METASEDIMENTARY ROCKS OF THE NORTHERN PORTION OF THE MACURURÉ DOMAIN, SERGIPANO BELT, NORTHEASTERN BRAZIL: GEOCHEMICAL CHARACTERIZATION OF THEIR PROTOLITHS AND TECTONIC IMPLICATIONS

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RESUMO

Caracterização dos protólitos de rochas metaclásticas de unidades metamórficas do domínio Macururé, Cinturão Sergipano, com base em elementos maiores e traços, é discutida neste trabalho. Dados geoquímicos para essas rochas metassedimentares indicam predominância de grauvacas nos protólitos que contem também folhelhos e arcóseos subordinados. Elementos maiores, traços e terras raras sugerem fonte para estas rochas com composição da crosta superior média para os protólitos das rochas metassedimentares deste domínio. Mistura de fonte de detritos são indicados para estas rochas resultantes principalmente de detritos de composição intermediária a ácido. Dados de rocha total sugerem arco de ilhas e/ou de margem ativa como cenário geodinâmico mais provável para deposição dos precursores sedimentares das unidades estudadas. Neste contexto, uma configuração *back-arc* explicaria a natureza mista das áreas fontes inferidas, com detritos do embasamento soerguido e relacionadas ao arco como membros finais das misturas. A geoquímica semelhante das metassedimentares e litologias subjacentes atesta derivação a partir de uma mesma fonte crustal.

Palavras chave: Cinturão Sergipano; rochas metassedimentares; litogeoquímica; proveniência; ambiente tectônico.

ABSTRACT

Characterization of the metasedimentary protoliths of metamorphic units of the Macururé Domain, Sergipano Belt, in northeastern Brazil, based on the behavior of their major and trace element chemistry is discussed in this paper. Geochemical data indicate predominance of greywackes in the protoliths of metaclastics of the Macururé Domain, with subordinate shales and arkoses. Major, trace and rare-earth element chemistry indicates a source with an average upper crustal composition for the protoliths of metasedimentary rocks of Macururé Domain. Mixed-sourced detritus are suggested for these rocks mainly derived from felsic and acidic/recycled detritus. The overall data consistently suggest a continental magmatic arc and/or active margin setting as the more probable geodynamic scenario for the deposition of the sedimentary precursors of the studied units. In this context, a back-arc setting can account for the mixed nature of the inferred source areas with uplifted old basement and arc-related detritus as the end members of the mixtures. The comparable geochemistry of the metasediments and their underlying lithologies attests to their derivation from same crustal source.

Keywords: Sergipano Belt; metasedimentary rocks; lithochemistry; provenance; tectonic setting

INTRODUCTION

Determining the source of clastic components in (meta)sedimentary rocks can be performed by means of different techniques. In addition to more traditional methods of point counting various detrital components, mineral chemistry and geochronology of detrital constituents, isotopic character of the rocks and minerals, and trace element chemistry of the rocks are used to establish more details on the provenance of clastic material. It has been long recognized that the chemical composition of sedimentary rocks image the nature of the source region and this, in turn, is closely related to the plate tectonic setting. Moreover the evolution of crustal processes can be delineated by means of chemical studies (Bathia 1983; Roser and Korsch 1986, 1988; Floyd et al. 1991; McLennan et al. 1993).

The provenance signatures can survive to relatively high-grade metamorphism if no-open system process has occurred (i.e. anatexis, metasomatism, veining, and so on). Ratios of low-solubility trace elements generally reflect those of source rocks rather than the products of diagenesis or metamorphism (Cullers et al. 1975; Taylor and McLennan 1985, McLennan et al. 1990), making them valuable tools for provenance analysis.

Many trace elements are extremely insoluble in aqueous solutions, and tend, therefore, to be transferred from the source rock to the sediments without significant fractionation (McLennan 1989; Nesbitt 1979; Bierlein 1995). Most hydrothermal fluids have very low concentrations of insoluble trace elements such as the rare-earth elements (REE); hence, alteration of whole-rock trace element patterns during hydrothermal alteration and metamorphism is generally ineffective (Bau, 1991). The REEs, Th, Sc, Hf, and Co are the most suitable for provenance determination because of their relatively low mobility during weathering, transport, diagenesis (Girty et al. 1994) and metamorphism (McLennan and Taylor 1991). REE distribution in shales and sandstones, in particular, has been used to characterize source rocks and sandstones, in particular, has been used to characterize source terranes and tectonic setting (Taylor and McLennan 1985, McLennan et al., 1990).

Detrital sediments may constitute the only record of a crust that was removed by erosion, covered with younger deposits or buried deeper in the crust (Condie et al. 1995). The importance of sedimentary geochemistry in understanding the evolution of clastic sedimentary suites, their provenance, and source weathering is now well established in the literature. Geochemical studies also provide support for recognition of tectonic settings in which ancient sediments were deposited (e.g. Bhatia, 1985; Bhatia and Crook, 1986; Roser and Korsch, 1986). Immobile trace element abundances and rare-earth element compositions of sediments are important indicators of source rock chemistry, since such elements are little-fractionated by sedimentary processes and low-grade metamorphism (Taylor and McLennan, 1985; McLennan, 1989). However, evaluation of abundances of more mobile elements is also helpful for understanding ancient weathering regimes, paleoenvironmental conditions, and other chemical processes to which the sediments and their sources may have been subjected (Nesbitt and Young, 1984; Fedo et al., 1995).

