A RADIATIVE HEATING MODEL FOR THE FORMATION OF CHONDRITES AND THE LAST MELTING EVENT OF CHONDRULES.

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Introduction: We have recently proposed a chondrite formation model that accounts for most properties of chondrules and chondrites [1]. This radiative heating model builds upon our earlier work on forming chondrules during short flyby's of molten planetesimals in the early solar system (< 5 Ma) [2]. To form chondrites, we envision that small porous planetesimals (m-to-km scale) are heated during close encounters with large (~100 km scale) differentiated planetesimals via radiative heating by exposed magma oceans or lava on their surfaces. Chondrite lithification occurs by hot isotatic pressing simultaneously with chondrule melting and crystallization. Thermal models of large differentiated planetesimals predict a narrow time window in the planet-forming disk when the crusts of these bodies are thin enough to be ruptured frequently by impact and magmatism [3], coincident with the ages of chondrules [4]. We have modeled the heating and cooling of the small porous planetesimals as they are accreted to these large differentiated planetesimals. This leads to symmetrical heating and cooling curves above 1000K on the order of several 10's of minutes for the objects. The heating of the small porous planetesimal leads to excess pressure of Na, Si, and O (over the solar nebula) in the last chondrule forming event, thus accounting for properties of chondrules not expected in typical nebular environments. This type of heating environment would naturally lead to nucleosynthetic isotopic complementarity [4] as well as the phenomena of cluster chondrites [5].

Experimental: Laboratory experiments demonstrate that FeO-poor porphyritic olivine chondrules can be synthesized with the predicted thermal histories of this model. We have undertaken 1 atm experiments at IW-1 with chondrule analog materials that possess a range of chemistry and mineralogy. Porphyritic olivine chondrules are a dominant textural product, with barred and skeletal olivines much lower abundance, using symmetrical heating and cooling curves from [1]. Experimental olivine Mg# and glass compositions are excellent chemical matches to Semarkona Type I PO chondrules [6]. Experiments using a Type IAB composition show olivine and pyroxene chondrules with textures expected from equilibrium crystallization. These textures are not similar to pyroxene-rimmed Type IAB chondrules [7], demonstrating that Type IAB chondrule textures support open-system behavior with a Si-enhanced gas [7]. Further work on the similarity of our experiments with chondrules in primitive meteorites will be presented by [8]. For the meeting, we will present work on Type II porphyritic olivine chondrule synthesis. We are also working on the replication of chondrule olivine minor element zoning [9], and will report on this progress as well.

Implications of this model for the abundance of chondrites in primitive asteroids: One of the interesting predictions of this model is that the majority of material in the asteroid belt cannot be similar to the chondritic meteorites, as the mass of material heated in this fashion cannot be similar to the mass of the asteroid belt. This would predict that the material of primitive asteroids would be mostly chondritic in composition, but not in texture, porosity, and density. We would predict that asteroids such as Ryugu and Bennu will be composed mostly of much lower density material, material that has been less thermally processed in comparison to the chondritic meteorites in our collections. The asteroidal material is likely more representative of the material hitting the upper atmosphere of Earth. The chondritic meteorites are the objects from those asteroids able to survive passage through our atmosphere, rather than the main type of material from these bodies.

References:

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