GEOLOGY OF THE SOUTHERN AMAZON CRATON IN SOUTHWESTERN MATO GROSSO, BRAZIL: A REVIEW

JAYME ALFREDO DEXHEIMER LEITE AND GÉRSON SOUZA SAES

ABSTRACT The southern Amazon Craton in Mato Grosso, is reviewed in light of more recent geological, petrological, structural and geochronological data. Jaurú and Rio Alegre terranes, the Santa Helena Granite Complex and the Aguapeí Belt are the major tectonic units of the area. The Jaurú terrain consists of MORB suite and arc basalts with minor chert and felsic volcanics, calc-alkaline tonalites, orthogneisses, and migmatites of ca. 1.78 Ga. Two well-marked granitic events occurred in this terrain between 1.55 to 1.48 Ga (the Cachoeirinha magmatic arc) and close to 1.0 Ga (the Guapé Intrusive Suite). The Rio Alegre terrain consists of mafic volcanics and ultramafic intrusives with minor chert and tonalite intrusions and its minimum age is given 1.55 Ga tonalites. The Santa Helena Granite Complex (1.45 Ga) is a NW-trending, A-type, hornblende-biotite syenogranite batholith with abundant xenoliths of older rocks and emplaced between the Rio Alegre and Jauru terranes. The Aguapeí Belt is a narrow NW-trending zone that follows the limits between the Rio Alegre terrain and the Santa Helena Complex. It consists of low-grade, folded shallow marine to fluvial sediments. The Jaurú Terrain is interpreted as representing an island arc and the Rio Alegre as ophiolite, both with an age between 1.9 Ga and 1.55 Ga. The Cachoeirinha magmatic arc of ca. 1.55 Ga is likely to result from the amalgamation of these two terranes. The suture between the Rio Alegre and Jaurú terranes was intruded by the Santa Helena Granite Complex at about 1.45 Ga. The youngest events (1.2 Ga to 1.0 Ga) are represented in the Aguapeí Belt, by extensional reactivation, intracontinental rifting, sedimentation, deformation, and low-grade metamorphism, and are correlated to the Sunsas Orogeny of eastern Bolivia.

Keywords:

INTRODUCTION The Amazon Craton (Fig.1a) has an area of aboeafter considered as the southern portion of the Amazon Craton, the main subject of this contribution.

Researches in this area date back at least to the 50's with reconnaissance and a few regional surveys (Almeida 1964, Figueiredo *et al.*1974), and followed by detailed geological mapping (Monteiro *et al.*1986, and more than 15 field surveys by undergraduate students of the Geology Department of the Federal University of Mato Grosso), as well as MSc and PhD thesis (Carneiro 1985, Leite 1989, Matos 1991, Pinho 1993, Ruiz 1992, Pinho 1996, Geraldes 1996, Saes 1999). As a result, a large amount of new data became available that constrained evolution models for the area (Cordani *et al.*1979, Cordani *and* Brito Neves 1982, Teixeira *et al.*1989, Carneiro *et al.*1992, Saes *and* Fragoso César 1994, 1996, Tassinari *et al.*1996, Sadowski *and* Bettencourt 1996, Tassinari *and* Macambira 1999) leading to a better understanding of the complexity of this key Paleo-Mesoproterozoic are of the South American Continent. This contribution aims to present the state-of-the-art of the geological, geochronological, petrological, tectonic, and structural data and stress some constraints to the evolution models.

GEOLOGY OF THE SOUTHERN AMAZON CRATON The area under consideration includes southwestern Mato Grosso and contains several rock associations that differ in age, petrologic evolution, and tectonic settings. They comprise (Fig.2) the Jaurú and Rio Alegre terranes (Saes *and* Fragoso Cesar 1996), the Santa Helena Granite Complex (Saes *et al.*1984, Leite 1989) and the Aguapeí Belt (Saes *and* Leite 1993**).**

