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PROVENANCE OF THE SEDIMENTARY ROCKS OF THE BOM JARDIM GROUP (NEOPROTEROZOIC, SOUTHERN BRAZIL): EVIDENCE FROM PETROGRAPHY, GEOCHEMISTRY AND NEODYMIUM ISOTOPES

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Abstract: Provenance studies are helpful in reconstructing the tectonic, climatic and geographic setting of terrigenous sedimentary basins. The primary controls on the composition of detrital sedimentary rocks are the composition, climate and relief conditions of the source areas, the transport mechanisms, and diagenesis. In order to constrain the provenance of the Neoproterozoic (ca. 600 - 580 Ma) sedimentary rocks of the Bom Jardim Group (Arroio dos Nobres Formation) in the Lavras do Sul (west), Bom Jardim (central) and Cerro da Árvore (east) areas, petrography, major and trace element geochemistry, and Nd isotopic data were analyzed together. The results indicate a clear lateral variation of provenance parameters. In the region of Lavras do Sul, near syn-sedimentary volcanic rocks of shoshonitic affinity (the Hilário Formation), the sandstones are epiclastic, plotting in the undissected and transitional arc fields of the QFL diagram, display relatively higher values of Na, Ba, Sr and Zr, and yield a $^{143}Nd/^{144}Nd$ ratio of 0.512263 and present-day ε_{Nd} of -7.32. In the Bom Jardim area, east of Caçapava do Sul, the sedimentary rocks are also dominated by volcanic fragments, but display significant values of metamorphic detritus. The relatively higher values of Cr, Co and Ni suggest some contribution of ophiolitic or lamprophyric source areas, while the $^{143}Nd/^{144}Nd$ ratio is 0.511906 and the $\varepsilon_{Nd(0)}$ is around -14.28. In the easternmost outcropping area, the Cerro da Árvore (or Piquiri) region, the sedimentary rocks are rich in metasedimentary clasts, with significant amounts of polycrystalline quartz fragments, plotting in the orogenic recycling field. Comparatively, the value of the K_2O/Na_2O ratio is higher, the $^{143}Nd/^{144}Nd$ ratio is 0.511887 and the $\varepsilon_{Nd(0)}$ is of -14.65, suggesting older and more acidic source rocks, probably constituents of the Porongos metamorphic complex.

Keywords: Neoproterozoic, Bom Jardim Group, sedimentary rocks, provenance, Nd isotopes

Resumen: Estudios de proveniencia son importantes en la reconstrución del escenario tectónico, climático y geográfico de cuencas sedimentarias siliciclásticas. Los controles primarios para la composición de rocas sedimentarias detríticas son las características de las rocas fuentes, condiciones climáticas y topográficas, procesos de transporte y diagénesis. Para investigar la proveniencia de las rocas sedimentarias de la Formación Arroio dos Nobres del Grupo Bom Jardim (Neoproterozóico, 600 - 580 Ma) en tres regiones del Escudo Sul-rio-grandense, fueron obtenidos e interpretados de manera integrada datos de petrografía, geoquímica y isótopos de Nd. Los resultados muestran una clara variación lateral de proveniencia durante la evolución de la cuenca deposiacional del Grupo Bom Jardim. En la región de Lavras do Sul (oeste), cerca de rocas volcánicas intermediarias de

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afinidad shoshonítica (Formación Hilário), las areniscas son epiclásticas, cayendo en los campos del arco magmatico no disecado y transicional del diagrama QFL. Las limolitas son relativamente ricas en Na, Ba, Sr y Zr, y su razón $^{143}Nd/^{144}Nd$ de 0,512263 se asocia a un ε_{Nd} de -7,32. En el área de Bom Jardim, al este de Caçapava do Sul, las rocas sedimentarias también son dominadas por detritos volcánicos, pero muestran cantidades significativas de fragmentos metamórficos. Valores relativamente altos de Cr, Co y Ni permiten suponer alguna contribución de rocas fuentes ofioliticas o lamprofíricas, mientras la razón $^{143}Nd/^{144}Nd$ de 0,511906 se asocía a un ε_{Nd} de -14,28. En sus exposiciones más orientales, en la área del Cerro da Árvore (o Piquiri), las areniscas son ricas en fragmentos metamórficos y cuarzo policristalino, con proveniencia típica orogénica. Comparativamente, los valores de K_2O/Na_2O son más altos, la razón $^{143}Nd/^{144}Nd$ es 0,511887 y el $\varepsilon_{Nd(0)}$ es de -14.65, indicando fuentes más antiguas y ácidas, probablemente del complejo metamórfico Porongos.

Resumo: Estudos de proveniência são decisivos na reconstrução tectônica, climática e geográfica de bacias sedimentares terrígenas. Os controles primários da composição de rochas sedimentares detríticas são as características das rochas-fonte, o clima e o relevo da área-fonte, os processos de transporte e a diagênese. Para investigar a proveniência das rochas sedimentares da Formação Arroio dos Nobres do Grupo Bom Jardim (Neoproterozóico, 600 a 580 Ma) em três setores de afloramento do Escudo Sul-rio-grandense, foram obtidos e interpretados dados de petrografia, geoquímica e isótopos de Nd. Os resultados demonstram uma clara variação lateral de proveniência na bacia deposicional do Grupo Bom Jardim. Na região de Lavras do Sul (oeste), próximo a afloramentos de vulcânicas sin-sedimentares da Formação Hilário, de afinidade shoshonítica, os arenitos são epiclásticos, e plotam nos campos de arco magmático não dissecado e transicional do diagrama QFL. As rochas de granulometria fina são relativamente ricas em Na, Ba, Sr e Zr, e sua razão $^{143}Nd/^{144}Nd$ de 0,512263 se associa a um ε_{Nd} de -7,32. Na área de Bom Jardim, no leste de Caçapava do Sul, as rochas sedimentares também são dominadas por detritos vulcânicos, mas com quantidades significativas de fragmentos metamórficos. Valores relativamente altos de Cr, Co e Ni permiten sugerir alguma contribuição de rochas-fonte ofiolíticas ou lamprofíricas, enquanto a razão $^{143}Nd/^{144}Nd$ de 0,511906 se refere a um ε_{Nd} de -14,28. Mais a leste, na área do Cerro da Árvore (ou Piquiri), os arenitos são ricos em fragmentos metamórficos e quartzo policristalino, com proveniência típica de reciclagem orogênica. Comparativamente, os valores de K_2O/Na_2O são mais altos, a razão $^{143}Nd/^{144}Nd$ fica em 0,511887 e o $\varepsilon_{Nd(0)}$ é de -14.65, indicando fontes mais antigas e ácidas, provavelmente do complexo metamórfico Porongos.

INTRODUCTION

The latest stages of the Neoproterozoic were characterized, in the Sul-rio-grandense Shield, by intense post-collisional magmatic events, which are recorded by thick volcanic successions and widespread intrusive bodies. The geochemical affinity of these rocks evolved from high-K calc-alkaline to shoshonitic and alkaline (Wildner *et al.*, 2002). A dominantly intermediate, shoshonitic volcanism, recorded by the Hilário Formation (Ribeiro and Fantinel, 1978), covered a significant portion of the Sul-rio-grandense Shield between 600 and 580 Ma (Gastal *et al.*, 2003). This unit is composed of lava flows, pyroclastic deposits and related dykes, cropping out especially in the Lavras do Sul region.

Laterally associated with the volcanogenic rocks, dark-brown ("chocolate-colored") sedimentary deposits occur, and these are assembled in the Arroio dos Nobres Formation (Ribeiro *et al.*, 1966). The Arroio dos Nobres and Hilário formations, together, make up the Bom Jardim Group (BJG), which displays features indicating deep burial and strong deformation, such as significant induration, normal and strike-slip faults, thrusts and open folds. The sedimentary rocks ascribed to the Arroio dos Nobres Formation are sandstones, conglomerates, siltstones and subordinated shales, which crop out in several isolated sectors (Lavras do Sul, Bom Jardim, Minas do Camaquã, Cerro da Árvore, Boici). Previous studies in the sedimentary rocks of the BJG focused on facies analysis (CPRM, 1995), stratigraphy (Caravaca *et al.*, 2003), diagenesis (Flores *et al.*, 1992) and conglomerate clast provenance (Caravaca, 1998).

The aim of this paper is to present and interpret results of the integrated application of petrography, geochemistry and Nd isotopes to the question of provenance of the sedimentary rocks of the BJG. Modal counting of detrital components by the Gazzi-Dickinson method (Zuffa, 1985), plotting of results in provenance discrimination diagrams (Dickinson *et al.*, 1983), major, minor and trace-element geochemistry and Nd isotopic analysis (McLennan *et al.*, 1990) were the selected tools. The integrated interpretation of these data made it possible to suggest a tectonic and geographic setting of different source areas which reflected in the spatial variation of the provenance parameters of the sedimentary rocks of the BJG.

THE PRECAMBRIAN SUL-RIO-GRANDENSE SHIELD - CRUSTAL DOMAINS AND EVOLUTION

The Sul-rio-grandense Shield of southern Brazil (Fig. 1a) records events of juvenile accretion and crustal reworking which occurred in the Paleoproterozoic (Trans-amazonian, 2.5 to 2.0 Ga, e.g. Tickyj *et al.*, 2004) and Neoproterozoic (Brasiliano/Pan-African, 900 to 540 Ma, Chemale Jr., 2000). Four distinct petrotectonic-structural-isotopic domains are recognized in the Sul-rio-grandense Shield:

a) Taquarembó Domain, characterized by 2.55 to 2.35 Ga old TTG granitoids metamorphosed to the granulite facies at 2.02 Ga (Hartmann *et al.*, 1999), with T_{DM} ages between 2.3 and 2.6 Ga and $\varepsilon_{Nd(t)}$ around +3.

b) São Gabriel Domain, made up of orthogneisses, metavolcanic and metasedimentary rocks (Cambaí and Vacacaí units) of intra-oceanic juvenile arc origin during the Neoproterozoic (from 879 ± 14 Ma to 703 ± 13 Ma, Leite *et al.*, 1998), yielding T_{DM} ages between 930 and 800 Ma and $\varepsilon_{Nd(t)}$ from +0.7 to +4.4 (Babinski *et al.*, 1996; Saalmann *et al.*, 2005).

c) Santana da Boa Vista Domain, comprising the Paleoproterozoic basement Encantadas gneisses (Jost and Bitencourt, 1980) with T_{DM} from 2.0 to 3.2 Ga (Soliani Jr. *et al.*, 2000), and a Neoproterozoic supracrustal volcanosedimentary cover dated at 783 ± 6 Ma (Porcher *et al.*, 1999) with Paleoproterozoic provenance (Vasconcellos *et al.*, 2003; Saalmann *et al.*, 2006).

d) Pelotas Domain, composed of collisional and post-collisional intrusive suites (Bitencourt and Nardi, 1993; Frantz *et al.*, 2003) emplaced from 658 to 600 Ma, Paleoproterozoic xenoliths and roof-pendants (Philipp and Machado, 2002); a recent proposal (Bossi and Gaucher, 2004) suggests an alochthonous origin for the Pelotas Domain (Cuchilla Dionisio terrain in Uruguay), and a 530 Ma lateral collision along the Dorsal de Cancuçu (or Sierra Ballena) trascurrent shear zone.

