Geochemical and isotopic signatures of Proterozoic granitoids in terranes of the Borborema structural province, northeastern Brazil

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Abstract — Two large E–W trending megastructures, the Patos and Pernambuco shear zones, subdivide the Borborema Province (BP), northeastern Brazil, into three main domains: Northern (ND), Transverse Zone (TZD) and Southern (SD). These domains evolved through reworking and amalgamations, during the Brasiliano cycle (0.70–0.50 Ga), of several tectonotratigraphic terranes and major crustal blocks previously deformed during Meso and Paleoproterozoic orogenic cycles. Petrological and geochemical characteristics of granitoids and syenitoids in these domains allow their classification into nine groups. These groups are enriched in K and Ba and have low Nb (usually < 20 ppm), which seems to be a peculiar feature of the lithosphere in the BP. As an isolated criterion, the characteristics of the granitoid groups do not allow a clear individualization of different terranes, in most cases, but point nevertheless to important contrasts among the major tectonic domains. Calc-alkalic magmatic epidote (mEp)-bearing granitoids in the ND display low δ18O (+6 to +8‰SMOW), magnetic susceptibility (MS) > 1.0 × 10⁵ SI, εNd(0.6 Ga) from −15 to −20, and tDM model ages > 2.0 Ga. Within the TZD, in contrast, calc-alkalic and high-K calc-alkalic mEp-bearing granitoids, respectively, in the Cachoeirinha–Salgueiro and Alto Pajeú terranes, display lower MS (0.4 × 10⁵ SI), high δ18O (+10 to +13‰SMOW), lower εNd (−1 to −4), and younger tDM (1.1–1.4 Ga). In high-K mEp-free granitoids, εNd values cluster around −12 in the Granjeiro terrane and from −12 to −15 in the Capibaribe terrane. The Alto Pajeú terrane in the TZD is characterized by intrusions of peraluminous ultra-potassic syenitoids that show negative εNd (−15 to −19), tDM from 2.1 to 2.4 Ga, and MS from 0.7 to 1.0 × 10⁵ SI, and are regarded as derived from a metasomatized lithospheric mantle source. Granitoids in the TZD are isotopically more complex. Three tDM Nd model-age intervals (1.0–1.5, 1.8–2.2 and 2.4–2.5 Ga) are found in the Pernambuco–Alagoas terrane, the largest one within this domain. MS values are rather low, approaching zero in leucocratic granitoids, and up to 15 × 10⁵, in high-K mEluminous syenitoids. Calc-alkalic mEp-bearing plutons in the Macurú terrane are similar to those in the TZD in all respects and distinguish the Macurú terrane from the neighbouring terranes. Altogether, the geochemical and isotopic characteristics of the different granitoid types suggest that: (1) the ND is rather homogeneous, at least vertically, in spite of lateral differences in terms of composition of source rocks and magmatic processes that produced the granitoids; (2) the TZD has lateral and vertical heterogeneities, except for the Cachoeirinha–Salgueiro terrane, which is very homogeneous; (3) the SD is even more heterogeneous than the TZD. The SD had a long and complex accretory/cessory history, as suggested by the presence of a large number of in situ, leucocratic melts associated with large areas of migmatisation, both northern and southern boundaries of the Pernambuco–Alagoas terrane, coupled with a large volume of high-K calc-alkalic granitoids emplaced in several pulses.

INTRODUCTION

The Borborema Structural Province (BP), northeastern Brazil (Fig. 1), encompasses an area of 380,000 km² and is composed of a complex network of Proterozoic supracrustal belts surrounding Archean to Paleoproterozoic blocks or intrusions. A system of branched, anastomosed E-W and NE-trending shear zones define tectonic blocks which differ in lithology, metamorphic grade and structure. Two continental-scale shear zone systems, the E-W-trending Patos and Pernambuco shear zones, divide the BP into three major domains: (i) north of the Patos shear zone (the Northern Domain, ND), (ii) south of the Pernambuco shear zone (the Southern Domain, SD), and (iii) between the two shear zones (the so-called Transverse Zone Domain, TZD: Fig. 1). Mylonitization associated with the shear zones was frequently coeval with partial melting at shallow crustal levels and in the lithospheric mantle (Corsini et al., 1991; Ferreira and Sial 1992; Jardim de Sá, 1994; Vauchez et al., 1995). These magma sources display distinct geochemical and isotopic signatures along the different belts (Sial et al., 1990; Van Schmus et al., 1995, 1996).

Four major tectonothermal events are recorded in the BP by Rb–Sr, Sm–Nd and U–Pb dating: 2.6 Ga (Jequié cycle), 2.2–1.8 Ga (Transamazonian cycle), 1.1–0.95 Ga (Cariris Velhos orogeny), and 0.7–0.55 Ga (Brasiliano cycle). U–Pb dating on pre-Brasiliano cycle granitoids in different domains suggest that they were emplaced during the Cariris Velhos or Transamazonian orogenies (Jardim de Sá et al., 1995; Brito Neves et al., 1995). The Brasiliano orogeny was an important tectonothermal event leading to penetrative structures and fabrics along the BP. This orogeny was accompanied by the emplacement of

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voluminous acid and basic-to-intermediate magmas, most of which display mixed crustal- and mantle-derived components.

The successive orogenies in the region masked most of the original stratigraphic relations in the supracrustal belts and older blocks, making it difficult to interpret the tectonic evolution of the Province. Studies on regional structural geology by Jardim de Sá et al. (1992), emphasized the deformation kinematics and available age dating, allowing the recognition of major blocks with contrasting tectonic evolution. Possible location of suture zones were tentatively located, for the first time, in the BP. A preliminary subdivision of this province into a number of tectonostratigraphic terranes was proposed by Santos (1996), and the most recent developments on the subject were discussed by Santos and Medeiros (1997) and Jardim de Sá et al. (1997), the latter emphasizing the major gravimetric features of the BP.

The aim of this paper is to examine the geochemical and isotopic characteristics of the Brasiliano-age granitoids, as well as their geographic distribution within the BP, leading to the identification of different crustal and mantle reservoirs involved in their petrogenesis. Correlation of these parameters with major structures, stratigraphic contrasts and geophysical anomalies across the BP, may help to discriminate different tectonostratigraphic terranes and blocks in the three major tectonic domains.

