TECTONO-LITHOLOGIC ASSOCIATIONS OF THE ALTEROSA PALEO SUTURE ZONE – SOUTHEASTERN BRAZIL

ASSOCIAÇÃO TECTONO-LITOLÓGICA DA PALEOZONA DE SUTURA ALTEROSA- SUDESTE DO BRASIL

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Abstract: Along the Alterosa Paleosuture Zone occurs a metavolcanosedimentary sequence associated to orthogneisses and syn- to tardi- tectonic granites. Intercalations of mafic and ultramafic rocks with lenses of iron formations are interpreted as ophiolites. The rocks units that crop out in the Northern and the South portions of the Alterosa suture zone were juxtaposed during Neoproterozoic continental collision when the Archaean terrenes and Neoproterozoic metasedimentary rocks were overthrusted by Guaxupé Complex resulting in present geological scenario.In the Northern of Alterosa suture an Archaean gneissic-granitic-greenstone terrene crops out, locally crosscut by Paleoproterozoic intrusive basic rocks or covered by Neoproterozoic platform metasedimentary rocks. This association was inhomogeneous affected by the Neoproterozoic tectono-metamorphic processes in the greenschist facies environment. In the south of Alterosa suture the lower crust of the obducted plate crops out, constituted by basic to acid granulites, syn-tectonic granitoid rocks and metasedimentary intercalations. In side this domain, the metamorphic peak reached temperatures over 950ºC and pressures of the order of 15 kbar, as shown by uplifted portions during the movement to the East. Along the Alterosa suture zone the metamorphism was stronger in the Southern portion, where pressures higher than 15 kbar and temperatures of the order of 800ºC were reached.

Keywords: Metamorphism. Guaxupé Complex. Proterozoic continental collision. Alterosa Paleo Suture Zone. Overthrusted Terrenes.

Resumo: Na Sutura de Alterosa ocorre uma seqüência metavulcanossedimentar intercalada com ortognaisses, granitos sin- a tardi-tectônicos e intercalações tectônicas de rochas máficas e ultramáficas, às vezes associadas com formações ferríferas, interpretadas como ofiólitos. As unidades que afloram a norte e a sul da zona de sutura de Alterosa foram justapostas durante uma colisão continental que ocorreu no Neoproterozóico. Nesse processo, os terrenos arqueanos e as rochas metassedimentares neoproterozóicas foram cavalgados pelo Complexo Guaxupé, resultando na atual configuração geológica. A norte da Sutura de Alterosa afloram os terrenos gnáissicos-graníticos-greenstone arqueanos, cortados localmente por rochas básicas intrusivas paleoproterozóicas ou cobertos por metassedimentos neoproterozóicos de origem plataformal. Essa associação foi afetada de maneira heterogênea, em ambiente de fácies xisto verde, pelos processos tectono-metamórficos neoproterozóicos. A sul da Sutura de Alterosa aflora a crosta inferior da placa obductada, constituída por granulitos básicos a ácidos, granitóides sin-tectônicos e intercalações metassedimentares. Nesse domínio, o auge metamórfico, exibido por porções soerguidas durante a movimentação para leste, atingiu temperatura superior a 950ºC e pressão da ordem de 15 kbars. Na Sutura de Alterosa, o metamorfismo foi mais forte na parte sul, atingindo temperatura da ordem de 800ºC e pressão superior a 15 kbars.

Palavras-chave: Metarmorfismo. Complexo Guaxupé. Colisão continental proterozóica. Zona da Paleostura Alterózia. Terrenos Cavalgados.

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INTRODUCTION

This paper describes the petrographic evolution of different Precambrian lithologies that crop out along the Alterosa paleo suture and adjacent units, based on field, laboratory and existing data in the literature. The area in focus is adjacent to the southern border of the São Francisco Craton and it is geographically placed in southeastern Brazil, situated between the 20°45' and 22°30'S parallels and 45° and 47°W meridians (Figure 1).

Two continental tectonic blocks were recognized: one is the Overthrusted Terrenes, constituted by Archaean terrenes (Barbacena Complex, Amparo Group and Greenstone Sequence), reworked during younger geotectonic cycles and affected by shear zones. Those Archaean terrenes were partially covered by supracrustal allochthonous (Araxá, Canastra, Itapira, Andrelândia, São João del Rei Groups, etc.) and autochthonous to parautochthonous (Bambuí Group) sequences syn- to tardi-collision (Figures 2 and 3).

The other continental block that overthrusts the previous one promoted the exposition of rocks from the lower to upper crust partially to strongly modified by anatexis, partial melting and injections of acid to intermediate compositions (Guaxupé and Socorro Complexes), all of them syn-kinematic to the low angle shear zones of the collisional process.

The two continental tectonic blocks are joined by the Alterosa Paleo Suture Zone composed by metasedimentary psamo-pelitic sequence, ophiolitic sequence and orthogneisses and granitoids.

Late shear belts were established deforming the previous structural framework and reactivating locally preexisting shear zones, remarkable in the southern portion of the gneissic-granitic-greenstone terrene, where older shear zones that produced amphibolite facies paragenesis were reactivated, promoting recalibration to greenschist facies conditions.

GEOLOGIC SETTING

The Guaxupé Complex has a triangular shape form that was considered as a Median Massif (Guaxupé Massif) by Almeida et al. (1976). This complex was tectonically emplaced between other tectono-stratigraphic units that were juxtaposed during Neoproterozoic continental collision. Campos Neto and Caby (1999) divide this unit in Socorro-Guaxupé nappe and high-pressure kyanite granulite nappe, regarded the Southern Tocantins Orogenic System with Neoproterozoic age (CAMPOS NETO, 2000) or Brasilía Belt (TROUW et al., 2000). The Guaxupé Complex is bounded by two shear belts, a sinistral one at its N/NE margin (Campo do Meio Shear Belt) and a dextral one at its SE margin (Ouro Fino Shear Belt) (Figure 2).

North of Guaxupé Complex a metavolcanosedimentary belt occurs associated with pre- to syn- tectonic orthogneisses emplaced during a sinistral shear deformation. This belt is large in the order of 20 km and it was interpreted by Zanardo (1992) as belonging to the Araxá Group, an allochthonous sequence; towards south and southeast, the strata were considered by Trouw et al. (1984) as the continuation of the Andrelândia and São João del Rei Groups. The Araxá Group and the Guaxupé Complex are separated by the Varginha Shear Zone (Figure 4) with sub vertical straike-slip sinistral characteristic (MORALES, 1993). Along a southeastward inflection this shear zone exhibits locally frontal ramp characteristics with possible uplift of deep level blocks (DEL LAMA, 1998; DEL LAMA et al., 2000). Northwards, this allochthonous sequence (Araxá Group) is in high- to low-angle tectonic contact with Archaean gneissic-granitic-greenstone terrenes that are locally overlain by low metamorphic grade covers - Bambuí Group (HEILBRON et al., 1987; SIMÕES; VALERIANO, 1990; VALERIANO, 1993; SIMÕES, 1995). Along this contact between the Araxá Group and the Archaean terrenes countless of tectonic intercalations of ultramafic rocks occur, forming a concordant belt interpreted as an ophiolitic sequence (SOARES et al., 1990; ZANARDO, 1992; ROIG, 1993; ZANARDO et al., 1996b) - Figure 3.

