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PROGRAMA DE PÓS-GRADUAÇÃO EM GEOCIÊNCIAS E MEIO AMBIENTE

CICLICIDADE DE ALTA FREQUÊNCIA E QUIMIOESTRATIGRAFIA DA FORMAÇÃO TAGATIYA GUAZU, GRUPO ITAPUCUMI, PARAGUAI: EVIDÊNCIAS DA PASSAGEM EDIACARANO-CAMBRIANO

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Orientador: Prof. Dr. Lucas Veríssimo Warren

Coorientadora: Dra. Juliana Okubo

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RESUMO

O intervalo final do Período Ediacarano e sua transição para o Cambriano reúnem algumas das maiores mudanças já ocorridas na história da Terra, como a formação do supercontinente Gondwana, distintos padrões e anomalias geoquímicas, bem como sua relação com o surgimento dos animais e a "Explosão Cambriana". Com o objetivo de compreender tais fenômenos, diversas sucessões ao redor do mundo vêm sendo intensamente estudadas. Nesse contexto se insere a Formação Tagatiya Guazu (Grupo Itapucumi, Paraguai). No entanto, ao contrário de sucessões muito bem estudadas na China, Namíbia e Rússia, a sucessão superior da Formação Tagatiya Guazu ainda carece de estudos de detalhe quanto seus aspectos estratigráficos e geoquímicos. Frente a esta perspectiva, duas seções colunares de detalhe foram estudadas. As fácies sedimentares descritas constituem típica associação de rochas carbonáticas de perimaré depositadas em ambiente lagunar, organizadas em ciclos de raseamento ascendente, formados por *grainstones* em sua base, trombólitos, estromatólitos planares, margas e *mudstones* no topo, verticalmente configurando sucessões maiores de progradação e retrogradação. A presença de espécimes *in situ* de *Cloudina* sp. e *Corumbella* sp. bem preservados atestam a idade ediacarana terminal. Os valores entre +1 e +5 ‰ obtidos para $\delta^{13}C_{carb}$ se enquadram no platô positivo globalmente observado em sucessões contendo *Cloudina* (EPIP, *Late Ediacaran Positive Carbon Isotope Plateau*), reforçando a idade ediacarana terminal. Variações cíclicas de alta frequência nos valores de $\delta^{13}C_{carb}$ resultam de um gradiente isotópico gerado pela estratificação redox do corpo aquoso ou pela diminuição das taxas de produtividade juntamente à oxidação de matéria orgânica, mostrando forte relação com as fácies e batimetria. A presença de icnofósseis com hábitos complexos permite afirmar que a Fm. Tagatiya Guazu registra a passagem para o Cambriano e o Éon Fanerozoico, resultando em quatro hipóteses a serem testadas: (a) a anomalia isotópica negativa da base do Cambriano (BACE, *Basal Cambrian Negative Carbon Isotope Excursion*) não possui caráter global; (b) a anomalia BACE ocorre acima do limite E-C; (c) um aumento na restrição durante a deposição da porção de topo da unidade impediu o registro do sinal oceânico global, ou (d) processos orgânicos e/ou inorgânicos locais obliteraram o sinal global. De qualquer maneira, o incomum grau de preservação da assembleia fóssil presente e o detalhamento e originalidade do sinal isotópico preservado fazem com que a Fm. Tagatiya Guazu se configure como seção-chave para o entendimento do Ediacarano terminal na porção oeste de Gondwana.

Palavras-chave: Ediacarano terminal; geoquímica de rochas carbonáticas; isótopos de C e O; reconstrução paleoambiental; correlação quimioestratigráfica.

