



## **U-Pb SHRIMP geochronological constraints on Puga and Serra Azul glacial diamictites, Northern Paraguay belt**

**Marly Babinski<sup>1</sup>, Milene Freitas Figueiredo<sup>1</sup>, Mark Fanning<sup>2</sup>**

1. Instituto de Geociências, Universidade de São Paulo, Rua do Lago, 562, CEP 05508-080, São Paulo, SP, Brazil. E-mail: [babinski@usp.br](mailto:babinski@usp.br), [milene.figueiredo@gmail.com](mailto:milene.figueiredo@gmail.com)
2. Research School of Earth Sciences, The Australian National University, Canberra, Australia. E-mail: [Mark.Fanning@anu.edu.au](mailto:Mark.Fanning@anu.edu.au)

### **INTRODUCTION**

The Paraguay belt comprises a thick sedimentary succession affected by the Brasiliano Orogeny, and can be further divided into two segments: the northern and the southern part. The south part borders the southeastern margin of the Amazonian craton and the Rio Apa Block, and the northern domain, where our study area is located, borders the eastern side of the Amazon craton.

The sedimentary pile of both segments includes a basal glacial diamictite, known as Puga Formation, overlain by a carbonatic cover. However, towards the top of the succession, clear differences on the stratigraphy of the two segments can be recognized. In the northern part of the belt, a younger level of glacially influenced diamictites of the Serra Azul Formation and other siliciclastic rocks from the Raizama and Diamantino formations, unconformably overlie the carbonates of the Araras Group (Figueiredo et al., 2008). These units have not been described in the south part of the belt. Such differences suggest an independent sedimentary evolution for both segments. However, the lack of geochronological data inhibits the proposition of alternative and robust tectonic evolution models.

In order to help to understand the evolution of the Paraguay Belt, we present the first U-Pb SHRIMP geochronological data obtained on detrital zircon grains separated from the matrix of glacially-influenced diamictites and post-glacial sandstones from the northern part of the Paraguay belt.

### **GEOLOGICAL SETTING AND SAMPLING**

In the platform portion of Northern Paraguay belt (NPB), two levels of glacial diamictites occur and are represented by the Puga and Serra Azul formations, separated by a thick interval of carbonates from Araras Group. The younger glacial level (Serra Azul Formation) grades upward into peritidal sandstones of the Raizama Formation.

The Puga Formation is more than 200 m thick and comprises diamictites, rudstones, and pelites and has been interpreted as a subaqueous glacial succession. Towards the basin, this formation grades into the Cuiabá Group which is composed by organic-rich shales, dolomites, diamictites, rudstones, and sandstones, interpreted as glaciomarine and turbiditic sediments (Alvarenga & Trompette, 1992).

The Araras Group (about 1000 m thick) is divided into 4 formations (Nogueira & Riccomini, 2006): Mirassol d'Oeste, Guia, Serra do Quilombo and Nobres. The Mirassol d'Oeste Formation is composed of pink cap dolostones (c. 30 m), with stromatolites, tubestones and mega ripples structures. The Guia Formation mainly comprises laminated





limestones and marls (c. 250 m) deposited in a deep platform environment. The Serra do Quilombo Formation contains dolomites and cemented breccias from a moderate deep platform (< 300 m). The Nobres Formation (< 500 m) has dolostones that were deposited in a shallow platform and peritidal environments (Almeida, 1964; Alvarenga et al., 2000).

The Serra Azul Formation contains, from base to top, diamictites (c. 70 m), brownish laminated siltstone and claystone (c. 70 m) with intercalations of fine hummocky laminations towards the top of the section (Alvarenga et al., 2007, Figueiredo et al., 2008). This formation grades upward into an intercalation of pelites, sandstones, arkoses and rudstones of the Raizama Formation.

Three samples were collected for this study. Two of them, PS22 and PS14, were sampled from middle to the upper part of the Puga Formation, northeastern of NPB (near Planalto da Serra town). At the outcrop, they occur in the diamictite as thin layers, no more than 2 cm thick, and were considered as ash beds. Since these rocks are deformed, the whitish are irregular, slightly folded. This situation does not allow sampling only the presumably ash beds, and some matrix of the diamictite was included in the sample. However, no more than 500 g were collected of each sample. The identification of ash bed through petrographic study was not possible due to its high alteration condition.

The third sample, NB01, was collected near Nobres town, MT. It is a sandstone with cross stratification and stratigraphically is in the interval where Serra Azul Formation grades to the Raizama Formation. We interpret this sample as the uppermost part of the Serra Azul Formation.

