THE PRECAMBRIAN EVOLUTION OF THE AMAZONIAN CRATON

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Introduction

The division of the Amazonian craton in tectonic provinces was proposed initially by Cordani and Brito Neves (1982), Hasui et al. (1984), Lima (1984). Hasui et al. (1984) considered that the craton formation occurred essentially in the Archean and that it would be affected by reactivation events during the Proterozoic. The other mentioned authors admitted, in turn, that a primitive province was formed during the Archean, and accretionary processes promoted the generation of new, gradually younger provinces along the Proterozoic.

The knowledge of the Amazonian craton has been improved significantly in the last ten years by: (1) The development of systematic geological mapping in key areas, employing remote sensing and modern field and structural geology techniques (Costa et al. 1995; Scandolara et al. 1999; CPRM in press; Klein and Vasquez 1999); (2) the improvement of geochronological data by the dissemination of U-Pb and Pb-Pb techniques (Machado et al. 1991; Macambira and Lafon 1995; Gaudette et al. 1996; Tassinari 1996; Vanderhaege et al. 1998; Lafon et al. 1998; Bettencourt et al. 1999; Santos et al. subm.; Geraldes et al. 1999); (3) the introduction of Nd and Pb isotopic data in the interpretation of crustal evolution (Sato and Tassinari 1997; Santos et al. subm.; Rizzotto et al. 1999; Geraldes et al. 1999); (4) the more systematic petrogenetic and geochemical studies of the major magmatic suites of the craton (Dall'Agnol et al. 1997, 1999; Fraga et al. 1997); (5) the prospection and metallogenic research undertaken in Carajas, Tapajos, Pitinga, Rondônia and northern Guyana shield, demonstrating the existence of large ore deposits in the craton (Klein and Vasquez 1999; Ledru and Milési 1999; Cordeiro 1999). As a consequence, the models to explain the evolution of the Amazonian craton have been reviewed and its tectonic provinces redefined (Tassinari 1996; Santos et al. subm.). The relationship between the craton evolution and the widespread Proterozoic rapakivi magmatism was discussed by Dall'Agnol et al. (1999). The major aspects of the evolution of the craton will be discussed taking as a reference the provinces or tectonic domains defined in these more recent models.

Archean Domains

Large Archean terranes are only preserved in the Carajas province, in the southeastern domain of the craton (Machado et al. 1991; Macambira and Lafon 1995; Dall'Agnol et al. 1997), and possibly in the Imataca Complex situated in its northwesternmost margin in Venezuela (Montgomery 1979; Sidder and Mendoza 1991). More restricted Archean terranes have been found in the Amapa region (Lima 1984; Sato and Tassinari 1997; Lafon et al. 1998).

The Imataca Complex is a northeast-trending belt composed by amphibolitic to granulitic rocks, separated from Paleoproterozoic granite-greenstone terranes by the Guri shear zone (Sidder and Mendoza 1991). The age of the Imataca Complex is not well constrained but it is situated in the range between 3.7 to 3.0 Ga. This age could, however, reflect an inherited detrital component rather than a primary age (Sidder and Mendoza 1991 and references therein). In spite of this, an Archean age is generally admitted for the complex that was deformed and metamorphosed during the Trans-Amazonian event, at ca. 2.0 Ga.