THE MOSAIC OF TERRANES IN THE BORBOREMA PROVINCE

North of the Patos shear zone domain (northern domain)

At least five allochthonous or suspect terranes are recognized in this domain on the basis of gravimetric data and distinct tectonostratigraphic features (Santos, 1996; Jardim de Sá et al., 1997): Médio Coreu, Central Ceará, Orós-Jaguaribe, Serridó (Sd) and São José de Campestre (SJC) (Fig. 1). In terms of Brasiliano-cycle granitoids, this subdivision is supported mostly by isotopic data instead of significant differences in the plutonic rock bulk chemistry. Most relevant contributions to granite study come from the Serridó terrane (e.g. Galindo, 1993; Archanjo et al., 1992; Sial, 1987, 1993; Jardim de Sá, 1994). Present discussions are thus centered on this terrane. It is made up of Proterozoic supracrustals of the Serridó Group, including garnet + cordierite ± sillimanite biotite schists, paragneisses, quartzites, marbles and minor metavolcanic rocks, underlain by Paleoproterozoic basement. Allochthonous supracrustal slices are also known to the east, in the São José de Campestre terrane, overlying Paleoproterozoic to Archean high-grade assemblages.

Plutons in these terranes are mainly metaluminous, high-K calc-alkaline porphyritic monzogranites, but other types also occur, such as metaluminous to peraluminous, magmatic epidote-bearing (mEp) calc-alkaline tonalites and granodiorites, as well as peraluminous leucogranites, shoshonitic basic-to-intermediate rocks and alkaline granites. Depleted mantle Sm–Nd model ages (tDM) for Brasiliano-cycle plutons in the Sd terrane are 2.0–2.5 Ga old, younger than tDM Nd model ages in the SJC terrane, which may reach 3.0 Ga, in accordance with Archean crustal protoliths in this block (Dantas et al., 1996).

The transverse zone domain

This domain, bounded in the north by the Patos shear zone and in the south by the Pernambuco shear zone, consists of late Mesoproterozoic metavolcanosedimentary belts alternated with blocks of Archean to Paleoproterozoic high-grade gneisses and migmatites. Within this domain, five NW elongated terranes have been recognized (Granjeiro, Cachoeirinha–Salgueiro, Alto Pajeú, Alto Moxotó and Capibaribe; Santos, 1996; Santos and Medeiros, 1997; Ferreira et al., 1997), all containing a large number of Brasiliano cycle granitoids.

The Granjeiro terrane, mostly covered by sediments of the Mesozoic Araripe basin, is bounded in the south by the Cachoeirinha–Salgueiro terrane. Along this boundary, three high-K calc-alkaline porphyritic granodiorite plutons and smaller, aligned peralkaline syenite stocks and narrow dikes have been emplaced.

The Cachoeirinha–Salgueiro terrane (CST) is a complex tectonic unit comprising Meso- and possibly Neoproterozoic orogenic assemblages amalgamated during the Cariris Velhos and/or Brasiliano cycles (Santos and Medeiros, 1997). Along its extension, the terrane is characterized by the intrusion of over 30 magmatic epidote (mEp)-bearing calc-alkaline tonalites and granodiorites, as well as unique ring-structured plutons with cores composed of trondhjemitic tonalites and granodiorites, bordered by peralkaline syenite rings. This terrane is intruded by high-K metaluminous syenite and ultrapotassic peralkaline syenites, which form stocks and two dike swarms with over 50 narrow dikes each, next to the southeastern and northeastern borders.

The Alto Pajeú terrane (APT) is a thick Meso- to Neoproterozoic volcanosedimentary sequence metamorphosed up to amphibolite facies; gneisses and migmatites are quite common in this terrane. It is characterized by the presence of mantle-derived high-K intermediate to felsic magmasm that includes a large volume of unique ultrapotassic magmas, not found in any other terrane of the BP (except for a small pluton in the Pernambuco–Alagoas terrane). It is also cut by trondhjemitic, high-K calc-alkaline, calc-
Fig. 1. Generalized geologic map of the Proterozoic Borborema structural province, northeastern Brazil, emphasizing the main granitoid and syenitoid groups. 1 = Phanerozoic undeformed sedimentary cover; 2 = major shear zones and terrane boundaries. Granitoids: 3 = high-K calc-alkalic magmatic-epidote free; 4 = high-K calc-alkalic magmatic epidote-bearing; 5 = calc-alkalic magmatic epidote-bearing; 6 = trondhjemitic; 7 = peralkalic; 8 = shoshonite; 9 = calc-alkalic peraluminous. Syenitoids: 10 = high-K metaluminous; 11 = ultrapotassic peralkalic; 12 = peralkalic dikes. Terranes modified from Santos (1996), Ferreira et al. (1997), Jardim de Sá et al. (1997). MD = Médio Coreu; CC = Central Ceará; OJ = Orós-Jaguaribe; Sd = Seridó; SJC = São José do Campestre; GJ = Granjeiro; CS = Cachoeirinha-Salgueiro; AP = Alto Pajeú; CP = Capibaribe; PA = Pernambuco-Alagoas; M = Maracanã; MC = Macururé; VB = Vaza Barris; RP = Rio de Janeiro.
alkalic mEp-bearing and shoshonitic granitoids, as well as high-K metaluminous syenitoids.

The Alto Moxotó terrane is part of a 1.0 Ga old Cariris Velhos belt, almost devoid of Neoproterozoic magmatism (Santos and Medeiros, 1997) and will not be considered in the following discussions.

The Capibaribe terrane is composed of Mesoproterozoic terrigenous, in part turbiditic, sequences, a calcareous sequence with intercalations of skarns (Sial and Menor, 1969) petrographically similar to those in the Northern Domain, and Paleoproterozoic gneiss-migmatite blocks (Santos and Medeiros, 1997). There are a few identified Brasiliano cycle intermediate to acid intrusions in this terrane. Most of them are elongate peralkaline granitoids that have been emplaced and sheared at the southern border of this terrane, plus small plutons of medium- to coarse-grained calc-alkaline biotite granites and fine- to medium-grained magmatic epidote-bearing biotite tonalite dikes.

South of Pernambuco shear zone domain (southern domain)

In this area, five terranes have been recognized: Pernambuco–Alagoas (PA), Marancó (M), Macurúre (Mc), Vaza Barris (VB) and Riacho do Pontal terranes. In the VB terrane no plutonic rocks have been observed so far, while in the PA terrane one can find the largest volume of Brasiliano-age granitic rocks in the Borborema Province. In this discussion, three terranes (PA, M and Mc) will be considered. The M, Mc and VB are part of the Sergipano belt which resulted from a Neoproterozoic collage followed by continental collision between the São Francisco craton in the south (Fig. 1) with the PA terrane in the north (Brito Neves et al., 1977; Silva Filho et al., 1978; Jardim de Sá et al., 1986; Davison and Santos, 1989). A suture zone was inferred from a mafic-ultramafic sequence (Canindé Complex; Silva Filho et al., 1978) associated with intermediate to felsic calc-alkaline lavas, hosted by metaturbidites and marbles, interpreted by some authors as a former island arc complex (e.g. Jardim de Sá et al., 1986; Bezerra et al., 1992; Amorim and Torres, 1994).