The Jaurú Terrain The Jaurú Terrain consists of volcano-sedimentary sequences, tonalite intrusions, orthogneisses, migmatites, syn- to late-kinematic granitoids, younger and undeformed granitoids, and basic sills. The oldest unit of this terrain comprises three NW-SE trending volcano-sedimentary belts with lower sub-aqueous to sub-aerial basaltic flows interlayered with minor chert and banded iron formations, upper intermediate to felsic flows, and peridotite to gabbro intrusions. From east to west, these belts are named as Quatro Meninas, Araputanga and Cabaçal (Saes *et al.*1984, Leite *et al.*1986, Leite 1989), and are grouped under the Alto Jauru Greenstone Belt (Pinho *et al.*1997). The belts are intruded by NW-trending, elongated tonalites with abundant xenoliths of mafic rocks. Geochemical data (Leite 1989, Pinho *et al.*1997) show that the mafic volcanic rocks have an easterly trend from mid-ocean ridge to arc-related basalts, while the tonalite bodies are arc-derived (Pinho *et al.*1997). SHRIMP U-Pb zircon data of the Cabaçal tonalite (Pinho 1996) yield a $^{207}Pb/^{206}Pb$ age of 1.78 ± 10 Ga, interpreted as the crystallization age of the intrusion.

Orthogneisses and migmatites crop out as cores of dome-like structures in the flanks of and between the belts, and are known under different names, depending on the locality (Brigadeirinho Gneiss Complex of Saes *et al.*1984, Quatro Marcos Gneiss of Carneiro 1985 and Carneiro *et al.*1992, Rio Vermelho Gneissic Complex of Leite 1989). These complexes have been interpreted as resulting from deformation and metamorphism at the roots of the volcano-sedimentary belts. Geochronological data include one Pb/Pb isochron of 1.717 ± 120 Ma with a single stage model µ1 value of 8.09 (Tassinari *et al.*1996) and a $^{207}Pb/^{206}Pb$ age of 1.795 ± 10 Ma (Geraldes *et al.*1999). Carneiro (1985) obtained a Rb-Sr isochron age of 1.961 Ma and low initial $^{87}Sr/^{86}Sr$ ratio of 0.702 for gneisses of the area.

Late to post-kinematic granitoids within this terrain include the Alvorada and Cachoeirinha granites and the Água Clara Granodiorite (Saes *et al.*1984, Monteiro *et al.*1986, Leite 1989, Ruiz 1991, Geraldes *et al.*1997, Saes 1999). The granites are medium- to coarse-grained, vary from isotropic to strongly foliated, and span for ca. 70 Ma, between 1.55 and 1.48 Ga (Geraldes *et al.*1999). Geochemically, they have a calc-alkaline arc signature (Pinho 1996 and Pinho *et al.*1997).

The younger granites of the Jaurú Terrain, collectively reported as the Guapé Intrusive Suite (Barros *et al.*1982, Saes *et al.*1984, Leite 1989), occur mainly along the Indiavaí-Lucialva Shear Zone as circular stocks mostly of granodiorite with a within-plate calk-alkaline trend (Menezes *et al.*1993). Only Rb-Sr geochronological data are available for these granites, and yielded ages between 1.0 Ga and 0.9 Ga, which corresponds to the late stages of the Sunsas orogeny in eastern Bolivia (Litherland *et al.*1986). Differentiated mafic sills, known as the Rio Branco Intrusive Suite (Leite et al. 1985) occur in eastern Jaurú Terrain. They consist of fine-grained olivine gabbro, followed by gabbro and quartz gabbro and thin layers of quartz-syenite and granophyre. Geochronological data include a Rb-Sr isochronic age of 1.1 Ga and high initial $^{87}Sr/^{86}Sr$ ratio of 0.734. U-Pb zircon ages of ca. 1.45 Ga are presented by Geraldes *et al.* (1999) for this unit.

The Rio Alegre Terrain This terrain occurs as a narrow belt flooring the central zone of the Aguapeí Aulacogen (Saes *and* Fragoso César 1996) and is limited by sub-parallel N20W-trending faults. The eastern faults approximately coincide with the Aguapeí tectonic front, while the western, close to the Bolivian border, are less precisely mapped due to the sedimentary cover of Pantanal Matogrossense wetlands and of the Alto Guaporé river.

This terrain consists dominantly of metamorphosed mafic-ultramafic rocks and rare felsic rocks. They include peridotite, pyroxenite, gabbro, basalts, and dacites (Figueiredo *et al.*1974, Barros *et al.*1982, Monteiro *et al.*1986, Matos 1994, Angeli *et al.*1997). The mafic volcanic rocks contain thin intercalations of chemical and clastic sedimentary rocks (Leite *et al.*1986, Matos 1994). Granitoid intrusions in this terrain are of tonalite with minor granodiorite and granite, which crop out along the Aguapeí River and the Aguapeí Tectonic Front (Pinho 1990, Saes *and* Leite 1993, Geraldes 1996). Geochemically, the mafic rocks have a tholeiitic to calk-alkaline trend of back-arc ocean floor tectonic setting (Pinho 1990, Matos *and* Schorscher 1997). Chemical and petrographic data of metaultramafic rocks led Angeli *et al.* (1997) to correlate them with the basal sections of an ophiolite. Geochronological data are scarce and were mostly obtained from

