Toward a semantic representation of geoheritage (short paper)

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Abstract

In this paper we address the semantic representation of the geoheritage. In literature, geoheritage is defined as those elements of geodiversity that are outstanding for their value/importance for humanity. It is part of the UNESCO heritage, included in the point concerning the cultural aspect of natural features. The issue addressed in this paper is that the concept of value and the lists of values are quite an open question: the concept of value is given for granted in the geoheritage literature, and the lists of values are proposed in multiple versions, by multiple authors in multiple application fields. The result is the incoherence in the assessment of what is and what is not an element of geoheritage. In this paper we explore the issue, presenting how a semantic approach may be an opportunity to reduce the level of incoherence in the representation of the concept of geoheritage.

Keywords

Geoheritage, Geodiversity, semantics, ontology

1. Introduction

Our planet has a very rich ecosystem, based on the existence of many different living forms (biodiversity), but also of non-living forms (geodiversity). The latter category, essential for the existence of the first, encompasses all the geological formations, landforms and processes that are our natural environment. Some of these geological elements are very relevant for the life on the planet and the human society, considering both the supply and the cultural aspects, respectively. The cultural aspects are summed up into the notion of geological heritage, or geoheritage. In literature, geoheritage is defined by Sharples as "those elements of natural geodiversity which are of significant value to humans for non-depleting purposes which do not decrease their intrinsic or ecological values" [1, p.11]. From this definition, we can extract two claims: first, the elements of the geoheritage are part of a wider group of elements, i.e., the elements of geodiversity; second, what distinguishes a "regular" element of geodiversity from an element that is worth considering geoheritage is that it has a particular importance, or value for the humankind.

However, Sharples' definition is only one of the many definitions in the literature, though the concepts of geodiversity and value, respectively, are mostly recurrent. This paper explores these two concepts and addresses a possible formalization. The aim is to reach a clarification about some core aspects of the definitions, improving comparability and, possibly, consensus. Our starting point is the definition of values. In fact, in literature, there are several lists of values to support the definition of the geoheritage: a few values are common to all the lists, some values are partially shared, other values are not shared at all. This aspect is clearly problematic: in acknowledging an element of geodiversity as an element of geoheritage, we typically assign one specific value to that element, but what if that specific value is not shared by all the definitions? For example, the Recreational value is one of the values that is only partially shared: some authors consider acceptable a geological item that is relevant, e.g., for its

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capacity of attracting tourists, others do not consider it as a valid criterion for the assessment of geoheritage.

Another problematic issue is the attribution of the value, i.e., what are the conditions to satisfy for the attribution of a value to some item? Going back to the example cited above, is the capacity of attracting tourists a valid and shared criterion for the attribution of the Recreational value? From this point of view, and, considering that geoheritage is built on geodiversity, we aim to explore the possibility to connect the values of geoheritage to the geosystem services, which can be recognized as the goods and functions associated with geodiversity [2].

These are the issues explored in this paper, addressing their semantic representation to reduce the level of subjectivity in the definition of the elements of the geoheritage. In the next sections, we will explore the values of the geoheritage and of the geosystem services, respectively, and how they can be related. A key for addressing this relationship comes from the analysis of the concept of value, deepened by Perry [3], through the notion of interest.

The paper is structured as follows. In section 2, we review the concept of value and the values of the geoheritage and the geodiversity, respectively. In section 3, we illustrate the first steps of the connection of values and services, followed by some formal representation. In section 4 we provide an example. Finally, section 5 provides some conclusions and future steps.

2. State of the art

As introduced before, the knowledge of the concept of geoheritage is dependent on two main knowledge domains: the knowledge on the values that characterize the geoheritage and the knowledge about the geodiversity and geosystem services, as geoheritage is built on the geodiversity. In this section we analyze these domains, to access further analysis.

2.1. The values of geoheritage

The assessment of an element of the geoheritage is strictly dependent from the attribution of one or more value to that element. Despite the variety of definitions present in literature, the relation of the elements of geoheritage to the concept of value is widely acknowledged. What is not shared, vice versa, are the individual values that contribution to the assessment. For our study, we selected four lists of values, published in different scopes and for different goals. The lists are from Sharples [1] and Brilha [4], for what concerns a theoretical and more "academic" approach, and from Georgousis et al [5] and the US National Park Service (NPS) [6], for what concerns a non-specialized public (such as, e.g., students and tourists). The variety of goals provides us a wide range of points of view about the assessment of geoheritage.

