



**Nd-Sr constraints and Ar-Ar thermochronology of the 1.54 Ga
 Figueira Branca Intrusive Suite: petrogenesis and tectonic inferences
 for the SW Amazonian Craton**

Wilson Teixeira⁽¹⁾, Mauro C. Geraldés⁽²⁾, Manoel S. D'Agrella-Filho⁽³⁾, Márcia A. Sant'Ana Barros⁽⁴⁾, Amarildo S. Ruiz⁽⁴⁾, Eric Tohver⁽⁵⁾, Paulo C. Corrêa da Costa⁽⁴⁾

(1) Inst. Geociências, Universidade de São Paulo (USP), São Paulo, SP, Brasil. wteixeir@usp.br; (2) Fac. Geologia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, RJ, Brasil; (3) Inst. Astronômico, Geofísico e de Ciências Atmosféricas, USP, SP, Brasil; (4) Inst. Ciências Exatas e da Terra, Universidade Federal do Mato Grosso, Cuiabá, MT, Brasil; (5) School of Earth and Geographical Sciences, The University of Western Australia, Perth, Australia.

INTRODUCTION AND GEOLOGICAL FRAMEWORK

This paper deals with the Figueira Branca Intrusive Suite (FBIS) which emplaced the so-called Jauru polycyclic domain, tectonically assigned to the Rio Negro-Juruena province at the southeastern edge of the Amazonian Craton. The new Ar/Ar and Nd-Sr isotopic data are interpreted in the light of the geologic and geochronologic knowledge, providing new insights on the Proterozoic crustal evolution.

The Jauru domain is made up of Paleoproterozoic rocks of the Alto Jauru Group (Lacerda Filho et al., 2004), intruded by Mesoproterozoic granitoid rocks, and partly covered by the Aguapeí Group (1.17–1.15 Ga). The granitoid intrusions are genetically related to the Rondonian-San Ignacio province – as magmatic products from the Cachoeirinha (1587–1522 Ma) and Santa Helena (1485–1434 Ma) arcs. Toward west the Jauru domain is bounded by the Rio Alegre orogen (1517–1481 Ma) – Geraldés et al. (2001), Matos et al. (2004), Bettencourt et al. (2010). The Jauru domain exhibits heterogeneous Ar/Ar pattern: in its eastern portion (Cabaçal-Araputanga belts) the apparent ages are between 1539–1503 (hornblende) and 1529–1510 Ma (biotite) with one exception (1452 Ma; biotite). The western domain shows apparent ages from 1532 (hornblende) to 1322 Ma (biotite), besides the 0.93–0.91 Ga pattern related to faults and shear zones (Bettencourt et al., 2010). The latter structures are collision-related offshoots of the Sunsás belt (1.11–1.00 Ga) - Teixeira et al. (2010).

The Alto Jauru Group is composed of metamorphics volcano-sedimentary sequences, as well as granitic and gneissic rocks (U-Pb zircon ages between 1790–1750 Ma). They show TTG composition and calc-alkaline affinity, compatible with derivation from island arc setting. The Sm/Nd systematics [$\epsilon_{Nd(t)}$ = +2.2 and T_{DM} ages (1.90 - 1.75 Ga)] imply to juvenile protholiths as main source from which the Jauru gneisses derived. The metavolcano-sedimentary sequences make up three distinct NW-trending belts that are named from East to West: Cabaçal, Araputanga and Jauru (Geraldés et al., 2001). According to Saes et al. (1984) two fault systems are recorded over the Jauru domain. The NW-SE one constitutes regional faults associated with breccia and mylonite zones (e.g., Indiavaí-Lucialva tectonic system). This structure tectonically controls the Jauru belt, as well as FBIS occurrences (e.g., Ruiz, 2005). The second, NE system crosscuts the NW one and produced graben structures.



