

FURTHER MODELING OF LIQUID WATER ON CM PARENT BODIES. B. A. Cohen¹ and R. F. Coker², Department of Planetary Sciences, 1629 E. University Blvd., The University of Arizona, Tucson AZ 85721 (bcohen@lpl.arizona.edu), ²Department of Physics and Astronomy, University of Leeds, Leeds LS2 9JT UK.

Introduction: We have continued our development of an asteroid thermal model [1, 2] with the goal of determining constraints on the duration and temperature of liquid water in a 100-km diameter potential parent body of CM-type meteorites. Our model is a one-dimensional solution to the heat-flow equation with a suite of long- and short-lived radionuclides as the heat source. The materials are forsterite, enstatite, inert rock, and water in the solid, liquid, and vapor phases. We include serpentinization, dehydration, vapor diffusion, gas fracturing, and convection.

Recent runs: Our standard model parameters are summarized in Table 1. These parameters have been explored previously [1, 2]. For the set of model runs reported here, we have updated the expressions for vapor pressure, thermal conductivity, viscosity, heat capacity, and density for the different chemical components. We have also run one model including ⁶⁰Fe as an early heat source [3], which adds approximately 25% to the initial heat budget. Another new run has a nebula that is twice as warm as the standard model (i.e. initially 160K) surrounding the asteroid at the time of accretion [4]. These new run parameters are summarized in Table 2.

Results: The new runs so far result in major changes in accretion time, peak temperatures, and the location of zones that match CM characteristics. The duration and temperature of the liquid water phase are also affected.

Accretion time. The changes in heat capacity and thermal conductivity of ice as well as the additional ⁶⁰Fe heat source pushes the latest possible time of formation to >1 Ma later than previous results suggest [1]. The asteroid must accrete no later than ~4.5 Ma after nucleosynthesis in a cold nebula to produce liquid water *in situ*. For a body accreting in a warmer nebula, the time of accretion can be delayed even further to ~5 Ma.

Peak temperatures. In every case where liquid water is produced, a thermal runaway ensues due to the exothermic serpentinization reaction, producing peak temperatures in the center of the asteroid in excess of 400K. The overall thermal profile does not change much simply due to updating the physical expressions within the model (Figure 1). Additionally, the final fractional composition of the asteroid does not change substantively by changing these expressions. However, as seen in Figure 2, a plot of the temperatures at the center of the asteroid versus time, the central peak temperature increases from 375K to 425K from run 1 to 2. As can be seen by comparing run 3 to run 2 in Figure 2, the effect of ⁶⁰Fe is to increase the peak central temperature, as expected. This temperature ex-

ceeds 623K, the serpentine dehydration temperature, and would likely destroy any hydrated mineral suite there. The warmer outside nebula in run 4 prevents the asteroid from losing heat as rapidly, and this effect causes the central temperature to rise even further above 600K.

Duration of liquid water. The liquid water not consumed by serpentinization diffuses outwards at a rate dependent on the temperature profile and the bulk permeability. Liquid water can persist for 10⁵-10⁶ years. Figure 3 shows the duration of liquid water versus radius for the different model runs. More heat (from ⁶⁰Fe or a warm nebula) decreases the time liquid water persists in the central zones because it is rapidly vaporized and diffused out. However, the hotter central zones also push liquid water further outwards, resulting in hydration regions closer to the surface than was previously possible. In fact, with an initial 200K nebula, the zone of hydration can effectively reach the surface of the asteroid.

Temperature of liquid water. When the central temperature rises, as in all the new runs, liquid water there (while it is overpressured) gets hotter (>400K) before diffusing away. There are still zones where the liquid water can stay cool (below 300K) but they are further from the center of the asteroid.

Comparison with CM meteorites characteristics: The inclusion of updated physical expressions, the decay of ⁶⁰Fe, and a warmer nebula all work to increase the peak temperatures seen by the asteroid and the water phase within it to well beyond the apparent constraints set by CM meteorites ($\leq 300\text{K}$ water for $\leq 10^4$ years [5]). On the other hand, the zones of the asteroid which do see only liquid water at low temperatures (the CM-matching zones) become closer to the surface and probably wider.

Conclusions: Our model updates do not succeed at creating an entire 100-km body with CM meteorite characteristics. However, the areas of the asteroid that match these characteristics are close to the surface and able to be sampled by impacts.

References: [1] Cohen, B.A. and Coker, R.F. (2000) *Icarus*, in press. [2] Cohen, B.A. and Coker, R.F. (1999) *Meteoritics & Planet. Sci.* 34, A26. [3] Shukolyukov, A. and Lugmair, G.W. (1993) *Science* 259, 1138-1142. [4] Wood, J.A. and Morfill, G.E. (1988) in *Meteorites and the Early Solar System*, University of Arizona Press, 329-347. [5] Zolensky, M. and McSween, H.Y. (1988) in *Meteorites and the Early Solar System*, University of Arizona Press, 114-143.

Table 1: Standard model parameters

Accretion begins	3 Ma
Heliocentric distance	3 AU
Permeability	10^{-12} m^2
Volume fraction of ice accreted	30%
Initial ambient nebula temperature	80K

Table 2: New Model Runs





Model	Legend	Changes
1		None (standard model)
2		Updated physical expressions
3		Updated physical expressions and addition of ^{60}Fe
4		Updated physical expressions, addition of ^{60}Fe , and warm nebula

Figure 1: Temperature 1 Ma After Accretion

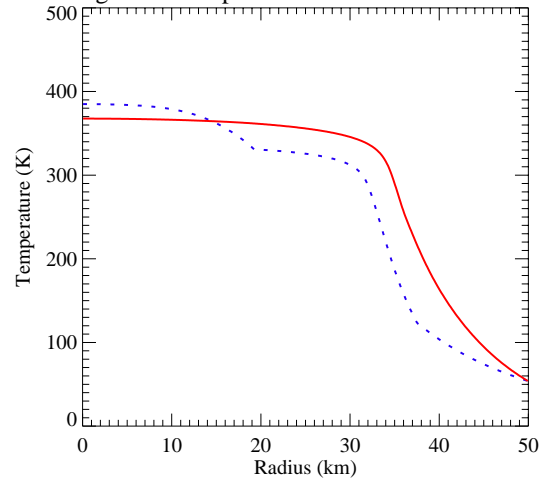


Figure 2: Central Temperature

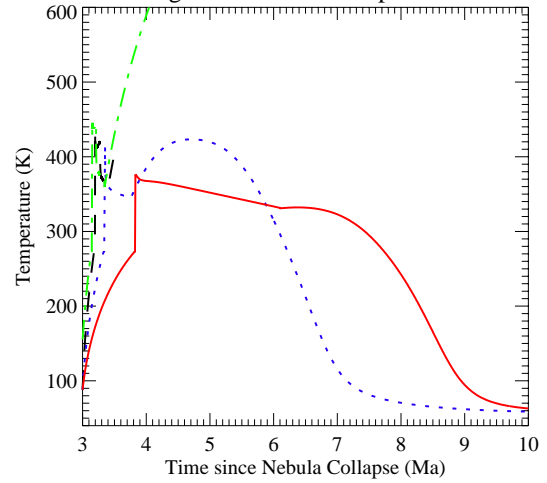


Figure 3: Radial Duration of Liquid Water

