Estimation of Depositional Environment of Ediacaran Carbonates by Trace Element Abundances

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Introduction

In later Neoproterozoic, at least 3 times glacial event occurred including Marinoan and Gaskiers glacial periods (Hoffman and Li, 2009). Diamictite deposited during the Marinoan glacial event was covered by cap carbonate, which indicates that the sudden change of temperature occurred (Hoffman and Li, 2009). It is thought that by this change living species were selected, which eventually leads to the Cambrian explosion (Hoffman et all, 1998). Hence, it is thought that these cap carbonates give an important hint about the most important environmental change after glacial period for primary animal diversification in the earth history.

Trace elements in deposited sediments can be a proxy of the depositional environment. REE abundances in carbonate rocks reflect those in seawater (Tanaka et al., 2006). Parameters in the REE pattern can be useful to interpret the depositional environment in each sample: (i) Ce anomaly can be proxy of paleoceanographical redox state (Wang et al., 2014); (ii) Y/Ho and tetrad effect include information of water mass in the ocean; (iii) slope of REE pattern (= Pr/Er) reflects water depth in the ocean, if we can assume that variation of REE pattern can be similar in the late Neoproterozoic ocean.

In this study, these REE concentration were compared with carbon isotope ratio that was measured at Kunimitsu et al. (2011). Kunimitsu et al. (2011) divided the section into four units based on the carbon isotope variation. Among them, Unit 1 and 3 correspond to the period after the Marinoan glacial event and cooling period during Gaskiers glacial event, respectively.

Samples and Methods

In this study, Carbonates collected at Yanjiaping in Hunan Province, China were used as analysis samples (Kunimitsu et al., 2011). This section covers the interval from late Cryogenian to earliest Cambrian (655-542Ma; Amthor et al., 2003).

Trace element concentrations in carbonate were measured by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS). Samples were crashed by hummer and grinded by agate mortar. Carbonates were dissolved into acetic acid and diluted to 10 or 1000 times. In and Bi were used as internal standard for the measurement by ICP-MS.

Results and discussion

REE patterns are measured by ICP-MS and normalized by using Post-Archaean Australian Shale (PS). Ce and Eu anomaly was calculated by using PAAS as below, whereas the degree of tetrad effect level was reflected by the Dy/Dy* ratio. Variation of trace elements were also examined.

Carbonate samples used in this study is same as the carbonate samples analyzed in Kunimitsu et al. (2012) and Furuyama et al. (2012) and discussed by segmenting from Unit 1 to 4 much as Kunimitsu et al. (2012).

It was clear that the degree of Ce anomaly is correlated with Y/Ho ratio. Although Ce anomaly is primary redox indicator, but the degree of negative Ce anomaly increases with increase of the water depth in the ocean, but almost no Ce anomaly can be expected in river water. Y/Ho ratio, which is originally sensitive to ionic-covalent character of reactions, increases with the increase of the ratio. As a result, there is a

clear relationship between the two parameters with plots of modern seawater, river water, and coastal water. The close correlation showed the environmental change that occurred within the Yanjiaping section is the frequent shifts between coastal or estuarine environment and deeper marine environment.
In particular, water mass from deep ocean must have been supplied when negative Ce anomaly and Y/Ho ratio became large. Such trends were clearly found in Unit 3, which can explain the supply of nutrients including phosphorous to form phosphate sediments within the Unit 3.
Similar discussion is valid when we plot Y/Ho ratio and Dy/Dy* ratios. In this plot, it was again clear that depositional environment changed greatly during the Unit 3.
Increase of the slope of the REE pattern toward heavy REE correlated with the increase of the Y/Ho also shows the supply of deep sea water mass was supplied to the shallow depositional environment in the Unit 3.
Relatively intense Ce anomaly in 0-20 cm from the boundary with Nantuo formation in Unit 1 is notable, when black shale sediments were predominant, which suggests reductive environment. The positive Ce anomaly in carbonite, or seawater is very unique signature, which cannot be observed in normal oxic environment. Concentration of Mn in the carbonate was also high during the period. There results suggested that ferromanganese nodule which generally have positive Ce anomaly and can be formed right after the end of snowball earth were dissolved into water by the reducing environment in the period.

