CHONDRULES AND THEIR FINE-GRAINED RIMS WITHIN UNEQUILIBRATED ORDINARY CHONDRITES: NEBULAR VS. PARENT BODY PROCESSING

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Introduction: Chondrules and other inclusions in primitive meteorites record both pre-accretionary and parent body processes, which include deposition of FeO-rich fine-grained rims (FGRs), followed by deformation and, in some cases, aqueous alteration [1,2]. Although the origins of FGRs have remained unsettled, several studies support formation from pre-accretionary processes within a nebular environment [1–4]. The primary characteristics of FGRs, as well as their containing microchondrules, suggest chondrule reheating [1–3], and have been used to constrain dust densities during early-stages of accretion [5]. FGR-bearing chondrules in some EL3 chondrites are deformed, suggesting parent body deformation possibly during parent body accretion or impact processing [2]. The focus here is on unequilibrated ordinary chondrites (UOCs), in particular Watonga (LL3.10) that has been previous reported to have numerous chondrules with FGRs, as well as cluster chondrite clasts that possess deformed surfaces [cf., 2,7].

Results: Watonga (AMNH #5290) has a multitude of well-preserved FGRs, with 70% of all chondrules possessing FeO-rich FGRs. Of these, 47% are type I (MgO-rich), 23% are type II (FeO-rich), and a small amount (5%) are Al-rich chondrules. Watonga also has cluster clasts (Fig. 1), as well as compound chondrules spread throughout, often with mutually indented FGRs that surround deformed chondrules. Some compound objects also include sharply imbricated angular fragments of type I and type II material with rim material embedded between the two conjoined objects. The abundance of FGRs in other UOCs are similar to Watonga, with FeO-rich rims predominating in North West Africa (NWA) 5717 (Ung. UOC 3.05) and Bishunpur (LL3.15). Roughly half of the FeO-rich FGRs in both NWA 5717 and Bishunpur occur around type II chondrules, while as little as ~10% of such rims are found on type II chondrules in Bishunpur. Semarkona (LL3.00) on the other hand has FeO-rich FGRs, ~65% of them occurring on type I chondrules. Some rims seem to have undergone subsequent hydrous alteration (e.g., in Semarkona), yet relatively less so in the other UOCs.

Discussion and Implications: The presence of deformed FGRs supports prior interpretations that rims formed before incorporation into the parent body. The presence of deformed FGRs within compound objects, including chondrule clusters, as well as sharply imbricated objects, offers strong evidence of rim modification and deformation prior to parent body incorporation. It seems unlikely that high-velocity impacts would lead to such deformation, although impacting chondrules may account for some populations of microchondrules among interchondrule matrix. Concerning the populations of chondrules found in the different C chondrite groups, recent investigations have found similar FGRs bearing microchondrules [4,5]. Microchondrules are interpreted to result from re-heating of chondrule surfaces consistent with FGRs as pre-accretionary features. FeO-rich FGRs likely formed towards the tail-end of chondrule formation while chondrule surfaces still retained residual heat or were re-heated. Later aqueous alteration overprinted primary rim characteristics [5]. Remelting of type I chondrules with their characteristic FeO-rich FGRs may explain the discrepancy of rim abundance among type II chondrules. Such a distinction for C chondrites cannot be completely ruled out. A working model of FGR in the early nebular must readily reconcile multiple stages of rimming, including coarse-grained igneous rims, or multi-layered dust mantles. Asteroidal processing on ephemeral planetesimals may account for FGRs containing higher degrees of hydrous alteration products [6,7]. Rims provide evidence of the complex history of chondrule formation in dust-rich environments, re-heating of chondrules surfaces, sintering of the fine-grained portions of rims, followed by chondrite accretion, rim deformation (potentially during accretion) and in some cases aqueous alteration. Features of rims in O and C chondrites suggest similarity in these processes both in the inner and outer Solar System.

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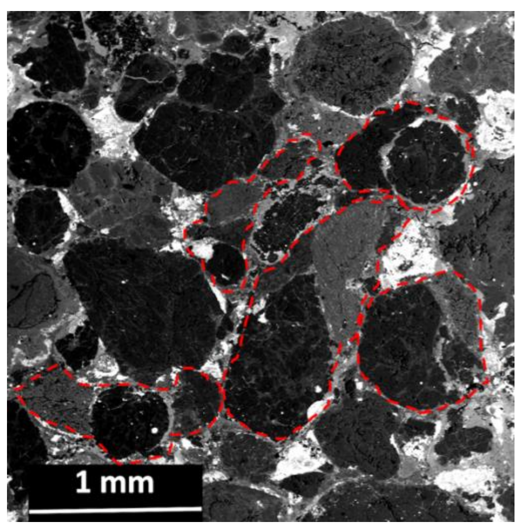

Fig. 1 BSE image showing chondrule clusters outlined in red.