Archean CO_2 flux from ocean to oceanic crust; estimate from hydrothermal carbonatization at an Archean mid-ocean ridge

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It is well known that CO_2 level in the atmosphere-ocean has fluctuated through the Earth history, which should be caused by the secular change of CO_2 cycle in the surface of Earth (e.g. Sleep and Zahnle, 2001). Especially in the Archean, the CO_2 cycle might be governed mainly by mantle degassing and hydrothermal carbonatization of oceanic crust because of the absence of mature continents (e.g. Condie, 1998) and the lack of voluminous sedimentary carbonate (Veizer et al., 1989). Here we estimated CO_2 flux from ocean to oceanic crust at Archean mid-ocean ridge based on hydrothermal carbonatization of Archean mid-ocean ridge basalt in the Cleaverville area located in the north western part of the Pilbara Craton, Western Australia.

The stratigraphically upper part of the Cleaverville area is composed mainly of sedimentary rocks of bedded chert, banded iron formation, and clastic rocks of sandstone, mudstone and minor conglomerate (Cleaverville Formation), whereas the lower part comprises at lease 4 km-thick basaltic greenstones with volcanic structures of pillow lava, pillow breccia and sheeted flows (Regal Formation). Because of the low metamorphic grade that ranges from sub-greenschist to greenschist facies at low-pressure condition (Shibuya et al., 2007), the greenstones well preserve original igneous texture such as intersertal, intergranular and hyaloophitic textures.

The carbonate minerals occur primarily as matrix minerals that replace igneous phases such as glass, plagioclase and clinopyroxene, which suggest that the carbonate minerals were formed by the first hydration event, namely mid-ocean ridge hydrothermal alteration. The greenstones show various extent of carbonatization but volume concentration of the carbonate minerals in the greenstones decreases stratigraphically downward, which most likely reflect the geothermal gradient of ancient oceanic crust because carbonate minerals become unstable with increasing temperature in the basalt-H_2O-CO_2 system. Stable carbon and oxygen isotope ratios of carbonate minerals indicate that the CO_2 in hydrothermal fluid was derived mainly from seawater and that magmatic contribution of mantle-derived CO_2 was quite small. These results revealed that CO_2 flux from ocean to upper oceanic crust at Archean mid-ocean ridge was extremely higher than modern equivalent. It is therefore concluded that the Archean hydrothermal carbonatization of upper oceanic crust had a great potential to change CO_2 level in the atmosphere-ocean.