Anatetic granites of the Sierras Pampeanas from Córdoba (Argentina): U-Pb SHRIMP and zircon trace element LA-ICP-MS study of diachronic metamorphism and crystallization

Granitos anatécticos de las Sierras Pampeanas de Córdoba (Argentina): edades U-Pb SHRIMP y estudio LA-ICP-MS de elementos traza en circun de metamorfismo y cristalización diacrónicos

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ABSTRACT

In this contribution we present new U-Pb SHRIMP ages and in situ LA-ICP-MS trace element geochemistry of zircon crystals from the Río de los Sauces anatetic granite, Córdoba, Argentina. Notable difference in texture and composition allowed us to identify two zircon populations in a single granite sample that are interpreted as reflecting metamorphic and igneous origins. Zircons regarded as restitic crystals entrained during the melt segregation yielded a slightly older concordia age of 537.1 ± 4.8 Ma (2σ) than those interpreted as igneous, dated at 529 ± 6 (2σ) Ma. Inherited metamorphic zircons are interpreted to represent solid-state growth during high temperature metamorphism of the Pampean orogeny at the onset of the anatectic or metamorphic peak. By contrast, igneous zircons would record the crystallization age of Zr within the Río de los Sauces granite. The textural, compositional and geochronological data of both zircon populations suggest that the inception of the anatectic, the melt segregation and crystallization occurred during a short period of time of 8 my.

Key-words: Pampean orogeny, Pampean metamorphism, Río de Los Sauces granite, U-Pb SHRIMP dating, LA-ICP-MS

RESUMEN

En este trabajo se aportan nuevos datos de edades U-Pb SHRIMP y análisis in situ LA-ICP-MS de elementos traza de circones provenientes del granito Río de los Sauces, Córdoba, Argentina. A partir de marcadas diferencias texturales y composicionales se pudieron identificar dos poblaciones de circones en una misma muestra del granito, las cuales sugieren orígenes metamórficos e igneos. Las edades concordia obtenidas en los circones metamórficos e igneos fueron de 537.1 ± 4.8 Ma (2σ) y 529 ± 6 (2σ) Ma, respectivamente. Se interpreta que los circones metamórficos representan el crecimiento en estado sólido durante el metamorfismo de alta temperatura de la orogenia Pampeana, durante el inicio o el climax de la anatexis. Por su parte, las edades de los circones igneos representan la edad de cristalización del granito Río de los Sauces. Los datos texturales, composicionales y geocronológicos de ambas poblaciones de circones sugieren que el inicio de la anatexia, la segregación del fundido y la cristalización ocurrieron durante un período breve de tiempo de 8 ma.

Palabras clave: orogenia Pampeana, metamorfismo pampeano, granito Río de Los Sauces, datación U-Pb SHRIMP, LA-ICP-MS

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Introduction

The Sierras Pampeanas geological province, in central Argentina, comprises several mountain ranges constituted by an igneous and metamorphic basement that was mostly generated during two main orogenic events: the Pampean and the Famatinian orogenies (Casquet et al., 2018; Rapela et al., 2018; Weinberg et al., 2018). The Pampean orogeny is widely represented in the Sierras de Córdoba (Fig. 1), the southernmost part of the Sierras Pampeanas geological province, in which the main tectonic-thermal event led to an upper amphibolite to granulite facies metamorphism and anatexis (Rapela et al., 1998; Guereschi and Martino, 2014). Gneisses and schists evolved into meta-textites and diatexitès at P-T conditions that reached 8–9 kbar and more than 800 °C (Rapela et al., 1998; Otamendi et al., 2004; Weinberg et al., 2018), generating melts that were segregated to form granite bodies. Available ages suggest that this HT metamorphic event has lasted for at least 35 Ma, between 550 and 515 Ma (Rapela et al., 1998; Weinberg et al., 2018). The studies addressing the peraluminous magmatism associated with this metamorphic event are concentrated in specific parts of the Sierras de Córdoba, and have dated magmatism at 522 Ma, synchronous with metamorphism and anatexis (Rapela et al., 1998, 2002; Tibaldi et al., 2008). However, anatexis and associated magmatism are not necessarily coeval and the time gap between them may differ in each single case (Vanderhaeghe et al., 1999; Keay et al., 2001; Esteban et al., 2015).

In this contribution we present LA-ICP-MS trace element data and U-Pb SHRIMP ages of zircon crystals sampled from a single site of the Río de los Sauces granite, Sierra de Comechingones (Argentina), in which both metamorphic and igneous events have been recorded. We report here for the first time in the Pampean orogeny the diachronic character of metamorphism and associated granitic magmatism.

The Río de los Sauces granite

The Río de los Sauces granite is a 1200 x 150 m tabular body located two kilome-
Sixty-eight zircon crystals from both populations of the same sample, after SHRIMP acquisition, were analyzed by Laser Ablation Quadrupole Inductively Coupled Plasma Mass Spectrometry (LA-Q-ICP-MS) at the University of the Basque Country to obtain trace and rare earth element (REE) concentrations.

