NEOPROTEROZOIC OROGENIC SYSTEMS IN EASTERN, CENTRAL AND NORTHEASTERN BRAZIL, AND THE ASSEMBLY OF GONDWANA

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In eastern, central and northeastern Brazil, a large and intricate orogenic system record the geologic history of the West Gondwana amalgamation from Early Neoproterozoic to Cambrian times. This long-lived orogenic collage resulted from the diachronic interaction of the São Francisco-Congo, West Africa, Paraná-Rio de La Plata, and Amazonia paleocontinents (Brito-Neves et al., 1999). It may be subdivided into three main orogenic provinces, called Tocantins, Mantiqueira, and Borborema, that record complete Wilson Cycles, from continental rifting to generation of passive margins, arc/back-arc systems, and subduction of oceanic lithosphere followed by arc-continent and/or continent-continent collisions. Basement inliers of varied size, nature and tectonic role, mainly of Paleoproterozoic age, are common in all those orogenic systems. From this diachronic plate convergence (Fig 1) resulted the South American Platform, the region of West Gondwana where large ensialic basins developed from Ordovician time to the onset of South Atlantic Ocean spreading.

The Borborema Province

The Borborema Province, in eastern-northeastern South America, brings the record of two events of tectonic collage and consequent supercontinental amalgamation, during the Mesoproterozoic-Neoproterozoic (Cariris Velhos Cycle, 1050-950 Ma) and during the Neoproterozoic-Cambrian (Panafrican-Brasiliano Cycle). The superimposition of the latter onto the former is a notable fact. The present divergent structural outline, with fan geometry, is the result of the final Brasiliano tectonic stages during the Cambrian.

The records of the Cariris Velhos Cycle stretch along ca. 800 Km in WSW-ENE orientation, up to 200 m wide, transversally to the central portion of the Province. They are formed by volcano-sedimentary (mainly of medium metamorphic grade) accretion and collision products. Most characteristic features are hundreds of granitic augen-gneiss bodies (ca. 960 Ma) of varied shapes, as result of arc-magmatism and collisional interaction. This belt is the orogenic tract of the interaction of two continent-scale Paleoproterozoic (with subordinate Archean nuclei) lithospheric fragments, that united with other ones during the assembly of Rodinia supercontinent.

As Rodinia diachronically broke up in this region (ca. 950 to 700 Ma), several large lithospheric fragments were individualised, such as S. Francisco, West Africa-S. Luis, Parnaíba, Rio Grande do Norte, and other smaller landmasses of pre-950 Ma basement. In the intervening spaces, continental and oceanic basin formation took place. The interaction between these continental fragments and basin closure, around 640-590 Ma, created a complex mosaic of reworked basement blocks and proximal/marginal and distal orogenic belts. Among the latter, some display ophiolitic remains.

The syn-tectonic plutonism is expressive in number and typology, followed by numerous late-tectonic stocks (ca. 590 to 570 Ma), emplaced both within the mobile belts and the intervening basement massifs. Starting at 550 Ma, up to 500 Ma., the province was affected by renewed granitic plutonism, dyke swarm and pegmatite dyke field development, all associated

to escape (or extrusion) tectonics. This wrench-dominated crustal deformation took place preferentially along belt/basement block boundaries, with the development of shear zones of hundreds of kilometer long, up to 20 km wide. This tectonism ultimately defined the geological-geographical style of the province and its main structural lines which, along the whole Phanerozoic, controlled the location of sedimentary basins.

The Tocantins Province

The Brasilia Belt represents one of the best preserved Brasiliano/Pan-African fold belts in Brazil. It forms an approximately 1000 km long NS belt occupying the eastern part of the Tocantins Province, in central Brazil and is formed by: (i) a thick sedimentary/ metasedimentary sequence deposited and deformed along the western margin of the Sao Francisco/Congo continent, (ii) strongly reworked Paleoproterozoic sialic basement (Central Goias Massif) and (iii) a large juvenile Neoproterozoic magmatic arc (the Goias Magmatic Arc) exposed in the western part of the belt.