The Cabaçal and Araputanga belts are characterized by the Quatro Meninas and Cabaçal complexes (Ruiz, 2005). The Cabaçal volcanic and plutonic rocks have U–Pb ages from 1795 to 1720 Ma, T_{DM} ages from 2.0 to 1.8 Ga and $\epsilon_{Nd(t)}$ values from +2.8 to +2.2 – Geraldes et al. (2001), Ruiz (2005). Such Nd signatures agree well with the idea that successive accretion of intra-oceanic arcs originated much of the Alto Jauru Group, during the continental margin Paleoproterozoic evolution of the Rio Negro-Juruena province. The Jauru belt consists of orthogneisses and migmatites (as dome shaped bodies) surrounded by the metavolcanic-sedimentary assemblages, and intruded by the FBIS among other plutons. The gneisses yield a Pb/Pb whole rock isochron age of 1717 ± 120 Ma ($Pb\mu 1 = 8.1$) – e.g. Bettencourt et al. (2000). Pinho et al. (1997a) reported as an isochron age of 1988 ± 45 Ma for the Jauru metabasalts, considered a questionable result. The metabasalts display Nd signatures and geochemical affinity with N-MORB rocks which contrasts with the arc-type chemistry shown by the Cabaçal and Quatro Meninas volcanic rocks (Araputanga and Cabaçal belts).

The Cachoeirinha orogen evolved during two stages: development of intraoceanic arcs (1.59 to 1.56 Ga) succeeded by extensive granitic magmatism of continental arc setting (1.56-1.52 Ga) – Ruiz (2005). The related T_{DM} ages are 1.9 - 1.7 Ga and $\epsilon_{Nd(t)}$ values vary from +1.0 to -0.8 (Geraldes et al., 2001). The calc-alkaline affinity and variations in major and trace elements indicate that the Cachoeirinha rocks are probably the exposed roots of magmatic arcs. The Santa Helena arc (1.48–1.43 Ga) represents the core of a large plutonic body that borders the Jauru belt along the Indiavaí-Lucialva tectonic system. Coeval rocks (Rio Branco bimodal suite) are also present at the extreme East of the study area. The 1517–1481 Ma Rio Alegre orogen (intermediate volcanic and mafic-felsic plutonic rocks; iron-rich sedimentary units and quartzites) was laterally accreted to the western fringe of the Jauru domain. The metadacites (U–Pb zircon ages of 1517 ± 27 Ma and 1513 ± 9 Ma) give T_{DM} ages of c. 1.54-1.48 Ga and $\epsilon_{Nd(t)}$ values of +4.3 and +4.8, whereas the mafic–ultramafic rocks (U–Pb zircon age of 1509 ± 10 Ma and 1494 ± 11 Ma) have $\epsilon_{Nd(t)}$ values of +4.5 to +2.5 (Geraldes et al., 2001; Matos et al., 2004). The Nd signatures and geochemical affinities are consistent with a mid-oceanic ridge setting for the Rio Alegre orogen.

The Figueira Branca Intrusive Suite

Figueira Branca Intrusive Suite (FBIS) constitutes a string of NW-elongated stocks and plugs of gabbro, anorthosite and norite, whereas peridotite, gabbro-norite, gabbro-anorthosite, pyroxenite, dunite and troctolite are subordinate (Saes et al., 1984). These plutons crop out along the eastern site of the Indiavaí-Lucialva system, and are intrusive into the Quatro Meninas complex, as showed by the roof pendants with typical rocks and xenoliths of the metabasalts (e.g., Souza et al. 2010). Coeval mafic dikes (diabases, gabbros) occur in the vicinity of Indiavaí, and are also assigned to the FBIS. The crystallization age of the FBIS is 1541 ± 23 Ma, defined by SHRIMP igneous titanite (6 fractions) from one pristine olivine gabbro that crops out in the Figueira Branca farm (Barros et al., 2010).