As it was stated above, one of the most prominent geochemical differences is the Th/U ratio, being lower in the ZP 1 and higher in the ZP 2. This ratio has been used to discriminate between magmatic (Th/U > 0.1) and metamorphic (Th/U < 0.1) zircons (e.g., Hoskin and Schaltegger, 2003), although some discrepancies have been stated (Harley et al., 2007). In our study, the differences in Th/U ratios between both populations are even greater (Fig. 4A), suggesting clear contrasting origins (metamorphic vs. igneous).

Other geochemical ratio, such as Nb/Ta, also suggests differences in their origin, being almost invariably higher in ZP 2 when compared with ZP 1 (Fig. 4B). Regarding the rare earth elements (REE), both zircon populations show positive patterns of normalized values with high overlap between them. Heavy REE contents, however, are somewhat different. For example, the (Lu/Dy)N ratios are less variable in zircons from ZP 1 (1.3-2.4) than those from ZP 2 (0.8-3.6).

The release of U during dehydration reactions in partial melting processes leads to an increase in the U/Ce ratio of zircons with metamorphic origin (Castiñeiras et al., 2011). Zircons from the ZP 1 display U/Ce values that range between 21 and 936, whereas those from the ZP 2 vary only from 6-54 (Fig. 4C).

Two types of zircons were identified from CL images (Fig. 2): zircon population 1 and 2 (ZP 1 and ZP 2). The first one (ZP 1) is represented by complex zoned patterns, with dark rims at CL images surrounding inherited xenomorphic cores, dark luminescent idiomorphic zircons with weak oscillatory zoning and Th/U ratios lower than 0.02. Zircons from the second population (ZP 2) are prismatic and bipyramidal with concentric undisturbed oscillatory growth zoning.

Nine and eight spot analyses in zircon crystals from ZP 1 and ZP 2 yielded 206Pb/238U concordia ages of 537.1 ± 4.8 (2σ) (Fig. 3A) and 529 ± 6 (2σ) Ma (Fig. 3B), respectively. Although these two ages partially overlap each other, they could indicate that both zircon populations are not coeval.

LA-ICP-MS geochemistry

The main leucogranite facies of the Río de los Sauces pluton was sampled in only one station (32°30′37.7″S / 64°34′18.8″W). Zircon crystals were separated and mounted by conventional methods. Further imaging by cathodoluminescence and analyses on a SHRIMP-IIe/MC were performed at the Centro de Pesquisas Geocronológicas, University of São Paulo (CPGeo-IGC-USP, Brazil).
The results here presented imply that crystallization of melt segregations after partial melting of metasedimentary rocks took place around 8 Ma later than the HT regional metamorphism.

A time lag between syntectonic granites and regional metamorphism was previously reported by some authors in other orogenic domains. Keay et al. (2001), for example, proposed that Miocene peak metamorphism and related magmatism in the Naxos Island, Greece, were separated more than 5 Ma each other. Esteban et al. (2015) also established a time span of 7 Ma between the metamorphic climax of the high-grade Variscan HT/LP metamorphism (Late Carboniferous) and the final emplacement of the Lys-Caillouas pluton at middle crustal levels.

The presence of metamorphic zircons in the Río de los Sauces granite suggests that zircon crystals derived from the metamorphic protoliths have crystallized in the Sierras de Córdoba. Therefore, the age of 537.1 Ma obtained in dark CL rims of metamorphic zircons from ZP1 are deemed to represent the age of the HT Pampean metamorphism. This metamorphic event might be the responsible for the solid-state growth of the zircon rims. The zircon crystals would have been further transported within the anatectic magma until it was emplaced and crystallized at 529 Ma. The obtained ages in both zircon populations are strongly correlated with other ages reported by several authors for the Pampean metamorphism and magmatism in the Sierras de Córdoba (Guereschi and Martino, 2014; and references therein). The results here presented imply that crystallization of melt segregations after partial melting of metasedimentary rocks took place around 8 Ma later than the HT regional metamorphism.

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been incompletely dissolved and then included as restitic crystals thus allowing to study the timing of the metamorphism prior to the emplacement of the pluton. The mean temperatures of 735 and 750 ºC in metamorphic and igneous zircons respectively are coherent with calculated metamorphic conditions in Sierras de Córdoba (Rapela et al., 1998; Otamendi et al., 2004). Since the crystallisation temperatures calculated for both zircon populations are within the uncertainty of each other, a further increase in the regional temperature during anatexis cannot be inferred.

Conclusions

The anatectic Río de los Sauces granite represents the coalescence, expelling, emplacement and crystallization of leucosomes from the surrounding migmatites. Zircons analyzed from a single sample of the Río de los Sauces pluton were grouped into two populations whose textural, compositional and geochronological features point to a contrasting origin: near peak high-temperature metamorphic solid-state growth vs. magma crystallization. These two events were separated in time by ~8 ma (537.1 vs. 529 Ma). Our contribution is the first constraint of this time lag for the Pampean orogeny in the Sierras de Córdoba.

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