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Complex, 3D strain patterns in a synkinematic tonalite batholith from the Araçuaí Neoproterozoic orogen (Eastern Brazil): Evidence from combined magnetic and isotopic chronology studies

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ABSTRACT

This work combines structural and geochronological data to improve our understanding of the mechanical behaviour of continental crust involving large amount of magma or partially melted material in an abnormally hot collisional belt. We performed a magnetic and geochronological (U/Pb) study on a huge tonalitic batholith from the Neoproterozoic Araçuaí belt of East Brazil to determine the strain distribution through space and time. Anisotropy of magnetic susceptibility, combined with rock magnetism investigations, supports that the magnetic fabric is a good proxy of the structural fabric. Field measurements together with the magnetic fabrics highlight the presence in the batholith of four domains characterized by contrasted magmatic flow patterns. The western part is characterized by a gently dipping, orogen-parallel (~NS) magmatic foliation that bears down-dip lineations, in agreement with westward thrusting onto the São Francisco craton. Eastward, the magmatic foliation progressively turns sub-vertical with a lineation that flips from sub-horizontal to sub-vertical over short distances. This latter domain involves an elongated corridor in which the magmatic foliation is sub-horizontal and bears an orogen-parallel lineation. Finally the fourth, narrow domain displays sub-horizontal lineations on a sub-vertical magmatic foliation oblique (~N150°E) to the trend of the belt.

U/Pb dating of zircons from the various domains revealed homogeneity in age for all samples. This, together with the lack of solid-state deformation suggests that: 1) the whole batholith emplaced during a magmatic event at ~580 Ma, 2) the deformation occurred before complete solidification, and 3) the various fabrics are roughly contemporaneous.

The complex structural pattern mapped in the studied tonalitic batholith suggests a 3D deformation of a slowly cooling, large magmatic body and its country rock. We suggest that the development of the observed 3D flow field was promoted by the low viscosity of the middle crust that turned gravitational force as an active tectonic force combining with the East-West convergence between the São Francisco and Congo cratons.

1. Introduction

The evolution of collisional orogenic belts at convergent plate boundaries is always associated with magma ascent, pluton emplacement and sometimes, extensive partial melting of the continental crust. It is well known that presence of melt, even in limited proportions, significantly modifies the mechanical behaviour of rocks (Rosenberg and Handy, 2000). Less than 7% of melt in a rock drastically decreases rock strength, triggering strain localization where the melt is located (Brown, 1994; Tommasi et al., 1994; Brown and Solar, 1999; Rosenberg and Handy, 2005). Volumes of melt in solid rocks, able to promote strain localization over large domains (Petitgirard et al., 2009), have been identified in the middle crust of several orogenic belts associated with high geothermal gradients. Such "hot orogens" have been recognized in Achaean and Proterozoic belts involving TTGs (tonalites, trondhjemites, granodiotites), migmatites and greenstones (Cagnard et al., 2006), but also in Phanerozoic and active orogenic belts involving tonalites, granodiorites, diorites and partially melted materials

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(Nelson et al., 1996; Schmitz et al., 1997; Alsdorf and Nelson, 1999; Clark and Royden, 2000; Beaumont et al., 2001). Typical behaviours in such orogens includes: (1) distributed horizontal shortening with vertical stretching along transpressive zones (Windley, 1992; Ehlers et al., 1993; Choukroune et al., 1995; Benn and Peschler, 2005), and (2) channelized horizontal escape (Royden, 1996; Royden et al., 1997), due to inability of the weak lithosphere to sustain the load of high topographies (England and Bickle, 1984). Cagnard et al. (2006) and Chardon et al. (2009) suggested that these two mechanisms might be in competition and the bulk deformation may result from a combination of tangential tectonics, inducing distributed horizontal shortening, with gravitational force leading to channelized horizontal escape. Even if numerical and analogue models have been built to account for such complex deformations, the main parameters, conditions or thresholds that permit such peculiar kinematics are poorly understood. Natural examples of orogens involving large amounts of melted material allow refining our knowledge about the initial conditions leading these complex 3D strain patterns. To better constrain the effect of large volume of magma on the tectonic behaviour of the crust, we studied the strain repartition in the central unit of the Araçuaí belt (Eastern Brazil; Fig. 1A), >250 km long and >50 km wide, that contains large volumes (50–90%) of tonalitic to granodioritic magmas emplaced into host metasediments (Fig. 1B). The Araçuaí belt is a “modern” (Neoproterozoic) hot orogen characterized by a high orogenic geotherm (30–35 °C/km), a slow cooling rate (<5°C/Ma), widespread partial melting and intrusion of large batholiths (e.g., Vauchez et al., 2007; Petitgirard et al., 2009).

To constrain the deformation history during batholith emplacement in the Araçuaí belt, we combined structural and geochronological studies on the tonalitic batholith of the Central Plutonic Unit of the Araçuaí belt. Since the foliation and especially the lineation are not always observable in the field, we measured the Anisotropy of Magnetic Susceptibility (AMS) to obtain a reliable and useful structural map (Borradaile, 1988, 2001; Henry, 1989; Bouchez et al., 1990; Tarling and Hrouda, 1993; Borradaile and Henry, 1997; Bouchez, 1997, 2000; Ferré et al., 2003; Borradaile and Jackson, 2004; Egydio-Silva et al., 2005; Raposo and Berquo, 2008; Raposo and Gastal, 2009). In addition, to determine the carriers of the magnetic anisotropies, we performed a detailed rock magnetism study. Large variations of the magmatic fabric across the batholith raise the question of the timing of its formation: Are the various fabrics representative of modifications of the strain field through time or of a spatial heterogeneity of strain during a single magmatic event? To place time constrains on the batholith evolution, we performed systematic U/Pb dating on zircons from samples representative of the different facies and structural fabrics observed in the studied area.

