



The southern Araçuaí belt and the Dom Silvério Group: geologic architecture and tectonic significance

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ABSTRACT

The Araçuaí belt corresponds to the external portion of the western half of the Araçuaí-West Congo Neoproterozoic orogen. The Araçuaí belt fringes the São Francisco craton to east and is separated from the crystalline core of the orogen by the Abre Campo geophysical discontinuity. The southern Araçuaí belt involves four major lithologic units: the Archean and Paleoproterozoic gneisses of the Mantiqueira Complex, the Pedra Dourada Charnockite, the Paleoproterozoic Borrachudos Granitoid, and the metavolcanosedimentary rocks of the Dom Silvério Group. The Dom Silvério Group occurs in a NNE-SSW striking belt and consists of a thick package of metapelitic rocks with intercalations of quartzites, amphibolites, meta-ultramafics, banded iron formations, gondites and marbles. All units of the southern Araçuaí belt underwent four syn-metamorphic phases of deformation in the course of the Brasiliano event. The first phase, synchronous to a regional amphibolite facies metamorphism, was associated to a general tectonic transport towards north along the left-lateral Dom Silvério shear zone and its low angle segment. The second and third phases represent progressive stages of a west directed shortening, which led to the development of local thrusts and pervasive folds in several scales. The fourth phase is extensional and reflects the collapse of the orogen.

Key words: Araçuaí-West Congo orogen, Araçuaí belt, Dom Silvério Group, Brasiliano event.

INTRODUCTION

The vast region of the Doce and Jequitinhonha river basins, located between the São Francisco craton and the eastern continental margin of Brazil, is encompassed by the northern and central sectors of the Neoproterozoic Mantiqueira structural province (Almeida and Hasui 1984). This portion of the Brazilian shield has been viewed as part of the Araçuaí-West Congo orogen (Torquato and Cordani 1981, Brito-Neves and Cordani 1991, Pedrosa-Soares et al. 1992, 1998, 2001, Pedrosa-Soares and

Wiedemann-Leonardos 2000). The Araçuaí-West Congo orogen, made up by the Araçuaí orogen in Brazil and the West Congolian belt in Africa, developed between the São Francisco and Congo cratons in the course of the Brasiliano-PanAfrican assembly of West Gondwana during the Neoproterozoic (Trompette 1997, Brito-Neves et al. 1999, Campos-Neto et al. 2000, Tack et al. 2001) (Fig. 1).

The Araçuaí belt, consisting of a curved, basement-involved fold-thrust belt, corresponds to the external portion of the Araçuaí orogen that fringes the São Francisco craton to the east (Fig. 1). In the present paper we first provide a description

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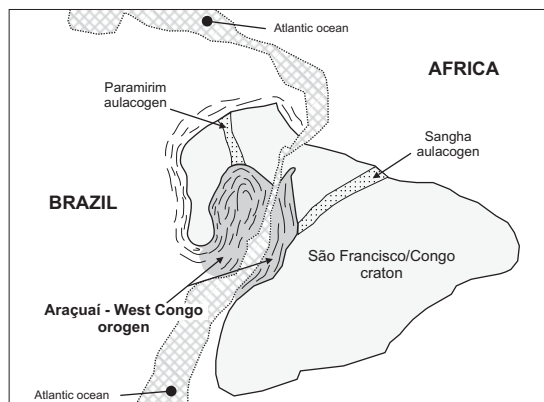


Fig. 1 – Actual coastline of South America and Africa in a schematic reconstruction of the western portion of Gondwana highlighting the São Francisco-Congo craton and the Araçuaí-West Congo orogen. Modified from Pedrosa-Soares et al. (1992).

of the main lithological components and overall geologic architecture of the southern segment of the Araçuaí belt, emphasizing petrological and structural aspects of the Dom Silvério Group. The Dom Silvério Group, made up by a package of deep marine sediments, represents a potential correlative of ophiolitic assemblages characterized in the other Neoproterozoic Brasiliano belts around the southern portion of the São Francisco craton. Based on discussion of the results of a structural analysis performed at micro, meso and macro scales, we suggest a model for the tectonic evolution of the southern Araçuaí belt during the Brasiliano event.

THE ARAÇUAÍ OROGEN AND THE ARAÇUAÍ BELT

According to Pedrosa-Soares and Wiedemann-Leonardos (2000), the Araçuaí orogen occupies the area between the São Francisco craton and the Brazilian continental margin, displaying an arbitrary boundary with the Neoproterozoic Ribeira belt to the south. This boundary, located at approximately 21°S Lat., is marked by an inflection of the structural trend lines, which slightly bend from NNE, in the Araçuaí orogen, to NE in the Ribeira belt (Fig. 2).

The Araçuaí orogen consists of two major tec-

tonic features: the Araçuaí belt and the crystalline core (Fig. 2). According to the original definition by Almeida (1977), the Araçuaí corresponds to the fold-thrust belt developed along the eastern margin of the São Francisco craton, in which the Mesoproterozoic and Neoproterozoic metasedimentary rocks of the Espinhaço and São Francisco supergroups, respectively, are involved. Defined as such, the Araçuaí belt would encompass the area of the southern Serra do Espinhaço in Minas Gerais and the Serra Geral along Minas Gerais-Bahia border together with its continuation up to the Atlantic coast in southern Bahia (e.g., Uhlein 1991). However, as a west-verging Neoproterozoic fold-thrust belt, the Araçuaí belt can be followed along the eastern boundary of the São Francisco craton beyond the southern termination of the Serra do Espinhaço, involving the eastern half of the Quadrilátero Ferrífero and reaching at least the region immediately south of the town of Barbacena in Minas Gerais, where it overprints the southern Brasília belt (e.g., Alkmim et al. 1993, Chemale Jr. et al. 1994) (Fig. 2 and 3). The eastern boundary of the Araçuaí belt is considered here to be marked by the Abre Campo geophysical discontinuity (Haralyi and Hsui 1982). The expression of the Abre Campo discontinuity in the field is a wide NS to NE-oriented dextral shear zone (Fig. 4).

The crystalline core of the Araçuaí orogen corresponds to its internal portion, characterized by the dominance of high-grade metamorphic rocks and a large volume of Neoproterozoic granites. The basement of the crystalline core is composed of rocks older than 1.8 Ga, including Archean rocks and the Paleoproterozoic Juiz de Fora Complex (Fischel 1998, Brueckner et al. 2000, Silva et al. 2002). Other lithological units of the crystalline core are the high grade Neoproterozoic Paraíba do Sul, Jequitinhonha and Costeiro complexes, as well as a large volume of Neoproterozoic pre-, syn-, late- and post-collisional granites (G1, G2, G3, G4 and G5 suites, according to Pedrosa-Soares et al. 1999). The tectonic grain of the crystalline core involves a system of NNE-trending dextral strike-slip shear

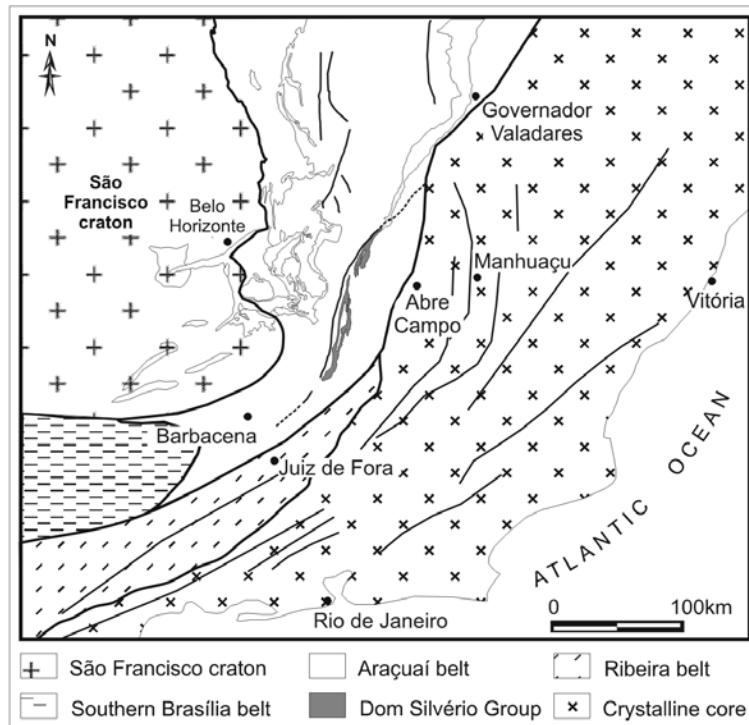


Fig. 2 – Simplified geologic map showing the location of the Araçuaí, Ribeira and Brasília belts and the crystalline core of the southern Araçuaí-West Congo orogen. Modified from Brueckner et al. (2000).

zones (Cunningham et al. 1996, 1998, Wiedemann-Leonardos et al. 2000).