The Carajas province (CP) is the more important Archean province of the Amazonian craton. The CP is divided in two tectonic domains, the Rio Maria Granite-Greenstone Terrane (RMGGT) and the Carajas Basin (CB) which show some striking differences (Dall'Agnol et al. 1997): (1) In the RMGGT, the greenstone belts are aged of 2.97 to 2.9 Ga and formed dominantly by komatiites and tholeiitic basalts. In the CB, the supracrustal sequences of the Itacaiúnas Supergroup are comparatively younger (2.76 Ga; Machado et al., 1991) and composed essentially by mafic metavolcanics and banded iron formations. (2) The rocks exposed in the RMGGT were formed in between 3.0 and 2.86 Ga (Macambira and Lafon 1995) and an important shearing event affected this block at around 2.87 Ga. In the CB, the major stratigraphic units were formed in the range of 2.76 to 2.70 Ga and the last Archean deformational events have been dated at 2.58 to 2.50 Ga (Machado et al. 1991). (3) Three groups of Archean granitoids have been distinguished in the RMGGT (Dall'Agnol et al. 1997 and references therein): TTG-type, trondhjemites and tonalites with rare granodiorites, high-MgO granodiorites akin of the sanukitic granitoids, and high-K20 leucogranites. These granitoids yielded ages between 2.96 and 2.87 Ga. The Plaque granitic suite, aged of 2.73 Ga, occurs immediately to the south of CB and should be related to its evolution. In the CB, the occurrence of syntectonic A-type granites, dated at ca. 2.55 Ga is noteworthy.

The tectonic stabilization of the RMGGT preceded that of the CB. In the CB, Lindenmayer (1990) assumed the hypothesis that the supracrustal sequences were related to a continental rift tectonic setting, while Teixeira and Egler (1994) proposed a model involving a continental margin setting, which evolution was related to the subduction of an oceanic crust, followed by a continental collision. For the present authors, the rift model better explains the principal geological aspects of the Carajas Basin evolution.

Archean vs. Paleoproterozoic provinces - The limits between the Archean Carajas province and the Paleoproterozoic domains situated to the north (Maroni-Itacaiúnas or Northern Guyana province) and west (Central Amazonian province) are not well defined. Geochronological data indicate the existence of reworked Archean basement formed by granulites and granitoids in the Amapa region and detrital zircons from a metaquartzite of southeastern French Guyana yielded Pb evaporation ages ranging between 2.77 and 3.19 Ga (Lafon et al. 1998). The available geological information about the Bacajas region, situated between the Carajas and Amapa regions, is extremely limited, making impossible a correct evaluation of the volume of Archean or Paleoproterozic rocks in the former region.

Tassinari (1996) and Sato and Tassinari (1997) have included the Xingu-Mapuera region in the central part of the craton in an Archean Central Amazonian province, because the Paleoproterozoic volcanic rocks and granitoids of this domain have given Archean TNdDM ages. Dall'Agnol et al. (1999) argued, however, that the geological evolution and magmatism of this region is totally distinct from that of the Carajas province and considered them as two different tectonic domains. Santos et al. (subm.) go in the same direction and propose to individualize the

Carajas province and to designate as Central Amazon province the domain extending from the Xingu and Mapuera regions to the Roraima state of Brazil.

Paleoproterozoic Provinces Related to the Trans-Amazonian Event

Northern Guyana Province - This province covers the northern part of the Guyana shield and corresponds mostly to the Maroni-Itacaiúnas and Transamazonic provinces of, respectively, Tassinari (1996) and Santos et al. (subm.), but excluding the Bacajas region.

The Northern Guyana province is the domain of the craton where the tectonic evolution and lithologies related to the Trans-Amazonian event are better exposed and studied (Bosma et al. 1983; Sidder and Mendoza 1991; Gibbs and Barron 1993; Vanderhaeghe et al. 1998). Vanderhaeghe et al. (1998) proposed for the French Guyana an evolution similar to that of modern orogens in the following sequence of events: (1) Crustal growth by the formation of an oceanic crust at 2.17 Ga (2) emplacement/extrusion of calc-alkaline plutonic-volcanic complexes in a magmatic arc environment at 2.16-2.14 Ga. (3) An erosional period with the deposition of sediments in the marginal Orapu basin. (4) Oblique convergence between crustal blocks during the Trans-Amazonian orogeny. (5) Crustal thickening, anatexis and emplacement of syntectonic granitic plutons along major strike-slip shear zones at 2.09-2.08 Ga. Delor et al. (1998) admitted, in turn, for the same region a model emphasizing mantle plume processes for the juvenile crust formation and minimizing the importance of modern collisional processes for its tectonic evolution.

