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Assessing the Ediacaran Doushantuo Formation: Improving stratigraphic correlation of the Upper Doushantuo Black Shales via mercury content

Evaluación de la Formación ediacárica de Doushantuo: mejora de la correlación estratigráfica de las pizarras negras de Doushantuo superior a partir del contenido en mercurio

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ABSTRACT

Mercury enrichments in the black shale unit of the Ediacaran Doushantuo Formation are, likely the result of volcanic input or anoxia-driven mercury deposition. If the Hg enrichments are volcanic in origin, or are due to synchronous regional anoxia, then the patterns of Hg enrichment are consistent with the conventional correlation of these units, with the tripartite units equivalent to Member IV black shales. Additionally comparing redox proxy data from the intervals of Hg enrichment could indicate if the enrichments are due to comparable changes in redox conditions, or increased Hg input under differing redox conditions, consistent with volcanic input.

Keywords: Mercury; Organic carbon content; Doushantuo Formation; Ediacaran; China.

RESUMEN

Los enriquecimientos de mercurio en la unidad de esquisto negro de la Formación ediacárica de Doushantuo son probablemente el resultado de la influencia volcánica o del depósito de mercurio mediante anoxia. Si los enriquecimientos de Hg son de origen volcánico, o se deben a una anoxia regional contemporánea, entonces los patrones de enriquecimiento de Hg son consistentes con la correlación convencional de estas unidades, con las unidades tripartitas equivalentes a la pizarra negra del Miembro IV. Además, la comparación de los datos redox de los intervalos de enriquecimiento en Hg podría indicar si los enriquecimientos se deben a cambios comparables en las condiciones redox, o a un aumento de la entrada de Hg bajo diferentes condiciones redox, consistente con la influencia volcánica.

Palabras clave: Mercurio; Contenido en carbon orgánico; Formación de Doushantuo; Ediacárico; China.

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Introduction

The Ediacaran Period is a critical time interval in the history of life, when environmental changes and evolutionary events set the stage for the Cambrian explosion of animal diversity (e.g. Marshall, 2006). The Ediacaran Doushantuo Formation of South China hosts exceptionally preserved fossils and has yielded geochemical data detailing major events, most importantly the Shuram Carbon Isotope Anomaly (e.g. McFadden *et al.*, 2009).

Results

Understanding these histories requires stratigraphic correlation between sections of the Doushantuo Formation, especially correlations among black shale units (Member IV, Miaohe Member, and Lower Black Shale). Conventionally, the Member IV is correlated to the tripartite Lower Black Shale, Upper Dolostone, and Miaohe Member; however, some δC_{carb} data suggests that only the Lower Black Shale correlates to the Member IV, thus the Miaohe Member correlates to the Shibantan Member and the Upper Dolostone correlates to the Hamajing Member of the overlying Dengying Formation (An *et al.*, 2015). These correlations have significant consequences for interpreting the age and duration of the Shuram Event and the age of the fossils preserved in these units (Zhou *et al.*, 2017). Building on current lithostratigraphic and stable carbon isotopic chemostratigraphic correlations, we use mercury [Hg] contents to refine stratigraphic correlations of the Doushantuo, as Hg contents can provide information on regional and potentially global volcanic input and local redox conditions, the former of which could facilitate stratigraphic correlation (see Selin, 2009 for discussion of the global mercury cycle, and Thibodeau *et al.*, 2016 for an example of volcanic mercury correlation).

Samples were collected from six sections of the Doushantuo Formation around the Huangling Anticline of south China (Fig. 1G.). These sections include the Qinglinkuo, Zhimaping, Sixi,

Jiulongwan, Maxi, and Yinyin roadcut sections (Fig. 1A-F.). They represent both Member IV and tripartite sequences. The trends in mercury concentration are presented in figure 1A-F. The Zhimaping and Yinyin road sections have the lowest mercury concentrations, though both contain potential interval of Hg enrichments. In each of the six sections, there is at least one mercury concentration enrichment in either the Miaohe Member or the upper part of the Member IV, and another interval of Hg enrichment in the Lower Black Shale, or lower portion of the Member IV. For each section, this enrichment is of a greater magnitude than the upper one.

To improve sectional comparisons, mercury concentration is normalized with Total Organic Carbon content (TOC) to account for differential sedimentation rates between sections over time. TOC data are available only for the Jiulongwan section (McFadden *et al.*, 2008). When normalized against TOC data, [Hg]/TOC data from the Jiulongwan (Fig. 2.) also show two peaks in enrichment in lower and upper parts of Member IV, again with a larger magnitude in the lower enrichment, consistent with the non-normalized data from the other sections. Beyond these signals, there are several TOC normalized mercury enrichments in the Member III at Jiulongwan. However, this unit generally has very low non-normalized mercury concentrations, and very low TOC values, suggesting the high and variable [Hg]/TOC ratios result from the low TOC values rather than actual increased sedimentary input of Hg during a volcanic or redox related event.

