



**U-Pb and Sm-Nd geochronology from Yarituses suite and San Ramón granite, SW Amazonian craton: implications for the crustal evolution of the Eastern Precambrian shield of Bolivia**

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## INTRODUCTION

Three dominant periods of granitic magmatism mark the evolution of the Paraguá terrane (Bettencourt et al., 2010), as supported by field geology, petrology and U-Pb (SHRIMP, TIMS and laser ablation-ICP-MS) and Sm-Nd results: the Yarituses suite, the San Ramón granite and the San Ignacio granites. The new U-Pb zircon ages document crust formation events during the time interval of 1673 Ma to 1621 Ma. Our data show that these granitoid rocks are not only the granitic sills, as reported by Boger et al. (2005) for the so-called Lomas Maneches suite, instead they represent several, large contemporary plutons, in the San Javier and San Ramón areas such as the La Cruz, Refugio and San Pablo granites. This fact allows us to propose the Yarituses suite for such a widespread plutonic event over the Paraguá Craton. Meanwhile, we maintain the Lomas Manechis Granulite Complex (Litherland et al., 1986) as the oldest chrono-stratigraphic unit of the Bolivian Precambrian shield, as supported by the  $1818 \pm 13$  Ma SHRIMP zircon age of granulite gneiss in the Las Rengas area, to the eastern of San Ignacio town (Santos et al., 2008). The other basement units of the Paraguá terrane are the Chiquitania Complex and San Ignacio Schist Group, as supported by radiometric data in the range between 1690 and 1830 (Boger et al., 2005; Santos et al., 2008). This paper reports and integrates SHRIMP, TIMS U-Pb and Laser Ablation zircon ages for the Yarituses suite and the San Ramón granite coupled with new Sm-Nd  $T_{DM}$  ages. The data show that two granitic pulses, preceded the 1.37-1.34 Ga San Ignacio orogeny (Pensamiento Granitoid Complex), developed in an Andean-type magmatic arc.

The La Cruz granite crops out 15 km northeast from San Ramón, and constitutes two individual bodies hosted by the San Ignacio Schist Group. It shows clear contacts with the hosted San Ignacio Schist Group and presents a roughly sigmoidal-shape showing the typical deformation trend related to the 1.1-1.0 Ga Sunsás orogeny. This body (sample 558) is a pale pink leucocratic syenogranite with K-feldspar (perthite) and scarce biotite as the mafic mineral. The dominant texture is allotriomorphic granular. The Refugio granite is a large body that crops out along the road San Javier – Concepción. We have sampled this granite in two places: sample RF408 and SR83. The first one was collected 17 km eastern of San Javier, along the road to Concepción. The rock is a weakly foliated syenogranite, with hipidiomorphic-granular texture; the alkali feldspar is subhedral, the plagioclase tends to be euhedral and the quartz occupies irregular intergranular interspaces. The mafic mineral is green biotite seldom chloritized. SR83 was sampled 8 km eastern of San Javier on the road to Talcoso hill. This is a white, massive to weakly





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foliated leucogranite. The K-feldspar is the microcline and orthoclase is subordinate. Plagioclase tends to be euhedral. The mafic mineral is biotite (<2%); the principal accessory mineral is brown granular sphene. Santos et al. (2008) reported SHRIMP U-Pb zircon, monazite and titanite ages from the Refugio granite, which has zircons with no metamorphic rim, and yields a  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1641 \pm 4$  Ma and  $T_{\text{DM}}$  age of 1.66 Ga ( $\varepsilon_{\text{Nd}(t)} = +4.06$ ). Finally the San Pablo granite, exposed 25 km southern of San Antonio de Lomerío, comprises an oriented batholith (11 km long by 4 km wide). The rock is a pink, fine to medium-grained biotite-quartz-monzonite with an anhedral-granular texture. The plagioclase shows curved twins and quartz is anhedral, occupying irregular intergranular spaces. Biotite is the mafic mineral, straw to green in color.

The San Ramón granite represents a distinct igneous episode dated at  $1429 \pm 4$  Ma (Santos et al., 2008) which invaded the metamorphic basement (Paraguá terrane), and still to be confirmed in the near future as an important rock generation event associated to others plutons in the area. The San Ramón granite is an intrusive body of ca. 35 km<sup>2</sup> that hosts NNW shear zones, and probably extends farther west, but the contact relationships with the Chiquitania Gneiss Complex are largely hidden by Cenozoic sediments. The representative sample SR0401 is a gray, biotite granodiorite which has anhedral granular texture. Aggregates of mafic minerals show an irregular distribution. The main accessory minerals are: titanite, allanite and zircon. This pluton yields similar SHRIMP U/Pb zircon and titanite ages of  $1429 \pm 4$  Ma (Santos et al., 2008). One coeval body has been recently reported on the Paragua terrane, close to the Brazilian-Bolivian boundary; zircons from the Cascata granite yields a  $^{207}\text{Pb}/^{206}\text{Pb}$  zircon evaporation age of  $1412 \pm 5$  Ma (Cabrera et al., 2009). On the other hand, J. O. Santos (oral comm., 2009) obtained Hf isotope analysis from the San Ramón granite yielding a  $T_{\text{DM}}$  model age of 1.7 Ga and a  $\varepsilon_{\text{Hf}}$  between +3.5 and +5.5. As such this suggests a juvenile accretion event of mainly Mesoproterozoic mantle source in Bolivia, as similar as recognized in the Brazilian counterpart, such as the Santa Helena and Rio Branco suites (Geraldes et al., 2001; Cordani and Teixeira, 2007; Bettencourt et al., 2010).

