NEW CONSTRAINTS ON THE FORMATION OF IGNEOUS RIMS AROUND CHONDRULES. **M. A. Morris**[1] and **Laurence A. J. Garvie**[1]. [1]Center for Meteorite Studies, Arizona State University, Tempe, AZ 85287. (melissa.a.morris@asu.edu).

Introduction: It has long been recognized that igneous rims (IRs) around chondrules are indicative of a second heating event, occurring after a dust-rich mantle was acquired [1-8,14,15]. The textures of IRs suggest they were formed by the same type of heating mechanism as the majority of chondrules [1-8]. IRs have igneous textures, and contain larger, less-ferroan mafic silicate grains than those found in fine-grained rims of matrix-like material [2]. As defined by [5], IRs show petrographic evidence that these rims experienced heating events resulting in an appreciable ($> 20\%$) degree of silicate melting. According to [1], igenous rims surround $\sim 50\%$ of the chondrules in CV3 meteorites, $\sim 10\%$ in H-L-LL3 meteorites, and $\leq 1\%$ in CO3 meteoreites. A compositional relationship exists between the core (primary) and the rim (secondary), with both showing similar degrees of oxidation [3,5]. This suggests that the primary accreted its dust mantle after cooling, while still in the chondrule-forming region [6]. IRs around low-FeO chondrules show high degrees of melting (90 ± 10 %), and those around high-FeO chondrules show a lesser degree of melting [3-5]. Low-FeO and high-FeO rims, therefore, seem to have experienced different thermal histories. Nevertheless, both types are consistent with formation in a high-temperature event, with peak temperature $\geq$ 1400K [5].

Shocks in the solar nebula are the most generally accepted chondrule-forming mechanism [9,10]. Solids will be pre-heated ahead of the shock (in the pre-shock region; Figure 1), due to the propagation of a radiation front (known as a Marshak wave) originating in the hot, post-shock region [9-10]. Models show that temperatures in the pre-shock region will exceed the liquidus temperatures of solids ($\sim$ 1400 K), and evaporation will occur [9-10]. This pre-heating of chondrules $\geq$ 1300 K is constrained to under 30 minutes, in order to prevent isotopic fractionation of sulfur [12]. Recent shock models [10] meet this condition. Even within this short time frame, some degree of evaporation will occur, as the models show that the temperature can reach as much as 1700 K within 10-30 minutes prior to the shock front. It is therefore expected that the dust mantles from which IRs are formed will experience a reduction in volume due to loss of porosity, concomitant with evaporation.

Observations of chondrules with accretionary rims [12] found a relationship between the size of the core and the dusty rim. It is important to note that they disaggregated the chondrules in their study, in order to measure the true radius of core and rim [12]. They [12] found that the volume of the rim was approximately equal to the volume of the core. Modeling of the mass of dust swept up by a particle suggests just such a relationship [12]. Using this relationship, we can predict the size of the remaining IR after melting and evaporation of the precursor accretionary rim.

Methods: Assuming the same chondrule-forming conditions as in [10-11], and a beginning core and rim radius given by the relationship found by [12], we calculated the remaining particle size. Evaporation of material is dependent on pressure, time, temperature, size of the particle, and the experimentally derived evaporation coefficient for the material. We used the evaporation coefficient for forsterite determined by [13], in conjunction with the Hertz-Knudsen equation, to determine the change in radius of typical chondrule-sized particles ranging from from 300-800 μm over typical pre-heating timescales ranging from 10-30 minutes. The Hertz-Knudsen equation, J_i, gives the rate of change in mass over time, and is given by:

$$J_i = \sum_{j=1}^{n} \frac{n_{ij}\gamma_{ij}P_{ij}^{sat}}{\sqrt{2\pi m_{ij}RT}}, \qquad (1)$$

in units of mol cm^{-2} s^{-1}, where i is the isotope or element considered, j is the gas species containing i, n is the number density of i, γ is the evaporation coefficient of i, P^{sat} is the saturation vapor pressure for j, m is the molecular weight of j, R is the gas constant, and T is the temperature.

Our measurements of final particle size were then compared to the meteoritic record.