The cited domains compose the pre-600 Ma basement recorded in the Sul-rio-grandense Shield. In the latest stages of the Brasiliano/Pan-african cycle, several sedimentary and volcanosedimentary units of diverse ages were deposited in different basins which occupied a preferentially subsiding locus - the "Camaquã Basin" (Paim *et al.*, 2000). Presently, the stratigraphic record of these basins crops out in geographically disrupted, isolated, fault-bounded outcrop sectors.

The Maricá Formation (Leinz *et al.*, 1941), cropping out exclusively within the juvenile São Gabriel Domain, comprises fluvial (base and top) and marine (middle section) deposits, with dominant Paleoproterozoic granite-gneiss provenance, as revealed by T_{DM} ages between 1.76 and 2.37 Ga (Borba *et al.*, 2004, 2006). The Bom Jardim Group, object of the present paper, is made up of andesites, pyroclastic deposits and continental sedimentary rocks, dated between 580 and 600 Ma. This unit crops out in four different sectors, the Lavras do Sul, Bom Jardim, Minas do Camaquã and Cerro da Árvore (or Piquiri) regions.

The Acampamento Velho Formation consists in a bimodal volcanic succession (Almeida *et al.*, 2002), with strongly weathered basalts in the base, rhyolitic lava flows and pyroclastic rocks at the top. U-Pb SHRIMP analyses yielded a magmatic age of 549 ± 5 Ma (Sommer *et al.*, 2003). The Santa Bárbara Formation (Robertson, 1966), deposited in the Early Paleozoic, is composed by alluvial fan, fluvial and lacustrine deposits subdivided in three depositional sequences (Borba and Mizusaki, 2003). Finally, the Ordovician Guaritas Formation (Goñi *et al.*, 1962) comprises alluvial facies at the base, interlayered with alkaline basalts of the Rodeio Velho Member, dated at 470 ± 19 Ma (Hartmann *et al.*, 1998). Upsection, two eolian sequences and unconformable fluvial deposits with paleocurrents to SW (Scherer *et al.*, 2003).

CHARACTERIZATION AND STRATIGRAPHY OF THE BOM JARDIM GROUP

The nomenclature Bom Jardim Group (BJG) was first used by Ribeiro *et al.* (1966) to describe a succession of andesites and continental sedimentary rocks. The volcanic component dominates the region of Lavras do

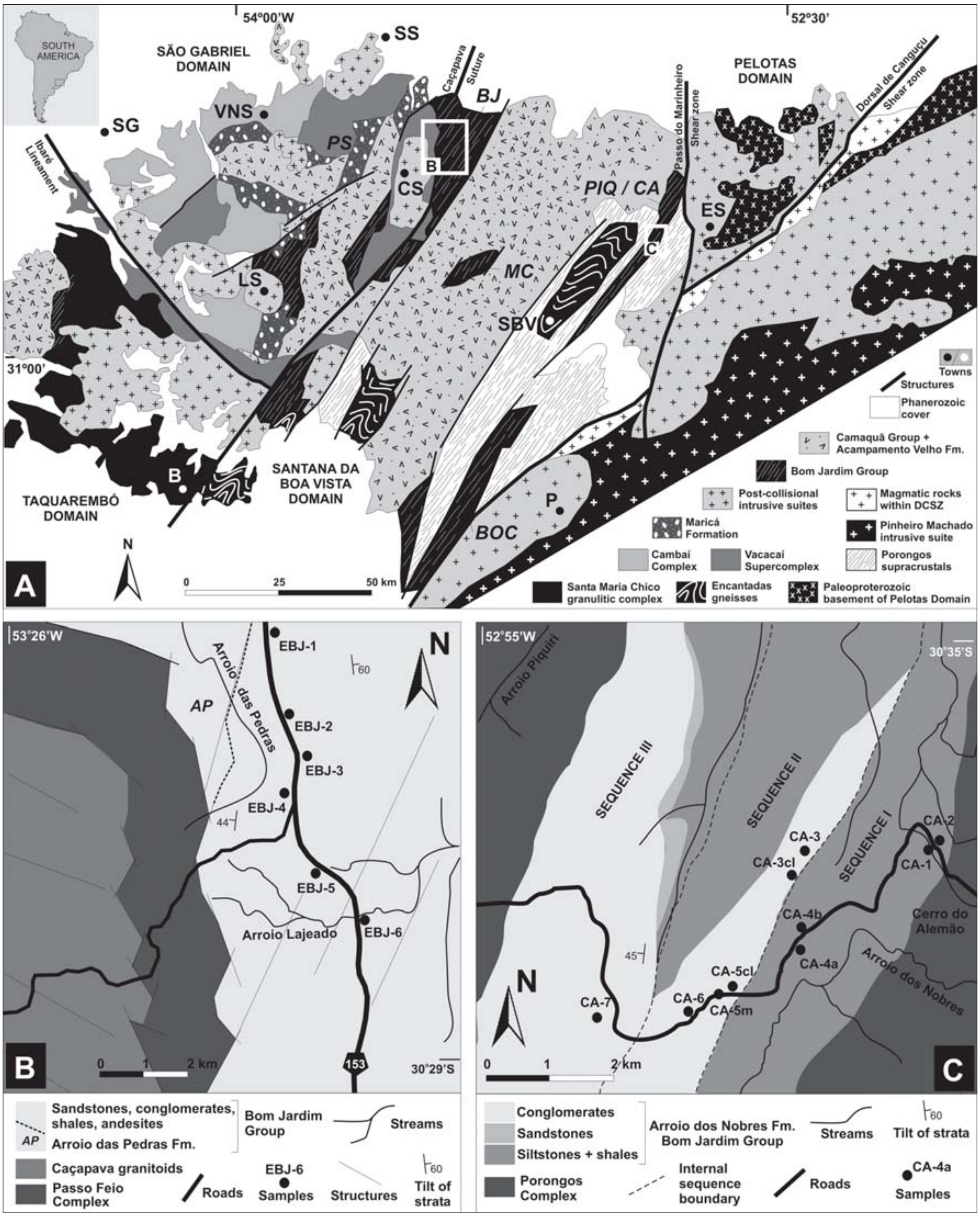

Figure 1. a) Schematic geological map of the Sul-rio-grandense Shield, showing the subdivision in four geotectonic domains and the main outcrop sectors of the Bom Jardim Group. Towns: SG - São Gabriel; VNS - Vila Nova do Sul; SS - São Sepé; CS - Caçapava do Sul; B - Bagé; LS - Lavras do Sul; SBV - Santana da Boa Vista; P - Piratini; ES - Encruzilhada do Sul. Other localities are: PS - Passo do Salsinho; MC - Minas do Camaquã; BJ - Bom Jardim; BOC - Boici; PIQ/CA - Piquiri or Cerro da Árvore region. Modified from partial maps presented by Chemale Jr. (2000). **b)** Schematic geological map and of the Bom Jardim region, east of Caçapava do Sul, with collected samples. **c)** Schematic geological map of the Cerro da Árvore / Piquiri area, with samples collected for the present work.

Figura 1. a) Mapa geológico esquemático do Escudo Sul-rio-grandense, com a subdivisão em quatro domínios geotectônicos e os principais setores de afloramento do Grupo Bom Jardim. Cidades: SG - São Gabriel; VNS - Vila Nova do Sul; SS - São Sepé; CS - Caçapava do Sul; B - Bagé; LS - Lavras do Sul; SBV - Santana da Boa Vista; P - Piratini; ES - Encruzilhada do Sul. Other localities cited in text: PS - Passo do Salsinho; MC - Minas do Camaquã; BJ - Bom Jardim; BOC - Boici; PIQ/CA - Piquiri ou Cerro da árvore. Modificado de mapas parciais apresentados por Chemale Jr. (2000). **b)** Mapa geológico esquemático da região de Bom Jardim, ilustrando locais de coleta de amostras. **c)** Mapa geológico esquemático da região de Cerro da Árvore/Piquiri, com as amostras coletadas para este trabalho.

