U-Pb DETRITAL ZIRCON DATA FROM THE PALEOZOIC SIERRA GRANDE FORMATION, NORTH PATAGONIAN MASSIF, ARGENTINA

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ABSTRACT

The Sierra Grande Formation is a siliciclastic sedimentary unit with oolithic iron levels of economical importance which crops out in the Argentinean North Patagonian Massif. It was deposited within an open marine environment, with littoral to sub-littoral conditions. A Silurian-Lower Devonian age is assigned based on fossil content. It is mainly composed of medium to fine quartz arenites, wackes, silts, shales and conglomerate beds. In order to establish the source rocks for the Silurian-Devonian basin and also to constrain the sedimentation age, different U-Pb geochronological studies have been carried out on detrital zircons. The zircons have been studied with comparative morphology analysis using SEM images to asses the different population types. For dating using U-Pb isotopes in zircon detrital grains, the high resolution SHRIMP and LA-ICP-MS methodologies were used. The predominant obtained age groups are: Neoproterozoic (547–991 Ma), Cambrian (497-546 Ma) and Ordovician (443-495 Ma). All the analyzed samples also comprise Mesoproterozoic ages of about 1009 to 1382 Ma and smaller proportion Paleoproterozic (1641 to 2248 Ma) and Neo-Archean (2649-2657 Ma) ages. It is important to note that Silurian ages (428 and 440 Ma) were obtained from a group of zircon crystals, constraining the sedimentation age of the Sierra Grande basin to be not older than Middle Silurian. With these isotopic data it is possible to discuss the provenance of the Silurian-Devonian siliciclastic sedimentary cover of the North Patagonian Massif.

INTRODUCTION

The Sierra Grande Formation (Müller, 1965) is a siliciclastic sedimentary unit with oolithic iron levels of economical importance (Zanettini, 1981 and references therein). This unit shows different exposures in the eastern sector of the Argentinean North Patagonian Massif, being the most representative, the one located close to the town of Sierra Grande in the Río Negro Province (Fig. 1). The southernmost exposures of this unit are located close to the Gastre Town, to the northeast of the Chubut Province. During the last decades, several contributions were published on the fields of tectonic and paleogeography (Ramos, 1984; 1988; Dalla Salda *et al.* 1992), gravimetry (Kostadinoff and Gelós, 1994), paleomagnetism (Rapalini, 1998), sedimentology (Spalletti *et al*. 1991; Spalletti, 1993), petrology and geochronology of basement, sedimentary rocks and intrusive bodies of the North Patagonian Massif (Varela *et al*., 1991; 1997). Detailed structural analysis carried out by Japas (2001) and especially zircon data on Sierra Grande Formation among others by Pankhurst *et al.* (2006) promoted deeper understanding of the geological processes that have taken place in the region.

The aim of this contribution is to present new U-Pb detrital zircon ages, in order to constraint the sedimentation age of the Sierra Grande sequence and also to get more information regarding the probable source areas that contributed to the basin during the Silurian and Lower Devonian. The data here presented are part of N. Uriz PhD thesis carried out at the Faculty of Natural Sciences, University of La Plata, Argentina.

GEOLOGICAL FRAMEWORK

The pre-Silurian basement in this sector of the North Patagonian Massif is characterized by several igneous and metamorphic rocks (Giacosa, 1999; Pankhurst *et al.* 2006). The marine siliciclastic sedimentary rocks of the Sierra Grande Formation crops over an erosive unconformity following a patchy trend. It is mainly composed of medium to fine quartz arenites, wackes, silts, shales and conglomerate beds with iron beds. This unit is approximately 2130m thick based on drilling data (Zanettini, 1981).

The Sierra Grande Formation was deposited within an open marine environment, with littoral to sub-littoral conditions (de Alba, 1964; Müller, 1965; Nuñez *et al.,* 1975; Cortés, 1981), in wave and storm shallow marine platform areas (Spalletti *et al*., 1991). A Silurian-Lower Devonian age is assigned based on fossil content (Manceñido and Damborenea, 1984 and references therein). It is important to mention that the first work on heavy minerals from Sierra Grande Formation was presented by Huber-Grünberg (1990).