The major difference concerns the values that are listed in the several approaches. As it is possible to see in Figure 1, not all the values are shared by all the authors. In fact, only Aesthetic, Cultural, Educational and Scientific values are in common, while the others are shared by 3 to 1 list. For instance, the Economic value, for elements that are a resource for some area (such as, e.g., a mineral resource or a touristic resort) is listed by all the authors except Sharples. The consequence is that an element with this kind of value would be considered geoheritage by Brilha, Georgousis and the NPS, but not by Sharples. Moreover, some other issues arise for the Economic value: in fact, the meaning associated to the value are actually two, that is, the existence, in some area, of a natural resource that is directly involved in the economy of the area (e.g., a mine), and the consequences of tourism in some area (e.g., hotels, museums, restaurants, are sources of earning for the local population), respectively. Hence, this causes a different assessment of geoheritage if we apply different lists to the same item. E.g., Brilha [4] presents as an example of the Economic value the Escondida mine, a very important copper mine in Chile, which makes the country the number one exporter of copper in the world. This site has a relevance that fits with the first of the two meanings of the value, which is encompassed by Brilha and NPS [6]. Vice versa, Georgousis et al [5] see differently this value, then this site is not geoheritage following their criteria (as well as of Sharples, who doesn't even have that value).

In this paper, we address the systematization of the lists through a semantic approach that can encompass all the information provided by the several accounts mentioned above.

	Sharples 2002	Brilha 2018	Georgousis 2021	NPS
Aesthetic	YES	YES	YES	YES
Cultural	YES	YES	YES	YES
Educational	YES	YES	YES	YES
Scientific	YES	YES	YES	YES
Ecological	YES	NO	YES	YES
Economic	NO	YES	YES	YES
Intrinsic	YES	YES	NO	NO
Recreational	YES	NO	NO	YES
Artistic	NO	NO	NO	YES
Functional	NO	YES	NO	NO

Figure 1: Comparison of the lists of values. In green the values shared by all the lists, yellow values in three lists, blue two lists, purple one list [1,4,5,6].

2.2. The concept of value, a philosophical question

Before the formulation of a semantic approach, we must clarify the concept of value itself: this is a very old question, explored in several literature domains. Here we address the definition provided by Perry [3], who proposes an approach based on the *interests* that contribute the assessment of some value. In fact, the question that the author explores concerns how the value forms and how it can be satisfied. His answer leans on the idea that a value is the fulfilment of one or multiple interests, which are subjective, i.e., dependent on some individual or community perspective. So, it is paramount to define at least one interest that an item can have to possess a value. For example, "Recreational value" may have many different interests, based on what people likes to do in their free time. For example, some people like to sunbath on the beaches in their free time, so a place like Algarve, Portugal, has an interest for those people (interest that satisfies the Recreational Value). Differently, some people like to climb in their free time, so climb is another interest for the Recreational Value. Moreover, the interest of climbing is multiple: different places are important as climbing site of different types. El Capitan, Yosemite National Park, USA, is famous for the numerous (more than seventy) thousand-meter-long multi-pitch climbing routes (climbing with ropes, quick draw, and other equipment) while Fontainebleau, France, is well known for the bouldering activity (climbing of few-meter-high boulders, with no equipment except for crash pads and climbing shoes). A different example concerns the Educational value: the goal of an high school teacher can be instructing the young students in general concept about nature and geosciences, as well as for "Sunday tourists", so a glaciological path like the one in Alagna Valsesia, Sesia Val Grande UNESCO Global Geopark, Italy, is perfect to show to a non-specialized audience (e.g., undergraduate students, or tourists) the traces of the glacial processes. Vice versa, outcrops like the one in Zumaya, Spain, famous in the geological world for the presence of the

GSSP (Global Stratigraphic Section and Point) marking the limit between Selandian and Thanetian, two stages of the Geologic Time Scale, part of the Paleocene Age, can be useful for the instruction of the geoscience students, who are learning about stratigraphy.

