our understanding of the climatic and vegetation history during the Cretaceous of Northern Asia. The research was supported by the Grants Council for state aid of Russian young scientists (project no. MK-2993.2015.4).

***Keywords*:** Gymnospermae, Angiospermae, fossil wood, Cretaceous, Russian Far East.

Triassic *Kykloxylon* wood (Corystospermaceae, Gymnospermopsida) from Skinner Ridge (northern Victoria Land, East Antarctica)

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During the first Korea Antarctic Geological Expedition (KAGEX I, 2013/2014), fossil wood was collected from the Triassic fluvial deposits of the Beacon Supergroup at Skinner Ridge in northern Victoria Land, Antarctica. The material is coalified and partially silicified; most specimens are slightly compressed due to burial compaction. In spite of this imperfect preservation, anatomical features of both the xylem and the pith could be observed in some specimens. The xylem displays prominent growth rings and usually araucarioid or somewhat mixed-type radial pitting with some abnormal rings partly composed of parenchymatous tissues. Some specimens also have a wood cylinder which is divided radially by parenchymatous zones. These anatomical features indicate a systematic affinity with *Kykloxylon* Mey.-Berth., T.N.Taylor *et* Ed.L.Taylor, a characteristic wood type of the Corystospermaceae, which flourished throughout Gondwana during the Triassic. The *Kykloxylon* specimens in this study represent the only wood fossil taxon in the Triassic of Victoria Land, except for a dubious report of *Antarcticoxylon* Seward in 1914. This may indicates a low diversity of the Triassic wood fossils in this area, as in other parts of Antarctica. On the contrary, diverse other gymnosperm organs are known to occur in the Triassic of Antarctica. This low diversity of wood taxa compared to the various organs in the Triassic of Antarctica is remarkable. We hypothesize three major reasons for this: 1) the overall structural uniformity of gymnosperm wood compared to the assimilating and especially reproductive organs diversity; 2) the overwhelming dominance of corystosperm plants, with a minor component of voltzialean conifers in the canopy-forming forest vegetation during the Triassic in Antarctica; and 3) the much scarcer systematic

studies of fossil wood compared to other plant macrofossils. More studies, however, are needed to further examine this presumably low diversity and to unravel the composition of the Triassic forest vegetation of Antarctica.

***Keywords*:** Triassic, *Kykloxylon*, Corystospermaceae, Skinner Ridge, Antarctica

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On the presence of *Arcellites disciformis* Miner emend. Ellis & Tschudy (Salviniales), and other megaspores, from the Cenomanian of Patagonia, Argentina

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We report here the first South American record of *Arcellites disciformis* from the Cenomanian Cerro Waring section (S49°31'16.8'' - W71°29'07.7''), Mata Amarilla Formation, Santa Cruz Province, Argentina. This taxon corresponds to a heterosporous fern related to Salviniales on the bases of general morphological features; it has been widely recorded from the Albian to the Cenomanian (Cretaceous) of North America, but there is no previous record for the Southern Hemisphere. The Mata Amarilla Formation consists of three lithostratigraphic members; the Lower and the Upper Members represent an estuarine paleoenvironment developed in a shallow marine embayment, and the Middle (radiometrically dated at 96.23 ± 0.71 Ma, middle Cenomanian) a fluvial setting. *A. disciformis* was recovered from the lower member associated with other megaspores assigned to *Balmeisporites* sp., and at least one other undetermined form. These megaspores were analyzed under light and scanning electronic microscopes. The Patagonian specimens of *Arcellites disciformis* fit with the original diagnosis; they present a spherical spore body with pitted exoexine and several appendages, and a neck formed by six leaf-like appendages with crenulate margins. *Arcellites* has previous records only from the Albian of the Santa Cruz province, represented by four species: *A. santacrucensis* Baldoni, *A. humilis* Villar de Seoane & Archangelsky, *A. pentagonalis* Villar de Seoane & Archangelsky and *Arcellites* sp. A. This new record in the Cenomanian extends the stratigraphic distribution of *Arcellites* in the Austral Basin and enlarges the importance of these water ferns, probably related to an extinct family of Salviniales, in Late Cretaceous ecosystems of Patagonia; it also supports a bi-hemispheric distribution for *A. disciformis*. New studies in yet unexplored areas would help to a better understanding of the evolutionary history of this important group of water ferns.

***Keywords*:** Megaspores, Late Cretaceous, South America, Salviniales

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Diapir collapse features in the Upper Jurassic from the Dutch offshore

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In the northern part of the Dutch offshore Zechstein salt structures are abundant. In some cases, these structures are capped by a predominantly clastic, heterolithic layer, consisting of breccia, sandstones, shales and sulphates. The coarse nature of the sediments provides good reservoir characteristics, but the lateral continuity is difficult to predict. The hotchpotch of lithologies is the result of subrosion and dissolution of the salt that occurred during the Late Jurassic rift phase. Large angular clasts point to an *in situ* origin of the cap rock. Palynological analyses on these successions reveal the presence of excellently preserved Permian pollen in combination with Late Jurassic dinoflagellate cysts and pollen and spores. The Late Jurassic dinoflagellate cysts and sporomorphs provide information on the timing of the diapir collapse, while the perfect preservation of the Permian palynomorphs indicates the very local provenance of the sediments. The cause for collapse of the salt structures is related to flooding by sea water. The base of the cap rock

succession of well F15-06 for example, can be dated as latest Callovian and correlates with the J46 regional maximum flooding surface *lamberti* Ammonite Zone. Interestingly, well F15-06 is situated on the Schill Grund Plateau, an area where Jurassic rocks are normally absent. Apparently, the subrosion and dissolution created a mini-basin in which the sediments were preserved and protected from subsequent regression and erosion in the Oxfordian.

***Keywords*:** dinoflagellate cysts, sporomorphs, Late Jurassic, Permian, NW Europe

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Aptian-Albian seeds related to Eudicots (Romualdo Formation, Araripe Basin) from Pernambuco State, Northeastern Brazil

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The Araripe Basin Santana Group palaeoflora is a testimony of the Early Cretaceous angiosperm diversity. However, the vast majority of the Santana Group plant fossils derived from the basal Crato Formation. Few fossil plants are known from the upper Romualdo Formation. Most of these are angiosperms fossils collected in the Ceará State. This research describes isolated seeds associated with gastropods and bivalves collected in calciferous sandstones deposited during the Aptian marine transgression of the Romualdo Formation, at the Torrinha site, Araripina municipality, Pernambuco state. The excellent preservation of the seeds and their small size (ranging from 10.16 to 18.57 mm^3) allowed their study using Scanning Electron Microscope and X-ray microtomography. The specimens have oblong, elliptical in shape, with rounded hilum and sigmoid pleurogram, and a distinct root lobe. The testa is composed of papillary cells. In longitudinal section, it is possible to observe the internal structure of the exotesta, which consists of radially arranged macrosclereids and meristems followed by thickened wall cells or possibly endosperm. The botanical affinity of the specimens is unknown, as usual for the majority of the dispersed basal angiosperm seeds. However, the presence of a pleurogram and other typical features of extant Fabaceae would indicate an association with the eudicot lineage. Therefore, the described seeds suggested that the eudicot related angiosperms are present in the tropical and arid areas of Brazil, since the beginning of Cretaceous

***Keywords*:** Leguminosae, Gondwana, Cretaceous, Romualdo Formation

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Conifers of the Early Cretaceous Araripe Basin, northeastern Brazil: state of the art and paleoecological implications

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Conifers have played a major role in terrestrial ecosystems since the end of the Carboniferous. They often formed the dominant canopy of the vegetation during the Mesozoic era. However, the evolution of the angiosperms from the Early Cretaceous onwards triggered a competition in all biomes, resulting in the ulterior decline of conifer diversity and its frequency in most regions or habitats, i.e. in the tropics. Conifer diversity can be studied in the Aptian of Araripe Basin, northeastern Brazil. This diversity might have been influenced by semiarid climate and the diversification of well adapted angiosperms that occupied habitat space and started to dominate terrestrial ecosystems. Highly diversified gnetalean plants are often R-strategists, which are better adapted to stress habitats like the Crato lake environment than relatively slowly growing conifer trees. Nowadays, only families Araucariaceae and Podocarpaceae are present in the natural vegetation of South America. In the Aptian, additional families and genera such as Cheirolepidiaceae and *Lindleycladus* (*incertae sedis*) are recognized

by several fossil organs or plant parts. This diversity will be briefly summarized with special consideration of the whole-plant approach, just as in the case of recently described *Pseudofrenelopsis capillata*. Preliminary considerations of paleoecological aspects of individual conifer species will be mentioned as well. Beside angiosperms and gnetalean plants conifers also show the importance of this unique paleontological site in the south of Ceará State. Crato fossils contribute to the knowledge of the respective taxa, to the establishment of phylogenetic relationships and in particular to that of their paleogeographic distribution.

Keywords**:** Conifers, paleobiodiversity, paleoecology, Araripe Basin, Early Cretaceous

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The plant community of the Apeleg Formation (Lower Cretaceous), Patagonia. Diversity and its comparison with coetaneous megafloras of Western Gondwana

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The Lower Cretaceous has proved to be a period of great diversification and development of plant communities all across Western Gondwana. This is demonstrated by the abundant plant fossils found in different litostratigraphic units such as those of the Springhill, Anfiteatro de Ticó and Kachaike formations in Santa Cruz Province (Argentine), the Cerro Negro Formation in Antarctica and the Crato Formation in Brazil. However, other plant assemblages are merely mentioned as part of old geological studies and stratigraphical works without a complete analysis of their floras, as it is the case of the megaflora from the Apeleg Formation (Hauterivian/Barremian) in the Chubut Province of Argentine. This unit is part of the sedimentary sequence that comprises the region between the Apeleg Village, the Alto Río Senguerr city and the Lago Fontana area in the Patagonian Cordillera. It is described as deposits of transition from a marine to a continental paleoenvironment overlaying the Katterfeld Formation deposits. The outcrops of the Apeleg Formation are typically composed by levels of dark grey massive sandstones intercalated with layers of consolidated black lutites. The knowledge regarding the plant community composition of this unit is very limited, only one paleobotany study was made with descriptions and illustrations of the flora found at the proximities of the Estancia Victoria locality and includes impressions of fronds of *Scleropteris* sp., *Cladophlebis* sp., *Taeniopteris dissecta* Baldoni et De Vera, *Ptilophyllum* aff. *antarcticum* and *Ptilophyllum* sp.. In this work, fossil plants found in new fossiliferous deposits of the Apeleg Formation outcropping in the same locality are described. The new materials consist of numerous impressions of fronds and branches that belong to *Baiera* (Braun) Florin (Ginkgoales), *Brachyphyllum* (Lindley et Hutton) Harrris, *Elatocladus* Halle (Coniferales) and bract-scale complex most probable attributable to Araucariaceae. These findings increment the diversity and richness of the Apeleg Formation megaflora. In comparison with other Lower Cretaceous plant communities mentioned above from Western Gondwana, the plant assemblage of the Apeleg Formation is the less diverse of all. The intense volcanic activity and thermic metamorphism that is present in the entire sequence, may have probably affected the preservation of the original flora that inhabited the area during the Lower Cretaceous. Future studies of the deposits of the Apeleg Formation may reveal new and more varied flora. It is a contribution to grants ANPCyT PICT 2012/528 and CONICET PIP 112-201201-00212

Keywords**:** Megaflora, Vulcanism, Apeleg Formation, Lower Cretaceous, Patagonia

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Recurrent volcanic activity recorded in araucarian wood from the Lower Cretaceous Springhill Formation, Patagonia, Argentina and its paleoenvironmental implication

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Periodic volcanic activity was one of the most stressful events that affected the plant assemblages inhabiting Patagonia during the Lower Cretaceous. Although recurrent eruptions are well recorded in this area, this is the first time that they are registered in the coniferous wood described herein. The permineralized trunk was collected in a fine-grained gravel bed of the Springhill Formation, Berriasian-Valanginian in age, which outcrops at the El Álamo locality in Santa Cruz Province, Argentina. Its allochtonous preservation and subhorizontal position was probably due to fluvial remobilization in the alluvial plain. The trunk

exhibits slightly marked growth rings and anatomical characters of *Agathoxylon* Hartig, Araucariaceae. Sedimentological and megafloristic based proxies of the Springhill Formation reveal that the araucarian tree was growing under a warm and wet climate most probably reflecting a subtropical paleoenvironment. However, the occurrence of at least 5 subsequent frost rings in the earlywood of this araucarian wood suggests recurrent disturbances at El Álamo locality, mainly caused by the regional continuous volcanic activity originated in the not far volcanic arc nowadays located at west and coinciding with the Andean south–north oriented volcanoes Due to this activity, stratospheric winds could have promoted a rapid drop in air temperatures, below freezing point, that results in stressing condition and in the preservation of multiple frost rings. A probable scenario showing pre-eruption, eruption and post-eruption succession occurred at the El Álamo locality is here suggested. The presence of frost damages in the *Agathoxylon* wood described herein would probably be a useful tool to search extreme climates back into the geological time, particularly during the Lower Cretaceous in Patagonia. It is a contribution to grants ANPCyT PICT 2012/528 and CONICET PIP 112-201201-00212, PIP 112-200901-01016.

***Keywords*:** Volcanic eruptions, wood, Araucariaceae, Lower Cretaceous, Patagonia.

Fossilized resin as a marker for assembling dispersed plant organs: enigmatic Jurassic conifer leaves *Mirovia* Reymanówna and associated shoot fragments

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Mirovia (sensu Nosova, 2013) includes dispersed Mesozoic linear conifer leaves with single stomatal band not sunken in a groove. This reportedly unique pattern of stomata arrangement resembles that of the extant *Sciadopytis* Siebold & Zucc., but detailed investigations refuted the idea of taxonomic relationships between the two taxa. Phylogenetic relationships of *Mirovia* remain unclear, mainly due to the absence of data on organs other than leaves. *Mirovia eximia* (Gordenko) N. Nosova from Kursk region, Russia (Batonian), in contrast to other species of the genus, have a well preserved internal structure. The main feature of these leaves is the alternation of two normally orientated bundles with three resin ducts (Gordenko, 2007). Resin in ducts of *M. eximia* remain as solid chemically resistant filaments. We found similar filaments in two buds and six shoot fragments possessing cataphylls with several stomata in abaxial epiderm and explored a possibility of use of this character to establish a link between dispersed fossil organs. The stomata are similar to those of *M. eximia*, but also lack any characteristic features for a doubtless association. Adaxial epiderm is thin, and each cell has a large hollow papilla on distal side. There are a large middle resin duct and two small vascular bundles (associated with sclereids) on each side of the duct in cross section of the cataphylls. The occurrence of two bundles is a rare feature and it seems to be a good proof for association between the cataphylls and *M. eximia*. The cataphylls differ from those of extant conifers and as such apparently do not provide evidence on relationships of *M. eximia*. Relative arrangement of vascular bundles and resin ducts in foliage leaves is similar in *M. eximia* and most Araucariaceae. We believe that the leaves of *Mirovia* evolved by decrease of width from multi-veined leaves with several stomatal bands alternating with veins (resembling those of some extant Araucariaceae and Podocarpaceae). Transfusion tracheids with bordered pits and spiral thickenings are situated at the adaxial side of each bundle in *M. eximia* and Araucariaceae. The presence of well-developed tori in pits and structure of stomatal apparati of *M. eximia* are not characteristic of extant Araucariaceae. In general, our data provide a lot of features that distinguish *M. eximia* and associated cataphylls from extant conifers but allow a possibility of their distant relationships with Araucariaceae. The study is supported by RFBR, project № 14-04-01412a.

***Keywords*:** Jurassic, conifers, *Mirovia*, leaf anatomy, association

Late Aptian (Cretaceous) climate changes in northeastern Brazil, based on indicator species analysis (IndVal) of palynomorphs

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The flora preserved in upper Aptian rocks of South America and Africa is typical of warm climate conditions and commonly associated with semi-arid to arid climate. Warmth-loving conifers of the family Cheirolepidiaceae and their pollen *Classopollis* are recorded in upper Aptian rocks in most of the South Atlantic margin basins. However, an increase in indicators of humid conditions (e.g., ferns) is recorded in most sedimentary basins of Brazil. The method of indicator species analysis (IndVal) was applied as a tool for reconstructing the vegetation during the late Aptian. The IndVal index expresses which taxa are strongly associated with particular groups of samples. The vegetation reflects climate changes, and the IndVal indices illustrate how the taxa interacted through time and reveal patterns in the changing composition of the vegetation. The material studied derives from two well sections drilled through the Riachuelo Formation in the Sergipe Basin, GTP-17-SE (Angico Member, 70 samples) and GTP-24-SE (Taquari Member, 108 samples). Samples were prepared using the standard method of palynological preparation. The indicator species are strongly associated with particular stratigraphic intervals. IndVal indices for the Angico section indicate seven taxa associated with four intervals, viz. the *Classopollis classoides* (Interval AS-1), *Callialasporites segmentatus* and *Cicatricosisporites avnimelechi* (Interval AS-2)*; Verrucosisporites* spp. and *Cicatricosisporites microstriatus* (Interval AS-3) and *Araucariacites australis* and *Cyathidites* spp. (Interval AS-4). Values for the Taquari section indicate nine taxa associated with four intervals, viz. the *Classopollis classoides* (Interval TS-1), *Uesuguipollenites callosus*, *Callialasporites segmentatus Bennettitaepollenites regaliae*, *Cyathidites* spp., *Cicatricosisporites* spp., *Araucariacites australis* (Interval TS-2)*; Retitriletes* spp. (Interval TS-3) and *Araucariacites australis* and *Verrucosisporites* spp. (Interval TS-4). In both sections, two phases, dry and wet, are recognized. The dry phase is characterized by high to very high abundance of *Classopollis classoides*. A conspicuous change in vegetation is recorded, with an increase in ferns and mountain flora, in particular *Araucariacites australis*. *A. australis* is the second most abundant of the terrestrial palynomorphs. In the late Aptian of South America and Africa *Araucariacites* is generally associated with a high-relief flora and warm and wet climates, which may explain its association with fern spores. The replacement of *Classopollis* by *Araucariacites* and ferns reflects a change from a dry to wet phase. The change in flora may be the result of dislocation of the Intertropical Convergence Zone (ITCZ) and a relative sea-level rise.

***Keywords*:** climate changes, palynomorphs, IndVal, Cretaceous, Sergipe Basin, Brazil

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Biogeographic implications of a Track analysis (panbiogeography) applied to the Jurassic flora Ginkgoales-Czekanowskiales-Caytoniales, including new records from Mexico

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The apparent absence of Ginkgoales and Czekanowskiales in Mesoamerica has been explained as a result of the dominance of a tropical climate during the Jurassic. This claim created a gap in the palaeofloristic information, and resulted in incomplete conclusions of the palaeoclimate, diversity and distribution of paleoflora of Mexico. However, there are reports of recent discoveries of Ginkgoales and Czekanowskiales and new records of Caytoniales in Jurassic outcrops of the Mesoamerican region. These findings allow us to address from a new perspective the distribution of the flora Ginkgoales-Czekanowskiales-Caytoniales (fGCC). For this reason, with the new discoveries, we did a Track analysis (panbiogeography), with the

intention to discern and suggest hypotheses to explain the distribution of fGCC in the Jurassic. To make the Track analysis, we first compiled the coordinates of 880 global records of the following genres: *Ginkgo*, *Ginkgoites*, *Eretmophyllum*, *Karkenia*, *Ginkgoidium*, *Sphenobaiera*, *Czekanowskia* and *Sagenopteris*. Thus, we used the program ArcView GIS 3.2 and the extension Trazos2004 to generate Individual tracks (IT) and Generalized tracks. Finally, we analyzed the projection of Tracks on the Jurassic geography on a global scale as well as the historical biogeography form the fGCC. Generalized track resulting from this analysis allow us to interpret that the mobility of the ancestral fGCC was optimal during the Triassic, and the fGCC inhabited a great variety of environments in the northern and southern regions of Pangea. In the Jurassic, the tracks show a distribution pattern peculiar to the Euro-American and Gondwana region, a pattern which we believe was affected by geographical barriers during the Triassic, for example the Appalachian-Ouachita-Marathon-Sonora orogene, which was at that time a prominent a high relief range, and the aridity of central Gondwana. This distribution pattern of fGCC spread to the paleo-Pacific coasts of North and South America and West Africa and to India. In addition, the pattern of IT shows that the Mesoamerican region was a center of confluence of the fGCC in the paleo-Pacific tropical coast. The analysis of our results allows us to argue that the distribution of the fGCC was clearly influenced by two events, the first, a mobility event during the Triassic and second a fragmentation and isolation event during the Jurassic. Therefore, we concluded that the new findings of flora and Track analysis of fGCC on the Mesoamerican region are the first step in understanding the biogeographic patterns of the region including the Jurassic biota.

***Keywords*:** Distribution pattern, Historical biogeography, Paleobotanic, Mixteco Terrane, Mesoamerica region, Appalachian-Ouachita-Marathon-Sonora Orogeny

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A new megaflora from the Huancané Formation (Lower Cretaceous), Peru

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The Cretaceous flora of Peru has received little interest. In this communication we present new fossil remains from the Huancané Formation (Lower Cretaceous). The fossil plants are very well preserved and come from a single locality with three different stratigraphic levels close to Cusco city. The fossil flora is dominated by *Brachyphyllum* Brongniar, *Cupressinocladus* Seward and leaves and seeds assigned to the Araucariaceae. The rest of the assemblage consists of ferns and putative pteridosperms, such as *Cladophlebis* Brongniart and *Weichselia* Stiehler. In addition, scarce and disperse pinnae of *Sagenopteris*? Presl and *Sphenopteris* Sternberg were also recorded. The presence of *Weichselia* is interesting, because this taxon has a worldwide distribution mainly in Cretaceous strata, and supports the age inferred to the Huancané Formation based on sedimentological and palynological studies. Therefore, the plant assemblage would suggest a forest canopy dominated by conifers, with an understory composed by ferns (*Cladophlebis*, *Sphenopteris* and *Weichselia*) and pteridosperms (*Sagenopteris*). This flora would have developed in a warm and humid climate during the deposition of the Huancané Formation. These new data contribute to the fossil record of South America, and particularly to the Cretaceous flora near equatorial regions.

***Keywords*:** fossil leaves, seeds, conifers, ferns, Pteridosperms.

Early Jurassic permineralised woods from Carapace Nunatak, South Victoria Land, Antarctica: affinities and paleoenvironmental implications.

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Among the few Lower Jurassic sites with plant remains known from Antarctica, Carapace Nunatak, in South Victoria Land, is emerging as one of the richest. It contains different types of plant fossils (pollen, silicified plants, compressions/impressions, and fusain), which opens the door to promising multidisciplinary studies on past biodiversity and ecosystem functioning. In this study, we describe 8 permineralised wood samples collected at Carapace Nunatak during the 2014–2015 austral field season. The size and preservation of specimens are variable, but most anatomical characters can be observed. The woods are assigned to two morphogenera: *Agathoxylon* (?Araucariaceae) and *Brachyoxylon* (Cheirolepidiaceae). The two taxa principally differ in radial tracheid pitting, which is araucarian in *Agathoxylon* and mixed in *Brachyoxylon* (i.e., containing both araucarian and abietinean radial pitting). No intrageneric variability has been observed. These two wood morphogenera fit with previous interpretations made at Carapace Nunatak (macrofloristic and palynological), and with the proposed warm-temperate paleoclimate reported in the literature. Fungal structures (i.e., hyphae and spores) also occur in some of the wood specimens. Although their exact systematic affinity is currently equivocal, the presence of regularly spaced septa indicates an affinity with Ascomycota or Basidiomycota, which is concurrent with extant wood colonizing fungi. There is little information available on Jurassic fungi from Antarctica, but their presence within the Carapace Nunatak woods could partly explain the poor preservation of some specimens. Finally, analysis of the sedimentary matrix associated with some of the woods revealed the presence of charcoalified secondary xylem tracheids. Their presence suggests fire activity at this locality, which contrasts with the low levels of atmospheric oxygen proposed for the Early Jurassic. All these results need to be considered within the paleoenvironmental context of a volcanically influenced, relatively high-latitude environment (~60°S). The wood samples generate new questions, both about the Carapace Nunatak palaeoecosystems and at a bigger scale. For example, were *Agathoxylon* and *Brachioxylon* the only trees present at the locality? What was their place in this type of paleoecosystem? What was the systematic and ecological fungal diversity associated with these trees? Further studies on fossil plants and fungi from Carapace Nunatak may provide answers to these questions and lead to a more complete and detailed reconstruction of the Early Jurassic vegetation of Antarctica.

***Keywords*:** Jurassic; wood; Antarctica; fungi; charcoal.

First evidence of the Triassic seed fern *Ptilozamites* in the Southern Hemisphere

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The genus *Ptilozamites* Nathorst is a common Middle Triassic to Early Jurassic morphotaxon, found only in Northern Hemisphere localities (i.e., Europe, Greenland, and Asia). However, recent work at the San Rafael Block, in Mendoza province (Argentina) yielded new plant macrofossils, among which abundant pteridosperm foliage attributable to *Ptilozamites* was found. The fossil plants were recovered from the Quebrada de los Fósiles Formation (lower unit of the Puesto Viejo Group), a continental succession composed of alluvial and fluvial deposits intercalated with volcaniclastic sediments, and radiometrically dated in ~245 – ~235 My. The largest pinnate frond measures 22 cm long and 10 cm wide. The leaves are characterized by long, subquadrate pinnae with an obtuse to rounded apex, attached sub-oppositely to the rachis by their entire base at a 35°-70° angle. Veins arise from the rachis and run almost parallel to the apex, with very few dichotomies and anastomoses. The rachis is thick, longitudinally striated, and bifurcated. The epidermis is thick. Epidermal cells

are irregular to isodiametric polygonal, with thickened trichomes bases. The stomata are surrounded by 5-6 subsidiary cells, forming a strong ring, a defining character of the genus. Although the pinnae are very similar to those of the cycadophyta, the bifurcated rachis and cuticular characters allow placing it under *Ptilozamites*, a pteridospermous morphogenus of unknown affinities. Until now, only lycopsids and sphenophytes had been described from the unit. Thus, this pteridosperm foliage represents the first evidence of seed ferns for the formation, suggesting the flora that grew in proximity of these shallow floodplain lake deposits was more heterogeneous than originally thought. The thick epidermis with trichomes in *Ptilozamites* could have been a way of protecting the plant from the intense volcanic activity that influenced the sedimentary evolution of this succession. Sedimentation was dominated by arid or semiarid climates, and a concomitant seasonality. The finding of *Ptilozamites* represents the first record in all fossil assemblages in Gondwana, proving a wider paleogeographic distribution for this genus, and further corroborating the floral interchange between the northern and southern hemispheres during the Triassic.

***Keywords*:** Pteridosperm, Gondwana, Argentina, Middle Triassic, Puesto Viejo Group.

Jurassic conifer woods from the Lajas Formation (Neuquén Basin), Argentina. Anatomical, systematic and palaeoecological inferences

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The Neuquén Basin is located on the eastern side of the Andes in Argentina and Chile, between 32° and 40°S latitude. It comprises an almost continuous record from Late Triassic to Early Cenozoic stratigraphy. The Bajocian – Callovian Lajas Formation is a 600 m thick unit composed of several unconformity-bounded tide-dominated sequences. Sequence boundaries are marked by stacked fluvial channel fills developed on widespread incision surfaces. Though fossil plants, especially those bearing fossil woods, are scarce in the Lajas Formation, trunks from three localities (Rincón del Águila, Paraje los Molles and Cerro Lotena) were recovered and allowed anatomic and systematic studies. All samples collected come from large logs, with a length between 1 and 13 m. To study fossil woods, petrographic slides in three sections (cross, radial and tangential) were made, and analyzed under light microscopy and SEM. The fossils were assigned to three conifer genera: *Podocarpoxylon* Gothan, *Agathoxylon* Hartig, and *Cupressinoxylon* Goppert. In order to obtain palaeoecological data, the growth rings were analyzed, and combined with sedimentological studies. All fossil woods have growth rings, and in most cases marked only by one or two rows of latewood; this condition suggests seasonality. The mean sensibility index was employed to obtain palaeoecological data, with values between 0.31 and 0.70, indicating that they were "sensitive" to local climate conditions. All these data suggest that trees grew under several fluctuations of environmental conditions. The preliminary conclusions propose that conifers were the most diverse large trees in the studied localities, with taxa related to extant families (e.g. Araucariaceae, Podocarpaceae, and Cupressaceae s.l.). The abundance of large and well preserved fossil wood could suggest that those plants numerically dominated the forest communities of the Neuquén Basin during the Middle Jurassic.

***Keywords*:** Neuquén Basin, Fossil wood, mean sensibility, *Agathoxylon*, *Podocarpoxylon*, *Cupressinoxylon.*

Maastrichtian and Danian palynologic records in northwestern Argentina. Biostratigraphic indicators

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The Salta Group contains Lower Cretaceous to Paleogene sediments that filled a rift basin developed in northwestern Argentina. The studied palynomorph samples correspond to Maastrichtian and Danian levels from the Yacoraite and Olmedo/Tunal formations respectively. The Yacoraite Formation outcropping at the Tonco river valley (southwestern Salta province), yields a palynoflora containing continental elements represented by angiosperms (52.5%), monilophytes (25.9%), gymnosperms (11.3%; mainly Gnetalean species), bryophytes (2.6%), fungi (2.9%) and algae (4.8%). Taxa like *Aquilapollenites magnus* and *Psilastephanoporites brasiliensis* allow assigning a Maastrichtian age for this association. These pollen grains have also been recorded in associations from Bolivia and Brazil but they do not appear in other Maastrichtian associations from central or southern Argentina (e.g. Jagüel, La Irene, Monte Chico, or Ciénaga del Río Huaco formations). On the other hand, the stratigraphically equivalents Olmedo and Tunal formations overly the Yacoraite Formation in different parts of the basin. The samples yielding palynomorphs come from the El Chorro creek (Salta province) and Garabatal localities (Jujuy province). These associations are also characterized by having high percentages of angiosperms (5-(47)-81%; with dominance of the Ulmaceae pollen *Verrustephanoporites simplex*), monilophyte and bryophyte spores (1-46%), gymnosperms (0.5-6%), and also a high representation of the chlorococcalean green algae *Pediastrum* spp. (16-92%). The Danian assemblages are included in the *Mtchedlishvilia saltenia* palynozone characterized by the presence of *Mtchedlishvilia saltenia* pollen grains associated with *Pandaniidites texus* and *Gemmatricolpites subsphaericus*, and they belong to the Ulmaceae phytogeographic province as the Danian Pedro Luro and Salamanca/Bororó formations from southern Argentina. The Maastrichtian and Danian palynologic records presented here are a contribution to future studies of the vegetation changes through the Cretaceous-Paleogene in northern Argentina, and the phytogeographic context.

***Keywords*:** Palynology, Maastrichtian, Danian, Salta Group Basin, Argentina

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Chrono-stratigraphy of the mid-Cretaceous Dalazi Formation in eastern Jilin Province, Northeast China: organic carbon isotope chemostratigraphy and U-Pb isotopic dating

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The Cretaceous period is characterized by supper "Greenhouse" climate, accompanied by large-scale episodic volcanic activities, sea-level rise, oceanic anoxic events and oceanic red beds deposits. Volcanogenic atmospheric CO_2 from large igneous volcanic provinces are considered as primary driver of climate change, i.e. global warming. Extense forested biomes developed in high northern latitudes, and the Cretaceous atmospheric CO_2 concentrations might be three or four times high than that of the present level. Distinct methods can be used to date and correlate all those events in the world, including paleontological and geochemical ones. The Cretaceous Dalazi Formation in the Yanji Basin, eastern Jilin Province of China, represents one of the typical lacustrine horizons in the Cretaceous deposits of eastern Eurasia that could provide an insight into the terrestrial feedback to the Cretaceous global events. The depositional succession of the formation is composed of conglomerates, sandstones in the basal part and mainly dark grey mudstones,

siltstones and oil-shales, in the middle and upper parts. The dark grey mudstones and oil-shales are rich in fossils of conchostracans, ostracods, bivalves, gastropods, fishes, dinoflagellate and chlorophyte alga, which indicate fresh to brackish-waters. Siltstones yield numerous plant fossils, including ferns, conifers, angiosperms, that inform about a warm and wet seasonal climate. However, the age calibration of the Dalazi Formation is unsubstantial and the Early Cretaceous age previously proposed was not precisely confirmed. Recently, two bentonites layers were dated to this geological unit and inform about a weighted mean $^{206}Pb/^{238}U$ ages of 96.2±1.7 Ma and 109.9±2.9 Ma respectively, indicating an Albian-Cenomanian age to the Dalazi Formation. Additionally, a time in the boundary between Albian and Cenomanian is here ascertained for the first time, taking into account the first occurrence of the angiosperm pollen *Tricolporopollenites* and a fern spore peak. Furthermore, by the analysis of total organic carbon (TOC) content in 74 samples, 42 of them selected for organic carbon isotope ($\delta^{13}C_{org}$) analysis, allows detect three positive $\delta^{13}C_{org}$ excursions, regarded as the answer to the mid Cenomanian event (MCE), OAE 1d and OAE 1b, respectively and in descending order. This work is financially supported by NSFC (No. 31270277), and Sincere thanks are given to the anonymous reviewer for his nice revision.

***Keywords*:** Organic carbon isotope, zircon U-Pb geochronology, mid-Cretaceous, Dalazi Formation

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Occurrence of the genus *Galeacornea* (elaterate pollen) at the Cretaceous of central-western Argentina

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Elater-bearing taxa are characteristic of the Albian-Cenomanian Elaterate Province corresponding to northern South America, Central and North Africa and the Arabian Peninsula. Species of the elaterate complex occur in high abundances and diversity only in the circum-Atlantic basins. A new elaterate species named *Galeacornea guayaguensis* Prámparo, Narváez and Mego, has been recently described from sediments of the Lagarcito Formation (San Luis Basin) at the 'La Yesera Sur' section, Sierra de Guayaguás ranges, San Juan Province, central-western Argentina. The psamopelitic-evaporitic sequence with gypsum and anhydrite intercalations yields a rich palynoflora of continental origin (fluvio-lacustrine). *G. guayaguensis* shares with other *Galeacornea* species the shape of the grain, the presence of an annular rim and the distal appendages. The ridge-like appendages are similar to those of *G. stoveri* and *G. tarimensis*, although they never fuse with the annular rim or with each other at their ends as it respectively occurs in other species. The new species from Argentina provides further evidence on the morphological variation of elaterate grains and extends the geographical distribution of the genus *Galeacornea* to South America midlatitudes, far beyond the palaeophytogeographic Albian–Cenomanian Elaterates Province of the equatorial region. However, it is important to note, that elaterates in Argentina are less diverse and abundant than at lower latitudes. Several studies suggest that elaterates and polyplicate pollen are botanically related. At the Lagarcito Formation *Galeacornea guayaguensis* was found within an association dominated by gymnospermous elements, mainly represented by polyplicate (diverse and abundant *Ephedripites*, *Gnetaceaepollenites*, *Steevesipollenites*) and rimulate grains (*Classopollis*). An Aptian-Albian range was estimated for the palynologic association recovered in the studied area, based on the occurrence and biostratigraphical value of different verrucate spores. It is remarkable the presence of *Reyrea polymorphus* Herngreen, a significant marker taxon from the early–middle Albian of Brazil, associated with the new elaterate species in central-western Argentina.

***Keywords*:** elaterate pollen grains, *Galeacornea*, Lower Cretaceous, Lagarcito Formation, central-western Argentina.

Charcoalified Palm Stems from the Coniacian of James Ross Island, Antarctic Peninsula

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The fossil record from Arecaceae dates from Mid-Late Cretaceous (Turonian to Santonian). Their fossil palm stems are generally preserved as petrifactions or permineralizations and knowing to the Late Cretaceous of Argentina and India. In Antarctic Peninsula, the scarce previous record is limited to the Campanian and refers to pollen grains and fragments of leaves. Here is discussed the results of a study in two small fragments of charcoal detected in sandstone levels of Hidden Lake Formation, northern sector of James Ross Island. This unit is interpreted as a marine environment with volcaniclastic influence, deposited during a warmer period (15° - 20°C). The charcoalified materials were analyzed on reflected light microscope, following the method applied on Quaternary charcoals. Comparison was performed with fossil materials described in the literature and with histological slides of extant *Butia capitata* Becc stems. Macroscopically the fossils are black, friable, with a silky lustre and give a black streak on paper, which characterize them as a charcoal. Many charred-plant remains have an excellent anatomical preservation, yet it can vary with the plant nature and the temperature during the taphonomic processes. In this case, the increase of temperature or the time of natural pyrolysis resulted in a higher homogenization of cell walls, which leads to the obliteration of cells. The herein analyzed stem fragments shows vascular bundles of xylem and phloem associated to a unilateral fiber cap and embedded in a parenchymatic matrix, which corroborate the association with stems found in members of Arecaceae. Additionally, the cortical region of the stem and vascular bundles exhibits just one metaxylem element, as is observed too in modern *B. capitata*. The low occurrence and the small charred fossils in the studied levels may results from the nature of the palm tissues, rich in water and starch, allied with the climate conditions (characterized by strong winds and humidity) and the volcanic context of the Hidden Lake deposits, stimulating allochthonous preservations and a rapid decay. It is possible to infer also that after the pyrolysis and transport, only the most fibrous and resistant part of stem could be preserved. The associated fern spores and fungi remains confirm the warm and humid climate conditions. Despite the poor preservation of the material on which more accurate descriptions was difficult, the visible features indicates the first evidence of palm stem to the Cretaceous of Antarctic Peninsula.

***Keywords*:** Arecaceae, palm stem, charcoal, Coniacian, James Ross Island

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Paleocene occurrence of two *Pseudotorellia* species and discussion on the history of the genus

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Pseudotorellia Florin (1936) has long been noticed as a Mesozoic Ginkgoalean genus found from Rhaetic to Late Cretaceous of Northern Hemisphere. Two new species were recognized in the Paleocene Minato Formation (63.4 ± 0.9 Ma) of the Noda Group, and Nameiri Formation of the Kogawa Group, Northeast Japan, based on cuticular studies of the specimens. The two species are characterized by narrow lanceolate to oblanceolate leaves having sinuous anticlinal cell walls of the normal cells and longitudinal orientation of the stomatal openings. Up to date, there are 56 records of *Pseudotorellia* and *Torellia* species with described cuticles. The earliest record of *Pseudotorellia* is from the Rhaetic of Sweden which is the only Triassic record with described cuticles. The genus was most wide spread during the Early and Middle Jurassic, extending from Greenland through to central Eurasia and Southeast China. The Late Jurassic distribution of the genus was restricted to small areas in the high latitude regions divided into eastern and western areas, due to the invasion of the Turgai Sea. Decreasing aridity in the Early Cretaceous slightly expanded the distribution of the genus although separation of eastern and western populations continued. In Late Cretaceous, the distribution of *Pseudotorellia* (and *Torellia* which is considered as closely allied to *Pseudotorellia*) is restricted further northeast while western distribution is no longer recognized in the plant fossil record.

***Keywords*:** *Pseudotorellia*, Paleocene, distribution, history, Japan

Fossil Woods from Cretaceous of James Ross Island, Antarctic Peninsula

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The Antarctic Peninsula shows the thickest Cretaceous sedimentary succession of the Southern Hemisphere and the study of its wood floras has been increased in the latest 30 years. But, despite the outcrops of James Ross Island being rich in plant fossils, few studies focuses on wood identification. The majority of works describe angiospermous woods, as *Antarctoxylon mixai*, two species of *Illicioxylon*, *Laurelites jamesrossii*, *Sassafrasoxylon gottwaldii*, *Weinmannioxylon nordenskjoeldii* and *Winteroxylon jamesrossi.* Only *Agathoxylon* sp. and *Cetricycas antarcticus* are reported as gymnospermous woods from James Ross Island. This study analyzes two hundred wood fossils, with 1-15 cm lenght and 0,5-10 cm diameter. Apparently all of them are charred and come from the deposits of Whisky Bay, Hidden Lake and Santa Marta formations, wich comprises sucessions from Albian to Campanian. The Whisky Bay Formation (Albian to Coniacian) has deep marine deposits which are dominated by conglomerates and breccias, as well as, gross sandstones. Hidden Lake Formation dates back from Coniacian and is interpreted as a marine environment below the influence of storm waves with volcanoclastic sediments. The facies associations of this unit mainly cover slope aprons and fan deltas. The Santa Marta Formation (Late Coniacian to Santonian) shows mudstones, siltstones and interbedded sandstones, is interpreted as a shallow marine environment of low energy. The fossils were embedded in polished resin blocks and observed at reflected light microscopy under ultraviolet light. Using this method was possible to discover that they are not all charred, they are preserved as charcoal (49%), permineralizations (37%) and petrifactions (14%). The fossils from Whisky Bay cannot be precisely identified because of its poor preservation, it is just possible to recognize that they are in a 7 gymnospermous to 2 angiospermous woods ratio. In Hidden Lake were recognized *Agathoxylon* sp., *Cupressinoxylon parenchymatosum*, *Taxodioxylon* sp.1 and *Taxodioxylon* sp.2, *Podocarpoxylon* sp.1, *Podocarpoxylon* sp.2, *Paraphyllantoxylon* sp. and *Weinmannioxylon* sp. The 16 fossils from the Santa Marta Formation are all of *Phyllocladoxylon antarcticum*. Although part of these fossils is poorly preserved, this study is important as a contribution to a better knowledge of the wood floras from James Ross Island. Indeed, the majority of the fossils described here is common to the Cretaceous flora of Antarctic Peninsula and indicates that the flora of James Ross Island is composed too mainly of Gymnosperms and less frequently, woody Angiosperms.

***Keywords*:** wood flora, Cretaceous, James Ross Island, Antarctic Peninsula

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Palynofaciology of the 9-PIF-4A-MA well – Codó Formation, Parnaíba Basin- Northeastern Brazil

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Organic residue of 22 samples of Codó Formation shales at 9-PIF-4A-MA well were analyzed. With the TOC values and visual evaluation of the organic content, it was possible individualize and characterize the dispersed organic matter that yielded inferences on the environmental conditions during sedimentation. The TOC values reach the maximum of 3.95% at some levels. The thin sections showed a predomination of amorphous organic matter at the lower part of the section, whereas at the upper part the higher plants are well represented. The low fluorescence observed at the whole section indicates that the sediments of this well were submitted to oxidation during depositional phase. The results of spores coloration index show values between 3.0 and 4.0 corresponding to 0.3-0.4 % Ro values (vitrinite reflectance). This allow us say that such sediments, from this studied interval, are at immature stage for hydrocarbon generation.

