HIGH – K CALC-ALKALINE GRANITOIDS OF CA. 1 GA. T_{DM} ALONG THE LIMIT PE-AL MASSIF/SERGIPANO FOLD BELT, NE BRAZIL AND THEIR GEOTECTONIC SIGNIFICANCE.

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ABSTRACT The Pernambuco - Alagoas Massif is located in the Southern Domain of the Borborema Province. Sm/Nd isotopic data show the existence of 15 Brasiliano granitic intrusions (ca. 0.6 Ga) with Sm/Nd T_{DM} ages ranging from 0.9 Ga to 1.2 Ga. They can be divided into two groups: Group 1 includes metaluminous diorites, monzogranites, and granodiorites showing SiO_2 contents between 60 and 68 wt.%, $Na_2O + K_2O$ ~8 wt.%, high LILE/HFSE ratios, and spiderdiagrams characterized by troughs at Nb, Sr and Ti. Group 2 comprises peraluminous leuco-syenogranites and leuco-monzogranites. They have high SiO_2 (70 - 75 wt.%), and spidergrams and LILE contents similar to those of Group 1. Both groups show volcanic arc signatures and εNd(t) at 0.6 Ga from +3.0 to -1.7. Granitoids from both groups were generated from sources with similar Sm/Nd signatures. Brasiliano granitoids showing such young Nd isotopic signatures have not been recorded in other domains of the BP. Geochemical and isotopic data suggest mafic underplating during the late Mesoproterozoic or early Neoproterozoic in the Southern Domain of the Borborema Province. The volcanic arc and Nd signatures suggest that the mafic magma may have been a mixture from a subducting oceanic slab (~1.0 Ga?) and older lithospheric mantle. The mafic magmas differentiated to yield a zoned lower crust, explaining the geochemical differences among the granitoid magmas subsequently derived from it. T_{DM} values < 1.0 Ga require later addition of younger juvenile material to the 1.0 Ga lower crust.

INTRODUCTION The PE-AL Massif is located in the Southern Domain (Van Schmus *et al*. 1995) of the Borborema Province, NE Brazil. It is comprised by two high grade metamorphic complexes, respectively Cabrobó and Belém do São Francisco, and by 5 "sensu latu" granitic batholiths (Ipojuca-Atalaia, Jaboatão-Garanhuns, Buique - Paulo Afonso, Águas Belas – Canindé and Marimbondo – Correntes) (Fig. 1). All granitic batholiths are located in the eastern sector of the massif. The Belém do São Francisco complex comprises gray tonalitic/granodioritic leucocratic gneisses, generally migmatized. The mesosomes are dioritic to tonalitic.

The PE-AL Massif is one of the largest tectonic units of the Borborema Province, being the major unit in terms of granites occurrence. It is bounded in the north by the Pernambuco shear zone and in the south by the Sergipano fold belt paleo suture. Voluminous high-K calc-alkaline granitic batholiths, high-K to shoshonitic and ultrapotassic syenitic/quartz syenitic intrusions, and a varied range of calc-alkaline peraluminous granitic plutons characterize it. A recent survey has showed the existence of 15 granitic intrusions, along the southeastern margin of the PE-AL Massif. They show similar Mesoproterozoic T_{DM} Sm/Nd model age, but contrasting geochemical composition and facies association. This paper approaches preliminarily their chemical character and significance for the Meso/Neoproterozoic crustal evolution of the Southern Domain of the Borborema Province.

