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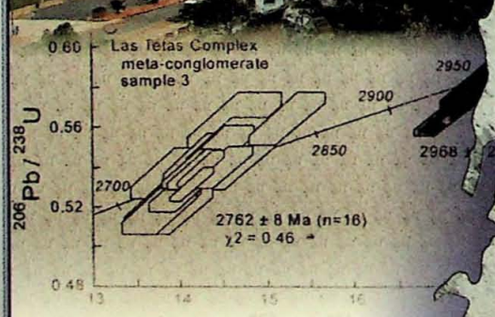
Punta del Est[illegible] - Uruguay. 2[illegible] 27th April, 2006



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THE CARBON AND OXYGEN ISOTOPES OF POST-MARINOAN OUTER PLATFORM CARBONATES, PARAGUAY BELT, CENTRAL BRAZIL

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Keywords: Carbon and Oxygen isotopes, Neoproterozoic, Araras Group, Amazon craton, glaciation

INTRODUCTION

After the severe glaciation that finished at about 630 million years ago, during the late Neoproterozoic, the central region of Brazil was the site of extensive deposition of platformal carbonates of Araras Group, exposed along the southern border of the Amazon craton and at the northern Paraguay belt (Fig. 1). These over 600 m thick carbonate succession overlies Marinoan glaciogenic diamictites and includes the first well-documented cap carbonate sequence in South America (Nogueira et al. 2003). The post-glacial cap carbonate was succeeded by an impressive transgression recorded by a thick accumulation of bituminous lime mudstone and shale, discontinuously distributed for more than 400 km in the region, and considered as deep platform deposits (Nogueira et al. 2003). The most complete section of these deposits occurs in the Nossa Senhora da Guia mine, preserved in an asymmetric syncline with NE-SW-oriented axis, located 30 km northwest of Cuiabá (Fig. 1). Facies and stratigraphic data combined with carbon and oxygen analysis were used to evaluate the depositional paleoenvironment and to test the correlation of these deposits along the belt and with other units worldwide.

CHEMOSTRATIGRAPHY OF ARARAS GROUP

The $\delta^{13}C_{PDB}$ values for Araras carbonate rocks, interpreted as representative of the original seawater ($\delta^{18}O_{PDB}$ >-10‰, Jacobsen and Kaufman, 1999), exhibit a trend from strongly negative values around -9‰ at the base to enriched compositions towards the top of the succession, reaching values above 0‰ (Fig. 2). The cap carbonate succession is composed of moderately deep platform deposits of dolomite (Mirassol d'Oeste Formation) covered by limestone rich in crusts and cements with $\delta^{13}C_{PDB}$ values around -5 to -4‰ (Lower Guia Formation). The anoxic deep-platform limestone succession (Upper Guia Formation) overlying the cap succession presents a homogeneous isotope curve, with $\delta^{13}C_{PDB}$ values around -2.5 to -1‰ (Fig. 2). Upsection, values switch to positive (+0.1 to +0.3‰) in dolomites of shallow-platform and peritidal deposits (Serra do Quilombo and Nobres formations).

SAMPLING AND ANALYTICAL METHODS

Sampling for C- and O-isotope analyses were performed on 38 fine-grained limestone samples, collected from a 150 m of two stratigraphic sections of Guia formation, organized in a composite stratigraphic profile representative of the proposed stacking for the Araras Group. As the carbonate succession of this area was affected by low-grade metamorphism, homogeneous samples with little diagenetic or metamorphic alteration were selected although some dolomitized samples were also analyzed. Fractured, mineral-filled and weathered zones were avoided. Samples were microdrilled with a 1 mm drill. Carbon-isotope analyses were performed at the Stable Isotope Laboratory (LABISE) of the Department of Geology, Federal University of Pernambuco, Brazil.

THE OUTER PLATFORM DEPOSITS IN THE GUIA SYNCLINE

The succession consists of 150 m thick of tabular beds of black to grey lime mudstone and shale (Fig. 2). Silt and fine sand are disseminated in the limestones and pyrite crystals are found locally. These rocks are disposed in compositionaly uniform and laterally extensive beds for dozens of meters in the Nossa Senhora da Guia mine, but certainly extends for more than 200 km to the southwest, reaching the region of Cáceres (Figs. 1, 2). This succession overlies diamictite with abundant siltic matrix or graded pebbly siltstone. The first meters of limestone above the diamictite are dolomitized and exhibit a pinkish color. The main structure in these rocks is the even parallel lamination but cross-lamination occurs locally associated with the thin beds of intraclastic packstone. A level of intensely dolomitized breccia with clasts of fine limestone occurs at the top of section 1 (Fig. 2).

