ORIGIN OF A LATE-NEOPROTEROZOIC VOLCANO-SEDIMENTARY HIGH GRADE SEQUENCE IN SE BRAZILIAN COAST – GEOCHEMISTRY AND Sm-Nd DATA

Renata da Silva Schmitt[1], Silvia Regina Medeiros[1], Gilberto da Silva Vaz[1], Rudolph Allard Johannes Trouw[2]

1- Faculdade de Geologia, UERJ, Maracanã, Rio de Janeiro, Brazil, CEP:21959-900; renataschmitt@uol.com.br, silviarm@uerj.br, gsvaz2000@yahoo.com.br
2- Depto. de Geologia, Igeo/UFRJ, Ilha do Fundão, Rio de Janeiro, Brazil, CEP: 21900-900; trouw@geologia.ufrj.br

Keywords: Late-Neoproterozoic, Ribeira Belt, supracrustal rocks, Sm-Nd isotopic data, SW-Gondwana.

INTRODUCTION

The latest events of SW-Gondwana assembly included the development of many sedimentary basins coeval with volcanic episodes. Some are well preserved in the cratonic platforms (e.g. Nama Basin, SW Africa). Others are strongly deformed and metamorphosed within the Pan-African-Brasiliano belts. We present here evidence on the origin of a high grade metavolcano-sedimentary sequence deposited/crystallized in the Late Neoproterozoic, based on new geochemistry and Sm-Nd data.

GEOLOGICAL SETTING

The supracrustal sequence is located in the southeastern tip of the Ribeira Belt (Rio de Janeiro state, Brazil), a Neoproterozoic unit (Brasiliano/Pan-African) that runs along the Brazilian coast (Heilbron & Machado, 2003). It comprises the Cabo Frio Tectonic Domain (Schmitt et al., 2004) together with a Paleoproterozoic basement. Both lithotectonic units are affected by a high grade metamorphic event and deformational phases that generated several ductile structures. This tectono-metamorphic event occurred during the Cambrian (525 to 490 Ma), and is named the Búzios orogeny (Schmitt et al., 2004). The basement is composed of felsic orthogneisses (from tonalites to sienogranites) and orthoamphibolites. The metagranitoids have crystallization ages of 2.0 to 1.95 Ga. The mafic rocks represent more than one generation, occurring as xenoliths, tectonic sheets and paleodykes.

BÚZIOS-PALMITAL BASIN

The Supracrustal Unit is at least 500 meters thick and is divided into four compositional groups: quartz-feldspathic, aluminous with kyanite/sillimanite, calcsilicate rocks and mafic gneisses. The contact with the basement units is always strongly tectonized. The compositional layering of these gneisses is interpreted to reflect the original bedding; therefore this unit was subdivided into two main sedimentary (volcanic) successions that grade laterally one into the other based on the frequency of the interbedded lithotypes.

The **Búzios Succession** is a thick, aluminous metasediment package (sillimanite-kyanite-garnet-biotite gneiss) with numerous calcsilicate and amphibolitic intercalation. The **sillimanite-kyanite-garnet-biotite gneiss** also contains orthoclase, minor microcline, oligoclase-andesine, and quartz. Trace minerals are sphene, monazite, rutile, zircon, tourmaline, and apatite. **The calcsilicate layers** show two gneiss types: one composed of diopside (40-70%), garnet and minor biotite; and a second composed of diopside (15-25%), amphibole, quartz, biotite, plagioclase, orthoclase, and garnet. **The mafic layers** are subdivided into garnet amphibolites, diopside amphibolites, spinel-garnet-cpx gneisses and metahornblendites (Góes et al., 2004). The amphibolites occur in layers of a few centimeters to meters or grouped in packages up to 15 meters thick interbedded with the aluminous metasediments and the calcsilicate rocks. Actinolite, scapolite, sphene, epidote, rutile, chlorite, and zircon are trace minerals.

