U-Pb (LA-ICP-MS) AGES ON DETRITAL ZIRCON GRAINS FROM ANGACOS LIMESTONE SILICICLASTIC LEVELS (CAUCETE GROUP), SAN JUAN PROVINCE, ARGENTINA: PROVENANCE IMPLICATIONS FOR THE CUYANIA TERRANE

Naipauer, M.[1], Cingolani, C.A.[2], McClelland, W.C.[3], Vujovich, G.I.[4] and Ellis, J.R.[3]

1 Laboratorio de Tectónica Andina, Becario Fundación YPF (maxinaipauer@gl.fcen.uba.ar).
2 Centro de Investigaciones Geológicas, UNLP-CONICET.
3 Geological Sciences, University of Idaho.
4 Laboratorio de Tectónica Andina, UBA-CONICET.

Key word: Caucete Group, Cuyania Terrane, U/Pb Geochronology, provenance, detrital zircons.

INTRODUCTION

In this work, we present isotopic results on detrital zircon grains in siliciclastic levels from Angacos Limestone. This unit, together with the El Quemado, La Paz and El Desecho Formations, constitute the Caucete Group (Borrello, 1969; emend. Vujovich, 2003), which occurs on the western side of the Pie de Palo range in northwestern Argentina (Fig. 1). The Pie de Palo Complex is bordered by the Las Pirquitas Thrust and is characterized by Grenville-age basement with medium- to high-grade metamorphic and minor igneous rocks (Vujovich et al., 2004, and references therein). The Pie de Palo range is part of the Cuyania composite terrane (Ramos et al., 1998) and has been recognized as an allochthonous microcontinent derived from Laurentia or as paraautochthonous unit from Gondwana (Finney et al., 2005).

The Angacos Limestone is mainly composed of limestone, calcareous schist, dolostone, and calcitic marble. The metamorphism indicates greenschist facies (Ramos and Vujovich, 2000). Moreover, mylonitic products of the high deformation that affected the entire zone are present. The protolith of these carbonates is interpreted as a succession of limestone and dolostone with minor sandstone interbeds.

The age of the Angacos Limestone is uncertain because of the absence of diagnostic fossils. Isotopic studies of Sr, C and O has led to the correlation with the Early Paleozoic platform limestone sequence from the Precordillera (Linares et al., 1982; Galindo et al., 2004; Naipauer et al., 2005). It is important to note that the El Quemado Formation as a part of the Caucete Group has a maximum depositional age of 550 Ma as defined by detrital zircon data (Naipauer et al., 2005).

The main purpose of this work is to present isotopic data of the detrital zircons separated from siliciclastic levels interlayered within the Angacos Limestone. We compare the obtained results with detrital zircon data from the El Quemado Formation (Naipauer et al., 2005; Ellis, 2005), and discuss some provenance implications in the tectonic terrane.

STUDY AREA AND SAMPLE DESCRIPTION

The Pie de Palo range is located between the Precordillera fold and thrust belt to the west and the Valle Fértil Lineament towards the east. In the southwestern part of the range at the El Gato, La Petaca and La Lichona creeks several thin sandstone beds mainly composed of siliciclastic minerals were found. These beds do not have more than one meter of thickness and are always intercalated between the limestone sequence. We have selected the sample (GPS: 31°29’44’’S-68°14’30’’W) from La Lichona creek for heavy minerals separation (Fig. 1). It presents quartz grains as the main mineral phase with minor grains of feldspars.

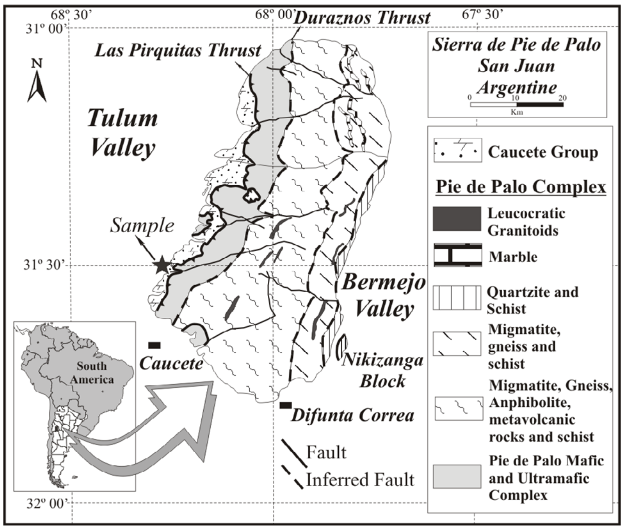

Figure 1.Geological map of the Pie de Palo range (modified from Ellis, 2005).