Since interests are multiple and subjective, there can be many different interests based on the individual/community needs and/or points of view: and this is not an easy task. Let's however focus on which are the interests of the human society for the elements of geoheritage.

As anticipated in the introduction of the paper, one of the common points concerning geoheritage is the fact that every element of geoheritage is built upon an element of geodiversity. Hence, we can explore the relevant characteristics of the elements of geodiversity to identify possible sets of interest. A possible way, hence, is to explore the geosystem services, which are the benefits that the humankind has from the existence of geodiversity. In the next section, we will deepen the topic, focusing on the possibility to identify possible interests for the values of geoheritage.

2.3. Geodiversity and geosystem services

Geodiversity can be defined as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, physical processes) and soil features. It includes their assemblages, relationships, properties, interpretations, and systems" [7].

Geodiversity makes our planet a house for many forms of life and provides the human society with many resources for its wellness and development. All these benefits are represented with the geosystem services paradigm, which is the abiotic correspondent of the Ecosystem Services, namely the goods and functions of the ecosystems that society benefits of [8]. The geosystem services are inspired by the ecosystem services and represent the benefits that the diversity of our planet brings to the environment, to the life on earth, for the human society wellness and development. In the central part of Figure 2, we represent the geosystem services: they are grouped into five categories, two concerning the processes and the involvement in the use of the land by humans and other forms of life (marked as 1 and 2 in the picture), one concerning the materials that humans use for feed and live (marked as 3), other two concerning the intellectual part of the human society (culture and knowledge, 4 and 5 respectively).

Geodiversity plays a role essential in the existence of the services: for example, in our planet there is diversity of soils, altitudes and climates, that are the reason for such a diversity in animals and plants, hence food. Different vine plants grow in different geographical areas, and this has the consequence of the existence of different wines, such as Brunello, from Montalcino area, Negramaro, from Salento region, or Barbera, from Monferrato region.

3. Toward a semantic approach to the definition of geoheritage

To provide a semantic approach to the definitions of the values of the geoheritage, built upon the geosystem services, we proceed through a formal alignment of the definitions, starting from different lists of values. We go through a convergence of the meanings associated with the values enlisted for the geoheritage and the geosystem services, respectively. First, we have carried out bibliographic research, to collect all the information about the values and the services (namely, definitions and/or examples and explanation); then, we have analyzed the lexicon used for the naming of the systems and the values, respectively. Finally, we have designed a semantic representation from these findings.

Figure 2 represents a mapping between the values and the geosystem services (one value can be connected to one or more services; vice versa, not necessary the services are connected to a value). In the central part of the pictures there are the geosystem services [9], while on the lateral sections there are some squares with the values, identified with different colors, plus some keywords extracted from the definitions of the values. The arrows connect the whole value or singular keywords to the services.

This mapping is the result of a comparison between the definitions of the values and the examples reported in the literature for the corresponding services, as they appear in the corresponding articles.

For example, the Ecological value, that appears in Sharples', Georgousis' and NPS's lists, can be assigned to those elements of geodiversity that have an essential role in the maintenance of the natural ecosystem processes. For example, in the geosystem services, this is instantiated in some types of processes, like the oceanic processes: the oceanic currents have an essential role in the climate dynamics.

However, these associations are subjective, made on some informal association between the perceived meanings attributed across the papers. To overcome such subjectivity and build sound relationships, we have then carried out a lexicographic study, to verify the associations between terms and possibly search for other relationships.

The idea has been to check the lexical relationships between the terms used for the geosystem services and for the values of geoheritage, respectively. This was made through the Wordnet resource [10]. This online resource provides, for an entered word, all its synset, with the definition of the word in the context and the listing of related words (such as synonyms, hypernyms, and hyponyms). We analyzed each term used for the services and for the values, respectively, and looked for the correspondences. For the analysis, we started from the list of geosystem services, and analyzed one by one all the terms, willing to find some association with the values or, at least, the keywords extracted from the definitions of the values.

Unfortunately, this brough no results, there are no lexical correspondences between the list of services and the values of geoheritage, even if many concepts are very similar for a human reader.

