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WHOLE-ROCK AND ISOTOPE GEOCHEMISTRY OF ORDOVICIAN TO SILURIAN UNITS OF THE CUYANIA TERRANE, ARGENTINA: INSIGHTS FOR THE EVOLUTION OF SW GONDWANA MARGIN

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INTRODUCTION

The Cuyania terrane in central Argentina (Fig. 1) is characterized by a Mesoproterozoic (Grenvillian-age) basement with depleted Pb isotopic signatures and Mesoproterozoic Nd model ages resembling basement rocks of the same age from Laurentia (Ramos, 2004; Sato et al., 2004 and references therein). Several authors have proposed para-autochthonous (Aceñolaza et al., 2002; Finney et al., 2005) versus allochthonous (e. g. Ramos et al., 1986; Dalziel et al., 1994; Astini et al., 1995; Thomas and Astini, 1996) geotectonic models for the early Palaeozoic evolution of the Cuyania terrane. The tectonic evolution of the Cuyania terrane is a substantial part of the understanding of the evolution of the western border of southwest Gondwana. Several morphostructural units form the Cuyania composite terrane (Fig. 1; Ramos et al., 1996): The Precordillera *s.s.*, the Western Pampeanas Ranges and the San Rafael and Las Matras blocks. However, the boundaries of the terrane are still not well-constrained (Astini and Dávila, 2004; Porcher et al., 2004; Casquet et al., 2006).

A combination of several methodologies including geochemistry, Sm-Nd, Pb-Pb and U-Pb detrital zircon dating was applied to several clastic Ordovician (Los Sombreros, Gualcamayo, Los Azules, La Cantera, Yerba Loca, Empozada, Trapiche, Sierra de la Invernada, Portezuelo del Tontal, Las Vacas, Las Plantas and Alcaparrosa Formations) and Ordovician to Silurian (Don Braulio and La Chilca Formations) units of the Cuyania terrane (Fig. 2). The combination of these different approaches can give accurate information in order to constrain the probable sources that provided detritus to the Cuyania terrane and ultimately to constrain the existing models about its origin.

GEOLOGICAL SETTING

The fourteen units here studied crop out within the Precordillera *s.s.* Based on stratigraphy and structural features, the Precordillera *s.s.* has classically been divided into Eastern, Central, Western and Mendoza domains (Fig. 2). A carbonate platform overlaid by predominately clastic deposition within a shallow basin characterized the Eastern and Central domains (comprises the Gualcamayo, Los Azules, Las Vacas, Las Plantas, Trapiche, La Cantera, Don Braulio and La Chilca Formations).

Western Precordillera is characterized by turbidite deposition within a deep-sea basin with interlayered and intruded mafic to ultramafic igneous rocks and comprises the slope-type (olistostromic) deposits adjacent to the continental rise (Los Sombreros, Sierra de la Invernada, Portezuelo del Tontal Yerba Loca and Alcaparrosa Formations).

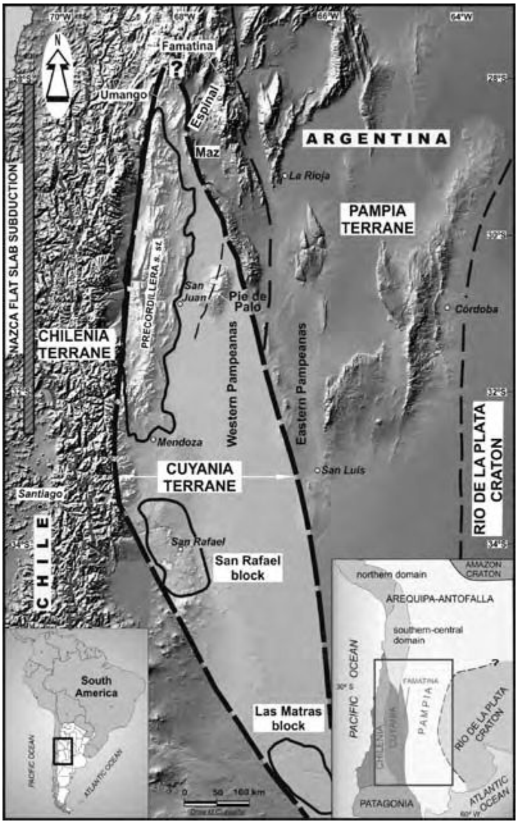

Figure 1. Satellite image based map showing Cuyania terrane boundaries as dashed lines and blocks boundaries as continuum lines. All the entities forming the Cuyania terrane develop a Grenvillian-age basement characterized by Nd, Sr and Pb depleted isotopic signatures (Ramos, 2004, Sato et al., 2004). Righter inlet: location of neighboring terranes.