***Keywords*:** Codó Formation, Parnaíba Basin, Palynofaciology.

Preliminary analysis of sedimentary organic matter of the interval Aptian-Turonian (Cretaceous) of the Pernambuco Basin, northeastern Brazil

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In order to recognize the changes in depositional paleoenvironments, palynofacies analysis was carried out on 17 samples from the one well section (1-LABIO-PE3) drilled through the Cabo and Estiva formations in the Pernambuco Basin. Samples were prepared using the standardized method of palynological preparation. The three main categories of particulate organic matter (POM), viz. phytoclasts, amorphous organic matter (AOM) and palynomorphs were identified and counted. The stratigraphic distribution of the constituents was used to infer the paleoenvironment changes based on the existing sedimentological interpretation. The section is conspicuously dominated by phytoclasts (non-opaque non-biostructured and opaque particles). In the base part of the section (Cabo Formation), the almost 100% of opaque particles indicates a subaerial exposure or, at least, extremely shallow conditions. The AOM identified is mainly derived from macrophyte tissues after amorphization process. The presence of marine elements (dinoflagellate cysts and microforaminiferal linings), especially in the upper part of the section, indicates a marine environment. The dominance of phytoclasts reflects the continuous terrestrial influx throughout the section. However, from the base to top, an increase in marine influence or change in distance of fluvial-deltaic source areas.

***Keywords*:** palynofacies, paleoenvironment changes, Cretaceous, Pernambuco Basin, Brazil

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Brachyphyllum obesum Heer from the Crato Formation, Brazil, and its botanical affinity to the conifer family Araucariaceae

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Since the begining of paleobotanical studies in the late Aptian Crato Formation flora and several years later, fossils assigned to the genus *Brachyphyllum* Brongniart, has been recognized as the most abundant fossil plant specimens from this geological unit. In this laminated limestones of lacustrine origin, deposited under arid to semiarid environmental conditions, two different species of *Brachyphyllum* can be found, *B. obesum* Heer, described originally from the late Aptian to early Albian from Portugal, and *B. castilhoi* Duarte, recorded originally for the Romualdo Formation, an Aptian-Albian geological unit, occurring in the same basin (Araripe basin), but stratigraphically above the Crato Formation. Botanical affinity for *Brachyphyllum* has not been adequately discussed and no consensus has been obtained since its vegetative morphology is common to many Mesozoic conifers of the families Araucariaceae and Cheirolepidiaceae, also because of the absence of organic connections of twigs with more confident reproductive organs to define familiar affinities. By histological analysis through SEM of epidermal and stomatal cells as well as vascular system features as tracheid and cross-field pittings, botanical affinities of *B. obesum* to the family Araucariaceae from the Crato Formation is demonstrated and discussed. Additionally is suggested an organic connection of *B. obesum* leaves to a female cone bearing bract-scale complexes of the species *Araucarites vulcanoi* Duarte, another fossil plant commonly found in Crato Formation Flora, corroborating the idea of its Araucarian botanical affinity. [Contribution to FAPESP Project 2008/02884-5].

***Keywords*:** *Brachyphyllum obesum*, Crato Formation Flora, Araucariaceae, late Aptian, histology

Araucaria megastrobili from Crato Formation Flora, Brazil

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Crato Formation has been recognized as a prolific source of information about Early Cretaceous paleobotany, with species of diverse groups as pteridophytes, conifers, gnetales and angiosperms. Conifers are abundant and their representatives belong to the families Araucariaceae and Cheirolepidiaceae, although several fossil plants sharing features with conifers are still with uncertain affinity. One of the most abundant of these fossil fragments, correspond to putative megastrobili formerly assigned to *Araucaria* Jussieau, its affinity is based in the araucarioid shape and size of the cone, the helically arrangement of bract-scale complexes with araucarioid shape, and the presence of a single, probably, wingless seed. Here, were analyzed 25 of that megastrobili, with two different modes of preservation, as iron oxides and coalifications. Variations in shape, and size ranges of several features were determined, and its botanical affinity and ontogeny discussed. Also a detailed analysis of an isolated bract-scale belonging to this type of cone, using Synchrotron X-Ray Fluorescence elemental mapping was performed in order to reveal hidden morphological structures in matrix and have some clues to understand taphonomic processes. [*Acknowledgements to Fundação CAPES*, *Process 1536356 and Laboratório Nacional de Luz Síncrotron (LNLS)*, *Proposal 20150110*, *XRF Beamline]*

Keywords: Crato Formation Flora, late Aptian, *Araucaria*, megastrobili, X-Ray Fluorescence

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Tracking the depositional associations of palynological assemblages within southeastern Australia's Early Cretaceous Gippsland Basin

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Palynofacies assessment of kerogens sourced from fluvial deposits with distinctive sedimentary stacking patterns is a unique approach to unravelling spatial distributions of palaeofloral communities. This approach may be applied in the subdivision of other undifferentiated (regionally uniform) fluvial units found globally. Understanding of the early stratigraphic and biogeographic development of the Gippsland Basin, southeastern Australia, has been hindered by the lithologically undifferentiated character of the basin's basal unit, the Early Cretaceous Strzelecki Group. This unit represents the early phases of rift development, largely comprising volcanogenic deposits of fluvial sandstone and siltstone facies, lacustrine siltstone and claystone facies, and multiple thin coal beds. These elements are stratigraphically discrete, with minimal lateral extension depicting complex fluvial geomorphological architecture. Strzelecki Group outcrops contain multiple vertebrate and invertebrate animal fossil beds from which bird, fish, reptile, mammal, dinosaur, and insect material have been recovered. In addition to this fossil fauna, the deposits contain assemblages of macro-, meso-, and microfloral fossils. To date, detailed determination of the biogeographic distribution of floral elements within this rich ecosystem has not been possible. This is due to an incomplete understanding of the role of tectonic controls on sedimentation style and the subsequent distribution of local vegetation types within the rift valley. This research is focused on: i) determining the environmental and depositional associations of facies present throughout outcrop of the Strzelecki Group on southeastern Australia's west Gippsland coast; and ii) investigating the relationship of these associations to the spore-pollen and sedimentary organic matter assemblages recovered. This enables placement of these deposits, and their preserved biota, into a derived palynological framework. Assemblages can be correlated with their respective environmental positions (i.e. palaeochannel proximity), and placed into the broad palaeobiogeography of the high-latitude and relatively warm Early Cretaceous eastern Gondwana. Detailed stratigraphic logging and facies description of coastal outcrops has enabled the classification of three major fluvial depositional associations (active channel, abandoned channel, and floodplain). Each being defined by its stratigraphic stacking pattern, sedimentary geometries, and textural features, allowing a novel palynological sampling approach. The parameters investigated during kerogen palynofacies analyses on assemblages recovered from each major facies association are presented, along with results to date. Within this study, preliminary

findings of spore-pollen biostratigraphy aimed at establishing the ages of selected Strzelecki Group materials show the attribution of one field locality to the Middle – Upper *Cyclosporites hughesii* Subzone, a narrower range than that previously reported, giving a mid-Barremian – mid-Aptian age.

***Keywords*:** Cretaceous, sedimentary organic matter, Gippsland Basin, fluvial palynofacies, palynology.

Mesozoic palynostratigraphy of Poland after archival stratigraphic examinations and my own results of facies studies.

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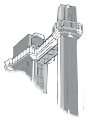
The analyzed palynostratigraphic material displays variability of the Mesozoic stratigraphic spectra. However, it cannot be a base of detail palynostratigraphic subdivision. Re-worked archival material of T. Orłowska – Zwolińska and A. Fijałkowska (Triassic), J. Rogalska (Jurassic) and J. Mamczar (Lower Cretaceous) did not show also clear results of the geological age, but they may be useful in limited range for intercontinental correlation: T, $T_3 - J_1$, $J_1 - J_2$, $T_3 - J_2$, Cr_1, $J_3 - Cr$ and Cr_1. Detail analysis of the miospore morphology, difficult to see, and sedimentary environment confirmed the influence of the sedimentary conditions for this morphology. However, detail analysis of the palynological matter, quantitive analysis of palynological spectrum and analysis of miospore morphology made possible to define me the palynofacies and distinction of predepositional corrisional structures (the results of mechanic, biochemical and epigenetic corrosion) and postdepositional ones (the results of thermal corrosion). It shows that palynofacies analysis may be useful also in palynostratigraphy.

***Keywords*:** Mesozoic, miospors, analysis, archival and facies material, palynostratygraphy.



METHOD IN PALYNOLOGY AND PALAEOBOTANY

Tânia Lindner Dutra & Jaílson Santos Novais

A novel method to detect inter-annual pollen variability in ice cores

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Glacier ice cores are treasured items for palaeo-ecological studies, because they store essential information on past climate and human activities in a high time resolution. In this frame, the Ortles project (www.ortles.org) aims to study the Mt. Ortles Glacier (Alto-Adige, Northern Italy) as an indicator of past and current climate change in the Eastern Alps (Central Europe). The study includes pollen, isotopes, major ions, trace elements and levoglucosan analyses on 4 glacier ice cores, as well as the investigation of the glacier physical features and the surrounding permafrost areas. However, the crucial part of studying glacier ice is the chronology. Here we present the first palynological results obtained from a 10 m firn core drilled on the top of the glacier, revealing the potential of palynology as a tool for ice core dating. Based on the single species flowering periods, our results show that the Ortles' pollen spectra show seasonal and inter-annual variability that enables to discriminate three different flowering seasons (spring, summer, autumn?) and winter snow in layers accumulated on the glacier. According to these four components a seasonal and annual chronology is established, proving that the 10 m firn core encompasses five years of snow accumulation with a distinct palynological signal. Moreover, a pollen-based daily timescale was established by numerical comparison of the Ortles firn pollen data with the daily pollen monitoring data of the aerobiological station of Solda, located

at the foot of the Mt. Ortles in 1906 m a.s.l. The application of the daily timescale to the observed isotopes, main ions and trace element data obtained from the core, enables a direct comparison with meteorological parameters and allows to gain essential information on snow deposition and persistence on the glacier.

Keywords**:** cryopalynology, pollen monitoring, glacier ice

Sporopollenin chemistry and environmental signals: new uses for old sporomorphs

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The pollen and spore fossil record is one of the most complete archives available to palaeontologists in terms of temporal and spatial range. This record is a function of both their production and their preservation potential due to their chemistry. This enhanced preservation is due to the exine of both spores and pollen being composed of the biomacromolecule sporopollenin, which is regarded as one of the most resilient naturally occurring compounds. Sporopollenin is composed of a mixture of fatty acids (saturated and unsaturated) and two aromatic compounds, ferulic and p-Coumaric acid. Due to their chemical structure ferulic and p-Coumaric acid provides the male gamete with protection from the harmful effects of UVB exposure. There is now a growing body of work that demonstrates that the chemical composition of sporopollenin is under environmental control with plants upregulating the aromatic component (ferulic and p-Coumaric acid) of sporopollenin in response to enhanced UV-B flux. This, when coupled with our enhanced understanding of the fate of sporopollenin during diagenesis and how palynological sample preparation effects spore and pollen chemistry is enabling the development of a new proxy based of pollen and spore chemistry that has the capacity to track past ultraviolet and solar irradiance through geological time. These findings facilitate the development of a new suite of proxies with which to probe the Earth system.

Keywords**:** *Pollen*, *spore*, *FTIR*, *sporopollenin*, *UV-B*

Neutron tomography to virtually extract Late Cretaceous conifer seed cones of the Tupuangi Flora, Chatham Islands, New Zealand

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Neutron tomography provides a high-resolution, non-destructive approach to virtually extract three-dimensional (3-D) fossil material from the surrounding rock matrix. The technique has been particularly applicable to 3-D fossils which are too delicate to physically extract from their host sediment using traditional methods. When applied to plant fossils, this method allows for a greater contrast between the matrix and fossils than X-ray tomographic techniques. One drawback of this technique is that the neutron absorbance can lead to levels of radioactivity (depending on the minerals present) that require the specimen to undergo an extended interval of radioactive decay before it can be handled again safely. Neutron tomography was carried out at the DINGO Neutron facility at the Australian Nuclear Science and Technology Organisation, Sydney, Australia. The technique was applied to two species of newly discovered conifer seed cones from the Late Cretaceous (Cenomanian–Turonian; 95–89 Ma) Tupuangi Flora, Chatham Islands, New Zealand. These deposits record flourishing fossil forests at polar latitudes (~ 75–80°S) during an interval of global hothouse climate. 3-D virtual extraction facilitated full taxonomic descriptions of these two species. The probable cupressaceous and araucarian cones provide important palaeobiogeographic links to coeval Gondwanan assemblages in Australia, such as the Winton Flora of central Queensland. Furthermore, differential neutron absorbance presents a unique perspective into compositional differences within single specimens; these include evidence of oxidation, desiccation and other degradation features in the carbonised fossils. The

study demonstrates the untapped potential for applying neutron tomography to a range of taxonomic and taphonomic puzzles in palaeobotany.

***Keywords*:** Neutron tomography, Chatham Islands (New Zealand), Cretaceous, seed cone, virtual extraction.

Characterisation of the modern pollen rain-vegetation relationship of *Araucaria* forest of southern Brazil by analysis of moss polsters

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Analysis of fossil pollen records can provide important insights into the centennial-millennial scale dynamics of *Araucaria* forests of southern Brazil. In order to extract ecological information from these fossil pollen records, an understanding of modern pollen-vegetation relationships is first required. Here, we present pollen data from moss polsters, along with vegetation data from floristic inventories, to characterise the pollen rain-vegetation relationships of *Araucaria* forests. The study area is Fazenda Gateados, a private reserve (28°1'14.50"S, 50°48'20.10"W) in Santa Catarina, Brazil, one of the few remaining intact areas of *Araucaria* forests of southern Brazil. Sixteen forest plots were selected from across the reserve, spanning gradients in topography (slope, close to rivers, rock outcrops) and ecosystem disturbance (disturbed by animals) and canopy density (open, closed). At each of these 50 x 10 m forest plots, moss polsters were collected for pollen analysis and compared with the floristic inventories of all trees >10 cm d.b.h. Percentages, cluster and multi-variate analyses were used to explore the degree to which different *Araucaria* plant communities could be differentiated, both in terms of their constituent flora and pollen rain. These 16 plots are comprised of 51 tree taxa and 207 pollen and spore taxa, all of which are characteristic of *Araucaria* forest with the exception of *Pinus* pollen which was excluded from our analyses. We find significant variability, in terms of floristic and palynological composition, among different plots. For example, the most distinctive plots in terms of the vegetation are 'open' and 'riverine' plots, where *Cyathea* sp., *Myrceugenia* sp., and *Sebastiana* sp. are abundant or exclusive, whereas *Araucaria angustifolia* is rare or absent. *Cinnamodendron* sp. and *Eugenia* sp. are important components of the vegetation of 'disturbed' plots. However, these floristic differences are not apparent in the pollen data; for example, *Araucaria angustifolia* appears in the pollen rain of all plots. *Araucaria angustifolia* varies from absent to 26.1% in the vegetation, but from 5.2 to 30.4% in the pollen record. Other key (> 10%) pollen taxa representative of these *Araucaria* forest plots are *Myrsine* sp., *Podocarpus lambertii*, *Eugenia* sp. and *Lamanonia* sp. The DCA analyses of the floristic data show relationships between tree taxa, soil moisture, and canopy density, which may provide potential for drawing such relationships from pollen data. This modern pollen-vegetation study for the *Araucaria* forests helps to draw more detailed ecological information from fossil pollen data from *Araucaria* ecosystems than has hitherto been possible.

***Keywords*:** Araucaria, south of Brazil, modern pollen rain, human land use, modern analogues

Palynology and Paleoenvironmental Reconstruction of the Early Initial Period of Gramalote in Northern Peru

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The Gramalote site is an early Initial Period (1500-1200 cal. BC) fishing village located in the Moche Valley in Northern Peru. It has been studied with a focus mainly on the social dynamics and economic interactions within that fishing settlement. Because of the well-preserved plant and animal record, archaeologists are able to study the diet and subsistence strategies through time. The examinations of faunal remains of seabirds, sea mammals, terrestrial mammals, and mollusk shells support the expected marine-oriented subsistence strategy. However, the site also contains a long record of botanical remains suggesting that people had access to plant resources obtained by gathering or trading with other cultures. For this reason,

a palynological study has been carried out with a focus mainly on reconstructing the fossil pollen record. Soil samples from the site were collected and analyzed to reconstruct the paleoenvironment and to identify which plants, considering other botanical proxies, were present in this region of Northern Peru. Grasses, reeds, edible plants and wild plants were identified suggesting an environment that allowed an early agriculture and a trading network during the Initial period of Gramalote. The availability of these plant resources complemented the diet rich in marine proteins that these fishermen had and contributed to the emergence of social complexity found in the later cultures along the northern coast of Peru.

***Keywords*:** Initial Period, Northern Peru, pollen record, paleoenvironment

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Viability and *in vitro* germination of pollen grain of açaí palm (*Euterpe oleraceae* Jacq.)

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The açaí palm is a fruit tree, known for its the economic expression and is marketed in the form of ice cream, popsicles, energy food, jellies, etc. With of the commercial expansion of the açaí fruit, many Brazilian producers have shown interest in its cultivation on a commercial scale, especially in the Northern and Northeastern regions. The agricultural pollination is an important factor of production and data on the development of pollen grains are essential for reproductive biology and breeding programs, as they allow safety at hybridization. Thus studies of germination and pollen viability are important tools for fruit production, because the pollen germinated is proportional to the amount of seeds and fruits. The objective of this study was to verify the viability and germination of pollen grains of Açai palm (*E. oleracea*) from the Nilo Peçanha municipality in the south southeastern part of the state of Bahia. Pollen viability was estimated aniline blue in lactophenol and *in vitro* germination in medium BCa (H_3BO_3 at 0.01% and $Ca(NO_3)_2$ at 0.03%) with sucrose at 10%, agar at 0.4% and adjusted to pH 6.5. The pollen grains have been dried over silica gel for 4 hours and subsequently placed on slides containing means, kept in a Petri dish with filter paper wetted with distilled water, stored in B.O.D. (*Biological Oxygen Demand*) at 30 °C for 24 hours. The viability and germination rates were determined in 1000 pollen grains. The experiment was carried out with five replicates in a completely randomized design. There was no significant difference between viability and germination rates evaluated by ANOVA. The greater viability rate was 87%. The highest germination rate was 84%. The Pearson correlation showed strong positive relationship between viability and germination, indicating that the selected genotypes had pollen grains with cellular content and formation of pollen tube directly proportional, in the composition of environmental and conditions of temperature and dehydration used in this test.

***Keywords*:** breeding program, pollen physiology, pollen tube, Palm, reproductive biology

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Mid-European *Caryanthus* species under X-ray

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The genus *Caryanthus*, with fourteen species represents the most diversified genus in the Normapolles complex. From the Late Cretaceous of Central Europe we report *Caryanthus communis* Knobloch et Mai, *Caryanthus deltoides* (Knobloch) Friis, *Caryanthus microtriasseris* Knobloch et Mai, *Caryanthus multiasseris* (Knobloch) Knobloch et Mai, *Caryanthus pseudooctcostatus* (Knobloch) Knobloch et Mai, *Caryanthus trebecensis* Knobloch et Mai, and *Caryanthus triasseris* (Knobloch) Knobloch et Mai. Based on shape, ornamentation and position of tepal scars, we emended their diagnoses. Specimens of *Caryanthus* were extracted from several sedimentary units in the Bohemian Cretaceous Basin, the South Bohemian Basins, the Carpathian Flysch in Moravia, the Opole Cretaceous Basin, the North Sudetic Basin, the Santonian of the Liege-Limburg Basin, the middle Santonian to early Campanian of Quedlinburg and the Gosau Series in Austria. All specimens are small, charcoalified or coalified three-dimensionally preserved mesofossils.

We used X-ray micro-tomography for their examination. Radiation imaging methods such as X-ray micro-tomography present a promising non-destructive tool for investigation of various types of fossil material. The methods can produce a virtual 3D voxel-based model of the sample with isotropic spatial resolution at the micrometer level, without physical cuts of the sample. The reconstructed volume can be consequently rendered and sliced in any required plane, giving many possibilities in data observation, evaluation and presentation. Thanks to the non-destructive nature of the tomograph scan, the method can be applied to extremely rare or valuable samples with no significant risk. X-rays of *Caryanthus* fruits show general anatomy of the fruit, consisting of central cavity with fragments of seed and variously elaborated fruit wall, bearing ribs and tepal scars, which are the most important differential characters.

Keywords**:** *Caryanthus*, fossil flowers, fossil fruits, Late Cretaceous, Central Europe, radiation imaging methods

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Chemotaxonomy as a tool for interpreting the cryptic diversity of Poaceae pollen

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Identifying Poaceae pollen to below family level is a long-standing problem in palynology. The uniform nature of the family's pollen, the diversity of species and environmental preferences it exhibits, and its abundance in the fossil record contribute to this issue. Methods such as Scanning Electron Microscopy (SEM), confocal microscopy and detailed morphological studies have all seen some success in identifying grains to below family level. These techniques, however, require considerable time, sample preparation and expertise. Fourier Transform Infra-red Spectroscopy (FTIR) has recently been used to identify pollen grains using their chemical composition. We have applied this technique to the Poaceae from tropical West Africa, analysing 12 species across 8 subfamilies. We demonstrate that successful classification success rates at subfamily level of up to 80% are possible, depending on the processing methodologies used. These data demonstrate that FTIR can be used as a relatively fast, inexpensive method of differentiating between different taxa within the Poaceae family. This has the potential to improve the interpretation of the fossil record, in which, due to its wind-pollinated nature, Poaceae is often abundant but not necessarily indicative of a grassland ecosystem, as it has sometimes been used as in the past. The ability to identify grains to even sub-family level has the potential to improve the characterization of ecotones and consequently climate variations. There are also potential applications of this method in fields such as forensic palynology and melissopalynology, both of which require accurate taxonomic identification of pollen taxa.

Keywords**:** Poaceae, FTIR, palynology, palaeoecology

Aloe vera L. gel implementation as means of grain pollen germination

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The family Solanaceae has various species of agricultural interest in Colombia, like, *Nicotina tabacum* L. which is used for Medicinal substances extraction and in the tobacco industry. Previous pollen viability studies show that close to 52% of its grains is viable; however, not all the grains, even being viable, germinate. In this research; germination effectiveness was evaluated from pollen grain. The samples were processed with Marks carmine glycerol staining technique at 2% and it was used as a means of *Aloe vera* gel germination mesophyll in different developed stages. This leafs species contains boric acid, glucose, calcium, potassium,

phosphate, magnesium, sodium, auxin and giberellin. 250 pollen grains of *N. tabacum* L were analyzed, the red stained pollen grains are viable, rose colored ones have medium viability and the ones without staining process are non-viability. For germination, amid in vitro as germinated pollen was taken. With mayor longitude pollen or equal to pollen diameter. A total of 185 viable grains (74%) of viability was obtained, 17 (6.8%) medium viability and 48 (19.2%) unfeasible. The germination results with *A. Vera* gel produced 137 (54.8%) germinated grains and the remaining 113(45, 2 %) did not germinate with these process. A comparative analysis using Reddy & Kakani culture technique produced only 76 grains of germinated pollen (30.4%), allowing to conclude that *A. Vera gel* is a natural medium, fast, of easy implementation and it has more effectiveness that the medium proposed for Reddy & Kakany. The current study about pollen grains germination with natural means, has a great importance, not only for understanding the reproductive cycle of the species, but also, as a proposal to pollen grain stimulation in the germination process, therefore, optimize the reproduction of this species as economic and medicinal importance.

***Keywords*:** *Aloe vera*, germination, pollen, pollen tube, viabilty.

Palynological studies using Cluster and Principal Component Analysis to identify paleoclimatic conditions in relation to Anemiaceae of selected strata from sedimentary basins of Brazil

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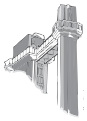
Palynological studies were carried out in regard to seven geological formations, namely Areado (Sanfranciscan Basin), Codó (Parnaíba Basin), Urucutuca (Almada Basin), Gramame (Pernambuco-Paraíba Basin), Resende (Resende Basin), Tremembé (Taubaté Basin) and Itaquaquecetuba (São Paulo Basin) in order to understand the paleoenvironment and paleoclimatic conditions which allowed the development of palynomorphs. The emphasis of this work is given to the family Anemiaceae, which generated cicatricose spores, and its correlation and interaction with other distinguishing palynomorphs like ephedroides, *Classopollis*, bisaccate, trilete spores, monoletes, dinoflagellates and others. This relationship provides the framework for the multivariate analysis to draw conclusions relative to paleoclimatic conditions where Anemiaceae lived. To this end, palynological grain counting in thin sections was performed for each of the mentioned geological units. After identifying the palynomorph types, they were classified into taxonomic groups in accordance with similar characteristics like aperture, ornamentation, etc. Before applying the multivariate methods, the palynological count data was rescaled. That was done in order to achieve more consistency for the correlation based factor analysis since the original distributions showed strong skewness and significant presence of outliers. The statistical multivariate methods Cluster and Principal Components Analysis were applied since they achieved good results in defining trends and relationships in data. This was carried out with the help of diagnostic palynomorphs which are particular to specific paleoenvironments and paleoclimatic contexts. One of the conclusions accomplished by the present studies pointed out to cicatricose spores, belonging to family Anemiaceae, living in more than one paleoclimate. Unlike the paleoclimatic conditions where cicatricose spores, belonging to family Anemiaceae, lived in other parts of the world in, cold and arid settings, in Brazil these spores were in higher numbers in paleoclimatic conditions of warm and wet predominance. An example of this analysis can be found, in the Urucutuca formation of the Almada Basin.

***Keywords*:** Anemiaceae, cicatricose spores, cluster analysis, principal component analysis, multivariate analysis.



PALAEOZOIC PALYNOLOGY AND BOTANY

Mercedes di Pasquo

Flora Group Analysis for the Itararé Group in Brazil

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The floras of Paleozoic consisted of species of Lycopodiophyta, Pteridophyta *(*Marattiopsida and Equisetopsida), and some groups of Spermatophyta (like Pteridospermatophyta, Pinophyta and Ginkgophyta). The rocks of Itararé Group – deposited during the Late Paleozoic Ice Age of the Paraná Basin, Brazil – offer a wide range of fossils plants. Using data concerning the outcrops described in the Itararé Group and Group Analysis it was possible to correlate the outcrops based on their fossiliferous content. Four types of Assemblages for the outucrops of this period will be introduced named as Associations. The Association A would represent a pro-glacial tundra environment, with low diversity due to extreme climates - a record of the vegetation that was resistant to the mildest moments of glaciations, not of interglacial intervals. Thus, Association B offers a great variety of genera and can also be related to cold environments in interglacial periods. The characteristic presence of Equisetopsida and of Lycopodiophyta in these floras would indicate swampy environments in flood plains. The Association C would also have developed in interglacial periods with a great abundance exists of xeric elements, which were probably transported. Finally, Association D, which also developed in interglacial periods, could be related to water body banks such as flood plains.
For such, using this methodology, we were able to determine that the fossil plants found indicate that the paleoenvironments of the Itararé Group varied between dry and humid. As to paleotemperature, strong evidence exists that one of the Assemblages described represented a paleo tundra, a hard-to-record environment, since it may have a low supply of liquid water. This methodology validates the studies introduced until now concerning these floras.

Keywords**:** Paraná Basin, Paleozoic, Floras, Group Analysis

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A conifer-like plant *Steirophyllum* from the Guadalupian of the Russian Platform

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The genus *Steirophyllum* established by E. I. Eichwald in 1854 has been being considered as a junior synonym of *Ullmannia* for many years. Only in 1986 S. V. Meyen reminded its nomenclatorial rights in connection with the separation of *Quadrocladus* from *Ullmannia*. However longing for keeping *Quadrocladus* he suggested that one should assign to *Steirophyllum* only specimens which came from its type locality, that is from the Kargala Mines in the Southern Fore-Urals. The new concept of the genus under consideration was brought forward by A. V. Gomankov in 1995. The attention was paid to some conifer-like plants from the Kargala Mines which unlike *Ullmannia* and *Quadrocladus* possessed two dorsal furrows on the lower side of a leaf with all stomata being sunken into these furrows. Eichwald's original diagnosis of *Steirophyllum* strongly suggests the presence of such dorsal furrows in the type material of the genus. This new interpretation of *Steirophyllum* makes us to assign to this genus the remains of leafy shoots from the Guadalupian of the Pechora Basin and the Timan Range described previously by S. V. Meyen and G. G. Smoller (1986) as *Mostotchkia gomankovii.* Additional material of this species was studied during the present study from the Gudalupian of Sukhona River (Vologda Region, Russia). These remains are compressions of isolated thick linear leaves with rounded apices. Two dorsal furrows are present at the lower (?) side of each leaf although stomata themselves cannot be observed due to the dense bands of mesophyll underlying the dorsal furrows. The peculiar feature of these remains is the presence of two systems of cells visible in the preparations of the cuticle when observed in the light microscope. The examination of these preparations in SEM has shown that the epidermal cells are

fully cutinized (from all sides) so that cutine penetrates between hypodermal cells forming their imprints on the inner surface of the epidermis. No fructifications of these plants are known and hence their taxonomic position is uncertain. They may belong to Dicranophyllales, Rufloriaceae (cordaites), or conifers. The work is funded by the Russian Foundation for Basic Research (grant 15-05-07528).

***Keywords*:** Pinopsida, Guadalupian, Russia, epidermal structure.

Lignophyte roots from the Late Devonian of Morocco and Early Carboniferous of France: anatomy, affinities, and implications

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Isolated fossil roots are often difficult to assign to a given taxa due to the limited number of anatomical characters with taxonomic value available compared to stems. In the case of lignophytes (progymnosperms and seed plants) however, secondary xylem and phloem anatomy can provide strong clues about the affinities of isolated roots. This in turn makes it possible to compare the evolution of aerial and underground structures and to better reconstruct the habit and ecology of fossil lignophytes. In this talk we will focus on two examples, from the Late Devonian and Early Carboniferous respectively. Archaopteridalean progymnosperms were the first lignophytes to develop the tree habit and likely the first plants to develop a deep and complex root system. New information on the anatomy and branching of these roots was recently provided by Famennian fossils from the Anti-Atlas region in Morocco. The specimens are 2.5-8 cm wide. They have a well-developed secondary xylem and occasionally some secondary phloem preserved. The secondary xylem of the specimens displays the typical grouped radial pits characteristic of archaeopteridalean wood (*Callixylon)*. The primary vascular tissues consist of a 4 or 5-lobed protostele. Two morphotaxa are present, roots with a *trifilievii*-type of wood and roots with an *erianum*-type of wood. Lateral roots are of endogeneous origin and arranged along several rows corresponding to the number of lobes in the protostele of the parent root. After the extinction of the Archaeopteridales around the D-C boundary, the Early Carboniferous corresponds to a time of morpho-anatomical diversification of the lignophyte vegetative body. Numerous new taxa of seed plants, both arborescent and non-self-supporting, are documented but apart from rare exceptions only their aerial parts are known. Early Carboniferous (Tournaisian) deposits from Montagne Noire, France, contain isolated woody roots that range from 2.5 to 7 cm in diameter. Their secondary xylem (and phloem when present) was compared to that of the 10 genera of lignophytes previously recognized in Montagne Noire based on permineralized stems. The root specimens can be assigned to three very different types of lignophytes: (1) the arborescent seed plant *Eristophyton*, (2) smaller, lianescent to shrubby seed plants belonging to the Calamopityaceae or *Lyginopitys*, and (3) *Protopitys* or *Stauroxylon*, the only putative progymnosperms known in the Early Carboniferous. We will discuss the implications of this new data for our understanding of each taxa and, more generally, of the evolution of root systems in Devonian-Carboniferous lignophytes.

***Keywords*:** Devonian, Carboniferous, progymnosperms, seed plants, roots.

Medullosan seed ferns – diverse, fast-growing, well-adapted, but still very puzzling

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Stimulated by new *in-situ* finds we shed light on one of the most prominent but still very enigmatic groups of arboreal pteridosperms – the medullosans. At their type locality of Chemnitz, SE Germany (Chemnitz Basin, Leukersdorf Formation) they were common part of a dense hygrophilous plant community growing on a mineral substrate of an immature alluvial soil. Amongst multi-aged, species-diverse vegetation thriving under a strong seasonal monsoonal climate, particular medullosan forms represent the fastest growing woody plants in the environment. This evidence is provided by current tree-ring studies of *M. stellata* var.

lignosa and obviously contrasts the slow-growing extant cycads – a group often used for comparisons. The plant community was buried during a catastrophic event in the late Sakmarian, 290.6 ± 1.8 million years ago. A series of volcanic ashes and flows deposited on a prospering multifaceted ecosystem and ultimately resulted in a significant T^0 assemblage. This "Permian Pompeii" yields a rich spectrum of pteridophytes and gymnosperms, but also diverse arthropods and vertebrates. At the excavation site Chemnitz-Hilbersdorf, medullosans were proven to represent the most frequent elements amidst the still upright standing fossil trees. Although not challenging the height of neighbouring calamitaleans and cordaitaleans, the medullosan fossil record seems to represent a remarkable diversity of growth forms. *Medullosa leuckartii* soft-tissue stems are densely armoured by still-attached sclerenchymatous frond bases of the *Myeloxylon elegans* type and show taphonomic proximity to large compound leaves of *Taeniopteris abnormis*. However, recently time-consuming preparation work yielded true organ connections. Two levels of spirally arranged large fronds of the *Alethopteris schneideri* type were found still attached to a medullosan crown. Probably forced by violent emplacement processes, the crown apparently twisted off under the increasing load of wet pyroclastics. Although fossilised upside down, the sizeable fossil plant shows 3D aspects of all organs. The vascular system of the uppermost stem reveals the highest number of vascular segments ever recognised in a medullosan stem, but largely resembles *Medullosa stellata*. Anatomically preserved vascular units show a very regular anastomosing arrangement. Despite frequent branching, the number of bundles remains unexpectedly constant, at least during the preserved stem length of 20 cm. To decipher the vascular architecture of medullosans we applied X-Ray micro-CT, but realised that only a small portion of the fossil material, excluding the anatomically best preserved specimens, yield insightful results.Nevertheless, whether anatomical and growth form diversities are reflecting diversity in terms of natural species or rather a whole slew of ontogenetic stages needs further investigation, like the assessment of numerous isolated organs, such as stems, roots, leaves or reproductive organs.

Keywords**:** Permian, T^0 assemblage, medullosan seed ferns, volcanic taphonomy, growth form.

The last 80 years of an early Permian ecosystem captured in a unique archive of nature

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Dendrology is a powerful tool to assess ecological parameters in chronological time series of trees in modern forest ecosystems of middle and high latitudes, but even in tropical regions too. Due to taphonomic biases, its application to ancient forests so far remained restricted; particularly in the deep-time geological record. For the first time we utilise dendrological methods, usually applied to modern trees, to characterise Paleozoic plants' responses to palaeoenvironmental changes over a scale of years. We present a data base of c. 2,000 ring width measurements from 43 perennial woody trees, which were growing at the same time in the same habitat. As a significant requirement for that analysis our object of investigation, the Chemnitz Fossil Forest, SE Germany, represents a so called T^0 assemblage, and thus was buried in growth position in a geological instant. Colonising a mineral substrate alluvial plain, the hygrophilous plant community with accompanying faunal elements was entombed during a series of volcanic eruptions. Pyroclastic deposits revealed an age radiometrically constrained by magmatic zircons to 290.6±1.8 Ma. A sub-humid local palaeoclimate characterised by a monsoonal alternation of distinct dry and wet phases caused the formation of tree-rings, which were formed in pycnoxylic gymnosperms, medullosan seed ferns and calamitaleans. The annual character of these tree-rings was suggested by comparing them morphologically and statistically with modern and fossil tree-rings from monsoonal regions. According to different physiological and palaeoecological adaptations of these plant groups, both morphological and quantitative variations occur. Medullosans were shown to be the fastest-growing plants, followed by pycnoxylic gymnosperms and calamitaleans with lower growth rates. In addition, both medullosans and calamitaleans reacted especially sensitively to environmental perturbances, expressed by striking "event rings", which occur in many specimens and witness severe droughts or individual damage caused by wildfire or lightning strikes. Pycnoxylic gymnosperms were less sensitive and thus serve as reliable short-term environmental archives. As one of the major results, it became possible to correlate the majority of ring sequences amongst the fossil

trees back as far as 80 years. A mean value curve from ring indices of several specimens was calculated, which shows a clear and regular cyclic pattern in a statistically estimated scale of 10.6 years, at a 99% confidence level. The most reliable analogy of such cyclicity is the 11-year solar cycle, which has rarely been recognised in both modern and ancient trees. We are inclined to interpret the decade periodicity in our specimens as a palaeoclimatic response to extrinsic impact of solar activity. Evidence of the 11-year solar cycle is thus extended to Paleozoic plants, testifying them as unique archives of terrestrial nature.

***Keywords*:** Permian, T^0 assemblage, tree-rings, dendroecology, 11-year solar cycle.

Unraveling interrelatedness in ancient ecosystems: Diversity, development, and complexity of fungal interactions in the Lower Devonian Rhynie chert

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As our understanding of the importance of fungal interactions today significantly increases, we are still in the early stages of understanding the roles that these interrelationships played in ancient ecosystems. The Lower Devonian (~407 Ma) Rhynie chert contains a remarkable diversity of fungi and fungus-like organisms, many of which are involved with other organisms in various patterns of saprotrophic, parasitic, and mutualistic relationships. However, only a small fraction of these relationships have been documented in detail. In this contribution we present three examples of fungal interactions that recently have been discovered in the Rhynie chert. The first interaction involves a diverse suite of microfungi that form mycelia and reproductive units in glomeromycotan vesicles and can be categorized into three distinct developmental types. A second type of fungal interaction has been discovered in fungal sporangia containing ornamented sporangiospores. Several sporangia are colonized by a chytrid-like organism that forms prominent, apophysate zoospoprangia on the outside of the host and multi-branched rhizoids extending into the sporangium. Rhizoidal branches may penetrate individual host spores to form tenuous wefts in the lumen. Some of the chytrid zoosporangia have served as host to other microorganisms as there is evidence of host responses in the form of callosities. The last example that will be discussed are chytrids that colonize and further develop on spores of the land plant *Horneophyton lignieri*. The most interesting aspect of this interaction is that some of the chytrids demonstrate a developmental pattern in the form of cascading zoosporangia, i.e. new zoosporangia developing within old, empty zoosporangia. The fungal interactions presented herein contribute to our knowledge of the diversity of fungi and the multiple levels of biological relationships that define complexity in early continental ecosystems.

***Keywords*:** fungi, parasitism, chytrids, plant-fungus, host response, life cycle

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The Cottonwood Canyon flora of Wyoming (USA): a window onto the Early Devonian vegetation of western North America

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The Early Devonian witnessed the first major evolutionary radiation of tracheophytes, during which several lineages of structurally-simple vascular plants diversified to generate the different types of structurally-complex tracheophytes found as early as the Middle Devonian. Understanding Early Devonian plant diversity is, thus, essential for untangling the evolution and relationships of early tracheophytes. The Cottonwood Canyon flora consists of Lochkovian-Pragian (419-410 Ma) plant assemblages preserved in rocks assigned to the Beartooth Butte Formation of northern Wyoming. Although at least 90 Lochkovian and Pragian plant fossil assemblages are known worldwide, the Cottonwood Canyon flora is the only Early Devonian flora of any significance known in Western North America; two other Devonian floras in this geographic region

(Martin Formation of Arizona and Chilliwack Group of Washington) have not been accurately dated and are poorly sampled. This flora has been sampled since the 1980s and collections are housed at several major museums in the United States. However, despite its geographic significance and extensive sampling, the Cottonwood Canyon flora has not received a modern formal taxonomic treatment. Plants are preserved in abundance at Cottonwood Canyon, as coalified compressions or impressions. A survey of all the material collected from this flora reveals plants with diverse taxonomic affinities including cooksonioids, zosterophylls, lycophytes, trimerophytes, and thalloid gametophytes of riccioid appearance. The two most abundant types are a drepanophycalean lycophyte and a morphotype represented by naked axes branching at wide angles, both of which are found predominantly in monospecific layers. Reproductive remains of both these two taxa as well as of other plants present in the flora are very rare. The paucity of reproductive structures at this locality is striking, considering the large number of vegetative remains, and points to clonality as the prevailing reproductive strategy. This has been noted previously in other Early Devonian plant assemblages, e.g., the Battery Point Formation of Gaspé (Canada). The frequent occurrence of thalloid gametophytes is also striking and may be due to the depositional environment of the fossiliferous strata: layers preserving rooted, in situ plant populations (primarly drepanophycaleans) alternate with flood deposits containing parautochthonous plant material, in a fluvial-estuarine sequence. While the level of plant diversity documented at Cottonwood Canyon is not unusual for Lochovian-Pragian localities, this flora is the only source of information on the vegetation of western North America during the Early Devonian, thus contributing significantly to the picture of Early Devonian plant diversity and biogeography.

Keywords**:** Early Devonian; Wyoming; Paleozoic; compressions; tracheophytes

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Secondary growth in Devonian cladoxylopsid trees

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Devonian cladoxylopsids are widely regarded as the earliest trees in the fossil record. Yet how they achieved tree size is until now a mystery. Cladoxylopsid trunks consist of a ring of radially-oriented plates of xylem (cauline strands) connected to an internal ring of anastomosing xylem strands (medullary strands), some with an exterior root mantle, all embedded in a parenchymatous ground mass. The centre of large specimens may be entirely hollow. This is one of the most complex stem anatomies known. While some well-preserved cladoxylopsids show clearly that they were largely formed by primary growth, others display aligned files of xylem cells around individual xylem strands. Using pyrite permineralizations from *Eospermatopteris* (Middle Devonian of New York State, USA) and new silicified material from China, we will demonstrate the presence of secondary growth ('wood'), and suggest exciting new ideas about how some cladoxylopsid trunks might have grown by a process of apical and lateral expansion to achieve their tree size.

