Geochemistry of the manganese ore and black shale in the Datangpo Formation: Implications for the ore genesis and oceanic redox during the interglaciation of Neoprozeotoic Snowball Earth

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**Introduction:** The Cryogenian are critical period for the evolution of ocean system and biosphere, and black shales have been frequently found during the interglaciation. The Datangpo Formation from South China is a typical interglacial stratum with black shale in lower section, and unique by the development of manganese (Mn) carbonate underlying the black shale. Details about the hydrothermal fluids and the enrichment of OM for ores need further investigation, and the geochemistry of global black shales in the interglaciation should be summarized for elucidating the oceanic oxygenation.

**Samples and Methods:** One typical section, composed of both Mn carbonate and overlying black shale, was selected for detailed sampling. Pulverized samples were analysed for the content and carbon isotopes of both organic carbon and inorganic carbon, the abundance of major and trace elements as well as the molybdenum (Mo) isotopes.

**Results:** (1). The samples with Mn content greater than 5% have an average TOC value of 2.4%, which is lower than that (~3.06%) of the samples with less Mn. (2). The abundance of redox-sensitive element (Mo, U, V) and TOC/P ratio are very low for Mn carbonate, indicating suboxic to oxic condition. (3). A hydrothermal source for the Mn carbonate is indicated by clear positive Eu anomaly, relatively large Fe/Ti ratios but low Al/(Al+Fe+Mn) ratios. In addition, more mafic material could have contributed to the Mn carbonate, as suggested by overall larger La/Th ratios but lower abundance of high field strength elements (Nb, Ta, Zr and Hf) relative to the overlying balck shale.
(4) The nutrient elements, such as redox-sensitive Fe, Ba and P and OM-related Cu, Zn and Ni, all show much higher level for Mn carbonate relative to overly black shale. This is consistent with reported statistical results for overall larger abundance of P for mafic magmatic rocks relative to felsic ones, which is called as “mafic nutrient pump”. (5) A compiling of elemental and Mo isotopic data for interglacial shale worldwide in the Cryogenian has been performed, which shows the maximal Mo content, Mo/TOC ratio and δ^{98}\text{Mo} value mostly less than 50 ppm, 20 and 1.5\%.

Conclusion: Relatively abundant residual OM in Mn carbonate may be due to abundant nutrients associated with the hydrothermal fluid that has contributed to a high productivity level. The hydrothermal fluid may be from continental origin as previously reported Sr and Nd isotopes, however, elemental data supported large contribution from mafic material which can give more nutrient than felsic one. The interglacial ocean for the Snow Ball Earth was generally anoxic, and episodic bottom water oxygenation may be arose by the influx of high-density ice melting water.