

Alkaline hydrothermal metamorphism in the Archean: Implications for behavior of chalcophile elements and the deposits

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Coevolution of the surface environment and life through the time is one of the most significant features of the earth. Decoding of ocean chemistry in the early Earth is a key issue to understand the origin and evolution of life. Copper is one of chalcophile elements and the 27th most abundant element in a crust. Zinc and cobalt also belong to the chalcophile elements. The copper is an essential element for oxygen-producing photosynthesis because the Cu is utilized for plastocyanin. The plastocyanin is used by higher plants whereas cytochrome (an iron-protein) is used by red and brown algae. And, some of green algae and cyanobacteria can use both plastocyanin and cytochrome depending on the copper contents. The copper is essential for cyanobacteria, green algae and higher plants. Because another copper protein, Hemocyanin, is a protein that transports oxygen throughout the bodies, Cu is also important for some invertebrate animals such as Arthropoda and some of Mollusca. It is also well-known that chalcophile elements possibly played an important role on prebiotic evolution because presence of Co and Zn promotes formation of oligomers. The behavior of the chalcophile elements in the hydrothermal environments influenced formation of copper deposits in the Eoarchean.

Comparison of copper contents between modern unaltered and hydrothermally-altered ocean floor basalts indicates that the altered basalts have more copper contents than the unaltered basalts. On the other hand, zinc contents of the altered basalts increase with the increasing alteration. Although both the copper and zinc belong to chalcophile elements, their behaviors are different during the hydrothermal alteration of basalts.

The North Pole and Mable Bar greenstone belts in Pilbara, Western Australia, are characterized by ocean plate stratigraphy and duplex structures so that they originate from accretionary complexes in the Archean. We classified the greenstones into MORB- and OIB-types based on the relationship of the greenstones with cherts: the greenstones on thick cherts are classified into MORB-type whereas the greenstones interlayered with thin chert layers into OIB-type, respectively (Komiya et al., 2002). Moreover, a previous work classified the hydrothermally-altered MORBs into Type I with magmatic texture, Type II without magmatic texture and Highly silicified groups, and reported their geochemical compositions (Nakamura & Kato, 2004).

Comparison of the copper contents between the unaltered and hydrothermally-altered MORBs in the Paleoarchean shows that the highly silicified group has lower Cu contents than the unaltered MORBs. The Type-I and II groups are highly scattered in Cu contents. On the other hand, the highly silicified group has lower Zn contents than the unaltered MORBs, but the Type-I and II groups are higher Zn contents.

A pH-Eh diagram of the copper shows that the copper can be dissolved only in a narrow pH-Eh condition, namely relatively acidic and oxic condition because Cu forms sulfide under anoxic ($E_h < 0.3$) condition whereas forms oxides and metal of CuO , Cu_2O and Cu under high (>7) pH condition. On the other hand, zinc has a large stability field of dissolved zinc under lower pH (<8) and higher E_h (>0.2) condition.

As a result, it is considered that the behavior of zinc in seawater and hydrothermal fluid in the Archean was similar that in the Phanerozoic. On the other hand, the behavior of copper in the Archean was different from that in the Phanerozoic because the Archean seawater was anoxic and a

little acidic to neutral whereas hydrothermal fluid was more alkaline. The difference possibly accounts for the difference in behaviors of copper of the hydrothermally-altered basalts between in the Archean and Phanerozoic. Hydrothermal fluid unrelated with silicification in the Archean possibly supplied more copper than that in the Phanerozoic.

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