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GEOCHEMISTRY AND GEOLOGICAL SETTING OF THE GABBRO-ANORTHOSITE MASSIFS OF SOUTHERN BAHIA, BRAZIL

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ABSTRACT

A series of small (<100 km^2) gabbro-anorthosite massifs occur along the interface between Jequié block and Itabuna belt, in southern Bahia. Their association with gabbro clearly reflects that they are products of basaltic magmas crystallization, with enrichment trends in Fe, Ti and P. The feldspar supersaturation has been translated into positive Eu anomalies, besides higher Sr and Al_2O_3 contents.

The temperature and pressures would be in the order of 850°C and 5 kb in conditions of dry environment, in accordance with models of South Bahia high grade metamorphism domains. These massifs probably have been driven out into the crust by sinistral shear zones dynamics, contemporaneous with the granulitic metamorphism, dated around 2.1 Ga.

RESUMO

Nos terrenos geológicos do Sul da Bahia, posicionados na interface entre o Bloco Jequié e o Cinturão Itabuna, ocorrem vários maciços gabro-anortosíticos, elipsoidais e de pequenas dimensões (<100 km+). As associações com gabros indicam que os maciços teriam se originado da cristalização de magma basáltico, enriquecidos em Fe, Ti e P. A supersaturação em feldspato é demonstrada pela forte anomalia de Eu e altos teores em Sr e Al_2O_3.

As condições de equilíbrio químico são da ordem de 850° C e 5 kb, à seco, de acordo com o modelo evolutivo de alto grau metamórfico dos domínios do Sul da Bahia. Estes maciços são associados a zonas de rifts continentais, cuja implantação na crosta deu-se por uma dinâmica de cisalhamento sinistral, contemporânea ao metamorfismo granulítico, datado em torno de 2,1 Ga.

INTRODUCTION

Anorthosite massifs are Precambrian rock associations that do not possess any modern equivalent. They are essentially composed of calcic plagioclase (anorthite to andesine) and occur systematically associated with high grade metamorphic terrains of granulitic facies (Martignole, 1996). A series of gabbro-anorthosite intrusions with small dimensions (<100 km+) and elliptical shape occur in São Francisco Craton geologic domain (Almeida, 1977), southern Bahia. These are distributed along a submeridian line that marks the contact between the Jequié block and the Atlantic Coast granulitic belt. Six individual intrusions have yet being identified. They follow a NNE/SSW-oriented, 300 km long lineament associated with the structures of the regionally dominant granulites (Cruz & Sabaté, 1995; Sabaté & Cruz, 1998). From north to south, the massifs are named Rio Piau (RP), Samaritana (S), Carapussê (C), Mirabela (Mi), Palestina (Pa), and Potiraguá (Po) (Fig. 1).

Despite their reduced dimensions, the gabbro-anorthosite massifs of southern Bahia can be petrologically compared with worldwide larger ones. This is important not only for determining their origin but also for a better understanding of the relations of that lithological association with the evolution of the Gondwana supercontinent.

GEOTECTONIC SETTING

One of the old nuclei of São Francisco Craton is the Jequié block or complex (Cordani, 1973), also named Jequié-Mutuípe domain (Barbosa, 1986) or Mutuípe-Maracás domain (Barbosa *et al.,* 1992). That crustal unit is composed of high-grade metamorphic rocks divided into two different parts: a predominantly charnockitic unit, to the east side, and a mainly migmatitic unit to the west side. The granulitic rocks present isotopic ages between 2.7 and 2.8 Ga (Barbosa *et al.*, 1992), which probably characterizes a geotectonic event, the Jequié cycle (Barbosa & Dominguez, 1996).

Surrounding the Jequié block lies the Jequié belt, reworked during the Paleoproterozoic (Transamazonian cycle, Mascarenhas & Sá, 1982; Oliveira *et al.*, 1982). This mobile belt defined by Figueiredo (1989) and Figueiredo & Barbosa (1993) as Itabuna belt, corresponds to the Itabuna block of Pedreira *et al.* (1975) and to the Atlantic Coast mobile belt of Costa & Mascarenhas (1982) or to the domain of the Atlantic Coast belt of Barbosa (1986). These metamorphic rocks are strongly NNE-oriented and are broadly composed of granulite with isotopic ages around 2.1 Ga (Ledru *et al.*, 1994). Figueiredo & Barbosa (1993) proposed a geotectonic model for these crustal units, and have argued that the Itabuna belt could represent an active continental margin of the Jequié protocraton. The collision of the Jequié with the Congo protocraton allowed the development of shear belts, thrust faults, and continental rifts. Sabaté & Cruz (1998), in agreement with the model proposed by Figueiredo & Barbosa (1993), pondered that the southern Bahia massifs would be markers of deep continental rifts, which coincide with the contact of the Jequié block and the Atlantic Coast belt.

The local geology indicates that the emplacement of the anorthositic bodies could be related to the dynamics of sinistral shear zones, contemporary to the granulitic metamorphism, dated at 2.1 Ga (Ledru *et al.*, 1994). Pull-apart mechanisms have been suggested to explain the magma storage deep into the continental crust (Cruz & Sabaté, 1995; Sabaté & Cruz, 1998).

Isotopic Sm-Nd determinations for the Mirabela intrusion indicate an emplacement age of 2.2 Ga (Silva *et al.,* 1996). On the other hand, negative eeNd values suggest a low rate of crustal contamination of the mafic-ultramafic magma. Therefore, the maximum age considered for that magmatic series is 2.2 Ga (Silva *et al.*, 1996).

The southern Bahia gabbro-anorthosite massifs present geologic and geochronologic aspects that correspond to the classifications of Morse (1980), Ashwal (1993) and Martignole (1996) for Proterozoic massif type anorthosite, including the Phanerozoic anorthosite massifs of Canada and the Paleozoic anorthosites of Aïr Ring, Niger.

The intrusions of Bahia are mostly layered, with anorthosite, leucogabbronorite, gabbronorite, pyroxenite and dunite, in a variety of internal gradations. The bodies composed of true anorthosite (Rio Piau, Samaritana and Potiraguá) lack ultramafic terms. The mineralogical composition is monotonous. Olivine (if present) is always a cumulus phase. Orthopyroxene occurs both as intercumulus (in peridotite) or as cumulus phase (in pyroxenite). Clinopyroxene and plagioclase are always intercumulus minerals. The

