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The 2-Ga peraluminous magmatism of the Jacobina–Contendas Mirante belts (Bahia, Brazil): Geologic and isotopic constraints on the sources

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ABSTRACT

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A 500-km north–south alignment of granitic intrusions cross-cuts the central part of the São Francisco craton. These late- to post-tectonic granitic bodies are emplaced between two Archean blocks (Jequié and Gavião blocks) and cross-cut the Contendas Mirante volcano-sedimentary sequence and the metasedimentary rocks of the Serra de Jacobina. They are two-mica or muscovite–garnet-bearing peraluminous granites.

Rb–Sr systematics show that these granites were emplaced during the Transamazonian orogeny ($\sim$1.9 Ga). The high initial $^{87}Sr/^{86}Sr$ ratios (0.706–0.748) and the very low $\epsilon_{Nd(t)}$ (-13 to -5) indicate a crustal origin. The possible sources are: (1) the Jequié block; (2) the Contendas Mirante sequence; and (3) the Gavião block, including some early Archean domes [trondhjemitic–tonalitic–granodioritic (TTG), Boa Vista type] which were tectonically emplaced within the volcano-sedimentary sequence.

The currently available Rb–Sr and Sm–Nd data are not consistent with reworking of the 3.5-Ga TTG. The combination of field and isotopic constraints preclude the Jequié block and the Contendas Mirante sequence and favour instead the Gavião block medium-grade terrains as the source for the peraluminous granitic line.

The available data suggest that a continent–continent collision occurred during the Transamazonian orogeny, which followed subduction/obduction marked by volcanism (arc-tholeiitic, calc-alkaline and shoshonitic) and related plutonism.

1. Introduction

The São Francisco craton (Almeida, 1967; Almeida et al., 1977) provides an excellent area to study crust formation events that occurred during the transition between the Archean and Proterozoic ($\sim$2.5 Ga) and the orogenic processes that operated during the lower–middle Proterozoic ($\sim$2 Ga). The São Francisco craton is one of the main remnants of the Archean and early Proterozoic crust of South America. The part of this structural province (Almeida et al., 1981) which consolidated at 1.7 Ga is mainly exposed in Bahia state.

Available geochronologic data (Marinho et al., 1979, 1980; Brito Neves et al., 1980; Cordani et al., 1985) recently synthesized by Mascarenhas and Garcia (1987), and supplemented (Wilson, 1987; Wilson et al., 1988) indicate a remarkable succession of igneous events from 3.5 to 1.9 Ga. In addition, a long alignment of 2-Ga-old peraluminous leucogranites (Himalayan-type) marks the limit between the Jequié block and the Gavião block.

This boundary is also marked by low- to medium-grade supracrustal fold belts. The existence of good indicators of a continent–continent collision, such as high-grade metamorphism (Newton, 1987) and leucogranites (Le Fort, 1981), in addition to the existence in the Jequié block of a lower Proterozoic arc series metamorphosed in the granulite facies (Barbosa, 1986), indicates that a continent–continent collision occurred around 2 Ga following subduction under the Jequié block.

The goals of the present work were: (1) to determine the absolute chronology of the magmatic episodes; (2) to identify the sources of the different magmas; and (3) to constrain the geodynamic processes that occurred during the Transamazonian orogeny.

2. Geologic setting

The main Archean to Proterozoic features of the São Francisco craton in Bahia state, Brazil, may be summarized by three commonly accepted units (Fig. 1).

(1) High-grade terrains form the Jequié block and its mobile belts (Mascarenhas, 1973, 1979) extend for >700 km from north to south, and correspond to the Salvador Curaça and the Atlantic Coast or Itabuna granulitic belts, respectively (Fig. 2).

(2) A medium-grade gneiss-migmatitic complex forms the large western band of these older terrains (Gavião block) and a northeastern nucleus in the middle Itapicuru river region.

(3) Supracrustal sequences, metamorphosed in the greenschist to amphibolite facies, are associated with the medium-grade gneiss migmatitic complex (Fig. 2). They correspond to the volcano-sedimentary belts of Jacobina and Contendas Mirante as well as less extensive occurrences.

2.2. High-grade terrains

The high-grade terrains consist of granulite-facies charnockites, enderbites, and a volcano-sedimentary sequence. In the Atlantic Coast belt (Fig. 2), Barbosa (1986) presented evidence for volcanic series similar to modern island arc associations. The distribution of the arc tholeiites, and the calc-alkaline and the shoshonite metavolcanics of these series suggests an early subduction system preceding the strong deformation and granulitic metamorphism. This subduction system is also recognized by Figueiredo (1989) on the basis of geochemical data.

2.2. Medium-grade terrains

The medium-grade terrains occupy roughly the western part of the São Francisco craton and correspond to the Gavião block (Fig. 1). The separated nucleus of the middle Itapicuru river in the northeastern part of the craton, now juxtaposed with the Salvador Curaça granulitic belt, has similar lithologies and metamorphic history, and is related to the Gavião block.

The terrains are composed of an assemblage of various gneiss–amphibolite associations, which include migmatites and plutonic rocks. Some of the gneiss formations are paragneiss, but most of the gneiss–leptite–amphibolite piles are considered as volcanic and volcanoclastic or volcano-sedimentary sequences. The plutonic rocks are widely distributed in the gneiss migmatite complex. Among them a 3.1–3.5-Ga trondhjemitic–tonalitic–granodioritic (TTG) association forms huge massifs such as Lagoa do Morro, Sete Voltas, Boa Vista, etc. (Fig. 2), which probably represent the oldest lithologies of the craton (Cordani et al., 1985).