The Sergipano Belt (Fig. 1) is a ESE-WNW trending volcano-sedimentary wedge polydeformed and metamorphosed (700-600 Ma) due to the collision of the Pernambuco-Alagoas Massif, to the north, with the São Francisco Craton, to the south (Brito Neves et al, 1977), during the Pan-African/Brasiliano orogeny and is one of the most important Precambrian orogenic belts of northeastern Brazil, not only because it was considered as evidence for continental drift (e.g. Allard and Hurst, 1969), but also because it contains several structural and lithologic domains that allow it to be compared with Phanerozoic orogens. The structure and lithology of the Sergipano Belt have been compared to the Ndjolé Series of northern Gabon in Africa (Allard and Hurst, 1969). Later, it has been compared with sequences of Mbalmayo-Bengbis, Dja, and Sembe Ouesso of southern Cameroon and northern Congo (Cordani, 1973). According to Trompette (1994), this belt represents the Brazilian counterpart of the Oubanguides and, together, they form a roughly E–W elongated mega-orogeny more than 5000 km long. More recently, the Sergipano Belt has been correlated with the Yaoundé Belt (Cameroon, Africa) by Oliveira et al. (2006). The belt is divided into the Canindé, Poço Redondo-Marancó, Macururé, Vaza Barris, and Estância lithostratigraphic domains (Santos and Souza,1988, Davison and Santos,1989, and Silva Filho,1998); the latter three are composed mostly of metasedimentary rocks with metamorphic grade increasing from weakly- or non-metamorphic in the Estância Domain through greenschist grade in the Vaza Barris to amphibolite facies in the Macururé Domain. Silva Filho and Torres (2002) and Silva Filho et al. (2003) suggested three additional Domains: Rio Coruripe, Viçosa and Pernambuco-Alagoas. The Macururé Domain consists mostly of garnet micaschists (Fig.1) and phyllites with minor quartzite and marble, all intruded by granitic bodies and a mafic to ultramafic sheets. The Macururé Domain merges northeastwards into the Rio Coruripe Domain, which has been metamorphosed in the granulite facies and later retrogressed to amphibolite and greenschist grade. Pan-African-Brasiliano granitoids are intrusive into all domains except into the southernmost low-grade Vaza Barris and Estância domains. In this paper we examine the geochemistry of metasedimentary rocks from part north of the Macururé Domain, next to the limit with the Pernambuco-Alagoas domain in the Alagoas state of northeast Brazil. We discuss the geochemical relationships between these metasedimentars rocks, their provenance, and their depositional settings.

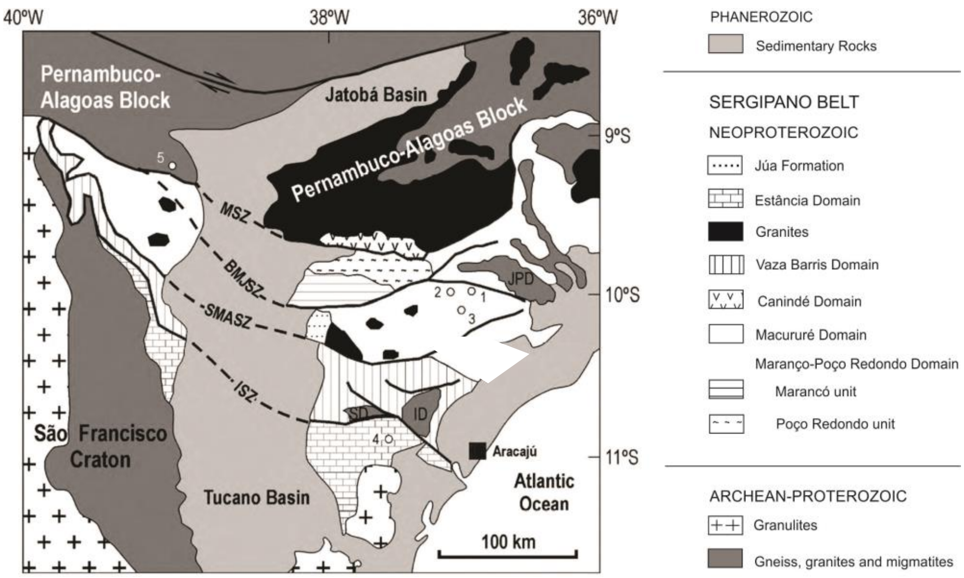

Figure 1 - The Sergipano Belt and its division into domains (modified from D'el-Rey Silva, 1999). The Poço Redondo-Marancó Domain is separated into two sub-domains. MSZ, BMJSZ, SMASZ and ISZ stand, respectively, for Macururé, Belo Monte-Jeremoabo, São Miguel do Aleixo and Itaporanga shear zones. ID – Itabaiana dome; SD – Simão Dias dome; JPD – Jirau do Ponciano dome.

LITHOTYPES OF THE STUDY AREA

Stratigraphic and petrographic studies of the Macururé Domain revealed that it is composed of amphibolite facies garnet bearing metaturbidites, feldspathic-aluminous mica schists with minor intercalations of quartzite, marble, metaleucogranites and meta-volcanic rocks, and lenses of amphibolite, garnet–amphibolite and chlorite schist. The studied rocks of the Macururé Domain encompass an extensive metasedimentary cover east of the City of Major Isidoro, State of Alagoas (Fig. 2), composed of garnet-paragneiss, schist, quartzite and leucogranites metamorphosed under conditions of high amphibolite to granulite facies.

The paragneiss is the predominant lithotypein the study area (Fig. 2). This is a foliated rock, fine to medium-grained, composed of plagioclase ± K-feldspar, quartz, garnet, biotite, muscovite, sillimanite (fibrolite), zircon, apatite and opaque minerals. The texture is commonly granolepdoblastic, protomylonitic to mylonitic texture may occur. The paragneisses are often migmatitic. The banding is marked by centimeter quartz-feldspar felsic bands alternating with biotite ± garnet rich bands. The felsic bands are composed of quartz + plagioclase + K-feldspar, while that the mafic bands is composed of biotite + plagioclase + garnet + zircon + quartz ± opaque minerals. Migmatitic structures of the stromatic and vein type are common. These migmatites form an elongate NNW-SSE unit referred to as indiscriminate granitic rocks in regional geologic maps, described by Mendes et al. (2009) as composed of coarse- to medium-grained pinkish, locally gray garnet-biotite gneiss of granitic to granodioritic composition.

