U/Pb DETRITAL ZIRCON GEOCHRONOLOGY AND Nd ISOTOPES FROM PALEOZOIC META-SEDIMENTARY ROCKS OF THE MARAÑON COMPLEX: INSIGHTS ON THE PROTO-ANDEAN TECTONIC EVOLUTION OF THE EASTERN PERUVIAN ANDES

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INTRODUCTION

Detrital zircon U/Pb geochronology and Sm-Nd whole rock isotopes from sedimentary or meta-sedimentary rocks are valuable tools for stratigraphic, provenance and tectonic analyses (see Fedo et al., 2003, McLennan et al., 1993 for general reviews). They may help to define a general stratigraphic framework, identify source areas and track the continuous evolution of an orogen. In some cases they are the only clue to characterize unexposed or eroded crustal areas.

In contrast with other Andean segments, the understanding of the Proto-Andean tectonic evolution of the Peruvian Andes between 6°-10° lat. S is weak. This is a consequence of the limited basement exposures, the extensive sedimentary cover on the peripheral cratonic area, and the still limited geological studies.

In this contribution, U/Pb LA-ICP-MS measurements on detrital zircon crystals, and whole rock Sm-Nd analyses from selected samples of pre-Triassic metamorphic rocks of the Marañon Complex in the Eastern Peruvian Andes are presented. These data are complemented with a U/Pb SHRIMP zircon analysis of a paragneiss from the same area. They are used in order to understand the main tectonic evolution of the region, track the provenance of the meta-sedimentary units and uncover the hidden geological record of this segment of the proto-Andean margin.

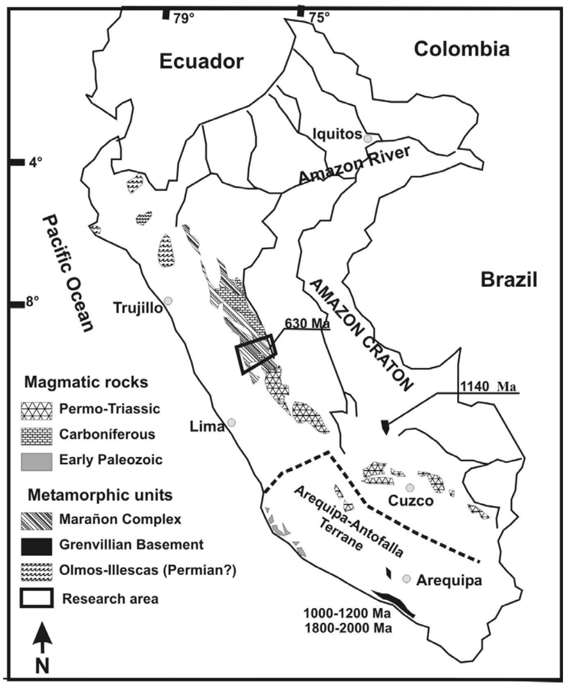

Figure 1. Pre-Mesozoic units of the Peruvian Andes.

GEOLOGICAL SETTING

The Central Peruvian Andes between 6° and 10° S corresponds to one of the current flat slab subduction segments of the Andean Chain. Its geological framework includes a prominent Late Mesozoic volcano-sedimentary and plutonic record that widespread along the Western Cordillera and coastal regions. Sedimentary, plutonic and meta-sedimentary units attributed to Paleozoic or older pre-Andean cycles are confined to the Eastern Cordillera (Figure 1). The sedimentary units include fossiliferous Llanvirian-Arenigian, Mississipian and Late Permian sequences (Dalmaryac et al., 1988, Zapata et al., 2004). Magmatic rocks are mainly of plutonic character, with ages from the Early Carboniferous to Early Triassic (MacFarlane et al., 1999, Cardona et al., 2005).

The metamorphic rocks have been grouped within the Marañon Complex (Wilson and Reyes, 1967), made up of discontinuous belts of intercalated metapelitic and metapsamitic rocks with minor calc-silicate layers and locally extensive metabasitic units. Metamorphism is predominantly on the greenschist facies. The metamorphic character and the apparent local stratigraphic relations with Ordovician rocks have been used to suggest a Pre-Llanvirian age for the entire region of metamorphic rocks. Moreover, a ~630 Ma zircon age from a paragneiss was considered by Dalmaryac et al. (1988) as evidence of a Neoproterozoic orogenic belt in the region.

However, as it will be seen from U/Pb zircon results here presented, the Marañon Complex is clearly composed by different metamorphic units encompassing most of the Paleozoic.