The **Palmital Succession** is constituted mainly of quartz-feldspathic metasedimentary (paragneiss) thick packages (>300 meters), with some aluminous intercalation, calcsilicate rocks and feldspathic quartzite layers (3 meters thick). The paragneiss shows a regular compositional layering varying from 5 to 30 cm, determined by felsic layers (rich in quartz and feldspar) and more biotite-rich layers with kyanite and sillimanite, which are interpreted as representative of the bedding of a probably turbiditic succession. The main mineralogical constituents are orthoclase, quartz, biotite, plagioclase, and sillimanite. Accessories are garnet, apatite, sphene, zircon, and kyanite (only in the metamorphic KY zone). Within the calcsilicate lenses, there is a one-meter thick layer of sphene-bearing amphibolite interpreted to be of sedimentary origin. It is constituted mainly of plagioclase (bytownite- anortite) and amphibole, with garnet, sphene, and ilmenite as accessories.

In both successions, the metamorphic minerals, zircon, monazite, sphene and rutile, show U-Pb ages between 520 and 480 Ma, interpreted as metamorphic and cooling events (Schmitt et al., 2004). U-Pb SHRIMP analyses on detrital zircons from Palmital Succession (Schmitt et al., 2003, 2004) revealed crystallization ages at 2.6, 2.0, 1.2, 1.0 and 0.8 Ga. The youngest detrital zircon is 620 Ma old, interpreted as the depositional age of the basin, named Búzios-Palmital basin. Sm-Nd data from whole-rock samples of the supracrustal unit indicate T_{DM} model ages ranging from 1.75 to 1.0 Ga. These could be interpreted as maximum ages for the basin formation.

GEOCHEMISTRY

Major, trace elements and REE analysis of ten mafic gneisses were carried out at the Active Lab, Canada. Trace elements and REE of four metasedimentary rocks were analyzed at the ICP-MS Laboratory in the Department of Geology of the University of Kansas, USA. The mafic rocks were tested in discrimination diagrams for ortho- and para-amphibolites, considering that in the field some layers are interbedded with meta-sedimentary layers. With the only exception of sample BUZ-84-2A, all other samples presented ortho-derived chemical signatures. The Cr- diagrams, suggested by Leake (1964), are particularly good, separating also the four metapelites analyzed. The mg against c Niggli parameters plot (Leake, 1964) show a differentiation trend, from early to middle stage differentiates. In the TiO_2 versus FeOt diagram (Peloggia and Figueiredo, 1991), the mafic rocks separated in two fields: basic meta-tuffs and orthoamphibolites.

The REE pattern diagram clearly separates 4 groups of samples (Figure 1). The samples were normalized for the primitive mantle and chondritic values, for comparison (Sun and McDonough, 1989). The metapelites define a pattern with high LREE values, La mainly, and a Eu negative anomaly (Figure 1). The mafic rocks are divided in three patterns varying from a high LREE content to a horizontal pattern. The LREE enriched group include samples 84-2 (probably a para-amphibolite) and 06-04 (garnet amphibolite). The second group is also LREE enriched, with lower absolute values. Two samples show a negative Sm anomaly that could be explained by the migration of the Sm to the garnet rich layer (Grauch, 1989). Sample 93 is the only that have a horizontal pattern, similar to the normal mid-ocean ridge basalts (N-MORB)(Hess,1989). The direct comparison of REE patterns of not metamorphosed rocks with metamorphosed rocks is made here due to the following reasons: (1) the REE patterns were similar between rocks with contrasting metamorphic mineralogical content; (2) the REE patterns were similar between rocks with distinct modes of occurrence in the field, for example, dykes (which are expected to be largely contaminated by the wall rock geochemistry) and thick successions of gabbro/ basalt (?); (3) REE patterns were similar between samples collected more than a 100 km away from each other.