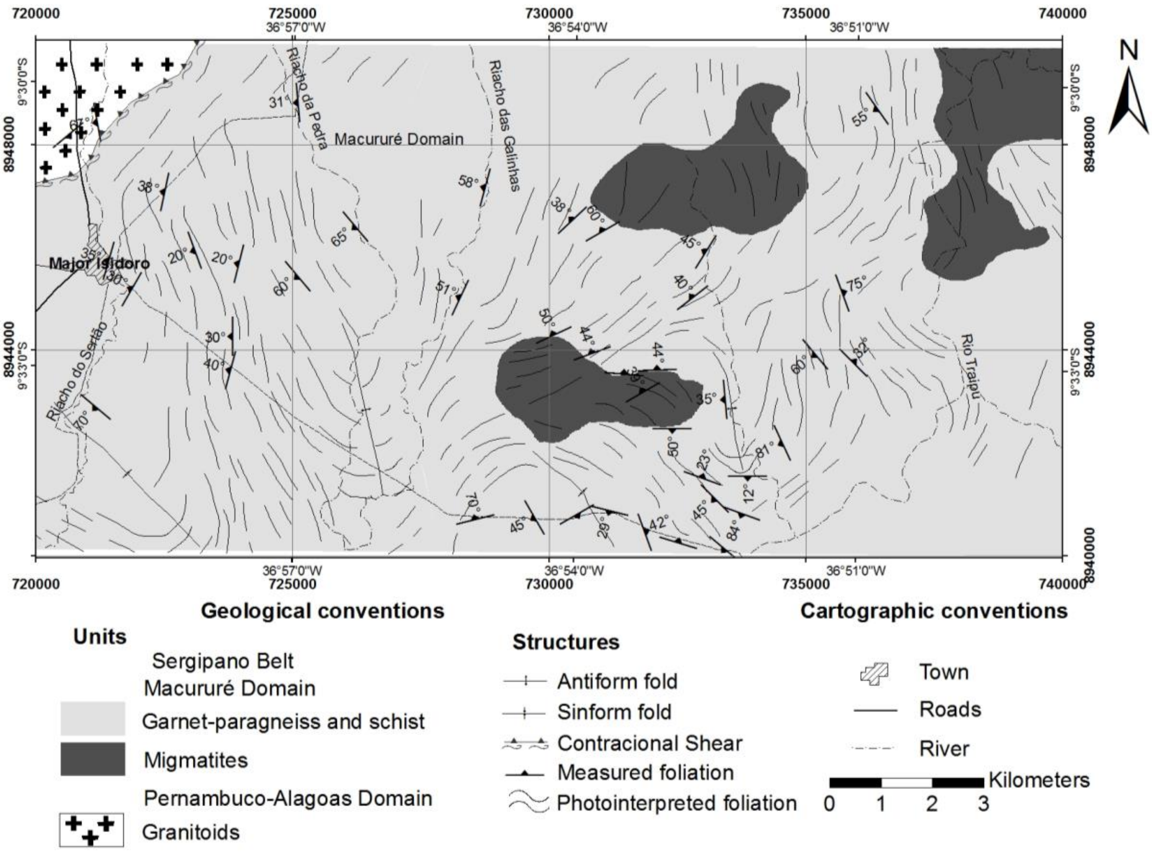

Figure 2 - Location and geology in the studied area.

The metasedimentary rocks studied in this domain are similar to the rocks designated by Silva Filho and Torres (2002) and Silva Filho et al. (2003) as Rio Coruripe Domain, which Oliveira et. al (2006) believes to be higher grade metamorphic rocks of Macururé Domain.

Petrography

The garnet-muscovite-biotite paragneisses have granolepdoblastic texture, and a well marked foliation defined by biotite. The garnet occurs as porphyroblasts. The mineralogy of the matrix consists of plagioclase, microcline, quartz, biotite, muscovite, apatite, zircon and opaque minerals. Biotite defines the foliation. Garnet occurs as subdioblastic to idioblastic crystals. This unit is migmatized indicating that metamorphism reached the anatexis curve and produced small degree of melting. Mylonitic paragneiss is observed next to contact zone shear. Biotite occurs as xenomorphic flakes often with inclusions of opaque minerals along cleavages, and apatite. It shows pleochroism from light to reddish brown. Plagioclase occurs as xenomorphic to hipidiomorphic, sometimes tabular, crystals, with polysynthetic or albite-Carlsbad twinning; inclusions of apatite and biotite are present. Some small crystals present saussuritization. Quartz occurs as xenomorphic crystals with wavy extinction associated with biotite forming the foliation of the rock. Muscovite occurs as xenomorphic flakes in small quantity dispersed by the thin section, but usually associated with biotite forming lepidoblastic texture. A few garnet grains occur as porphyroblastic grains. Rare K-feldspar crystals show cross twinning; apatite, zircon and opaque minerals are other phases observed. The Study of the geochemical data reveal two rocks types to protholits these paragneisses.

MATERIALS AND METHODS

Sixteen metasedimentary rock samples were selected for determination of their geochemical and isotopic compositions and provenance signatures. Whole-rock major and some trace element were performed by X-ray fluorescence spectrometer (XRF) at the NEGLABISE - Department of Geology, Federal University of Pernambuco, Recife, Brazil. Chipped samples were crushed using a ring mill with a tungsten carbide head, and the powdered samples dried at 110 °C for more than 24 h. Loss on ignition (LOI) was determined from total weight loss after ignition at 1000 °C for 2 h. Abundances of the major elements and 14 trace elements were determined using a Rigaku RIX 3000 by XRF. Both major and trace element analyses were made on glass beads (5:1 flux to sample ratio) containing 1g combined with 5g of alkaline flux ($Li_2B_4O_7$), following the method of Kimura and Yamada (1996).

The REE analyses were done by ICP-OES at the SDS-Geosol Laboratory, Belo Horizonte, Brazil. Rare-earth element (REE), Zn, V, Ag, Co, Cs, Cu, Ga, Hf, Mo, Sn, Ta, Tb, Th, Tl, U and W abundances were determined in selected samples by inductively coupled plasma mass spectrometry (ICPMS), using a software (CCLAS). More detail of the ICP-MS methodology is given by Kimura et al. (1995) and Roser et al. (2000).

GEOCHEMISTRY

The major and trace element compositions of the analyzed samples are given in Table 1. Comparison of average compositions reveals that there are few geochemical differences between the metagraywackes and the metapelites. However, SiO_2 content is relatively lower, and Fe_2O_3 (total Fe as Fe_2O_3) and K_2O relatively higher in the metapelites, possibly due to a decrease in quartz content and an increase in the clay fraction in the metapelites.

Major and trace elements

Chemical analyses of the metasedimentary rocks (Table 1) show that they have intermediate but variable SiO_2 contents (average 69 %). Al_2O_3 abundance as well as CaO, K_2O and Na_2O contents are generally high, suggesting rather limited weathering in the source area. The metasedimentary rocks have relatively low concentrations of TiO_2, and MgO (Average: 0.5 wt.%; 1.8wt.%, respectively), but are enriched in total alkalis (K_2O + Na_2O; range: 4.1-6.8 wt.%). Trace element abundances are highly variable, but Cr is more abundant in both rock types (average: 259 ppm) compared to the upper continental crust (UCC) (Average: 83ppm; Taylor and McLennan, 1985). Selected major and trace elements plotted on variation diagrams against SiO_2 (Fig. 3) show that Al_2O_3 has scatter correlation with SiO_2, whilst TiO_2, MgO and Fe_2O_3t are negatively correlated. Correlations are weaker with the other oxides. Correlation of Na_2O and CaO with SiO_2 (not shown) is poor, suggesting mobility during weathering and metamorphism.

