SM/ND DATA OF METASEDIMENTARY ROCKS FROM THE CENTRAL SEGMENT OF RIBEIRA BELT, SOUTHEASTERN BRAZIL

DIANA RAGATKY[1], MIGUEL TUPINAMBÁ[1] AND BEATRIZ PASCHOAL DUARTE[1]

ABSTRACT The central segment of Ribeira Belt, southeastern Brazil, comprises several tectonic domains where, during the Proterozoic, extensive detritic material was deposited over pre-1.8 Ga basement rocks. This paper presents Sm-Nd isotopic data on the high-grade metasedimentary rocks of this belt and discusses some possible implications on their sedimentary provenance. The pre-1.8 Ga basement rocks display different Nd isotopic evolution and thus can be promptly discriminated as sources of different Nd model ages (T_{DM}) and isotopic characteristics such as: Mantiqueira Complex, 3.0 and 2.6 Ga T_{DM} isochrons ages; Juiz de Fora Complex, 2.2 Ga T_{DM} isochron age and Quirino Complex, 2.0 Ga and 3.2 Ga T_{DM} ages. At the Juiz de Fora Domain, metapelites from the Andrelândia Depositional Cycle display a very narrow range of Sm/Nd values (0.15 to 0.17) and T_{DM} ages between 1.8 and 2.0 Ga. The corresponding measured ε_{Nd} values [$\varepsilon_{Nd}(0)$] vary between –20.8 and –29.1. The metapsammopelites of the Jardim Glória Unit, in the same geologic domain, display very different isotopic characteristics: higher Sm/Nd ratios (0.22 and 0.24), lower $\varepsilon_{Nd}(0)$ values (–15.3 and –18.3) and Neoarchean T_{DM} ages (2.5 and 2.6 Ga). At the Paraíba do Sul Klippe, the analyzed metapelites from the middle unit of Paraíba do Sul Group show T_{DM} ages close to 1.7 Ga with $e_{Nd}(0)$ values of -14.10 and -17.34. The metapsammopelites from the basal and uppermost units plot along the 2.0 Ga T_{DM} isochron and display $\varepsilon_{Nd}(0)$ values varying between -21 and –32. An isolated T_{DM} of an amphibolitic body, probably intrusive in the metasedimentary rocks of Paraíba do Sul Group, yields 1.0 Ga T_{DM} age, with a $^{147}Sm/^{144}Nd$ value of 0.1428.

Keywords: Neodymium isotopes, sedimentary provenance, Ribeira Belt, Proterozoic.

INTRODUCTION The Ribeira Belt (Almeida *et al*. 1973), in southeastern Brazil, is a Brasiliano/Pan-African belt that resulted from the agglutination of the Gondwana Supercontinent (750-500 Ma). Its central segment comprises several tectonic domains, most of them presenting pre-1.8 Ga basement rocks and distinct Proterozoic siliciclastic covers. During the Neoproterozoic, both basement and cover were intruded by several granitic plutons. Despite the well-determined ages of the Transamazonic basement and Brasiliano granitic rocks (U/Pb in accessory minerals, Machado *et al*. 1996), the time of deposition of the siliciclastic covers remains poorly constrained. However, the preservation of detrital sedimentary successions provides a record of the continental crust that was exposed and subject to erosion at the time of deposition. In this way, the Sm-Nd isotopic system, due to its relative immobility, is of particular interest. Nd isotopic studies on detrital metasedimentary rocks constitute an important additional tool of investigation in areas of complex geological evolution.

This paper presents Sm-Nd isotopic data of high-grade metasedimentary rocks from the central Ribeira Belt and discusses some possible implications about their sedimentary provenance.