THE DOM SILVÉRIO GROUP AND OTHER UNITS OF THE SOUTHERN ARAÇUAÍ BELT

The main lithological units of the southern Araçuaí belt are (Fig. 4): the Dom Silvério Group, the Mantiqueira Complex, the Pedra Dourada Charnockite, and the Borrachudos Granitoid. Deformed pegmatite bodies intrude the Mantiqueira, Pedra Dourada and Borrachudos rocks. Metamafic intrusives of tholeiitic affinity crosscut all previously mentioned units (Jordt-Evangelista and Cotta 1995).

THE DOM SILVÉRIO GROUP

The Dom Silvério Group was defined by Lima et al. (1973) as composed of quartz-mica schists overlain by quartzites. The work by Lima et al. (1973) was followed by detailed investigations undertaken by

Jordt-Evangelista and Roeser (1988), Jordt-Evangelista et al. (1990), Jordt-Evangelista (1992), Dürkop et al. (1997) and Peres (2000), as well as by CPRM/DNPM mapping projects (Brandalise 1991, Raposo 1991, Baltazar and Raposo 1993).

The Dom Silvério Group occurs as a roughly 10 km wide belt, which extends in a NNE direction for ca. 150 km in eastern Minas Gerais, between the towns of Ipatinga to the north, and Viçosa to the south (Fig. 4). It comprises a metavolcanosedimentary assemblage including pelitic schists, amphibolites, quartzites and subordinate occurrences of gondites, marbles, metaultramafic rocks and iron formations. The most common rocks are biotite schists, usually garnet-bearing.

The Dom Silvério rocks crop out in form of layers no thicker than tens of meters. The contact between different compositional layers is commonly abrupt. A pervasive foliation is always present and

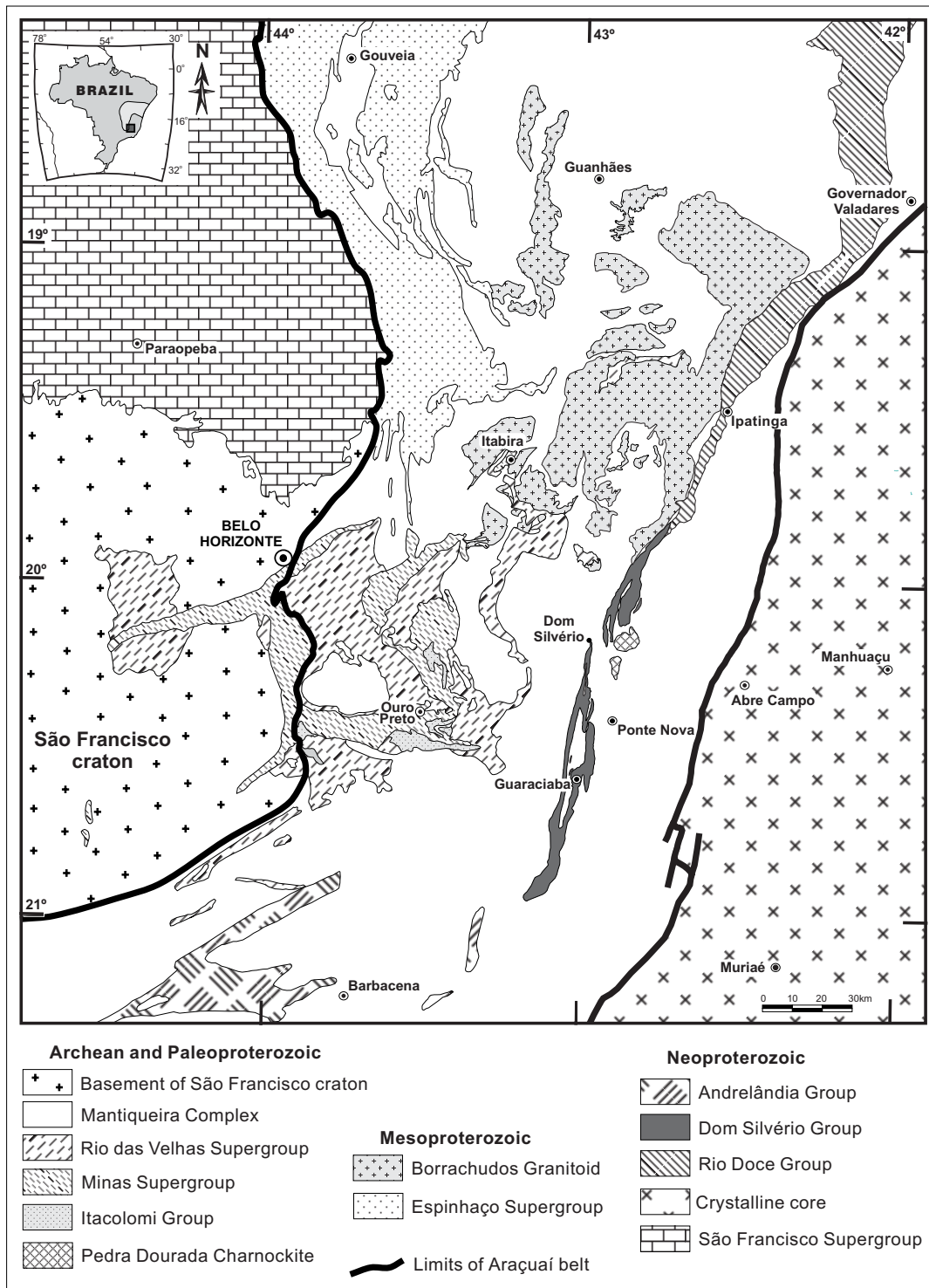


Fig. 3 – Geologic map of the southern portion of the Araçuaí belt showing the boundaries of the São Francisco craton and the crystalline core. Compiled from Machado F^o et al. (1983), Pinto et al. (1997), Grossi-Sad et al. (1997) and Peres (2000).