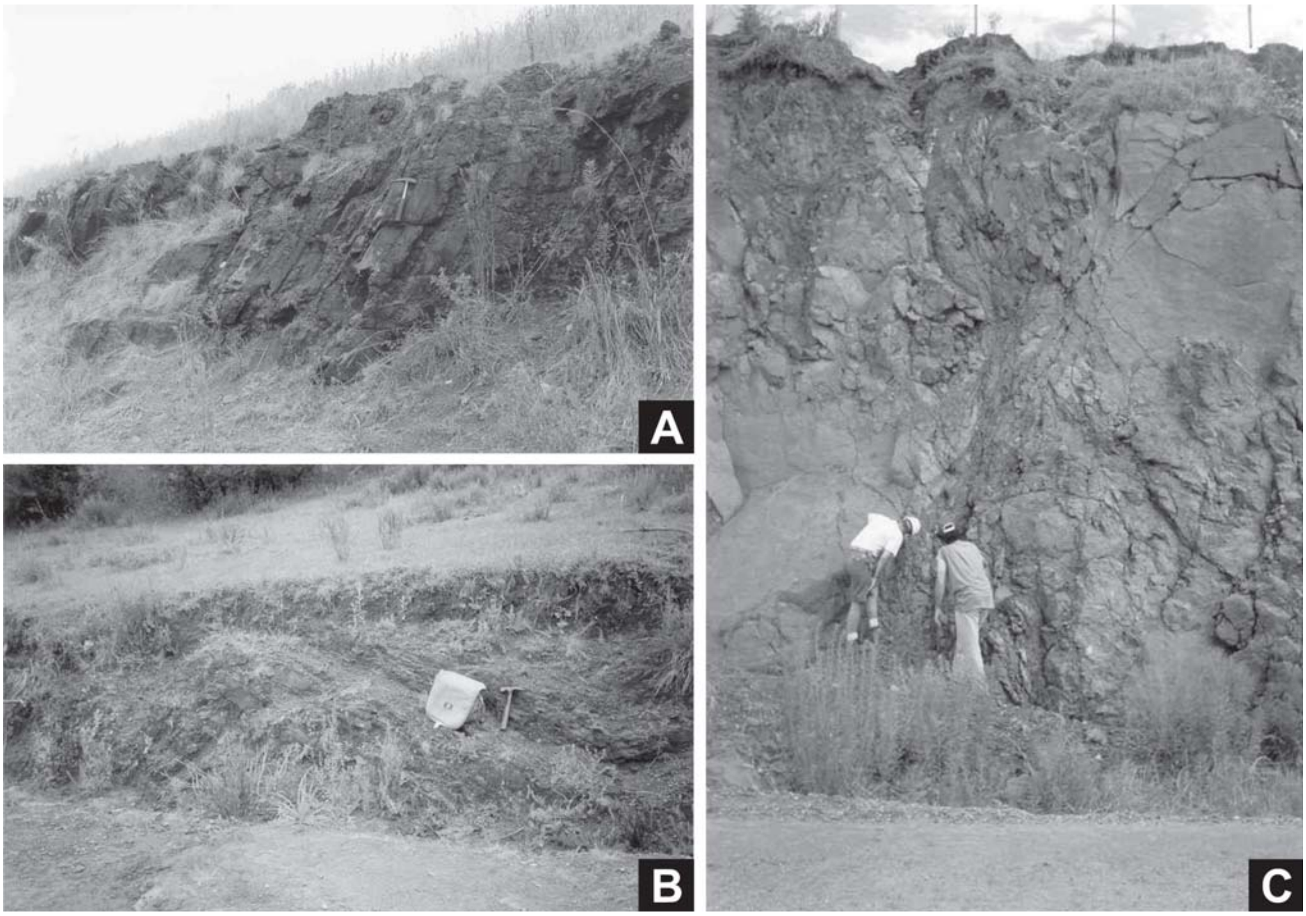

Figure 2. Field aspects of the Bom Jardim Group: **a)** tilted sedimentary beds of the BJG in the Bom Jardim area, BR 153 road; **b)** folded strata of the BJG and **c)** positive-flower (transcurrence) structure in the Minas do Camaquã area (MC in Fig. 1a).
Figura 2. Aspectos de campo do Grupo Bom Jardim: **a)** camadas sedimentares basculadas do Grupo Bom Jardim na área de Bom Jardim, rodovia BR-153; **b)** estratos dobrados do Grupo Bom Jardim e **c)** estrutura em flor positiva na área das Minas do Camaquã (MC na Fig. 1a)

Sul, constituting the Hilário Formation (Ribeiro and Fantinel, 1978). This unit comprises, at its base, an association of potassic trachybasalts and shoshonites. The volcanic package is dominated by andesites with oriented phenocrysts of labradorite and andesine, immersed in a matrix composed by plagioclase, augite, olivine, Ti-magnetite and apatite (Nardi, 1984; Lima and Nardi, 1998; Wildner *et al.*, 2002). Lithic and lapilli tuffs, andesitic vitroclasts and subaerial pyroclastic deposits (mass- and suspension-flow) are the main volcaniclastic facies. Sub-volcanic intrusions are of monzonite, quartz monzonite, spessartitic lamprophyres and rhyolites.

The Hilário Formation has a shoshonitic affinity (Lima and Nardi, 1998), and it is comagmatic with the Lavras do Sul intrusive complex (Gastal and Lafon, 1998), dated at 601 ± 5 Ma (monzonites), 599 ± 7 Ma (monzodiorites) and 598 ± 3 Ma (syenogranite) by the $^{207}Pb/^{206}Pb$ method (Gastal and Lafon, 2001; Gastal *et al.*, 2003). Zircons obtained from samples of the Hilário Formation yielded a U-Pb age of 580 ± 11 Ma (Remus *et al.*, 1999). The Sm-Nd isotopic composition of the Lavras do Sul granitoids (and associated volcanics) shows a weakly negative $\varepsilon_{Nd(t)}$ parameter (-0.28 to -4.3) and T_{DM} model ages between 1.3 and 1.6 Ga (Gastal *et al.*, 2003), attesting a very important contribution of mantle sources in the magma generation. In Lavras do Sul, sedimentary rocks are very subordinate, being restricted to epiclastic terms. Fining-upward cycles of organized conglomerates, composed by angulose, poorly-sorted volcanic fragments, were recognized in the Passo do Salsinho region (CPRM, 1995). Tabular beds of fine-grained, poorly sorted, arkosean sandstones also occur, interlayered with thinly laminated siltstones and shales.

In the Bom Jardim region, located east of Caçapava do Sul (Fig. 1a, b), as well as in the Minas do Camaquã area, stratigraphic relationships are very disturbed by successive deformational events. Correlation between strata is virtually impossible, since tilting to steep angles (Fig. 2a), open folding (Fig. 2b) and transpressive faulting (Fig. 2c) have affected the entire succession. Two rock units of the BJG were described by UFRGS (1998) in the Bom Jardim region. The Arroio das Pedras Formation (DOCEGEO, 1977) is made up by greenish grey, massive or thinly laminated tuffs, crystal and lapilli tuffs with andesite fragments, amphibole and plagioclase crystalloclasts, deposited under subaerial conditions, as well as andesitic and lamprophyric dykes. The second unit, ascribed to the Arroio dos Nobres Formation, comprises horizontally- or cross-stratified sandstones (Fig. 2a), organized conglomerates (Fig. 3a, b) with subrounded to angulose clasts (andesites, schists, granitoids and rhyolites). These facies are closely associated with volcanic breccias containing sandstone clasts (Fig. 3c), and tabular rythmites with widespread shallow-water features such as mudcracks, rill marks, wave- and climbing-ripples, as well as raindrop imprints (Fig. 3d). The few paleocurrents measured in the cited regional mapping campaign indicate significant flow dispersion, with dominance to east. Interlayering with andesite lava flows and dykes is very common (UFRGS, 1998).

The Cerro da Árvore or Piquiri region (Fig. 1a, c), located northeast of Santana da Boa Vista, contains the better preserved outcrop sector of the BJG. This isolated outcrop area has a controversial stratigraphic position, being sometimes ascribed to the Maricá Formation (Paim *et al.*, 2000). In the present paper, it is considered as part of the Bom Jardim Group. In this sector, volcanic facies are virtually absent, and the stratigraphic relationships are very well preserved. The *ca.* 4 km thick sedimentary pile was studied in detail by Caravaca (1998) and Caravaca *et al.* (2003), authors who proposed a subdivision in three depositional sequences made up of conglomerates, sandstones and rythmites. Paleocurrents indicate sedimentary transport to northeast, and a progressive change in the clast composition: in sequence I, schists and quartzites dominate; in sequence II, a significant amount of siltstones and sandstones is recorded, pointing to basin reworking; in sequence III, clasts of mylonitic granitoids occur, ascribed to the Encantadas gneiss, the Paleoproterozoic basement of the Santana da Boa Vista Domain. Studies focusing petrography, boron contents and diagenetic illite crystallinity (Flores, 1992; Flores *et al.*, 1992) indicate continental diagenesis, deep burial (anquimetamorphic illite) and a composition clearly dominated by quartz, typical of orogenic recycling, for the BJG in the Cerro da Árvore outcrop sector.

METHODOLOGY, SAMPLING AND ANALYTICAL PROCEDURES

Provenance studies play important role in reconstructing the tectonic, climatic and geographic setting of a region during the evolution of a siliciclastic sedimentary basin. The main controling factor on the composition of a sedimentary rock is the source rock composition, strongly associated with the plate tectonic setting (Dickinson and Suczek, 1979; Dickinson, 1985). Source area climate and relief, transport mechanisms and diagenetic modifications also influence the final composition of sedimentary rocks (Basu, 1985; Ricci-Lucchi, 1985; McBride, 1985). Thus, many different analytical tools can be integrated in provenance studies: sandstone petrography, major and trace element geochemistry, and Nd isotope geology, among others.

The basic method for studying provenance in thin-sections of sandstones is the statistical point-counting through the Gazzi-Dickinson (G-D) method, which allows the comparison of results obtained in rocks of different grain-size and sorting (Zuffa, 1985). The contents of quartz, feldspars and lithic fine-grained fragments are plotted in diagrams for provenance discrimination (QFL and derivate, Dickinson *et al.*, 1983).

Geochemical analyses of major-, trace-, and rare earth elements (REE), especially co-variancy trends, are widely used as provenance tracers in fine-grained or strongly weathered sedimentary rocks. van de Kamp and Leake (1995), for example, integrated petrographic and geochemical analyses, and suggested that ultramafic, ophiolitic provenance can be identified by high contents of Co, Cr and Ni, correlated to MgO, even if the fragments are weathered. The immobile character of some elements such as Th, Zr, Sc, Ti and REE during the sedimentary cycle also favors their usage as provenance indicators (Taylor and McLennan, 1985; McLennan *et al.*, 1990).

