

## LOMAGUNDI CARBON ISOTOPE ANOMALY IN PALEOPROTEROZOIC CARBONATES OF BRAZIL AND URUGUAY

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**Keywords:** Paleoproterozoic, Lomagundi, C isotopes, Brazil, Uruguay

### INTRODUCTION

A systematic investigation of the Lomagundi Dolomite Belt in Zimbabwe, southern Africa, was started by Schidlowski et al. (1975) after the observation of  $^{13}\text{C}$ -enriched ( $\delta^{13}\text{C} \sim +5$  to  $+14$  ‰<sub>PDB</sub>) sedimentary carbonates from several Paleoproterozoic sequences (Galimov et al., 1975). The persistence of high  $\delta^{13}\text{C}$  values along the 300 km of this belt made clear that this was a regional phenomenon. A Paleoproterozoic age of  $2.15 \pm 0.050$  Ga for the Lomagundi Province carbonates, based on lead isotope ratios in carbonates of the Sinoia Caves, was reported by Schidlowski and Todt (1998).

A comprehensive isotopic survey in different parts of the world demonstrated that the “Lomagundi phenomenon” (Lomagundi-Jatuli isotope excursion) is a global event and seems to have happened between 2.33 and 2.06 Ga interval (Schidlowski et al., 1976; Baker and Fallick, 1989<sub>a,b</sub>; Melezhik and Fallick, 1996; Karhu and Holland, 1996; Buick et al., 1998; Melezhik et al., 1999; Maheshwari et al., 1999; Sreenivas et al., 2001; Lindsay and Brasier, 2002; among others). One possible interpretation for this positive  $\delta^{13}\text{C}$  anomaly is that it is a consequence of a large-scale sequestration and/or burial of organic  $^{12}\text{C}$  in the lower compartment of a stratified ocean that progressively increased the heavy complement in the surface waters (Schidlowski and Todt, 1998).

Melezhik et al. (1999) presented a detailed overview on the record and characteristics of the Lomagundi phenomenon and pointed that there is a close association of  $^{13}\text{C}$ -rich carbonates with abundant stromatolites, and that it corresponds with substantial increase in the level of atmospheric  $\text{O}_2$ . They proposed that the extreme

enrichment in  $^{13}\text{C}$  (above 5 ‰<sub>PDB</sub>) might well have been caused by local factors such as an intense development of cyanobacteria, coupled with evaporation in restricted basins which were apparently not in full equilibrium with atmospheric  $\text{CO}_2$ .

Melezhik et al. (1999) claimed a global character for the Lomagundi phenomenon, but up to now, this isotope anomaly in South America was recognized only in carbonates of the Fecho do Funil and Cercadinho Formations in the Iron Quadrangle, Minas Gerais in Brazil (Sial et al., 2000; Bekker et al., 2003). In the present study, we report new C and O isotope data for carbonates of the Fecho do Funil Formation, and examine Paleoproterozoic carbonates of the Rio Grande do Sul shield, in Brazil, as well as from the Paso Severino Formation, Piedra Alta terrane, Uruguay.

### GEOLOGICAL SETTING

#### BRAZIL

The Fecho do Funil Formation has a Pb-Pb metamorphic/deformation age of  $2.11 \pm 0.110$  Ga (Babinski et al., 1995), similar to that of the carbonates of the Lomagundi Province. For this reason, it has been selected as a likely proxy for the Lomagundi phenomenon in South America by Sial et al. (2002) and Bekker et al. (2003). These authors have studied dolostones of the Fecho do Funil Formation (Cumbi quarry) and of the Cercadinho Formation at Sabará town.

The little investigated marbles of the Rio Grande do Sul shield are distributed in all major Precambrian belts there.

The region displays a complex tectono-metamorphic evolution since the Archean. Major crustal accretion occurred during the 2.2–2.0 Ga Trans-Amazonian orogeny which represents the most important orogenic event in southern Brazil, but juvenile Neoproterozoic igneous rocks (ca. 750–700 Ma) have been identified and dated in the western portion (reviews in Hartmann et al., 2000a; Chemale, 2000; Gastal et al., 2005; Saalman et al., 2005).