ABSTRACT

The final interval of the Ediacaran Period and its transition to the Cambrian bring together some of the biggest changes ever to take place in Earth's history, such as the formation of the supercontinent Gondwana, different geochemical patterns and anomalies, as well as their relationship with the emergence of animals and the so-called "Cambrian Explosion". In order to understand such phenomena, several successions around the world have been intensively studied. In this context, the upper portion of the Tagatiya Guazu Formation (Itapucumi Group, Paraguay), a unit deposited in the terminal Ediacaran, is inserted. However, unlike the very well-studied successions in China, Namibia and Russia, the upper succession of the Tagatiya Guazu Fm. still lacks detailed studies regarding its stratigraphic and geochemical aspects. With this perspective, two columnar sections were studied in detail. The described sedimentary facies constitute a typical association of peritidal carbonates deposited in a lagoonal environment. The studied successions are organized in shallowing-upward cycles, formed essentially by grainstone at the base, thrombolite, planar stromatolite, marl and mudstone at the top, vertically configuring larger successions of progradation and retrogradation. The presence of well preserved *in situ* specimens of *Cloudina* sp. and *Corumbella* sp. attests the terminal Ediacaran age. The obtained $\delta^{13}C_{carb}$ values varies between +1 and +5 ‰, matching the globally observed positive plateau in successions containing *Cloudina* (EPIP, Late Ediacaran Positive Isotope Plateau), reinforcing the terminal Ediacaran age. High-frequency cyclical variations in $\delta^{13}C_{carb}$ values result from an isotopic gradient generated by the redox stratification of the aqueous body or by decreasing primary productivity rates together with organic matter oxidation, showing a strong relationship with facies and bathymetry. The presence of trace fossils with complex habits allows us to affirm that the Tagatiya Guazu Fm. records the passage to the Cambrian and the Phanerozoic Eon, resulting in four hypotheses to be tested: (a) the basal Cambrian negative isotopic anomaly (BACE, Basal Cambrian Negative Isotope Excursion) does not have a global character; (b) the BACE anomaly occurs above the E-C limit; (c) an increase in restriction during deposition of the upper portion of the unit prevented the recording of the global oceanic signal, or (d) local organic and/or inorganic processes obliterated the global signal. Anyway, the unusual degree of preservation of the fossil assemblage and the detail and originality of the preserved isotopic signal makes the Tagatiya Guazu Fm. a key section for understanding the terminal Ediacaran in western Gondwana.

Keywords: Terminal Ediacaran; carbonate geochemistry; C and O isotopes; paleoenvironmental reconstruction; chemostratigraphic correlation.

SUMÁRIO

1 INTRODUÇÃO

O aparecimento dos primeiros macrofósseis ao final do Período Ediacarano figura como uma das principais inovações bioevolutivas ocorridas em toda a história geológica (NARBONNE, 1998). Durante a transição Ediacarano-Cambriano, dois grandes eventos biológicos - a extinção da biota ediacarana e a irradiação evolutiva denominada de Explosão Cambriana - ocorreram juntamente a importantes perturbações no ciclo global do carbono (CANFIELD; TESKE, 1996; DES MARAIS et al., 1992; KNOLL; CARROLL, 1999; NARBONNE et al., 2012; WOOD et al., 2019; XIAO et al., 2016; XIAO; NARBONNE, 2020).

Além do advento dos primeiros animais, o surgimento de organismos biocalcificadores (*Sinotubulites*, *Cloudina*, *Namacalathus*, entre outros) e a primeira ocorrência de traços complexos (*Treptichnus pedum*) também configuram grandes marcos bioevolutivos (BRENNAN; LOWENSTEIN; HORITA, 2004; GEYER; LANDING, 2017; GROTZINGER; WATTERS; KNOLL, 2000; LANDING, 1994; PENG; BABCOCK; COOPER, 2012; TARHAN et al., 2018). Em termos do registro quimioestratigráfico, tal limite é marcado pela transição de um platô persistentemente positivo de $\delta^{13}C_{carb}$ no Ediacarano terminal, denominado *Late Ediacaran Positive Carbon Isotope Plateau* (EPIP, ZHU et al., 2017), para uma excursão isotópica negativa de $\delta^{13}C_{carb}$, denominada *Basal Cambrian Carbon Isotope Excursion* (BACE), presente na base do Período Cambriano (ZHU; BABCOCK; PENG, 2006). Por possuírem caráter global e importante relação com o surgimento dos primeiros metazoários e organismos de hábitos complexos, o reconhecimento de tais padrões isotópicos no registro geológico é fundamental para o estabelecimento de correlações cronoestratigráficas de sucessões do Ediacarano terminal e da passagem Ediacarano-Cambriano ao redor do mundo.

Atualmente, a utilização de abordagens multi-indicadores, aplicando técnicas integradas de geoquímica, estratigrafia, geocronologia e paleontologia, tem se mostrado bastante adequada à obtenção de dados paleoambientais de unidades ediacaranas detentoras de fósseis (AMTHOR et al., 2003; CUI et al., 2016a, 2016b; FIKE et al., 2006; WOOD et al., 2015). Da mesma maneira, esta abordagem permite a contextualização e o posicionamento espaço-temporal destes dados, possibilitando aumentar a resolução bioestratigráfica e quimioestratigráfica do Neoproterozoico terminal e permitindo aferir se existe relação causal entre variações ambientais e eventos evolutivos importantes.