Departamento de Recursos Minerais, Universidade Federal de Mato Grosso, Av. Fernando Correa da Costa s/n, Cuiabá, MT. CEP 78060-900

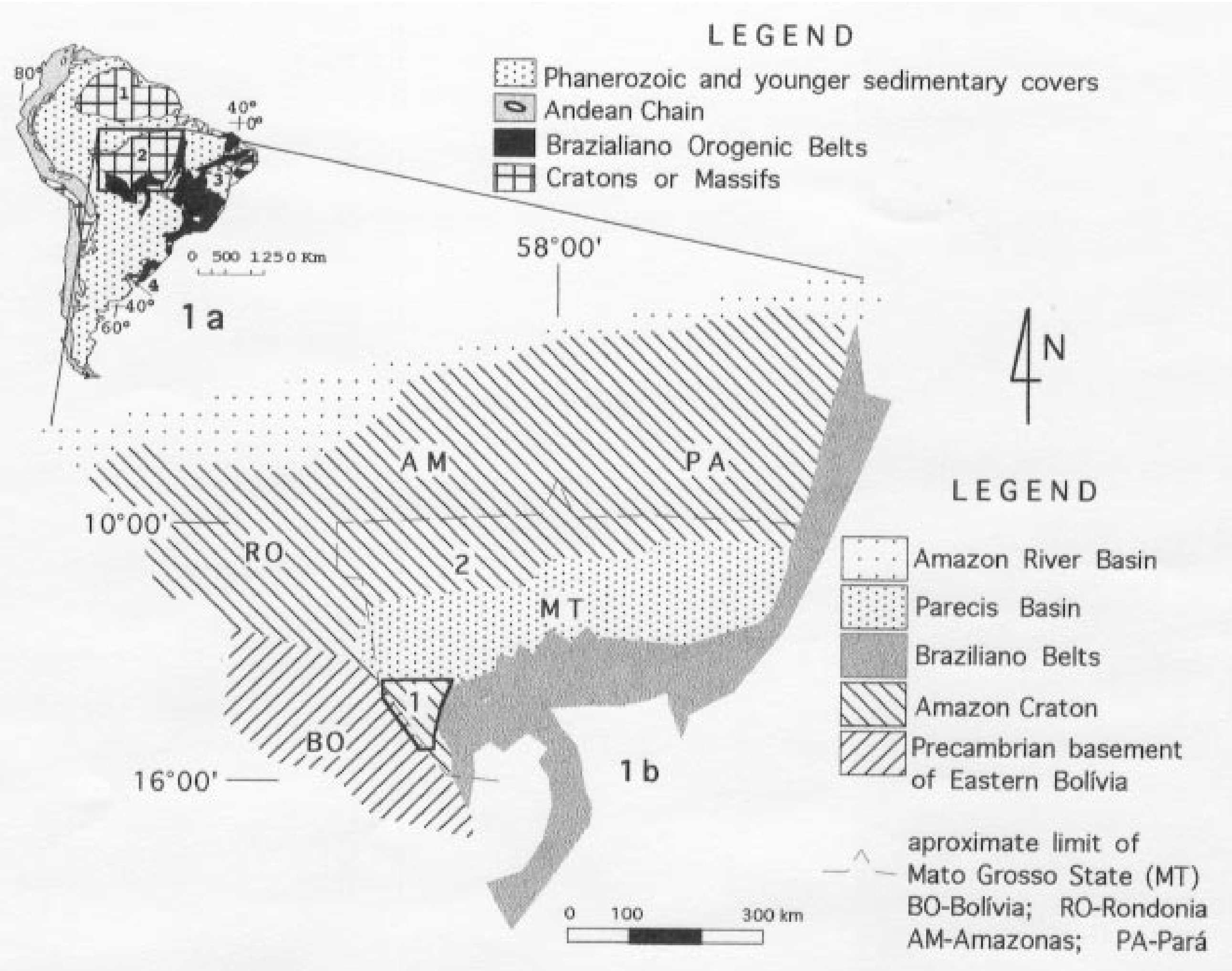

Figure 1 – (a) Main tectonic units of the South American Platform and location map of the Amazon Craton. 1) Guyana Shield, 2) Guaporé Shield, 3) Sao Fransisco Craton and 4) Rio de La Plata Craton. (b) Location of the studied area (dotted) and the main limits of the southern Amazon Craton in Mato Grosso.

intrusive granitoids (Geraldes *et al.*1999) which yielded a range between 1.55 and 1.42 Ga, the older age indicating the minimum age of the Rio Alegre Terrain.

