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Tracking the basement of early Andean magmatism: U-Pb ages of zircon xenocrysts of the La Negra Formation in the Coastal Cordillera near Chañaral (~26°S), Northern Chile

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Introduction

Subduction has been a continuously active process in the Central Andes since the Jurassic, i.e. since the Pangea-Gondwana break-up (Coira et al., 1982; Mpodozis and Ramos, 1990). Recently, Gelcich et al. (2004) reported precise U-Pb ages for andesitic lavas from the base of the La Negra Formation (193.0 ± 0.6) and coeval plutonic phases (191.10 ± 0.4 Ma) in the Coastal Cordillera near Chañaral (~26°S), that record the onset of Andean mantle derived magmatism. The lower levels of the La Negra formation contain abundant zircon xenocrysts. We present here new U-Pb ages (Palaeozoic to Proterozoic) of these accidental zircons and discuss their significance in the context of the nature and age of the basement of the Mesozoic Andean arc system.

Pre-Andean basement

Complex Proterozoic and Palaeozoic metamorphic assemblages account for the crustal basement where the Andean arcs have been constructed (from the early Jurassic to the present). These assemblages consist mainly of high grade metamorphic rocks and granitoids that define crustal domains that have been interpreted either as discrete accreted blocks (Bahlburg and Hervé, 1997; Mpodozis and Ramos, 1990; Ramos, 1988) and/or as a result of progressive metamorphism along mobile belts (Lucassen et al., 2000).

Proterozoic rocks in the central Andes outcrop discontinuously from beneath a cover of Mesozoic and Cenozoic rocks. The two best known examples are the Arequipa massif in southern Peru and the basement of the Precordillera terrane of western Argentina (Tosdal, 1996). The Arequipa Massif (AM) represents an exposed area of a major cratonic block, the Arequipa-Antofalla Craton (AAC). The AAC is a major component of the central Andean orogenic basement. It has been recognised in several areas in southern Peru, western Bolivia, northern Chile and northwestern Argentina (Loewy et al., 2004) and geographically overlaps the domain of the Jurassic volcanic arc. The geochronology of the AAC defines a general Proterozoic age for the block as a whole. Wasteneys et al. (1995) interpreted early Proterozoic (~1900 Ma) whole rock Rb-Sr ages as the age of the granitic protolith, and late Proterozoic U-Pb zircon discordia ages (970 and 1198 Ma) as the time of high grade granulitic metamorphism. Loewy et al. (2004) defined three domains for the AAC based mainly on geochronology: a northern Domain (2.02-1.79 Ma), a central domain (1.20 – 0.94 Ga) and a southern domain dominated by Ordovician metasediments derived partially from Proterozoic crust. The extension of the AAC is not well defined.

Two distinctive Paleozoic metamorphic complexes are exposed in the Coastal Cordillera in northern Chile: the high-grade metamorphic assemblage of the Mejillones Peninsula in the Antofagasta Region (~24° S) and the Chañaral Epimetamorphic Complex (CEC; ~ 26° S). The Mejillones complex occurs very isolated in the

Coastal Cordillera, and includes schists, gneisses, and amphibolites that record a Cambrian magmatic and metamorphic event (Baeza and Pichowiak, 1988). The CEC occurrence is limited to the coast of Chañaral were it outcrops discontinuously for ~ 200 km (Bell, 1987). The epimetamorphic complex comprises mainly metamorphosed turbidites that were deposited in the Carboniferous/and or Devonian which underwent syn-sedimentary deformation and later tectonic folding and metamorphism.

Geology of the Coastal Cordillera near Chañaral

The oldest rocks in the area are grouped in the CEC which consists mainly of turbiditic metasediments, including melange facies, and minor metabasites and metalimestones (Godoy and Lara, 1998). Berg and Baumann (1985) estimated a maximum depositional age of the sediments based on $^{87}Sr/^{86}Sr$ around 380 Ma. The sedimentary sequences are intruded by S-type Permo-Triassic plutons. The CEC is unconformably overlayed by the Pan de Azucar formation which is defined as a ~250 m thick sequence of limestones, calcareous sandstones and conglomerates that shows strong lateral facies variations (Godoy and Lara, 1998). It contains Hettangian-Sinemurian (~202 – 192 Ma) marine fossils (Naranjo et al., 1986). The La Negra formation overlies the Pan de Azucar formation and is mainly composed of andesites, basaltic andesites and andesitic tabular intrusions with a few intercalations of conglomerates, sandstone and tuffs (Godoy and Lara, 1998). The andesites in this area contain low-grade metamorphic alteration assemblages characterised by chlorites, actinolitic amphibole and calcite. Most of this alteration is associated with multiple intrusions of Jurassic and Cretaceous plutons, for which the la Negra sequence is the main country rock.

