PLANETARY DIFFERENTIATION OF PLANETESIMALS DUE TO RADIOACTIVE HEATING. G. Gupta and S. Sahijpal, Department of Physics, Panjab University, Chandigarh. (sandeep@pu.ac.in)

Introduction: ^{26}Al and ^{60}Fe were probably the major heat sources for the melting and the planetary differentiation of planetesimals in the early solar system [1-7]. We are making efforts to numerically simulate the various proposed planetary differentiation scenarios [5-7]. In our recent work [7], we have developed detailed thermal models for the planetary differentiation of planetesimals undergoing accretion growth for a wide range of planetesimal sizes; 20-270 km. The planetesimals were accreted as unconsolidated bodies [4] over the duration of 0.001—1 Ma (Mega annum). The planetesimals experienced sintering at ~700 K [4], and were consolidated as compact bodies of the final radii 20, 50, 100 and 270 km. For the first time the gradual growth of the Fe-FeS core during the segregation of Fe-FeS has been executed numerically according to the thermal evolution of the planetesimals. The extrusion of the ^{26}Al-rich basaltic melt to form a crust has been also parametrically modeled for the first time. The dependence of the growth rate of the Fe-FeS core and the extent of silicate melting on the onset time of the planetesimal accretion, the accretion duration, the final size of the body and the $(^{60}Fe/^{56}Fe)_{initial}$ ratio has been comprehensively analyzed [7].

Previous models: Distinct scenarios have been proposed for the planetary differentiation [1,8-9]. These include the segregation of the $(Fe\text{-}Ni)_{metal}$-FeS melt from the bulk chondrite in the temperature range of 1450-1850 K once the silicate melt fraction exceeds ~0.4 [8-9]. The alternative scenario involves the initiation of the melt segregation at comparatively lower temperatures of 1213-1233 K before significant melting of the bulk chondrite [1]. In our previous work [7], we have numerically simulated two proposed planetary differentiation scenarios. These scenarios differ in the temporal sequence of the core-mantle differentiation with respect to silicate melting. In the set of simulations (*marked A*) [7], the initiation of the segregation of $(Fe\text{-}Ni)_{metal}$-FeS melt occurred at 1213-1233 K, prior to silicate melting. This was followed by silicate melting at higher temperatures and the extrusion of the basaltic melt to the planetesimal surface. In the alternative set of simulations (*marked B*), the initiation of the segregation of $(Fe\text{-}Ni)_{metal}$-FeS melt commences once the silicate melt fraction exceeds ~0.4. Subsequent to silicate melting the basaltic melt was not removed from its source region in this set of simulations.

Present work: We are now presenting preliminary results for the planetary differentiation scenario (*marked C*), where the extrusion of the basaltic melt occurs subsequent to 0.2 fraction silicate melting. This is followed by the the core-mantle differentiation at 0.4 fraction silicate melting. This scenario will result in the formation of crust prior to core [1].

The accretion of the planetesimals as unconsolidated bodies with H-chondrite composition was considered over the duration of 0.001-1 Ma. Subsequent to the sintering of the bodies at ~700 K, the planetesimals acquired their final radii of 20, 50, 100, 270 km for the different set of simulations [7]. Identical procedure was followed for solving the heat conduction differential equation [5-7]. The melting of Fe-FeS and silicate were carried out at 1213-1233 K and 1450-1850 K, respectively. The molten Fe-FeS was retained at its melt region till 0.4 fraction of silicate melting. The basaltic melt pockets generated at different regions of the planetasimals were moved upwards at 0.2 fraction of silicate melting following our previous criteria for the ascend of the basaltic melt [5-7]. The core-mantle differentiation was triggered at 0.4 fraction of silicate melting. In order to imitate thermal convection in the molten Fe-FeS core and the mantle subsequent to 0.5 fraction silicate melting [4], a three orders of high thermal diffusivity (5×10^{-3} m^2 s^{-1}) was incorporated in the model. The diffusivity was gradually increased over the range of 1680-1800 K by using a 3 parameter Sigmoid function.

The thermal profiles and the growth of the Fe-FeS core of the planetesimals at different epochs during the accretion and planetary differentiation for a representative set of simulations are presented in fig. 1. In the case of the simulations with $t_{Onset} < 2$ Ma, the entire planetesimal, including their surface, naturally experienced sintering due to the onset of convection that effectively transfers heat to the surface. In contrast to the simulation 4, the surface of the planetesimal in simulation 5 was forced sintered at the time of the extrusion of the basaltic melt to the surface. In the case of simulation 6, the convection was not incorporated in the model. The simulations 4-6 present the dependence of the thermal processing of the planetesimal on the choice of the opted criteria for the core/mantle convections and the surface sintering. Apart from these debatable criteria, the sharp variations in the thermal profiles subsequent to the onset of the convection require considerations in the future works.

