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FORMATION OF CHONDRITES IN A THICK DYNAMIC REGOLITH.

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In a companion abstract we have proposed that chondrules formed as the products of energetic impacts in a very thick dynamic dust layer of an accreting asteroid-sized object and that the various chondrule groups, and thus chondrite classes, formed by variations in the number and intensity of impacts [1]. We here argue that in such a dust layer there was probably a steady flow of volatiles and that on occasion conditions may have resembled those of a fluidized bed in which density and size sorting produced the metal-silicate fractionation and chondrule size distributions observed among the chondrites.

The existence of a temporary atmosphere is suggested by the elemental and isotopic abundance patterns observed in chondrules [2–4]. The atmosphere may have been permanent, but was probably transient, consisting of water and other volatiles from the parent body most probably produced during accretion and chondrule formation [5]. It seems unlikely that such an atmosphere would be cosmic in composition and there are experimental reasons for suspecting that the H/O ratio was many orders of magnitude below cosmic [6] and the P(Na) was much higher than expected for gases of cosmic composition [7]. The requirements for minimal fluidization are determined by equating the upward drag force of the escaping volatiles (which is dependent on the Reynold's number, R_e, which in turn depends primarily on the flow rate of the gases) and the downward gravitational force on the particles [8]

$$\frac{1.75R_e^2}{\varepsilon^3\phi} + \frac{150(1-\varepsilon)R_e}{\varepsilon^3\phi^2} = \frac{d^3\rho_g(\rho_s-\rho_g)g}{\mu^2}$$

where ε is the void fraction under minimum flow conditions (typically 0.6), ϕ is the sphericity (also typically 0.6) and d the diameter of the particles (typically 100 µm), ρ_g and ρ_s are the densities of the gas (calculated assuming an ideal H_2O gas) and solids (3.2 g/cm³), μ is the viscosity of the gas (typically 1.8×10^{-4} poise), and g is the acceleration due to gravity. We calculate that most asteroids smaller than a few hundred kilometers should be capable of producing a sufficiently high flow rate of volatiles to produce fluidization.

It seems to us that a thick dynamic dust layer on an asteroid-sized body into which material is falling energetically would create an environment in which all the major properties of chondrules and the chondrite classes are readily explicable. The different lithophile-element patterns and the redox states reflect the chondrule-forming process, while the siderophile-element fractionations and size sorting reflect density and size separations in an environment resembling a fluidized bed. Density separations are rapid in a fluidized bed, with a relatively pure high-density layer forming at the bottom and a less pure low-density layer forming at the top [8,9]. The size sorting experienced by several chondrite classes also infers conditions resembling those of a fluidized bed [10,11]. Thus we suggest that fluidization was especially important on the EH and EL parent objects, the EH chondrites being from the metal-enriched deep layer and the EL chondrites being from the metal-depleted surface, while on the ordinary chondrite parent object the depth increased along the series LL, L, and H. Except perhaps for CO and CV chondrites, carbonaceous chondrites generally suffered little density separation. The extent of presumed fluidization seems to decrease with present volatile contents of the classes, consistent with the loss of volatiles during fluidization from parents of generally similar original composition.

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