GEOLOGIC SETTING The Ribeira Belt extends 1400 km along the Brazilian Atlantic Coast. It was generated in the last orogenic stage of the Brasiliano Collage. This complex belt borders the southeastern margin of the São Francisco Craton (Fig. 1). At the central segment of the Ribeira Belt, the Brasiliano Collage was characterized by northwestward thrusting and intermediate pressure-type metamorphism, followed by the development of steep dextral shear zones and refolding of previous structures (Heilbron *et al*. 1998). The first tangential tectonic episode has provided the major tectonic organization of the central segment of Ribeira Belt, defined by four tectono-stratigraphic terranes (Heilbron *et al*. 1998, 2000): a) the Occidental Terrane (Heilbron *et al*. 1995) constitutes the reworked margin of the São Francisco Craton; it comprises an Autochthonous Domain and two crustal scale thrust sheets (Andrelândia and Juiz de Fora domains); b) the Paraíba do Sul Klippe is the uppermost thrust slice of the central segment of the belt; c) the Oriental Terrane is the *locus* of the Ribeira Magmatic Arc (Tupinambá *et al*. 1998). The contact with the Occidental Terrane is given by a conspicuous NW dipping shear zone (the Central Tectonic Boundary, Almeida *et al*. 1998); d) the Cabo Frio Terrane occupies a small coastal area in the State of Rio the Janeiro. It is envisaged as a small fragment of the Congo Craton (Fonseca 1994).

In general terms, within each terrane three lithological associations were identified: a) pre- 1.8 Ga basement rocks; b) post- 1.8 Ga metasedimentary cover including metabasic rocks of continental to MORB geochemical affinity; and c) Brasiliano/Pan African granitoids.

JUIZ DE FORA DOMAIN AND PARAÍBA DO SUL KLIPPE The Juiz de Fora Domain is made up of three tectonic interlayered units (Duarte 1998; Heilbron *et al*. 2000): pre- 1.8 Ga orthogranulites (Juiz de Fora Complex); post-1.8 Ga metasedimentary cover of the Andrelândia Depositional Cycle and associated amphibolites; and migmatitic semipelitic paragneisses of unknown stratigraphic position (Jardim Glória Unit). Brasiliano granitoids/charnockitoids occur as plutonic bodies within this domain.

Based on field relations, few Nd model ages and geological correlation with other basins, Trouw *et al*. (1997) attributed a time interval of 1.0-0.6 Ga for the Andrelândia Basin. For the rocks from Jardim Glória Unit, Tupinambá *et al.* (1997) obtained Rb/Sr reference isochronic ages of 2.3-2.4 Ga.

The pre-1.8 Ga rocks of the Paraíba do Sul Klippe comprise granitic to granodioritic orthogneisses with basic and calc-silicate enclaves (Quirino Complex) of Paleoproterozoic age. The overlying metasedimentary cover belongs to the Paraíba do Sul Group. In the southern segment of Rio de Janeiro State, Almeida *et al*. (1993) proposed a subdivision of this group into three units: basal psammites with calc-silicate, marble and pelitic intercalations; intermediate pelites; and a stratified top unit with psammitic and pelitic layers with abundant marble, calc-silicate and Mn-rich rocks. Both basement and metasedimentary rocks are intruded by Brasiliano granitoids.

The stratigraphic relationship between pre-1.8 Ga rocks of the Quirino Complex and the cover are not clear and the time interval of sedimentation of the Paraíba do Sul basin is unknown. Recent paleogeographical reconstruction (Heilbron *et al*. 2000) related it to the passive margin of Oriental Terrane associated to Rodinia Supercontinent break-up and drift. Therefore, it is considered, tentatively, a Neoproterozoic basin (1.0-0.6 Ga) and equivalent to Italva basin, at the Oriental Terrane.

The selected samples and their mineralogical composition are shown on Table 1.

RESULTS AND DISCUSSION A significant question about the source of a Neoproterozoic sedimentary rock that displays a Mesoproterozoic Nd model age (T_{DM}) is if it represents a single Mesoproterozoic juvenile crust or a mixing of an Archaean and/or Paleoproterozoic crust with a juvenile Neoproterozoic one. Another question is the identification of sediment source areas. In this case, not only the T_{DM} and isotopic characteristics of probable source rocks should be known, but also the crystallization age of the regional basement rocks capable of providing detritus for the sediments.

The ε_{Nd} -$^{147}Sm/^{144}Nd$ isochronic plot allows a quick and easy manner of comparing the isotopic composition of the sedimentary rocks and their potential source rocks, since the isotopic composition of the sediments must plot in the same range as those of the source rocks. This method was proposed by Reed *et al*. (1993) and subsequently applied by Lang Farmer and Ball (1997) and Ball and Lang Farmer (1998). The same method is applied in this study in order to determine sedimentary provenance at the central Ribeira Belt. We used the measured ε_{Nd} -$^{147}Sm/^{144}Nd$ values because the age of

1 Tektos - Geotectonic Research Group of the Faculty of Geology, Rio de Janeiro State University (UERJ), Brazil. Rua São Francisco Xavier, 524 – sala A-4006, Maracanã, Rio de Janeiro, RJ, Brazil. CEP: 20550-013.

