

THE BORBOREMA PROVINCE: A COLLAGE OF POLYCYCLIC CRUSTAL DOMAINS IN NE BRAZIL

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INTRODUCTION

The Borborema Province (BP) of NE Brazil comprises the west-central part of a wide Pan-African - Brasiliano orogenic collage that formed during late Neoproterozoic (ca. 600 Ma) assembly of West Gondwana. Our Rb/Sr, Sm/Nd, and U/Pb geochronologic results and recent work by other workers demonstrate the presence of several major tectonic cycles (2.7 Ga, 2.1 Ga, 1.0 Ga, and 0.6 Ga) and some discrete events (3.4 Ga, 3.2 Ga, 1.7 Ga, 0.8 Ga) that created and modified various domains. The domains in the BP represent several episodes of continental assembly, stasis, extension, and rifting prior to terminal stabilization at the end of the Pan African - Brasiliano orogeny.

GENERAL GEOLOGY AND STRUCTURES

The Borborema Province is bounded on the south by the São Francisco Craton (SFC) and, in pre-drift reconstruction, on the northwest by the São Luiz-West African craton (WAC). Recent studies indicate that structures and rock units of the BP extend from Brazil into the Pan African belt of central Africa, forming a large wedge between the WAC, SFC, and Congo craton (CC) [1, 2]. The extension of the BP to the west is obscured by a Phanerozoic basin. There are several major structural boundaries within BP, and some may represent terrane boundaries. From south to north, the major structures are (Fig. 1): the northern edge of SFC basement, the Pernambuco shear zone, the Patos shear zone, the Sobral Fault (SF), and the eastern edge of WAC basement. These structures divide BP into three subprovinces. Brasiliano plutons were extensively intruded in all three subprovinces [3].

Subprovince 1 (SP1) is between the Patos shear zone and the northern edge of the SFC; the Pernambuco shear zone is a structural feature within SP1 and does not represent a boundary between terranes. There are several structural domains within this SP1 (Fig. 1), including the Sergipano fold belt (SFB), Riacho Pontal fold belt (RPFb), Piancó-Alto

Brigida fold belt (PABFB), and Pajeú-Paraíba fold belt (PPFB). All these fold belts formed about 1050 to 950 Ma, during the Cariris Velhos (CV) tectonic cycle. Additional domains include the Teixeira - Terra Nova (TTN) structural high between PABFB and PPFB, the Pernambuco - Alagoas massif (PAM) between the PPFB and SFB, several isolated blocks of early Paleoproterozoic to Archean basement, and small occurrences of middle Neoproterozoic supracrustal rocks.

Subprovince 2 (SP2) is north of the Patos shear zone and east of the Sobral fault. The basement in SP2 is mostly Transamazonian (TA, ca. 2.1 Ga) orthogneisses with isolated domains of Archean crust as old as 3.45 Ga [4]. Late Paleoproterozoic (ca. 1.7-1.8 Ga) supracrustal rocks occur in eastern Ceara state [5, 6]. Middle Neoproterozoic (ca. 750 to 800 Ma) supracrustal rocks are widely distributed in SP2 and include the Seridó Group in Rio Grande do Norte and the Independência and Ceará groups in Ceará. There are several faults and shear zones within SP2, and some may represent crustal boundaries, although it is not possible to define individual crustal blocks or terranes at this time.

Subprovince 3 (SP3) is in NW Ceará state between the Sobral fault and the São Luiz-West African craton. Most basement in SP3 is also early Paleoproterozoic, although it is somewhat older than the TA orogeny and may include a significant area of juvenile (at 2.35 Ga) crust. Middle Neoproterozoic supracrustal rocks (Martinópolis Group) are also locally present.

TECTONIC CYCLES ARCHEAN

Recent studies in eastern SP2 have defined several Archean crustal blocks that were welded together during the TA orogeny [4]. These are in the Presidente Juscelino area of Rio Grande do Norte and include gneissic assemblages with ages of ca. 3.45 Ga, 3.2 Ga, and 2.7 Ga. The older gneiss have

juvenile Sm/Nd properties (TDM = U/Pb age) and are remnants of Archean microcontinents. The 2.7 Ga gneiss has a TDM age of 3.2 Ga, indicating that it was derived from older crust. Domains or blocks of Archean crust have also been recognized in western SP2 (2.7-2.9 Ga, south-central Ceará), and others may be defined as studies continue. These blocks have not yielded enough information to define their histories in detail. The Archean nuclei were probably incorporated into a major continental mass during the Transamazonian (Brazil)-Eburian (West Africa) orogenic cycle at ca. 2.1 Ga.