The Pernambuco–Alagoas terrane is one of the largest and most heterogeneous of the BP, in terms of granitic rocks. It is bounded in the north by the Pernambuco shear zone and by the Serra do Orobó nappe, and in the south by the Palmeira dos Indios thrust zone. The eastern part of the terrane has several >2.0 Ga Nd model ages granitoid rocks, while in the western part most Nd model ages are 1.0–1.49 Ga (Silva Filho et al., 1997). The terrane is characterized by voluminous high-K calc-alkaline granite and monzonitic batholiths, most formed by multiple intrusions and involving, sometimes, mingling and mixing of host felsic and dioritic magmas. High-K metaluminous syenitic and quartz syenitic intrusions, as well as shoshonitic and ultrapotassic granitoids and syenitoids, besides magmatic epidote-bearing tonalitic dikes, are also found in this terrane, although they do not form plutons as large as the high-K calc-alkaline ones.

The Marancó and Macururé terranes, geologically part of the Sergipano foldbelt, are bounded in the north by the PA terrane and in the south by the São Miguel do Aleixo fault system. They are separated by the Belo Monte–Jeremoabo fault zone. The Marancó terrane is chiefly composed of a volcanosedimentary sequence that ranges in metamorphic grade from greenschist to amphibolite facies (Davison and Santos, 1989). This sequence is intruded by peralkaline to metaluminous granitic plutons. The Macururé terrane, which is also observed east and west of the Mesozoic Tucano sedimentary basin (Fig. 1), is made up of amphibolite-facies metasedimentary rocks with intercalated felsic and mafic metavolcanics, intruded by magmatic epidote-bearing calc-alkaline tonalites and granodiorites.

PETROLOGY AND GEOCHEMISTRY OF THE GRANITOID AND SYENITOID SUITES

Over 200 granitic and syenitic intrusions occur in the Borborema Province. They vary in size from a few square km elongated plutons to huge, thousand square km multiple intrusions. Almeida et al. (1971) summarized in a broad sense some of the granitic suites in the Transverse zone (TZD). They recognized, on the basis of textural features, the existence of four granite types, later were classified by Sial (1986) on the basis of petrography and geochemical compositions. New field, petrographic and geochemical data of the studied plutons indicate a large number of K- and Ba-rich granitoids and syenitoids and allow their grouping into the following main types, as described below: high-K calc-alkaline, high-K calc alkalic magmatic epidote-bearing, calc alkalic magmatic epidote-bearing, trondhjemitic, peralkaline, shoshonitic and calc-alkaline peraluminous granitoids, and high-K metaluminous and ultrapotassic peralkaline syenitoids.

High-K calc-alkaline magmatic epidote-free granitoids

These rocks are found in almost all terranes in the BP, usually forming composite, hundred- to thousand-square km batholiths. Most high-K calc-alkaline plutons are porphyritic (K-feldspar crystals up to 5-cm long) monzogranitic, granodioritic and granitic in composition, usually containing biotite and hornblende as their main mafic phases, and apatite and sphene as the most common accessory minerals. They are frequently associated with basic-to-intermediate dioritic rocks of shoshonitic affinity (biotite diorite or K-diorites; Jardim de Sá et al., 1986; Sial et al., 1989;
Leterrier et al., 1990), with evidence of local mingling and mixing between the two. One large batholith of this type characterizes the northern portion of the Pernambuco–Alagoas terrane (Fig. 1), outcropping in both sides of the Pernambuco shear zone. Several magmatic pulses gave rise to this composite, 400 km-long, almost continuous batholith.

In all terranes, plutons of this type are enriched in incompatible elements, with Ba, Rb and La contents >100 times primitive-mantle abundances. All studied plutons exhibit depletion in Nb and Sr, and positive anomalies in Ba, K and P in a primitive mantle-normalized trace element diagram (Fig. 2b). Plutons in the Granjeiro terrane of the Transverse Zone Domain display slightly positive to negative Eu anomalies in chondrite-normalized REE patterns (Fig. 2a), differing from the plutons in the Seridó and PA terranes, which display negative Eu anomalies. In the Granjeiro terrane, granitoids of this type are more enriched in MgO (>2 wt%), CaO (>3 wt%), P2O5 (>0.4 wt%) and Ba (>1800 ppm) than in the Northern and Southern structural domains. Plutons north of the PA terrane (e.g., Venturiosa and Fazenda Nova batholiths) are K-enriched and Na-depleted compared with the ones to the south (e.g., Santana do Ipanema pluton).

In the Northern domain, Rb–Sr, Ar–Ar and Pb–Pb zircon ages suggest that most plutons of this type were emplaced between 620 and 550 Ma (McMurry et al., 1987; Leterrier et al., 1994; Jardim de Sá, 1994; Galindo et al., 1995). The Sr0 ratios are between 0.707 and 0.710, suggesting either a deep crustal source or a mantle source that mixed with continental crust. A coarse-grained facies of the Acari composite pluton, one of the best studied plutons in the Seridó terrane, has Sr0 ratios between 0.707 to 0.708, suggesting a higher degree of partial melting, so that isotopic homogenization could have taken place. On the other hand, a medium-grained, more acidic porphyritic facies has scattered Sr0 (0.707–0.710), possibly reflecting source heterogeneities (Jardim de Sá, 1994). These features and the strongly negative εNd values for all granitic plutons in the Northern domain (−11.8 to −19.7 at 0.6 Ga) are consistent with partial fusion of crustal sources, but the contribution of an enriched mantle component cannot be excluded (Jardim de Sá, 1994; Jardim de Sá et al., 1996).

The high-K calc-alkalic granodioritic to granitic plutons in the Granjeiro terrane were also emplaced in the time interval 620–550 Ma (Itaporanga and Bodocó plutons, respectively; Sial et al., 1989; McMurry, 1991). Sr0 ratios are lower and more uniform for both plutons (0.7058 and 0.7061, respectively) than for similar types of the Northern domain, as well as the δ18O values (+8 to +8.6‰SMOW; Sial et al., op cit.). These features are consistent with younger, I-type lower-crustal sources or alternatively, with a higher proportion of juvenile components in these felsic magmas.

