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Gravimetric, radiometric, and magnetic susceptibility study of the Paleoproterozoic Redenção and Bannach plutons, eastern Amazonian Craton, Brazil: Implications for architecture and zoning of A-type granites

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Abstract

The 1.88 Ga, anorogenic, A-type Redenção and Bannach granites, representative of the Jamon suite and associated dikes, are intrusive in Archean granitoids of the Rio Maria Granite–Greenstone Terrane in the eastern Amazonian Craton in northern Brazil. Petrographic and geochemical aspects associated with magnetic susceptibility and gamma-ray spectrometry data show that the Redenção and the northern part of Bannach plutons are normally zoned. They were formed by two magmatic pulses: (1) a first magma pulse was fractionated in situ after emplacement at shallow crustal level, generating a series of coarse, even-grained monzogranites with variable modal proportions of biotite and hornblende; and (2) a second, slightly younger magma pulse, located to the center of the plutons, was composed of a more evolved liquid from which even-grained leucogranites derived. Gravity modeling indicates that the Redenção and Bannach plutons are sheeted-like composite intrusions, approximately 6 and 2 km thick, respectively. These plutons follow the general power law for laccolith dimension and are similar in this respect to classical rapakivi granite plutons. Gravity data suggest that the growth of the northern part of the Bannach pluton resulted from the amalgamation of smaller sheeted-like plutons that intruded in sequence from northwest to southeast. The Jamon suite plutons were emplaced in an extensional tectonic setting, and the stress was oriented approximately NNE–SSW to ENE–WSW, as indicated by the occurrence of diabase and granite porphyry dyke swarms, orientated WNW–ESE to NNW–SSE and coeval with the Jamon suite. The 1.88 Ga A-type granite plutons and stocks of Carajás are disposed along a belt that follows the general trend defined by the dikes. The inferred tabular geometry of the studied plutons and the high contrast of viscosity between the granites and their Archean country rocks can be explained by magma transport via dikes.

Keywords: Gravity; Magmatic zoning; Laccolith; Anorogenic; Amazonian Craton

1. Introduction

During the past two decades, Proterozoic, A-type granites, dominantly rapakivi, have been described from many Precambrian shield areas, such as North America (Anderson and Bender, 1989; Emslie, 1991; Barnes et al., 2002; Anderson and Morrison, 2005), Fennoscandia (Haapala and Rämö, 1990; Rämö and Haapala, 1995; Kosunen, 2004), and the Amazonian Craton (Bettencourt et al., 1999; Dall'Agnol et al., 1999a, 2005). In the Amazonian Craton, felsic volcanic rocks and mafic and charnockitic plutonic rocks are also associated with rapakivi granites (Bettencourt et al., 1999; Dall'Agnol et al., 1999a; Fraga, 2002).

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A-type, rapakivi granites show a pronounced peak in the Proterozoic (∼1.88–1.0 Ga) and a bimodal mafic-felsic magmatic association (Rämö, 1991; Rämö and Haapala, 1995). The Proterozoic A-type granites also reveal large variation in their redox behavior, ranging from reduced to oxidized (Haapala and Rämö, 1990; Frost and Frost, 1997; Frost et al., 1999; Elliott, 2001; Anderson and Morrison, 2005; Dall'Agnol and Oliveira, 2007) and thus show evidence of substantial variation in crystallization conditions and source composition.

The tectonic setting of the Proterozoic A-type, rapakivi granites has remained an issue of controversy. The classic Proterozoic rapakivi granites are associated with mafic dike swarms, listric shear zones, and thinned crust (Rämö and Haapala, 1995). They were intruded into a crust that predates them by some hundred million years (e.g., Rämö and Haapala, 1995; Rämö et al., 2002; Dall'Agnol et al., 2005) and are found as discordant multiple plutons, which indicates an extensional tectonic setting and anorogenic origin (lack of direct association to convergent processes and resulting mountain building; Haapala and Rämö, 1999). However, other authors suggest that rapakivi granites could be related to distal orogenesis (Åhäll et al., 2000). Rapakivi granites and related "anorogenic" granites have become important tools for modeling Precambrian intraplate crustal processes and global-scale lithospheric evolution. An origin associated with crustal anatexis promoted by magmatic underplating is generally admitted (Huppert and Sparks, 1988; Rämö and Haapala, 1995; Dall'Agnol et al., 1999a).

