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The late stages of the Pampean Orogeny, Córdoba (Argentina): Evidence of postcollisional Early Cambrian slab break-off magmatism

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ABSTRACT

Widespread rhyolitic and mafic volcanism in the northern and southern sectors respectively of Eastern Sierras Pampeanas, central western Argentina, are associated with an important phase of extension and uplift linked to slab break-off on latest stages of the Pampean Orogeny. The main orogenic deformation took place between 540 and 535 Ma based on new ages available for this region. New U–Pb ages in zircons from the Oncán Rhyolite and new and old recalculated zircons from Los Burros Rhyodacite in the northern sector of Sierras de Córdoba, together with new U–Pb ages of the southern sector, indicate that volcanic and subvolcanic rocks of both sectors are partially coeval and unconformably overlying and/or intruding the basement rocks during a period of exhumation and subsequent cooling at 530-520 Ma. These data are in agreement with previous estimates for the final uplift of the Sierras de Córdoba based on the K–Ar cooling ages. The southern sector of Eastern Sierras Pampeanas may represent deeper structural levels within the crust and is characterized by the occurrence of small mafic bodies with OIB-like signature. New and reinterpreted U–Pb SHRIMP and TIMS ages on zircons and monazites in the metamorphic associated rocks date this episode, which is related to a rapid slab break-off event at 519-515 Ma. This episode is also associated with the emplacement of peraluminous granitoids, and with the extension, cooling and final uplift of the rocks affected by the Pampean Orogeny all along the Eastern Sierras Pampeanas.

1. Introduction

A long-standing controversy in the geological evolution of the Sierras Pampeanas of central Argentina has been the age of their metamorphic rocks and granitoids, which varies from Precambrian to Paleozoic (Gordillo and Lencinas, 1972). The Sierras Pampeanas are a series of blocks uplifted during Andean deformation in the broken foreland of central Argentina that expose crystalline basement (Ramos et al., 2002). Early isotopic data from this basement showed that many metamorphic rocks, mainly the amphibolites dated by K–Ar, had a late Neoproterozoic minimum age, whereas the granitoids were early Paleozoic (Linares and Latorre, 1969; Linares and Cordani, 1976). However, subsequent refinement and precision achieved by U–Pb geochronology, suggested that most of the orogeny affecting the eastern Sierras Pampeanas was short-lived and developed during early Cambrian times (Rapela et al., 1998). Nevertheless, several authors relate this orogeny to the main collision between the Rio de La Plata craton and the accreted Pampia block during late Neoproterozoic times (Kraemer et al., 1995; Escayola et al., 2007; among others). The last stage of the orogeny is evidenced in the northern Sierras de Córdoba by rhyolitic lavas, associated domes and dikes preserved at shallow structural levels intruding deformed granitoids and metamorphic rocks which are unconformably covered by these sequences. In the southern Sierras de Córdoba coeval rocks represented by gabbroic OIB like plutons are emplaced in granulitic and charnockite metamorphic rocks, and represent a much deeper crustal level, but both sectors together provide an opportunity to date the minimum age of the deformation and subsequent collision.

The objective of this paper is to describe these volcanic rocks, present precise radiometric ages and to analyze the tectonic

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implication of their emplacement. In order to refine our model described here for the evolution of Eastern Sierras Pampeanas we include new SHRIMP and TIMS data of migmatites genetically related to OIB-like gabbros generated during the late stages of the Pampean orogeny in the southern part of the present study area.

2. Geologic setting of Eastern Sierras Pampeanas

The study area is located in northern and southern Sierras de Córdoba, which is part of the Eastern Sierras Pampeanas of central-western Argentina (Fig. 1).This region is characterized by a series of crystalline basement blocks uplifted during the Andean deformation at the northeastern end of the present flat-slab subduction zone (Jordan et al., 1983). The basement of the Eastern Sierras Pampeanas of Córdoba is composed by three different rock assemblages:(1) supracrustal mainly metasedimentary rocks in medium to high amphibolite to granulite facies including metatexites and diatexites and carbonate sequences which have poorly constrained ages between late Neoproterozoic and Early Cambrian, associated with syn to post migmatitic gabbroic intrusions (Cañada del Puerto at the migmatitic San Carlos massif to the north and several mafic plutons as Suya Taco and others to the south) and ultramafic rocks; (2) a series of metaluminous granitoids ranging from granodiorites to monzogranites (Lira et al., 1997) with arc signature and late Neoproterozoic to Early Cambrian ages (Miró et al., 2005); and (3) minor domes and small intrusives of dacitic composition like the Los Burros Rhyodacite (Leal et al., 2003), and widespread dikes and small domes of rhyolites that make up the Oncán Rhyolite and are associated with small aplitic bodies (Miró and Sapp, 2001) assigned to the late Cambrian based on a whole rock Rb–Sr age (Rapela et al., 1991).

