GEOLOGICAL NOTE

Early Cambrian U-Pb zircon age and Hf-isotope data from the Guasayán pluton, Sierras Pampeanas, Argentina: implications for the northwestern boundary of the Pampean arc

*Juan A. Dahlquist1, Sebastián O. Verdecchia1, Edgardo G. Baldo1, Miguel A.S. Basei2, Pablo H. Alasino3,4, Gimena A. Urán5, Carlos W. Rapela6, Mario da Costa Campos Neto2, Priscila S. Zandomeni1

1 CICTERRA-CONICET-UNC, Avda. Vélez Sarsfield 1611, Edificio CICTERRA, X5016CGA Córdoba, Argentina. jdahlquist@efn.uncor.edu; sverdecchia@gmail.com; ebaldo@efn.uncor.edu; priscilazandomeni@hotmail.com
2 Instituto de Geociências da Universidade de São Paulo, Rua do Lago 562, 05508-080 São Paulo, SP, Brasil. baseimas@usp.br; camposnt@usp.br
3 INGeReN-CENIIT-UNLaR, Avda. Gobernador Vernet y Apostol Felipe 5300, La Rioja, Argentina. phalasino@gmail.com
4 CRILAR-CONICET, Entre Ríos y Mendoza 5301, Anillaco, La Rioja, Argentina.
5 FCEFyN-UNC, Avda. Vélez Sarsfield 1611, X5016CGA Córdoba, Argentina. gimeuran@gmail.com
6 CIG-CONICET-UNLP, Calle 1 N° 644, 1900 La Plata, Argentina. crapela@cig.museo.unlp.edu.ar

* Corresponding author: jdahlquist@efn.uncor.edu

ABSTRACT. An Early Cambrian pluton, known as the Guasayán pluton, has been identified in the central area of Sierra de Guasayán, northwestern Argentina. A U-Pb zircon Concordia age of 533±4 Ma was obtained by LA-MC-ICP-MS and represents the first report of robustly dated Early Cambrian magmatism for the northwestern Sierras Pampeanas. The pluton was emplaced in low-grade metasedimentary rocks and its magmatic assemblage consists of K-feldspar (phenocrysts)+plagioclase+quartz+biotite, with zircon, apatite, ilmenite, magnetite and monazite as accessory minerals. Geochemically, the granitic rock is a metaluminous subalkaline felsic granodiorite with SiO$_2$=69.24%, Na$_2$O+K$_2$O=7.08%, CaO=2.45%, Na$_2$O/K$_2$O=0.71 and FeO/MgO=3.58%. Rare earth element patterns show moderate slope (La$_N$/Yb$_N$=8.05) with a slightly negative Eu anomalies (Eu/Eu*=0.76). We report the first in situ Hf isotopes data ($\varepsilon_{Hf}$=-0.12 to -4.76) from crystallized zircons in the Early Cambrian granites of the Sierras Pampeanas, helping to constrain the magma source and enabling comparison with other Pampean granites. The Guasayán pluton might provide a link between Early Cambrian magmatism of the central Sierras Pampeanas and that of the Eastern Cordillera, contributing to define the western boundary of the Pampean paleo-arc.

Keywords: U-Pb Geochronology, Hf isotopes, Pampean granites, Sierra de Guasayán.
1. Introduction

The Sierras Pampeanas were divided into Western and Eastern sectors according to their dominant lithologies (Caminos, 1972) (Fig. 1), whereas modern geochronological studies demonstrate that they correspond to different geological histories, as summarized below.

The Western Sierras Pampeanas are dominated by 1030-1330 Ma (“Grenville orogen”) igneous and metamorphic rocks, intruded by relatively scarce Ordovician granites of the Famatinian cycle (e.g., Casquet et al., 2001; Sato et al., 2003; Rapela et al., 2010; Varela et al., 2011 and references therein). The Eastern Sierras Pampeanas are characterized instead by a low- to high-grade Late Ediacaran to Early Palaeozoic basement, intruded by voluminous granitic rocks of Early Cambrian age forming in the Pampean magmatic arc (e.g., Rapela et al., 1998; Omarini et al., 2001; Sato et al., 2007; Rapela et al., 2007; von Gosen and Prozzi, 2009; Rapela et al., 2015 and references therein). Early Cambrian magmatism recognized in the Eastern Cordillera and Eastern Sierras Pampeanas is known as Pampean magmatic arc (e.g., Rapela et al., 1998; Omarini et al., 2008; Hauser et al., 2011; Iannizzotto et al., 2013; von Gosen et al., 2014 and references therein).