The deep water setting is indicated by the predominance of low energy carbonate facies (laminated lime mudstone) and suspension deposits (shale). Their

distribution in monotonous, laterally extensive beds for more than 200 km, suggest deposition into an ample deep platform (Pfeil and Read, 1980; Coniglio and James, 1990). The dark color of lime mudstone associated with bituminous and pyritous shale indicate anoxic conditions responsible for the accumulation and preservation of organic matter. Weak to moderate currents caused ripple migration. Locally brecciated limestone beds were accumulated within the slope setting (Coniglio and Dix, 1992).

The position of the Guia syncline, more than 200 km far from the craton, suggests that the studied succession represents the most distal part of Araras carbonate platform.

The $\delta^{13}C_{PDB}$ values for the carbonate succession of the Guia syncline are interpreted as representative of the original seawater ($\delta^{18}O$ >-10‰). The predominantly negative $\delta^{13}C$ values around -2.5 to -1‰, as well documented in section 2, indicate that the low

syncline is related to relief evolution forming an isolated testimony.

Another important observation concerns the relationship between pink dolostone and diamictite observed in the Guia syncline. This relationship, although very similar to that observed in cap dolomites, certainly may cause misinterpretations because the dolomite is secondary and the anomalous structures commonly found in cap dolomites are absent. Therefore, these evidences lead us to discard the interpretation as a cap carbonate.

It is difficult to estimate the elapsed time of erosion that represent the transgressive boundary between pebbly siltstone and the limestone, but it is possible to considerer that the Guia Formation represents a long-term transgression deposit, not influenced by Marinoan glaciation.

REGIONAL AND GLOBAL CORRELATIONS

The $\delta^{13}C_{PDB}$ profile, with negative values around 0‰, for more than 600 m of Araras Group, is comparable with $\delta^{13}C_{PDB}$ profiles of post-Marinoan units of the Kalahari and Congo cratons, western Canada and southern Paraguay Belt (Nogueira et al. 2006). It is worth mentioning the perfect match between the stratigraphy and the carbon isotopic profile of the Araras Group in Amazonia and the middle Tsumeb Subgroup in northern Namibia (Halverson et al. 2005). The similarity of facies associations with this Namibian succession is the base for assigning the Araras Group carbonate rocks to the post-Marinoan time-interval.

CONCLUSIONS

1. The carbonate succession in the Guia syncline is represented by limestone and shales deposited in an outer platform;

2. the clear comparison of facies, paleoenvironment and carbon isotopes with the Guia Formation of Araras Group in Cáceres region is incontestable and indicate that the studied section in the Guia syncline belongs to the upper part of Guia Formation;

3. pinkish dolomitized beds overlying glaciogenic metamorphism do not affected the original $\delta^{13}C$ values (Fig. 2). Contrarily, in section 1 (Fig. 2) dolomitization may have modified slightly the $\delta^{13}C$ values that reach 4‰, as indicated by $\delta^{18}O$ values lower than -10‰.

DISCUSSION

STRATIGRAPHIC IMPLICATIONS

The isolated occurrence of bituminous limestone and shales in Guia syncline has been previously positioned as a unit of the Cuiabá Group (Alvarenga et al. 2004), but our data demonstrates a clear comparison of facies, paleoenvironmental significance and C and O isotopic values between the Cáceres and Guia regions (Fig. 2). The $\delta^{13}C_{PDB}$ profile of Guia syncline shows a remarkable correlation with the upper portion of Guia Formation of Cáceres region, indicating that the succession in the Guia syncline belongs to the Araras Group (Fig. 2). The present-day distribution of this limestone within a

pebbly siltstone in the Guia syncline are not considered as a cap carbonate;

4. the Guia Formation represents a long-term transgression deposit not influenced by the Marinoan glaciation;

5. the composite $\delta^{13}C_{PDB}$ profile of Araras Group shows the same pattern of other post-Marinoan units worldwide; the similarity of facies associations with the Namíbia succession lead us to assign the Araras Group carbonate rocks to the post-Marinoan time-interval.

ACKNOWLEDGEMENTS

This research was developed with financial support of the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, grant 00/02903-8). Thanks are due to P.F. Hoffman, T.R. Fairchild, R.I.F. Trindade and E. Font for discussions.

