Carbon cycle dominated by subduction in Hadean to Archean Earth and ancient Mars

Soichi Omori[1]; Kouki Kitajima[2]

[1] Dept. of Earth and Planet., Tokyo Tech.; [2] Earth and Planetary Sci., T.I.T.

In the present Earth, the crustal Urey cycle of CO2 involving silicate weathering and carbonate deposition acts as a dominant climate buffer over a million year scale. On the other hand, it is revealed that immature continent and lack of massive carbonate-rock body are characteristics of the Archean era, therefore the Urey cycle could not work in the Early Earth. Geological studies in the Archean greenstone belt have shown that plate tectonics had already started at 3.8Ga, and the ocean floor hydrothermal alteration had formed much carbonate in oceanic crust before subduction [Ohta et al. 1996; Komiya et al. 1999; Nakamura 1999; Hayashi et al. 2000; Kitajima 2003; Shibuya 2003MS]. Therefore, the subduction of CO2 to the mantle, and volcanic degassing from mid-ocean ridges could be dominant fluxes in the Archean carbon cycle.

In this study, we investigated a mode of carbonation of oceanic metabasite in 3.5 Ga North Pole area, East Pilbara Greenstone Belt, Australia, and estimated the amount of CO2 fixed in the metabasite. Then, subduction flux of CO2 carried into the deep mantle was estimated by mineralogical modeling for the carbonated metabasite and peridotite using a geologically estimated thermal-structure model of the Archean subduction zone. In the North Pole area, carbonate-bearing mineral assemblage is restricted within upper 1 km from the bottom of bedded chert indicating ancient ocean floor. The highly carbonated sample indicates that the mean value of mode of carbonate mineral in the carbonated zone is roughly 30 vol%. During the subduction-zone metamorphism along the Archean subduction-zone geotherm, the oceanic crust releases CO2-bearing fluid to the wedge mantle, and carbonates are formed in the hanging-wall peridotite. The peridotite could contain about 6 wt% of CO2 as carbonate, and the carbonates are stable in the dragged down-going peridotite during subduction. The subduction flux of CO2 is estimated to ca. 1E12 kg/y. The rate of volcanic degassing can be assumed to be ca. 1E10 kg/y, therefore the balance of carbon flux means that subduction of carbonated crust reduced surface CO2 by ca. 1E12 kg/y. Compared to previous estimate for the Archean atmospheric CO2 level, the estimated rate of CO2 subtraction is enough for substantial change of the CO2 level with succession of the process over 1 billion years. A possible CO2 level at the formation of juvenile ocean is constrained by back tracking this subtraction process.

It is reported by infrared spectroscopic studies that the present surface of Mars lacks massive carbonate bodies. This observation is considered to be a negative evidence for the former wet and warm Mars, because precipitation of carbonates in ancient ocean or other small water bodies would be the evidence, if the hypotheses for a ancient greenhouse by thick carbon dioxide atmosphere and water on Mars are true. However, taking account of a similarity of the Archean Earth and the present Mars, i.e. the lack of massive carbonate bodies, it is plausible that the subduction of carbonated oceanic crust had removed much surface CO2 in the ancient Mars before Urey cycle had been started. This hypothesis gives a constraint for the evolutional stage of Mars compared to Earth.