The Santa Helena Granite Complex The Santa Helena Complex occurs in a northwest-trending area of about 6,000 km^2 between the Jaurú and Rio Alegre terranes. To the west, it is roughly limited by the 1.2-1.0 Ga Aguapeí tectonic front, but some outcrops occur farther west where its intrusive contacts are clearly exposed. Its eastern limit was originally traced at the Indiavaí-Lucialva Shear Zone (Saes *et al.*1984, Leite 1989, Saes *and* Fragoso Cesar 1996, Geraldes *et al.*1999), but it also crops out farther east. To the north and south, younger sedimentary covers conceal the complex.

The batholith is compositionally homogeneous and consists of hornblende-biotite syenogranite with a conspicuous N20W-trending metamorphic foliation. Near the Indiavaí-Lucialva Shear Zone and the Aguapeí Tectonic Front, the granite turns into protomylonite, mylonite, and augen gneisses. Contact relationships indicate that the complex intrudes the gneisses of the Brigadeirinho Complex and the mafic and ultramafic rocks of the Quatro Meninas and Araputanga belts of the Jaurú Terrain.

Geochemically, the intrusion has high Na_2O+K_20, low Al_2O_3, very low CaO and high total REE, which led Menezes *et al.*(1993) to intepret it as an A-type granite, but Geraldes *et al.*(1997) suggest that this granite has a calk-alkaline trend.

The Santa Helena Complex yielded a Rb-Sr isochronic age of 1.308 ± 45 Ma and high initial $^{87}Sr/^{86}Sr$ ratio of 0.715 (Menezes *et al.*1993), which agrees with a crustal reworking origin. U-Pb data of zircon yielded an age of 1.450 ± 2 Ma, with inherited core of 2.82 Ga (Geraldes *et al.*1997) that confirms the participation of an important older crustal component. Th age interval of the Camplex (1.45 to 1.3 Ga) is roughly coeval with the Rondonian-San Ignácio Orogeny, considered to have evolved under ensialic conditions (Tassinari *et al.*1996).

The Aguapeí Belt The Aguapeí Belt is a sedimentary basin that overlaps the limits of previously accreted terranes. Its evolution starts with the extensional reactivation of the southern margin of the Amazon Craton and formation of an intracontinental rift (Aguapeí Aulacogen) after 1.2 Ga (Litherland *et al.*1989, Saes *and* Fragoso César 1994, 1996). The thick siliciclastic sedimentary record indicates that the basin evolved under a rift, sineclise, and inversion stages.

The Aguapeí Belt occurs as a NW-trending narrow zone of intense deformation and very low metamorphic grade along the central parts of the area, roughly coinciding with the limits between the Rio Alegre terrain and the Santa Helena Granitic Complex. Regionally, its deformation seems to reflect a large dextral transpression zone. At a local scale, oblique high-angle northeast-verging thrusts and low angle nappes dominate, and are correlated with Sunsas Orogeny, between 1.2 Ga and 1.0 Ga, of eastern Bolivia.

TECTONIC MODELS Several tectonic models have been proposed to explain the evolution of the southern Amazon Craton. (Teixeira *et al.*1989, Tassinari *et al.*1996, Saes *and* Fragoso César 1994, 1996, Geraldes 1999).

Teixeira *et al.* (1989), Tassinari (1984), Tassinari *et al.* (1996) and Tassinari *and* Macambira (1999) interpret the tectonic evolution of the Amazon Craton on a continental scale under a continuous westward amalgamation of Paleoproterozoic (Ventuari-Tapajós Province) to