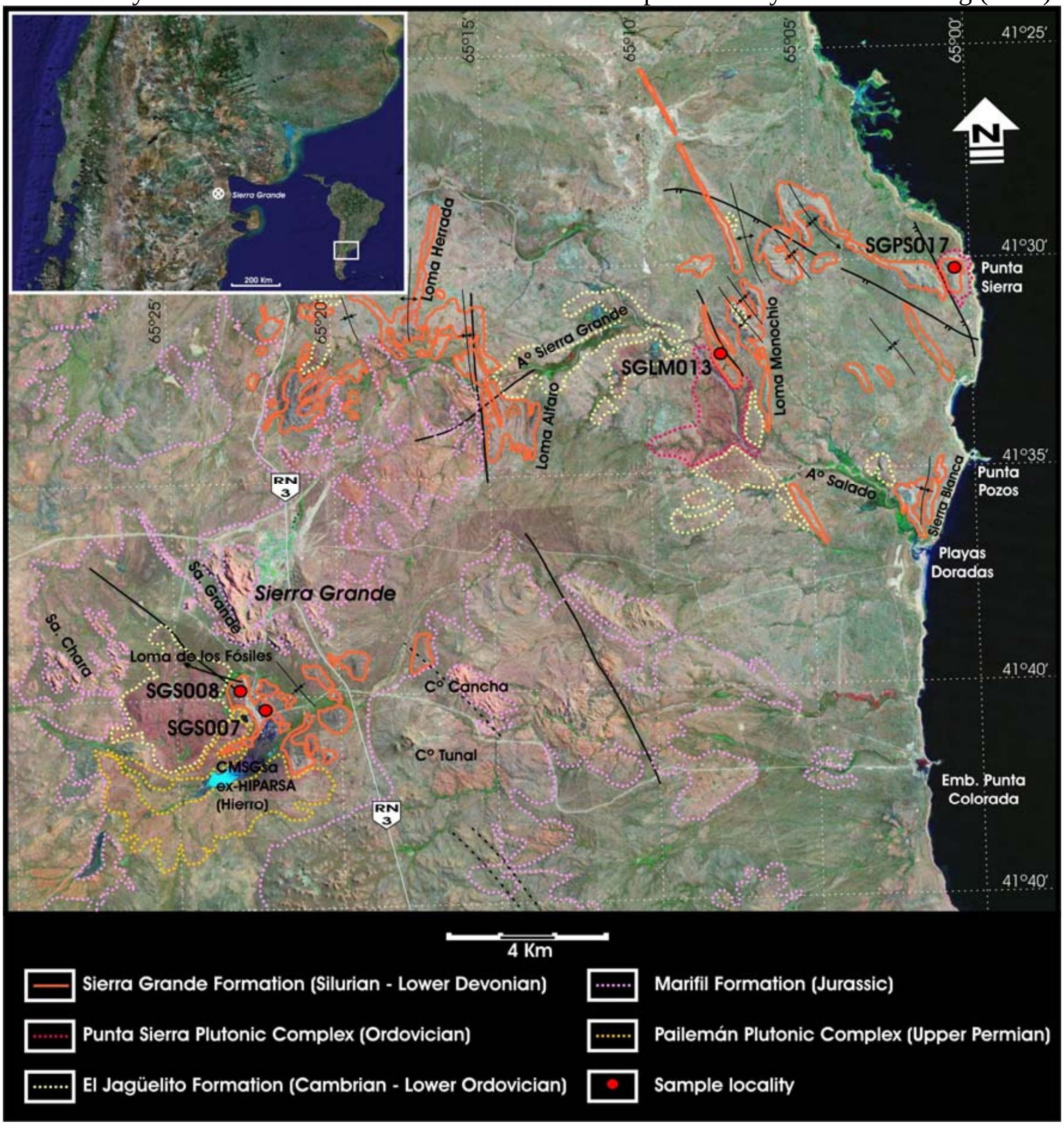

Figure 1: Regional geological sketch map and sampling localities of the Sierra Grande Formation.

METHODOLOGY

New U-Pb geochronological studies had been carried out on detrital zircons of the Sierra Grande Fm. The sample localities are shown in Figure 1. The obtained detrital zircons had been studied with comparative morphology analysis using SEM (scanning electron microscope) to asses the different populations and types. The isotopic ages were obtained by U-Pb LA-ICP-MS (Laboratorio de Geología Isotópica, UFRGS, Porto Alegre, Brazil) and SHRIMP (Research School of Earth Sciences, The Australian National University, Canberra, Australia) methods.

MORPHOLOGY OF ZIRCONS

To understand the probable source areas of the Silurian-Devonian siliciclastic rocks of the Sierra Grande Formation, new morphological studies on zircon typology were carried out (Huber-Grünberg, 1990). They show that it is possible to discriminate four different groups of populations (A, B, C and D) following the scheme of Pupin (1980):

Group A. It comprises the euhedral to subhedral prismatic and elongated zircons, typical from both volcanic and plutonic sources. Rounded to subrounded subhedral morphologies are the most common and suggest transport before deposition, but still keeping the characteristic long prismatic morphology. These crystals show different degree of internal zonation, related to diverse growing phases, allowing the grouping of them. They show crystal elongation ratios between 2.4 and 4.28, with sizes ranging from 115µm long and 46µm wide, to a maximum of 333µm long and 73µm wide. These types belong to the subgroup of Pupin (1980) known as: P2, P3, P4, P5, R2, R3 and R4 (Figure 2-A).