Keywords**:** Devonian, trees, wood, Cladoxylopsida, Pseudosporochnales

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Mid and Late Devonian Flora of Venezuela

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Between 1984 and 2001 we undertook several field campaigns in the Devonian rocks of the Sierra de Perijá, western Venezuela, with colleagues and students from Venezuela and the UK. During this time we revealed the most diverse mid-Late Devonian flora yet known from Gondwana, in a surprisingly limited geographical area. Outcrops are mainly located at the sides of road bulldozed across the hilly foothills of the northwest Andes, Zulia State. Most types of mid-late Devonian plant groups are represented. In the lower part of the terrestrial Campo Chico Formation (probably Givetian in age) diversity was highest, including rhyniophytes (cf. *Sennicaulis*), zosterophylls (*Serrulacaulis*, *Sawdonia*), probably herbaceous lycopsids (*Leclercqia*, *Colpodexylon* spp., *Haskinsia* spp., *Gilboaphyton*), iridopteridaleans (*Compsocradus*, *Anapaulia*),

pseudosporochnaleans (*Wattieza*), aneurophytaleans (?*Rellimia*, *Tetraxylopteris*), and at least three species of as yet unnamed yet interesting unclassified diminutive plants. In the upper part of the Campo Chico Formation (probably Frasnian) *Archaeopteris* species dominate. Arborescent lycopsids are absent to date. We will survey the results of our studies, and make comparisons with other South and North American contemporaneous assemblages including *in situ* 'fossil forests' which may elucidate the palaeoecology of the Campo Chico flora.

***Keywords*:** Devonian, Gondwana, diversity, forests, flora

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A large collection of *Rigbya arberioides* fructifications from South Africa supports glossopterid affinities

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These *Rigbya arberioides*, a typical seed-bearing fructification of the Upper Permian floras of South Africa, is a wide-spread taxon that has also been found in Australia and Antarctica. The distinctive fan-shaped, dichotomizing fertile branch system of *Rigbya* is in contrast to the more typical, capitate fructifications of the Dictyopteridiaceae that have been found in direct, organic attachment to midrib of *Glossopteris* leaves. Additionally, the long, slender pedicels and probable axillary attachment of *Rigbya* fructifications have apparently precluded the preservation of fructifications in organic connection to stems and leaves. For these reasons, compounded by the rarity of the fructifications, the botanical affiliations of *Rigbya* have been a source of debate, despite their consistent association with glossopterid – dominated leaf mats. Detailed examination of well-preserved impression material housed in South African collections demonstrates a clear morphological link between fructifications of the Arberiaceae, Dictyopteridiaceae, Lidgettoniaceae and Rigbyaceae, suggesting that these organs are all glossopterid, and represent modified branching axes, rather than the traditionally-held view that they are leaf homologs. A fossil locality in KwaZulu-Natal has produced an exceptionally well-preserved, large and informative Upper Permian fossil plant collection, containing over 100 specimens of *Rigbya* among over 1500 fossiliferous hand specimens. This collection provides strong support for a glossopterid leaf association with this fructification that was first proposed by Anderson and Anderson (1985).

***Keywords*:** *Rigbya*, *Glossopteris*, Upper Permian, Karoo Basin, South Africa

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Rhachiphyllum sahnii (Zalessky, 1929) Burago, 2006, emend. nov. from the Lopingian (Upper Permian) Linxi Formation of Inner Mongolia, China

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Since the generic name *Callipteris* Brongniart 1849, being a later homonym of the *Callipteris* Bory 1804, is illegitimate, the morphological group of callipterids has been reclassified into several morphological genera, including *Autunia* Krasser emend. Kerp, *Rhachiphyllum* Kerp, *Lodevia* Haubold et Kerp, *Gracilopteris* Kerp, Naugolnykh and Haubold, *Arnhardtia* Haubold et Kerp, *Dichophyllum* Elias ex Andrews, *Compsopteris* Zalessky, 1934, *Comia* Zalessky, 1934, etc. The formal genus *Rhachiphyllum* Kerp is characterized by the presence of alethopteroid to pinnately lobed pinnules, and intercalary pinnules which resemble the ordinary pinnules. The Angaran species *Callipteris sahnii* Zalessky from the South Primorye of Russia was described for the first time by M.D. Zalessky in 1929, and published as a new combination as *Rhachiphyllum sahnii* (Zalessky) by V.I. Burago. Some specimens of *Rhachiphyllum sahnii* (Zalessky) Burago are reported from the eastern Mongolia also. These specimens, as well as the type specimen, are not well-preserved. Most of

them are ultimate pinnae. *Rhachiphyllum orientale* (Zalessky) Burago was also established together with *R. sahnii* (Zalessky) in the Upper Permian in South Primorye. Both two species are recorded together from the eastern Mongolia as well. The specimens of *R. orientale* (Zalessky) Burago in the South Primorye and eastern Mongolia are represented by ultimate pinnae also. Based on the new materials of Callipterids from the Upper Permian Linxi Formation, in Guandi of Linxi, Inner Mongolia, China, *Rhachiphyllum sahnii* (Zalessky) Burago, emend. nov. is proposed, after careful comparison with those of *Callipteris sahnii* Zalessky and *C. orientalis* Zalessky. The neotype of *Rhachiphyllum sahnii* (Zalessky) Burago, emend. nov. is selected, and *Rhachiphyllum orientalis* (Zalessky) Burago is regarded as a later synonym of *Rh. sahnii* (Zalessky) Burago. During the Carboniferous and Permian, four types of floras, including the Cathaysian, Angaran, Euramerican and Gondwana floras, are recognized in the world. The Angaran and Cathaysian floras are widely distributed in northeastern China. They are separated by the Xar Moron River suture. The Cathaysian flora to the south of the suture developed on the North China Plate can be represented by the Yujiabeigou Flora, characterized by the presence of *Gingantonoclea*, *Lobatannularia*, *Sphenophyllum* and so on. The Angaran flora to the north of the suture developed on the Jiamusi-Mongolia Block are characterized by the presence of Lopingian '*Callipteris*', *Comia*, *Supaia*, *Xinganphyllum*, *Rufloria* (=*Noeggerathiopsis*), etc. The species *Rhachiphyllum sahnii* (Zalessky) Burago, emend. nov. distributed in South Primorye, Inner Mongolia of China and eastern Mongolia can be recognized as an important and palaeophytogeographically significant element of the Angaran flora on the Jiamusi-Mongolia Block .

***Keywords*:** Permian, *Rhachiphyllum*, China, Jiamusi-Mongolia Block

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High intensity plant-arthropod interaction in Early Permian deposit of Paraná Basin, southern Brazil

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Paleozoic plant-insect interactions are well-documented for the Paraná Basin, southern Brazil. Mostly of the known data are derived from the Gondwana I Supergroup, which Carboniferous-Permian deposits preserved wide range of paleobotanical data. This contribution provides a new record of plant-insect interaction evidences from the Itanema II outcrop, located at the municipality of Criciúma, southeast of Santa Catarina state. Belonging to uppermost Rio Bonito Formation, the Itanema II overlies the Barro Branco Coal, corresponding laterally to Treviso Coal bed, the topmost coal seam of this unit. Rio Bonito Formation has been considered Cisuralian in age, based on both fossil content and recent radiometric ages obtained from tonsteins found interbedded with the coal seams in Rio Grande do Sul State. This study is focused in the compressed/impressed specimens of *Glossopteris*-type leaves, larger than 1cm^2, containing evidences of plant-insect interactions. The analysis has used the Damage Type (DT) classification by "Guide to Insect Damage Types on Compressed Plant Fossils" and the results compared with previous studies carried out with leaves of *Glossopteris* Flora from Gondwana. As preliminary conclusions, few differences were found concerning the DTs recorded, being mostly constant with types that were previously noticed for Paleozoic of Paraná Basin. However, one peculiar marginal feeding was often noticed, a pectineous cut in the leaf margin, removing the leaf blade and cuticle, preserving partially the leaf veins. Another relevant data obtained refers to rate of herbivory acquired by simple counting of presence or absence per each specimen analyzed. Previous studies pointed an herbivory rate around 8% in Permian glossopterid leaves in Western Gondwana, meanwhile, the current analysis obtained a preliminary rate similar to ones found in leaves from paleotropics during the early Permian, i.e. around 30%. At the same time, the plant assemblage of Itanema II outcrop is highly diverse and shows a singular composition, where the typical taxa from early Permian are found in association with others commonly encountered in younger strata of this period, represented by deposits of the Teresina and Rio do Rasto formations in the basin. In conclusion, apparently is recorded here is an interval within which the plant productivity and diversity have become extremely high with a simultaneous increase in herbivory rate, which could indicate a significant climatic amelioration related perhaps with the end of the Late Paleozoic Ice Age and the beginning of the Greenhouse phase in a mid-latitudinal belt.

***Keywords*:** Plant-arthropod interactions, herbivory ratio, glossopterid leaves, Early Permian, Paraná Basin.

Cuticular analysis of Permian gymnosperms of central Shanxi, China

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Cathaysia is one of the four major late Paleozoic floral provinces and includes the paleotropical plant assemblages from present-day China and East Asia. It was originally established based on fossils from the Permian of central Shanxi Province, China. It is characterized by several typical endemic genera (e.g., *Tingia*, *Paratingia*, *Emplectopteris*) but it contains also floral elements that are known from Euramerica (e.g., *Gigantoperis*). As the taxonomy is primarily based on macromorphological criteria and relationships of taxa often remain unclear, detailed studies of the Cathaysia flora are necessary for a better understanding of its relationships to other floral provinces. Cuticular analysis not only allows a much more precise definition and delimitation of individual taxa, but it also provides important information on the paleoecology and paleoclimate on the basis of biological criteria, i.e. the epidermal anatomy. The Palougou section in Shanxi, which is generally regarded as a standard reference section for the Cathaysia flora, is a continuously exposed section that starts in the Upper Carboniferous and runs up to the Permian-Triassic boundary. Newly identified plant-bearing horizons of the late Early Permian Lower Shihhotse Formation of this section reveal a diverse and well-preserved macroflora with *in situ* cuticular preservation of different taxa. Here we present the first results of cuticular analyses of *in situ* and bulk-macerated material including cuticles of *Taeniopteris* sp., *Cordaites* sp. and also typical Cathaysian elements as *Tingia carbonica*. Our on-going study promises to yield important new insights about the taxonomy and paleoecology of these plants.

***Keywords*:** Cathaysia flora, cuticular analysis, paleoecology, phytogeography, paleoclimate

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New data on the mixed flora from the Upper Permian of the Dead Sea region, Jordan

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The Upper Permian Um Irna Formation of the Dead Sea region in Jordan has revealed several Cathaysian and Gondwanan elements, partly with exceptionally well-preserved cuticles (Mustafa, 2003; Kerp *et al.* 2006, Abu Hamad *et al.* 2008). The latter include at least four species of *Dicroidium*, a genus traditionally regarded as a marker for the Triassic of Gondwana. Recent field work revealed several new plant localities. Apart from several almost complete *Dicroidium* fronds, including a new species, various new taxa, including fructifications, were found. New are two species of *Lobatannularia*, *Quasimia* cf. *schijfsmae*, the conifers *Rissikia* and *Elatocladus*, the putative early ginkgophytes *Rhibidopsis* and *Pseudorhipidopsis*, and a *Pterophyllum*-like cycad leaf. With these new finds the number of taxa known from the Permian of the Dead Sea region has been more than doubled and now comprises over 20 taxa. The new material further confirms the mixed nature of the flora. The Near and Middle East appears to be a key region for palaeophytogeographic studies as mixed floras have also been reported from the Permian of Hazro (Turkey), the Gharif (Oman), and Unayzah (Saudi Arabia). Gondwanan elements in these latter floras are always glossopterids, but the Dead Sea region seems the only region, where the Gondwanan elements comprise precocious occurrences of "typical Mesozoic" taxa. These are always meso- to xerophilous elements, whereas typical Permian Cathaysian taxa usually occurred in more humid environments.

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***Keywords*:** Permian, Palaeogeography, Mixed floras, Cathaysia, Gondwana

New advances on community ecology of Wuda Tuff Flora as a fossil lagerstätten (Inner Mongolia, China)

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The Wuda Tuff Flora as a peat forming vegetation from the earliest Permian (ca. 298Ma) of Inner Mongolia buried in volcanic ash has been called as a Chinese "vegetational Pompeii". This T^0 deposits allows palaeoecologists to examine the Late Palaeozoic coal forest ecology in much the same way as neoecologists appraise modern environments. Seven major plant groups consist of the flora, including Lycopsids, Sphenopsids, Noeggerathialeans, ferns and seed ferns, primitive cycadophytes and coniferophytes. Most abundant were the marattialean tree ferns represented by *Pecopteris*. Herbaceous ferns include *Nemejcopteris feminaeformis*, *Cladophlebis*, and *Sphenopteris*. Lycopsids are represented by *Sigillaria* cf. *ichthyolepis*, tall pole-like trees. Two sphenopsids were encountered, *Sphenophyllum*, and *Asterophyllites*. Noeggerathiales, an extinct spore-bearing group of uncertain systematic position, are small trees represented by species of *Tingia* and *Paratingia*. Gymnosperms include possible early representatives of the cycads, *Taeniopteris* and *Pterophyllum*, and tall trees of *Cordaites* that were early coniferophytes, and seed ferns including species of *Sphenopteris* and *Alethopteris*. In addition to the proportional taxonomic composition and individual plant growth habit, landscape heterogeneity (species-area curve), forest structure (ecological assembly, density of individuals) and vegetational recovery are evaluated. This flora growing on peat is also taxonomically distinct from those growing on clastic soils in the same area and during the same time interval. More significant is that a preliminary investigation of ontogeny of the individual taxa of the forest suggests that phenology had appeared in this 300 mys vegetation. This Permian flora demonstrates both similarities and differences to floras of the same age in Europe and North America, and confirms the distinct character of the Cathaysian floral realm.

***Keywords*:** In situ preservation, peat-forming vegetation, community ecology, Permian.

Paleoecological and taphonomic analysis of Permian coal seam of Rio Bonito Formation, Paraná basin, western Gondwana*.

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Permian coal seams of Paraná basin present interesting paleoecological community evolution. Paleopalynological and petrographic studies were performed at the basal portion of Rio Bonito Formation on coal, tonstein, carbonate, and siltstone sequence of Mine 08 - Coal Company of Cambuí, Paraná State, southeastern of Brazil. The main objective was to characterize floras and the environmental evolution prevailing during the deposition of this sequence. For palynological studies, samples of coal and siltstone were chemically treated. For petrographic studies, thin sections of carbonates and tonstein were performed. They all studied and described through microscope and SEM/EDS. The sequence deposited during the Asselian-Sakmarian interval showed two different plant assemblages. One basal related to coal layers, reflecting a swamp community living close to the depositional environment (dominated by spores and algae), and another for the top, related to siltstones with fossil cuticles (gondwanic conifers, *Buriadia)*, and gymnosperm pollen grains, reflecting an inland community living distal from the depositional environment. For tonstein layer, the primary mineral assemblage reflects volcanic origin. The secondary mineral assemblage, originated from the primary assemblage, shows an essentially kaolinitic matrix with carbonate. The carbonate layers are related with microbial mats deposition with abundant bivalve, gastropods and ostracod shells. In this context, we conclude that the environment was previously reductor and acid, and responsible for generating coal beds surrounded by swamp vegetation (e.g., Lycopsida, Equisetopsida). Later, with the fall of volcanic ashes, it changed to a more alkaline and stressful environment, resulting in the disappearance of swamp vegetation. Eventually, the environment was recolonized by microbial mats, and by a new plant community mainly represented by gymnosperms. *FAPESP 2013/11563-6

***Keywords*:** paleopalynological studies, Rio Bonito Formation, coal, tonstein, paleoenvironment reconstruction.

Fourier transform infrared spectroscopy of *Spongiophyton* (Spongiophytaceae) from the Middle Devonian of Paraná Basin, Brazil

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Spectroscopy information (functional groups and semi-quantitative data) by Fourier transform infrared (FTIR) spectroscopy of *Spongiophyton* Kräusel emend. Chaloner, Mensah *et* Crane is reported in an attempt to identify spectroscopic patterns that would differentiate three species of this genus, namely: *S. lenticularis* (Barbosa) Kräusel emend. Chaloner *et al*., *S. nanum* Kräusel emend. Chaloner *et al*. and *S. minutissimum* Kräusel emend. Gensel, Chaloner *et* Forb. Thirty-three specimens preserved as compressions were analyzed were recovered from the same fossiliferous horizon of the Itáytyba outcrop situated in the uppermost Middle Devonian São Domingos Formation of the Paraná Basin in southern Brazil. The results revealed that functional groups in the 3000-2800 cm^{-1} and 1800-700 cm^{-1} wavenumber regions are present in all specimens. Infrared-derived ratios (CH_2/CH_3, Al/Ox, Ox1/Ox2, C=O cont., C=C cont., Al2 and Ar/Al) and types of kerogen led to a comparison of the morphological characteristics of the studied material, and indicated that compressions of *S. lenticularis*, *S. nanum* and *S. minutissimum* contain different organic compounds. *S. nanum* and *S. minutissimum* showed higher oxidation and lower aromaticity of their organic matters than *S. lenticularis*. Additionally, *S. lenticularis* showed low A-Factor values, suggesting a composition similar to Type III kerogen while *S. nanum* and *S. minutissimum* showed intermediate to high A-Factor values, suggesting a composition similar to Type II kerogen. In conclusion, the chemical-analytical techniques and statistical analysis (using PCA technique) revealed a closer taxonomic relationship between *S. nanum* and *S. minutissimum* than either has with *S. lenticularis*, that the first two could represent the most distal lamina-like portions (semi-flattened thalli) while *S. lenticularis* the most proximal caulinar-like parts (rounded axes) of the plant body. Lastly, the chemical signatures supported the hypothesis that links these enigmatic fossils to a type of lichen or other early inland plant. [CNPq 141979/2011-9; PQ 300801/2012-2; PQ 309211/2013-1]

***Keywords*:** *Spongiophyton*, spectrochemistry, compressions, São Domingos Formation, Middle Devonian.

Middle Devonian herbaceous lycopsid *Haplostigma* from the Paraná Basin, Brazil: taxonomy, biostratigraphy and phytogeography

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The paleobotanical record of the Devonian in South America has been recognized since the early twentieth century. Over the past 100 years, discoveries of new fossiliferous localities in several countries of South America have provided significant advances. Indeed, descriptions of fossil plants from Brazil, Venezuela, Bolivia, Uruguay, Argentina, Chile, Colombia and Falkland Islands have provided important data on the origin and evolution of land plants, and have clarified the paleophytogeography of Western Gondwana. In Middle Devonian of the South America, most paleobotanical records consists of fragmented and defoliated stems of herbaceous lycopsids attributed mainly to *Haplostigma*. This study describes plant fossils assigned to the genus *Haplostigma* and, more specifically, to *H. irregularis*, *H. furquei*, *H. baldisii*, and *H.* cf. *kowiensis*, recently recovered from a new locality of the Middle Devonian São Domingos Formation from eastern rim of Paraná Basin, located in the Paraná state, southern Brazil. Morphometric analysis based on characters measured on stems supported the taxonomic separation in distinct species as well as previously proposed in literature. Also, the other Gondwanan occurrences of the *Haplostigma* were analyzed in order to summarize the stratigraphic distribution and perform a paleophytogeographic analysis of this genus. Apparently, the oldest record of *Haplostigma* occurs in the Pircas Negras Formation, from the (late?) Emsian of Argentina. Afterwards, during the Givetian-early Frasnian, the genus expanded geographically to almost all middle to high latitudes of Gondwana terrains, corresponding to the cool-temperate climate zone. As a conclusion, *Haplostigma* appears to be a small to medium-sized, fast-growing herbaceous lycopsid restricted to

Gondwana, and consequently well adapted to mid-to-high latitudes and cold climatic regimes characteristics of the Afro-South American Subrealm. [CNPq 141979/2011-9; PQ 309211/2013-1]

***Keywords*:** Haplostigma, Stratigraphic range, Paleophytogeography, São Domingos Formation, Middle Devonian.

On the Middle Devonian Hujiersite Flora from West Junggar (Xinjiang, China) and its characteristics, age and palaeoenvironment

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The Hujiersite flora was proposed based on the plant assemblage from the Hujiersite Formation, West Junggar, Xinjiang, China and was dated as the late Middle Devonian (Givetian) based on dispersed spores. Megaplants in the Hujiersite Flora include lycopsids: *Haskinsia*, *Leclercqia*, *Colpodexylon*, *Hoxtolgaya* and *Drepanophycus*; zosterophylls: *Serrulacaulis*; fern-like plants: *Compsocradus*; progymnosperms: *Aneurophyton* and *Tetraxylopteris*, and *incertae sedis* plants *Tsaiaconica*, *Taeniocrada* and *Blasaria*. The palynological assemblage in the flora is dominated by a single spore type, *Cymbosporites* cf. *magnificus*, whose parent plants are probably lycopsids, and megaspore *Verrycisporties lui*. Recently, detrital zircons are geochronologically studied from one of the best sections of the Hujiersite Flora, a Givetian to early Frasnian age, 385-380 Ma, is indicated. The characteristics of the Hujiersite flora can be summarized as, 1) Lycopsids are dominant and probably the main coal-forming plants in the Flora; 2) some small and/or herbaceous lycopsids are widespread but at the species level the widespread members are unique and endemic, such as *Haskinsia hastata* ssp. *denticulata*, a probable climber lycopsid *Leclercqia uncinata*, minor-sized lycopsid *Drepanophycus minor* and progymnosperm *Aneurophyton doui*. 3) Plants of the Order Pseudosporochnales that are common members of the North America Middle Devonian forest are absent. 4) The largest plant in the Flora belongs to the tree-like lycopsid, *Hoxtolgaya robusta*, which probably reaches the maximum of 4 m in height based on the width of its stem and is shorter than canopy cladoxylopsids (e.g., *Eospermatopteris*) in the Middle Devonian forest of North America.At least three depositional upward-fining sequences can be recognized in the Hujiersite Formation, consisting of conglomerate, sandstone, siltstone and mudstone in ascending order, and the thin layers of coal occur in bed of siltstone or mudstone. The occasional conglomerate layer and lenses of sandstone were deposited in the fluvial environment, probably in the alluvial flat or flood plain. It is suggested that West Junggar was an important land bridge in the global migration of the Devonian plants, including the herbaceous lycopsids, progymnosperms and plants with megaspore *Verrycisporties*.

***Keywords*:** palaeoenvironment; Hujiersite Formation; Devonian; Xinjiang

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A new species of *Cruciaetheca* (Equisetales) from the Arroyo Totoral Formation (La Rioja), Lower Permian of Argentina

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Equisetalean vegetative remains are common in the Upper Paleozoic sequences of Gondwana, but little is known about their reproductive traits. In this contribution a new species of *Cruciaetheca* Cúneo et Escapa from the Arroyo Totoral Formation is described. This formation crops out in Sierra de los Llanos, La Rioja Province (Argentina), and it is a well-known Lower Permian locality of the Paganzo Basin. Samples were deposited in the Museo Argentino de Ciencias Naturales and extracted from the fossiliferous point n° 8, at the type locality of the Arroyo Totoral Formation, near the Anzulón River. The material presented shows both vegetative and reproductive axes. The vegetative axes and leaf whorls are of the *Phyllotheca* Brogniart type. Leaf whorls are basally fused to form a short sheath (leaf length/sheat ratio = 10), distally composed

of 6 to 15 univeined leaves up to 4 cm long. Fertile internodes distributed in the proximal internodes of the last order axes. Each fertile internode is bounded by unmodified leaf whorls. One sporangiophore whorl attached to each internode, below the leaf whorl. Sporangiophores are cruciate and bear four pyriform sporangia. The unique combination of features such as cruciate sporangiophores and basally fused leaves is only seen in *Cruciaetheca*, a genus stablished for the Tepuel Genoa Basin (Chubut Province, Argentina), with three species recognized, namely *C. patagonica*, *C. feruglioi* and *C. genoensis*. From them, the most similar species is *Cruciaetheca patagonica*. Both share similar vegetative characteristics: size, leaf/sheath ratio, morphology and size of the leaf whorls. The specific distinction is based on the reproductive traits. The sporangiophores are smaller in this new species, and they also differ in the distribution of the rows of sporangiophores: while in *Cruciaetheca patagonica* two to four rows can be found over the entire length of the last order branches, the new species proposed shows only one row of sporangiophores per internode, near the top of the internode, and only in the proximal portion of the ultimate order branch. With four known taxa, *Cruciaetheca* is the most diverse recognized paleozoic equisetalean genus of South America and its distribution now is extended to the Paganzo Basin.

***Keywords*:** Equisetaleans, Permian, Argentina

The presence of ligule in southern South America neopaleozoic lycopsids: the case of *Bumbudendron versiforme*

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Lycopodiopsids are the oldest vascular plants living actually, they appeared in the Silurian and had their major diversity in the Carboniferous. Those were the times were the Isoetalean clade diversified and became cosmopolitan; *Lepidodendron* Sternberg dominated Euramerican coal swamps, while smaller lycopsids lived in the Angara and Gondwana lands. The leaf cushion helps to characterize and differentiate vegetative remains of lepidodendrids. Gondwanan and Angaran lycopodiopsids differs from Euramerican by the presence of an infrafoliar bladder instead of parichnos; Angaran and Euramerican bear ligule pits; absent in some of the South American lycopodiopsids. Ligule is a small structure located dorsally to the microphyll. For taxa historically known as eligulated (*Lepidodendropsis* Lutz), a considerable variation in the morphology of the leaf cushions and both ligule and ligule pit were detected dependent on the preservation of the stem. This motivates the revision of other eligulated taxa to clarify about the presence or absence of ligule. *Bumbudendron* Archangelsky, Azcuy et Wagner comprises South American lycopodiopsids with small cushions in lepidodendroid phyllotaxis, infrafoliar bladder and without ligule pit. *Bumbudendron versiforme* Gutiérrez, Césari et Limarino from Agua Colorada Formation (La Rioja) is characterized by fusiform leaf cushions with a variable length-width ratio in a single stem. The presence of ligule pit was suggested in stems assigned to this species from the Loma Larga and Solca Formations (Pennsylvannian). Similar ligulated remains were reported from the Melo Formation (Lower Permian of Uruguay). They belong to a small stem, possibly a branch end, and the leaf scars are similar to those of *B. versiforme.* The type material of *B. versiforme* were re-investigated and a structure assignable to ligule pit was recorded. It is suggestive that *B. versiforme* species should be removed from *Bumbudendron*. *Tomiodendron* Radczenko is the closest genus, which in some species shows fusiform cushions, infrafoliar bladder and ligule pit. These species are known from the Lower Carboniferous of Angara (*T. kemeroviense* Radczenko), and from the late Visean warm temperate beds of Paracas (*T. peruvianum* Pfefferkorn et Alleman, Ambo Formation, Perú). *Tomiodendron* sp. was reported from Loma de Los Piojos Formation (Córdoba, Argentina), referred to the FNC Biozone from Argentina. The dispersal of the tomiodendrids from Angara to Gondwana during the Carboniferous was recently proposed. The presence of ligulated "*B.*" *versiforme* in the Upper Carboniferous of Argentina suggests that, after the retreat of the warm temperate Paracas' belt, tomiodendrids could have remained until Permian in South America.

***Keywords*:** lycopsids, Carboniferous, Permian, ligule, Gondwana

Pennsylvanian *Ginkgophyllum* of the interglacial taphoflora of Monte Mor, Itararé Group, São Paulo State, Brazil: the earliest of the Paraná Basin

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The ginkgoaleans, typical deciduous gymnosperms of cold temperate climates, have their earliest South American record in the Argentinean Serpukhovian *Nothorhacopteris-Botrychiopsis-Ginkgophyllum* Phytozone (NBG) of the Paganzo and Callingasta-Uspallata basins. In Brazil, their oldest occurrence is in the *Paranocladus-Ginkgophyllum-Brasilodendron* Association (PGB), Kasimovian to Gzhelian (*Crucisaccites monoletus* Palynozone), of the middle part of the Itararé Group, Northeastern Paraná Basin. This Group is a complex association of facies composed of diamictites overlying striated pavements, rhythmites with dropstones at different stratigraphic levels, intercalated by sand bodies and shales deposited in fluvial, deltaic and marine environments under glacial or interglacial phases. The Pre-Glossopterid macroflora from Volpe Ranch, in Monte Mor (SP), is deposited in this context during an interglacial phase and characterizes the PGB Association. It is macrofloristically similar to the Argentine association *Krauselcladus-Asterotheca* Phytozone (KA = previous Interval Zone) which overlies the NBG Phytozone. The ginkgoalean plants in the Monte Mor taphoflora are represented by leaf impressions and compressions of *Ginkgophyllum cf. G. diazzi* Archangelsky & Arrondo *emend.* Archangelsky & Leguizamón 1980; *Ginkgophyllum cf. G.kidstonii* (Seward) *emend*. Anderson & Anderson 1985 and (?) *Ginkgophyllum spathulifolia* Anderson & Anderson 1985. The association of *Ginkgophyllum* and Conifers in this taphoflora corresponds to a meso-xerophitic tree community. These remains are very fragmented in the assemblage suggesting allochthonous origin for them. This *Ginkgophyllum* occurrence despite being the oldest in the Paraná Basin is younger to the Argentinean *Florizone NBG* (Serpukhovian) from the Paganzo Basin - Trampeadero, Malanzán, La Rioja, Tupe, Jejenes and Agua Colorada Formations, where it has in common the species *Ginkgophyllum cf. G. diazzi* Archangelsky & Arrondo *emend.* Archangelsky & Leguizamón 1980. But in Monte Mor taphoflora the association of this species with the South African species *Ginkgophyllum cf. G.kidstonii* (Seward) *emend*. Anderson & Anderson 1985 and (?) *Ginkgophyllum spathulifolia* Anderson & Anderson 1985, occurring in the younger Vryheid Formation (Middle Ecca, Lower Permian of the north Karoo Basin) suggests a transitional geographic and stratigraphic position for the *PGB Association* of Monte Mor. [CNPq 304978/2013-2, MECBO; CNPq-300578/2015-6, PSK].

***Keywords*:** *Paranocladus-Ginkgophyllum-Brasilodendron* Association; Kasimovian to Gzhelian flora.

Georeferencing petrified forests in the eastern margin of the Parnaíba Basin, Lower Permian (Pedra de Fogo Formation)

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Petrified plant-bearing outcrops of lower Permian strata of the Pedra de Fogo Formation located in the eastern margin of the Parnaíba Sedimentary Basin, are still poorly studied and/or known despite of the abundance of these fossiliferous exposures. The Pedra de Fogo Formation is characterized by rocks with predominance of silicified sandstone and siltstone, abundant layers of chert and limestone, and an abundance of fossil plant associations, especially gymnosperm logs, and also microbialites (ooids, pisoids, bacterial mats and stromatolites). This work aimed the prospection and preliminary analysis of outcrops in the aforementioned margin of the basin. Deposits with fossil plants under consideration are located in the municipalities of Teresina, Monsenhor Gil, Nazária and Altos, in Piauí state; and Duque Bacelar and Coelho Neto, in Maranhão state. The outcrops in Teresina and Altos are dominated by assemblages formed mostly by large gymnosperm woods (over 70 specimens), a number of them being found in life-position. Tree-ferns (petrified fronds and stems) were found in Monsenhor Gil and Nazária. In the Duque Bacelar and Coelho

Neto there are more than five exposures mostly formed by large gymnosperm stems, some of them in life position (reaching more than 1.0 m in diameter) and, less often, by tree-fern stems in horizontal position, e.g., *Psaronius* sp. (reaching up to 5 m in length). The plant fossils are commonly well preserved, especially the stems with largest diameters, and despite of considerable fragmentation of several specimens it is possible to recognize certain anatomical features, such as growth ring-like structures. It is worth mentioning that only the site located in Teresina (namely Fossil Florest of Poti River) was already known by the scientific community; all the other outcrops are new. The next step of our research will be the detailed study in terms of taxonomic and taphonomic aspects. This will provide a better knowledge of the fossil plant assemblages of this unit contributing to understanding about the complexity of Paleozoic plant relationships and the depositional environments present during the Permian times in the Parnaíba Basin.

Keywords**:** Petrified forests, Pedra de Fogo Formation, Parnaíba Basin, Lower Permian.

Palynological record and associated faunas of Serpukhovian-Bashkirian sequences (El Paso and Majaditas formations) from the Barreal area, San Juan province, Argentina

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The Gondwanic glaciations of the Late Paleozoic were one of the most important paleoclimatic events in the earth history. As a consequence of the glacial conditions, with glacial and interglacial periods, the sedimentation of the Gondwanic basins was affected with the deposition of different sedimentary facies. The Argentine Precordillera can be considered a classical study area where the glaciation was clearly recorded with different facies in particular paleoenvironments. At the Barreal area, San Juan province, the typical glacial deposits appear discontinued in an irregular pattern along western margin of the Tontal Hill. Their Carboniferous stratigraphic units, interpreted as product of advancing and retreating of the ice masses in dominant glaciomarine scenery, have been mainly dated through of their marine faunas. However, there are still some difficulties regarding the precise age of some stratigraphic units, such as the El Paso Formation and correlatives as the Majaditas Formation. This controversial interpretation is due to the determination at sequences of the El Paso Formation of different brachiopod assemblages: the *Rugosochonetes-Bulahdelia* biozone assigned to Late Visean-Early Namurian, placed below the base of the *Levipustula levis* Biozone (Serpukhovian–Bashkirian), and the *Aseptella-Tuberculatella* and *Rhipidomella-Micraphelia* associations that indicated a younger Carboniferous age. In this context, the recently known palynological content from the El Paso Formation, with the significant register of monosaccate pollen grains and diagnostic spores, allowed to propose a late Serpukhovian–Bashkirian age to the El Paso Formation, and a correlation with the Subzone A of the *Raistrickia densa-Convolutispora muriornata* (DM) Biozone from Western Argentina. This biozone have been assigned to the Serpukhovian–early Bashkirian (confirmed by radiometric age), concordant with the age of the *Levipustula* fauna that characterizes the glacial interval of marine facies of the Hoyada Verde Formation (also from the Barreal area and equivalent to El Paso Formation). Likewise, the palynological record of the middle part of the Majaditas Formation with the following taxa: *Granulatisporites parvus*, *Dibolisporites disfacies*, *Reticulatisporites passaspectus*, *Verrucosisporites chiqueritensis*, *Convolutispora muriornata*, *Raistrickia densa*, *R. rotunda*, *Apiculatisporites variornatus*, *Ahrensisporites cristatus*, *Cristatisporites rolleri*, *C. stellatus*, *Indotriradites volkheimeri*, *Psomospora detecta*, *Circumplicatipollis plicatus*, *Cannanoropolis janakii*, *Plicatipollenites* sp., *Crucisaccites monoletus*, *Potonieisporites* sp., among others, also allows to suggest a correlation with the Subzone A of the DM Biozone. In both assemblages is recorded microplancton. The differences between the microflores are the better preservation and diversification in the Majaditas assemblage that could be due to a different depositional environment, or a paleoclimatic improvement of a slightly younger microflore.

Keywords**:** Palynology, Faunas, Precordillera Argentina, El Paso and Majaditas formations, late Serpukhovian–Bashkirian.

Micropaleontology of the Vila Maria Formation, Ordovician-Silurian boundary of the Paraná Basin: preliminary results

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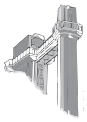
This paper presents the preliminary results of palynological study in four samples of the intermediate portion of the supplemental type outcrop section of Vila Maria Formation, the Parana basin. This study integrates with previous studies in ostracods and brachiopods recovered from the section now under study. The research aims to establish biostratigraphic refinement through the integration of pollen analysis and ostracodes data. The Vila Maria Formation is characterized by gray and black shales in the lower and middle portions, and sandstones toward the top, and features fossil content attributed in previous research to LLandoveriano. However, the occurrence of ostracodes species *Satiellina jamairensis* and *Conchoprimitia circularis*, the first is Ordovician characteristics Africa (Libya), along the lower and intermediate portions, promotes refinement and integration biostratigraphic data. Pollen preparation followed acid attack sequence (KOH, HCl, HF, HCl), screening, separation dense liquid and mounting slides with Entellan. The recovered palinological assembly comprises six species of cryptospores (*Imperfectotriletes patinatus*, *Imperfectotriletes vavrdovae*, *Tetrahedraletes medinensis*, *Pseudodyadospora laevigata*, *Segestrespora laevigata*, *Rimosotetras problematica*); three species of Chitinozoans (*Plectochitina* sp., *Ancyrochitina* sp., *Angochitina* sp), as well as acritarchs, prasinophytes and scolecodonts. Undeterminated species of palynomorphs will be revised in order to contribute for a better understanding of diversity in this interval. The assembly retrieved points to environment marine plataformal sedimentation with continental origin contribution defined by the cryptospores presence. The integration of proposed data can contribute to the biostratigraphic and paleoecological studies between basins that have coeval succession of glacial sediments deposited under neritic marine sediments in regional and Gondwana context.

***Keywords*:** Palynomophs, cryptospores, ostracodes, Paraná basin, Ordovician.



POLLEN/SPORE MORPHOLOGY

Andrea Pereira Luizi-Ponzo, Maria Teresa Buril & Vernie G. Sagun

Sporoderm wall layers in ferns: the deep perispore construction in not related groups

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The study of stratification and ultrastructure of ferns esporodermis is of great importance for the understanding the ontogeny in different groups and lineages, since they give us information about the role each stratum, both in the development of spores as during germination. This contribution aims to define a type of structural design, which forms the deepest part of the perispore and that was recognised as similar in not related groups of ferns. It consists in a three layered structure that surrounds the whole exospore outer layer. This “deep layer” or “inner perispore” is 200 nm to 1 µm thick, and is composed of an inner stratum of 90-250 nm, of spongy structure with thin fused channels forming a compact network. The middle stratum of 100-400 nm thick is composed of disjoint blocks traversed of channels of 100 nm in section, which connect with inner and outer strata. The outer stratum of 150-500 nm has an homogeneous structure. This kind of deep layer has been recognized in some genera of Cyatheaceae (*Alsophila*, *Sphaeropteris*), Pteridaceae (*Cheilanthes*, *Annogramma*, *Pteris*), Dennstaedtiaceae

(*Lindsaea*). The way in which the different strata of the deep perispore layer are combined and their relationships to with the outer layers of the rest of the perispore differs in each taxa, and would have physiologic and ontogenetic implicance. This structural basic construction was analysed from the architectural and functional aspects; and its use as a character in phylogeny is discussed, because few phyllogenetics analysis include the characters spores.

***Keywords*:** South America, ferns, sporoderm, deep perispore, ultrastructure.

The compilation of Asteraceae palynological researches conducting in Turkey between 1971 and 2015

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The palynological researches in Asteraceae family were increased in recent years. Therefore in this review we collected and summarized the researches related with pollen morphology of this family conducting in Turkey between 1971 and 2015 years. For this purpose we scanned and used 62 references that were electronically accessible. Asteraceae family is represented with 137 genera in Turkey. In terms of pollen morphology, we showed that 8 out of 11 Asteraceae tribe in Flora of Turkey were investigated. These tribe and their genera were as follows: Anthemideae tribe including 8 genera (*Achillea*, *Artemisia*, *Anthemis*, *Chrysanthemum*, *Cota*, *Matricaria*, *Tripleurospermum* and *Tanacetum*), Astereae tribe including 2 genera (*Aster* and *Bellis*), Cardueae tribe including 14 genera (*Carthamus*, *Carduus*, *Carlina*, *Centaurea*, *Cirsium*, *Crupina*, *Cyanus*, *Echinops*, *Jurinea*, *Klasea*, *Onopordum*, *Psephellus*, *Rhaponticoides* and *Xeranthemum*), Eupotarieae tribe including a genus *Eupatorium*, Heliantheae tribe including 2 genera (*Ambrosia* and *Xanthium*), Inuleae including 3 genera (*Helichrysum*, *Inula* and *Logfia*), Lactuceae tribe including 13 genera (*Chondrilla*, *Cichorium*, *Crepis*, *Hieracium*, *Lapsana*, *Leontadon*, *Mycelis*, *Pilosella*, *Scolymus*, *Scorzonera*, *Sonchus*, *Tragopogon* and *Taraxacum*) and Senecioneae tribe including 3 genera (*Doronicum*, *Senecio* and *Tussilago*). The pollen grain morphology of 387 taxa was investigated and 26 of them were performed again in different researches. Therefore, during this review, we scanned totally 414 taxa including the repeated researches also. All investigated taxa were grouped as 46 genera, 321 species, 65 subspecies and 27 varieties. We counted the Scanning Electron Microscopy (SEM) and Light microscopy (LM) images presented in the references and found that SEM images were more than LM images. The different palynological features such as pollen size and shape, aperture type and number and pollen grain ornamentations were taken into account. Spheroidal, oblate spheroidal and prolate spheroidal pollen shapes and medium pollen size were common in worked Asteraceae pollen grains. Also the common aperture types were found as colporate, porate and colpate; and the aperture numbers found as tri-, tetra-, penta- and stephano- in this family members. In addition, the frequent pollen grain ornamentations shown in Asteraceae family were echinate, scabrate, perforate, granulate, psilate, rugulate, lophate and caveata. Also we showed that some pollen grain ornamentations were defined differently with in the same taxon or taxa. With this compilation, we provide a comprehensive overview of literature pertaining to Asteraceae pollen morphology conducting last 44 years in Turkey.

***Keywords*:** Asteraceae, tribe, pollen morphology, bibliography, Turkey

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Sporoderm construction in microspore permanent tetrads of Selaginella convoluta (Lycophyta)

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Microspore tetrads produced by specimens of *S. convoluta* (Walk. Arn) Spring collected in Bolivia and North West Argentina (Salta) were found to be different from those produced by plants from Paraguay and Brazil. In order to find out the meaning of those differences there were observed as many sporangia as were available in each specimen collected by means of LM, SEM and TEM. The results were that, in each sporangium several kinds of tetrads were found, each kind of them correspond to different stages in maturation from totally immature microspores tetrads; intermediate stages that had two completely mature microspores and two immature microspores. The spaces between microspores were fool with globules of different sizes. Then

all the globules are fused at the equatorial outer side. There is a later morphological differentiation at the place of the distal junction. The several stages found in each sporangium were described and arranged in a sequence that provides valuable information about the differences in morphology and complex evolution of the outer and inner development of each microspore in a tetrad .There were followed the complete step in the outer tetrad envelopment. In section and with the aid of the TEM it is possible to follow tap the distal walls are thick and two-layered–while the inner proximal layer has low contrast. Early stages began to grow the bridges between microspores TEM sections showed that their construction begins by globules obstructing the equatorial space between adjacent microspores of a tetrad. Later in maturation the proximal walls became thin while equatorial and distal walls become alveolar. The microspores of each tetrad at maturity are covered by a continuous distal alveolar coat. There were also found tetrads composed of two small granular spores and two big alveolar spores. On the light of former important experiments, the meaning of the presence of microspore tetrads will be discussed as a mechanism of retention in development to facilitate the capacity in order to keep all the microspores in a sequence to be active in reproduction.