This portion is also marked by an important geophysical discontinuity (DAVINO, 1979; ALMEIDA et al., 1980) which joins the Guaxupé Complex (South) and the Archaean terrenes (Barbacena Complex and Greenstone sequence) and supracrustal sequences (Araxá, Canastra and Bambuí groups) in the North and was affected by the Campo do Meio Shear Belt (CAVALCANTE et al., 1979; HASUI et al., 1990). This 25 km large belt shows ductile to brittle features and sinistral strike-slip characteristic. It affects only a narrow strip of the Guaxupé Complex and a large strip of the Neoproterozoic supracrustal lithologies related to the Araxá and Andrelândia Groups. The São Francisco craton is covered north and northwest by the

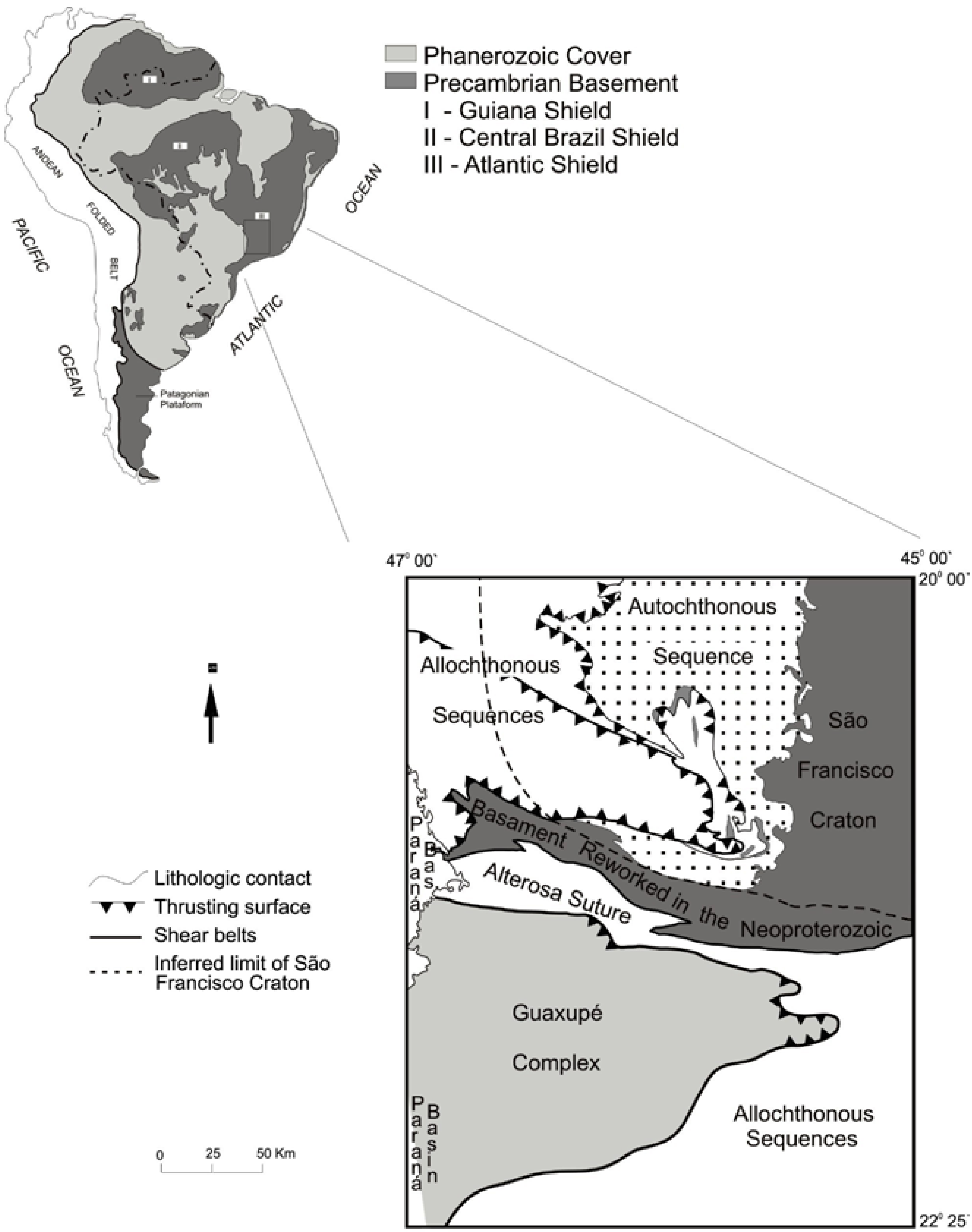

FIGURE 1: Map of Alterosa Suture Zone.

FIGURA 1: Mapa da Zona de Sutura Alterosa.