The parameters of the Sm-Nd isotopic system are also applicable to provenance research (DePaolo, 1988; Nelson and DePaolo, 1988; McLennan *et al.*, 1990). Positive or near-zero ε_{Nd} values, and T_{DM} values near the crystallization age of an igneous suite, correspond to juvenile, mantle-derived components. On the other hand, negative ε_{Nd} results and significant difference between T_{DM} and crystallization age point to contamination by crustal material. Even considering possible a slight modification of these parameters during the

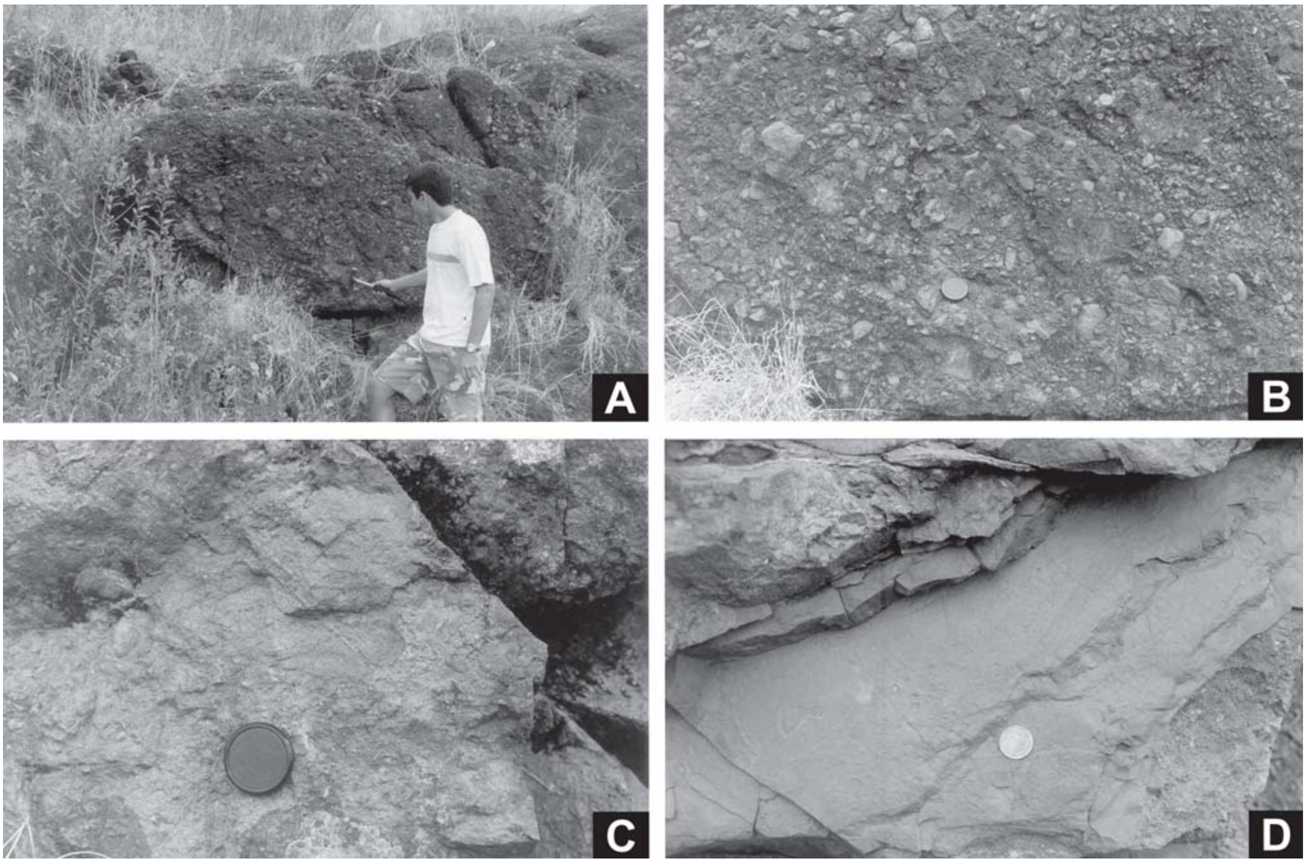

Figure 3. Field aspects of the Bom Jardim Group in the Bom Jardim area: **a)** and **b)** lens-shaped conglomerate with angulose to subrounded clasts; **c)** volcanic breccia with sedimentary cobbles; **d)** siltstone bed with raindrop imprints.
Figura 3. Aspectos de campo do Grupo Bom Jardim na região de Bom Jardim: **a)** e **b)** camadas lenticulares de conglomerados com clastos angulosos a subarredondados; **c)** brecha vulcânica com blocos de arenitos; **d)** nível de siltito com marcas de pingos de chuva.

sedimentary cycle (Awwiller and Mack, 1991; Zhao *et al.*, 1992), it is understood that the $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ ratios, ε_{Nd} and T_{DM} are well preserved in sediments and sedimentary rocks. Examples of this application were demonstrated in Paleozoic basins (Gleason *et al.*, 1994, 1995; Andersson *et al.*, 2003) and Neoproterozoic sedimentary (Ball and Farmer, 1998; Farmer *et al.*, 2001) and metasedimentary (Pimentel et al., 2001; Saalmann *et al.*, 2006) successions.

Sampling was performed in three outcrop sectors of the Bom Jardim Group: the Lavras do Sul, Bom Jardim (Fig. 1b) and Cerro da Árvore (Fig. 1c) regions. The samples collected in the Cerro da Árvore region are ordered from CA-1 in the east (sequence I) to CA-7 in the west (sequence III). CA-5m is a sample that represents the coarse sand-grained matrix of a poorly-sorted, clast-supported conglomerate, and CA-5cl corresponds to a sandstone clast within the same conglomerate. The samples from the Bom Jardim region (east of Caçapava do Sul) were collected in representative roadcuts in the BR-153 road (Fig. 1b), and their stratigraphic relationship is virtually unrecognizable due to deformational events. The samples from the Lavras do Sul region (labelled WBJ and EN) were collected in the Caçapava-Lavras road during previous works, and correspond to epiclastic rocks interlayered with andesites of the Hilário Formation.

Fourteen sandstone samples were selected for petrographic procedures, and three representative shale samples (one sample for each outcrop sector) were selected for geochemical and Nd isotopic analyses. Petrographic countings (300 to 500 points) were performed according to the Gazzi-Dickinson technique, and the results of quartz (Q), feldspars (F), metamorphic (L_m), volcanic (L_v) and sedimentary (L_s) fine-grained lithic fragments were plotted in the QFL and $L_mL_vL_s$ diagrams for provenance discrimination. Geochemical analyses of powdered shale samples were performed at the commercial laboratories of Lakefield Geosol Ltda. (Belo Horizonte, Brazil). Oxides and Rb were analyzed by X-ray fluorescence (special fusion), and the other elements by ICP multi-acid digestion. The chemical index of alteration (CIA, Nesbitt and Young, 1982) and the chemical index of weathering (CIW, Harnois, 1988) were calculated with the obtained results for Al_2O_3, CaO, Na_2O and K_2O. Natural Nd data were achieved in the Geochronology laboratory of the University of São Paulo (USP), Brazil. This procedure consists only of the acid digestion of the sample with HNO_3 and HF in the 1:3 proportion. The separation of rare earths and Nd is performed using RE-spec and LN-spec resins. The isotopic analyses were performed in a Finnigan MAT 262 mass spectrometer, with Faraday multi-collector system. Isotopic ratios were normalized to a $^{146}Nd/^{144}Nd$ ratio of 0.7219, and the La Jolla standard yielded a $^{143}Nd/^{144}Nd$ ratio of 0.511850 ± 0.00001.

RESULTS AND DISCUSSION

The results of the G-D counting of detrital (and diagenetic) components in fourteen thin sections of coarse-grained sandstones and conglomerates of the Bom Jardim Group are listed in Table I. The QFL and $L_mL_vL_s$ diagrams for provenance discrimination (Dickinson *et al.*, 1983), obtained by plotting the results, are represented in Figure 4. The results of whole-rock shale geochemistry and isotopic procedures, as well as calculated weathering indices, are listed in Table II.

The proposal of a basin scenario for the Bom Jardim Group (BJG) by considering the data presented here is based on the assumption that all studied outcrop sectors actually corrrespond to BJG deposits. The studied sectors (Lavras do Sul, Bom Jardim and Piquiri) of BJG, as well as others (Minas do Camaquã, Passo do Salsinho, Boici), are isolated remnants, distant *ca.* 50 km from each other, and BJG is afossiliferous, so correlation between outcrop sectors is not conclusive. Geochronological studies, despite being very abundant in the volcanic rocks of the Lavras do Sul sector (the Hilário Formation), are absent in the eastern occurrences of BJG. It is also necessary to remember that, for some authors (*e.g.* Paim *et al.*, 2000), the outcrop sector of Cerro da Árvore (Piquiri) could be ascribed to the Maricá Formation.