Geologic Setting The 15 studied plutons are part respectively of the *Buique – Paulo Afonso, Águas Belas – Canindé and Marimbondo – Correntes Batholiths* (Fig. 1). However they do not comprise continuous granitic area, i.e. they are not "sensu strictu" granitic batholiths. These batholiths were previously considered to be granitic-migmatitic complexes by Brito Neves (1975). Recent regional mapping (Medeiros 1998) identified several syn to late tectonic granitic intrusions within the diatexitic facies of the Belém do São Francisco complex (Fig. 1). Semi - detailed mapping, carried out in key areas, show that syn to late - tectonic peraluminous and metaluminous granitoids, intruding diatexites and metatexites of the Belém do São Francisco complex (Siqueira 1999) are very common. Actually, within the diatexitic areas, granites mainly occur as late tectonic bodies with low angle foliation, emphasizing the importance of the Brasiliano orogeny in the area. The focused intrusions have been divided into 2 broad groups, based on mineralogy and petrography;

GROUP 1 It comprises 08 plutons: Moxotó (PA), Cajueiro (CAJ), Curral Novo (CN), Buique (BUQ), Santana do Mundaú (SMU), Pindoba (PIN) and Tanquinho (TC) (Fig. 1). They occur in the *Buique - Paulo Afonso, Águas Belas – Canindé* and *Marimbondo – Correntes* batholiths. The majority of them are bounded by NE-SW faults, with sharp contacts with their country rocks and occupy areas of up to 200 sq. Km. Field relationship in the Tanquinho intrusion show magma mingling features, and low dipping magmatic layering, suggesting the action of low angle tectonics during its emplacement. The Moxotó and Tanquinho intrusions have been cut by brittle shear faults.

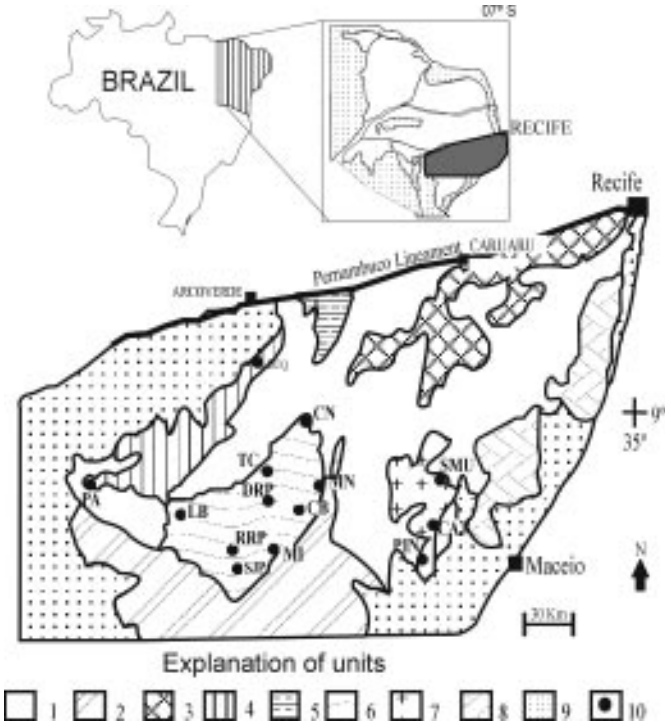

Figure 1–Geological sketch of the PE-Al Massif.

Their composition ranges from diorite and granodiorite to monzogranite. Except in the Buique intrusion, they all are porphyritic and very coarse-grained granodiorites containing dioritic enclaves. The phenocrysts are of K - feldspar up to 5cm long. Plagioclase and quartz mainly compose the matrix. The main accessories are ± biotite, ± garnet (only in the Moxotó intrusion), ± amphibole, opaque minerals, sphene, apatite, ± epidote, zircon, ± allanite.

GROUP 2 It comprises the Minador do Negrão (MN), Cacimbinhas (CB), Buique (BUQ), Rui Palmeira (RP), Chã Preta (CP), Major

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Isidoro (MI), Dois Riachos (DRP), Lagoa dos Bois (LB) and São José da Tapera (SJT) plutons which occur in the *Águas Belas – Canindé* and *Marimbondo – Correntes Batholiths* (Fig. 1*).* They are highly evolved, porphyritic to equigranular, coarse to medium grained sienogranites and monzogranites. The Pindoba and Major Isidoro intrusions show low angle magmatic foliation. Their accessory phases are biotite, ± muscovite, zircon, sphene, apatite, ± epidote and opaque minerals.

