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U–Pb ages, Sr–Nd- isotope geochemistry, and petrogenesis of kimberlites, kamafugites and phlogopite-picrites of the Alto Paranaíba Igneous Province, Brazil

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ABSTRACT

The kimberlites, kamafugites and phlogopite-picrites of Alto Paranaíba Igneous Province (APIP), southern Brazil, span a range between ~91 and 78 Ma with new in-situ, more tightly constrained U–Pb ages. The kimberlites show porphyritic texture with olivine xeno- and phenocrysts plus phlogopite, Fe-Ti-Cr oxides and perovskite microcrysts set in a carbonate-rich matrix. The kamafugites are feldspar-free rocks represented by ugandites and mafurites. Ugandites and mafurites are porphyritic and contain olivine and clinopyroxene phenocrysts in a fine-grained groundmass composed by clinopyroxene, perovskite, apatite, magnetite, phlogopite, leucite and/or analcime in ugandites, and by olivine, clinopyroxene, amphibole, phlogopite, perovskite, magnetite, kalsilite and Ba-zeolites in mafurites. Phlogopite-picrites have a pseudo-fluidal porphyritic texture with olivine phenocrysts and abundant phlogopite microcrysts in a groundmass composed by olivine, spinel, apatite, perovskite, calcite and rare garnet. New in-situ Sr and Nd isotopic data on perovskites ($^{87}Sr/^{86}Sr_i = 0.70467$–$0.70565$ and $^{143}Nd/^{144}Nd_i = 0.51222$–$0.51233$) fall within the known ranges of APIP rocks ($^{87}Sr/^{86}Sr_i = 0.70431$–$0.70686$; $^{143}Nd/^{144}Nd_i = 0.51205$–$0.51280$). The APIP magmas derived from a source assemblage made up of an old metasomatized mica-carbonate garnet lherzolite, that did not suffer interaction with convective mantle, nor with any hypothetical melts derived from a Trindade mantle plume. Geochemical modelling show that low degree melting ($f = 0.5$–2%) of such a source can produce compositions resembling the APIP rocks. The geochemical and isotopic composition of the magmas, the calculated degrees of partial melting, the composition of the calculated source and the absence of a hot spot track from Goias to Alto Paranaíba igneous provinces can be explained with the presence of chemically and mineralogically heterogeneous mantle sources that melted at different pressures.

1. Introduction

The Alto Paranaíba Igneous Province (hereafter APIP) extends over an area of ~20,000 km^2 in southeastern Brazil (Fig. 1). This province comprises Late Cretaceous strongly alkaline (kamafugites, kimberlites, lamprophyres) and carbonatitic rocks found as lava flows, pyroclastic successions and hypabyssal intrusions (Gibson et al., 1995; Brod et al., 2000; Araújo et al., 2001; Read et al., 2004; Gomes and Comin-Chiaramonti, 2005; Melluso et al., 2008). The Cretaceous alkaline magmatism of APIP developed along a NW–SE lineament (Bardet, 1977; Tompkins, 1991; Biondi, 2005). These rocks, with their economic potential in terms of high percentage of precious minerals and elements for industrial purposes, as for example diamonds in Três Ranchos kimberlites, or P, Nb, Ti, REE elements as residual and supergene enrichment over the Catalão I and II rocks (Biondi, 2005), moved the interest of a large number of researchers, who proposed different models to explain the origin and the petrological evolution of the igneous rocks of this area. The APIP magmatism has been related to asthenospheric or lithospheric melting caused by passage of the South American platform over a hotspot (Trindade Plume, Gibson et al., 1995; Thompson et al., 1998; Carlson et al., 2007; Bulanova et al., 2010). Such a mantle plume would have been successively channelled towards SE, in areas characterized by relatively thinned lithosphere, to form the Serra do Mar Igneous Province and the Trindade-Martin Vaz volcanic lineament (Thompson et al., 1998). This plume model is essentially based upon a supposed track of igneous activity, with ages decreasing from NW (APIP) to the SE (the easternmost sector of the Serra do Mar; Thompson et

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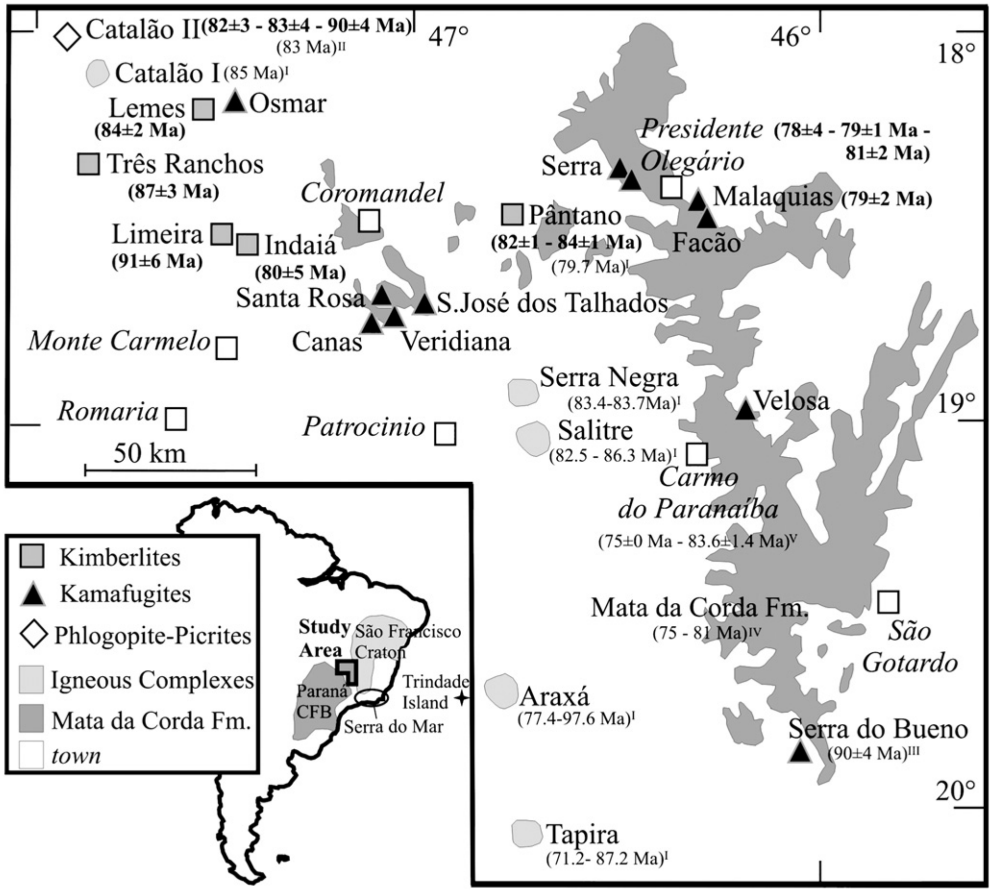