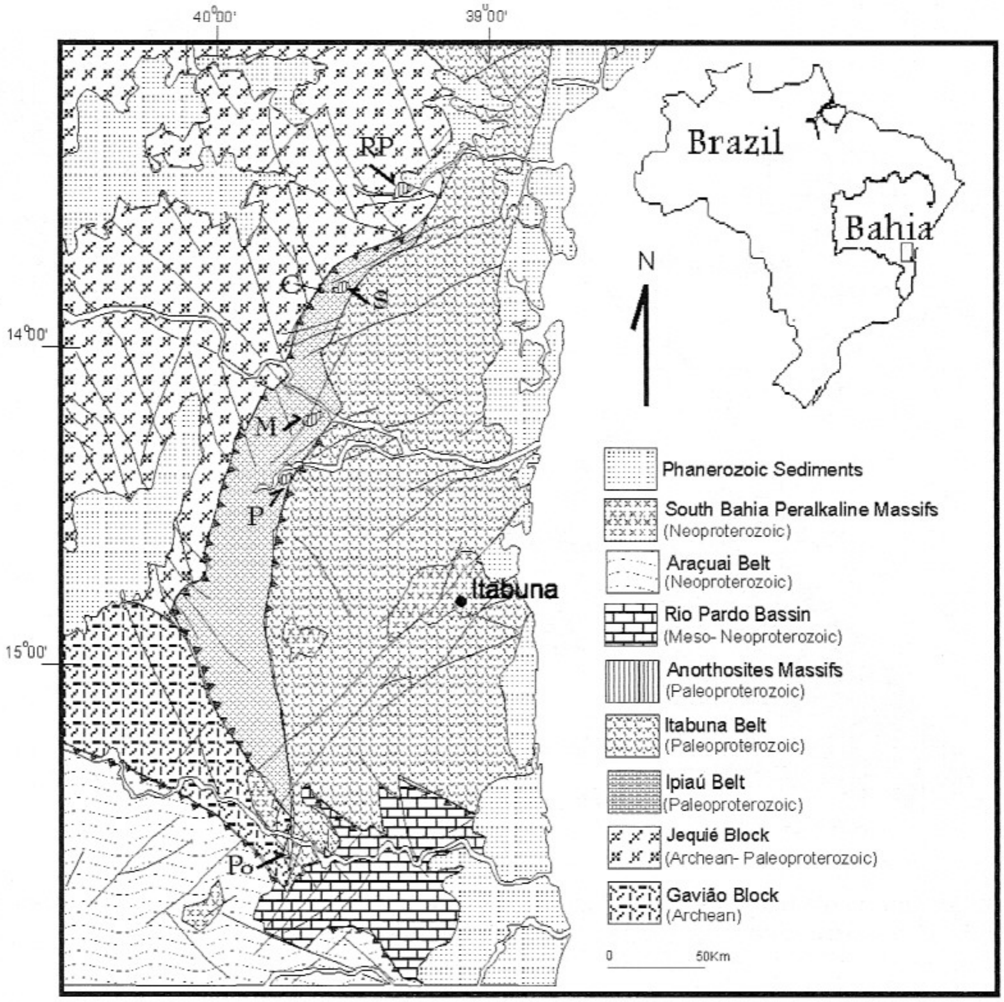

Figure 1 – Geological setting of the gabbro-anorthosite massifs of southern Bahia, Brazil. (RP) Rio Piau; (S) Samaritana; (C) Carapussê; (Mi+Pa) Mirabela and Palestina; (Po) Potiraguá.

relative proportions of this simple mineralogy determine a large spectrum of petrographic types. Several different facies of anorthositic and gabbronoritic compositions have been distinguished, based on the textures and mineral proportions. Some of the intrusions display high contents of Fe-Ti-V oxides and apatite along their margins.

Despite the syntectonic deformation effects, the intrusions commonly preserve, in the majority of the litologies, magmatic textures from ortho to adcumulate.

GEOLOGY OF THE GABBRO-ANORTHOSITE MASSIFS

The Rio Piau Massif

The Rio Piau massif is located in the source of the Piau river, close to Itabaína village, SW Bahia (Fig. 2). With about 70 km² of exposure the Rio Piau massif is the largest body of the anorthosite trend in Bahia (Cruz, 1989). It has an internal structure that broadly comprehends (1) a zone where anorthosite predominates; (2) a level composed of varied textural types and grain sizes grabbronorite; (3) a narrow troctolitic rocks layer; (4) a discontinuos belt of rocks enriched in Fe-Ti-V oxides and apatite, and (5) a frozen margin of gabbronoritic rocks (Fig. 2).

The plagioclase composition varies continuously among the various facies, in the interval An_{60} to An_{77} (Fig. 3-A). Ortho and clino pyroxenes display an ample spectrum of composition. The

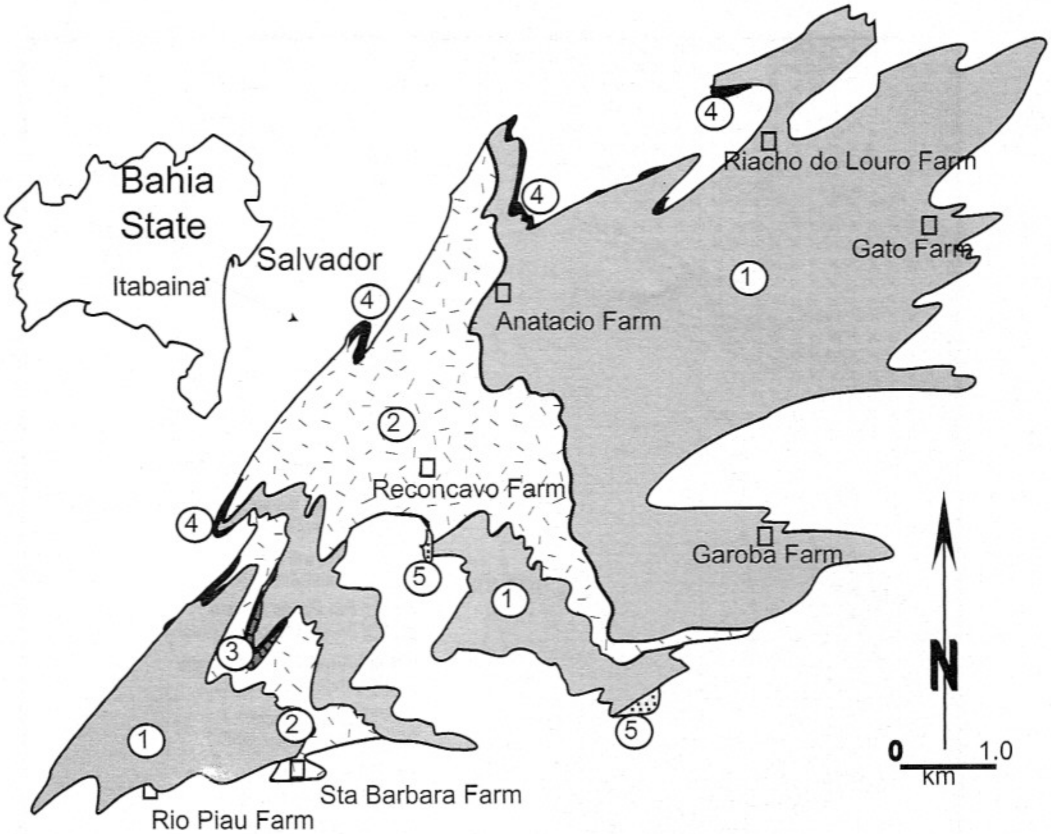

Figure 2 – Geological sketch map of the Rio Piau massif (Cruz, 1989). (1) anorthosite; (2) gabbronorite; (3) troctolite; (4) Fe-Ti-V oxides-rich rock; (5) gabbronorite (frozen margin).

clinopyroxene (Cpx) has a compositional trend that goes from hedenbergite (En_{23}-Fs_{42}-Wo_{37}) to salite (En_{38}-Fs_{15}-Wo_{46}) (Fig. 3-B). Every Cpx is tied to an orthopyroxene (Opx) whose composition determines also a trend going from hypersthene (En_{38}-Fs_{15}-Wo_{46}) towards eulite (En_{54}-Fs_{45}-Wo_{1}) (Fig. 3). Olivine (Ol), whose modal content never exceeds 5%, is quite Fe-rich in composition, ranging from Fo_{31} to Fo_{13}.

