

Carbonatization of oceanic crust and its implications for the atmosphere-hydrosphere system and carbon cycle in the Early Archean

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Hydrothermally carbonatized basaltic rocks from the Warrawoona Group, Pilbara Craton have been investigated in order to clarify physicochemical environment of the mid-ocean ridge hydrothermal system and to estimate the CO₂ flux sunk into altered oceanic crust in the Early Archean. The basaltic rocks are composed mainly of pillow basalt with minor massive dolerite. These are overlain by hydrothermal bedded cherts and are crosscut by massive black/gray silica veins that are considered as hydrothermal feeders.

The alteration mineral assemblage of dolerite is epidote + actinolite + chlorite + quartz + albite, whereas that of basalt is carbonate minerals + K-mica + quartz + chlorite. The carbonate minerals replace primary phases such as olivine, plagioclase, and glass and also fill veins, vesicles, and interpillow spaces. Electron microprobe analysis shows that the carbonate minerals are calcite, ankerite, and siderite. The delta-13C values of the carbonate minerals are mostly within the range of marine carbonate, indicating that the carbonate carbon is of seawater origin. Thermodynamic calculation suggests that the carbonatization was due to high-CO₂ fugacity of the hydrothermal fluid. As well as CO₂ fugacity, temperature and pH condition also played an important role in carbonate precipitation. Mass balance calculation for Ca and CO₂ between basalt and hydrothermal fluid implies that water/rock ratio was greater than 3. This probably causes the difference of alteration mineral assemblages between basalt and dolerite.

Bulk chemistry of the basaltic rocks is essentially similar to modern MORB except for highly mobile elements. Altered basalt samples are enriched in K₂O, Rb, and Ba, and are depleted in Na₂O, reflecting the presence of K-mica replacing primary plagioclase. Although noticeable CO₂ enrichment is recognized in the basalt, there is essentially neither gain nor loss of CaO. This suggests that the CO₂ in the hydrothermal fluid was trapped by using Ca in the basalt. The CO₂ flux sunk into the oceanic crust by the hydrothermal carbonatization can be estimated by multiplying the average carbon content in the altered oceanic crust by the production rate of altered oceanic crust. The calculated chemical flux of CO₂ was equivalent to, or higher than the present total carbon flux by carbonate precipitation and carbon burial. It can be concluded that the carbonatization of oceanic crust played an important role as a sink of CO₂ in the Early Archean atmosphere and ocean.