Lithos 121 (2011) 189–201

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Contrasting sources and P-T crystallization conditions of epidote-bearing granitic rocks, northeastern Brazil: O, Sr, and Nd isotopes

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ARTICLE INFO

Article history:
Received 15 February 2010
Accepted 1 November 2010
Available online 7 November 2010

Keywords:
Magmatic epidote
Nd isotopes
Sr isotopes
O isotopes
SHRIMP U–Pb ages
Granitoids

ABSTRACT

The 618 Ma Curral de Cima tonalite and 577 Ma Lourenço monzodiorite, northeastern Brazil, are magmatic epidote-bearing plutons that carry ferrohornblende, biotite, titanite, and epidote. Major, trace, and isotope chemistry suggests that the major magmas of the two plutons followed similar differentiation trends but derived from source rocks that differed in age and isotopic composition. The mineral phases of the Curral de Cima tonalite, the presence of amphibole-rich clots, and juvenile component (average $\varepsilon Nd = -3.55$) point to an I-type source for these rocks. These data and high calculated $\delta^{18}O$(w.r.) (10.0‰) for the tonalite and high $\delta^{18}O$ value for a clot (9.3‰) argue that the clots are fragments of a metabasaltic source rock that has been hydrothermally altered at a low temperature. In contrast, average calculated $\delta^{18}O$(w.r.) for the Lourenço monzodiorite = 7.8‰, $^{87}Sr/^{86}Sr = 0.7083$, $\varepsilon Nd = -14.6$, and $T_{DM} = 1.92$ Ga. These data are compatible with a long crustal residence time of lower crust amphibolites source. Epidote in the Curral de Cima pluton crystallized close to the NNO buffer, and hornblende chemistry, due to Al reequilibration, yielded sub-solidus temperature and pressure. In contrast, in the Lourenço pluton epidote crystallized close to the HM buffer and Al-in-hornblende points to near-solidus solidification (685 °C) around 4.4 Kbar. This study confirms that magmatic epidote in granitic plutons can crystallize at pressures lower than 5.5 Kbar under higher fO_2 as experimentally foreseen. Rapid magma transportation through hot continental crust during the peak of metamorphism in early stages of an orogenic cycle prevents epidote dissolution.

1. Introduction

Experiments by Naney (1983), who demonstrated that epidote can be stable above the solidus in granites and granodiorites and that its crystallization occurs at 6–8 kbar pressure, have stimulated great interest in magmatic epidote in granitic rocks. The two most important advances in the study of magmatic epidote and its significance have been published in the same year: (a) experimental studies have demonstrated that the minimum crystallization pressure of magmatic epidote depends on fO_2 (Schmidt and Thompson, 1996) and (b) epidote dissolution in granitic magmas is relatively rapid and the survival of this mineral in calc-alkalic granitoids implies rapid upward transport (Brandon et al., 1996).

Sial et al. (2008) used the epidote dissolution rate and initial size of partially corroded epidote grains to estimate the minimum speed of upward magma migration. Epidote in slowly rising magma, as in diapiric emplacement, may be totally resorbed before the final crystallization of the magma. If magma migrates rapidly (i.e. by diking), epidote grains can maybe partially preserved. Thus epidote may provide useful information about oxygen fugacity, pressure of solidification, and ascension rates of magmas (e.g., Sial et al., 2008 and references therein).

Pressures of solidification of magmatic epidote-bearing granitoids in the Cachoeirinha–Salgueiro belt, northeastern Brazil, are in the range of 6 to 9 kbar, whereas for plutons from the Seridó belt, pressures of crystallization are 3 to 5 kbar (Sial, 1993; Sial et al., 1999). At these lower pressures, the pistacite contents of epidote are 27–29 mole%, whereas at the higher pressures, pistacite is 20–24 mole%. Magmatic epidote-bearing granitic plutons have not been extensively studied elsewhere in northeastern Brazil except for isolated examples such as the Coronel João Sá granodiorite (e.g. Long et al., 2005) and the São Rafael granodiorite (e.g., Sial et al., 1999; Ferreira et al., 2003). Geologic mapping by Brito Neves et al. (2008) in the easternmost

