3.46Ga seafloor hydrothermal alteration as a CO_2 sink

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Hydrothermally altered greenstones from the Marble Bar area in the Pilbara Craton have been investigated in order to elucidate geological and geochemical characteristics of Early Archean (~3.46Ga) seafloor hydrothermal alteration. The greenstones, composed mainly of pillow lavas, are overlain by hydrothermal bedded cherts and are crosscut by massive black/gray silica veins that are considered as hydrothermal feeders (Kato and Nakamura, 2003). Greenstones in the vicinity of the bedded cherts and silica veins have been subjected to strong hydrothermal alteration.

The greenstones can be divided into two types on the basis of microscopic characteristics; basalt and minor dolerite. The altered basalt is characterized by the alteration mineral assemblage of K-mica + quartz + chlorite +/- carbonate minerals, indicating that the basalt was altered by the hydrothermal solution with high CO_2 fugacity and K^+ concentration.

The whole-rock chemical composition of relatively fresh samples is essentially similar to that of modern mid-ocean ridge basalt except for enrichment of K_2O, Rb, and Ba. Compared to the relatively fresh samples, hydrothermally altered greenstones are enriched in CO_2, K_2O, Rb, Ba and are depleted in Na_2O, reflecting the presence of carbonate minerals and K-mica and the disappearance of plagioclase. The $\delta^{13}C$ values of the carbonate minerals in the greenstones are close to zero permil, showing that carbonate carbon is of seawater origin (e.g., Gloves et al., 1988). A positive correlation between CO_2 and CaO in the altered greenstone shows that the CO_2 was substantially retaind as $CaCO_3$. There was essentially neither gain nor loss of Ca during the carbonatization. This indicates that CO_2 in the circulating seawater was trapped by using Ca contained in the oceanic crust.

Based on our geological and geochemical results, 3.46Ga carbon flux sunk into the oceanic crust by hydrothermal alteration is estimated to be comparable to the present-day total carbon flux by carbonate precipitation and carbon burial (Berner, 1989; 1991). This suggests that the carbonatization of oceanic crust by the seafloor hydrothermal activity played an important role as a CO_2 sink in the Early Archean atmosphere and ocean.

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Martian geochronology: Critical evaluation of the age data of the Martian meteorites

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Many chronological data have been reported for shergottites-nakhlites-Chassigny (SNC) meteorites as well as ALH 84001 until today. Since the Rb-Sr studies by Papanastassiou & Wasserburg (1974) and Gale et al. (1975), and the Sm-Nd and U-Pb work by Nakamura et al (1982) on Nakhla, the controversial discussion has been often repeated to evaluate the SNC age data obtained by different methods and/or from different laboratories. The difficulty seams to arise from the complex signatures recorded in the Martian meteorites which may have formed by interaction of initial magma with different magmas, fluid and/or crustal materials during the igneous processes followed by impact, metamorphic and weathering events through the Martian history. Then more sophisticated techniques such as leaching experiments are often introduced for separation of pure minerals and/or different genetic components in the meteorites. It is thus important to clarify what is the most reliable part of isotopic signatures for age determination. We present here results of our critical evaluation of age data reported for the Martian meteorites and discuss the implications for geologic histories of their parent planet Mars.

Our discussion will be focussed mainly on Rb-Sr and Sm-Nd (and partly U-Pb) systematics of shergottites-nakhlites. All the shergottites seems to have been severely shocked and thus the 150-170Ma or 327-350Ma ages obtained for these meteorites have been argued as to represent impact-melting or to igneous events (Nyquist et al., 1979; Jagoutz & Wänke, 1986; Jones, 1986; Morikawa et al., 2001). The 90Ma Rb-Sr age reported for mineral separate/leachate pairs of LEW 88156 is interpreted as an age of alteration proceses or shock metamorphism (Borg et al., 1998). The same analogy was also introduced to obtain alteration age by the Rb-Sr systematics of Yamato000593 nakhlite (Misawa et al., 2003). Our recent analyses suggest that age significance suggested for leachates and residue/leachate pairs needs further justification and that a few Sm-Nd isochron reported could be a two-component mixing line which has no age significance.

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