An example of expected "easy" association was between the Recreational value and its keywords (tourism and recreation) and "Geotourism and leisure". Except for tourism and geotourism, which have the same root, no correspondence has been found with leisure; in fact, except for the words that are re-used (like tourism), no associations were possible. A similar work of lexical comparison was between the list of services of Figure 2 [9] and the one proposed by Webber et al [11]. In this case, some associations were successful, for example between "Environmental quality" [9] and "Better living surroundings" [11]: in fact, environment and surroundings are marked as part of the same synset.

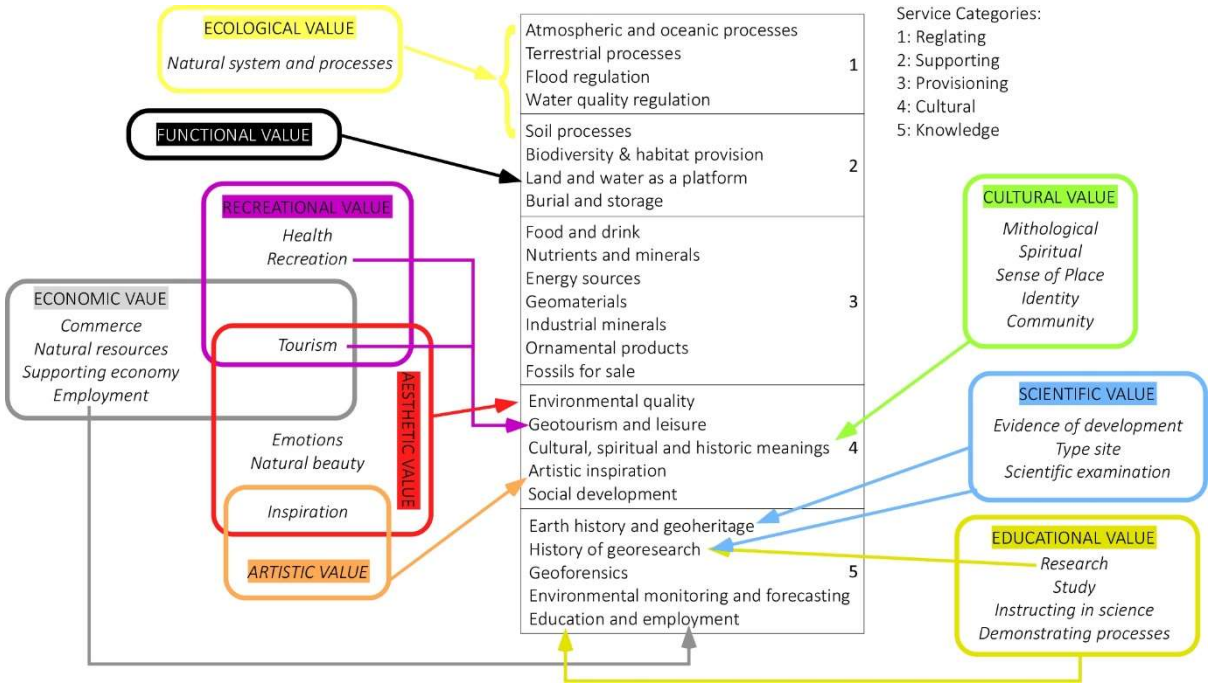

Figure 2: Association between values of geoheritage and geosystem services [9]

Hence, in Figure 2 there is a comprehensive representation of the alignments which are possible in this moment; as discussed above, they are mostly based on the bibliographic research, more than the lexical study, which brough few tangible results. The lack of some lexicographic relationship between the elements in the value lists leads to the necessity of the definition of the values in terms of low-level features, namely the notion of interest mentioned above. Perry describes the value as consisting *"in the*

fulfilment of bias or interest. An object would be said to possess value in so far as it fulfilled interest or assumed the relation of fulfilment to the term interest, where fulfilment is used in a generalized sense for the consummation of either liking or disliking" [3, p.150].

At the current stage of development, we have outlined the semantic representation of the geoheritage elements through a UML schema and a prototype of ontology, that connects the notions of geoheritage and geodiversity, respectively.

After this overview of the knowledge domains of geoheritage and geodiversity, we can conclude that by one hand, they are very rich in information, and by the other, this information presents a high level of vagueness and ambiguity. In particular,

- the existence of many lists of values that contain terms that are only partially shared and without a clear, unambiguous definition of the terms listed
- the possible differences in the definitions of the values, as resulted from the informal analysis, mostly concerning the Economic value.