Keywords**:** *Selaginella*, microspore tetrads, maturation, ultrastructure

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Pollen characters states evolution in neotropical Podostemaceae

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Podostemaceae Rich. ex Kunth is the largest strictly aquatic angiosperm. It contains three subfamilies well represented in the neotropics (Tristichoideae, Weddellinoideae and Podostemoideae), with 20 genera and about 150 species. Phylogenetic studies with morphologic and molecular data recognized Tristichoideae as the sister group of the remaining subfamilies, the monotypic Weddellinoideae and the highly diverse Podostemoideae. This latter has an exclusively neotropical clade and a "paleotropical clade" compound by few neo and all paleotropical species. We aimed to detect informative pollen characters states and trace their evolutionary path in Podostemaceae. We realized the pollen morphology study of 40 Podostemaceae species (18 genera) and three Hypericaceae species, as the outgroup to support the polarization the states. The palynological material was obtained from fertile anthers of flower buds and flowers deposited in R and WSCU herbaria, acetolised and examined through light microscopy and scanning electron microscopy. A matrix of the following characters was constructed: size, type, number and margin of apertures, polar area, pollen unity and ornamentation. These states were mapped in a consensus tree of the most recent phylogenetic hypothesis in the program Mesquite v.2.75. The results suggest that small pollen grains are a synapomorphy for Podostemaceae, the medium sized being a derivate state (reversal); colporate aperture is the ancestral character state that evolves to pores (an autapomorphy of Tristichoideae) or colpi (a synapomorphy for Podostemoideae); dyads are a synapomorphy for the "paleotropical clade" of Podostemoideae, dyads and tetrads arose independently in *Diamantina* and *Lophogyne*; spinulate ornamentation is a synapomorphy for Podostemaceae and rugulate is an autapomorphy for Weddellinoideae, emerging independently in *Ceratolacis*. Pollen data show to be phylogenetically informative, especially in high hierarchical levels.

Keywords**:** aquatic plants, neotropics, pollen evolution

Phylogenetic analyses and evolution of *Cicatricosisporites* and Anemiacean spores in geological time: a preliminary result

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Fossil cicatricose trilete spores belonging to family Anemiaceae are very common in the palynological assemblages of strata ranging from Middle Jurassic to Present. For this study 23 species were selected for phylogenetic analyses: *Anemia dregeana*, *Appendicisporites erdtmannii*, *A. potomacensis*, *A stylosus*, *A. tricuspidatus*, *Cicatricosisporites australiensis*, *C. avnimelechii*, *C. dorogensis*, *C. exilis*, *C. myrtellii*, *C. neumanii*, *C. potomacensis*, *C. purbeckensis*, *C. salardii*, *C. sternum*, *C. stoverii*, *Nodosisporites dentimarginatus* (Brazilian specimen), *N. dentimarginatus* (American specimen), *N. macrobaculatus*, *Plicatella baconicus*, *P. insignis*, *P. lucífera* and *P. singhii*. The analyses aimed at: 1- to understand the relationship among some genera of cicatricose spores group belonging to family Anemiaceae and to solve the following questions: should the genus of cicatricose complex be maintained in the phylogenetic analysis? And, is *Cicatricosisporites* monophyletic? 2-Tracing the evolutionary line of the morpho-evolutionary characters and stage in *Cicatricosisporites* to infer the evolutionary history of the family anemiaceae. The cicatricose spores of Anemiaceae were recovered from sedimentary rocks of different ages and geographical areas (Africa, Brazil, France and India). They have been taken from strata of different ages, to verify their morphological changes occurred during geological time. A spreadsheet was made with 23 characters and states of characters ranging from 0 to 1, 0 to 2 and 0 to 3, along with another spreadsheet showing analysis of these 23 species and state of morpho-evolutionary characters. For format TXT, two arrays were made, but with different groups of 16 species each, being one species (*Lygodium volubile*) the out-group. Afterward, all data was put in the standard configuration of the TNT/WINCLADA phylogenetic analysis programs. The following method has indicated studied morpho-evolutionary character with the value k=11.68. The conducted phylogenetic studies indicated that *Appendicisporites*, *Cicatricosisporites*, *Nodosisporites* and *Plicatella* are related to each other independently, demonstrating that their distinction in different genus is not suitable. All genera which are related to family Anemiaceae, consist of only one living genus. Therefore, the genera of cicatricose complex (*Appendicisporites*, *Cicatricosisporites*, *Nodosisporites* and *Plicatella*) associated with the Anemiaceae are not maintained in the phylogenetic analysis. However, if these genera were differentiated, the phylogenetic trees would show the genus *Cicatricosisporites* as polyphyletic, descending from two or more independent ancestors.

***Keywords*:** cicatricose spores, phylogeny, Anemiaceae, palynology, morphology.

Polinic study of species of Gardenieae (Rubiaceae Juss.) ocurring in "Restinga" of the Rio de Janeiro, Brazil

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Rubiaceae is one of the 39 families in the Gentianales order, it is considered one of the most important families of brazilian flora, presenting the 5th biggest number of species and being the 4th biggest family of Angiosperms. In Brazil, it's occurrence is estimated in circa 1395 species and 124 genera. The Gardeneiae tribe has 52 genera and circa 587 species. This study is part of the polinic catalog of Rio de Janeiro's "restinga" and at the moment are being analised four genera and six species: *Amaioua intermedia* Mart. ex Schult. & Schult. f., *Amaioua pilosa* K. Schum., *Melanopsidium nigrum* Colla., *Randia armata* (Sw.) DC., *Tocoyena sellowiana* (Cham. & Schltdl.) K. Schum. and *Tocoyena bullata* (Vell.) Mart. The pollen analysis is done through light microscopy, with 400x and 1000x, after the acetolysis treatment - with the exception of *Randia armata*, which was subjected to the ACLAC method. For said analysis, 25 randomly selected pollen grains of a standard specimen and ten grains

of three other specimens, for comparison, were measured. The results were statistically treated establishing parameters such as arithmetic mean, standard deviation, coefficient of variability and confidence interval. The pollen grains were analyzed, described and photomicrographed. For the scanning electron analysis, the non-acetolised pollen grains were spread on a double side carbon tape and metalized with gold for about 1 min. The results show diversity in the pollen unit (monads in *Amaioua* species, *Melanopsidium nigrum* and *Tocoyena* species; tetrads in *Randia armata*), the size varied from medium in the monads and large in the tetrads, there was also a variation found within *Tocoyena*, which presents both sizes of grains. *Amaioua* and *Tocoyena* both presented 3-4-porate grains, *Melanopsidium* presented 3-4-colporate grains and *Randia* presents 3-porate grains. The sexine is reticulate in most species and scabrate in *Randia.* It could be concluded then that Rubiaceae pollen grains vary in size, shape and ornamentation, making a polinic separation of genera possible, enabling the use of these characters as an aid to the family's taxonomy.

***Keywords*:** Palynology, Gardenieae, pollen diversity, Mata Atlantica

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Morphology and wall-ultrastructure of *Froelichsporites traversei*, an enigmatic sporomorph from the Late Triassic in North America

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Froelichsporites traversei (Dunay & Fisher) Litwin, Smoot, Weems is a prominent palynomorph in the Upper Triassic of Northern America which is permanently found in tetrahedral tetrads. The distribution of the taxon seems to be restricted to the Upper Triassic of North America. It is an important biostratigraphic marker in the Norian and a rise in its abundance around 215 Ma is associated with a significant faunal and floral turnover. Its most striking morphological features are the well-developed pores (ulci) and exine thickening around them on the distal side of each grain. Previous works suggested it was produced by spore producing plants e.g. sphenopsids, or Cheirolepidiaceae. Alternatively, it may represent a prepollen, but its botanical affinity is still unclear. We present preliminary results of a detailed morphological analysis (light microscopy and SEM) of newly collected outcrop material from the Chinle Formation at the Petrified Forest National Park (Arizona, USA). TEM analysis was applied to study the wall ultrastructure which may reveal more information on the botanical affinity of this peculiar palynomorph. The ultrastructure analysis revealed that it has a unique, simple wall structure consisting of only two layers. The outer layer is an electron dense layer with homogenous texture, while the inner layer has spongy-granular texture. A layer with lamination was lacking. The simple wall structure might point to an affinity to spore producing plants (possibly ferns, or bryophytes related the Andreaopsida; a group of mosses). However, the distal pores and the occurrence exclusively as permanent tetrads would suggest an affinity with seed plants. An explanation for the lack of the laminated layer and nexine is that it might represent an immature pollen grain with gnetalean affinity in the early stage of tetrad formation, where the nexine is not developed yet. Alternative solution of the unusual morphological and ultrastructural features is that they represent experimentation with angiosperm related features and functions, which often characterize Bennettitalean plants in the Late Triassic.

***Keywords*:** *Froelichsporites*, tetrad, TEM, botanical affinity

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Pollen morphology of Asterales

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The order Asterales comprises more than 10% of the Angiosperm species diversity. It includes 11 families (Alseuosmiaceae, Argophyllaceae, Asteraceae, Calyceraceae, Campanulaceae, Goodeniaceae, Menyanthaceae, Pentaphragmataceae, Phellinaceae, Roussaceae and Stylidiaceae), ca. 1723 genera and more than 26000

species. The largest family is Asteraceae with ca. 1600 genera and 23000 species. Most of these families inhabit in the Southern Hemisphere, only Asteraceae, Campanulaceae and some species of Menyanthaceae are cosmopolitan. The current knowledge on pollen morphology is detailed in Asteraceae, Goodeniaceae and Calyceraceae, but it is yet uneven and sparse in the remainder families. This unequal level of information make difficult to identify synapomorphies in cladistic contexts. In order to assess the pollen diversity within Asterales we examined pollen grains of 52 species belonging to 42 genera of Asterales (excepting Asteraceae, Calyceraceae and Phellinaceae) under LM and SEM. Pollen grains within Asterales exhibit varied morphology, they include monads or tetrads, single or compound aperture (tri-, tetra- or hexa-colpate, tri-, tetra- or hexa-porate or, tricolporate) and variable sculpture (scabrate, perforate-verrucate, microechinate, echinate, rugulate, striate or reticulate) and structure (tectate, semitectate, columellate or with compact aspect). Despite this degree variation most of the studied families are distinctive morphologically. A new pollen type in Rousseaceae was here identified. The large family Campanulaceae together the medium-sized Goodeniaceae and the small family Rousseaceae, have the most diverse types of pollen. By contrary, the medium-sized family Stylidiaceae is fairly uniform in pollen morphology. This study shows the pollen diversity within Asterales and provides support for future taxonomic, phylogenetic and palaeontological studies within the order.

Keywords: pollen morphology, Asterales.

Pollen morphology and its taxonomic significance in Passifloraceae *s.l.*

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The most representative genus of Passifloraceae *s.s.* it is *Passiflora* L. which is divided into five subgenera: *Astrophea* (DC) Mast, *Deidamioides* (Harms) Killip, *Decaloba* (DC.) Rchb, *Passiflora* and *Tetrapathea* (DC.) P. S. Green. The pollen characters of *Passiflora* species has been presented with a great diversity. Pollen characters, if necessary also support understanding the current infrageneric taxonomic classification. This work aims to study light microscopy and scanning electron species of Passifloraceae *s.l.* and compare with results of phylogenetic molecular analyzis. They have been featured four of the five subgenera currently accepted and four other genera of Passifloraceae *s.l.*, resulting in a total of 20 species. The pollen material was obtained from herbarium specimens deposited in national and international herbaria. The pollen grains were acetolysed, measured, described and illustrated using light microscopy (LM). For further details of surface and apertures, pollen grains not acetolysed were analyzed by scanning electron microscope (SEM). The monophyletic *Passiflora* subgenus *Astrophea* is supported by type 6-colporate with lalongate endoaperture, unique for each pair of ectoaperture, presents only pontopercula. *Passiflora* subgenus *Decaloba* is the most apomorphic group with greater numbers of the aperture, ranging from 6-12 colporate or 12-colpate, may present operculum and/or pseudoperculum. *Passiflora* subgenus *Passiflora* is supported by pollen with aperture fused in apocolpium region and derived from these (6-14 sincolpate) and it have pseudoperculum. *Passiflora* subgenus *Deidamioides* is characterized by having the type 6-colporate with pontoperculum. *Passiflora* subgenus *Astrophea* is the only species having intectada exine and/or remaining muri, and semitectate species. The subgenus *Passiflora* shows all reticulate pollen grains as well as the subgenera *Decaloba* and *Deidamioides*. The pollen grains of the species of the genera *Piriqueta* Aubl. and *Malesherbia* Ruiz & Pav. have 3-colporate aperture with perforated or reticulated sexine. The African genera *Barteria* Hook. f. presented 6 porate, which differs from other genera. The intectada sexine the closer to *P*. subgen. *Astrophea*, subgenera that presents the most pleisiomorphic characters. *Mitostemma* Mast. has pollen grains with 3-4 colporate and sexine also reticulated like most species analyzed of the Passifloraceae *s.l*. The pollen attributes are important to separate genera, subgenera, and even species. Os pollen grains which have a greater number of aperture and more than one type of operculum, form apomorphic groups.

***Keywords*:** Opercula, *Passiflora*, phylogeny, pollen analysis, sexine

Pollen morphology of Selected *Arabidopsis*, *Camelina*, *Capsella*, *Catolobus*, *Chrysochamela*, *Neslia*, *Noccidium* and *Pseudoarabidopsis* species (Camelineae, Brassicaceae)

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The tribe Camelineae (Brassicaceae) contains eight genera including *Arabidopsis*, *Camelina*, *Capsella*, *Catolobus*, *Chrysochamela*, *Neslia*, *Noccidium* and *Pseudoarabidopsis*. Little is known about pollen morphology in these taxa, and this limits research on gene flow, aerobiology, reproductive biology, systematics, and paleobotany. In this study, pollen from 13 taxa representing all of the genera in the tribe Camelineae were examined using light and scanning electron microscopy. Measurements of pollen size in *Camelina* and *Arabidopsis* showed that these genera contained taxa with pollen that could be classified as medium sized. The largest pollen were from *Camelina microcarpa* and *C. sativa*. Conversely, *Pseudoarabidopsis* had the smallest pollen in the Camelineae. *Capsella bursa-pastoris* was distinct in the tribe in having tectum discontinuities. *Catolobus* and *Neslia* shared similar pollen shape that tended to be subspheroidal and less prolate than others in the tribe. *Noccidium* had distinct microverrucate elements on its colpus membrane. Within *Camelina*, variations in pollen size and stratification were observed among the five species studied. The pollen morphology of *Chrysochamela* deviated from other members of the tribe and was distinct in having a homobrochate reticulum and the thickest exine, sexine, and infratectum. These results support research on diverse topics including pollen dispersal and gene flow in *Camelina*, pollen development in *Arabidopsis thaliana*, and phylogenetic studies in the Brassicaceae.

***Keywords*:** pollen morphology, Brassicaceae, *Camelina*, *Arabidopsis*, *Capsella*

Pollen morphology of eight Papilionoideae (Leguminosae) species from Brazilian Amazonia

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Leguminosae comprises 727 genera and about 19,325 species worldwide. Papilionoideae stands out as the major subfamily among legums, grouping 13,800 species and 28 tribes. Here, we describe the pollen morphology of eight Papilionoideae species from Brazilian Amazonia: *Deguelia rufescens* Aubl., *Machaerium inundatum* (Mart. ex Benth.) Ducke, *Macrolobium campestre* Huber, *Macrolobium pendulum* Willd. ex Vogel, *Ormosia holerythra* Ducke, *Ormosia excelsa* Benth., *Pterocarpus amazonum* (Mart. ex Benth.) Amshoff and *Swartzia laevicarpa* Amshoff. We have collected polliniferous material from exsiccates of the "Mineradora Rio do Norte" (MRN) Plant Collection – deposited in the Engenheira Agrônoma Fátima Meckedece Herbarium (HSTM), Santarém, Pará State, Brazil. After acetolysis, pollen grains were measured, qualitatively described under optical microscopy and photomicrographed. Slides are deposited in Palynothecas of the Universidade Federal do Oeste do Pará (P-UFOPA), Pará, and Universidade Estadual de Feira de Santana (PUEFS), Bahia. All species revealed pollen grains in isopolar 3-colporate monads. Pollen size ranged from small (*M. inundatum*, *P. amazonum* and *S. laevicarpa*) to medium (*D. rufescens*, *M. campestre*, *M. pendulum*, *O. excelsa* and *O. holerythra*). Pollen shape was oblate spheroidal (*D. rufescens*), prolate spheroidal (*O. excelsa*, *O. holerythra* and *S. laevicarpa*), subprolate (*M. campestre*, *M. pendulum* and *P. amazonum*) or prolate (*M. inundatum*). The exine is microreticulate in *D. rufescens*, *M. inundatum*, *M. campestre*, *M. pendulum*, *O. excelsa* and *P. amazonum*; reticulate in *O. holerythra* and psilate in *S. laevicarpa*. We also observed *M. inundatum*, *O. excelsa*, *O. holerythra* and *P. amazonum* have lalongate endoaperture, whereas *D. rufescens*, *M. campestre*, *M. pendulum* and *S. laevicarpa* exhibit circular endoaperture. *S. laevicarpa* presented syncolporate pollen

grains. We conclude morphopolynic charcaters distinguish the analyzed species. This emphasizes the group's eurypalynous condition.

***Keywords*:** Fabaceae, Faboideae, eurypalynous, palynology, palynotaxonomy

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Morphological and ultraestructural studies on spores of Dennstaedtiaceae from the Paranaense Province

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The spore morphology and wall ultrastructure of the Dennstaedtiaceae species from Phytogeographic Paranaense Province were studied. The study was based on herbarium specimens and fresh material, collected in field trips. Several techniques of fixation and differential stains were applied and the observations were performed with light microscopy (LM) and scanning and transmission electron microscopes (SEM and TEM). As general characteristics, the spores are monolete and trilete. Based on the diversity of sculptures observed, 6 morphological groups were recognized within the family: 1- verrucose, in *Dennstaedtia cicutaria*, *D. cornuta*, *D. dissecta*, *D.globulifera* and *D. obtusifolia*; 2- morphologic group with strands, in *Pteridium arachnoideum* and *Microlepia speluncae*; 3- baculate, in *Blotiella lindeniana*, 4- rugulate group, in *Paesia glandulosa*; 5- tuberculate, in *Histiopteris incisa*; 5- equinate, in *Hypolepis mitis*, *H. paulistana*, *H. repens*, *H. stolonifera* and 6- cristate, in *Hypolepis rugosula*. In most species (except in *Histiopteris incisa*) elements of ornamentation are part of the perispore. At ultrastructural level, the perispore has 1 to 4 layers which differ in structure. Respect to the exospore, all the species studied have an exospore two- layered with similar ultrastructural characteristics. The results obtained in this study show that the morphological variability observed in the sporophytes of Dennstaedtiaceae species, is equivalent to the variability observed on the sculptural characteristics of the spores. In relation to the evolutional history of the family, the results have shown that some palynological features, like kind of spore, and features of the exospore margin would bring information that would support the recent phylogenetic hypothesis. Additionally, these results let us suggest that the palynological characteristics do not have itself any evolutionary value that allow us to suggest relationships between groups at generic level. Finally, the descriptions and the images taken with LM, will give useful information for comparison with spores found in fossil material.

***Keywords*:** Dennstaedtiaceae, spores, sculpture, ultrastructure, Paranaense

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Evidence about the hybrid origin of *Hypolepis* × *paulistana* Schwartsb. & J. Prado (Dennstaedtiaceae)

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Hypolepis × *paulistana* is a putative hybrid between *H. stolonifera* (var. *stolonifera*) and *H. rugosula* (subsp. *pradoana*). The taxon has intermediate morphology between the two parents, and is probably narrow endemic to the highlands of São Paulo, Brazil. The aim of this work was to analyze the morphology of *H.* × *paulistana* and compare it with the parents in order to provide additional evidence of the hybrid origin. Spores were collected from herbarium material (RB, NY, LP, BA). The observations were made using LM and SEM. The spores of *Hypolepis* × *paulistana* are monolete and bilateral. In distal view, they are elliptic; the equatorial diameter is 22–39 µm. In equatorial view, are plane-convex to plane-subconical; the polar diameter is 20–31 µm. The lesurae is 25–27 µm. The perispore is light brown at LM, equinate, with laterally fused spines, frequently forming sinuous crests and covered by thread. The exospore is yellowish to hyaline at LM and has verrucate ornamentation with spinules between verrucae. The size and ornamentation of spores resemble those observed in *H. stolonifera* while in *H. rugosula* larger spores with cristate perispore

were found. Additionally, in *H. paulistana* mature spores are identified with various anomalies: collapsed spores, with concavities or plies in the wall and without protoplast; spores with anomalous lesurae or without it; spherical alete spores, of radial symmetry and 30–32 µm in diameter; diads of mature spores with irregular shapes and different sizes and amorphous small bodies ornamented by spines similar to those observed in the perispore. According to previous analyzes conducted in other species of ferns, the variability in the shape and size of the spores could be related to an abnormal division of spores stem cells and unequal distribution of chromosomes between daughter cells. Also, the collapse of some spores could be explained by protoplast loss. All these phenomena would be associated with hybridization events. To conclude, the diversity of anomalies observed in *Hypolepis × paulistana* and the similarities with previous studies in other taxa provide additional evidence about its hybrid origin.

Keywords**:** *Hypolepis*, hybridization, spores, Dennstaedtiaceae, actuopalynology.

The pollen morphology of seven taxa belong to *Picris* L. and *Crepis* L. of Lactuceae tribe (Asteraceae) in Turkey

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Asteraceae is one of the largest and cosmopolite family in the world except for Antarctica. Asteraceae family is represented with 11 tribes and 137 genera in Turkey. According to Flora of Turkey and The East Aegean Islands, *Picris* L. genus includes 9 species and *Crepis* L. genus represented with 33 species and 7 subspecies. In this research three taxa belong to *Picris* L. genus (*Picris pauciflora*, *Picris cyprica* and *Picris campylocarpa*) and 4 taxa belong to *Crepis* L. genus (*Crepis commutata*, *Crepis smyrnaea*, *Crepis micrantha* and *Crepis reuteriana* subsp. *reuteriana*) were used for investigating pollen morphologies. The light microscopy (LM) (Leica DM2500) and Scanning Electron Microscopy (SEM) (JEOL SM 7100F) were used for examining pollen grains. An average of 50 pollen grains was used for each pollen feature examining in the LM. The pollen samples for LM and SEM were prepared according to protocol proposed by Wodehouse and Erdtman, respectively. We used the pollen terminology suggested by Erdtman and Punt. The polar axis(P), equatorial axis (E), P/E ratio, mesocolpium (Meso), Sexine, Amb, intercolpus ridge length (Icrl), Icsn (intercolpus spinules number), Ilgl (interlacunal gaps length), Ilgw (interlacunal gaps width), Abporal lacuna width (Alw), Abporal lacuna length (All), pore width (Pw), pore length (Pl), poral lacuna width (Plw), poral lacuna length (Pll), number of spinules in the poral area (Pasn), spinule lenght equator view (Sle), and spinule lenght polar view (Slp) of the polen grains were measured by LM. The SPSS statistical program (ver. 22.0) was used to calculate the mean (M), standard deviation (SD) and variation (V) of LM measurements. Pollen ornamentations of all investigated taxa were found as echinulophate and grains have 15 Lacunae (3 poral, 6 abporal and 6 paraporal). There were distinct depressions in the polar area of grains. The pollen apertures was found as 3-zonocolporate. With this research pollen morphologies of 7 taxa belonging to two genera were investigated first time. These results also were contributed to researches executed in different fields of science.

Keywords**:** Asteraceae, *Picris* L., *Crepis* L., pollen morphology, Turkey

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Morphological and ultrastructural study of selected species of Frullaniaceae Lorch

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Frullaniaceae Lorch comprises leafy liverworts, the plants are medians to robust, with morphological variability related to habit of life; species are distinguished by the presence of lobes transformed into aquifers sacs. This study aimed to perform the morphological and ultrastructural study of eighteen species, under light and scanning electron microscopy, analyzing sporoderm thickness and the ornamentation patterns of spores for following species: *Frullania atrata* (Sw.) Nees, *F. arecae* (Spreng.) Göttsche,

F. beyrichiana (Lehm. & Lindenb.) Lehm. & Lindenb., *F. brasiliensis* Raddi, *F. caulisequa* (Nees) Nees, *F. dusenii* Steph., *F. ecklonii* (Spreng.) Göttsche *et al.*, *F. ericoides* (Nees) Mont., *F. gibbosa* Nees, *F. glomerata* (Lehm. & Lindenb.) Mont., *F. griffithsiana* Göttsche, *F. in*tumescens (Lehm. & Lindenb.) Lehm. & Lindenb., *F. kunzei* (Lehm. & Lindenb.) Lehm. & Lindenb., *F. lindenbergii* Lehm., *F. montagnei* Göttsche, *F. nodulosa* (Reinw. *et al.*) Ness, *F. riojaneirensis* (Raddi) Spruce and *F. setigera* Stephani. Spores were obtained from herbarium specimens and subjected to palynological preparations before and after acetolysis. To evaluate the spore's size, there were measured 50 acetolysed spores randomly in three slides for each sample, and for measuring sporoderm strata thickness were considered 10 non-acetolysed spores present in three slides. Multivariate analysis (cluster analysis and PCA) were conducted to observe the occurrence of species groups. Palynological analysis showed that spores are nonpolar, with subspheroidal amb, without preferred region for germination; the average size of spores ranged between 33 µm and 56 µm. Two different morphological types were observed based on ornamentation pattern. The first type includes species with exine ornamented by circular depressions, filled and circumscribed by elongated processes, which also vary morphologically; this type is represented by sixteen of the eighteen species studied here. The second morphological type includes species with exine ornamented with circular depressions in which a single process stands out, and is located in the center of the depression; it is represented by two of the eighteen species studied here. The variation on ornamentation density distributed on the spore surface, and the morphology of these elongated processes, as well as the presence of an ornate sexine were characteristics observed in both morphological types, especially in the first one. Concerning to sporoderm thickness, the species showed different combinations of thicknesses of this layers. Multivariate analysis showed that exine and intine thickness separated the species studied here into four groups composed by the same species in both analyzes. (FAPEMIG, Programa Bolsas Monitoria PGECOL/UFJF).

***Keywords*:** Frullaniaceae, Ornamentation, Multivariate analysis, Ultrastructure

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Pollen grains morphology of Caesalpinioideae (Fabaceae) at the Uneb's *Campus*, Paulo Afonso, Bahia, Brazil

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Fabaceae is the third largest family of Angiosperm, the second in economic importance in agriculture and widely distributed in the world, comprising about 727 genera and 19,325 species. In Brazil, it has an estimated number of 200 genera and 1,500 species. This paper described the pollen grain morphology of seven species belonging to five genera of Caesalpinioideae (Fabaceae) occurring at the *Campus* of University of Bahia State, Paulo Afonso, Bahia, Brazil. The pollen materials were obtained by the direct collecting in flowers, acetolyzed, measured, photomicrografed and described under light microscopy. The pollen grains of the analyzed species (*Bauhinia subclavata* Benth., *Caesalpinia echinata* Lam., *Caesalpinia pulcherrima* L. Sw., *Cassia fistula* L., *Delonix regia* (Bojer ex Hook.) Raf., *Senna silvestris* Vell. HSIrwin, *Tamarindus indica* L.) presented different pollen types regarding to size (from medium to large); varied oblate spheroidal (subprolate, prolate, subcircular and subtriangular); 3-colporate with three long colpi (only *S. silvestris* showed the central region constricted) and short colpi in *C. echinata*, *C. pulcherrima* and *D. regia*; rounded endoaperture, lalongate or lolongate and assorted patterns of ornamentation of exine in optic microscopy (microreticulate or reticulate). The pollen morphology variation in the studied species allowed characterizing the Caesalpinioideae as euripalynous at the *Campus* of the University, Paulo Afonso.

***Keywords*:** Fabaceae, Caesalpinioideae, Pollen morphology.

Pollen diversity of Bignoniaceae in forest fragments of Brazil

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Bignoniaceae Juss. has about 82 genera and 827 species, belongs to the Lamiales, with 22 more families. This is a family with great distribution in tropical and subtropical regions. Most species of the Bignoniaceae occurring in the Neotropics show the climber habit, which environmentally makes the family one of the most important in the Americas. This work aimed to study the pollen diversity of 33 Bignoniaceae native species from forest fragments in the northwestern of São Paulo state: *Adenocalymma bracteatum* (Cham.) DC.; *A. marginatum* (Cham.) DC.; *Amphilophium paniculatum* (L.) Kunth; *Anemopaegma chamberlaynii* (Sims) Bureau & K. Schum.; *Bignonia sciuripabula* (K.Schum.) L.G.Lohmann; *Cuspidaria floribunda* (DC.) A.H.Gentry; *Cybistax antisyphilitica* (Mart.) Mart.; *Fridericia chica* (Bonpl.) L.G.; *F. craterophora* (DC.) L.G.; *F. formosa* (Bureau) L.G.Lohmann; *F. leucopogon* (Cham.) L.G.Lohmann; *F. mutabilis* (Bureau & K. Schum.) L.G.Lohmann; *F. platyphylla* (Cham.) L.G. Lohmann; *F. pubescens* (L.) L.G.Lohmann; *F. pulchella* (Cham.) L.G. Lohmann; *F. samydoides* (Cham.) L.G.Lohmann; *F. triplinervia* (Mart. ex DC.) L.G. Lohmann *Handroanthus heptaphyllus* (Vell.) Mattos; *H. impetiginosus* Mattos; *H. ochraceus* (Cham.) Mattos; *H. serratifolius* (Vahl) S.O.Grose; *Jacaranda cuspidifolia* Mart.; *J. macranta* Cham.; *Lundia obliqua* Sond.; *Pithecoctenium crucigerum* (L.) A.H.Gentry; *Pleonotoma tetraquetra* (Cham.) Bureau; *Pyrostegia venusta* (Ker Gawl.) Miers; *Stizophyllum perforatum* (Cham.) Miers; *Tabebuia aurea* (Silva Manso) Benth. & Hook.F. ex S.Moore; *T. roseoalba* (Ridl.) Sandwith; *Tanaecium selloi* (Spreng.) L.G.Lohmann; *Tynanthus elegans* Miers; *Zeyheria tuberculosa* (Vell.) Bureau ex Verl. The pollen materials were obtained from dried herbarium specimens supplied from SJRP and SP herbaria. Pollen grains were acetolysed, measured, photographed, and described qualitatively. The quantitative data were analyzed by descriptive statistics and multivariate statistics. These species have pollen grains in tetrads or monads, medium to large, isopolar, with circular to subcircular amb, oblate, oblate spheroidal or suboblate, inaperturate, 3-colporate to (7)-8-(9)-colpate, with long colpi, lalongate or inconspicuous endoapertures, exine psilate-perforate, microreticulate or reticulate, homo or heterobrocate. The results obtained indicate a euripalynous family.

***Keywords*:** Bignonieae, palynology, pollen grains, euripalynous, forest fragments

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Pollen morphology in Brazilian species of Gloxiniinae (Gesneriaceae)

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Gesneriaceae Juss. has approximately 150 genera and 3500 species, widely distributed in the tropics and few representatives in temperate regions, being northwestern of South America and southeastern of Brazil main centers of diversity. The subtribe Gloxiniinae has about 21 genera and 160 species. In Brazil, the subtribe has 16 species, distributed in eight genera, exist three endemic and usually found on rocky outcrops of savannas, rock fields and gallery forests. They present as herbs and subshrubs, with scaly rhizomes and fruit with capsule dry or fleshy. The objective of this work is to study the pollen morphology of five Brazilian species: *Chautemsia* A. O. Araujo & V. C. Souza (*C. calcicola* A. O. Araujo & V.C.Souza), *Gloxinia* L'Hér. (*G. alterniflora* A. O. Araujo & Chautems, *G. erinoides* (DC.) Roalson & Boggan, *G. perennis* (L.) Fritsch), *Seemannia* Regel (*S. sylvatica* (Kunth) Hanst.). The pollen materials were obtained from dried herbarium or preserved in 70% ethanol specimens, supplied from UFABC and SP herbaria. Pollen grains were acetolysed, measured, photographed, and described qualitatively. The quantitative data were analyzed by descriptive statistics and multivariate statistics. These species have pollen grains in monads, small to medium, isopolar, with circular to subcircular amb, oblate spheroidal or suboblate, 3-colporate, with long colpi, lolongate endoapertures, exine microreticulate or reticulate, homo or heterobrocate. The results obtained in this study indicate that Brazilian species have diversified pollen grains, are then classified as euripalynous genera.

***Keywords*:** Gloxinieae, Brazilian species, palynology, pollen grains, euripalynous

Palynotaxonomy in Brazilian species of *Codonanthe-Codonanthopsis* complex (Gesneriaceae) and related genera

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The Gesneriaceae family has about 147 genera and 3.460 species, being positioned in the recent ratings Asterid I (Lamiales). This is a pantropical family with widespread distribution, in Brazil the species belongs to the subfamily Gesnerioideae with 211 species in 27 genera, and 140 endemic. Some authors state that both the family, as the subfamilies are considered monophyletic based on morphological and molecular data, but other authors stating that the available data are not sufficient for understanding the large groups of Gesneriaceae. This study aims is to describe the pollen morphology of 31 species divided into four genera: *Codonanthe* (Mart.) Hanst., *Codonanthopsis* Mansf., *Nematanthus* Schrad. and *Paradrymonia* Hanst., contributing to the morphological characterization of species, identifying pollen data can help the taxonomy of the group, and providing subsidies to a better understanding of the relationships between genera and species. The pollen grains were acetolysed, measured from 25 grains randomly taken in at least four slides and photographed under light microscopy, and pictures were taken using scanning electron microscopy to observe the exine ornamentation. Quantitative data given appropriate statistical analysis according to sample size and in order to identify the discriminating pollen characters for species identification, a multivariate analysis will be performed. Qualitative data were described and grouped into pollen types contributing to species identification and understanding of the evolution of the group. The pollen material analyzed were taken from cultivation in Mogi das Cruzes-SP, Herbarium of the São Paulo and Herbarium of the National Institute of Amazonian Research (INPA). The analyzed species have pollen grain: monads, small to large (large species: *Codonanthe calcarata* and *Codonanthopsis ulei*); isopolar; oblate spheroidal, prolate spheroidal, subprolate (*Nematanthus bijou* and *Paradrymonia glabra*) to prolate (*Codonanthe gibossa*); circular, subcircular to subtriangular (*Nematanthus* species) amb; 3-colpate, 3 (4)-colpate (*Codonanthopsis ulei*), long or short colpi. Foveolate, reticulate, microreticulate or rugulate exine. Were defined four pollen types based on pollen grain ornamentation. The results confirm the euripolinic character of the studied genera.

***Keywords*:** Gesneriaceae, Gesnerioideae, pollen, pollen morphology, palynotaxonomy

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Contribution to pollen characterization of Cactaceae (Juss.)

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The Cactaceae family has neotropical distribution (centers of diversity and endemism in Mexico, southwestern United States, Peru, Bolivia and eastern Brazil, the last with 37 *genera* and over 200 species). The plants are xerophytes, except the epiphytic species, that originated from tropical forests. The circumscription of many *taxa* shows inconsistencies in view of variation in morphological characters. To contribute to the pollen characterization, the following species were analyzed: *Opuntia ficus-indica* (L.) Mill., *Nopalea cochenillifera* (L.) Salm-Dyck, *Rhipsalis baccifera* (J. M. Muell.) Stearn, *Rhipsalis elliptica* Lindberg ex K. Schumann., *Pereskia aculeata* Mill., *Pereskia grandifolia* Haw., *Schlumbergera truncata* (Haw.) Moran e *Epiphyllum oxypetalum* (DC.) Haw. The grains were prepared by acetolysis method. The observations took place under light microscope and scanning electron microscope (SEM). Observations were made on the polar axis (P) and the equatorial axis (E) and are in micrometers (µm). The characterization of the form of the pollen grains was performed by calculating the ratio P/ E, based on the analysis of 25 photos of each species.Pollen grains were in monads, with circular *ambitus*, radial simmetry, isopolar. The form was prolate-spheroidal (*O. ficus-indica*, *N. cochenillifera*, *R. baccifera*, *R. elliptica*, *E. oxypetalum)*, spheroidal (*P. aculeata*, *P. grandifolia*) and oblate-spheroidal (*S. truncata*); size large (medium for *R. baccifera*); average measure of polar and equatorial axes: *O. fícus-indica* (P=94,05, E=89,92), *N. cochenillifera (*P=94,22, E=91,07*)*, *R. baccifera* (P=49,826, E=47,074), *R. elliptica (*P=56,08, E=50,07), *P. aculeata (*P=72,87, E=72,94*)*, *P. grandifolia* (P=71,08, E=71,22), *S. truncata* (P=65,83, E=67,02), *E. oxypetalum* (P=98,85, E=104,29). The exine presented semitectate for *O. fícus-indica* with thickness of 8,54 and tectate perforate for *N. cochenillifera*,thickness 3,95 (perforate without *annulus*);

R. baccifera 2,24 (with *annulus*); *R. elliptica* 1,97 (without *annulus)*; *P. aculeata* 4,21 (with *annulus*); *P. grandifolia* 4,53 (with *annulus)*; *S. truncata* 3,93 (with *annulus*); *E. oxypetalum* 4,39 (with *annulus*). The grains presented all aperturate with aperture membrane ornamented: pantoporate in *O. fícus-indica* and *N. cochenillifera;* pantocolpate in *R. bacífera*, *R. elliptica* and *S. truncata;* pantocolpate with varying number of apertures irregularly arranged and Ubish bodies present in *P. aculeata* and *P. grandifolia;* trizonocolpate in *E. oxypetalum*. The ornamentation of the grains was lophate reticulate in *O. ficus-indica;* echinate in *N. cochenillifera* and *S. truncata* and microechinate in *R. baccífera*, *R. elliptica*, *P. aculeata*, *P. grandifolia* and *E. oxypetalum.* Obtained data allow to separate the subfamilies Cactoideae, Pereskiodeae and Opuntiodeae.

***Palavras chave*:** cactus, *Epiphyllum*, *Opuntia*, *Pereskia*, *Rhipsalis*, *Schlumbergera.*

Palynotaxonomy of *Alcantarea* (E. Morren ex Mez) Harms and *Vriesea* Lindl. (Bromeliaceae Juss.)

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The genus *Alcantarea* (E. Morren ex Mez) Harms has been traditionally classified as a subgenus of *Vriesea* Lindl., both belonging to the Tillandsiodeae subfamily. However, in other works *Alcantarea* is treated as an independent genus. Thus, obtention of palynological data may contribute to intergeneric and infra-generic delimitation of *Alcantarea* and *Vriesea.* Here we accessed the pollen morphology of both taxa, including 19 species of *Alcantarea* and 17 of *Vriesea*, totaling 75 specimens. Pollen grains were collected from flower buds from herbarium specimens deposited at the Herbaria SP, SPF, RB, UFRN and from fresh material from the collection of bromeliads of the Centro de Pesquisa em Plantas Ornamentais of the Instituto de Botânica, São Paulo, Brazil. The pollen grains were acetolysed, measured, described and photographed by light microscopy and electron micrographed on scanning electron microscopy. The results showed that the pollen pattern of *Alcantarea* is similar to *Vriesea*: pollen grains are heteropolar, amb elliptic (although *Alcantarea aurantiaca*, *A. burle-marxii*, *A. glaziouana*, *A. nahoumii*, *A. roberto-kauskyi* and *A. trepida* had some spheroidal pollen grains), monosulcate, sulcus with margin, reticulate ornamentation of the exine on the center area of pollen grain (except in *A. imperialis*, which displayed foveolate ornamentation) and apex of equatorial axe with different ornamentation (microreticulate calota or psilate-perforate calota) from the center area of pollen grain. Due to similarity in the pollen morphology both groups were considered stenopalynous and palyno characters do not corroborate the segregation of those genera. Nevertheless, the secondary pollen characters obtained here showed useful tools to the infra- and intergeneric palynotaxonomy, as the calota ornamentation and sexine thickness contributed to separation of the majority of the species of *Alcantarea* from *Vriesea*, mainly due to the predominance of microreticulate calota and the smaller dimension of the sexine of the latter. Moreover, some groups confirmed the relationship between species according to the morphological vegetative evidences and/or by relationships suggested by analyses based on DNA sequences or microsatellites, e.g., between *Alcantarea aurantiaca*, *A. burle-marxii* and *A. nahoumii*; between *A. hatschbachii* and *A. duarteana*; between *A. roberto-kautsky* and *A. trepida*; between *Vriesea medusa* and *V. nanuzae*. These data increases the morphological characterization of both genera and can contribute to phylogenetic analyses or be used in a biosystematics approach to solve species complexes.

***Keywords*:** Bromeliaceae, pollen grains, pollen morphology, Tillandsioideae, Vrieseeae

Pollen flora of Asteraceae in the Parque Nacional do Itatiaia, Rio de Janeiro, Brazil

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The Southeast Region of Brazil represents the diversity of Greater Centers for Asteraceae family, and it is in this region that is the Itatiaia National Park, located between the coordinates 22°30'22°33 ' S; 44°30', 44°45'W. The Park was created in June 1937, the first Brazil 's Conservation Unit , currently has about 30.000 hectares of biotic and geomorphological heritage and is covered by dense rain forest, montane and upper montane in various stages of preservation, and *campos de altitude*. A previous survey showed the occurrence of 175 species of Asteraceae to the study area, until now were analyzed 51 species subordinate to 10 tribes (Barnadesioideae, Mutisieae, Cardueae, Vernonieae, Senecioneae, Gnaphalieae, Anthemideae, Astereae, Heliantheae and Eupatorieae). The material for pollen analysis was obtained from samples taken in the field and herbarium specimens deposited in the herbarium of the National Museum of Rio de Janeiro (R). The pollen grains were treated by the method of acetolysis, measured and photomicrographed by light microscopy and scanning electron microscopy. For the analysis of pollen grains were considered the size, shape, type and number of apertures and the ornamentation of sexine. The taxa analyzed present pollen grains in monads, isopolar, medium mostly large in Cardueae, small to medium in Astereae and medium to large in Mutisieae; subprolate in Barnadesieae, prolate in Mutisieae, prolate spheroidal, oblate spheroidal to the other tribes; 3- colporate (except in *Elephantopus mollis* L. - Vernonieae - porate); the polar area and the size of colpi varies greatly between species and tribes; the ornamentation of the sexine proved very important for the segregation of the tribes and their species. It was found sexine microechinate in Mutisieae, Cardue and Barnadesieae (the species of *Dasyphyllum* Kunth subordinate to Barnadesieae have a depression in mesocolpium forming a pseudopore), subechinolophate at echinolophate in species represented Vernonieae and echinate-perforate at echinate-scabrate in other tribes. The pollen analyzes reveal a variety between taxa of Asteraceae found in the study area. The sexine is of great value for the segregation of taxa, as well as the apertures that although the number is constant among taxa, type, shape, size and presence or absence of margins makes possible the recognition of tribes and genera.