The rocks were deformed by tectonic events during the Archean and Proterozoic. The latter is mainly marked by E–W shortening, associated with westward thrusting and crustal thickening related to the last migmatitic processes (Sabaté et al., 1988).

2.3. Supracrustal sequences

The most representative supracrustal sequences are located along the junction be-

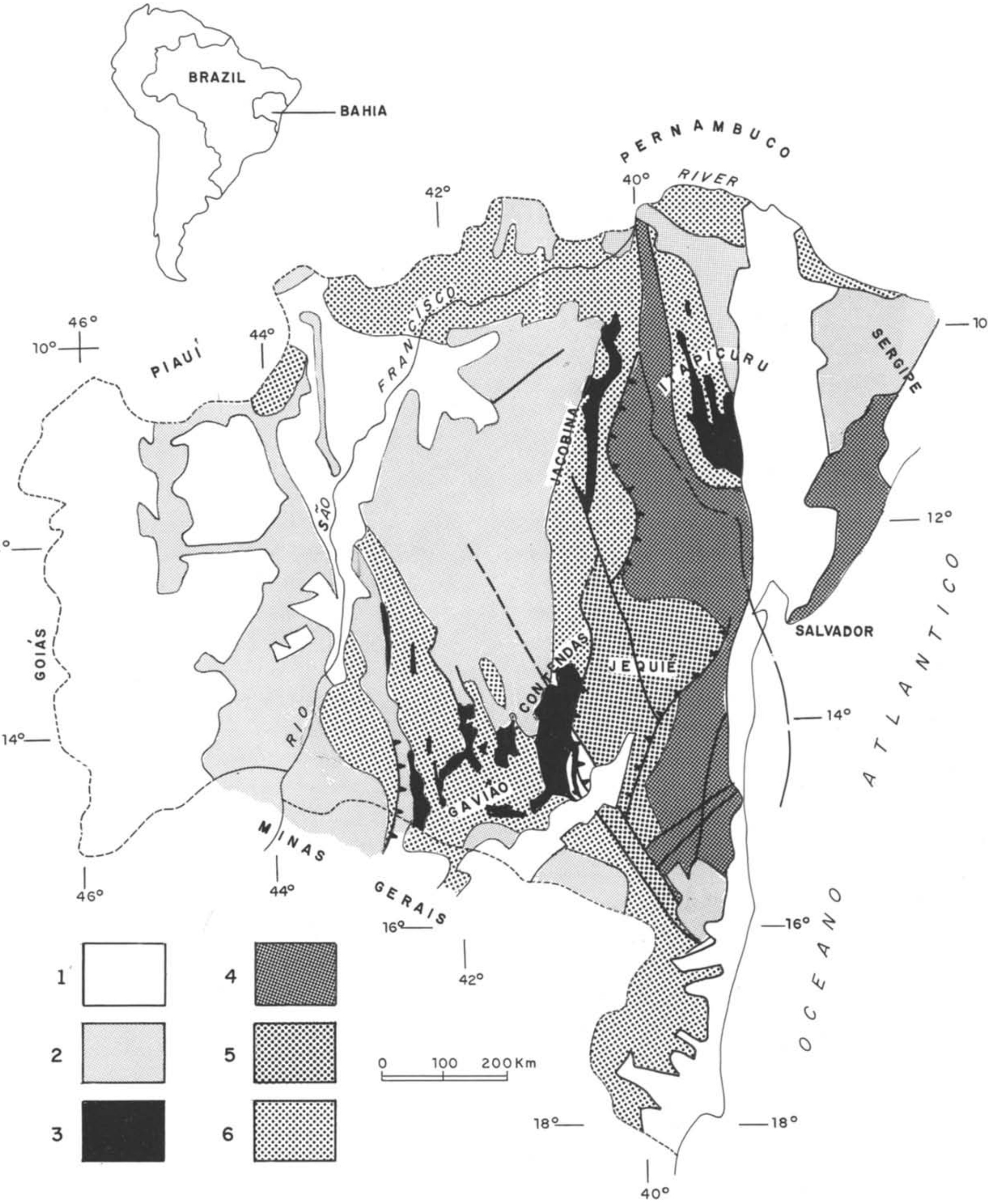

Fig. 1. Structural outline of Bahia state. [*1*=Phanerozoic cover; *2*=Brazilian and Pre-Brazilian covers (São Francisco and Espinhaço super groups); *3*=Archean to early Proterozoic supracrustal complexes (volcano-sedimentary and greenstone belts); *4*=Archean to early Proterozoic mobile belt (granulites, charnockites, migmatites and gneiss); *5*=Jequié granulitic complex (granulite facies volcano-sedimentary cover, charnockites and enderbites); *6*=Archean gneiss-migmatitic and granitic complex]. Modified from Mascarenhas (1976).