Figure 3 sketches the overall design of the ontological concepts. In the green-background area, there is the part concerning geoheritage and geodiversity. Geoheritage is a subclass of geodiversity, which are geological items. Both are described by CodeLists, which are vocabularies coming from the domain knowledge. For example, a CodeList is a list of "relator" terms, associated to definition and relation with other agents [12]. The geological items that are which compose the geodiversity is well described in the OntoGeonous ontology, an ontology for the geosciences [13,14,15,16,17]. A geodiversity element, then, can be either a physical element, such as the Geologic Unit (a body of earth material with precise physical boundaries [18]), the Geomorphologic Feature (feature describing the shape and nature of the Earth's land surface [18]), but also non-concrete features such as their relations, represented, e.g., by the Geologic Structure (a configuration of matter in the Earth based on describable inhomogeneity, pattern, or fracture in an earth material [18]).

In the green part of the picture there are also the CodeLists describing the GeodiversityElement class, and the one for the Geoheritage class. They are the services and the values, respectively. To be part of the Geoheritage class, an item must be an element of geodiversity (must belong to the GeodiversityElement class) and be associated to one or more Value from the CodeList. GeodiversityElement, vice versa, can have (please note "can", it is not a mandatory condition) a relation with the CodeList Service.

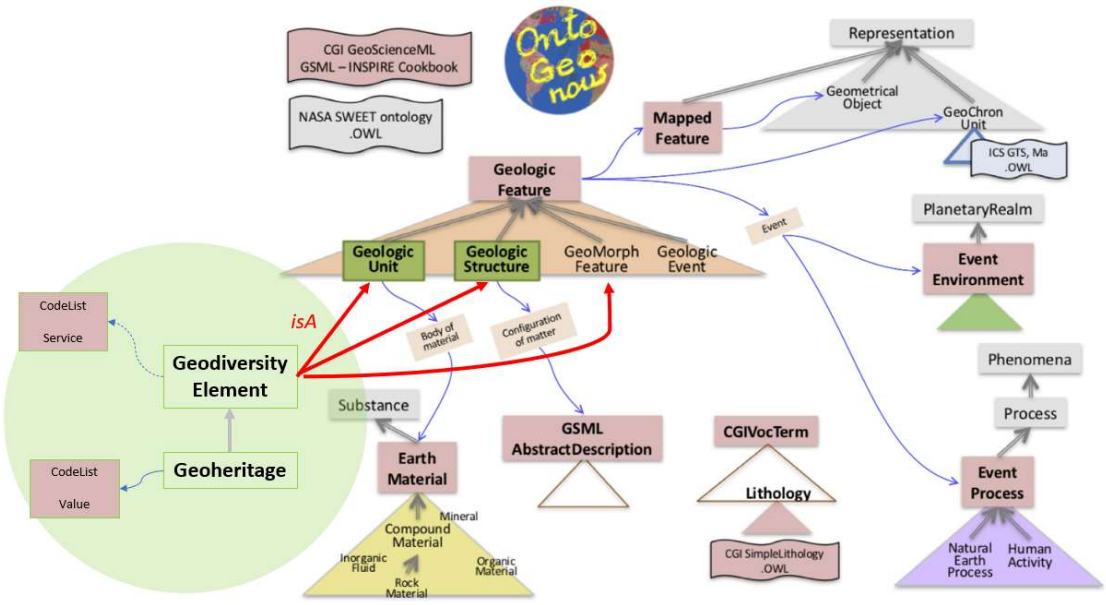

Figure 3: Representation of the main structure of the OntoGeonous ontology [13,14,15,16,17], on white background, connection with geodiversity and geoheritage in green background

The compilation of the CodeLists is a work in progress process. This is because of the value-interest-service connection that we aim to pursue, following the theory by Perry [3]: hence, there will be an additional part to this schema, collecting the interests, based on the services, that will be the base for the attribution of the value to a given element of GeodiversityElement class, allowing it to be included in its Geoheritage subclass. For example, the climbing activity, cited in section 2.2, can be an interest for the Recreational value. Our final goal is to encode similar connections, to better describe the values of geoheritage. We are basing the encoding of new concepts on the pre-existing encoded knowledge about geosciences, in the OntoGeonous ontology [13,14,15,16,17]. Moreover, this ontology has already been applied to the geological mapping process [19], which gives a ready method for the spatial description of the elements that are geoheritage (with useful consequences for institutions such as, e.g., geoparks).