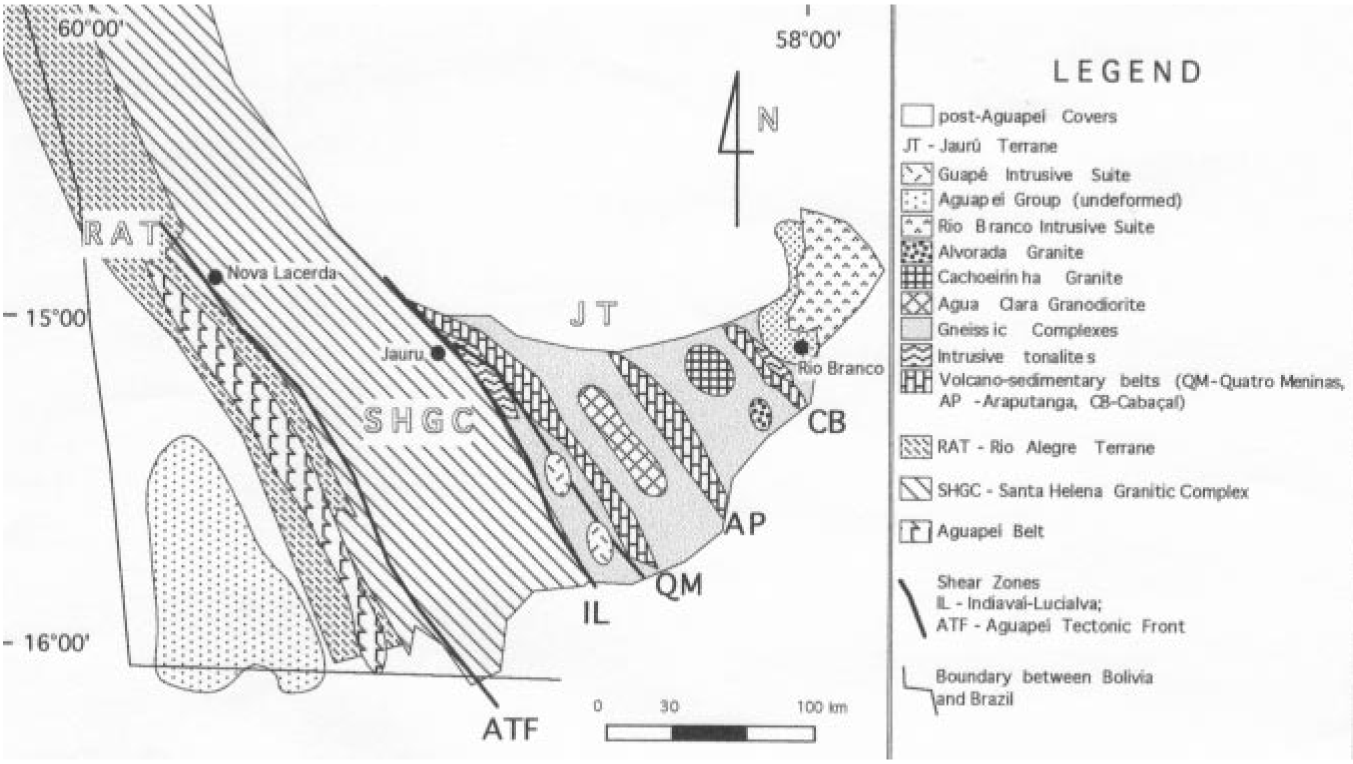

Figure 2 - Geological sketch of the southern Amazon Craton in Mato Grosso.

Mesoproterozoic (Rio Negro-Juruena Province) magmatic arcs onto the Archean Central Amazonia Province block. The westernmost provinces (Rondonian-San Ignácio and Sunsas) expose basement rocks belonging to the Rio Negro-Juruena Province and are, therefore, interpreted as having, in part, evolved as ensialic (Teixeira *et al.*1989, Tassinari *et al.*1996). These authors argue that the geology of the southern portion of the Amazon Craton exposed in southwestern Mato Grosso and Rondonia, corresponds to the southeastern extension of the Rio Negro-Juruena and Rondonia-San Ignácio provinces, as indicated by the common northwest-southeast structural trends, age range (1.75 Ga to 1.4 Ga), positive eNd(t), low $^{87}Sr/^{86}Sr$ initial and tectonic environment allover the province. On the other hand, isotopic data, time interval coherence between tonalites of the Jaurú (1.7 Ga) and Rio Alegre Terranes (1.55 Ga) and the granitoids of the Santa Helena Complex (1.45 Ga), the calc-alkaline trend of most of the granitoids ant their low T_{DM} model ages and positive εNd values, in some cases with low $^{87}Sr/^{86}Sr$ initial ratios, led Geraldes *et al.* (1997, 1999) to propose that the Amazonian Craton in southwestern Mato Grosso resulted from the amalgamation of three magmatic arcs (Rio Alegre, Santa Helena and Cachoeirinha).