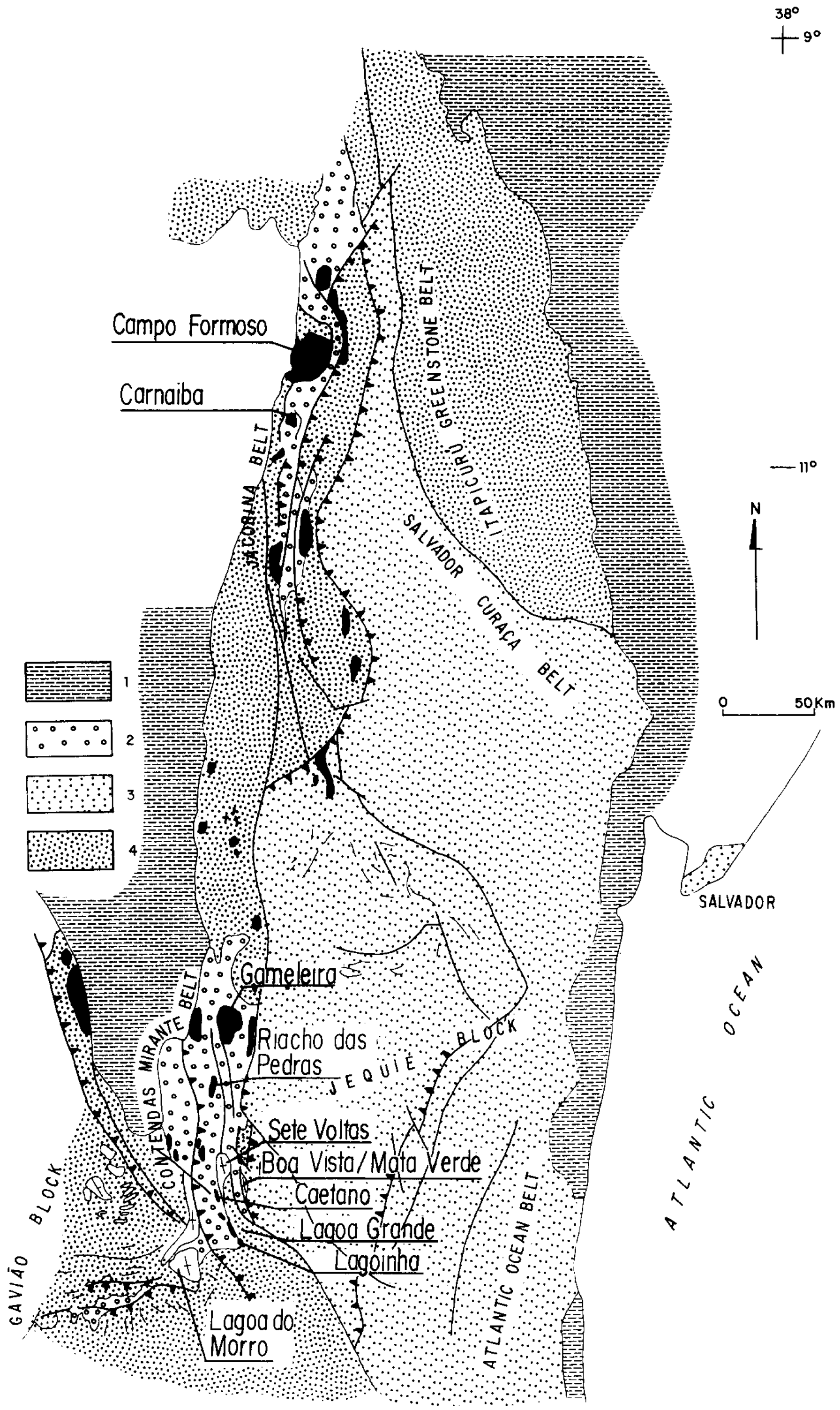

Fig. 2. Tectonic sketch map of the junction zone of the Gavião block and the Jequié block. Location of the studied intrusions relative to the main structures. *1* = Phanerozoic and middle and upper Proterozoic covers and belt; *2* = volcano-sedimentary belts; *3* = high-grade terrains; Jequié block granulitic formations and Archean to early Proterozoic mobile belts; *4* = Gavião block medium-grade formations; the late- to post-tectonic Transamazonian granitoids are *dark*; the older (Archean) and syn-tectonic (early Transamazonian event) plutons are shown by a *cross*.

tween the two Archean blocks and form the main meridian alignment of Contendas Mirante and Jacobina belts (Figs. 1 and 2). Some remnants of sequences somewhat analogous to the former are encountered into the Gavião block (Fig. 1). Each of these belts is associated with plutonic rocks.

2.3.1. Contendas Mirante belt. The volcano-sedimentary sequence of Contendas Mirante is composed of two stratigraphic units (Marinho et al., 1979, 1980). The lower unit contains almost all the volcanogenic components. These are basalts and intermediate metavolcanics intercalated with detrital and chemical sediments. The upper unit is essentially detrital. The rocks are metamorphosed in the greenschist facies grading to the amphibolite facies at the proximity of its eastern tectonic contact with the Jequié block. The two units are deformed by two principal phases (Sabaté et al., 1980). The first is isoclinal recumbent, with a west vergence and is accompanied by a westward overthrusting. The second is marked by E–W shortening which upturns the previous structures and progressively transforms the westward tangential movement into sub-horizontal N–S transcurrent shearing. With these phases, segments of the Gavião block are uplifted in the Contendas Mirante belt and its imbricated Gavião block segments.

