Nd ISOTOPES FROM YERBA LOCA FORMATION (UPPER ORDOVICIAN), CUYANIA TERRANE, ARGENTINA

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Keywords: Ordovician, Cuyania terrane, Sm-Nd, Gondwana margin, provenance.

INTRODUCTION

Several arguments as well as geochemical data from the basement rocks support the allochthonous models of the Precordillera (Cuyania) Terrane as derived from Laurentia (e.g. Ramos et al., 1986; Dalla Salda et al., 1992; Astini et al., 1995). Less certain are the time and type of collision with Gondwana. However, other authors have proposed a parautochthonous evolution based on biostratigraphical and structural data, displaced during Ordovician–Devonian times (e.g., Aceñolaza et al., 2002; Finney et al., 2005). To contribute to the discussion about tectonic models for the Precordillera, preliminary Nd isotope data from an ongoing provenance study on the Caradocian rocks from the Yerba Loca Formation are here presented.

GEOLOGICAL BACKGROUND

The Yerba Loca Formation was first described by Furque (1963); it crops out in the northern and central part of Western Precordillera, San Juan province, Argentina. The unit is characterized by pelites, arenites, hybrid arenites and greywackes (very frequently carbonate cemented), subordinated conglomerates and concordant to sub-concordant basic to ultrabasic magmatic rocks (Fernández Noia et al., 1990). The clastic rocks were affected by greenschist metamorphism and at least two major deformational events. The westernmost outcrops of the Yerba Loca Formation were deposited as fine grained turbidites interlayered with the mentioned basic magmatic rocks (e.g. Ramos et al., 1986), while the eastern section lacks such an igneous record and is interpreted as arenite-turbidites and mixed clastic-carbonate turbidites (Astini, 1994). Based on graptolites the age of the unit is Lower Llanvirn to Caradocian (Ortega et al., 1991). However, the samples used for Sm-Nd analysis were taken from Caradocian strata, thus an average Caradocian age (455 Ma) was preferable used to calculate the T_{DM} ages (see below and table 1).

The interlayered magmatic rocks are represented by pillow lavas, basalts with columnar junction and dykes. Based on geochemistry they were interpreted as evolved oceanic tholeiites formed at an early stage of a transitional-type or plume-type oceanic ridge segment, or in a retro-arc basin (Kay et al., 1984).

PETROGRAPHY AND GEOCHEMISTRY

Petrographical studies (Abre et al., 2005) show that the Yerba Loca Formation comprises predominantly fine- to medium-grained and poorly sorted metagreywackes composed of mono- and poly-crystalline quartz, partially altered K-feldspar and plagioclase, sedimentary lithoclasts (siltstones, mudstones and rarely carbonate), volcanic and metamorphic lithoclasts. Muscovite, chlorite and epidote are also present in minor amount. Accessory minerals are zircon, apatite and opaques.

Preliminary geochemical data indicate the presence of at least two components (Abre et al., 2005). The more abundant one has an upper crustal composition while the other is less fractionated. The first component exhibits Th/Sc values of 0.8 and average Zr/Sc values scattering around 24; using Ti/Zr vs. La/Sc an active continental margin was deduced as the depositional tectonic setting (Abre et al., 2005). In contrast, the second component has average Th/Sc values of 0.7 and Zr/Sc around 9.5; this less fractionated source was deduced from various provenance plots (Abre et al., 2005), using mainly La, Th, Sc and Zr, as related to a continental arc, although the absolute concentrations of arc-indicating elements such as Nb, Ta, Ti and Pb are not typical of a continental arc. Furthermore, the rare earth element patterns of both show an enrichment in LREE compared to HREE, a negative Eu anomaly and a flat distribution of the HREE, being thus similar to the PAAS pattern (typical of an upper continental crust signature). In summary, the geochemistry of the Yerba Loca Formation shows a mixed provenance, from upper continental crust and at least one less fractionated component (probably of arc provenance), and is comparable to the Caradocian Pavón Formation that crops out at the southern sector of the San Rafael block (Cuyania terrane).

Sm-Nd ISOTOPES

The application of the Sm-Nd method to sedimentary rocks is based on the fact that their detritus came from

older rocks what whose isotopic concentrations would not change through time (DePaolo, 1988). If the model ages of the possible source areas are known, it is likely to compare between them and identified the source (Nelson and DePaolo, 1988). Although the Sm-Nd method is a good provenance indicator, it should be used as complementary to other methods of provenance determination (Nelson and DePaolo, 1988).

The model ages based on Nd isotopes depend on assumptions about the fractionation of Sm-Nd ratios in major crustal processes. The single-stage model (DePaolo, 1981; T_{DM} in table 1) considers only the extraction of crustal material from a depleted upper mantle. However, other processes also fractionate the ratios (metamorphism, anatexis and weathering), thus a multi-stage model was developed (DePaolo, et al., 1991; $T_{DM(2)}$ in table 1). Although the latter model is probably more appropriate regarding the special case of the Cuyania terrane, the single-stage T_{DM} ages are also shown for comparison.

Measurements were done at the Laboratório de Geologia Isotópica da Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil (LGI-UFRGS) with a TIMS (Thermal Ionisation Mass Spectrometer).

εNd (t) indicates the deviation of the $^{143}Nd/^{144}Nd$ value of the sample from that of CHUR (Chondritic Uniform Reservoir). If at crystallization time the magma had a $^{143}Nd/^{144}Nd$ ratio lower than the chondrite then the εNd value is negative and the magma source was crustal. This is the case for Yerba Loca Formation samples, with εNd (t) values ranging from -4.8 to -7.3 (see table 1), implying a dominant crustal source. $T_{DM(2)}$ ages range from 1.56 to 1.74 Ga (see table 1).