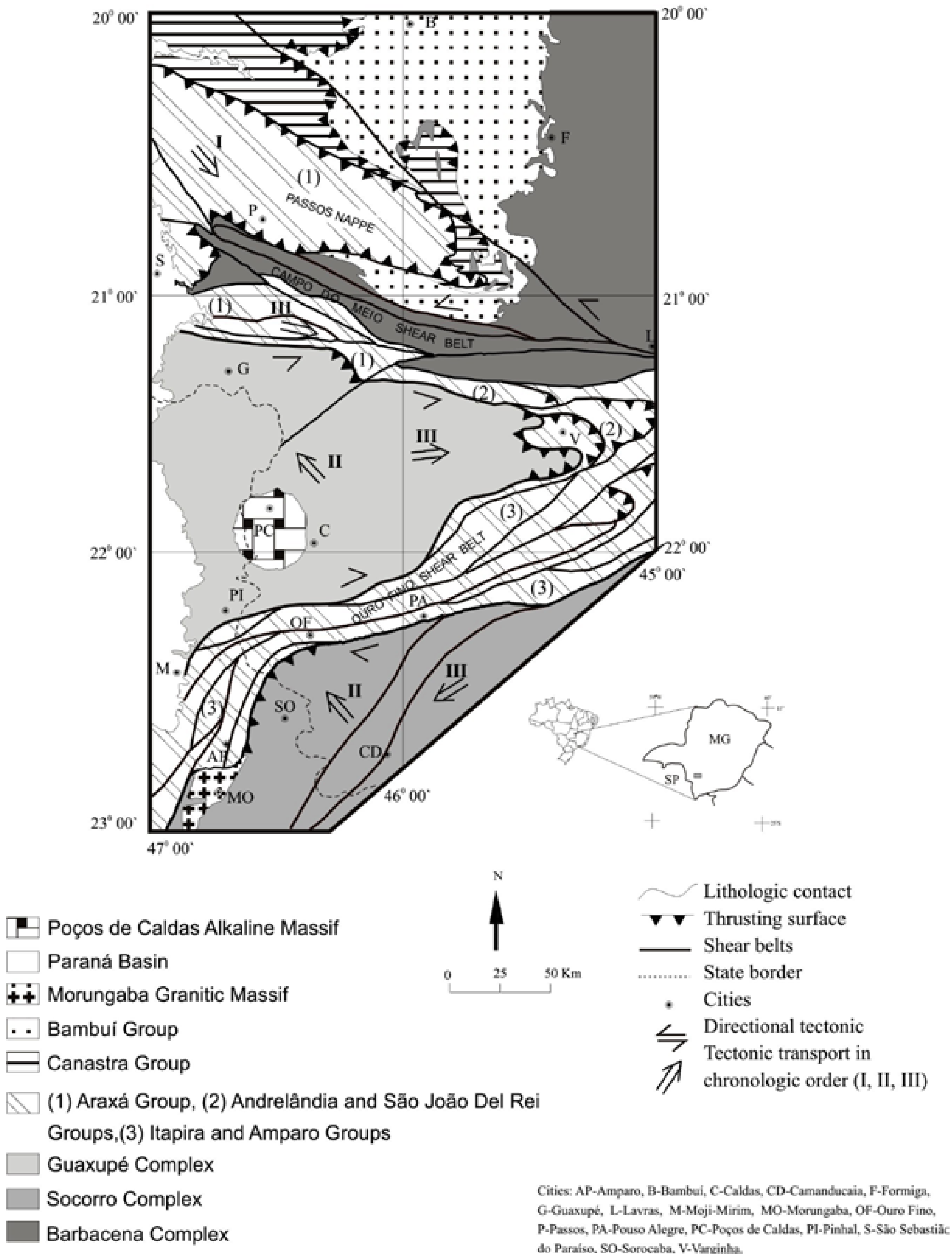

FIGURE 2: Schematic geological map (adapted from FONSECA et al., 1979).

FIGURA 2: Mapa geológico esquemático (Adaptado de FONSECA et al., 1979).

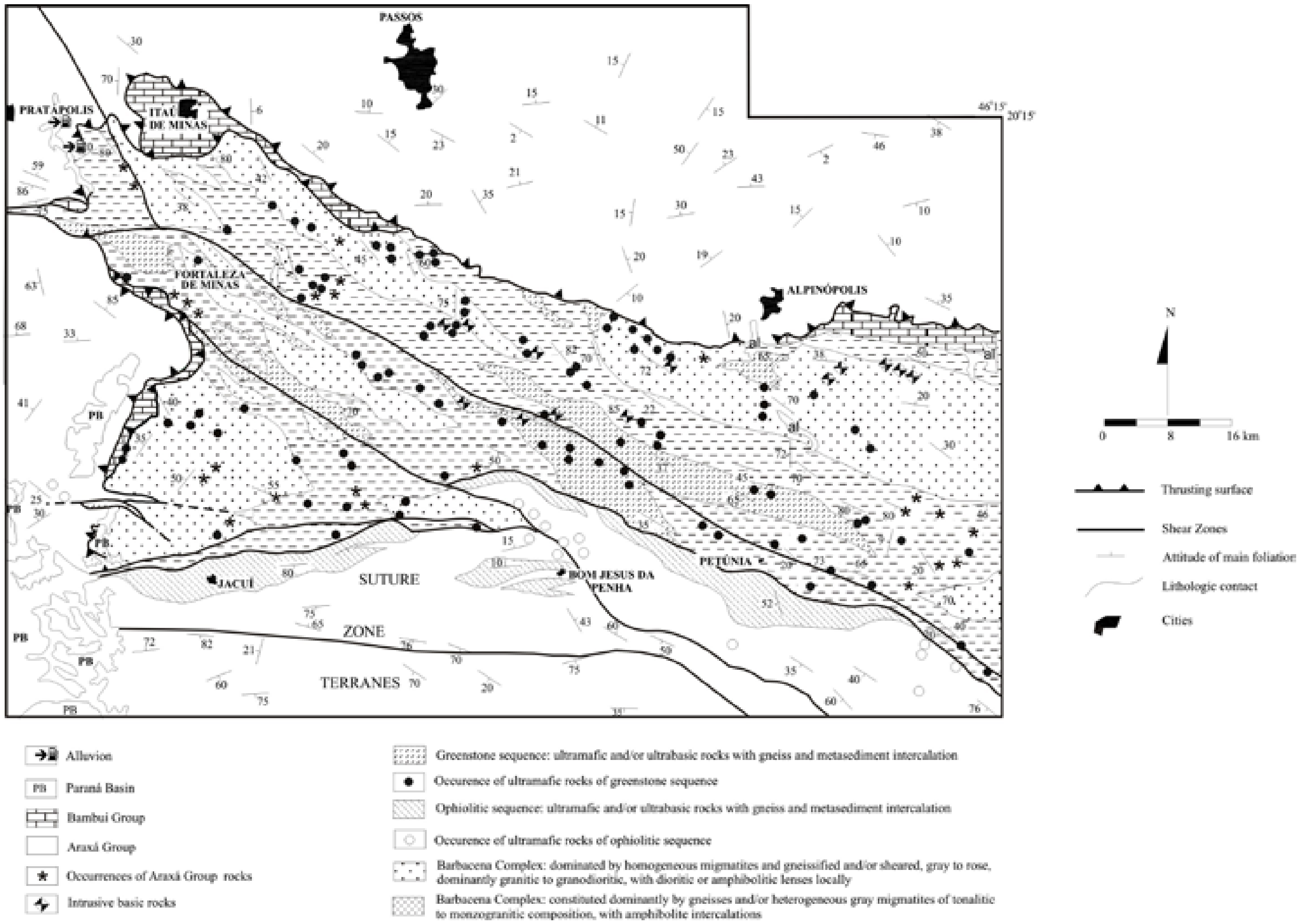

FIGURE 3: Overthrusted terrenes affected by the Campo do Meio Shear Belt.

FIGURA 3: Terrenos Cavalgados afetados pelo Cinturão de Cizalhamento Campo do Maio.

Neoproterozoic supracrustal sequence of the Araxá Group and northeast by the Bambuí Group lithologies and was also affected in its southernmost part by this shear belt for 5 to 10 km (ZANARDO, 1992) - Figure 2.

The Ouro Fino Shear Belt located southeast of the Guaxupé Complex (CAVALCANTE et al., 1979; HASUI et al., 1990) is narrower than the previous one. It is also of ductile-brittle nature, but of dextral movement (HASUI et al., 1990) and totally involves the Mesoproterozoic allochthonous supracrustal (Itapira Group; EBERT, 1968) and Archaean (Amparo Group; EBERT, 1968) and Paleoproterozoic (CAMPOS NETO, 1991) infracrustal lithologies. It affects only locally the Guaxupé Complex lithologies, allowing the emplacement of granitic bodies in the affected region. This belt corresponds to a branch of the Paraíba do Sul Transpression Belt (EBERT et al., 1993; EBERT; HASUI, 1998) or Atlântico Shear Belt (ARTUR; WERNICK, 1986; MACHADO; ENDO, 1993) and separates the Guaxupé Complex from the Socorro Complex (CAVALCANTE et al., 1979), this one represents litholypes very similar but smaller, with an approximately lenticular to triangular shape, partially affected and totally involved by the Paraíba do Sul Transpression Shear Belt.