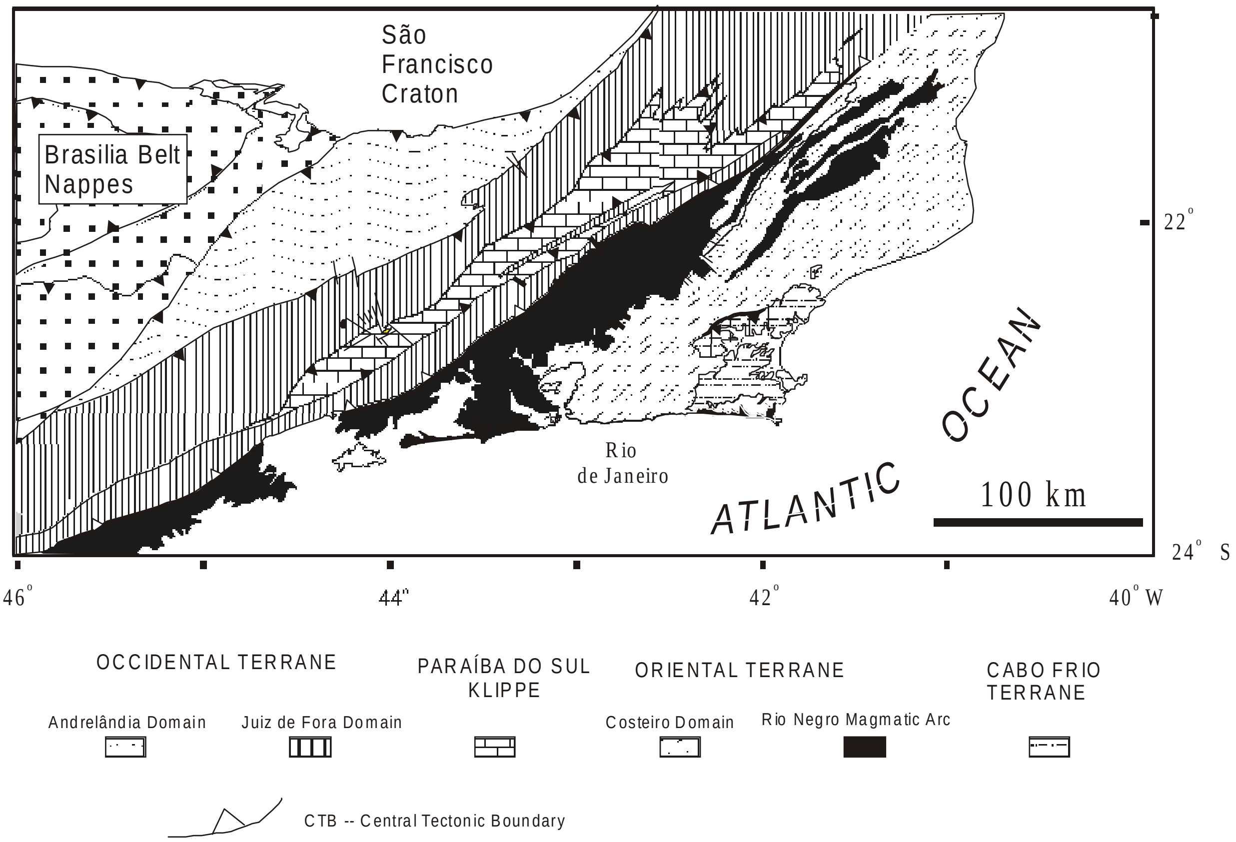

Figure 1-Tectonic map of the central Ribeira Belt. Modified from Heilbron et al. 2000.

Table 1 Mineralogy, location and isotopic characteristics of the metasedimentary rocks of central Ribeira Belt.