***Keywords*:** Mata Atlantic, Asteraceae, *campos de altitude*, Pollen flora.

Studies on the megaspore wall in selected South American taxa of *Isoetes* Franchet

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As part of the study of the Isoetales from the southern South America were analysed the ultrastructural aspects of the megaspore surfaces of *Isoetes savatieri* Franchet, *Isoetes gardneriana* Braun and *Isoetes panamensis* Maxon & Morton. The megaspore ornamentation is one of the main morphological characters utilized in the taxonomy of *Isoetes*. In all the species the megaspore surface has a mineral cover. There were analysed the general megaspore organization, structure, ultrastructure and resistance of the "outer cover". There were included also the characteristics of the structural elements that fill the spaces of the middle and outer exospore layers and, the surfaces of the cover layer and exospore. Spores were obtained from herbarium specimens from Brazil, Paraguay and Argentina. The megaspores were treated with hydrofluoric acid. The results were given with stereoscopic microscope, scanning and transmission electron microscopes. The megaspores are trilete, 350-580 µm in equatorial diameter. After chemical treatment the megaspores changed in color from white to light brown with angles and zone translucent with an inner network. When studied with episcopy the laesurae and zone looked like membranous and thin. The mineral contents were concentrated in the spore angles, zone and, outer exospore levels since they are observed as white in surface. The fact that the outermost layers of the outer cover were reduced was evidence that the chemical composition was mainly siliceous. The exospore surface ornamentation had lines in those megaspores untreated. Short elevations marked the position of the former ridges or rugae on the cover surface. The outer exospore and the whole mineral cover are open systems.

***Keywords*:** South America, Lycophyta, *Isoetes*, megaspores, ultrastructure.

Pollen morphology of *Tovomita* (Clusiaceae) and related genera

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Tovomita (Clusiaceae, tribe Clusieae) comprises about 70 neotropical species, one-half of which occur in the Brazilian Amazon and Atlantic forests. Except *Clusia*, pollen morphology of Clusieae representatives is insufficiently known. Our goal was to analyze pollen morphology of species of *Tovomita* and *Tovomitopsis*, a related genus with two Atlantic Forest species and find taxonomically useful characters for generic delimitation in Clusieae. Pollen grains of thirteen species of *Tovomita* and one species of *Tovomitopsis* were analyzed. Pollen was obtained from staminate floral buds held in CEPEC, HRB, HUEFS, INPA, and MG herbaria, and was characterized and morphologically compared among each other and with pollen from *Tovomitidium* and the fossil genus *Paleoclusia*. Pollen of the analyzed species are tricolporate, with amb circular to subtriangular, and exine psilate to reticulate. In *Tovomita*, only *T. volkeri* presented elongate lumina, different from the other species, which have circular lumina. Moreover, *Tovomita vismiifolia* showed a reticulate exine, while the remaining species had psilate, perforate, foveolate or microreticulate exine. Both *Tovomita* and *Tovomitopsis* pollen have a smooth tectum surface, but while the first has regular cylindrical baculae, the second has irregular twisted baculae. In addition to these palynological differences, the resin-producing flowers of *Tovomitopsis* help to distinguish the two genera. *Tovomitidium*, comprising two species from the Amazon Forest, is also related to *Tovomita*. Pollen grains of *Tovomitidium speciosum* are subprolate, tricolporate, and have reticulate exine, being very similar to pollen from most species of *Tovomita* studied so far. This result points to the necessary placement of *Tovomitidium* under *Tovomita*. *Paleoclusia* shares with *Tovomita* prolate, triaperturate pollen with reticulate exine and sexine elements inside the lumina, features that appear together only in *T. vismiifolia*. Despite the similarities in pollen morphology, these two genera do not appear phylogenetically related. Data presented here represent the first step to assess the palynological distinction between these poorly known genera of Neotropical Clusiaceae. Financial support: CNPq, PPGBot-UEFS.

***Keywords*:** Fossil pollen, Malpighiales, *Paleoclusia*, Palynology, *Tovomitopsis*

Palynology of species of Superorder Hypnanae W.R. Buck (Bryophyta)

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Mosses (Bryophyta) are cryptogamic, avascular plants that exhibit heteromorphic alternation of generations, in which the gametophyte is dominant and the sporophyte is ephemeral and spore producer. The spores have a great ecological importance, leading to the colonization of new environments, through long distance dispersal. Mosses sporoderm is divided into three layers: intine, exine and perine, the latter is responsible for ornamentation. The pleurocarpous mosses families, that show paraphylla, ovate leaves, and elongatedcells are included in superorder Hypnanae. This work is part of a project that aims to study the palynological features mosses, relating spores to adaptative features. At this time, it is presented the study of the following *Callicostella pallida* (Hornsch.) Ångström and *Thamniopsi sincurva* (Hornsch.) W.R. Buck (Pilotrichaceae), *Chryso-hypnum diminutivum* (Hampe) W.R. Buck, *Vesicularia vesicularis* (Schwägr.) Broth., *Isopterygium tenerum* (Sw.) Mitt. and *Isopterygium tenerifolium* Mitt.(Hypnaceae), *Donnellia commutata* (Müll.Hal.) W.R. Buck (Sematophyllaceae), *Entodontopsis nitens* (Mitt.) W.R. Buck & Ireland (Stereophyllaceae), *Hypopterygyum tamariscina* (Hedw.) Brid. Ex Müll. Hal. (Hypopeterygiaceae), *Fabronia ciliaris* (Brid.) Brid. (Fabroniaceae), *Schoenobryum concavifolium* (Griff.) Gangulee (Cryphaceae), *Neckeropsis undulata* (Hedw.) Reichardt and *Porotrichum mutabile* Hampe (Neckeraceae). The spores were analyzed under light microscopy (LM) and scanning electron microscopy (SEM). For LM, the spores were observed before and after acetolysis, taking standard measures with the aid of an ocular micrometer. Multivariate analysis (cluster analysis) was conducted to observe the grouping of species, including the palynological

and ecological features. The analyzed species have spores ranging from small to medium size, heteropolar, and ornate perine by granules of different sizes and kind of distribution. *V. vesicularia* has the smaller spores, and six species exhibit aborted spores in samples observed. Cluster analysis shows the formation of six groups with significance 0.65, highlighting *P. mutabile* in an exclusive group, with discreet ornamentation, and occurring only on two kinds of substrates. (FAPEMIG, CAPES, PGECOL/UFJF).

***Keywords*:** Moss, Multivariate analysis, Ornamentation, Sporoderm

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Variation of the structure of pollinarium in the subtribe *Stanhopeinae* (*Cymbidieae*, Epidendroideae, Orchidaceae)

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The *Stanhopeinae* is part of the group of subtribes belonging *to the* large *Cymbidieae*, having two bipartite pollinia. Within *Cymbidieae* ten subtribes are included showing a wide diversity in the pollinia characters, both in the presence of accessory structures, and in the number of pollinia (two, four or eight). To determine structural variations in the pollinarium of the *Stanhopeinae*, we studied fifteen characters in eight genera representing most of the tribe variation: *Acineta*, *Gongora*; *Houlletia*, *Paphinia*, *Polycycnis*, *Sievekingia*, *Stanhopea* and *Sotherosanthus*. *Stanhopeinae* is characterized by the presence of complete pollinarium that means all the accessory structures (caudicle, stipe and viscidium) but present variation: pollinia are compact, bipartite but morphologically distinct in each genus: oval (*Acineta*), elongated (*Gongora*), clavate-globose (*Gongora*), ellipsoid-globose (*Paphinia*), ellipsoid-flattened (*Polycycnis*), obovoid-globose *(Sievekingia)*, obovoid-flattened *(Sotherosanthus)* and, clavate-elongated (*Stanhopea)*. The exine is perforated fosulate. Its ornamentation is very similar in all taxa. The caudicles are freniculae, 50-500um long. The stipe is tegular in most genera, and variable in size. The stipe size is proved to be very informative and relevant because of its key role in the pollination process, since the long stipe facilitates the approximation of the pollinia to the stigmata. Two groups of the stipe size were differentiated: with short stipe≤ 2.3 mm (*Acineta*, *Gongora*, *Polycycnis*, *Sievekingia*, *Sotherosanthus*, *Stanhopea*) or long stipe 4.8-5.3 mm (*Houlletia* and *Paphinia*). Most of the *Stanhopeinae*, have removable viscidium, but diffuse in *Houlletia*, *Gongora*, and *Polycycnis*. In comparation to the smallest pollinaria (≤ 4.8 mm), a group of taxa present larger pollinaria: *Houlletia* (6.3 mm), *Stanhopea* (7 mm) and *Paphinia* (8 mm). A conclusion of this study is that within the *Epidendroideae*, subtribe *Stanhopeinae* presents most of the evolved characters states (e.g. two compact and bipartite pollinia). Within a genus, the pollinarium character states seem to be constant as were observed in different species. As a conclusion, our study, not only allow to know the variation in *Stanhopeinae*, but also to infer about which traits have co-evolved to make pollination more efficient in this subtribe.

***Keywords*:** Caudicle, Orchidaceae, Pollinia, Stipe and Viscidium.

Patterns exine in pollen grains of species of Dioscorea subgenus *Helmia* (Dioscoreaceae)

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Dioscoreaceae is comprised of four genera and about 650 species distributed worldwide, especially in the tropical and subtropical region. *Dioscorea* L. has the largest number of species, and it is the most widely distributed genus in the family. *Dioscorea* comprises four subgenera, and *Dioscorea* subgenus *Helmia* (Knuth) Uline is represented by 21 sections distributed in the tropical region, particularly in the neotropics.

D. subg. *Helmia* is characterized by an elongated wing toward the base of the seed. The palynological studyin *Dioscorea* species has characterized pollen grains with similar shape and aperture and different ornamentation of exine. The aims of this study were to describe the pollen grains of *D.* subg. *Helmia* species, and to assess their taxonomical relevance with respect to current biological knowledge of these species. The pollen grains of 10 species were studied and analyzed: *Dioscorea campestris* Griseb.; *Dioscorea stegelmaniana* R. Knuth; *Dioscorea chondrocarpa* Griseb.; *Dioscorea ovata* Vell.; *Dioscorea monadelpha* (Kunth) Griseb.; *Dioscorea subhastata* Vell.; *Dioscorea grisebachii* Kunth; *Dioscorea multiflora* Mart. ex Griseb. *Dioscorea glandulosa* (Griseb.) Knuth and *Dioscorea demourae* R. Knuth. Pollen material was obtained from fertile anthers of flowers in anthesis and/or in pre - anthesis from specimens deposited in the National Museum Herbarium (R). For study using light microscopy (LM), material was submitted to 60% lactic acetolysis, and measurements were taken within a maximum of three days after preparation. Non - acetolysed pollen grains were analyzed by scanning electron microscopy (SEM). The pollen grains are small or medium - sized. The aperture was mono or 2 - sulcate. When considering sexine, six groups were formed: Group Ia - reticulate, heterobrochate with granulae inside the lumina, the interrupted, narrow, straight muri (*D. campestris*) or Group Ib - reticulate, heterobrochate without granulae inside the lumina, narrow muri, straight reticulum (*D. multiflora*); Group II - microreticulate, narrow, straight muri, without ornamentation inside the lumen, variously lumina tending to elongate (*D. stegelmaniana*) with rounded lumina, with holes in the muri (*D. monadelpha*); Group III – perforate (*D. chondrocarpa* and *D. ovata*); Group IV - vermiculate, thick muri, sinuous, leaving spaces between them (*D. subhastata*); Group V - rugulate, rugulae conspicuous with sparse holes (*D. glandulosa*) and denser rugulae less conspicuous (*D. grisebachii*); Group VI – striato - reticulate with the striae of the rounded surface, narrow (*D. demourae*). After the analysis of pollen grains, it was concluded that the attributes of pollen distinguish the species. It is hoped that his study contributes to a better understanding of the taxonomy of the genus.

***Keywords*:** *Dioscorea*, exine, *Helmia*, pollen.

Pollen mporhology of Mimosoideae species (Fabaceae) at the UNEB, Paulo Afonso, Bahia, Brazil

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Fabaceae is recognized as the third largest botanical family with around 19.325 species. It is divided in three subfamilies: Caesalpinioideae, Faboideae and Mimosoideae. This family has a wide range and presents a high economic importance, and its ornamental species are present in landscaping, represented by woody plants such as the Mimosoideae subfamily, with about 3.270 species circumscribed in four tribes and 78 genera. Due to the wide distribution of Mimosoideae in Bahia it has a great potential regarding the landscaping and economic uses. This palynological study aimed to characterize the morphology of pollen grains from five shrub species of Mimosoideae found at the Bahia State University, *Campus* VIII, Paulo Afonso, Brazil. The pollen grains were collected directly in the flowers, acetolysed, measured, described, illustrated and examined by using light microscopy. The morphopolinic characteristics of the analyzed species revealed a great diversity in the pollen structure, since the species presented pollen grains in monads [*Prosopis juliflora* (Sw.) DC and *Leucaena leucocephala* (Lam.)]; size from medium to large, 3-colporate with psilate surface or fossulate, respectively; long type of colpi's ectoaperture and rounded or lolongate endoaperture. The polyads [*Calliandra riparia* Pittier, *Anadenanthera colubrina* (Vell) and *Senegalia* sp.]: whose average varied from 8 to 16 grains, with two central grains (*Calliandra riparia*) and eight grains in other species; the surfaces varied from rugulate, areolate or psilate. The great morphopolinic diversity found in the analyzed species of Mimosoideae raised at the UNEB *Campus* VIII, in Paulo Afonso, allows to classify this subfamily as euripalynous.

***Keywords*:** Pollen morphology, Fabaceae, Mimosoideae.

Taxonomic affinities of the Cactaceae fossil pollen grains recovered in Mexican Cenozoic basins

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The Cactaceae family is native of the New World and is divided into the Pereskioideae, Cactoideae and Opuntioideae subfamilies. Even though Cactaceae plants are well adapted to live in arid and semiarid climates, few is known about the ancestral environments of diversification. Mexico is the main diversification centre with 55 genera and about 850 species with high endemism. A comparative morphological study was conducted in modern Cactaceae pollen grains from the Tehuacán-Cuicatlán Valley (TCV) and pollen grains recovered from two Cenozoic basins exposed at the same valley: Mequitongo Formation (Eocene) and Tehuacán Formation (middle Miocene). Additionally, pollen grains from the late Oligocene San Gregorio Formation located at Baja California Sur, Mexico was analysed in this study. Both areas are at present important centers of cacti diversification. The objective of this contribution is to describe modern Cactaceae pollen grains in order to understand better the taxonomic affinities of fossil pollen grains. This research was supported by PAPIIT-DGAPA IN114914 project. Both modern and fossil Cactaceae pollen grains are tectate, perforate and supraechinate. Polar and equatorial axes, aperture types, as well as columellae diameter, dimension and density of echinae, together with type and density of perforations varied among taxa. In general, modern Cactaceae pollen grains showed bigger dimensions than fossil pollen grains and it could be related to polyploidy in modern grains. Pericolpate pollen type that has affinities to modern *Nopalea*, was recovered from the late Oligocene San Gregorio Formation. On the other hand, tricolpate pollen type related to *Neobuxbaumia* as well as pericolpate (aff. *Astrophytum*) and periporate (aff. *Cylindropuntia*) pollen types were recovered from the middle Miocene Tehuacán Formation. Finally, a periporate pollen grain was recovered from lower Eocene Mequitongo Formation. Paleoenvironmental reconstructions obtained from our palynological data suggest that during Paleogene and Neogene, the Cactaceae were part of the tropical deciduous forest. These results support molecular studies indicating cactus lineage divergence about 30 Ma, but with a major diversification occurring during middle Miocene.

Keywords: Cactaceae, Tehuacán-Cuicatlán, Paleopalynology, Cenozoic plants.

Palynotaxonomy of heterostylous species of *Psychotria* L. (Rubiaceae)

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Heterostyly is a controlled phenomenon genetically related to the way that a species produces its flowers, called brevistylous (long stilettos and short stamens) and longistylous (short stilettos and long stamens). Differences in the quantity produced, the size and ornamentation of pollen grains among the forms of heterostylous species can be explained by this floral polymorphism. In order to describe the pollen morphology and palynological attributes to be useful to the Rubiaceae family taxonomy, it was carried out the study of 36 specimens belonging to 11 species of *Psychotria* L. that have brevistylous and longistylous, most representative in the State of Paraná. The flower buds used were obtained from herbarium specimens deposited in Herbaria HUPG and MBM. The pollen grains were acetolysed, measured, described and photographed by light microscopy and electron micrographed on scanning electron microscopy. The pollen grains of the studied species varied from medium size [*P. carthagenensis* (longistylous) and *P. fractistipula* (brevistylous and longistylous)], to medium or large (*P. carthagenensis* (brevistylous); *P. leiocarpa* (brevistylous and longistylous), *P. myriantha* (brevistylous and longistylous); *P. nemorosa* (brevistylous and longistylous) and *P. vellosiana* (longistylous)], large [*P. brachypoda* (brevistylous); *P. fluminensis* (brevistylous and longistylous); *P. leiocarpa* (brevistylous); *P. nemorosa* (brevistylous and longistylous); *P. nuda* MBM5359 (brevistylous and longistylous); *P. stachyoides* (brevistylous and longistylous); *P. suterella* (brevistylous and longistylous) and *P. vellosiana* (brevistylous)], or very large [*P. fluminensis* (brevistylous)

and *P. nuda* (brevistylous)]; apolar or isopolar (only *P. carthagenensis* and *P. fractistipula*); spheroidal, suboblate, subprolate or prolate shape; inaperturate or 3-4-colpate (in *P. carthagenensis* 89% of 4-colpate in brevistylous form and 99% of 3-colpate in longistylous form, its at *P. fractistipula* 89% of 3-colpate in brevistylous form and 88% of 3-colpate in longistylous form), long and wide colpi with acute ends in *P. carthagenensis* (B) e *P. fractistipula* (B), or long and wide colpi with obtuse ends in *P. fractistipula* (L), long and narrow colpi with acute ends in *P. carthagenensis* (L); semitectate exine, microreticulate heterobrochate, microreticulate heterobrochate with intertwined muri or reticulate heterobrochate, sexine thicker than nexine. According to the results, it can be seen that the palynological data of *Psycothria* are important to the infra-generic palynotaxonomy, considered an euripalynous genus and, demonstrated the variations in the pollen morphology between brevistylous and longistylous specimens.

***Keywords*:** Heterostily, pollen grains, pollen morphology, *Psychotrieae*, Rubiaceae.

Palynological studies of *Chrysophyllum* L. (Sapotaceae) from Bahia State, Brazil

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In Brazil, Sapotaceae is represented by 12 genus and 232 species, estimated to Bahia the occurrence around 77 species in 11 genera. For *Chrysophyllum* L. genus there are 12 species cited so far. The aim this study is contributing to a best delimitation of the species as well as of extending knowledge on pollen morphology of this family. In present study, eight species of *Chrysophyllum* L. collected in Bahia state had analyzed pollen, such as: *Chrysophyllum flexuosum* Mart.; *C. inornatum* Mart.; *C. januariense* Mart; *C. marginatum* Hook. & Arn; *C. ramiflora* Mart.; *C. rufum* Mart.; *C. splendens* Spreng. and *C. viride* Mart. & Eichler. For pollen analysis, we collect floral buds and/or flowers from species. The pollen grains were acetolysed, prepared slide in jelly glycerin and their morphological characters were analyzed and micro photographed using light microscopy. *Chrysophyllum L*. genus presents pollen grains in monads isopolares; small to medium sizes; subprolate, prolate to perprolatos forms; subtriangular to subcircular ambitus; 3-colporate and 4-colporate; colpo ranging from short to long; endoapertures elongated with presence of costa; exine ranging from psilate the microreticulate. Based on the analysis of pollen morphology of the species studied, it can be concluded that genus has pollen homogeneity, thus confirming its stenopalynous character. Being one of the first studies in Bahia on the pollen morphology of the *Chrysophyllum L*. genus, this could support further studies both at local and regional level, in various areas of Palynology, as well as contributing to delimitation of its species.

Keywords: Pollen morphology, Pollen grains, Palynology, Palynotaxonomy

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Pollen morphology of *Aeschynomene* L. serie *Viscidulae* (Leguminosae - Papilionoideae)

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Recent combined data sequences revealed that *Aeschynomene* L is a genus segregated into two paraphyletic sections. The section *Aeschynomene* is also paraphyletic and the section *Ochopodium*, monophyletic and *Machaerium* Pers. sister. The *Ochopodium* section has four series (*Viscidulae* Rudd, *Pleuronerviae* Rudd, *Scopariae* Rudd, *Sclerosae* A. Fernandes), in which *Viscidulae* owns 11 species found in Brazil. Five of them [*A. histrix* Poir.- (SP287518, SP36784, SR175266, SP108007, SP82107, SP153559, SP139231), *A. vogelii* Rudd.- (SP166653, SP199425), *A. elegans* Schltdl. & Cham - (SP45342, SP25250, RB241043), *A. viscidula* Michx. - (SP249472), *A. falcata* (Poir.) DC.- (SP168465, SP138095, SP310002)] had their pollen grains

analyzed, aiming to assist in the *Aeschynomene* infrageneric delimitation. The pollen grains were acetolysed, measured and photographed in optical microscope, electromicrographed in scanning electron microscope, statistically analyzed and described according to the specialized literature. The pollen grains of the species of *Aeschynomene*, serie *Viscidulae* are monads; small (*A. histrix* has the smallest pollen grains and *A. falcata* the largest); isopolar; oblate-spheroidal, prolate-spheroidal to subprolate; circular, subcircular, subtriangular or triangular amb; 3-colporate, angulaperturate. The colporus shows pointed apices, longiaperturate (*A. viscidula*), longiaperturate to very longiaperturate (*A. histrix*, *A. falcata*) or only very longiaperturate (*A. vogelii*, *A. elegans*). Operculate colporus with rugulate-granulate (*A. viscidula*, *A. vogelii*) and/or insulate (*A. histrix*), rugulate-microreticulate (*A. falcata*) or microreticulate with sparse granulum (*A. elegans*) ornamentation. Endoaperture lalongate (*A. viscidula*), circular to lalongate (*A. vogelii*) or circular, lalongate to lolongate (*A. histrix*, *A. elegans*, *A. falcata*), with endoaperture protruding (*A. falcata*, *A. vogelii*). Sexine rugulate with perforation (*A. vogelii*) or microreticulate, heterobrochate (*A. histrix*, *A. elegans*, *A. falcata*, *A. viscidula*). *A. histrix* presents curved muri in mesocolpium with small lumina in apertural area and microreticulate apocolpium; *A. elegans* with curved, interrupted muri in mesocolpium and straight and curved, not interrupted muri in apocolpium; *A. falcata* with curved and intertwined muri; *A. viscidula* with intertwined muri, with predominance of curved muri in mesocolpium and straight muri in apocolpium. Sexine thicker than nexine. It was possible to characterize the *Aeschynomene* serie Viscidulae pollen grains and conclude that, the sexine ornamentation in mesocolpium, in apocolpium and in operculum helped in distinguishing species, although stenopalynous. Then the palynotaxonomy can be helpful for future phylogenetic analyzes for both the series and to higher levels taxa.

***Keywords*:** Aeschynomeneae, Ochopodium, pollen grains, palynology, palynotaxonomy.

Pollen morphology of *Thyrsacanthus* Moric

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Thyrsacanthus Moric. is a group represented by five species (*T. boliviensis* (Ness) A. Côrtes & Rapini, *T. microphyllus* A. Côrtes & Rapini, *T. ramosissimus* Moric., *T. ramosus* (Ness) A. Côrtes & Rapini and *T. secundus* (Leonad) A. Côrtes & Rapini). Occur in dry forests of South America, regions of the Caatinga, in salt marshes in the North and Northeast of Brazil and in dry forests in the interface areas of Cerrado and Atlantic Forest (*T. ramosus*). The genus is part of the family Acanthaceae, comprising about 200 genus and 3.500 species with a pantropical distribution. The pollen morphology has been used as an important source of character in the reorganization of its type within Acanthaceae, thus, the study aims to perform a detailed description of pollen morphology for the species of *Thyrsacanthus*. The pollen samples were obtained from herbarium specimens deposited in the Herbarium of the Universidade Estadual de Feira de Santana (HUEFS), Instituto Nacional de Pesquisas da Amazônia (INPA) and the Herbário Alexandre Leal Costa (ALCB). For light microscopy (LM) analysis the pollen grains were acetolyzed, mounted between slides and cover slips with glycerine gelatin, measured, photographed and described based on the shape, aperture, size, polarity, ornamentation and structure of the exine. Pollen grains, not acetolyzed, were mounted on stubs with carbon strip and subsequently coated with gold for scanning electron microscopy (SEM). Pollen grains were observed, photographed and described. *Thyrsacanthus* presents pollen grains in monads, subprolate to prolate spheroidal, medium to large (*T. secundus*) sized, amb subtriangular, heterocolpate (3-colporate, 6-pseudocolpate) - each colporus is two sided by two pseudocolpus. *T. microphylus* presented syncolporate pollen grains and *T. ramosus* have the following apertural features: parasyncolporate, pseudosyncolpate and parasyncolporate/pseudosyncolpate. Membrane and the margin of ectoaperture are granulated. The endoaperture membrane is microequinate. Exine is microreticulate to reticulate, except on *T. microphyllus* (granulate), with granules distributed like a reticulum in the analysis of SEM, but seen as microreticulated in LM. Sexine thicker than nexine. Based on these results, it is concluded that the *Thyrsacanthus* species share similar pollen characters, but *T. microphyllus* showed divergence in exine ornamentation when compared data of LM and SEM. Financial support CNPq, Capes, PPGBot-UEFS, Fiocruz-BA.

***Keywords*:** Acanthaceae, palynotaxonomy, pollen analysis, Brazil

Pollen morphology of species of Melastomataceae occurring in a semiarid region

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The Melastomataceae family is considered one of the greatest families among Angiosperms, distributed in tropical and subtropical regions. In Brazil, the family occurs in 60 genera with 1000 species distributed in all biomes. The present research aimed to characterize the pollen morphology of species of Melastomataceae with occurrence in the district of Brejinho das Ametistas, an area of ecotone (caatinga, cerrado, seasonal and seasonal deciduous rainforests). The pollen samples was obtained from herbaria specimens deposited at Universidade do Estado da Bahia - *Campus* VI (HUNEB) and Universidade Estadual de Feira de Santana (HUEFS). In addition, field trips were conducted to address the lack of pollen samples. The samples for ligth microscopy (ML) were acetolysed and mounted between slides, measured, photomicrographed and described according to the literature. For analysis of scanning electron microscopy (SEM), non-acetolysed pollen grains were placed in stub with carbon tape, metallized and analyzed. Twenty one species belonging to tribes Melastomeae (*Pterolepis* Miq. *Tibouchina* Aubl.) Memecyleae (*Mouriri* Aubl.) Miconieae (*Clidemia* D.Don, *Macairea* DC. *Miconia* Ruiz & Pav.) and Microlicieae (*Cambessedesia* DC. *Microlicia* Naudin, *Rhychanthera* DC. *Trembleya* DC.) were studied. The described species had dispersed pollen grains in monads; with small and medium size; shape ranging from prolate spheroidal to oblate spheroidal, prolate or subprolate; isopolar; amb ranging from constricted polygonal to quadrangular or subtriangular; heteroaperturate, 3-colporate and 3-colpate (some pollen grains with eight apertures); endoaperture is circular, lalongate or lolongate; exine is microreticulate, psilate, rugulate, microrrugulate, regulate perforate, perforate, striate, striate-rugulate, granulate, microverrucate, verrucate-perforate with granules in the apertures. The data corroborate the stenopalynous condition in the family under LM, however considerable morphological variation in exine ornamentation support the euripollinic condition for the family based on the SEM analysis. Financial support CNPq, PICIN, Fiocruz-BA.

***Keywords*:** Palynotaxonomy; ecotone; Brejinho das Ametistas; Bahia; Brazil

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Pollinic characterization of *Raulinoa echinata* R. S. Cowan (Rutaceae) and *Dyckia brevifolia* Baker (Bromeliaceae), reophyte and endemic species of Itajaí-Açu river, Santa Catarina, Brazil

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On the Itajai-Açu river, Southern Brazil, in the state of Santa Catarina, about 80 km between the municipalities of Lontras and Blumenau, there are shores, rapids and rocky islands where thrive some endemic riparian reophytes, among them *Raulinoa echinata* R. S. Cowan (Rutaceae) in groupings of discontinuous occurrence only on the right side of the river and *Dyckia brevifolia* Baker (Bromeliaceae) in disjunct populations. Besides their phylogenetic importance, these species are endangered as the environment is threatened by the construction of dams and hydroelectric plants. There is no description of the pollen grains of the species. Aiming to contribute to the pollinic characterization, the mentioned species were analyzed. The grains were prepared by acetolysis method. The observations took place under light microscope and scanning electron microscope (SEM). Observations were made on the polar axis (P) and the equatorial axis (E) and are in micrometers (µm). The characterization of the form of pollen grains was performed by calculating the ratio P/ E, based on the analysis of 25 photos of each species. The pollen grains of both species were in monads. *R. echinata* pollen grains presented radial symmetry, were isopolar and showed (as average maximum value) medium size (40.41). The form was prolate and the *ambitus* subcircular. The species is 3-aperturated, with long *colpi* and lalongate endoapertures. The ornamentation of the grains, at SEM, is striated. The average thickness of the exine was 1.53. *D. brevifolia* pollen grains presented bilateral symmetry, were heteropolar and showed (as average maximum value) medium size (32.28). The form was prolate and the *ambitus* elliptical. The species showed monoaperturated grains, with one long *colpus*. The ornamentation of the grains, at SEM, was reticulate. The average thickness of the exine was 1,662. Phylogenetic studies suggest the proximity of *Raulinoa*, monospecific *genus* included in subtribe Pilocarpinae, tribe Galipeeae, subfamily

Rutoideae, with *Metrodorea*, a *genus* with eight species, all native to Brazil and with few records in Suriname and Bolivia. Our results can contribute to sustain the proximity of these *taxa*, which show among them more synapomorphies than with other *genera.* On the other hand, the characteristics found for *D. brevifolia* match, in a general way, the pattern described for the *genus*, whose subfamily (Pticairnoideae) is considered stenopalynous, contributing to the insertion of the species in the group.

Keywords**:** *cutia-de-espinho*, *gravatá*, *hydroelectric plant*, *Salto Pilão*, *sarandi.*

Palynology of Brazilian species of *Lippia* L. sect. *Rhodolippia* Schauer (Verbenaceae)

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Lippia L., subordinated to tribe Lantanae (Moldenke, 1973), is the second largest genus of Verbenaceae, being described in 1753 for the first time by Linnaeus. It is represented by herbs, shrubs and small trees. It has approximately 100 species, ocurring in Brazil, Mexico, Central America, Africa, Paraguay and Argentina (Troncoso, 1974). The *Lippia* problematic due to the fact that many authors fail to reach a conclusion as to the current number of species of the genus, which has been the subject of several taxonomic studies. Currently, *Lippia* can be considered a poorly delimited and defined genus. Presents seven sections: *Dioicollipia* Troncoso, *Dipterocalyx* (Cham.) Schauer, *Goniostachyum* Schauer, *Lippia* Schauer, *Rhodolippia* Schauer, *Pseudoaloysia* Troncoso and *Zapania* Schauer. Were analysed the pollen grains of 11 species of *Lippia* sect. *Rhodolippia*: *L. diamantinensis* Glaziou, *L. elliptica* Schauer, *L. eupatorium* Schauer, *Lippia felippei* Moldenke, *L. florida* Cham, *L. gardneriana* Schauer, *L. gerthii* Moldenke, *L. lindmanii* Briq, *L. lupulina* Cham, *L. possensis* Moldenke and *L. rhodocnemis* Mart. & Schauer in order to offer higher subsidies to the taxonomy of the genus. Pollen material was obtained from fertile anthers of flowers in anthesis and/or from buds in pre-anthesis, derived from samples deposited in herbaria in southern Brazil: CESJ, MBM and SPF. The pollen grains were acetolysed, measured, described and illustrated using light microscopy (LM). For scanning electron microscopy (SEM), anthers were macerated and the pollen grains, non-acetolyzed, were pulverized over stubs covered in carbon tape. The pollen grains were characterized by the form, size, type of apertures, the polarity and the ornamentation of the exine. The species showed isopolar pollen grains, monads, medium size, prolate spheroidal (*L. lindmanii* and *L. lupulina*) and oblate spheroidal (other species), 3-colporate, with long colpi with tapered ends, small polar area, presence of fastigium, h endoaperture in *L.diamantinensis*, *L. lupulina and L. rhodocnemis* and lalongate endoaperture in other species; exine with perforated ornamentation. We conclude that, until now, the *Rhodolippia* section is estenopolinic. This study contributes to the knowledge of the taxonomy of the genus and provides important data for future analysis. (CNPq, FAPERJ).

Keywords**:** *Lippia*, Verbenaceae, Palinology, Brazil

Pollen morphology of the shrub and arboreal flora of Restingas of Bahia State, Brazil

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Restinga is a typical vegetation on quartzitic, sandy, nutrient-poor parent materials along the Brazilian coast, and considered to be marginal habitats of the Atlantic Rainforest Domain. Restingas includes herbaceous plant communities as well as assemblages dominated by shrubs or trees, with widely varying canopy coverage. Restingas occur along approximately 70% of the Brazilian coastline and presents differences in physiognomy, structure and floristic composition. The restingas of Bahia State occupies large areas along 1,120km of its coastline and they have 113 shrub and arboreal species, grouped into 82 genus and 41 families. This research aimed the characterization of the pollen morphology of the species of the shrub and arboreal flora of restingas of the Bahia. Pollen grains from flower buttons, obtained from herbarium specimens, were acetholysed, described, measured, and photomicrographed under optical microscope.

Myrtaceae, Fabaceae, Anacardiaceae, Malpighiaceae, Chrysobalanaceae and Sapotaceae are among the most representative families. All species had their pollen grains described and illustrated in that first atlas of the pollen flora of the restingas of Northeastern Brazil. The results will help in Palynology studies applied in the region and will contribute to taxonomic studies of groups.

***Keywords*:** pollen flora, Northeastern Brazil, coastland.

Diversity palynological of the species of Acalyphoideae (Euphorbiaceae) occurring in the Caatinga, with emphasis on endemic species

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The subfamily Acalyphoideae has a pantropical distribution, including 110 genera and about 1500 species, of these, five genera and 11 species are endemic from Caatinga. The group is considered the largest and most complex of the three subfamilies of Euphorbiaceae. Palynological studies focusing on species found in Caatinga areas are quite incipient, therefore, this study aimed to characterize the polinic morphology of the Acalyphoideae species occurring in the Caatinga, focusing on endemic species. For this, we studied six species and three genera: *Dalechampia allemii* G.L.Webster, *D. peckoltiana* Müll.Arg., *D. purpurata* Cordeiro, *Ditaxis gardneri* (Müll.Arg.) Pax & K.Hoffm., *D. malpighiacea* (Ule) Pax & K.Hoffm. and *Omphalea brasiliensis* Müll. Arg, four of these species are endemic from the Biome. The polliniferous material was obtained of duplicates or exsiccates deposited in the Herbário da Universidade de Feira de Santana (HUEFS), Herbário da Universidade do Estado da Bahia (HUNEB) e Herbário Professor Vasconcelos Sobrinho (PEUFR). The pollen grains were acetolysed, measured, analyzed statistically, photomicrographed and described under light microscopy and scanning electron microscopy. In general, the pollen grains are monads, with medium to large size, isopolar, ranging from suboblate to subprolate, amb subcircular, circular and subtriangular; with very small polar area, small to large, 3-(4)-colporate and 3-colpate, apertural membrane granulate to echinate-granulate, with endocingulum and costa (*Dalechampia* spp.), endoaperture lalongate; exine microreticulate (*Ditaxis gardneri*), reticulate (*Dalechampia* spp.), bireticulate (*Ditaxis malpighiacea*) to microechinate-perforate (*Omphalea brasiliensis*), with sexine thicker than nexine. Based on the exine ornamentation, it was possible to establish four pollen types, which gave well marked characters every genus analyzed, except only for the species of the genus *Ditaxis*, that presented two ornamental patterns of exine. Thus, the subfamily showed variations in morphopolinical characters of great diagnostic value, as the apertural type and ornamentation of exine, demonstrating the eurypalynous character of the group. Financial support: CAPES, CNPq (#405636/2013-0).

***Keywords*:** Euphorbiaceae, Acalyphoideae, Caatinga, pollen grains, pollen morphology

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Pollen morphology of species of tribe Hippomaneae (Euphorbiaceae) occurring in the Caatinga

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Hippomaneae A. Juss. ex Bartl. is considered the second largest tribe Euphorbioideae, it consists of 33 genera and about 300 species with pantropical distribution and greater representation in the America. Brazil is one of the centers of diversity, with 13 genera and about 120 species, has the most representatives occurring in the Northeast, where the Caatinga is inserted. Its systematic position and its main morphological diagnostic characters are still discussed, therefore, this study aimed to characterize morphologically the pollen grains of species representing of the Hippomaneae that occur in the Caatinga, contributing to the palynological knowledge and taxonomic and phylogenetic studies of the group. Flowers and flower buds of 12 species in

five genera [*Mabea glaziovii* Pax & K.Hoffm, *Microstachys heterodoxa* (Müll.Arg.) Esser, *M. marginata* (Mart. & Zucc.) Klotzsch ex Müll.Arg., *M. revoluta* (Ule) Esser, *M. uleana* (Pax & K.Hoffm.) Esser, *Sapium argutum* Huber, *Sebastiana corniculata* Müll. Arg., *S. jacobinensis* Müll. Arg., *S. macrocarpa* Müll. Arg., *S. myrtilloides* (Mart.) Pax, *S. larensis* Croizat & Tamayo, *Stillingia trapezoidea* Ule] were collected from herbarium specimens (UFP, HUEFS, HUNEB and HVASF). The pollen grains were acetolysed, measured, analyzed statistically, photomicrographed and described under light microscopy and scanning electron microscopy. Pollen grains are small and large, suboblate to prolate, amb subcircular to circular, with very little polar area to small; 3-(4) colporate, with psilate margin and granulated apertural membrane, sinuaperturated, parasyncolporate, endoaperture lalongate, exine microreticulate (sometimes with caveate) and reticulate, with sexine thicker than nexine. The results showed that the species of the group studied have variations in size, shape, amb, polar area and ornamentation of exine and that the presence of margin is a remarkable pollen character to the tribe.
Financial support: CAPES, CNPq (#405636/2013-0).'

***Keywords*:** Euphorbiaceae, Hippomaneae, Caatinga, pollen grains, pollen morphology

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Contribution to pollen morphology to the Leguminosae in a fragment of Atlantic Forest, Bahia, Brazil

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In the Atlantic Forest, Leguminosae is represented by about 154 genera and 997 species, of which about 40% are endemic. In a forest fragment in the municipality of Alagoinhas (12°08'08"S; 38°25'09"W) Bahia-Brazil, the family records about 40 species, with 12 species still unrecorded descriptions of pollen, leading to goal this work to characterize morphologically the pollen grains of these species. The species analyzed are divided into the subfamilies Caesalpinioideae (*Bauhinia corifolia* L. P de Queiroz, *Sclerolobium densiflorum* Benth, *Senna pinheiroi* H.S.Irwin & Barneby, *Senna quinquangulata* (Rich.) H. S. Irwin & Barneby); Mimosoideae (*Abarema cochliacarpos* Barneby & J. W. Grimes, *Abarema filamentosa* (Benth.), *Inga tenuis* (Vell.) Mart *Samanea tubulosa* (Benth) Barneby & J. W. Grimes.); Papilionoideae (*Crotalaria stipularia* Desv, *Dioclea lasiophylla* Mart. ex Benth, *Dioclea virgata* (Rich.) Amshoff and *Swartzia apetala* Raddi). The pollen grains was obtained from floral buds collected from exsiccate deposited in the Herbarium of the University of the State of Bahia (HUNEB) and Herbarium of the State University of the Feira de Santana (HUEFS), submitted to acetolysis treatment, was examined with LM. The species of the subfamily Mimosoideae presented pollen grains gathered in large polyads (83-141μm), with 16 pollen grains (*Abarema filamentosa*) or with 28 pollen grains in polyads (*Abarema cochliocarpos*, *Inga tenuis*, *Samanea tubulosa*); and exine microreticulate and areolate (*A. cochliacarpos* and *A. filamentosa*). In subfamilies Papilionoideae and Caesalpinioideae of the pollen grains presented in monads, with medium (29-46 μm), large (54-68 μm) and very large (152 μm) size; isopolar and heteropolar (*D. lasyophyla* and *D. virgata*); with triangular, circular and subtriangular amb prolate spheroidal, subprolate and suboblate 3-colporate except *Bauhinia corifolia* (3-porate); and exine microreticulate and reticulate. The results for the species of Leguminosae studied showed high diversity pollen, already highlighted as a hallmark of the family by several authors, in addition to contributing new descriptions pollen family, which had not yet bibliographic records for the pollen morphology.

***Keywords*:** Pollen grains, Polyads, Monads, Leguminosae.

Pollen Flora of the "Serra da Fumaça", Pindobaçu, State of Bahia, Brazil

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"Serra da Fumaça" is located in Pindobaçu, town in the State of Bahia, Brazil, and it is part of the so-called "Drought Polygon", with its climate varying from dry to sub-humid there can be long periods of drought in that region. The predominant vegetation is represented by contacts of savanna-seasonal forest and savanna-caatinga. Based on a checklist, previously conducted by researchers at the University of the State of Bahia (UNEB), this study aimed to describe the pollen morphology of species of the fanerogamous flora found in the study area. Samples of polliniferous material were obtained from herborized specimens deposited in herbaria. The pollen grains of 181 plant species of 60 families were acetolysed, measured, analyzed and described under light microscopy. Fabaceae, Asteraceae, Rubiaceae, Melastomataceae and Euphorbiaceae are among the most representative families. The pollen descriptions allowed the characterization of genera and species, occurring in the study area. We found a large range of pollen characters. In most species studied pollen grains are dispersed as monads, less frequently, tetrads (Fabaceae and Gentianaceae spp.), polyads (Fabaceae spp.) and pollinia (Apocynaceae spp.). The apertural type 3-colporate was predominant, and also being registered pollen grains: colpate, porate, heterocolpate (Acanthaceae and Melastomataceae spp.), spiraperturate (Eriocaulaceae spp.), sulcate (Cyperaceae spp.) and inaperturate (Euphorbiaceae spp). Regarding exine ornamentation, pollen grains (micro) reticulate have prevailed among some species, however, were also observed psilate pollen grains, scabrate, granular, verrucate, areolate, rugulate, micro (echinate), and the Croton pattern type in species of Euphorbiaceae family. We present micrographs of pollen grains, together with descriptions of the characteristics of their structure. The results will help in palynology studies applied in the region and will contribute to taxonomic studies of groups. Detailed descriptions and illustrations of pollen grains will be presented in an atlas of pollen flora from "Serra da Fumaça".

