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The Structural Geology of the of Quarries of Dimension Stones in the Mining District of Santo Antônio de Pádua, SE Brazil

Geologia Estrutural das Pedreiras de Rochas Ornamentais no Distrito Mineiro de Santo Antônio de Pádua, SE do Brasil

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Resumo

O distrito mineiro de Santo Antonio de Pádua apresenta a maior concentração de atividade mineira (excetuando a atividade petrolífera da Bacia de Campos) no Estado do Rio de Janeiro. Dois litotipos principais são lavrados, com finalidade de rocha ornamental, ao longo de duas zonas de falhas, às quais fazem parte de um feixe maior de falhas pertinentes à Zona de Cisalhamento do Rio Paraíba do Sul. Os dois litotipos são dois ortognaisses homogêneos, que tiveram suas colocações num regime transcorrente-transpressivo. Nós apresentamos aqui uma possível explicação para a gênese destas rochas.
Palavras-chave: Geologia Estrutural; rochas ornamentais; transcorrência; transpressão

Abstract

The mining district of Santo Antonio de Pádua is responsible for the greatest concentration of mining activity (except for oil offshore exploration) in the state of Rio de Janeiro. Two different lithotypes of dimension stones are quarried along two particular fault zones that are part of major splay of faults which branch off Rio Paraíba do Sul Shear Zone. The quarried dimension stones are two homogeneous orthogneisses that were emplaced in a transcurrent transpressive regime. We present here a possible explanation for the genesis of those rocks.
Keywords: structural geology; dimension stones; transcurrence; transpression

1 Introduction

The Rio Paraíba do Sul Shear Zone (RPSZ) is located in SE Brazil (Dayan & Corrêa Neto, 2000). This dextral transcurrent-transpressive fault zone, which is related to the tectonic evolution of the Ribeira Belt during the Brazilian orogeny (590-520 Ma) (Machado, 1998), cuts high-grade metamorphic rocks and controls the course of the Paraíba do Sul river for nearly 120 km (Figure 1). The average thickness of the mylonites in this zone is around 4 km (Dayan & Corrêa Neto, 2000). Branching off from this belt of high-grade mylonites there are two bundles of horsetail fault splays (Tikoff & Teyssier, 1992) (Figure 2); the uppermost (concave upwards), verging towards the NE, while the southernmost (concave downwards) is oriented to the SW. The Santo Antônio de Pádua district is outlined as a thick full line in Figure 2. Two fault traces are enhanced in the uppermost splay, for they mark the distribution of the ca. 300 quarries of dimension stones in this area. Along the Itajara-Pirapetinga Fault zone (IPF, Figure 2) the explored lithotype is a hornblende-biotite orthogneiss commercially named "gnaisse olho-de-pombo" (portuguese acronym GOP, see the green dots in Figure 2), while in the Santo Antonio de Padua Fault zone (SAPF, see Figure 2) the quarried rock is a microcline-plagioclase-quartz orthogneiss, commercially named "pedra-madeira" (GM, acronym for "granitoide-madeira", see the purple dots in Figure 2). The very existence of this industry is due to two important facts: (i) the quarried gneisses are extremely homogeneous, contrasting very much with their host rocks, which show alternate bands of different compositions and (ii) due to deformation effects, there is a characteristic protomylonitic to mylonitic narrow spaced foliation, which allows these gneisses to split along low rugosity fracture planes. This district area represents the biggest concentration of mining (inshore) activity of the State of Rio de Janeiro, employing some 6,000 workers, direct and indirectly.