Under optical microscopy, the studied sample comprises more than 85 vol% of quartz the grains of which are stretched due to the intense deformation and mylonitic recrystallization. The quartz texture is characterized by fine to very fine grains. Many crystals of plagioclase can also be distinguished with their size three times bigger than that of the quartz, and several albite. Carbonate is subordinate, appearing in secondary veins or between the quartz grains. Opaque minerals are concentrated in some thin layers.

ANALYTICAL TECHNIQUES

Heavy mineral fractions were concentrated from 4 to 5 kg samples and separated into 100, 150 and 250 μm size fractions by standard crushing and heavy liquid techniques. Then they were concentrated by magnetic susceptibility using Frantz isodynamic magnetic separators at the Centro de Investigaciones Geológicas laboratory of the Universidad Nacional de La Plata (UNLP). Finally detrital zircon fractions were handpicked in alcohol under a binocular microscope. A random selection of roughly 200 grains was mounted in epoxy along with known standards and then polished to expose grain centers.

The U/Pb data was obtained by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) using a New Wave UP-213 (213nm, Nd:YAG) laser system coupled to a ThermoFinnigan Element 2 ICP-MS instrument housed at Washington State University (USA). The laser operated with a fluence of 10-11 J/cm^2 and a frequency of 10Hz, with a 30μm diameter ablation spot. Signals were collected for 36 seconds in 300 sweeps with a counting efficiency of 86% per analysis. Blanks were measured before each analysis for blank correction. Standards with ages of 564 Ma ("Peixe"; Gehrels, unpublished data) and 1099 Ma ("FC1"; Paces and Miller, 1993) were analyzed after 5 to 10 unknown minerals to correct for mass bias and fractionation of U and Pb. Laser induced time dependent elemental fractionation, was corrected using the regression line method (Sylvester and Ghaderi, 1997; Horn et al., 2000; Kosler et al., 2002). Data reduction was completed with an in-house program at Washington State University (Chang et al., 2006). Plotting of cumulative probability plots used the program of Ludwig (1999).

RESULTS

DETRITAL ZIRCON POPULATION ANALYSIS

The zircons separated from the sample were morphologically analyzed under the stereomicroscope and the electronic microscope, and cathodoluminescense (CL) images were obtained to study the internal structure and guide the LA-ICP-MS analysis. In accordance with the zircon morphology and internal structure we grouped the zircon grains into three different populations:

The first group is represented by relatively small zircons, approximately 60μm in width and 110μm in length, with prismatic to rounded forms and the elongation is less than 2. Many grains are totally rounded, a fact that points to multiple sedimentation cycles or long periods of deposition (Fig. 2a).

The CL images show different types of textures in the crystals. Several grains have low luminescence (Fig. 3a), complex and diffuse zoning (Figs., 3b, c), probably originating from metamorphism. Some zircon grains display oscillatory zoning indicating a magmatic origin. (Figs., 3d, e).

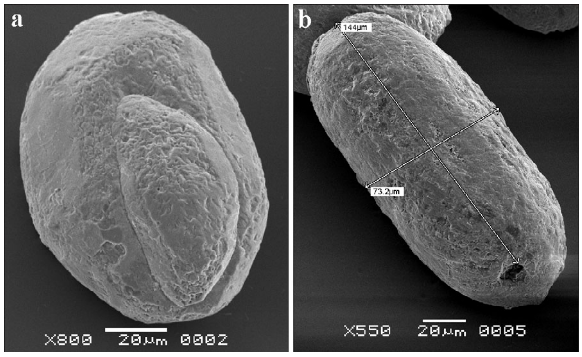

Figure 2. Scanning electrone microscope images showing the external morphology; (a) composite, resorbed zircon; and (b) prismatic zircon with rounded form.

