CRUSTAL RECYCLING IN ACCRETIONARY OROGENS: LA-ICP-MS GEOCHRONOLOGY AND Hf ISOTOPE EVIDENCE OF DETRITAL ZIRCONS IN LATE PALEOZOIC TURBIDITE UNITS OF THE SOUTHERN CENTRAL ANDES

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RESUMEN

Los orógenos acrecionarios de margenes activos se consideran los sitios importantes de la formación de corteza continental juvenil. En los Andes centrales septentrionales, los estudios geoquímicos del basamento metamórfico Proterozóico, la cubierta sedimentaria Neoproterozoica y Paleozoica y las rocas magmáticas coetáneas acentúan la homogeneidad temporal y espacial de las composiciones geoquímicas generalmente evolucionadas de las unidades respectivas. Sobre la base de analises in-situ de alta resolución por LA-ICPMS de zircones detríticos presentamos edades U-Pb y de isótopos del Hf de siete muestras de areniscas turbidíticas de edad Devonica-Pérmica del prisma de accreción del margen occidental de Gondwana en el norte de Chile. Los espectros de edades de zircones detríticos reflejan todos los ciclos orogénicos Proterozoicos que representan la evolución de manera gradual del sistema orogénico acrecionario del craton Amazónico entre 2.0 y 0.9 Ga, seguida por la del orógeno Terra Australis entre 0.9 y 0.25 Ga. Dos máximos prominentes caracterizan a la distribución de edades reflejando aportes dominantes de la provincia orogénica Sunsás (Grenville) de edad 1.2-0.9 Ga y del arco magmático Famatiniano (0.52-0.42 Ga). Los datos isotópicos del Hf demuestran que todas las rocas sedimentarias analizadas contienen un número significativo de zircones juveniles con valores positivos de $\varepsilon_{Hf\,(t)}$. Las edades modelo de estos granos caen casi exclusivamente entre 1.5 a 0.8 Ga e indican la formación de sus protolitos durante los ciclos orogénicos Rhondoniano-San Ignacio y Sunsás. Granos con valores negativos de $\varepsilon_{Hf\,(t)}$ se pueden también rastrear a los mismos dominios corticales. En conclusión nuestros datos indican que el reciclaje de la corteza continental de edad Mesoproterozoica ha sido el proceso principal de la evolución cortical del margen occidental de Gondwana en el norte de Chile durante el Neoproterozoico y Paleozoico.

INTRODUCTION

Active margin accretionary orogens are considered major sites of formation of juvenile continental crust (Condie, 2007). In the southern central Andes, geochemical studies of the Proterozoic metamorphic basement, the Neoproterozoic and Paleozoic sedimentary cover and the coeval magmatic rocks emphasize the temporal and spatial homogeneity of the evolved geochemical compositions of the respective rock units. Nd model ages of the sedimentary rocks and their plutonic and metamorphic basement cluster around 1.8 and 1.4 Ga and vary between 2.2 and 1.2 Ga (e.g. Bock et al., 2000; Lucassen et al., 2000). This indicates a dominant contribution of Meso- and Paleoproterozoic crustal material in the detritus constituting the sedimentary rocks.

For a detailed provenance study based on detrital zircon geochronology and geochemistry, we selected 7 samples of Late Devonian to Permian turbidite units of northern Chile, namely the El Toco, Las Tórtolas and Huentelauquen formations, the Huasco beds and a mica shist from the El Tránsito Metamorphic Complex (Fig. 1), because their detritus most likely reflects the provenance evolution of this margin prior to the onset of the Andean active margin cycle. The studied rocks represent parts of an accretionary wedge at Gondwana's late Paleozoic active margin in the present Central Andes (Hervé et al., 1987). The units overstep the boundary between the somewhat enigmatic Chilenia terrane of alleged Laurentian origin (Keppie and Ramos, 1999) in the south and coeval autochthonous regions of Gondwana to the north (Bahlburg and Hervé, 1997). Zircon populations of overstepping units deposited on and derived from Chilenia should ideally demonstrate the Laurentian heritage of the

terrane by an absence of geochronologic events typical of Gondwana and which are not present in Laurentia, i.e. the Brazilian orogenic cycle.