The metasedimentary rocks of Sierra Norte and Ambargasta are intruded by metaluminous and peraluminous granitic rocks of Early Cambrian age forming the Sierra Norte-Ambaragasta batholith (Lira et al., 1997; Iannizzotto et al., 2013). The Early Cambrian Tasiil batholith has two main intrusive phases, gray granodiorite and red granite. Extensive outcrops of a porphyry dacite are also associated with the intrusive rocks. In the southern part of the batholith the gray granodiorite intruded folded turbidites of the Neoproterozoic Puncoviscana Formation (Hauser et al., 2011). Studies of the Early Cambrian granites (541-530 Ma) of the Sierras Pampeanas and Eastern Cordillera indicate that crystallized from metaluminous calc-alkaline subduction-related magmas (e.g., Hauser et al., 2011; Iannizzotto et al., 2013 and references therein). In Sierras Pampeanas, late peraluminous granites (530-520 Ma) were linked with a postcollisional event (e.g., Rapela et al., 1998; Iannizzotto et al., 2013).

Located to the northwest of Sierra Norte-Ambaragasta batholith, the Sierra de Guasayán (Beder,
FIG. 1. Schematic geological map of the NW of Argentina including. A. Sierras Pampeanas, Western Sierras Pampeanas and Eastern Sierras Pampeanas, (WSP and ESP) and B. Northwestern Argentina (Puna and Eastern Cordillera). Abbreviations: San Salvador de Jujuy (Ju), Salta (Sa), Tucumán (Tu), La Rioja (LR), San Juan (SJ), Mendoza (Mz), San Luis (SL), Catamarca (Ca) and Córdoba (Cba). Main ranges and Early Cambrian batholith: Cañani batholith (CB), Tastil batholith (TB), Sierra de Quilmes (SQ), Sierra de Aconquija (Ac), Sierra de Chuquisaca (Sch), Sierra de Fiambala (Fi), Sierra de Ambato (Am), Sierra de Ancasti (An), Sierra de Guasayán (Gu), Sierra de Ancacaján (SAn), Sierra del Toro Negro (STN), Sierra de Umango (Um), Sierras de Maa-Espinal (ME), Sierra de Velasco (Ve), Sierra de Famatina (Fa), Sierras de Los Llanos (LLla) Sierra Brava (SBr), Sierra Norte-Ambargasta batholith (SNAB), Sierra de Valle Fértil (VF), Sierra de Pie de Palo (PP), Sierra de Córdoba (SC) and Sierra de San Luis (SSL) and Sierra del Gigante (SG). Inset: rectangle defining study area displayed in the figure 2.
Early Cambrian Guasayán pluton, and it is formed by metamorphic and intrusive granitic rocks (Fig. 2). The metamorphic basement has been subject to petrological and geochemical studies (Blasco et al., 1994; von Gosen et al., 2009), but petrological, geochemical, and geochronological data of the granitic rocks are general and scarce. González and Toselli (1974) reported a Cambrian K-Ar age in biotite (541±7 Ma) for a granitic rock collected in the southern Sierra de Guasayán, near Santa Catalina (Santiago del Estero province). To the best of our knowledge, no further ages have been reported from the Guasayán pluton.

Geochemical and geochronological studies in the Sierras Pampeanas and Eastern Cordillera (Fig. 1) during the past 15 years have improved our understanding of the Guasayán pluton's geological context. This improvement has allowed for a more comprehensive understanding of the pluton's tectonic and magmatic history.

FIG. 2. A. Geological map of Guasayán pluton with the location of the dated GUA-1 sample; B-D. Outcrops photography of the Guasayán granite.
understanding of the petrogenesis and timing of the Early Cambrian magmatism developed during the Pampean orogeny (e.g., Lira et al., 1997; Rapela et al., 1998; Omarini et al., 2008; Schwartz et al., 2008; Hongn et al., 2010; Hauser et al., 2011; Iannizzotto et al., 2013; Lira et al., 2014; von Gosen et al., 2014 and references therein). These studies were based on the large Sierra Norte-Ambargasta batholith (Fig. 1) and the existence of other outcrops in the Sierras Pampeanas being unproven.