OVERTHRUSTED TERRENES

The Overthrusted Terrenes are constituted by gneissic-granitic-greenstone terrenes (Barbacena Complex and Greenstone Sequence), intrusive basic rocks and tectonic intercalations of supracrustal lithologies attributed to the Araxá and Bambuí Groups, possible with small bodies of rocks of hydrothermal origin.

Oldest ages to the Barbacena Complex, an Archaean-Paleoproterozoic gneissic-granite terrene, studied in the region in detail by Zanardo (1992), Zanardo et al. (1996a),

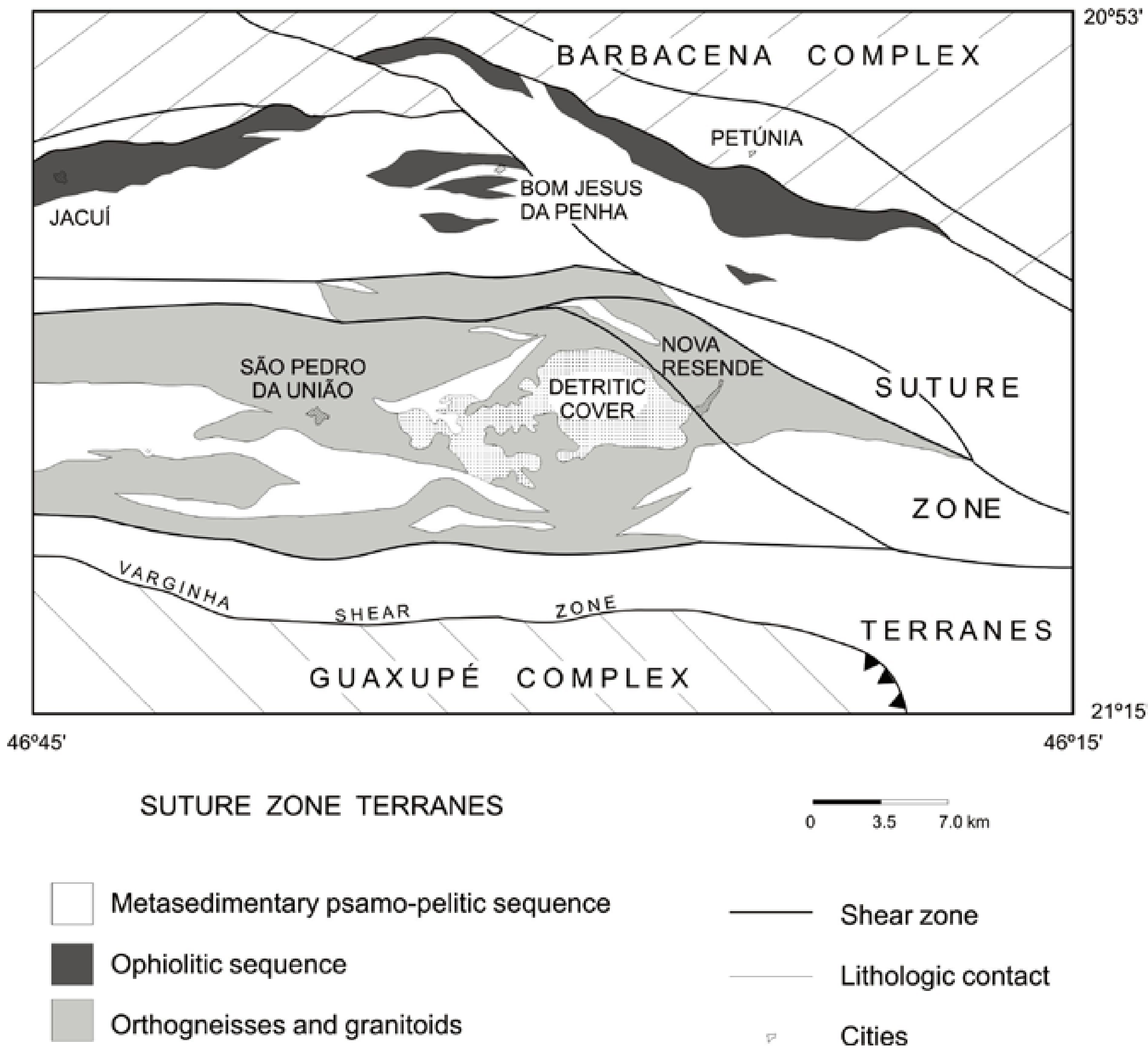

FIGURE 4: Lithologies of Suture Zone Terrenes.

FIGURA 4 : Litologias dos Terrenos ligados às Zonas de Sutura.

Szabó (1996) and Zanardo et al. (2000). Based on his research and on previous works (OLIVEIRA et al., 1983; MORALES et al., 1983), Zanardo (1992) divided it in two mapping units, one constituted dominantly by banded gneisses and/or heterogeneous gray migmatites of tonalitic to monzogranitic composition and the other dominated by homogeneous migmatites and dominantly gray to rose granitic to granodioritic granitoids gneissified and/or sheared. In a general way, it is constituted by banded to homogeneous, gneisses frequently with ocellar aspects, partial- to totally gneissified migmatites and granitoids. These different lithotypes form intercalated belts and lenses of varied dimensions, elongated in the WNW/ESE direction.

In the vicinities of Fortaleza de Minas city, emplaced in to the orthogneisses and migmatites occur the disrupted segments of the greenstone sequence roots (TEIXEIRA, 1978; TEIXEIRA AND DANNI, 1979a,b; CARVALHO, 1983, 1990; SZABÓ, 1989, 1996; ZANARDO, 1992). This sequence frequently exhibits mylonitic to ultramylonitic structures and relict features common to komatiitic flows (TEIXEIRA, 1978; CHOUDHURI et al., 1982; SCHMIDT, 1983; SZABÓ, 1989, 1996; CARVALHO, 1983, 1990). Several fragments of the greenstone sequence show a huge predominance of ultramafic lithotypes, specially ultrabasic of komatiitic composition. Subordinately metabasic, komatiitic, tholeiitic and more rarely calc-alkaline lithologies occur. Little inclusions of metasediments sequences with the iron formations constituting the most effective representatives. The parageneses of these rocks and the chemistry of the crystalline phases indicate that the metamorphic apex reached minimum conditions of the order of 750ºC for temperature and about 5 to 6 kbar for pressure (ZANARDO, 1992; SZABÓ, 1996; CARVALHO et al., 1998). However, these lithologies were intensively affected by retrograde metamorphism, recalibrating the great majority of the bodies to greenschist to lower amphibolite facies.