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0024-4937/$ – see front matter
doi:10.1016/j.lithos.2010.11.002

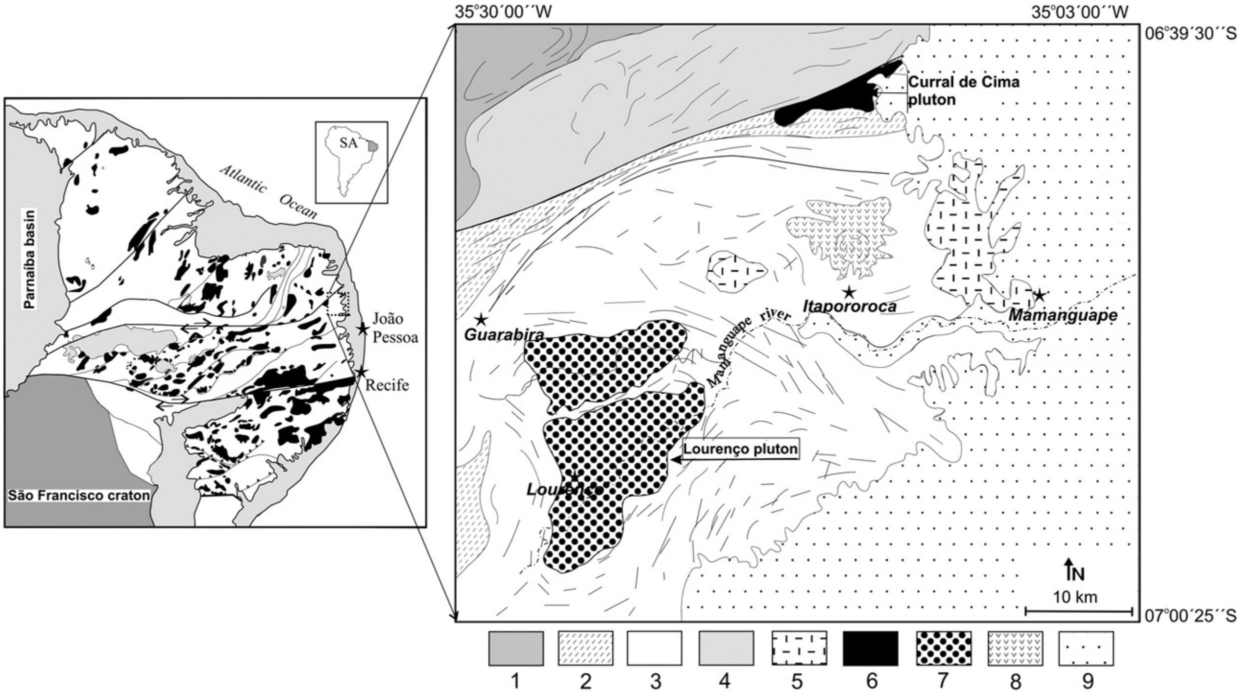

Fig. 1. Simplified geological map of the Guarabira region, State of Paraiba, northeastern Brazil, showing the two studied plutons, Lourenço and Curral de Cima. Modified after Santos et al. (2002) and Brito Neves et al. (2008). The location map is a geological draft of the Borborema province, northeastern Brazil, emphasizing major shear zones and Neoproterozoic plutons (in black). Legend: Paleoproterozoic: 1 = gneiss, migmatite, marble, quartzite (Serrinha–Pedro Velho complex); Mesoproterozoic: 2 = metagranitoid, migmatite (Cariris Velhos suite); 3 = muscovite biotite gneiss, biotite gneiss, muscovite schist (São Caetano complex); Neoproterozoic: 4 = garnet biotite schist, cordierite biotite schist (Seridó Formation), 5 = two mica granodiorite, 6 = tonalite (Curral de Cima pluton), 7 = monzodiorite (Lourenço pluton); Mesozoic: 8 = volcanic felsic rocks; Cenozoic: 9 = sedimentary cover.

portion of the Alto Pajeú terrane, Guarabira area, State of Paraíba, revealed the presence of petrographically similar magmatic epidote-bearing granitic plutons.