2.3.2. The Jacobina belt. the metasedimentary Jacobina sequence is mainly made up of detrital epicontinental sediments. Some ultramafics are intercalated in the tectonic edifice. The rocks are metamorphosed in the amphibolite facies. The structure of the belt corresponds to imbricated slices which also show westward vergence. As in the Contendas Mirante belt, the subsequent shortening and upturning led the tangential movement to be transformed to sub-horizontal N–S shearing. In the resulting framework, a large overthrusted imbricated slice related to the Gavião block separates the Jacobina belt from the Salvador Curaça mobile belt (Figs. 1 and 2).

3. The plutonic rocks

All these belts are intruded by several plutonic associations which are described as belonging to two distinct groups.

The Jacobina and Contendas Mirante belts are the locus of a remarkable up to 500-km alignment of syn- to late-tectonic granites that emphasize the axial shear zone and the borders of the belts. More than fifteen bodies are recognized as related to the Contendas Mirante belt (Marinho et al., 1979, 1980; Marinho and Sabaté, 1982; Conceição, 1986) and up to seven related to the Jacobina belt (Couto, 1978; Rudowski et al., 1987; Celino and Sabaté, 1988). Some bodies can also be seen in the same tectonic alignment between the two belts (Fig. 2) in the Itaberaba region (Fernandes and Sabaté, 1987; Giuliani et al., 1988). All of the plutons are peraluminous and show various degrees of differentiation (Conceição, 1986; Rudowski, 1989).

Seven areas were chosen for the present work:

- Five are located in the axial zone of the Contendas Mirante belt. From north to south they are the Gameleira, Riacho das Pedras, Caetano, Lagoa Grande and Lagoinha bodies.
- The composite Campo Formoso massif and the Carnaiba body are situated in the Jacobina belt.

3.1. Gameleira massif

The Gameleira is the largest peraluminous body of the axial line intrusions of the Contendas Mirante belt (Fig. 2). In the vicinity of the Jequié block, it intruded the volcano-sedimentary sequence where it induced a thermal metamorphism that developed cordierite and andalusite in the country rock. Its emplacement is synchronous with the late and important overprinting folding phase (Sabaté et al.,

1980) which represents shortening related to the crustal thrusting.

The mean composition is granodioritic with a quartz–oligoclase–andesine–microcline assemblage showing wide variations in relative proportions of the phases. The index mineral is a red-brown, green or sometimes bleached biotite. Muscovite may be abundant. It is generally deuteric, formed at expense of the K-feldspar and plagioclase. Microcline is also present. The accessory minerals are zircon, apatite, titanite, magnetite–ilmenite and secondary epidote.

3.2. Riacho das Pedras intrusion

The Riacho das Pedras granite (Fig. 2) is late tectonic relative to the folding phases and the accompanying overthrusting. It consists of a hololeucocratic granite associated with a network of aplite and pegmatite dikes that crosscut the sequence. The fine- to medium-grained granite is made up of quartz, albite and microcline. Muscovite may be abundant. The biotite is subordinate and sometimes absent. Apatite, magnetite, hematite, zircon and rare titanite are the typical accessory minerals, with less commonly tourmaline and garnet. The two latter minerals, especially tourmaline, are common in the related pegmatites and aplites.

3.3. Caetano, Lagoa Grande and Lagoinha bodies

The Caetano, Lagoa Grande and Lagoinha intrusions form elongate bodies (20, 10 and 4 km long, respectively) aligned along the axial shear zone of the Contendas Mirante belt. A narrow band of supracrustals separate them form the large N–S Archean dome of Sete Voltas (Fig. 2). Their emplacement is synchronous (Lagoinha, Lagoa Grande) to late (Caetano) with respect to the shearing.

The plutons consist of leucogranite with a two-mica ± garnet association. They have muscovite layering (Caetano), and schlieren with biotite (Caetano), biotite + garnet (Lagoa Grande), and biotite + muscovite (Lagoinha). Aplopegmatitic dikes or pockets with biotite, muscovite and tourmaline are associated.

3.4. Campo Formoso massif and Carnaiba body

The Campo Formoso massif is the most important intrusion in the Jacobina belt. It represents a multi-stage intrusion with several successive, roughly concentric, peraluminous granitic facies, and a suite of aplite and pegmatite dikes (Rudowski et al., 1987). Three successive main types are recognized (Rudowski, 1988): (1) a coarse-grained to porphyritic muscovite-rich granite; (2) a medium- to fine-grained two-mica granite and (3) a muscovite–garnet–albite granite with only relicts of biotite. In these three types, zircon and apatite are the common accessories. Garnet, tourmaline and beryl characterize the associated quartz–albite–microcline aplopegmatite suite.

Muscovite crystallized during several stages of the magmatic evolution. The early crystallization developed during the stage corresponding to the acquisition of the preferred orientation by the plutonic bodies. The muscovite also formed during the deuteric stage, and accompanies late shear zones or fills microfissures.

The Carnaiba body is a small circular intrusion composed of two types of granites corresponding to types (2) and (3) of Campo Formoso.

Chemically, all the granitic facies are peraluminous. Based on trace-element and rare-earth element (REE) behaviour, Rudowski (1988) distinguishes two “series”: one corresponding to the two-mica granite (type *2*) which leads by differentiation to the muscovite-garnet granite, and the other to a suite of muscovite granites (type *1*) marked by subsolidus transformations. The chemical characterteristics suggest a heterogeneous magmatic source (Rudowski, 1989).