Results

A total of 15 fractions from the 5 samples were analyzed by TIMS at the Jack Satterley Geochronology Laboratory, currently at the university of Toronto, following the method decribed in (Krogh, 1982). The volcanic samples containing zircon crystals included andesitic to basaltic andesitic lavas with mainly aphanitic and occasionally porphyritic textures. Two samples were collected from the lowest levels of the La Negra formation in the Sierra Minillas immediately south of the Pan de Azucar valley (SGD-25 and SGD-35; ~200 m stratigraphically over the contact with the Pan de Azucar formation), and three others were collected from higher stratigraphic levels at the Carrizalillo (SGD-27) and Manto Verde (SGD-73 and SGD-180) mines. The analyzed zircons were prismatic and color varied from transparent to yellow. Backscattered electron and cathodoluminescence images show magmatic zonations and lack of cores. U concentration in zircons range from ~ 80 ppm to ~ 550 ppm. Th/U varies from ~0.14 to 1.19. The results show both concordant and discordant data (Fig. 1). The concordant data (~200-300 Ma) is relatively younger than the discordant ages > 500 Ma. We have used Th/U ratio in zircons to discriminate between accessory (magmatic) and xenocrystal zircons. Zircons from Jurassic-Cretaceous early Andean granitoids in the area show typical Th/U ratio ~ 1 (Gelcich et al., 2002). From the 14 analyzed fractions, only one DWD 4089 (sample SGD-35) has a typical "Andean" magmatic signature with a Th/U ratio of 1.19. This fraction yields a concordant age (193 ± 0.6 Ma) interpreted as an extrusion age (Gelcich et al 2004). Considering the latter, we have modeled the age of the discordant pre-Mesozoic zircons (xenocrysts) from upper intercept ages of Pb loss lines, assuming that the Pb in the zircon grains was partially lost during the eruptive magmatic event (Fig. 1). The upper intercepts of the discordant zircons obtained in this way yield mainly Proterozoic ages ranging from 627.8 ± 5.9 Ma to 1762.6 ± 6.7 Ma.

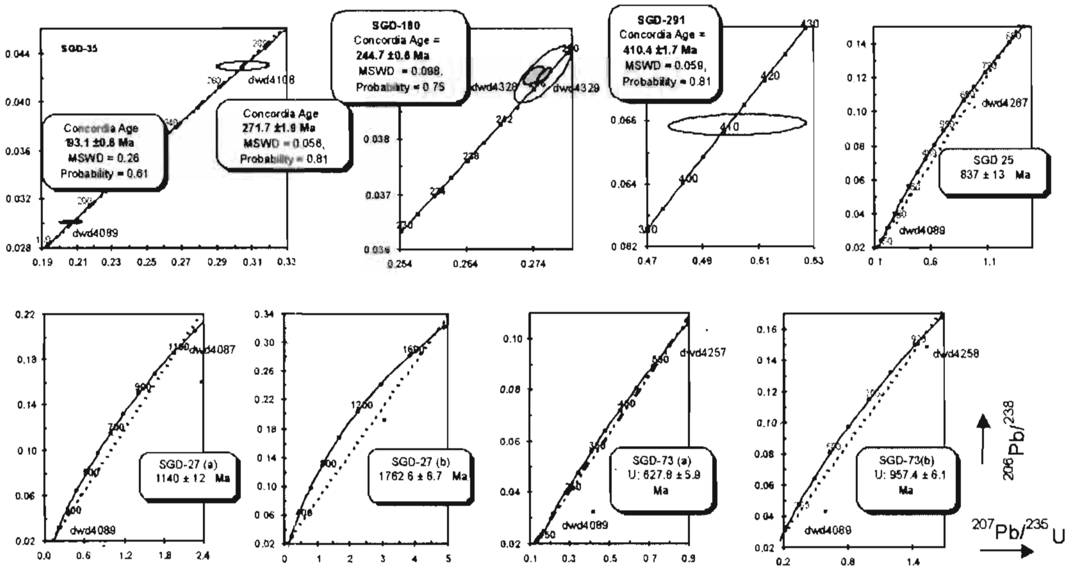

Fig. 1. Concordia diagrams of analyzed zircons of the La Negra formation, including concordant and discordant data. For the latter, upper intercept Pb Loss ages were obtained modeling Pb loss at 193 Ma.

Discussion: Crustal basement of the early Andean arc system

The relatively younger zircons from the xenocryst population, SGD-180 (~240 Ma) and SGD-291 (~410) are concordant (Fig. 1). The concordia curve for these relatively young ages is parallel to Pb loss lines, so any discordance due to Pb loss is obscured (graphically). The discordant zircon ages are meaningful in the context of available tectono-stratigraphic data and indicate Proterozoic crust under the Paleozoic metasedimentary sequence. The upper intercept ages obtained with the Pb loss model for the discordant fraction are mainly Proterozoic (Fig. 1.). These results are satisfactorily comparable to the inheritance signature described by Berg and Baumann (1985) for Triassic S-type granitoids in the area of Chañaral (~1050 Ma). The presence of an "old" Proterozoic basement is also strongly suggested by the geochemistry of early Jurassic to recent Andean magmatic rocks in the central Andes (e.g. Rogers and Hawkesworth, 1989). This old basement signature is also evident in most Paleozoic magmatic and metamorphic rocks from the central Andes, which show Proterozoic Nd model ages (Miller and Harris, 1989). The most probable source of Proterozoic zircons is the Arequipa-Antofalla Craton. Notable is the Paleoproterozoic age (~1760 Ma, SGD-27) and a cluster of ages ~ 900 Ma, in clear correspondence with the two clusters of ages reported for the ACC (Loewy et al., 2004; Wasteneys et al., 1995). A question is whether these zircons were derived from a Proterozoic crust block under the early La Negra Andean arc, or if they are detrital zircons contained in the metasedimentary sequences of the CEC. Turbidites from the CEC have a recycled orogenic provenance, and the ACC may have been a main detrital source (Bahlburg and Breitkreuz, 1993). However, initial Sr ratios in Triassic S-type granites in the Coastal Cordillera preclude the CEC from being a main crustal source of contamination (Berg and Baumann, 1985), suggesting that a different, unexposed basement exists in the area. This reasoning favours the inference that Paleozoic metasedimentary units rest on sialic basement and not on oceanic crust (Bahlburg and Breitkreuz, 1993).

Deposition and later deformation of the CEC may be explained by the development of a single N-S striking ensialic basin in which transpression was superimposed on an early transtensional regime (Bahlburg and Breitkreuz, 1993) . In the latter scenario it is possible to infer that the sediments accumulated on an ACC crust. ACC crust, therefore, is part of relatively deeper, unexposed level of the early Andean arcs.

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