The magnesium molar number of mafic minerals (*mg#* = MgO/MgO+FeO) remains nearly constant for all the Cpx+Opx+Ol associations, which translates the mutual equilibrium among the referred phases. The pyroxene geothermometers applied to the Rio Piau rocks indicated temperatures of chemical equilibrium around 850°C (Cruz, 1992).

The chemical data show constant values of SiO_2 and high, but variable contents of Al_2O_3 (25% in anorthosite and 11% in the gabbronorite). The *mg#* of rocks varies from 0.05 in the anorthosite to near 0.44 in the gabbronorite. The A_2O_3/CaO ratios stay around 1.51 for the Fe-Ti-rich rocks, reaching 2.19 in the anorthosite, and falling to 1.48 in the gabbronorite (troctolite) (Table 1). The chondrite-normalized REE spidergram shows little fractionation. Both the anorthosite and the gabbronoritic terms commonly present positive Eu anomaly (Fig. 4).

The Samaritana and Carapussê Massifs

These two adjacent intrusions are of small expression (Fig. 5), being located about 11 km to the northeast of Itamarí. They were discovered in the early 70's. The first geological investigation on these intrusions have been carried out by Lima (1997) and Cruz & Lima (1998). The Samaritana massif is oval-shaped, with about 7 km^2 of exposed area. Its longest axis is approximately concordant with the regional NE/SW structure. The contact of the massif with the country rocks is in part intrusive and in part by faults. A few small anorthosite dikes intrude the granulitic country rocks.

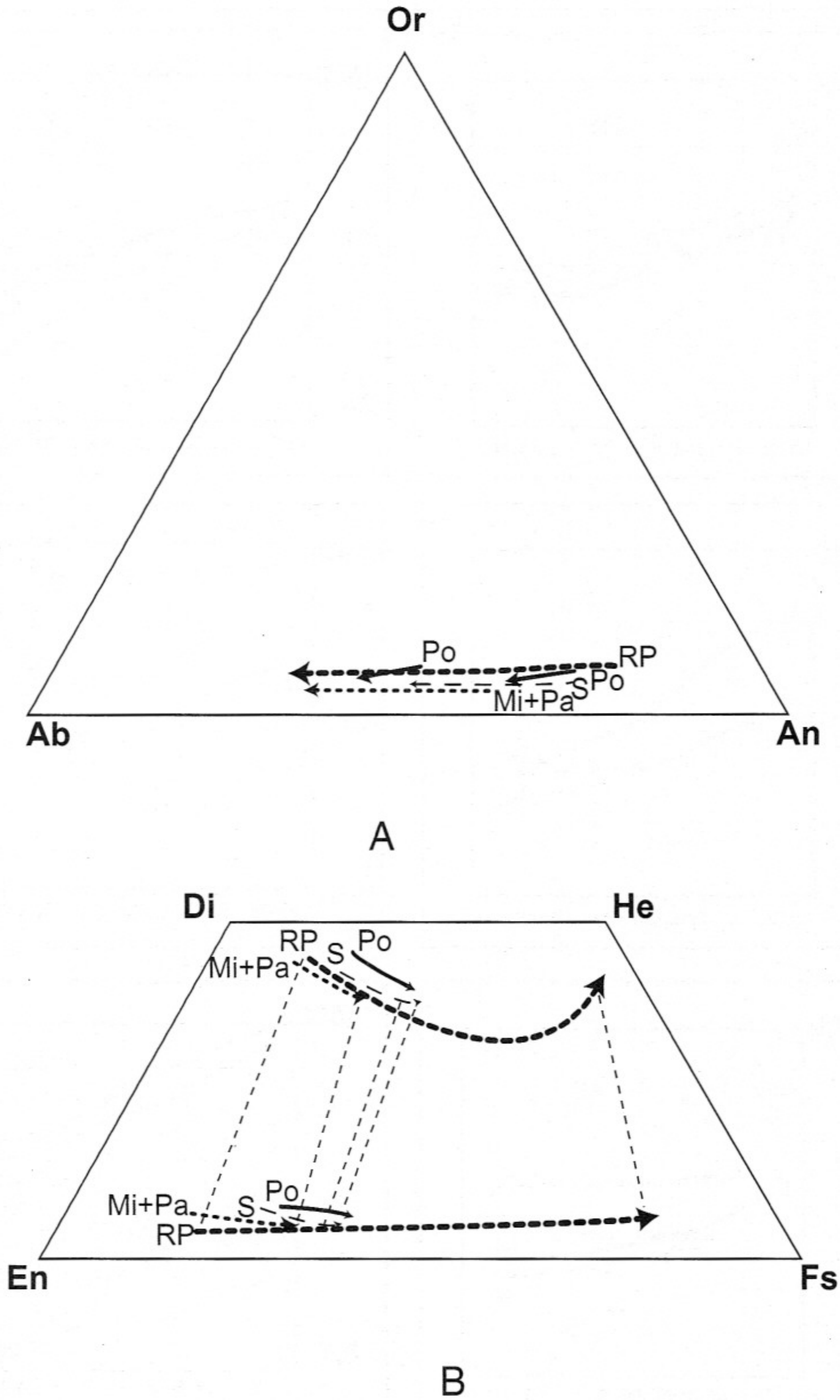

Figure 3 – Composition of plagioclase (A) and pyroxenes (B) of the gabbro-anorthosite massifs of southern Bahia. (RP) Rio Piau; (S) Samaritana and Carapussê; (Mi+Pa) Mirabela and Palestina; (Po) Potiraguá.