PALEOPROTEROZOIC

Pre-Transamazonian crust. We restrict the TA tectonic cycle to 2.2 to 2.0 Ga, with possible late-TA activity as young as 1.9 Ga. In this context, Pre-Transamazonian Paleoproterozoic crust is found mainly in SP3 [7]. Here the basement yielded U/Pb ages of ca. 2.35 Ga with similar TDM model ages, indicating that this is a juvenile terrane.

Transamazonian cycle. Most basement in BP is orthogneiss intruded and metamorphosed during the TA. In SP1 TA gneisses of the SFC underlie southern parts of the SFB [8]. This basement does not continue north of the São Miguel do Aleixo Fault (SMdAF); granites intruded north of this fault yield Sm/Nd model ages of ca. 1.5 Ga [9], implying that this basin is underlain by Mesoproterozoic crust. There are several smaller blocks of TA crust scattered throughout SP1. These may be remnants of formerly continuous TA (SFC?) basement that was broken up and left as small microcontinents in a new ocean (see below under CV cycle).

In SP2 the TA basement is continuous. The TA gneisses yield U/Pb ages of 2.2 to 2.1 Ga [4,9]. Sm/Nd model ages (TDM) are older, ranging from 2.3 to 2.7 Ga, showing a contribution from older crust. This is different from the WAC, where 2.2 to 2.1 Ga Birrimian-Eburnian rocks have juvenile Sm/Nd signatures [10]. SP2 is separated from SP1 by the Patos shear zone. It is unclear if TA basement of SP2 was originally continuous with that in SFC and SP1 or if the Patos shear zone is a major terrane boundary. Ledru et al. [11] argued for TA fusion of WAC and Guiana-Amazon craton (GAC) and of SFC and CC at 2 Ga. We suggest TA basement in the BP and 2.1 Ga gneiss in central Africa (e.g., Nigerian Province [2]) are tectonized remnants of crustal blocks that were part of a large post-TA continent that included the GAC, WAC, SFC, CC, and regions in between ("Atlantica" of Rogers [12]).

Post-Transamazonian. The Jaguaribeana Fold

Belt (JFB) in central SP2 contains meta-sedimentary and metavolcanic rocks which formed about 1.7 to 1.8 Ga [5, 6]. These rocks are similar to sequences found on the SFC and the GAC [13] and may be part of an extensive cover of cratonic sediments with extensional intracratonic felsic volcanics that were deposited on a post-TA supercontinent ("Atlantica" [12]).

MESOPROTEROZOIC

There is little evidence for tectonic activity in the Mesoproterozoic until about 1100 Ma. The exception is a U/Pb age of 1.52 Ga [14] for augen gneiss in Taquaratinga do Norte, in east-central Pernambuco. The first phase of the Cariris Velhos (CV) cycle [9, 15] began with rifting and deposition of turbiditic rocks in the basins. U/Pb ages for bimodal volcanics suggest rifting began after 1100 Ma. Deposition and bimodal volcanism continued at least until ca. 1012 Ma [9]. Sm/Nd data for both volcanic and sedimentary rocks and for Brasiliano granites, yield TDM ages of 1.4 to 1.6 Ga, indicating that detritus and magmas were not wholly derived from regional TA lithosphere. Basin-fill must include a substantial contribution from juvenile 1.1 to 1.0 Ga sources, but its provenance is unknown.

