

## POST-RHYACIAN/ EARLY-CRYOGENIAN OF NORTHEAST OF SOUTH AMERICA: CONTRIBUTION FOR UNRAVELING OF A MULTIFARIOUS HISTORY

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### INTRODUCTION

The Northeast part of South America (composed by São Francisco, Borborema and Parnaíba structural provinces) presents diverse and rich history of magmatic (mainly) and deformational events along the time interval of 1,250 Ma, as prescribed in the above title. Although the collage of these three provinces is a legacy of the last phases of Brasiliano Cycle, this treatment for all of them together is valid.

Brazilian geologists have somehow been paralysed, during some decades, due to a false duality of concentration of tectonic-magmatic processes: Trans-Amazonian (ca. 2,000 Ma) and Brasiliano (ca. 700-500 Ma) events. At the same time that geological and isotopic knowledge has left the reconnaissance stages, this false duality broken down. Nowadays there is a notable – and crescent – amount of geological and isotopic data of good quality, indicating notable and diverse history along the 1,250 Ma above mentioned time interval (post-Trans-Amazonian, pre-Brasiliano). In addition, it is necessary to emphasize that these events are not completely known yet, as well as most part of these events - which are marked in pre-Brasiliano basement (and cover sequences) – are not exclusive of the previously assigned provinces. Some of them (e.g. those ones related to “Statherian Taphrogenesis” of Brito Neves et al 1995) are gradually been identified in most of the pre-Mesoproterozoic segments of the continent.

In this paper, we selected only about 10 groups of notorious events for a preliminary discussion.

The basement consolidation of the mentioned provinces mainly occurred between ca 2,150 and ca 2,050 Ma (Brito Neves *et al.*, 2000, Barbosa *et al.*, 2003), with orogenic collages that involved many different (sizes and shapes) Archean seed nuclei. There is no evidence for an Orosirian orogeny in this part of the continent. Especially for Borborema province, these events should be looked (as they are being found out) in the many occurrences of pre-Brasiliano basement inliers (so-called “massifs”, microplate, microcontinent and alike).

### MAIN EVENTS

The most remote recorded manifestation of these intracratonic anorogenic events is Angico dos Dias complex, in the north of Bahia (ca. 3 km<sup>2</sup>), with pyroxenites, alkaline diorites, syenites, quartz-syenites,

carbonatites, and lamprophyres (Santos, 2001), displaying U-Pb ages of 2,011± 6 Ma. This complex is object of many different studies, some of them aiming its exploitation.

The anorogenic complex of Serrote das Lages, Arapiraca-Alagoas (Brito *et al.*, 2004), with U-Pb ages in zircon ca. 1.96 Ga is the next one more ancient to being referred. Being intrusive in basement inliers of Sergipano System, this complex is formed by an association of gabbros, noritic-gabbros, augite-pyroxenites, hyperstenites, websterites, and anorthosites, which have presented Fe-Ti-V economic occurrences. Besides that, there are several mafic-ultramafic rock units and iron ore occurrences associated to the Coruripe River domain, that may be part of the same event, demanding posterior investigation.

A sorted and variable context of anorogenic magmatism (+ brittle tectonics) reaches the studied provinces from Minas Gerais to the north of Ceará, cutting lithospheric Paleoproterozoic portions as well as more ancient ones, with age values systematically around 1,750 Ma (± 30Ma), designed of Statherian Taphrogenesis (see Brito Neves, 1995 *et al.*, having as a purpose the entire continent).

Among them it is possible be detached:

a. Felsic volcanism, from acid to intermediate character, with some associated breccias of the basal group of Espinhaço Supergroup, in Bahia (Rio dos Remédios group), but also occurring in Central Ceará (Orós, Peixe Gordo etc.), and north-occidental (“Saqueinho”), in Rio Grande do Norte (“Serra de São José” and surroundings), in Parnaíba Basin basement, and certainly in other no consigned localities yet (See Babinski *et al.*, 1999, Magini *et al.*, 1999).

b. Associated to the same global event, it is worthy of mention granitic magmatism (A-type) in central Ceará portion, where Sá (1995) and, *a posteriori*, Cavalcanti (1999) have identified augen-gneisses (granodioritic), sheets of tonalite, quartz-diorite, and granites, with ages around 1,760 Ma.

In Rio Grande do Norte, a series of granitic stocks (transformed into augen-gneisses), with aplitic and pegmatitic phases, cut Rio Piranhas Massif basement (where they are called “G2” granites). Those bodies

(Hollanda, in press) were recently dated of 1,740 Ma by SHRIMP methodology, and probably they could represent the continuity of similar occurrences already (previously) identified in the Hoggar region, in Africa.

c. In the Rio Capibaribe terrane, in Transversal/Central Zone of Borborema Province, there is the anorthositic batholith with about 250 km<sup>2</sup> formed from the mixture of gabbro-anorthositic, pyroxene-anorthosite, gabbro, and ultramafic bodies with Fe-Ti-V ores. Anorthosites are of 1.7 Ga of age, and alkaline granitoids that cut them are of age about 1.68 to 1.58 Ga, with age values reaching the Early-Calymmian. This is the best known and studied occurrence (Accioli, 2000).