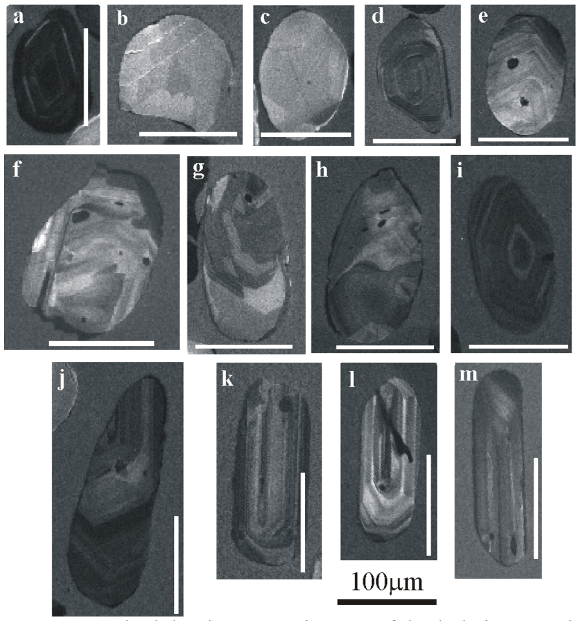

Figure 3. Cathodoluminescence images of detrital zircon grains from the sample analyzed by U/Pb (LA-ICP-MS). Dark crystal (a), rounded crystals with irregular and diffuse zoning (b, c) and grains with oscillatory zoning (d, e) (population 1). Zircon grains with complex zoning, patchy textures and metamorphic rim (f, g, h), prismatic zircons with oscillatory zoning (i, j) (population 2). Large prismatic zircons with oscillatory zoning and inclusions (k, l, m) (population 3).

Group II zircon grains are more abundant and heterogeneous, comprising large prismatic grains between 100μm and 250μm in length. In the CL analysis the oscillatory zoning predominates and there are many grains with complex and patchy zoning, which probably originated from medium to high-grade metamorphic conditions (Figs., 3f, g, h, i, j). We observed dark zircon (low luminescence).

Group III zircon grains is separated because they have a prismatic habit, subidiomorphic to rounded form and elongation of more than 3. The size is 60µm in breadth by 200µm in length approximately (Fig. 2b). Their internal structure is characterized by oscillatory zoning with inclusions typical of igneous grains (Figs., 3k, l, m).

U/Pb AGES IN DETRITAL ZIRCONS

A total of 142 analyses were obtained from the U/Pb methodology (LA-ICP-MS) on detrital zircons of the QLli 1 sample; 33 analyses were excluded because they gave discordant ages (more than 20%) or because of the presence of cores, recrystallization rim and/or inclusions that affect the age. The 109 ages selected can be grouped in 2 populations of principal ages:

The most important group comprises ages between 1471 to 1313 Ma (maximum peak ca. 1373 Ma; 58%). It is composed mainly of the zircons from population 2 and 3 (Fig. 4).

The younger group includes ages between 1148 to 1050 Ma (peak ca. 1114 Ma; 35%). The Group I, described above, has the same ages of this interval (Fig. 4).

There are also few grains that yielded ages in the range between 1149 and 1312 Ma (7%) and one zircon grain of Paleoproterozoic (1778 Ma) age (Fig. 4).

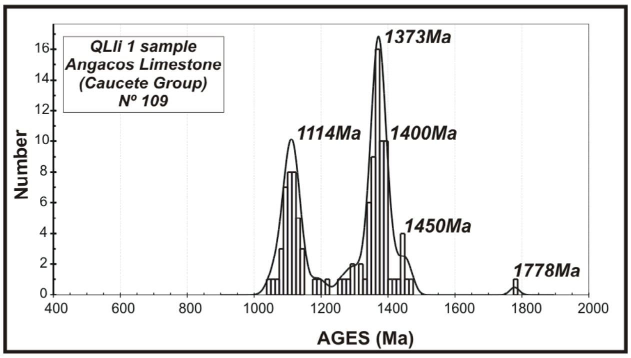

Figure 4. Relative age probability curve plot of $^{207}Pb/^{206}Pb$ ages on detrital zircons in a siliciclastic level from Angacos Limestone (Caucete Group).

