Behavior of phosphorous during the 2.7 Ga submarine hydrothermal activities at Abitibi Greenstone Belt, Canada

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Phosphorus is an essential element for life. The chemical specie of phosphorus is phosphate on the modern Earth, and most likely for Archean Earth. Weathering of continental rocks is the dominant source of phosphate in hydrosphere and biosphere of the modern Earth. On the other hand, the mass of continents in the Archean ara is considered to be smaller than that of modern. This leads to the hypothesis of phosphate-poor environments in Archean hydrosphere and biosphere. Leaching of phosphate from Archean oceanic basalts by submarine hydrothermal alteration has been proposed as an alternative process to supply phosphate into hydrosphere and then to biosphere. Although this hypothesis has many advantages, direct evidence has not yet been obtained. Clarification of the behavior of phosphorus due to hydrothermal activity in the Archean is expected to lead to a more advanced understanding of phosphorous cycle on the early Earth.
Therefore, the purpose of the present study is set to examine the behavior of phosphorus in pillow lava samples in the Archean during hydrothermal alteration of the seafloor. 2.7 Ga pillow lavas and hyaloclastites from the Abitibi Greenstone Belt in Canada were examined in the present study. The pillow lava was separated into core and rim portions depending on the degree of alteration, and mineralogical and geochemical studies were performed separately.
Veins of apatite and sphene were found only in the rim portion. Those veins were formed by migration of phosphorous and titanium in examined rocks and always associated with carbonate veins or carbonation alteration. This suggests that leaching and migration of phosphorous and titanium were caused by carbonate-rich hydrothermal fluids.
It is found that some of sphene veins formed at the edge of the volcanic glass and was not associated with carbonate minerals. Those observation and mineralogical assemblages suggest the following sequence of alteration: (1) early hydration of volcanic glasses, (2) later carbonation of buried and hydrated pillow lavas followed by (3) metamorphic overprint.
Major and trace element analyses were performed on the examined samples. Rim portions of pillow lavas, in general, enriched in Ti, Fe, Mg, Ca, V, Sr, Rb, Ba and P. Those enrichment trends are consistent with mineral assemblages with an increase in apatite, sphene, calcite and alteration minerals.
Carbon isotope compositions of carbonate are implying that the sources of CO_2 to form calcite were magmatic and oceanic. Sulfur isotope compositions of sulfides yield relatively homogeneous compositions. This suggests that reduction of seawater sulfate did not occur within the pillow lavas. Instead, H_2S, which has homogeneous $\delta^{34}S$ values, were introduced into pillow lavas from outer systems.
This study revealed that carbonate-rich hydrothermal fluids circulating deep near magma can migrate and concentrate phosphorus and titanium. A part of phosphorous and titanium was most likely released into seawater by discharge of the hydrothermal fluids. The behavior of phosphorus due to submarine hydrothermal activity during the Precambrian age is still not fully understood. The results of this study are expected to provide new insights into the problem of the origin of phosphorus during the Archean.

Keywords: Archean, phosphate, pillow lava