The metasomatic and/or hydrothermal rocks occur locally (not represented in the figures), linked to the late stages in the evolution of shear zones and seems to have been non-coeval and submitted to very different thermal conditions. The younger lower temperature lithologies are represented by epidosites, sericite schists (phyllonites) and/or fels, quartz veins and silexites, associated with hydrothermal activities.

The intrusive basic rocks cut in the Barbacena Complex and greenstone sequence and up to now they have not been observed crosscutting the Neoproterozoic allochthonous (Araxá and Canastra Groups) or autochthonous (Bambuí Group) covers.

The Bambuí Group is an autochthonous pelitic-carbonated platform sequence of Neoproterozoic age. In this area it is represented by phyllites and fine schists, with lenticular intercalations of metadiamictites and/or paraconglomerates constituted by clast-supported (pebbles attributed to basement rocks, greenstone sequence, and Araxá and Canastra Groups) and more rarely matrix-supported conglomerates.

Lithologies of the Canastra Group (Figure 2) occur placed between the Araxá Group and the autochthonous terrenes (gneissic-granitic-greenstone basement and Bambuí Group), but are missing in the south/southwestern portion of the Araxá Group. It is constituted by orthoquartzites (meta-arenites), micaceous quartzites (meta-arenites and metasiltites with the presence of a small quantity of argillaceous matrix) and phyllites, normally with preservation of grain rims.

In the domain of the gneissic-granitic-greenstone terrenes, the lithotypes attributable to the Araxá Group (Figures 2, 3 and 4) occur as lenticular tectonic inclusions dispersed throughout the domain, fitted along the shear zones, or also like as a klippen structure. These rocks are usually mylonitized and partially phyllonitized, fine- to medium-grained and are represented by psamitic to pelitic metasediments, represented by quartz schists, quartz-mica schists, schists and usually micaceous and schistose quartzites.

The Canastra Group exhibits low-grade metamorphism, whereas the Araxá Group presents a clear inverted metamorphic zoning, with no evidences of strata inversion, due to the action of intense tangential tectonics (SIMÕES et al., 1988). At the base of the sequence the metamorphic conditions are of the greenschist facies, and on top the conditions reach amphibolite to granulite facies and temperatures of the order of or higher than 800ºC and pressures of the order of 15 kbar, including retrograde eclogite inclusions. The metamorphic apex was pre- to early-kinematic, once, in a general way, the development of the main foliation attributed to allochthony occurs in retrograde conditions (amphibolite to greenschist). In side this unit, some orthogneiss levels seem to correspond to magmatic arc fragments.

ALTEROSA PALEO SUTURE ZONE

Under this denomination are included the lithotypes that appear forming a belt of approximately 20 km of thickness, intensely structured in the E-W strike, between the gneissic-granitic-greenstone terrenes to the north (overthrusted terrenes) and the high-grade terrenes representative of the lower crust of the overthrusting block (Guaxupé Complex) - Figure 4. In this belt can be individualized a psamo-pelitic metasedimentary sequence, rocks of mafic/ultramafic origin interpreted as an intensely tectonized ophiolitic sequence and orthogneisses and syn- to tardi-tectonic granitoids.

Psamo-pelitic metasedimentary sequence

This sequence can be correlated with the Araxá Group, based on lithologic, metamorphic, structural and cartographic criteria. It occurs intercalated or with intercalations of granitoids of sub-alkaline trend, granodioritic gneisses and some ultramafic intercalations sometimes associated with metasediments that locally presents iron formation characteristics. This unit presents physical continuity with

Andrelândia and São João Del Rei Groups towards the east (TROUW et al., 1984).

The lithotypes are represented by para- and orthoderived gneisses of granitic to tonalitic composition, with intercalations of typical metasedimentary rocks, amphibolites, amphibolitic gneisses, ultramafic rocks and more rarely iron formations, gondites and calc-silicate rocks. Constituting typical metasedimentary rocks there are schists with or without garnet, feldspars, kyanite and staurolite as essential minerals; (kyanite)-(garnet) quartzites and quartz schists; aluminous to quartzose garnet gneisses with or without kyanite; and feldspatic biotite-muscovite quartzites.

In this domain the oldest structures are inflected and cut by shear zones of moderate- to high-dip of varied thicknesses, generating elongated, frequently sigmoidal, blocks or WNW/ESE-trending belts. The shear zones had suffered several reactivations from ductile to brittle stages and they must had corresponded to lateral ramps or transfer faults in the initial stages.

This lithologic set is covered by Paraná Sedimentary Basin lithologies of Paleozoic age towards west and towards south the contacts with Guaxupé Complex high-grade terrenes is defined by the Varginha Shear Zone of predominantly ductile behavior. In the portions less affected by shear zones the foliation is parallel to the tectonic banding showing low to moderate dip angles with WNW/ESE-trending stretching and mineral lineation. Kinematic indicators suggest mass transport from WNW to ESE (ZANARDO, 1992; MORALES, 1993). In a general way, this framework is inflected or transposed by sinistral ductile to ductile/brittle shear zones, passing to a moderate to sub vertical dip angle foliation, whereas the lineation rotated to practically E-W strike and lower dip angles (ZANARDO, 1992; MORALES, 1993) and sinistral dislocations. These shear zones delimit sub parallel to lenticular blocks, showing tighter foliation, almost generating laminar or linear structures, with a linear trend (LS to L tectonites) well defined in the northern portion, and more planar (S to SL tectonites) in the southern portion (ZANARDO, 1992). This structural signature is similar to that of the Araxá Group in the north. Major differences are defined by the more effective behavior of the high-angle shear zones in this domain, resulting in the rotation from low to high foliation angle and/or in the generation of upright foliation.

The metamorphism in this area, as well as the tectono-stratigraphy is very complex, superposed by the reactivations that provoked retrogressive equilibration in various grades. The metasediments of the north suggest that metamorphic conditions reached at most moderate amphibolite facies, retrometamorphosed to the greenschist facies, whereas the metasediments of the southern portion surpass the orthoclase isograd and seem to had reached the granulite facies in the kyanite stability field, generating rocks with eclogitic aspect, whose mineralogy points to pressures of the order of 15 kbar. In general a slight metamorphic zoning can be recognized, with increase grade (temperature and pressure) to the south, towards the granulitic terrenes of the Guaxupé Complex.

Ophiolitic Sequence

The ultramafic lithologies attributable to a ophiolitic mélange (SOARES et al., 1990 and 1991; ZANARDO, 1992; ROIG, 1993; ZANARDO et al., 1996b; SZABÓ, 1996) occur dispersed throughout the belt, but are concentrated in the northernmost part, passing along Jacuí, Bom Jesus da Penha and south of Petúnia. The mafic/ultramafic bodies (schists and fels with tremolite/actinolite, chlorite, talc and less frequently cummingtonite/grunerite and anthophyllite) have lenticular to fusiform shapes, isoriented, usually with diffuse distribution at map scale. They are metric to kilometric in length and decimetric- to decametric in thickness, with a few bodies more than 100 m thick and are involved and/or intercalated, sometimes encompassing, by ortho and paraderived gneisses, migmatites, pelitic to psamitic metasediments and more rarely iron formations and gondites.

