Seafloor hydrothermal carbonatization as a CO2 sink in the Early Archean:Thermodynamic calculation

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Hydrothermal carbonatization of the Early Archean seafloor basalts from the Warrawoona Group, Pilbara Craton have been thermodynamically investigated in order to estimate physicochemical environment of the seafloor hydrothermal system and chemical features of circulating seawater and coexisting atmosphere in the Early Archean. The studied samples are divided into dolerite and basalt on the basis of field occurrences and microscopic characteristics. The dolerite is characterized by the alteration mineral assemblage of epidote + actinolite + chlorite + quartz + albite, indicating the alteration condition of typical greenshcist facies. On the other hand, the alteration mineral assemblage of basalt (carbonate minerals + K-mica + quartz + chlorite) implies that the basalt was altered by the hydrothermal solution with high CO2 amounts. The difference in the mineral assemblages between basalt and dolerite may be related to the following carbonatization reactions;

1) 2Ep + 3Act + 10CO2 + 8H2O = 10Cal + 3Chl + 21Qtz
2) Act + 3Cal + 7 CO2 = 5Ank + 8Qtz + H2O
3) Act + 7 CO2 = 2Ank + 3Sid + 8Qtz + H2O

Thermodynamic calculation using the internally consistent data set of Holland and Powell (1998) in the system CaFMASCH shows that the carbonatization was due to high-CO2 concentration of the hydrothermal fluid (seawater in origin), which was higher than 1 mol%. This high value of CO2 concentration in the Early Archean hydrothermal fluid is two orders of magnitude greater than that of modern counterpart. In addition to CO2 concentration, water/rock ratio was also considered as an important factor to the carbonatization reaction, based on mass balance calculation for Ca and CO2 between basalt and hydrothermal fluid. Atmospheric PCO2 of the coeval atmosphere existed in equilibrium with the CO2-rich ocean is estimated to be higher than 0.1 atm. This suggests that CO2 alone (without methane) could produce a greenhouse effect enough to maintain liquid oceans on the early Earth.