## **ANALYTICAL PROCEDURES**

Zircon grains were separated using standard heavy liquid and magnetic techniques at the Geochronological Research Center, University of São Paulo. The U-Pb analyses were carried out on the SHRIMP RG ion microprobe at the Australian National University. Grains were mounted in an epoxy disk with the Temora zircon standard, and polished to expose their centers. Internal structures of zircon grains were revealed by cathode-luminescence (CL) image. The analytical procedures were similar to those described by Williams (1998). Five to six scans through the mass stations were made for each age determination. U abundance was calibrated using the standard SL13 (U=238 ppm, Williams, 1998) and  $^{206}\text{Pb}/^{238}\text{U}$  ratio was calibrated using the Temora standard ( $^{206}\text{Pb}/^{238}\text{U}$  age=417 Ma; Black et al., 2003). Measured  $^{204}\text{Pb}$  was applied for the common lead correction, and data processing was carried out using the Squid and Isoplot programs (Ludwig, 2001).

## **RESULTS AND DISCUSSIONS**

Two samples from the Puga diamictites did not provide good yield of zircon crystals. No more than 12 zircons were recovered from sample PS22, and only 6 grains were dated since others were lost during the polishing procedure. U-Pb ages on this sample range from 880 to 1871 Ma. These results indicate that either the sample is not an ash bed or the volcanic crystals were not recovered from the sample. Sample PS14 yielded more zircons, and 27 grains were dated. Just a few showed sharp edges, suggesting a volcanic origin; most grains are rounded or slightly rounded indicating that these crystals are detrital and were transported by the ice. The U-Pb ages obtained in this sample show a large variation, ranging from 627 Ma to 3080 Ma, with clusters at 753 Ma, 1869 Ma, 1992 Ma, 2710 Ma, 2955 Ma, and 3077





Ma. If data from both samples were grouped ( $n=33$ ), the pattern is the same and the main peak ages are at 1869 and 3077 Ma. The age of the youngest zircon is  $627 \pm 8$  Ma. If the analytical error is considered, an age of 635 Ma can be obtained and allow us to suggest that the Puga diamictites could be correlated to other Marinoan glacial deposits already dated in Namibia (Hoffmann et al., 2004), China (Condon et al., 2005), and Oman (Bowring et al., 2007).

U-Pb ages determined on detrital zircons from Puga Formation indicate that most of the source areas were on the Amazonian craton, and are represented by the Carajás Province (3.1 to 2.7 Ga; Santos et al., 2003), Ventuari – Tapajós Province (1990 Ma; Tassinari & Macambira, 1999), Rio Negro – Juruena Province (1869 Ma) and Cachoeirinha Suite (1550 Ma; Geraldès et al., 2001). The sources of the 750 Ma zircons have not been recognized in the region, and the Goiás Magmatic Arc (Pimentel & Fuck, 1992) could be a possible source area.

Zircon crystals from the sandstone of the top of the Serra Azul Formation are rounded and slightly rounded; few grains are euhedral. Seventy seven grains were dated and the age interval is between 595 and 1950 Ma, with the main clusters at 717, 990, 1215, 1409, 1546, 1775, and 1947 Ma. Source areas for the old zircons are found in the Amazonian craton. Rocks from the Ventuari-Tapajós Province (Tassinari & Macambira, 1999) could have yielded the 1950 Ma zircons. The 1770 Ma zircons may have been derived from the Rio Negro-Juruena Province where rocks with similar ages have been reported (Geraldès et al., 2001). The main peak, represented by the 1546 Ma zircons, can be related to the Cachoeirinha Suite (Geraldès et al., 2001). Zircons with ages of 1400 and 1200 Ma could have been related to the Santa Helena batholith (Geraldès et al., 2001). The Sunsás Province can be responsible for the zircons with ages between 990 and 1200 Ma (Geraldès et al., 2001). Zircons with ages of 710 Ma are not found in the area and the Brasília fold belt (Pimentel & Fuck, 1992) may be the most probable source of the sediments. The youngest zircon dated at  $595 \pm 11$  Ma establishes the maximum sedimentation age of this sandstone, and indicates that the diamictites of the Serra Azul Formation are younger than 590 Ma. These results reinforce that the Serra Azul Formation glacial rocks can be correlated to the Gaskiers Glaciation (Alvarenga et al., 2007; Figueiredo et al., 2008) precisely dated at 582 Ma (Bowring et al., 2003).

## CONCLUSIONS

Our sediment provenance study on glacial diamictites of the Puga and post-glacial sandstones of the Serra Azul formations indicate that rocks with ages ranging from 700 Ma to 3080 Ma acted as the main source area of sediments. The young source (700 Ma) could have been related to the Goiás Magmatic Arc, while the older sources probable came from the Amazonian Craton. Archean sources were not found in the Serra Azul sandstones.

The youngest zircon found in the Puga Formation dated at  $628 \pm 7$  Ma, if the analytical error is considered, indicates that Puga diamictites were deposited during the global Marinoan Glaciation.

