UNDERSTANDING THE CONDITIONS OF PLANET FORMATION THROUGH CHONDRULES .

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Introduction: A major constituent of chondrites are mm-sized igneous inclusions called chondrules, which are known to have formed during the protoplanetary disk phase during the initial stages of the Solar System [1]. The heating mechanisms that initially melted chondrules in the nebula are key to constraining astrophysical models of the disk and the energetic processes that were present during planet formation, but their formation mechanism(s) remains a mystery.

Chondrules display a variety of different textures controlled by parameters such as grain size, peak temperature, heating duration, and cooling rate, but the most dominant texture are porphyritic, making approximately 82 to 99% of all chondrules [2]. These textures can be described as having euhedral to subhedral phenocrysts of olivine and/or pyroxene set within a fine grain matrix.

Large-scale (spiral density wave) shocks and bow shocks around planetary embryos (radius >1000 km) are currently the most favored astrophysical models for chondrule formation. These models meet all the constraints required for an ideal chondrule formation mechanism, which include ambient temperature, peak temperature, and heating duration [3]. We are investigating the planetary embryo bow shock model (PEBSM) [4,5], a relatively new and attractive model that suggests chondrules were byproducts of planet formation instead of the building blocks, but this model predicts cooling rates in excess of 3000 K/hr. Despite a plethora of experiments to understand chondrule formation, it is not clear whether or not porphyritic chondrules can be formed at cooling rates consistent with the PEBSM. So far, these textures have only been reproduced by cooling rates up to 2500-3000 K/hr [6].

Approach: To experimentally investigate the PEBSM, we created chondrule analogs by mixing the minerals olivine, diopside, and albite [7]. The analogs are suspended from a thermocouple inside a 1 atmosphere vertical gas mixing furnace located at the Experimental Petrology and Igneous process Center (EPIC) at ASU, and undergo various parameter combinations, including varying grain sizes, peak temperatures, heating durations, cooling rates, and further investigating nucleation sites through the addition of spinel into the starting bulk compositions. The resultant blebs are subsequently mounted in epoxy, polished, and carbon coated for electron probe microanalysis.

Results: Results show a continuum of textures at cooling rates around 5000 K/hr (Figure 1). These textures include spinifex-like, a quench crystal texture, skeletal grains, relic grains, and a combination of both spinifex and relic grains. Currently, we have not been able to reproduce porphyritic textures at cooling rates in excess of 3000 K/hr. However, the PEBSM shows a similar cooling rate of 2000 K/hr through the crystallization range if the evaporation of dust is present [8].

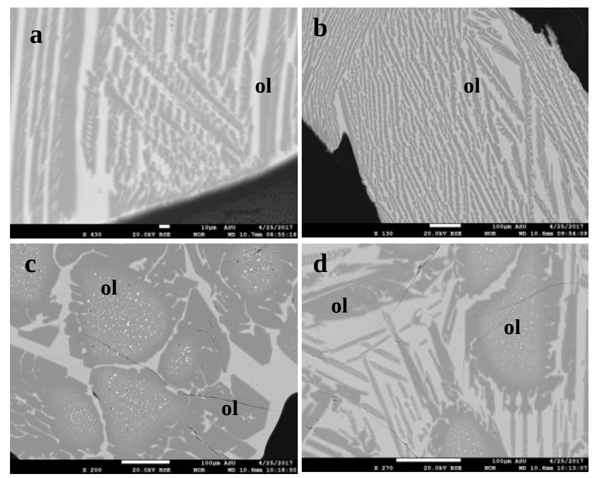

Figure 1. Experimental results with cooling rates at approximately 5000 K/hr. The analogs were heating for 10 minutes at the liquidus prior to being cooled. Runs (c) and (d) show possible Fe cores in olivine phenocrysts that could be a result due to lack of using oxygen fugacity.

If we are able to find the right parameter combination(s) consistent with the PEBSM to successfully reproduce porphyritic textures, this model would be found to be consistent with all the known chondrule properties to make a chondrule formation model successful, increasing our understanding of the energetic events that were present during the early stages of the Solar System responsible for planet formation.

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