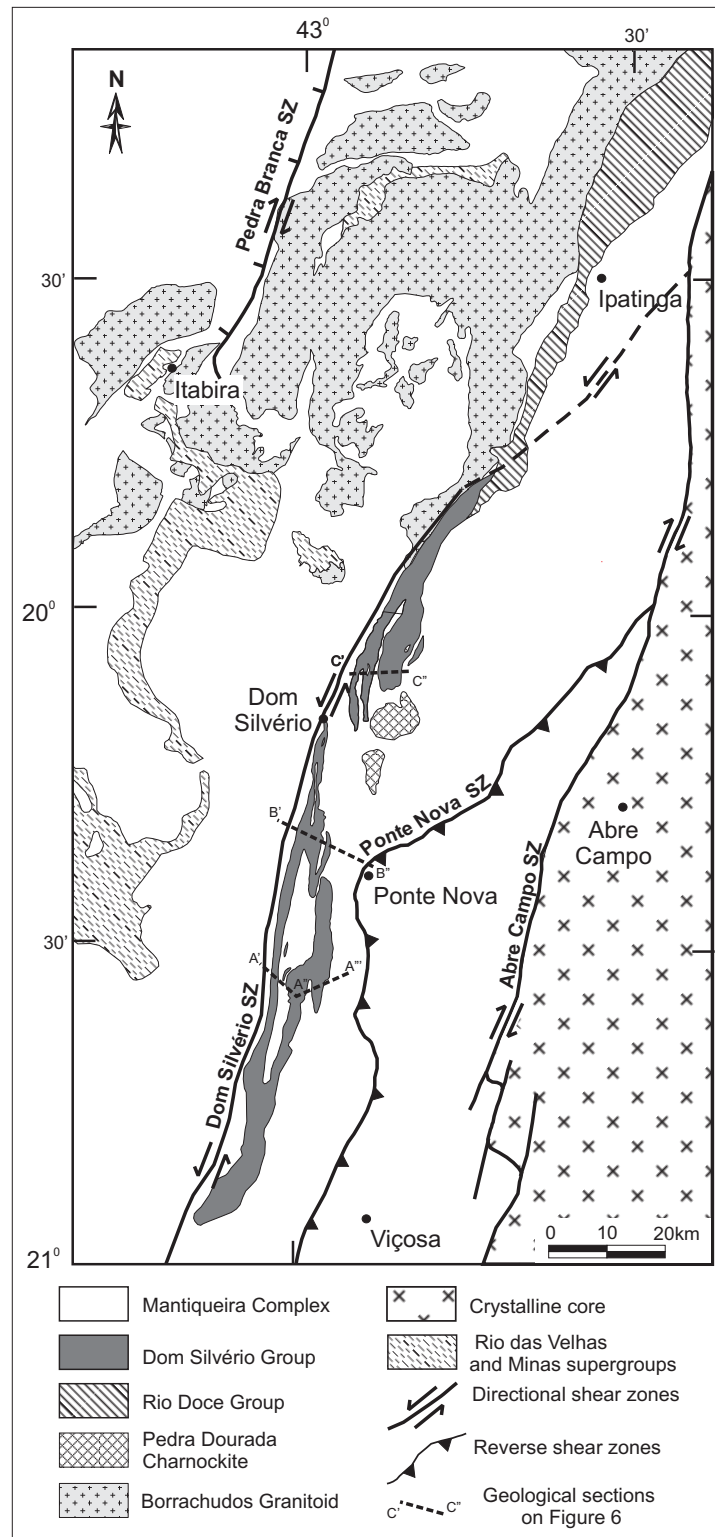


Fig. 4 – Simplified geologic map of the study area showing the distribution of main lithologic units.

parallel to the compositional banding. This compositional banding seems to result from transposition of the original bedding. The Dom Silvério rocks overlie the gneisses of the Mantiqueira Complex, and the abrupt contact runs parallel to both the compositional banding and the dominant foliation.

There is a substantial difference in the vertical succession of the various lithotypes of the Dom Silvério Group between the northern and southern segments of its occurrence area (Fig. 5). In the southern segment, the sequence starts with a thin layer (usually thinner than 1 m) of chlorite schists with intercalations of talc schists, followed by an approximately 50 m thick package of muscovite-rich garnet schists that grade into a gneissoid layer of quartz-feldspar-mica schist. Overlying this layer there is a 0.5 to 3 m thick bed of graphite schist that can be used as a marker horizon due to its great lateral continuity in the southern sector. A thick pile of garnet-biotite schists and sericite-quartz schists with intercalations of amphibolites and quartzites overlies the graphite schists. The quartzites, usually thin, commonly occur at the topmost portion of the pile; the amphibolites, on the contrary, are more frequent at the base of the sequence (Fig. 5).

In the northern portion of the study area the rock sequence is more complex than the southern one. Substantial lateral variations in composition and thickness have been observed in the field. The graphite schists, forming a marker bed in the southern sector, are absent here. There is a remarkable increase in the volume of amphibolitic and metaultramafic rocks, especially at the base of the package, where marbles, manganeseiferous rocks and banded iron formations also occur. The metaultramafic rocks are massive and occasionally thicker than 10 m. They are composed mainly of antophyllite in radial acicular crystal aggregates, that make up ca. 70% of the total rock volume.

Though more frequent in the northern sector, quartzites are widespread throughout the whole occurrence area of the Dom Silvério Group. Despite of their small thickness (usually between 0.5 and 1 m, rarely exceeding 5 m), they apparently define

horizons of great lateral continuity.

The mineral parageneses of the metapelitic rocks of the Dom Silvério Group are the most important data sources regarding the main synkinematic metamorphism of the southern Araçuaí belt. This episode of blastesis, here referred to as the M_1 metamorphism, was responsible for the growth of the main rock-forming minerals, as well as for the varietal and accessory phases such as garnet, staurolite, kyanite and tourmaline, among others. The kyanite + staurolite paragenesis and occurrence of muscovite in equilibrium with the other mineral phases indicate M_1 temperatures around 520-640°C and pressures higher than 4 kbar. Geothermobarometric calculations based on the partition of Fe and Mg between biotite and garnet yield temperatures of ca. 550°C for pressures around 5 kbar during M_1 (Jordt-Evangelista and Roeser 1988). Rettinger et al. (1998) found temperatures around 560°C and pressures of ca. 4.7 kbar for the same metamorphic phase.

Geochronological data for the Dom Silvério rocks are restricted to a single Sm-Nd date in garnet schists by Brueckner et al. (2000). These authors obtained a two-point isochron age of 547 ± 29 Ma, interpreted as the age of the M_1 metamorphism, and a model age (T_{DM} – whole rock) of 2.27 Ga. The latter indicates that sediments of the Dom Silvério Group may be derived from a Paleoproterozoic source or a mixed of Archean and Paleoproterozoic sources.

GNEISSES OF THE MANTIQUEIRA COMPLEX: THE SUBSTRATUM OF THE DOM SILVÉRIO GROUP

For simplicity, we consider that the Mantiqueira Complex includes the banded gneisses that occur to the south and to the east of the southern Serra do Espinhaço, the “Mantiqueira Series” of Barbosa (1954), as well as the mylonitic and banded gneisses that crop out in the surroundings of the town of Piedade (MG), called “Piedade Gneiss” or “Piedade Group” by Ebert (1958) (Fig. 3).

The gneisses of the Mantiqueira Complex dominate in ca. 60-70% of the study area. They