2 Geologic Setting

The uppermost fault splay cuts through a complex of migmatitic country rocks composed mainly of banded gneiss with amphibolitic, charnockitic and porphyroblastic domains, interfingered with some calc-silicatic and quartzitic rocks. These country rocks reached granulite facies and have been further retrogressed to high amphibolite facies of metamorphism. GPS point location of those quarries (Figure 2) clearly revealed an *en échelon* pattern (Figure 3) of multiple traces along the IPF (fault) line (see cartoon representation in Figure 8). Those traces are extremely elongated, anastomotic and are illustrated in a cartoon representation of Figure 4. The foliation planes along those faults, dip steeply (55º up 85º) to the SE. A subhorizontal stretching direction lineation is very conspicuous in the GM rocks but not very characteristically present in the GOP rocks, certainly, due to their phyllosilicatic content. In fact, both rock type present stretched quartz ribbons along their foliation planes, but in the GM mylonites they are longer, extremely stretched with ratios far greater than 20:1. This attests the large shear strain undergone by those rocks. Mullion structures found along the interface GM-rocks/ charnockite also show subhorizontal attitudes, concordant with the local stretching direction lineation (Figure 3). Folds are upright, hinges are subhorizontal, plunging gently along the NE-SW trend. Kinematic indicators are abundant and include porphyroblasts/clasts of feldspar forming characteristic tails (mainly Φ and σ). Asymmetric boudins of amphibolitic nuclei are fairly common and result from large finite extension. The thicknesses of the quarried orthogneisses vary from 3-5 m up to 100 m, the mean around 20 m, while there are cases where their length can easily reach 1.2 km. In fact, the linking of those quarries is already spotted from the available satellite images (*e.g.*: www.embrapa.com.br; google earth). The contact with the gneissic suite of country rocks is always sharp. Highly stretched xenoliths of the latter rock within the quarried gneisses (e.g. stromatic gneiss xenoliths within the GOP protomylonite) are commonly found along the IPF. In some places there are some bands (thicknesses from centimeter to meter) of very fine GOP in direct contact with the host rocks. These are chilled margin rocks, which underwent highly ductile deformation effects.

3 Discussion and Conclusions

The geometry of the upper-outward horsetail splay of faults, the stretching lineation and mullion structures are indicative of transcurrence as the main movement. The arcuation of the asymptotically faults, coupled with dextral movement direction, denotes a transpressive regime although no steep stretching lineation was observed in these rocks. The geometry of these opposite horsetails is illustrated

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in block-diagram of Figure 5. Section AB is based on attitudes of the foliations (schistosity, mylonitic foliation etc) observed in the field. Profile CD represents a palm-tree structure (Figure 6) through a section that includes the localities of Santo Antonio de Pádua and Itaocara (SAP and I, respectively in Figure 2). Magmatic processes occurred while this transcurrence was taking place, the emplaced material being squeezed together with the shear zones walls. The evidences of the extreme ductility of the highly deformed xenoliths plus the granulite-amphibolite facies of the mineral assemblages are indicative that these processes took place at crustal depths of 20 km or more. Igneous rocks were emplaced synkinematically with deformation processes producing the extremely narrow and lensoid bodies (Figure 4), mapped here. In cases where foliation transposition was not complete we still can recognize chilled border structures and hypidiomorphic feldspar phenocrysts slightly xenomorphic. There could be at least two different reasons for magma emplacement (Hutton & Reavy, 1992): (i) the steeply inclined shear planes allowed fluid migration to potential melting zones within the Transamazonian-Archean crust or at least allowed anatexis, due to transcurrent shearing or frictional heating with temperatures that could generate magma (Nicolas *et al.,* 1977). Or (ii) the steep shear zones are deep reaching and constitute the corridor for magma ascension. The problem is to access the origin of magma. Transpression implies in thickening of the shear zone itself, which may be responsible for oblique thrusting, pop-ups and positive flower structures (Harding & Lowell, 1979), it all being dependent on the crustal level where it takes place. The *en échelon* pattern distribution of the GOP quarries (Figure 3) is interpreted as being controlled by P-shears (Harding & Lowell, 1979) along which the magmatic bodies were emplaced (see Figures 4 , 7) and is also illustrated in the cartoon representation of Figure 8. This would explain the observed lack of linearity of the quarries, although occurring along the same fault zone. This could also suggest that each fault zone of the splay might in fact constitute an array of anastomotic lenses, originated by R-Riedel shears followed and merged by synthetic P-shear planes (Woodcock & Schubert, 1994), this whole set underwent rotation and became highly stretched, due to coupling of deformation processes in a transpressive regime (see Figures 4 , 7).

