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Frontal and oblique tectonics in the Brazilian Shield

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The Brazilian shield was assembled from a few Archean and Paleoproterozoic cratonic nuclei surrounded by Pan-African-Brasiliano mobile belts of Neoproterozoic age. While some of these mobile belts display a typical frontal collision tectonic style, others are dominated by transcurrent regimes, clearly indicating oblique collisional systems. This paper is an attempt to determine the mean orientation of the principal horizontal compressive stresses for each mobile belt, considering either the frontal or oblique convergence character. From these general observations a scheme with WNW – ESE to NW – SE trends of the main compressive stress is proposed. We suggest that this trend represents the mean displacement vectors, according to a coherent kinematic picture for the amalgamation of the West Gondwana during the final stages of convergence of the Brasiliano belts, where WNW–ESE to NW–SE are the main directions of final closure.

Introduction

The general framework of the Brazilian shield is made of a few Archean and Paleoproterozoic cratonic nuclei surrounded by Pan-African - Brasiliano mobile belts of Neoproterozoic age (Figure 1). Their overall description has been the subject of many papers (e.g. Brito Neves and Cordani, 1991; Almeida et al., 2000). On the African side, the broad picture are similar (Goodwin, 1991; Black and Liégeois, 1993).

The evolution of the Brasiliano belts is not yet completely understood. Their histories range from early Neoproterozoic to Cambrian, with complex histories of rifting, ocean opening and closure, magmatic arcs, and synchronic volcanic - sedimentary cratonic covers. Some Mesoproterozoic terranes may also be included. The model here proposed is applied to the final stages of amalgamation of the West Gondwana, i.e., the 580–480 Ma period.

In the classical view, these mobile belts have a typical curvilinear geometry surrounding the cratons, with centripetal vergences (e.g., Unrug, 1996). Assuming that this scenario is correct it would be difficult to figure out a simple kinematic model based upon plate tectonic interactions.

Some of these mobile belts display a typical frontal collision tectonic style. Examples are the Araçuaí and Brasília belts, striking N/S on both sides of the São Francisco Craton. Others, such as the Ribeira belt and the Borborema province, are dominated by transcurrent regimes, with NE or ENE directions, suggesting oblique collision systems.

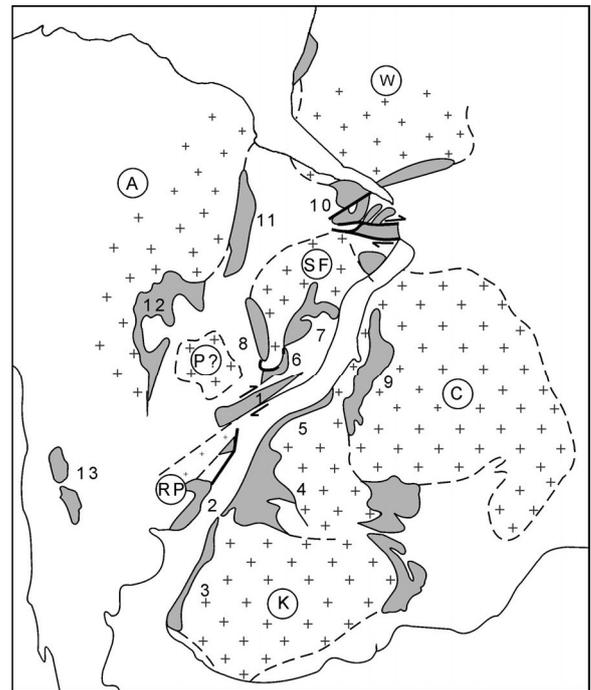


Figure 1 Pre-breakup South America and Africa showing the main cratonic units and Brasiliano-Pan-African belts of the West Gondwana. Cratons: A—Amazonian; SF—São Francisco; C—Congo; W—West African; K—Kalahari; RP—Rio de La Plata; P?—supposed Paranapanema. Fold Belts: 1—Ribeira; 2—Dom Feliciano; 3—Gariép; 4—Damara; 5—Kaoko; 6—Alto Rio Grande; 7—Araçuaí; 8—Brasília; 9—West Congo; 10—Borborema; 11—Araguaia; 12—Paraguai; 13—Sierras Pampeanas.

For the regions of oblique tectonics, both escape tectonics (Vauchez et al., 1994) and transform boundaries (Campanha, 2002) had been already proposed as geodynamic models.