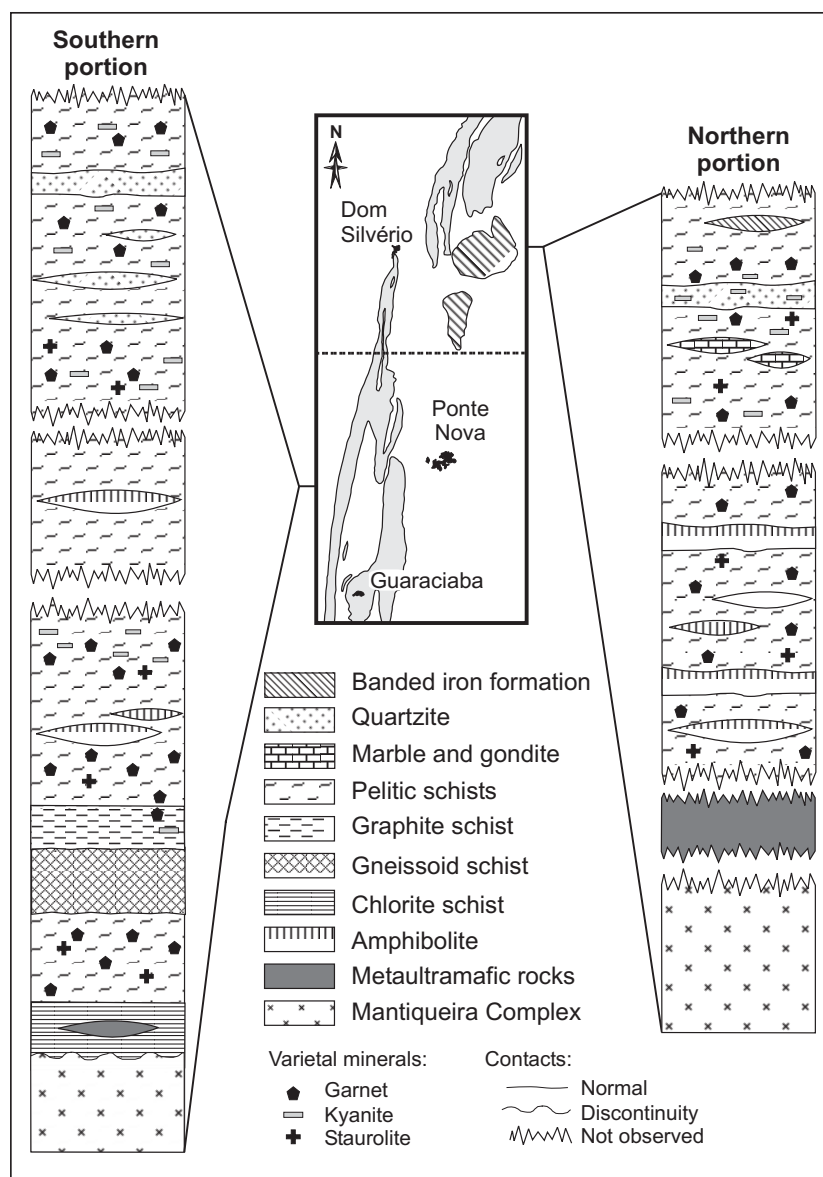


Fig. 5 – Vertical succession of the various rock types of the Dom Silvério Group in the northern and southern portions of the study area. Not in scale.

correspond to banded orthogneisses of granitic to tonalitic composition, showing in general protomylonitic to mylonitic fabrics. The thickness of the gneissic banding varies from centimetric to metric. Coarse grained porphyroclastic bands, and foliated amphibolitic boudins, lenses and layers parallel to the gneissic banding are very common.

In the absence of critical mineral parageneses, Jordt-Evangelista and Müller (1986), Brandalise (1991) and Figueiredo and Teixeira (1996) have used microstructures to conclude that the Mantiqueira gneisses were deformed and recrystallized under amphibolite facies conditions. In fact, the observed microstructures indicate that only ductile deforma-

tional processes were recorded in the Mantiqueira gneisses to the west of the town of Ponte Nova (Fig. 4). Dynamically recrystallized feldspars and quartz ribbons are common features, indicating intense deformation under amphibolite facies conditions and recording the same syn-kinematic metamorphic phase (M_1) that affected the Dom Silvério rocks.

To the east of the town of Ponte Nova (Fig. 4), the Mantiqueira gneisses underwent a second metamorphic phase (M_2) in greenschist facies conditions, marked by intense fluid percolation along discrete surfaces. The percolation of metamorphic fluids originated continuous horizons of retrometamorphic products, which consist of epidote, sericite, pyrite and calcite. The M_2 metamorphism is restricted to the Mantiqueira gneisses in the area bounded by the Ponte Nova shear zone as described in the next section. The effects of the M_2 metamorphism have not been observed in other units.

According to geochronological studies (*e.g.* Teixeira et al. 1987, Figueiredo and Teixeira 1996, Fischel 1998, Brueckner et al. 2000), the protoliths of the Mantiqueira Complex are essentially Archean and may represent an extension of the same crustal segment that forms the São Francisco craton. Fischel (1998) obtained two sets of Sm-Nd model ages (T_{DM}), an older one from 3.02 to 3.26 Ga, and a younger one from 2.53 to 2.64 Ga. Brueckner et al. (2000) obtained model ages between 2.78 and 2.83 Ga using the same method. Recently, Silva et al. (2002), based on U-Pb SHRIMP data in orthogneisses of Mantiqueira Complex, suggest a significant addition of Paleoproterozoic rocks to the complex between 2.21 and 2.05 Ga. These authors have also found records of two metamorphic events around 2.1 Ga and 560 Ma, that would correspond to the Transamazonian and Brasiliano events, respectively. According to Fischel (1998) and Brueckner et al. (2000), Sm-Nd isochrons from mineral phases and whole rock yield metamorphic ages between 781 and 528 Ma. K-Ar ages fall between 479 and 525 Ma, indicating cooling related to the Brasiliano event (Machado F^o et al. 1983, Teixeira et al. 1987).

PEDRA DOURADA CHARNOCKITE

The Pedra Dourada Charnockite comprises metaigneous and metasedimentary rocks of granulite facies. The composition of the metaigneous rocks range from charnockitic to gabbroic. Relictic igneous microstructures are partially overprinted by subsequent metamorphic and deformational processes (Jordt-Evangelista et al. 1994, Jordt-Evangelista 1996). These rocks occur as a large intrusive body in the Mantiqueira gneisses in the central part of the study area, near the Rio Doce town (Fig. 3 and 4), and also as smaller bodies in nearby localities. They contain xenoliths of metamafic rocks and of the Mantiqueira gneisses.

The M_1 phase, recorded by growth or recrystallization of biotite, amphibole, feldspar and quartz, is retrometamorphic in respect to the granulite facies metamorphism. Amphibole and muscovite aureoles, respectively, around pyroxene and kyanite, are also manifestations of the M_1 phase, indicating re-equilibrium at lower metamorphic conditions.

The metamorphic paragenesis observed in the metapelitic rocks include K-feldspar + kyanite, allowing their classification as high-pressure granulites. Jordt-Evangelista et al. (1994) and Jordt-Evangelista (1996) obtained temperatures between 620 and 716°C (average 670°C) and pressures around 7.3 kbar (~ 27 km depth) for the granulite facies metamorphism. Rettinger et al. (1998) determined temperatures between 547 and 679°C and pressures in the range of 7.0 to 10.8 kbar for the same metamorphic process.

No geochronological data are available for this unit; the understanding of its tectonic significance demands further investigations.

BORRACHUDOS GRANITOID

The Borrachudos Granitoid of Dorr and Barbosa (1963), or the Borrachudos Suite of Grossi-Sad et al. (1990), consists of metagranitic rocks that occur to the east of the southern Serra do Espinhaço (Fig. 3 and 4). They intrude the gneisses of the Mantiqueira Complex and are in some places thrust over or tectonically juxtaposed to supracrustal units

associated with the Rio das Velhas Supergroup and the Dom Silvério Group. The stratigraphic relationships between the Borrachudos Granitoid and the Dom Silvério Group are unknown.

The hololeucocratic Borrachudos alkali-granitoids shows restrict mineralogical variation. Microcline, nearly pure albite and quartz are its main components. Biotite and hornblende are the mafic mineral phases. Macroscopically they are very homogeneous, medium to coarse grained and always foliated. Discrete shear zones, marked by variable degrees of gneissification, are very frequent. In these shear zones, hornblende and biotite form fish-shaped aggregates.

The microstructures observed in the granitoids suggest a syn-deformational, amphibolite facies metamorphism, recording thus the M_1 metamorphism in the same conditions as observed in the Dom Silvério and Mantiqueira rocks.

Dussin et al. (1994), Fernandes et al. (1994), Pedrosa-Soares and Wiedemann-Leonardos (2000) and Dussin (2000) interpreted the Borrachudos rocks as the product of an anorogenic magmatism associated with the Paleoproterozoic (~ 1.75 Ga) Espinhaço rifting. Geochronological data obtained by Dussin et al. (1994), Chemale Jr et al. (1998), Fernandes et al. (2000) and Silva et al. (2002) support this interpretation, indicating crystallization ages around 1.7 Ga. Based on U-Pb geochronological data, Fernandes et al. (2000) showed that the main metamorphism recorded in the Borrachudos Granitoid took place around 600 Ma, i.e. associated to the Brasileiro Event.

GEOLOGIC ARCHITECTURE OF THE SOUTHERN ARAÇUAÍ BELT

The main components of the architecture of the southern Araçuaí belt are four major shear zones, which in turn delimit four compartments of distinct internal fabrics. The Abre Campo, Ponte Nova, Dom Silvério and Pedra Branca shear zones, occurring in this order from east to west (Fig. 4), are described below together with the compartments between them.