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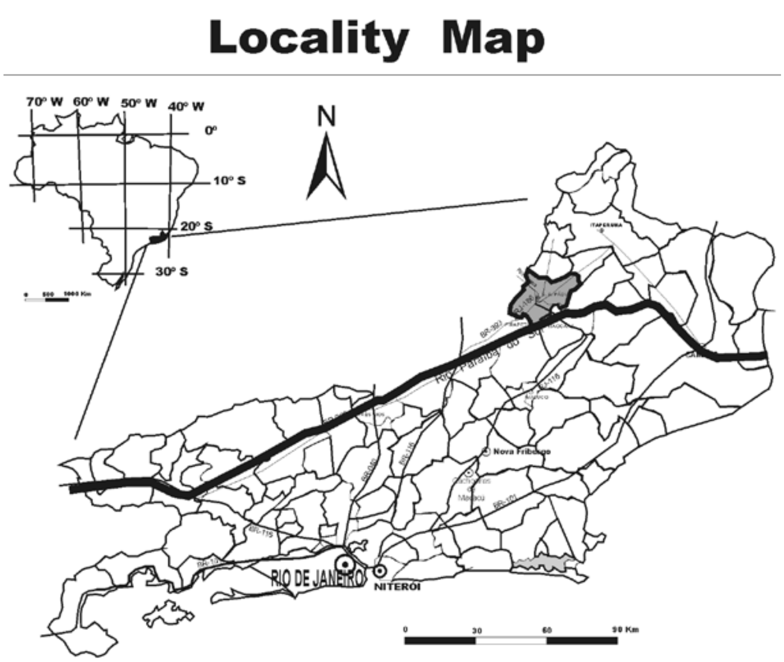

Figure 1 District area map of the State of Rio de Janeiro, exhibiting the main roads. Darkened area is the Santo Antonio de Pádua District. Thick line is the course the Paraíba do Sul River.

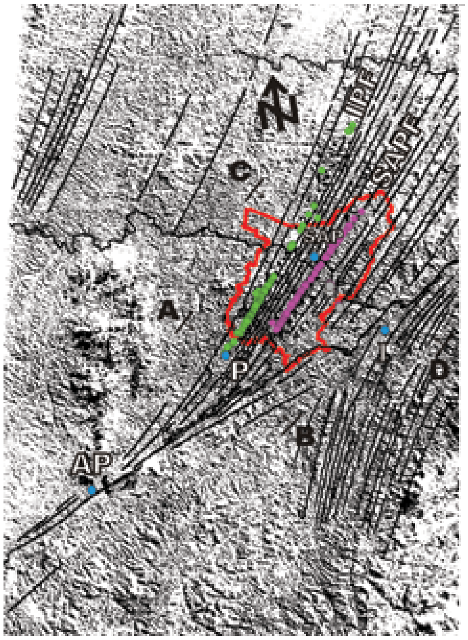

Figure 2 Satellite image that covers the course the Paraíba do Sul river, from Além Paraíba (west, AP) up to Itaocara (I). The enhanced arcuated lines are fault traces (splays) merging asymptotically to the Rio Paraíba do Sul Shear Zone. SAP and P mark the exact location of the localities: Santo Antonio de Pádua and Pirapetinga, respectively. Cross sections AB and CD are represented in the block diagrams of Figures 5 and 6 and discussed in the text. The Santo Antonio de Pádua District is outlined in red. The aligned purple dots mark the exact location of the "Pedra-Madeira" (GM) quarries, while the green dots show the exact location of the orthogneiss "olho-de-pombo" (GOP) quarries.

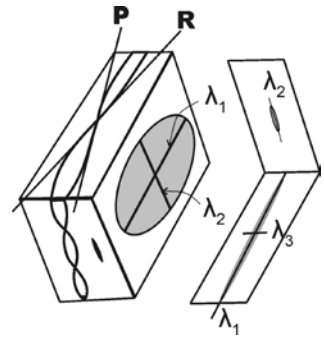

Figure 4 Cartoon representation of the anastomotic shear lenses. λ_1, λ_2 and λ_3 are the principal strain directions, ellipses have speculative ratios. P and R are the components of Riedel shears illustrated in Figure 7.

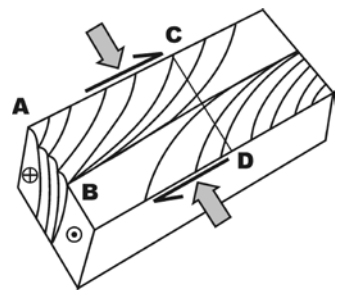

Figure 5 Block-diagram representing the portion covered by opposite fault splays seen in the satellite image of Figure 2. AB is the section across Pirapetinga (P).