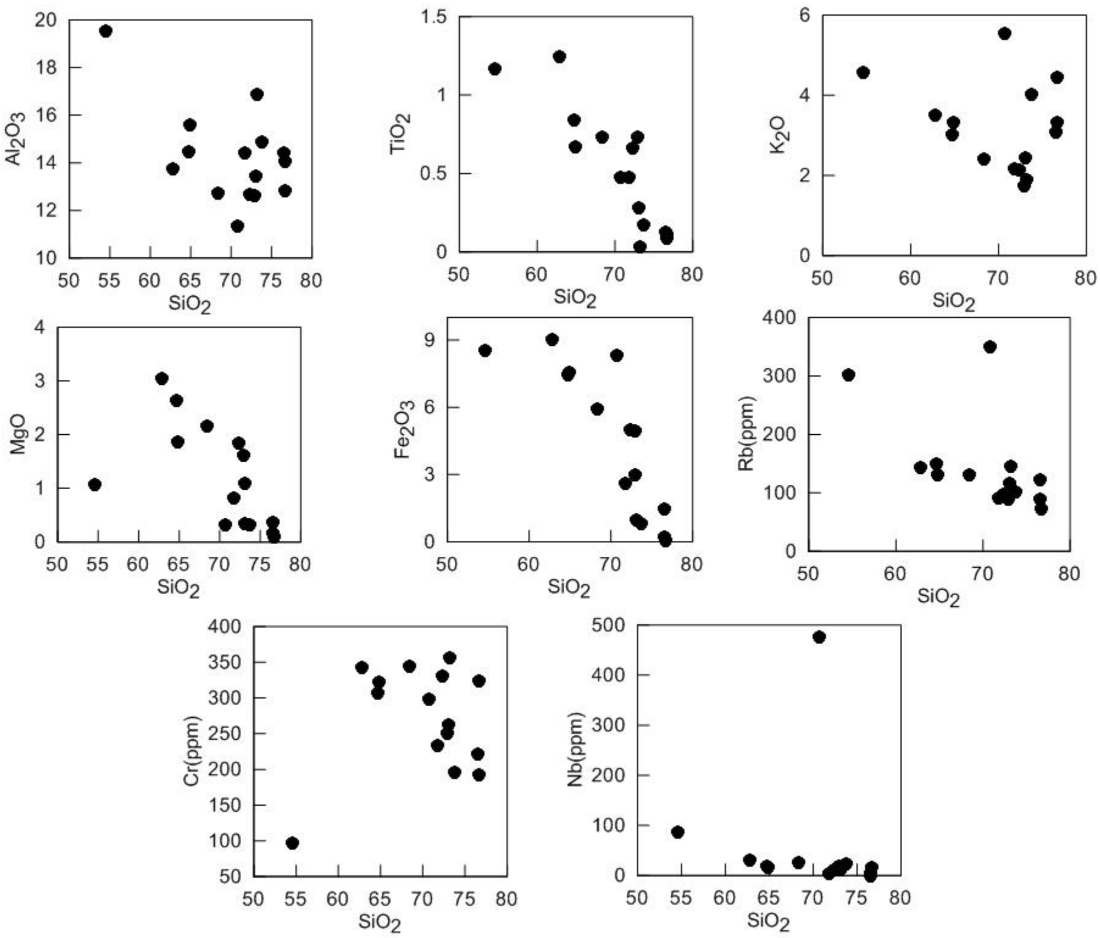

Figure 3 - Selected major element- and trace element-SiO_2 variation diagrams for the Macururé domain metasedimentary rocks.

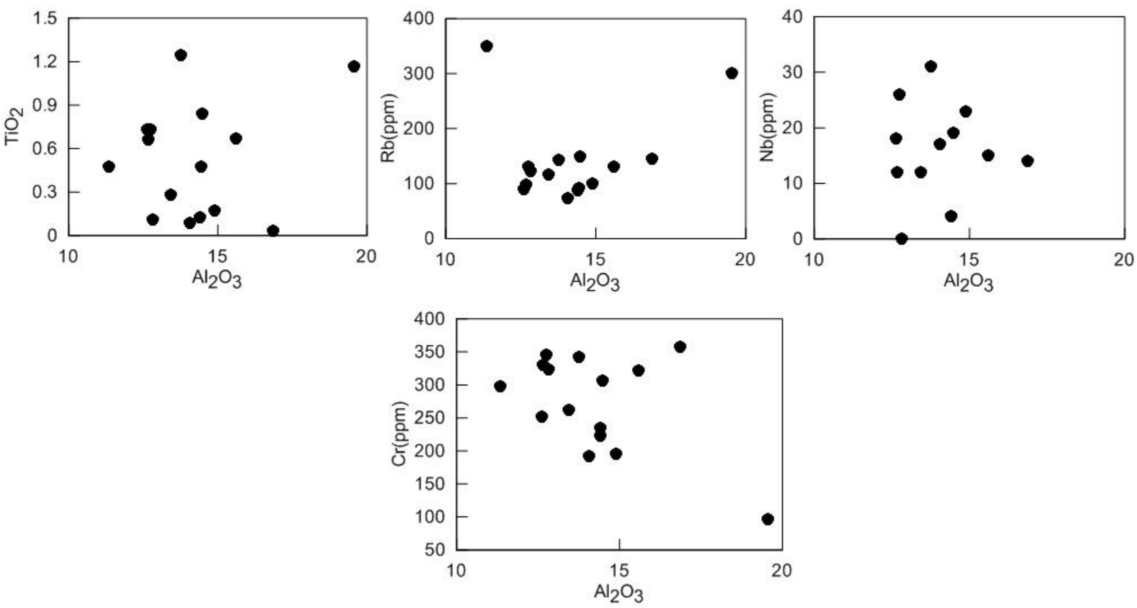

Figure 4 - Selected major element and trace element-Al_2O_3 variation diagrams for the Macururé domain rocks.