Sm-Nd ISOTOPES

Sm-Nd data were obtained at the Laboratory of Geochronology in the University of Brasília, Brazil. The analytical procedures were those presented by Gioia and Pimentel (2000). Eleven mafic gneisses and four metapelites samples were analyzed. The metapelites show $^{147}Sm/^{144}Nd$ values around 0.125, similar to the data already published (Schmitt et al., 2004). The T_{DM} model ages, however, varied from 1.25 Ga to 2.74 Ga (Figure 2), widening the previous data range, 1.4 to 1.75 Ga (Fonseca et al., 1994, Schmitt et al., 2004). Though, sample BUZ-85 (T_{DM} 2.7 Ga) could belong to an older supracrustal sequence (Archean-Paleoproterozoic). ε_{Nd} (T=600) vary from -16 to -3.7. These results indicate that the sediments derived probably from a mixture of an old basement (2.0 Ga- Figure 2) and a younger source (between 1.0 to 0.65 Ga – detrital zircons). It is important to emphasize that the sample which gave the youngest detrital zircons SHRIMP age, showed a T_{DM} model age of 2.0 Ga. The mafic samples pointed out $^{147}Sm/^{144}Nd$ ratios between 0.14 and 0.20. The T_{DM} model ages varied from 1.0 to 2.0 Ga. ε_{Nd} (T=600) range from 0 to +2, with the exception of sample BUZ-84-2A (Figure 2). The Nd evolution curve for this sample, probably of sedimentary origin, is quite similar to the metapelites envelope. Five mafic ortho-derived rocks plot in the same envelope defined previously with only two mafic rock samples in Schmitt et al. (2004). Three samples showed distinct patterns (06-08a, 84-8, 93). Sample 06-08a is a differentiate layer of amphibolite without garnet. In the same outcrop, sample 06-08b, with garnet and cpx, presents a younger T_{DM} model age. This suggests that the metamorphic event acted as a re-homogenizing the Sm-Nd system, during recrystallization and mineral segregation. The pattern of sample 84-8 (parallel to 06-08a) could be explained by the same reason above or it could fit in a double stage Sm-Nd model. Sample 93 has an Nd evolution curve similar to the depleted mantle. Considering its REE pattern, N-MORB-like, it is plausible to propose that this sample could be a candidate for a Neoproterozoic oceanic crust.

CONCLUSIONS

The mafic gneisses of the Buzios Succession are ortho-derived and could represent ancient lava or sub-volcanic intrusions. The REE signature distinguishes three groups of mafic rocks, grading from a horizontal (N-MORB like) to a LREE enriched pattern. These magmatic pulses are coeval with the sedimentation, deduced from the meter and even centimeter intercalation. In the Nd evolution diagram it is possible to separate both groups: orthoamphibolites and metasedimentary rocks (calc-silicates and metapelites). The orthoamphibolites have positive $\varepsilon_{Nd(t)}$ and T_{DM} of 1.1 Ga. The metasedimentary rocks have negative $\varepsilon_{Nd(t)}$ and T_{DM} of 1.7 Ga. Some samples show distinct curves. These pattern could be attributed to a mixture of processes (volcano-sedimentary) or even to basement tectonic sheets. The calcsilicate layers might represent chemical deposits possibly related to these volcanic events. Búzios and Palmital successions are interpreted as deposited as lateral varieties in the same basin (Búzios-Palmital basin). Minor layers of garnet-quartz gneiss and feldspathic quartzite within both successions could represent interdigitations. Based mainly on facies descriptions, the lithotypes are thought to be derived from turbiditic hemipelagic to pelagic sediments of a submarine fan. The quartzo-feldspathic dominated Palmital succession may represent deposits of the medium portion of the fan, and the pelitic Búzios succession may correspond to the pelagic distal facies.

The evidence presented here shed light on the hypothesis that, during the Late Neoproterozoic, there was a volcano-sedimentary basin developing in an active margin setting. The basin deposited/crystallized at least until 620 Ma and was subsequently deformed and metamorphosed at ca. 525 Ma. The correlation with other coeval volcano-sedimentary basins should be more careful, and depends on determining the age of the magmatic episodes and the chemical signatures and isotopes of the lithotectonic units.

ACKNOWLEDGEMENTS

The Sm-Nd analyses were financed by FAPERJ – Project APQ-1/2003 for Dr. Schmitt.

REFERENCES

Fonseca, A.C.; Cordani, U.G.; Kawashita, K.; Bigazzi, G. 1994. Geocronologia da região de Cabo Frio, Rio de Janeiro. In: SBG, Congresso Brasileiro Geologia, 38, Camboriú (SC), *Anais*.. (2): 386-387.

Gioia, S.M.C.L., Pimentel, M.M. 2000. The Sm-Nd isotopic method in the geochronology laboratory of the University of Brasília. *An. Acad. Bras. Ciênc.*, June 2000, vol.72, no.2, p.219-245.

Góes, N.F.B., Sales, C.R., Schmitt, R.S., Trouw. R.A.T. 2004. Caracterização petrográfica das rochas máficas-ultramáficas de uma sucessão supracrustal - implicações na evolução tectônica cambriana da Faixa Ribeira. In: XL Congresso Brasileiro de Geologia, Araxá (MG), Anais, v.1,S.07.