DISCUSSION After nearly 40 years of researches, the subdivision of the southern Amazon Craton in southwestern Mato Grosso based on lithological, structural, petrological, and geochronological data has reached a more consistent picture. However, many problems arise when evolution models are considered. One substantial aspect is the proposed extension of the Rio Negro-Juruena Province to southern Mato Grosso (Tassinari *et al.*1996, Geraldes *et al.1999*). This extension is not support by the following facts. First, the consistent structural trend described to extend all over the Rio Negro Juruena-Province changes geographically. As shown by Santos *et al.* (1998) in eastern Rondonia and its extension to the Aripuanã-Juruena and Tabaporã areas in northwestern Mato Grosso, the trend of folds and foliations in both the basement and volcanic rocks is clearly E-W to WNW and not NW-SE as found in the Jaurú Terrain. Second, whilst plagioclase-poor granites dominate in the Rio Negro-Jurena Province, basalts and plagioclase-rich granitoids are major rocks in the Jaurú Terrain. Third, a major NW-SE structural break between the Rio Negro-Juruena Province and the southern portion of the Amazonian Craton occurs beneath the Parecis basin (Siqueira 1989, Leite *et al.*1999). Fourth, the tectonic regime changes along the proposed Rio Negro-Juruena Province, as indicated by the contrasting regimes between the northern (Juruena area) and southern (Jaurú Terrain) portions of the Craton in Mato Grosso. In the Aripuanã and Roosevelt areas, an intracontinental rift formed at ca. 1.74 Ga, but at that time, an island-arc existed in the Cabaçal area (Pinho 1997). Fifth, in spite of the Rondonian Chronotectonic Province and the Santa Helena Granitc Complex being coeval, they do not have counterparts in Rondônia nor in northern Mato Grosso, but the later is similar, in age and composition, to the Pensamiento Granite Complex of eastern Bolívia. It seems, therefore, unlikely that the southern portion of the Amazon Craton is the extension of the northern.

Another conflicting point is the Geraldes *et al.*(1999) hypothesis according to which the southern Amazon Craton evolved by an eastward amalgamation of, at least, three magmatic arcs. At least for the Santa Helena batolith, the following features do not support the existence of one of the arcs: a) undeformed tonalites clearly associated to the Rio Alegre Terrain are coupled with the deformed and metamorphosed Santa Helena A-type granitoid, resulting in an apparent calc-alkaline trend misinterpreted as resulting from a ca. 1.45 Ga magmatic arc (Santa Helena volcano-plutonic arc of Geraldes *et al.*1999); b) felsic volcanic rocks interpreted as belonging to that arc are, actually, mylonites and ultramyllonites derived by shearing of the Santa Helena batholith, as clearly exposed along the highway BR-364 near Nova Lacerda; c) this indicates that the Santa Helena granite can not account for the origin of the proposed Cachoeirinha continental magmatic arc, and d) the Rio Alegre Terrain is dominated by ophiolite-type mafic and ultramafic rocks.

CONCLUSIONS The geologic framework of the southern Amazon Craton in Mato Grosso consists of a diversity of rock assemblage evolved under different tectonic settings within a time-span from ca 1.9 Ga to ca 1.0 Ga. This area is, therefore, a key to the understanding of the Paleo-Mesoprotezoic reconstruction of the Rodinia supercontinent. The Jaurú and Rio Alegre terranes are older than 1.5 Ga and their relationships with the Santa Helena Granite Complex indicate that they have been amalgamated prior to 1.45 Ga. Between 1.45 Ga and ca 1.3 Ga, the suture zone between these terranes underwent intrusion by the A-type Santa Helena Granitic Complex, resulting in a continental mass whose relationships with the northern Amazon Craton are still unclear. The break up of this part of the continent gave rise to a rift, the Aguapeí Group (Saes *and* Fragoso César *1*996). Closing of the continental margin during the Sunsas

Orogeny formed the Aguapeí Belt, which coincide with the stabilization of the Amazon Craton as a whole.

Future questions to be answered include a global view of the studied area, its relationship with the northern Amazon Craton and the eastern Bolívia, problems related to the evolution of the Cachoeirinha magmatic arc (Geraldes *et al.*1999) and the complete evolution of Santa Helena Granite Complex.

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