BJG - outcrop sector / stratigraphy	Cerro da Árvore (Piquiri Valley)						Bom Jardim (east of Caçapava do Sul)					Lavras do Sul		
Sample code:	CA-1	CA-4a	CA-3	CA-5m	CA-5cl	CA-7(cgl)	EBJ-1a	EBJ-2a	EBJ-2b	EBJ-3b	EBJ-3	WBJ-1	EN-178 (979)	EN-178 (980)
Monocrystalline quartz (Qm)	18.4	29.6	28.0	23.8	33.4	15.5	1.8	15.9	12.2	6.9	9.0	-	-	0.3
Polycrystalline quartz (Qp)	23.6	17.0	10.8	20.3	21.1	27.5	-	2.6	1.8	3.1	3.7	-	-	-
Quartz in metamorphic r.f.	1.6	4.9	2.2	1.6	1.6	11.7	-	-	-	-	-	-	-	-
Quartz in plutonic r. f.	-	0.9	-	0.3	-	0.6	-	0.3	1.0	2.2	1.0	-	-	-
Quartz in volcanic r. f.	-	0.3	-	-	-	-	-	0.3	1.3	0.6	4.5	-	0.3	-
K-feldspar	4.8	17.9	14.7	16.1	10.1	5.2	19.9	19.2	6.5	2.9	2.6	7.4	24.1	21.0
K-feldspar in plutonic r.f.	-	0.6	-	0.6	-	-	-	-	0.3	1.4	-	-	-	-
K-feldspar in volcanic r.f.	-	-	-	-	-	-	-	-	0.3	1.1	0.5	-	0.3	0.8
Plagioclase	4.2	7.1	6.2	5.1	7.9	1.2	13.0	13.1	8.8	3.1	4.2	15.8	14.3	15.5
Plagioclase in plutonic r.f.	-	0.3	-	-	-	-	-	0.3	0.3	0.8	0.3	-	-	-
Plagioclase in volcanic r.f.	-	-	-	-	-	-	7.6	2.9	5.2	5.8	2.7	3.2	3.6	2.7
Acidic volcanic/pyroclastic	-	1.5	2.5	2.6	1.3	2.9	12.4	8.8	16.9	15.8	22.7	23.2	3.1	7.3
Basic/intermediate volcanic	2.9	0.3	0.9	-	0.3	-	11.2	9.5	16.9	22.5	15.8	32.6	32.5	22.3
Lithic metamorphic	14.9	4.3	9.8	13.5	10.7	10.4	-	3.3	8.8	2.2	1.6	-	-	-
Lithic sedimentary	0.6	4.6	13.5	3.9	0.9	9.1	-	7.8	6.5	18.6	18.2	-	-	-
Mud intraclasts	-	0.6	0.9	-	-	-	-	-	-	-	-	-	-	-
Detrital opaques	-	0.6	0.6	-	0.9	0.3	5.4	1.3	1.3	-	2.4	-	4.5	2.2
Ferromagnesian minerals	-	0.3	-	-	-	-	-	0.6	-	1.9	-	-	-	-
Detrital micas	6.8	2.3	5.2	2.3	1.3	5.8	-	0.3	0.3	-	-	-	-	-
Carbonates	11.7	-	-	0.3	-	3.9	10.0	10.1	5.4	9.2	9.5	14.7	13.5	12.2
Kaolinite	3.5	-	0.7	0.3	-	-	5.1	1.3	1.4	1.9	-	-	-	-
Illite	5.2	1.6	1.8	1.0	2.2	0.9	4.0	0.6	0.9	-	-	-	-	-
Chlorite	-	-	-	-	-	0.3	8.4	1.6	3.9	-	1.3	3.2	3.9	15.8
Diagenetic iron oxides	-	5.3	2.2	5.5	6.9	4.9	1.2	6.8	6.5	1.9	1.3	3.2	3.6	1.4
Other components	-	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*
Q	*61.4*	*58.9*	*46.2*	*54.6*	*67.4*	*62.5*	*2.7*	*22.9*	*18.8*	*16.3*	*21.0*	-	*0.4*	*0.4*
F	*12.7*	*29.0*	*23.6*	*21.8*	*16.7*	*6.6*	*61.5*	*42.2*	*24.6*	*17.2*	*11.8*	*32.1*	*54.1*	*57.2*
L	*25.9*	*12.1*	*30.2*	*23.7*	*15.9*	*25.4*	*35.8*	*34.9*	*56.6*	*66.5*	*67.2*	*67.9*	*45.5*	*42.4*
Lm	*82.5*	*57.9*	*41.5*	*69.9*	*83.1*	*64.8*	-	*11.1*	*18.0*	*3.8*	*2.7*	-	-	-
Lv	*14.5*	*13.2*	*11.8*	*12.0*	*10.8*	*8.5*	*100.0*	*62.2*	*68.8*	*66.4*	*66.1*	*100.0*	*100.0*	*100.0*
Ls	*3.0*	*28.9*	*46.7*	*18.1*	*6.1*	*26.7*	-	*26.7*	*13.2*	*29.8*	*31.2*	-	-	-

Table 1. Results of the G-D counting method applied to the sedimentary samples of the Bom Jardim Group.
Tabela I . Resultados da contagem G-D aplicada às rochas sedimentares do Grupo Bom Jardim.

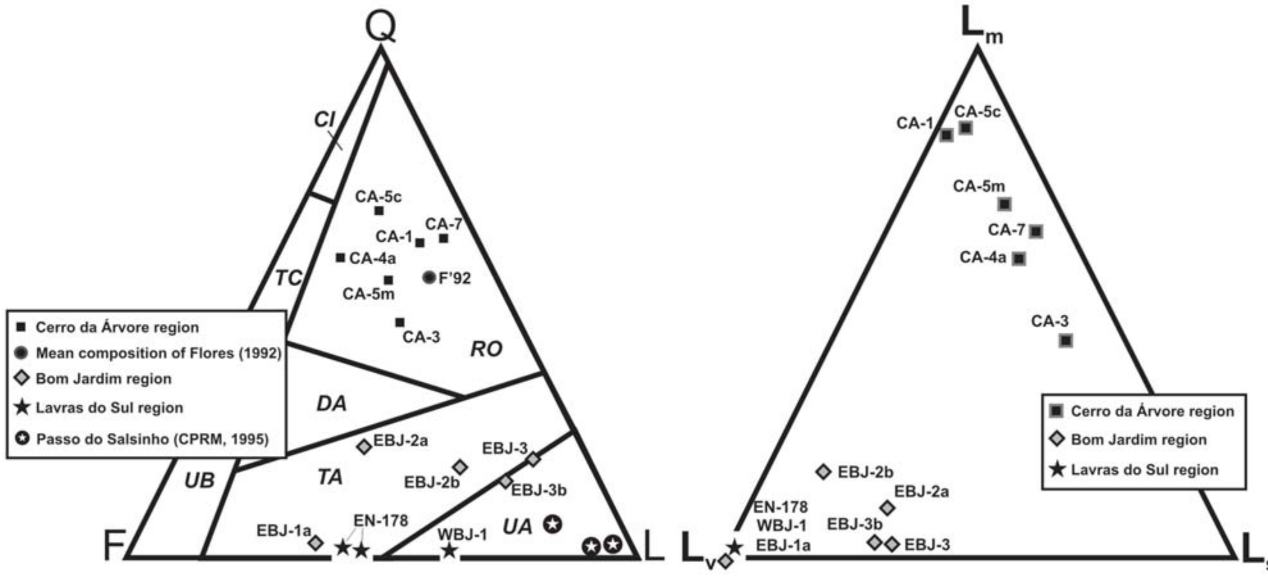

Figure 4. QFL (left) and $L_mL_vL_s$(right) diagrams (Dickinson *et al.*, 1983) obtained from plotting the results obtained for the Bom Jardim Group samples. Provenance fields: CI - craton interior; TC - transitional continental; UB - uplifted basement; RO - recycled orogenic; DA - dissected arc; TA - transitional arc; UA - undissected arc.

Figura 4. Diagramas QFL (esq.) e $L_mL_vL_s$ (dir.) (Dickinson *et al.*, 1983) para as amostras do Grupo Bom Jardim. Campos de proveniência: CI - interior cratônico; TC - continental transicional; UB - embasamento soerguido; RO - reciclagem orogênica; DA - arco dissecado; TA - arco transicional; UA - arco não dissecado.

Previous works (Borba *et al.*, 2004; 2006), however, showed that the Maricá Formation is characterized by an overall coastal setting, with fluvial and shallow marine deposits. The very good rounding of cobbles and pebbles within the conglomerates of the Maricá Formation, whatever it really means -long-lived transport, beach reworking or spheroidal chemical weathering-, is a character shared by every Maricá outcrop area, and it definitely contrasts with the features identified in the Cerro da Árvore (Piquiri) outcrop sector. The composition of clasts in the conglomerates of the Maricá Formation -dominant Paleoproterozoic gneiss and granitoids- neither fits with the composition of the samples from Cerro da Árvore obtained in this study. The present work, thus, considers the Maricá Formation older and unrelated to the Cerro da Árvore area, the latter being ascribed to the Bom Jardim Group.

The petrographic data presented here can be interpreted as a transition pattern, from sandstones with a clear lithic volcanic and feldspathic provenance in the west (Lavras do Sul), towards sedimentary rocks dominated by quartz, lithic metamorphic and intrabasinal sedimentary fragments in the east (Cerro da Árvore). The western BJG epiclastic rocks (labelled WBJ and EN), cropping out jointly and interlayered with volcanic beds, reflect very well a provenance derived directly from the Hilário Formation (Fig. 8). Andesitic clasts dominate the framework (Fig. 5), followed by feldspars and acidic rocks, and the obtained data display a correspondence between the almost equant contents of plagioclase and K-feldspars and the Na_2O/K_2O ratio of *ca.*1.0. Quartz is virtually absent (up to 0.3%). Diagenetic constituents are dominated by carbonates, chlorite and diagenetic iron oxides.

When plotted in the QFL diagram (Fig. 4, left), the sedimentary BJG rocks interlayered with the Hilário Formation in the Lavras do Sul area fall in the bottom of the triangle ("zero" quartz), within the "transitional arc (TA)" and "undissected arc (UA)" fields. For comparison, the results obtained by CPRM (1995) for the Passo do Salsinho region (west of Caçapava do Sul) are also plotted in figure 4. The slight difference between those results and the ones presented here are probably related to the utilization of the Gazzi-Dickinson method in the present paper, while in the quoted regional mapping the applied counting technique is not clearly stated. In the $L_mL_vL_s$ diagram, the samples fall in the L_v pole, since all three thin-sections have 100% of volcanic grains, among the fine-grained lithic components.

Sample	WBJ-1	EBJ-1	CA-2
SiO_2 (wt%)	66.3	58.1	63.0
TiO_2	0.75	0.86	0.69
Al_2O_3	14.7	17.3	17.9
Fe_2O_3	5.7	6.6	6.7
MgO	0.97	4.80	2.00
MnO	0.04	0.08	0.04
CaO	1.5	1.5	0.26
Na_2O	4.1	1.6	1.3
K_2O	4.1	4.3	4.7
P_2O_5	0.31	0.28	0.15
LOI	1.81	5.13	3.91
CIW	72.4	84.8	92.0
CIA	60.2	70.0	74.1
Rb (ppm)	99	148	193
As	120	< 10	33
Be	< 3	< 3	3.2
Sr	280	63	37
Ba	711	367	322
Zr	153	87	78
Y	16	17	26
Sc	11	11	18
V	25	80	56
Cr	21	84	36
Co	16	33	18
Ni	14	53	21
Cu	23	66	7.8
Zn	42	99	65
Pb	16	16	27
La	39	21	33
$^{143}Nd/^{144}Nd$	0.512263	0.511906	0.511887
$\varepsilon_{Nd(0)}$	-7.32	-14.28	-14.65

Table 2. Results of geochemical and Nd isotopic analyses and calculated parameters for shales from the Bom Jardim Group.
Tabela II. Resultados das análises geoquímicas e isotópicas e parâmetros calculados para os folhelhos do Grupo Bom Jardim.