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RESUMO

Após a glaciação Marinoana, a região central do Brasil foi palco de importante deposição de carbonatos plataformais do Grupo Araras, expostos ao longo da borda sul do Cráton Amazônico e porção norte da Faixa Paraguai. Este grupo inclui na sua base a primeira capa carbonática bem documentada na América do Sul e é sucedido por expressiva transgressão registrada por espessa acumulação de calcilutitos betuminosos e folhelhos, distribuídos descontinuamente por mais de 400 km de extensão, e considerados depósitos plataformais profundos. A seção mais completa desses depósitos está exposta no sinclinal da Guia, onde dados de fácies e estratigráficos, combinados com análises isotópicas de C e O, foram empregados para avaliar o paleoambiente deposicional e testar a correlação regional e global destes depósitos. A sucessão analisada possui 150 m de espessura de camadas tabulares de calcilutitos e folhelhos cinza a pretos com valores de $\delta^{13}C$ negativos, entre -2.5 e -1‰. O perfil de $\delta^{13}C$ do sinclinal da Guia apresenta notável correlação com a porção superior da Formação Guia da região de Cáceres, 200 km a sudoeste, indicando que a seção estudada pertence ao Grupo Araras. O perfil de $\delta^{13}C$ do Grupo Araras é comparável aos perfis de unidades pós-Marinoanas da porção sul da Faixa Paraguai, oeste do Canadá, e crátons do Congo e do Kalahari. A distribuição de fácies, estratigrafia e o perfil de $\delta^{13}C$ do Grupo Araras são coincidentes com a porção média do Subgrupo Tsumeb na Namíbia, o que reforça a atribuição de idade pós-Marinoana para o Grupo Araras.

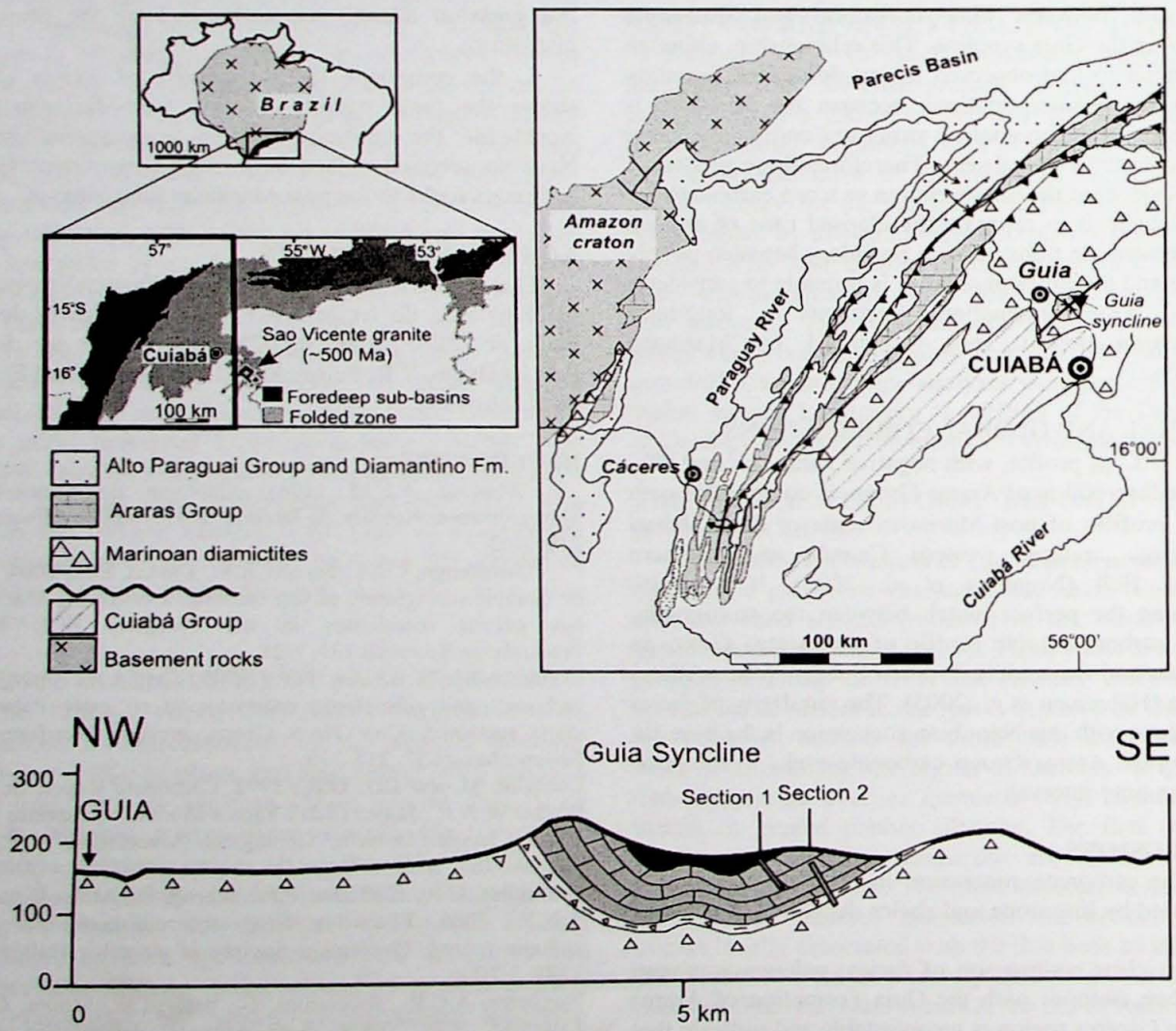

Figure 1. Geologic map of Paraguay belt with location of the Guia region (encircled area) and detailed geologic section of Guia syncline with location of studied profiles (after Almeida 1964, modified).

