EARLY THERMAL EVOLUTION OF HED PARENT BODY. H. Senshu, *Institute for Frontier Research on Earth Evolution, Japan Marine Science and Technology Center, 2-15 Natsushima-cho Yokosuka 237-0061, JAPAN (senshu@jamstec.go.jp)*, T. Matsui, *Department of Complexity Science and Engineering, Graduate School of Frontier Science, The University of Tokyo, 7-3-1 Hongo Bunkyo-ku Tokyo 113-0033, JAPAN*.

Background: Asteroid 4 Vesta has been considered as a candidate of the HED meteorite (Howardite, Eucrite and Diogenite) parent body based on their resemblance in reflectance spectrum (e.g., [1]). Many mineralogical studies about HED meteorites suggested that Vesta was differentiated and its mantle had been kept hot for ~100 Ma (e.g., [2], [3], [4]). Although Ghosh and McSween [5] studied numerically the thermal evolution of Vesta, they assumed instantaneous accretion and also instantaneous core and crust formations. Then it is not clear how Vesta differentiated. In this study, we consider an early thermal evolution of HED parent body by taking into account the effects of heating by short lived radio isotopes, sintering, and accretional heating and cooling by planetesimal impacts ([6], [7]).

We consider that the evolution of HED parent body is divided into two stages: the accretion and the following stages. At the accretion stage the asteroid grows by accretion of planetesimals. The duration of this stage, τ_{acc}, is assumed to be about 10^6 years. If Jupiter and Saturn formed during the accretion stage, kinetic energy of planetesimals is excited. When planetesimals have enough impact energy, a growing HED parent body would be broken and reassembled. At the latter stage of asteroid evolution, planetesimal accretion ceased but the heating by short lived radio isotopes has been still efficient during this stage.

We assume that HED parent body grows at the constant mass rate from initial radius 50km to the final mass M_f. Surface of the body is heated or cooled by planetesimal impacts [7]. The mass of the planetesimal m_p is assumed to be constant during accretion. When an accretion of planetesimal occurs, not only the mass but also internal energy of the planetesimal is added to a growing HED parent body. Thus we also need to calculate thermal evolution of planetesimals simultaneously. The impact energy of planetesimal is calculated from the escape velocity, v_{esc}, and random velocity, v_∞. We consider that a growing HED parent body was broken if the specific impact energy exceeded 1000J/kg [8].

We took into account the effect of heating by decay of ^{26}Al and ^{60}Fe. The isotopic ratio of Al and Fe at the formation time of CAI are $^{26}\mathrm{Al}/^{27}\mathrm{Al} = 5 \times 10^{-5}$ and $^{60}\mathrm{Fe}/^{56}\mathrm{Fe} = 4 \times 10^{-7}$, respectively ([9], [10]). The starting time of accretion, τ_0, is estimated as 10^6 years after CAI formation [11].

Numerical Results and Discussions: We performed

Table 1: parameters used in figures

τ_0	10^6 years	starting time of accretion after CAI formation
τ_{acc}	10^6 years	duration of accretion
a	2.36 AU	orbital radius of HED parent body
m_p	10^{15} kg	mass of planetesimals
M_f	2.7×10^{20}kg	final mass of HED parent body
v_∞	0m/s *or* 1000m/s	random velocity of planetesimals

numerous simulations with various parameter set. Here we show a typical case of the result with the parameters shown in table 1.

Figure 1 shows the thermal evolution of planetesimal. The temperature of inner part of planetesimal increases due to decay of ^{26}Al and ^{60}Fe. However, because of its small size and sintering effect, the heat was transferred conductively to the surface and was lost efficiently to the space by radiation. About 3×10^5 years after τ_0, the maximum temperature of 450K was achieved.