***Keywords*:** Pollen, Pollen flora, Caatinga, Brazil

Spores of Bryophyta and adaptative strategies

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Bryophyta are cryptogamic, avascular, land plants, that exhibit an alternation of generations, in which the haploid gametophyte is photosynthetic, and perennial. This group differs from Anthocerotophyta and Marchantiophyta because it shows radially symmetric gametophytes, formed by stem, leaves and multicellular rhizoids; the gametangia are superficial. The sporophytes, in general, possess foot, seta and capsule with collumelar tissue. Historically, the morphological characters used as relevant in mosses classifications were perichaetial position and peristome characterization. Studies on spore morphology of mosses show importance to taxonomic evaluation and to phylogeny of mosses, however, the relationship between spore morphology, and some adaptative strategies such as the presence of chloroplasts on spores and substrats preferences of species are still poorly studied. The aims of the present study are to increase the number of mosses spores descriptions, by developing palynological studies on light and electron microscopy (scanning and transmission), and to relate these characters to the adaptative strategies of these species, by means of cluster analysis. Observing the results of some palynological studies that we have participated before, concernig to the families Bruchiaceae Schimp., Dicranaceae Schimp., Fissidentaceae Schimp., Helicophyllaceae Broth., Leucobryaceae Schimp., Polytrichaceae Schwägr., Pottiaceae Schimp., Pylaisiadelphaceae Goffinet & W.R. Buck, Rhachitheciaceae H. Rob. and Sematophyllaceae Broth., and some new results related to the families Erpodiaceae Broth., Cryphaeaceae Schimp., Orthotrichaceae Arn., and Rhabdoweisiaceae Limpr., we have analysed the spore morphology and its relationship to adaptative strategies. Our results confirm that the spores of mosses show sporoderm formed by intine, exine and perine.

The intine may be homogeneous or stratified, the exine is, frequently, homogeneous, but it can exhibits a lamellar portion, and the perine is the only, or more important, stratum related to spores ornamentation. Observations on morphological characterization of spores, and its relationship to some adaptative strategies of the species allow us to conclude that those spores that have thin perine and thin exine show a greater number of chloroplasts, and the species are commonly corticicolous. On the other hand, spores that have thick exine and (or) thick perine show a lesser number of chloroplasts, and these characters are related to terrestrial occurrence. (FAPEMIG, CAPES, PGECOL/UFJF).

***Keywords*:** bryophytes, cluster analysis, mosses, ultrastructure.

Pollen morphology pistillate flowers in *Paullinia* L. (Sapindaceae)

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Paullinia is the second genus with the highest number of Sapindaceae family species with about 200 species of neotropical distribution. Their representatives are generally strong lianas, which preferentially occur in rainforests. *Paullinia* has unisexual flowers on the same inflorescence. The male flowers have pistillodes and female flowers staminodes, similar to the stamens of the male flowers, but with indehiscent anthers and pollen grains inside. The objective of this study was to characterize the palynology of pollen grains of staminodes of female flowers of six species of the genus: *P. alata* (Ruiz & Pav.) G. Don, *P.elongata* Radlk., *P. ingifolia* Rich. ex Juss., *P. pinnata* L., *P.rugosa* Benth. ex Radlk. and *P. weinmanniifolia* Mart. The palynological material was obtained from fertile anthers of flower buds and flowers deposited in R and RBR herbaria. The pollen grains were examined without chemical treatment, and then acetolysed and examined by light microscopy (LM) and scanning electron microscopy (SEM), described and illustrated. The results show that species *Paullinia* have pollen grains in monads, isopolar, medium, oblate, with triangular amb and very large area. The apertures are 3-4 porate in *P. weinmanniaefolia*, 3-porate in the other species, the presence of ornate annulo with 1,0-2,0mm. All species have the same thickness for nexine and sexine and mesopores the exine is thin (1,0-2,0mm) in most species. The surface is microreticulate in all species. *P. elongata* showed pollen grains without cytoplasmic contents, while other species have pollen grains with cytoplasmic content. It follows that the pollen grains are heterogeneous with respect to the number of apertures and the presence of cytoplasmic contents. The pollen morphology studied here contributes to a better knowledge of the species to assisting the *Paullinia* genus taxonomy.

***Keywords*:** Paullinieae, liana, palynology

Palynolgical considerations on species of *Senecio* L. occurring in the state of Rio de Janeiro, Brazil

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The tribe Senecioneae is composed of 100 species belonging to eight genera and it stands out due to its wide morphologic diversity and controversial circumcision. *Senecio* L. is the largest genus of this tribe and it has approximately 60 species living in fields and highland regions, especially in South and Southeast of Brazil, even though they can be found in other regions of the country. The pollen grains of fourteen species from Rio de Janeiro were analyzed: *Senecio adamantinus* Bong., *S. arctiifolius* Baker, *S. bonariensis* Hook & Arn., *S. brasiliensis* (Spreng.) Less., *S. grandis* Gardner, *S. icoglossus* DC., *S. juergensii* Mattf., *S. malacophyllus* Dusén, *S. nemoralis* Dusén, *S. oleosus* Vell., *S. pseudostigophlebius* Cabrera, *S. ramentaceus* Baker, *S. rossianus* Mattf., *S. stigophlebius* Baker. The pollen samples were obtained from herbarium specimens from RB and R

and they were prepared for being analysed under light microscopy using the acetolysis method. The grains were measured under light microscopy and the quantitative data was submitted to statistical treatment. For scanning electron microscopy, anthers were opened directly over a stub covered by double-faced self-adhesive carbon tape, coated with a thick gold layer and analysed. Photographs were taken under the both techniques of microscopy. The results showed pollen grains in isopolar monads, with medium size, circular to triangular amb, 3-colporates, ectocolpi long and lalongate endoaperture. The exine has a cavium and the sexine is echinate with perforations at the base of the spines, which are conic with a large base. Based on the results, we can conclude that the genus is stenopalynous.

***Keywords*:** Asteraceae, Senecioneae, *Senecio*, Palinotaxonomy, Rio de Janeiro

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Palynological study of 86 representative species of Northwest Relict Forest of Peru in rainy season

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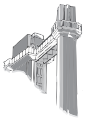
Relict forests in the northwestern Andean slopes of Peru, are fragile and important ecosystems, considered habitats with high plant diversity and with a very high rate of endemism because of the complicated topography and ecology of their habitats. In the department of Lambayeque in Norwest of Peru, Kañaris relict montane forests (2300msnm) have biological significance, as representatives of what was once a forest with a larger area in the past. Currently there are no work done on pollen morphology of existing plant species in these forests, so it definitely is in dire need palynological studies; First, allow them to be used as an auxiliary tool in the correct taxonomic determination of the species vegetables, and second, increase knowledge about the diversity of palynomorphs corresponding to the vegetation of the montane forests. The aim of this work was to compare pollen features in related groups in order to prove clear differences among them even when they are close clades. Besides, we wanted to make a report of the flowering species in the Upaypiteq forest (One of relict forests of Kañaris) in the rainy season. The collections were made at the time corresponding to January-July (Rainy season) in which we find 86 species distributed in 68 genera of 40 families and then processing them through the acetolysis method and we observed with optical microscopy and Scanning electron microscope. The most common form is oblate spheroidal; According to pollen units, the most abundant pollen unity is monad, but are also present in smaller amounts tetrads (Ericaceae and Pentaphylacaceae); According to its apertures, tricolporate pollen is found in abundance (Asteraceae, Calceolariaceae, Campanulaceae, Chlorantaceae, Clusiaceae, Columelliaceae, Fabaceae, Loranthaceae, Lythraceae, Melastomataceae, Myrtaceae and Solanaceae), pollen inaperturate we found in the species *Siparuna muricata* (Ruiz & Pav.) A. DC. (Siparunaceae) and genus *Palicourea* (Rubiaceae); the monosulcate pollen is present in the genus *Bomarea* (Alstromeriacea). The most abundant family in this collection is Asteraceae with 15 species, following Melastomataceae and Solanaceae with seven species each one. So, pollen morphology to be unaffected by environmental factors, we can say that it is a reliable and very useful as species identification tool and find differences into clades.

***Keywords*:** Relict forest, Pollen morphology, Norwest of Peru, Kañaris, Pollen grains



POLLINATION ECOLOGY

Luciene Cristina Lima e Lima

Pollen analysis in the provision of bee *Xylocopa* (*Monoxylocopa*) in the semiarid

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The species of bees *Xylocopa* (*Monoxylocopa*) *abbreviata* Hurd & Moure (1963) and *X.* (*M.*) *macambirae* Zanella & Silva, 2010 have predominant distribution in the Brazilian semiarid region. Both species nest in stem of *Encholirium spectabile* Mart. ex. Schult. f. (Bromeliaceae). Studies have indicated that all *Xylocopa* bee are polilectic, collect pollen on flowers of many families, especially those with poricidal anthers. Our hypothesis is that these bees, despite the generalistic behavior, use pollen grains of a few plant species to provision the brood cell. We aimed to analyze the provisioned pollen spectrum of *Xylocopa abbreviata* and *X. macambirae* to feed their offspring. The pollen samples were taken from brood cells of nests (n = 6) found in host plant stem in the semiarid region of the Bahia and Pernambuco states. In *X. abbreviata* nest we observed 19 pollen types related to twelve plant families. Leguminosae showed greatest richness (3 pollen types) and the pollen grains with greatest representation were *Chamaecrista ramosa* (27.4%) and *Mimosa tenuiflora* (26.6%). The pollen samples indicated that the plant species most exploited by female of both bees belonged to the Malpighiaceae, Melastomataceae and Solanaceae. The pollen types observed in all samples and those with greater representativity were *Byrsonima*, *Cabessedesia hilariana*, *Cestrum*, and *Solanum paniculatum*. Bees *X. macambirae* stored 20 pollen types from 14 botanical families, being Asteraceae with greatest richness (4 pollen types). The pollen types *Cestrum*, *Chamaecrista ramosa*, *Cuphea flava*, *Eupatorium*, *Solanum paniculatum*, *Vernunanthura*, and *Waltheria* were the most representative in the samples of *X. macambirae*. Despite the wide variety of plant species visited, the larval food samples showed low relative richness indicating that females concentrate their visits on flowers of few plant species. The pollen types with greater representation in *X. macambirae* nests were from flowers with poricidal anthers of *Chamaecrista* and *Solanum* genus. The results suggest that *Monoxylocopa* bees, although visit a wide variety of plants and may be considered polectic, have predictable behavior as the pollen collection. In the semiarid region, foraging for pollen must be associated with the reproductive cycle and the flowering period of key plants and with poricidal anther. On the other hand, the pollen collection activity by female bees should be directly related to the anther morphologies than with flowers and taxonomic categorization. An detailed comparative analysis on the phenology of particular plant groups visited by bees *Xylocopa* in Caatinga environment can provide data to support this interpretation.

***Keywords*:** Foraging, *Encholirium spectabile*, *Xylocopa abbreviata*, *Xylocopa macambirae*, nesting

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Pollination potential of bee species in *Vicia faba* field in Göttingen, Germany

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Bee pollinators are essential for crop production. Thus, the global decline in pollinators due to loss in habitat and foraging resources resulted in an increase in strategies aiming at enhancing pollination services in croplands as well as protection of bee species, which are found to be particularly important in relation to their pollination potential. We present the results from a study we conducted between May and July 2015 in two flowering faba bean stands (*Vicia faba*) close to Göttingen, Germany. The legume *Vicia faba* was selected due to its numerous benefits, including yield production, the ability to fix nitrogen thus enhancing soil fertility and

the potential of improving pollination services in croplands by enhancing floral resources. With our study we aimed at answering the question: What is the most effective potential bee pollinator of *Vicia faba*? The abundance and foraging behaviour of bee pollinators were evaluated by standardised transect walks. Seed set and the degree of cross-fertilisation were determined using exclusion cabins and phytometers. Flower constancy was measured based on the pollen analyses of both the corbicular pollen (from pollen basket) and the pollen load on the bees bodies (from hair). The three most frequently recorded species were *Apis mellifera* (56 % of all observed individuals), *Bombus terrestris* agg. (37 %) and *Bombus hortorum* (4 %). However, the species differed in their behaviour: *A. mellifera* and *B. terrestris* agg. were mainly robbing nectar, while *B. hortorum* was a regular pollinator. Seed set was significantly higher when the flower was visited by *B. hortorum* which additionally caused a higher degree of cross-fertilisation than the other common bee species. The pollen analysis and pollination probability index for pollen carried on the body indicate all three species excibited high pollination probability for *Vicia faba*, although *B. terrestris* agg. less so. The almost pure pollen loads on the body indicate that *Vicia faba* was a major pollen source for the three bee species. In conclusion, the behaviour of pollinators is crucial for pollination success and most abundant pollinator species do not always provide the best pollination service. The less frequent species *B. hortorum* turned out to be potentially the best pollinator for *Vicia faba*. Finally, we show that by bringing together results of foraging behaviour observations, seed set and cross-fertilisation experiments as well as flower constancy from pollen analysis, convincing conclusions can be drawn with respect to the pollination potential of different pollinator species.

Keywords**:** bees, *Vicia faba*, pollination potential, Germany

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Pollen loads on bees, floral visitors of *Tibouchina francavillana* Cogn. and *Tibouchina lhotzkyana* Cogn. (Melastomataceae), Bahia, Brazil

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The genus *Tibouchina* Aubl., one of the most representative of Melastomataceae family, consists of about 350 species, with a high degree of endemism. The species usually provide pollen as sole floral resource for bees that vibrate flowers; they are potential pollinators. The aim of this study was to evaluate the pollen load present on the body of bee species, floral visitors of *Tibouchina lhotzkyana* Cogn. and *Tibouchina francavillana* Cogn., located in a fragment of Atlantic Forest in Alagoinhas-BA. The bees that had their pollen loads analyzed were those who perform buzz pollination: *Bombus brevevilus* Franklin, 1913 *Xylocopa (Neoxylocopa) frontalis* Oliver, 1789, *Xylocopa suspecta* Moure & Camargo, 1988 *Xylocopa muscaria* (Fabricius, 1775), *Centris fuscata* Lepeletier (1841), *Centris decolorata* Lepeletier, 1841, *Centris sponsa* Smith, F. (1854), *Euglossa* sp., *Eulaema (Apeulaema) cingulata* (Fabricius, 1804) and *Eulaema (Eulaema) niveofasciata* (Friese, 1899). The pollen load was removed by washing the bee's body with absolute alcohol and subjected to palynological processing with acetolysis. We counted at least 1000 pollen grains per sample to determine the frequency of pollen types. The types were photomicrographed and identified with the help of catalogs and reference slides collection from Palynological Studies Laboratory of the Department of Exact Sciences and Earth II of UNEB. Analysis of *T. lhotzkyana*'s visitor bees showed the presence of 24 pollen types belonging to 10 botanical families and *T. francavillana*'s 12 pollen types related to seven families. The family with the most types was Fabaceae (seven and five pollen types on the body of *T. lhotzkyana* and *T. francavillana*'s visitor bees, respectively). The pollen types related to the two plant species stood out in the samples, varying between 72.22% to 97.91%, except in pollen load of: *Eulaema cingulata*, *T. lhotzkyana*'s visitor, whose related type presented frequency 53.13% in addition to the representative participation of pollen type *Senna* 01 (43, 54%); and *Eulaema niveofasciata* and *C. decolorata*, *T. francavillana*'s visitors, with registry of 10% and 48.26% of pollen type related to this plant species and 87% and 46.46% of *Senna* 01 and *Solanum* types, respectively. These results show the efficient collection of pollen grains by these bees, which allows to classifies them as potential pollinators of *T. lhotzkyana* and *T. francavillana*, and the importance of these plant species as a source of trophic resource for this guild of bees.

Keywords**:** Atlantic Forest, pollen types, buzz pollination, Melastomataceae, Apoidea.

Plant-insect interaction in hives established in the high Andean area of Boyacá – Colombia

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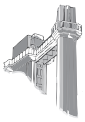
In Colombia, bee pollen consumption has increased in recent years due to its antioxidant properties and important nutritional value based on the content of protein, fiber and carbohydrates. Therefore, the continuous increase in production, in order to supply the current demand is necessary. The final product characteristics are directly related to environmental conditions, processing practices and mainly the flora visited by bees. However, establishing its botanical origin is a complicated task due to fluctuations in the floral availability and behavior of food selectivity registered in *Apis mellifera*. For this reason, knowledge of bee alimentary preferences and floral availability variations are essentials for sustaining production of bee-pollen at appropriates rates. The aim of this work is to determine the interaction between *A. mellifera* and plant species associated with apiaries established in some municipalities in the Andean highlands of Boyacá – Colombia. Bee-pollen samples, from 21 apiaries located in 6 towns between 2500 – 3100 m.a.s.l, were collected, which were acetolysed and disposed in slides for counting. In addition, a reference pollen library was created based on remove flowers of 83 flowered species during collection. A Jaccard similarity index was applied on the samples, based on pollen types. The number of pollen types was relatively high. The families Asteraceae, Fabaceae and Myrtaceae showed a significant number of pollen grains in the samples studied. On the other hand, pollen grains belonging to the families Brassicaceae, Adoxaceae, Urticaceae, Passifloraceae and Solanaceae were observed to a lesser amount. Nevertheless, most of the samples analyzed were classified as multifloral. In the study area, *A. mellifera* has a sustenance diet based on diverse species that serve as a source of food during most of year, adding plant species to this, as flowering periods occur in the area. The multifloral features of the products analyzed suggest that the samples collected are abundant in chemical compounds with biological activity. Thus, it is necessary to stimulate further research focused on products derived from Colombian beekeeping, dependent on the growth and development of the beekeeping industry.

***Keywords*:** Pollen, *Apis mellifera*, Andean highlands, similarity index, multifloral.



QUATERNARY PALYNOLOGY AND BOTANY

Maria Lúcia Absy & Cynthia Fernandes Pinto da Luz

A last glacial and deglacial pollen record from the northern South China Sea: New insight into coastal-shelf paleoenvironment reconstructions

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This study presents a palynological record of the Asian summer monsoon and sea level change from the Last Glacial Maximum to the deglacial period in the northern South China Sea. A fossil core STD 235 (855 cm in length) and 273 surface sediment samples from the northern South China Sea were pollen analysis to reconstruct the paleoenvironment of the continental shelf during the last glacial period. Results from surface and fossil pollen have shown that there were different sources of pollen between the LGM and the deglacial period as sea level changed. Pollen concentrations of all pollen taxa are extremely high in surface samples

from the estuary of Pearl River and assemblages correspond well with the regional vegetation, whereas, wind transport becames more important in the surface samples from the deeper ocean. Concentration of total pollen between surface and fossil pollen samples have been compared in order to determine past possible pollen source areas. Pollen concentration as high as >100 grains/g at the LGM suggested that the paleo-shoreline was located less than 75 km from land, about one third the present distance. Consequently, pollen grains must have mostly come from the exposed continental shelf. By contrast, pollen concentrations were low during the deglacial period and Holocene, due much longer distance from the shoreline and windblown pollen deposit played a more important role as limited riverine input into the deep ocean during high sea level periods. Such alternation of pollen flux and source distance should be repeated during all glacial-interglacial cycles, reflecting closely the sea-level and climate dynamics. According to fossil pollen assemblages from Core STD 235, we conclude that wetland and/or grassland communities with scattered subtropical trees dominated most of the exposed shelf in the SCS during the LGM. Such a landscape during the LGM firstly implies lower temperatures as subtropical arboreal trees, growing on the shelf indicates significant altitudinal lowering of this vegetation and secondly the dominance of herbs indicaties decreased precipitation as a result of a weak Asian summer monsoon. A similar picture of decreased precipitation with dominant herbs on the coastal-shelf is also evident from records in the Okinawa Trough, East China Sea. That means that the weakening of the summer monsoon was synchronous in both higher and lower latitudes, triggered by a significantly lower sea level during the LGM.

Keywords**:** South China Sea, Coastal-shelf, Vegetation, Sea-level change, Asian Summer monsoon

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Rodent middens pollen records as fundamental witnesses of the past climatic and environmental dynamics of the Atacama Desert

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Past climate dynamics of the Atacama Desert has been studied because of two main reasons (1) the strong impact that past climate variability would have had on the hydrologic resources of this region where water is a crucial factor for plant and animal survival as well as for human occupation and (2) its potential links with the continental and inter-hemispheric scale atmospheric circulation. Fossil rodent middens have not only been the main but the most valuable source of palaeoecological and palaeoclimatic evidence in the Atacama desert where "standard" depositional environments are scarce. Actually, the vegetation dynamics in the Atacama Desert during the last 50ka has been inferred from the joint analysis of pollen and plant macrofossils from fossil rodent middens. The present paper aims to trace the climatic and environmental dynamics of the Atacama Desert since the Late Pleistocene based on six rodent midden pollen records distributed at different latitude (19°-25°S) along the Atacama Desert and encompassing the last 14ka. Past climatic and environmental changes were inferred by comparing the fossil pollen records to a regional modern rodent midden pollen-climate calibration set. The modern rodent middens were collected along five west-east altitudinal transects (18°, 21°, 22°, 24°, 25°S) following the vegetation and climatic gradients at the regional scale. Furthermore, three or more modern rodent middens were collected at each point so as to analyze the modern pollen robustness to reflect vegetation. Modern rodent midden pollen robustly reflects the vegetation belts (Pre-Puna, Puna, High Andean Steppe and Subnival) along the climatic gradients, particularly annual (mostly summer) precipitation and mean annual temperature, in the Atacama Desert. Inter and intra variability of the vegetation belts are reflected in the rodent middens pollen record at the regional scale and along each transect. The fossil pollen records point out more humid conditions than present during the Late Pleistocene and early Holocene (~14-9ka) followed by dry mid-Holocene conditions (9-3ka) with extremely arid periods which were not synchronous all over the Atacama Desert and differed in timing and extent. The Late Holocene appeared to be similar to the present in the Central Atacama Desert (22°-25°S) but variable in the northern part (19-22°S). Thus, the pollen records reflect a more humid than present pulse between 2.4-1.0ka followed by less humid conditions (0.8-0.5ka) and dryer ones (and similar to the present) since 0.5ka in the northern part of the Atacama Desert. FONDECYT #11150089; 3130511; 1130279; CONICYT-PIA, Anillo código SOC1405

Keywords**:** Rodent middens, pollen, Atacama Desert, Pleistocene-Holocene

Vegetation changes in the Eastern Azov Sea coastal area during the Late Pleistocene and Holocene

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Palynological data on the main stratigraphic horizons of loess and paleosols of the Late Pleistocene and Holocene were obtained from Beglitsa section (47°08'N, 38°31'E) situated on the north-eastern shore of the Sea of Azov within the forb-grass steppe zone. The thickness of the Late Pleistocene deposits at the site (app. 10m) is the greatest for the region. Within the Salyn paleosol (PS), corresponding to the Mikulino (Eemian) Interglacial (OIS 5e), arboreal pollen (AP) comprises ~10% of the pollen sum. It is represented mainly by *Pinus sylvestris*, with rare pollen of birch, alder, oak, spruce, and *Pinus* s/g *Haploxylon*. Non-arboreal pollen (NAP) is abundant, especially that of Asteraceae, Cichoriaceae, and Chenopodiaceae, along with a variety of other herbaceous plants, including *Echinops* – one of the typical meadow species of the steppe zone. Pollen composition indicates that the role of intrazonal tree vegetation (pine woods on sandy soil, birch and alder copses on the wetter ground) remained minor even under a relatively humid interglacial climate. In the Bryansk PS correspondent to the Middle Valdai Interstadial (OIS 3), pine pollen content is higher than in the Salyn PS (~25% of AP+NAP), which agrees well with sandy composition of this soil. Locations with higher ground moisture were occupied then by birch and alder communities with rare oak and elm. Among NAP, Chenopodiaceae were predominant (~35% of AP+NAP); a great variety of forbs included species of Polygonaceae, *Artemisia* and other Asteraceae, *Centaurea*, *Plantago*, *Valeriana*, thus indicating widespread steppe communities rich in species. Pollen composition of the Late Valdai (Weichselian) loess (OIS 2) reflects a decrease in participation of forbs in the steppe communities under colder and dryer climatic conditions. Among NAP, Apiaceae, Asteraceae, Brassicaceae, and Rubiaceae are the most common, pollen grains of *Echinops* and *Linum* are registered. Scares AP is represented by *Pinus*, *Betula* and *Salix*. The presence of saline soils is indicated by finds of Plumbaginaceae pollen. NAP content in the Holocene chernozem soil exceeds 80%. Its composition and diversity, as well as the presence of typical plants of steppe zone (*Plantago*, *Ephedra distachya*), indicates that vegetation similar to the present-day steppe existed in the area during the entire Holocene. The study was supported by the Russian Science Foundation Project 14-17-00705.

***Keywords*:** Late Pleistocene, Holocene, Eastern Azov Sea region, pollen analysis, steppe vegetation

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Characterization of the modern pollen-vegetation relationship across the savannah-forest transition in tropical West Africa

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The impact of past global climate change on tropical vegetation often focuses on the switching between stable states such as grassland (savannah) to forest and vice versa. Modern ecological studies, however, demonstrate that the transition between grassland and forest is complex, and is characterised by a large gradation in biodiversity and carbon storage. This suggests the current interpretation of past vegetation change, (pollen records) may be over simplistic and that new data could be recovered from these archives. One factor limiting our interpretation of tropical fossil pollen records is the lack of modern pollen-vegetation relationships studies. Here, we present data from a modern pollen-vegetation study across an environmental gradient from wooded savannah to true savannah in tropical West Africa (Kogyae Nature Reserve, Ghana). Fifteen artificial pollen traps were deployed within three permanent vegetation study plots in 2013 and 2014 to study forest-savannah transition. Each vegetation plot was 100m by 100m and the traps were positioned along the 40m line

at 10m intervals. The sampling strategy provides the opportunity to characterize the overall pollen rain within each study plot, and for an assessment of the within plot variation. Comparison between trap and vegetation survey data provides the first estimates of relative pollen productivity of different taxa across a forest-savannah transition in tropical West Africa. By comparison to the vegetation diversity and carbon storage data with the palynological information, an indication of what additional ecological information might be effectively extracted from the fossil record can be gained. The new information on the palynological signature of forest-savannah transitions in tropical West Africa may provide new insights into abrupt vegetation change in the c. 520,000 year fossil pollen record from Lake Bosumtwi c. 80km to the south of Kogyae, and thus improve understanding of the nature of vegetation transitions related to glacial-interglacial cycles in the tropics.

***Keywords*:** Savannah-transition, palaeoecology, palynology, Ghana, Poaceae

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The last glacial interglacial transition at Lake St Clair, Tasmania, Australia

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High resolution analysis of the period of the last glacial interglacial transition is presented for a new core from Lake St Clair, Tasmania located in the mid latitudes of the Southern Hemisphere. Deglaciation was complete and subalpine rainforest had replaced herbfields by c. 18.3 cal kyr BP in step with onset of Antarctic warming during the Last Termination. *Phyllocladus aspleniifolius* dominated rainforest and *Eucalyptus* had established at the site by 15 cal kyr BP followed in short by an increase in Poaceae between 15.2-13.8 cal kyr BP suggesting a return to cooler conditions slightly preceding the Antarctic Cold Reversal (14.7-13.0 cal kyr BP). The abrupt decline in *Phyllocladus aspleniifolius* dominated rainforest and replacement with *Nothofagus cunninghamii-Atherosperma moschatum* rainforest at c. 12.4 cal kyr BP indicates a significant increase in temperature and improved soil fertility. Coarser sediments deposited during the Early Holocene between c. 10.6 – 8.2 cal kyr BP are interpreted to represent increased precipitation and support the idea of a Southern Westerly Wind dominated climate regime during this period as suggested at other Tasmanian sites. Increased fire activity and an increase in sclerophyllous vegetation after c. 5 cal kyr BP indicates a shift towards a climate more strongly influenced by El Nino Southern Oscillation.

***Keywords*:** Last glacial interglacial transition, Tasmania, Antarctic Cold Reversal, Southern Westerly Winds, El Nino Southern Oscillation.

Human societies and landscape transformations in Roman-Medieval Sicily: archaeopalynology at Villa del Casale and Philosophiana

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Sicily has been continuously occupied and exploited by different cultures during Middle and Late Holocene and its landscape is a result of the long-term shaping that humans and climate made on the environment. This 'joint action' of humans and climate is recorded in palaeobiological records, but it is hard to disentangle the single role of this two agents in modeling the environment, that results as a 'mixed, natural and cultural' plant landscape. Archaeopalynological investigations may improve the resolution of vegetational-environmental events recorded from extra-local palynological sequences by giving local information on plant landscape and human influence in the region. Archaeopalynological research of two renown sites located in central Sicily allows the reconstruction of agrarian landscapes in the Roman-Medieval ages with a very high resolution given by the stratigraphy discovered from these archaeological sites. Villa del Casale of Piazza Armerina (a monumental villa included in the UNESCO World Heritage List) and the near 'agro-town' of Philosophiana are key sites to understand the countryside exploitation in the Roman world. Due to their long occupation phases (from Roman to Medieval periods), these extraordinary rural complexes offer the opportunity to investigate land use and economy transformations that had occurred in the area from Antiquity to the Middle Ages. The palynological research is carried out on more than 100 samples dated from the end of the 1st to the

15th century AD. Integrated data from pollen, non-pollen palynomorphs (NPPs) and micro-charcoal analyses suggest that the sites have been built in an open area, characterized by low forest cover, with signs of both natural/semi-natural cover and complex anthropogenic activities, including cereal fields and pasture. The pollen history of the two sites shows a continuity of the agrarian landscape during the Roman and Medieval times. Although changes occurred, the different cultures were progressively incorporated and the plant uses and main landscape features showed some continuity. The intense land exploitation emerging from these archaeopalynological analyses fits well with the signs of land-use intensification and unambiguous human impact recorded in Sicily from off-site cores since historical times.

***Keywords*:** pollen analysis, archaeological sites, Sicily.

Vegetation and environmental changes during the past 2000 years in Yamzhog Yumco Lake, southern Tibetan Plateau, China

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The Tibetan Plateau is a sensitive region to climate changes controlled by interactions of large-scale atmospheric circulations, including the East Asian monsoon, Indian monsoon and mid-latitude westerlies. We present a high-resolution paleovegetational and paleoenvironmental reconstruction over the past 2000 years from Yamzhog Yumco Lake (28°27′~29°12′N, 90°08′~91°45′E; altitude in 4440m a.s.l.), a representative inland lake located at southern Tibetan Plateau, China. A suite of 50cm-long cores was drilled using Russian drill. 50 samples were sampled by 1cm intervals. 19 samples collected from the upper portion of the core were used in ^{210}Pb dating and two plant materials from the lower portion of the core were dated by AMS^{14}C dating method, and then an age-depth model was established for the past 2000 years. According to the analysis of pollen, grain-size, chemical elements and loss on ignition (LOL), the reconstruction indicated that there were four periods during the last 2000 years. The vegetation from 100 to 820A.D.was mainly steppe under relatively high effective moisture, and a moderately wet and cool period corresponding to the Dark Age Cold Period (DACP). Subsequently, a relatively low effective moisture prevailed between 820 and 1200A.D., the vegetation during this period was desert steppe and a dry climate might have occurred during the Medieval Warm Period (MWP). During 1200~1910A.D., the arboreal pollen increased under high effective moisture climate. The wetter climate in this period, which could correspond to the Little Ice Age (LIA). Since the 20th century, the effective moisture quickly lowered and a dry climate prevailed. Two views were obtained by comparison with the solar insolation, Northern Hemisphere temperature proxy and Asian monsoon index from other regions. (1) During the last 2000 years the humidity changes in Yamzhog Yumco lake basin was in broad consistent with the records from the Tibetan Plateau and surrounding areas, but the amplitude and duration of regional phases were different. (2) The pattern of climate change in the southern Tibetan Plateau during the past 2000 years probably was warm-dry and cold-wet types, which might be in close relationship with the temperature and solar insolation. It can help us better understand the mechanisms of the climate change in the high elevation of monsoon areas over the past two millennia.

***Keywords*:** past 2000 years, Yamzhog Yumco Lake, pollen analysis, climate change

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Modern habitats and Holocene history of *Pinus sylvestris* in Mongolian plateau and surrounding areas and the significance of this species as a paleo-environmental indicator

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The Mongolian Plateau, extensive northeastern highland region of the great plateau of Central Asia, includes the independent state of Mongolia and the Inner Mongolian Autonomous Region of China. The Holocene environmental variations recorded by pollen in the Mongolian Plateau and surrounding areas have been

the center of debate for the past two decades. One of the most prominent transitions during the Holocene is the expansion of Scots pine (*Pinus sylvestris*) in northern Mongolian plateau and surrounding areas (mainly including Lake Baikal area, the Sayan and the Altai Mountains). Therefore, the environment (temperatures, precipitation and soil moisture availability) reconstruction needs a boost from in-depth investigations of pollen–climate relationships and also from further bioclimatic understanding of Scots pine Scots pine (*Pinus sylvestris*). Here we review recently published data on the modern habitat of *P. sylvestris* and sedimentary pollen records during the Holocene from a number of sites in Mongolian plateau and surrounding areas, to illustrate the significance of *P. sylvestris* as a paleo-environmental indicator and propose a set of pollen-based temperature (T) and moisture (M) indices. The review of botanical literature show: 1) Scots pine (*Pinus sylvestris*) is a eurythermic species of native to Europe and Asia, which also adapts to a wide range of precipitation conditions. Over 100 *Pinus sylvestris* varieties have been described, but only three or four are now accepted. The Mongolian pine (*Pinus sylvestris var. mongolica* Litv.) is a characteristic element of the Mongolian–Daurian forest steppe. It plays a dominant role and are found only in Mongolia and adjoining parts of southern Siberia and northeastern China. 2) Mongolian pine woodland mainly grows on sandy soils between 300 and 1000 m A.S.L. and experiences a continental climate with a mean annual temperature of -0.2 to -2.9°C, and annual precipitation from 300 to 450 mm. In other words, this woodland requires higher moisture and lower temperatures than steppe vegetation and lower moisture and higher temperatures than dark taiga forest. The pollen record during the Holocene and the comparison with insolation forcing and 500-yr timeslice GCM simulations illustrate: 1) *Pinus sylvestris* abundance increases significantly in mid-late Holocene coincident with a temperature rise predicted by GCM modeling and insolation forcing, 2) the Holocene expansion of Scots pine indicates that this species requires higher temperatures than dark taiga forest and higher relative humidity than steppe vegetation. Then we devise a semi-quantitative set of temperature and moisture indices.

Keywords**:** *Pinus sylvestris*; modern habitat; pollen records; temperature and moisture indices; Holocene

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Pollen-inferred vegetation and environmental changes in the Lake Cuona from the central Tibetan Plateau since 13800 yr BP

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Palynological analyses of a Holocene borehole (91°24′25.474′′E, 32°02′49.526′′N) in the Lake Cuona from the central Tibetan Plateau documented the local vegetation history perfectly. Based on the dating of ^{14}C, we reconstruct the palaeoclimate for the first time in this area during the past 13800 years. From 13800 to 11200 cal. B.P. , the climate was cold and dry. From 11200 to 7380 cal. B.P., the climate improved and became warm and humid, that indicated the lake area was influenced by the summer monsoon. After 7380, on the whole, the palaeovegetation show little change, that means the climate was still humid. But there were some climate fluctuations happened during 6200-6400 cal. B.P. and 5200-5300 cal. B.P., that suggested some dry events. The pollen record of Lake Cuona provide the new climate data for the study of central Tibetan Plateau, and can be attributed to influence of the summer monsoon.

Keywords**:** Palynology, Palaeovegetation and Palaeoclimate, Summer monsoon. Lake Cuona, Central Tibetan Plateau

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Late Pleistocene high Andean pollen records from subtropical South America

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High Andes from Subtropical Central Chile (30°-33°S) emerges as a key area to study interaction between Subtropical Southeast Pacific High and Southern Westerlies Wind Belt in the past since its location, the

availability of proper palaeoclimatic archives and the low human disturbance. Here, the interplay between both systems determines the current mediteranean-type climate characterized by rainy winters and dry summers. High Andean vegetation belts follow the decreasing precipitation W-E gradient and are easily identifiable in modern pollen assemblages which are dominated by Asteraceae, Poaceae, Fabaceae and *Ephedra*-type from the highlands to the lowlands. In the present paper we present four high Andean lake pollen records from Subtropical Central Chile which encompasses the last 15ka at centennial scale. Laguna Grande record (32°S; 3600masl) show three major changes during the last 15ka. Around 12ka, an Asteraceae-dominated community was replaced by a Poaceae-dominated one implying a temperature increase or a precipitation decrease. A community dominated by Fabaceae occurred from 7-2ka when was replaced by a Poaceae-dominated one suggesting mid Holocene dry conditions followed by more humid ones and similar to the modern conditions during the Late Holocene. Laguna El Cepo record (30°S; 2900masl) encompasses the last 12ka and is dominated by Poaceae along the whole record, presenting maximum values between 12-11.5ka, 9.6-8.1ka and 5.8-0.5ka, which imply moments of increased effective moisture. High percentages of *Ephedra* during the early and mid Holocene, peaking at 7-6ka are inferred as drier conditions. Laguna Chica record (32°S; 3600masl) span the last 4.8ka and show the dominance of Fabaceae until 2ka when Poaceae reach maximum values of 70% that last until the present. Climatic inferences and vegetation change chronology match those of Laguna Grande for the mid-to-late Holocene. Laguna Cerritos Blancos (30°S; 3850masl) encompasses the last 4.6ka showing the continuous presence of *Ephedra* (around 20%), and variable minor percentages of Poaceae, Fabaceae and other taxa along the record. A decrease of *Ephedra* around 2.3ka, was followed by an increase of Fabaceae between 2.2-1.7ka and subsequently of Poaceae peaking at 1.3-0.9ka. Regionally, changes in the high Andean lakes pollen assemblages suggest cooler than present conditions during the late Pleistocene followed by warm and humid conditions during early Holocene, which change to very dry conditions between 7-6ka and then gradually turned to more humid conditions at 2ka. These climatic trends show high concordance with records of lowlands from Subtropical central Chile, suggesting a regional climatic control. FONDECYT#1140837

***Keywords*:** Holocene, pollen analysis, subtropical Chile, precipitation, high Andes

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Long-term quantitative climate reconstructions in south-central Chile (37-40°S)

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The climatic transition between 38-40°S in south central Chile, present an excellent possibility to evaluate different Southern Westerly Winds patterns/movement observed from sedimentological and vegetation changes. Many paleoclimatic proxy records suggest that the Holocene climate of southern South America was highly variable, especially during the mid- and late Holocene. However, for the Last Glacial Maximun period, very few records are focused on this time window being the detail and its climate variability and quantitative magnitudes rather unknown. Here we present a preliminary quantitative climate reconstruction applied in the Lago Espejo pollen record using a modern regional pollen calibration data set and non-linear unimodal-based reconstruction techniques, such as weighted-averaging regression. The calibration set consists of 40 sites distributed over different regional vegetational units, which roughly encompasses the temperate rainforests, deciduous forests, evergreen forests and high Andean forests with conifers. Pollen records from different depositional environments: lakes, swamps and mosses, which were analyzed under standard procedures and recorded approximately 100 pollen taxa. Climatic variables precipitation and temperature were obtained from records of meteorological stations and correspond to normal climate period between 1980 - 2015. The relationship of the different pollen types registered with climatic variables selected as the basis for the construction and subsequent evaluation of different models of quantitative climate reconstruction is presented. The 26,000 cal yr BP time window addressed by the high resolution Lago Espejo pollen record have the opportunity to quantify in detail the climatic trends and biogeographical patterns at the west side of the Andes. The preliminary reconstructed precipitation values suggest hiper-humid conditions during the LGM until 17,000 cal yr BP, when becomes dryer and warmer as today. Pleistocene–Holocene transition (12,500–10,500 cal yr BP) is marked by high fire activity under cold conditions. Precipitation was low from 10,500 to 7000 cal yr BP and increased between 7000 and 2300 cal yr BP. These results will allow deepening our understanding concerning timing, quantitative magnitudes, and directions of climate variations and disturbance regimes during the Last Glacial period

and the Holocene in south-central Chile, and their relationship with regional, inter-hemispheric, and global climate trends. Acknowledgment: FONDECYT 11149677

***Keywords*:** Quantitative climatic reconstruction, pollen record, southern Chile, Last Glacial Maximun, Holocene.

Sea-level and climate change impacts on the Brazilian coastal ecosystems during the Holocene

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The present study investigates a paleo-estuary at the Doce River Delta, southeastern Brazil, through a multi-proxy approach based on palynology, diatoms, sedimentology and geochemistry analyses (i.e., C/N, $\delta^{13}C$ and $\delta^{15}N$). These analyses, temporally synchronized with five radiocarbon ages, revealed environmental changes from marine to continental over the last ~7550 years. The studied sedimentary succession recorded the upward transition from estuarine channel (until ~7550 cal yr BP) to estuarine central basin (~7550 to ~5250 cal yr BP) deposits, the latter containing increased mangrove vegetation, marine and marine/brackish water diatoms. The range of geochemical values ($\delta^{13}C$= -30 – -10‰, $\delta^{15}N$= 2 – 8‰ and C/N= 4 – 40) also indicate marine/estuarine organic matter and C_3 terrestrial plants to that time interval. A following period recorded two phases: lake/ria (~5250 to ~400 cal yr BP) and fluvial channel (~400 cal yr BP until modern age). During that stage, mangroves were replaced by trees/shrubs and herbs/grasses due to the marine disconnection. As a result, the corresponding sediments contain only organic matter sourced from freshwater and C_3 terrestrial plants ($\delta^{13}C$= -29 – -26‰, $\delta^{15}N$= 0 – 8‰ and C/N= 10 – 45). The equilibrium between fluvial sediment supply and relative sea-level changes during the Holocene controlled the morphologic and vegetation changes in that coastal region. The estuary became established during the early Holocene as a resulted of an eustatic sea-level rise, when the fluvial sediment supply to the coast was relatively lower due to a dry period. However, during the middle to late Holocene, the climatic force was more significant to the development of coastal morphology due to a wet period that caused an increase in sandy sediment supply to coastal system. Therefore, the increase of fluvial discharge associated to a relative sea-level fall caused a marine regression and shrinkage of mangroves during the late Holocene. The evaluation of mangrove dynamics according to climatic and sea-level changes mainly during the late Holocene is essential for the understanding of their survival ability under future scenarios, with a probable accelerated sea-level rise and intensification of extreme climatic events in southeastern Brazil for the next century.