In the present study, dolostones of the Fecho do Funil Formation in contact with silvery phyllites from the Ribeirão do Eixo quarry (near the BR-040 highway), from a quarry in the Marinho da Serra map sheet and from the Serra da Moeda (Moeda plateau), have been studied. Paleoproterozoic sedimentary carbonates from the Rio Grande do Sul shield (southernmost Brazil) have been also examined at the following localities: (a) Rigoletto quarry about 40 km from Cachoeira do Sul, (b) Elias Zeca quarry (Palma Group) between São Miguel and Bagé, (c) Dagoberto Barcellos mine near Caçapava do Sul. At Rigoletto, carbonates are represented by finely laminated dolostones which become slightly Fe-enriched towards the top of the sequence. A quartzite which covers this carbonate sequence has a maximum U-Pb age of 2.02 Ga (detrital zircon). At the Elias Zeca quarry, one has a basaltic plateau intruded by lamprophyric dikes. Most carbonates are represented by saccharoidal, calcitic, laminated marble, locally sulphide and graphite-bearing. At the Dagoberto Barcellos Mine, basal limestones are covered by marls. Up section, dolostones and stratified, sulphide-bearing, gray to white limestone occur. This carbonate package has been intruded by dark granitic dikes and sills.

## URUGUAY

In the Piedra Alta tectonostratigraphic terrane, Uruguay, the Paso Severino Formation represents a volcano-sedimentary sequence integrated by black pelites, sericitic phyllites, meta-conglomerates, meta-basalts and meta-keratophyres (Bossi et al., 1998). The depositional age of this Formation was obtained from meta-rhyolites at the top of this unit ( $2.145 \pm 21$  Ma, U-Pb SHRIMP). On the other hand, minimum age have been obtained from the Isla Mala granodiorite ( $2.074 \pm 6$  Ma, U-Pb SHRIMP age: Hartmann et al., 2000b). Therefore, an age around 2.150 Ma is well established for the studied succession. Carbonates are a rare component in this sequence but can be sampled from the abandoned Assandri quarry, where dark, fine-grained limestones and carbonate breccias are exposed almost free of recrystallization. Some acidic tuffs underly these carbonate rocks.

## CARBON AND OXYGEN ISOTOPES

### FECHO DO FUNIL FORMATION

In the Iron quadrangle, Minas Gerais, Fecho do Funil

Formation dolostones at the Ribeirão do Eixo quarry (10 samples) show a very narrow variation of  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  (respectively from +6.0 to 6.5‰ and from -10 to -10.3‰<sub>V-PDB</sub>) in a similar behavior to what has been observed in carbonates at the Cumbi quarry by Sial et al (2002) and Bekker et al. (2003). However, dolostone samples (11) from a quarry in the Marinho da Serra map sheet showed more widespread  $\delta^{13}\text{C}$  values (+3.8 to +6.0‰) and relatively narrow variation for  $\delta^{18}\text{O}$  (-11.8 to -13.9‰<sub>V-PDB</sub>). Five samples from the Serra da Moeda (Moeda plateau) exhibited  $\delta^{13}\text{C}$  values from +1.6 to +5.0‰ but also narrow variation for  $\delta^{18}\text{O}$  (-12.4 to -12.1‰<sub>V-PDB</sub>). Carbon isotope behavior in carbonates of these two quarries are in consonance with the range observed for the Cercadinho Formation carbonates (Sial et al. 2002 and Bekker et al., 2003).

### RIO GRANDE DO SUL SHIELD

In the Rio Grande do Sul Shield, the examined carbonates exhibit  $\delta^{13}\text{C}$  values lower (< 2.5‰) than the Fecho do Funil Formation. Dolostones from the Rigoletto quarry (21 samples) yielded  $\delta^{13}\text{C}$  from +0.2 to +2.4‰ and  $\delta^{18}\text{O}$  from -16.0 to -7.0‰<sub>V-PDB</sub>, while carbonates from the Dagoberto Barcellos quarry (9 samples) yielded  $\delta^{13}\text{C}$  values in the -0.9 to +2.1‰ and  $\delta^{18}\text{O}$  from -13.9 to -11.8‰<sub>V-PDB</sub> range.

