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GEOCHRONOLOGICAL CONSTRAINTS ON THE NEOPROTEROZOIC GLACIATIONS IN BRAZIL

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The end of the Precambrian Eon is punctuated by glacial events rapidly followed by widespread carbonate sedimentation (cap carbonates), marking severe climatic changes that could have been the evolutionary bottle-necks for the Cambrian "life-explosion". Such strong environmental changes have been accounted for by several models, including the "snowball earth" hypothesis and its softer variants (slushball earth) as well as the high-obliquity hypothesis. All of them rely on the contemporaneity of the Neoproterozoic glacial deposits and the cap carbonates, given their similar (and unusual) sedimentary structures and isotopic record. Nevertheless, the limited number of radiometric ages in these deposits and their associated errors makes difficult to test the synchrony of glacial episodes, so that the Neoproterozoic glacial deposits may be explained in terms of limited diachronous glacial episodes, global scale glacial episodes or both.

Glacial deposits conformably covered by carbonate rocks have been described in Brazil since the 30's. In the São Francisco craton and surrounding fold belts they correspond to the Jequitaí/Macaúbas/Bebedouro diamictites and the overlying carbonates of the Bambuí Group. In the southern border of the Amazon craton and the Northern Paraguay fold-belt, these successions are grouped into the Puga Formation (diamictites) and the Araras Group (carbonates). To the south, along the Southern Paraguay belt, the Puga diamictites are covered by carbonates of the Corumbá Group. The Araras and Corumbá Groups have been classically correlated, despite the lack of age constraints in both units. In the last decade we have conducted a geochronological survey on the carbonates found above the Neoproterozoic glacial deposits in Brazil. Here we present and discuss these ages.
In the **São Francisco craton** we have dated the lowermost carbonates of the Sete Lagoas Formation (Bambuí Group). These deep platform deposits are 90 m thick and contain, in their first ten meters, calcite crystal-fans (aragonite-pseudomorph). They are characterized by negative $\delta^{13}C$ values, which increase to values towards 0‰ accompanying the vanishing of sea-floor precipitates upward. Eight carbonate samples from the Sambra quarry were selected for the geochronology study; six from the base of the quarry, corresponding to the deep-platform crystal-rich sediments, and two from the upper part of the quarry, which includes storm-wave crystalline limestones. Samples from the lower Sambra quarry yielded variably radiogenic Pb isotopic compositions with $^{206}Pb/^{204}Pb$ ratios ranging from 19.1 to 32.8, $^{207}Pb/^{204}Pb$ from 15.68 to 16.56, and $^{208}Pb/^{204}Pb$ from 38.1 to 39.0. The fibrous precipitates preserved the most radiogenic Pb ratios. Samples from the upper part of the quarry revealed uniform and non-radiogenic Pb ratios ($^{206}Pb/^{204}Pb$ = 18.8; $^{207}Pb/^{204}Pb$ = 15.65), and the results of these two samples were not used for regression. The Pb ratios obtained from the lower part of the succession yielded a Pb-Pb isochron age of 740 ± 22 Ma (95% confidence level) (Babinski and Kaufman, 2003). Because the rocks of this outcrop are extremely well preserved and undeformed, suggesting that the Pb isotopic system was not disturbed by later events, we interpret it as the depositional age for this cap carbonate.

In the **Northern Paraguay belt** we have dated the cap carbonates of the Mirassol d'Oeste Formation (Araras Group), which directly overly the diamictites of the Puga Formation, and have been detailed studied by Nogueira et al. (2003) and Alvarenga et al. (2004). The carbonate section is made up of a lower unit ca. 22 m thick composed of laminated pink dolostones containing tepee-like structures and stromatolites. The upper part of the section (ca. 23 m thick) is characterized by the intercalation of homogeneous and laminated fine-grained limestone and laminated mudstone; calcite crystal-fans (aragonite-pseudomorph) can be found in this section. Twelve samples (six from each part to the section) were selected for the geochronology study. The $^{206}Pb/^{204}Pb$ ratios range from 18.5 to 65.2, $^{207}Pb/^{204}Pb$ from 15.72 to 18.56, and $^{208}Pb/^{204}Pb$ from 38.3 to 52.7 and yielded a Pb-Pb isochron age of 627 ± 32 Ma (95% confidence level), which is interpreted as the depositional age of these cap carbonates.

Snowball Earth, 2006

In the **Southern Paraguay Belt**, we have studied the fossil-bearing Tamengo Formation, upper Corumbá Group. Twelve ash beds intercalated with three levels of *Cloudina* were found within a 15-m thick limestone section of the lower part of the Tamengo Formation, at the Corcal quarry, east of Corumbá city. Two 10-cm thick ash beds were collected for geochronological analysis, one (CTUF-6) from about 30 cm below and the other (CTUF-9) from about 15 cm above the lowest occurrence of *Cloudina*. Standard separation procedures yielded a small amount of zircon crystals for each sample. The U-Pb analyses were carried out at the Beijing SHRIMP Laboratory, and both samples presented complex results (Boggiani et al., 2005). The data obtained on sample CTUF-9 do not permit a simple interpretation. Seven spot analyses from five grains yielded a weighted-mean $^{238}U/^{208}Pb$ age of 570 ± 11 Ma, which is difficult to interpret in view of the possibly younger age (545 ± 6 Ma) of the lower ash bed (CTUF-6). It is worth mentioning that a $^{238}U/^{206}Pb$ age of ca. 545 Ma was observed on two spots for which older ages (570 Ma) were also obtained. Three grains of sample CTUF-6 yielded Paleoproterozoic age (ca. 1.9Ga); other grains (14 spots) produced very discordant data. However, the least discordant data (6 spots in 3 grains) give a weighted-mean $^{238}U/^{206}Pb$ age of 545 ± 6 Ma, which could indicate the age of this volcanic tuff. Nevertheless, the complexity of the results prevents any conclusive interpretation, and more data is necessary to define the age of these rocks (Boggiani et al., 2005).

Three glacial intervals have been recently proposed for the Neoproterozoic: Sturtian, Marinoan and Gaskiers (Halverson et al., 2005). The age of the older one, the Sturtian glacials, is controversial. Ages in the wide range of 750 to 680 Ma were attributed to purported Sturtian glacial rocks or the associated carbonates. This distribution could indicate diachronous glacial deposition at the beginning of the Neoproterozoic. Our age obtained on cap carbonates from the Sete Lagoas Formation fits to the older 'Sturtian' ages obtained in Namibia (741± 6 Ma in Pinah Volcanics; Frimmel et al., 1996), Zambia (735 ± 5 Ma in Grand Conglomerat; Key et al., 2001) and Oman (723 +16/-10 Ma in Ghubrah Formation; Brasier et al., 2000). The Marinoan successions yield coincident ages at ca. 635 Ma for Namibia and China (Hoffmann et al., 2004; Condon et al. 2005). The age obtained for the base of the Araras Group fits well these ages suggesting that Marinoan Glaciation represents a global and synchronous event. Finally, the ages obtained on ash beds in the Southern Paraguay belt, although promising, show a very complex behavior and are difficult to interpret. If the ca. 545 Ma age holds true, the Marinoan Araras Group and the upper part (Tamengo Fm.) of the Corumbá Group (north and south Paraguay belt, respectively) can not be correlated.