4. Example: Yosemite National Park

To show how we intend to connect values and services through the interests, here we analyze an example of a UNESCO heritage site, that encompass many of the described features. We will analyze the Yosemite National Park, California, USA: with its altitude variation from 600 to 3997 meters, it is rich in geological and geomorphological formations as well as a great variety of flora and fauna. Moreover, it is the destination of many outdoor lovers, especially climbers, who wish to climb the famous walls of El Capitan.

Let's analyze the point brought by UNESCO for the park to be defined as a geoheritage element [20]:

Criterion (vii): Yosemite has exceptional natural beauty, including five of the world's highest waterfalls, a combination of granite domes and walls, deeply incised valleys, three groves of giant sequoia, numerous alpine meadows, lakes, and a diversity of life zones.

Criterion (viii): Glacial action combined with the granitic bedrock has produced unique and pronounced landform features including distinctive polished dome structures, as well as hanging valleys, tarns, moraines, and U-shaped valleys. Granitic landforms such as Half Dome and the vertical walls of El Capitan are classic distinctive reflections of geologic history. No other area portrays the effects of glaciation on underlying granitic domes as well as Yosemite does.

The most salient points in this description are natural beauty, five outstanding waterfalls, best showcasing in the world of the glacial action in the granitic rocks, giant sequoias, and diversity of life zones (which likely refers to many habitats for plants and animals).

To provide an illustrative example, we address:

- Environmental quality, for the natural beauty of the area, among which the spectacularism of the waterfalls
- Biodiversity and Habitat provisioning for the existence of the giant sequoia and many forms of life, due to the high-altitude variation
- Earth history, as it is a perfect showcase of how the glacial erosion act in the granitic rocks: in the area, the intense glacial activity caused the formation of many landforms which stands and are highly representative
- moreover, Geotourism and leisure for the high number of visits for leisure or sport

The connection that we aim to underline is between the services cited above, seen as interests for the example area, and the values of geoheritage that can be, consequently, associated to the area. In this case, these services can be connected to the:

- Aesthetic value, typical of areas with wonderful landscapes
- Ecological value, for the areas that are involved in natural processes and protection of natural species and equilibrium of the ecosystem
- Scientific value, for what concern elements that are important for the reconstruction of the history of the earth
- Recreational value, because of the touristic frequentation

With this example, we want to demonstrate that to the same area, on the same description, we can apply the geoheritage value association, as well as the geosystem services classification. However, they are both the associations based on some specific conditions or elements of the park: these are the interests. It is a specific case of the Yosemite Park, the existence of the groves of giant sequoia, or the presence of the El Capitan climbing wall. These are interests of habitat provisioning and geotourism and leisure respectively. Our goal is to identify exhaustive lists of these interests and assess a formal relation between values, services, and interests. For example, the sequoias, are an interest for the "Biodiversity and Habitat provisioning" service, that can be related to the Ecological value, because of the importance of the existence of the sequoias for the global diversity in the flora.

5. Conclusions and expected solutions

In this paper, we have described the problem of the definition of the geoheritage elements, and we have addressed how a sound approach can be built on a semantic approach that connects geoheritage elements and geosystem services.

We aim to develop a thorough representation of the geosystem services and of the values till getting to a formal representation through UML, and then through an ontological representation. With respect to our ontology design, we aim at introducing the additional class of the interests, which will be in relation with both values and services. In fact, a deep analysis of the geosystem services can provide the categories for the interests, and the formalized description will connect with coherence the values to the elements that might be or not geoheritage. A description organized like this would also respond to the first issue explained at the beginning of the paper, i.e., the informal assignment of the title of geoheritage to some feature: in fact, an element can be described in the system and go into some geoheritage class (one or more) based on the values that it gets from the interests. In this way, we aim at preserving most information referred to by the experts, each considered feature would have its set of value-system-interest and be included (if worthy) into one or more classes of geoheritage.

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