Rb–Sr, Ar–Ar and Pb–Pb zircon ages on plutons north of the PA terrane (McMurry et al., 1987; Silva Filho et al., 1996; Neves, 1996) indicate two peaks of magma emplacement, at 660 and at 550 Ma. The Santana do Ipanema batholith in the central-southern portion of this terrane displays εNd values from −3.5 to −5.0, while a lower value (−12.24) is found for the Fazenda Nova pluton, north of the PA terrane (Van Schmus et al., 1995). Depleted-mantle Nd model ages vary from 1.2 to 1.4 Ga (Santana do Ipanema pluton) to 1.92 Ga (Fazenda Nova pluton; Van Schmus et al., 1995), interpreted as a mixing of Transamazonian and Cariris Velhos crustal components.

High-K calc-alkalic magmatic epidote-bearing granitoids

These granitic plutons differ from those of the previous group because they are magmatic epidote-bear-

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![Fig. 2. Minor- and trace-element patterns for high-K calc-alkalic granitoids. Plutons are from Granjeiro (1), Pernambuco–Alagoas (2) and Seridó (3) terranes. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical analyses for the plutons are from Sial (1986) and McMurry (1991) (Granjeiro terrane), Jardim de Sá (1994, Seridó terrane) and this work (Pernambuco–Alagoas terrane).]
ing; furthermore, some do not display evidence of interaction with more mafic magmas. They are coarse-grained, locally porphyritic, metaluminous to slightly peraluminous granodiorites to granites, and appear to have a restricted presence in the BP (one pluton in the SdT and four in the APT).

The São Rafael pluton in the SdT is characterized by incipient Eu anomalies in chondrite-normalized patterns, in contrast with plutons in the APT, which display slightly negative Eu anomalies (Fig. 3a). Plutons from the two terranes also display contrasting behavior in terms of Rb and Sr. In a primitive mantle-normalized trace element diagram (Fig. 3b), the pluton in the SdT shows depletion in Rb and a positive anomaly in Sr, the opposite being observed in plutons of the APT. In all cases, the plutons display positive K and P, and negative Nb anomalies. The SdT plutons are more enriched in Sr and Na (600–950 ppm; 5–6 wt%) than the APT plutons (Sr varies from 280 to 550 ppm and Na2O is between 3 and 4 wt%).

Chemistry of epidote from plutons in the APT indicates values from pistacite P50 to P52, suggesting crystallization along the NNO buffer (Brasilino et al., in press), while epidote chemistry (P52-30) from the pluton in the SdT indicates crystallization under fO2 near the N–NO buffer (Sial, 1993).

The SdT pluton has a high Sr₀ ratio (0.713), negative εNd (−18 to −21) and Archean Nd model age (t₀DM = 2.7 Ga) (Ketcham et al., 1995), suggesting that the source rock was ancient continental crust. On the other hand, the APT plutons have lower initial ⁸⁷Sr/⁸⁶Sr ratio (0.7093, Brasilino et al., op cit.), higher εNd value (−3.6), and a Mesoproterozoic Nd model age (1.32 Ga), suggestive of mixed mantle and continental crust material. Low whole-rock δ¹⁸O values (+6 to +9‰SMOW; Sial, 1993) are reported for the São Rafael pluton in the Northern Domain. A Rb–Sr isochron for one pluton in the APT indicates a Neoproterozoic age (638 ± 29 Ma; Brasilino et al., op cit.).

Calc-alkalic magmatic epidote-bearing granitoids

This granitoid type is only observed in the Cachoeirinha-Salgueiro and Macururé terranes, where they form over thirty plutons with similar petrographic, geochemical and isotopic characteristics all along the extension of these terranes.

These I-type, calc-alkalic, metaluminous to peraluminous plutons are medium-grained, equigranular tonalites to granodiorites, containing biotite and hornblende as main mafic phases. Diopside-salite is found in only three plutons and, in this case, modal epidote decreases down to near zero. The tonalites and granodiorites have Na₂O < K₂O, high Ba, moderate Sr and Zr and low Nb contents. Plutons of this kind in the CS and Macururé terranes display similar chondrite-normalized rare earth and primitive mantle-normalized trace element patterns, where those in the CST are slightly more enriched in HREE than those in the MT (Fig. 4a). In both terranes, plutons display depletions in Nb, Sr and Sm, and positive anomalies in K (Fig. 4b).

Plutons in the CST exhibit high δ¹⁸O values (11–13‰SMOW; Sial, 1993), low Sr₀ ratios (0.7058), negative εNd (at 0.6 Ga) values (−1 to −4), Mesoproterozoic Nd t₀DM ages (1.2–1.4 Ga) and low magnetic susceptibility (average 0.4 × 10⁻³ SI; with opaques almost totally absent). Epidote compositions in these granitoids (P520-24) differ from the mEp granitoids in the SdT (P527-30; Sial 1993), but are rather similar to the ones from plutons in the APT (P520-25). Aluminum-in-hornblende barometry suggests that they were emplaced mostly at 5–7 kbar pressures, consistent with the presence of magmatic epidote. Amphibole-rich clots (actinolite-rich amphibolite restitic nodules, usually armored by an external layer of biotite + hornblende, crystallized from the host magma) are present in almost every pluton, being interpreted as fragments of a metasaltic source (Sial, 1993). A ca. 620 Ma Ar–Ar hornblende age was

![Fig. 3](image.png)

Fig. 3. Minor- and trace-element patterns for high-K calc-alkalic magmatic-epidote bearing granitoids. Plutons are from Alto Pajeú (1 = northwest; 2 = southwest) and Seridó terranes (3). Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical data from this work.
obtained from one of these plutons in the CST (Dallmeyer et al., 1987).

In the Macururé terrane, granitoids of this type display low MS (<0.4 × 10^{-3} SI), Mesoproterozoic Nd model age (t_{DM}=1.55 Ga), negative ε_{Nd} values (≈ -5.0; Castellana 1998) and high crystallization pressures, in the same range as for plutons in the CST (5–6 kbar; Al-in-hornblende barometry). However, the Sr_{0} values are higher (0.708–0.719, McReath et al., in press), suggesting continental contribution. A 642 Ma age was found for one of these plutons from U–Pb zircon data (Castellana, 1998). The Nd model age for amphibolite xenoliths, believed by Sial (1993) to be the source for these rocks, is ≈2.6 Ga old (Castellana, op cit.), in contrast with the Mesoproterozoic Nd model ages for their host rocks. This feature can be explained either by mixing of Archean material with Cariris Velhos-age (0.95–1.1 Ga) material, or by fractionation of Sm from Nd during melting of the magma source (Castellana, 1998).

