ROLE OF HOT ACCRETION AND DEFORMATION IN PRODUCING CLUSTER AND TYPE 3 ORDINARY CHONDRITES. Alex M. Ruzicka[1], Secana Goudy[1,2], and Richard C. Hugo[1], [1]Cascadia Meteorite Laboratory, Department of Geology, Portland State University (ruzickaa@pdx.edu, hugo@pdx.edu), [2]Earth and Planetary Sciences, University of California Santa Cruz (sgoudy@ucsc.edu).

Introduction: Whether chondrules in chondrites accreted largely cold [1] or hot [2,3] has been debated, with evidence for hot accretion recently supported by observations of so-called cluster chondrite texture [4]. To address this question and to provide constraints on the overall role of deformation in producing chondrites, we studied five type 3 ordinary chondrites of differing cluster texture development (conforming chondrule boundaries), ranging from poor (Ragland LL3.4; lithology B of Northwest Africa (NWA) 5205 LL3.2), to moderate (Tieschitz H/L3.6), to good (Northwest Africa 5781 LL3.3), to excellent (lithology A of NWA 5205; Northwest Africa 5421 LL3.7), using optical microscopy (OM) and electron backscatter diffraction (EBSD). Our results support the idea of "hot accretion", but show that *all* of the type 3 chondrites could have been deformed at elevated temperature, which has implications for chondrite formation more generally.

Methods: OM was used to determine shock stages [5], weighted (or mean) shock stages [6], and to assess textures, whereas EBSD was used to determine deformation metrics and to produce crystallographic maps and plots following the procedures of Ruzicka and Hugo [7] for type 6 ordinary chondrites. For this work we acquired EBSD large area maps (LAMs) covering ~36-118 mm^2 at 3.6-5 µm step size and "mini-LAMs" covering ~11-34 mm^2 at 1.6-3.5 µm step size. The data reported here pertain mainly to chondrule olivine grains with effective diameters (d) > 50 µm (d > 5-10 µm for slip parameter).

Results and Discussion: All of the meteorites have relatively low shock stages (S1-S3), with weighted shock stage generally correlating with mean Grain Orientation Spread (GOS, the average misorientation within a grain) in olivine (Fig. 1). As a group, the type 3 chondrites are more inhomogeneously deformed than type 6 chondrites, as evidenced by large standard deviations in olivine GOS values (Fig. 1). The weak-cluster chondrites (Ragland, Lithology B of NWA 5205, and Tieschitz) are less-deformed than the strong-cluster chondrites (NWA 5781, lithology A of NWA 5205, NWA 5421) (Fig. 1). All of the strong-cluster chondrites show good evidence for impingement deformation between chondrules. This supports the idea that the cluster chondrites were formed by chondrule collisions during accretion [4]. Much deformation in such chondrites is associated with fracturing. The weak-cluster chondrites show good evidence for fragmentation (broken chondrules and fragments).

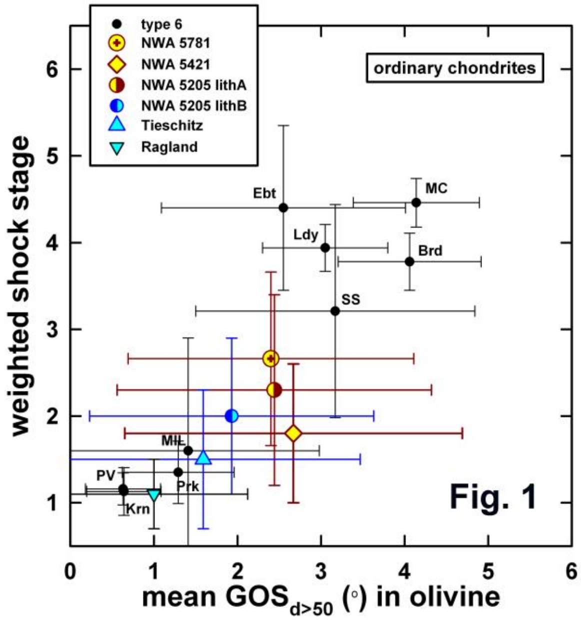
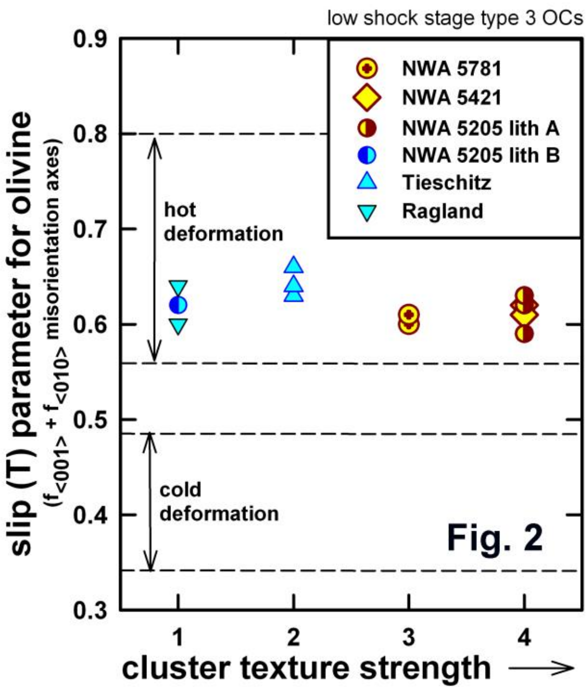