THE ABRE CAMPO SHEAR ZONE

The Abre Campo shear zone extends over ca. 300 km between Governador Valadares, to the north, and Juiz de Fora, to the south, showing in its central portion an average width of 5 km (Fig. 3 and 4). It is the surface expression of a remarkable gravimetric and magnetic anomaly (Haralyi and Hasui 1982) that separates the Archean/Paleoproterozoic rocks of the Mantiqueira Complex, to the west, from the Juiz de Fora and Paraíba do Sul complexes, respectively of Paleo and Neoproterozoic ages, to the east (Machado et al. 1996, Fischel 1998, Silva et al. 2002). Fischel (1998) points out that this zone also delimits units with different metamorphic and deformational histories, interpreting it as a Neoproterozoic suture zone.

Within the shear zone, domains with high angle foliation progressively grade into domains with intermediate to low angle foliation dipping to the east. Shear sense indicators show predominant dextral displacement; indicators of opposite sense can be, however, occasionally found.

Together with the Abre Campo, other major dextral strike-slip shear zones form the main components of the tectonic scenario of the crystalline core of the Araçuaí-West Congo orogen, among them the Manhuaçu, Guaçuí and Batatais shear zones (Cunningham et al. 1998).

THE PONTE NOVA SHEAR ZONE

The Ponte Nova shear zone displays in map view a sinuous trace with an overall N-S orientation in the southern and central portions of the study area. To the north it also bends towards NE, reaching the Abre Campo shear zone, to which it is linked (Fig. 4). The Ponte Nova shear zone is an approximately 150m thick brittle-ductile, low-angle thrust shear zone, whose topographic expression is very modest, not being evident in satellite images or aerial photographs. Despite this, the Ponte Nova shear zone exerts a strong control on the course of the Piranga and Doce rivers north of the Ponte Nova town. The interior and the hanging-wall of the Ponte Nova

shear zone are dominated by west-verging folds in association with smaller scale shear zones.

THE GUARACIABA SYNCLINORIUM

Together with underlying Mantiqueira gnaisses, the Dom Silvério Group metasediments occur in a large, open and slightly asymmetric west-verging synform, the Guaraciaba synclinorium. Defined by the trajectory of the gneissic foliation and compositional layering of the units involved, this structure has a maximum width of 15 km, narrowing down to the north (Fig. 4 and 6). To the west, the synclinorium is bounded by the Dom Silvério, and to east, by the Ponte Nova shear zones. Close to the latter, the compositional layering is sub-horizontal or affected by open west-verging folds. On the west limb, near the Dom Silvério shear zone, there is an intensive parasitic folding.

Along the Guaraciaba synclinorium cross-sections, the Dom Silvério metasediments are involved in a series of large scale double-plunging and NS-trending folds (Fig. 6). This results in an alternation of synformal depressions and antiformal culminations, dominated by the Dom Silvério and Mantiqueira rocks respectively.

THE DOM SILVÉRIO SHEAR ZONE

The Dom Silvério shear zone was originally described by Endo (1997) as a dextral strike-slip shear zone, generated during the Paleoproterozoic Transamazonian event and later reactivated during the Brasiliano orogenies.

The Dom Silvério shear zone extends for at least 100 km in a N-S direction in the southern and central portions of the study area. North of the Carmo River, near the town of Ipatinga, it bends towards NNE, merging with the Abre Campo shear zone (Fig. 4). Showing a width of 1 to 4 km, the Dom Silvério is a high angle structure, whose topographic expression is a series of aligned hills making up the region's highest altitudes.

Movement recorded within the Dom Silvério zone is mostly sinistral, as attested by the vast majority of shear sense indicators.

PEDRA BRANCA SHEAR ZONE

The Pedra Branca shear zone is located in the external portion of the southern Araçuaí belt, extending in a NNE direction from the vicinity of the Itabira town up to Dores de Guanhães (Fig. 4). A series of splays with mostly NW-SE traces are connected to the main zone. Its internal portions are characterized by a mylonitic foliation that dips steeply to WNW. The rake of associated stretching lineation varies between 0 and 50°. Dextral normal displacements predominate; however, older, partially overprinted reverse-sinistral shear sense indicators can be occasionally observed. An intense hydrothermal alteration associated with retrometamorphism characterizes the central portion of the zone.

DEFORMATION HISTORY IN THE SOUTHERN ARAÇUAÍ BELT

Four deformation phases affected the Mantiqueira, Borrachudos and Dom Silvério rocks in the southern Araçuaí belt, as indicated by crosscut relationships among structures of different scales. These phases are:

- D₁: North-directed tectonic transport in association with the M₁ amphibolite facies metamorphism;
- D₂: West-verging folding and thrusting associated with the development of a dextral transpressional system in the crystalline core and the M₂ greenschist facies metamorphism;
- D₃: Coaxial refolding of the structures from the previous phase;
- D₄: Normal faulting and normal reactivation of pre-existing shear zones.

STRUCTURES OF THE D₁ PHASE

The D₁ structures are dominant in the southern Araçuaí belt. The S₁ foliation and the associated L₁ mineral and stretching lineation are the main fabric elements of this phase. The previous described Abre Campo, Dom Silvério and Pedra Branca shear zones also nucleated in the course of D₁ deformation.

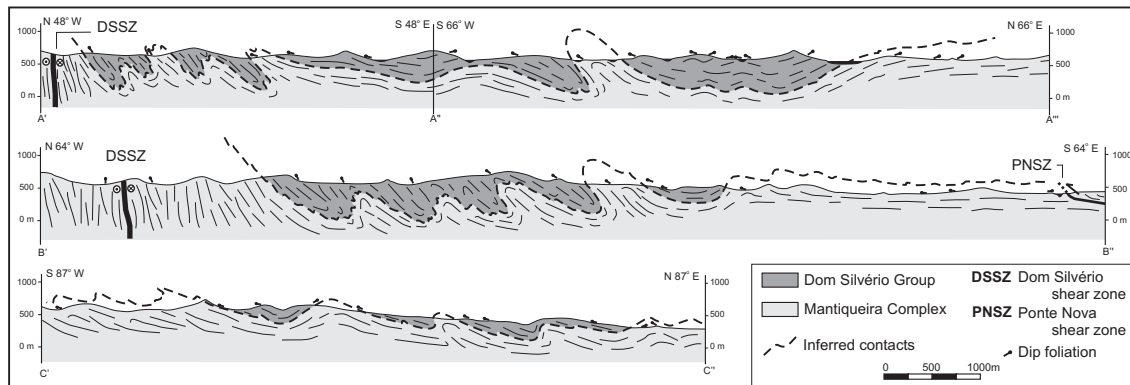


Fig. 6 – Simplified cross-sections of the Guaraciaba Synclinorium. The location of the section is indicated in Figure 4.

The S_1 foliation pervasively affects all previously described units. In the gneisses of the Mantiqueira Complex and in the Dom Silvério metasediments, S_1 parallels the gneissic banding and the compositional layering. In the Borrachudos Granitoid S_1 is well defined by the planar arrangement of biotite clusters and by the flattening and stretching of quartz and feldspar aggregates. S_1 is in general a sub-horizontal surface overprinted by D_2 structures in variable intensity. In the stereographic diagrams of Figure 7, the poles to S_1 describe a broad girdle around a N-S oriented axis. This distribution results from the F_2 folding of S_1 throughout the study area. S_1 shows steeper dips ($50-90^\circ$) near the Dom Silvério and Abre Campo shear zones.

The S_1 foliation contains the stretching and mineral lineation L_1 , which is marked by the elongation of recrystallized quartz, mica and feldspar grains, by the long axis of quartz and feldspar ribbons, as well as by the preferential orientation of amphibole, kyanite and staurolite.

In the Guaraciaba synclinorium, L_1 shows gentle plunges to the north and to the south (Fig. 7 and 8). Between the Ponte Nova and Abre Campo shear zones, L_1 , a relict fabric element, is rarely observed. In the Borrachudos Granitoid near the town of Ipatinga L_1 is defined by the stretching of grains and aggregates of quartz, microcline and biotite in the N-S direction (Fig. 7 and 8). To the west of the Dom Silvério shear zone, L_1 inflects progressively

towards NW and W, becoming E-W oriented close to the Quadrilátero Ferrífero and the southern Serra do Espinhaço (Fig. 7 and 8).