SAMPLES AND ANALYTICAL METHODS

Nineteen whole rock Sm-Nd samples and five U/Pb zircon samples from the Huanuco-La Union regions at 10° S (Figure 2) were analyzed. This area presents the most extensive diversity of the metamorphic units included within the Marañon Complex, and was the focus of an earlier geochronological study by Dalmaryac et al. (1988).

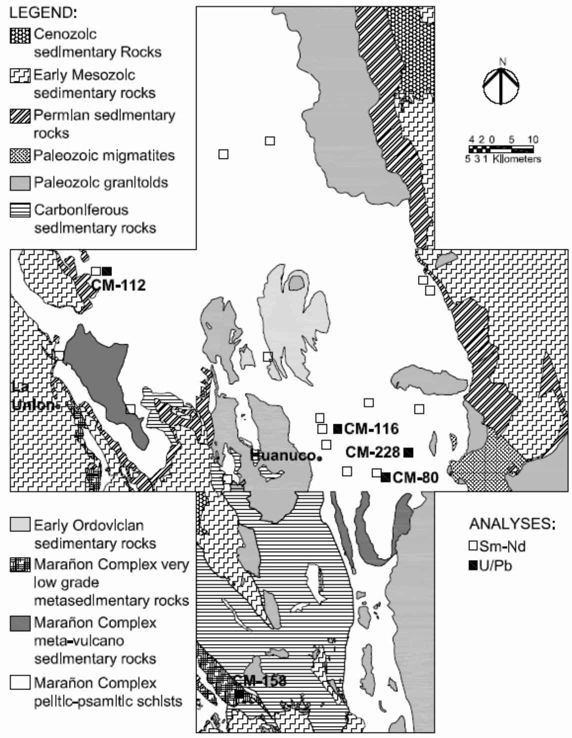

Figure 2. Geological map of the sampled area.

Following standard sample preparation for zircon and whole rock analysis, detrital zircons crystals from four metapsamitic and semi-pelitic schists where analyzed by U/Pb LA-ICP-MS method at the University of Arizona, following the procedure presented by Dickinson and Gehlers (2003). U/Pb SHRIMP results from one sample were obtained at the Australian National University, methods after Williams (1998). The Sm-Nd whole rock samples where analyzed at the Geochronological Research Center of the University of São Paulo, methods after Sato et al. (1995).

RESULTS AND DISCUSSION

A geologic sketch map with the location of analyzed samples is presented in Figure 2. Four hundred eleven detrital zircon analyses were obtained by the U/Pb LA-ICP-MS in samples CM-158, CM-112, CM-228 and CM-116. The results are presented in Figures 3A to 3D.

The youngest detrital zircon ages can be used to constrain temporality for sedimentation and metamorphism. Sample CM-158 (Figure 3a) from the western segment of the study area, shows detrital zircon crystal ages as young as 300 Ma, defining a maximum Late Paleozoic age for the sedimentation. Stratigraphic relations in this area suggest that metamorphism must have taken place before the Permian. Samples CM-112 and CM-228 (Figures 3b and 3c) from the eastern segment define a maximum age of ~480 Ma for sedimentation. Metamorphism on this segment is probably of Late Ordovician-Silurian ages as suggested by Silurian Ar-Ar data from micas and intrusive relations with an undeformed Carboniferous granodiorite still unpublished results. The metamorphic evolution is complicated further when the U/Pb SHRIMP results on sample CM-80 (Figure 4) are taken into account. This sample is from a higher grade inlier, and presents metamorphic overgrowths in zircon crystals with an age of 484 ± 12 Ma, and detrital zircon grains ages in the 530-650 Ma interval, limiting its sedimentary and metamorphic evolution between 530 and 480 Ma.

Taken together, the samples include detrital zircon grains with U/Pb ages between 0.3 to 3.0 Ga (Figures 3a to 3d), with practically continuous interval from 0.3 to 2.0 Ga. The four studied samples present overlapping spectra, with variations related only to the absence in some samples of a specific population. The two more important detrital zircon populations are between 0.47 -0.62 Ga and 1.0-1.4 Ga.

The "Grenvillian-type" Late Mesoproterozoic (1.0-1.4 Ga) ages suggest an extension of the Rondonian-San Ignacio and Sunsas Provinces beneath the Amazon river sedimentary basin. Such ages may also be related to allocthonous to para-autocthonous "Grenvillian" type orogenic inliers that are a common feature along the northern part of the Andean belt (Cordani et al., 2005).