We suggest here that each of these two kinds of mobile belt has some typical geometric and geological features, and that is possible to drive a general picture for the South American Platform as a whole, accomplishing a coherent kinematic interpretation for the final assembly (Neoproterozoic III – Cambrian) of West Gondwana.

Areas with typical frontal tectonics

Regions with typical frontal convergent tectonics are the Araçuaí Belt (in its western and southern portion, pushed over the São Francisco Craton, Figure 3), the Brasília Belt (in its marginal portion to the São Francisco Craton, Figure 3), the Paraguai Belt (Figure 2), and the Araguaia Belt, the last with some obliquity (Figure 4).

The Araçuaí and Brasília belts (Dardenne, 2000; Alkmim et al., 2001; Pedrosa Soares et al., 2000) show tectonic patterns with

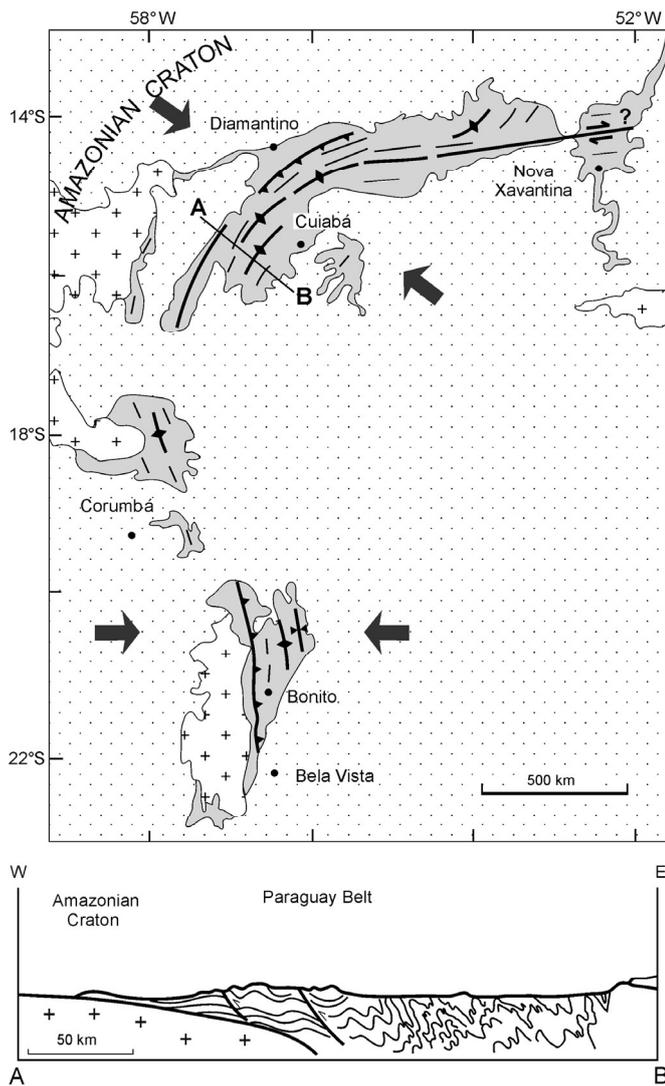


Figure 2 Map and section for the Paraguay Belt (after Boggiani, 1997 and Alvarenga et al., 2000). Location and symbols explained on Figure 7.

frontal thrusts with vergence towards the São Francisco Craton, and stretching lineations normal to the belts. The Paraguay and Araçuaia belts (Alvarenga et al., 2000, Boggiani, 1997) exhibit similar patterns, representing frontal collisions against the Amazonian Craton, as in Africa the West Congolian Belt represents a frontal collision with the Congo Craton.

These regions are characterized by the following main features:

- fold-and-thrust belts striking parallel to the borders of the foreland with clear vergence to the craton;
- foliation dipping toward the mobile belt, with large areas with gentle dipping foliation, associated with overlapped nappes developed on the marginal areas;
- down-dip stretching lineations normal to the belt;
- presence of late foreland basins.

Areas with typical oblique tectonics

The Borborema Province in the Northeast Brazil (Figure 5), the Ribeira Belt in the Southeast Brazil (Figure 3), and Dom Feliciano Belt, in the South (Figure 6), are typical branching systems of orogens that presented oblique convergence during the Neoproterozoic and Early Paleozoic West Gondwana collage.