When compared to the other samples, the epiclastic rocks from the Lavras do Sul region show relatively high contents of Ba (711 ppm), Sr (280 ppm), Zr (153 ppm) and the REE La (39 ppm), as well as relatively low contents of Cr, Ni and Co. These characters, jointly with the petrographic features, allow suggesting a significant (if not exclusive) contribution of the trachyandesitic rocks of shoshonitic affinity of the Hilário Formation (see Nardi and Lima, 2000) as the dominant source rocks. This suggestion is reinforced by the obtained Nd data, of 0.512263 for $^{143}Nd/^{144}Nd$ and the $\varepsilon_{Nd(0)}$ of -7.32. Granitoids and minettes co-magmatic to the Hilário shoshonitic rocks were studied by Gastal *et al.* (2003), and they yielded $\varepsilon_{Nd(600\ Ma)}$ values between zero and -4.5, and T_{DM} ages of 1.4 to 1.6 Ga, suggesting mantle-derived components in this post-collisional magmatism. It is suggested here that, during the deposition of the studied sandstones, most of the western Sul-rio-grandense Shield Paleoproterozoic cratonic blocks and Neoproterozoic juvenile arc terranes remained covered by a thick package of BJG volcanic rocks (Fig. 8).

In the Cerro da Árvore region, the easternmost outcrop sector of BJG, the detrital framework (Fig. 6) of sandstones is dominated by quartz (mono- and polycrystalline), K feldspars and lithic metamorphic rock fragments, in a typical orogenic recycling provenance. The dominance of K-feldspars over plagioclase (K/P ratio of 2.2) finds correspondence in the relatively low Na_2O/K_2O value of 0.2766. Sample CA-3, collected at the base of sequence II (stratigraphy by Caravaca *et al.*, 2003), and the conglomerate CA-7, in sequence III, have very significant amounts of lithic sedimentary clasts (13.5 and 9.1%, respectively). This confirms the autophagical character of BJG in the Cerro da Árvore region, as proposed by Caravaca (1998) and Caravaca *et al.* (2003) through conglomerate clast counting. Acidic volcanic lithic fragments are also important components, reaching up to 2.9%, same proportion reached by basic/intermediate detritus. Diagenetic constituents are dominated by diagenetic iron oxides, carbonates, illite and kaolinite. When plotted in the QFL diagram (Fig. 4, left), these samples fall in the "recycled orogen (RO)" field. The mean sandstone composition obtained by Flores *et al.* (1992) for samples of the same section is also plotted in Fig. 4, for comparison. In the $L_mL_vL_s$ diagram (Fig. 4, right), the samples from the Cerro da Árvore area cluster in the upper half of the triangle, close to the L_m vortex.

These data allow the proposition, for the Cerro da Árvore region, of a source area dominated by quartzites, schists, minor volcanic rocks and reworking of fine-grained sedimentary rocks of the same BJG. The obtained $^{143}Nd/^{144}Nd$ ratio of 0.511887 and the $\varepsilon_{Nd(0)}$ of -14.65 point to a crustal metasedimentary unit as the principal source area for the BJG sediments. It is suggested here that the Porongos complex of the Santana da Boa Vista Domain (Fig. 1a), which comprises metasediments and acidic metavolcanics, could be the main source of the studied sedimentation (Fig. 8). In fact, $\varepsilon_{Nd(0)}$ around -13 and -14 and $^{143}Nd/^{144}Nd$ ratios of around 0.51188 were achieved by Saalmann *et al.* (2006) for graphite schists, dacites and metapelites from their "Porongos belt". Other samples of quartzites and metarhyolites of the Porongos complex, as well as the sedimentary rocks of the Maricá Formation, display more crustal values of $\varepsilon_{Nd(0)}$ from -18 to -29, and lower $^{143}Nd/$

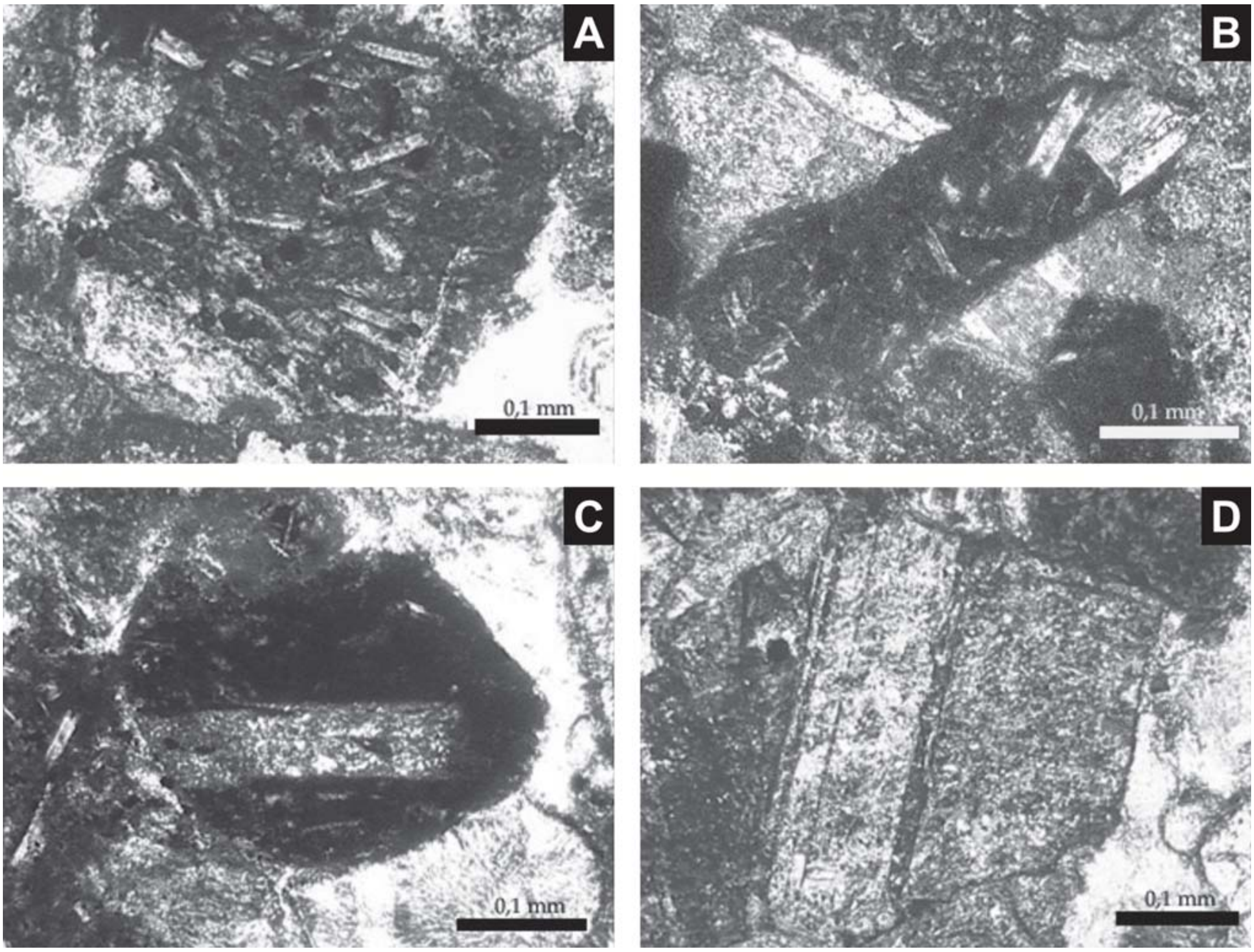

Figure 5. Photomicrographs (crossed nicols) of sandstones from the Lavras do Sul region (epiclastic rocks): **a)**, **b)** and **c)** volcanic fragments of andesitic/basaltic composition; **d)** plagioclase.
Figura 5. Fotomicrografias (nicóis cruzados) de arenitos da região de Lavras do Sul (rochas epiclásticas): **a)**, **b)** e **c)** fragmentos vulcânicos de composição basáltico-andesítica; **d)** plagioclásio.

^{144}Nd ratios (Saalmann *et al.*, 2006; Borba *et al.*, 2006).

The Bom Jardim region is located just east of Caçapava do Sul, half-way of the Lavras do Sul and Cerro da Árvore regions (*ca*. 50 km distant from each). The data obtained here for the Bom Jardim area samples show that this outcrop sector marks the transition between eastern and western BJG, sharing some characteristics with each of the end-members, and displaying some relevant singularities. The detrital framework of these rocks (Fig. 7) is dominated by equant contents of basic/intermediate and acidic volcanic rock fragments, as well as significant amounts of K feldspars and plagioclase.

When plotted in the QFL diagram, these sandstones from the Bom Jardim area fall mainly in the "transitional arc (TA)" field, and in the vicinity of the "undissected arc (UA)" field (Fig. 4, left). In the $L_mL_vL_s$ diagram, the samples cluster around the L_v pole (Fig. 4, right). Major diagenetic constituents are carbonates, iron oxides, kaolinite, illite and chlorite (Table 1). The Na_2O/K_2O ratio is also intermediate between the end-members, yielding 0.3721. The quartz content is much higher than in Lavras do Sul, although it is still very subordinated in the rock composition, when compared to the Cerro da Árvore rocks.

The more relevant characteristic of the geochemical signature of sample EBJ-1 (representative of Bom Jardim region), when compared to the other ones, is its relatively higher values of MgO (4.8%), TiO_2 (0.86), Co (33 ppm), Cr (84 ppm), Ni (53 ppm), Li, V and Zn. The