Neoproterozoic to Cambrian sources are not present within Amazonian Craton. Therefore, our results within this age interval, have important tectonic implications due the complexity of the paleogeographic reconstructions and the role of the proto-Andean margin on this period (Murphy et al., 2004). A rifting event that separated Gondwana from Laurentia has been temporally constraint on 570-550 Ma (Cawood et al., 2001) and Neoproterozoic silicic magmatism at 620-550 Ma has been related to this extensional evolution (Tollo et al.,2004). Magmatic rocks of similar age, whose possible location is not available at present, may have provided some of the zircon grains to the basins were these sediment accumulated. An alternative scenario include a fast Laurentia-Baltica departure from Gondwana, followed by the installation of an active Meso-Neoproterozoic continental margin. For example, there are remnants of Neoproterozoic tectono-magmatic activity in the Caparo and Merida terranes of the Venezuelan Andes (Aleman and Ramos, 2000).

The presence of a significant Early Ordovician detrital zircon population in samples CM-158, CM-112, CM-228, and the existence of a gneissic rock with similar metamorphic ages (CM-80) clearly establish that Early Paleozoic tectonic event are relevant for the geologic evolution of this Andean margin. The younger Late Paleozoic detrital ages have direct counterparts in the magmatic rocks of the Central Andes (Cardona et al., 2005).

The analyzed whole rock Sm-Nd samples are from greenschist facies meta-sedimentary rocks. They yield always negative values for $\epsilon_{Nd\,(T)}$, between -7 and -12, calculated for a chosen T= 400 Ma, idicating sources with important crustal residence time.

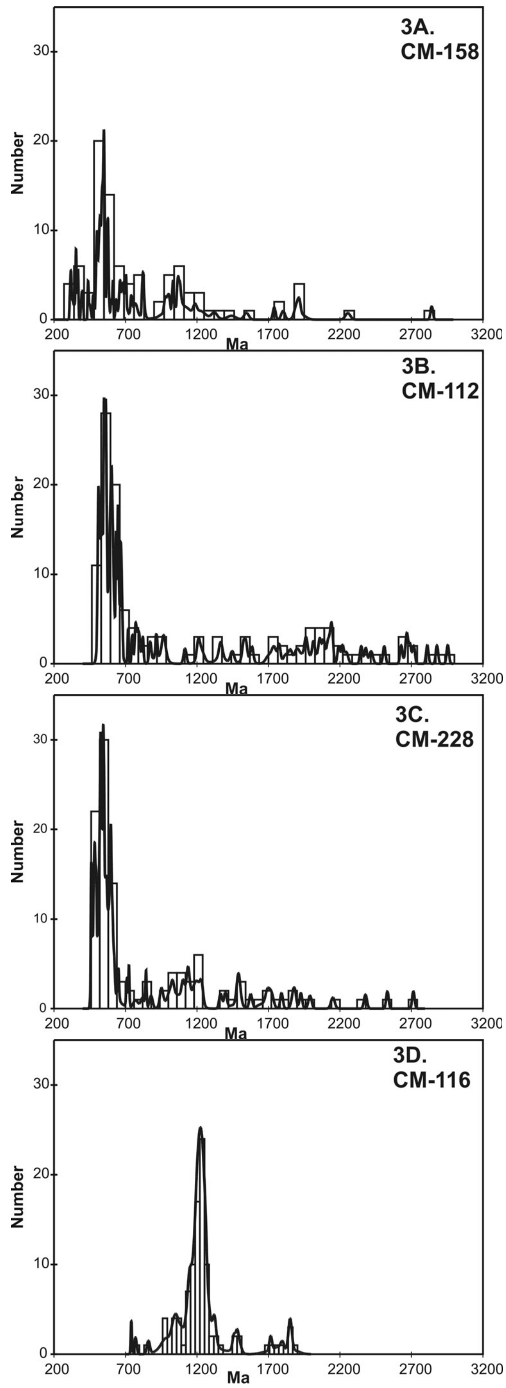

Figure 3. U/Pb age probability plot from the analyzed samples.

Sm-Nd T_{DM} model ages interpreted as average crustal residence time (McLennan et al, 1993), are predominantly Late Mesoproterozoic to Early Paleoproterozoic (1.6-2.1 Ga) with no significant variations between units (Figure 5). In this figure, the T_{Dm} model ages related to granitoid rocks of the Rondonian-San Ignacio and Sunsas provinces of the Amazonian Craton (Tassinari et al., 2000) are included for comparison. The correlation is very strong, suggesting that a feasible source for the meta-sedimentary rocks of the Marañon Complex may be found in the SW part of the Amazonian Craton.