A low-angle foliation can also be recognized, sub-parallel to the compositional banding associated with intense lensing. The foliation has an E-W to WNW/ESE-trending low dip angle lineation that associated with the asymmetry of the bodies and other kinematic indicators points out a tectonic transport from WNW to ESE. These structures exhibit varied reorientation due to the action of upright shear zones that completely erased the evidences of the low angle foliation by rotation, transposition, folding or crenulations. Thus, the present configuration results from the tectonic imbrications of lithologies of different origins and distinct ages. On the other hand, the general framework and the dynamics deduced from the kinematic indicators are similar to those observed in the metasedimentary units that occur south, attributed to the Araxá Group (ZANARDO, 1992; ZANARDO et al., 1996b) and to the domain of the Araxá and Canastra Groups occurring north-northwest.

The contacts between the mafic/ultramafic bodies and the host lithologies are of tectonic nature, marked by the development of mylonitic foliation and lensing. Frequently banded intercalations resulting from deformation occur between the host and ultramafic rocks, locally with injections of granitic material along the shear planes, during the progression of the syn- to tardi- thermal apex deformation.

The mineral composition that represents higher thermodynamic conditions suffered brittle to brittle/ ductile deformation locally, resulting in intense retrograde neomineralization composed of pistacite/clinozoisite, actinolite, albite, chlorite, carbonate, fine sericite/muscovite, adularia and prenhite in some fractures.

The mineral associations and microstructural aspects that confirm higher temperatures appear in less deformed metaultramafic and metamafic rocks, corresponding to nuclei of lenticular bodies. The mineralogical and textural aspects show that the plutonic mafic/ultramafic rocks underwent reequilibrium under high amphibolite to granulite facies conditions, with temperatures higher than 750ºC, possibly reaching more than 800ºC, in an apparently low to moderate pressure environment. These lithologies together with others that form the belt, or even isolated bodies to the south, underwent dynamo-thermal metamorphism of retrograde character, beginning at temperatures of the order of or little higher than 700ºC, that dropped continuously to values of the order of 500ºC. The metamorphic conditions evaluated reaching lower temperatures along transcurrent faulting, mingling in this case with reactivation processes that took place at temperatures from 280ºC to 450ºC, resulting in the formation of serpentine and carbonates. Regarding the pressure environment, the clinopyroxene-garnet-plagioclase-quartz assembly indicates pressures of 7.9 to 10.5 kbars and the hornblende-garnet-plagioclase-quartz association points to the 8.9-11.1 kbar interval with average pressures of 9.6 kbars (DEL LAMA, 1993).

Orthogneisses and granitoids

These rocks occur as tabular to lenticular bodies, tens to hundreds of meters thick, rarely reaching more than 2 km. They are intercalated with pelitic and psamitic to psamo-pelitic metasediments of the previous unit, locally exhibit features indicating assimilation and/or mixture of host migmatitic rocks, and are of sub-alkaline trend (ZANARDO, 1992; DEL LAMA, 1993; ZANARDO et al., 1996a; GODOY et al., 1999).

Biotite and hornblende are the dominant mafic minerals. Clinopyroxene, garnet, titanite, allanite, magnetite and ilmenite can appear in considerable amounts. The compositions vary from tonalitic to syenogranitic, predominating monzogranites.

Some of the less-deformed granitoids only exhibit high-angle foliation related to the action of the upright shear zones, aspects that in association with the mineralogical composition suggest non-coeval granitoid emplacement, qualifying them as pre- to early-kinematic or collisional, syn- and tardi-collisional. Chemically they belong to the potassic calc-alkaline series, presenting peraluminous to metaluminous character, with geochemical characteristics similar to those formed in island arc environments or continental arcs associated with a collisional event (GODOY et al., 1999).

GUAXUPÉ COMPLEX

This unit occupies a triangular area, delimited north/northeast by supracrustal rocks correlated with the Araxá and Andrelândia groups, and southeast by the Itapira Group, tectonically intercalated with the Amparo Group (EBERT, 1968) by the action of the dextral Ouro Fino Shear Belt (Figure 2). This unit is constituted by an orthoderived lithology of acid to intermediate nature, anhydrous or not, with metasedimentary (pelitic, psamitic, carbonatic, etc.), mafic and more rarely ultramafic intercalations.

Structural geology

The structural pattern is marked by a penetrative, frequently blastomylonitic foliation striking W to WNW, parallel to the compositional banding, common to almost all lithotypes of the area, recognizable both in mesoscopic and microscopic scales. It exhibits a shallow to moderate dip towards the SSW. The foliation is moulded in lenses (almonds and sigmoids) or is undulated and/or folded, so that the highest dip angles result from the action of upright shear zones that rotate the low-angle foliation.

In general the kinematic indicators indicate mass transport from SE to NW, as observed by Campos Neto and Figueiredo (1985), Zanardo (1987, 1992), Hasui et al. (1988), Morales (1988, 1993), among others. Later, in special in the eastern portion, the transport is to NNE, and in the southern portion, close to Monte Belo city, from WNW to ESE (DEL

LAMA, 1998; DEL LAMA et al., 2000).

Also affecting the principal foliation newer high dip angle shear zones appear, with centimetric to decametric thicknesses, provoking local foliation reorientation until it parallels the limits of the shear zones like drag folds. Normally in these planes an increase in biotite contents occurs and/or granitic mobilizates appear, in the form of lenses and veins with amphibole and/or clinopyroxene phenocrystals. In some zones, the progression of this deformation generates ultramylonites, with retrograde parageneses of the upper greenschist facies levels.

Lithologic composition

Excepting the Poços de Caldas Alkaline Massif and some granitoid bodies that occur south of this geologic entity, the different lithologies occur intercalated as strata, lenses or boudins, with thicknesses varying from centimeters to hundred of meters, predominating the decimetric to decametric. Instead they have large lateral continuity they exhibit frequent lateral and vertical compositional and textural changes, intercalated, interfingered or tectonically imbricated, exhibiting gradational to sharp contacts, and not rarely a lithotype changing to another occurs with banded repetition. The lithologies can be grouped as orthoderived and metasedimentary, undergoing high-grade metamorphism in the amphibolite and granulite facies. As possible vulcanosedimentary representatives some metabasic rocks occur intercalated with typical metasediments and remains of probable iron formations. The orthoderived lithologies can be subdivided in three groups or associations: charnockitic/mangeritic, migmatitic and gneissic/granitic.