Fig. 1. Localization of APIP complexes studied, southern Brazil (modified after Melluso et al., 2008). In this figures are summarized all ages referred of the APIP complex, specifically we are reported our new U–Pb perovskite data ages (in bold) and the data ages taken by: Sonoki and Garda, 1988 (I); Machado, 1991 (II); Gibson et al., 1994 (III); Sgarbi et al., 2004 (IV); Gibson et al., 1995 (V).

al., 1998; Bennio et al., 2002, 2003; Brotzu et al., 2005, 2007), but without strong geochemical and/or petrological constraints.

We present new in-situ U–Pb ages and Sr–Nd isotopic ratios on perovskites. New bulk-rock Sr–Nd isotopic ratios are also reported for phlogopite-picrite rocks of Catalão II complex. In addition, we expand the data on the mineral chemical and bulk-rock major and trace element data of APIP rocks from the districts of Limeira, Lemes, Indaiá, Pantano, Presidente Olegario, Facão, São Josè dos Talhados, Osmar, Serra, Serra do Bueno, Velosa and Catalão II (Fig. 1), some reported here for the first time, thus completing and improving the data set of Melluso et al. (2008).

2. Geological setting and previous age determinations

The APIP is a large igneous province located across SE Minas Gerais and SW Góias on a late Precambrian mobile belt (the Brasilia Belt), between the NE margin of the Paraná Basin and the SW margin of the São Francisco Craton (Almeida et al., 2000; D'Agrella-Filho et al., 2011; Peucat et al., 2011, and references therein). The Late Cretaceous–Cenozoic igneous rocks of southeastern Brazil are aligned along two main trends: the first is oriented along NW–SE (APIP), whereas the second trends W–E (Serra do Mar Igneous Province). The mafic potassic to ultrapotassic magmatism of APIP consists of different igneous forms including plugs, dykes, lava flows, pipes, pyroclastic deposits and plutonic complexes. The most continuous and extensive cover of lava flows and tuff beds of the APIP is the Mata da Corda formation, extending over an area of ~8000 km^2 and an average thickness of ~100–120 m (Leonardos et al., 1991; Sgarbi et al., 2000; Read et al., 2004).

These complexes have been thoroughly investigated by means of geochronology. Sonoki and Garda (1988) obtained K–Ar ages on Catalão I (85 Ma, whole-rock), Pantano (79.7 Ma, whole-rock), Serra Negra (83.4–83.7 Ma, biotite separates), Salitre (82.5–86.3 Ma, biotite separates and 79.0–94.5 Ma, whole-rock), Araxá (77.4–97.6 Ma, biotite separates) and Tapira (71.2–87.2 Ma, biotite separates); Machado (1991) reported a Rb-Sr age of 83 Ma for the Catalão II igneous complex; Gibson et al. (1994) reported a $^{40}Ar/^{39}Ar$ ages for Serra do Bueno (90 ± 4 Ma on groundmass); Sgarbi et al. (2004) defined U–Pb perovskite ages for the Mata da Corda kamafugites (75–81 Ma) and Gibson et al. (1995) reported K–Ar ages of Carmo do Paranaíba (75 ± 0 and 83.6 ± 1.4 Ma on phlogopite separates).

3. Analytical techniques

Major and trace elements (Sc, V, Cr, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba) of APIP rocks were obtained using a Philips PW1400 X-ray fluorescence spectrometer at C.I.S.A.G., University of Napoli Federico II, following methods described by Melluso et al. (2005). Major elements for Catalão II rocks are obtained with ICP-OES methods at Actlabs (Canada). Lanthanides (REE) and other trace elements from the APIP rocks have been analysed using ICP-MS at Actlabs (Canada). Mineral analyses were performed at C.I.S.A.G., University of Napoli Federico II, utilizing an Oxford Instruments Microanalysis Unit: a JEOL JSM-5310 electron microscope equipped with an INCAx-act EDS detector operating at 15 kV accelerating voltage, 50–100 nA beam current and variable spot size. Details of standards are provided in Melluso et al. (2010). Bulk-rock Sr and Nd isotope analyses were performed at the Geochronological Research Center, University of