According to Saes et al (1984) the FBIS is mainly composed of coarse grained, usually massive to deformed rocks. The ultrabasic types may show layered structure (olivine rich versus labradorite rich layers) suggesting derivation from fractional crystallization processes (Pinho et al., 1997b). In the vicinity of the Figueira Branca farm the suite is composed of basal peridotites with interlayered pyroxenites, gabbro-



norites and anorthosites (Barros et al., 2010). The petrography revealed well-preserved rocks, locally affected late to post-magmatic fluids, tectonism and greenschist facies metamorphism, such as the presence of uraltite (resulted from pyroxene), fractured and deformed plagioclase, undulatory extinction or partial re-crystallization of quartz, as well as the plagioclase-actinolite-epidote assemblage (in anorthosite), respectively. In addition, intense cataclasis and metamorphic foliation (greenschist to amphibolite facies) were reported for the metagabbros and pyroxenites (Souza et al., 2010).

RESULTS

Five Rb/Sr and Sm/Nd analyses were carried out in gabbro, gabbro-norite, peridotite and anorthosite from the layered intrusion of Figueira Branca farm. The Sm/Nd analyses have “normal” $f_{\text{Sm/Nd}}$ for mafic-ultramafic rocks (-1.18 to -0.23), and the T_{DM} ages are roughly comparable (1.7-1.6 Ga). The calculated $\epsilon_{\text{Nd}(1.54\text{Ga})}$ parameters are positive ones (+3.4 e +4.0) while the $\epsilon_{\text{Sr}(1.54\text{Ga})}$ are variable, ranging from -40.0 to -6.7, except for sample P-16 ($\epsilon_{\text{Sr}(1.54\text{Ga})} = +1.7$) which anomalous signature is probably due to epidotization. The Nd-Sr constraints indicate that the FBIS probably derived from a short-lived juvenile, homogenous depleted source.

The Nd evolution diagram provides additional petrogenetic inferences for the FBIS when compared to the isotopic characteristics of host rocks. The investigated rocks show significantly lower $\epsilon_{\text{Nd}(0)}$ values (-5 to -3) compared to the Cachoeirinha rocks (1590-1520 Ma), although the comparable SHRIMP age of the FBIS (1541 ± 23 Ma). The Nd signature of the Cachoeirinha arc ($\epsilon_{\text{Nd}(0)}$ between -15 and -22) is clearly influenced by contribution of Alto Jauru crust ($\epsilon_{\text{Nd}(0)}$ between -17 and -20) into the magmatic source – whereas the FBIS signature is consistent with a independent juvenile environment but time-related with the Cachoeirinha continental arc.

Two Ar/Ar age determinations (duplicate analyses) were performed in FBIS gabbros. Biotite from sample AZ-23 yielded similar plateau ages of 1222 Ma (ideogram age of 1222 ± 5 Ma). In contrast, gabbro AZ-110 gave comparable biotite ages of 1275 ± 4 Ma and 1268 ± 4 Ma, whereas the amphibole analysis showed disturbed spectra with pseudo plateau ages of 1222 ± 7 Ma and 1159 ± 4 Ma (integrated ages of 1152 ± 2 Ma and 1077 ± 7 Ma, respectively). These apparent ages are significantly younger than the Ar/Ar pattern (between 1539-1503 Ma and 1452 Ma) reported for the Jauru domain. One amphibolite (AZ-95) from the Jauru belt was also analyzed. It yielded a plateau biotite age of 1811 ± 8 Ma that demonstrates the time of regional cooling of the Jauru belt.

SUMMARY AND CONCLUSIONS

The Jauru domain consists of Paleoproterozoic TTG associations and coeval metasedimentary-volcanic belts originated in magmatic arc and ocean ridge settings, further invaded by Cachoeirinha and Santa Helena orogenic rocks. Particularly the Cachoeirinha arc magmatism (1590-1520 Ma) has Nd signature, calc-alkaline affinity and major and trace element patterns related with intra-oceanic and continental margin settings (eastward slab subduction below the Paleoproterozoic crust).

The U/Pb age of the FBIS suggests a tectonic relationship with the Cachoeirinha plutonic rocks. Nevertheless, the distinct juvenile-like Nd signature of the layered outcrop points to the role of extensional dynamics in a Mesoproterozoic intra-oceanic environment – in agreement with the model of Mesoproterozoic soft accretion arc



dynamics proposed by Bettencourt et al. (2010) for the SW portion of the Amazonian Craton. If so, we speculate that the scattered, disrupted FBSI occurrences that roughly accompany the NW-trending architecture of the Indivai-Lucialva tectonic system may signal the tectonic limit (suture) of the Cachoeirinha arc over the Jauru domain.