The majority of the analyzed trace elements show positive correlations with Al_2O_3, but scatter is appreciable, even within the individual rock types, and negative correlations with SiO_2 (Fig. 4).The concentrations of trace elements of the metasedimentary rocks normalized relative to UCC values (McLennan, 2001) show that the rocks are is moderately depleted in Sr, Th, U, Zr, Hf, Y and V relative to UCC values.

Rare earth elements

Total REE contents vary from 123 to 195 ppm, except for two samples that have much lower or higher values, respectively of 74 and 298 ppm (Table 2). Chondrite-normalized patterns (Fig. 5) show La_N concentrations ranging between about 0.5x· and 2x· chondrite abundances, although most samples have La_N of ~1. This feature suggests that the metasedimentary rocks are first cycle-sediments lacking appreciable recycling and mixing (McLennan, 1989). The REE patterns are flat to mildly fractionated, with average La_N/Yb_N values of 1.56. Average Eu/Eu* value is 1.57. The REE patterns of these metasedimentary rocks contrast sharply with that of the Neoproterozoic UCC, which has a markedly more fractionated pattern (La_N/Yb_N = 8.7), and a significant negative Eu anomaly (Eu/Eu* 0.62) (Taylor and Mclennan, 1985) (Fig.5).

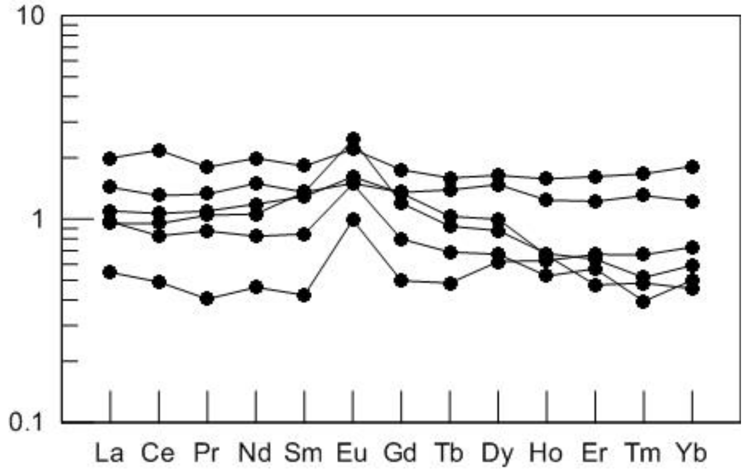

Figure 5 - UCC-normalized REE patterns for the Macururé domain metasedimentary rocks. Chondrite normalizing values from Taylor and McLennan (1985).

Protoliths

Considering the relationships between SiO_2/Al_2O_3 vs Fe_2O_3/K_2O and Na_2O/K_2O in the chemical classification diagram of sedimentary rocks of Herron (1988, Fig.6) and Pettijohn (1972, Fig. 7), the analyzed samples from the metasedimentary rocks of Macururé domain plot mostly in the field of greywacke, pelitic and arkose rocks, with two samples lying in the field of shale, and two samples in the field of arkose.

Therefore we infer that the rocks represent a sequence of alternating metapsamites and metapelites. The compositional variation between SiO_2 versus Al_2O_3 contents are inversely proportional, and the concentrations of these elements (~ SiO_2> 67% Al_2O_3> 15%) allow to infer also that psamites are the protoliths of these metamorphic rocks.

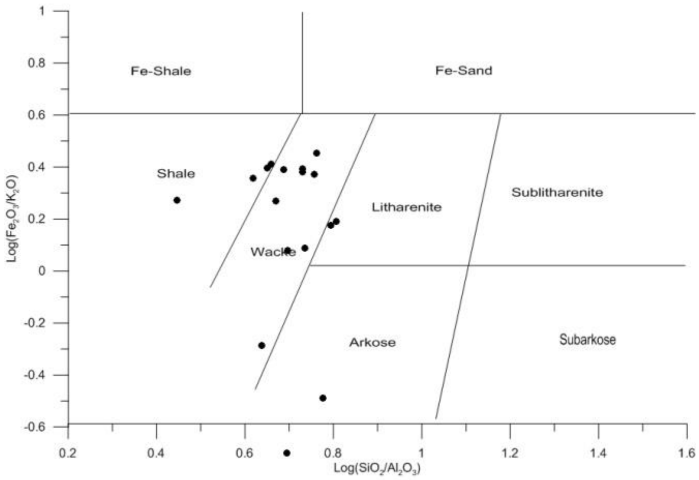

Figure 6 - Chemical classification of the metaclastic rocks of the Macururé domain based on the log SiO_2/Al_2O_3vs. log (Fe_2O_3t/K_2O) diagram of Herron (1986).

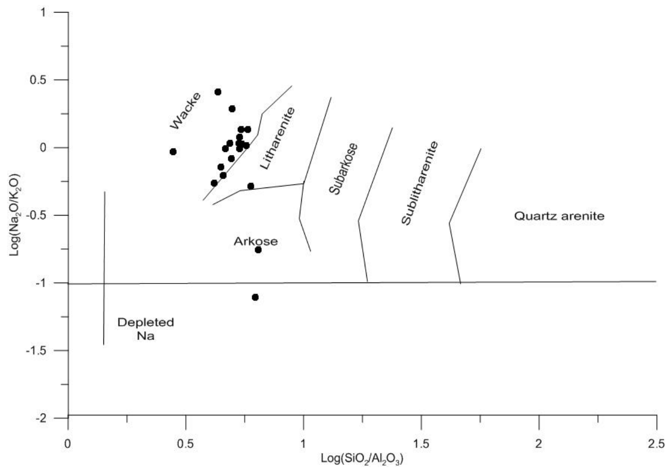

Figure 7 - Chemical classification of the metaclastic rocks of the Macururé domain based on the log SiO_2/Al_2O_3vs. log (Na_2O/K_2O) diagram of Pettijohn (1972).