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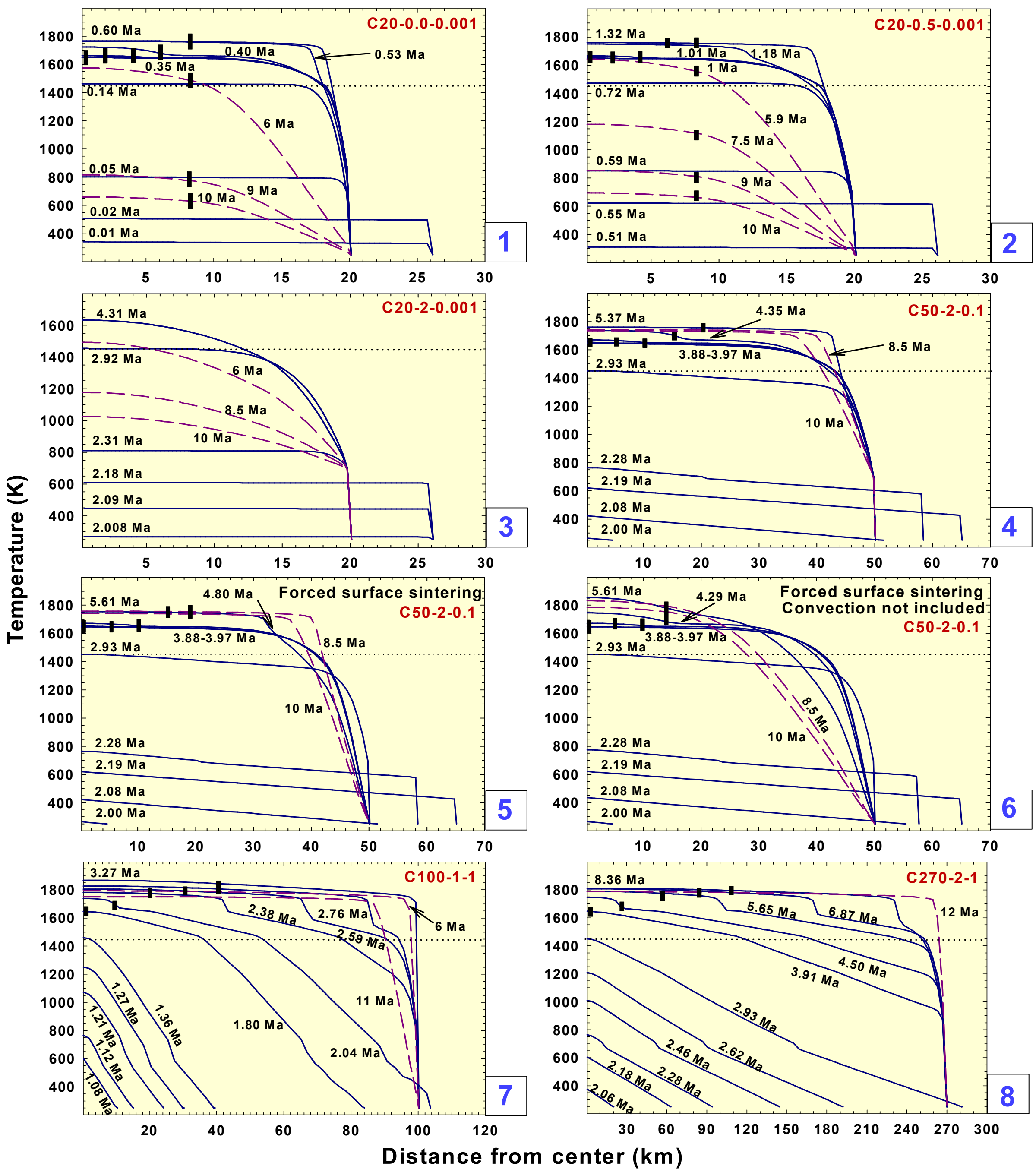

Figure 1. Thermal profiles of the planetesimals at different epochs during the accretion and planetary differentiation. All time spans are marked with respect to the initiation of the formation of CAIs. The thick vertical bars represent the core size at a given time for a specific thermal profile(s). The horizontal dotted line represents the solidus temperature of silicate (1450 K). The thermal profiles subsequent to the cooling of the planetesimals are represented by dashed curves for an easier view. The simulations are titled according the choice of the various parameters. These parameters are separated by hyphens. In order these parameters are; i) the simulation type (C) and the radius of the planetesimals subsequent to complete sintering, ii) the onset time, t_{Onset}(Ma; Mega annum) to initiate the formation of a planetesimal after the formation of the CAIs with the canonical value of $(^{26}Al/^{27}Al)_{initial}$ =5×10^{-5}, iii) the accretion duration, $t_{Duration}$(Ma), of the planetesimal. A value of 2×10^{-6} was assumed for the $^{60}Fe/^{56}Fe$ ratio at the time of formation of the CAIs with the canonical value of $(^{26}Al/^{27}Al)_{initial}$. Except for the simulations 6, the thermal convection was included in all the simulations. In the case of simulations 5 & 6, the surface of the planetesimal experienced complete sintering subsequent to the extrusion of the basaltic melt to the surface, whereas in the remaining cases the planetesimals natuarlly acquired complete sintering for t_{Onset} < 2 Ma due to onset of thermal convection.