EVOLUTION OF AN IMPACT-GENERATED H_2O-CO_2 ATMOSPHERE AND FORMATION OF A HOT PROTO-OCEAN ON EARTH; Yutaka Abe and Takafumi Matsui, Geophysical Institute, Faculty of Science, University of Tokyo Bunkyo-ku, Tokyo 113, JAPAN.

Due to the impact degassing during accretion a hot H_2O-rich proto-atmosphere was possibly formed on the growing Earth(1,2). At the end of accretion the total mass of H_2O in an impact-induced atmosphere has been shown to be about 10^{21}kg, which is very close to the present mass of the hydrosphere of the Earth (about $1.4x10^{21}$kg)(2). In this paper, we investigate the evolution of an impact-generated H_2O-CO_2 atmosphere and formation of a proto-ocean at the final stage of accretion by using one-dimensional radiative-convective atmosphere model.

Since the atmospheric pressure and temperature is high (200bar and 400~1500K), which is close to the critical point of water vapor (200bar, 647K), we need to take into account non-ideal behaviors of gases. Thus we use the Peng and Robinson's equation of state(3). We also take into account the following effects: 1. condensation of H_2O, 2. wavelength-, pressure-, temperature- and pathlength-dependences of the absorption coefficient, 3. greenhouse effect, 4. Rayleigh scattering at short wavelength, and 5. geometrical effect (sphericity) of the atmosphere on the radiative transfer. We assume that the temperature gradient in a convective layer is equal to the adiabatic temperature gradient. The effect of cloud on the radiative transfer is neglected.

Based on the previous results(2) and the present CO_2 inventory in the near-surface layers of the Earth(4), the total H_2O and CO_2 masses in the atmosphere and oceans are fixed to be about 10^{21}kg and about $2.5x10^{20}$kg, respectively. The atmospheric structure is then determined by the solar flux density, S_0, and heat flux density given at the base of the atmosphere, F_0. F_0 may be considered as an impact energy flux during accretion, which decreases from about $300W/m^2$ to $0W/m^2$ at the final stage of accretion. The solar radiation is assumed to be about 30% lower than the present value(5).

Figure 1 shows the temperature profile of the atmosphere for various values of F_0. When $F_0>100W/m^2$, the lower atmosphere is dry (no condensation of H_2O occurs) and no ocean could be formed. Vertical thickness of the dry-convective layer decreases with decreasing F_0. The dry convective layer disappears at $F_0=100W/m^2$ and a proto-ocean is formed. Figure 2 shows the variation of the surface temperature, total H_2O mass in the atmosphere (excluding the mass of the ocean), and H_2O mixing ratio at the cold trap as a function of F_0.

We can summarize an early evolution

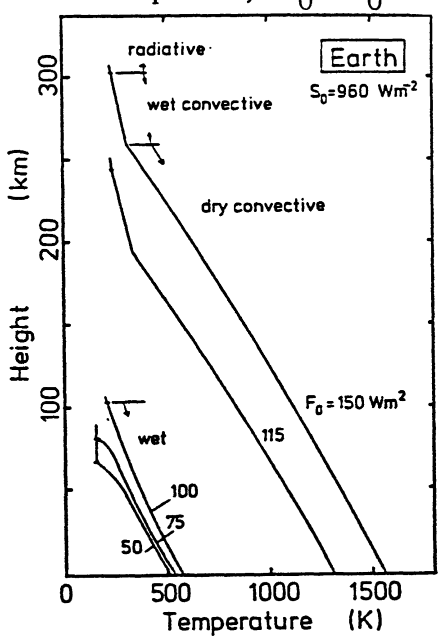

Figure 1.

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of the proto-atmosphere on the Earth as follows:
1. The surface temperature suddenly decreases when the impact energy flux decreases to about $100 W/m^2$, and a proto-ocean is formed on the growing Earth. This result does not change, even if we take into account the effect of cloud. This is because the cloud effect even lowers the surface temperature(6). However, the critical F_0 value necessary to cause formation of a proto-ocean may depend on the cloudiness.
2. Being accompanied with the proto-ocean formation, H_2O concentration in the upper atmosphere decreases (Figure 2), which prevents the photo-dissociation of H_2O in the atmosphere and subsequent escape of hydrogen.
3. The surface temperature after the end of accretion ($F_0 = 0 W/m^2$) is estimated to be about 400K. This result is consistent with the estimated temperature of an archaean ocean based on oxygen isotope data of 3.8×10^9 years old chert(7).
4. The surface temperature goes down gradually with decreasing CO_2 in the atmosphere due to geochemical reaction in a proto-ocean. This is because the lower atmosphere is saturated by water vapor and the surface temperature varies along the adiabat with changing the mass of CO_2 in the atmosphere. Hence, without any ad hoc assumption, we could show that an impact-generated atmosphere evolves to the present atmosphere. The freezing of the proto-Earth(8) is automatically avoided as a consequence of the formation of an impact-generated atmosphere during accretion.

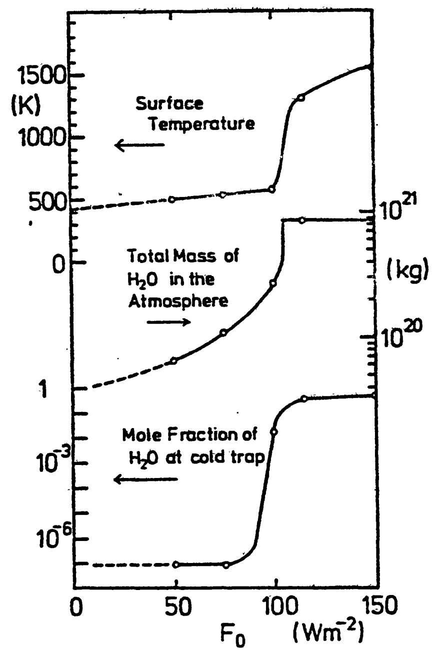

Figure 2.

If we apply this model to a proto-venusian atmosphere, the mass of H_2O in an impact-generated atmosphere is shown to be smaller than that of the Earth. This is different from the previous result.(9) No water ocean may be formed on Venus because of its high solar flux and greenhouse effect.

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