Clear tectonic and metamorphic vergences are towards the Sao Francisco cratonic area. One of the most important structural aspects of the belt is the Pirineus Sintaxis (Araujo Filho 1999), a ca. 150 km long WNW-ESE lineament which separates the belt in the northern and southern segments, with very distinct structural characteristics. In the northern segment, the sedimentary units display a smaller degree of deformation and metamorphism and the stratigraphic relationships between the different units of the belt are well preserved. In the southern segment, however, the Brasiliano deformation and metamorphism was very intense, with the development of a complex imbricated system of thrusts and nappes indicating eastward tectonic transport of large amplitude.

Many aspects of the belt suggest a long-lived tectonic history with sedimentation of a passive margin sequence starting at ca. 1.1 Ga (Paranoa, Canastra and Vazante groups), development of a intraoceanic island arc system starting at ca. 0.9 Ga (Pimentel & Fuck 1992, Pimentel et al 1999) and final closure of the large oceanic basin and continental collision at ca. 0.6 Ga.

In the southern segment of the belt, a subduction zone tectonic regime is recorded in the superior nappes, which display early intense recumbent folding with associated high-pressure metamorphism dating ca 620 Ma (Seer, 1999). In the Passos nappe, a well documented inverted metamorphic gradient ranging from the biotite zone up to the amphibolite-granulite facies transition (Simões, 1995). These nappes, represented by distal shelf and deep marine lithological assemblages also contain a long and narrow ophiolitic melange within the Araxá group (Strieder & Nilson 1992).

Persistent sinistral transpressive tectonic styles succeeded as result of the oblique E-W convergence of the Rio de la Plata-Paranapanema cratonic block against the NW-SE southeastern border of the Francisco craton.

The thin-skinned style of allochthony in the external zone resulted in a thrust-fold belt of low-grade passive margin lithologic assemblages, with numerous basement inliers represented by tectonic lenses of granite-gneiss or granite-greenstone lithology. The allochthonous front at the 23 degree parallel is characterised by the presence of the Samburá foreland basin. Sedimentation is characterised by sub-aqueous fan deposits of polymict rudaceous facies and associated pelites, developed discordantly on top of the Neoproterozoic Bambuí group carbonatic shelf and its autochthonous cratonic basement.

The superior high-pressure allochthons, represented by successive ESE-oriented spoon-shaped nappes, bounded by ESE lateral ramps, were extruded as out-of-sequence mega-thrusts involving tectonic transport of at least 200 km onto the external zone.

Late sinistral transpression affected all tectonic units in shallower crustal levels and led to the reactivation of the old lateral ramps as sinistral brittle-ductile ESE transcurrent faults associated to N-S orientation of fold axes. K-Ar ages around 580 Ma constrain the regional cooling of this collisional event.

U-Pb and Sm-Nd metamorphic ages in sphenes and garnets, respectively, are mostly within the range between 0.63 and 0.60 and are thought to represent the collision between the Sao Francisco/Congo, Amazon and Parana (or Rio de la Plata) continents. However, more recently geochronological studies have indicated an early metamorphic peak at ca. 0.78 Ga (Ferreira Filho et al. 1994, Correia et al 1997, Pimentel & Junges 1997), especially for rocks in the northern segment of the belt. Although this early Neoproterozoic metamorphic peak is still poorly understood, there has been the suggestion that it is the result of docking of the Goias Magmatic Arc onto the western edge of the belt. The final stages of evolution of the Brasilia Belt are marked by the emplacement of large <600 Ma K-rich granite plutons, indicating rapid uplift and unroofing of the region, after continental collision (Pimentel et al. 1996).

The southeasternmost recognised stretches of the Brasilia belt display increasing deformational overprint caused by the later collisional deformation related to the Mantiqueira Province, that started at ca. 600 Ma, with predominant NE-trending structural fabric (Trouw et al., 2000).