TECTONIC DOMAIN/ UNIT SAMPLE/ROCK	Mineralogy	Location	Sm ppm	Nd ppm	Sm/ Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ ($\pm 1\sigma$)	T_{DM} (Ga)	ε_{Nd} (0)
JUIZ DE FORA DOMAIN									
Andrelândia Deposicional Cycle									
VAL-M274D metapelite	pg, kf, bt, qt, gt, op,ms, zr, ap	43°46'-22°10'	8.26	49.35	0.17	0.1012	0.511506(22)	2.1	-22.1
TR-MMC26F metapelite	pl, kf, qz, bt, gt, zr	43°07'-22°14	10.21	59.90	0.17	0.1030	0.511580(17)	2.0	-20.6
CJE-158 metapelite	pg, kf, bt, qt, zr, ap, all, op, ser	44° 03'-22°14'	15.81	104.6	0.15	0.0914	0.511573(13)	1.8	-20.8
JF-CM297G metapelite	pl, kf,, bt, qz, gt, op, ap, zr, ms	21°59'-43°18	2.51	15.29	0.16	0.0991	0.511146(16)	2.5	-29.1
Jardím Glória Unit									
MB-CM242Ametapsammopelite	pl, or, qz, cpx, opx, gt, bt, op	43° 22'-21°45'	4.01	17.55	0.24	0.1428	0.511892(20)	2.6	-15.3
MB-CM36A metapsammopelite	pl, qz, or, opx, bt, gt, op, ap, zr, ms	43°36'-21°49'	8.44	38.03	0.22	0.1337	0.511701(22)	2.5	-18.3
PARAÍBA DO SUL KLIPPE									
Paraíba do Sul Group									
Upper unit									
BAN150B metapsammopelite	pl, kf, qz, amp, ap, zr, op	44° 26'-22° 41'	3.38	22.00	0.15	0.0928	0.511336(13)	2.0	-25.4
Middle unit									
BAN02A metapelite	bt, sil, gr, pl, musc, qz, ap, chl	44° 21'-22° 41'	6.60	34.74	0.19	0.1149	0.511915(12)	1.7	-14.1
NF067 metapelite	bt, sil, gr, pl, kf, qz, ap, op	41°45´-21°44´	7.36	44.60	0.16	0.0998	0.511764(24)	1.7	-17.4
Lower unit									
BAN590 metapsammopelite	kf, pl, qz, bt, ap, zr, all, op	44° 23'-22° 44'	2.97	16.92	0.17	0.1066	0.511544(18)	2.0	-21.3
MMC17B metapsammopelite	kf, pl, qz, bt, ap, zr, op	43° 10'-22° 05'	3.12	27.95	0.11	0.0675	0.510985(13)	2.0	-32.3
MMC17D amphibolite	hbl, pl, bt, qz, opx, op, tit	43° 10'-22° 05'	4.71	19.95	0.23	0.1428	0.512556(13)	1.0	-1.2

Abbreviations used on the table: allanite: all; amphibole: amp; apatite: ap; biotite: bt; chlorite: chl; garnet: gt; clinopyroxene: cpx; hornblende: hbl; muscovite: ms; opaque minerals: op; orthoclase: or; plagioclase: pl; k-feldspar: kf; orthopyroxene: op; quartz: qz; silimanite: sil; zircon: zr.

The isotopic analyses were carried out at the Laboratory of Geochronology of University of Brasília (UnB), Brazil. Sm and Nd concentrations were determinate by the isotope dilution method, using a mixed ^{149}Sm-^{150}Nd spike. Measurements were done on a Finnigan MAT 262 mass spectrometer. Sm and Nd data was acquired in the static mode. The elements were loaded as phosphates on double Re filament. Total procedure blank was minor of 0.2 Ng for Nd. Values for La Jolla Nd standard $^{143}Nd/^{144}Nd = 0.511853 \pm 7$ (1σ). Nd isotopic compositions were normalised to $^{146}Nd/^{144}Nd = 0.7219$. Nd model ages calculated according to DePaolo 1981.

sediment deposition is not well determined. The isotopic data from the analyzed samples are shown on Table 1.