WHOLE ROCK GEOCHEMISTRY Major and trace elements were analyzed by ICP-AES, in the ACME Laboratory, Canada, while the Sm/Nd isotope analysis were done at the Isotope Geochemistry Laboratory, University of Kansas, following the procedures described by Van Schmus *et al*. (1995). The A/NK versus A/CNK diagram (Fig. 2-C), TiO_2 and SiO_2 contents divided the studied granitoids in two groups: *Group 1* - metaluminous, SiO_2 contents < 70% (64 to 68wt.%) and higher TiO_2 (0.53 - 1.12wt.%) and *Group 2* - weakly peraluminous, showing SiO_2 > 70 wt.% (70.2 - 74wt.%) and lower TiO_2 contents (0.2 -0.4wt.%). They all show a calc - alkaline trend in the AFM diagram (Fig. 2-B), with the *Group2* samples being more alkali-rich. Both groups fall into the field of sub - alkaline rocks in the diagram $K_2O + Na_2O$ versus SiO_2 (Fig. 2-A) with fields after Irvine and Baragar (1971). The alkali contents ($K_2O + Na_2O$) are in the 6.9 - 8.8 wt.% range. The K_2O/Na_2O ratios range from 0.84 to 2 characterizing them as high-K calc-alkaline granitoids. The Ba contents are similar in both groups (750 and 2300 ppm). The Sr and Zr contents are slightly lower in the granitoids from group 2, as follows; (1) Sr contents ranges between 150 and 620ppm in group 2, and between 400 and 900ppm in group 1; (2) Zr contents are lower than 200ppm in the granitoids from group 2, and ranges between 170 and 350 ppm in the group 1.

The REE patterns of both groups show similar LREE enrichment and lack of significant Eu anomalies (Fig. 3-A). However the patterns of the granitoids from group 2 show higher HREE/LREE ratios with $(La/Yb)_N$ ratios in the 12 - 25 range. The $(La/Yb)_N$ ratios of granitoids from group 1 range from 30 to 40. (Fig. 3-A).

Troughs at Nb, Sr and Ti (Fig. 3-B) characterize the spiderdiagram patterns of the studied granitoids. However, differences between the patterns from the two groups of granitoids do exist and are mainly reflected in the higher contents of HREE (including Y) and deeper troughs at Ti in the patterns of granitoids of group 2. The Nb trough is classically ascribed to subduction-related rocks and the Sr one to plagioclase fractionation, or to low Sr contents in the source.

Nd ISOTOPIC GEOCHEMISTRY The εNd (0.6 Ga) of the whole analyzed sample set ranges between +3 and –1.7, which are values considered by Van Schmus *et al*. (1995) as typical of granitoids derived from an ortho derived protholith, without a major upper crust component. The group 1 show eNd (0.6 Ga) ranging from -2.0 to 0.7. The group 2 show εNd (0.6 Ga) ranging from - 0.6 to +3.2. Only one pluton from group 2 (Rui Palmeira) show lower eNd (0.6 Ga) (-1.7). Because the sample was collected close to the external pluton contact, the lower εNd could be interpreted as due to wall rock contamination. The figures 4-A and 4-B show a plot of ÎNd values versus T_{DM} ages for both groups of granitoids.

The granitoids from group 1 show T_{DM} ages ≥ 1.0Ga, while the T_{DM} ages of the granitoids from group 2 are mostly < 1.0Ga which suggests that the protholiths of the granitoids from group 2 had a larger contribution of the Brasiliano juvenile material. Such younger T_{DM} ages have not been described in Brasiliano granitoids from others