Trondhjemitic granitoids

Plutons of this type are restricted to the CST (three bodies), where they intrude schists of the Salgueiro Group, and to the APT (one body), next to the boundary with the CST. Two plutons at the CST are composite, ring-structured stocks in which their inner parts are composed of trondhjemitic leucocotanlite to leucogranodiorite and the margins are formed by peralkaline granitic rocks. A third composite pluton in this terrane, the Salgueiro batholith, is made up of trondhjemitic tonalite in most of its western portion and shoshonitic to peralkaline monzonite and quartz syenite in the eastern one. In this pluton, both rock types are characterized by very high Sr (up to 8700 ppm) and Ba (up to 6100 ppm), and low Rb (30–120 ppm) and Nb (<20 ppm) contents (Sial et al., 1983). Moreover, the trondhjemitic portion has Na_{2}O > K_{2}O while Na_{2}O usually < K_{2}O in the shoshonitic one.

Biotite ± magmatic epidote are the main mafic minerals in the trondhjemitic tonalites and granodiorites, forming <10% (usually <5%) of the total amount. In these rocks, Al_{2}O_{3} ranges from 15 to 19%, K_{2}O < 3% in plutons of the CST (>4% in the APT), with Na_{2}O > K_{2}O. Positive Eu anomalies are shown by chondrite-normalized REE patterns and positive Ba, K and Sr anomalies are observed in primitive mantle-normalized trace element patterns (Fig. 5a and b). Magnetic susceptibility values for the Serrita pluton, in the CST, are very low, usually around 0.05 × 10^{-3} SI.

A very low initial 87Sr/86Sr ratio observed for the trondhjemitic tonalites in the CST (Sr_{0}=0.7035; Sial 1987) reflect their derivation from an I-type source (eclogite or basalt). Trondhjemitic granitoids in the APT (e.g., the Palmeira pluton) display a very low ε_{Nd} signature (−14.10) and a Paleoproterozoic t_{DM} age (2.15 Ga; Kozuch et al., 1996), in the range for other plutons along the syenitoid line (see later).

Peralkaline granitoids

Peralkaline granitic stocks are mainly found emplaced along shear zones (Patos shear zone, along the northern boundary of the CST and in its eastern continuation bordering the SdT; also along the Pernambuco shear zone), besides small syenitic and granitic plutons, ring dikes around trondhjemitic tonalites as well as one dike swarm within the CST (Fig. 1).

These are peralkaline syenogranites and syenites characterized by presence of aegirine-augite and/or blue amphibole as their main mafic phases, and

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Fig. 4. Minor- and trace-element patterns for calc-alkaline magmatic epidote-bearing granitoids. Plutons are from the Cachoeirinha-Salqueiro (1) and Macururé (2) terranes. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical analyses for the plutons of the Cachoeirinha–Salgueiro terrane are from Sial (1986) and of the Macururé terrane from this work.
Fig. 5. Minor- and trace-element pattern for trondhjemitic granitoids from Cachoeirinha-Salgueiro terrane. Chondrite-normalizing values from Evensen et al. (1978) (a) and primitive-mantle values from Thompson et al. (1983) (b). Chemical analyses are from Sial (1986).

Sphene and apatite as the main accessory phases. Minor biotite and rare fluorite are found in some plutons. All plutons analysed have very fractionated chondrite-normalized REE patterns with nearly no Eu anomaly (Fig. 6a). The granitoids are enriched in most incompatible elements; the plutons along the Patos shear zones show a strong positive Sr anomaly (Fig. 6b). Granitoids are enriched in Ba (up to 7900 ppm) and Sr (up to 3000 ppm), have low Nb (<20 ppm) and Rb (42–140 ppm) contents and Na2O > K2O (except in rocks of the dike set, in which K2O, up to 8.6 wt%, is > Na2O). Magnetic susceptibility values are rather high, around 2 × 10^{-3} SI. A low εNd value (~15.6) and a Paleoproterozoic Nd model age (2.39 Ga; Van Schmus et al., 1995) were found for a pluton, emplaced along the Patos shear zone, consistent with an old, enriched lithospheric mantle source for this kind of magma.

**Shoshonitic granitoids**

Shoshonitic granitoids in the BP are emplaced next to terrane boundaries and/or along shear zones (e.g., the Teixeira batholith, in the northern APT; the plutons along the Afoados da Ingazeira shear zone), or within terranes and between major shear zones (e.g., the eastern portion of the Salgueiro pluton, in the CST). These are medium- to coarse-grained, sometimes porphyritic, syenogranites, quartz monzonites and quartz monzodiorites, in which clinopyroxene and/or amphibole and/or biotite are the main mafic phases. Orthopyroxene and clinopyroxene are found in one facies of a pluton in the SdT (Quixaba pluton; Galindo, 1993).

They are metaluminous to peraluminous (the Teixeira pluton, in the APT, is also slightly peralkalic)

Fig. 6. Minor- and trace-element patterns for peralkaline granitoids from the Cachoeirinha–Salgueiro terrane. 1 = pluton emplaced at the Patos shear zone; 2 = ring dike fringing a trondhjemitic pluton; 3 = dike set. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical data are from Ferreira and Sial (1986).
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Fig. 7. Minor- and trace-element patterns for shoshonitic granitoids. Plutons are from the Cachoeirinha–Salgueiro (1); Seridô (2) and Alto Pajeú (3) terranes. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical analyses for the plutons are from Galindo (1991; Seridô terrane), Silva Filho et al. (1982, Cachoeirinha–Salgueiro terrane) and this work (Alto Pajeú terrane).

granitoids, characterized by enrichment in most incompatible elements, with (K₂O + Na₂O) > 8 wt%, and K₂O usually > Na₂O. In primitive mantle-normalized trace element diagrams, one pluton in the SdT displays positive Ba anomaly and troughs at Sr, while plutons in the CST and APT show positive Sr (Fig. 7b). No or slightly positive Eu anomalies are typical for plutons of this type in the BP. Magnetic susceptibility measurements for the Teixeira pluton yield low values, around 0.1 x 10⁻³ SI.

