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Petrogenesis and Tectonic Setting of the Lagoa das Pedras Magmatism, Floresta, State of Pernambuco, Borborema Province, Northeast Brazil

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ABSTRACT

A long-lived magmatism has developed in the Lagoa das Pedras complex of the Extremo Nordeste domain of the Borborema Province, from the ending of the Middle Proterozoic to the beginning of the Paleozoic. It is situated in an important crustal boundary, probably having a collisional nature, where we can recognize an early accretionary mafic-ultramafic segment chemically similar to MORB, then representing evidence of an oceanic stage; and a dacitic to rhyolitic dominantly volcaniclastic sequence with an arc-related signature. Collisional granites are thrusting-controlled and comprises meta and peraluminous types. They are crustal anatectic granites with igneous or sedimentary sources, intruded by a series of late-collisional granitoids dominantly metaluminous granodiorites and by post-collisional peraluminous and peralkalic granites. This evolution resembles a progressive magmatism produced through a Wilson cycle; however geochronological data indicate that the collisional episode would have occurred nearly 950 Ma, therefore much earlier than post-collisional granites, whose intrusion occurred at about 515 Ma, what suggest a two-cycle evolution.

Key words: collisional event, terranes, collisional granitoids, late-collisional granitoids, post-collisional granitoids

INTRODUCTION

The Lagoa das Pedras magmatic complex is situated in the semi-arid region of northeast Brazil, near Floresta town, 450km far from Recife, capital of the State of Pernambuco. This is one of the various composite batholiths that form a series of large granitic ridges trending subparalell along the Extremo Nordeste domain at the Borborema structural province (Fig. 1). The framework of this magmatic assemblage reveals a long-lived history of magmatic activity developed since the ending of the middle Proterozoic to the beginning of the Paleozoic. Moreover, it is situated in an expressive tectonic line in which associations with distinct geochemical and tectonic signatures are present, then representing an important lithological association for the understanding of the Borborema province evolution. This paper describes the main characteristics of the components of the complex, their arrangement and relationship with the metamorphic envelope and evolution through time.

STRUCTURAL SETTING AND MAGMATISM

The Borborema province tectonic pattern results from a terrane amalgamation process involving belts and massifs, as defined by Brito Neves (1984) or domains and sub-domains, as described by Santos et al. (1984). In general, most of the