3. Methodology

The isotopic analyses have been done in three different laboratories. The volcanic rocks were analyzed by Sensitive High Mass Resolution Ion MicroProbe (SHRIMP II) U–Pb at Curtin University, Western Australia, in two sessions using an analytical spot size of about 20–25 μm (Tables 1 and 2). Individual analyses are composed of measurement of nine masses repeated in five scans. The following masses were analyzed for zircon: (Zr_2O, ^{204}Pb, background, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{238}U, ^{248}ThO, ^{254}UO). The standards D23 and NBS611 were used to identify the position of the peak of the mass ^{204}Pb, whereas the calibration of the U-content and the Pb/U ratio were done using the zircon standard BR266 (559 Ma, 903 ppm U). Data were reduced using the SQUID 1.03 software (Ludwig, 2001a,b) and the ages calculated using Isoplot 3.0 (Ludwig, 2003). The Phanerozoic ages are mean average $^{206}Pb/^{238}U$ ages whereas the Precambrian ages are mean average $^{207}Pb/^{206}Pb$ ages all calculated at 2σ level.

Additional ion microprobe analyses were carried out using SHRIMP–RG at the Research School of Earth Sciences, Australian National University, Canberra, Australia (Table 3). Transmitted and reflected light microscopy, as well as scanning electron microscope cathodo-luminescence images were used to investigate the internal structure of zircon crystals prior to analysis. The data was collected and reduced using the method described by Williams and Claesson (1987) and Compston et al. (1992). Uncertainties are reported at the 1σ level and final ages are quoted with a 95% confidence level. Reduction of raw data and age calculation were carried out using SQUID 1.02 and Isoplot-Ex (Ludwig, 2003). U/Pb isotope ratios were referenced to the RSES standard zircon FC1 (1099 Ma, $^{206}Pb^{*}/^{238}U = 0.1859$). U and Th concentrations were determined relative to those measured in the RSES standard SL13.

The third set of isotopic analyses (Tables 4 and 5) was carried out at the Geochronology Laboratory of the University of Brasília by TIMS – Thermal Ionization Mass Spectrometry. Zircon dissolution and chemical extraction of U and Pb were done according to the general procedures described by Krogh and Davis (1973).

The errors of the isotopic ratios and ages are quoted at 2 sigma for the data generated on SHRIMP II (Tables 1 and 2) and SHRIMP-RG (Table 3), as well as the data produced by TIMS (Tables 4 and 5).

3.1. The metamorphic rocks of the northern sector of Eastern Sierras Pampeanas

The metamorphic sequence exposed in the Sierra Norte de Córdoba is composed of medium- to high-grade metamorphic rocks represented by quartz-biotite schists, tonalitic gneisses, amphibolites and migmatites grouped in the Pozo del Macho Formation by Castellote (1985). Isolated remnants of low grade metamorphic rocks such as metalimestones, quartz phyllites and metacoglomerates are part of the Simbol Huasi Formation defined by Lucero (1969) and Miró and Sapp (2001), and recently described by Von Gosen and Prozzi (2010).

The protoliths of the Sierras de Córdoba metasedimentary rocks have a maximum age of sedimentation in the latest Proterozoic–Early Cambrian based on limited detrital zircon analyses (Rapela et al., 1998; Sims et al., 1998; Steenken et al., 2011). Recent studies based on a larger population indicate two dominant ages, Neoproterozoic (~600–700 Ma) and Mesoproterozoic (950–1050 Ma), and a limited presence of Paleoproterozoic (~1900 Ma) zircons (Schwartz and Gromet, 2004). Almost half of the zircons have a Mesoproterozoic age indicating erosion of a Grenville-age source, which may indicate an older basement in the western and northern sectors as pointed out by Cingolani and Varela (1975) and Escayola et al. (2007). Some gneisses yielded U–Pb ages of 553 ± 7 Ma (Schwartz et al., 2008) and 533 ± 12 Ma (Siegesmund et al., 2010) (see Fig. 2 for location).

3.2. The granitoids of the northern sector of Eastern Sierras Pampeanas

The granitic batholith of Eastern Sierras Pampeanas has been studied by several authors. Calc-alkaline magmatic rocks of latest Proterozoic and Cambrian age underlie much of the Sierra Norte, Sierra de Ambargasta and Sierra de Sumampa regions in the Eastern Sierras Pampeanas (Fig. 2). These metaluminous to weakly peraluminous granitoids have been analyzed by Lira et al. (1997) and mapped in detail by Candiani et al. (2000) and Miró and Sapp (2001), among others. Geochemical characteristics suggest that these granitoids are arc-related (Lira et al., 1997) and provide a record of subduction and convergent margin tectonics along the western margin of Gondwana in the late Neoproterozoic (Ramos, 1988; Rapela et al., 1998; Miró et al., 2005; Schwartz et al., 2008).

Early K–Ar geochronological studies show a wide range of ages between 600 and 510 Ma (Castellote, 1982, 1985; González et al., 1985), and other ages within this range were obtained by Rb–Sr analyses (Millone et al., 2003). However, new studies based on U–Pb dating of zircons offer better constraints on the crystallization age of the different granitic suites of the batholith. The first ages reported by Rapela et al. (1998) for granitic rocks of this batholith have been partially confirmed by subsequent work of Schwartz et al. (2008), Siegesmund et al. (2010) and Ianizzotto et al. (2013). Ages are indicated in Fig. 2. The age of the granitoids varies from more than 540 Ma to 530 Ma as established by Schwartz et al. (2008). However, some granites such as the Tres Lomas Granite have ages around 533 Ma, which is similar to the San Miguel Orthogneiss (533 ± 2 Ma and 533 ± 12 Ma, Siegesmund et al., 2010).