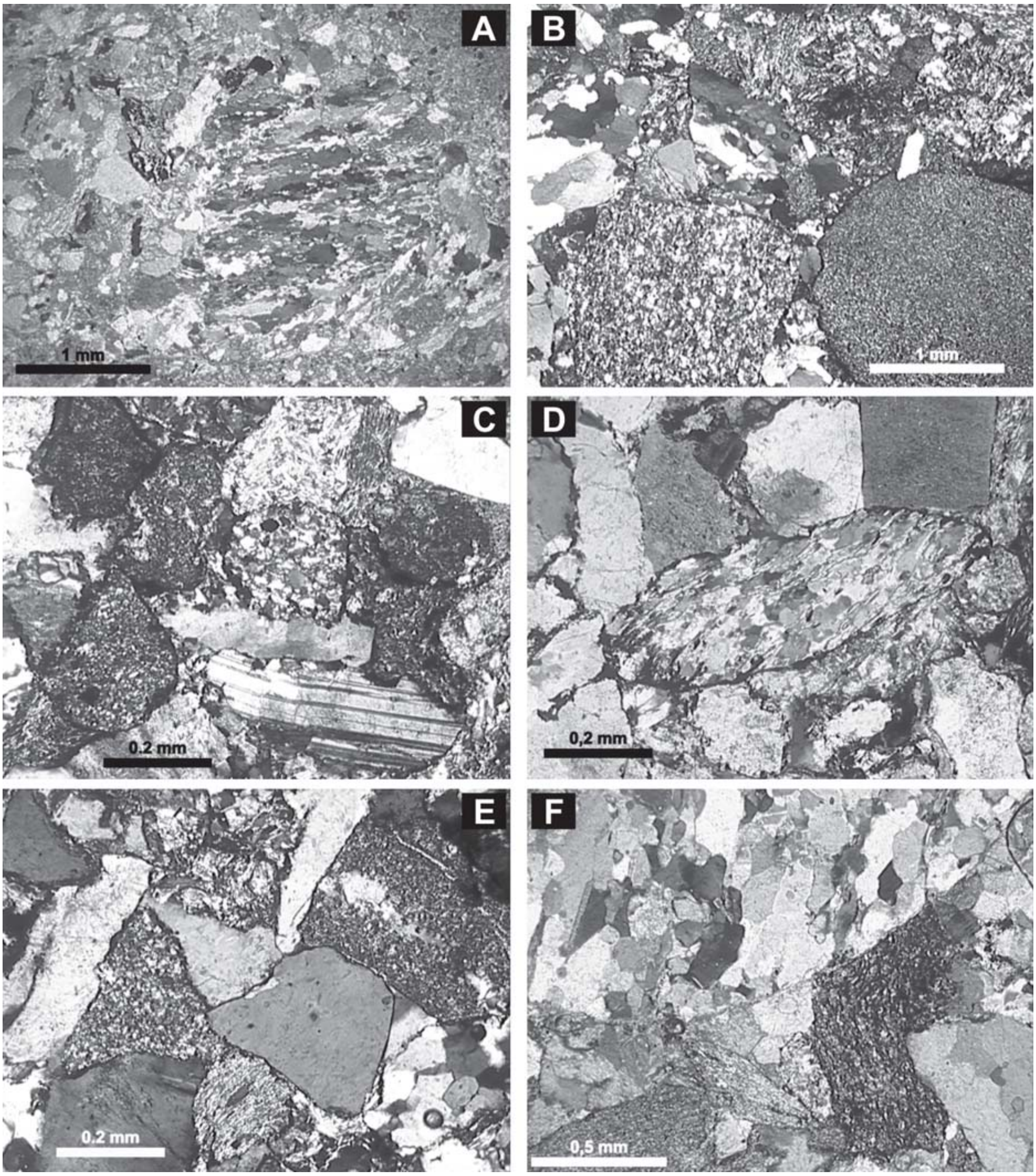

Figure 6. Photomicrographs (crossed nicols) of sandstones and conglomerates from the Cerro da Árvore region: detrital composition is dominated by polycrystalline quartz (a, center; b, left; f, top), monocrystalline quartz (d, top; e, center), metamorphic lithic (d, center) and sedimentary (b, bottom) grains, as well as feldspars (c, bottom, plagioclase).
Figura 6. Fotomicrografias (nicóis cruzados) de arenitos e conglomerados da região do Cerro da Árvore: composição detrítica é dominada por quartzo policristalino (a, centro; b, esquerda; f, topo), quartzo monocristalino (d, topo; e, centro), fragmentos líticos metamórficos (d, centro) e sedimentares (b, parte inferior), assim como feldspatos (c, base, plagioclásio).

observed correlation of Co, Cr and Ni with MgO could reflect a contribution of a small amount of ophiolitic source rocks (petrographically unrecognized), as proposed by van de Kamp and Leake (1995), or variations in the BJG volcanic package (Fig. 8). Both hypotheses are possible, since ophiolitic and oceanic plateau (Hartmann *et al.*, 2003) rocks have been recognized in the Vacacaí supercomplex of the São Gabriel Domain

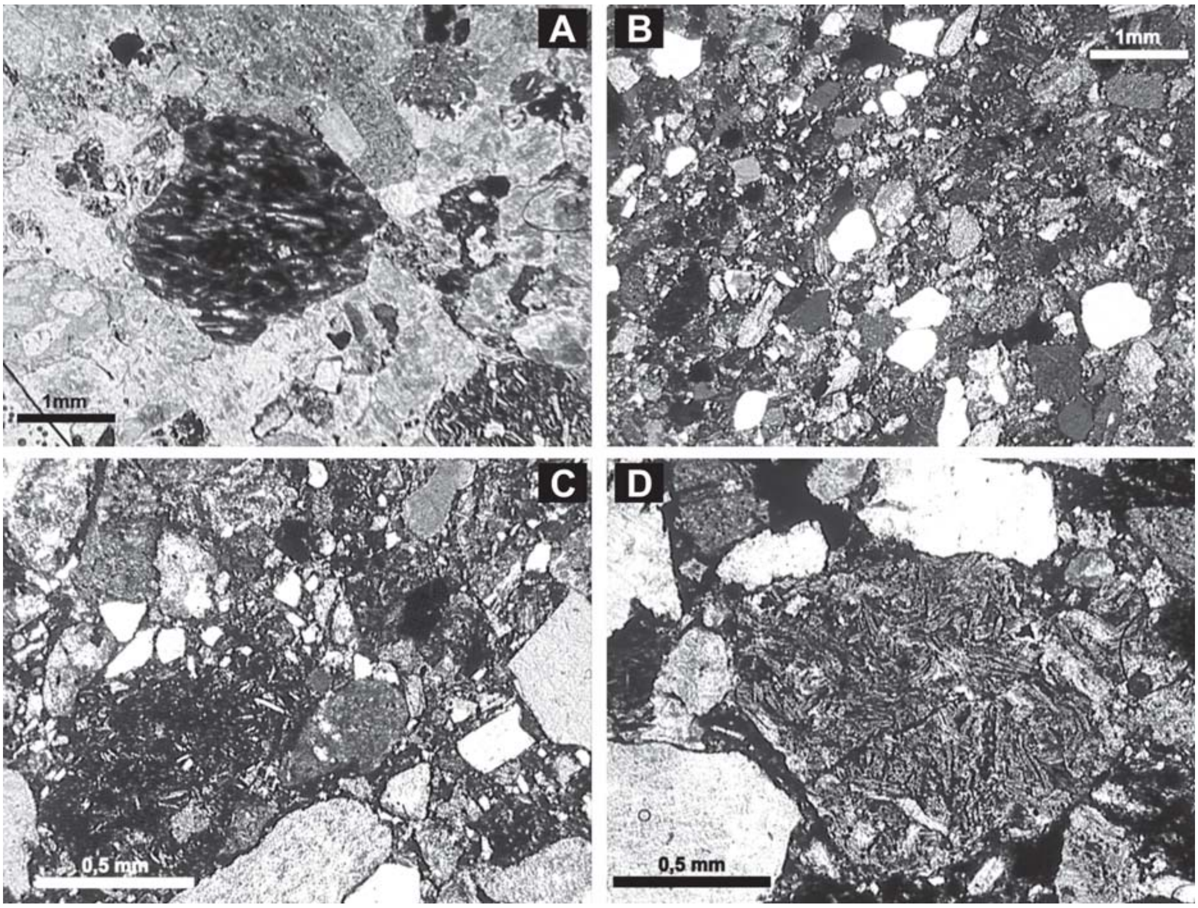

Figure 7. Photomicrographs of sandstones from the Bom Jardim area: a) volcanic grains in plane-polarized light; b) significant amounts of monocrystalline quartz; c) and d) volcanic, pyroclastic grains and angulose quartz; b, c and d – crossed nicols.
Figura 7. Fotomicrografias de arenitos da área de Bom Jardim: a) grãos vulcânicos à luz natural; b) quantidades significativas de quartzo monocristalino; c) e d) grãos vulcânicos, piroclásticos e qurtzo; b, c, d) – nicóis cruzados.

(Fig. 1a), and spessartitic lamprophyres of the BJG in the Arroio das Pedras Formation (Fig. 1b) and adjacent areas show enrichment in MgO correlated with Cr and Ni (Nardi and Lima, 2000).

The obtained ^{143}Nd/^{144}Nd ratio of 0.511906 and the $\varepsilon_{Nd(0)}$ of -14.28 are very similar to those of the Cerro da Árvore region, showing that probably uplifted areas of the Porongos metasediments would be the dominant source areas for the BJG in the Bom Jardim region. This fact corroborates the positioning of the boundary between the Santana da Boa Vista and São Gabriel domains along the Caçapava suture (Figs. 1a and 8). This extension of the Porongos complex towards the Bom Jardim region is covered by the *ca.* 1,500m thick Early Paleozoic Guaritas Formation.

The data and interpretation presented here, despite the preliminary character of this study and the low number of samples, allow to suggest a fault-bounded, NE-SW trending, possibly continuous basin, with intrabasinal structural highs, flat alluvial plains and shallow lakes at the depocenters. The continental character of the sedimentation has been sustained on the basis of continental onlap, desiccation features (mudcracks, raindrop imprints), boron contents (Flores, 1992) and diagenetic components (Flores *et al.*, 1992). The volcanic event of the Hilário Formation, co-magmatic to subvolcanic and intrusive bodies in western Sul-rio-grandense Shield, and dated between 580 and 600 Ma, is also considered to be subaerial (Wildner *et al.*, 2002). This volcanic package would have covered the entire cratonic (Taquarembó Domain), juvenile arc (São Gabriel Domain), and sedimentary (Maricá Formation) areas in the west. Thus, the western border of the Bom Jardim depositional basin is thought to have been composed almost exclusively by volcanic rocks of shoshonitic affiliation (Fig. 8).