Grauch, R.I. 1989. Rare Earth Elements in metamorphic rocks. In: Lipin, B.R.; McKay, G.A. (eds). Geochemistry and Mineralogy of Rare Earth Elements. Reviews in Mineralogy. Vol. 21. pp. 147-167.

Heilbron, M. and Machado, N., 2003. Timing of terrane accretion in the Neoproterozoic-Eopaleozoic Ribeira belt SE Brazil. Precambrian Research, 125 (1-2), 87-112.

Hess, P.C. 1989. Origin of Igneous rocks. Harvard University Press. Massachussets. 336 pp.

Leake, B.E. 1964. The chemical distinction between ortho- and para-amphibolites. Journal of Petrology, 5(2), 238-254.

Peloggia, A.U.G., Figueiredo, M.C.H. 1991. Utilização de diagrama ferro-titânio na distinção entre orto- e para-anfibolitos. Boletim IG-USP, Série Científica, 22, 51-60.

Schmitt, R.S., Pimentel, M.M., Van Schmus, W.R., Trouw, R.A.J., Armstrong, R.A. 2003. Marine sedimentation related to the latest stages of Gondwana assembly in the Ribeira Belt: new U-Pb data. In: IV South American Symposium on Isotope Geology, IV SSAGI, Salvador, Short Papers Volume, 1: 294-297.

Schmitt, R. S., Trouw, R. A J, Van Schmus, W.R. and Pimentel, M. M., 2004. Late amalgamation in the central part of West Gondwana: new geochronological data and the characterization of a Cambrian orogeny in the Ribeira Belt - SE Brazil. Precambrian Research, 133 (1-2), 29-61.

Sun, S.S., McDonough, W.F. 1989. Chemical and isotopic systematic of oceanic basalts: implications for mantle composition and processes. Geological Society Special Publications, no. 42, pp. 313-345.

RESUMO

Os últimos eventos relacionados à aglutinação da porção sudoeste do Gondwana incluíram o desenvolvimento de bacias sedimentares contemporâneas com episódios vulcânicos. Algumas bacias estão preservadas nas plataformas cratônicas, outras estão deformadas e metamorfisadas dentro das faixas móveis Pan-Africanas-Brasilianas. Apresentamos aqui evidências acerca da origem de uma seqüência de alto grau vulcano-sedimentar depositada/cristalisada no final do Neoproterozóico, com base em novos dados gequímicos e de Sm-Nd. A seqüência supracrustal está localizada na ponta sudeste da Faixa Ribeira (Rio de Janeiro, Brazil). Foram identificadas duas sucessões: Buzios e Palmital. Os gnaisses máficos da Sucessão Búzios são ortoderivados e podem representar intrusões subvulcânicas e lavas antigas. O padrão de terras raras separa três grupos de rochas máficas, desde um padrão horizontal até um padrão enriquecido em terras raras leves. Estes pulsos magmáticos são contemporâneos com a sedimentação. No diagrama de evolução do Nd é possível separar dois grupos: ortoanfibolitos e rochas metassedimentares (calciosilicáticas e metapelitos). Os ortoanfibolitos têm $\varepsilon_{Nd(t)}$ positivo e idade-modelo T_{DM} de 1.1Ga. As rochas metassedimentares apresentam um $\varepsilon_{Nd(t)}$ negativo e idade-modelo T_{DM} de 1.7Ga. As sucessões Búzios e Palmital são interpretadas como variações laterais depositadas na mesma bacia (Bacia Búzios-Palmital). Os litotipos são derivados de sedimentos turbidíticos hemipelágicos a pelágicos de leque submarino. A Sucessão Palmital, dominada por litotipos quartzo-feldspáticos, pode representar depósitos de porções medianas no leque, enquanto que a Sucessão Búzios pode corresponder ao fácies pelágico mais distal. As evidências aqui apresentadas reforçam a hipótese de que desenvolveu-se num ambiente tectônico de margem ativa uma bacia vulcano-sedimentar durante o final do Neoproterozóico.

