CHONDRULES: CLUES TO EARLY PLANETESIMALS

I. S. Sanders[1] and E. R. D. Scott[2], [1]Trinity College Dublin, Ireland. E-mail: isanders@tcd.ie [2]University of Hawaii.

Introduction: Most chondrules were evidently made in huge batches of closely spaced droplets [1] about 2 Myr after the solar system began. Modelling by [2] suggests that at that time enormous fan-shaped plumes of chondrule droplets, like 'spray from a hose-pipe nozzle', would have emerged downstream from the overshooting fraction of molten impactors following oblique low-velocity collisions and partial planetesimal mergers. If chondrules originated in this way, then what can they tell us about their planetesimal antecedents?

Planetesimal oxidation state: Two main kinds of molten planetesimal probably existed – reduced and oxidized – to account for Type I (FeO-poor) and Type II (FeO-bearing) chondrules respectively. Reduced planetesimals perhaps accreted from partially condensed matter in the young, hot inner nebula, as proposed by [3], and their cores in some cases had evidently formed in the first 0.5 Myr [4]. The timing of disruption of one particularly large molten planetesimal, which left the IVA iron parent body in its wake, suitably coincides with the time of chondrule formation [5,6]. Oxidized planetesimals, on the other hand, perhaps accreted in a cold part of the disk, possibly later or further from the sun than the reduced ones, and incorporated grains of water ice. As the planetesimals became heated, hydrated and eventually melted, the H_2O plausibly oxidized the metal, and supplied the ^{16}O-poor oxygen whose abundance in chondrules in E, H, L, LL and R chondrites correlates so well with FeO/(FeO+MgO). To make Type II chondrules in conventional ways is, incidentally, beset with problems [7]

Planetesimal anatomy: A typical molten planetesimal perhaps had a coating of cold loose regolith passing downwards with increasing temperature into sintered rigid 'crust', through a zone of incipient melting into the molten silicate interior from which the metal core was separating. Hence the overshooting plume would have carried a diverse suite of materials. The spray would probably have sampled much more mantle than core, thus explaining iron depletion in all chondrite groups relative to CIs. Phenocrysts in the melt would explain chondrules with mm-sized single crystals. With olivine phenocrysts settling through time, later-formed chondrules would have become increasingly pyroxene-rich, as is observed [8]. Incipiently melted fragments of the crust would account for chondrules packed full of unmelted 'relict' grains [9]. Small solid objects, including fragments of sintered crust [10], perhaps became wetted and engulfed by droplets they encountered in flight, accounting for the presence of these objects within chondrules.

Reservoirs of ingredients: Chondrules and other debris launched by collisions presumably accreted to new or existing planetesimals before having time to become homogenized in the disk by radial mixing and turbulence. Thus each chondrite parent body (chondrite group?) was dominated by ingredients supplied by recent impacts in its 'feeding zone' and so acquired its own distinctive petrographic and chemical characteristics [11].

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