GRANITOIDES OF THE STATE OF BAHIA, BRAZIL

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I. INTRODUCTION

In Bahia State, the main geological elements of interest to the present summary are a part of the São Francisco Craton, with some of its surrounding late Proterozoic (Brasiliano Pan African) fold-belts. Very large areas of the State are covered by late Precambrian to Quaternary Sediments.

The term "São Francisco Craton" (SFC) was introduced by Almeida (1967) to indicate a region which became stabilised in the late Proterozoic It is very widley used in Brazilian literature. The main elements in Bahia are (Mascarenhas and Sá, 1982; Bernasconi, 1983): (i) high-grade terrains, subdivided into toponymic complexes whose boundaries are often imprecise and mutual relationships, obscure. These terrains have Archean elements with varying degrees of Proterozoic addition and reworking; (ii) granite-greenstone (s.l.) terrains, whose ages are still open to debate; (iii) early to middle Proterozoic fold belts in which mafic volcanic rocks form a small fraction, or are absent. The late Proterozoic fold belts have a restricted occurrence in the State. Part of the Sergipe fold belt extends into the extreme northeastern part, while the extreme southeastern and south-central parts of the State are on the fringes of the Araçuai belt.

Granitoids and related rocks are encountered throughout the Precambrian. In this summary, a chronological presentation is generally adopted, though some older granitoids are described within what we believe to be their much younger geological context. The areas described are not all known personally to the authors. Published descriptions have widely different degrees of detail and in many cases, a detailed discussion of the granitoids and their genesis was not the principal aim of the study. The presentations vary, therefore, from purely descriptive to more analytic.

II. ARCHEAN

High-grade terrains of known or inferred Archean ages form a large part of the SFC Polyphase deformation, open-system metamorphism and anatexis are frequently intense, and the identification of many of the protoliths is consequently difficult.

Large areas of the *Caraiba* and *Itabuna* complexes are believed to be derived from supracrustal rocks (Figueiredo, 1982; Sighinolfi, 1970; Sighinolfi *et al.,* 1981; Oliveira *et al.,* 1982) in which granitoids intrusives bodies are not a conspicuous feature.

The *Jequié* granulite complex preserves some nucleii with Rb/Sr whole-rock isochron ages of about 3.1 G.a, but was widely affected by a 2.7 G.a event (Mascarenhas and Sá, 1982). Augen and other gneisses with a wide range in composition from granite to norite and anorthosite form an important component of parts of this complex. Augen of alkali feldspar and/or sodic plagioclase are sometimes abundant, hypersthene is usually present, sometimes pseudomorphed by amphibole, and most rocks contain traces of amphibole and/or biotite. Secondary quartz is often present, and localised retrograde metamorphism at low grade is not un common.

Most analysed samples from a prominent belt of these rocks are felsic ($SiO_2 \geqslant 63\%$). Compared to many other granulite terrains, they are undepleted or even enriched in K, Rb, Ba, etc. REE patterns are moderately LREE-enriched with pronounced negative Eu anomalies and sometimes, negative Ce anomalies. (Sighinolfi *et al., op. cit.;* Oliveira *et al., op.cit.*).

The *Paramirim* gneiss-migmatite complex in the Paramirim River valley has orthogneisses of predominantly granodioritic composition and sodic affinities ($Na_2O > K_2O$ in wt %; Sr/Rb >1). They were metamorphosed at about 2.7 Ga. Low initial $^{87}Sr/^{86}Sr$ ratios have been interpreted in terms of short crustal residence times. The 2.7 Ga metamorphism reached anatexis, with the formation of potassic granites (Sr/Rb < 1) intruded as dikes and sills. REE patterns for both types are rather similar, with strong LREE enrichment and pronounced Eu anomalies. (Jardim de Sá, 1978).

Granitic rocks are also recorded from the Santa Isabel and Guanambi complexes, but few details are available.

III. TRANSAMAZÔNICO

A – The terranes whose tectonic history is related to the Transamazônico (Eburnean) form two great meridian belts. almost aligned. along the median axis of the SFC, that correspond respectively with the volcano-sedimentary formations of the *Serra de Jacobina*, in the North and of the *Contendas-Mirante* complex, in the south.

The age of deposition of the later is still controversial. Isotopic determinations Rb/Sr, on the metavolcanics and phyllite of the Contendas Mirante complex indicate ages about 2.4 to 2.0 Ga (Cordani *et al.*, 1985) but the authors do not rule out an original Archean age, at least for the volcanics.

The two principal continuous phases of deformation and the accompanying epizonal metamorphism are, on the other hand, attributed to Transamazônico events (Sabaté *et al.,* 1979). The forced "mise en place" of the muscovite bearing granites occurred, according to the authors, during the second folding phase. The isotopic age of those intrusions is established between 1.9 and 1.8 Ga (Petta, 1979; Cordani *et al.,* 1985).

An age of 2.3 Ga is advanced for the sedimentary deposits of the Jacobina Group (Brito Neves *et al.*, 1980) but here again, the "mise en place" of the granites, which followed a tectonic episode of overthrusting is established around 1.9 Ga (Torquato *et al.*, 1978).

