

U-Pb detrital ages on tuffaceous and sandstone levels from a Neogene foreland basin of the Central Andes of Argentina

Idades U-Pb em zircões detríticos em níveis tufaceos e areníticos de uma bacia de antepaís neogénica nos Andes Centrais da Argentina

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Abstract: Six tuffaceous and sandstone levels from an Andean (Mio-Pliocene) synorogenic succession were analyzed using the U-Pb LA-ICP-MS method on detrital zircons, in order to constrain maximum depositional ages and to define the basin provenance and likely connections with the volcanic history of the South-Central Andes. The detrital ages of the different samples were rather similar, ranging from ~2007 to ~5 Ma (Paleoproterozoic to Cenozoic). The pool of ages suggests reworking and detrital contribution for the studied volcanoclastics. The main detrital populations have age mode at 460 and 480 Ma (Ordovician), whereas three main Andean volcanic episodes at ~5, 13 and 21 Ma were identified. From these new data sets, a sedimentation rate of ~0.7mm/yr would characterize the basin fill between ~13 and 5 Ma.

Keywords: Miocene Andean Foreland, Detrital U-Pb ages, Depositional ages, Provenance.

Resumo: Seis níveis de rochas tufaceas e areníticas de uma sucessão sin-orogénica Andina (mio-pleiocénica) foram analisados pelo método U-Pb LA-ICP-MS em zircões detríticos, com o intuito de inferir as idades máximas de deposição e a proveniência da bacia, com implicações quanto à história vulcânica do Andes Centro-Sul. As idades em grãos detríticos das diferentes amostras mostraram um padrão similar, variando de ~ 2007 a ~5 Ma (Paleoproterozóico ao Cenozóico). O conjunto de dados sugere retrabalhamento e contaminação detrítica nos níveis vulcanoclásticos estudados. As principais populações detríticas têm moda de idade em 460 e 480 Ma (Ordovícico) enquanto que três principais episódios vulcânicos andinos, datados em ~ 5, 13 e 21 Ma, foram identificados no presente estudo. A partir do conjunto de dados, estima-se uma taxa de sedimentação de ~ 0.7mm/ano para a evolução da bacia no intervalo entre ~ 13 e 5 Ma.

Palavras-chave: Antepaís Andino miocénico, Idades detríticas U-Pb, Idades de deposição, Proveniência.

This basin comprises the lower Vinchina and upper Toro Negro Formations (Turner, 1964; Ramos, 1970) that were exhumed during the late Pliocene-Pleistocene. Although the Vinchina basin was studied by diverse methods, its geochronology is still not well known. Magnetostratigraphic studies (Reynolds *et al.*, 1990; Re & Barredo, 1993), zircon fission track ages (Tabbutt, 1986) as well as detrital zircon U-Pb dating (Dávila *et al.*, 2008; Collo *et al.*, 2011; Ciccio *et al.*, 2012) on tuffaceous levels, allowed constraining the timing of basin sedimentation between ~19 and ~3.4 Ma. K-Ar whole-rock analyses from the same levels suggested, however, a wider range of ages (from Eocene-Oligocene in lower sections, to late Miocene in the upper part of the units, Ciccio *et al.*, 2005, 2008) which is consistent with the observed recycling. Considering these ages, the sedimentation of the Vinchina basin would have lasted ~16 my and must have been at maximum burial conditions a relatively short time. Three main sedimentation rate stages were recognized in the Sierra de los Colorados: (i) 0.09 mm/yr between 19 and 7.30 myr; (ii) 0.9mm/yr between 7.30 and 4.30 myr; and (iii) 2.2 mm/yr between 4.30 and 3.40 myr (Collo *et al.*, 2011).

We re-analyzed six different levels (four tuffaceous and two sandstones) from the Sierra de los Colorados using the U-Pb LA-ICP-MS method on zircons, not only to constrain the maximum depositional age but also to define the basin provenance and likely connections with the volcanic history of the South-Central Andes. The detrital ages of the different samples were rather similar, ranging from ~2007 to ~5 Ma (Paleoproterozoic to Cenozoic). The pool of ages supports reworking and high detrital contribution of the tuffaceous levels. The main detrital populations have age mode at 460 and 480 Ma (Ordovician) with minor peaks at 258, 283-294, 335, 380, 394-396, 415-426, 442-447, 504, 564, 635-664, 789-876, 915-934 and 1031 Ma. The detrital populations are also similar from the bottom (Vinchina Formation) to top (Toro Negro Formation), showing a recurrent age gap between the Late Triassic and Oligocene.

The lowest tuffaceous level (TRT3 at ~5500 m in depth), at Los Colorados creek, has two main Andean populations

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The Vinchina basin is a very thick (up to 12 km) Andean (Mio-Pliocene) synorogenic succession formed by alluvial strata, mainly exposed across the Sierra de los Colorados (28°-30° LS), La Rioja province, NW Argentina (Fig. 1).

of 12.7 Ma ($n=3$) and 21 ($n=7$), with Th/U ratios between 0.30 and 2.2. The tuffaceous level at the top (TRT4 at ~350 m depth), in turn, has an only population of 5.5 Ma ($n=13$) with Th/U ratios between 0.41 and 0.96. In both levels, the youngest ages were interpreted as sedimentation ages. In the bottom section, at the La Flecha creek, the tuffaceous level (RLT4) shows an Andean population of 13.7 ± 1.5 Ma (Th/U ratios between 0.3 and 1.2), also interpreted as the maximum sedimentation age. From these new data sets, a sedimentation rate of ~0.7mm/yr would characterize the basin fill between ~13 and 5 Ma. This, in turn, would affect the calculated time-temperature conditions given that sedimentation rate controls the basin thermal evolution (see Collo *et al.*, 2011).