The available geological and geochronological data, even if more limited, suggest that a similar geologic evolution also occurred in northern Suriname and Guyana, as well as in the northernmost part of the Guyana shield in Venezuela (Bosma et al. 1983; Gibbs and Barron 1993; Sidder and Mendoza 1991). Generally, subduction related processes are considered as fundamental during the continental accretion and the dominant sequences are described as Paleoproterozoic granite-greenstone belts.

The Tapajos-Parima province - Santos et al. (subm.) individualized in the central part of the Amazonian craton the orogenic Tapajos-Parima province, dated at ca. 2.10-1.88 Ga, related to the Trans-Amazonian event and trending NW-SE. This province corresponds approximately to the Ventuari-Tapajos magmatic arc of Tassinari (1996), interpreted as being formed in the range between 1.95 to 1.80 Ga.

The Tapajos-Parima province was better studied in the Tapajos region, where new U-Pb and Pb-Pb zircon ages (Santos et al. subm.; Lamarão et al. 1999; Klein and Vasquez 1999) demonstrated that the oldest supracrustal sequences of the Jacareacanga Group contain three detrital zircon crystals dated at ca. 2.1 Ga, with an isolated grain yielding an age of 2.87 Ga. The oldest calc-alkaline granitoids found in this region yielded U-Pb and Pb-Pb zircon ages of ca. 2.10 Ga (Cuiu-Cuiu Suite; Santos et al. subm.) and 1.98 Ga (Creporizão Suite; Klein and Vasquez 1999; Lamarão et al. 1999). A younger generation of calc-alkaline granitoids (Parauari Suite) and another of subalkaline, possibly A-type granites (Maloquinha Suite), both dated at ca. 1.89 Ga, have also been identified. Intermediate to felsic volcanic sequences included in the Iriri Group of the Uatumã Supergroup are abundant in the Tapajos region. These sequences show, however, geochemical and petrologic contrasts and, at least, two different ages of ca. 2.00 Ga and 1.88 Ga (Lamarão et al. 1999). The relationships between the older volcanic sequences and the Tapajos-Parima province evolution, as well as the transition between the latter and the Central Amazonian province are not clear.

Greenstone belts, possibly similar to those of the Northern Guyana province, are dominant in the Parima region, situated in the northwestern Roraima state of Brazil, in the border with Venezuela. Considering that the geological and geochronological data are scarce and not conclusive, the correlation of this region with the Tapajos or Northern Guyana province is open to discussion.

The Central Amazonian province

Cordani and Brito Neves (1982) and Tassinari (1996) considered the Central Amazonian province as an Archean province integrated with the Carajas province. Dall'Agnol et al. (1999) discussed the geological contrasts between the Carajas province and the other areas of the Central Amazonian province and separate these regions in two tectonic domains named Eastern and Central blocks. Excepting the domains of the new defined Tapajos-Parima province, these blocks correspond to the Carajas and Central Amazon province of Santos et al. (subm.).

The Central Amazonian province is formed dominantly by Paleoproterozoic and Mesoproterozoic rocks represented essentially by: (1) the Parauari, Água Branca, Pedra Pintada and similar calc-alkaline granitoids yielding ages in the range between 1.98 and 1.88 Ga; (2) the Uatumã Supergroup composed by felsic and intermediate vulcanites, formed in the range between 2.00 and 1.88 Ga (Lamarão et al. 1999 and references therein); (3) a series of subalkaline to alkaline granite bodies, forming batholiths and stocks dated at ca. 1.83 Ga in the Pitinga mine and at 1.88 Ga in the Tapajos region. An Archean basement was not identified so far in the province, but TNdDM ages and strongly negative epsilon Nd values (Sato and Tassinari 1997; Santos et al. subm.) suggest that plutonic and volcanic magmas derived from Archean crustal sources. A model of underplating of mafic magmas at the base of the crust, acting as heat source for anatexis was proposed by Dall'Agnol et al. (1999) to explain the genesis of the anorogenic granites of this province. Santos et al. (subm.) also relate the Uatumã magmas to partial melting of crustal sources but they argue that the heat source would be a low angle descending slab associated with the Parauari Arc. However, the coincidence in age between the Paruari Arc and the 1.88 Ga Uatumã sequences makes this hypothesis unrealistic.