Results and Discussion: Petrographic measurements of chondrules with IRs show that the thickness of the rims are $\geq 10\%$ of the core diameter [5,6]. Using this petrographic evidence as a modeling constraint, we have calculated the minimum size of chondrules with dust rims that will form chondrules with IRs. We show in Table 1 the results of our modeling. We predict all chondrules with IRs should be larger than $\sim 200\mu$m. Indeed, this prediction seems to hold, based on our observations of all thin sections of carbonaceous chondrites and unequilibrated ordinary chondrites in the collection of the Center for Meteorite Studies (See Figure 2, for example). All chondrules in the study by [5] were > 450 μm in diameter. In the study of compound chondrules by [6], all those with IRs were over 200 μm in radius, with one exception (175 μm radius).

Conclusion: Our modeling shows that a minimum particle size (core plus dust rim) is required in order to retain an igneous rim upon subsequent heating. Dust rims around smaller particles would evaporate completely. Therefore, we predict that particles with igneous rims will be larger than $\sim 200\mu$m. The results of this study provide new constraints on the formation of igneous rims around chondrules.

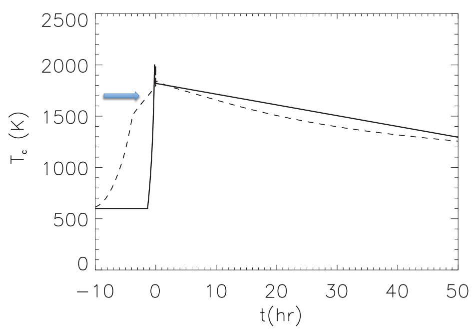

Figure 1: Thermal histories of chondrules. The dashed curve indicates those predicted by the shock model of Morris & Desch (2010), as compared to those inferred from experimental constraints (solid curve). The arrow shows the region where evaporation occurs.

Table 1.

Time (min)	Original Radius [a]	Final Radius [a]
10	250	218
15	370	323
20	490	427
25	610	532
30	740	646

[a]Both original and final radii are given in μm

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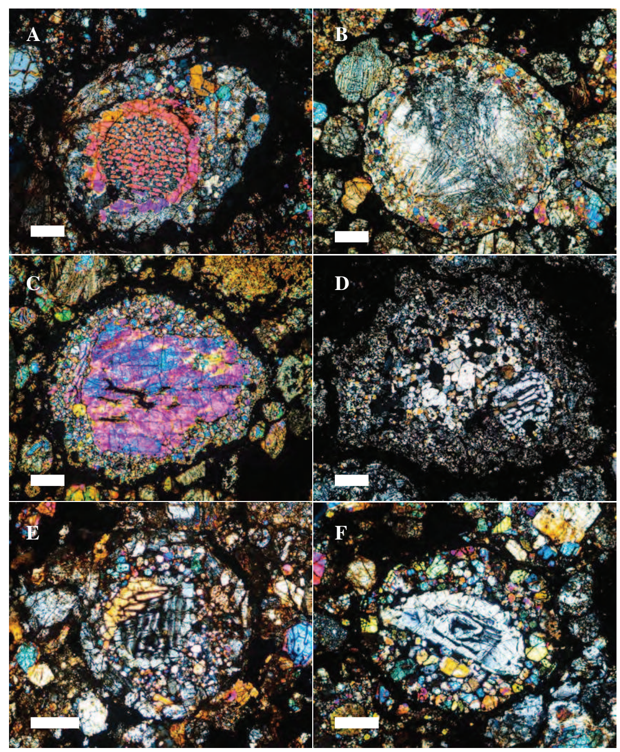

Figure 2: Representative examples of chondrules with igneous rims. A) Coolidge (C4-ung). Barred olivine chondrule with POP rim. B) Mezö-Madara (L3.7), RP core with POP rim. C) Catalina 001 (L3.4). Olivine core with PO rim. D) Allende (CV3) BO+PO core with fine-grained PO rim. E) Camp Creek (H4) BO core with POP rim. F) Kediri (L4) Core with BO fragment and PO rim. Scale bar = 200 μm.