The charnockitic/mangeritic association is represented by amphibole gneisses, with or without clinopyroxene, and hyperstene gneisses, occurring subordinated portions of alaskitic gneisses with flaser structures and rare metasedimentary (mainly calc-silicate) intercalations. The composition of these rocks vary from syenogranitic to granodioritic and from quartz syenitic to monzogranitic, appearing noritic and tonalitic compositions in some more basic terms and alkali-granitic in some late mobilizates.

The migmatitic association that expressively occurs in the southern portion is constituted by banded to homogeneous gneisses, infiltrated and assimilated in variable degrees by neosome of a dominant monzogranitic composition, with syenogranitic and granodioritic domains, and late alkali-granitic veins. The paleosome is of very diversified nature (ortho- and paraderived) and locally exhibit features typical of anatexis and/or injection.

The gneissic/granitic group involves the other lithologies and is represented by ocellar gneisses of monzogranitic to tonalitic matrix, biotite gneisses, amphibole-biotite gneisses, alaskitic gneisses and some porphyroid and equigranular granitic bodies that occur in the southernmost part. The composition is dominantly syenogranitic to monzogranitic, locally appearing quartz-syenitic, alkali-granitic, granodioritic and more rarely tonalitic terms.

Typical metasedimentary lithologies recognized are quartzites, quartzose gneisses, paragneisses, fels and calc-silicate gneisses, marbles and probable volcanogenic metasediments.

The metasedimentary rocks occur as strata, lenses, boudins and may show assimilation features concentrated in certain levels where they are intercalated or involved by quartz-feldspatic gneisses. They are rare where typical orthoderived lithotypes predominate. This enables the separation of the lithologies in two major groups, one rich in metasedimentary intercalations and another constituted mainly by orthoderived lithotypes. These metasediments were correlated with the Itapira Group (CAMPOS NETO; FIGUEIREDO, 1985), named Caconde Group by Hasui et al. (1988), whereas the orthoderived lithologies are named: Varginha Complex, Varginha-Guaxupé Complex, Pinhal Group, São José do Rio Pardo Suite, Pinhal Suite, etc., and Guaxupé Complex in this paper.

Metamorphism

The Guaxupé Complex metamorphic apex reached the granulite facies, as demonstrated by several researchers (OLIVEIRA et al. ,1973). The parageneses and mineral associations characteristic of the granulitic facies are observed being substituted more or less intensely by amphibolite and greenschist facies associations, so the typical parageneses of the granulite facies are more frequently found northwards, being not found in the southern- and southwesternmost portions. The association of granulithic rocks forms a belt some kilometers thick that thins up eastwards. From south to north, in the western and central-western sectors the first granulite facies associations were observed in paleosome bands in the proximity of São João da Boa Vista and in a small charnockite/mangerite body that crops out immediately to the south of the Poços de Caldas Alkaline Complex.

The changes in pressure and temperature conditions, responsible for the implantation of the granulite facies, seem to increase slowly northwards and even more slowly eastwards, at least up to *ca.* 10 km of the northern limit of this terrene, when cordierite disappear from the aluminous metasediments and garnet starts to appear in charnockitic rocks, becoming frequent in the northernmost part (Figure 5). This aspect is clear at ENE from Guaxupé, where a significant increase in garnet content in the typically orthoderived lithologies is observed from south to north and from west to east. The maximal occurs in the proximity of a Varginha Shear Zone southward inflection where it acquires an oblique to frontal character (DEL LAMA et al., 2000).

The metamorphic apex crystallization conditions recorded are approximately 1040ºC and 14.4 kbar estimated in the charnockitoids, the values obtained between 980ºC to 710ºC and 14.0 kbar to 8.0 kbar indicative of their cooling history that followed the kyanite-sillimanite stability limits within the sillimanite stability field. The retrograde metamorphic equilibration, more intense in the northern portion, occurred between 735º-790ºC and 9.0-10.5 kbar (DEL LAMA et al., 2000). In the central to southern portion it appears to have occurred at temperatures similar or a little lower than 700º-750ºC and much lower pressures, estimated between 5 and 8 kbar (OLIVEIRA; ALVES, 1976; OLIVEIRA; RUBERTI, 1979; ZANARDO, 1992).

ALTEROSA PALEO SUTURE ZONE EVOLUTIONS

The data obtained indicate that the present geological scenario resulted from continental collision in the Neoproterozoic (630-700 Ma), involving two continental blocks: the block that contains the São Francisco Craton and Guaxupé Complex that were joined by the Alterosa suture. The first block is represented by Archean gneissic-granitic-greenstone terrenes and by plataformal covers attributed to the Neoproterozoic (Bambuí Group). These units were overthrusted from NW/W to SE/E by a dominantly psamitic-pelitic metasedimentary sequence (Canastra Group) and by a metavolcanosedimentary sequence (pelitic, psamitic, graywacke, carbonatic with volcanic contribution of basic and acid nature) named Araxá Group. The whole group was overthrusted by the second continental block, represented in the area by granulitic terrenes (Guaxupé Complex).

In the Guaxupé Complex the parageneses typical of the granulite facies appear throughout the studied area, corresponding to the metamorphic apex better preserved northwards, suggesting an apparent increase of the metamorphic conditions in this direction. These parageneses indicate that the temperature exceeded 800ºC, and must have reached more than 950ºC, in a pressure environment of at least 7 to 8 kbar, and where decarbonation reactions or juvenile CO_2 pressure had an important rule in the equilibrium of the reactions and in the generation of melted material.

The metasedimentary association of this domain suggests stable platform environment, though representing resistates in lower crust environments, where anatexis and intrusions affected by ductile flow took place. Therefore the metasedimentary sequence, possibly deposited in a more dynamic environment, such as island arc or convergent plate margins, could have totally lost its characteristics, penetrating lower crust levels by means of movements related to density differences or other tectonic process linked to plate motion. It was not possible to clarify whether this lithologic group originated in more than one geotectonic environment.

The exhumation of granulitic terrenes in the early stages took place due to tangential shear, with tectonic transport from SE-S to NW-N, not well characterized due to the superimposed deformation. This deformation, in its progression, catalyzed mineralogical equilibration at the granulite to medium amphibolite facies, in an environment where pressure decreased more rapidly than temperature, configuring a clockwise metamorphic path, always within the sillimanite stability field. In the northern portion the estimated pressure difference reaches *ca.* 5 kbar, evidencing ascension higher than 15 km for this area as a result of low-angle shearing.

