THE BRASILIANO STRUCTURAL FRAMEWORK OF THE SOUTHERN SERRA DO ESPINHAÇO IN MINAS GERAIS, BRAZIL: EXAMPLE OF DUPLEX THRUST SYSTEM

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INTRODUCTION

Presence of neoproterozoic duplex thrust systems have already been recognized in the southern Serra do Espinhaço. Marshak & Alkmim (1989) have interpreted the frontal thrust fault in the western border of the cordillera as a detachment fault, with a duplex thrust system developed above it. Kalt (1991), Rolim (1992) and Dussin et al. (1992) have speculated about the occurrence of duplex thrust systems in this region, despite the fact that the location and the basic characteristics of such a tectonic system still require further description. Silva & Toledo (1994) have presented geological profile, advancing the interpretation of a large duplex thrust system. Thus, the sole-thrust of the duplex was connected with the roof-thrust by a subsidiary thrust system, within a complex structural framework. Although the advances made in the spacial characterization of the structural framework of the southern Serra do Espinhaço, litle or even nothing have been added in the bibliography since then. As a matter of fact, this happened so because geological mapping was always based on lithostratigraphic criteria; making any basin analysis or even any genetic reconstructions impossible (for examples see Pflug & Renger 1973 and Schöll & Fogaça 1981) . As a consequence, contractional structural analysis were also performed based on wrong stratigraphic criteria.
The aim of this report is to describe the structural framework of the central portion of the southern Serra do Espinhaço, located in Minas Gerais state (Figure 1). Our data is supported on detailed geological mapping. The basic unit used during geological mapping is the depositional sequence, an allostratigraphic unit. The sequence boundaries are mapped until the outcrop scale. For publisching purposes, the mapped depositional sequences are grouped into genetic-related units. Each unit represents a distinct phase of the tectonic/statigraphic evolution. A interpretative structural cross-section of the Espinhaço duplex thrust system is also presented.

GEOLOGICAL SETTING

The southern Serra do Espinhaço in Minas Gerais is dominated by a high-grade Archean Basement complex, remnants of an Archean/Paleoproterozoic greenstone belt and two Proterozoic metasedimentary successions: deposited in the Espinhaço and São Francisco Basins. The Archean igneous complex consists of granitic to granodioritic igneous rocks associated with migmatites. U/Pb zircon-age determinations have indicated that the primary crystallization of the igneous rocks occurred at about 2.8 Ga. The Archean igneous complex was reworked at about 1.8 Ga, during the Transamazonian Orogeny (Machado et al. 1989). Sedimentation in the Archean greenstone belt has begun since the Archean. U/Pb zircon dating yields an age of 2.9 Ga for the crystallization of a metarhyolite found in the lowermost portions of the deposits (Machado et al. 1989). Sedimentation has finished at about 2.0 Ga, as demostrated by U/Pb zircon-age determinations of metaryollites found in the uppermost portions of the same stratigraphic record.
The Espinhaço Basin unconformably overlies the Archean Basement complex and on the top is dissected by an interregional uncorformity, marking the onset of the São Francisco Basin sedimentation. The stratigraphic record is characterized by several unconformities, wich subdivide it into depositional sequences, all of them are of first-order hierarchy. Sedimentological analysis and paleogeographic interpretations of the depositional sequences indicate that the basins evolved from

half-graben (the Espinhaço Basin) into continental margin (the São Francisco Basin). The sedimentation in the São Francisco Basin begins at about 1.0 Ga, as shown by basic intrusive dyques, that cut across the deposits of the Espinhaço Basin but do not cut across the deposits of the São Francisco Basin (Machado et al. 1989). Sedimentation in the São Francisco Basin finished just before the Brasiliano Orogeny, at about 0.6Ga, when the duplex thrust system was developed in the area.