Juiz de Fora Domain *PRE-1.8 Ga BASEMENT ROCKS* The available isotopic data of potential source rocks (data from Fischel 1998; Sato 1998; Ragatky *et al*. 1999), the Mantiqueira Complex (MC) and Juiz de Fora Complex (JFC), are presented in Fig. 2. The graph shows that: a) the complexes display different isotopic evolution trends; b) half of the JFC samples plot in the 2.2 Ga isochron; c) the JFC include basic (0.125<$^{147}Sm/^{144}Nd$ <0.15) and more acid rocks (*ca*. 0.07 $^{147}Sm/^{144}Nd$); d) most of the MC samples plot along two well-defined isochrons, an Archaean one (3.2 Ga) and a Neoarchean one (2.6 Ga); e) MC samples display typical $^{147}Sm/^{144}Nd$ values of granitic rocks (0.08 to 0.12).

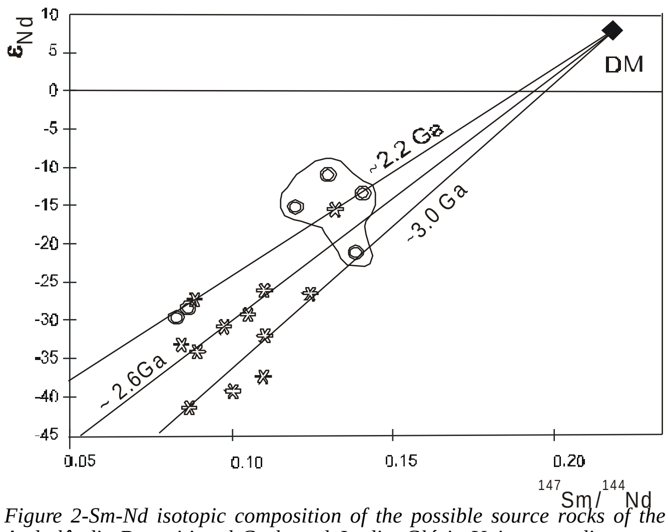

Figure 2-Sm-Nd isotopic composition of the possible source rocks of the Andrelândia Depositional Cycle and Jardim Glória Unit metasedimentary rocks (data from Sato 1998, Fischel 1998 and Ragatky et al. 1999). Reference lines correspond to Nd model ages of ~2.2, 2.6 and 3.0 Ga. The enclosed area indicates the field for the Juiz de Fora basic rocks. DM: depleted mantle. Symbols: circles - Juiz de Fora Complex; asterisk - Mantiqueira Complex.

METASEDIMENTARY ROCKS Metapelites from the Andrelândia Depositional Cycle (ADC) show a very narrow range of Sm/Nd values (0.15 to 0.17). This homogeneity is usually attributed to efficient mixing of the detritus during transport and sedimentation (Taylor and McLennon 1985). The correspondent $^{147}Sm/^{144}Nd$ values vary between 0.0914 and 0.1030. The $^{143}Nd/^{144}Nd$ isotopic values, represented as $\varepsilon_{Nd}(0)$, range between –20.8 to –29.1.

Metapsammopelites from the Jardim Glória Unit (JGU) have contrasting concentrations of Sm and Nd (Table 1). However, both show similar high Sm/Nd values (0.22 and 0.24) and consequently high $^{147}Sm/^{144}Nd$ values (0.1337 and 0.1428). The $\varepsilon_{Nd}(0)$ values are –15.3 and –18.3. The different isotopic evolution of the rocks of ADC and the JGU are easily visualized in the T_{DM} *versus* $\varepsilon_{Nd}(0)$ diagram (Fig. 3).

The fact that the two analyzed samples of JGU, in spite of the very different Sm and Nd concentrations (Table 1 and Fig. 4), plot close to the 2.5 - 2.6 Ga isochron, suggests that they derive from a single source. This source seems to be distinct from the regional basement rock types, because MC rocks present lower Sm/Nd values and JFC basic rocks, although chemically compatible, do not fit in the JGU isochron.

For the ADC samples (Fig. 4), the main sedimentary sources seems to be both the MC and JFC. However, the upward displacement of the ADC samples in relation to the basement isochrons suggests the participation of an younger source in order to explain the observed isotopic characteristics. The only rocks already known in the Ribeira Belt that could represent this younger source are the metabasites associated to ADC metasedimentary rocks. These rocks display a 1.2 - 1.0 Ga T_{DM} ages (Heilbron *et al*. 1989) (Fig. 4) and predominantly continental tholeiite chemical composition (Paciullo 1997).