The intrusions form a string of bodies aligned on the axis of the volcano-sedimentary belts or over an extension of nearly 600km. They are composed of leucocratic granites where muscovite is the characteristic varietal mineral. The crustal origin of these granites is argumented. From their juxtaposition with the chromitiferous ultramafic formation of Anagé, in the Southern part of the Contendas-Mirante Complex, or in Campo Formoso and Carnaiba in the northern part of the Serra de Jacobina, results probably the emerald mineralization exploited in the prospectors pits.

Rudowski *et al.,* (1986 and this volume) associate to hydrothermal phases, related to the aplopegmatite cortege of the granite, the metasomatic zonations in the ultramafic host rocks and the Be, Mo, W related mineralizations of Socotó and Carnaiba.

B – Several authors (Inda and Barbosa, 1978; Mascarenhas, 1979a, b; Brito Neves *et al.,* 1980) also associated the *"Serrinha Complex"* with the Transamazônico lithostructual units, although with some reserves. The current consensus is that, since the complex has a structure similar to Archean greenstone belts known at the time of these earlier works, then the age, by analogy, should be Archean or, at least, Lower Proterozoic.

However the Rb/Sr isotopic ages for migmatites of the greenstone belt envelope, the intrusive granites of Arací, Santa Luz and Nordestina, as well as the metavolcanites of the supracrustal unit are similar at about 2.1 Ga, and also consistent with the K/Ar determinations.

They are attributed, with some restrictions, to the epoch of formation of the rocks (Brito Neves *et al.,* 1980) and seem to be confirmed by U/Pb results still unpublished (see Matos and Davison, this Symposium).

The granites associated with these terrains, hence forward designated "greenstone belt of the Rio Itapicuru" (Kishida, 1979) are of two kinds: (1) concordant massifs structured with the supracrustal formations and that are probably intrusive domes (see Matos and Davison, this Symposium) of forced "mise en place"; (2) later intrusions.

1. Granitoid Domes. The Rio Itapicuru greenstone belt is laterally bounded by granites and granite-gneisses. Some of the granites are clearly intrusive into the greenstone and post-date the deformation, while others have been suggested to be sialic basement of the greenstone (Jardim de Sá, 1982, Silva, 1983). Recent studies further clarify the evolution of this greenstone.

In granite gneisses to the SW of the area, tectonic banding is usually discordant with the trend of the greenstone, no contact metamorfism is observed and no veins cut the greenstone. This gneiss complex is therefore believed to be the basement. In complete contrast, the Ambrósio and Pedra Alta domes within the greenstone show ample evidence to indicate that they were intruded as a near-solid crystal mush in which basement or supracrustal xenoliths are concentrated near the highly deformed margins, the cores of the domes consisting of weakly deformed biotite granodiorite.

2. The subconcordant to discordant intrusions with late "mise en place" relative to tectonic strains are medium grained granitoids which pertain to three distinct calc-alkaline suites, respectively tonalitic, granodioritic and monzonitic (Machado *et al.,* 1984; Sabaté *et al.,* this symposium).

C – The Syenite massif of Itiuba is a huge N-S aligned, 150 x 12km batholith which occurs in the center-north region of the state, occupying a suture between granulite terrains to the west, and gneiss-migmatite terrains to the east. Structures and textures present have been interpreted as the results of regional metamorphism, and the 1.8-2.2 Ga ages found (Figueiredo, 1976; Bartels *et al.,* 1984) are considered as reflecting this event. A model emplacement age of 2.7 Ga has been calculated (Figueiredo, *op. cit.*). In the Poço de Fora area at the extreme north of the batholith, Leube (1972) found ages of 1.0 Ga which may reflect reactivation.

Work in progress on the southern part of the batholith (Conceição, unpublished) demonstrates that the principal rock types present are leuco to mesocratic oversatured syenites. Overall, a distinction can be made between magmatic and tectonic facies. The magmatic facies, with little modification of primary textures, are observed in the central parts of the pluton. Intermediate and ultramafic enclaves are abundant. Bands of amphibole and clinopyroxene, often rich in apatite, magnetite and sphene, are widely ~ distributed. Syenitic and alkali-feldspar granite pegmatite dykes are also present. The tectonic facies, composed of mylonitic and ultramylonitic gneisses, occur at the borders of the body and in close association with the faults which cross-cut the body.

At the western border, near the city of Itiúba, a granite dyke generation was intruded simultaneously with the deformation under NW-SE compression. On the other hand, the northern part of the Pedra Solta granite lacks signs of this deformation, nor does it have the deformations which are seen in the granulite terrain to the west.

There is some doubt, therefore, as to what extent the gneissic fabrics reported in other areas of the body are due to phenomena related to emplacement on the one hand, and later tectonic effects on the other.

Chemically, the syenites are miaskitic, and chemical variations observed correspond well with the mineralogical variation. The rocks are notable for very high Sr and Ba contents (Figueiredo, 1976, 1981). REE patterns show very strong enrichment of LREE relative to HREE and lack Eu anomalies, characteristics which are similar to Archean syenites believed to result from partial melting of a mixed garnet peridotite-eclogite mantle source (Figueiredo, 1981; Arth and Hanson, 1975).