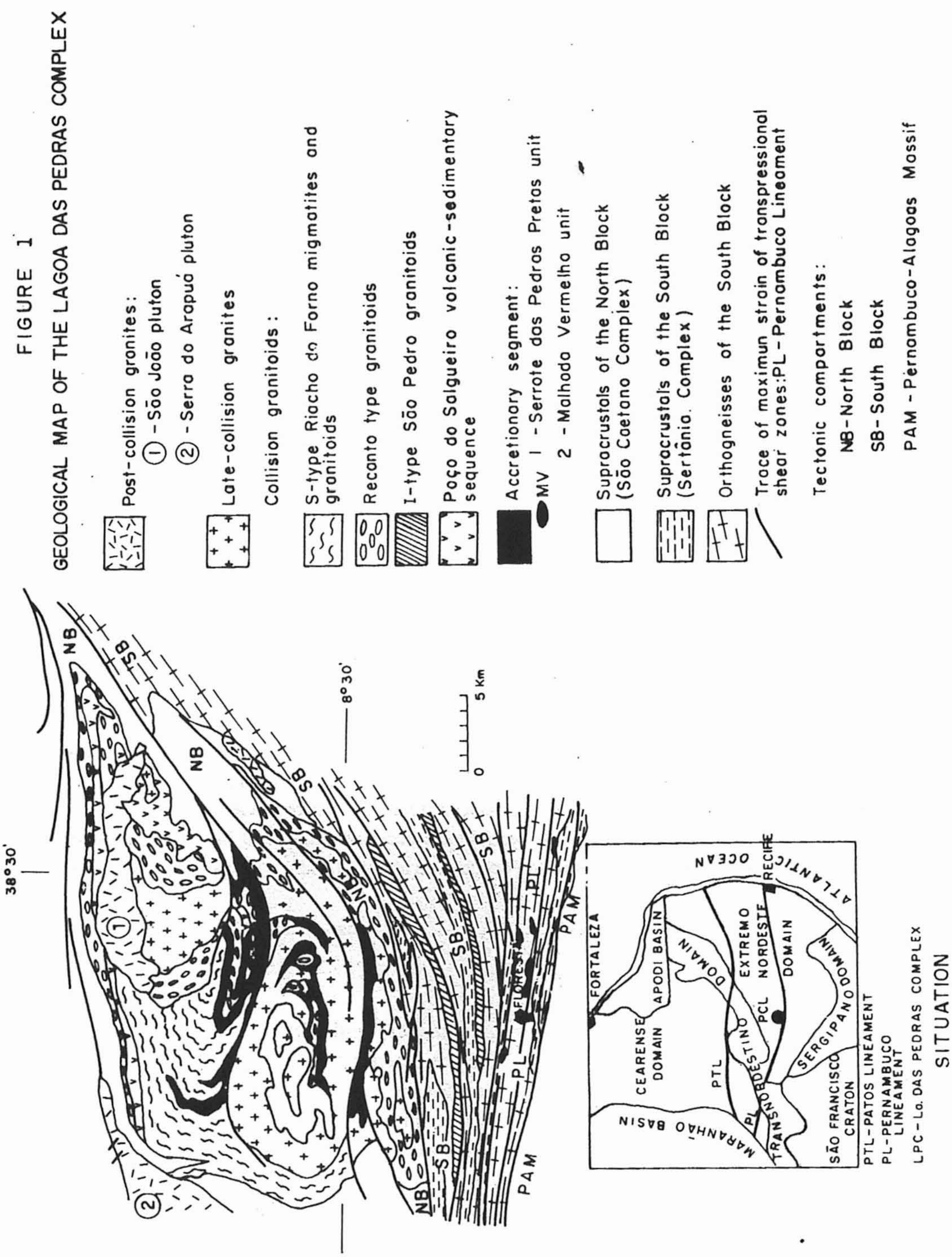


Fig. 1 — Simplified geological map of the Lagoa das Pedras complex, State of Pernambuco, northeastern Brazil.

geotectonic concept about the Borborema province takes into account an ensialic evolution, some of them referring to a Pan-African/Brasiliano intraplate shear zone system of continental scale (Vauchez & Silva, 1992). Some other authors (e.g. Leterrier et al., 1990), observed patterns of a far-subduction phenomenon in the Brasiliano granitic plutonism of the Seridó region, admitting a genetic relationship with a mafic magma invasion in the lower crust. In the Transnordestino domain, Sial &

Ferreira (1988) and Sial et al. (1990) described granitic rocks of continental trondhjemitic affiliation and a zone of shoshonitic and ultrapotassic intrusions controlled by a pull-apart episode, developed between Pernambuco and Patos lineaments. According to these authors, there is a control by a shallow enriched-mantle source present in this region, since the Proterozoic or even from Archean times. On the contrary, Silva Filho & Guimarães (1990) and Guimarães & Silva Filho (1990) observed subduction-related geochemical signatures in calc-alkalic, shoshonitic and ultrapotassic rocks of the Terra Nova and Bom Jardim complexes, of the Piancó-Alto Brígida and Pajeú-Paraiba belts; both thought to be products of a Brasiliano arc-continent collision. Recently, some authors have observed geological and geophysical evidences of a median line (ML) in the Extremo Nordeste domain, separating terranes with different litho-stratigraphic sequences and history of magmatism. A gravimetric pair similar in form to those of the sutural limits, present in various orogenic belts of the world (e.g. Gibb et al. 1982; R. G. Oliveira, pers. comm., 1993) occurs along this zone, bringing together terranes of distinct gravimetric and magnetic signatures. It is characterized also for the occurrence of sequences with arc or fore-arc patterns, and of mafic and ultramafic slices having relicts of a high pressure/medium temperature metamorphism.

In the area of the Lagoa das Pedras complex, the supracrustals in the north part of the ML, the São Caetano complex, are composed mainly by a pelitic-psammitic sequence with minor arkoses, graphitic shales, limestones and scarce basites metamorphosed in a medium grade metamorphism. Migmatites of *lit-par-lit* injection and stromatic types probably developed below the first sillimanite isograd. A younger volcanic-sedimentary sequence, the Poço do Salgueiro unit, occurs also in this northern segment, having mainly a pyroclastic character with minor interbedded basic and acid lavas; it can be an equivalent of the Irajaí Complex (Wanderley et al. 1992). The supracrustals in the south of the ML are dominantly of sedimentary nature - the Sertânia complex -, which is metamorphosed at a high grade, where typical anatectic migmatites are common. Besides, there are wide zones of felsic meta-igneous rocks or of bimodal composition, which may represent relics of an early magmatic episode or a gneissic basement. The first tectonic episode is a thrusting and nappe event with a roughly southward transport, developed in P-T conditions of amphibolite facies. The ML is a major feature of this event, supracrustal and mafic-ultramafic wedges and intrusive granitic sheets occurring along this line. It is thought to represent a collisional zone. A late tectonic episode is mainly of transpressional character, maybe occurred progressively after the main collisional event. Therefore, the magmatism of this area can be described in terms of an accretionary segment, a volcanic-sedimentary pile, a collisional and a late and post-collisional plutonism.