NEOPROTEROZOIC

The second phase of the CV cycle continued into the early Neoproterozoic. Numerous orthogneisses along the TTN structural high have U/Pb ages of ca. 970 Ma [16] and may represent the center of a 750 km long plutonic belt (arc?) intruded into supracrustal sequences southeast of the TTN high. Neoproterozoic supracrustal rocks NW of the TTN high, in the PABFB, are generally low grade; interbedded felsic volcanics yield U/Pb ages of ca. 970 Ma, similar to those for orthogneisses of the TTN high [16]. Supracrustal rocks SE of the TTN high are generally upper amphibolite grade and more deformed than those to the NW. The sequence near Floresta (PE) is intruded by the 750 Ma Riacho do Ico granite that is less deformed, showing that much deformation in the region was due to compressional phases of the CV cycle [17]. Thus, the CV cycle began with crustal extension about 1100 Ma, ended with a convergent phase about 950 Ma, and included a major plutonic phase about 970 Ma. This cycle could be explained by development of a continental magmatic arc along a rifted continental margin (now the TTN high), although other alternatives are also being investigated.

Many suites of rock previously considered to

be TA or Brasiliano were, in fact, formed about 820 Ma to 740 Ma [7, 16, 18] and are found in all three subprovinces. The Martinópolis, Ceará, and Independência sequences of SP2 and SP3, plus a possible sequence in the PABFB of SP1 include clastic rocks as well as felsic volcanics. The Seridó Group in eastern SP2 is widespread and consists mainly of siliclastic and carbonate rocks in the lower part, with volcanoclastic metaturbites and minor metatuffs in the upper part. There are no large igneous provinces of similar age known at present that could serve as source regions for the Seridó Group. The Baixa Grande and Canindé sequences in SP1 contain bimodal volcanics that may represent intraplate volcanism. The 750 Ma Riacho do Ico granite in the Floresta (PE) region [17] is apparently coeval with the Baixa Grande and Canindé volcanism. If SP1 and SP2 were proximal in the middle Neoproterozoic, then the igneous suites in SP1 may be remnants of a larger igneous province that fed detritus on to cratonic basement of SP2.

The Brasiliano orogeny has three main phases. The oldest is compressive deformation and metamorphism associated with assembly of West Gondwana from 620 to 590 Ma. The masses involved were the SFC-CC, GAC-WAC, and microcontinents now in BP and west-central Africa. Compression of CV extensional basins and 750-800 Ma supracrustal rocks also occurred at this time. The second phase is crustal melting and granitic plutonism. No juvenile Brasiliano volcanic arcs have been recognized within BP, but Fetter [7] argued that Brasiliano magmatism SE of the Sobral Fault (Santa Quitéria complex, SQ) is a continental margin magmatic arc. Most plutons post-date the first phase; ages on plutons and high-grade gneisses show that the Brasiliano orogeny peaked about 600 Ma in BP, with late-stage events lasting another 20 to 30 m.y. The third phase of the Brasiliano orogeny is extensive strike-slip deformation that occurred as various crustal blocks were shuffled around, perhaps as a result of collisional "escape tectonics". The Pernambuco and Patos shear zones are the largest examples, but there are many smaller faults [19, 20]. The age of this phase is not well defined, and it may have continued into the Cambrian [21].

SUMMARY AND GLOBAL IMPLICATIONS

Crustal evolution in northeast Brazil involved several tectonic cycles that caused progressively older domains to go through polycyclic deformation and metamorphism. Unravelling this history has revealed Archean continental nuclei; 2.1 Ga

supercontinent formation; 1.8 Ga intracratonic sedimentation and volcanism; 1.1-1.0 Ga extension, continental breakup, sedimentation, volcanism, magmatism, and compressive deformation; 750-800 Ma volcanism, sedimentation, and magmatism; and 600 Ma continental collision and supercontinent formation (West Gondwanaland). These episodes have important counterparts elsewhere, and the 1.0 Ga activity is probably related to the major global tectonic system that culminated with formation of Rodinia. Thus, the tectonic evolution of the Borborema Province is a composite of much of the Proterozoic tectonism which culminated in the formation of Gondwanaland.