According to these data, then Yerba Loca Formation model ages are similar to slightly older than the Grenvillian ages known from the Precordillera basement (Kay et al., 1996) as well as from the basement present in the Ponon Trehue area (Cerro La Ventana Formation; Cingolani et al., 2005). They are also slightly older than those from correlate units like Pavón Formation (Caradocian), San Rafael block of the Cuyania terrane, with model ages between 1.4 to 1.5 Ga (Cingolani et al., 2003). However, caution on interpretation must be taken, as the model ages in sediments are a mix of ages of different sources. In this sense, it has to be noted that these sediments are interlayered with basic volcanic rocks that are expected to have rather less negative to more probably positive εNd and as it was demonstrated by petrography, they were incorporated into the sediments due to cannibalistic processes. Petrographic results have also shown that sedimentary and metamorphic lithoclasts are not uncommon, implying that there were at least two more different sources (although both of crustal character). The presence of at least two different types of sources (a crustal and a less evolved one) was also demonstrated using geochemical data (see above and Abre et al., 2005). Even when these sources are not been clearly identified yet, it could be preliminarily assumed that the Grenville basement and older sedimentary strata from the Cuyania terrane itself were eroded into Yerba Loca basin.

sample	Sm	Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd_{(t=0)}$	t (Ma)	εNd(t)	T_{DM}	$T_{DM(2)}$
YL 451	5.03	25.82	0.1178	0.512108	455	-5.8	1469	1631
YL-449	5.08	26.55	0.1157	0.512024	455	-7.3	1559	1739
YL-3	3.76	18.26	0.1245	0.512176	455	-4.8	1464	1563
YL-2	4.77	24.82	0.1162	0.512110	455	-5.6	1444	1622
YL-1	5.07	25.88	0.1184	0.512089	455	-6.2	1506	1661

Table 1: T_{DM} = model age (DePaolo, 1981) based on the depleted mantle model. This model implies that the mantle suffered fractionation that leads to a residual mantle enriched in Sm/Nd ratio but geochemically depleted in large ions lithophile elements (LILE). $T_{DM(2)}$ = model age (DePaolo, 1991) based on a major fractionation occurred when the crustal reservoir was formed from the depleted mantle and was followed by a single stage of crustal residence up to the time of a new fractionation process (i.e. magma generation or metamorphism).

CONCLUSIONS

Nd isotopes from Yerba Loca Formation have $T_{DM(2)}$ ages ranging from 1.5 to 1.7 Ga and εNd (t) from -4.8 to -7.3. However it should be taken into account that the Sm-Nd data in these sediments are a result of a mixing of different sources which would have different ages and isotope compositions. Combining Nd isotope data with geochemical and petrographic results it can be deduced that one general source was of upper continental crust composition (sedimentary and metamorphic) and the other one has a less fractionated character (probably the adjacent basic lava flows). According to the present state of our knowledge, we can not strongly support neither reject any tectonic model that proposed an allochthonous or paraautochthonous origin for the Precordillera (Cuyania) terrane. A more comprehensive provenance study should be done to strongly support a Laurentian influence, including the identification of the probable different sources and a more strict comparison of their isotope signatures (including Pb isotopes).

ACKNOWLEDGEMENTS

We are grateful to the Centro de Investigaciones Geológicas (La Plata, Argentina), LGI-UFRGS (Porto Alegre, Brazil) and SPECTRAU (University of Johannesburg, South Africa) for the use of their laboratories. P.A. is also grateful to Prof. K. Kawashita

for his helpfulness during isotopes measurements. Financial support was provided by IAS (International Association of Sedimentologists) through an economical support grant gave to P.A. Fieldwork was financed by CONICET and ANPCYT (Argentina) and U.Z. scientific resources.

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RESUMEN

Distintos argumentos dan soporte a los modelos que proponen a la Precordillera (Terrane Cuyania) como un alóctono proveniente de Laurentia. Sin embargo, modelos de paraautoctonía fueron también propuestos, basados en datos bioestratigráficos y estructurales. Con el objetivo de contribuir a la discusión de estos modelos, se presentan aquí datos preliminares de isótopos de Nd de la Formación Yerba Loca (FYL).

La FYL (Precordillera Occidental) esta caracterizada por pelitas, arenitas, vaques, escasos conglomerados e intrusiones de rocas magmáticas básicas. Vaques y arenitas son de grano fino a medio, pobremente seleccionados y compuestos por: cuarzo, feldespato potásico, plagioclasa y líticos sedimentarios, volcánicos y metamórficos. La geoquímica indica la presencia de al menos dos componentes: uno de carácter cortical y el otro menos fraccionado.

Los valores de εNd (t) varían entre -4.8 y -7.3 implicando una fuente cortical dominante. Las edades $T_{DM(2)}$ varían entre 1.56 y 1.74 Ga. Las edades modelo de la FYL son similares o ligeramente más viejas que las edades grenvillianas determinadas para el basamento de la Precordillera y para otras unidades correlacionables.

Debe tenerse en cuenta que los datos Sm-Nd en estos sedimentos son el resultado de la mezcla de diferentes fuentes. La combinación de los datos isotópicos de Nd con los de geoquímica y petrografía indican que hubo al menos dos fuentes aportando detritos, siendo una de tipo corteza continental superior y la otra de carácter menos fraccionado. De acuerdo con el estado de avance del estudio de proveniencia de esta unidad no podemos sostener ni rechazar ninguno de los modelos existentes sobre el origen de la Precordillera.