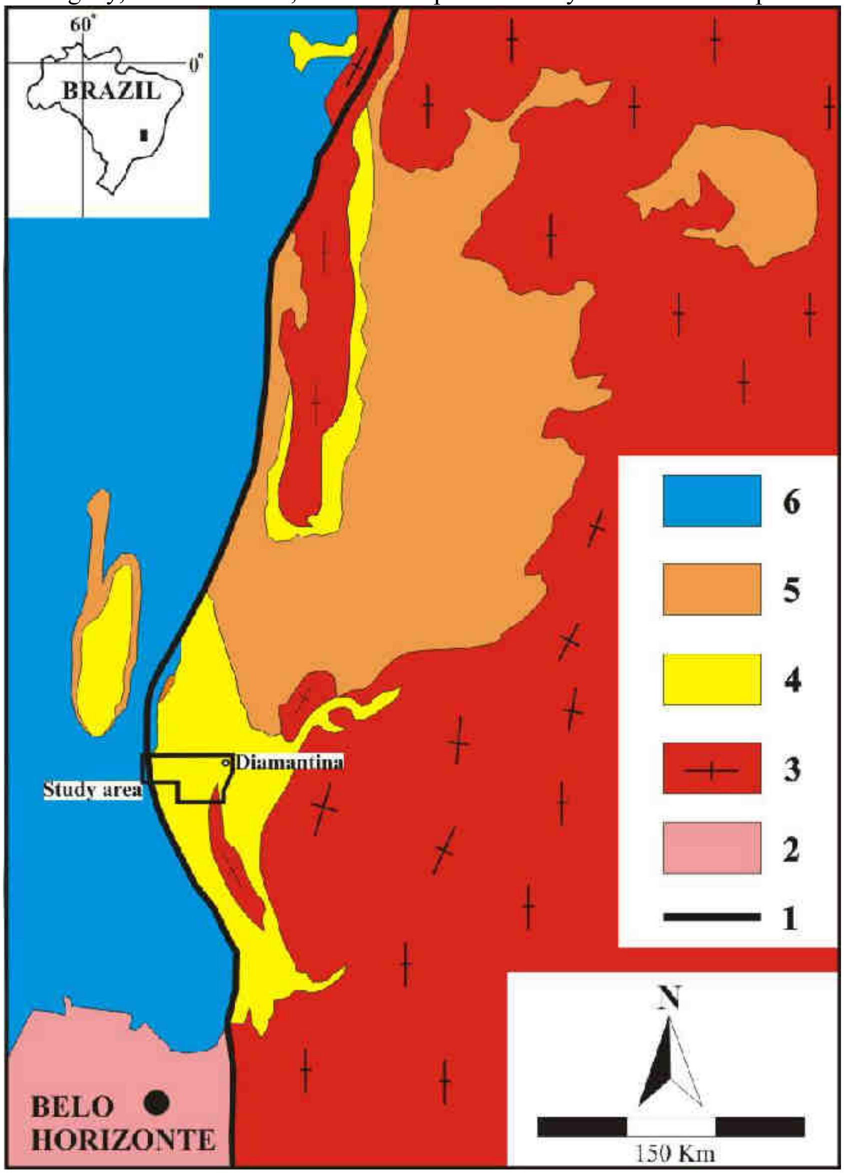

Figure 1. Geotectonic setting of the southern Serra do Espinhaço in Minas Gerais (after Schobbenhaus 1993, modified). Inset shows location of the mapped area, presented in Figure 2. Legende: 1=Cratonic borders; 2=Archean/Peleoproterozic basement complex, reworked during the Transamazonian Orogeny; 3=Archean /Peleoproterozoic Basement complex, reworked during the Transamazonian and Brasiliano Orogenies; 4=Espinhaço Supergroup; 5=São Francisco Supergroup (Macaúbas Group) and 6=São Francisco Supergroup (Bambuí Group).

THE STRUCTURAL FRAMEWORK OF THE SOUTHERN SERRA DO ESPINHAÇO

The geological map of the studied area is shown in Figure 2. The structural cross section is presented in Figure 3. The Espinhaço duplex thrust system is composed of two main horizontal thrust-shear zones (sole- and roof-thrust), wich are connected to one another by a system of small subsidiay thrusts.

