THE CAP CARBONATE OF THE PUGA HILL (CENTRAL SOUTH AMERICA) IN THE CONTEXT OF THE POST-VARANGER GLACIATION

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INTRODUCTION

The cap carbonates are thin, laterally persistent carbonate layers that usually cover the Neoproterozoic glacial deposits, without significant hiatus. These deposits typically have $\delta^{13}C_{PDB}$ values in the range of 0 to –5‰, and exhibits anomalous sedimentary structures (Kaufman et al., 1993, 1997; Kennedy et al., 2001; Hoffman & Schrag, 2002). These ubiquitous negative anomalies in C isotopes together with the low-latitude of glacial deposits derived from paleomagnetic data, and the anomalous occurrence of banded iron formations (BIFs) associated with these rocks are the main evidence in support to the Snowball Earth hypothesis put forward by Kirschvink (1992) and Hoffman et al. (1998).

If the Neoproterozoic glaciations have attained tropical latitudes over millions of years, as suggested by the paleomagnetic results from Elatina Formation in Australia (Sohl et al., 1999), then the global oceanic circulation would be inhibited resulting in a stratified ocean. The build up of atmospheric CO_2 along this time span would trigger a strong greenhouse event, rapidly melting the ice cover. Recovering of the oceanic global circulation would promote the deposition of iron in BIFs; the increase in ocean alkalinity associated to the strong weathering of the Earth surface would promote the precipitation of mostly inorganic, and thus ^{12}C depleted, cap carbonates.

In central South America, all these key features (glacial deposits, BIFs and cap carbonates) are present within the Neoproterozoic-Cambrian Corumbá basin context. Here we present preliminary results of an isotope, paleomagnetic and sedimentological study on the Puga Hill region, where Vendian glacial deposits of the Puga Formation are covered by carbonate rocks of the Corumbá Group (Boggiani, 1998; Gaucher et al., 2003). Also discussed are the implications of these results to the Snowball Earth debate.

STRATIGRAPHY

The Corumbá Basin (500-km-long and NNW oriented) was developed along the eastern border of the Rio Apa Block (Amazonian Craton). It comprises Varanger glaciomarine sediments of the Puga Formation (Alvarenga & Trompette, 1992), and the terrigenous and carbonate sediments of the Corumbá Group (Almeida, 1965). The lower units of the Corumbá Group (Cadiueus and Cerradinho Formations) were deposited in a fault-limited, confined basin. The shallow-water dolomitic and phosphatic rocks of the overlying unit (Bocaina Formation) have spread along a larger area, covering the other units and also the granitic-gneissic basement. Subsequent regression eroded part of these sediments and re-deposited them as slope breccia. Carbonaceous limestones and shales of the Tamengo formation, with *Cloudina* and *Corumbella*, cover these deposits (Fairchild & Zaine, 1987). They have positive $\delta^{13}C_{PDB}$ of +5‰. These limestones are covered by shales of Guaicurus Formation, under unconfined oceanic conditions. In this context, the Corumbá Basin is interpreted as associated to the contemporaneous Iapetus opening (Cawood et al., 2001). It has closed/inverted as a result of the Brasiliano collision.

THE PUGA HILL CAP CARBONATE

The carbonates of the Puga Hill are located at the right margin of Paraguay River (19°37'20''S, 57°31'40''W), where the underlying glacial deposits of the Puga Formation were first described by Maciel (1959). These diamictites contain abundant carbonate clasts and the presence of these could be a cause of a high matrix carbonate content, considering the relative softness of carbonate minerals.

The studied section is a ca. 12 m thick section located in the northen sector of the Puga Hill (Fig. 1). It consists of alternating pinkish and grey, laminated limestone (rhythmite), alternating peloidal and microcrystaline carbonate.

Since, the Puga Hill is isolated from other carbonate occurrences, its stratigraphic position within the Bocaina Formation (Corumbá Group) is a matter of discussion. The Bocaina Formation (Almeida, 1965; Boggiani 1998) is a 30 to 80 m thick dolomitic carbonate unit, at the base of the carbonate succession of the Corumbá Group. These sediments were deposited shallow-water, under warm-water conditions. They comprise stromatolitic path reef, shoal and lagoonal ooides, and phosphorite rocks formed by the arrival of upwelling fluxes (Boggiani et al., 1993). In contrast, the Puga Hill carbonates were probably deposited at deep-water conditions. They have distinct isotopic signature; the cap carbonates of the Puga Hill showing homogeneous values of $\delta^{13}C_{PDB}$ near -5‰, while the dolomites of the Bocaina formation exhibit values near zero ($\delta^{13}C$ between -1.0 and +0.6‰).