In this paper, we present the first precisely defined age by U-Pb LA-MC-ICP-MS zircon dating, together with complete petrological characterization, and major and trace element data for the dated sample collected from the Guasayán granitic pluton. We also report the first in situ Hf isotope data for zircons that crystallized in Early Cambrian granites of the Sierras Pampeanas, in order to evaluate their source.

The geochronological, isotopical, petrological, and geochemical data of the GUA-1 sample from the Guasayán pluton is important in that: i) this is the first report of robustly dated Early Cambrian magmatism in Sierra de Guasayán, ii) it is the north westernmost example of Early Cambrian magmatism in Sierras Pampeanas and thus might represents the link between the Pampean magmatism of Sierras Pampeanas and Eastern Cordillera in the northwest of Argentina.

2. Petrological and whole-rock chemical characteristics of the Guasayán pluton

The Guasayán pluton is located in the central area of Sierra de Guasayán (Figs. 1 and 2). It was emplaced discordantly in a metamorphic complex. It is mainly composed of interbedded phyllites, metapsammites and scarce calc-silicates layers, displaying a mean NNE-SSW S1 metamorphic foliation subparallel to primary foliation (S0). Localized hornfels is developed in the contact with Guasayán Pluton. The hornfels has fine-grained granoblastic texture with biotite+plagioclase+K-feldspar+quartz and probable andalusite (pseudomorphs of muscovite), and zircon, apatite and opaque minerals as accessory minerals. This subsolidus mineral assemblage with andalusite is typical of low-pressure conditions, suggesting a relatively superficial emplacement of the Guasayán pluton.

A porphyritic granitic rock is the dominant facies in the Guasayán pluton, and it crops out in the studied area. It is located in the western area of the pluton (Fig. 2) as a porphyritic biotitic granodiorite, with 3.0×1.5 cm to 2.0×1.0 cm K-feldspar megacrysts in an equigranular matrix formed of quartz, plagioclase and biotite. K-feldspar crystals are oriented and define a dominant N-S magmatic foliation. Biotitic clusters and centimetric basement fragments are recognized in the granite. Similar porphyritic biotitic granites have been recognized in our field works in the southern Sierra de Guasayán (La Punta village).

Petrographic studies of sample GUA-1 reveal that the modal magmatic assemblage is plagioclase (33.0%), quartz (34.3%), K-feldspar (12.3%), biotite (17.5%) with apatite and zircon as accessory minerals (~1.85%). The modal data in the Streckeisen (1976) diagram indicate that the granitic rock is a granodiorite. Chlorite is a common secondary mineral associated with biotite. Scarc secondary epidote occurs associated with biotite and chlorite. Two main varieties of plagioclase were recognized: a) coarse-grained (Pla, 8.0×5.0 mm; minerals abbreviation after Whitney and Evans 2010 and size of individual grains from Hibbard 1995), tabular and mostly subhedral crystals, showing optical zoning and polysynthetic twinning; b) medium-grained: Plb, ranging from 5.0×2.0 mm to 4.0×2.0 mm; and Plc, ranging from 2.0×2.0 mm to 2.4×1.2, forming tabular and mostly subhedral crystals with polysynthetic twins. Pla is scarce whereas Plb and Plc occurs evenly distributed throughout the rock. Systematic analysis using electron microprobe reveals compositions ranges from An47.0 to An33.2 for Pla, An33.2 to An23.6, and An21.5 to An21.5, for Plb, Plc, Pla, respectively. The alkali feldspar is perthite, medium-grained, ranging from 3.0×1.5 mm to 4×2 mm, and forms tabular or irregular subhedral-anhedral crystals, with distinctive perthitic texture. Feldspar is interstitial to the crystalline framework. The composition of alkali feldspar is uncertain since the abundance of perthite prevents determination of the original Na2O content, leading to a low total.