4. Geologic constraints on the sources

The structural evolution indicates that peraluminous plutonism accompanied continent–continent collision marked by overthrusting and subsequent shortening that terminated with transcurrent shearing.

The presence in the Gameleira massif of mica-rich garnet-bearing xenoliths, which may represent the residual phase of partial melting, led Petta (1979) to attribute the source rocks to the neighbouring blocks. The overthrusting of the Jequié block previous to or synchronous with the intrusion rules out the Jequié block alternative for the source, and restricts the source to within the Gavião block formations and/or the volcano-sedimentary sequence.

For the Riacho das pedras granite, as for the similar bodies of the axial Contendas Mirante line (Caetano, Lagoa Grande, Lagoinha), a crustal source is assumed by Marinho and Sabaté (1982) on the basis of the peraluminous and sodi-potassic paragenesis, and confirmed by the very high $^{87}Sr/^{86}Sr$ ratio (~ 0.768) obtained during a previous dating program (Sato, 1982; Cordani et al., 1985). Compared with the Gameleira intrusion, they probably had the same petrogenesis. Crystallization occurred under conditions corresponding to the mesozone and epizone where mica and cordierite are in equilibrium, implying a high water pressure. Thus, the rocks must have crystallized relatively close to their source regions. However, the migration of leucogranitic magmas could have been more extensive because of higher fluid pressure linked to the presence of boron, which reduces both the solidus temperature and the magma viscosity (Pichavant, 1984, 1987). This is suggested as much by the petrographic associations, with its abundant pegmatite suites, as by the presence of tourmaline. Consequently, the source is less likely to have been in the Contendas Mirante formations than in either the Gavião block or the Jequié high-grade lithotypes.

The structural framework clearly shows the presence of Gavião block terrains as infrastructure to the Contendas Mirante edifice. The geologic configuration of the leucogranitic intrusion line located on the western border of the Gavião block segment uplifted into the Contendas Mirante belt, and their chronologic relation as syn- to late-tectonic relative to the transcurrent shearing following overthrusting, rule out the possibility that the Jequié block is a good candidate for the source of the granites. In addition, the granulitic metamorphism, which is related to continental collision (Newton, 1987), and, in the case of the Jequié block, is approximately synchronous with leucogranite intrusion (Wilson, 1987; Wilson et al., 1988), indicates that the Jequié block should separated in space from the peraluminous granite production zone. Thus the potential sources probably are in the non-granulitic formations of the Gavião block. Similarly, the chronologic and tectonic setting of the peraluminous diapirs of Campo Formoso and Carnaiba, and their field relations with the medium-grade gneiss-migmatites related to the Gavião block, support the Gavião terrains as a possible source and rule out involvement of the granulitic Jequié block. The deep metasedimentary Jacobina sequence, intruded by the granites may also have contributed to their genesis.

Are the supracrustals a possible source for the granites? The lower unit of the Contendas Mirante sequence is composed of ultramafics, mafics, carbonate rocks and banded iron formations, and consequently is not a good candidate. The clastic sediments, tuffs and graywacke of the upper unit are a possible source; however, they are cross-cut by the granites and are located in the emplacement zone of the massifs, not in the source zone of the magma. The total absence of mafic enclaves and the geochemical patterns (Rudowski, 1989; Cuney et al., 1990) tend to exclude a mantle source. The composition of all the granites, which is very close to the ternary minimum of the granitic system, and the absence of fractionated crystallization suites (Cuney et al., 1990) support the hypothesis of magma production exclusively by crustal melting. Alternatively, Cuney et al. (1990) show that the mineralogical and chemical features of these granites reflect the dominantly meta-igneous character of the source and propose the Archean TTG as the possible source material.

5. Isotopic study

5.1. *Analytical techniques*

Sr and Nd isotopic compositions have been obtained in Clermont-Ferrand, on a VG54E® mass spectrometer using the procedures described by Pin and Carme (1987). During the course of the experiments, NBS 987 and La Jolla standards gave $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ of 0.71025±0.00004 and 0.51186±0.00003, respectively (the quoted errors represent the external reproducibility at 2σ on 10 Sr runs and 8 Nd runs). Sm and Nd were obtained by isotope dilution with a precision of ±1% on their ratio. Rb and Sr were obtained by X-ray fluorescence spectrometry (XRF) with a precision of ±2% on their ratio.

5.2. *Results*

Five granites were dated using the Rb/Sr whole-rock isochron technique. The data are reported in Table I and in Fig. 3. Three of the granites (Campo Formoso, Gameleira and Riacho das Pedras) yield well-defined isochrons and cluster in the age range of 1.93–1.97 Ga. The isochrons for the two other granites are based only on three samples and need confirmation, although it is probably not fortuitous that the age of the Lagoinha–Lagoa Grande granite lies within the same range as the others. The Caetano data plot below the Lagoinha–Lagoa Grande isochron, and may reflect disturbance during the Brazilian event. In addition, the Carnaiba granite is very probably the source of fluids that developed the emerald-rich metasomatic zones in the enclos-