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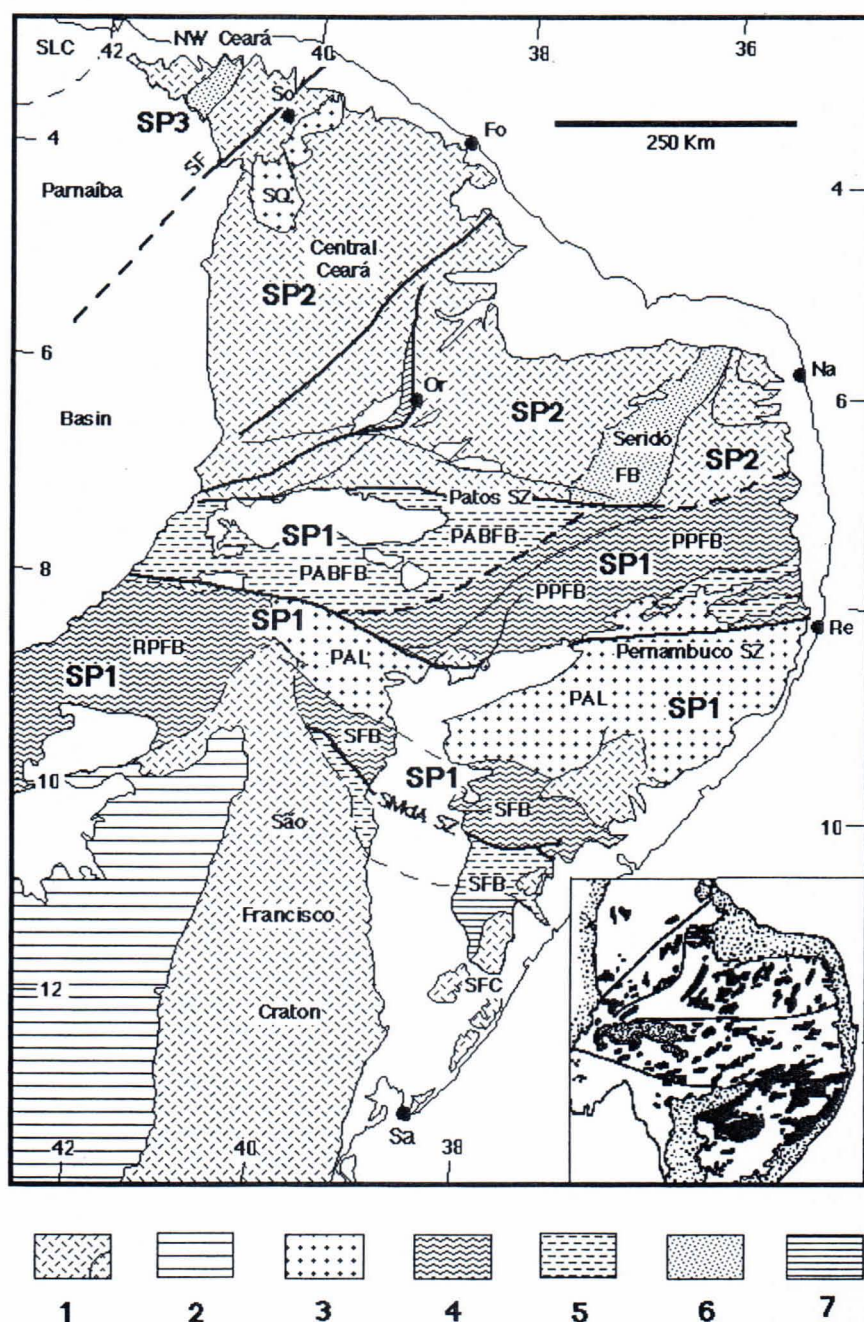


Figure 1. Borborema Province. 1, Archean to Paleoproterozoic basement (inset: Archean nucleus near Natal); 2, Paleoproterozoic cover of SFC; 3, granite-gneiss of PAL massif and hybrid rocks of Santa Quitéria Complex (SQ); 4, medium to high grade meta-sedimentary and metavolcanic rocks of ~ 1 Ga fold belts; 5, lower grade ~ 1 Ga meta-sedimentary and metavolcanic rocks of various fold belts; 6, Seridó fold belt (0.8-0.7 Ga) and Médio Coreá fold belt in NW Ceará; 7, undeformed cratonic cover of Sergipano fold belt; white: Phanerozoic. SP1, SP2, SP3 = subprovinces discussed in text. SF = Sobral Fault; SMdA SZ = São Miguel do Aleixo shear zone. Cities: Fo = Fortaleza; Na = Natal; Or = Oros; Re = Recife; Sa = Salvador; So = Sobral. Younger Proterozoic units in Ceará not shown. Inset: Brasiliano granites.