The quartz has mostly irregular form and two sizes are recognized: (a) coarse-grained (Qtz, 4.2×2.0 mm) and medium-grained (Qtz, 2.2×1.0 mm).

Biotite has variable size, ranging from 3.0×1.0 mm to 1.3×1.0 mm, and is frequently found forming clusters. It occurs as subhedral plates or irregular sections with light-to-dark brown pleochroism and abundant inclusions of apatite and zircon. In terms of Alliv versus (XFe=[Fe2+/(Fe2++Mg)]) the biotites...
show relatively high siderophyllite-castonite content (average AlIV=2.53 atom/formula unit and XFe=0.65) together with moderate to low F contents (average F=0.38 wt%, n=5).

Fluorapatite is an abundant accessory mineral; it is euhedral to subhedral with dominant hexagonal and short prismatic forms. It is variably fine-grained, 0.3 to 1.0 mm of diameter or 1.1×0.3 mm (short prismatic), and is commonly observed as inclusions in biotite.

Systematic analysis using the electron microprobe (determining Zr and LREE data) reveals the presence of two radioactive minerals, zircon and monazite, as well as the occurrence of small-scale ilmenite and magnetite crystals (no greater than 100 µm), all mostly included in biotite.

The data show that the dated granitic rock can be classified in the TAS and diagram (figure not included, data in Table 1) as subalkaline felsic granodiorite, with 69% SiO₂. For similar SiO₂ content this rock has comparable composition to those commonly observed in calc-alkaline rocks of the Pampean magmatism in the Sierras Pampeanas (e.g., Iannizzotto et al., 2013) with CaO=2.45%, total alkalis (7.08%), CaO/K₂O=0.59, Na₂O/K₂O=0.71, and [FeO/(FeO+MgO)]=0.78 (i.e., magnesian granite) (Table 1). The porphyritic monzogranite has an alumina saturation index (ASI) of 1.05 (see Table 1) similar to other metaluminous calc-alkaline monzogranites, with a relatively low aegpaitic index of 0.65.

In the spider-diagram (figure not included, data in Table 1) the sample GUA-1 shows depletion in Nb, Ti and Sr and enrichment in Ba, Rb, Th and K, typically characteristic of Pampean calc-alkaline magmatism (Iannizzotto et al., 2013). The total rare earth element (REE) total abundance is 204 ppm (Table 1), with moderate slope (LaN/YbN=8.05) and slightly negative Eu anomaly (Eu/Eu*=0.76).

3. U-Pb geochronology and Hf isotopes data

A representative sample (GUA-1) from Sierra de Guasayán was analysed for whole-rock major and trace elements using a ThermoARL sequential X-ray fluorescence spectrometer, following the procedure described by Johnson et al. (1999). Trace element compositions were determined using an Agilent 7700 ICP-MS, following the procedure described in http://cahnrs.wsu.edu/soe/facilities/geoablab/technotes/icp-ms_method/ (last visit 20-11-2015). The data is included in Table 1.
LA-MC-ICP-MS U-Pb analysis of separated zircons from GUA-1 (Table 2) sample was carried out at the Geochronological Research Center, Sao Paulo University, Brazil, using a 193 nm excimer laser (Photon Machines) coupled to a Neptune multicollector, double-focusing, magnetic sector ICP-MS. Operating procedures and parameters are discussed by Sato et al. (2011). Fractionation in the plasma was corrected by normalizing U-Pb and Pb-Pb ratios of the unknowns to those of zircon standards (GJ 1, $^{206}$Pb/$^{238}$Pb age by IDTIMS = 599.8±2.4 Ma).

In-situ LA-MC-ICP-MS Lu-Hf isotope analyses were conducted at Geochronological Research Center, Sao Paulo University, Brazil using a Photon laser system (Sato et al., 2010) coupled to a Thermo-Finnigan Neptune MC-ICP-MS with 9 Faraday collectors. Lu-Hf isotopic analyses reported here were performed on the same zircon domains that were previously dated. The laser spot used was 47 μm in diameter with an ablation time of 60 seconds and a repetition rate of 7 Hz, and He was the carrier gas (Sato et al., 2009, 2010). $^{176}$Hf/$^{177}$Hf ratios were normalized to $^{176}$Hf/$^{177}$Hf=0.7235. The isotopes $^{172}$Yb, $^{173}$Yb, $^{175}$Lu, $^{176}$Hf, $^{177}$Hf, $^{178}$Hf, and $^{176}$Hf+$^{172}$Yb+$^{175}$Lu were collected simultaneously. A $^{176}$Lu/$^{177}$Lu ratio of 0.02669 was used to calculate $^{176}$Lu/$^{177}$Hf. Mass bias corrections of Lu-Hf isotopic ratios were according to variation in the GJ1 standard (Basei et al., 2013). Laser operating conditions and results are reported in Table 3.

