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FORMATION OF CHONDRULES IN A THICK DYNAMIC REGOLITH. D. W. G. Sears, S. Huang, and P. H. Benoit, Cosmochemistry Group, University of Arkansas, Fayetteville AR 72701, USA.

Chondrule formation resulted in the formation of four more-or-less discrete chondrule groups [1]: (1) the A1 chondrules that suffered considerable volatile loss and reduction during their formation and subsequently cooled slowly enough that the phenocrysts and melt remained at equilibrium; (2) group A2, which are closely related to group A1 but for which volatilization caused Fe loss (but not Si loss) so that pyroxene became the dominant silicate; (3) group B1, in which volatile loss and reduction were minimal but supercooling occurred during subsequent crystallization; and (4) group A5, in which volatile loss and reduction did not occur and equilibrium was maintained between phenocrysts and melt during cooling [2]. Although detailed studies have yet to be made, to a reasonable approximation it appears that the chondrules in enstatite chondrites are predominantly group A2, while chondrules in carbonaceous chondrites are group A1 and group B1 in the ratio of 2:1. In ordinary chondrites, group A1 and A2 chondrules coexist with group A5 and B1 chondrules, B1 being the major group, the ratio of group A to group B chondrules being about 1:2.

We suggest that a scenario for the formation of chondrules that is consistent with this variety of properties is that they are the product of impact on a thick dusty regolith of an accreting asteroid on which evaporated volatiles (mainly water) caused fluidization. This scenario, which has elements in common with several recent discussions of chondrule origin [3–6], explains why chondrules have some properties consistent with a nebula origin (open-system behavior, gas-solid interactions) but avoids the difficulties associated with assuming nebula pressures and cosmic compositions for the gas. In such an environment, reduction and volatile loss would occur as a result of the most intense impacts, while a greater number of less-intense events would produce an environment with a high dust to gas ratio and with the properties (e.g., multiple reworking, relic grains) of the group B chondrules. Such an environment would also permit size sorting (and the metal-silicate fractionation, see [7]) displayed by the chondrite groups and explain prompt assembly and complementary compositions of components [8], high frequency of compound chondrules [9], lack of charged-particle tracks in chondrules [10], and the high frequency of occurrence of fine-grained rims on group A chondrules relative to group B chondrules [11].

The evaporation of water and other volatiles would produce a temporary "atmosphere" (see also [3]), which we suspect had a composition near the terrestrial line on the O three-isotope plot. Data for refractory inclusions in CV and similar meteorites, and components from the ordinary chondrite ALH 76004 [12], indicate that the precursor material had a range of O isotopes plotting along a slope 1 line, and this material exchanged and equilibrated with the temporary atmosphere, which was sometimes in liquid form [13].

Formation of chondrules by impact on a thick dusty regolith of an asteroid during accretion avoids most of the difficulties pointed out by Taylor et al. [14] for the formation of chondrules by impact on a lunarlike asteroid. We think that impact velocities will be much greater than calculated from the gravitational field of an asteroid because the impactors will often have a large component heliocentric velocity relative to the asteroid and additional velocity vectors due to turbulence in the accreting phases of the nebula. Variation in the energy and number of impacts was probably the major factor in determining chondrule properties and varied with location in the early solar system.

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