GEOCHEMISTRY

The Chemical Index of Alteration (CIA) quantitatively assesses the weathering effects on sedimentary rocks. The CIA values of the Mendoza, Western, Central and Eastern Precordillera range from 52 to 77, indicating intermediate to strong chemical alteration. In general, samples of all the units studied have Th/U ratios between 3.5 and 4, which is typical for derivation from upper crustal rocks. Samples with high Th/U ratios probably caused by loss of U due to weathering are also observed, particularly within units of the Western Precordillera.

Th/Sc ratios of the units studied show a general tendency indicating an unrecycled upper continental crust source composition, particularly for samples of the Western Precordillera. Effects of sedimentary recycling are evident for the Central and Eastern Precordillera where they are also accompanied by concomitant high SiO_2 concentration. Sandstones of the Precordillera of Mendoza show Zr/Sc values indicating the influence of recycling. The chondrite normalized REE patterns for all the sequence studied tend to be depleted in LREE and enriched in HREE compared with the PAAS (which reflects the average composition of the upper continental crust). A negative Eu-anomaly ($Eu_N/Eu^* = Eu_N/(0.67Sm_N+0.33Tb_N)$) can be observed and samples also display a flat heavy REE distribution. Disturbed

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pattern in few samples of the Los Sombreros Formation (Western Precordillera) indicate remobilization of REE.

ISOTOPE GEOCHEMISTRY

Nd isotopes indicate ε_{Nd} of -5.4, fSm/Nd -0.34 and T_{DM} 1.57 Ga in average for all the units studied. T_{DM} ages of two samples of the Los Sombreros Formation are aberrant due to REE fractionation, as indicated by geochemistry. The dataset is similar to those from other Ordovician to Silurian units of the Cuyania terrane (Cingolani et al., 2003; Gleason et al., 2007; Abre et al., 2011).

ε_{Nd} values for Ordovician to Silurian clastic rocks of the Cuyania terrane are within the ranges of variation of data from Famatina, the Laurentian Grenville crust, Central and Southern domains of the Arequipa-Antofalla Basement, basement of the Cuyania terrane and from the Western Pampeanas Ranges. The T_{DM} ages are comparable to T_{DM} ages for Mesoproterozoic and Palaeozoic rocks of the Cuyania terrane. Similar data are known from Mesoproterozoic rocks from Antarctica, Malvinas plateau and Natal-Namaqua Metamorphic belt and the Western Pampeanas Ranges.

$^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ range from 18.82 to 21.20, 15.67 to 17.27, and 38.7 to 42.93 respectively, for the Ordovician to Silurian units of the Cuyania terrane. Pb ratios are similar to values obtained for the Ponón Trehué Formation of the San Rafael block (Abre et al., 2011). Comparing the lead isotopic system with probable source areas it is evident that the datasets from the basement of the Cuyania terrane and from Proterozoic rocks of Eastern North America. Mesoproterozoic rocks from the Natal-Namaqua Metamorphic belt, Malvinas Microplate, West Antarctica and East Antarctica have different Pb isotopic signatures from those of the Cuyania terrane.

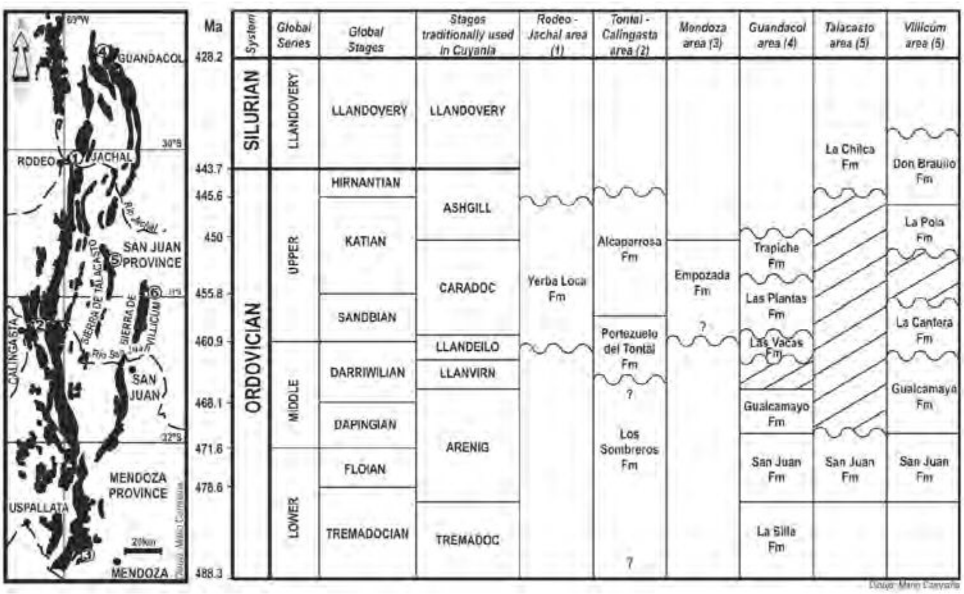

Figure 2. Ordovician to Silurian units correlation chart and location of the studied regions within the Precordillera of Western Argentina.