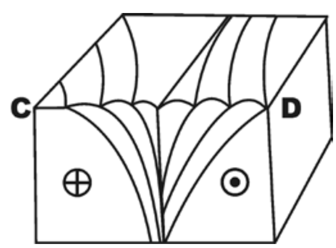

Figure 6 Represents a section (through S.A. de Pádua and Itaocara direction) cutting both splays, and is interpreted as a palm-tree structure. Horizontal and vertical dimensions are merely speculative. CD is the section across Santo Antonio de Pádua (SAP) and Itaocara (I), seen in Figure 2.

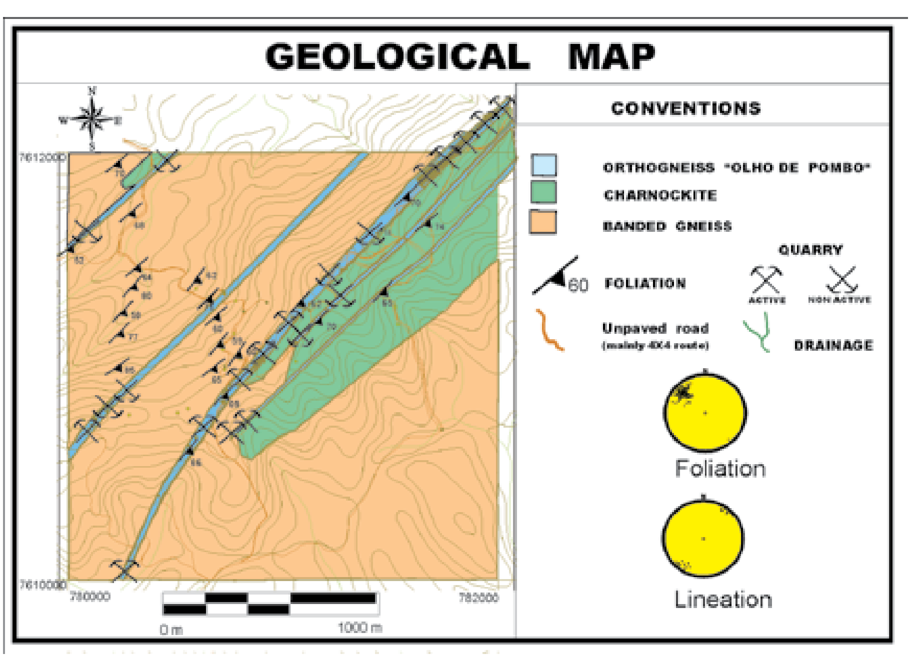

Figure 3 Geologic Map showing the orthogneiss "olho-de-pombo" (GOP) in an *en échelon* pattern.

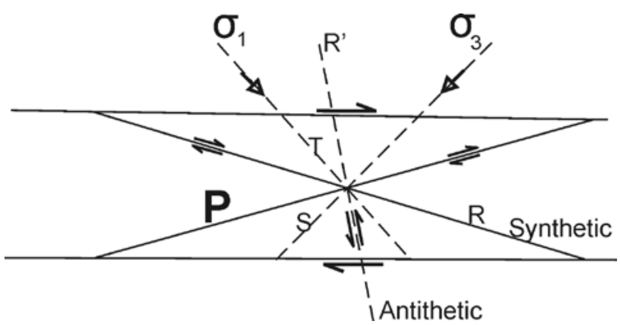

Figure 7 Riedel shears in dextral strike-slip system. Tension fractures (T), cleavage (S), synthetic shears (R), antithetic shears (R') and P-shears (P). σ_1 and σ_3 are the great and the least principal stress axes respectively.

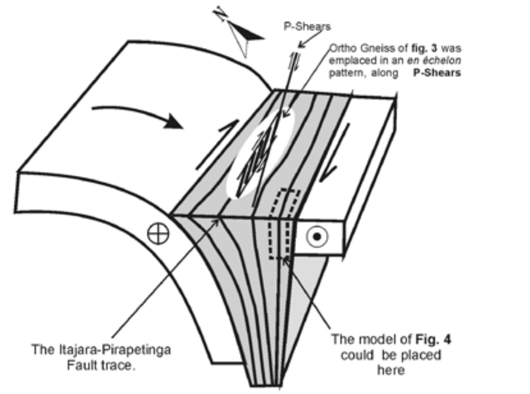

Figure 8 Cartoon representation of the emplacement of Orthogneiss GOP along P-Shears in the Itajara-Pirapetinga Fault Zone. The anastomotic lenses of Figure 4 would well fit along a fault line of the splay.

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