THE ACCRETIONARY SEGMENT AND THE POÇO DO SALGUEIRO VOLCANIC ROCKS

The accretionary segment is formed by metamafic and ultramafic rocks, usually mineralized in Fe-Ti (Veronese et al., 1985; Beurlen, 1988). The Malhada Vermelha unit comprises lenses and fragments of mafic rocks, present in the south part of this block. They have dioritic, gabbroic and anorthositic composition, although felsic-gneissic rocks and more mafic amphibole or pyroxene-rich rocks with or without garnet also occur. The Serrote das Pedras Pretas unit is hosted by supracrustal rocks of the northern block and by collisional granitoids, apparently through a tectonic contact. There is evidence of interbedding with the Poço do Salgueiro volcanic rocks in the north part of the complex. Beurlen (op. cit.) described dunites with olivine cumulates in intercumulus matrix of Fe-Ti oxides and sulphides. However, primary features are rarely preserved. Generally, these metabasite rocks are composed by winchitic hornblende, crossite, with relics of olivine and, more often, clinopyroxene, plagioclase, variable amounts of quartz, epidote-allanite, garnet and minor amounts of titanite, apatite, ilmenite, rutile, actinolite/ tremolite, scarce titaniferous biotite, chlorite and other alteration products such as talc, serpentine, sericite, carbonate, etc. Garnet is always poikiloblastic, having inclusions of rutile, quartz, and less often epidote and amphibole. Moreover, poikiloblastic spinel occurs with relics of amphibole and garnet; poikiloblastic plagioclase is also present. Symplectitic, kelyphytic and atoll textures are common, involving garnet-amphibole-plagioclase-epidote, clinopyroxene (amphibole)-plagioclase (ilmenite), amphibole-plagioclase. These are probably residual features of an original mineral assemblage involving garnet and omphacitic pyroxene in the Bodocó area, further west of this region (Beurlen et al., 1990). Geochemically, this suite has tholeiitic nature (mainly gabbro-basalt and picrite), occurring minor rocks of intermediate compositions. Some major and trace element diagrams as well as REE patterns suggest similarity with MORB (Figs. 2 and 3).

The Riacho das Lajes metagranitoids seem to represent a felsic suite of this accretionary segment. These metagranitoids are trondhjemitic, being composed by albite-oligoclase, quartz and minor K-feldspar, clinopyroxene partially retrograded to amphibole, secondary pistacite, titanite, allanite, apatite and rare garnet. The K_20 content is comparable to that of oceanic plagiogranites and the K/Rb, Rb/Sr and Rb/Ba are similar to the primitive M-type association of granitoids as described by Whalen et al. (1987).

The Poço do Salgueiro volcanic rocks represent a component of a volcanic-sedimentary pile, where volcanoclastic, pelitic, chemical and cherty sediments are dominant. There are local evidence of lava flows and, in some places, they occur associated with basaltic rocks of the Serrote das Pedras Pretas unit. Tuffs and fine-grained volcanoclastic rocks usually bedded, sometimes graded bedding, are the dominant component; breccias and coarse-grained deposits (agglomerates ?) rarely being observed. This volcanoclastic component grades laterally into greywackes and pelites of the São Caetano complex, in a behavior similar to that of the Irajaí complex. Rocks are lepidogranoblastic, with rare relics of phenocrysts. Quartz, plagioclase, microcline and biotite are the main minerals, occurring also muscovite, titanite, apatite, zircon, secondary clinozoisite-epidote, calcite, and rare ore mineral. Sporadic garnet and clinopyroxene are found as xenocrysts. Compositionally, these rocks are dacites, dacitic andesites and trachydacites, grading into rhyolites. They are mainly peraluminous, calc-alkalic rocks, whose spidergram and chondrite-normalized REE patterns are similar to that for high-K calc-alkalic series of mature magmatic arcs (Figs. 4 and 5). Alternatively, they can represent tuffs of sedimentary olistoliths in a mélange ophiolitic-flysch association, as described by Floyd et al. (1992) in the Misis Complex, Turkey.