Another common feature of the A-type granite plutons is their internal compositional zoning (Paradella et al., 1998; Costi et al., 2000; Rajesh, 2000; Teruiya, 2002; Richardson, 2004); generally, they are more mafic at the margins and grade inward, with or without discontinuities, to more felsic zones (near normal zoning). Reverse zoning (more mafic core than outer zones) may also be observed (Ceci and Frederick, 2002) but is most common in calc-alkaline granitoid plutons (Zorpi et al., 1989; Paterson and Vernon, 1995). Generally, the zoned plutons are interpreted as having been intruded in a continuous series of magmatic pulses, leading to in situ growing of the pluton (Bateman and Chappel, 1979; Pitcher, 1979; Zorpi et al., 1989; Petford, 1996). Their cores formed by subsequently emplaced, more mobile, differentiated rocks. In the case of anorogenic granites, neither the mechanisms nor the timing for zoning development are entirely understood.

Deep seismic sounding studies in the classical Wiborg rapakivi batholith indicate that it is a shallow, sheeted-like intrusion with associated mafic intrusions in deeper crustal levels (Rämö et al., 1994). The common occurrence of granite intrusions as sheet-shaped bodies is now recognized (Rocchi et al., 2002; Aranguren et al., 2003; Pons et al., 2006), and models of the formation of such intrusions have been discussed (Román-Berdiel et al., 1995). The classic diapiric models for granite intrusion (Ramberg, 1970; Weinberg, 1996) have been criticized, and the role of dikes in the ascent of felsic magmas was emphasized (Clemens and Mawer, 1992; Petford et al., 1994; Petford, 1996).

Proterozoic A-type granites have been described from the Archean Rio Maria region in the eastern Amazonian Craton in Brazil (Dall'Agnol et al., 1999b, 2005). The Jamon Paleoproterozoic A-type granite suite has been dated at 1.88 Ga and was intruded into an approximately 3 Ga old crust characterized by greenstone belts and granitoid rocks. The Archean crust remained stable until the 1.88 Ga granite magmatism commenced. The Jamon suite is formed by the Redenção, Bannach, Jamon, Musa, Marajoara, Manda Saia, Seringa, São João, and Gradaús plutons (Fig. 1b). These granites are usually undeformed, shallow-level plutons associated with bimodal dyke swarms, locally forming composite mafic-felsic dikes. They are high-K granites with subalkaline A-type chemistry, show a pronounced oxidized character (Dall'Agnol et al., 2005; Dall'Agnol and Oliveira, 2007), and display many characteristics of the oxidized, mid-Proterozoic A-type granites of the western United States (Anderson and Bender, 1989; Barnes et al., 2002; Anderson and Morrison, 2005).

The mineralogy, geochemistry, and petrology of the Jamon suite granites are relatively well studied (Dall'Agnol et al., 1999b, 2005; Almeida, 2005). However, the internal zoning, tridimensional shape, and emplacement history of its plutons needs additional investigation. Airborne magnetic and radarsat image analysis provide an integrated view of the regional geological features of the area of the Redenção and Bannach plutons. Aeroradiometric (gamma ray) surveys and magnetic susceptibility data are associated with field, petrographic, and geochemical data to clarify their internal zoning. In parallel, a gravity survey on the mentioned plutons is conducted. Tridimensional modeling provides an estimate of the mass distribution at depth and allows estimation of the shape and thickening of the plutons. The new geophysical data acquired in the Redenção and Bannach plutons enable a reinterpretation of the magmatic evolution and serves as a basis for an initial discussion about the mechanisms of their emplacement.

2. Geologic setting

The Jamon suite is situated in the Carajás province of the eastern Amazonian Craton (Dall'Agnol et al., 2005). The Carajás province, included in the Central Amazonian province (Tassinari and Macambira, 2004; Fig. 1a), is dominated by Archean terrains intruded by Paleoproterozoic anorogenic granites. To the west, it is limited by a terrane dominated by Proterozoic granitoids and Uatumã volcanic-pyroclastic assemblages; to the east, by the Neoproterozoic Araguaia Belt, whose evolution is associated with the Brasiliano (Pan-African) cycle that did not significantly affect the Amazonian Craton; and to the north, by the Maroni-Itacaiúnas province, formed during the 2.2–2.1 Ga Trans-Amazonian event (Fig. 1a).