THERMAL HISTORY OF 6 HEBE AS THE H-CHONDRITE PARENT BODY. Glen Akridge, Paul H. Benoit, and Derek W.G. Sears. Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, Arkansas 72701, USA. E-mail: dakridge@comp.uark.edu

We have modeled the thermal history of asteroid 6 Hebe using a finite difference approximation for the radial heat conduction equation. Unlike previous work our computer code accounts for regolith/megaregolith insulation effects for both "instantaneous" accretion as well as "slow" accretion (1-50 m/yr). Thermal conductivity, diffusivity, heat capacity, porosity, and bulk density are all functions of radius and temperature. The heat source used is homogeneously distributed ^{26}Al and other long-lived nuclides. Impact heating is not considered. ^{40}K, ^{232}Th, ^{235}U, and ^{238}U are insignificant sources of heat for asteroid-sized bodies. The model is constrained primarily by the radius of Hebe, maximum temperatures for H-chondrite petrologic types, and observed cooling rates. Assuming instantaneous accretion and initial ^{26}Al/^{27}Al of 6 x 10^{-6} results in predicted cooling rates for material buried at 10 km below the surface of ~10 K/Ma for a body with a 5 km deep regolith/megaregolith exterior and ~50 K/Ma for a solid rock body. The model also predicts peak temperatures at the base of a 2.5 km deep regolith to be ~1000 K equivalent to metamorphic type 5 H-chondrites, whereas, type 6 H-chondrites may sample sub-regolith regions with peak temperatures ~1250 K.

Introduction: There have been many attempts at modeling the thermal history of an ordinary chondrite parent body [e.g. 1-4]. Many of these models do not account for regolith insulation, sintering, or accretion over 10^4-10^5 years. To address these problems we have evaluated the heat conduction equation for a spherically symmetric body using a finite difference method of solution [5,6]. Gaffey [7] has suggested that asteroid 6 Hebe may be the parent body of H chondrites due to its spectral reflectivity properties and location near the orbital resonances of Jupiter and Saturn. Thus, we have used the radius of Hebe (R=93 km) as a constraint in our numerical models.

Thermal Model: The model allows for both "instantaneous" accretion and "slow" accretion over 10^5 years. The instantaneous accretion model is similar to other static models [1,3,4], but allows for the existence of a regolith and megaregolith. The slow accretionary model allows for the addition of material to an initial 5 or 10 km body at rates of 1-50 m/yr. The results shown below, however, are from the instantaneous accretion model. Hebe is modeled with three distinct regions: an outer regolith 2.5 km deep, an underlying megaregolith 2.5 km thick, and an inner core of unmelted solid rock 95 km thick. Thermal conductivity and diffusivity are functions of radius and temperature and are modeled using proxy H chondrites whose thermal diffusivity has been measured [8]. Porosity differences [9] in each region are estimated using the method of Yomogida and Matsui [10]. Hebe is modeled using the heat capacity equation for olivine [11]. Initial temperature is assumed to be 200 K and the surface is fixed at this temperature as a radiation boundary condition.

Asteroid Thermal Profile: Numerous models have attempted to predict the original burial depths of H-chondrites using ^{26}Al as the heat source. These models usually result in an onion-skin structure with the highly metamorphosed type 6's comprising the innermost regions and the least metamorphosed type 3's residing near the surface. Bennett and McSween [4] found that for a compacted model the type 6 region comprises about 72 vol% of the body. The lesser metamorphosed petrologic types comprise the remaining outer 28 vol%. The addition of a regolith in our model essentially moves the boundaries separating each petrologic type nearer to the surface (Table 1). The regolith blankets the rocky material underneath it and results in a high (~1250 K) peak temperature that is uniform throughout the interior. Our model predicts a type 6 region comprising about 91 vol% of the H-chondrite parent body. Thus, types 3-5 can be made in a regolith (Figure 1) and may not represent the body as a whole. Deepening the regolith can enlarge the type 6 region into the base of the regolith. This may be significant since solar gas bearing H-chondrites consist of all petrologic types and are believed to have spent time on the surface of the parent body [12]. Impact gardening of the regolith could bring highly metamorphosed material to the surface for exposure to solar wind. The H-chondrite flux to earth is dominated by an ~8 Ma cosmic ray exposure age peak in which all the petrologic types are represented [12]. An impact into a regolith containing material of mixed petrologic type could explain the metamorphic diversity of H-chondrites resulting from a single collisional event.