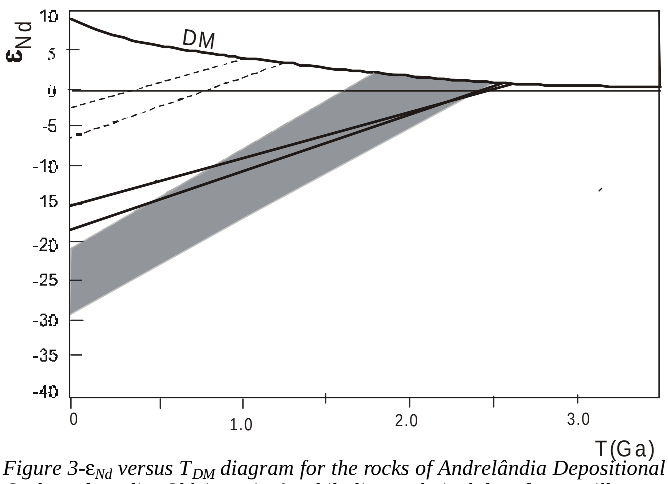

Figure 3-ε_{Nd} versus T_{DM} diagram for the rocks of Andrelândia Depositional Cycle and Jardim Glória Unit. Amphibolite analytical data from Heilbron et al. 1989. DM: depleted mantle evolution curve. Symbols: shaded area - Andrelândia Depositional Cycle metasedimentary rocks; dashed lines - Andrelândia Depositional Cycle intercalated amphibolites; full lines - Jardim Glória Unit metasedimentary rocks.

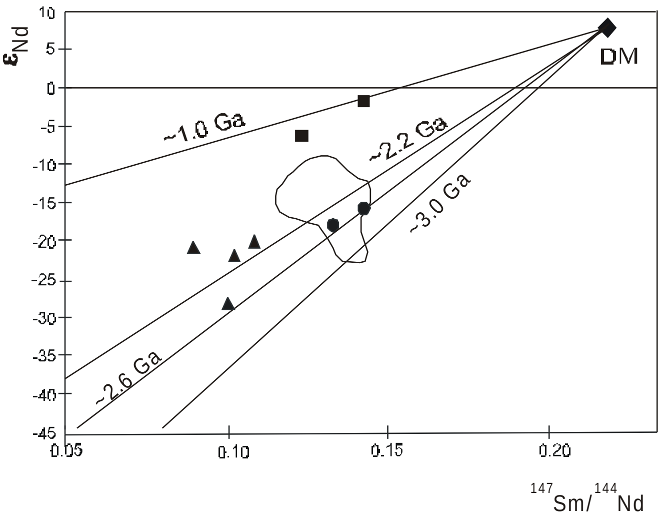

Figure 4-Sm-Nd isotopic composition of Andrelândia Depositional Cycle and Jardim Glória Unit rocks. DM: depleted mantle. Reference lines and enclosed area as in Fig. 2. Symbols: circles - Jardim Glória Unit metapsammopelites; triangles - Andrelândia Depositional Cycle metapelites; squares - Andrelândia Depositional Cycle intercalated amphibolites.

Paraíba do Sul Klippe *PRE-1.8 Ga BASEMENT ROCKS:* The basement rocks of this tectonic domain are the orthogneisses from the Quirino Complex (QC). The U/Pb crystallization ages of the Quirino gneisses are close to 2.1 Ga, with an Archaean inheritance (Machado *et al.* 1996). For these rocks the only available Nd isotopic data are due to Ragatky *et al*. (1999) that report a Paleoproterozoic (2.1 Ga) and another Archaean (3.2 Ga) T_{DM} values.

METASEDIMENTARY ROCKS: Metapelites from the middle unit of the Paraíba do Sul Group (PSG) have higher Sm and Nd contents (6.6-7.3 ppm and 34.7-44.6 ppm, respectively, Table 1) than metapsammopelites from the basal and uppermost units (*ca*. 3 ppm of Sm and 17-27 ppm of Nd). Thus, only the metapelites show the typical crustal range of 30-40 ppm of Nd (Taylor and McLennan 1985). The Sm/Nd values are distinct for all samples, varying between 0.15 and 0.19, with exception of sample TR-MMC-17B that displays a Sm/Nd value of 0.11. The $^{147}Sm/^{144}Nd$ values of all units range from 0.0928 to 0.1149, similar to continental fine-grained sediments (Goldstein *et al*. 1984). Only sample TR-MMC-17B contains a lower $^{147}Sm/^{144}Nd$ value of 0.0675.