D – The Transamazônico constitutes a major event of the SFC evolution. We can ascribe to it: (1) the deposition (at least) of supracrustal series; (2) the specific tectonometamorphic phenomena, responsible for the uplift, in distinct geotectonic conditions, of supracrustal complexes as Contendas-Mirante and Jacobina on one hand, and of the Rio Itapicuru on the other hand; (3) the specific magmatism associated with each of these complexes: leucogranitic intrusion of crustal origin for the median axis of the SFC, calc-alkaline intrusions with deep mantle-crustal (?) contribution for the greenstone belt; (4) the fixation of petrogenetic processes: closing of isotopic systems, probably related to a quick uplift, and consequently, cooling, of the thus formed continental crust. This fixation of the processes is expressed by isotopic ages Rb/Sr and K-Ar (pro-parte) of 2.0 to 1.8 Ba, widely distributed over the whole SFC.

We may also assign to this event a powerful remobilization of previous terrains. This is marked by the development of generalized anatectic processes, with production of important masses of migmatites, diatexites and enrooted granitoides.

This found expression in the isotopic rejuvenation (Bartels *et al.,* 1977; Jardim de Sá *et al.,* 1978; Brito Neves *et al.,* 1980) evidencied in the migmatites producted by anatexis of all the formations, including granulitic terms of the Archean crust.

IV. ESPINHAÇO AND BRASILIANO

Located in centre-west Bahia, the Paramirim basin has been recognised as an intracontinental rift (Jardim de Sá, 1981) or aulacogene (Costa and Inda, 1982) established in late archean basement (see earlier). Initial intrusive activity in the central part of the rift has been dated in the interval 1.8-1.5 Ga (Jardim de Sá *et al.,* 1976; Fernandes *et al.,* 1982). The presence of a large negative gravity anomaly in the region (Motta *et al.,* 1981) suggests that the exposed rocks may represent only the upper parts of a large batholith. Felsic volcanism accompanied the deposition of the sedimentary rocks on both sides of the basin, early products with a probable age of about 1.8 Ga being conformable with the basal sediments and later products cutting all but the uppermost sedimentary horizons. Early mafic magmatism may also be present, although this is still a debatable point (Feijão, 1981), but a prominent mafic episode with a minimum age of about 1.2 Ga is represented by intrusives within the sedimentary sequence. Late felsic volcanism is registered to the west of the rift, within the basement. This activity has a probable age of about 1.0 Ga (McReath *et al.,* 1981). Dynamic metamorphism and hydrothermal activity has caused severe textural, chemical and isotopic modifications of many of the rocks, and appears to have had one peak of latest Proterozoic age.

The granites have sub-alkaline mineralogical compositions (Fernandes *et al., op. cit.*), and mineralogical and chemical characteristics in common with some facies of rapakivi (Vorma, 1976). A suite of underformed enclaves includes gabbro, norite and charnockitic granite, the mafic members of which have suggested heavy introduction of potassium and other elements. Early felsic metavolcanics within the eastern sediments have many features of Phanerozoic continental tholeiitic rocks, while the later felsic volcanics to the west are weakly peralkaline (McReath *et al., op. cit.*).

The basin therefore has been the site of anorogenic magmatism over a relatively long time span (McReath, 1985). It is rich in mineral occurrences, although at present only barite from vein deposits is actively mined. Tin, including interesting occurrences of wood cassiterite, is associated with the felsic metavolcanics. Lead is found very rarely, in association with barite veins. Gold occurs within both host metavolcanic and quartz veins, although much production in earlier centuries probably came from the colluvia and alluvia associated with these mineralizations. Finally, uraniferous albitites of Lagoa Real are believed to have been formed as a result of the late Proterozoic hydrotermal activity (Lobato *et al.,* 1982).

Several folded belts surround the SFC. These are the fold systems of Riacho do Pontal and Sergipano to the North, Araçuai (Southern Espinhaço) to the south, which extend beyond the limits of the Bahia State. Granitic rocks are associated with them in Pernambuco, Sergipe and Minas Gerais states respectively.

In the Bahia state, the Piripá Massif has been atributed to the Brasiliano cycle (Lima *et al.,* 1981). This is a porphyritic muscovite granite which seems to intrude and develop contact metamorphism in, the folded platform deposits of the Southern Espinhaço. Isotopic determinations, as yet unpublished (Mascarenhas com. pes.) assign to the massif a Transamazônico age. This may force a fundamental revision of the interpretative framework of this fronter region of southern Bahia. Studies on this massif are in progress (Granitoid project of Bahia).

It is also worth noting that there exists a spectacular alkaline and peralkaline rock suite which forms several dispersed bodies in the Itabuna-Itapebi region (Fujimori, 1967; Barbosa de Deus, 1976; Fujimori, 1978). The isotopic determinations (Cordani *et al.,* 1969, 1974; Bernart *et al.,* 1977) indicate a "mise en place" age of 0.77 to 0.68 Ga, according to the body studied. A synthesis of data on this suite is presented (Fujimori, this Symposium).

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