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Geological and geochemical study of Archean sedimentary rocks of the 3.0 Ga Lumby Lake Group, Canada

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Ecosystems at ca. 3.0 Ga on the Earth's surface environments are not well understood. In particular, it is uncertain (1) whether phototrophic microorganisms were active and (2) where methanogens and methanotrophs were active. In order to answer those questions, we have conducted geological survey of sedimentary rocks of the Lumby Lake Group, located in the Atikokan area, Ontario, Canada.

Ultramafic-mafic volcanic rocks, including pillow and massive lavas and hyaloclastite were dominant in the area. In the studied area, marine sedimentary rocks, including banded iron formations (BIFs), were also observed. Black shales were spatially associated with the BIFs making alternate layer.

Petrographical and geochemical analyses were performed on the BIFs and black shales. The BIFs were composed of alternating magnetite-rich and silica-rich layers. Apatite was found in magnetite-rich zone. This support that a primary phase before magnetite was hematite (or goethite) because phosphates are easily adsorbed on Fe-(hydro) oxides. The black shales contain 0.1 to 4.3 wt% of total organic carbon and 0.0 to 24.9 wt% of Ssulfide. The carbon isotope compositions of organic carbon in the black shales showed a bimodal distribution: -47 to -38 per mil (studied area A) and -27 to -20 per mil (studied area C). The carbon isotope compositions of the black shales is negatively correlated with Ssulfide contents. The lighter values suggest the activity of methanogens and methanotrophs while the heavier values suggest the activity of photoautotrophic primary producer. Methanogens could have been active in this anoxic part of ocean water.

These shales also contain two types of pyrite: fine-grained layered type and nodular type. Layered deposition of pyrites indicates that these pyrites were formed syngenetically with other matrix materials. On the other hand, the nodular pyrites were composed of aggregates of pyrite and other sulfides (e.g., chalcopyrite, sphalerite and pyrrhotite), indicating that they were precipitated from later hydrothermal fluids. Therefore, alterations of the sedimentary rocks by submarine hydrothermal activities was widely recognized in the area.

REEs concentrations in the BIFs were analyzed by inductively-coupled plasma mass spectrometry (ICP-MS). BIFs in the all studied area contain insignificant or positive Ce anomalies. This trend in Ce anomalies indicates that the BIFs would have formed in low oxygen condition. On the other hand, studied area A contains significant positive Eu anomalies which contrast with studied area C having insignificant Eu anomalies. This suggests that submarine hydrothermal activities in the studied area A was more larger than studied area C. In particular, methanogens activities were constrained in very reducing bottom water environments where hydrogen from hydrothermal fluids was available.

Keywords: submarine hydrothermal activity, methanogens, phototrophic microorganisms, REEs