Plutons of this type in the CS and PA terranes display slightly negative εNd values (−3.8 in the Salgueiro pluton, CST, Van Schmus et al., 1995; −4.6 in the Serra do Catu complex, PA terrane, Silva Filho et al., 1997) and similar Mesoproterozoic Nd model ages (1.4 and 1.42 Ga, for the former and latter plutons, respectively). A Rb–Sr isochron for a pluton in the CST indicates an age of t = 557 ± 71 Ma and low, mantle-type Sr₀ = 0.7047 (Silva Filho et al., 1993), while an age of t = 600 ± 78 Ma, with higher initial ⁸⁷Sr/⁸⁶Sr ratio (0.7072), was obtained for a pluton in the PA terrane (Silva Filho et al., 1997). All these features suggest mixed crustal and mantle contributions. Sm–Nd isotopic data for the Teixeira pluton in the APT is quite different, as its εNd value is very negative (−13.9) and the Nd model age is 2.1 Ga.

Peraluminous calc-alkaline granitoids

Peraluminous calc-alkaline granitoids in the BP have been observed in the Northern Domain and in the AP and PA terranes. Plutons of this type are usually leucocratic, containing biotite in low amounts as their main mafic phase, and muscovite is found in some cases. They are usually associated with migmatites, and probably reflect mid-crustal melting. In the Northern Domain, plutons of this kind display narrow SiO₂ variation and highly fractionated REE patterns, with moderate negative Eu anomalies which increase with increasing SiO₂ contents, suggesting feldspar fractionation. High Sr₀ ratios (0.708 to 0.714; in the Acari pluton > 0.716), coupled with low εNd (−18.3), suggest a high degree of partial fusion of a crustal igneous source including metagreywacke or volcanoclastic components (Jardim de Sá, 1994).

The largest number of this kind of peraluminous granitoids within the BP is found in the PA terrane, including in situ melting bodies (e.g., the Xingó Complex; Silva Filho et al., 1997) and two-mica garnet-bearing granitoids (e.g., the Ouro Branco pluton; Pessoa et al., 1996), which have the lowest MS values for granitoids in the BP (0.10 x 10⁻³ SI). They are interpreted as products of mid-crustal (including metasedimentary protoliths) anatexis. Presence of muscovite in late pegmatitic phases in most plutons of this type suggest crystallization at P > 4 kbar.

Chondrite-normalized REE patterns for two mica granodiorites in the PA terrane and a leucocratic pluton in the SdT are highly fractionated, with a strong negative Eu anomaly (Fig. 8a). Patterns for one topaz- and tourmaline-bearing pluton in the PA terrane (Ouro Branco stock) are approximately horizontal for the heavy rare earths, a feature typical of crustal, very fractionated mineralized granites. Even though being highly fractionated, REE patterns for granitoids derived from in situ melt (e.g., the Caielas pluton) in the PA terrane have weaker negative or no Eu anomaly. In primitive mantle-normalized trace element diagrams (Fig. 8b), plutons from the two domains are characterized by troughs in Nb and Zr; although Ba is rather high, it does not form positive anomalies like in most plutons of the BP.

A Rb–Sr isochron for the Ouro Branco pluton in the PA terrane yields an age of t = 745 Ma (Gava et al., 1983). A Paleoproterozoic Nd model age (2.32 Ga) and a small negative εNd value (−2.3) was determined by Silva Filho et al. (1997) for the in situ melt-
Minor- and trace-element patterns for peraluminous calc-alkaline granitoids. Plutons are from the Pernambuco-Alagoas terrane (PAT): in situ melting granitoids (Caetés,1); Perpétuo Socorro (north PAT, 2); Ouro Branco (central PAT, 3) and from the Seridó terrane (4). Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical analyses for the plutons are from from Jardim de Sá (1994, Seridó terrane) and this work (PAT).

High-K metaluminous syenitoids

Plutons of this type occur either near terrane boundaries (e.g. the Terra Nova pluton, in the CST next to the boundary with APT; Bom Jardim pluton, Capibaribe terrane), or within terranes (e.g., the Pajeú syenite in the APT, and the Santana do Mundaú pluton, in the PAT). They are syenites and monzonites that often display porphyritic textures, with K-feldspar phenocrysts up to 5-cm-long and containing calcic amphibole and biotite as major mafic phases. They are metaluminous to peraluminous, high-K (3.3 to 6 wt% K₂O) plutons, characterized by moderate concentrations of Ba (up to 1200 ppm), Sr (700 ppm), Th (up to 60 ppm), U (up to 6 ppm), Pb (up to 60 ppm) and Rb (up to 300 ppm), and low Nb (< 20 ppm). These rocks are enriched in the total REE, and in chondrite-normalized patterns display negative Eu anomaly, except for a pluton in the Capibaribe terrane, in which Eu anomalies are insignificant (Fig. 9a), suggestive of high oxygen fugacity conditions during magma differentiation. Expressive troughs in Nb, as well as positive anomalies in P, are characteristic of all these plutons (Fig. 9b).

Amphibole-rich cumulates, up to 0.8 m long, are locally observed in plutons of this type in the CS and PA terranes, suggesting that amphibole fractionation was an important process leading to the peraluminous character of these syenites.

LILE/HFSE ratios are usually high, and together with Sr₀ (0.70714) and highly negative ε Nd (−19) values in some of the plutons (e.g., the Bom Jardim

Fig. 9. Minor- and trace-element patterns for high-K metaluminous syenitoids. Plutons are from the Cacheoirinha-Salgueiro (CST; 1), Alto Pajeú (APT; 2), Capibaribe (CT;3) and Pernambuco-Alagoas (PAT; 4) terranes. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical analyses for the plutons are from Silva Filho et al. (1993; CST), Guimarães and Silva Filho (1992; CT), and this work (APT and PAT).
pluton in the Capibaribe terrane, Guimarães and Silva Filho, 1992, 1997; the Terra Nova pluton in the Cachoeirinha–Salgueiro terrane, Silva Filho et al., 1993) are consistent with their origin by partial melting of an old (tDM = 2.0 Ga for the Bom Jardim pluton; Guimarães and Silva Filho, 1997) metasomatized mantle. A pluton of this type in the APT, however, displays much higher εNd value (−3.9), even though its Nd model age is also Paleoproterozoic (tDM = 1.76 Ga).

Magnetic susceptibility values for the Terra Nova pluton in the CST are low, averaging 0.37 × 10⁻³ SI, contrasting with values for the Pajeu pluton, APT, which average is 8.44 × 10⁻³ SI and the Santana do Mundaú pluton in the PA terrane, with an average around 14.4 × 10⁻³ SI.

These plutons were emplaced in two distinct time intervals: at 617 Ma (Águas Belas pluton, Gava et al., 1983, and Curituba pluton, Silva Filho et al., 1997, both in the PA terrane) and at 570 ± 15 Ma (Cachoeirinha pluton in the PA terrane, Pessôa et al., 1978; Terra Nova syenite, in the CST, Silva Filho et al., 1993; Bom Jardim pluton, Capibaribe terrane, Guimarães and Silva Filho, 1997).