Table 1 -. Whole-rock XRF analyses of the Macururé Domain metasedimentary rocks

	MA-12	MA 14	MA-15	MA 55	MA-61	MA 62	MA 29	MA 30	MA-35	MA 36	MA-41	MA-42	MA 48	MA-50	MA-51	MA-54
SiO_2	70,77	72,91	54,6	64,86	73,18	76,50	64,71	72,32	68,39	51,45	62,85	73,75	71,75	73,04	76,61	76,74
Al_2O_3	11,35	12,62	19,6	15,60	16,86	14,40	14,48	12,66	12,74	6,24	13,75	14,90	14,43	13,43	12,81	14,06
TiO_2	0,48	0,73	1,2	0,67	0,04	0,13	0,84	0,66	0,73	0,21	1,24	0,17	0,48	0,28	0,11	0,09
MgO	0,32	1,62	1,1	1,86	0,33	0,17	2,64	1,83	2,15	16,07	3,05	0,32	0,82	1,10	0,35	0,09
MnO	0,20	0,09	0,1	0,07	0,23	0,02	0,10	0,07	0,07	0,36	0,09	0,01	0,02	0,02	0,08	0,00
CaO	0,77	2,38	3,3	0,25	0,88	0,97	0,43	2,18	2,16	15,34	1,49	2,11	2,25	1,76	0,59	1,34
Fe_2O_3	8,30	4,94	8,5	7,53	0,98	0,23	7,45	5,01	5,92	7,85	9,00	0,81	2,61	2,98	1,45	0,06
Na_2O	0,43	2,36	4,3	1,80	4,84	3,28	2,15	2,21	2,36	0,36	2,17	3,33	4,22	3,31	2,30	3,49
K_2O	5,54	1,74	4,6	3,31	1,89	3,06	3,00	2,13	2,40	0,07	3,49	4,03	2,18	2,44	4,46	3,31
P_2O_5	0,03	0,03	0,1	0,04	0,02	0,06	0,13	0,17	0,14	0,23	0,04	0,05	0,14	0,07	0,07	0,01
LOI	1,86	2,26	2,4	5,43	2,15	1,18	3,67	1,15	1,11	2,54	1,14	0,42	1,13	2,08	0,93	0,66
Total	100,04	101,67	99,6	101,41	101,40	99,99	99,61	100,39	98,17	100,72	98,31	99,89	100,02	100,50	99,75	99,84
SiO_2/Al_2O_3	6,23	5,77	2,79	4,15	4,33	5,31	4,46	5,71	5,36	8,24	4,57	4,95	4,974	5,43	5,98	5,45
K_2O/Na_2O	12,76	0,73	1,07	1,83	0,39	0,93	1,39	0,96	1,01	0,19	1,61	1,20	0,516	0,73	1,93	0,94
Cr	298	251	97	322	357	222	306	330	345	78	343	195	234	262	323	192
Ba	166	605	676	1044	218	258	452	439	383	194	959	1946	1216	1966	2071	642
Rb	349	89	301	131	146	88	149	97	131	-6	143	101	91	116	122	73
Sr	49	563	312	290	255	247	170	241	260	5	344	1056	1405	1054	800	480
Zr	1604	186	298	188	37	20	137	210	171	47	255	199	194	198	65	57
Y	167	27	81	53	36	22	39	39	36	16	44	28	23	34	31	75
Nb	475	18	86	15	14	4	19	12	26	1	31	23	4	12	nd	17
Ni	16	28	36	52	34	25	53	44	53	38	83	30	24	37	30	26

Major elements wt.%, trace elements ppm. nd = Not detected

Table 2 - Solution ICP-MS analyses of REE, Hf, Ta, Th, U, Co and V (ppm) of the Macururé Domain metasedimentary rocks

	MA-14	MA-30	MA-35	MA-50	MA-55	MA-61
La	16,4	28,6	32,9	43,0	59,8	29,1
Ce	31,4	60,7	68,1	83,5	139,6	52,9
Pr	2,9	7,4	7,8	9,4	12,8	6,2
Nd	12,0	27,5	30,8	38,9	51,8	21,4
Sm	1,9	6,1	5,8	6,1	8,2	3,8
Eu	0,9	1,3	1,4	2,2	1,9	1,3
Gd	1,9	5,1	5,1	4,6	6,6	3,0
Tb	0,3	0,9	0,7	0,6	1,0	0,4
Dy	2,2	5,2	3,5	3,1	5,7	2,4
Ho	0,5	1,0	0,5	0,5	1,3	0,4
Er	1,5	2,8	1,1	1,5	3,7	1,3
Tm	0,2	0,4	0,2	0,2	0,6	0,1
Yb	1,6	2,7	1,0	1,3	4,0	1,1
Lu	0,2	0,2	0,1	0,2	0,6	0,1
∑REE	73,9	150,0	158,9	194,9	297,6	123,5
LREE/HREE	7,7	7,2	12,2	15,4	11,6	13,0
La_N/Yb_N	0,75	2,43	1,10	1,94	0,78	2,41
Eu/Eu*	2,16	1,93	1,24	1,81	1,11	1,23
Hf	4,1	6,6	4,9	3,3	4,7	4,7
Ta	0,4	1,8	1,7	0,1	0,1	0,7
Th	6,0	9,5	10,8	7,6	12,4	5,4
U	1,4	5,4	3,0	1,7	2,2	0,9
Co	11,0	13,8	17,8	7,2	19,8	15,7
V	113,0	100,0	127,0	32,0	116,0	59,0

REE indexes calculated using the UCC values of Taylor and McLennan (1985).

DISCUSSION

Provenance

In order to characterize the provenance of clastic sedimentary rocks, the major element based diagram of Roser and Korsch (1988) is largely used because this bivariate plot uses parameters that are largely independent of grain size effects (sandstone mudstone). The discriminant functions of the diagram use Al_2O_3, TiO_2, Fe_2O_3T, MgO, CaO, Na_2O, and K_2O contents as variables. This discriminant diagram is useful for characterizing bulk provenance in metamorphic terranes where recrystallization has obscured or destroyed original detrital mineralogy. These functions discriminate among four sedimentary provenances: mafic, P1: ocean island arc; intermediate, P2: mature island arc; felsic, P3: active continental margin; and recycled, P4: granitic–gneissic or sedimentary source. Provenance discrimination diagrams based only on major elements are somewhat unreliable because of the mobilization of these components during weathering and alteration (Roser and Korsch1988).