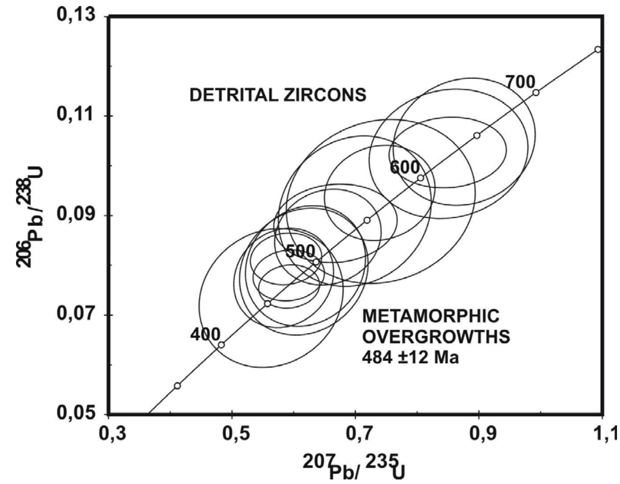

Figure 4. U/Pb SHRIMP ages for sample CM-80.

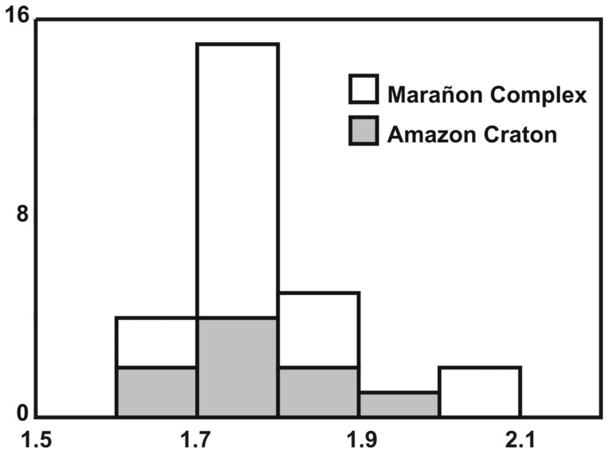

Figure 5. Sm-Nd model T_{DM} ages from the Marañon Complex and the SW Amazonian Craton (Tassinari et al., 2000).

From figures 3A to 3D, is it apparent that most of the Mesoproterozoic detrital zircon grains here representing the ages of magmatic crystallization events within the source area are included in the same 1.6-2.1 Ga age interval, thus strengthening the correlation attempted above wtih the Amazonian Craton.

CONCLUSIONS

1. Geochronological data from the Marañon Complex suggest that it may include at least three tectono-metamorphic sequences, originated in the Early, Middle and Late Paleozoic times.
2. U-Pb detrital zircon data and Nd isotopic results indicate that the Amazonian Craton is the most probable source area. However the Neoproterozoic-Cambrian source is still open to different alternatives.
3. Up to now there are no clear indications of rocks older than the Early Ordovician within the studied area between 6°-10° Lat. S.
4. The presence of successive metamorphic belts formed by reworking of the previously formed sequences characterize a

cannibalistic-type succession of orogenic phases within the Central Andes.

5. From the Paleozoic age of most sedimentary related units, their probable formation within a marine environment, the presence of relevant amounts of organic matter, and the low grade nature of the metamorphic units, we foresee that it may be possible in the future to find important fossil occurrences.

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RESUMEN

La evolución tectónica Proto-Andina de los Andes Peruanos se encuentra registrada en una serie discontinua de unidades metamórficas pre-Triásicas (Complejo Marañon), que se extienden entre los 6°-10° lat. S, a lo largo de la Cordillera Oriental. Con el fin de definir las características generales de su evolución tectónica y su proveniencia, fueron realizados análisis geocronológicos en rocas meta-sedimentarias, utilizando los métodos U/Pb LA-ICP-MS y SHRIMP en cristales de circones detríticos y metamórficos, así como análisis isotópico por el método Sm-Nd de muestras de roca total. Los resultados obtenidos en circones indican la existencia de tres unidades metamórficas formadas durante el Paleozoico Inferior, Medio y Superior. De otro lado, la existencia de circones detríticos con edades entre 1.0-3.0 Ga sugieren que el Craton Amazónico es una de las fuentes principales en la formación de los sedimentos, mientras que la presencia de edades Neoproterozoicas indica la existencia de un marco geodinámico mas complejo para este segmento de la margen. Las edades modelo Sm-Nd T_{DM} se encuentran entre 1.-2.1 Ga, y el $\epsilon_{Nd(T)}$ calculado para el Paleozoico presenta valores negativos entre -7 y -12, que conjuntamente sugieren una correlación con las provincias Rondoniano-San Ignacio y Sunsas del Craton Amazónico, así como la presencia de un retrabajamiento de corteza mas antigua. Estas características geocronológicas indican que la Proto-margen Andina durante el Paleozoico registra una evolución orogénica caracterizada por eventos sucesivos de erosión, sedimentación y metamorfismo que retrabajan el material previamente formado.