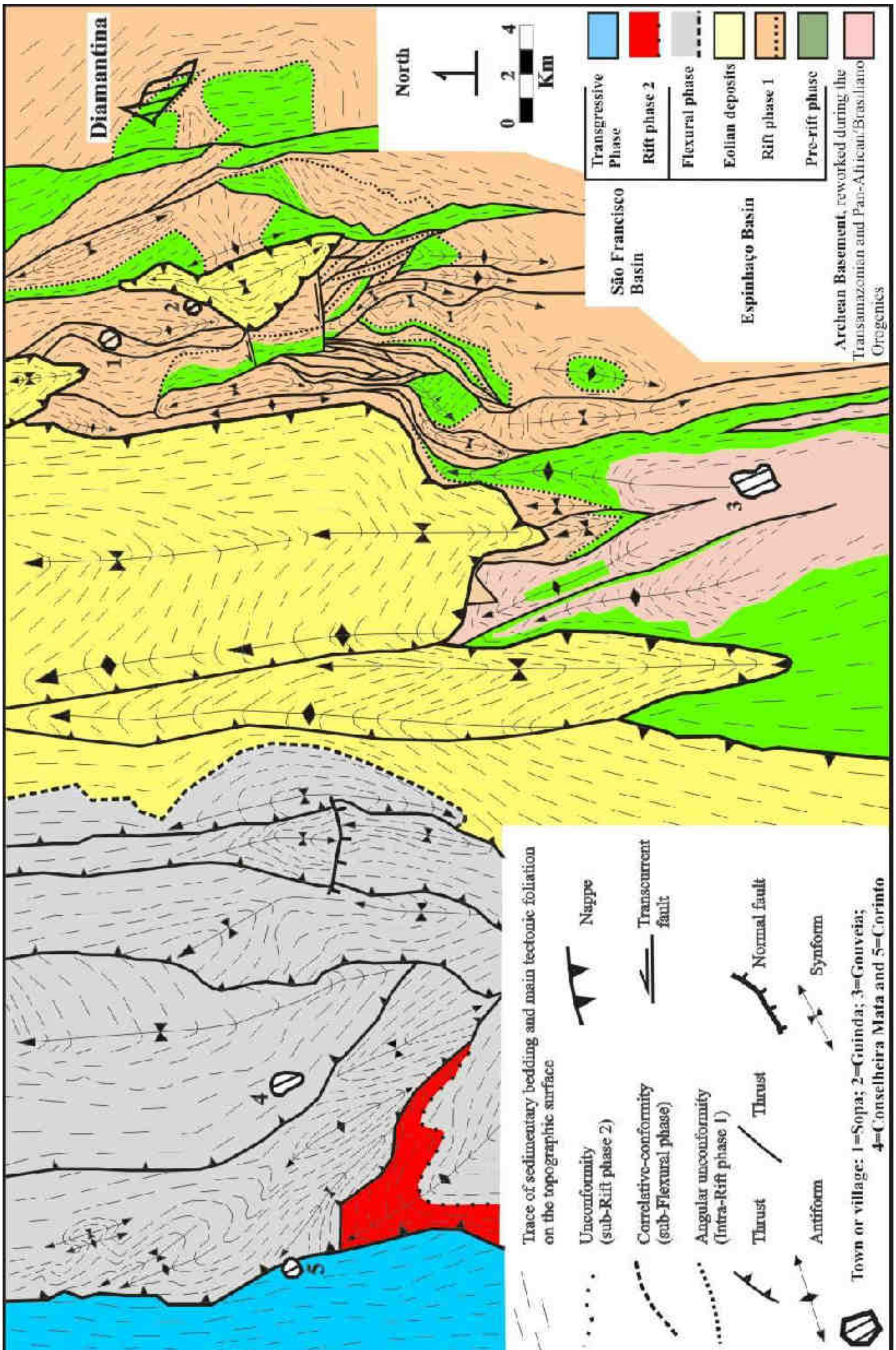

Figure 2. Geological map of the central portion of the southern Serra do Espinhaço in Minas Gerais.