### Table 2. U-Pb LA-MC-ICP-MS Zircon Results for GUA-1, Guasayán Pluton.

<table>
<thead>
<tr>
<th>Grain/Spot</th>
<th>GCh SS</th>
<th>Ratios $^{238}$U/$^{206}$Pb</th>
<th>1σ</th>
<th>$^{207}$Pb/$^{206}$Pb</th>
<th>1σ</th>
<th>$^{206}$Pb/$^{238}$U</th>
<th>1σ</th>
<th>$^{207}$Pb/$^{206}$Pb</th>
<th>1σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>e, p, osc</td>
<td>11.7691</td>
<td>0.1628</td>
<td>0.0564</td>
<td>0.0020</td>
<td>526</td>
<td>0.007</td>
<td>470</td>
<td>0.077</td>
</tr>
<tr>
<td>5.1</td>
<td>e, p, osc</td>
<td>11.6819</td>
<td>0.1880</td>
<td>0.0561</td>
<td>0.0029</td>
<td>529</td>
<td>0.008</td>
<td>456</td>
<td>0.106</td>
</tr>
<tr>
<td>7.1</td>
<td>e, p, osc</td>
<td>11.7740</td>
<td>0.1627</td>
<td>0.0574</td>
<td>0.0021</td>
<td>525</td>
<td>0.007</td>
<td>505</td>
<td>0.083</td>
</tr>
<tr>
<td>8.1</td>
<td>e, p/fr, osc</td>
<td>11.4686</td>
<td>0.1660</td>
<td>0.0566</td>
<td>0.0021</td>
<td>539</td>
<td>0.007</td>
<td>476</td>
<td>0.081</td>
</tr>
<tr>
<td>10.1</td>
<td>e, p, osc</td>
<td>11.3888</td>
<td>0.1490</td>
<td>0.0577</td>
<td>0.0018</td>
<td>543</td>
<td>0.007</td>
<td>520</td>
<td>0.068</td>
</tr>
<tr>
<td>11.1</td>
<td>e, p, osc</td>
<td>11.5700</td>
<td>0.1801</td>
<td>0.0587</td>
<td>0.0027</td>
<td>534</td>
<td>0.008</td>
<td>554</td>
<td>0.104</td>
</tr>
<tr>
<td>15.1</td>
<td>e, p, osc</td>
<td>11.7634</td>
<td>0.1532</td>
<td>0.0573</td>
<td>0.0018</td>
<td>526</td>
<td>0.007</td>
<td>502</td>
<td>0.069</td>
</tr>
<tr>
<td>16.1</td>
<td>e, p, osc</td>
<td>11.4484</td>
<td>0.1682</td>
<td>0.0570</td>
<td>0.0025</td>
<td>540</td>
<td>0.008</td>
<td>493</td>
<td>0.094</td>
</tr>
<tr>
<td>17.1</td>
<td>e, p, osc</td>
<td>11.7352</td>
<td>0.1616</td>
<td>0.0577</td>
<td>0.0021</td>
<td>527</td>
<td>0.007</td>
<td>519</td>
<td>0.080</td>
</tr>
<tr>
<td>18.1</td>
<td>e, p, osc</td>
<td>11.5385</td>
<td>0.1775</td>
<td>0.0576</td>
<td>0.0026</td>
<td>536</td>
<td>0.008</td>
<td>516</td>
<td>0.103</td>
</tr>
<tr>
<td>19.1</td>
<td>e, p, osc</td>
<td>11.5373</td>
<td>0.1713</td>
<td>0.0567</td>
<td>0.0024</td>
<td>536</td>
<td>0.008</td>
<td>480</td>
<td>0.094</td>
</tr>
<tr>
<td>23.1</td>
<td>e, p, osc</td>
<td>11.5327</td>
<td>0.1508</td>
<td>0.0582</td>
<td>0.0020</td>
<td>536</td>
<td>0.007</td>
<td>538</td>
<td>0.077</td>
</tr>
<tr>
<td>13.1 (inh-age)</td>
<td>e, p, c</td>
<td>6.1830</td>
<td>0.0807</td>
<td>0.0696</td>
<td>0.0020</td>
<td>966</td>
<td>0.012</td>
<td>916</td>
<td>0.058</td>
</tr>
<tr>
<td>14.1 (inh-age)</td>
<td>e, p, m</td>
<td>9.9660</td>
<td>0.1214</td>
<td>0.0579</td>
<td>0.0017</td>
<td>616</td>
<td>0.007</td>
<td>527</td>
<td>0.064</td>
</tr>
</tbody>
</table>