COLLISIONAL GRANITOIDS

These crustal-derived granitoids result from anatexis during the collision between the two blocks along the ML; metaluminous and peraluminous rocks being distinguished. The difference in terms of alumina saturation is a function of the protolith. The protolith of the metaluminous rocks is the metaluminous mafic-intermediate orthogneisses in the southern block, whilst the peraluminous rocks are derived from the sedimentary and volcanic-sedimentary sequences of the São Caetano and Poço do Salgueiro complexes in the northern block.

The metaluminous São Pedro leucocratic metagranitoids show recrystallized granoblastic textures, with vestige of hipidiomorphic ones. In general, these are quartz and plagioclase-rich rocks, with late, interstitial K-feldspar. The dominant mafic mineral is bluish green hornblende, rarely clinopyroxene (diopside-hedenbergite), chocolate brown-biotite, besides apatite, titanite, epidote-zoisite, rare garnet and ore mineral. The metaluminous character and the trace element patterns of these rocks show that they are equivalent to oxidized I-type granites as defined by White

Figs. 2-7 — Primordial mantle-normalized incompatible element diagram and chondrite-normalized REE patterns for: accretionary segment (Figs. 2 and 3), volcanic-sedimentary sequence (Figs. 4 and 5) and Recanto metagranitoids (Figs. 6 and 7). Normalizing values from Sun (1980).

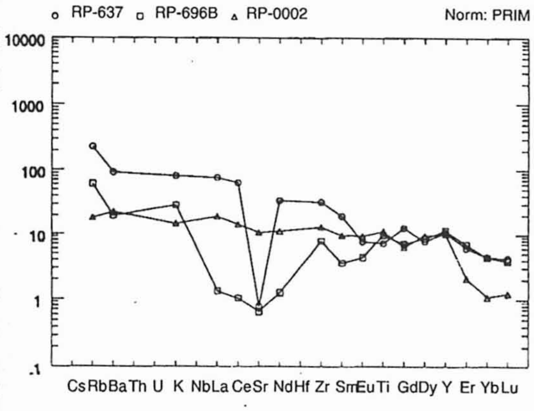
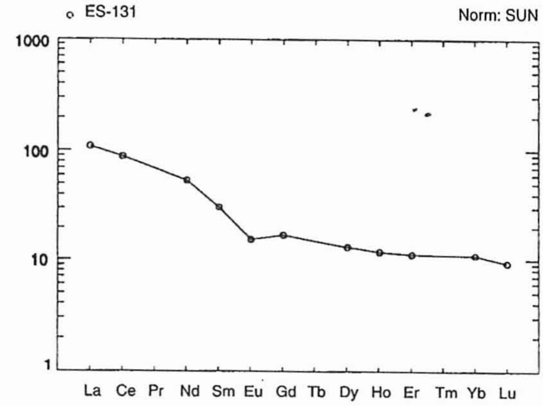


FIGURE 2



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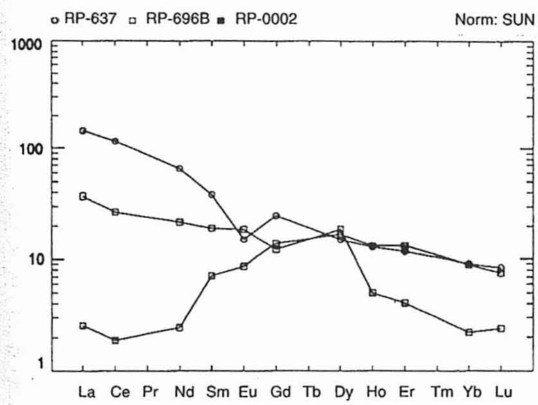

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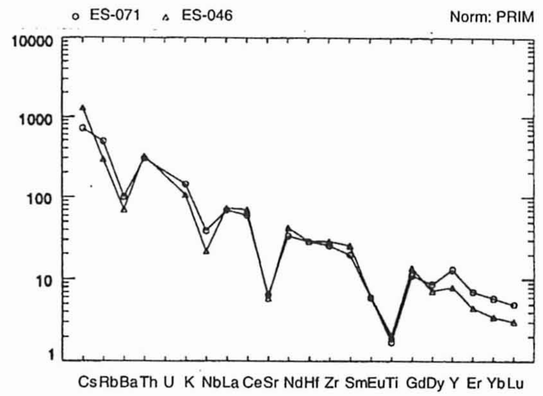