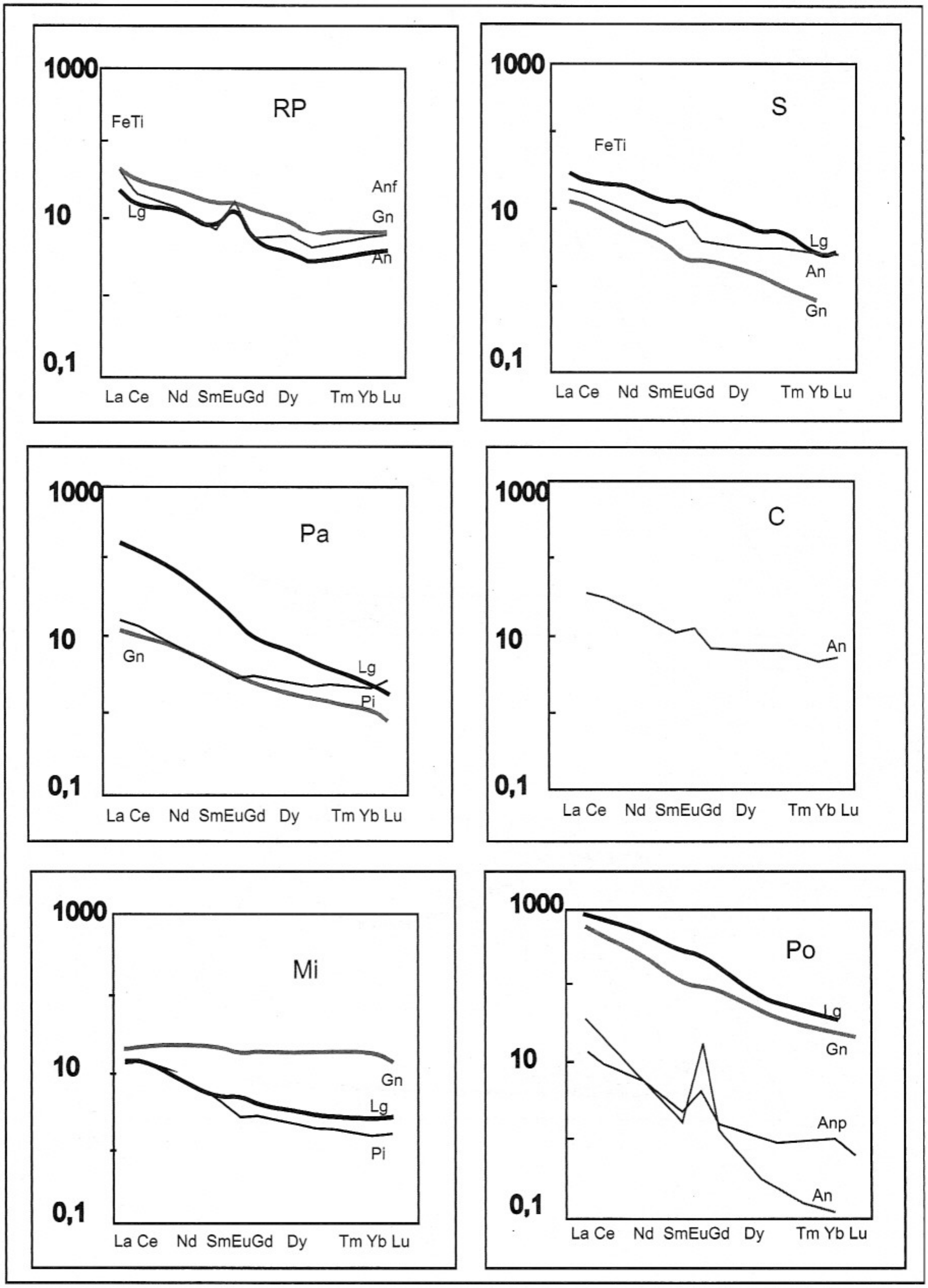

Figure 4 – Rare-earth element patterns of the gabbro-anorthosite massifs of southern Bahia. (An) anorthosite; (Anp) pyroxene-bearing anorthosite; (Anf) olivine-bearing anorthosite; (Fe-Ti) gabbronorite rich in Fe-Ti-V oxides; (Lg) leucogabbronorite; (Gn) gabbronorite; (Pi) pyroxenite and dunite. (RP) Rio Piau; (S) Samaritana; (C) Carapussê; (Mi+Pa) Mirabela and Palestina; (Po) Potiraguá.