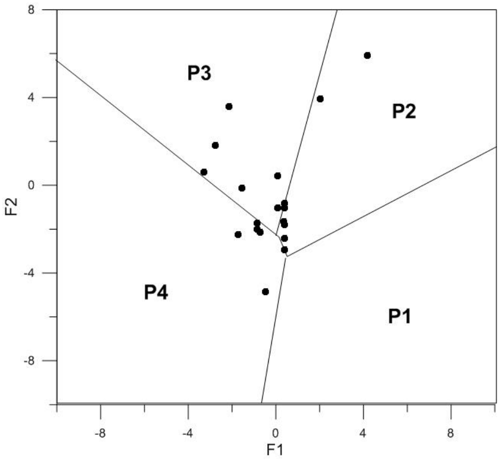

Figure 8. Plot of the metasedimentary rocks of the Macururé domain in the discriminant function diagram for the provenance signature of mudstone suites based on major element chemistry (modified after Roser and Korsch 1988). P1: mafic detritus; P2: intermediate detritus; P3: felsic detritus; and P4: recycled detritus, granitic–gneissic or sedimentary source.

Notwithstanding this difficulty, in this diagram (Fig. 8) we can observe some differences between the different analyzed samples. The majority of the metamorphic rock samples plot on the P3 and P4 fields. P3 would indicate a provenance from active continental margins whereas P4 indicate recycled continental sources associated with a passive continental margin, intracratonic sedimentary basins, and recycled orogenic provinces. Only two samples plot in the P2 field.

The geochemical signatures of these rocks were used for the purpose of characterizing the origin of the protoliths. The compositions of source rocks may be inferred using the relationship Al_2O_3/TiO_2 that tends to increase as the rock becomes more felsic (3 to 8 in mafic rocks, 8 to 21 in the intermediate rocks, 21-70 in felsic rocks; Hayashi et al. 1997). The Al_2O_3/TiO_2 ratios of the studied samples mostly range from 11 to ~80, in some cases with larger values. These data compared to the compositional values established by Hayashi et al. (1997) indicate intermediate to felsic igneous rocks as the source.

REE patterns have been widely used in geochemical studies of metasedimentary rocks. The degree of differentiation of LREE from HREE is a measure of the proportion of felsic to mafic components in the source region, whereas Eu anomalies may provide information about the nature of the processes affecting the source area, such as whether plagioclase has been removed from the ultimate igneous source areas of the sediments (Taylor and McLennan, 1985). The overall characteristics of the average chondrite-normalized REE patterns of the studied metasedimentary rocks are similar (Fig.5), implying in common source. The minor differences among the samples are more likely controlled by local scale variations of catchment lithologies in the source area.

The behavior of rare earth elements of both rock analyzed types seems not to be affected by the degree of metamorphism. Cullers (2000), has shown that variation in the concentrations of elements between adjacent sediments makes depreciable the influence of mobility for the same metamorphic processes. The lower values for the concentrations of HREE (Fig. 5) indicate a contribution of material from sources depleted in these elements, for example, very different igneous rocks, but also may be controlled by different content of heavy minerals, such as garnet and zircon that generally tend to contain these elements.

The diagram K_2O versus Rb of Floyd and Leveridge (1987) and Floyd et al. (1989) (Fig. 9) indicates that the studied metasedimentary rocks come from acidic to intermediate igneous materials, although these elements are considered mobile during the sedimentary process. However, the lack of significant negative Eu anomalies for most of the metagraywackes and the metapelites suggest the dominance of andesitic and/or basaltic rocks in the source region, and that K-rich granitic rocks were not present in significant proportion (Taylor and McLennan, 1985).

An additional evidence of the paucity of mafic sources for the metamorphic rocks under study is provided by the TiO_2 vs Ni correlation (Fig. 10), which indicates that the magmatic protoliths of the metasedimentary pile were largely derived from acidic to acid/intermediate magmatic compositions.

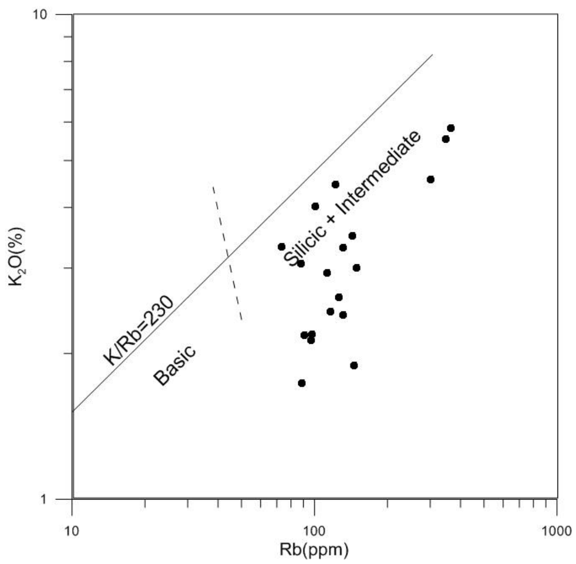

Figure 9 - Distribution of K and Rb in the metasedimentary rocks of Macururé domain relative to a K/Rb ratio of 230 (=main trend of Shaw, 1968).

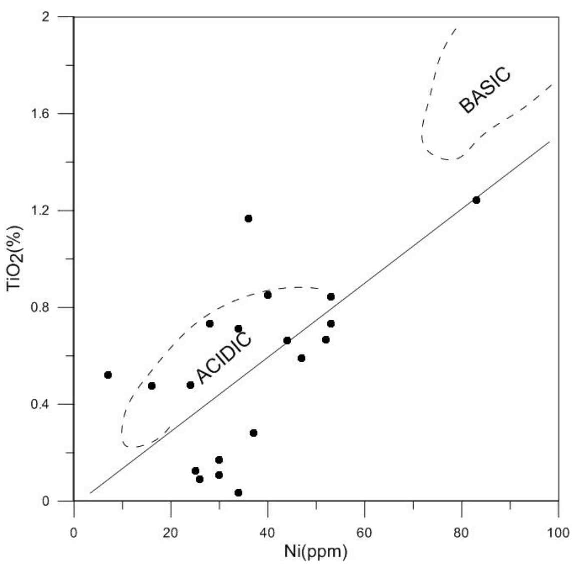

Figure 10 - TiO_2 vs. Ni for the metasedimentary rocks of Macururé domain. Fields for acidic and basic source materials after Floyd et al. (1989)

Tectonic setting

The compositions of sediments are broadly related to the tectonic setting in which they are deposited (Bhatia, 1985; Bhatia and Crook, 1986; Roser and Korsch, 1986; McLennan et al., 1990). In cases where the original sources have been completely removed or eroded, derived sediments provide the only records of source (Bhatia and Crook, 1986). However, care is required when assessing tectonic setting, because sediments can be transported across boundaries and be deposited in tectonic environments differing from those in which they originated (McLennan, 1989; McLennan et al., 1990). Based on these concepts, attempts have been made to characterize sediment chemistry and tectonic setting of deposition, and to build discrimination diagrams or criteria that help to decipher ancient sedimentary basins (Bhatia, 1983; Bhatia and Crook, 1986; Roser and Korsch, 1986).