RESULTS AND DISCUSSION

We collected a 12-m thick series of samples from the entire rhythmite unit, with sampling spacing of 1 to 2 m (Fig. 2). Distribution of $\delta^{13}C_{PDB}$ values in the section is homogeneous and close to -5‰ (Fig. 2). Paleomagnetic samples were collected at only two layers. Negative inclinations between 10° and 25° obtained for one of these sites suggest low paleolatitudes for deposition of these sequences.

These results are in agreement with those obtained for the Mirassol d'Oeste quarry, located 600 km northwards along the margin of the Amazonian Craton. In the Mirassol d'Oeste region, cap carbonates of the Araras Group cover diamictites of the Puga Formation (Nogueira et al., 2003). The contact between the diamictite and the carbonate was plastically deformed, implying a short time between the end of glaciation and the deposition of platform carbonates. Previous work by Boggiani et al. (1997) has interpreted the Araras carbonate facies as related to a sedimentation in a restricted sea, without communication with neoproterozoic global ocean according to their C and O isotope signature. The Araras and Corumbá succession have contrasting lithological palaeontological record; the metazoan fossils being exclusively found in the Corumbá Group.

The negative values of $\delta^{13}C_{PDB}$ observed on the Puga Hill cap carbonate and on several other Varanger-type cap-carbonates are similar to the isotopic composition of the mantle-derived carbon ($\delta^{13}C_{PDB}$ = -6 ±1‰). Strongly negative $\delta^{13}C_{PDB}$ values would be generated by the following processes (or more probably the combination of them): (a) millions of years of low organic productivity during snowball events; (b) high rates of carbonate sedimentation due to the intensive silicate weathering in the ultra-greenhouse aftermath; (c) Rayleigh distillation of atmospheric carbon source as the large CO_2 reservoir is transferred rapidly to the ocean; (d) ocean overturn,; (e) enhanced organic weathering, and (e) massive methane burst (Hoffman et. al.1998; Kennedy et al. 2001; Higgins & Schrag, 2003).

Prave et al. (2001) have examined in detail the Varanger and Sturtian cap carbonates on three cratons (southeastern Congo, northwestern Kalahari and southwestern Laurentia) in terms of their isotopic record. They have found a great variability in $\delta^{13}C_{PDB}$ trends of as much as ±10‰); the isotopic signatures showing strong differences for different sedimentary succession and palaeogeographic settings (shelf, slope, basinal). If cap carbonate deposition was synchronous worldwide then wide variability in $\delta^{13}C$ trends indicates that Earth's oceans in the immediate aftermath of Neoproterozoic glaciations were not sterile, -5‰ realms, but rather a richly isotopically varied world whose local diversity was captured in the rapidly precipitating cap carbonates. In contrast to Prave's findings, the isotopic record derived from different facies of the Puga Hill and the correlative Mirassol d'Oeste indicate that the isotopic composition of the ocean's water was rather constant and similar to the -5‰ mantle-carbon values. These results are consistent with a 3-box model recently run by Higgins and Schrag (2003). Increased alkalinity was derived from the extreme surface water, but also by oceanic overturn. In the Puga Hill, the association of glacial sediments with BIF's of Jacadigo Group (Urucum Massif), and the occurrence of phosphatic rocks in the top of the Bocaina Formation suggest the influence of oceanic overturn in increasing alkalinity. In this scenario, the ocean re-oxygenate and dissolved Fe oxidizes to form iron formation.

The inconsistencies in the isotopic record found by Prave and co-authors may lay in the lack of a complete sedimentological and stratigraphic characterization of carbonates topping glacials around the world. Different isotopic values may arise if not true cap carbonates are compared to true ones, as occurs on most of the Bocaina Formation outcrops, where upper carbonates overlie diamictites; only the Puga Hill occurrence, described consists of a true post-glacial cap carbonate.

CONCLUSION

The values of $\delta^{13}C$ observed in the Puga Hills, close to -5‰, are against the Prave et al. (2001) conclusion, that find a strong variability in $\delta^{13}C_{PDB}$ trends in different caps carbonates, and favor a global-scale homogeneity of the C isotopes in these carbonates.