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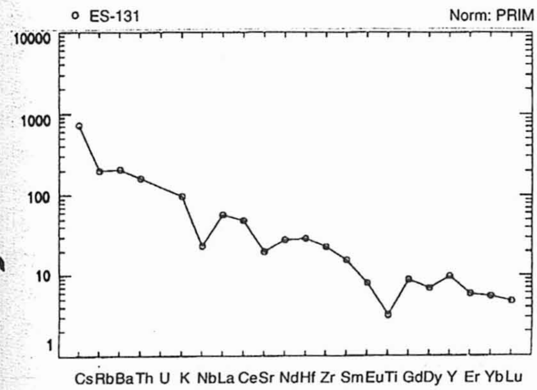

FIGURE 4

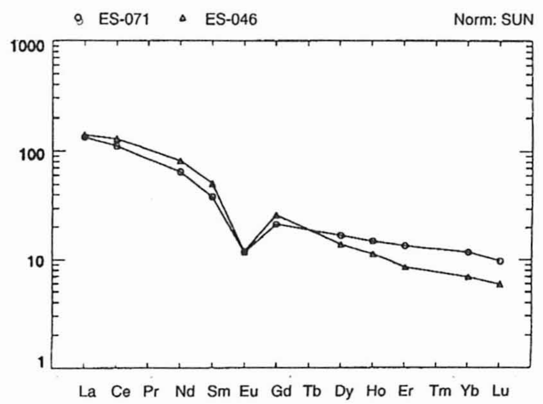

FIGURE 7

(1992) of calc-alkalic magmatic arc suites. Moreover, the K/Rb, Rb/Sr, Rb/Ba ratios are similar to those for little evolved granitoids, except for some samples which have strong K_2O enrichment. The ORG-normalized spidergrams (not shown) are comparable to those for oceanic volcanic arc granites, according to Pearce et al. (1984), in spite of the high Al_2O_3 content of the study rocks. The chondrite-normalized REE pattern exhibits strongly fractionated curves, similar to those produced by small fraction of partial fusion of a tholeiitic or quartz-tholeiitic source, leaving an eclogite residua (Arth & Hanson, 1975; Barker, 1979). Furthermore, recent experimental studies by Rapp et al. (1991) demonstrate that at T = 1000-1100°C and P = 8-16 kb, partial fusion of amphibolites produces melts with compositions similar to that for the São Pedro metagranitoids, implying in crustal thickness around 25-45km.

The peraluminous suite comprises the S-types Recanto and Riacho do Forno metagranitoids. They differ from each other due to heterogeneity in the source composition. The Recanto metagranitoid has a volcanoclastic and greywacke protolith, while the Riacho do Forno was generated by gradual migmatization of pelites. The Recanto metagranitoids include biotite or two-micas facies, being characterized by coarse equigranular and porphyritic (augen) textures. Compositionally, they are peraluminous granodiorites and granites, similar to syn-collisional granites of Batchelor & Bowden (1985). However, the negative Nb and Ti anomalies in primordial mantle-normalized spidergrams and REE patterns (Figs. 6 and 7) reflect a calc-alkalic tendency in possible relationship with volcanic arc granites, coherent with the nature of the protolith. The ORG-normalized spidergram is the similar to that for active continental margin granites (Pearce et al., op. cit.), although the Recanto type is more Yb-depleted than the Chilean granitoids, mentioned by those authors.

The Riacho do Forno S-types granitoids show all gradations from stromatic and *lit-par-lit* migmatites to homophanous types. Usually, they are muscovite-rich or two-mica rocks, suggesting the mica may have played some role in the generation of the mobilizates. The absence of sillimanite may reflect T conditions lower than that for the first sillimanite isograd, and then a migmatite formation in conditions similar to that for the haplogranite system (Johannes, 1985; Ashworth, 1985). Compositions are similar to crustal monzo and syenogranites of Lameyre & Bowden (1982). The mafic minerals are muscovite and fox-red biotite, then having a reduced character, according to White's (1992) parameters. Common accessories are garnet, apatite, epidote, titanite, and occasionally tourmaline and monazite. The chondrite-normalized REE patterns (Figs. 8 and 9) are similar to those for the volcanoclastic rocks and the Recanto metagranitoids, except for they present a slightly lower HREE contents.