TABLE I

Rb–Sr isotopic data for Bahia Transamazonian peraluminous granites

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Campo Formoso granite:				
6	230	167	4.040	0.82143
13	265	153	5.067	0.85094
22c	265	129	6.058	0.87784
180	320	121	7.808	0.92704
88	289	105	8.148	0.93140
54A	274	93	8.697	0.94536
29	285	89	9.542	0.98643
62A	371	71	15.90	1.16032
48C	282	30.3	29.050	1.52168
48B	342	37.0	28.847	1.50898
Carnaiba granite:				
CA5	350	90.7	11.53	1.04894
CA9	404	92.0	13.16	1.08494
CA16	460	64.0	22.08	1.33340
Riacho das Pedras granite:				
99D	215	13.5	53.03	2.25953
99H	281	6.0	211.9	6.53939
99I	134	14.5	28.89	1.54825
99J	334	5.5	349.6	10.48640
99K	311	5.6	291.2	8.96639
99B	200	14.5	44.68	1.96824
99C	215	14.4	49.07	2.08941
99F	214	15.5	44.89	2.01100
99M	327	4.8	417.8	12.22670
Gameleira granite:				
91A	271	146	5.429	0.86052
92	225	172	3.828	0.81478
95	282	161	5.129	0.84709
96	259	94	8.124	0.93353
97B	276	146	5.582	0.86737
101	275	114	7.114	0.90776
11218	342	148	6.790	0.89570
Lagoa Grande–Lagoinha–Caetano granite:				
GO9HC-BC	243	76	9.430	0.97237
G54HC	205	182	3.300	0.80295
G58HC	173	248	2.028	0.76428
CAE2	66.0	31.0	6.241	0.84683

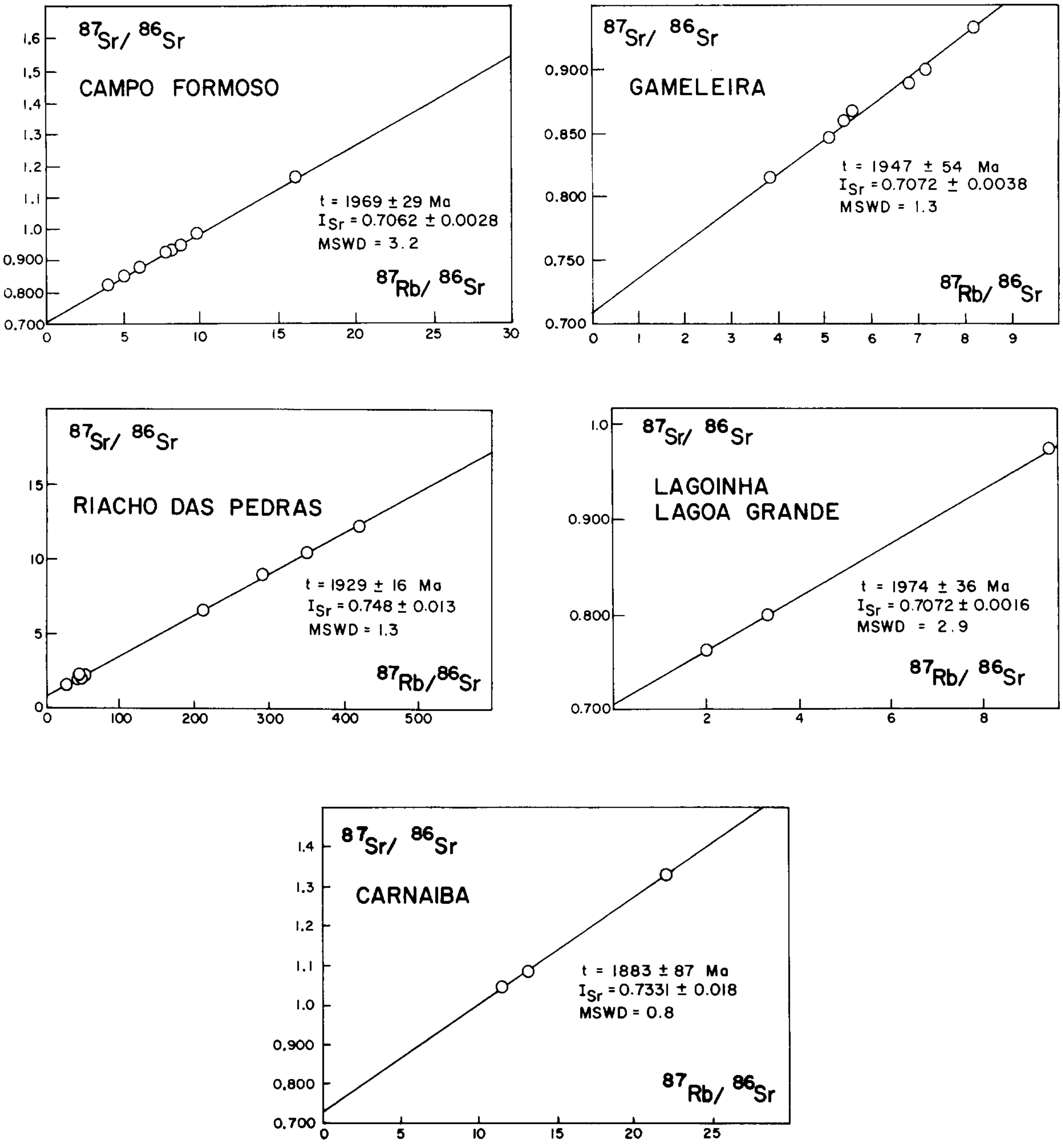

Fig. 3. Rb–Sr isochron diagrams for the Bahia Transamazonian peraluminous granites. I_{Sr} = initial Sr ratio = $(^{87}Sr/^{86}Sr)_i$.

ing serpentinites (Rudowski, 1989). Rb–Sr dating of these zones provided an age of 1.869 ± 0.028 Ga (L. Rudowski, Ph. Vidal and M. Caen-Vachette, in prep.) which is within error of the 1.88-Ga age obtained on the Carnaiba granite. Therefore, the Carnaiba granite probably represents a late-magmatic event subsequent to the main phase of the Transamazonian emplacement between 1.97 and 1.93 Ga.