$^{238}$U/$^{206}$Pb and $^{207}$Pb/$^{206}$Pb ratios corrected for static fractionation using GJ 1.

Measurement errors represent within-run uncertainty only. All data points were used in calculated concordia age.


Location of sample is: 27°53' 08.1'' and 64°50' 35.2''.
The combined SEM-CL and optical images reveal that the zircons separated from GUA-1 are mostly elongate prismatic grains with oscillatory zoning and subhedral to euhedral-terminations. Analysis spots were mostly located in the outer oscillatory zoning and the majority of the zircon ages are concentrated at about 533 Ma (see Table 2). Twelve data points yield a Tera-Wasserburg Concordia age (Ludwig, 2003) of 533±4 Ma (2σ confidence limits, allowing for the uncertainty in U-Pb calibration). This is considered the best estimate for the crystallization of the host felsic granodiorite (Fig. 3). Two inheritance ages (“Grenvillian” and “Brazilian”) were obtained from zircon core (966 Ma and 616 Ma, Table 2 and Fig. 3).

The Early Cambrian zircons have variable εHf(t=533 Ma) values ranging from -0.12 to -4.76. The average model age is calculated as 1.56 Ga (Table 3 and Fig. 4).

4. Discussion

Petrological and whole-rock geochemical indicate that GUA-1 is a subalkaline porphyritic biotite monzogranite. Frost et al. (2001) and Frost and Frost (2011) have provided exhaustive analysis and classification of granitic suites based on a range of major element indices. According to the Frost et al. (2001) classification scheme, GUA-1 is dominantly magnesian-type and it is projected close to the boundary separating calcic and calc-alkaline series in the modified alkaline-lime index of Peacock (1931) (figures not included, data in Table 1). This composition is those reported in classical calc-alkaline magmatism (Frost et al., 2001, Frost and Frost, 2011). As mentioned in the Section 2, sample GUA-1 shows depletion in Nb, Ti, Ta and Sr and enrichment in Ba, Rb, Th and K typical of magmas formed in Pampean subduction zone.

González and Toselli (1974) reported a Cambrian K-Ar age in biotite (541±7 Ma) for a granitic rock collected in the eastern flank of the Sierra de Guasayán, near Santa Catalina (Santiago del Estero province), located 25 km to the southeast of the studied area. To the best of our knowledge, no further ages have been reported from the Guasayán pluton.

Recent petrological and geochronological (U-Pb SHRIMP zircon ages) studies in the Sierra Norte-Ambargasta batholith (Iannizzotto et al., 2013) indicate an episodic intrusion history: i) an early stage constrained to 537-530 Ma, and ii) a second stage with post-kinematic peraluminous magmatism emplaced between 530-520 Ma. The earlier, dominant group was derived largely from metaluminous calc-alkaline subduction-related magmas, whereas...
FIG. 3. U-Pb LA-MC-ICP-MS zircon dating of GUA-1 sample from Guasayán pluton. The main Tera-Wasserburg plot shows most analyses plotting between 526 and 540 Ma and the inset shows a Concordia age of 533±4 Ma. Selected zircon images are also shown. Data reported in Table 2.