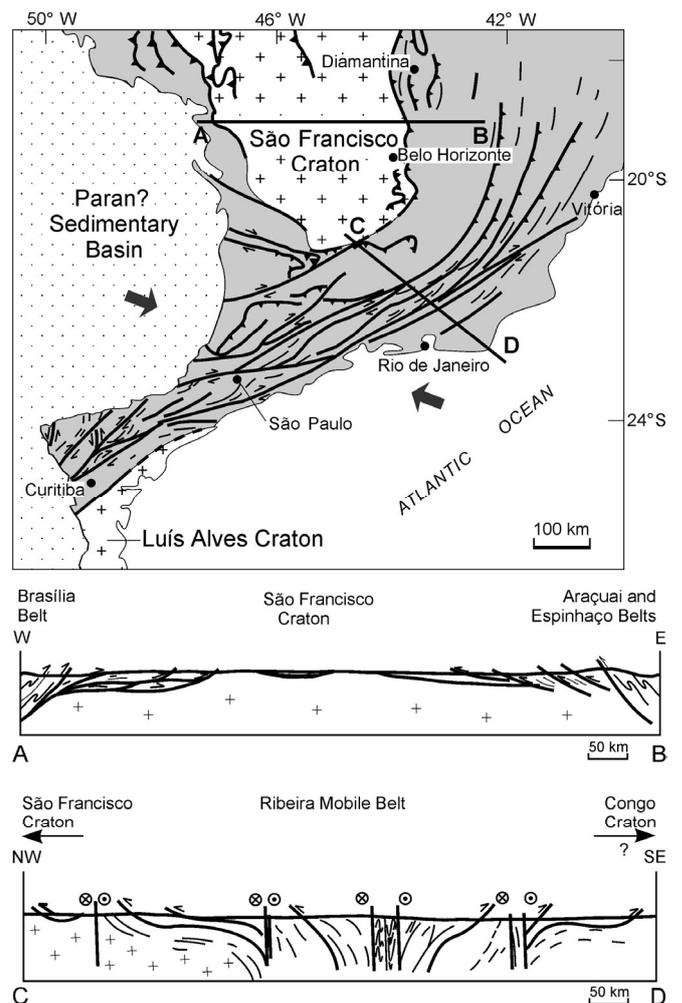


Figure 3 Map and sections for the Ribeira, Southern Brasília and Southern Araçuaí Belts. AB—Schematic cross-section over the São Francisco Craton (after Alkmin et al., 1996): a typical frontal collision structural pattern; CD—Schematic cross-section over the Ribeira Belt (after Machado and Endo, 1993, and others): a typical oblique collision structural style.

In the Ribeira Belt (Campanha, 1981, 2002; Machado and Endo, 1993; Vauchez et al., 1994; Ebert and Hasui, 1998; Campanha and Sadowski, 1999; Campanha and Brito Neves, 2001) and Borborema Province (Brito Neves et al., 2000; Davison and McCarthy, 1995) the tectonic fabric is characterized by right-handed, ductile to ductile/brittle ENE or EW transcurrent shear zones, with the development of large sigmoid (S/C) structures and subsidiary conjugate left-handed NNE or NS shear zones. The stretching lineations are mainly ENE with sub horizontal dip, although early oblique NW lineations associated with thrusts are also observed. A similar situation is observed in the Dom Feliciano Belt (Bitencourt and Nardi, 2000).

These belts are characterized by the following main features:

- large vertical strike-slip shear zones parallel to the mobile belt, with S/C patterns of foliation in the intervening blocks and an internal sigmoid network of shear lenses, at all scales of observation;
- complex internal branching organization with different domains, displaced terranes or blocks, showing different ages, structural, metamorphic and sedimentary patterns, bounded by transcurrent shear zones;
- subsidiary shear zones oblique to the mobile belt, with opposite shear sense from that of the main zones;
- early thrusts and/or on echelon folds oblique to the mobile belt, rotated in to the main strike-slip shear direction;

