THE FORMATION OF AN IMPACT-GENERATED H_2O ATMOSPHERE AND ITS IMPLICATIONS FOR THE EARLY THERMAL HISTORY OF THE EARTH.

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Because the impact velocity of planetesimals exceeded probably some critical value, an impact-induced H_2O atmosphere may have been formed on the Earth during its formation (Arrhenius et al., 1974; Benlow and Meadows, 1977; Jakosky and Ahrens, 1979; Lange and Ahrens, 1982). The evolution of such an impact-generated atmosphere was studied by Jakosky and Ahrens (1979) and Lange and Ahrens (1982). Because they calculated the surface temperature using basically the accretion model of Weidenschilling (1976) who calculated the thermal evolution of the Earth resulting from accretion of particulate matters, their studies are incomplete to understand the evolution of such an atmosphere. As is well-known, H_2O gas absorbs most of the infrared radiation. Therefore, once an H_2O atmosphere was formed, the surface temperature increased due to the blanketing effect of the H_2O atmosphere.

Considering the impact energy distribution at the surface as calculated by Kaula (1979) and the impact degassing process as proposed by Lange and Ahrens (1982), and assuming the atmospheric structure radiatively equilibrated, we can calculate the thermal regime of the Earth during its formation. For simplicity the mass of the impacting planetesimal is assumed to be constant (10^{15} kg). The absorption coefficient of the H_2O gas is also assumed to be constant (0.001 m^2/kg), so that the optical depth is a function of the amount of H_2O atmosphere generated. The initial temperature profiles of two simple models with accretion time of 5×10^7 years are shown in Fig. 1. The dotted lines are temperature profiles without the H_2O atmosphere and the solid lines are for the H_2O atmosphere. As is shown in these figures, the surface temperature increases rapidly once the impact dehydration initiates. The numerals attached to the solid lines indicate the H_2O content. The total amount of H_2O of the Earth is more than $\sim 10^{21}$ kg and hence the H_2O content should be larger than 0.01%. The difference in density of planetesimals causes the difference in peak pressure generated and hence the density controls the radius over which the impact dehydration initiates.

One of the most important implications for the internal constitution is that the Earth cannot retain significant amount of H_2O within the mantle. In addition, dissociation of H_2O into H and O, and the escape of H from the exosphere may produce a large amount of free oxygen, which is possibly consumed at the surface by the oxidization of Fe. Therefore, the oxidation state of the mantle may have been established during the accretion stage. Although we have not so far taken into account the hydration reaction, that is, a sort of serpentinization process which is one of the most important sinks of the generated H_2O atmosphere, this may not significantly influence the above results, because such a hydration reactions will occur only at the uppermost layer.

References

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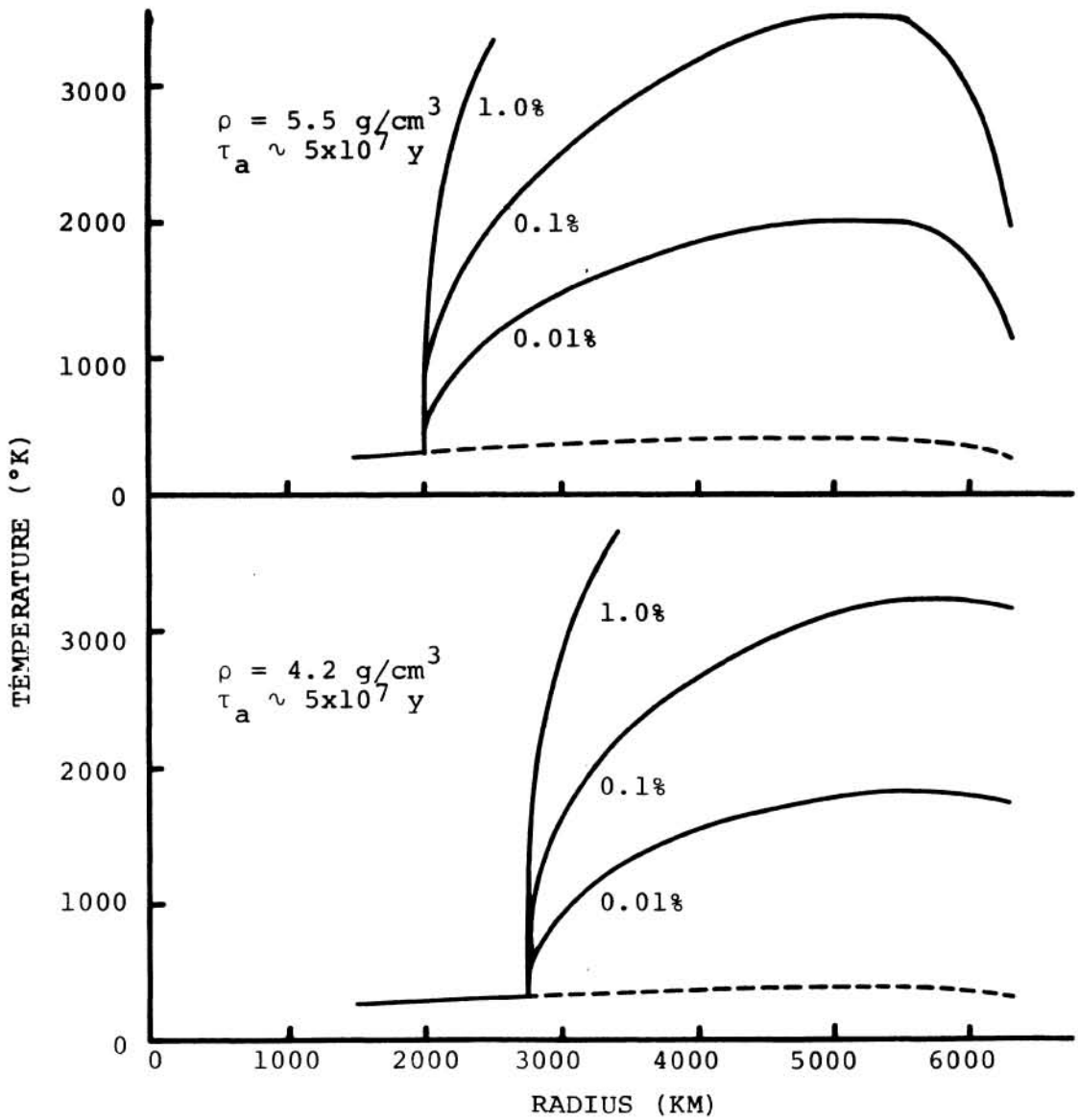

Fig. 1. Early thermal profiles for the Earth