FIG. 4. Age versus ε_Hf values for Early Cambrian zircon hosted in GUA-1 granite, showing both measured and initial epsilon Hf values as function of crystallization age. Depleted-mantle Hf evolution curve from Vervoort and Blichert-Toft (1999).
the late granites are peraluminous and they have been linked with a post-collisional event. The geochronological data (533±4 Ma) from the Guasayán pluton indicate that this pluton could be included in early stage of the Pampean magmatism.

In the Eastern Cordillera, northwest of Argentina, the metaluminous to slightly peraluminous, Tastil batholith yield two U-Pb LA-MC-ICP-MS zircon ages of 534±7 Ma and 541±4 Ma, for the grey and red granitic facies, respectively (Hauser et al., 2011), and can be also assigned to the early Pampean magmatism. Thus, the crystallization age obtained from the Guasayán pluton is similar to those reported for Pampean granites of Sierra Norte-Ambargasta and Tastil batholith.

The Guasayán pluton might provide a link between Early Cambrian magmatism of the central Sierras Pampeanas and that of the Eastern Cordillera, contributing to define the western boundary of the Pampean paleo-arc (Fig. 5).

Additionally, the studied area is relevant because the Famatinian and Pampean magmatic belts are close to each other in this area. In the Sierra de Ancasti (located to the west of the Sierra de Guasayán;
Fig. 1), a precise Famatinian U-Pb age in zircon using LA-ICP-MS was reported by Dahlquist et al. (2012) but Pampean magmatism is absent. Conversely, Famatinian magmatism is not recognized in the Sierra de Guasayán where Pampean magmatism is now known (Fig. 1).

The εHf(t) values for magmatic zircons are reported in Table 3 and Fig. 4. As in the general study reported by Kemp et al. (2007), an important feature of the Hf isotope data is the significant range of εHf(t) values exhibited by zircons within the same sample (up to 10 ε units). Such scatter can be in part because zircon can crystallize very early and retain vestiges of the original (e.g., juvenile) Hf isotope signature (Kemp et al., 2007; Dahlquist et al., 2013), whereas the 176Hf/177Hf ratio of the melt from which the zircons precipitated might change from early to late crystallization stages due to progressive assimilation of crustal material. The εHf(t) values reported here suggest interaction between juvenile and continental material, although the latter appear to be dominant. Thus, a petrogenetic model invoking interaction between a juvenile magma and crustal material of probable Early Mesoproterozoic age (see TDM in Table 3) could explain evolution of the parental magma of the Guasayán pluton. Alternatively, a heterogeneous crust could be assumed as the source of the parental magma. Hf in zircon isotope data reported for the granites of the Tastil batholith suggest a similar petrogenetic process involving significant crustal participation.

3. The new age from Guasayán pluton might contribute to define the western boundary of the Pampean paleo-arc between the Sierras Pampeanas and the Eastern Cordillera.

Acknowledgments

Financial support was provided by grant CONICET-FAPESP 2013-2014, PIP CONICET 0229, and FONCyT-PICT 2013-0472 and PICT 2013-0226. We are also grateful to V. Loios, W. Sproesser, S. Souza, and N. Coelho by the technical support. We thank R.J. Pankhurst for his English review.

References


5. Conclusions

1. The whole-rock chemical data from GUA-1 suggest that this pluton is a metaluminous subalkaline felsic granodiorite. The first precise U-Pb LA-ICP-MS zircon age from GUA-1 indicate that the Guasayán pluton was emplaced in Early Cambrian time, 533±4 Ma. The Guasayán pluton is the north westernmost outcrop of the Early Cambrian magmatism in the Sierras Pampeanas.

2. Based on Hf in zircon isotope data, an interaction between dominant crust of hypothetical Early Mesoproterozoic ages and juvenile magmas could be applied to the generation of the parental magma of the Guasayán pluton. Alternatively, a heterogeneous crust could be assumed as the source of the parental magma. Hf in zircon isotope data reported for the granites of the Tastil batholith suggest a similar petrogenetic process involving significant crustal participation.

3. The new age from Guasayán pluton might contribute to define the western boundary of the Pampean paleo-arc between the Sierras Pampeanas and the Eastern Cordillera.
geológicas de la República Argentina, 1:250.000, SEGEMAR: 50 p.