Bhatia (1983) and Bhatia and Crook (1986) proposed various tectonic environment discrimination diagrams based on the geochemical characteristics of sedimentary rocks. These diagrams are widely used to infer the tectonic environment in which developed ancient sedimentary basins (e.g. Ryan and Williams, 2007; Drobe et al. 2009). Projections of discrimination diagrams of the tectonic environments of metasedimentary rocks is observed in F1-F2 diagram of Bhatia (1983) (Fig. 11) suggests an active continental margin environment, and to a lesser extent, a continental island arc for the metapsammites. Thus the protoliths of the studied rocks would be related to magmatic arc environments (ie, continental island arcs and active continental margin, according to the criteria of Bhatia, 1983, Bhatia and Crook, 1986). This is in agreement with the results presented by Oliveira et. al (2010) and Bueno (2008, 2009) for the metasedimentary rocks of Macururé domain and for other metamorphic units outcropping in the Sergipano Belt.

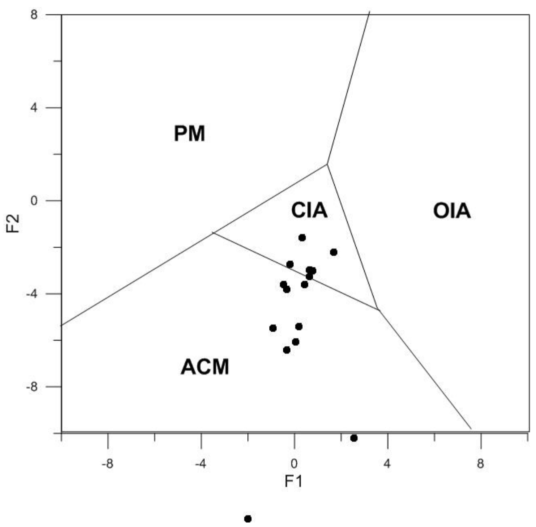

Figure11 - Discriminant function diagram (after Bathia, 1983) for the metasedimentary rocks of the Macururé domain. PM: Passive Margin; OIA: Oceanic Island Arc; ACM: Active Continental Margin; CIA: Continental Island Arc.

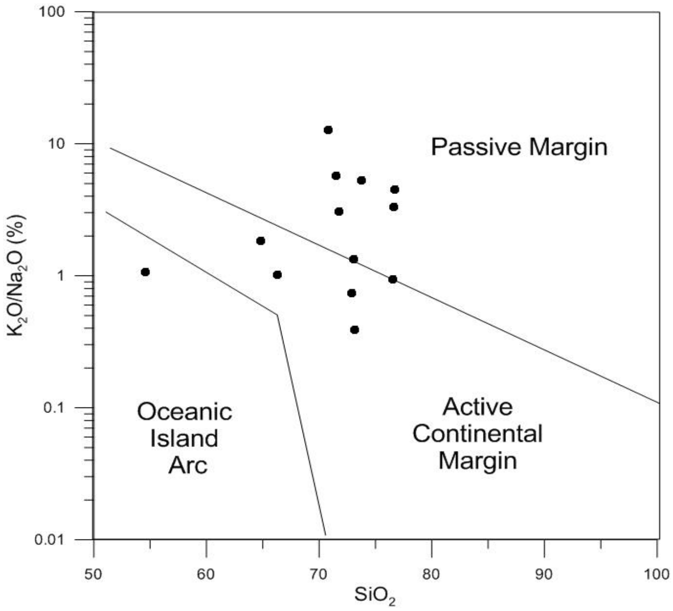

Figure 12 - K_2O/Na_2O *vs.* SiO_2 discriminant plot of tectonic setting for mudstone suites (after Roser and Korsch, 1986).

Most inferences about the tectonic setting of metagreywackes point to a continental island arc, a tendency observed for the metamorphic rocks of Macururé domain to active continental margins (Fig. 12). Continental island arcs correspond to the sedimentary basins adjacent to island arcs formed on a well developed continental crust or on thin continental margins (detached and noncontracted type arc-trench systems, respectively) (Bathia, 1983). Arcs are continental fragments, detached from the mainland. Sediments are deposited in inter-arc, back-arc and fore-arc basins and are mainly derived from felsic volcanic rocks. Back-arc basins formed on the continental side of the island arc are included in this setting. Active continental margins include sedimentary basins of the Andean type thick continental margins and the strike slip types. These basins are developed on or adjacent to a thick continental crust composed of rocks of older fold belts. Sediments are dominantly derived from granite-gneisses and siliceous volcanic rocks of the uplifted takes place in marginal and retro-arc basins.

CONCLUSIONS

The combined petrographic and geochemical studies applied to metamorphic units of Macururé domain suggest that the protoliths belonged to rock sequences mainly composed of clastic sedimentary greywackes and shales. Immobile trace element abundances and ratios in the metasedimentary succession are comparable with acidic to intermediate rocks, suggesting the sediments were derived from igneous or quartz-rich sedimentary source with similar composition. Major and trace elements used to discriminate tectonic environments indicate that are related to magmatic arc environments.

The metasedimentary rocks are similar in their immobile trace element compositions, their ratios and REE patterns. These geochemical similarities suggest the metamorphic rocks of Macururé Domain, which are mapped as different formations or members (e.g.: Mendes and Brito, 2009), are more likely a continuation of the same sedimentary succession derived from a common source area.

Acknowledgments

Our thanks to financial support of Brazilian Agencies PRONEX/FACEPE APQ-0479-1.07/06, APQ 0844-1.07/08 and CNPq Universal 478554/2009-5. This paper is part of a M.Sc. study by M. M. C. Lima, who was supported with a Masters scholarship (Process: IBPG-0204-1.07/11) from the Fundação de Amparo à Ciência e Tecnologia de Pernambuco (FACEPE).

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