The substitution of the tangential for directional tectonics seems to have occurred and started with the implantation of the Varginha Shear Zone, that worked as a lateral, locally oblique to frontal ramp generating compressive arcs (restraining bend), due to inflections of this zone to NW-NS, thus allowing the ejection of deeper levels with temperatures of the order of 950ºC and 12 kbar. In the sequence others directional shear zones are nucleated configuring the sinistral Campo do Meio Shear Belt to northeast and the dextral Ouro Fino Shear Belt to southeast, branch of the Atlântico Shear Belt. During the action of shear belts the high-grade terrene (Guaxupé Complex) presented a relative movement from W to E, with higher uplift in the easternmost portion and in the northeastern flank, stressing out and rotating the metamorphic

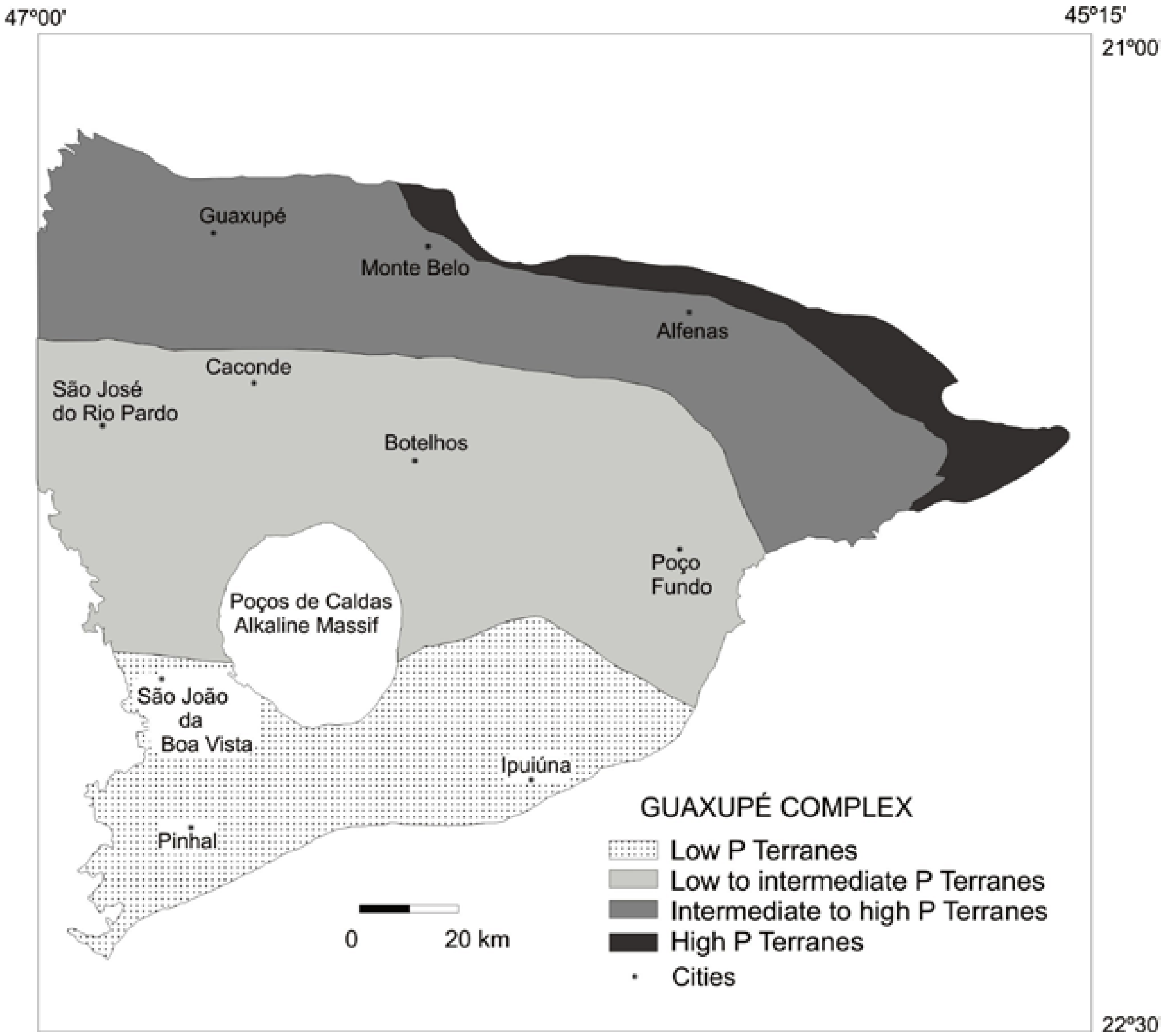

FIGURE 5: Delimitation of Guaxupé Complex showing metamorphic pressure variations.

FIGURA 5: Delimitação do Complexo Guaxupé evidenciando as variações das pressões por metamorfismo.

zoning to the present scenario. In this phase the high-grade terrene raised less than 5 km, except in the compressive arcs, where the uplift seems to have reached more than 10 km.

The upright shear zones, both in the sinistral and dextral belts, catalyze textural and mineralogical equilibration that grade from the amphibolite to the medium greenschist facies attesting long duration of this process.

Late-stages reactivations of the fault zones occurred in the Eocambrian, Mezosoic and Tertiary, not discussed at this paper.

FINAL REMARKS

The collisional process followed by erosion enabled the exposition of the present tectono-stratigraphic scenario: the granulithic terrenes (Guaxupé Complex) dip south/southwestwards are placed to the north close to a metasedimentary or metavolcanosedimentary sequence (correlated with the Araxá and Andrelândia Groups); this supracrustal sequence is situated between the high-grade (Guaxupé Complex) and the gneissic-granite-greenstone terrenes (São Francisco Craton); associated with it can be recognized lithotypes attributable to the ophiolitic complex, magmatic arc, platform sequence (basal metasediments of the Araxá tectono-stratigraphy), etc.

In the Guaxupé Complex the petrologic data suggest the possibility of the existence of more than one geotectonic environment as generator of non-coeval orthoderived rocks, representing various evolution stages of Wilson's Cycle been possible that more than one cycle had occurred. However the structural, petrographic, geochronologic, cartographic and lithochemical data available do not allow to separate different lithologic groups or suites in space and time.

The structural scenario according to the lithologic distribution and metamorphic zoning shows that the Guaxupé Complex underwent non-coaxial tangential deformation with tectonic transport from SE/S to NW/N, event responsible for the generation of the principal foliation and other closely related structures. As a sequence, this dynamics was succeeded by a relative movement from W to E, contemporaneous to the implantation of the Campo do Meio and Ouro Fino/Atlântico Shear Belts. This movement, in the initial stages, occurred in the amphibolite facies, causing a slight uplift of the eastern portion in relation to the western, and took place in lateral to frontal ramps. It was basically absorbed by the overthrusted supracrustal rocks, being locally registered in the Guaxupé Complex lithologies, specially in the easternmost part and in inflections of the lateral ramps, such as the one that occurs northeast of Monte Belo, places where higher-pressure granulites also appear lifted by frontal to oblique ramp movements.

Many doubts still exist in these terrenes such as the pre-shear tectonic transport directions, the position and evolution of the ophiolitic sequences, their time/spatial relation to the granite genesis, recognition and delimitation of the magmatic arcs, the mechanisms that place supracrustal sequences (psamites, pelites, marls, limestones and iron formations) in the lower crust, the processes that lead to the generation of the anhydrous parageneses, why the outcropping lower crust in a general way is much more acid than what is deduced by geophysics, the age of the geologic events - issues that are still being investigated, among other aspects.

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