THE FORMATION OF AN IMPACT-GENERATED H₂O 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 H₂O 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, H₂O gas absorbs most of the infrared radiation. Therefore, once an H₂O atmosphere was formed, the surface temperature increased due to the blanketing effect of the H₂O 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 (10⁻⁷ kg). The absorption coefficient of the H₂O gas is also assumed to be constant (0.001 m²/kg), so that the optical depth is a function of the amount of H₂O atmosphere generated. The initial temperature profiles of two simple models with accretion time of 5x10⁸ years are shown in Fig. 1. The dotted lines are temperature profiles without the H₂O atmosphere and the solid lines are for the H₂O 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 H₂O content. The total amount of H₂O of the Earth is more than 10¹³ kg and hence the H₂O 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 H₂O within the mantle. In addition, dissociation of H₂O 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 H₂O atmosphere, this may not significantly influence the above results, because such a hydration reactions will occur only at the uppermost layer.

References

Fig. 1. Early thermal profiles for the Earth