The $^{87}Sr/^{86}Sr$ initial ratios of the granites are much higher than the mantle ratio at the time of their production (Fig. 4). This indicates that they were formed by melting of materials hav-

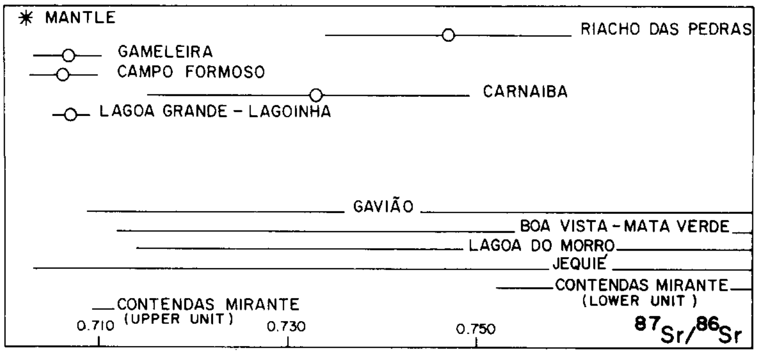

Fig. 4. $^{87}Sr/^{86}Sr$ vs. time for Bahia Transamazonian granitoids and their potential source rocks. The field of the source rocks have been drawn using the data of Cordani et al. (1985) and M.M. Marinho (unpublished data, 1988).

ing had a significant crustal residence time. To consider potential sources, the range of $^{87}Sr/^{86}Sr$ ratios (corrected for 1.95 Ga and using their extreme Rb/Sr ratios and isotopic composition) of the various formations exposed in this part of the São Francisco craton have been plotted in Fig. 4. The field for Boa Vista–Sete Voltas and Lagoa de Morro TTG, the Gavião block migmatites and granitoids, and the Jequié high-grade rocks are rather well constrained (Cordani and Iyer, 1978; Cordani et al., 1985; Wilson, 1987). In contrast, the Rb–Sr characteristics of the Contendas Mirante volcano-sedimentary sequence are poorly constrained. We have reported in Fig. 4 the few available data for the formations which could, from petrologic arguments, possibly be good candidates for the granitic source, i.e. the phyllites of the upper unit and the felsic metavolcanics of the lower unit (Cordani et al., 1985; Wilson, 1987). The Gameleira, Campo Formoso and Lagoa Grande–Lagoinha granites match only the Jequié and Gavião fields, whereas the origin is less constrained for the Riacho das Pedras and Carnaiba granites. However, for the Riacho das Pedras granite, its very high initial Sr isotopic ratio (0.747) might not be that of the source because this highly evolved magma had exceedingly high Rb/Sr ratios. The $^{87}Sr/^{86}Sr$ ratio can increase very rapidly during the magmatic stage itself (Vidal et al., 1979). High initial ratios also have been proposed to result from exchange with country rocks through convective cells (Bonin et al., 1987). However, there is no indication of hydrothermal activity or low-temperature changes in granite mineralogy.

In conclusion, Sr isotopes alone cannot identify with precision the source rocks. In addition, it must be recalled that despite the fact that Sr isotope geochemistry indicates that all granitoids possess a crustal signature, the exact characteristics of their sources are impossible to deduce by Rb–Sr systematics since variable Rb/Sr ratios can be produced by partial melting of a given source without changing $^{87}Sr/^{86}Sr$.

In contrast to Sr isotopes, Nd isotopes are more straightforward to interpret because Sm/Nd ratio fractionation during partial melting is much smaller and more confidently modelled. The Sm–Nd results are given in Table II. The calculated $\epsilon_{Nd(t)}$-values are negative (-13 to -5) and confirm the crustal origin of the granitoids as inferred from Sr isotopes. The time of first extraction of the material out of the mantle can be obtained by calculating model ages relative to the depleted mantle. Ages range between 2421 and 3165 Ma. The case of Riacho das Pedras granite ($t_{DM}=3165$ Ma is peculiar. It exhibits very high Rb/Sr ratios, low REE contents and high Sm/Nd ratios. These features are typical of highly evolved granites. In this case, the Sm/Nd ratio

TABLE II

Sm–Nd isotopic data for Bahia Transamazonian peraluminous granites t_{DM} is calculated using $(^{143}Nd/^{144}Nd)_i = 0.513114$ and $^{147}Sm/^{144}Nd = 0.222$ (Ben Othman et al., 1984)