Other similar complexes occur for all Borborema, mainly along Alto Moxotó terrane (basement inlier, Paleoproterozoic in age) from central Paraíba to west of Pernambuco, where there is a series of occurrences of anorthositic complexes (with Fe-Ti-V ores), and associated rocks (cut by younger granites), which deserve detach, though there is no geochronological control. In here, they are considered as possible part of the Statherian events. Itatuba complex (plagioclasic-orthogneisses, diorites, gabbros, garnet-gabbro, ultramafic bodies), Malhada Vermelha complex (gabbro-dioritic rocks, anorthosites, monzodiorites, and granites) as well as Barro Vermelho complex (anorthosites, leuco-gabbros, gabbro-norite, associated skarns, etc.) are mention worthy. There are some other occurrences but they are less studied and without age control.

In Taquaritinga do Norte, to the south of Transversal Zone of Borborema a great batholith of amphibole-garnet syenogranite to monzogranite occurred, typically in A-type granitoid, intrusive in Paleoproterozoic terranes with U-Pb age in zircon of 1.52 Ga, which is considered the most important Calymmian granite (AMCGr) activity of the three provinces. This batholith is pervasively penetrated by a low-angle foliation, probably of Brasiliano age, so mostly occurring as augen-gneisses. In Pernambuco-Alagoas massif, to the south, there are many similar batholithic occurrences (petrology, structure) but for which there are no available isotopic data yet.

In Brotas de Macaúbas, Chapada Diamantina-BA, several basic igneous manifestations took place, a sill of amphibole-gabbro, coarse-grained, inserted in sandstones of Mangabeira Formation (Group from the intermediate part of Espinhaço). Zircons collected in this unity defined an age of  $1,514 \pm 22$  Ma (Babinski *et al.*, 1999, such age was selected to countersign the basic magmatism (and that define a minimal age for the enclosing Mangabeira clastic rocks).

Additionally, farther east, in Lençóis-BA, there are many occurrences of small dykes of muscovite-marthite, possessing (micro-) diamonds, and that outcrop cutting across the Tombador Formation, basal unity of the Chapada Diamantina Group. Some Ar-Ar data (Battilani *et al.*, 2005) have indicated plateau ages of  $1,512 \pm 6$  and  $1,514 \pm 5$  Ma. Although these dykes could not have their own mineralogy considered like original (there are more than an hypothesis to explain them), they define an

important Calymmian event in the studied area (hydrothermalism, for instance), and a minimal age to Tombador Formation. Some of these dykes were reworked by deformation/events of the Brasiliano Cycle (Ar-Ar ages ca. 516-512 Ma).

An important deformational event (ductile >> brittle), with debatable nature, and still precariously known, is exhibited by rock units of Espinhaço Group, Bahia (several open folds – Eastern Chapada Diamantina), and in Minas Gerais (Romeiro Silva and Zalán, 2005), in Pirapora aulacogen. This deformational event contains sufferable indications of ages (Pb-Pb in limestones, Rb-Sr in phyllites) around 1,140-1,250 Ma, though there are clearly basic intrusive ones (of 910 Ma), which cut across sediments from Espinhaço and do not cut across glacial deposits (Cryogenian in age, < 740 Ma) of the overlaid Bambui group, that was deposited according to erosional and structural unconformities. In spite of the fact we know the age of the beginning (ca. 1,750-1,780 Ma), the end of the Espinhaço ranges development in Mesoproterozoic times is an unclosed problem, which can be in Ectasian or in Stenian period.

Recently, Pereira and Fuck (2005) reported the occurrence of a phlogopite-kimberlite body to the west of Barra do Mendes-BA, which according to the authors cuts across Rio dos Remédios and Paraguaçu Groups, and seems to be older than Tombador Formation (that has diamonds from kimberlite, according those authors' opinion). Rb-Sr age in phlogopite is reported with age value of 1,150 Ma (therefore from Stenian); however it is related to an age that should be observed with reserves (additional processes of alteration are reported). The presence of this kimberlitic magmatism event at the end of Mesoproterozoic is remarkable, and it should be added to evolutionary history of São Francisco province, even with all unclosed, involved questions.

For all Espinhaço domains, many mafic dykes (partly already mentioned, such as families of ca. 1,512-1,514 Ma) occur. Some of these dykes were dated between 1,000 and 900 Ma, with indications of the end of an important cycle. Mafic cycles with same age are common in Bahia coastline, surrounding Salvador and Ilhéus-Olivença cities, cutting across granulitic rocks from Itabuna-Salvador-Juazeiro belt. These dykes have correspondent in African counterpart, associated to plumes (an assumed longitudinal extension of the process is more than 6,000 km, Correia Gomes, 1992). Ruptural process associated to tholeiitic basaltic magmatism are poorly dated yet, nevertheless they represent, in our understanding, part of a global event (Early-Tonian Taphrogenesis) probably linked to plume activities, and they can represent initial trying of the broking up of the Rodinia Supercontinent (in Congo-São Francisco domain).