DISCUSSION AND INTERPRETATION

The pattern of ages of the detrital zircons found in siliciclastic levels in the Angacos Limestone (ca. 1.45, 1.40, 1.37 and 1.11 Ga) are comparable to those which appear in the El Quemado Formation, i.e. ca. 1400, 1360, 1220, 1115 and 1070 Ma (Naipauer et al., 2005; Ellis, 2005).

It is also similar to the age distribution in detrital zircon grains from the ca. 1400 Ma and 1050-1150 Ma Difunta Correa unit (Rapela et al., 2005).

We highlight that in all of these metasedimentary rocks there appears an important zircon source area with ages between 1350 and 1450 Ma mainly with zircon grains of igneous and metamorphic origin. The other source is characterized by typically Grenvillian ages and metamorphic zircon grains. Besides, there are Neoproterozoic-Cambrian age zircons, which are not abundant or which are absent as in the studied sample.

This pattern of ages is observed only in units located in the center west of the Pie de Palo range, in the units from the Caucete Group and Difunta Correa. Contrary to this, in the east flank of the sierra, in the Nikizanga block and in Loma de las Chacras, the prominence of the metasedimentary rocks indicates a mainly Neoproterozoic-Cambrian pattern (ca. 530-650 Ma; McClelland et al., 2005).

In the Sierras Pampeanas Orientales (Escayola et al., 2005) it has been observed that Neoproterozoic detrital zircons age are found to the extreme east, decreasing in proportion to the west, where the Grenvillian sources increase (950-1050 Ma; Schwartz and Gromet, 2003).

On the other hand, in the Precordillera, the units of the Middle Cambrian present an age distribution of about 1.39, 1.45 and 1.51 Ga (Finney et al., 2005).

As we can see in this preliminary study, the detrital provenance in the Angacos Limestone (Caucete Group) shows that there is an important Grenvillian source linked to the basement of Cuyania (Pie de Palo Complex). The other group of ages found around the 1370 Ma is more difficult to interpret because the absence of these ages in the area of the Sierras Pampeanas (Rapela et al., 2005). But if we consider the Caucete Group as a part of the Precordillera-Cuyania terrane derived from Southeastern of Laurentia, these zircons might link with a provenance from the Granite-Rhyolite province (Thomas et al., 2004; Naipauer et al., 2005).

ACKNOWLEDGMENTS

Field and laboratory works were partially supported by CONICET and ANPCYT-PICT 07-10829. Analyses were partially funded by U.S. National Science Foundation grant EAR 0126299 awarded to W. McClelland. We are grateful to the anonymous referees and editors whose reviews improved the paper. This is a contribution to IGCP 478 "Neoproterozoic-Early Paleozoic Events in SW-Gondwana".

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RESUMEN

Se presentan análisis isotópicos sobre circones detríticos separados de un nivel silicoclástico intercalado en la Caliza Angacos. Esta unidad forma parte del Grupo Caucete que aflora en el borde occidental de la sierra de Pie de Palo, provincia de San Juan, y es integrando en el denominado terreno Precordillera-Cuyania, ubicado en el centro oeste de Argentina. Los grupos de edades U/Pb obtenidas con la metodología LA-ICP-MS presentaron picos de mayor frecuencia a: 1.45, 1.40, 1.37 y 1.11 Ga, resultando comparables con los que se registran en la Cuarcita El Quemado (Grupo Caucete) y la unidad metasedimentaria Difunta Correa. Con estos datos isotópicos se interpreta que la procedencia de la Caliza Angacos esta caracterizada por una fuente con edades grenvillianas (1.11 Ga) similares a las del basamento de Cuyania (Complejo Pie de Palo). Por otra parte la procedencia del grupo de edades de 1.45 a 1.37 Ga es más difícil de explicar por la ausencia o escasez de estas en el ámbito de las Sierras Pampeanas. Pero si consideramos que el Grupo Caucete es parte del terreno alóctono de Precordillera-Cuyania derivado del sudeste lauréntico, estos circones detríticos podrían tener una procedencia desde la provincia Granite-Rhyolite.