Regolith Effects: The insulation effects of an asteroidal regolith have been pointed out previously [13]. The regolith serves primarily to slow the cooling rate for the interior and keeps the interior at a remarkably uniform temperature. Figure 2 is a comparison of two asteroid structural models. Interior peak temperatures are similar but the addition of a regolith slows the cooling rate dramatically. Cooling rates at the center of Hebe with a regolith exterior would be ~5 K/Ma. Near the surface, regolith effects are more even more important. The addition of a regolith lowers the cooling rate at 10 km below the surface from 50 K/Ma to 10 K/Ma. The peak temperature at 10 km deep is much lower for a solid rock model due to the greater thermal conductivity of non-porous rock.

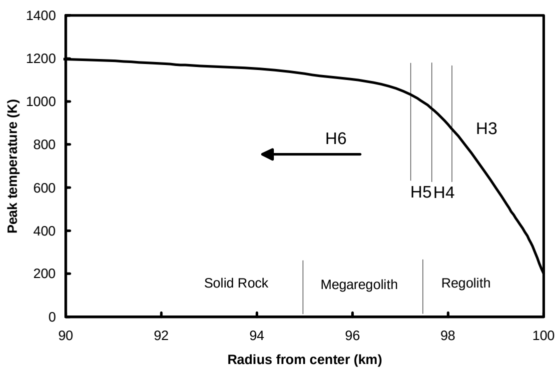

Figure 1. Peak temperature profile for a Hebe sized body (R=100 km) showing the modeled positions of the regolith and megaregolith regions. Assuming an initial onion skin model burial depths of each H-chondrite petrologic type can be predicted.

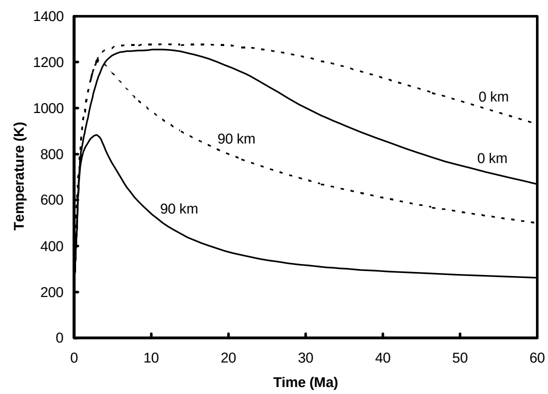

Figure 2. Temperature variations between two asteroid structural models. Solid lines represent a 100 km radius asteroid modeled as solid rock throughout, whereas dashed lines represent a body with a solid rock interior overlain with a 2.5 km megaregolith and 2.5 km regolith. Positions refer to distance from center of body.

Cooling Rates: Metallographic and fission track data from chondrites have been used to constrain thermal models. Previous models without regolith insulation required deep burial of petrologic types 4-6 to match the observed cooling rate trends found in H-chondrites. Taylor *et al.* [14] suggested that the cooling rates of H6 required burial depths of >40 km on a body of radius >50 km. Cooling rates predicted by our model match more closely the observed values than previous attempts at modeling an ordinary chondrite parent body [3,4] and result in very shallow burial depths for H-chondrites in an insulating regolith.

Type	model radius	volume %	present model (870-670 K)	metallographic[15,16] (870-670 K)	fission track[16] (870-670 K)
H3	98-100	5.9			
H4	97.5-98	1.4	21-28	10-150	25-30
H5	97-97.5	1.4	17-21	15-50	15
H6	0-97	91.3	5-17	5-10	5-9

Table 1. Comparison of observed metallographic and fission track cooling rates for H-chondrites and prediction by present model.

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