METHODS

We determined the U-Pb age spectra of detrital zircons using LA-ICPMS following the methodology of Chang et al. (2006). We also analyzed individual dated zircons for their Hf-isotope compositions using LA-MC-ICPMS (DuFrane et al., 2007). We analysed 140 to 145 grains from each sample for for their U-Pb isotope composition. We only included grains with U-Pb ages falling within 10% of concordia in our interpretations. Typically this included between 97 and 118 grains per sample. Subsequent to the U-Pb age determinations, between 18 and 28 of the dated grains per sample were analyzed for Hf isotopes.

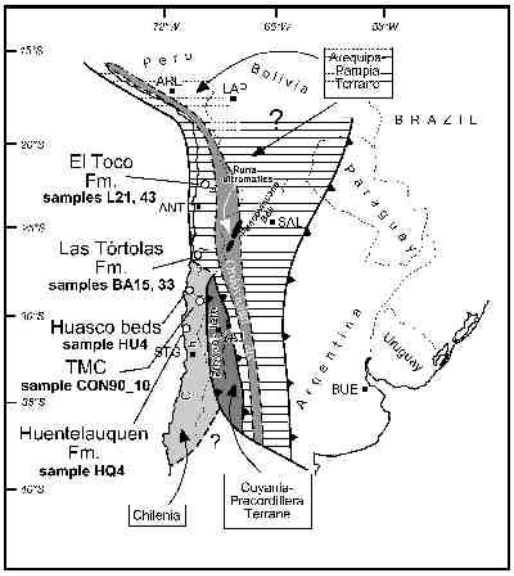

Figure 1: Sample locations and formations plotted on a terrane map of the southern Central Andes modified after Bahlburg and Hervé (1997), Ramos (2000), and Bahlburg et al. (2006). TMC: El Tránsito metamorphic complex. ANT, Antofagasta; ARE, Arequipa; LAP, La Paz; SAJ, San Juan; SAL, Salta; STG, Santiago de Chile.

RESULTS

The U-Pb ages of all samples reflect the same distribution of main events: the Rhondonia-San Ignacio orogeny of the southwestern Amazon craton between 1.5 and 1.2 Ga; the Grenville-age Sunsas orogenic cycle between 1.2 and 0.9 Ga; the Brazilian cycle between 0.8 and 0.55 Ga; and the early Paleozoic Famatinian cycle between 0.55 and 0.42 Ga. The Late Carboniferous-Permian turbidites also register a cluster of ages between 0.33 and 0.25 Ga marking the re-initiation of subduction magmatism at this margin after a period of magmatic, tectonic, and metamorphic quiescence mainly in the Devonian.

All of the turbidite deposits we examined in this study have a very similar zircon age distribution and succession of geochronologic events, including evidence of the Gondwanan Brazilian cycle in all samples. Considering a potential Laurentian derivation of the Chilenia Terrane, detritus derived from it should not record evidence of the Brazilian cycle. Even though margin-parallel sediment transport could account for some of the latter grains, the size of Chilenia (>1000 km N-S) should have kept this influence small. In conclusion, we find that our data cast doubt on a Laurentian origin of the Chilenia terrane in northern and central Chile.

The Hf isotope data demonstrate that all analyzed sedimentary rocks contain a significant number of juvenile zircons yielding positive epsilon Hf values calculated at the time of zircon crystallisation ($\varepsilon_{Hf(t)}$). The model ages of these grains almost exclusively fall in the 1.5 to 0.8 Ga age bracket and

indicate formation of their protoliths during the Rhondonian and "Grenvillian" orogenic cycles. Grains with negative $\varepsilon_{Hf(t)}$ values can also be traced back to the same juvenile Mesoproterozoic crustal domains.

In conclusion, the available data indicate that formation of juvenile crust played a minor role in all post-"Grenvillian" orogenic cycles affecting the region of the southern central Andes between 0.8 and 0.25 Ga. The crustal evolution of the accretionary orogen of the proto-Andes seems to have been characterized by repeated recycling of continental crust originally formed mainly in the Mesoproterozoic.

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