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Petrogenesis of A-type Granitoids from the Alto Moxoto and Alto Pajeu Terranes of the Borborema Province, NE Brazil: Constraints from Geochemistry and Isotopic Composition

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Abstract

A-type granitoids (~512 Ma) either intruded into Paleoproterozoic gneiss of the Alto Moxoto Terrane (Prata Complex and Serra da Engabelada Pluton) or into Early Neoproterozoic metavolcanic metasedimentary sequence of the Alto Pajeu Terrane (Serrote Santo Antonio Pluton), constitute a small proportion of Brasiliano (= Pan-African) granitoids in the Central Tectonic Domain of the Borborema Province, northeastern Brazil. The Prata Complex consists of syenogranites, monzogranites, mafic enclaves of diorites and norites. The felsic and mafic members are not genetically related through fractionation. Mingling and mixing were extensive processes within the Prata Complex. The granites evolution appears to have involved fractionation of alkali feldspar, biotite, apatite and sphene without significant wall-rock assimilation. The Serra da Engabelada and Serrote Santo Antonio plutons consist of biotite syenogranites, with rare mafic enclaves. The studied granitoids are dominantly metaluminous, characterized by Fe-rich biotite and Fe-hornblende. High total alkalis, Y, Nb and REE and low CaO, MgO and Sr abundances and high FeO/(FeO+MgO) ratios characterize these granitoids. Chondrite-normalized REE patterns show enriched LREE, moderate to strong negative Eu anomalies and more or less flat heavy REE.

The studied granitoids and diabase from dykes and enclaves show negative $\varepsilon Nd_{(512Ma)}$ values (–14 to –10), high incompatible elements such as LILE, HFSE and REE, suggesting important contribution of Paleoproterozoic crust. The origin of the granites is thought to have involved partial melting of granodioritic or tonalitic lower crust. Such isotopic signature of the diabase from the dykes also reflects a Paleoproterozoic enriched lithospheric mantle in the area. The intrusion of the studied granitoids contemporary with sub-volcanic bimodal magmatism and deposition of many Cambrian "pull-apart" basins in the north and central tectonic Domain of the Borborema Province, suggest intrusion during post-tectonic relaxation of the Brasiliano orogeny following the assembly of West Gondwana.

Key words: A-type granitoids, Cambrian, Borborema Province, post-tectonic magmatism, magma mixing.

Introduction

A-type granitoids as defined by Loiselle and Wones (1979) are anorogenic, characterized by high alkalis (Na_2O+K_2O) contents, FeO/(FeO+MgO) ratios, Ga/Al, Zr, Y, Nb, F, Cl and REE (except Eu), and low abundances of CaO and MgO (Collins et al., 1982; Whalen et al., 1987). They are also characterized by the presence of one or more of such ferromagnesian minerals as annite-rich biotite, ferro hastingsite, alkali amphibole and Na-pyroxene (Collins et al., 1982; Whalen et al., 1987; Eby, 1990). Landenberger and Collins (1996) argued that the elevated F contents in A-type granites could be due to fractional crystallization processes and as consequence, high-halogens contents are not a major feature of A-type granite.

Because A-type granitoids can be emplaced at any time during a tectonic-magmatic episode, the term anorogenic should not be used to characterize A-type granitoids (e.g., King et al., 1997; Barbarin, 1999; Wu et al., 2002; Kebede and Koeberl, 2003; Mushkin et al., 2003).

Many models have been proposed to the origin of A-type granitoids:

(1) Partial melting of deep crust of granulitic metaigneous sources previously depleted in a hydrous felsic melt (Collins et al., 1982; Clemens et al., 1986;

Whalen et al., 1987). This idea has been questioned by Creaser et al. (1991); Landenberger and Collins (1996) and Patiño Douce (1997), under the arguments that melting of a wide range of crustal rocks produces refractory granulitic residues that are depleted in alkalis relative to alumina and in TiO_2 relative to MgO. Remelting of such residue cannot produces magmas with A-type (high $Na_2O + K_2O/Al_2O_3$ and TiO_2/MgO) characteristics.

(2) Partial melting of charnockitic lower crust, formed as a residue from an earlier I-type magma extracted, at temperature >900°C, in a subduction-related tectonic setting (Landenberg and Collins, 1996).

