PROVENANCE OF THE EARLY PALEOZOIC OLLANTAYTAMBO FORMATION, SOUTHERN PERU: THE U-Pb AND Hf ISOTOPE EVIDENCE OF DETRITAL ZIRCONS

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The plate-tectonic setting of the Ordovician sedimentary basin of southern Peru and northern Bolivia has been diversely interpreted as that of an intracratonic marginal basin, an aulacogen, a back-arc rift or a passive margin (see summary in Bahlburg et al., 2006). The basin developed on a crustal collage represented by the Arequipa Massif as part of the Arequipa Terrane to the west and the Amazonia craton to the east (Fig. 1). The Arequipa Massif, in turn, is part of a 1.9 to 1.8 Ga arc terrane (Loewy and Bahlburg, 2007), which is considered to have docked against the SW Amazonia craton in Grenvillian time leading to the formation of the Sunsás orogenic belt in southwestern Brazil and eastern Bolivia (Fig. 1; Litherland et al., 1989; Loewy et al., 2004). Geochronologic data demonstrated that early Paleozoic granitoids intruded into the Arequipa Massif have an Ordovician age (473-440 Ma, Wörner et al., 2000; Loewy et al., 2004). Early results of an ongoing geochemical study characterize these rocks as having formed in a magmatic arc environment (Loewy and Bahlburg, unpublished data). The only evidence of early Paleozoic volcanism in the northern central Andes of northern Bolivia and southern Peru is represented by the mafic to intermediate lapilli tuffs of the Ordovician Ollantaytambo Formation and Umachiri beds in the Cordillera Oriental and Altiplano of southern Peru (Bahlburg et al., 2006).

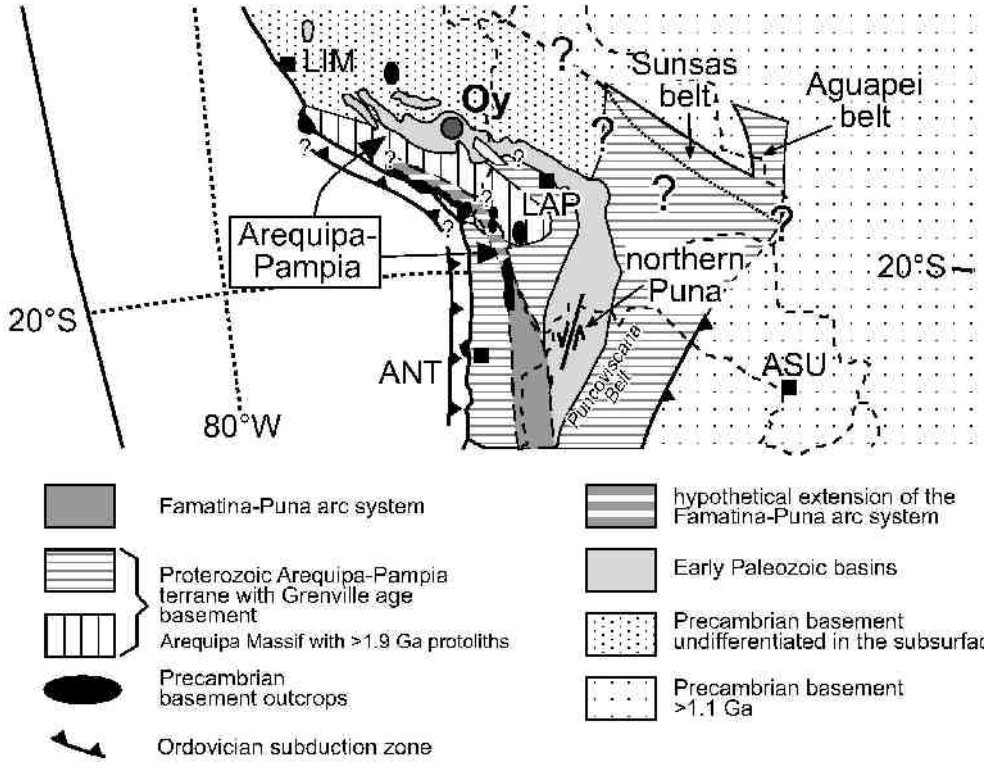

Figure 1: Plate tectonic setting of the Ordovician Gondwana margin in the Central Andes of NW Argentina, N Chile, S Bolivia, and S Peru (modified from Bahlburg et al., 2006). Oy = Ollantaytambo Formation; ANT = Antofagasta, ASU = Asunción, LAP = La Paz, LIM = Lima.