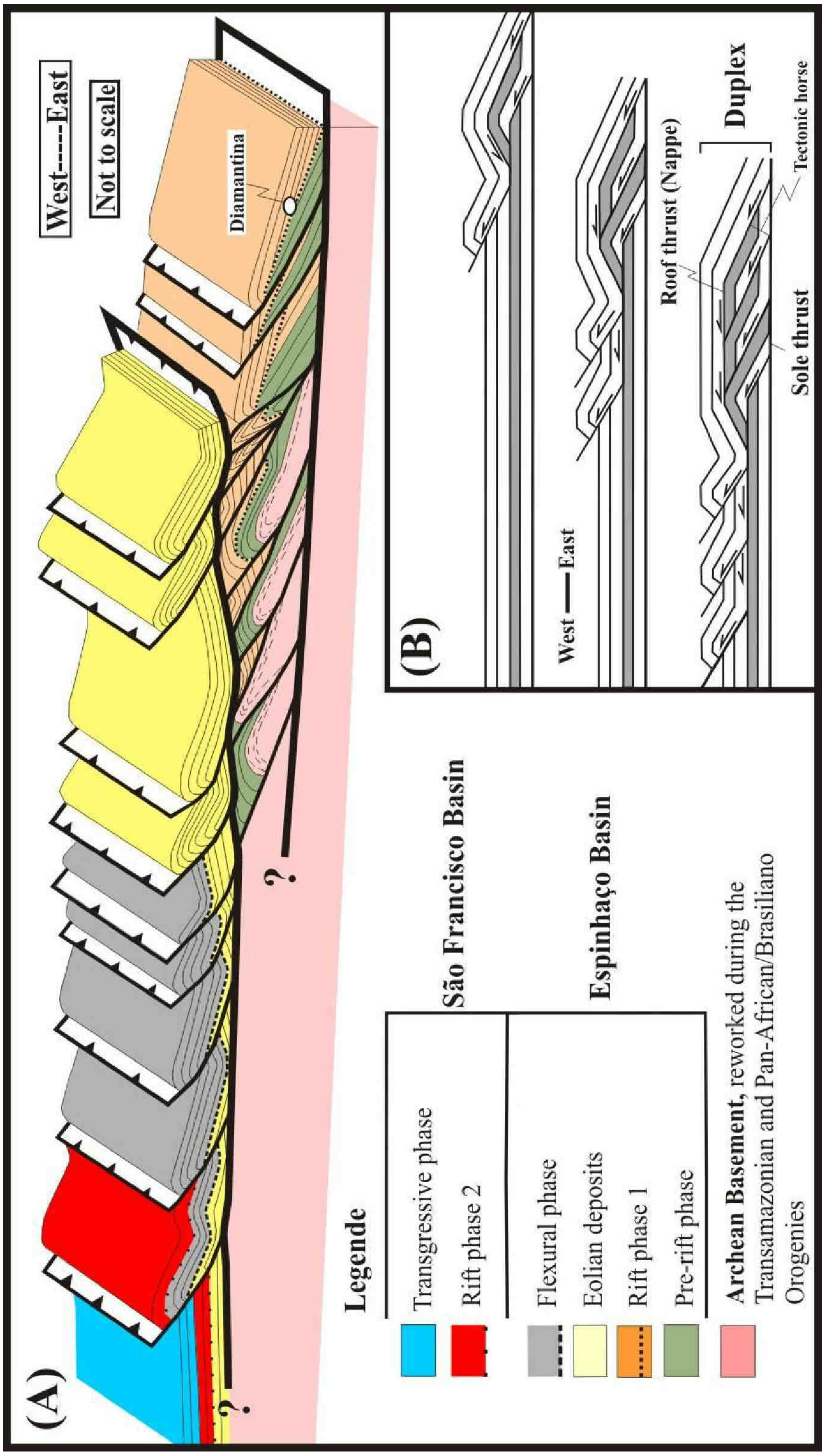

Figure 3. (A) Structural cross section of the central portion of the southern Serra do Espinhaço in Minas Gerais (after Silva & Toledo, modified). (B) Model for the development of the southern Serra do Espinhaço duplex thrust system in Minas Gerais (after Boyer & Elliot 1982, modified).

The large horizontal roof thrust -shear zone can be directly observed at the western border of the cordillera. There, the intense deformation is shown by the development of an array of intrafolial isoclinal folding and is by the total transposition of sedimentary structures. The roof-thrust also crops out in the central portions of the mapped area. The geological map (Figure 2) shows the roof-thrust running across the subsidiary thrusts and apparently truncating them. This tectonic contact is shown by a 10m thick shear zone, with an ubiquitous, anastomosing tectonic foliation that is associated with gold-bearing vein quartz. Weakly deformed metasediments of eolian origin are found above and concordant with the displacement zone. Below this zone, the rocks are intensely deformed, and a N-S drag antiformal indicates westward tectonic transport. Above the roof thrust, a large nappe is tectonically emplaced, with westward transport. The displacement along the roof thrust could not be calculated, as a palinspatic reconstruction coud not be carried out. The sole thrust-shear zone does not outcrop in the mapped area. As subsurface data are still not available, the existence of the sole thrust is interpretative.