(3) Dehydration melting of calc-alkaline granitoids (Anderson, 1983; Creaser et al., 1991). The experimental data of Patiño Douce (1997) confirm that A-type granitic melts can be generated in this way but, it is only possible if melting takes place in the shallow crust. The necessary high melting temperature requires the participation of hot mafic magmas in the origin of A-type granites, may be restricted to heat transfer or may entails shallow chemical interactions between basaltic melts and crustal rocks (Patiño Douce, 1997).

(4) Dehydration melting of amphibole-bearing tonalite at 6–10 kbar, leaving behind a granulitic residue, produces melts that resembles A-type granites, except for their somewhat high Al_2O_3 contents (Skjerlie and Johnston, 1992).

(5) Differentiation from basaltic magmas (Loiselle and Wones, 1979; Eby, 1992; Turner et al., 1992; Beyth et al., 1994).

(6) Small degree of partial melting of a felsic infracrustal source region, with water and F contents similar to those recorded in I-type granitoids source regions (King et al., 1997).

Only few granitic intrusions with geochemistry characteristics of A-type have been described in the Central Tectonic Domain of the Borborema Province (Melo et al., 1995; Melo et al., 1996). In this work, we provide geochemical, geochronological and isotopic data for the Prata Complex, Serra da Engabelada and Serrote Santo Antonio plutons and discuss their sources.

Regional Geological Aspects

The Borborema Province comprises a large region in northeastern Brazil, north of the São Francisco Craton (Fig. 1A). In pre-drift reconstructions, this province is adjacent to similar Pan-African and terranes in western Africa; thus, the Borborema Province represents the western part of a belt that occupies northern Gondwana (Van Schmus et al., 1995).

The Brasiliano – Pan-African Orogeny within the Borborema Province is characterized by the development of shear zones hundreds of kilometers long, large amount of granitic intrusions and metamorphism under high temperature conditions (Bittar, 1999; Leite et al., 2000). The majority of the granitoid intrusions had their emplacement controlled by shear zones.

The Central Tectonic Domain (Van Schmus et al., 1995), previously named Transversal Zone by Ebert (1970), was interpreted by Santos (1995), Santos et al. (1997) and Santos and Medeiros (1999), as the result of Brasiliano accretion of exotic terranes. According to this terrane-accretion model, the studied granitoids are located (Fig. 1A) in the Alto Moxoto and Alto Pajeú Terranes.

The Alto Moxoto Terrane is composed of metavolcano-metasedimentary sequences, including a calc-alkaline volcanic sequence of arc affinities and Paleoproterozoic blocks (2.1–2.4 Ga) of tonalitic-granodioritic composition (Santos, 1995). Only few granitic intrusions have been identified within the Alto Moxoto Terrane and they are mainly intruded along the contact zone between the Alto Moxoto Terrane, and either the Alto Pajeú and Rio Capibaribe Terranes.

The Alto Pajeú Terrane comprises muscovite-biotite gneisses, garnet-biotite schists, and metavolcanic rocks intruded by Early Neoproterozoic granitic gneisses (~ 950 Ma), deformed during the Brasiliano cycle, initially by a transcurrent episode and later by extension (Santos et al., 1997; Brito Neves et al., 2001). It is cut by large granitic intrusions, with ages in the 512–644 Ma range (Guimarães et al., 1999).

The timing of the peak of the metamorphism has not been determined systematically in the Central Tectonic Domain of the Borborema Province. In the Alto Pajeú Terrane, Leite et al. (2000) reported an upper intercept U-Pb zircon age of 972±4 Ma for orthogneisses intruded by the Brasiliano Tabira pluton, and a concordant sphene fraction from the same sample that is 612±9 Ma old. Guimarães et al. (2004) demonstrated that the intrusion of Timbaúba Complex (644 Ma) was pre- to syn-metamorphism. This evidence suggests that the metamorphism took place between 612–640 Ma.

Narrow and elongated deposits of detritic sediments, sandstones, arkoses and conglomerates occur to the west of the Alto Pajeú Terrane. These sediments have been interpreted as part of the Tacaratu Formation of the Jatobá Basin, of Upper Silurian age (Veiga Júnior and Ferreira, 1990). Other small Paleozoic basins occur in the Central Tectonic Domain (Betânia, Fátima, Carnaubeira, Mirandiba, São José do Belmonte-Veiga Júnior and Ferreira, 1990). The sediments cropping out in all of these small basins have been interpreted as chrono-correlated to the Tacaratu Formation. The absence of fossils in these sediments make it difficult to date them. The Upper Silurian age was estimated from lithologic correlation.