LATE-COLLISIONAL GRANITES

The late-collisional event represents the most voluminous intrusive pulse of the study region, comprising three main plutonic bodies: a large mass in the central area and two hybrid intrusive zones in the north and south of the complex. The emplacement of these plutons was controlled by extensional regime (transcurrent shear zones and associated frontal ramps) developed immediately after the collisional event. Mafic autoliths are common; xenoliths of the host rocks, on the other hand, are abundant only in a large collapsed central roof of the central intrusion. Compositionally, the intrusions vary from quartz-monzonites, quartz-monzodiorites, granodiorites to more evolved adamellitic-granitic types, granodioritic compositions being dominant. They display granular and porphyritic textures, usually with xenomorphic grains. Automorphic K-feldspar and/or plagioclase occur in a matrix of quartz, plagioclase, bluish-green amphibole and greenish-brown biotite, and apatite, titanite, allanite-epidote, ore

Figs. 8-13 — Primordial mantle-normalized incompatible element diagram and chondrite-normalized REE patterns for: Riacho do Forno metagranitoids (Figs. 8 and 9). Riacho do Icó granodiorite (Figs. 10 and 11) and São João granite (Figs. 12 and 13). Normalizing values from Sun (1980).

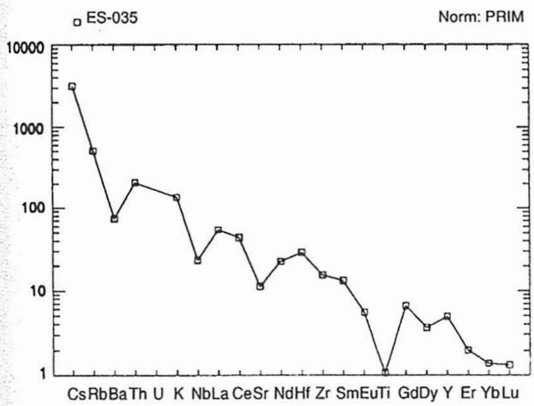

FIGURE 8

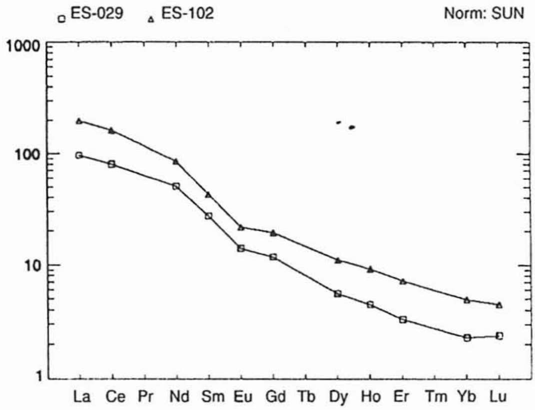

FIGURE 11

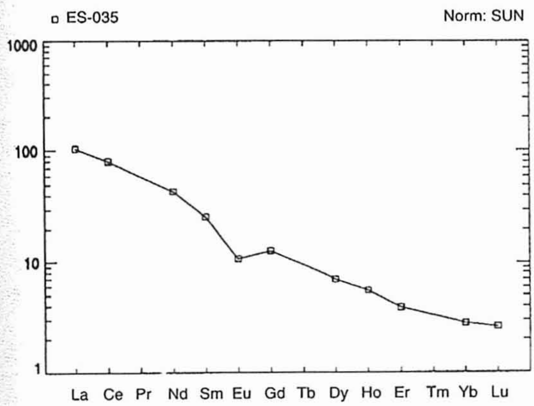

FIGURE 9

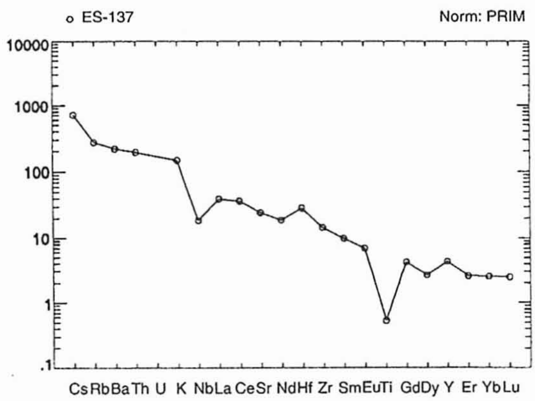

FIGURE 12

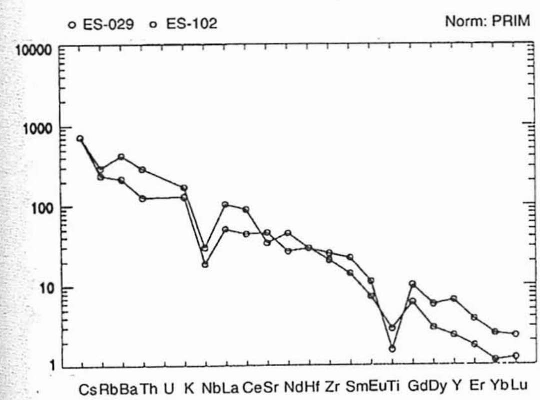

FIGURE 10

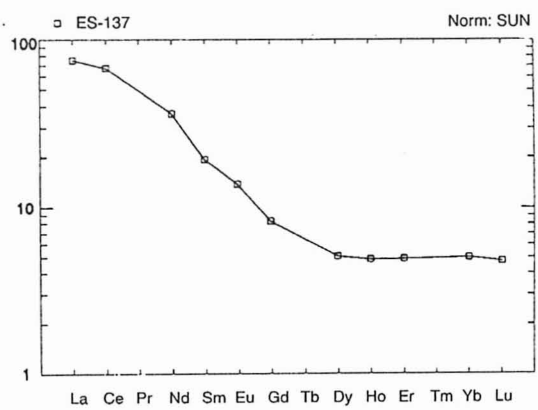

FIGURE 13

minerals and rare zircon as accessory phases. They are mainly metaluminous of the oxidized unfractionated I-type, exhibiting a trend from pre-collisional and post-collision uplift environment fields, in the R_1-R_2 diagram (not shown). Major and minor element contents are similar to the corresponding ones in volcanic arc-related granites, corresponding to the group III of Harris et al. (1986). Chondrite-normalized REE pattern and spidergrams normalized to primitive mantle (Figs. 10 and 11) reinforce the above conclusion. The ORG-normalized pattern (not shown) is similar to that for volcanic arc granites, such as those of Jamaica, described by Pearce et al. (1984).