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U–Pb dating of single detrital zircons was carried out in six samples of the Ordovician to Silurian record of the Cuyania terrane. Three units from the Eastern and Central Precordillera were analyzed: The La Cantera Formation (n= 38) show peaks at 1140.6 Ma, 1351 Ma, and 1553 Ma in order of abundance. The Trapiche Formation (n= 60) shows main peaks at 1024 Ma, 1089 Ma, 1162 Ma, 1360 Ma, 1456 Ma and 1265 Ma, with minor peaks at 661 Ma, 802 Ma and 1789 Ma. Detrital zircon ages main peaks for the Don Braulio Formation (n= 42) cluster at 989 Ma, 1151 Ma, 1392 Ma, 658 Ma and 1553 Ma in order of abundance. Only three grains are Palaeoproterozoic in age (peak at 1941 Ma).

Two formations were studied from the Western Precordillera: Detrital zircon ages main peaks for the Yerba Loca Formation (n= 63) are at 1023 Ma, 1099 Ma, 617 Ma, 1420 Ma, 1210 Ma, 526 Ma and 1361 Ma. Minor peaks are displayed at 760 Ma, 1567 Ma, 2224 Ma and 2499 Ma. Detrital zircon dates of the Alcaparrosa Formation (n=49) display main peaks at 1083 Ma, 544 Ma, 1275 Ma and 940 Ma in order of abundance. Minor peaks are found at 1825 Ma and at 1597 Ma. Three grains have an age in between 460 and 495 Ma.

The Empozada Formation (n= 38), cropping out at Precordillera of Mendoza, shows main peaks at 1040 Ma, 1341 Ma, 1153 Ma and at 982 Ma. Minor peaks are displayed at 603 Ma and at 1106 Ma.

The detrital zircon dating here presented constrain the sources as being dominantly of Mesoproterozoic age, with a main peak in the range 1.0 to 1.3 Ga and a subordinate peak between 1.3 and 1.6 Ga, but inputs from both older (1.6 to 2.5 Ga) and younger (Neoproterozoic, Cambrian and Ordovician) sources are also recorded.

DISCUSSION

Several areas should be evaluated as sources with regards to the palaeogeography of the Ordovician to Silurian Cuyanian basin. Sedimentological characteristics such as palaeocurrents and the lack of important recycling tend to indicate that areas located far away of Cuyania and/or those located to the west can be ruled out as sources (e.g. the Amazon craton and the Chilenia terrane). Comparison of isotope data, including detrital zircon dating allow concluding that the Famatinian magmatic arc, the Grenville Province of Laurentia, the Natal- Namaqua Metamorphic belt, Malvinas Microplate, West Antarctica and East Antarctica were not sources for the Ordovician to Silurian basin of the Cuyania terrane.

On the other hand, Mesoproterozoic rocks that could have contributed to the bulk of detritus are: 1) the southern extensions of the basement of the Cuyania named the Cerro la Ventana Formation (Cingolani et al., 2005) of the San Rafael block; 2) the Western Pampeanas Ranges; 3) the Arequipa-Antofalla Basement, however, the northern termination of the Cuyania terrane (Jagüé area) is still under investigation and therefore the tectonic relationship with the Arequipa-Antofalla rocks is currently not well determined (Astini and Dávila, 2004). A provenance from the basement of the Cuyania terrane (Cerro La Ventana Formation) and from the Western Pampeanas Ranges was also deduced for clastic sedimentary Ordovician units of the San Rafael block (Cingolani et al., 2003; Abre, 2007; Abre et al., 2011).

CONCLUSIONS

The uniformity shown by the provenance proxies indicate that there were no important changes in the provenance within Eastern, Central, Western Precordillera and the Precordillera of Mendoza. Geochemical analyses indicate a dominant unrecycled upper crustal component. Sm-Nd and Pb-Pb data allow discarding certain areas as probable sources. Detrital zircon dating further constrains the sources as being dominantly of Mesoproterozoic age, but with contributions from Ordovician, Cambrian, Neoproterozoic and Palaeoproterozoic sources. The combination of the different provenance approaches applied indicates that the Cuyanian basement and the Western Pampeanas Ranges (and less probably the Arequipa-Antofalla Basement) were the main sources.

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