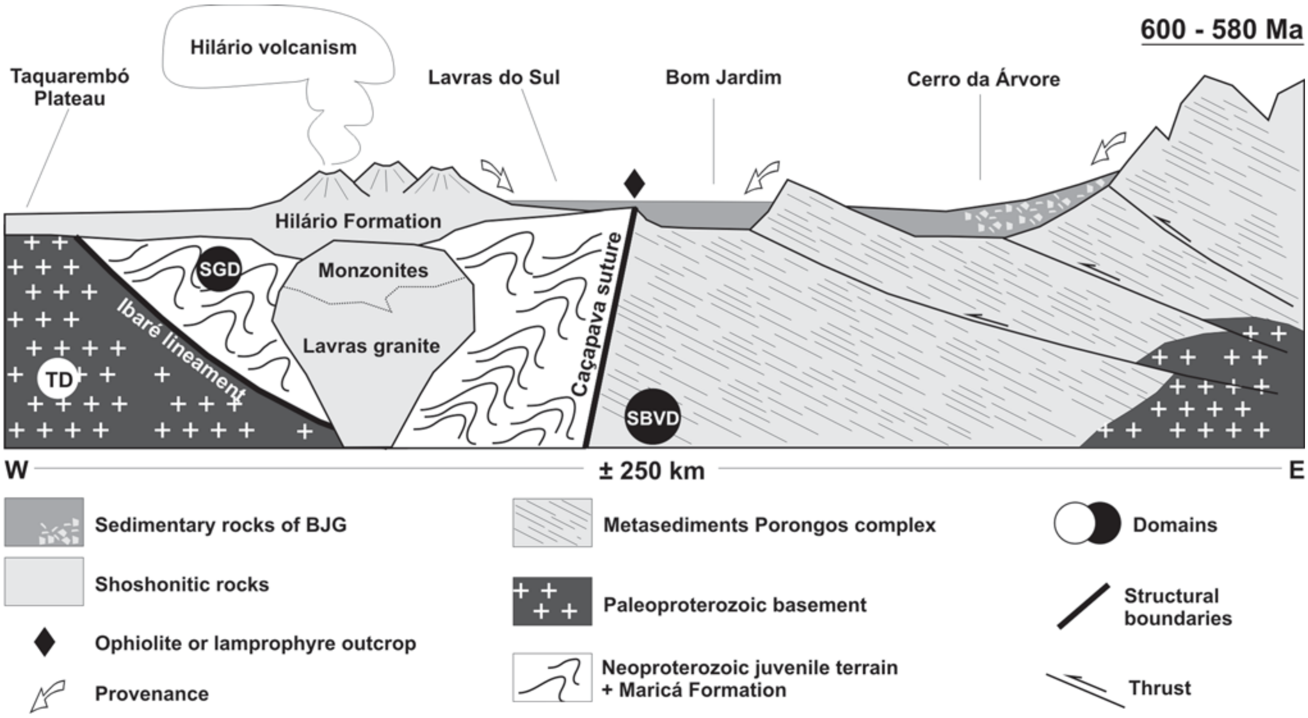

Figure 8. Interpreted geological setting during the evolution of the depositional basin of the Bom Jardim Group, between 600 and 580 Ma; the Hilário Formation possibly covered the entire juvenile and cratonic domains in the west, while the Porongos complex was uplifted and available for erosion in the east; coarse-grained and authophagical deposits in the Cerro da Árvore region suggest the activity of thrust planes; the occurrence of ophiolitic or lamprophyric rocks near the Caçapava suture is also illustrated.
Figura 8. Panorama geológico interpretativo para a bacia deposicional do Grupo Bom Jardim, entre 600 e 580 Ma; a Formação Hilário possivelmente recobria todos os domínios cratônicos e juvenis a oeste, enquanto o complexo Porongos era soerguido e disponibilizado para erosão no leste; depósitos grossos e autofágicos da região do Cerro da Árvore sugerem a atividade de planos de falha de empurrão; a ocorrência provável de rochas ofiolíticas ou lamprofíricas próximo à sutura de Caçapava também é ilustrada.

To the east of Caçapava do Sul, a possible intrabasinal structural high would have consisted of ophiolitic rocks of the Vacacaí supercomplex or spessartitic lamprophyres of the same BJG (Fig. 8). Even though, the dominant source areas to the east of the Caçapava suture had been the metapelites, quartzites, schists and metarhyolites of the Porongos complex. It is probable that the eastern border of this basin was also composed by the Porongos complex rocks, since other extrabasinal fragments show up only in the sequence III, represented by fragments of the basement Encantadas gneisses (Caravaca, 1998). The coarser nature of the Cerro da Árvore BJG deposits suggests that slopes in the eastern border were steeper than in the west, where volcanoes dominated the landscape (Fig. 8). The present-day proximity between BJG sedimentary rocks and their source areas (Hilário Formation and Porongos complex), and the strongly autophagical character of the sedimentation in the east indicates that the tectonic setting during BJG basin evolution was probably influenced by compressive stresses in a fold-and-thrust belt (Fig. 8) rather than a pure strike-slip behavior.

The weathering indices (CIA and CIW) calculated for the shale samples also show a transition pattern, from relatively lower values in the Lavras do Sul area (60.2 for CIA and 72.4 for CIW), passing through medium values in the Bom Jardim region (70.0 for CIA and 84.8 for CIW), and reaching very high values (74.1 for CIA and 92.0 for CIW) in the Cerro da Árvore outcrop sector (Table 2). The observed transition pattern, despite the low number of samples, also reinforces the synchronous deposition of the three sedimentary successions. These data do not imply different climates in the east and west, but suggest that source rocks in the Cerro da Árvore region experienced possibly more phases of weathering. This evinces that the metasedimentary rocks of the Porongos complex were the dominant source rocks in the east, since one metapelite sample (BR-144/1) analysed by Saalmann *et al.* (2006) displays also high values for CIA (78%) and CIW (around

95%). Thus, the high values of CIA and CIW in the Cerro da Árvore sedimentary rocks represent, in fact, multiple weathering phases and recycling of metasedimentary units.

Conglomerate clast counting (Caravaca, 1998), sandstone petrography and Sm-Nd isotope geology (this study) show no evidence for the existence of Neoproterozoic, mantle-influenced magmatic rocks in the source areas of the BJG. However, in the 600 - 580 Ma interval, most of the magmatic rocks of the Pelotas Domain, presently distant only *ca.* 25 km from the Cerro da Árvore outcrop sector, were already emplaced, including those inside the Dorsal de Canguçu shear zone (DCSZ, Fig. 1a). An isotopic signature (Sr, Nd) diagnostic of the erosion and contribution of syn-DCSZ granitoids to sedimentary basins was obtained only for the Camaquã Group, probably younger than 540 Ma, by Borba *et al*. (2003). This fact suggests two options: a) the magmatic rocks of the Pelotas Domain would be in a deeper crustal level, and would have no volcanic "suprastructure" correspondents; or b) the Pelotas Domain could represent an exotic block juxtaposed to the rest of the Sul-rio-grandense Shield after 580 Ma. The latter suggestion was sustained by Bossi and Gaucher (2004), who stated that the Cuchilla Dionisio Terrane (the Uruguayan correlative of the Pelotas Domain) collided to the Gondwana continent during a 530 Ma sinistral transcurrent event.

Considering the age of the Bom Jardim Group (580 to 600 Ma), and the published plate tectonic models for the evolution of the Sul-rio-grandense Shield, it is possible that, right after the end of the collision between the Neoproterozoic juvenile terrain (São Gabriel arc) and the cratonic masses (La Plata and Encantadas or Congo-Kalahari cratons), a post-collisional fold-and-thust belt composed by metasediments and metavolcanic rocks (Porongos belt) was significantly uplifted and became available for erosion. During the latest stages of the compressive (transpressive?) regime, still under the influence of active thrust planes, a tectonic NE-SW trough evolved, with the deposition of the coarse-grained BJG deposits of the Cerro da Árvore region. Tectonic movements also formed the intrabasinal highs, that created sediment availability and accommodation space in the Bom Jardim region, and a post-collisional volcanism composed by basalts, shoshonites, andesites and lamprophyres dominated the west. This basin was filled in with alluvial, fluvial and lacustrine deposits, interlayered with the subaerial andesitic lava flows and pyroclastic rocks provenant from west.

The tectonic regime shifted completely towards strike-slip-dominated after the end of the sedimentation, and affected the stratigraphy and contact relationships of BJG, especially in the Bom Jardim region. That area, under strike-slip stresses, was the site for the syn transcurrent emplacement of the Caçapava do Sul granitoids, intruded at 560 - 540 Ma (Sartori and Kawashita, 1985; Leite *et al.*, 1995; Remus *et al.*, 2000). To the west, the Acampamento Velho Formation, a bimodal volcanic succession of alkaline affinity (Almeida *et al.*, 2002), developed until 549 ± 5 Ma (Sommer *et al*., 2003) and covered the BJG occurrences. After 540 Ma, during the Early Paleozoic, the sedimentary, continental Santa Bárbara and Guaritas formations also covered the central portion of the Sul-rio-grandense Shield.

CONCLUSIONS

The integration of petrographic and preliminary geochemical and isotopic data allowed the proposition of a paleogeographic setting, with tectonic implications, for the sedimentary rocks of the Bom Jardim Group, normally ascribed in the lithostratigraphy to the Arroio dos Nobres Formation. A transition pattern was recognized, from a lithic "volcanic arc" provenance in the west, with a low weathering pattern, towards a quartzose "recycling orogen" provenance in the east, with high alteration suggesting metasedimentary recycling and/or more weathering cycles. Geochemical and isotopic data, despite the low number of samples, point to: a) higher values of Ba, Sr and Zr in the west (Lavras do Sul), near shoshonitic andesite occurrences, with a $^{143}Nd/^{144}Nd$ ratio of 0.512263 and $\varepsilon_{Nd(0)}$ of -7.32; b) relatively higher values of MgO, Cr, Co and Ni in the central area (Bom Jardim), pointing to the existence of ophiolitic or lamprophyric source rocks; and c) a higher K_2O/Na_2O ratio in the east (Cerro da Árvore), pointing to the influence of more acidic rocks as sources of sedimentation. In the central and eastern area, the $^{143}Nd/^{144}Nd$ ratios are very similar (0.511906 and 0.511887), as well as the $\varepsilon_{Nd(0)}$ (-14.28 and -14.65, respectively), indicating a crustal source, probably the metasediments of the Porongos complex. The obtained data allowed the correlation of the three areas effectively as outcrop sectors of the Bom Jardim Group, based on the observed transition pattern, the similarity of isotopic data between the eastern and the central areas and the interlayering with andesitic flows and pyroclastic rocks in the western and central outcrop sectors. This study also allowed inferring a basin evolution model for the Bom Jardim

Group in the Sul-rio-grandense Shield area, as well as other tectonic implications, such as the extension of the Porongos complex beneath the sedimentary rocks of the BJG and Guaritas Formation towards the Caçapava suture. Future work shall involve the study of other BJG outcrop sectors, collection and analysis of more samples, in order to enrich the interpretations performed here or to recognize other patterns, eventually not identified by this study.

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