## RESULTS AND DISCUSSION

Zircons from the La Cruz granite are between 100-220  $\mu\text{m}$  long and generally have elongation ratios close to 2:1. The U content of zircon is variable from 138 to 932 ppm, only one grain (4.1) contains 1413 ppm. The Th/U ratios vary between 0.27 and 0.92, denoting magmatic origin. The cathodoluminescent images show that most of the crystals are euhedral and have both parallel-zoning faces and distinct oscillatory zoning. SHRIMP analysis were carried out on eight zircon spots; five cores lie on the Concordia, three are discordant and using all result with a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1673 \pm 21$  Ma (MSWD=0.67), considered as the crystallization age (Fig 1). This age compares, within error, with two ages obtained by Boger et al. (2005) and Santos et al. (2008) for the Lomas Manechis suite, ranging from 1689 to 1663 Ma.

Zircons from Refugio granite (sample SR83) mostly occur as colourless elongated prisms; light brown stubby grains are also present. Cores and oscillatory zoning were observed in a number of zircon grains by transmitted-light microscopy. U-Pb TIMS analyses among four multigrain zircon fractions yield three concordant points with a  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1673 \pm 25$  Ma (MSWD=36), taken as the best estimate for the time of crystallization of the pluton.

Zircons from the San Pablo quartz-monzonite (SP601) appear to be colorless, transparent, with well crystallized prismatic form. Oscillatory zoning, observed in CL images, indicates their magmatic origin of the zircons, as also suggested by Th/U ratios from 0.17 to 0.54. From the eighth analyses an upper intercept  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1621 \pm 80$  Ma (MSWD= 134 was obtained ( $2\sigma$ ).





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These La Cruz, Refúgio and San Pablo granites (Yarituses suite) show  $f_{\text{Sm/Nd}}$  ratios from -0.38 to -0.56,  $T_{\text{DM}}$  model ages of 1.7 - 1.9 Ga, and calculated  $\epsilon_{\text{Nd}}(t)$  values from +0.2 to +4.0. This suggests a significant contribution of a juvenile component in the petrogenetic process.

The 1.42 Ga San Ramón granite represents juvenile material accreted to the the metamorphic basement (Paraguá terrane) as is suggested by the  $\epsilon_{\text{Hf}}$  between +3.5 and +5.5 and the  $T_{\text{DM}}$  model age of 1.7 Ga. This pluton is coeval with the Cascata granite of 1.41 Ga (Cabrera et al., 2009) and the Santa Helena and Rio Branco suites (Geraldes et al., 2001).

## CONCLUSIONS

The Lomas Manechis complex, Chiquitania complex and San Ignacio Schist Group constitute the Paleoproterozoic polymetamorphic basement formed during the 1.82-1.69 Ga time interval. U-Pb SHRIMP zircon and Sm-Nd isotopic data have identified three dominant periods of granitic magmatism in the Precambrian framework. These are the Yarituses suite, The San Ramón granite and the San Ignacio granites. The Yarituses suite represents a juvenile accretion event during the time interval 1.67 - 1.62 Ga. Figueiredo et al. (2009) reported a coeval pluton in the Mato Grosso state (Turvo orthogneiss) which yields a 207Pb-206Pb zircon age of  $1651 \pm 4$  Ma, indicating a more regional scale for such event. U-Pb zircon data from the San Ramón granite yield 207Pb/206Pb age of 1.43 Ga,  $T_{\text{DM}}$  model ages of 1.6-1.7 and positive  $\epsilon_{\text{Nd}}$  values. This granite is time correlated to the Santa Helena orogeny (1.48-1.42 Ga) and the Cascata granite (1.41 Ga).

The San Ignacio orogenic plutonism named the Pensamiento Granitoid Complex comprises syn- to late- to post-tectonic plutons that took place between 1370 and 1320 Ma, as constrained by the SHRIMP U/Pb ages and a  $T_{\text{DM}}$  ages of 2.04 - 1.87 Ga and 1.74 - 1.58 Ga respectively. The syn-tectonic plutons have Nd signatures consistent with derivation from mixing of juvenile material with older crust, possibly within a continental margin setting; conversely, the late- to post-tectonic granitic pulses were largely originated in an intra-oceanic arc setting (Matos et al, 2009). This multiple tectonic and magmatic evolution of the Paragua terrane is comparable to the events in the RNJP and the RSIP of the SW Amazonian craton.

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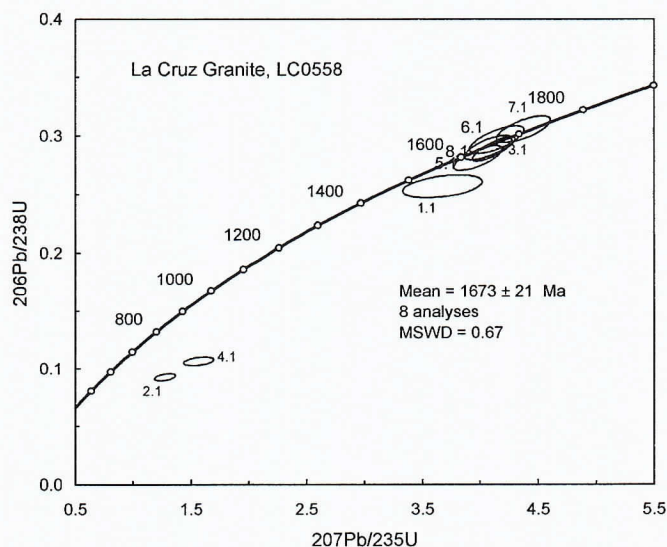


Figure 1. SHRIMP zircon U-Pb concordia diagram of the sample LC0558, La Cruz granite.