### PIEDRA ALTA TERRANE (URUGUAY)

Carbonates from the Assandri quarry (15 samples) in Uruguay show enormous fractionation with  $\delta^{13}\text{C}$  values from -5.6 to +7.6‰ and  $\delta^{18}\text{O}$  from -12.2 to -5.1‰<sub>V-PDB</sub>. The lowest  $\delta^{13}\text{C}$  value was observed in a gray massive limestone while the highest one corresponds to a carbonate breccia with clasts of very fine-grained carbonates. Our data suggest a relatively rapid succession of short-lived, high amplitude C-isotope excursions.

## CONCLUSIONS

The new C-isotope data for carbonates from the Iron Quadrangle confirm that carbonates of the Fecho do Funil and Cercadinho Formations have recorded the Lomagundi isotopic anomaly. Carbonates from the Paso Severino Formation in Uruguay seem also to have recorded this anomaly with positive values around +8‰ but with an enormous C isotope fractionation (from -5.0 to +8.0‰) which is absent in carbonates of the Fecho do Funil Formation. This type of fractionation is expected in carbonates from this age (regarding the U-Pb SHRIMP age of the rhyolites at the top of this unit) if one takes into account Lindsay and Brasier (2002) composite secular carbon isotope curve.

Carbonates from the Rio Grande do Sul shield whose ages are less constrained, have been probably deposited

around 2.0Ga if C isotope data presented here are compared to Lindsay and Brasier's curve, therefore outside the range of the Lomagundi ano-maly.

#### ACKNOWLEDGEMENTS.

Field work was partially financed by the CNPq/PROSUL project n. 490349 /2004-8 and by the CNPq project n. 472506/2003-0 granted to A.N. Sial. We want to thank Gilsa M. Santana and Vilma S. Bezerra for assistance with the isotope analyses at the LABISE, in Recife, Brazil.

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## RESUMO

O “fenômeno Lomagundi” caracterizado por uma anomalia positiva  $\delta^{13}\text{C}$  ( $\sim +5$  to  $+14\%$ <sub>PDB</sub>) observado no Cinturão Dolomítico Lomagundi de Zimbabwe, sul da África, é um evento global, ocorrido no intervalo entre 2.33 e 2.06 Ga. Diversas interpretações para esta anomalia isotópica positiva incluem: a) seqüestro em grande escala de/ou soterramento de  $^{12}\text{C}$  orgânico no compartimento inferior de um oceano estratificado que gradualmente elevou seu complemento pesado em suas águas superficiais; b) íntima associação de carbonatos ricos em  $^{13}\text{C}$  com abundantes estromatólitos, o que corresponde a uma substancial elevação do nível de oxigênio atmosférico.

Novos dados de isótopos de C em carbonatos do Quadrilátero Ferrífero, Minas Gerais, confirmam que as Formações Fecho do Funil e Cercadinho registraram a anomalia isotópica Lomagundi ( $\delta^{13}\text{C}$  de até  $+7\%$ ). Carbonatos da Formação Paso Severino, Uruguai, parecem ter também registrado esta anomalia com valores de  $\sim +8\%$  mas com um enorme fracionamento isotópico de C ( $-5.0$  a  $+8.0\%$ ), ausente em carbonatos das Formações Fecho do Funil e Cercadinho. Este fracionamento é esperado em carbonatos desta idade (2,150 Ma, U-Pb SHRIMP em riolito, ao topo desta unidade) como deduzido da curva de variação isotópica secular de Lindsay and Brasier (2002).

Carbonatos Paleoproterozoicos do escudo do Rio Grande do Sul, Brasil foram provavelmente depositados em torno de 2.0Ga (se os dados de isótopos de C são levados em consideração) fora do intervalo de idade para a anomalia Lomagundi.