Porphyroclast tails and foliation sigmoids are the most common shear sense indicators among many others associated to S_1 and L_1 . Over the major part of the study area and especially in the interior of the Guaraciaba synclinorium, these structures attest an overall top-to-the-north motion along a sub-horizontal surface. To the west of the Dom Silvério shear zone, the D_1 structures record motion to NW and W along curved trajectories (Fig. 8).

The syn-kinematic growth of staurolite, kyanite, micas and amphiboles associated with the development of S_1 and L_1 indicates that metamorphic conditions of the D_1 phase attained the amphibolite facies and represents a manifestation of the M_1 regional metamorphism.

Folds associated with D_1 are intrafolial and rare. They are restricted to the gneissic rocks of the Mantiqueira Complex, where they normally show disrupted limbs and S_1 a their axial planar foliation.

The age of the D_1 phase can be given by the age of the M_1 metamorphism, as documented by Machado F^o et al. (1983), Teixeira et al. (1987), Fischel (1998), Brueckner et al. (2000), Fernandes et al. (2000) and Silva et al. (2002). These geochronological data define, however, a large spectrum of ages between 781 and 479 Ma. A careful analysis of the data indicates a significant concen-

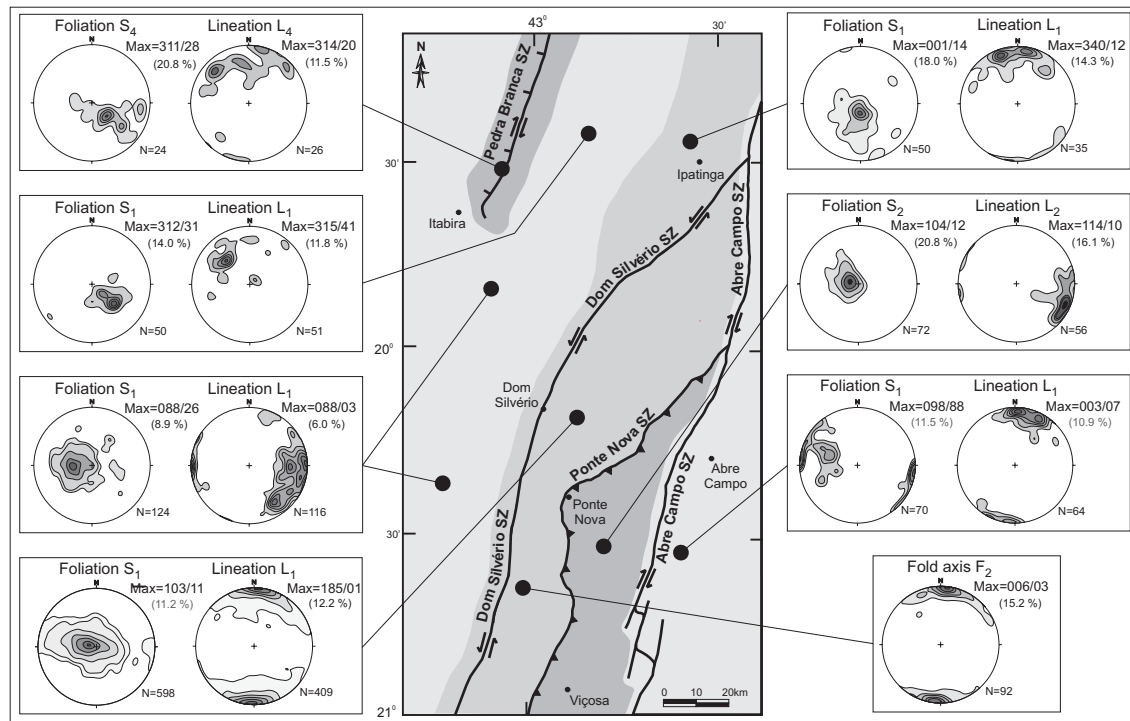


Fig. 7 – Stereographic diagrams of D_1 , D_2 and D_4 structures in the study area.

tration of ages between 580 and 560 Ma. that can be assumed as the time interval of the D_1 phase.

STRUCTURES OF THE D_2 PHASE

The D_2 phase was responsible for the generation of the Guaraciaba synclinorium and the Ponte Nova shear zone. However, the folds are the most conspicuous structures of the D_2 phase. Trains and cascades of F_2 folds of various scales can be observed within and outside the Guaraciaba synclinorium. F_2 folds are typically conical with double plunges to the north and to the south (Fig. 7). They are west verging or show upright axial surfaces. Inclined or even recumbent folds are less common. The frequency, wavelengths and spatial distribution of F_2 folds vary systematically from east to west throughout the Guaraciaba synclinorium, as shown by the cross-sections of Figure 6. F_2 folds are, in general, asymmetric, gentle to open and show east dipping axial surfaces in the east limb of the synclinorium, becoming, however, progressively tighter

with smaller wavelengths and upright axial surfaces towards west. This distribution of F_2 folds shows a close relationship to the Dom Silvério shear zone, which apparently forms an obstacle to the propagation of the D_2 deformation front. Beyond the Dom Silvério shear zone (Fig. 4 and 7) the F_2 folds gradually attenuate.

In the vicinity of the Ponte Nova shear zone, the F_2 folds occur with tight to isoclinal shapes, frequently with disrupted hinge zones. A S_2 foliation developed as axial planar cleavage of the F_2 folds. S_2 is a curvilinear surface with shallow dips to the east (Fig. 7), usually representing a reactivation of S_1 . The components of the latter are re-oriented to form the L_2 stretching and mineral lineation. L_2 and also S_2 have been observed only in Mantiqueira gneisses in the compartment bounded by the Ponte Nova and Abre Campo shear zones (Fig. 4). These structures also delimit the occurrence of the M_2 metamorphic phase in the study area, to which S_2 and L_2 are genetically related.