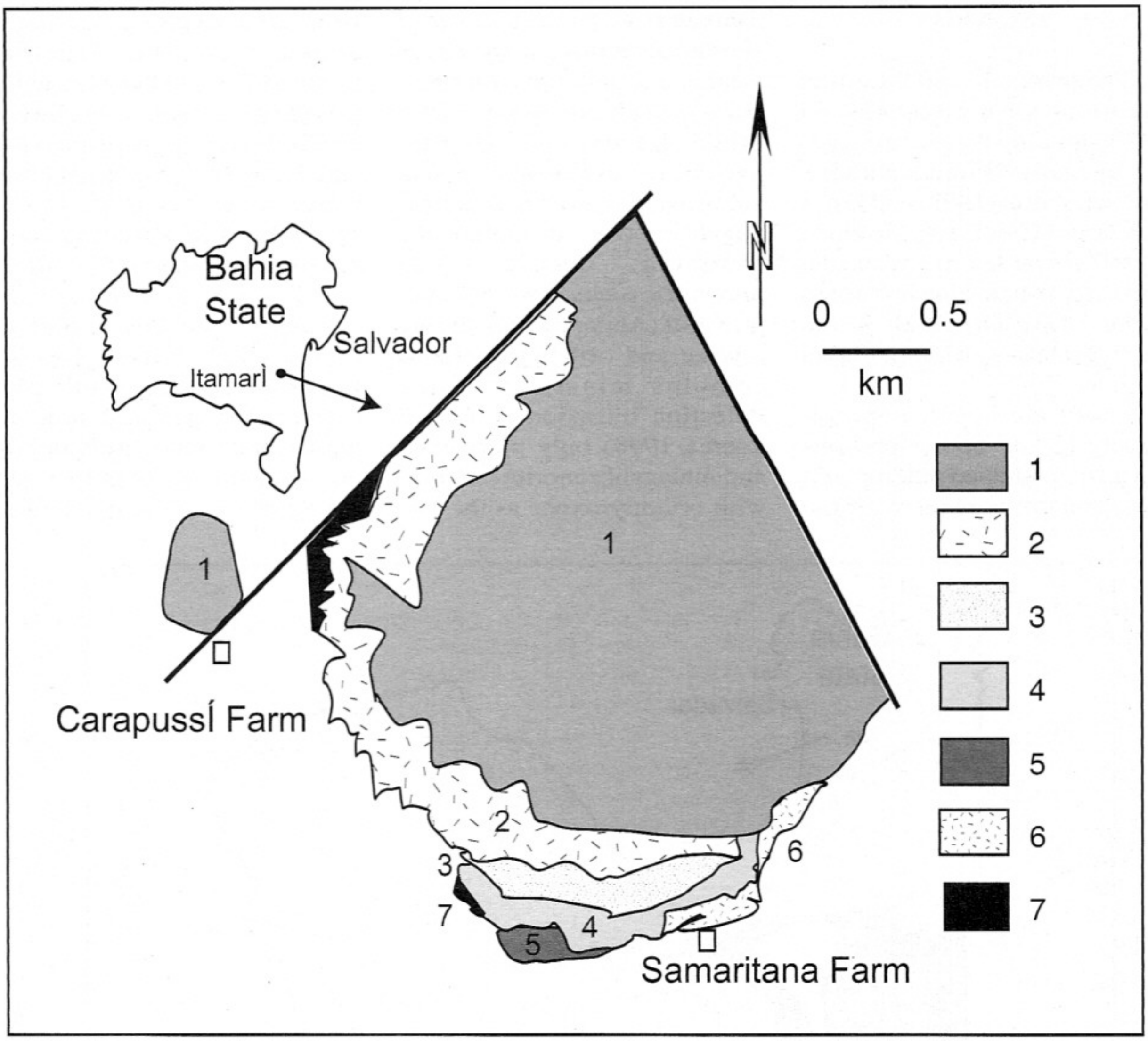

Figure 5 – Geological sketch map of the Samaritana & Carapussê massifs (Lima, 1997, Macêdo 2000). (1) anorthosite; (2) gabbronorite; (3) leucogabbronorite/gabbronorite; (4) gabbronorite/pyroxenite; (5) gabbronorites rich in Fe oxide; (6) rocks rich in Fe-Ti-V oxides; (7) gabbronorite (frozen margin).

The Carapussê monolith (Macêdo, 2000) lies close to the north of the Samaritana massif, close to that intrusion. Part of its contact with the granulitic country rock is controlled by regional shear zones. Radar images, however, clearly demonstrate that the relation intrusion/country rock is characterized by a high strain intrusive process. In the Carapussê massif, differently from the Rio Piau and Samaritana massifs, only anorthosite terms have been identified. Also, olivine is present in this massif, but does not occur in the Samaritana massif (Lima, 1997). Cpx and Opx fall, respectively, in the following intervals of compositions: En_{37}-Fs_{19}-Wo_{44} and En_{50-52}-Fs_{37-48}-Wo_4 (Fig. 3-B). Geothermometric calculations (Lima, 1997) showed temperatures comparable to those of the Rio Piau massif (850°, Cruz, 1992). Most of features of the Samaritana anorthosite are similar to those ones of Rio Piau. The mafic terms however shows a higher *mg#* and the REE distribution pattern indicates a stronger cumulatic process for the Samaritana layered rocks.

The Mirabela and Palestina Massifs

The Mirabela and Palestina intrusions were discovered in 1979 and they have been studied by many different authors, such as Abram (1993) and Fróes & Soares (1998). The Mirabela massif is near Ipiaú city, and the intrusion of Palestina is close to Dario Meira city, both in the southwestern portion of Bahia (Fig. 6).

These are small, approximately 12 km² bodies presenting an oval-shaped outcrop pattern, and concordant with the country rock structure. They are characterized by the absence of anorthosite terms and by the appearance of ultramafic differentiates, which are absent in the other intrusions. Dunite, peridotite, pyroxenite, melagabbronorite and meso- to leucogabbronorite dominate the Mirabela massif. The ultramafic rocks of the Mirabela massif (Abram, 1993) display olivine and orthopyroxene as cumulus minerals. In the Palestina intrusion (Fróes & Soares, 1998), only pyroxenite and melagabbronorite outcrop, with orthopyroxene as the single cumulus phase. The Mirabela rocks are grouped into two zones, a smaller, layered, ultramafic one to the west, comprised of melagabbronorite (I), peridotite (II), pyroxenite (III) and dunite (IV), and a gabbroic massif to the east (Fig. 6). The pyroxenites of Palestina comprise only small bands, intercalated with the dominant melagabbronorites (Fróes & Soares, 1998). It is worth to notice the outstanding similarities regarding the textural, mineralogical and chemical characteristics of the pyroxenites and melagabbros of the two bodies

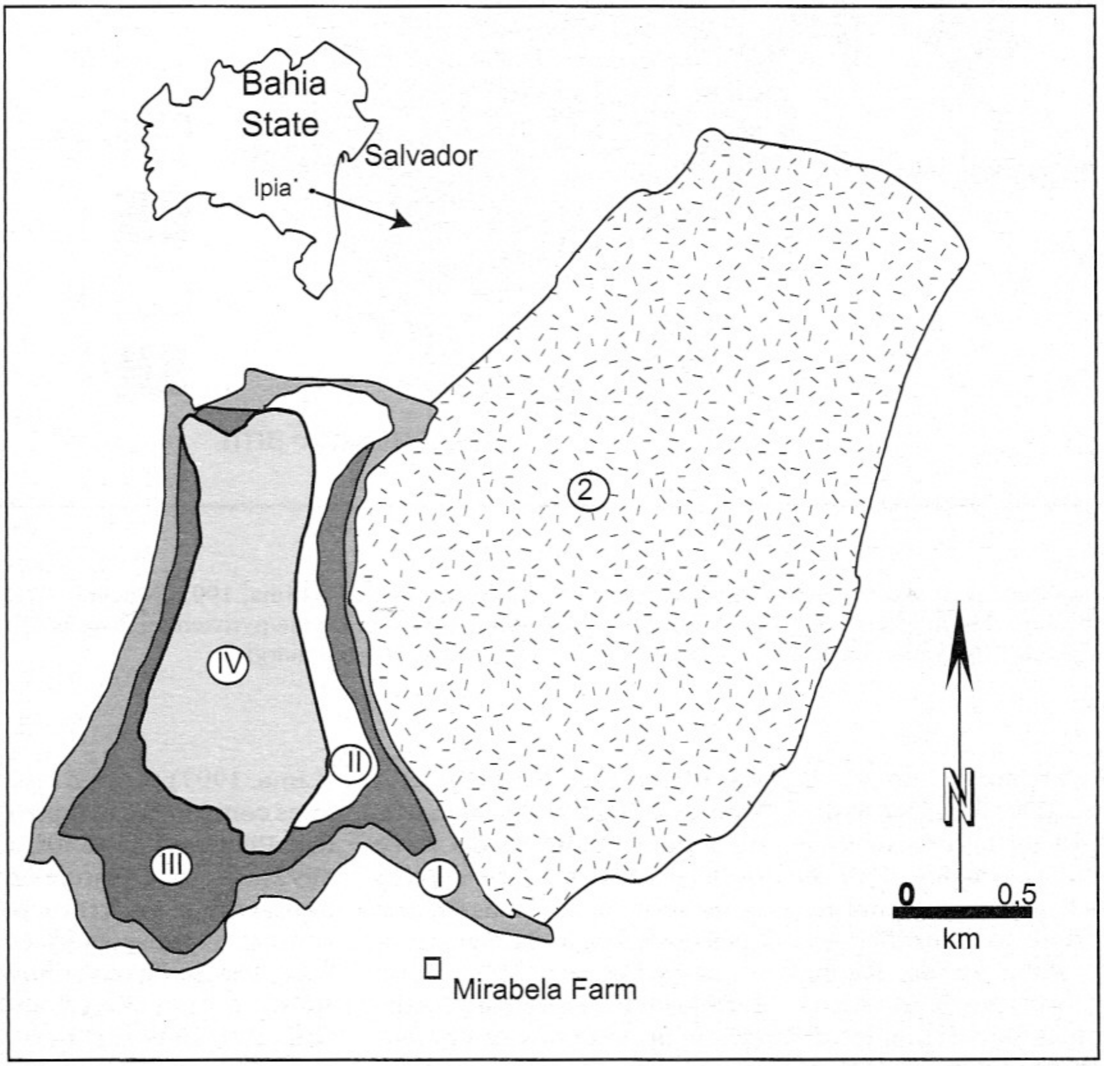

Figure 6 – Geological sketch map of the Mirabela massif (Abram, 1993), (2) gabbroic rocks, (I) melagabbronorite, (II) peridotite, (III) pyroxenite, (IV) dunite.