The Central Guyana Belt

The Central Guyana Belt extends from Suriname and Guyana trough southern Roraima to the Alto Rio Negro region in Brazil. It is a 200 km wide, NE-SW trending belt, formed by intensely reworked and mylonitized granulites, granitoids and metavolcanosedimentary sequences of Trans-Amazonian age (>2.0 Ga), associated with dominant younger granitoids and charnockitic rocks (<2,0 to 1.5 Ga). It is interpreted as a transamazonian ensimatic domain of the Maroni-Itacaiúnas province by Tassinari (1996), while it is named K'Mudku Shear Belt by Santos et al. (subm.) that consider that it was formed in between 1.5 and 1.2 Ga. Fraga et al. (1998) argue that the belt was formed at the end of the collisional stage of the Trans-Amazonian event. Fraga (written comunn.) considers that the Central Guyana Belt contrasts with the Northern Guyana province in geological evolution and in the age of the dominant rocks and admits that it has probably evolved as an intracontinental belt. Besides the gneisses and charnockitic rocks dated at 1.96 to 1.90 Ga (Gaudette et al. 1996; Fraga et al. 1998), this belt is marked by the emplacement of anorthosite-charnockite-rapakivi granites at about 1.54 Ga (Gaudette et al. 1996; Fraga et al. 1997). The K'Mudku event locally affected all these sequences, but the Central Guyana Belt was formed before it (Fraga et al. 1998).

The Mesoproterozoic provinces

The Rio Negro province - This region, situated in the border area between Brazil, Venezuela and Colombia, presents a very complex and peculiar evolution, as pointed out by Sidder and Mendoza (1991) and Dall'Agnol and Macambira (1992). U-Pb and Pb-Pb zircon ages are concentrated in the interval between 1.86 and 1.5 Ga (Gaudette et al. 1996; Tassinari 1996), suggesting that the major tectonic event in the entire block occurred after the Trans-Amazonian event. The available TNdDM model ages (Sato and Tassinari 1997) indicate, however, that the exposed magmatic sequences are derived from sources separated from the mantle at the end of the Paleoproterozoic, during the Trans-Amazonian event. Two dominant types of granitoid rocks, dated at ca 1.55-1.52 Ga (cf. Santos et al. subm.), have been identified. The first is an A-type granite extremely enriched in modal titanite, magnetite and apatite and the second a tourmaline-bearing, two-mica, S-type granitoid, including metasedimentary enclaves (Dall'Agnol and Macambira 1992). These evidences suggest that this province is related to a tectonic setting of continental collision (Lima 1984; Dall'Agnol and Macambira 1992; Santos et al. subm.), better than to a subduction related magmatic arc (Tassinari 1996).

The Juruena and Rondonian province - The Juruena and part of the Rondonia region were considered by Tassinari (1996) as an extension of the Rio Negro province and included in the Rio Negro-Juruena province. Other areas of the Rondonia region and its extension in Bolivia were included by the same authors in the Rondonian-San Ignacio province formed at 1.5-1.3 Ga. Scandolara and Amorim (1999) and Santos et al. (subm.) argue, in turn, that only one major tectonic event occurred in these regions in the period between 1.85 and 1.30 Ga.