The heterogeneous Ar/Ar patterns shown by the Jauru domain are further indications of the overprinted Mesoproterozoic dynamics. A homogeneous uplift and cooling in the eastern part (1539-1503 Ma), reflected by hornblende and biotite, are probably related to tectonic stability of the Cachoeirinha orogen, whereas an isolated 1452 biotite age record may suggest a younger metamorphic cooling episode. In contrast, the western portion of the Jauru domain was subjected to a lower cooling rate (from 1532 to 1322 Ma), as indicated by the Ar/Ar ages in hornblende and biotite, respectively. Particularly the biotite age (1322 Ma) may reflect the cratonization stage of the Rondonian-San Ignacio province which ultimate accretion event was dated at c. 1350 Ma (Bettencourt et al., 2010). Extensional tectonics (faults, shear zones) and anorogenic granites, with Ar/Ar ages below 1.0 Ga are probably late Sunsás offshoots.

REFERENCES

- Barros, M. A. S., Teixeira, W., Santos, J. O. S., Correa da Costa, P. C., Fraga, L. D., 2010. Suíte Intrusiva Figueira Branca - SW do Cráton Amazônico - Idade, geoquímica isotópica de Nd e características petrográficas. 45º Congresso Brasileiro de Geologia, Belém, Pará (submitted).
- Bettencourt, J.S., Leite Jr., W., Payolla, B., Ruiz, A.S., Matos, R.S., Tosdal, R.M., 2010. The Rondonian-San Ignacio Province in the SW Amazonian Craton: an overview. *Journal of South American Earth Sciences*, 29: 28–46.
- Geraldes, M.C., Van Schmus, W.R., Condie, K.C., Bell, S., Teixeira, W. and Babinski, M., 2001. Proterozoic geologic evolution of the SW part of the Amazonian Craton in Mato Grosso state, Brazil: *Precambrian Research*, 111: 91-128.
- Pinho, F.E.C., Fyfe, W.S., Pinho, M.A.S.B., 1997a. Early Proterozoic evolution of the Alto Jauru greenstone belt, southern Amazonian Craton, Brazil. *International Geology Review*, 39: 220-229.
- Pinho, M. A. S. B., Leite, J. D. A., Moraes, C. F., Arruda, R. C. C., Guimarães, F. T., 1997b. Petrografia da suíte intrusiva Figueira Branca: Evidências de uma associação básico-ultrabásica estratiforme no sudeste de Mato Grosso, porção sul do Craton Amazônico. *Anais do VI Simpósio de Geologia do Centro-Oeste, Cuiabá – MT, 1997*.
- Ruiz, A. R., 2005. Evolução geológica do sudoeste do Craton Amazônico, região limítrofe Brasil–Bolívia–Mato Grosso. Doctoral Thesis, USP, UNESP-Rio Claro, SP, Brazil, p. 260.
- Saes, G. S.; Leite, J. A. D.; Weska, R. K., 1984. Geologia da Folha Jauru (SD-21-Y-C-III): Uma síntese dos conhecimentos. XXXIII Congr. Brás. Geol. Rio de Janeiro, v.5: 2193-2204.
- Souza, M. Z., Batata, M. E. F., Ruiz, A. S., Lima, G. A., Matos, J. B.; Paz, J. D. S., Costa, A. C. D., Silva, C. H.; Corrêa da Costa, P. C., 2010. Geologia e Recursos Minerais da Folha Rio Branco (SD-21-Y-D-I). PRONAGEO, CPRM-UFMT (unpublished report).
- Teixeira, W., Geraldes, M.C., Matos, R., Ruiz, A.S., Saes, G., Vargas-Matos, G., 2010. A review of the tectonic evolution of the Sunsás belt, SW portion of the Amazonian Craton. *Journal of South American Earth Sciences*, 29, 47–60.