The age determined on the youngest zircon from the Serra Azul Formation ( $595 \pm 11$  Ma) reinforces the hypothesis that these sediments may be correlated to the 580 Ma Gaskiers Glaciation, as already suggested by Alvarenga et al. (2007) and Figueiredo et al. (2008) based on stratigraphic studies.





## REFERENCES

- Almeida, F.F.M., 1964. Geologia do Centro-Oeste Matogrossense. Ministério de Minas e Energia/DNPM, Boletim de Divisão de Geologia Mineral, 215:1-137.
- Alvarenga, C.J.S. & Trompette, R., 1992. Glacial influenced turbidite sedimentation in the uppermost Proterozoic and Lower Cambrian of the Paraguay Belt (Mato Grosso, Brazil). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 92:85-105.
- Alvarenga, C.J.S., Moura, C.A.V., Gorayeb, P.S.S., Abreu, F.A.M., 2000. Paraguay and Araguaia Belts. In: U.G. Cordani, E.J. Milani, A. Thomaz Filho & D.A. Campos, *Tectonic Evolution of South America*, p. 183-193, Rio de Janeiro, Brazil.
- Alvarenga, C.J.S., Figueiredo, M.F., Babinski, M., Pinho, F.E.C., 2007. Glacial diamictites of Serra Azul Formation (Ediacaran, Paraguay Belt): Evidence of the Gaskiers glacial event in Brazil. *Journal of South American Earth Sciences*, 23:236-241.
- Black, L.P., Kamo, S.L., Allen, C.M., Aleinikoff, J.N., Davis, D.W., Korsch R.J., Foudoulis, C., 2003. TEMORA 1: a new zircon standard for Phanerozoic U-Pb geochronology. *Chemical Geology*, 200:155-170.
- Bowring, S., Myrow, P., Landing, E., Ramezani, J., Grotzinger, J., 2003. Geochronological constraints on terminal Neoproterozoic events and the rise of metazoans. *Geophysical Research Abstracts*, 5, 13219.
- Bowring, S.A., Grotzinger, J.P., Condon, D.J., Ramezani, J., Newall, M., 2007. Geochronologic constraints on the chronostratigraphic framework of the Neoproterozoic Huqf Supergroup, Sultanate of Oman. *American Journal of Science*, 307: 1097-1145.
- Condon, D., Zhu, M., Bowring, S., Wang, W., Yang, A., Jin, Y., 2005. U-Pb ages from the Neoproterozoic Doushantuo Formation, China. *Science*, 308:95-98.
- Figueiredo, M.F., Babinski, M., Alvarenga, C.J.S., Pinho, F.E.C., 2008. Nova unidade litoestratigráfica registra glaciação Ediacarana em Mato Grosso: Formação Serra Azul. *Geologia USP*, 8: 65-75.
- Geraldes, M.C., Van Schmus, W.R., Condie, K.C., Bell, S., Teixeira, W., Babinski, M., 2001. Proterozoic geologic evolution of the SW part of the Amazonian Craton in Mato Grosso state, Brazil. *Precambrian Research*, 111:91-128.
- Hoffmann, K.-H., Condon, D., Bowring, S., Crowley, J.L., 2004. U-Pb zircon date from the Neoproterozoic Ghaub Formation, Namibia: constraints on Marinoan glaciation. *Geology*, 32:817-820.
- Ludwig, K.R., 2001. User's manual for Isoplot/Ex Version 2.49 A geochronological toolkit for Microsoft Excel. Berkeley Geochronological Center, Special Publication 1a, 55p.
- Nogueira, A.C.R. & Riccomini, C., 2006. Grupo Araras (Neoproterozoico) na parte norte da Faixa Paraguai e Sul do Craton Amazônico, Brasil. *Revista Brasileira de Geociências*, 36: 576-587.
- Pimentel, M.M., Fuck, R.A., 1992. Neoproterozoic crustal accretion in central Brazil. *Geology* 20:375-379.
- Santos, J.O.S., 2003. Geotectônica dos Escudos das guianas e Brasil-Central. In: Bizzi, L.S., Schobbenhaus, C., Vidotti, R.M., Gonçalves, J.H. (Eds.) *Geologia, tectônica e recursos minerais do Brasil*. CPRM, Brasília, pp. 169-195.
- Tassinari, C.C.G. & Macambira, M.J.B., 1999. Geochronological provinces of the Amazonian Craton. *Episodes*, 22(3):174-182.
- Williams, I.S., 1998. U-Th-Pb geochronology by ion microprobe. In: M.A. McKibben, W.C. Shanks and W.I. Ridley, Editors, *Applications of microanalytical techniques to understanding mineralizing processes*. *Reviews in Economic Geology*, 7:1-35.