The Mantiqueira Province

The southern and northern segments of this province are called Ribeira and Araçuaí belts, respectively.

The Araçuaí Belt extends over the region from the eastern edge of the São Francisco Craton to the Atlantic Ocean, between 15º and 21º S parallels. The Araçuaí Belt together with its African counterpart (the West Congo Belt) occupy a peculiar place, *i. e.*, they make up an orogen confined to the embayment outlined by the São Francisco and Congo cratons (Pedrosa-Soares and Wiedemann-Leonardos 2000). The external tectonic domain of the Araçuaí Belt is marked by shallowly- to moderately-dipping structures. The tectonic transport vectors point towards the São Francisco Craton. The NNE structural trend of the internal tectonic domain is intersected by the bent trend that makes the northern curvature of the Araçuaí Belt. Both the external and internal tectonic domains are represented in that arch-shaped zone. Two distinct subdomains are recognized in the internal tectonic domain. A northern subdomain (north of 19° S) shows well marked SW-vergence formed by shallowly- to moderately-dipping thrusts with dextral strike-slip component, where the anatectic zone of the orogen is better exposed. A southern subdomain is characterized by prominent steeply-dipping, dextral shear zones, granulite facies rocks and granitic plutons with mafic cores. This subdomain preserves consequently the deepest crustal levels of the orogen. The regional metamorphism shows a centripetal pattern, with increasing temperatures converging from the cratonic borders to the anatectic-granulitic core disclosed in the internal tectonic domain. Late Neoproterozoic to Cambro-Ordovician granitic plutonism is widespread along this domain. We summarize some stages of the evolutionary model proposed by Pedrosa-Soares and Wiedemann-Leonardos (2000): i) in late Mesoproterozoic time, the focused region acted as a platform; ii) ascent of a mantle plume generated mafic dike swarms and volcanics, and induced anorogenic felsic magmatism and a rifting process (*ca*. 1.05-0.9 Ga), partly coeval to a glaciation; iii) this Neoproterozoic rift went through a complete Wilson Cycle, evolving to an ocean basin (slivers of oceanic lithosphere yielded ages around 816 Ma), although its northern portion remained ensialic; iv) during the B-subduction-controlled orogenic stage (*ca*. 625-595 Ma), a small but significant precollisional, calc-alkaline magmatic arc developed in a continental active margin (this arc was entirely inherited by the Araçuaí Belt after South Atlantic opening in Mesozoic time); v) during the collisional stage (*ca*. 595-575 Ma), thrust tectonics, regional metamorphism and widespread crustal anatexis built the major portion of the orogenic architecture; and late collisional to postcollisional granitoid suites (*ca*. 575-560 Ma) formed along strike-slip shear zones, probably record a docking stage; vi) some 40 Ma after the end of the collisional stage, in Cambro-Ordovician times (535-490 Ma), the last

plutonic suites crystallized during the final stages of the orogeny.

The Ribeira belt is the usual denomination for the segment of the Mantiqueira Province south of the 21°S parallel. A wider oceanic space probably with interaction with other minor continental masses, a huge volume of arc-related rocks and a large volume of basement thrusts are important differences for the Araçuaí belt segment

The crustal structure of the Ribeira segment is defined by two major tectono-stratigraphic terranes (Heilbron et al., 2000a): a) the Occidental Terrane is interpreted as the reworked margin of the São Francisco Plate and comprises an autochthonous domain, the Andrelândia nappe system, which contains records of the older Brasilia belt deformation, and the Juiz de Fora thrust system; b) the Oriental terrane is envisaged as part of the Congo Plate (Heilbron et al, 2000a) with other(s) minor plate(s) like the Serra do Mar microplate (Campos Neto e Figueiredo, 1995). encompasses the Paraíba do Sul Klippe, the Costeiro and the Cabo Frio domains. The plutonic segment of a cordilleran magmatic arc (ca.640-600 Ma) is located at the Oriental Terrane (Tupinambá et al., 1998,1999). The suture zone between these two terranes is a conspicuous NW-dipping shear zone that can be traced continuously along at least 200 km. This structure, called the Central Tectonic Boundary (Almeida et al., 1998) was developed during the early stages and reactivated during the late stages of the Brasiliano orogeny. Three major lithological associations were recognised and mapped in the central Ribeira belt : a) the reworked Paleoproterozoic /Archaean basement; b)deformed Paleoproterozoic to Neoproterozoic cover successions; and c) Neoproterozoic granitoid rocks which characterize five distinct tectono-magmatic stages

