Journal of South American Earth Sciences 70 (2016) 224–236

Contents lists available at ScienceDirect

Journal of South American Earth Sciences

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

Crystallization conditions of porphyritic high-K calc-alkaline granitoids in the extreme northeastern Borborema Province, NE Brazil, and geodynamic implications

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ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form
9 May 2016
Accepted 25 May 2016
Available online 27 May 2016

Keywords:
Mineral chemistry
Crystallization parameters
High-K calc-alkaline granites
Borborema Province
NE Brazil

ABSTRACT

An integrated textural and chemical study on amphibole, biotite, plagioclase, titanite, epidote, and magnetite was conducted in order to estimate crystallization conditions, along with possible geodynamic implications, for six Ediacaran porphyritic high-K calc-alkaline granite plutons (Monte das Gameleiras, Barcelona, Acari, Caraúbas, Tourão, and Catolé do Rocha) intrusive into Archean to Paleoproterozoic rocks of the São José do Campestre (SJCD) and Rio Piranhas-Seridó (RPSD) domains, northern Borborema Province. The studied rocks include mainly porphyritic leucocratic monzogranites, as well as quartz-monzonites and granodiorites. Textures are marked by K-feldspar megacrysts (5–15 cm long) in a fine-to medium-grained matrix composed of quartz, plagioclase, amphibole, biotite, as well as titanite, epidote, Fe–Ti oxides, allanite, apatite, and zircon as accessory minerals. Amphibole, biotite and titanite share similar compositional variations defined by increasing Al and Fe, and decreasing Mg contents from the plutons emplaced into the SJCP (Monte das Gameleiras and Barcelona) towards those in the RPSD (Acari, Caraúbas, Tourão, and Catolé do Rocha). Estimated intensive crystallization parameters reveal a weak westward range of increasing depth of emplacement, pressure and temperature in the study area. The SJCD plutons (to the east) crystallized at shallower crustal depths (14–21 km), under slightly lower pressure (3.8–5.5 kbar) and temperature (701–718 °C) intervals, and high to moderate oxygen fugacity conditions ($+0.8 < \Delta_{FQM} < +2.0$). On the other hand, the RPSD plutons (to the west) were emplaced at slightly deeper depths (18–23 km), under higher, yet variable pressures (4.8–6.2 kbar), temperatures (723–776 °C), and moderate to low oxygen fugacity conditions ($-1.0 < \Delta_{FQM} < +1.8$). These results reinforce the contrasts between the tectono-strutuctural domains of São José do Campestre and Rio Piranhas-Seridó in the northern Borborema Province.

1. Introduction

Mineral chemistry of ferromagnesian minerals and coexisting phases has been widely used for estimating intensive crystallization parameters of granitic rocks (e.g., Anderson, 1996; Elliott, 2001; Stein and Dietl, 2001; Helmy et al., 2004; Anderson et al., 2008). This is due to the close relationship between the observed mineral assemblages and the nature and evolution of a crystallizing magma (Abbott, 1985). For instance, amphiboles have been successfully used for geothermobarometry (Hammarstrom and Zen, 1986; Schmidt, 1992; Holland and Blundy, 1994; Ridolfi and Renzulli, 2012; Erdmann et al., 2014); and their compositional variations can be related to the alumina saturation index and the degree of magma alkalinity, as well as to the redox conditions during crystallization (e.g., Strong and Taylor, 1984; Papoutsa and Pe-Piper, 2014; Vilalva et al., 2016). Biotite is also a major ferromagnesian phase in many granite plutons. Its composition is strongly dependent on the nature and redox conditions of the

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http://dx.doi.org/10.1016/j.jsames.2016.05.010
0895-9811/

magma from which it has crystallized (e.g., Wones and Eugster, 1965; Abdel-Rahman, 1994; Stussi and Cuney, 1996). Furthermore, qualitative and quantitative estimates of pressure, temperature and oxygen fugacity can be obtained from the composition of accessory minerals such as titanite, epidote, and Fe–Ti oxides (e.g., Zen and Hammarstrom, 1984; Andersen and Lindsley, 1985; Wones, 1989; Enami et al., 1993; Sial et al., 2008).

Calc-alkaline granites commonly contain the mafic assemblage biotite + hornblende + titanite + Fe–Ti oxides, along with quartz and feldspars; a feature that renders these rocks as important sites for petrologic studies using mineral chemistry (e.g. Vyhnal et al., 1991; Ague, 1997; Stein and Dietl, 2001; Helmy et al., 2004). The northeastern portion of the Borborema Province (NE Brazil) is marked by an extensive Ediacaran granitic magmatism, in which porphyritic high-K calc-alkaline granitoids are the most voluminous varieties (Nascimento et al., 2015). These rocks share similar textures and mineralogy, but contrasted chemical features as seen in their mineral chemistry. Although this is of major importance for understanding the nature and evolution of the magmatism in this region, there are few papers (e.g., Cavalcante et al., 2014) dedicated to report and discuss mineralogical aspects and intensive crystallization parameters for these rocks.

The present work reports textural studies and chemical data for amphibole, biotite, plagioclase, titanite, epidote, and magnetite for six different porphyritic, high-K calc-alkaline granite plutons within the northeastern Borborema Province. The integrated results are used to verify chemical contrasts among the plutons, as well as to provide estimates of intensive crystallization parameters (temperature, pressure, oxygen fugacity), and to discuss possible geodynamic implications.

