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Constraining Ejecta Blanket Conditions of Dhofar 018 from a Single Pristine Chondrule

Introduction: A thin section of howardite Dhofar 018 preserving an pristine radial pyroxene chondrule has been analysed in order to constrain ejecta blanket conditions on asteroid 4 Vesta. This meteorite is known to contain clasts and fragments of exogenic material, including ordinary and chondrites, enstatite meteorites, and ureilites [1]. However, a single intact chondrule has yet to be reported.
Results: The chondrule has a mean composition of En70.6Fs23.6Wo7.0 and Mg#76 (n=24), and is most likely associated with ordinary chondrites. Electron microprobe analysis reveals a sharp unaltered contact with the surrounding howardite with no major element diffusion across the chondrule itself. Sulfur veins are observed cutting through both the chondrule and surrounding howardite matrix. The matrix is composed of diogenite/eucrite associated pyroxenes, olivine, and plagioclase.
Discussion: Studying the chondrule in Dhofar 018 allows the conditions of the ejecta blanket at the time of entrainment to be constrained. The unaltered matrix-chondrule contact and lack of major element diffusion suggests that the ejecta blanket was moderately cool during lithification, as noticeable Mg-Fe diffusion is typically observed at temperatures well exceeding 900 ℃ in experimental conditions [2, 3] – thus giving an upper limit to the temperature conditions experienced by the chondrule within the howardite. Following lithification of the ejecta blanket into the Dhofar 018 howardite, a period of sulfurization occurred and resulted in the narrow sulfide veins that cut through both the howardite matrix and into the chondrule. This process is often observed in brecciated HED meteorites, and is thought to occur rapidly (on a timescale of weeks) at approximately 800 ℃ from impact heating [4]. These conditions are further supported by observations of troilite-metal interactions in chondritic meteorites, in which small-volume post-impact metamorphism allows for the rapid precipitation of sulfides without altering the silicate phases [5]. This therefore constrains ejecta blanket conditions at the time of chondrule entrainment in Dhofar 018 to 800-900 ℃. Pressure has not yet been calculated but is assumed to be low as the meteorite does not show shock features. 40Ar-39Ar dating of Dhofar 018 gives an approximate age of ejection of 2.3 Ga [6], meaning that ordinary chondrite-associated chondrules were available in the inner Solar System post-Late Heavy Bombardment, and that these “micro” meteorites may be incorporated into various planetary surfaces and preserved in other groups of meteoritic breccias.
References: [1] Lorenz et al. (2007), Petrology 15:109-125; [2] Fisler et al. (1997), Physics and Chemistry of Minerals, 24:264-273; [3] Dimanov & Sautter (2000), European Journal of Mineralogy 12:749-760; [4] Zhang et al. (2013), Geochimica et Cosmochimica Acta 109:1-13; [5] Tomkins (2009), Meteoritics & Planetary Science 44:1133-1149; [6] Korochantseva et al. (2010), 73rd Annual Meeting of the Meteoritical Society #5349.

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