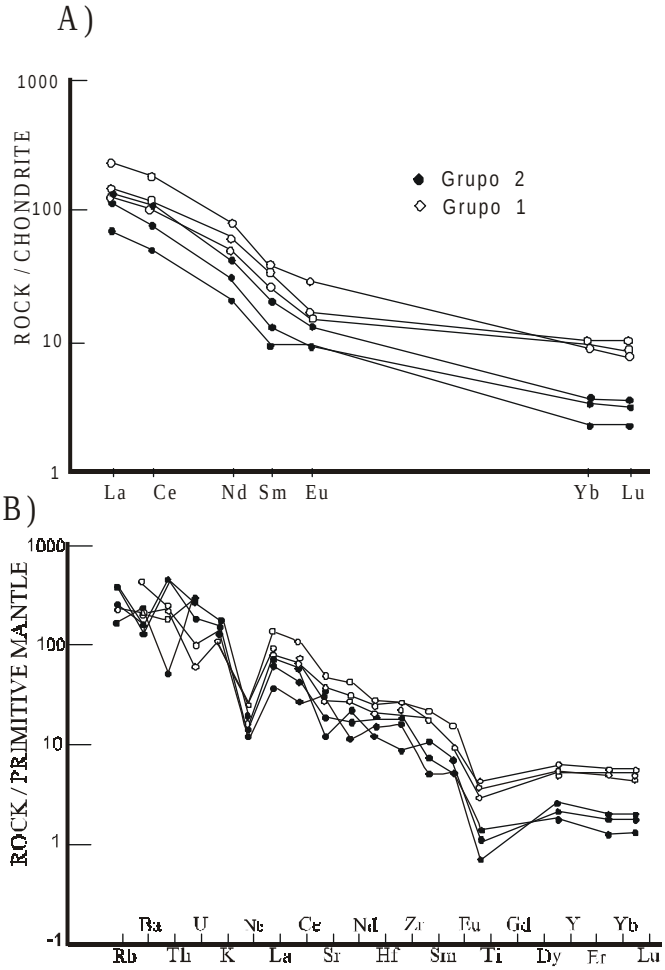

Figure 3–(A) Chondrite normalized REE diagram with Group 1 and Group 2 samples. Open Circles – Group 1. Filled Circles – Group 2 ; (B) Chondrite normalized spidergram with Group 1 and Group 2 samples. Open Circles – Group 1. Filled Circles – Group 2

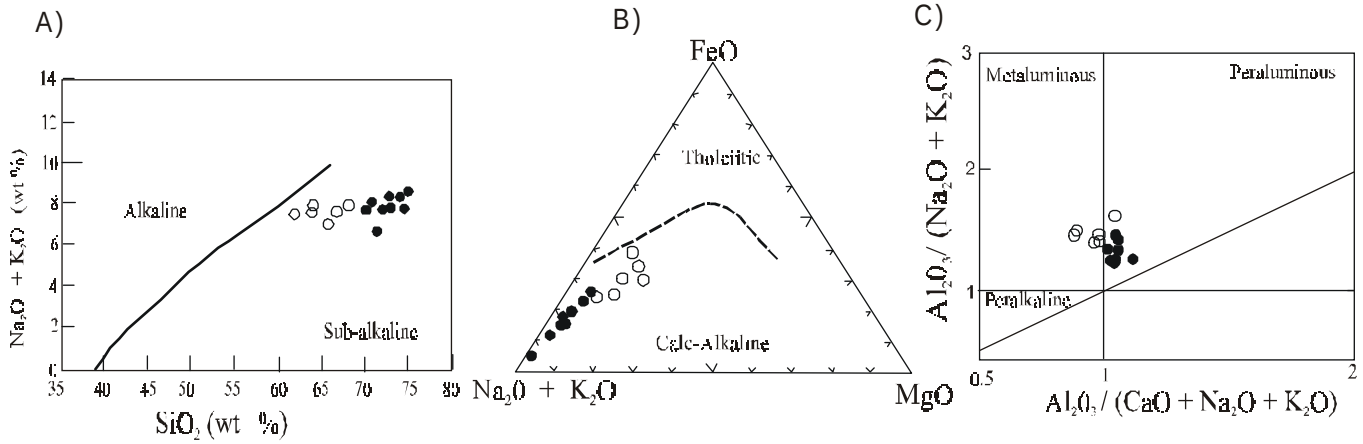

Figure 2–(A) Diagram $Na_2O + K_2O$ vs. SiO_2 with field after Myiashiro (1968) and study samples. Open Circles – Group 1. Filled Circles – Group 2; (B) AFM diagram after Irvine and Baragar (1971) with study samples. Open Circles – Group 1. Filled Circles – Group 2; (C) Diagram A/NK vs. A/CNK after Shand (1931) with study samples. Open Circles – Group 1. Filled Circles – Group 2.

