THERMAL HISTORY MATCH BETWEEN CB_b CHONDRULES AND IMPACT PLUME MODELS.

R. H. Hewins[1,2], C. Condie[1,3], M. Morris[4,5], M.L.A. Richardson[6], N. Ouellette[5], M. Metcalf[5].
[1]EPS, Rutgers University, Piscataway NJ 08816, [2]IMPMC, MNHN, Paris 75005, [3]Chemistry & Physics, Monmouth University, West Long Branch NJ 07764, [4]Arizona State University, Tempe AZ 85287, [5]Physics, SUNY Cortland NY 13045, [6]Physics, University of Oxford, OX1 3RH.

Introduction: The CB_b chondrites contain skeletal olivine (SO) and cryptocrystalline (CC) chondrules with distinctive textures not found in 'normal' chondrites. The bulk compositions of these chondrules are consistent with origins as evaporation residues and condensed liquids, respectively, in an impact plume [1]. We have used experimental petrology to determine the thermal histories required for these textures, and computer modeling to find the thermal histories of particles in impact plumes, to provide a test of this model.

Experimental Petrology: Because no previous simulation experiments had reproduced these chondrule textures, we selected bulk compositions specifically for SO and CC chondrules from the CB_b chondrite QUE 94411 from [2]. We performed a matrix of dynamic melting/crystallization experiments, varying primarily peak temperature (1500-1580°C), quench temperature and cooling rate [3]. We generated a series of glassy, barred and elongated hopper textures, but not the SO texture. The distinction between our barred olivine charges and the SO chondrules is that the former have dendritic crystals reflecting rapid growth, while the SO olivine is blebby with rounded boundaries suggesting annealing or resorbtion. We therefore performed subsequent experiments with a complex heating-cooling sequence involving 100° fluctuations: the charge was melted totally, dropped below the liquidus to induce crystallization and then raised to near the liquidus again one or more times before final cooling. The partial remelting produced the SO texture. (Reheating above the liquidus again destroyed the skeletal olivine so that barred olivine could be regrown.) Thus transport of a crystallizing chondrule from a colder to a hotter zone seems required for the formation of SO chondrules.

Computer Simulations: Chondrule formation due to collisions of large bodies was investigated using a Lagrangian Smoothed Particle Hydrodynamics code [4]. We followed this approach for the free expansion of the ejecta plume into vacuum, and after 4000s we mapped the ejecta fan into the Eulerian Adaptive Mesh Refinement code, FLASH [5]. This allowed us to resolve the plume, and model its interaction with the solar nebula. In FLASH we employed tracer particles that probed the local density and temperature, allowing us to track the thermal history of individual fluid parcels. The plume began with a uniform temperature of 2,200 K. It extended about 1,500 km, with a typical expansion speed of 1000 km/hr. We observed temperature fluctuations of several tens of degrees throughout the crystallization temperature range, and cooling rates are complex, varying even for a single fluid parcel.

Discussion: The parent liquid for the SO chondrule evaporation trend corresponds approximately to bulk CR silicate melt with 3% FeO. The liquidus temperature of the least Al-enriched melt, "BO1" of [2] , about 1602°C, represents a minimum estimate of the plume temperature at the time of droplet formation. The CC chondrules probably condensed at close to their liquidus temperares, 1640-1680°C. The peak temperatures in the calculations, 2200 K would lead to superheated liquids and facilitate evaporation

The unique textures of CB_b chondrules have been reproduced experimentally only when using temperature fluctuations during the crystallization of olivine. Modelling of the expansion and cooling of an impact plume shows that such fluctuations arise naturally. These findings strengthen the idea that CB_b chondrites are accumulations of impact ejecta and condensates. The cooling rates derived, >1000°/hr, are higher than most of those estimated for 'normal' (porphyritic) chondrules. The heterogeneity in the plume may permit mixtures of less heated material, including 'normal' chondrules, and the impact spherules (residues and condensates), as in CH chondrites.

References: [1] Krot A. N. et al. (2007) *Chemie der Erde - Geochemistry* 67, 283-300. [2] Krot A. N. et al. (2002) *Meteoritics & Planetary Science* 37, 1451–1490. [3] Condie C. (2012) Ph. D. thesis, Rutgers University. [4] Asphaug E. et al. (2011) *Earth & Planet. Sci. Lett.* 308, 369-379. [5] Fryxell B. et al. (2000) *Astrophysical Journal Supp. Series*. 131, 273-334.