Sample	Granitoids	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$\epsilon_{Nd(t)}$	t_{DM} (Ma)
11217	Riacho das Pedras	0.55	2.02	0.1646	0.51191	−6.2	3,165
11218	Gameleira	4.1	27.2	0.09111	0.51087	−8.8	2,600
GO*9*HC-BC	Lagoinha	4.1	17.5	0.1420	0.51169	−4.9	2,698
G*58*HC	Lagoa Grande	2.5	15.6	0.0966	0.51097	−7.6	2,592
CAE*2*	Caetano	1.47	10.03	0.0889	0.51099	−5.2	2,421
6	Campo Formoso	5.81	41.1	0.08536	0.51057	−13.1	2.821
13	Campo Formoso	4.07	25.5	0.09646	0.51101	−7.4	2,541

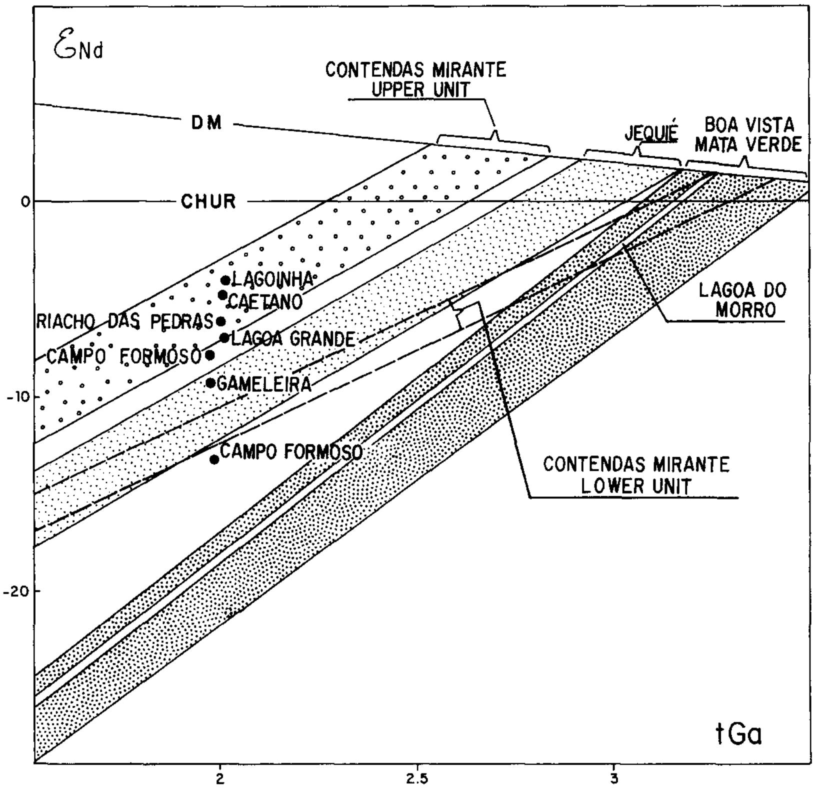

Fig. 5. Nd vs. time for Bahia Transamazonian granitoids and their potential source rocks. The field of the source rocks have been drawn using the data of Wilson (1987) and M.M. Marinho (unpublished data, 1988).

of the magma can be increased with respect to the source by retaining monazite in the partial melting residue, or removing it during an early stage of the magmatic history. This situation can lead to a gross overestimation of the model ages (Vidal et al., 1984; Vidal, 1987). Instead, using a typical crustal REE pattern (e.g., shale pattern) for the source provides a source age in agreement with the other granitoids.

The age of the sources, the close grouping of

t_{DM} between 2.4 and 2.8 Ga, and comparison of the $\epsilon_{Nd(t)}$ of the granites with their potential sources (Fig. 5) (data from Wilson, 1987; M.M. Marinho, unpublished data, 1988), strongly support the hypothesis that the crust that has produced these granitoids by partial melting is neither the 3.5-Ga-old Boa Vista–Mata Verde orthogneisses nor the 3.1-Ga-old Lagoa do Morro orthogneisses (which originally belonged to the Gavião block). Instead the sources must be late Archean in age.

5.3. Discussion

Although Nd isotopes are consistent with the felsic rocks from the Contendas Mirante sequence (upper and/or lower unit) as the source of the Transamazonian peraluminous granites (Fig. 5), the hypothesis is ruled out by structural constraints. The same conclusions are reached for the Jequié block formations.

In addition, isotopic data also show that the old TTG cannot be considered as a good candidate for the source. Therefore, the only possible source left is the late Archean migmatized gneiss-amphibolites and granitoids of the Gavião block. These fit the structural, petrologic and Sr isotope constraints. Although there are no Nd isotopic data available yet, at the present time this is the best working hypothesis.

Finally, in the attempt to relate the production of the peraluminous granites to a continent–continent collision, the similarity in the isotopic characteristics of the Transamazonian and Himalayan granites is striking. In both cases, very low $\epsilon_{Nd(t)}$-values are observed which implies essentially a crustal contribution. The only difference is the apparent isotopic homogeneity in the Transamazonian granites suggested by the good straight line of the data points in the Rb–Sr isochron diagrams. This differs strongly from the Himalayan situation (Vidal et al., 1982; Deniel et al., 1987). This could simply be due to an "aging effect" (Vidal et al., 1985) which tends to wipe out the initial isotopic heterogeneities. Nd isotopes are far less sensitive to this effect. This is reflected in the Campo Formoso granite where the two analyzed samples have different $\epsilon_{Nd(t)}$.

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