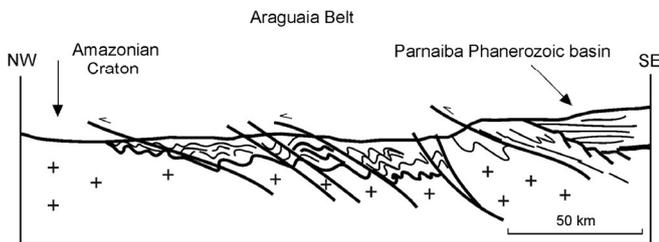
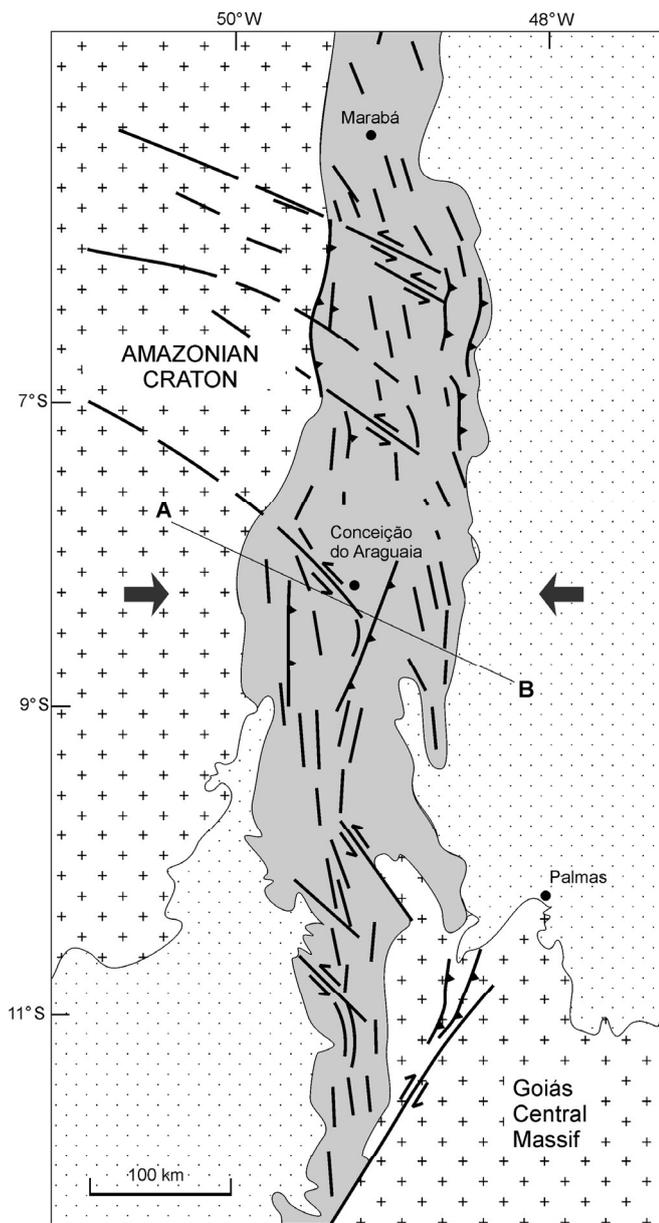


Figure 4 Map and section for the Araguaia Belt (after Alvarenga et al., 2000).

- no clear vergence; the usual pattern is a positive flower or fan structure, with a central zone exhibiting a steeply dipping foliation, and external zones with moderate- to low-dip foliations dipping toward the central zone;
- horizontal stretching lineations parallel or oblique to the mobile belt;
- development of late pull-apart basins (usually referred as "molassic basins"), associated to the transcurrent shear zone network, broadly chrono-correlated with the foreland basins in the areas of frontal convergence tectonics (ca. 570–540 Ma).