2. Geological setting

The Araçuaí Neoproterozoic belt, the northern continuation of the Ribeira belt (Almeida, 1977), represents the counterpart of the West Congo belt (Trompette, 1994; Pedrosa-Soares et al., 1998; Heilbron et al., 2010 and references therein). The Ribeira-Araçuaí belt was formed during the Brasiliano/Pan-African orogeny caused by the convergence between the South American and African protocontinents (Fig. 1A). To the South, the belt trends NE-SW and is characterized by a transpressional regime (Trompette, 1994; Vauchez et al., 1994; Egydio-Silva et al., 2002, 2005; Schmitt et al.,

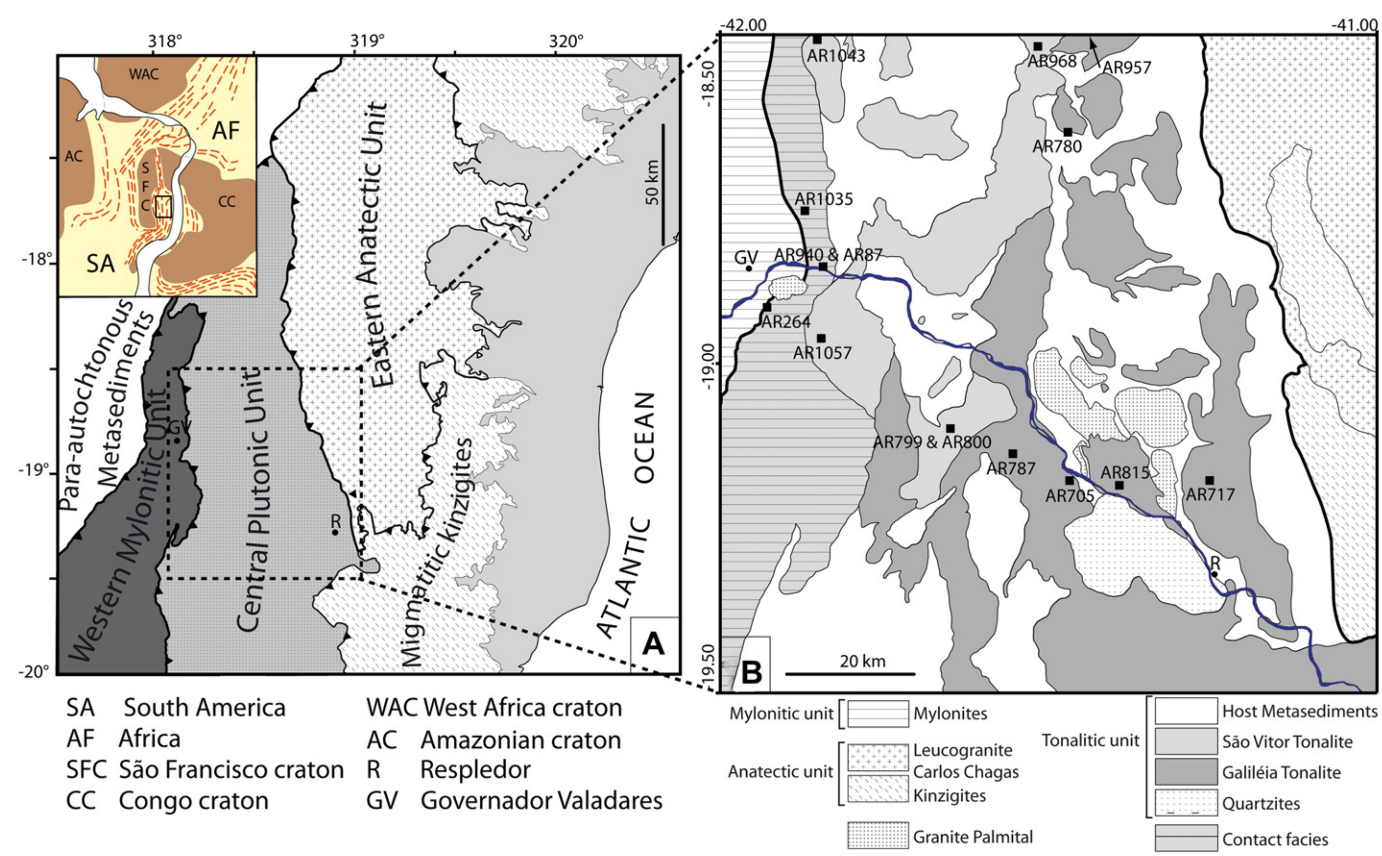

Fig. 1. A: Schematic maps of the Northern part of the Ribeira-Araçuaí belt (from Vauchez et al., 2007) showing the 3 main allochtonous units thrust westward upon the para-autochthonous metasediments of the São Francisco craton. Upper left corner inset is a schematic map of the final stage of assembly of the West Gondwana. B: Blow up showing the repartition of the various rock types in the central plutonic domain. Points with numbers show the location for magnetic and geochronological samples.