**Ultrapotassic peralkaline syenitoids**

This kind of pluton occurs within the APT and along the boundary of this terrane with the CST, as an elongated batholith and several stocks. The ultrapotassic plutons along the terrane boundary form the syenitoid line (Ferreira et al., 1994), which is composed of peralkaline alkali feldspar syenites characterized by the presence of aegirine-augite and richterite (formed at the expense of clinopyroxene);apatite and spinel are the main accessory phases. These syenites are enriched in incompatible elements (Ba up to 9,000 ppm, Sr up to 6700 ppm, K₂O up to 13 wt%, total REE up to 380 ppm), have high Sr₀ (0.7098) and low εNd (mean = −16). They are characterized by a slight negative Eu anomaly in chondrite-normalized patterns and troughs at Nb, Sr and Zr in primitive mantle-normalized trace element patterns (Fig. 10a and b).

The peralkaline syenites have alkalic pyroxenite as co-genetic enclaves, syn-plutonic or late-stage dikes, with field aspects that, together with similar geochemical and isotopic signatures of the two magma types, suggest liquid immiscibility as the major process in their formation (Ferreira et al., 1994). High Sr₀ and δ¹⁸O values (mean + 8.1‰SMOW), LILE enrichment and low εNd values, together with the presence of calcite-bearing mica pyroxenite xenoliths, were interpreted as an indication of a metasomatized lithospheric mantle source for these magmas (Ferreira et al., op cit.). They present one of the oldest tDM model ages known in Brasiliano cycle plutonic rocks of the BP, averaging 2.4 Ga.

Although having similar age (580 Ma) and Sr₀ (0.71087) as those along the syenitoid line, ultrapotassic syenitic plutons within the APT display distinct Nd isotope signature (εNd = −8.0, tDM = 1.81 Ga), suggesting a different, or an heterogeneous mantle source for these magmas.

Ultrapotassic peralkaline trachytic/ syenitic dikes occur near to and cut across the boundary between the Cachoeirinha–Salgueiro and the Alto Pajeú terranes, comprising the Manáu–Princesa Isabel (MPI) and the Terra Nova (TN) dike swarms, with over 50 dikes each (Ferreira and Sial, 1997). These rocks are composed of orthoclase as their main felsic phase, and aegirine-augite to aegirine and blue amphibole as the main mafic ones. Although sharing similar petrographical and geochemical features, the syenites belonging to two dike swarms differ in their δ¹⁸O values (+8.1 to +9.7‰SMOW in the MPI, +9.7‰SMOW in the TN) and εNd (at 0.6 Ga) values (−3.6 in the first; −17.5 in the latter), with correspondingly distinct Nd model ages (tDM = 1.38 Ga in the MPI and tDM = 2.37 Ga in the TN) which suggest distinct sources for these ultrapotassic magmas.

![Fig. 10. Minor- and trace-element patterns for ultrapotassic peralkaline syenitoids from the Alto Pajeú terrane. Chondrite-normalizing values from Evensen et al. (1978) and primitive-mantle values from Thompson et al. (1983). Chemical data from Ferreira (1991).](image-url)
Field measurements indicate low magnetic susceptibility values for this kind of rock (0.4–0.9 \times 10^{-3} SI for the plutons along the syenitoid line and 0.23 \times 10^{-3} for the dikes).

**SUMMARY AND CONCLUSIONS**

Petrographic and geochemical characteristics of granitoids and syenitoids of the Borborema Province allow their classification into nine main groups. Most groups are characterized by enrichment in K and Ba, and other incompatible elements, as well as very low Nb (usually < 20 ppm). These features seem to be characteristic of the lithosphere in northeastern Brazil, perhaps due to incomplete homogenization and recycling during Archean times. The low concentration of Nb does not allow the utilization of tectonic discrimination diagrams, such as those of Pearce (1996). Nb-rich plutons in the BP are only found in the Northern domain, where a large pegmatite province occurs. The majority of the studied plutons are of I-type source and include a mantle component.

Brasiliano cycle upper- to mid-crust-derived plutons are not very common. Most plutons of this type are emplaced in the Pernambuco–Alagoas terrane, associated with gneisses and migmatites. In this case, they have syn-collisional characteristics.

Inasmuch as contrasts in age and petrological characteristics of granitoid rocks reflect differences in source rocks and are related to tectonic settings, they may also be useful in identifying tectonosтратigraphic terranes (Barr, 1990). In this sense, the petrological and geochemical characteristics of the granitoids of the three analysed domains, with few exceptions, do not allow the individualization of different terranes. Nevertheless, they are very useful in showing the contrasts among the three domains, reinforcing that they had unrelated histories before being juxtaposed by the end of the Brasiliano cycle, as already pointed out by Sial et al. (1990), Jardim de Sâ et al. (1992) and Van Schmus et al. (1995, 1996).

All granitoid groups of the Northern domain are characterized by rather low $\delta^{18}$O (6–8‰ SMOW). Most of them have magnetic susceptibility values > 1.0 \times 10^{-3} SI (the majority of the values are > 7.5 \times 10^{-3} SI, Fig. 11a, typical of I-type granitoids), low $\varepsilon_{Nd}$ values (–15 to –20, at 0.6 Ga; Fig. 11b) and $T_D$ model ages > 2.0 Ga. In this domain, high-K calc-alkalic granitoids have lower Sr$_0$ than petrographically equivalent plutons in the other domains, while mEp-bearing calc-alkalic granitoids have lower $\delta^{18}$O values than equivalent plutons in the other two domains. Low or very low $\varepsilon_{Nd}$ values for all studied plutons are consistent with recycling of Archean and Transamazonian crust or, alternatively, with the involvement of an enriched mantle component. Isotopic data suggests that, in the Northern domain, an important Paleoproterozoic (and to a less extent, Archean) event took place, in which juvenile material was transferred to the crust. Later on, during the Brasiliano cycle, mantle-derived material was remelted and mixed with lower crust components, in different proportions, giving rise to the large volume of high-K calc-alkalic and other magma types.

Altogether, the geochemical and isotopic characteristics of the different granitoid types of the Northern domain reveal their link with lithospheric segments of broadly the same age, as their source rocks have similar Nd model ages (Fig. 12a). This is in spite of lateral differences in terms of composition of the sources and the magmatic processes that gave rise to the granitoids.