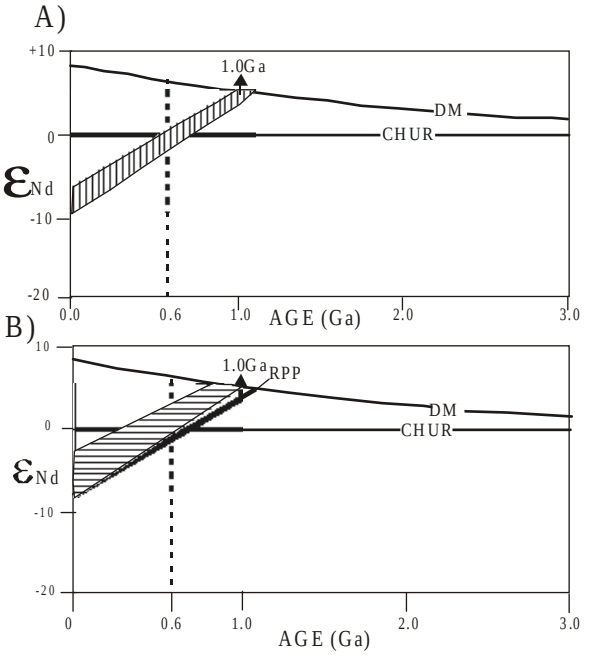

Figure 4–εNd vs. Age (Ga.) diagram. CHUR – Chur isotopic evolution with time. DM – Depleted mantle isotopic evolution with time; (A) The showed envelope is for Group 1 samples; (B) The showed envelope is for Group 2 samples. RPP – Stands for Rui Palmeira pluton sample.

domains within the Borborema Province. A Rb-Sr isochron available for the metaluminous high-K Tanquinho intrusion yields an age of ca. 580 Ma. (Silva Filho *et al*. 1997), which suggest these granites were not extracted from a Brasiliano juvenile protholith.

DISCUSSION AND CONCLUSIONS Recent petrologic works over the main metaluminous high –K to shoshonitic granitic suites from the Borborema Province (Silva Filho *et al.* 1997; Guimarães and Silva Filho 1998, Neves *et al*. 1998, Mariano *et al*. 1999) point unanimously to the existence of an upper mantle metasomatized during the Paleoproterozoic, respectively in the Northern, Central and Southern Domains. This paper shows that the high-K calc alkaline granites in the Southern Domain of the Borborema Province could not be generated from a Paleoproterozoic lithospheric mantle.

The granitoids from *Group 1* are weakly peraluminous, with some of them being garnet bearing (Moxotó pluton), and show HREE/LREE ratios higher than those recorded in granitoids from group 1. They could be generated by melting of metapelites, because such composition with Sm - Nd signatures similar to those recorded in these granitoids have been described in the south at the Sergipano Fold Belt. However, the granitoids from group 1 have low silica contents and they are too rich in ($CaO + Na_2O + K_2O$) relative to Al_2O_3 to be primary melts of biotite-bearing metasediments. The group 1 granitoids could not represent primary melts of "normal" amphibolites due to high ($Na_2O + K_2O$) contents and (FeO+MgO) relative to Al_2O_3 (Patiño Dulce 1995). Thus, melting of a hybrid source may generate the granitoids from group 1. This source could be either: alkali-rich (metasomatized) garnet bearing amphibolites(Mesoproterozoic) mixed with Neoproterozoic tholeiitic basalts or, Mesoproterozoic greywackes mixed with Neoproterozoic tholeiitic basalts. The low SiO_2 contents recorded in these granitoids, disagree with their source from melting of greywackes. (Patiño Dulce 1995).