The ε_{Nd} -$^{147}Sm/^{144}Nd$ isochronic plot (Fig. 5) shows that, in spite of the large distance between the sample localities, the metasedimentary rocks of PSG may be divided into two groups, which are correlated with petrographic and field data: a group consisting of metapsammopelites of uppermost and basal units, with T_{DM} of *ca*. 2.0 Ga and $e_{Nd}(0)$ varying between -21 and -32; and another group, with T_{DM} ages close to 1.7 Ga and higher $\varepsilon_{Nd}(0)$ values (-14.10 and -17.34). The isochron alignment suggests that each group derives from a single source with the same initial $^{143}Nd/^{144}Nd$, the $^{147}Sm/^{144}Nd$ differences arising from unmixing during sediment transport and deposition.

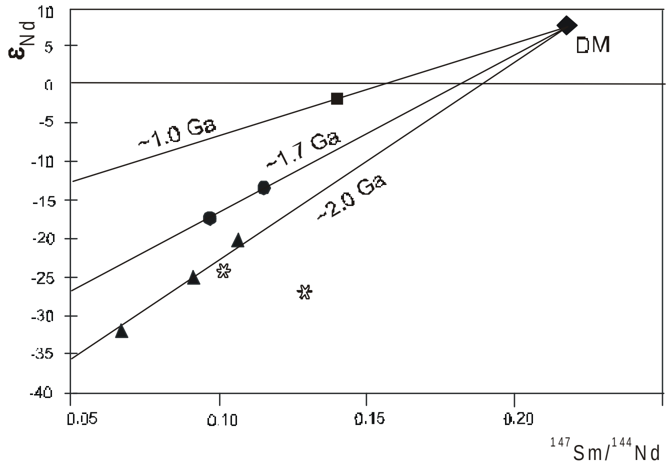

Figure 5-Sm-Nd isotopic composition of metasedimentary rocks of Paraíba do Sul Group, amphibolite and basement rocks of Paraíba do Sul Klippe (analytical data from Ragatky et al. 1999). DM: depleted mantle. Symbols: triangles - metapsammopelites; circles - metapelites; square - amphibolite; asterisk - basement rocks (Quirino Complex).

The possible source for the metapsammopelites is the QC, mainly its granitic facies, which plots close to the 2.0 Ga isochron (Fig. 5). For the metapelites, however, its 1.7 Ga isochron points to a single source not yet found in the Paraíba do Sul Klippe. Due to the allochthonous character of this terrane, source rocks from the pelitic group may be located elsewhere, probably at the Oriental Terrane.

An isolated T_{DM} of an amphibolitic body, probably intrusive in the metasedimentary rocks of PSG, yields 1.0 Ga, with $^{147}Sm/^{144}Nd$ value of 0.1428.

FINAL REMARKS The isotopic data of the central segment of the Ribeira Belt, when integrated with field, petrographic and litogeochemical data reveal that: a) pre-1.8 Ga basement rocks from the Juiz de Fora Domain (Juiz de Fora and Mantiqueira complexes) are isotopically distinct; b) the source rocks from the Jardim Gloria Unit metasedimentary rocks are presently unclear, but preclude both Juiz de Fora and Mantiqueira complexes; c) the Andrelândia Depositional Cycle metasedimentary rocks point to a mixing between pre-1.8 Ga basement rocks and younger rocks, probably 1.0 Ga T_{DM} age interlayered amphibolites; d) for the psammopelites of the Paraíba do Sul Group, the granitic rocks of the Quirino Complex are the most probable source rocks; but for the pelite rocks a 1.7 Ga T_{DM} age source that is not described yet at the Ribeira Belt is necessary; e) the widespread occurrence of *ca.* 1.0 Ga T_{DM} ages amphibolites at the Juiz Domain and the Paraíba do Sul Klippe is consistent with the time interval proposed for the break-up of Rodinia Supercontinent (Brito Neves *et al*. 1996).

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