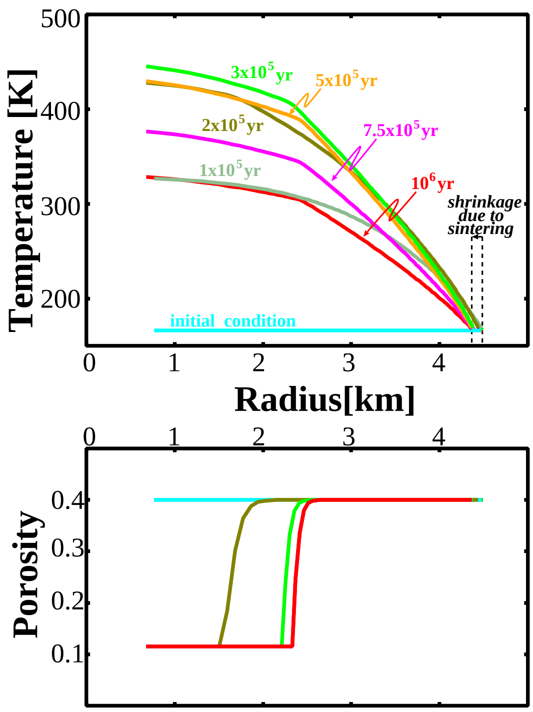

Figure 1: Thermal evolution of planetesimal with the mass of 10^{15}kg (upper figure). The interior of planetesimal was heated due to decay of short lived radioisotopes. Porosity of the interior of the planetesimal (lower figure). As the interior heated, sintering took place and pores shrunk from 0.4 to 0.1.

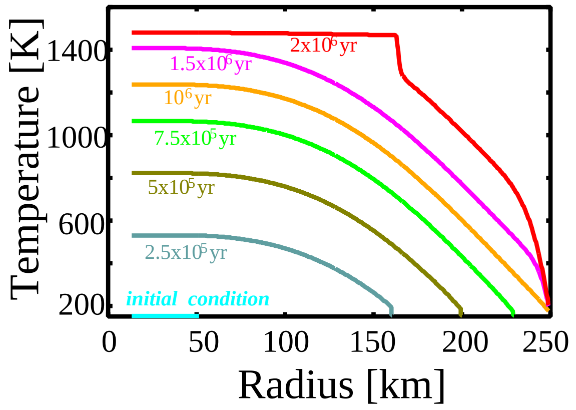

Figure 2: Thermal structure of a growing HED parent body. Numerals attached on each curve represent the time after τ_0. Accretion is assumed to stop at 10^6 years (orange curve).

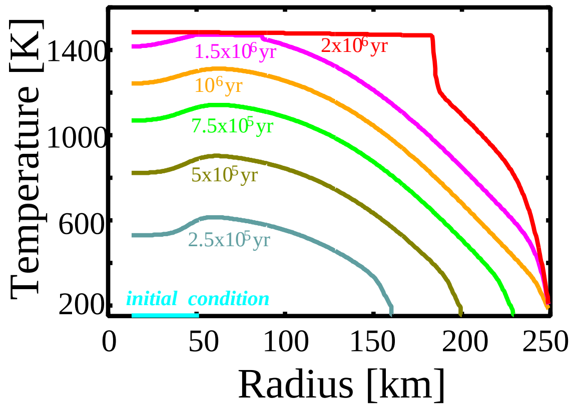

Figure 3: Thermal structure of a growing HED parent body for the case of $v_\infty = 1000$m/s. Numerals attached on each curve represent the time after τ_0. Accretion is assumed to stop at 10^6 years (orange curve).

Within the first 10^6 years, sintering took place at the inner part of the planetesimal and the radius of the planetesimal shrunk by 0.1km.

Figure 2 shows the early thermal evolution of HED parent body during the accretion and following stages. During the accretion stage (10^6 years after τ_0) the central part was heated by decay of short lived radioisotopes while the surface was kept cold. Thus the temperature decreases with distance from the center of the asteroid. Such a thermal structure is different from the previous study [5]. At the end of accretion the temperature of the central part of the asteroid reached 1200K. It took about another 10^6 years for the central part to reach the melting temperature of silicate. Melting of silicate started from the center and the melting region extended toward the outer part.

To study the effect of impact velocity on thermal evolution we show in figure 3 the early thermal evolution of HED parent body for the case of $v_\infty = 1000$m/s. The temperature of central part is resemble to that for the previous case. This is because the impact of planetesimals repeatedly broke the growing HED parent body until the size of a growing body became larger than a thershold size. On the other hand the temperature of outer part was slightly higher than that for the previous case due to the impact heating. It is to be noted that for the case of larger planetesimal, the thershold size becomes larger and thus the interior of a growing body cannot be kept hot [12]. As a result, the interior of HED parent body remain un-melted. Thus, if the planetesimals grew by mutual accretion (orderly growth mode), melting of silicate would not take place within the HED parent body.

Summary: We conducted a numerical calculation of early thermal history of HED parent body by taking into account the thermal evolution of planetesimals. Our result shows that the interior of HED parent body could not melt during accretion without heat source in addition to short lived radioisotopes and impact heating. Melting of silicate took place about 10^6 years after the end of accretion. Increase in random velocity excited by formation of giant planets seldom affected thermal structure if the growth of planetesimals could not be taken into account.

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