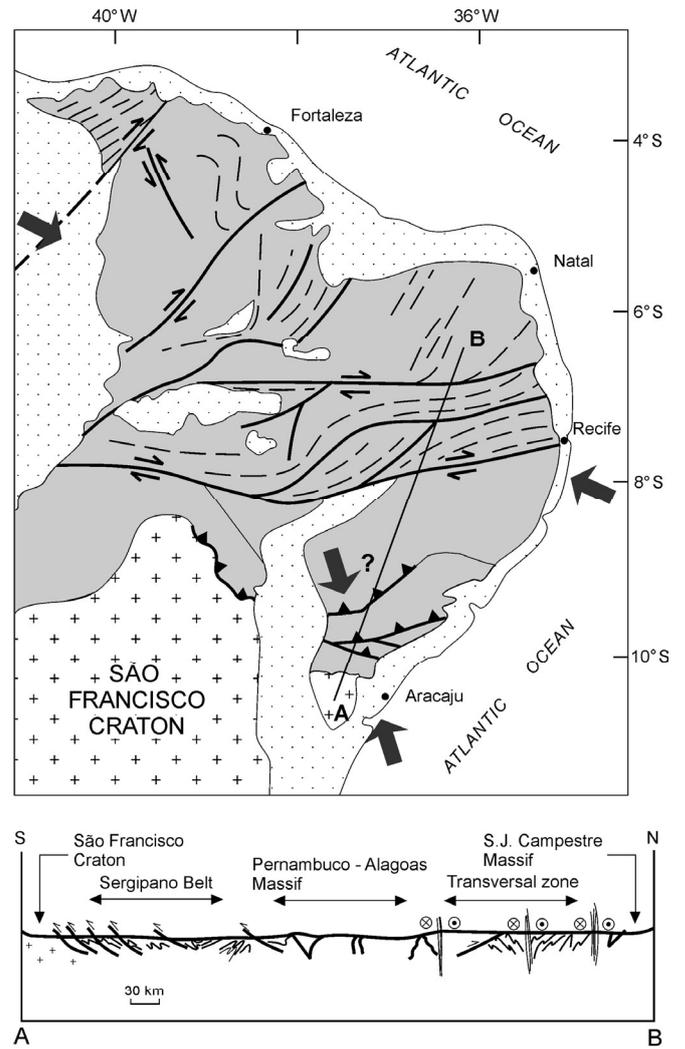


Figure 5 Map and section for the Borborema Province (after Brito Neves et al., 2000).

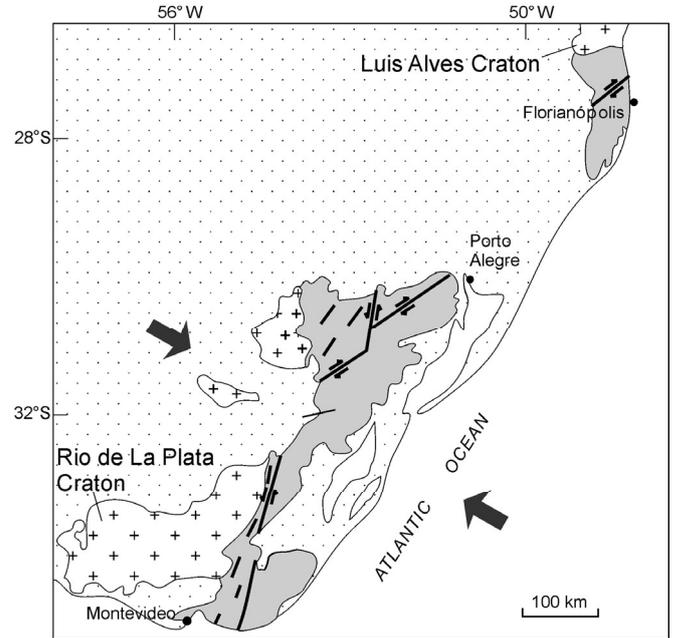


Figure 6 Dom Feliciano Belt.