Conclusions

There are clear mercury enrichments in the black shale units, likely the result of volcanic input or anoxia-driven mercury deposition. If the Hg enrichments are volcanic in origin, or are due to synchronous regional anoxia, then the patterns of Hg enrichment are consistent with the conventional correlation of these units, with the tripartite units equivalent to Member IV

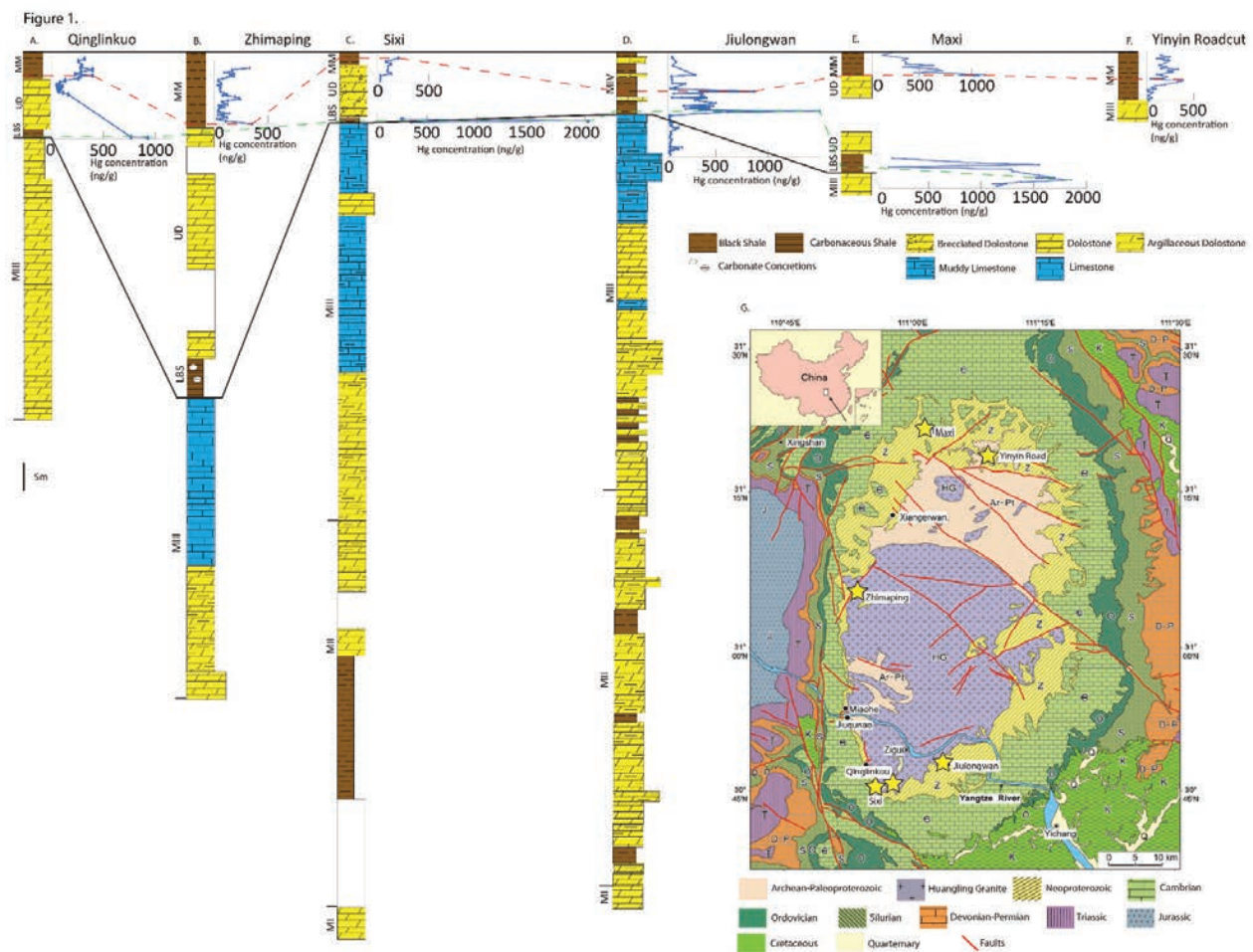


Figure 1.—Mercury concentrations from sections of the Doushantuo Formation around the Huangling Anticline. A. Qinglinkuo Section. There is a large positive mercury concentration enrichment in the LBS unit and a moderate enrichment in the MM unit. Stratigraphic column modified from An *et al.* (2015) B. Zhimaping Section. The Miaohe Member of the Zhimaping section contains three mercury enrichment peaks, near the top, middle, and base. Stratigraphic column modified from An *et al.* (2015) C. Sixi Section. There is a very large mercury anomaly near the base of the LBS unit and a moderate enrichment near the top of the Miaohe Member unit. Stratigraphic column modified from Muscente *et al.* (2015) D. Jiulongwan Section. There are two mercury enrichments, one near the base and one near the middle of the Member IV unit. Stratigraphic section modified from McFadden *et al.* (2008) E. Maxi Section. This section hosts mercury enrichments near the base of both the Lower Black Shale and Miaohe Member units. F. Yinyin Road Section. There is a moderate mercury enrichment near the middle of the Miaohe Member. G. Geologic map of the Huangling Anticline showing the locations of the sampled sections, modified from An *et al.