(Fróes & Soares, 1998). According to these authors, the Palestina massif is only an outcrop of a major intrusive body, very similar to that of Mirabela. For both the intrusions, the plagioclase is much more sodic than those of the Rio Piau massif, varying from An_{32} to An_{44} and the pyroxenes have intervals of composition from En_{45-57}-Fs_{5-12}-Wo_{31-50} for the Cpx, and En_{81} to En_{88} for the Opx (Fig. 3-A,B). The olivine, the only present, is forsteritic (Fo_{80-87}) in composition. Geothermometric calculations for gabbroic terms of the Mirabela massif yielded equilibrium temperatures around 850°C. The same calculations for ultramafic terms indicated equilibrium temperatures around 1000°C (Abram, 1993).

The REE chondrite-normalized diagram shows a relatively flat and accumulated pattern for the gabbronorite and ultramafic rocks (Fig. 4). The Al_2O_3/CaO ratio of 2,24 for the leucogabbronorite of the Mirabela body is similar to the values of Rio Piau and Samaritana, falling to 1.23 and 1.10 in the pyroxenitic and dunitic rocks, respectively.

The Potiraguá Massif

This intrusion was recently defined by Bordini *et al.* (1999). It is an intrusive massif located about 6 km to the east of the town of Potiraguá, south of Bahia (Fig. 7).

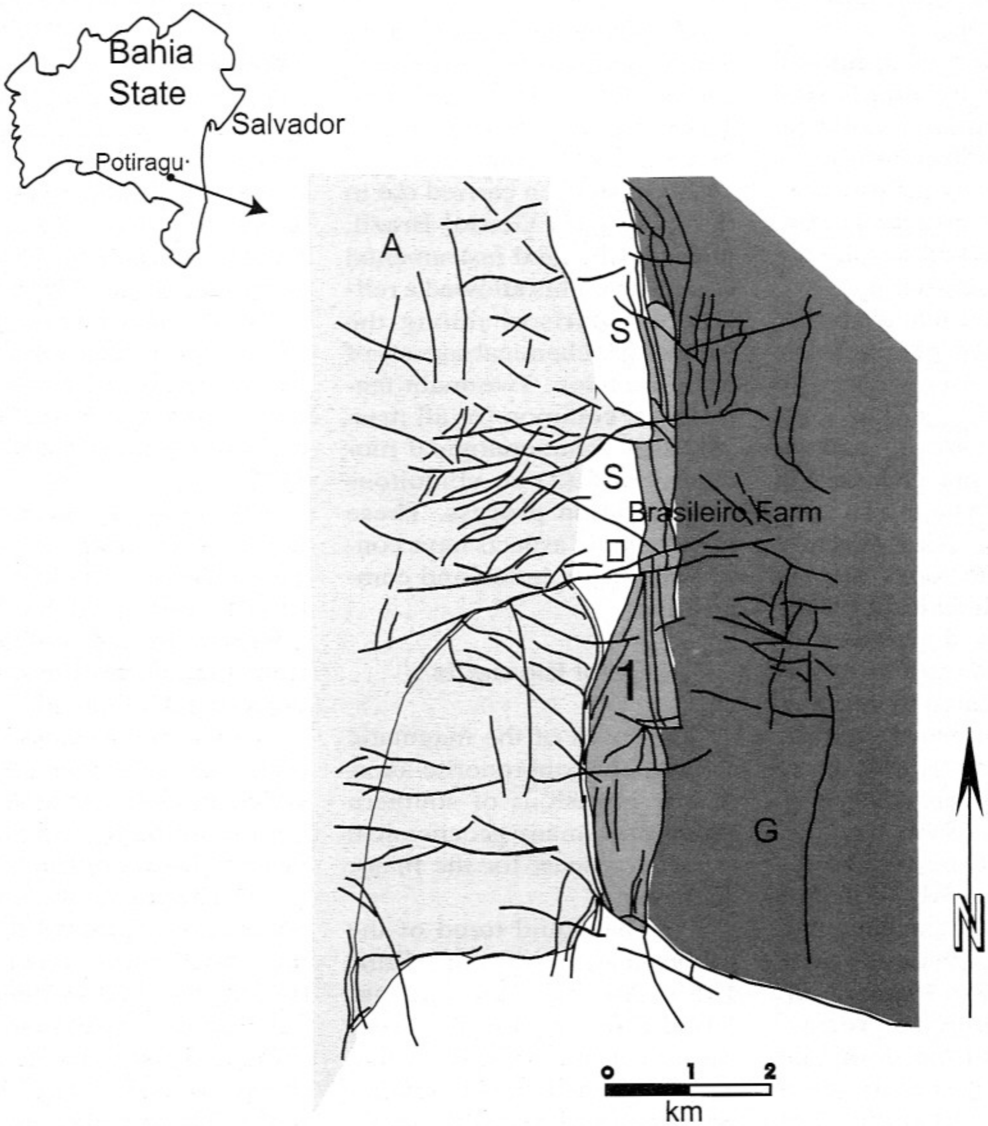

Figure 7 – Geological sketch map of the Potiraguá massif (Bordini *et al.,* 1999). (1) anorthosite. Host rock: (G) Granulitic rocks of the Itabuna belt; (A) Amphibolitic rocks of the Gavião block; (S) Peralkaline massifs (nepheline-syenites) of Brasiliano age (Bordini, in prep.).

It constitutes a narrow body, with about 20 km² of exposition, which lies to the southern extremity of the Bahia's gabbro-anorthosite trend (Fig.1), in the limit of the granulitic rocks of the Itabuna belt (Barbosa, 1986) to the east and the amphibolitic terms of the Gavião block (Barbosa & Dominguez, 1996) to the west. Although these bodies are very close to peralkaline massifs emplaced during the Brasiliano tectonic cycle (about 600 Ma), their geological relationships are still under investigation (Bordini, in prep.).

The intrusion is composed predominantly by anorthositic rocks. Fine grained gabbroic dikes swarms structurally accompany the body deformation. Accumulated magmatic textures are preserved despite the expression of shortening.