Com base na presença do platô positivo de $\delta^{13}C_{carb}$ e do fóssil-guia *Cloudina sp.*, os recentes trabalhos de Warren (2011) e Warren et al. (2011; 2012; 2013; 2017; 2019) inseriram a Formação Tagatiya Guazu (Grupo Itapucumi, Paraguai) em restrito grupo de sucessões no qual características sedimentológicas, paleontológicas e geoquímicas excepcionalmente semelhantes convergem para o entendimento deste intervalo chave na história evolutiva de nosso planeta. Ressalta-se, no entanto, que apesar da estratigrafia e paleontologia desta unidade ser relativamente bem conhecida, ainda inexistem trabalhos geoquímicos de detalhe que permitam detectar padrões e variações ambientais importantes de maior frequência.

Considerando esta problemática, o presente trabalho buscou auxiliar no entendimento paleoambiental da porção superior da Formação Tagatiya Guazu, enfocando na obtenção e interpretação de dados quimioestratigráficos de alta resolução, bem como na análise de isótopos de C ($\delta^{13}C_{carb}$) e O ($\delta^{18}O_{carb}$), elementos maiores e traços. Com este propósito, esta pesquisa se insere em uma linha de estudos globais que pretendem detalhar, à partir de distintos indicadores geoquímicos, a passagem Ediacarano-Cambriano em diferentes localidades ao redor do mundo (e.g., Namíbia, sul e norte da China, Sibéria; CUI et al., 2016a, 2016b, 2019; WOOD et al., 2015). Deste modo, pretendeu-se neste trabalho também contribuir para a identificação de padrões nas curvas de variação de razões isotópicas e análise de seu significado paleoambiental, auxiliando na compreensão das causas e efeitos das variações geoquímicas dos oceanos e sua relação com a transição/sucessão entre as faunas ediacarana e cambriana.

8 CONCLUSÕES

A busca pelo entendimento das condições paleoambientais atuantes durante uma das transições mais importantes da história de nosso planeta vem atraindo atenção para diversas sucessões do Ediacarano Terminal ao redor do mundo. A Formação Tagatiya Guazu, foco deste trabalho, foi depositada durante este intervalo de tempo e ainda carece de estudos que permitam compreender em detalhe as condições paleoambientais em que se deu esta passagem na porção W do supercontinente Gondwana.

Na área de estudo, a Formação Tagatiya Guazu é composta por quatorze fácies sedimentares carbonáticas ou mistas depositadas em ambiente de perimaré raso, em contexto de rampa proximal barrada. O empilhamento vertical das fácies de sub e intermaré configura ciclos de raseamento ascendente, revelando variações internas importantes na arquitetura da unidade e a intercalação de ciclos de menor frequência de progradação e retrogradação.

Dados de $\delta^{13}C_{carb}$ indicam valores entre + 1 e + 5 ‰ PDB e apresentam forte controle faciológico, sendo que os valores mais positivos estão associados às fácies depositadas em condições de inter/supramaré e os menos positivos àquelas depositadas em submaré. De forma análoga a outras sucessões ediacaranas ao redor do mundo, tais dados sugerem a existência de um gradiente isotópico no corpo d'água em que se depositou a Formação Tagatiya Guazu, embora de forma menos evidente. Tal gradiente pode ser atribuído à: a) uma estratificação redox do corpo aquoso, resultado da restrição fisiográfica da rampa carbonática e da já baixa concentração de O_2 no Ediacarano terminal, ou b) menores taxas de produtividade primária, juntamente à oxidação de matéria orgânica, conforme afasta-se da zona fótica. De qualquer maneira, as porções mais rasas e proximais se apresentavam oxigenadas, como evidenciado pela presença de icnofósseis e dos organismos *Cloudina sp.* e *Corumbella sp. in situ* em fácies de inter/supramaré.

Devido à existência deste gradiente isotópico e à baixa amplitude de variação batimétrica atestada pelas fácies sedimentares, o comportamento da curva de valores de $\delta^{13}C_{carb}$ espelha o empilhamento dos ciclos carbonáticos da unidade, fazendo com que a ciclicidade de alta frequência das fácies sedimentares se reflita em uma ciclicidade isotópica.

Além disso, a presença de icnofósseis com hábitos complexos permite afirmar que a Fm. Tagatiya Guazu registra a passagem para o Cambriano e o Éon Fanerozoico. A identificação desses icnofósseis, aliada ao caráter global dos isótopos de carbono, sugere quatro hipóteses a serem testadas em trabalhos futuros: a) a anomalia BACE não possui caráter global; b) a anomalia ocorre acima do limite E-C; c) um aumento na restrição impediu o registro do sinal oceânico global, ou d) processos orgânicos e/ou inorgânicos locais obliteraram o sinal global.

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