In this study of two of them, the Lourenço and Curral de Cima plutons (Fig. 1), we present petrographic and geochemical data (bulk and mineral chemistries, oxygen, Sm–Nd and Rb–Sr isotopes) that constrain their evolution and emplacement. We show that these plutons, which are located only a few kilometers apart, derived from distinct magmas that experienced different evolution, and crystallized under different P-T conditions.

2. Geologic setting

Two continental-scale E–W-trending shear zones (Patos and Pernambuco) and associated NE–SW-trending shear zones divide the Borborema structural province into suspected tectonostratigraphic terranes. The major features of this province developed during the Meso/Neoproterozoic transition (the 1.1–0.95 Ga Cariris Velhos orogenic event), and at the end of the Neoproterozoic (the ca. 0.70–0.55 Ga Brasiliano orogeny) (Santos et al., 2010). Movement along the shear zones began at around 0.59–0.58 Ga. Flat-lying foliation developed during the early Brasiliano orogeny, changing to high-angle foliation toward the end of the orogeny. A large volume of Neoproterozoic intermediate to acidic magma was emplaced into the crust at 0.65–0.56 Ga, during the Brasiliano event, the major tectonothermal Borborema event.

Granitic magmatism in the Transversal Zone domain, the region between the Patos and Pernambuco shear zones, occurred in the intervals 0.65–0.62 Ga, 0.59–0.57 Ga, and 0.54–0.52 Ga (Ferreira et al., 1998, 2004; Guimarães et al., 2004). The oldest is characterized by intrusions of syn-kinematic high-K calc-alkalic, calc-alkalic, and shoshonitic granitoids with $T_{DM}<2.0$ Ga and ε_{Nd} from ca. −2 to −14, characterized by the presence of magmatic epidote and rapid rate of magma ascent (Sial et al., 2008). Identified with the 590–570 Ma time interval are abundant intrusions of magmatic epidote-free high-K calc-alkalic magmas, and peralkalic, metaluminous high-K syenitic, unique ultrapotassic, and rare shoshonitic magmas, for which T_{DM} ages vary from ca 1.5 to 2.5 Ga, and ε_{Nd} from ca. −8 to −20. Peralkalic and rare A-type magmas (T_{DM} 2.0–2.3 Ga) mark the end of the Brasiliano cycle. Outside the Transversal Zone domain, Neoproterozoic magmatic epidote-bearing granitoids also occur in the Seridó, Riacho do Pontal, and Macururé terranes of the Borborema province (Sial et al., 1999).

3. Field relationships and petrography

The Lourenço pluton intrudes the southern portion of the Alto Pajeú terrane, adjacent to its boundary with the Alto Moxotó terrane. The NNE-trending elongate body occupies ca. 170 km^2 and intrudes paragneisses and migmatites assigned to the São Caetano Complex (Gomes and Santos, 2001). Trends of regional foliation curve around the pluton, suggesting late-tectonic emplacement relative to the main stage of Brasiliano deformation. Most of the pluton presents NE–SW-trending magmatic foliation marked by sub-parallel feldspar and amphibole crystals, along which elongate 0.2 up to 5 m long quartz dioritic enclaves occur. Many of these typical co-magmatic enclaves have sharp contacts with the host pluton, with interfingered or rounded contours. Both enclaves and host rocks are locally cut by veins and dikes of pegmatite up to 1 m wide.

Major rock types are porphyritic to equigranular medium-to coarse-grained monzodiorite to monzonite with plagioclase ($An_{17–25}$) and K-feldspar ($Or_{87–89}Ab_{13–11}$) megacrysts up 4 cm long in random orientation in a medium-grained matrix. Major phases are amphibole, biotite, titanite, apatite, zircon, allanite, and epidote (Fig. 2A). Plagioclase is euhedral to subhedral with inclusions of amphibole or biotite, and many grains display myrmekite intergrowths. Amphibole occurs as subhedral megacrysts nearly as large as feldspars; it can also form millimeter-size clots in association with biotite.