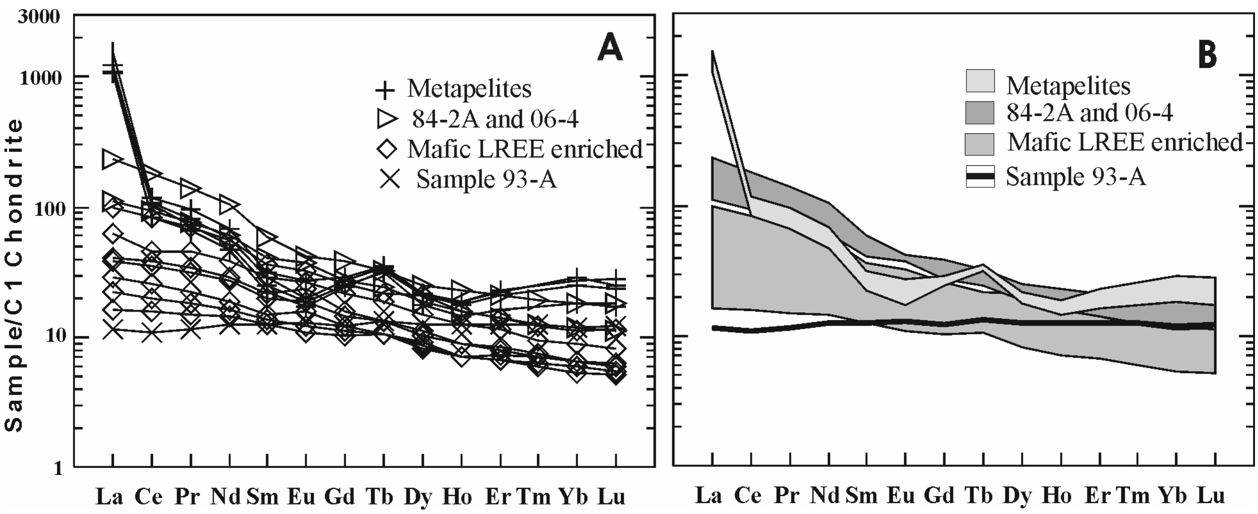

Figure 1. REE pattern for metapelites and mafic gneisses from the Supracrustal unit (Búzios and Palmital successions). **A.** Plot with all samples discriminated in symbols. **B.** Groups of samples separated in envelopes.

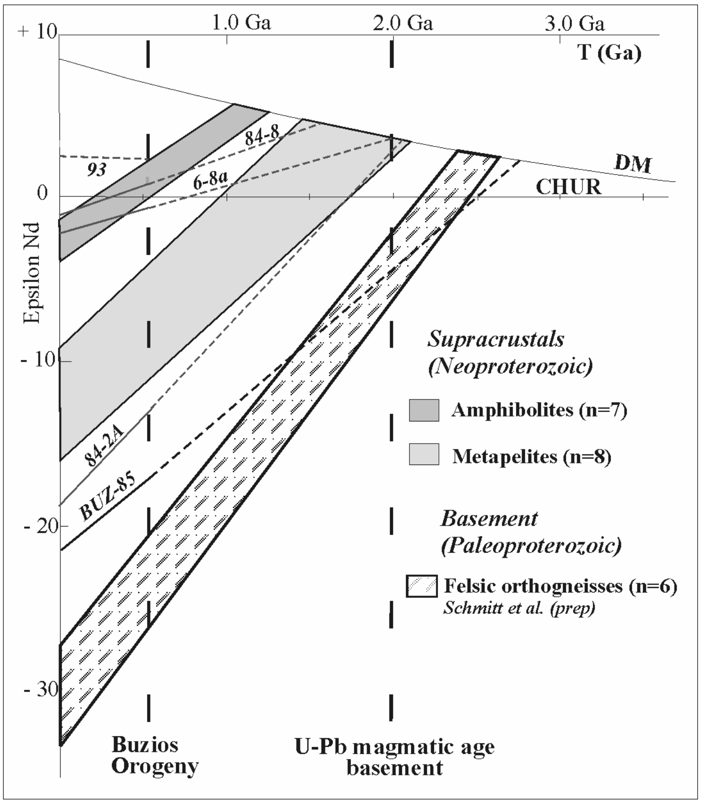

Figure 2. Nd evolution curve for supracrustal samples of Búzios-Palmital basin. The amphibolites and the metapelites draw two envelopes (n= number of samples that plot in the field). Samples that do not fit are in evidence (see discussion in text). For comparison, note the envelope with the Nd characteristics of basement samples from the Cabo Frio Tectonic Domain (Schmitt et al., in prep).