Scandolara et al. (1999), based in systematic structural and geological mapping of Rondonia state, have identified the following sequences as markers of the Juruena - Rondonia evolution: (1) The dominantly igneous derived Jamari complex (1.85 - 1.75 Ga) should correspond to the basement of the Juruena belt; (2) The Jaru complex (1.75 - 1.65 Ga) and the Roosevelt sequence (ca. 1.74 Ga) represent orogenic metavolcanosedimentary sequences; (3) the A-type, rapakivi granites and associated mafic rocks of the Serra da Providencia Suite (1.62 - 1.57 Ga) correspond to a post-tectonic magmatism; (4) the Santo Antônio, Teotônio and Alto Candeias granitic suites (1.40 - 1.35 Ga), as well as the contemporaneous charnockites, mangerites and associated mafic rocks, are extensional, intraplate, rapakivi and charnockite series igneous plutons, possibly related to the San Ignacio belt, as defined in Bolivia (Litherland et al. 1989).

The San Ignacio belt in Bolivia is related to a ca. 1.30 Ga magmatic and tectonic event, defined on the basis of Rb-Sr and K-Ar data (Litherland et al. 1989). However, the age of the probable basement of the San Ignacio belt is poorly constrained and there are uncertainties about the correlation between the geologic evolution in Brazil and Bolivia in this period.

On the basis of U-Pb geochronological and Nd isotopic data obtained in the southwestern area of Mato Grosso state of Brazil, Geraldes et al. (1999) concluded that: (1) the Jauru Terrane, located in the Juruena province, corresponds to a juvenile island arc formed about 1.75 Ga ago. (2) A comparatively younger calc-alkaline suite containing a significant older crustal component was formed at 1.55 Ga. (3) At ca. 1.45 Ga was formed the Santa Helena volcano-plutonic arc, that is partially juvenile and in part derived from older crustal sources. Geraldes et al. (1999) propose the existence of several magmatic arcs in this region. However, excepting the older Jauru arc, the other proposed arcs need more investigation.

The Sunsas province - The Sunsas Orogenic Cycle involved sedimentation and orogeny in the range between 1.30-0.95 Ga (Litherland et al. 1989). This event has been now clearly identified in Rondonia and SW Mato Grosso states of Brazil (Scandolara and Amorim 1999). Crustal extension and emplacement of A-type granites (São Lourenço - Caripunas Suite at 1.30 to 1.25 Ga), marked its first stage of evolution. The Nova Brasilândia and Mutum-Paraná volcano-sedimentary sequences were accumulated in basins formed at these times, deformed and metamorphosed around 1.15 - 1.10 Ga (Rizzotto et al. 1999). The Rio Branco Granite and gabbroic rocks of the Nova Brasilândia Terrane dated at ca 1.10 Ga are interpreted as related to the sin-cinematic stage of the Sunsas event, while the Rio Pardo Granitic Suite dated at ca. 1.01 Ga is associated with its late- to postkinematic stage (Rizzotto et al. 1999). Tin-mineralized, A-type, intracratonic granites of both mentioned ages occur in the Jamari Terrane, to the north of the Sunsas front (Bettencourt et al. 1999). The Palmeiral and Prosperança sedimentary covers are also related to the late distensional phase of the Sunsas event.

Conclusions

The tectonic evolution of the Amazonian craton was clarified in the last decade. Exposed Archean domains are restricted to the Carajas province and the Imataca Complex. 2.2 to 0.9 Ga old, Proterozoic rocks form the major part of the craton, and the youngest sequences are exposed in its southwestern part. The absence of a relevant Brasiliano-Panafrican influence in the evolution of the Amazonian craton is a fundamental tectonic distinction between it and other Precambrian provinces of Brazil. The tectonic evolution and magmatism of the Paleoproterozoic northern terranes of the Guyana shield looks similar to that of West-African craton, while the younger Mesoproterozoic terranes are correlated with those of Laurentia-Baltica. Paleoproterozoic to Mesoproterozoic rapakivi granites and related rocks are widespread in the craton.

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