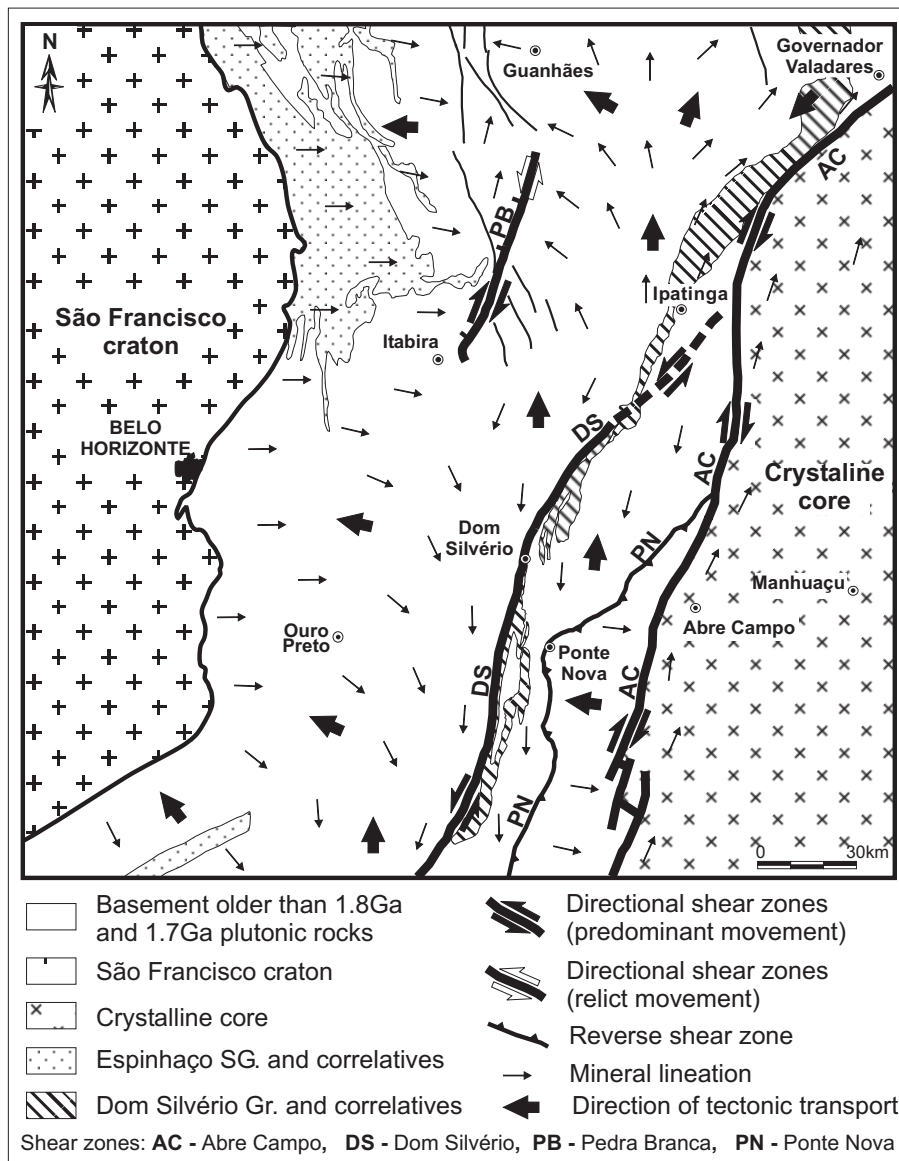


Fig. 8 – Simplified tectonic map of the southern Araçuaí belt.

In the gneisses of the Ponte Nova region, L_2 appears as an E-plunging mineral and stretching lineation (Fig. 7). Blastesis and recrystallization of quartz, chlorite and micas, especially biotite, in association with deformation of quartz and feldspar grains are the processes involved in the development of both S_2 and L_2 . Microstructures related to S_2 and L_2 reveal a partial brittle behavior, especially on plagioclase grains that show deformed twins and

fractures. S_2 is commonly a mylonitic foliation.

D_2 microstructures indicate lower P-T conditions than those related to the generation of S_1 , being compatible with greenschist facies metamorphism (M_2). Retrometamorphic reactions such as saussurization and sericitization confirm this interpretation.

No specific geochronological data are available for D_2 . However, the D_2 deformation and associated

metamorphic reactions must be younger than the upper limit established for D₁, i.e. 560 Ma.

STRUCTURES OF THE D₃ PHASE

The deformational phase D₃ has been individualized merely by geometrical relationships, since there is no change in the kinematic field or in the rheological behavior of the materials in respect to the previous D₂ phase. D₃ phase structures consist of a second family of W-verging folds superimposed on the F₂ generation. They can be rather interpreted as progression of D₂. F₃ folds are more frequent in the interior of the Guaraciaba synclinorium and in the region to the east of the Ponte Nova shear zone.

STRUCTURES OF THE D₄ PHASE

Discrete occurrences of D₄ structures were observed throughout the whole study area. They display a better expression in the region northeast of the town of Itabira, in the interior and in the lateral splays of the Pedra Branca shear zone. The Pedra Branca shear zone, generated during D₁, underwent major reactivation in the course of D₄ (Figs. 4, 7 and 8). The S₄ foliation is characteristically mylonitic, associated to an intense process of retrometamorphism. It occurs as WNW-dipping surfaces (Fig. 7) defined by the preferred orientation of micas and the elongation of various mineral aggregates.

The retrometamorphic character of the reactions associated with the development of the D₄ structures is attested by abundant muscovite/sericite in quartz-feldspathic protolithes, as well as the presence of chlorite, biotite, phlogopite, antophyllite and actinolite in the mafic and ultramafic rocks of the beryliferous district of Itabira-Nova Era (Machado and Schorscher 1997). Reactions associated with D₄ structures suggest greenschist facies conditions for their development.

The stretching lineation L₄ is genetically associated with S₄ and has a NNW-SSE bearing and shallow plunges. L₄ is defined by the stretching of quartz grains and by the oriented growth of biotite, muscovite, and chlorite.

Other D₄ structures are F₄ folds of variable

scales, S₄ crenulation cleavages and slickensides on brittle-ductile shear zones. These structures indicate dominant dextral shear sense, with a significant normal component.

Ar-Ar ages of 509 ± 2 Ma (Ribeiro-Althoff et al. 1997) and Rb-Sr ages of 480 Ma (Preinfalk et al. 2002) were obtained in biotites/phlogopites associated with emerald mineralizations within the Pedra Branca shear zone. These ages probably reflect the time when D₄ took place.

TECTONIC SIGNIFICANCE OF THE DOM SILVÉRIO GROUP AND AN EVOLUTIONARY MODEL FOR THE SOUTHERN ARAÇUAÍ BELT

The Dom Silvério sequence includes marbles, manganeseiferous and graphitic rocks, banded iron formations in association with thick packages of pelitic schists are evidences for a marine environment during deposition of these sediments. The absence of coarse grained siliciclastics and the relative small volume of sands suggest that this environment could be a distal marine platform or oceanic floor, in both cases, sites of distal clastic and chemical deposition. Brandalise (1991) carried out a geochemical study of the amphibolitic rocks intercalated into the Dom Silvério Group. He interpreted them as alkaline tholeiites generated in an island arc environment. Metaultramafic and amphibolitic intercalations at the base of the Dom Silvério Group favor the hypothesis that this unit represents a deep marine assembly, possibly containing some slices of the oceanic floor.

Pedrosa-Soares and Wiedemann-Leonardos (2000) and Pedrosa-Soares et al. (2001) suggest a correlation between the Dom Silvério Group and the Neoproterozoic Rio Doce Group and Ribeirão da Folha Formation (according to Lima et al. 2002), thereby forming an extensive and continuous belt in the more internal portions of the Araçuaí belt. From an even broader perspective, a possible correlation of the mentioned units with the Araxá and Andrelândia groups (Seer et al. 2001) of the southern Brasília belt would compose an extensive belt of rocks of ophiolitic affinity, characterizing thus the record of a

Neoproterozoic ocean, continuous around the southern lobe of the São Francisco craton (Fig. 9). Later in the Neoproterozoic, the branches of this ocean would undergo diachronic closure, giving rise to the development of the southern Brasília and Araçuaí belts.

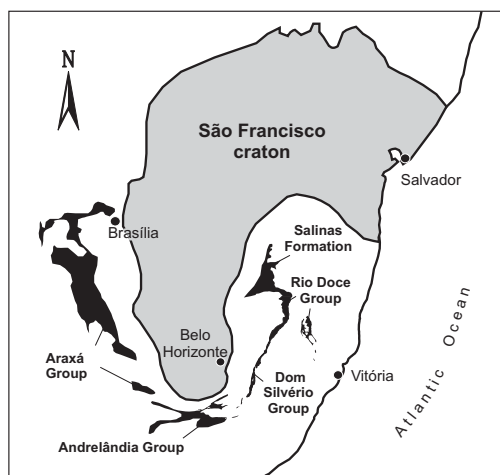


Fig. 9 – Simplified map showing the localization of the metasedimentary belt around the southern lobe of the São Francisco craton.

Based on the data obtained in the present study and those available in the literature, we postulate the following model for the tectonic evolution of the southern Araçuaí belt in the course of the Brasiliano event.

The first deformation phase (D_1), followed by regional amphibolite facies M_1 metamorphism, reflects conditions of the transition between the lower and upper crust, recording an overall north-directed tectonic motion (Fig. 10). Having in mind the spatial distribution of the D_1 fabric elements, we interpret this phase as the first stage of the closure of the ocean branch to the east of the São Francisco craton due to a northward moving indenter. In this scenario, the Abre Campo (dextral) and Dom Silvério (sinistral) shear zones together with the compartment in-between would represent the lateral ramps and root zone of the north-moving indenter (Fig. 10 and 11). Taking the Abre Campo shear zone as a suture it would be the site of an oblique NNE directed subduction.

