Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS21-09 Room:201A Time:May 22 09:30-09:45

Newly proposed formation process of terrestrial ocean: Application to the early evolution of Earth and Venus

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Many possible sources of water on the Earth have been proposed so far (Matsui & Abe, 1986; Gomes et al., 2005; Ikoma & Genda, 2006). Recently, the snow line is considered to passes the heliocentric distance of 1 AU during the planet formation stage (Oka et al., 2011). How much amount of water accumulated into terrestrial planets should be a fundamental question. From the viewpoint of origin and evolution of life, it is also considered to be necessary to accumulate (or escape) of proper amount of water on the early Earth.

There is a paradox of redox state of early Earth. The chemical analysis based on the incorporation of cerium into zircon crystals showed that the mantle reached its present-day oxidation state (FMQ) about 4,350 Myr ago (Trail et al., 2011). On the other hand, the isotopic analysis of sulfur requires the Earth's atmosphere to be maintained reductive at least 2,500 Myr ago (Farquhar et al. 2000). For Venus, there is a problem about the escape of ocean. The hydrogen would escape from the Venus by hydrodynamic escape while the oxygen would be left behind even though thermal/non-thermal escape and oxidation of surface are considered. The oxygen inevitably concentrates in the Venusian atmosphere (Sasaki & Abe, 2008).

In this paper, we propose a new scenario for loss and re-formation of ocean based on Genda et al. (in prep.) as below: (1) Accretion of Fe into primitive ocean as late veneer makes the ocean lose and generates hydrogen atmosphere. (2) Hydrodynamic escape of the hydrogen atmosphere and re-formation of ocean by adding the volcanic gas into the atmosphere occur. (3) One ocean mass is generated taking about one billion years. (4) Coexistence of oxidative mantle and reductive atmosphere on early Earth is realized. (5) Two times ocean loss produces CO_2-dominated Venusian atmosphere.

Our new scenario present an exhaustive framework of early evolution of terrestrial planets especially for the formation of ocean on the Earth. The scenario would be able to applied to extrasolar terrestrial planets as well.

Keywords: formation of ocean, early evolution of planets, Earth, Venus, atmospheric escape, redox