The chemical signature of the metaluminous high-K calc - alkaline granitoids from *Group 2* suggests that they were generated from melting of a lithospheric mantle metasomatized during the Mesoproterozoic.

The source of both groups of granitoids point to a (1.0 Ga) metasomatized mantle along the southern border of the PE-AL Massif. It means the occurrence of a lithospheric plate, between the Sergipano Fold Belt and the PE-AL Massif. Such plate shows isotopic signature younger than the rest of the Borborema Province.

Lack of evidence for a suture in the area could suggest that a small mafic crust formed during the Mesoproterozoic, related to a small basin, where sediments were deposited to the south/Sergipano Fold Belt. Crustal accretion starts with rifting of a continental crust and then formation of an oceanic crust, continuing later with the consumption of this oceanic crust along a subduction zone and with the formation of magmatic arcs. The present lack of clear evidence of a paleo suture between the PE-AL Massif and the Sergipano Fold Belt, as gravimetric anomalies and ophiolitic complexes, does not rule out *a priori* this hypothesis, as the identified PE-AL Massif batholiths could be the remnants of an arc. On the other hand, as other authors defend (Van Schmus *et al*. 1995; Neves *et al*. 2000), the absence of Brasiliano - age suture zones in the inner part of BP, and the voluminous predominance of I - type granitoids far away from the boundary zones with the adjoining cratons (Silva Filho *et al*. 1997; Neves and Mariano 1997; Ferreira *et al*. 1998; Guimarães and Silva Filho 1998) suggests the magmatism is not directly subduction- related. As the southern part of the PE-AL Massif is close to the NE margin of the São Francisco Craton the generation of the study rocks by subduction process should be examined carefully. As they are not juvenile, they should be reworked Cariris Velhos materials, during the Brasiliano continental collision. Up to now we have dated only one pluton, the Tanquinho (Silva Filho *et al*. 1997), which yields Brasiliano age. However, field relationship clearly points to Brasiliano ages for the studied granitoids.

Group 2 granites are mildly peraluminous, however they do not show either geochemical or mineralogical signature of S - type granites. So its peraluminous character could have been inherited from orthoderived metamorphic rocks.

There are three hypotheses regarding the isotopic signatures of *Group 1* and *Group 2* granites;

Reworking of mafic metaigneous (*Group 1*) rocks. Several authors show that metaluminous granites are usually extracted from metaigneous sources, amphibolitic or eclogitic, with or without a mantle component. The major and trace elements contents of *Group 1* plutons Tanquinho, Santana do Mundaú suggest that they have a mantle component. The occurrence of magma mixing features in the Tanquinho intrusion suggests mafic magma interacted with crustal material of similar T_{DM}.

Reworking of metasedimentary/metavolcanic rocks formed during the Cariris Velhos event at a continental margin, during the Brasiliano collision. The common occurrence of low angle foliation in the *Group 2* granitoids suggests that they were intruded during the action of a low angle crustal shortening/collision tectonics.

(3) Mixture of Brasiliano underplated mafic juvenile magma with crust formed during the Cariris Velhos event. The lack of juvenile Brasiliano magma in the area up to now, rule out the hypothesis of partial melt of an older crust, generated during the Cariris Velhos event, triggered by the underplating of juvenile Brasiliano or early Neoproterozoic mafic magma.

(4) Geochemical and isotopic data suggest mafic underplating during the late Mesoproterozoic or early Neoproterozoic in the Southern Domain of the Borborema Province. The volcanic arc and Nd signatures suggest that the mafic magma may have been a mixture from a subducting oceanic slab (~1.0 Ga?) and older lithospheric mantle. The mafic magmas differentiated to yield a zoned lower crust, explaining the geochemical differences among the granitoid magmas subsequently derived from it. T_{DM} values < 1.0 Ga require later addition of younger juvenile material to the 1.0 Ga lower crust.

(5) The subduction - related signatures of these granitoids could have been inherited from their source.

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