Mineralogy is marked by the presence of two plagioclases, labradorite (An_{70-76}) and andesine (An_{48-54}). The Cpx (En_{40-43}, Fs_{12-16}, Wo_{41-48}) and the Opx (En_{71-77}) are rich in Mg (Fig. 3 A, B). The modal ratio of olivine (Fo_{69-79}) is frequently above 6%. The rocks display iron oxides minerals, as resultant of olivine and pyroxene alteration. Pyroxene geothermometry indicated lower temperatures of mineral equilibrium, in relation to that of the Rio Piau massif, around 800°C (Bordini *et al.*, 1999).

The anorthositic rocks present similar SiO_2 contents (≈»48 %) and the same interval (0.10 - 0.40) for the *mg#,* close to the that of Rio Piau massif. The gabbronorite terms, intercaled with the dominant anorthosites, present an intermediate *mg#* (≈» 0.20). The Al_2O_3/CaO ratio stays in the order of 1.30 for the leucogabbronorite and of 2.02 for the anorthosite. These values are slightly inferior in comparison to those of the Rio Piau massif. The REE patterns for Potiraguá are analogous to those of the leucogabbro terms of the Rio Piau massif, with little fractionation of the light REE. The normalized values, as a whole, are higher than those of the anorthosite terms, which present a characteristic Eu anomaly (Fig. 4).

GEOCHEMISTRY

Chemical analyses of a diversity southern Bahia massifs rocks (Cruz, 1989; Abram, 1993; Lima, 1997; Fróes & Soares, 1998; Bordini *et al.*, 1999) have been carried out in the laboratory Geosol-Brazil, under unchanged instrumental conditions. This allowed a reliable comparison among the various geochemical aspects of each intrusion. Two main features are common for all massifs: (1) a mineralogical monotony and (2) an ubiquitous accumulation process. These two geologic aspects have controlled the evolution and composition.

Major Elements

The rocks of the magmatic series of the gabbronorite-anorthosite intrusions of southern Bahia share many geochemical aspects, at least for the major elements:

(1) The liquid trend of the gabbro-anorthosite units (Cruz, 1989; Abram, 1993; Lima, 1997; Fróes & Soares, 1998; Bordini *et al.*, 1999) show that they are iron-rich, characterizing, thus, a classical tholeiitic trend.

(2) The comparison of these trends (Cruz, 1989; Abram, 1993; Lima, 1997; Fróes & Soares, 1998; Bordini *et al.*, 1999) with the classical tholeiitic trend of the extremely differentiated and iron-rich intrusions, like Skaergaard and Kiglapait (Wager & Brown, 1968; Morse, 1981) indicates that, in the intrusions of southern Bahia, the iron enrichment is not function of an extreme fractionation, since the rocks are not highly differentiated (Fig. 8).

(3) The iron enrichment is generally followed by a silica depletion. Equal behavior is observed for the pair TiO_2 - V_2O_5. These relations are compatible with the Fenner's (1929) sequence of crystallization, indicating that the Fe-Ti oxides had not been crystallized late in the series and also reflecting low oxygen fugacity of these basic magmas (Morse, 1980, 1990).

(4) The aluminum content of the southern Bahia intrusions can reach up to 25% of Al_2O_3, and such value is sufficiently high for basaltic liquids (Kuno, 1960).

(5) The Al_2O_3/CaO ratios are high, varying from 1.01 to 2.30. These figures are closer to the results obtained by Upton (1996) for the ratios of magmas from the anorthosite province of Gardar, Greenland.

(6) The Sr concentrations are high, normally over 300 ppm, which are close to the saturated high aluminum basaltic magmas of Upton (1996).

(7) The *mg#* in the intrusive bodies goes from 0.1 to 0.4 in the anorthosite rocks; from 0.23 to the 0.68 in the leucogabbronorite and gabbronorite rocks and stays around 0.7 for the pyroxenitic and dunitic rocks. These values are small when compared with modern MORB magmas (Emslie, 1980). In accordance with

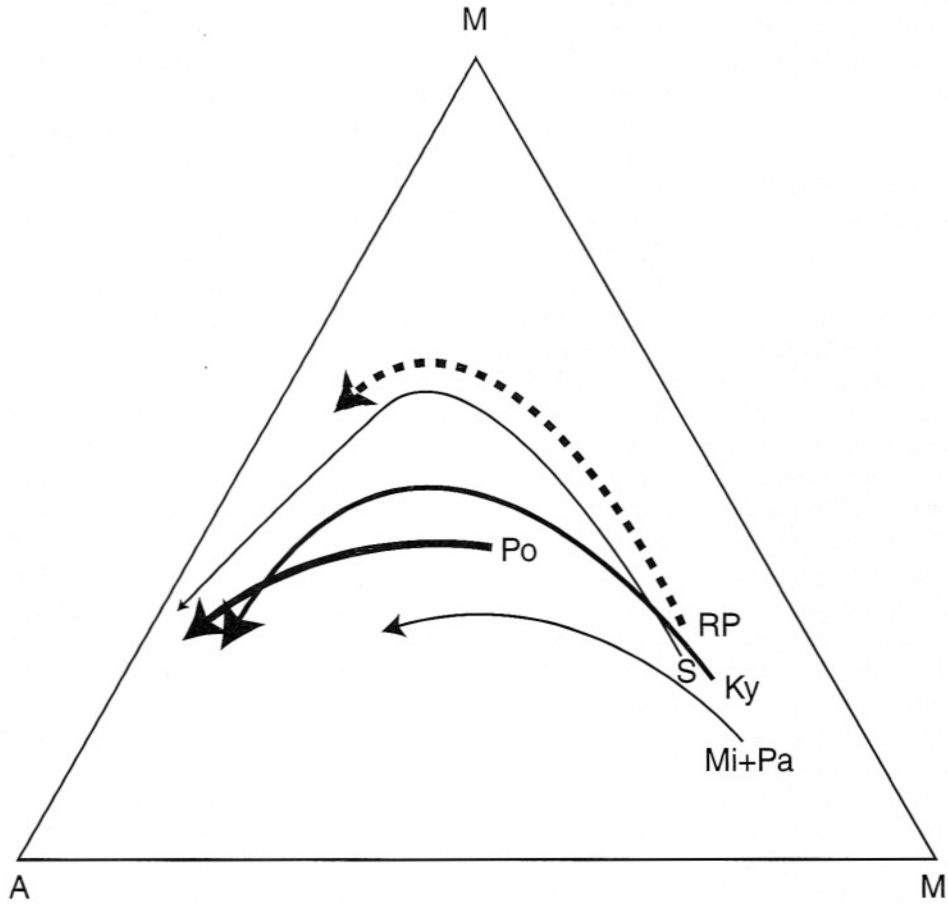

Figure 8 – AFM diagram for Rio Piau - RP (Cruz, 1989), Mirabela-Palestina – Mi-Pa (Abram, 1993, Fróes & Soares, 1998), Samaritana - S (Lima, 1997), Potiraguá – Po (Bordini *et al.*, 1999), Skaergaard - S (Wager & Brown, 1968) and Kiglapait – Ky (Morse, 1981),

Morse (1982), these results could be attributed to the initial fractionation of mafic minerals that would enhance this difference. We assume that the rocks of southern Bahia were originated from a parental magma of a similar composition to the modern suboceanic mantle.

