

Ocean floor metamorphism recorded in the 3.0 Ga accreted oceanic crust

Takazo Shibuya[1], Kouki Kitajima[2], Yuichiro Ueno[3], Tsuyoshi Komiya[4], Masaru Terabayashi[5], Yukio Isozaki[6], Shigenori Maruyama[7]

[1] Earth and Planetary Sci., T.I.T., [2] Earth and Planetary Sci., T.I.T., [3] Earth Science and Astronomy, Univ. Tokyo, [4] Earth & Planet. Sci., Tokyo Inst. Tech., [5] Dept. Safety Systems Construction Engineering, Kagawa Univ., [6] Earth Sci. & Astron., Univ. Tokyo Komaba, [7] Earth and Planetary Sci., Tokyo Institute of Technology

Ocean floor metamorphism is important process of interaction between sea-water and oceanic crust, namely surface environment and solid earth. The atmosphere of the early earth was highly enriched in CO₂ content (Tajika and Matsui, 1990). The fact means secular change of CO₂ content in atmosphere, and operation of CO₂ removal process in the surface environment of the earth.

Kitajima and others (2001) studied 3.5Ga ocean floor metamorphism of North Pole area in Pilbara and showed high CO₂ fugacity in the hydrothermal fluid because of occurrence of large amount of carbonate minerals in the metabasites. The evidence means that sea-water and atmosphere at 3.5Ga were highly enriched in CO₂ content.

In this study, we will show that the metamorphism of the Cleaverville area in Pilbara granite-greenstone terrain, Western Australia, originates from the 3.0Ga ocean floor metamorphism based on the geological mapping, detail geological sketches of some critical outcrops, and that the metamorphism was also caused by CO₂-rich hydrothermal fluid.

The Cleaverville area is composed mainly of basaltic greenstones, over 2600m thick, with subordinate amounts of chert and clastic rocks. The basaltic greenstones are derived from pillow lava and sheet flows. The clastic rocks consist of mudstone, sandstone and conglomerate. These greenstones and associated sedimentary rocks have NE-SW-trending strikes, and the dipping is 50-90 degrees to the north. The basaltic greenstone and the bedded chert have no clastic material, on the other hand the clastic rock is terrigenous sediment. The lithostratigraphy is quite similar to the oceanic plate stratigraphy in the Phanerozoic accretionary complex. In addition, duplex structures are also present at northern part of this unit. The presence of the duplex structure and the oceanic plate stratigraphy indicate that the mid-Archean Cleaverville Formation is an accretionary complex (Isozaki et al., 1995).

The greenstones in the upper 2200m part of the basaltic flow unit include carbonate minerals. Especially, greenstones in the upper 300m part include a lot of carbonate minerals. The extent of the carbonatization decreases southward, namely stratigraphically downward. We detailedly investigate the presence and distribution of several to 30cm wide quartz veins. The distribution of the cm-scale quartz veins is limited to the upper 1800m of the greenstone sequence. In the upper 1800m part, Ca-Al silicates including Ca-zeolite, prehnite, pumpellyite are almost absent in the metabasites. Instead, abundant carbonates are present with chlorite, suggesting high CO₂ content in the fluid. In the lower part below the upper 1800m greenstone, fine needle-like actinolitic amphiboles are present. The mineral paragenesis of the metabasites indicates that the metamorphic grade increases from sub-greenschist to greenschist facies stratigraphically downward.

The metamorphic grade increases and the degree of the carbonatization decreases stratigraphically downward. The isograds of carbonate minerals-out and thick quartz veins-out are parallel to the bedding plane of the bedded chert, ancient seafloor. The greenstones in the Cleaverville area include much more carbonate minerals than that of modern oceanic crust, as well as the greenstones in the 3.5Ga North Pole area.

The alteration and metamorphism of the Cleaverville area are not subduction-related because the isograds of carbonate-out, quartz veins-out and amphibole-in are parallel to the ancient seafloor. The greenstones underwent the alteration by high-XCO₂ hydrothermal fluid, because carbonate minerals are stable in the upper oceanic crust instead of Ca-Al silicates. The severe carbonatization of oceanic crust suggest high activity of CO₂ in the 3.0Ga sea-water, too. We propose that the removal of CO₂ content in sea-water is caused by this carbonatization of oceanic crust.