2. Geological background

The Borborema Province (NE Brazil) is characterized by expressive Ediacaran to Cambrian granitic magmatism, important shear zones, and evolution through a complex collage of Archean to Paleoproterozoic gneissic-migmatitic crustal blocks, and supracrustal units that include Proterozoic metasediments and metavolcanic rocks (Almeida et al., 1981; Brito Neves et al., 2000; Ganade de Araújo et al., 2014). Angelim et al. (2006) divide the northeasternmost portion of the province into three distinct tectono-structural domains: the Jaguaribeano, the Rio Piranhas-Seridó, and the São José de Campestre domains (Fig. 1). A number of chemically distinct igneous bodies (Nascimento et al., 2015) associated to the Ediacaran magmatism intrude Archean to Paleoproterozoic migmatitic gneisses of the São José do Campestre (SJCD), and Paleoproterozoic migmatitic gneisses (Caicó Complex) and Neoproterozoic supracrustal rocks (Seridó Group) of the Rio Piranhas-Seridó (RPSD) domains. Based on petrographic and chemical properties, Nascimento et al. (2015) defined six granitoid suites (Fig. 1), namely shoshonitic, porphyritic high-K calc-alkaline, equigranular high-K calc-alkaline, calc-alkaline, alkaline, and alkaline charnockitic. For the purposes of this work, six different granite bodies from the most voluminous porphyritic high-K calc-alkaline suite were select from both SJCD (Monte das Gameleiras and Barcelona plutons) and RPSD (Acari, Caraúbas, Tourão, and Catolé do Rocha plutons). In common, they all constitute relatively homogeneous bodies of batholithic dimensions (260–880 km^2)

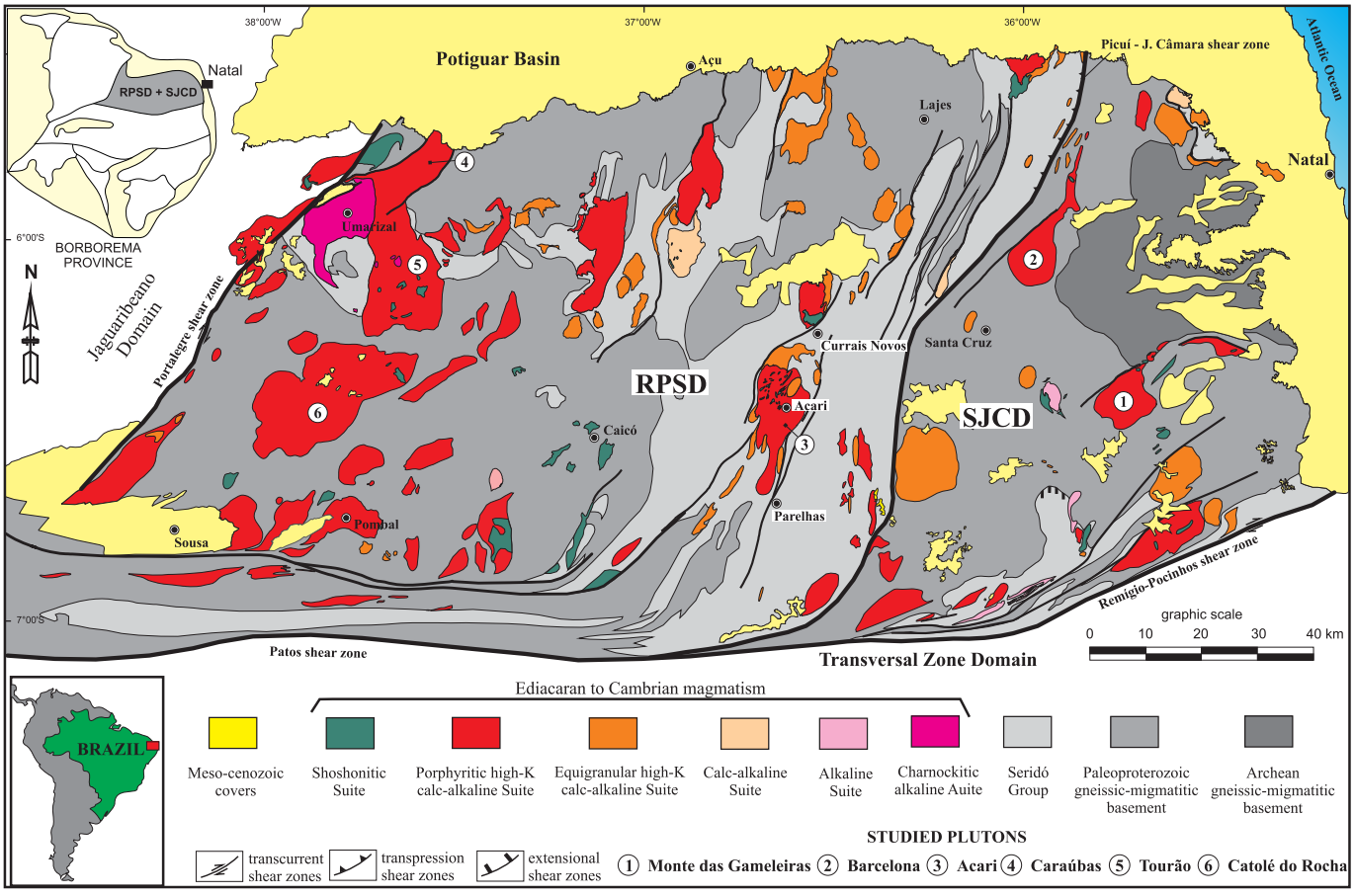

Fig. 1. Geological framework of the extreme northeastern Borborema Province (NE Brazil) showing the Jaguaribeano, the Rio Piranhas-Seridó, and the São José de Campestre domains (Medeiros, 2013), and the Ediacaran to Cambrian magmatism (modified from Nascimento et al., 2015), with the location of the studied plutons.