Below and above the roof-thrust, two different styles of deformation can be recognized. Below the roof-thrust, deformation is represented by the development of tectonic horses, wich are limited by subsidiary thrust faults and marked by a penetrative sigmoidal tectonic pattern. Stratigraphic reconstruction, however, is only possible inside the tectonic horses. The Archean/Paleoproterozoic basement complex and the lowermost stratigraphic record of the Espinhaço Basin are exposed within the tectonic horses. Deformation of rocks is very intense and transposition of primary structures is a general rule. Above the roof-thrust, a forward (westward) embricated fan of thrusts characterizes the deformation. The distance between thrust sheets is much greater as compared with the distance between the tectonic horses. Stratigraphic record exposed within the thrust sheets represents both the uppermost portions of the Espinhaço Basin and the base of the São Francisco Basin. Deformation of rocks is weak and preservation of sedimentary structures is common.

THE TECTONIC EVOLUTION

Using the overprinting criteria, two phases of deformation can be recognized. Deformation of both horses and thrust sheets, after imbrication, records the overpring of D_2 on D_1 structures. During D_1, the Espinhaço duplex thrust system was built. In relation with this aspect, a main tectonic foliation is developed parallel to the sedimentary bedding. The S_1 foliation includes slaty and fracture cleavagens, as well as schistosity. Narrow bedding-parallel shear zones are developed in the metapellitic rocks. Cataclastic as well mylonitic rocks are also generated on the D_1 thrust planes. Small sheat folds are also generated in shear zones associated with D_1 thrusting. Westward tectonic transport during D_1 is mainly indicated by slickensides and stretching lineations on fault planes and by a penetrative mineral lineations on the S_1 foliation. In general, inside the horses or even inside the trust sheets, D_2 deformation is represented by synclinal and anticlinal folding, in most cases, with disrupted limbs. Locally, in the hing zones, a penetrative axial-plane foliation is developed, with transposition of former foliations and even transposition of sedimentary structures.Thrust planes were not folded during D_2. The thrust planes were reactived during D_2, in order to absorb the crustal shortening.

THE METAMORPHIC EVOLUTION

Metamorphic mineral associations are typically composed of phengite, muscovite, quartz, kyanite, pyrophillite, tourmaline, clorite, cloritoid, lazulite, stilpnomelane, magnetite and opaque minerals. These mineral associations are characteristic of lower greenschist facies conditions (Winkler 1977: 209). Interpreting the relationships of porphyroblasts (kyanite and muscovite) to the S_1 tectonic foliation allow us to locate the syntectonic metamorphic peak within D_2. In the metapelites and in the kyanite-phengite-quartz schist, crenulations of an early S_1 slaty cleavage were observed. Millimetric phengite and kyanite on the S_1 foliation were deformed and recrystallized as centimetric porphyroblasts on the S_2 crenulation cleavage planes. A progressive change in metamorphic conditions during tectonic evolution (from D_1 to D_2) can be demostrated by the transformation from phengite (D_1) to muscovite (D_2) and by the growth, deformation and recrystallization of kyanite crystals on S_2 planes. The change from predominantly brittle deformation during D_1, represented by the development of thrust-faults, to predominantly ductile deformation during D_2, shown by the generalized folding, also confirms the hypothesis of progressive syntectonic metamorphic conditions. D_1 thrusting probably caused crustal thickening and consequently the increase of metamorphic conditions during D_2.

CONCLUSIONS

The tectonic framework of the southern Serra do Espinhaço is characterized by the development of a large duplex thrust system. Westward, progressive, heterogeneous, brittle/ductil, simple-shear deformation generated the duplex thrust system during the initial deformational phase (D_1). The second phase (D_2) caused crustal shortening by generalized asymmetric folding and reactivation of D_1 thrusts. During progressive syntectonic metamorphism, mineral associations of lower greenshist facies were crystallized.

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