***Keywords*:** Holocene, pollen analysis, Amazon basin, precipitation, climatic changes

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Vegetation and climate changes in the Mediterranean area during the middle and late Quaternary: a new long sediment record from el Padul, Sierra Nevada (southern Spain)

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Long paleoenvironmental records are necessary in order to understand recurrent climatic or paleoenvironmental changes occurring with a certain periodicity (i.e., glacial-interglacial cycles). In this respect, the Padul peat bog has one of the best available records of Pleistocene sediments in semiarid Southern Europe. The sedimentary sequence is more than 100 m thick and has been used to study palaeoenvironmental change for the past ca. 1 Ma. Since the 1960s several cores have already been taken from this basin showing oscillations in many proxies (pollen, organic geochemistry and sedimentation) related with paleoclimatic and paleohydrological changes. However, a more detailed and higher resolution study, using new dating and analytical techniques (AMS ^{14}C, OSL, AAR, continuous XRF-scanning, high-resolution pollen analysis and geochemistry), needs to be done in such an interesting site. Here we present preliminary paleoenvironmental data from a new sediment core, Padul-15-05, which shows significant changes in the environment and lake sedimentation, probably related with glacial-interglacial climate dynamics during the past ca. 300,000 years. These data confirm that orbital- as well as suborbital-scale variability (i.e., Heinrich events) are recorded in the studied core. This unique record thus has very high potential for paleoenvironmental and paleoclimatic reconstructions for, at least, the two last climatic cycles in this semiarid Mediterranean area.

Keywords: Quaternary, pollen analysis, vegetation, Mediterranean, climatic changes

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Some problems of palynology in Arctic Islands

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The study of Arctic islands based on pollen analysis provides a great importance for paleoenvironmental reconstructions in this region. However, during the study of cores situated on Arctic islands the researchers face numerous problems. The first of them is lack of sediments available for palynological investigations. Pollen concentration in deposits is usually low (Govorukha, Zauer, 1967; Dymov, Sharin, 2005; Bolshiyanov *et al.*, 2009 etc), what makes the use of pollen analysis more complicated. Another serious problem of pollen records in Arctic islands is the considerable content of transferred pollen in spectra (Andreev *et al.*, 1997; Anisimov, Moskalenko, 2006). Therefore, methodical researches of recent and subrecent spectra from Arctic islands and continental Arctic seacoasts (as far as they might be the regions of pollen transfer) are topical. Such investigations are few: recent and subrecent pollen spectra were studied at Severnaya Zemlya Archipelago (Kalugina *et al.*, 1967; Andreev et.al, 2008), recent spectra are investigated at Novosibirskie islands (Anisimov, Moskalenko, 2006) and only three subrecent pollen spectra were received at Franz Josef Land Archipelago (Krenke, Fedorova, 1961). Long distance transferred pollen present in all studied samples. Recent and subrecent spectra of continental Arctic seacoasts are studied better (Malyasova *et al.*, 1974; MacDonald, 2000; Sapelko T., Nosevich E., 2013 etc.), but researches comparing islands and continental surface spectra are absent. In frame of studying pollen records in different cores of Franz Josef Land Archipelago, we have faced the problem of transferred pollen (Sapelko *et al.*, 2015; Nosevich et.al, 2015) and we examined surface samples of Artic archipelago: Franz Josef Land, Severnaya Zemlya, Novaya Zemlya and Svalbard. Among transferred pollen grains, trees and herbs are both presented. We analyzed subrecent pollen spectra of Barents Sea coast at Kola Peninsula, Barents Sea surface samples and Bolshezemelskaya tundra surface samples for establishing the sources of wind transfer. As a result, the correct paleoenvironmental reconstructions in Arctic region are not possible without study of recent and subrecent pollen spectra, so, such data are important for future palaeogeographical investigations.

***Keywords*:** Arctic, surface samples, pollen transfer, recent and subrecent spectra

Paleoenvironmental characterization of Quaternary deposits of the north coast of the Espírito Santo state (ES – Brazil): an interdisciplinary approach

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An interdisciplinary study was carried out in the north coast of the state of the Espírito Santo in order to understand the environmental changes that occurred during the Holocene in the region. The results were obtained from palynofacies analysis, granulometry, isotope geochemistry (total organic carbon - TOC, total nitrogen - TN, total sulfur - TS, $\delta^{13}C$, $\delta^{15}N$, C/N and C/S), and radiocarbon dating. The sedimentary deposits studied were obtained from three lakes (Lake Macuco, Lake Bonita and Lake Canto Grande) using a modified Livingstone piston sampler on a floating platform. Isotopic and elemental values suggest that the sedimentary organic matter was derived from different sources, such as land plants (mostly C3 plants), and marine and/or freshwater phytoplankton. The multidisciplinary data was used to infer the formation of a lagoon-estuarine system between ~ 7500 cal years BP and ~ 4000 cal years BP due to increase in relative sea level. Mangrove, "Restinga" and Atlantic rainforest vegetation occupied the region. As a consequence of marine regression after ~4000 years BP, the estuary and mangrove vegetation shifted seaward. The estuarine basin was gradually abandoned and closed off as a result of progradation of the Doce River delta and higher fluvial input. The evolution of Lake Macuco and Lake Bonita was directly related to the changes in relative sea level, while Lake Canto Grande formed as a result of changes in the river input and to the base level. Palynofacies analysis, in combination with other analyses, proved to be invaluable as an important tool for paleoenvironmental characterization of lacustrine deposits that evolved under the influence of marine transgression followed by regression events. [Grants: FAPESP 2010/52606-1, 2011/00995-7; CNPq 245572/2012-0, 470210/02012-5, 2013-0/405060].

Keywords: Holocene, palynofacies, stable isotopes, marine dynamics, coastal evolution

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The Iberian Peninsula (SW Europe) as glacier refuge during the Last Glacial Maximum. A palaeoenvironmental approach

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Relationships between humans and climatic conditions are currently an issue of great interest both from the palaeoenvironmental and archaeological perspective. Climate, as a determining factor in the evolution of past societies, is an element with decisive influence and implications for determining the subsistence strategies, settlement patterns and mobility of human groups. This is a particularly interesting question in ancient chronologies, when the succession of severe climatic conditions with other more favourable, could influence the adaptative strategies among human groups, helping to develop the concept of glacier human refugia. In this work we discuss about the climatic conditions of the final stages of the late Pleistocene and its influences on human behaviours in SW Europe from *ca*. 27300-11500 cal BP. For this purpose we present the palaeoenvironmental study of the Verdeospesoa mire (Northern Iberian Peninsula) through the analysis of pollen, spores, non-pollen palynomorphs, Magnetic Susceptibility, Loss on Ignition and Microcharcoals. The main results shows the existence of an unstable climate, with large fluctuations in temperature and rainfall, leading to some cold and dry episodes (GS-3, GS-2 and GS -2) followed by other more humid and temperate (GI-2 and GI-1). At the same time of those climatic fluctuations the archaeological record show a relatively augmentation of archaeological sites, particularly during the Last Glacial Maximum, highlighting the hypothesis of SW Europe as refuge area for humans during the worse climatic periods, with influences in the adaptive models and the development of different cultures in Europe such as Gravettian, Solutrean, Magdalenian and Azilian. In relation with this idea,

we focus this study in the final stages of the Late Pleistocene in SW Europe, meaning the whole MIS-2 period (*ca*. 28,000 to 11,700 cal BP). This time is a period with great interest from the palaeoenvironmental point of view. The sequences recording the end of the last glacial cycle indicate the occurrence of climatic fluctuations. Moreover, these different fluctuations do not occur in the same way in all regions of Europe, existing, according to the available record, differences both in the intensity and in the timing of these climatic events.

***Keywords*:** Palaeoenvironment, Human occupation, Upper Late Pleistocene, South-western Europe, Glacial refuge.

Long-term landscape change mirrors in seagrass *Posidonia oceanica* mats

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Seagrass meadows maintain high levels of biodiversity and are among the world's most important carbon sinks, but are facing a worldwide decline becoming one of the most threatened ecosystems. At least 1.5% of Earth's seagrass meadows are lost every year emitting up to 25% as much carbon dioxide as from land deforestation. The seagrass *Posidonia oceanica*, endemic to the Mediterranean, is strictly protected by the European Union and was declared a priority conservation habitat by the Habitat Directive, but *P. oceanica* meadows are declining rapidly at an estimated rate of 5% annually due to human pressure on coastal areas. Understanding its long-term dynamics may help habitat restoration, but a palaeoecological view is missing. The sequential accumulation of sediments and biogenic particles (i.e. mats) beneath their meadows over millenary time scales turns the *Posidonia* mat into a worthy studying palaeoenvironmental archive. This work aims to explore the palaeoecological potential of *Posidonia* mats with a study case from the Western Mediterranean (Portlligat Bay, Spain). Palaeoecological analyses have delivered long-term environmental data-series providing insights into processes impacting the continental landscape and mirroring in *P. oceanica* mat sediment archives. First, pollen and microcharcoal records enabled to reconstruct climate changes and anthropogenic disturbances (agriculture) for the last six millennia. Second, the record of glomalin-related soil protein (GRSP) accumulated in the *P. oceanica* mat showed that agrarian activities affected the arbuscular mycorrhizal fungi (AMF) microbiota, decreasing continental soil quality. Finally, sedimentological records revealed that cultivation resulted in coastal waters eutrophication and in an enhancement of soil erosion reducing the ability of *P. oceanica* to store carbon. Disturbances to *P. oceanica* inducing its current fast loss, hence its associated carbon storage capacity, are mainly related to chemical (eutrophication and urban sewage) and mechanical (fish farming, trawl fishing, anchoring and coastal development) processes. Continental land-use change, although not being the main factor inducing seagrass meadows disappearance, has affected the ability to store carbon for a much longer period of time. Under the Global Change scenario in which CO_2 emissions are projected to increase, the preservation of natural carbon sinks is important. Our evidences suggest that measures to reduce soil erosion caused by cultivation have to be implemented in the Mediterranean coastal areas in order to contribute to the preservation of the important socio-ecological ecosystem services provided by seagrasses.

***Keywords*:** *Posidonia* mat, palaeoecological archive, land-use change, soil erosion, carbon storage.

Paleoforest and vegetation remnants after impact of mining activity

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The Mining District Tlalpujahua is a cloud forest region that suffered strong deforestation and almost a complete biotic devastation for more than four centuries of mining activity (1550-1959). However, since the mining activity ceased and successively it was abandoned 60 years ago, this region also represents an example of an area with natural regeneration processes. The "new" vegetation that has spread at Tlalpujahua region can be related with a patches cloud mountain vegetation, isolated slow slope or deeply dissected areas and commonly to the rivers of intermittent water flow path (riparian). In order to understand the ecological impact as well as the vegetation recovering processes, we present a multiproxy study (geomorphological, geochemical and palynological study of soils, paleosoils and tailing mines) of the Tlalpujahua district. Based on the geomorphological and actual vegetation analysis criteria we have selected seven profile soil sites, which has maintained its character of pre-mining activity. On the profile sites, the soils show variable thicknesses of 0.30 up to 1.80 m, as well as variable composition with abundance from clay to silt composition that supports lithic fragments. The pH varies from 5.2 to 8.4 and CE 0 to 312 µS/cm. On the bottom of the paleosoils, we identify *Alnus Piperaceae Betulaceae Quercus Malvaceae Cupresaceae*, *Abies*, which suggest cloud forest; whereas on the upper horizons we identify *Poaceae Asteraceae Cyperaceae Fabaceae Chenopodiaceae* y *Buddleja*, which indicate an open vegetation with herbaceous species and is worth to note the *Buddleja* gender is identified as a pioneer to site a degree of disturbance. On the other hand, the contemporary pollen record obtained from moss gives 30 families which *Pinus*, *Quercus*, *Poaceae* and *Asteraceae* was the most abundant but the interaction with the other families shows a pine oak forest. The clay horizons of soils commonly show relatively low but variable abundance of the pollen record. Comparing old and contemporary pollen record suggest a drastic vegetation change from cloud forest to pine oak forest. Between these two kind of vegetation we note an open vegetation marker that suggests the beginning of the process of disturbance associated with mining activity.

***Keywords*:** Tlalpujahua Paleoecology, pollen analysis, geochemistry.

West African Monsoon variability across glacial-interglacial transitions: Integrated marine and terrestrial evidence from offshore Gabon

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Millennial-scale re-organisations of the strength of the West African Monsoon across glacial – interglacial transitions are commonly attributed to shifts in the position and intensity of the Intertropical Convergence Zone (ITCZ). Past hydrological changes have been inferred from palaeolimnological evidence, but these records are often discontinuous and difficult to date. Here we present an integrated record of terrestrial palynomorphs and $\delta^{18}O$ & $\delta^{13}C$ isotopic records derived from foraminifera (*Globigerinoides ruber* & *Cibicidoides wuellerstorfi*) from a marine sediment core taken at 01°N off the coast of Gabon to reconstruct the climatic evolution of western Equatorial Africa over the past 160,000 years (160 ka). Aquatic and mangrove (*Rhizophora)* pollen grains document large-scale changes in river discharge over the two glacial – interglacial transitions(140 – 125 ka & 30-15 ka) that are linked to variations in Atlantic Monsoonal rainfall, as well as acting an indicator of sea-level change. Two main taxa dominate the algal record: *Scendesmus*, an indicator of the strongest riverine input, and *Botryococcus*, which records surficial runoff in more arid periods, particularly at the onset of the two deglaciations. Dry glacial conditions are recorded on the continent with a significant representation of the Afromontane taxon *Podocarpus.* Further, a strong correlation between foraminifera and coccolith carbonate abundance and the Ca/Fe ratio during the two glacial periods (160-130 ka & 29-14 ka) suggests enhanced marine productivity in association with

cooler sea surface temperatures and heightened nutrient input linked to the proximal river mouth and/or coastal upwelling. Changes in the proxy records indicate that both terrestrial and oceanic domains off Gabon were impacted synchronously by significant climate changes since the penultimate glacial period. These combined data provide a coherent record of Ogooué River palaeodischarge that we interpret as reflecting a continental-scale precipitation signal, which we suggest may have been driven by the migration of the mean annual position of the ITCZ. Our data demonstrate the intrinsic link between marine and terrestrial systems and suggest a close linkage to northern high-latitude climate oscillations.

***Keywords*:** ITCZ, Ogooué, palynology, precipitation, marine

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Palynological investigations on biostratigraphy, biodiversity and climate variability of Pleistocene lake sediments in Thuringia/Central Germany

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Central Europe is a key region for investigations on Pleistocene faunal turnover and floral relationships. The special significance of this region has arisen from the drastically changing influences of the North Atlantic maritime climate and Eurasian continental climate regimes, resulting in repeated replacements of plant communities and faunal assemblages. A wealth of fossil records documents the Pleistocene faunal and vegetation history in Northern Central Germany. Several locally defined warm or cold periods of the Early to Middle Pleistocene have been established, which are not yet completely over-regionally correlated. One of them is the Arternian interglacial, which has been established on the base of a fragmentary pollen record of Erd (1978) within the so-called Muschelton (shell clay) horizon of Voigtstedt. Although the term Arternian interglacial is widely used in local stratigraphic discussions, its relative stratigraphic position has long been disputed, as well as the palaeoenvironmental conditions. A number of new outcrops appeared near Voigtstedt in 2009–2011, uncovering large parts of various Tertiary and Quaternary sedimentary sequences, including the shell clay deposits. The discovery of a variety of plant, invertebrate and vertebrate fossils within the Muschelton sequence provided the opportunity for new interdisciplinary investigations, to illuminate the stratigraphic age the Arternian interglacial including the palaeoenvironmental conditions. First interdisciplinary results indicate an Early Pleistocene age for the Muschelton deposition, within the range of MIS (marine isotope stages) 29–21 (c. 990–810 ka) (Maul *et al.* 2013). Here we present results from a new detailed palynological study of two sections of the Muschelton sediments, enabling a more precise biostratigraphical assignment and the investigation of the vegetation environmental changes, including seasonality, in great detail. The pollen assemblages reveal a complete interglacial sequence with a development of a distinctive temperate mixed forest followed by clear continental conditions represented by *Pinus* dominated boreal forests and partial open ground vegetation. Outstanding features of this warm phase are the very rare proofs of *Carpinus* and high values of *Abies* at the same time. A comparison of the shell clay vegetation development with other palynological results of neighboring European regions enables a most likely assignment to the established interglacial profiles of Leerdam which is synchronous with the Pinneberg interglacial and Augustovian I. Further similarities were detected by comparing our results with partly uncertain biostratigraphically classified data from Southwestern Germany (Schifferstadt), North Western Germany (Surheide, Hunteburg, Mosebeck) and possibly Denmark (Ølgod).

***Keywords*:** quaternary lake sediments, palynology, Early Pleistocene biostratigraphy

Late Quaternary pollen and stable isotopes record in Serra do Cabral region, Minas Gerais State, Brazil

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Pollen and stable isotopes (C and N) analyses from sediments of *Carrasco da Raposa* palm swamp, resulted in a model for the late Quaternary paleoenvironmental reconstitution in the *Serra do Cabral* mountain range region. The pollen record analysis suggested colder and less humid climate conditions at the Last Glacial Maximum, between 21,160 cal. years BP and 12,360 cal. years BP compared to present day climate, due to the presence of *Podocarpus* and *Drymis brasiliensis* pollen grains. During the Pleistocene-Holocene boundary an increased variability of grass and arboreal pollen grains indicates a warmer and wetter climate until 1,670 cal. years BP, characterizing a *Campo Sujo* associated with *Cerrado* forest formations landscape. From 1,670 cal. years BP the presence of palm swamp with *Mauritia flexuosa* trees indicates average annual rainfall above 1,000 mm and the length of the dry season between five and six months. The isotopic data (C and N) indicates changes in humidity reflected in the vegetation composition and organic matter source of *Carrasco da Raposa* palm swamp. Between 21, 160 cal. years BP and 5, 300cal. years BP, the $\delta^{13}C$ values ranged from ~-24 ‰ to -21.5 ‰ indicating the presence of C3 and C4 plants as sedimentary organic matter source, but with the predominance of C3 plants. Values of C/N ranged from 1.5 to 11.5 and indicated a predominance of organic matter originated from phytoplankton. The $\delta^{15}N$ values ranged from 3.5 ‰ to ~1.0 ‰ and represents a mixture of organic material derived from *algae* e and land plants. From ~4.100 cal. years BP it was observed a decrease in the C/N values, which ranged from 1.5 to ~6, reflecting the dominant presence of a flooded environment with greater influence of *algae* in the sedimentary organic matter. Support/thanks: CAPES and FAPEMIG.

***Keywords*:** Pollen analysis, C and N stable isotopes, Holocene, climatic changes, *Cerrado.*

Vegetation evolution during the Late Pleistocene in Restinga de Jurubatiba National Park, Northern Rio de Janeiro State, Brazil

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The Restinga de Jurubatiba National Park (PARNA Jurubatiba), the largest restinga system in a Brazilian Conservation Unit, is located on the continental section of Campos basin, Rio de Janeiro State. In this region, pleistocenic and holocenic sediments outcrop and spread through the basin emersed area, comprising the whole northern coast of Rio de Janeiro State. The PARNA Jurubatiba presents the State's longest quaternay plain, with terraces and paleo-beach ridges formed by pleistocenic/holocenic marine sand and, between the beach ridges, floodable areas, some fed by rivers or coastal lagoons transversal to the coast. This National Park displays a mosaic of land and aquatic ecosystems, comprehending forests and island-like vegetation formations, intertwined by freshwater and brackish water lagoons. In this scenario, peat sediments were found emerging at the foreshore. Aiming to know the landscape evolution and the past climatic conditions as well, an undeformed peat block was collected for palynological analyses and radiocarbon dating. Samples for palynological analyses were successively treated with HF at 40%, HCl at 10% and classic acetolysis, with posterior sonication. Subsequently, permanent slides were mounted with glycerin jelly and sealed with paraffin. The radiocarbon dating of the peat deposits points to a pleistocenic age and the palynological analyses indicate an open environment, probably associated with restinga ecosystem. Around 43500 years BP a predominance of Poaceae was checked, as well as the presence of taxa related to humid environments and forest pioneer species, like *Trema* and Melastomataceae. Such vegetation carries out until around 27000 years BP, when species of Myrtaceae and Aquifoliaceae

(*Ilex*) increase. These families are found in restinga vegetation nowadays. Fungi, ferns and lycophytes spores and plant tissues were observed in all analyzed peat levels. Other coastal peats, investigated along the Brazilian coast presented holocenic ages only, making the peat from Jurubatiba unique and quite meaningful from the micropaleontological, paleoenvironmental and paleocological points of view.

***Keywords*:** Restinga de Jurubatiba National Park, coastal peats, Late Pleistocene, pollen analysis

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Palynological analysis of teeth calculi of the gomphothere *Notiomastodon platensis* (Mammalia: Proboscidea) from Northeastern and Southern lowlands of Brazil

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Tooth calculus is a mineralized matrix, formed by a conglomeration of oral bacterial flora and saliva components. Due to its progressive accumulation and good condition after fossilization, many diet microremains can be recovered, making calculus analysis an excellent tool for paleodiet reconstruction. This study aims to reconstruct the paleodiet of the South American gomphothere *Notiomastodon platensis* (Ameghino, 1888), by identifying palynomorphs assemblies from tooth calculus. We selected 12 molars teeth from Northeastern (Pernambuco and Sergipe States) and Southern (Rio Grande do Sul State) Brazilian localities. The teeth were cleaned with acetone and alcohol for posterior calculi removal. Altogether, 17 samples were extracted and submitted to the chemical processing to recover plant microfossils. Permanent slides were mounted and examined at 20x and 40x magnification of a photonic microscope. The results indicate a high percentage of indeterminate pollen grains/palynomorphs for all specimens evaluated (37.7% of total), due to damaging effects caused by chewing and posterior preservation. Among the pollen grains identified, Northeastern specimens showed only herbaceous pollen grains (Poaceae: 26.1%, Asteraceae: 8.7%, Chenopodiaceae: 4.2%). On the other hand, Southern specimens presented proportional percentages between herbaceous and arboreal plants from grasslands (15.6%), Atlantic forest (33.3%) and Araucaria forest (1.25%) biomes. The most significant pollen types representing each biome include Poaceae (14.4%), Myrtaceae aff. *Myrcia* (21.3%), *Podocarpus lambertii* (0.6%) and Cunoniaceae aff. *Lamanonia* (0.6%). These results suggest an opportunistic behavior among Brazilian gomphotheres and corroborate previous paleodiet studies. Northeastern individuals possibly inhabited open regions with grasslands domains, agreeing with previous palynological analysis of Quaternary sediments from Northeast, which suggests coverage by Caatinga vegetation. Although, palynological studies from the sediments in Rio Grande do Sul coast suggest dominance by grasslands. Our results indicate that the Southern gomphotheres also had access to forest fragments, which contributed to the significant percentage found in the samples. Therefore, it is suggested that these individuals had generalist dietary habits and probably varied their diet based on migrations and/or sazonal behaviors. This study has proved effective and contributed to the enrichment of information about the Gomphotheriidae paleoecology in Brazilian lowlands. In addition, other plant microfossils detected will help us refine these proboscideans's diet, as well as the climatic/environmental aspects surrounding the sites during the Pleistocene.

***Keywords*:** Gomphothere, Quaternary, paleodiet, tooth calculus, palynomorphs

Palynological studies in archaeological sites of Zona da Mata Mineira (Minas Gerais and Rio de Janeiro States), Southeastern Brazil

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Pollen analyses were carried out in archaeological sites located between Minas Gerais and Rio de Janeiro States, Southeastern Brazil, comprising the Zona da Mata Mineira and vicinities. This area is geographically characterized by the presence of small and medium size hydrographic basins and by the "mar de morros" aspect, due to a series of lowered hills. The local climate is tropical of altitude, with annual mean temperature varying from 19° to 22°C, creating a proper environment to the establishment of human groups. The local vegetation is inserted in the Atlantic Forest domain, with diversified composition. For this study, Campo Belo (Queluzito/ Minas Gerais) and Ubá (Vassouras/Rio de Janeiro) archaeological sites were selected. The techniques here adopted for collection, sampling, chemical treatment of quaternary sediments, palynomorphs counting and palynological diagrams presentation were based on the Laboratory of Palynology's published methodology. Comparing the palynological analyses results of the evaluated sites, we suppose the management and land use techniques were different between the human groups that occupied these areas. In Ubá site, the concentration of carbonized particles is low, pointing to few local events of fires for land clearing, which is called "coivara". On the other hand, the abundance of these particles in the sediments from Campo Belo site indicates a higher frequency of such practice in this locality, hypothesis reinforced by the presence of darkened pollen grains. In the sediments from both sites, pollen types typical of Atlantic Forest were not representative, suggesting that tree species did not occupied the area *in situ*, but were present in the surroundings. This might indicate that the human groups removed the vegetation for land clearing and occupancy. Pollen grains of cultivars were not found, making possible to affirm that the "coivara" practice was meant for other purposes, but agriculture. Ubá archeological site is located in the middle of a valley and close to the source area of tree pollen grains, favouring in theory the pollen rain deposition. However, the biodiversity of these pollen types is low, probably due to wind dynamics that carry these pollen grains to long distances. Pollen types characteristic of anthropic field are also scarce, suggesting that may be the vegetation was poorer in terms of richness and diversity in Vassouras, when compared to the past vegetation in Queluzito.

Keywords: Archaeopalynology, Zona da Mata Mineira, human occupations

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Past environment and cultural connections through archaeobotany: new insights from Italy (BRAIN)

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Plant remains - including mainly pollen, non-pollen palynomorphs, seeds and fruits, woods and charcoals - are among the most important biological archives upon which past environmental reconstructions are based. In archaeological contexts, humans and their animals largely bring plant micro- and macro- remains to the site and thus cultural variables strongly influence the pollen spectrum and the archaeobotanical record. This taphonomical peculiarity is crucial to explore human behaviour and cultural aspects of plant exploitation. A set of palynological / archaeobotanical research has been carried out in the last decades by the members of BRAIN - *Botanical Records of the Archaeobotany Italian Network*. The research joins multidisciplinary archaeological study to palaeoenvironmental – ecological approach, with focus on the Italian peninsula and its impressive prehistoric and historic archaeological heritage. The framework of these integrated researches is very promising with a view to defining fairly precisely the onset and development of

human-influenced landscapes from which the cultural landscapes and most of our current 'green heritage' has derived. In 2014, BRAIN became a database of plant records from archeological sites and human-related deposits in throughout Italy. The free on line database reporting on the list of sites and main geographical and chronological information is available at https://brainplants.unimore.it/. The BRAIN database may be useful for projects dealing with landscape evolution, ethnography and ethnobotany, the application of biology to archaeology, the application of archaeology to ecology, botany and nature conservation: these are among the best tools to develop this multifaceted science.

Keywords**:** pollen, plant remains, Holocene, Italian archeological sites, database.

Paleoenvironmental records inside the Cerrado biome associated with meandering river dynamics during the Holocene — Southeast region of Brazil.

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The study of paleoenvironmental evolution of the Biome of Cerrado during the Holocene resulted in the recovery of vegetation, climate and fluvial dynamics of Mogi Guaçú River in The Mogi Guaçú Ecological Station (EEcMG) - São Paulo State. The paleoecological and paleoclimatic inferences were based on palynomorphs assemblies, charcoal fragments, and isotopic analyzes contained in three shallow cores drilling in three lakes. The analysis of these *proxy* highlighted the changes occurred in the vegetation and the main course of Mogi Guaçú River at EEcMG to characterize the paleoenvironmental changes from 7.750 years BP to current days. Thus, approximately 7.750 years BP, the EEcMG underwent a wetter climate than the current phase, enabling the development of a Riparian Forest with the abundant presence of *Mauritia* sp. The isotopic data features a transition between forest and more open vegetation (Forest). Around 3.000 years BP, there was an increase in the Cerrado elements, as the presence of *Curatella* sp., and a decrease in *Mauritia* sp. In fact, *Mauritia* sp. was not an important element to configure the vegetation of the period with a drier climate for EEcMG, and the isotopic composition corroborate the predominance of C3 plants (Forest). Between 310 and 105 years BP., the humidity increased in the region with the permanence of *Mauritia* sp., but the Cerrado types also increased, indicating that the Riparian Forest remained. Thus, the palynological assemblies show that the Riparian Forest was present in all stages, unlike Forest, during the last 7.750 years BP., underwent phases of expansion and contraction. Through the study of current pollen rain of the three lakes was possible to infer that the elements of Riparian Forest are prevalent, as the presence of *Mauritia* sp. and the abundance of spores that confirms this type of dominant vegetation for current days, featuring a more humid climate at EEcMG. Isotopic analyzes show that the Forest remains with a predominance of C3 plants (Forest) in relation to C4 plants (field). *Charcoal* fragments were identified in all three cores showing the evidence that paleofires occurred at EEcMG throughout the Holocene. The behavior of fluvial dynamics of Mogi Guaçú River during the Holocene showed the influence of climatic events and consequently, the meanders constantly changed position along the plain through erosion and deposition processes, these changes affected the local vegetation.

Keywords**:** Holocene, River Dynamics, Pollen grains, Isotopic analysis and *Charcoal* fragments.

Paleoenvironmental study during the last 20,000 years AP around the city of Campinas, State of São Paulo, Brazil

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The study of climate changes allows a better understanding of how these changes influenced the distribution of standing vegetation; it is known that plant communities changes their composition and distribution under the influences of different rainfall patterns occurred during the Quaternary. In this sense, this research aims to make a paleoenvironmental reconstruction in the last 20,000 years BP, ranging from the last glacial maximum (LGM) to the present, around the city of Campinas, SP. It was carried out by palynological and isotopic analysis in a core of 182 cm deep drilling in a natural soil system of riparian forest of Cerrado Biome, located in the Quilombo river, Fazenda Santa Elisa (IAC). The dates obtained by the method of 14 C-AMS Lab Beta Analytic, the age of the basis of core was 20850 +/- 60, at 90 cm deep 14910 +/- 60 and 40 cm 2890 +/- 30. Likewise was identified the isotopic composition of carbon and nitrogen (δ13C e δ15N) every 10 cm along the witness , for a total of 19 samples in the Stable Isotope Laboratory of the Center for Nuclear Energy in Agriculture CENA-USP. The palynological study was carried out by applying the classical protocol for Quaternary sediments. For identification of the types of pollen was necessary to build a pollen library with 58 taxa, corresponding to 29 families present the current vegetation, based on flowers collected in the herbarium UEC. Being in an area with Cerrado physiognomy, water conditions are the mayor factors to influence the floristic composition, in this sense it is interesting to know how the role of precipitation and its relation to the changes in the composition of palynological assemblages studied. Considering whereas in period with less rainfall totals, Cerrado or dry forests occupied more extension, than during wet periods. Similarly it was evaluated the anthropic role in shaping these landscapes. This type of study allows us to understand the response of vegetation to these changes both natural and anthropic, and comparisons with other cities in Brazil and Latin America.

***Keywords*:** Quaternary, Cerrado, 14C

Lithological and palynological implication for the Holocene environmental histories in Gomso Bay, the west coast of Korea

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To better understand Holocene environmental history in Gomso Bay, the west coast of Korea, we obtained a sediment core 14DH-C01 from the mouth of Gomso Bay to reconstruct the Holocene depositional environment and climate changes. AMS^{14}C ages controlled multi-proxy data including sediment composition, grain size, texture, and palynology were showing that the Holocene stratigraphy was divided into the five four units: paleo-river, tidal flat, delta front and sand bar. The sedimentary environment was a retrogradational process of paleo-river and estuary tidal flat from pre-Holocene to 8.22 cal ka BP, and subsequently, this environment has been change to delta front by there was a progradational process. The maximum flooding surface was formed at the boundary of the retrogradation and progradational processes. After 6.27 cal ka BP, there is a sand bar with aggradational process and slightly. The climate was warm and wet during 8.48 to 6.27 cal yr ka BP, after then, the climate was relatively cold and dry. However, there was a relatively cold and wetter period during 8.25-8.18 cal ka BP. The sedimentary rate was changed followed the climate change, regional climate change was very important for Holocene sedimentary change.

***Keywords*:** sedimentary environment, palynology, climate change, Holocene, sea level change.

Change of pollen assemblages during MIS 22-21 in the latest Early Pleistocene: an example from the Omma Formation, central Japan

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The Lower Pleistocene Omma Formation at the type locality is mainly composed of shallow-marine sediments with abundant fossils. The geological framework such as the age (c. 1.6-0.8 Ma), marine climates and the relationship with the marine isotope stages (MIS 56-21.3) have been well documented. The formation distributes along the Sea of Japan and the marine environments are reflected by the warm Tsushima current, which links to the sea-level changes due to the shallow strait at the south. We present the change of pollen assemblages of the lower part of the depositional sequence U4 in the upper part of the formation. The U4 sediments show the back-mash to inner-shelf environments and are correlated to MIS 22-21, which are the important stages of the Mid-Pleistocene Climatic Transition (MPT). We have got pollen fossils from 37 samples so far: eight from lower back-mash sediments (MIS 22), others from upper marine sediments (MIS 21) with warm-water molluscan species. Pollen assemblages are generally concordant with the sedimentary facies and environments. Pollen assemblages from the back-mash sediments (zone I) consists mainly of *Fagus*, *Alnus* and *Quercus* (deciduous type). In contrast, pollen assemblages from the marine sediments (zone II) are comprised mainly of 'Taxodiaceae' type and *Fagus*. The pollen assemblage change from zone I to zone II is similar to that in the early stage of the postglacial period of the latest Pleistocene and Holocene. The climatic climaxes of the cold and warm intervals are not extensive in comparison with the last glacial maximum and hypsithermal periods, respectively. The pollen assemblage change of this study is mainly attributed to the precipitation change rather than temperature. *Cryptomeria*, the most probable taxon of the 'Taxodiaceae' type, is considered to be an indicator of the high precipitation up to 1,800 mm/year. In the period of the zone I, the warm Tsushima current was not or weak in the Sea of Japan because the sea level was low. In the period of the zone II, sea level rising caused the inflow of the warm Tsushima current to the Sea of Japan, resulting in humid climate especially in winter due to the interaction between the warm Tsushima current and Asian winter monsoon as in present. We conclude that the terrestrial climatic change during MIS 22-21 would be considerable weaker than that of the latest Pleistocene and Holocene.

Keywords: MPT, marine climate, 'Taxodiaceae' type, warm Tsushima current, precipitation

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Climate and human influences on changes in a Japanese cedar forest in the northern region of the Sea of Japan since the Holocene

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In the northern region of the Sea of Japan, people have been using Japanese cedar (*Cryptomeria japonica*) wood since ca. 3000 years ago, as it has been abundant in a natural *C. japonica* forest since that time. Reconstructing the expansion and formation of the *C. japonica* forest and determining the influences of climate change and human activities will be useful for continuing forest administration. In this study, we reconstructed changes in the *C. japonica* forest during the past 10,000 years through age dating and pollen analysis of seven peat sediments collected from Akita Prefecture, northern Japan. Ancient documents recording past landscape use and human activity near the sampling sites were collected and compared to reconstruct vegetation change. The expansion of *C. japonica* occurred 3000–2500 cal year BP at most sites, but before 3500 cal year BP at sites within its natural distribution area. In addition, *C. japonica* was present before 6000 cal year BP at all sites. Tsukada (1980) assumed that the expansion of *C. japonica* forests in the northern region of the Sea of Japan was due to the migration of *C. japonica* from the south with increasingly humid conditions. However, we consider that some small *C. japonica* groups, scattered near the sites, expanded around 3000 cal year BP. A recent decrease in *C. japonica* began ca. 500 cal year BP at most sites. It was associated with increases in diploxylon pines and herbaceous taxa, such as Gramineae and *Artemisia*, at all sites. Moreover, results showed that *Fagopyrum* was cultivated at

some sites. *C. japonica* wood has been exported since about AD 1450 from Akita to the Kinki region, the location of the capital of Japan at that time, and was consumed enormously in the region from the 1590s. Human influences, such as agriculture and timber utilization, began to increase in the Edo Period around this region.

***Keywords*:** Japanese cedar, Akita, Holocene, pollen analysis, human influence

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Palaeoenvironment and vegetation changes in southwest Nigeria during the past 1375 cal YBP

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Pollen data from a 200 cm sediment core from Awerele, a wetland in Orile-Owu, southwest Nigeria, were recovered. Previous studies in the area had focused on the archaeology of the local without consideration of the environment. This study attempts a reconstruction of the vegetation history with the aim of providing insight into the palaeoenvironment and possible glimpses of human influence on the landscape over time. Thirty-eight sediment subsamples were subjected to pollen extraction procedure. A total of 100 pollen and spore taxa were identified in the analysed samples. Stratigraphically constrained cluster analysis suggests six pollen zones with eight phytoecological groups: secondary forest, montane forest, lowland rainforest, freshwater swamp forest, savanna, weeds, fresh water swamp and ubiquitous vegetation, fern spores, *inter alia*, individual taxa. Well preserved pollen that could not be identified beyond the genus level were categorised as ubiquitous since they have the potential of being widely distributed. Results showed that zone I (195-175 cm; 1490 ± 30 BP, ca. 1375-1300 cal BP) was a period marked by high value of charcoal particles associated with paucity of pollen of lowland rainforest (LRF) species (only *Canthium vulgare*), low frequency of *Elaeis guineensis* (oil palm tree) pollen grains and high values of unidentified pollen grains, indicating the occurrence of rudimentary burning techniques related to clearing land for planting, hence an opening of the vegetation. In zone II (175-135 cm), the environment experienced wet conditions depicted by high percentage of arable weeds, Cyperaceae, fern spores, increase values of *E. guineensis* and the higher frequency of *Phyllanthus discoideus* pollen grains (a natural grass hay used nowadays to sheep feed), coupled with a remarkable reduction in charcoal amount. However, *E. guineensis* decreased at the upper part of the zone II with a corresponding slightly increase in charcoal particles. Zone III (135-105 cm) to Zone VI (50-0 cm) were characterised by the prevalence of *E. guineensis* with fluctuating frequencies of LRF, *Alchornea*, Poaceae, arable weeds, charcoal and occurrence of pollen of plants exploited for food and medicinal purposes: *Irvingia gabonensis*, *Chromolaena odorata*, *Vernonia perrottetii*, *Tetrapleura tetraptera* and *Cola acuminata.* Increasing frequency and diversity of herbaceous arable and ruderal pollen and, plants with ethnobotanical significance from zone II to zone VI indicate enlarged local landscape disturbance during the period probably associated with humans activities. Thus, recovered pollen grains were instrumental in providing clues into the ecology of the area and possible plant utilization by the people.

Keywords: Awerele wetland, Orile-Owu, vegetation history, archaeopalynology, arable weeds

Late Glacial pioneer vegetation and paleoenvironments in the Beagle Channel, Tierra del Fuego, southernmost Argentina: preliminary results

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We interpret Late Glacial vegetational communities and paleoenvironments from a peat bog located in the north coast of the Beagle Channel, southernmost South America, based on plant macrofossils, palynology and diatoms. The Harberton peat bog is located 700 m north of the Beagle Channel coast, in an inter-drumlin area into a drumlin field formed during the Late Pleistocene glaciation (Last Glacial Maximum, 24.000 yr BP) when the front of the Beagle glacier reached Punta Moat, about 60 km east of the study area. Laminated silty-clay deposits were identified in the base of the peat core (between 10.37 and 9.94 m). We analyzed this basal portion of the core with the aim to identify the pioneer species that colonize the first deglaciated land, before the development of extensive peat bogs in the area. The base of the silty-clay sequence has been radiocarbon dated as 16,152 yr BP and the top as 13,298 yr BP. First results show the presence of two main groups of plant macrofossils: angiosperms and Bryophyta s.s. The angiosperms include 3 families [Poaceae, Cyperaceae and Ericaceae] and the bryophytes include 9 families with 10 taxa [Amblystegiaceae (*Limprichtia*), Bryaceae (*Bryum pseudotrichetrum*), Dicranaceae, Dicranellaceae (*Dicranella*), Ditrichaceae (*Distichium capillaceum*), Hypnaceae (*Isopterygiopsis*.), Meesiaceae (*Meesia uliginosa*), Plagiotheciaceae (*Plagiothecium*) and Sphagnaceae]. Samples were analyzed each 5cm, to study the palynomorphs and diatoms content. The palynomorphs identified in the studied section are represented by *Nothofagus dombeyi* type, Poaceae, *Gunnera*, *Empetrum rubrum*, Cyperaceae, *Myriophyllum* and Sordaria-type fungi spores. The aquatic palynomorphs are represented by microfossil type 181 (van Geel). The diatom analysis showed the presence of fragilarioids in all basal sequence. In summary, the pioneer vegetation development in this recently deglaciated land mainly that included herbs (Poaceae and Cyperaceae), heath (*Empetrum rubrum*) and wet and rocky mosses (*Isopterygiopsis*, *Plagiothecium*). The low frequency and concentration values of *Nothofagus* pollen imply sources from distant forest. These preliminary data show the presence of a shallow lagoon environment close to recently deglaciated land, affected by local glacier meltwater discharge.

***Keywords*:** macrofossil, Bryophyta, palynology, diatoms, Pleistocene

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The contribution of dinocyst assemblages to the reconstruction conundrum of past water levels in the Caspian Sea

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The Caspian Sea (CS) is a brackish lake mainly fed by the Volga River. As the worldwide largest endorheic lake, understanding the patterns involved in the CS level change is the uppermost importance, not only owing to the impact that water level has on oil industry and fisheries, but also to improve global climate models. However, Late Quaternary CS level changes are insufficiently documented and their causes poorly understood. To shed light on this problematic a compilation of existing CS level curves since the Last Glacial Maximum is presented. These reconstructions, although showing some common patterns, exhibit great discrepancies during the Holocene, highlighting the complexity of the CS. In addition, the generalised lack of metadata makes difficult to understand how data were obtained and evaluate their reliability. Owing to the CS idiosyncrasy, the sound methods used to reconstruct sea levels in the global ocean (e.g. oxygen isotopes in foraminifera) do not provide good results. Here the use organic-walled dinoflagellate cysts is proposed to reconstruct qualitative CS level changes based on the relative proportions of low (≤7 psu) versus brackish (~13 psu) salinity dinocysts.