Group B. Short prismatic crystals, poly-faceted, a few of them have preserved the euhedral morphology. The predominant morphology is the subhedral, with different roundness. The complex zonation patterns and crystalline structures are related to metamorphic sources. They show crystal elongation ratios between 1.8 and 2.7 with an average long/wide ratio of 2.2. The crystal size ranges from 107µm long and 53µm wide, to a maximum of 242µm long and 102µm wide. These types belong to the subgroup of Pupin (1980) known as: S2, S7, S12, S18 and S19 (Figure 2-B).

Group C. It comprises the equidimensional crystals (short prisms), poly-faceted, showing different degree of roundness, within the age range of the Middle Precambrian. They suggest a metamorphic source rock which has been providing the basin with these materials with their characteristically morphologies (Figure 2-C).

Group D. Comprises rounded and equidimensional zircons. Although some of them show internal zonation they can not be discriminated based on their morphologies. They have an age range from the Neo-Archean to the Neoproterozoic (Figure 2-D). In some of the crystals the old cores show overgrowing that suggests that they have suffered other events before their final deposition. On the other hand it is clear the relationship between the degree of roundness and the age, since the more rounded zircon crystals are the Neo-Archean to Neoproterozoic ones, whereas towards younger ages the crystals are sub-rounded.

RESULTS

For age dating using U-Pb method on zircon detrital grains, the high resolution SHRIMP methodology was used for samples SGS008 and SGLM013, whereas the LA-ICP-MS for samples SGS007, SGLM013 and SGPS017 (Figure 2). The results show a striking similarity regarding the ages obtained using both age-dating methodologies, underlying the importance of the Neoproterozoic materials dated between 547 and 991 Ma.

The age groups are: Neoproterozoic (547–991 Ma), Cambrian between 497 and 546 Ma and Ordovician between 443 and 495 Ma. In a restricted aspect, but present in all the analyzed samples, we register Mesoproterozoic ages close to 1009 to 1382 Ma and in a smaller fashion Paleoproterozic ages (1641 to 2248 Ma) and Neo-Archean (2649 to 2657 Ma).

It is important to stress the fact that we have got two Silurian ages (428 and 440 Ma) from a group of zircon crystals, constraining the sedimentation age of the Sierra Grande basin to a maximum the Middle Silurian.

The Cambrian ages can be subdivided into two groups, one with ages from 521 to 546 Ma and another one with ages ranging from 501 to 520 Ma (Lower and Middle Cambrian respectively). The Ordovician ages are concentrated in two main ranges, one between 475 and 495 Ma, and the other one between 462 and 472 Ma (Lower and Middle Ordovician respectively).

The Neoproterozoic age is the most representative element of the analyzed samples. The ages show dispersion, comprising Early, Middle and Late Neoproterozoic zircons. A similar trend is displayed for the Mesoproterozoic zircon ages. The recorded ages are coherent for all the samples, since almost all of them show a Late Mesoproterozoic age. The Paleoproterozoic and Neo-Archean ages, although sparse, are present in most of the samples.