In order to better constrain the sedimentary provenance and the timing of the early Paleozoic volcanic activity in the northern central Andes, we determined U-Pb ages of detrital zircons by LA-ICPMS following the methodology of Chang et al. (2006). For analysis we selected an immature, volcanically influenced sandstone sample from the lower part of the Ordovician Ollantaytambo Formation ("Oy" in Fig. 1). Zircons are mostly elongate, slightly rounded and, in many cases, euhedral. More than 90% of the zircons have oscillatory zoning indicative of a magmatic origin. We analysed 140 zircon grains and determined 118 U-Pb ages that were within 10% of concordia. These ages were combined with Hf isotope compositions from 14 individually dated zircons. The Hf isotope data provide an indication of the geochemical character of the protolith of the zircon, with positive epsilon Hf values ($\varepsilon_{Hf(t)}$) indicating juvenile protoliths, and negative $\varepsilon_{Hf(t)}$ values representing evolved upper crustal origins.

The U-Pb age distribution displays several distinct peaks between 2.0 Ga and 0.45 Ma. The most pronounced peak occurs over a narrow age range between 490 and 445 Ma and represents 30% of the zircon population. These ages broadly coincide with deposition of the lapilli tuffs of the Ollantaytambo Formation and most likely represent the activity of the Famatinian magmatic arc in the northern central Andes between the topmost Cambrian and the lower boundary of the Hirnantian stage of the Upper Ordovician. Ages related to the Brasiliano orogenic cycle lie between 770 and 640 Ma and constitute 14% of the age spectrum.

Almost 60% of the data fall between 2.0 to 0.9 Ga reflecting the successively developed accretionary orogens at the southwestern margin of the Amazonia craton. Other prominent peaks occur between 1200 and 950 Ma (23% of the ages) and document input from the Grenville age Sunsás orogen in southwest Amazonia and northeast Bolivia, and between 1600 and 1200 Ma (31% of the ages), which represent sediment contributions from the Rhondonia-San Ignacio orogen. The remaining 3% of the ages are between 2 Ga and 1600 Ma and can be related to the Rio Negro-Juruena and Transamazonian orogens.

The Hf isotope composition of the zircons we examined from the Ollantaytambo Formation provide another layer of information about sediment sources. $\varepsilon_{Hf(t)}$ values of the zircons were calculated for the time of zircon crystallisation. In total, $\varepsilon_{Hf(t)}$ range from –22 to +3. The grains derived from contemporaneous Ordovician volcanic sources have markedly negative values between –9 and –6. Positive $\varepsilon_{Hf\,(t)}$ values indicating derivation from relatively juvenile source rocks are restricted to 4 grains and are between 0 and +3. The U-Pb crystallisation ages of 3 of these grains (748±15 Ma, 729±28 and 644±24) are linked to the Brasiliano cycle; the fourth grain has an age of 1600 Ma. The Hf T_{DM} model ages of all grains vary between 2300 and 1200 Ma and cluster from 1400 to 1200 Ma and 2300 to 1700 Ma. In summary, the Hf isotope data point to a zircon provenance from crustal provinces in Amazonia characterised mainly by the Rhondonia-San Ignacio and Transamazonian orogenic events.

In conclusion, our data give strong evidence of Ordovician volcanism in the region of southern Peru. They also indicate that Ordovician magmatism was connected to the recycling of older crust of the Amazonia craton which had most likely formed in the Mesoproterozoic, and in particular during the Rhondonia-San Ignacio and Transamazonian orogenic cycles.

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