The D_2 phase, developed in ductile to brittle-ductile regime and associated to the M_2 greenschist facies metamorphism can be viewed as a product of a contractional event. After ceasing the NNE directed subduction, the development of the southern Araçuaí belt progresses as a general E-W shortening, synchronous or immediately followed by the southward escape of internal portions of the orogen along a system of dextral shear zones. The west-verging folds and thrusts were then nucleated. The high angle segment of the pre-existent Dom Silvério shear zone probably acted as an obstacle to the progression of the D_2 front, therefore imposing a local amplification of F_2 folds (Fig. 11b, 11c and 11d). During this phase, besides folding, the D_1 structures also experienced reactivation or complete transposition, especially in the compartment between the Ponte Nova and Abre Campo shear zones. As mentioned before, the D_3 deformation phase is here considered a progression of the previous phase, reflecting the same kinematics.

The fourth deformational phase (D_4) would be the product of the collapse of the Araçuaí orogen, representing the structures and processes described by Alkmim et al. (2002) in the northern portion of the Araçuaí belt.

The model presented above portrayed the development of the southern Araçuaí belt as resulting basically from displacements along strike, accommodated in high and low angle shear zones, nucleated in the transition zone between the upper and lower crust. The overall picture of the Araçuaí orogen reveals, however, that frontal displacements dominate in the shallower and external portions of the belt.

CONCLUSIONS

The Dom Silvério Group comprises an approximately 10 km wide belt that extends in a NNE direction for about 150 km in eastern Minas Gerais (Fig. 3). The Dom Silvério rocks represent distal marine deposits, probably corresponding to an ocean floor. The geochemical signature of the as-

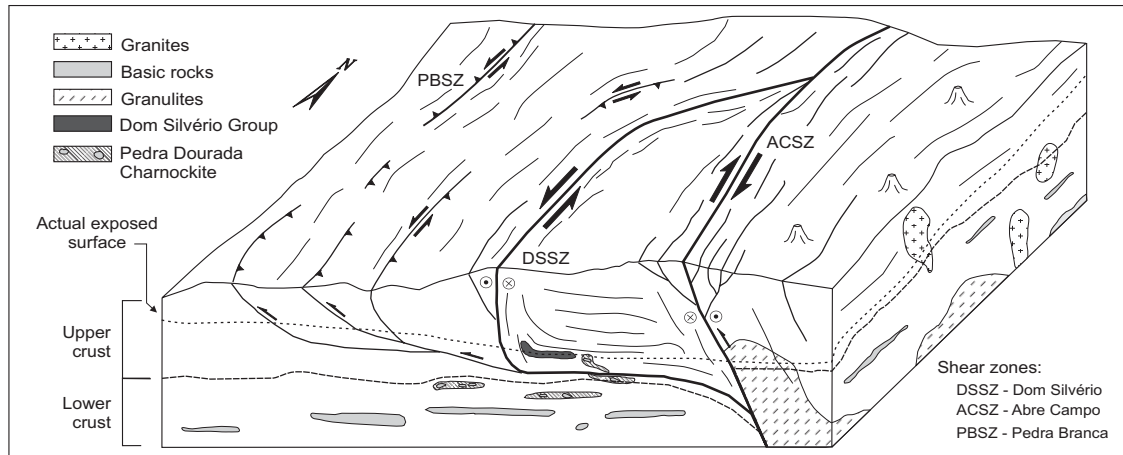


Fig. 10 – Model for the tectonic evolution of the southern portion of the Araçuaí belt during D₁ phase.

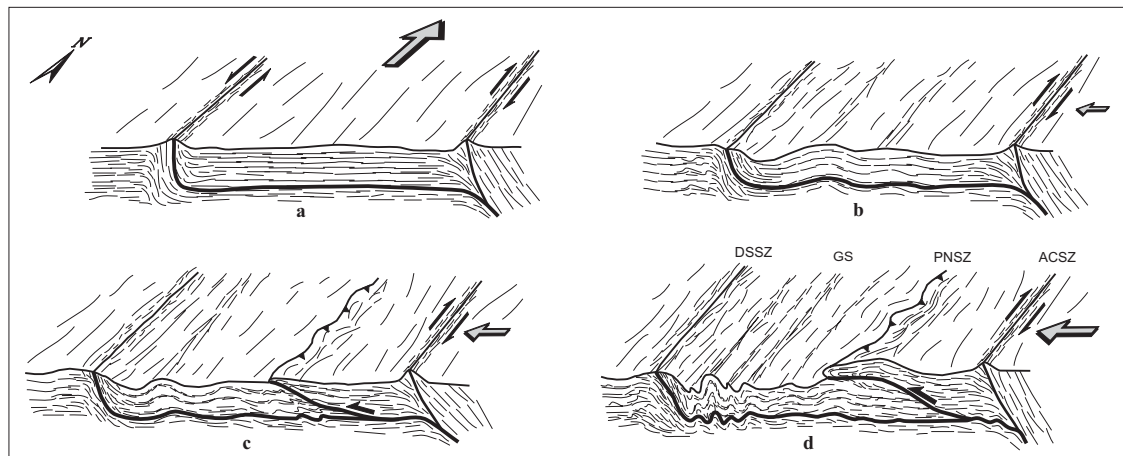


Fig. 11 – Model for the tectonic evolution of the central portion of the studied area, between the Dom Silvério and Abre Campo shear zones during D₁ and D₂ phases.

sociated amphibolitic rocks is an evidence of the oceanic affinity of its basaltic protholites (Brandalise 1991). Typical ophiolitic rocks were not yet found in this unit.

A connection between the Dom Silvério Group, Rio Doce Group and Ribeirão da Folha Formation, thereby making a long and continuous belt of metasediments to the east of the São Francisco craton, was proposed by Pedrosa-Soares and Wiedemann-Leonardos (2000). This metasediments belt would record the existence of a restricted Neoproterozoic ocean – the termination of the Adamastor ocean de-

veloped around 800 Ma (Trompette 1997, Pedrosa-Soares et al. 1998) – whose closure would have originated the Araçuaí-West Congo orogen.

The tectonic structures shown by the rocks of the Dom Silvério Group and associated units were developed in four phases of deformation here attributed to the Brasiliano event. The main phase, D₁, was associated to the movement of a crustal fragment towards north, coupled to a NE-directed subduction along a roughly NS zone, the present-day Abre Campo discontinuity. The available geochronological data indicate that this phase took

place in the period between 580-560 Ma. Subsequent D₂ and D₃ deformational phases are compatible with general contractional deformation during the end stages of the tectonic collage of East Gondwana. The final D₄ phase reflects the collapse of the Araçuaí-West Congo orogen already in the Phanerozoic, with estimated ages around 509-480 Ma.

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RESUMO

A Faixa Araçuaí corresponde à porção ocidental externa do orógeno neoproterozóico Araçuaí-Congo Ocidental. Margeia a borda leste do Cráton do São Francisco e é separada do núcleo cristalino do orógeno pela descontinuidade geofísica de Abre Campo. A porção meridional da Faixa Araçuaí envolve quatro unidades litológicas principais: os ortognaisses arqueanos e paleoproterozóicos do Complexo Mantiqueira, os charnoquitos Pedra Dourada, os granitóides paleoproterozóicos da Suíte Borrachudos e as rochas metavulcanossedimentares do Grupo Dom Silvério. O Grupo Dom Silvério ocorre em uma faixa NNE-SSW e engloba um pacote de rochas metapelíticas com intercalações de quartzitos, anfibolitos, metaultramáficas, formações ferríferas, gonditos e mármores. Todas as unidades da porção meridional da Faixa Araçuaí foram envolvidas em quatro fases deformacionais sinmetamórficas no curso do Evento Brasileiro. A primeira fase, sincrônica a um metamorfismo regional de fácies anfibolito, associou-se a um transporte tectônico geral para norte ao longo da zona de cisalhamento sinistral de Dom Silvério e no segmento de baixo ângulo a ela conectado. A segunda e terceira fases representam estágios progres-

sivos de um encurtamento com movimentação geral para oeste, com desenvolvimento de empurrões localizados e intenso dobramento em todas as escalas. A quarta fase é extensional e reflete o colapso do orógeno.

Palavras-chave: Orógeno Araçuaí-Congo Ocidental, Faixa Araçuaí, Grupo Dom Silvério, Evento Brasileiro.

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