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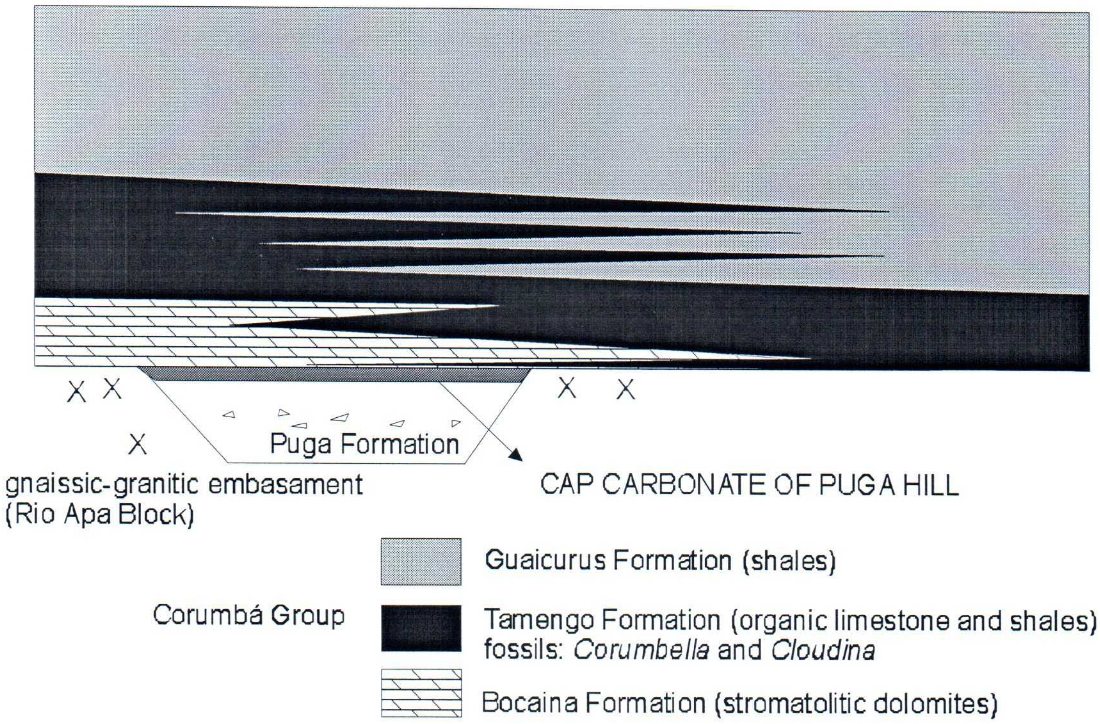

Figure 1. Geological sketch of the Puga Hill cap carbonate occurrence.

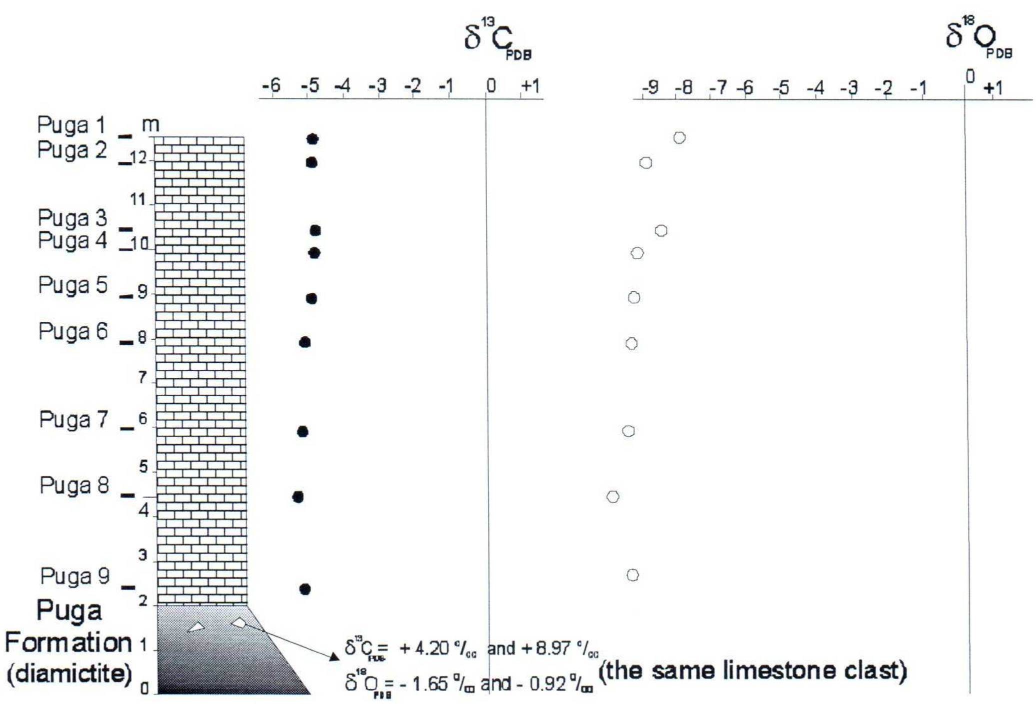

Figure 2. Isotopic record of Puga Hill Cap Carbonate.

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