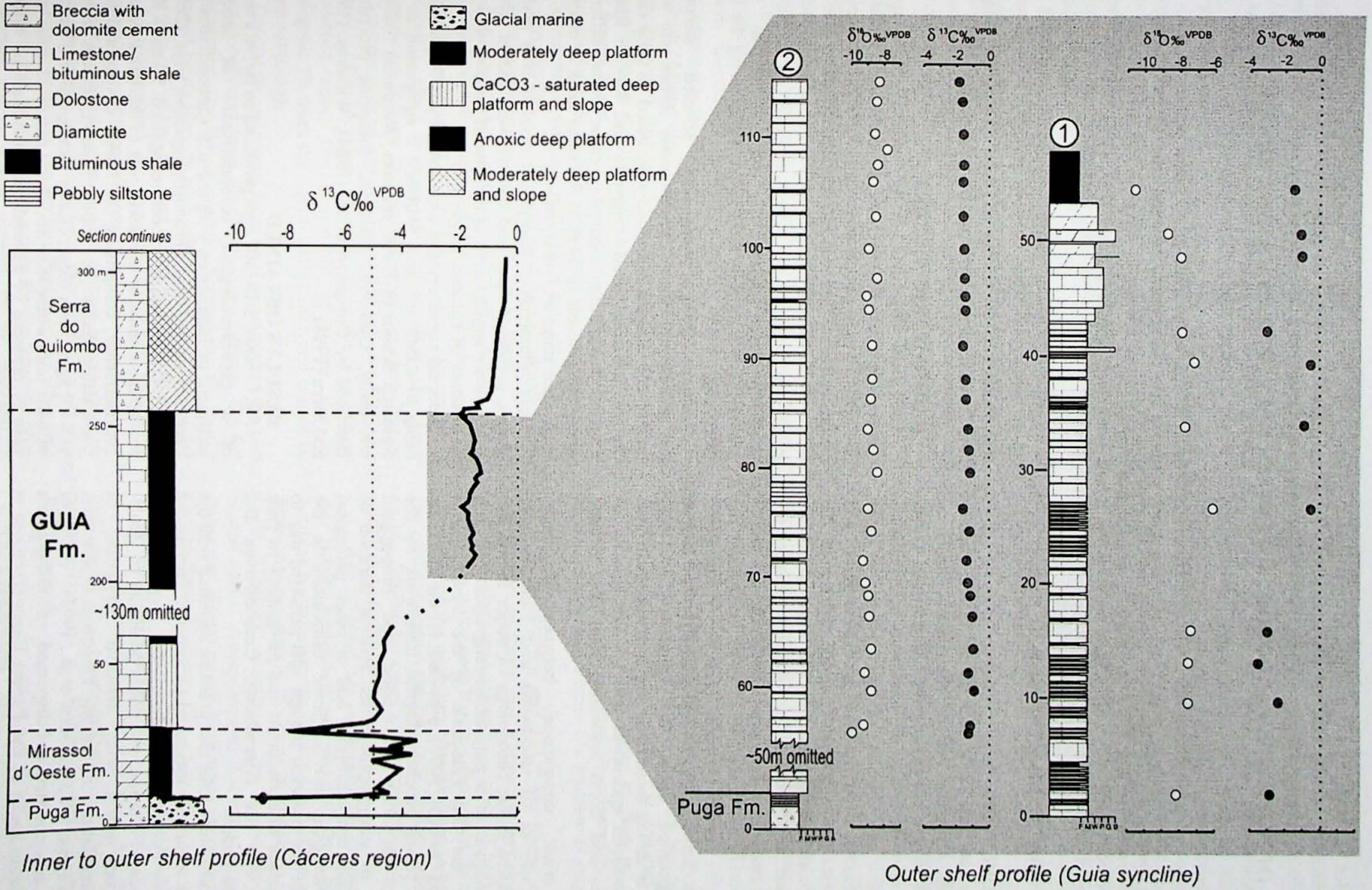

Figure 2. Isotopic correlation of outer shelf deposits of Cáceres and Guia regions. The d13C profiles of both regions are perfectly comparable and the measured sections can be correlated to the top of Guia Formation.