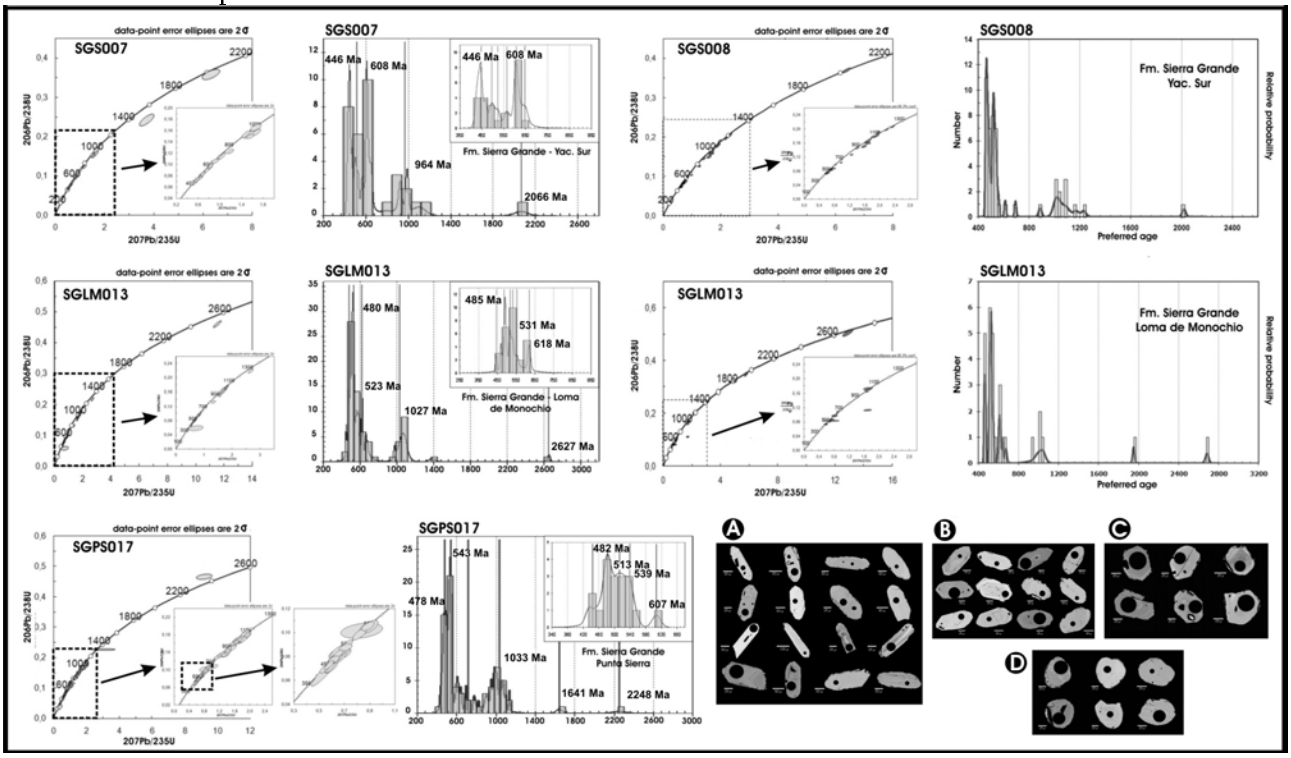

Figure 2: U-Pb concordia diagrams and age histograms from the analyzed samples. A, B, C and D: SEM images of the study zircon populations.

DISCUSSION AND CONCLUSIONS

Using the U-Pb isotopic data on detrital zircons and the respective morphological studies, it is possible to discuss the provenance of the siliciclastic sedimentary rocks of the Silurian-Devonian basin from the north eastern sector of the Argentinean North Patagonian Massif and also to adjust the sedimentation age according to the following scheme:

1-The data reveal a strong influence of Mesoproterozoic-Neoproterozoic, Cambrian and Ordovician sources.

2-These ages can be mainly related to the igneous-metamorphic basement of the North Patagonian Massif, outcropping from the pre-Andean sector towards the Atlantic Ocean (Pankhurst e*t al.* 2006). In this basement different lithologies and metamorphic degrees had been recognized, with ages that go from the Late Proterozoic to the Early Paleozoic. These data are coherent with the present contribution. Within the igneous-metamorphic basement the Mina Gonzalito Complex can be mentioned (Caminos and Llambías, 1984; Giacosa, 1987; Linares *et al*., 1990; Caminos *et al*., 1994; Varela *et al*., 1998); the Yaminué Complex (Caminos, 1983; Varela *et al*., 2001; Basei *et al*., 2002; Llambías *et al*., 2002); the Las Piedras Metamorficas Complex (Tickyj *et al*., 2002), among others, that together are potential source areas for the analysed material.

Locally, the Cambrian-Ordovician ages are represented by the low metamorphic rocks of the El Jaguelito and equivalent units in the area such as the Nahuel Niyeu Formation at the Valcheta region (Caminos and Llambías, 1984; Giacosa, 1987; 1994; 1999; Chernicoff and Caminos, 1996 a, b). Regarding the plutonic intrusive rocks the Punta Sierra Complex can be mentioned, which comprises the Punta Sierra Granite and the Arroyo Salado Granodiorite, with ages of 476±4 Ma (Varela *et al.*, 1998) to 475±6 Ma (Pankhurst *et al*., 2006).

3- The zircon grains that show plutonic morphologies, with ages ranging from the Late Neoproterozoic to Early Cambrian can be related to those intrusive rocks that preceded the collisional event of the Pampia Terrane (Rapela *et al*., 1998). On the other hand, there are A-type granite rocks close to the fold and thrust belt of Sierra de la Ventana, that have been linked to the final plutonic event that took place during the postorogenic collisional event (Gregori *et al*., 2005). This ended with the rhyolites of La Ermita (509±5.3 Ma), related to the postcollisional tensional event in this sector of Gondwana (Pankhurst *et al*., 2006). Within the Chadileuvú Block equivalent units to the North Patagonian Massif basement rocks are present (Tickyj *et al*., 1999a) which can also be interpreted as a source area of detritus.

4-The highest ages of the detrital zircons are Paleoproterozoic and Neo-Archean, that although rare they suggest recycling from old cratons (Río de la Plata, Kalahari?) with a restricted input to the basin.

5-It is important to underline that the Silurian ages (428 – 440 Ma) from two zircon samples allowed us to establish a maximum sedimentation age between the Lower and Middle Silurian for the Sierra Grande Basin.

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