Three main Andean volcanic episodes at ~5, 13 and 21 Ma can be interpreted from the U-Pb detrital ages. These are consistent with the Late Oligocene to Recent magmatic pulses reported along the Andes between 28.5 - 32.5 LS (Kay and Mpodozis, 2002). Our detrital ages, concentrated in the Vinchina basin testify the eastward shifting of the magmatic activity from the Early Miocene as evidenced by previous works (Furque, 1963, 1979; Simon, 1985; Jordan *et al.*, 1993; Vergés *et al.*, 2001; Limarino *et al.*, 2001; Kay & Mpodozis, 2002; Dávila *et al.*, 2004). This migration has been associated with the initiation of shallow subduction and changes in plate convergence

patterns along the Andean arc at about 18 Ma (Kay & Mpodozis, 2002; Dávila *et al.*, 2004).

Previous paleocurrent and compositional studies proposed a regional sediment supplies for the Vinchina basin from the west and north (Tripaldi *et al.*, 2001; Ciccio *et al.*, 2014). On the base of this and considering the main features of the Ordovician zircons reported in this work (most important age population, euhedral geometries suggesting the igneous nature of the zircons, with little to no reworking), a close Ordovician source to the north and west might be considered that might match with the Toro Negro Range and High Cordillera, respectively. Moreover, the overlap between the two Ordovician detrital populations and the main magmatic episodes recorded in the Famatinian belt located immediately to the east (Dahlquist *et al.*, 2005) suggests that it could be some contribution from this region. The lack of Late Triassic to Early Tertiary detrital ages suggests that the Jurassic-Cretaceous volcanic arcs as well as the earliest Andean (Paleocene-Eocene) volcanism would not have supplied to the Vinchina basin, and likely, these volcanic sources would have kept along the western flank of the Andes since the Miocene, far from the depositional area of the Vinchina basin. This gap also supports a migration towards the east of the main volcanic arc from the Mesozoic to the Cenozoic (Ramos, 2010).

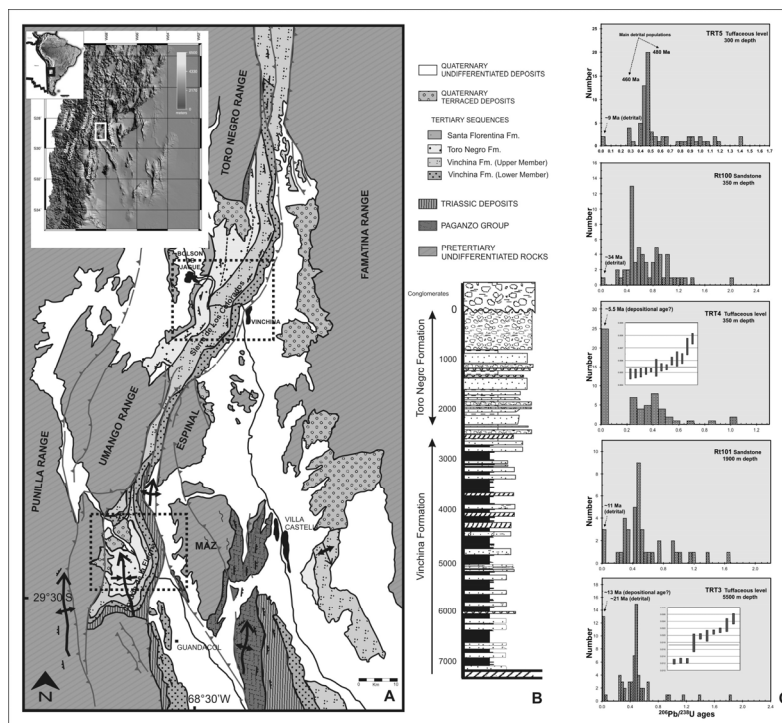


Fig. 1. (A) Geological map from the western region of the La Rioja Province, showing the distribution of the Tertiary deposits within the Vinchina Basin. To the left corner a shaded topographic relief image (U.S. Geological Survey), shows the Central Andean Foreland of Argentina and the location of the basin. (B) Representative stratigraphic column of the basin at Sierra de los Colorados in which the Vinchina and Toro Negro Formations are distinguished. Modified from Collo *et al.* (2011). (C) U-Pb detrital zircon ages of the analyzed samples.

Fig. 1. (A) Mapa geológico da porção oriental da Província La Rioja, mostrando a distribuição dos depósitos terciários da Bacia Vinchina, Argentina. No canto esquerdo, apresenta-se uma imagem do relevo (Serviço Geológico dos EUA) dos Andes Centrais, Argentina, e a localização da bacia foreland estudada. (B) Coluna estratigráfica da bacia, na seção Sierra de los Colorados na qual as formações Vinchina e Toro Negro estão destacadas. Modificado de Collo *et al.* (2011). (C) Idades U-Pb em zircão detrítico das amostras estudadas. Ver texto para detalhes.

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