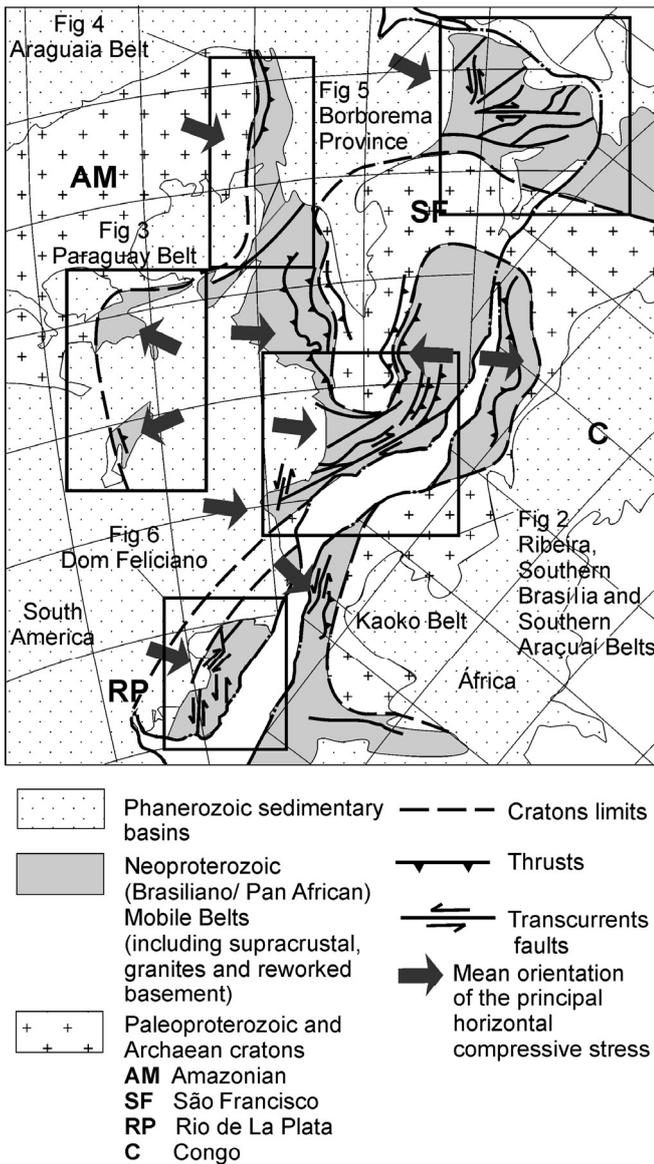


Figure 7 Sketch for the Western Gondwana (South America and Africa) assembly.

Direction for the main compressive stress

According to classical mechanics (e.g. Anderson 1951) the orientation of the maximum compressive principal stress σ_1 for both thrust and wrench faulting is horizontal. In the former the minimum compressive principal stress σ_3 is vertical whereas in the later the intermediate principal stress σ_2 is vertical. A change from a thrusting to a wrench regime can be achieved by permuting σ_3 and σ_2 , keeping σ_1 horizontal.

If we consider the stress evolution during plate collision, it is probable that initial thrusting occurs. This implies that σ_1 is horizontal and perpendicular to the thrust strike while σ_3 is vertical. The process of thrusting increases the vertical stress and it is possible that at some point in the deformational history it will grow to the point where it becomes σ_2 . When this occurs thrusting will give way to wrenching. The wrench faults are oriented ideally at 30° at each side of σ_1 i.e. striking at 60° to the strike direction of the initial thrusts.

However, it is likely that during the plate collision the boundary conditions override this tendency and determine that the wrenching will occur parallel to the plate margin, a direction of relatively easy slip.

We consider that the main compressive stress σ_1 in the frontal belts is horizontal and perpendicular to the thrusts and fold axis. The absence of obliquity precludes the development of major late transcurrent shear zones.

In the oblique belts the main compressive stress σ_1 is taken as horizontal, bisecting the conjugated pairs of right-handed and left-handed shear zones, and is also perpendicular to the initial direction of the thrusts, schistosity and fold axis (*S* directions), which are later rotated by the transcurrent movements.

Some restrictions can be made regarding the determination of stress directions in ductile zones associated with finite (large, accumulated) rotation. The main stress directions are usually correlated with infinitesimal (small, instantaneous) strains and not with finite strains, and geological ductile structures such as foliations and lineations are considered to be associated with the finite strain.

In our view, even in ductile shear zones it is reasonable to assume a main compressive stress σ_1 making an angle about 45 degrees with the *C* direction and perpendicular with the external *S* direction. The sigmoid fabric of foliations is due to the accumulated rotation deformation. In addition, where conjugated right- and left-handed shear zones are observed, it is still more acceptable to consider σ_1 to be the bisector of the compressive quadrant.

We also assume that the directions of principal compressive stress on a continental scale was broadly parallel to the mean plate displacement vectors, as is currently observed in the pattern of average stress (Zoback, 1992) and plate displacement vectors in the present global tectonic situation.

Conclusions

From the general framework of frontal and oblique mobile belts of the Brazilian shield and West Africa, it is possible to propose a model with WNW-ESE to NW-SE directions of principal compressive stress (Figure 7) during the final stages of convergence of the Brasiliano. We suggest this represents the mean displacement vectors, according to a coherent kinematic picture for the amalgamation of the West Gondwana.

Two minor branches seem not to fit with the general scheme. This is the case of the northeastern portion of the Araçuaí belt, and the southern part of the Borborema Province. By the available information these particular participants of the general branching systems of orogens follow the frontal type of collision, and their tectonic vergence would be broadly N/S to the São Francisco Craton.

Taking in account the usual Gondwana reconstructions (Figure 7) the Kaoko belt in Africa with its left-handed transcurrent regimes (Dürr and Dingeldey, 1996) fits into this general scheme as it is parallel to some left-handed NS shear zones in the Ribeira Belt.

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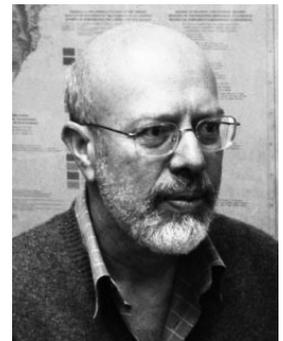
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