*, (2015). Mercury concentration data from these sections broadly support two positive enrichments: one in the Lower Black Shale or lower Member IV; and another in the Miaohe Member or upper Member IV. LBS- Lower Black Shale, MM- Miaohe Member, UD- Upper Dolostone, MIV- Member IV, MIII- Member III, MII- Member II, MI- Member 1.

black shales. Furthermore, a volcanic origin would offer targets for radiometric dating. The source of the Hg enrichment can be explored via comparison of mass-independent and mass dependent Hg. isotopic fractionation. Additionally comparing redox

proxy data from the intervals of Hg enrichment could indicate if the enrichments are due to comparable changes in redox conditions, or increased Hg input under differing redox conditions, consistent with volcanic input.

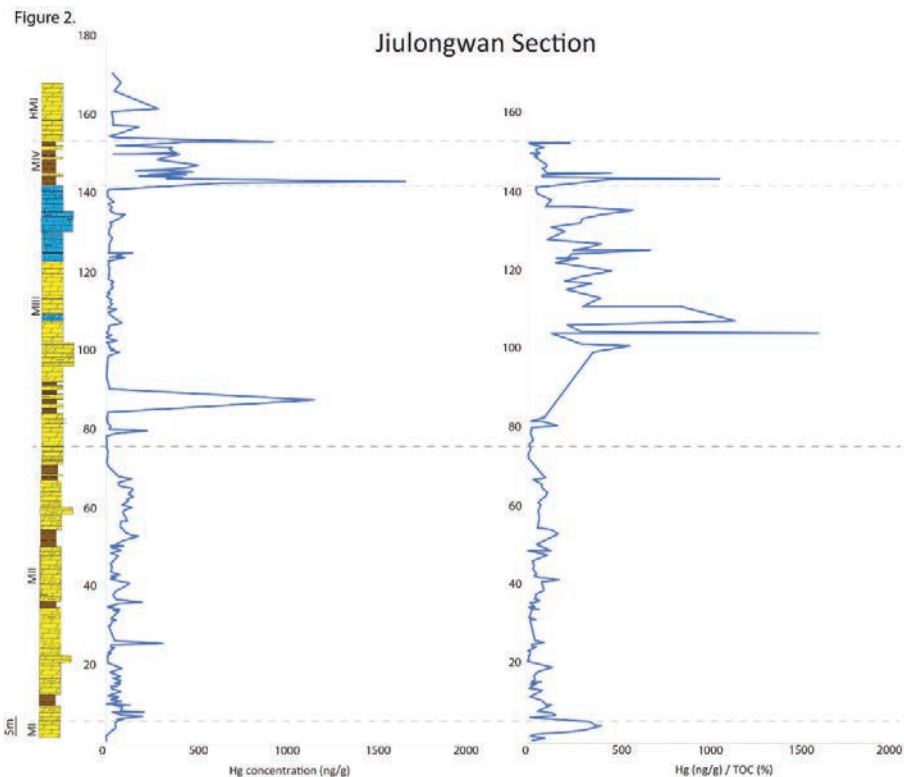


Figure 2.—Mercury concentration data of the Doushantuo Formation from the Jiulongwan Section. Left profile shows concentrations, and right profile shows mercury concentrations normalized by total organic carbon content (TOC). The data support intervals of heightened mercury concentration in the upper and lower parts of Member IV. The normalized data also show considerable variance and large mercury spikes. These are likely noise due to very low organic carbon content (< 0.1% TOC), while the Member IV signals are all based on greater organic carbon content (between 0.2% and 8% TOC). TOC data from McFadden *et al.* (2008).

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