(8) The analytical results show two distinct trends: (i) one group represents lithotypes where the event of magmatic accumulation has been barely present, corresponding to liquid alignment of tholeiitic basalt magmas. According to Cruz (1989), this trend implies of an accumulation rate lower than 40%; (ii) another group is formed by cumulate rocks, in which three different types can be distinguished: (a) the ferric domain, formed by Fe-Ti oxide-rich gabbronorite; (b) the magnesian domain, represented by melanocratic gabbronorite-pyroxenite to dunite terms; and (c) the aluminous domain, composed essentially by anorthosite rocks.

Each domain in the diagram present particularities in respect of the different massifs. The magnesian domain comprehends rocks from Mirabela, Palestina and some of the Samaritana massif. The ferric domain comprehends rocks from all the massifs, indistinctly, and the aluminous domain is not represented only in Palestina and Mirabela massifs. The magnesian and aluminous domains can be interpreted as the product of a bipolar accumulation occurred during the evolution of a tholeiitic magma (Cruz, 1989).

In order to understand the ferric domain, one can consider a sample located in the triangular diagram next to the classic tholeiitic trend, and applying it a simple mass balance modeling. The calculated values form a curve parallel to these points characterize the ferric domain.

Trace and Rare-Earth Elements

The crystallization trends for the southern Bahia gabbro-anorthosite massifs have been monitored using Zr as the chemically immobile element, following the suggestion of Erkland & Kable (1976) for the case of basaltic rocks. As expected from the rock types assortment, the fractionation of FeO, TiO_2, Nb, and Ce caused the increment of their concentrations, accompanied by concomitant decreasing of the *mg#*. The internal comparison of the values indicates a direct relation among low Zr with high Mg contents, and even better, of low Zr contents with higher anorthite concentrations, and also with relatively low incompatible element concentrations. On the other hand, the higher Zr values are related with higher V_2O_5, P_2O_5, K_2O and MnO concentrations (Cruz, 1989).

The Nb/Zr ratios vary little, being normally lower than 10, except for the Potiraguá massif. These results suggest a clear distinction of these magmas in relation to the standard magmas of Taylor & McLennan (1985), which are differentiated modern basalts. The southern Bahia massifs REE patterns are shown in Figure 4 and Table 2.

According to Hanson (1980, 1989), a diversity of REE patterns can be produced by different ratios of partial fusion. However, southern Bahia massifs REE patterns are quite parallel and regular. The parallelism can be interpreted as the crystallization product of an assemblage with relatively constant mineral constitution. The REE spidergrams for all of the massifs are similar, with normalized values generally in the order of 10 to 100 times chondrite for the LREE, and lower than 10 times chondrite for the HREE (Cruz, 1989; Lima, 1997; Macêdo, 2000). The La/Lu ratios are also constant, except for the Potiraguá massif, which shows a striking diminution of this ratio (Bordini, in prep.).

The Al_2O_3/CaO ratios are directly related with positive Eu anomalies and also with higher Sr and reduced Rb contents, which is related with the presence of plagioclase.

DISCUSSION

The petrographical features associated with the geochemical aspects indicate a likely fractional crystallization and gravitational accumulation process, in the evolution of these intrusions, with enrichment in iron, as they follow the alignment of Fenner (1929) for closed systems.

The supersaturation in feldspar in southern Bahia anorthositic rocks is characterized also by two aspects (1) the positive anomaly of Eu, possibly caused by the fact that this element possess high partition coefficient in relation to plagioclase, and the low one to the pyroxene (Sun *et al.*, 1974; Gromet & Dymek, 1980), and (2) the textural character of the rocks, which do not present aphyric types.

The total absence of enclaves and xenoliths in southern Bahia rocks could be explained by the little interaction of the gabbro-anorthositic rocks with oxidized and quartz-poor host rocks (e.g. Osborne, 1959; Morse, 1980).

Geochemical data are available for all southern Bahia massifs (Cruz, 1989; Abram, 1993; Lima, 1997; Fróes & Soares, 1998; Bordini *et al.*, 1999). They have provided good evidence that the conditions of crystallization of southern Bahia anorthositic bodies would be similar to the intrusions of Kiglapait (Morse, 1981), the Nain complex (Wiebe, 1978, 1979, 1980), the anorthosite of Harp Lake (Huntington, 1980), the Adirondacks (Emslie, 1980; Ashwal, 1982) and the massifs of the region of Rogaland (Wiebe, 1980). In these environments, the conditions would be of high temperature of crystallization, demonstrated by the hipersolvus or the subsolvus barrier of the ternary pyroxenes and feldspar (Morse, 1982).

Based also on the geological aspects of the massifs and taking into account the statements of Mitchel *et al.* (1995, 1996), it is considered here that the magmatic evolution of these intrusions has been comprised of crystallization of a silicate melt initially clutched within small magmatic chambers, distributed in the base of the crust and involving aluminous gabbroic rocks. Anorthosite formation could be related to a mechanism considered by Morse (1982) as hyperfeldspatic, or plagioclasic magma by Michot (1968). This involves a mechanical enrichment or supersaturation in plagioclase, which is the product of mechanic concentration of this mineral in the magma, followed by the removal of the vestigial liquids that would originate the rocks rich in Fe-Ti-V.

CONCLUSION

The Potiraguá massif is very particular and bear similar features whit the Phanerozoic anorthosite of Aïr Ring, of Niger described by Brown *et al.* (1989) and Demaiffe *et al.* (1991), including the frequent presence of forsterite olivine. These petrological characteristic suggests that the Potiraguá massif would be related to an upper crustal level, where plagioclase fractionation is not significant, thus differing from the other southern Bahia massifs.

The geochemical character of the southern Bahia intrusions is similar to that described by Olson (1992) for the basaltic rocks associated with the anorthosite of the Adirondack, and comparable to that of the Gardar, Greenland (Upton, 1996). The high Al_2O_3/CaO ratios, allied to the high Sr values and positive Eu anomalies would be related to supersaturate high aluminum basalt, where the crystallization of plagioclase and olivine is the result of low rate of nucleation.

Their association with gabbro clearly reflect that they are products of basaltic magmas crystallization, with enrichment trends in Fe, Ti and P. These features are similar to the bimodal suites associated with continental rift zones, as had already been observed by Emslie (1980) and reinforce the hypothesis proposed by Cruz & Sabaté (1995) and Sabaté & Cruz (1998), based solely on structural elements, that the southern Bahia massifs are related with a continental rift zone developed within tensional sites, with a basic melt have resided into the crust.

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