The Neoproterozoic evolution of the Ribeira segment developed via a complex Wilson Cycle between the São Francisco – Rio de la Plata (SFP) and Congo (CP) cratons. Evolution of this segment involved sea-floor spreading and passive-margin sedimentation, subduction with arc and back-arc formation, and continent-arc (stage I) and back-arc (stage II) collisions (Heilbron et al., 2000b).

Ocean basin closure (stage I) resulted from E-directed subduction under the Congo Plate to generate a W-migrating magmatic arc on the upper plate and back-arc basin to the E (ca 640-600 Ma). Oblique collision between the arc and the São Francisco plate between ca. 600 and ca. 550 Ma induced a dextral-oblique, W-vergent thrust system, associated with intermediate-*P* metamorphism and emplacement of crust-derived granites. (Machado et al., 1996, Heilbron et al., 19995, 2000). The suture between passive-margin rocks/crustal units of the São Francisco Plate side and passive-margin/arc rocks of the Congo Plate side of the former ocean basin is represented by the Central Tectonic boundary. Continued convergence until ca. 490 Ma produced subvertical folding and steep dextral-oblique shear zones, which controlled emplacement of late-collisional granites and associated tholeiites, and overprinting low-*P* metamorphism. We relate these effects to slab detachment and consequent enhanced mantle heat flux, leading to uplift/exhumation while compressional deformation continued.

Concurrent closure of the back-arc basin to the E (stage II, ca. 530-480 Ma) drove NNW-thrusting of the Cabo Frio terrane (Schmitt et al., 1999) over the arc, causing high-*P* metamorphism of the marginal basin rocks. This tectonic episode is the latest orogenic record registered at Western Gondwana

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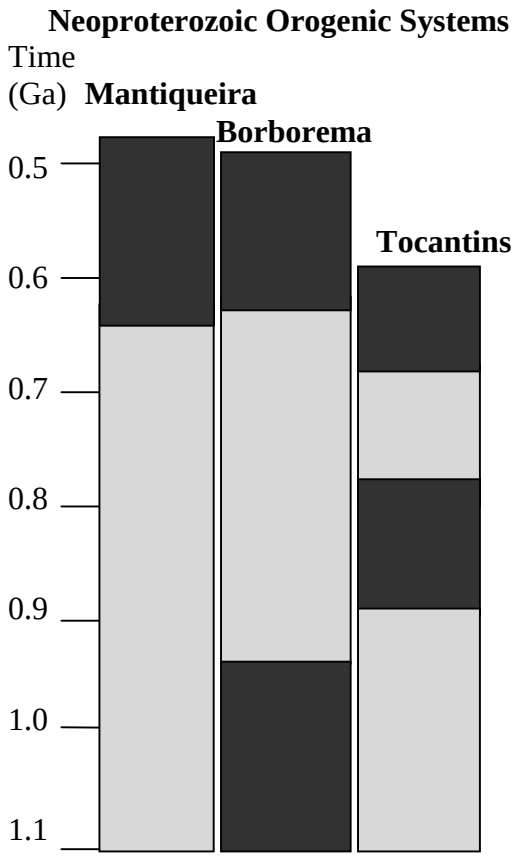

Figure 1: Comparative tectonic evolution of the
Neoproterozoic orogenic systems in central, eastern and northeastern Brazil.
Legend: Light grey: Extensional sedimentary record;
Dark grey: Orogenic periods;