It is necessary to add important and thick bimodal metavolcanic and metasedimentary sequences of Zadinian (< 1000Ma), and Mayumbian (> 910 ma) groups, from the West Congo system, do not have representation in the Brazilian side, at least up to the present.

In central domain of Borborema province (from the east of Paraíba to the southwest of Pernambuco, for more than 800km long, ca. 100-150 km wide), and in the north portion of basement from Sergipano System (Alagoas and Sergipe) are consigned concrete records of an orogenic cycle, with oceanic opening, subsequent accretion (arc magmatism), and continental collision, in a time interval of 980-930 Ma. This cycle (Cariris Velhos) counts on very extensive bibliography, notable richness of geological and geochemical data, being object of many theses (Santos, 1995; Kozuch, 2003, Carvalho, 2005) as well as several synthesis works (e.g. Brito Neves *et al.*, 2005). Despite of intense reworking processes by Brasiliano cycle, rocks from orogenic context (metagraywacke with diverse volcanic intercalation, biotite-muscovite granites; metapsamites, and metapelites of low degree) can be identified, presenting several isotopic evidences of juvenile nature (Stenian, Tonian). In African continent, the first inferences/records of this Cariris Velhos cycle continuity are preliminarily assigned last years.

The fission of Rodinia (and the formation of paleo-basins for the Brasiliano Systems) certainly was a longliving, and diacronic process. Age values ca, 910 Ma of basic magmatism were assigned as precursors (beginning of Araçuaí development, post-Espinhaço), as already mentioned, but demanded additional investigations. In (SW) São Francisco domain there is a singular rock unit that could predates such events.

It is Salto da Divisa granitic massif (extreme northeast of Araçuaí belt), intrusive in rocks of high degree, with monzogranite, syenogranite, and alkaligranite, metaluminous, and sub-alkaline (high K) composition, according to Silva *et al.*, 2002, that exhibited SHRIMP age of  $875 \pm 9$  Ma.

The interpretation given to this Late-Tonian age and the alkaline signature is that of an anorogenic granite (pre-Cryogenian) from the rift phase, precursor of Araçuaí-West Congo system, in Brazilian side. Even if it is an isolate data, their localizations and age value are important and they serve as alert in order to look for similar bodies.

In Borborema province, there are up to now two concrete evidences of Brazilian precursor rifting, with felsic magmatism, and associated psammitic-pelitic sedimentation, both in the septentrional domain, in Ceará state, in domains of Paleoproterozoic basement. One in Médio Coreaú (Martinópole group) System with meta-rhyolites of  $777 \pm 11$ Ma, and other one in “Rio Curú-Independência System” (Independência group) also with meta-rhyolites of U-Pb age of  $772 \pm 31$  Ma. There are some other rock units with age values close to 810 Ma, but with strong analytical errors.

## CONCLUSIONS

Ten groups of events were intentionally specified (in special the anorogenic ones) in post-Rhyacian/Early Cryogenian time interval, in the three provinces of northeast of South America. Unfold and future refinement of these data should be stimulated. However,

the present stage of knowledge serve as alert to a rich and diverse history in the mentioned time interval, as well as to advert geologists about the failure and impropriety of staking out all knowledge around “Trans-Amazonian”– “Brasiliano” duality (unfortunately as rooted in our publications as it had to be banished). Moreover, the definition/concept of “Trans-Amazonian” needs a review.

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## RESUMO

No passado recente, muitos geólogos brasileiros estiveram algo paralisados, quando tentavam colocar todos os eventos tectono-magmáticos do Proterozóico na (inadequada dualidade) dos ciclos “ Transamazônico” (ca. 2000Ma) e Brasiliano (750-500Ma). Durante s últimas décadas com os avanços consideráveis nos estudos geológicos e isotópicos, uma série notória de eventos magmáticos ( a maioria), deformacionais e mesmo orogênico foram catalogados e incorporados neste intervalo de cerca de 1250 Ma, entre o período Riacciano (idade para a consolidação do embasamento cratônico) e o Eo-Criogeniano (início do Brasiliano). Isto é especialmente verdadeiro para o caso do nordeste do continente, domínio das províncias estruturais do São Francisco (para o sul), Borborema e Parnaíba. Os autores procuraram selecionar (seguindo a ordem de idade) os 10 mais importantes eventos para serem colocados naquele intervalo de tempo de 1250 Ma, onde fica conspícua a ênfase ao magmtismo intracratônico (+ rifteamentos e formação de bacias), lado a lado com deformação intracratônica (1 caso) e um ciclo orogênico ( Cariris Velhos). Além dos fundamentos de geologia regional e isotópica, ocorrências e depósitos minerais importantes são feições de vulto. Certamente, com o progresso esperado nas investigações, outros eventos/ assembléias litológicas de magnitudes similares estão sendo esperadas. Na verdade, já existem muitas unidades litológicas e complexos magmáticos (diferentes natureza e afinidades químicas) que estão encarados como candidatos potenciais a serem incluídos em tal relação. A demanda or estudos isotópicos é grande e digna de menção.