Composition of seawater before the Sturtian Snowball Earth estimated by the occurrence of late Tonian evaporitic magnesite

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Neoproterozoic is an important period for biological evolution when the spread of algae, protozoan, and multicellular animal were radiated. Understanding of climate changes and fossil records after Ediacaran has been largely improved. But environmental background behind how the Earth’ s surface reached the Snowball Earth state has not been understood.
In Flinders Ranges, South Australia, thick shallow marine sequence preserves excellent geological records especially before and after Sturtian glaciation. This study targets Skillogalee Dolomite exposed at Leigh Creek, Northern Flinders Ranges (LC section) which was deposited around 788±7Ma(Late Tonian) before the Sturtian glaciation (Hood and Wallace 2018). The lithology of LC section contains a small amount of siliciclastics, but mainly consists of shallow water carbonate that exhibits various structures including intraformational conglomerate, stromatolite and tepee structure. However, the most remarkable feature is a large quantity of magnesite. Magnesite alternates with dolostone and occurs as layers of ~1m in thickness or crusts of intraformational conglomerate. The Tepee structure indicates an evaporative environment, and higher d13C and d18O of magnesite indicates that the magnesite deposited after the dolomite. These rocks lack gypsum pseudomorphs.
Evaportive mineral assemblage of the Skillogalee Dolomite can be recognized only in Proterozoic. While the Phanerozoic evaporate sequence starts from Ca carbonate-dolomite, follows to gypsum and halite, but does not include magnesite (Hardie and Eugster 1980). In order to explain this specific mineral assemblage, we made model calculations about the order of precipitated minerals, which expected by continuous evaporation of seawater. Then, we found the Skillogalee mineral sequence was achieved only from seawater of Mg/Ca > 10 and Mg > Alkalinity > Ca. We used sulfate concentration of the modern seawater, but it does no influence to the result. Alkalinity over 10 times higher than the modern level likely reflects from high partial pressure of carbon dioxide or low Ca concentration in seawater. Possible causes of high Mg/Ca ratio were inactive seawater circulation at low mid-ocean ridge, active carbonate sedimentation, or Ca depletion due to extensive evaporite formation including gypsum around 800 Ma. If pH of seawater has been controlled by the solubility equilibrium of CaCO3, the drastic decrease in Ca concentration would encouraged pH rise of sea water and lead to decline of atmospheric carbon dioxide.

Evans 2006, Nature 444, 51-55.
Hardie and Eugster 1980, Science 208, 498-500.
Hood and Wallace 2018. Global and Planetary Change 160, 28-45.

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