POST-COLLISIONAL GRANITES

The latest magmatic activity gave rise to dike swarms, stocks and large granitic plutons. These intrusions post-dated the transpressional event that affected the older rocks. Their emplacement mechanism is not yet sufficiently understood, but certainly occurred as passive intrusion, probably in a process of dilatation fracture.

The São João pluton is a homogeneous leucocratic syenogranite with a chocolate-brown biotite, garnet and allanite. It is peraluminous, fractionated, with major element compositional trends (not shown) similar to those for post-orogenic granites, according to Batchelor & Bowden (op. cit.) and Maniar & Piccoli (1989). Primordial mantle-normalized incompatible element diagram and REE pattern (Figs. 12 and 13), coupled with lack of negative Ba anomaly and greater degree of fractionation displayed in the ORG-normalized spidergram (not shown), suggest a relationship with an arc environment. The Serra do Arapuá pluton, in the NW limit of the study area, is a peralkalic aegirine-augite quartz-monzonite to granite that has not been studied in detail.

GEOCHRONOLOGICAL DATA AND CONCLUSIONS

U/Pb concordia of the Poço do Salgueiro volcanic-sedimentary sequence indicates an age of 1.012 Ga (W.R. Van Schmus, written comm., 1992), that represents the age of deposition of the supracrustal rocks in the northern block. Preliminary data suggest that the southern block is older, as indicated by a 2.4 Ga Sm/Nd model age of orthogneisses (W.R. Van Schmus, pers. comm., 1993) and a 1.99 Ga Rb-Sr isochron of intrusive metagranitoids of this block (Lima et al. 1985). The collisional event may have occurred at about 950 Ma according to some preliminary Rb-Sr isochron of the peraluminous granites and the post-collisional Serra do Arapuá granite intruded at 515 Ma ago, as indicated by Rb-Sr isochron (Lima et al., op cit.). The evolution of this complex can be interpreted in terms of a complete Wilson cycle, suggesting that ML is a suture zone within the Extremo Nordeste domain. However, the large span of time separating the collisional event of the latest granitoids may indicates this Brasiliano plutonism represent an independent tectonic episode.

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