To show the potential of this method the dinocyst assemblages of two unique deep-sea sediment sequences from the south and middle basins are compared with the compiled curves. They show an overall fit up to the Mangyshlak lowstand. However, during the Holocene, when most curves show discrepancies, we detect several main differences: the higher water levels after the Mangyshlak lowstand, and a sharp water level drop after 4 cal. ka BP. While for most of the period a N to S salinity gradient is reconstructed in agreement with the current status, a reverse salinity gradient is proposed at 8.5-4 cal. ka BP. The source of water is attributed to the Amu-Darya, currently disconnected from the CS drainage basin. It is likely that the CS was at that time strongly influenced by low latitude climates in the Hindu-Kush and Pamir at the contact with the Indian Summer Monsoon in contrast to the present situation where the climate of its drainage basin is the main forcing factor. In conclusion, the use of dinocyst assemblages on the CS provides reliable water level changes information although more quantitative approaches have to be developed using this proxy in combination with the use of a range of isotopes to disentangle freshwater sources and inflow directions.

Keywords**:** Caspian Sea, dinocysts, water level reconstruction, freshwater sources, Amu-Darya.

Fluvial valley evolution in the southern coast of Bahia during the Holocene based on palynofacies and stable isotopes

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Organic matter in sediments records the environmental sources that influenced its production, transport and deposition. The main aim of this work was to understand the sea level variations that occurred during the last ~8000 years Before Present (BP) in the coastal southern Bahia, based upon the integration of palynofacies and stable isotopes (C and N) from a 740-cm sediment core collected from Jucuruçu River valley, far ~33km from the coast. Isotopic ($\delta^{13}C$: -23.9‰ to -28.6‰; $\delta^{15}N$: -1.3‰ to 18.1‰) and elemental (total organic carbon - TOC: 0.03% to 78.9%; total nitrogen - TN: 0.001% to 1.1%; C/N: 5 to 152; S: 0.001% to 5.9%; C/S: 0.08 to 41.5) values recorded suggest that the sedimentary organic matter was derived mostly from C_3 land plants and freshwater and/or marine phytoplankton. About 7800 cal years BP, the depositional environment probably was an estuary/tidal channel, where the sediments were composed of sand and sterile for particulate organic matter. Between ~7450 and ~5520 years cal BP the presence of heterolithic deposits, besides the predominance of amorphous organic matter (MOA), non-opaque phytoclasts (NOP), pyrite crystals and marine indicators (dinoflagellates and foraminiferal test linings) reflect a tidal flat environment formed during the marine transgression. A fluvial plain was formed in the last 5000 years cal BP, owing to marine regression and an increase in the river flow. No marine influence was recorded during this period. The results of palynofacies used in interdisciplinary studies of Quaternary have shown to be essential for characterizing the origin, transport and settling of particulate organic matter. [Grants: FAPESP 2015/05111-0, 2011/00995-7; CNPq 470210/02012-5, 2013-0/405060].

Keywords**:** Holocene, palynofacies, stable isotopes, marine dynamics, fluvial valley.

Palynology and vegetation dynamics in the last 2600 years in the coastal plain of extreme Southern Brazil

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Paleopalynology studies based on sedimentary profiles and radiocarbon dating enables the investigation of plant succession and dynamics of vegetation. Understanding this dynamics in coastal plain allows inferences about past climates and marine oscillations. Furthermore, comparisons to studies from other regions yield a

broader and more accurate view about climate dynamics in greater areas. As the physiognomy of present-days landscape is, besides a response to the current climate conditions, a resultant of climatic and vegetation events occurred in the past, combining vegetation dynamics studies enables predictions about vegetation and climate natural tendencies, which is important in environmental monitoring, conservation and preservation. Thereby, we realized a palynological study in a paleolagoon in the coastal plain of extreme southern Rio Grande do Sul, the southernmost state in Brazil, aiming to unravel the vegetation dynamics both locally and regionally in the last millennia. For that purpose, reliable sources are essential to support identification of preserved material, especially palynological catalogues and palynothecae, both covering actual and preserved grains. For that reason, we prepared palynological catalogues, which, along with the collection at the palynotheca of the Palynology Laboratory (Dept. of Botany, UFRGS), served to subsidize this paleoenvironmental study. We counted preserved palynomorphs and generated pollen diagrams to elucidate past environments. Results indicate the vegetation succession in a paleolagoon in the interval ranging from 2600 to 1800 yrs BP (years before present), when transgressive sands sealed the sedimentary pack. For the phase between 2600 and 2400 yrs BP, occurrence of aquatic organisms, such as *Botryococcus*, *Spirogyra* and *Zygnema*, indicated aquatic environment. Occurrence of dinoflagellate cysts, *Michrystridium* and microforaminifera, indicated marine influence, probably reflecting sea retreats initiated about 4000 yrs BP. The presence of these organisms declined progressively between 2400 and 2000 yrs BP, until it disappeared, being substituted by a growing occurrence of fresh water indicators, such as *Myriophyllum* and *Cabomba*, evincing gradual desalination process. Between 2000 and 1800 yrs BP, indicators of aquatic environment stopped occurring, and there was an expressive increase of grassland and marsh indicators (e.g., Cyperaceae, Poaceae, and *Blechnum imperiale*). The vegetation succession was ceased at the marshy phase by transgressive sands, sealing the sedimentary pack. Studies in the coastal plain in the north of the State evidenced that succession continued and formed forests, what did not happen in the southernmost region. This may be explained for the great latitude and the climate conditions, which do not allow the formation of forests.

***Keywords*:** Holocene, coastal plain, paleoenvironments, pollen analysis, Rio Grande do Sul

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Late Pleistocene-Early Holocene scale climatic changes in the Mediterranean region based on high-resolution pollen and multi-proxy analyses (Padul peat bog, southern Spain)

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The Mediterranean region and specially, the southern Iberian Peninsula, is a very sensitive area for palaeoenvironmental studies due to its location, between arid and temperate climates. The Padul basin, located in southern Spain, is an extraordinary site for palaeoclimatic studies as it contains a long and continuous sediment record of ca. 0.8-1 Ma until Present. In 2015, a 42 m long core was taken from the Padul peat bog, providing with an excellent sediment record to identify and understand past environments and climate changes. This study focused on the paleoenvironmental and climatic reconstruction of the Late Pleistocene and the Early Holocene (ca. from 50,000 to 9,500 cal yrs BP), using high-resolution pollen analysis and other different proxies (lithology, XRF-scanning, magnetic susceptibility and organic geochemistry) to identify the LGM (Last Glacial Maximum) as well as different Heinrich events during the Late Pleistocene, with special attention to the deglaciation and the Younger Dryas event (Pleistocene-Holocene transition). These different proxies give us information not only about the regional environment change (given by pollen analysis), but also about local changes in the conditions of the Padul lake/peat bog because of variations in water temperature, pH or nutrients. The study of high-resolution multi-proxy records of the Late Pleistocene-Early Holocene transition is essential to understand past and future climate change.

***Keywords*:** Climatic changes, Pleistocene-Holocene transition, Heinrich events, Multi-proxy analysis, Mediterranean region.

Particulate Organic Matter and Dinoflagellate of a sediment core of 29.235 cal yrs BP from Rio de Janeiro Platform

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The study of particles from organic origin and dinoflagellate cysts present in marine sediments provide important information for the understanding of paleoenvironmental changes, and climate fluctuations that marked the Quaternary. This study was carried out to perform palynofacies analysis and dinoflagellate cysts in a sediment core of 186 cm deep (PC - PRIMA 2), in order to verify the change in the distribution of organic matter during Late Pleistocene. The sediment core was collected in the platform of Rio de Janeiro under the coordinates 23°29'54'S, 42°30'29'W, at a water depth of 130 m. To establish the chronology of the material, three samples were dated by the 14C method, with the base age of 24.235 years cal BP (186 cm), 22.806 cal yrs BP in 43 cm and 19.995 cal yrs BP at the top. It used non-oxidative preparation techniques, sifting and screening for analysis of dinoflagellate cysts and non-oxidative technical standard for palynofacies. Total organic carbon-TOC results were obtained whose value has not changed, remaining in 0.4% for all samples; and total nitrogen (NT) ranging between 0.06% and 0.1%. The C/N ratio had an average value of 5.2, it may be associated with an organic material of marine phytoplankton origin. For palynofacies analysis, they were classified and accounted for about five hundred particles on each sample. The raw data were transformed into percentages and employees in statistical methods of grouping. The group of particles with the highest abundance was phytoclasts with 60% of the total particulate organic matter of the sediment core, followed by 36% of Palynomorphs and 3.3% of AOM. The particles with a higher frequency were Non - Opaque (NOP) with 74.9% of the total followed by phytoclasts particles of marine origin with the value of 89% of the total Palynomorphs. The dinoflagellate cysts analysis along of the core has identified 38 species, *Lingulodinium machaerophorum*, *Nematosphaeropsis labyrinthus*, *Operculodinium centrocarpum*, *Selenopemphix nephroides*, *Spiniferites spp.* and *Tuberculodinium vancampoae* the most representative. The ratio Peridinoids/Gonyaulacoid was established in order to observe variations in the productivity and in the coast line. The total values remained between - 0.9 and -1, indicating a dominance of dinoflagellates of Gonyaulacoids group. The palynofacies data indicate that the environment can be considered as proximal marine which was under constant fluvial influence. While the data provided by dinoflagellates analysis indicate a shoreline proximity with water temperature between 28°C to 32 °C and salinity between 21 to 31.3 ppm.

***Keywords*:** Quaternary, dinoflagellate analysis, Palynofacies, climatic changes

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A high resolution pollen record of resilient vegetation for the last 11400 years cal BP in northern Iberian Peninsula (Spain)

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In this study we present a new paleoenvironmental high resolution pollen record from Northern Iberian Peninsula (Spain), the mire of Gesaleta. It is located in the Anue valley, in Navarra (30T, 616427 E/ 4759802 N/ 900 m. asl. 2.74 has). This region is very interesting from the biogeographical point of view because, although it is located in a Mediterranean area, it is very close to the frontier with the Eurosiberian area of northern Spain. The existence of mountain barriers parallel to the coastline limits the progressive arrival of Atlantic influences, favouring complex and rich floristic variability. For this reason, at the present time this mountain region has a great variety of landscapes, where floristic elements typical of the humid deciduous forests of the Bay of Biscay coexist with species better adapted to more continental climate. Through the high resolution study of pollen, spores, non-pollen palynomorphs, loss on ignition, carbon accumulation and microcharcoal, with the support of 9 AMS radiocarbon dates, we analyze the paleoenvironmental conditions

of this region since *ca*. 11400 years cal BP. The main results shows the dominance through all the sequence of deciduous forests with *Corylus*, *Betula* and deciduos *Quercus* as main taxa, with riverside vegetal formations (*Alnus*, *Salix*, *Ulmus*) and, from *ca*. 2765 cal BP a clear expansion of *Fagus sylvatica*. Shrubs and herbs are less abundant. The main singularity of this area is the stability in its vegetal systems, suggesting that we are facing a complex ecosystem with a high degree of resilience.

***Keywords*:** Palaeoenvironment, Resilience, Holocene, Northern Iberian Peninsula, Spain.

Late Holocene human impact in the Gredos range (central Spain) by combining palynological data and statistical analysis

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Since 2014, an integrated palaeoenvironmental and archaeological research programme has been developed in the Spanish Central System using sedimentary records preserved in bogs and archaeological sites, with the aim of studying the long-term landscape shaping and the socio-ecological history of this high-mountain environment. Its main focus was on understanding human exploitation of natural resources ant its environmental consequences. The current landscape of this territory is characterized by a remarkable variability, closely related to a pronounced spatial heterogeneity in terms of geomorphology and vegetation. Palaeoenvironmental data obtained from palynological analyses and megafossil evidences, excavations and radiocarbon dating suggest that such landscape variability would be also the expression of different land-use patterns developed over time. To provide more insight into the vegetation changes through time and to compare the pollen records over the different study sites, non-metric multidimensional scaling (NMDS) was applied to six pollen records from peat-bogs of the Gredos range (Pozo de la Nieve, Puerto del Pico, Puerto de Serranillos, Tiemblo, Redondo and Peña Negra). NMDS is an unconstrained ordination technique providing views into a high-dimensional datasets, such as pollen data. The NMDS analysis on the pollen data of the Gredos range clearly shows how the study sites evolve through time from a forested landscape with low human impact to a deforested landscape associated with high human impact. Human impact especially increased from ca. 1750 cal BP onwards, i.e. Late Roman Period. A second important increase in human impact is clear from ca. 800 ca BP, i.e. Feudal Period, to reach highest levels during the last two centuries. The applied method, NMDS, is shown to be a useful tool to provide more insight into the vegetation changes through time, and to compare and integrate pollen datasets from different study sites. This work was funded by DESIRÈ-HAR2013-43701-P (Plan Nacional I+D+I, Spanish Ministry of Economy and Competitiveness) and RELICFLORA-P11-RNM-7033 (Excellence Research Projects Program from the Andalusian Government).

***Keywords*:** pollen records, NMDS, human activities, Gredos range, central Spain

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Holocene decline of *Abies pinsapo* and *Cedrus atlantica* populations in Western Mediterranean

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The aim of this study is to determine the role of climate and human activities in the decline of Western Mediterranean ecosystems through the Holocene. We focus on *Abies pinsapo* Boiss. and *Cedrus atlantica* (Endl.) Manetti ex Carrière populations at both sides of the Gibraltar Strait. *A. pinsapo* is a Tertiary relict tree and currently a threatened species, extending along few coastal mountain ranges of southern Spain (West Betic Range) and northern Morocco (Rif Mountains). *C. atlantica* forests are distributed in Morocco

(Rif, Middle Atlas and north-east of the High Atlas) and Algeria. *Cedar* populations are also threatened by global warming, particularly by the projected increase of winter temperatures. Cedar and fir pinsapo forests have undergone a dramatic decline during the Late Holocene along Betic-Rif arc. To understand the factors involved in this decline, a long-term approach on climate change and anthropogenic disturbances is needed. But to date, few well-dated environmental and pollen records are available for this area to draw significant conclusions. Here, we present high-resolution pollen sequences sampled in western/eastern Rif Mountains (Fifi, Targuist, etc.), as well as Sierra de las Nieves (Ánimas) in Betic Mountains. The results of the available data explain the role of climate and human activities as drivers of the observed transformations during the last millennia. However, it is still very difficult to identify which is the main responsible for the reduction on the cedar and fir pinsapo forests along the Betic-Rif Mountains: the human impact, climate or both. This work was funded by RELICFLORA-P11-RNM-7033 (Excellence Research Projects Program from the Andalusian Government) and DESIRÈ-HAR2013-43701-P (Plan Nacional I+D+I, Spanish Ministry of Economy and Competitiveness).

***Keywords*:** pollen records, forest decline, climate, human activities

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Vegetation changes and perturbation events by anthropic activity basedoncore peat bogs in Escalerani (Bolivia)

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We realized a palynological study from1 m depth sediment core.The study area is in the Paramo yungueño, nearest a *Polylepis* forest remnant, in the eastside of the Cordillera Real, Escalerani*.* The results show a relationship between Poaceae and Asteraceae pollen before 7505 cal. yr BP, during a phase wetter than the present. The literature shows that *Polylepis* does not disperse beyond 100 m, then we can conclude that the presence of *Polylepis* pollen around 5600 cal. yr BP, could give us insights about a major extension of the *Polylepis* forest near the peat bog. Additionally, there is another charcoal peak 3655 cal. yr BP that is coincident with a Poaceae, probably Festuca-type, the results might indicate the beginning of the camelids harvest nearby. Furthermore, there are charcoal peaks starting at 450 cal. yr BP, which indicate an increase in fire frequency until the present. These results are also supported with a reduction of pollen taxa concentration, and are coincident with the beginning of the Columbian colonization. The top of the core is characterized by high values of *Plantago* pollen, presently the most important element in the peat bog. Recent C13/15N and XRF analyses provide a better understand of Climate Change by analyzing their responses to major types of continental climate forcing.

***Keywords*:** Escalerani, pollen, charcoal, isotopes.

Pollen records in sediments from Encantada Lake, Ilhéus, Bahia, Brazil

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The aiming this study is to investigate the sediments from Encantada Lake (14°36'28"S and 39°08'28"W), located in the Southern part of the State of Bahia. This region contains one of the most important tracts of the primary Brazilian Atlantic Rainforest, a hotspot of biodiversity characterized by high rates of rare and endemic plant and animal taxa. We collected a 600 cm long core (last 1510 +/-30 cal. yr BP), using a Livingstone sampler and $1cm^3$ samples at 5 cm intervals along the core, treated with hydrochloric acid,

hydrofluoric acid and potassium hydroxide. Afterwards, sediment samples were submitted to acetolysis and mounted on glycerin-coated slides for light microscopy analysis. Spores of *Lycopodium clavatum* L. were added in order to get the concentration of pollen grains at the samples. Preliminary pollen analyses revealed the presence of 157 pollen types associated to 47 families, which is in accordance to floristic studies of Atlantic Rainforest for region. Considering a minimum of five taxa by family, Asteraceae, Bromeliaceae and Meliaceae (5), Cyperaceae (7), Arecaceae and Bignoniaceae (8), Mimosaceae and Rubiaceae (9), Euphorbiaceae (10) and Fabaceae (22) are the family best represented. Pollen analysis have not yet been completed, but it is possible conclude that the diversity of pollen types registered, express the high floristic diversity that characterizes the Brazilian Atlantic Rainforest, especially in Bahia, which has no records in palaeopalynological studies. Moreover, this sedimentary basin can reveal the environmental history from Atlantic Rainforest for Bahia. Financial support: CNPq (485672/2013-8).

Keywords: Palaeopalynology, Atlantic rainforest, Pollen types, Palaeoenviromental, Late Holocene.

Paleovegetation changes in the last 10,000 years, Rio Doce Basin, southeastern Brazil: evidences from palynology

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Paleovegetation changes in the last 10,000 years Before Present (BP) of the largest natural lacustrine system in South America, the mid-valley of Doce river, specifically within the *Parque Estadual do Rio Doce (PERD)*, inside the Atlantic rainforest, were accessed using the palynology analysis. Cores LC-02 were drilled in the north-central region of the PERD (19°39'01''W and 42°34'47 ''S). Seventeen core samples of LC-02 were prepared using the standard method of palynological preparation. At least 300 grains of palynomorphs were counted for each sample. The basal age of 10,375 cal. yrs BP for LC-02 indicates that the sediments provide a Holocene history. The non-arboreal taxa Cyperaceae, Poaceae and Pteridophytes *Blechnum* were the most abundant taxa in the fossil pollen spectra in most samples (up to >46%). The palynomorphs were grouped into five vegetation groups: swamp, *Cerrado*, Atlantic forest, Pteridophytes and algae. The paleovegetation changes were evidenced from an analysis of hierarchical clustering and stratigraphically constrained, where four main zones were distinguished: Zone A (10,375—9,350 cal. yr BP); Zone B (9,350 —8,195 cal. yr BP); Zone C (8,195—4,500 cal. yr BP) and Zone D (4,500—102 cal. yr BP). The changes in floral composition were confirmed using a detrended correspondence analysis (DCA). The Zone A has low pollen concentration that is coincident with a more coarse-grained interval. The zone is dominated by herbaceous taxa (Poaceae and Cyperaceae). The woody taxa are represented by *Ilex*, *Baccharis*, *Vernonia*. The Zone A is interpreted as fluvial environment. In the Zone B persists the dominance of herbaceous taxa accompanied by lowest values of pollen concentration. In this zone is first time recorded the *Mauritia flexuosa* (at 9.350 cal. yrs BP) that is indicator of "veredas" now-a-days (palm swamps today). These vegetation communities support a swampy or water-logged forest interpretation, corroborated by the first recorded with security the presence of algae, especially of *Spirogyra.* The transition from Zone B to Zone C is coincident with abruptly decrease of Poaceae pollen and increase of Cyperaceae. The lacustrine system already installed and high abundance and diversity of Pteridophytes are recorded. The last 4500 years (Zone D) occurs the highest pollen concentration (at ~2705 cal.). The herbaceous flora recorded the lowest abundance and is replaced by other vegetation groups (e.g. swamp, *Cerrado*, Atlantic forest). The topmost sample (102 cal yr BP) represents the environment today, i.e. a seasonally water-logged situation and therefore reflects the colmatation of the lacustrine system.

***Keywords*:** Paleovegetation, pollen analysis, Holocene, South America, *Parque Estadual do Rio Doce (PERD).*

Reconstruction of palm swamps evolution in the *Cerrado* vegetation of northwest Minas Gerais State (central Brazil) from modern and fossil pollen data

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The *Cerrado* is the second largest biome in Brazil and covers the plateaus and plains of the central part of the country. A distinctive feature of the *Cerrado* landscape are the palm swamps, known locally as *veredas*, that develop in marshy areas containing stream headwaters and are characterized by a typical flora dominated by the *buriti* palm (*Mauritia flexuosa*). The *veredas* constitute a particularly favorable environment for the preservation of palynomorphs and thus its sediments have been used as records of paleovegetation and paleoclimate during Late Pleistocene and Holocene. These pollen records provide information about the changes in the vegetation that surrounds the *vereda* and also about the evolution of the *vereda* itself. To analyze the evolution of two *veredas* of the northwest region of Minas Gerais State in central Brazil, the pollen records of Laçador and São José palm swamps were compared to a database of modern pollen spectra from surface samples. The Laçador palm swamp stands over a plateau of 900 m of altitude and the São José is located further north, upon lower hills of 680 m. Principal components analysis, considering only pollen taxa related to local vegetation, was used to assign modern analogs for the fossil samples. The results show that the *buriti* palm first appeared on the Laçador and São José swamps between 14,000 to 13,000 cal. years BP. At that time, the *veredas* were in an initial state of development but the presence of the *buriti* attest a warm climate. Between 12,500 and 9,500 cal. years BP, both palm swamps experienced an expansion of their central zone indicating a phase of generally high humidity, although some fluctuations caused a temporary retraction of the Laçador around 11,000 cal. years BP. Between 9,000 and 7,500 cal. years BP, a retraction of the northernmost São José palm swamp indicates drier conditions there while Laçador palm swamp, located 90 km further south, experienced a pronounced expansion of its central zone, suggesting wetter conditions. Between 7,500 and 3,000 cal. years BP, these trends are reversed and while São José has its greater expansion, which reaches a maximum around 6,200 cal. years BP, the Laçador retracts. After 3,000 cal. years BP, the shrinkage of the central zone of both *veredas* suggest the onset of drier conditions. The different evolutions of these *veredas* during most part of the Holocene could be due to their different geomorphological positions.

***Keywords*:** Cerrado, pollen analysis, palm swamps, modern analogs, climatic changes

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Late Holocene environmental and vegetation changes in the NE coastal plains, Buenos Aires province, Argentina

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The northeastern coastal plains located between 35° and 36° S in Buenos Aires province, Argentina, are characterized by a semi-circular bay of 140-km long (Bahía Samborombón) in which important wetlands (RAMSAR site) extend along the coastal zone. These wetlands encompass aquatic and terrestrial ecosystems under the influence of mixing waters from Río de la Plata and the Atlantic Ocean. Consequently, there are particular ecological conditions that support high biodiversity of the wetlands. The sedimentary sequences from this area have a stratigraphic continuity and high fossiliferous wealth from which it has been established the development of different depositional environments during Late Quaternary such as coastal barriers, beach ridges, tidal flats and lagoons. These sedimentary sequences represent key archives for reconstructing the geomorphological history, past vegetation and environments, particularly related to the Holocene sea-level changes and climatic conditions, which provide information to understand the resilience of plant communities and the environmental dynamic over time in this area, which is currently

under the risk of inundations and erosion processes due to sea-level rise and global warming. Thus, the aim of this study is to reconstruct the vegetation and environmental changes during the Late Holocene related to the sea-level regressive phase, based on palynological content, lithology and stratigraphy from an outcropping sedimentary sequence from Bahía Samborombón (35°58'14.86"S; 57°24'49.72"W). The results show that after *circa* 2350 cal years BP saltmarsh vegetation predominated, with some variations over time regarding plant distribution and environmental conditions that can be described in several stages: -Firstly, the dominance of Chenopodiaceae and Poaceae suggest a halophytic saline-to brackish marsh, under frequent marine influence from an intertidal flat environment reflected by high proportions of *Spinierites* sp. and *Operculodinium* sp dinoflagellate-cysts and *Mactra isabelleana* valves. –Then, the increase of Chenopodiaceae and *Limonium brasiliense* record suggest a saltmarsh with higher salinity in an environment with less marine tidal frequency indicated by lower dinoflagellate-cyst records; all of which is associated with sea-level fall; –Toward the present, mixed halophytic- hydrophytic community developed, revealed by an increase in Cyperaceae and *Ambrosia* types, the decrease of Chenopodiaceae and high proportions of spores from the freshwater fern *Azolla filiculoides*. These environmental conditions can be related to the isolation of this area from the bay shoreline by beach ridge progradation and to increasing fluvial-freshwater influence. In the uppermost part of the sequence a soil developed supporting introduced herbs and trees, with the bay shoreline located 5 km to the east.

***Keywords*:** Late Holocene, Sea-level, saltmarsh, NE coastal-plains, Argentina

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Modern pollen rainfall from the Chilean Andes (18-33°S) and its application in palaeoclimatic reconstructions

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Modern pollen rainfall has been a key tool to understand and interpret fossil pollen records worldwide. The present paper present the modern pollen signal from vegetation units along subtropical and Mediterranean Chile (18-33°S) through the analysis of 11 west-east transects of soil samples along the west slope of the Andes. Samples were collected each ~100 m of altitude, from 4650masl at 23°S to 700masl at 27°S. Pollen rainfall signal shows a good correspondence with vegetation units across the study area reflecting therefore the climatic variability related to the tropical and extratropical rainfall systems dominating South America climates. Thus, modern pollen signal reflects the pre-Puna, Puna, High Andean steppe and subnival belts closely related to a summer precipitation regime between 18-24°S; a transition zone related to precipitation regime change (summer-to-winter rainfall) around 25°S where the Atacama desert present its maximum development into the continent; and Mediterranean-type vegetation belts from 26° to 33°, associated to dry summers and rainy winters. Some of these modern pollen samples were then applied to explore a Late Holocene cultural pattern found in the core of the Atacama Desert, the most arid desert in the world. The archaeological record revealed that human societies developed extensive field crops and built villages during the late Holocene and until the last millennium when they suddenly abandoned the area. The role of climatic changes on this cultural pattern where then investigated by combining modern pollen rainfall and pollen records from two series of rodent middens located in an altitudinal gradient at 3550 and 3750 masl (21°S). The fossil midden pollen record shows a transition from mid-Holocene extremely dry conditions to more humid ones around 2.2ka coinciding with a major human settlement and the development of agricultural fields in the core of the Atacama desert. Then, drier conditions than before (and today) were established around 0.75ka associated to the abandonment of the villages and crop fields but revealing an up slope migration following more productive environments, as pinpointed by the pollen record. FONDECYT #1140837; FONDECYT #1130279; CONICYT-PIA, Anillo código SOC1405.

***Keywords*:** pollen rainfall, rodent middens pollen record, Late Holocene, Chile

Environmental constrains of early hominid expansion into Southern Europe from paleobotanical evidences

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The earliest hominid expansions from Africa into Eurasia date to about 2 Ma based on the Dmanisi record of *Homo erectus* in Georgia. In South Europe however records (notably from Spain and Italy) are much younger and extend back to 1.2 and possibly 1.4 Ma. The scarce records may represent a single or several out-of-Africa events, and questions remain as to what extent climate and environmental change facilitated or hindered the occupation of Europe by early *Homo*. Climate change is considered a major driving factor of hominin evolution and dispersal patterns. In fact directly or indirectly by its severe influence on vegetation, physiography of landscape, and animal distribution, climate modulates the availability of resources. Several researchers suggest that orbital cycles (especially the obliquity 41 ka cycle) were driving regional climate providing short time windows of favorable landscape and vegetation conditions for hominine expansions in Europe. Early Pleistocene vegetation successions with more and less favorable conditions for hominine occupations at the end of each glacial period (warm, but still dry enough to enable open landscapes) have been documented from Southern Europe. Yet vegetation successions apparently out of phase or showing a complex regional response exist as well. Based on own results from the Caucasus region, we extrapolate the maximum extend of forests and mosaic landscapes for different climatic phases during Early Pleistocene as a prerequisite for the reconstruction of early human environments. In comparison with existing paleobotanical records from Southern Europe possible climatic constraints of early hominid expansions into Europe become evident and imply restricted expansion corridors during warm and humid climatic phases.

***Keywords*:** Hominin expansions, Early Pleistocene, Southern Europe, climate, vegetation maps

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Out of Amazonia: Late Holocene Climate Change and the Tupi-Guarani Trans-Continental Expansion

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The late Holocene expansion of the Tupi-Guarani languages from southern Amazonia to SE South America constitutes one of the largest expansions of any linguistic family in the world, spanning ~ 4000 km between latitudes 0°S and 35°S at about 2500 yr B.P. However, the underlying reasons for this expansion are a matter of debate. Here, we compare continental-scale paleoecological, paleoclimate, and archaeological datasets, to examine the role of climate change in facilitating the expansion of this forest-farming culture. Because this expansion lies within the path of the South American Low-Level Jet, the key mechanism for moisture transport across lowland South America, we were able to explore the relationship between climate change, forest expansion, and the Tupi-Guarani. Our data synthesis shows broad synchrony between late Holocene increasing precipitation and southerly expansion of both tropical forest and Guarani archaeological sites – the southernmost branch of the Tupi-Guarani. We conclude that climate change likely facilitated the agricultural expansion of the Guarani forest-farming culture by increasing the area of forested landscape that they could exploit, showing a prime example of ecological opportunism.

***Keywords*:** Late Holocene, climate change, forest expansion, Tupi-Guarani

The Bulgarian fossil record of edible plants

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According to palaeobotanical data based on macro-remains, 49 edible plant taxa in total are known from the Bulgarian Cenozoic. The knowledge on the diversity evolution of edible plants in this part of the Eastern Paratethys is of great importance because major Cenozoic migration routes of mammal fauna including hominids crossed the area, probably also the pathways of early human expansion in the late Pliocene to early Pleistocene. Based on the interpretation of Nearest Living Relatives (NLRs), the Cenozoic edible plant record of Bulgaria can be subdivided into four groups: 1) Ancestors of Recent plants still registered on the territory of Bulgaria; 2) Fossil plant taxa whose NLRs thrive under climatic conditions comparable to those existing in Bulgaria today, but that are no more present in the modern European vegetation; 3) Fossil plant taxa with NLRs presently inhabiting tropical and subtropical areas; 4) Fossil plant taxa with uncertain NLR concept. The Palaeogene record of Bulgarian edible plants mainly comprises elements of groups 3) and 4), in agreement with the thermophilous character of these elements and the warm, equable climate conditions prevailing in the Tethyan archipelago at that time. From the middle Miocene on, additional, mainly "arctotertiary" taxa appeared in the record now being native to Europe. Our data show that diversity of edible plants culminated in the late Miocene. Throughout the early and late Pliocene, diversity of edible plants declined again because of the loss of most of the taxa belonging to group 3), related to coeval global climate cooling and increase in seasonality of the regional climate. It is however noteworthy that despite this overall declining trend along the Pliocene, several edible plants appeared for the first time in the Bulgarian record, just before the onset of the Pleistocene, such as black hawthorn, walnut, European dwarf cherry, scarlet firethorn, and common dogwood, all distributed today in Southeastern Europe and West Asia. Thus diversity of edible plant prior to the arrival of homo in the area was most probably comparable to modern.

***Keywords*:** Bulgaria, Cenozoic, palaeobotanical record, edible plants, diversity

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Interactions between plant-insect in fossil leaves from West Amazon, Acre, Brazil

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Plants and herbivores have dominated terrestrial ecosystems from about 300 million years. Fossil leaves with damage can be preserved abundant information on habits of herbivores, ecological characteristics linked to the food web and even paleoclimate. On the west Amazonian the larger area today occupied by the Amazon rainforest Biome is characterized by a high biodiversity in plants and animals and this vegetation and its subsequent physiognomy depends on the climatic and soil factors, where the weather determining the distribution of plants. The known hypothesis "Refuge Theory" helps to understand how relate geoclimatic events past tenses to explain such biodiversity in that region, which assumes that during the Pleistocene, the Amazon forest was fragmented, sharing space with Cerrado vegetation in lower rainfall areas during the current time. The fossil flora of the state of Acre is in a discovery stage, being objective of this study to identify it and raise taphonomic and paleoecological parameters to assist in the understanding of their evolutionary relationship to current Amazon flora with insect interaction. Samples of nice macrofossils preserved as mummified leaf fragments show marks by herbivory and oviposition, this last indicated by the presence of galls, as are perceptible marks made by fungal attack. Environmental interpretation brings a flood plain where there is presence of facies with laminate pelites and sandstone, indicating a depositional environment with increased energy, which would be similar to the current environment known as lowland forest, a typical forest formation of the Amazon region, seasonally flooded. The spatial relationship of these deposits allows inferring stability in paleoenvironmental and remained the meandering fluvial system with active channels, as geological data on floodplain. The fossils leaves, predominantly mesophilic elements induce the interpretation of a flora of hot/humid environment in tropical lowland rainforest. This megafossils are important source of data for paleoecological and taphonomic studies, which should be

present in paleoclimate reconstruction and paleoenvironmental of the southwestern Amazon. This work is part of the Project: "Biochronostratigraphy and Paleoecologia Based on Potential Fossil of Cretaceous - Neogene of Acre Basin, Jurua Valley, South Western Amazon". Process: 01200.001631 / 2010-32 - MCTI / UFAC / PALEONTOLOGY area - UFAC - FOREST CAMPUS

***Keywords*:** Paleobotany, Paleointerpretation, Fitofossils, Megafossils, Southwestern Amazonia.

Plant-insect interactions in fossil leaves from the outcrop paleolago cemitério, Catalão, Goiás

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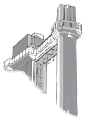
The outcrop Paleolake Cemitério located in Catalão, Goiás, Brazil, has a rich fossil flora from late Pleistocene. Catalão's paleoflora is composed by leaf impressions that preserve morphological details like venation, margin, base and apex shape. Once the fossil material has an excellent conservation it is possible to visualize the occurrence of damage done by insects, thus allowing the study of interactions between these animals and plants that lived in that environment. Land plants and insects are the largest part of Earth's biodiversity maintaining a relationship of extreme dependence in some cases. These interactions can be beneficial, neutral or harmful to plants, such as herbivory, which is very common in modern plants since around half of insect species has herbivore behavior. Herbivory is recognized by the reaction of living tissue of plants to damage, forming necrosis on the affected area, being this interaction preserved in fossil records. Among the various types of interactions that can be found in leaf impressions, the most common ones are endophytic drilling, mine, skeletization and galls by oviposition. The intention of this approach is to interpret damage found in fossil leaves from the outcrop Paleolake Cemitério Catalão, documenting the evolution of insect-plant interactions in the area. Preliminary results allow such investigation to find relationship between the found evidences and taxonomic and climatic information already available for this outcrop, confronting paleoclimatic, paleoenvironmental and paleoecological information from this preterit environment. Deeper paleoecological studies will be necessary in order to understand how local and continental factors had influence on the paleocommunities in the Cerrado Biome in Brazil.

***Keywords*:** Catalão Paleoflora, Herbivorie, Fossil Leaves, Biome Cerrado, Plant x animal interactions



TAPHONOMY

Tânia Lindner Dutra & Jaílson Santos de Novais

Taphonomy of early Permian plant assemblages from the Papaléo Section, southeastern Paraná Basin

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The Itararé Group deposits (mid Pennsylvanian-Sakmarian) represent the glacial/peri-glacial environments, recording the Late Paleozoic Ice Age in the Paraná Basin. The post-glacial coal-bearing Rio Bonito Formation (Sakmarian-Artinskian) was deposited in mainly coastal environments, during a time where the Paraná Basin represented a large gulf in the ancient supercontinent Gondwana. The Papaléo Hill, located some 100 km from Porto Alegre, in the southeastern margin of the Paraná Basin, was extensively mined for clay extraction from sixties up to eighties, exposing several fossil plant beds. To evaluate the taphonomic behavior throughout the section, nine fossiliferous levels (5 in upper Itararé and 4 in the Rio Bonito) were examined, yielding 2,088 samples and over 2,300 identifiable plant specimens. Each identifiable specimen on a rock sample was counted once, in order to avoid problems relating to differential fragmentation and the question of "what to count". Groups of sampling levels were evaluated using Q-mode cluster analysis (average linkage) and non-metric multidimensional scaling (NMDS) with Bray-Curtis distance index after square root transformation of raw abundances. Floral associations were delimitated using R-mode cluster analysis. To explore the effect of (inferred) environmental factors on flora distribution throughout the sampling levels, we used Constrained Analysis of Proximities (CAP, also based on Bray-Curtis index). Three distinct plant associations were identified after the multivariate analysis. Assemblage 1 (upper Itararé; levels 2, 2A, 3 and 3A) is characterized by *Botrychiopsis* leaf shoots and *Glossopteris* leaves. It represents an undisturbed, stable margin lake with very low energy and low sedimentation rate, which also allowed accumulation of organic matter. Sphenopsid plant-parts (*Pinnularia*, *Paracalamites* and *Phyllotheca*) and *Cordaites* leaves characterize the Assemblage 2 (uppermost Itararé; levels 4A and 4B). This assemblage represents a very disturbed lacustrine system, where fast-growing sphenopsids colonized ephemeral settings, and unstable margins (with medium sediment input and environmental energy). Assemblage 3 (uppermost Rio Bonito; levels 7, 8A, 8B and 8C) is characterized by lycophytes, and *Cordaites*, *Gangamopteris* and *Glossopteris* leaves. Complete, articulated fern fronds are dominant in level 8A, which may indicate a stable and hypoauthochtonous remains rapidly buried at times of levee ruptures. Transported *Brasilodendron* stems, preserved parallel to the bedding plane, compose more than 90% of floral elements at level 8B. Highly transportable seeds, cordaitalean and glossopterid leaves are dominant in the pure claystone of level 8C, indicating very low sedimentary ratios. All those features allow interpreting Assemblage 3 as getting preserved within an alluvial system.

***Keywords*:** *Glossopteris* Flora, plant taphonomy, multivariate analysis, Paraná Basin, Lower Permian.

Macrophytofossil Assemblage of Capivari River's Outcrop: the Pre-*Glossopteris* Flora – State of São Paulo, Brazil

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Paraná Basin Upper Carboniferous and Early Permian fossiliferous assemblages exhibit great vegetal content diversity, which is also observed in Capivari River's taphoflora, proving the establishment of *Glossopteris* flora before glaciation's end in the Gondwana paleocontinent. Capivari River's outcrop is located at the left margin of Capivari river, next to the place where it used to be Piracicaba-Tietê road (UTM 23K0217,99/7455,18). Its fossil content demonstrates glacial and interglacial influence in distinct levels in

pulses of glacial period. Through the analysis of shape, size, density and orientation of coalified leaves, seeds and trunks, fragmented by transportation, it was possible to develop the taphonomic interpretation and describe its paleoenvironment. Altogether, the sampling step resulted in more than five levels, described and oriented, 40 samples and 20 identified *taxa*. It is important to preserve the organic layer and its orientation and density establishing a proper sampling method, being necessary to open a trench, from top to bottom, revealing its stratigraphy and yet preserving its spatial distribution. Results show the prevalence of the genus *Gangamopteris*, more specifically *G. obovatta*, and suggest that these assemblages constitute the Pre-*Glossopteris* Flora, elucidating how marine incursions may have affected climate. In the leaves of Capivari River taphoflora, main venation is absent and indicates that these fossils are somewhat younger than Cerquilho flora and belong to the *Vittatina* zone, *Protohaploxypinus goraiensis* subzone, Asselian-Sakmarian interval. Orientation and distribution indicate variable paleocurrents, which were possibly related to marine incursions during the interglacial cycle. The occurrence is stratigraphically below diamictites and represents a vehement proof of interglacial period setting during assemblage formation.

Keywords**:** *Glossopteris*, *Gangamopteris*, Parana basin, taphonomy, glaciation

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Analysis of the accumulations of plant macroremains in a meandering fluvial system, northeast of São Paulo state, Brazil

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The study of the accumulations of plant macroremains along present-day fluvial systems allows us to understand fossil plant associations and perform more realistic reconstructions of ancient communities. To better understand this relationship two of 30×30×15 cm blocks were collected consisting almost exclusively of leaves from a meandering fluvial system in the hydrographic basin of the Mogi Guaçu river, São Paulo, Brazil, where the riparian forest is associated with the Cerrado. The blocks analyzed contain between 38 and 54 species, and of the identified species 68–71% are arboreal and 29–31% are climbers. Between the 73 and 84% of all leaves/leaflets represent 2 to 3 arboreal species, and the majority of the identified species belong to the families Fabaceae (23–28%), Sapindaceae (12–18%), and Bignoniaceae (9–14%). The foliar physiognomy allowed the calculation of mean annual temperature (MAT) and mean annual precipitation (MAP) for the time the packages of plant macroremains were deposited. The real value of the MAT was underestimated by 0.3°C and overestimated by 3.3°C respectively, and the real value of the MAP was underestimated between 330 and 360 mm. The major amount of the leaves that form these packages originated during the dry season and their rapid sedimentation is due to the floods which occur in the initial months of the rainy season. Hence, the sedimentation rate seems to depend on the interaction between river and forest vegetation, and the preservation appears to depend on geochemistry and groundwater fluctuations. These packages were deposited in the periods 1957–1958 and 2002–2007, and they can be considered a high-resolution record of El Niño, the warm phase of the global climate phenomenon El Niño-Southern Oscillation. Processo FAPESP 2013/22729-2

Keywords**:** Plant macroremains, meandering fluvial system, Cerrado, foliar physiognomy, El Niño-Southern Oscillation

Organizers


IFPS


IOP


ALPP


UEFS


UNEB

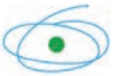
Co-Organizers


SBB


UFBA



URCA



Secretary