In contrast, granitoids in the Transverse zone have magnetic susceptibility values < 0.4 \times 10^{-3} SI (Fig. 11a), in spite of the fact that most plutons display I-type characteristics. Epsilon Nd values for the plutons cluster into two main intervals (Fig. 11b). Higher $\varepsilon_{Nd}$ values are observed in (high K-) calc-alkalic mEp-bearing granitoids of the Cachoeirinha–Salgueiro and Alto Pajeú terranes (–1 to –4), while lower values are found in the ultrapotassic rocks of the syenitoid line and other plutons along terrane boundaries (–15 to –18). These very low $\varepsilon_{Nd}$ values, coupled with enriched LILE signatures, are compatible with an origin by partial melting of old, recycled lithospheric mantle source for the ultrapotassic magmas. In the same domain, $\varepsilon_{Nd}$ values for megacrystic high-K calc alkaline mEp-free granitoids are around –9 (e.g., the Itaporanga pluton, Van Schmus et al., 1995), contrasting with values for equivalent plutons in the Alto Pajeú terrane (around –14; e.g., the Campina Grande pluton, Almeida et al., 1997). The 580 Ma old ultrapotassic plutons along the syenitoid line and the two dike swarms, intruded across the CST and APT boundaries, define a minimum age by which the terranes were amalgamated.

The geochemical and isotopic signatures of granitoids and syenitoids of the Transverse Zone domain point to important lateral and vertical heterogeneities of the continental lithosphere through which magmas ascended. An exception is the Cachoeirinha–Salgueiro terrane, which is homogenous both laterally and vertically, as indicated by the presence of over 30 mEp-bearing calc-alkalic granitoids bearing similar petrological, geochemical and isotopic behavior all over the extension of this terrane. Only two plutons of distinct geochemical signature are known to have been emplaced within the terrane (peralkalic granitoids), besides the trondhjemitic and shoshonitic granitoids and high-K syenitoids in the Salgueiro Group (see Fig. 1). This feature appears to support the interpretation of the CS as a terrane, even though bounding sutures require better characterization. It is noteworthy that K contents in plutons in this area, as well as their Nd model ages, increase, while $\varepsilon_{Nd}$ values
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Fig. 11. Histograms for granitoids and syenitoids from the Northern, Transverse zone and Southern domains of the Borborema province, northeastern Brazil. (a) Magnetic susceptibility, (b) $\varepsilon_{Nd}$ (at 0.6 Ga) values. Source of data for the magnetic susceptibility values are from this work, except for some plutons from the northern domain, which are from Archanjo (1993). Source of data for the (Nd values are from Jardim de Sá (1994), Van Schmus et al. (1995), Ketcham et al. (1995), Ferreira et al. (1997), Silva Filho et al. (1997) and this work.

decrease, towards the south (trondhjemitic tonalites in which Na$_2$O $\gg$ K$_2$O, shoshonitic granitoids, high-K syenitoids and ultrapotassic syenitoids) until the Pernambuco shear zone, an inferred suture between the southern Alto Pajeú terrane and the CST.

The Alto Pajeú terrane is intruded by unique ultrapotassic magmas with a metasomatized mantle-derived signature, both along the terrane boundary with the CST and within it. The plutons along the syenitoid line, including the trondhjemitic Palmeira pluton and the shoshonitic Teixeira granitoid (compositionally distinct types of magmas, an evidence of lateral heterogeneity in their source), present the only Paleoproterozoic Nd $\varepsilon_{Nd}$ model ages in the Transverse Zone (Fig. 12b), probably inherited from old, recycled lithospheric mantle. High-K calc-alkaline mEp-bearing granitoids in this terrane have similar geochemical signatures to those of the high-K calc-alkaline mEp-free granitoids in the Granjeiro and Seridó terranes, and have evolved by similar magmatic processes. However, they present quite different Nd model ages and $\varepsilon_{Nd}$ values, so that mode of emplacement, alone, cannot explain the presence or absence of magmatic epidote in these plutons. The Nd
Fig. 12. Epsilon Nd evolution versus time for granitoids and syenitoids of the Northern (a), Transverse zone (b) and Southern (c) domains, Borborema province, northeastern Brazil. Source of data are from Jardim de Sá (1994), Van Schmus et al. (1995), Ketcham et al. (1995), Ferreira et al. (1997), Silva Filho et al. (1997), and this work.
isotopic values indicate that they originated from sources of different ages and probably of distinct compositions.

In the Transverse zone, an important Mesoproterozoic crust-formation event (1.4–1.2 Ga old) may be reflected by the $^{187}$Os values of the Brasiliano-cycle granitoids, in correspondence to the petrographic and geochronological evidence of the 1.1–0.95 Ga old Cariris Velhos orogeny. In this domain, several shear zones, interpreted as terrane boundaries, are characterized by the presence of peraluminous granitoids emplaced towards the end of the Brasiliano orogeny, providing a minimum age for terrane amalgamation.

Granitoids in the Southern domain display an even more heterogeneous behavior than those in the Transverse zone (Fig. 12c). Magnetic susceptibility values of the granitoids and syenitoids from the Pernambuco–Alagoas terrane are variable (Fig. 11a), the lowest values being found in the leucocratic and in-situ melting granitoids, close to zero. These are compatible with a S-type crustal source for this type of magma, while the highest values are found in high-K metaluminous syenitoids, compatible with an I-type source. Large areas of migmatization followed by the intrusion (and in situ melting) of leucocratic granitoids, in both north-central and southern terrane boundaries, coupled with a large volume of high-K calc-alkaline granitoids originated by mixing of mantle and crustal components, represent outstanding features of this terrane, which suggest a complex petrogenetic evolution. Magma production involved partial melting of source rocks distinct both in composition and in age, as indicated by heterogeneous Nd isotopic signatures. Three distinct $^{187}$Os time intervals were found (1.0–1.5 Ga; 1.8–2.2 Ga; 2.4–2.5 Ga), the first being the lowest Nd model ages found among Brasiliano-cycle granitoids in the BP, as observed by Silva Filho et al. (1997).

On the basis of geochemical and isotopic signatures of the different granitoids in the Maranhão terrane, Silva Filho et al. (1997) concluded that this terrane is complexly structured into vertical age domains and that it had undergone a complex, multiple-stage evolution during the Brasiliano collisional event.

The only recognized types of granitoids in the Macururê terrane are calc-alkaline mPg-bearing granodiorites and tonalites which share similar petrographic, geochemical and isotopic characteristics with other plutons in the CST. These features suggest that the terrane is rather homogeneous laterally and vertically.

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