Fig. 1. Correlation between weighted shock stage and GOS (d >50 µm grains) in olivine from ordinary chondrites. Black symbols type 6 [7,8]; colored symbols type 3 chondrites (GOS weighted by area of maps) of this study. Bar lengths represent standard deviations and intrinsic variations in deformation.

All of the chondrites show an elevated EBSD slip ("T") parameter, as defined by misorientation rotation directions in olivine [7] (data for different LAMs and mini-LAMs shown in Fig. 2). This T parameter is related to deformation temperature [7], and in the type 3 chondrites does not correlate with degree of cluster texture strength (Fig. 2). This indicates that the elevated T values are a signature of type 3 chondrites in general. The data can be explained by deformation of chondrules as they were cooling shortly after formation, whether or not they formed cluster textures.

The weak-cluster and strong-cluster chondrites differ more strongly in EBSD olivine GOS skewness ("A") parameter, defined by the mean/median GOS value [7] (Fig. 3). This A parameter for grains larger than 50 µm in diameter ($A_{d>50}$) can be interpreted either as a result of annealing, or by the admixture of more heavily deformed material to less-deformed material [7]. The latter is more plausible for type 3 chondrites and is supported by EBSD maps of the weak-cluster chondrites, which show deformed objects adjacent to nearly undeformed. $A_{d>50}$ values are smaller for the strong-cluster chondrites than for the weak-cluster chondrites, especially Tieschitz and Ragland (Fig. 3). This implies mixing of variably-deformed material for the latter two chondrites prior to final agglomeration.



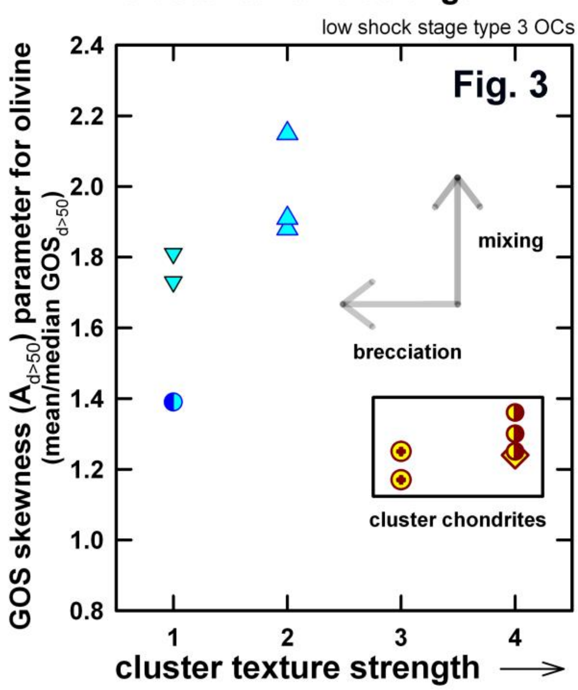


Fig. 2 and 3. Relationship between relative cluster texture strength and EBSD T and A deformation parameters [after 7] for different EBSD maps.

Roles of Accretion and Deformation in Chondrite Formation: The data can be interpreted with one of two models. In Model 1, cluster chondrites represent a primary accretionary rock that formed by hot accretion, and less clustered type 3 chondrites could have formed by brecciation and disaggregation of such cluster chondrites, in agreement with Metzler [4]. In this case, NWA 5205 lithology B could have formed mainly by disaggregation of a cluster chondrite (leftward movement in Fig. 3), whereas Ragland and Tieschitz could have formed both by brecciation of a cluster chondrite and the addition of more deformed material (movement to upper-left in Fig. 3). However, with this model one might expect brecciation to result in more deformation of the weak-cluster chondrites compared to the strong-cluster chondrites, but the opposite is true (Fig. 1).

Alternatively, in Model 2, both strong- and weak-cluster type 3 chondrites formed not in sequence, but rather in parallel under different accretion conditions, with less significant chondrule collisions for the weak-cluster chondrites, and more for the strong-cluster chondrites. The former chondrites could have accreted in a dynamically less energetic setting, although even for them there must have been chondrule fragmentation to result in obvious chondrule clasts, as well as mixing of variably-deformed material to result in high GOS skewness.

The two models might be distinguished based on ages (similar ages for strong- and weak-cluster would support Model 2) or based on evidence for more-or-less processing histories (more protracted for weak-cluster would support Model 1). In any case, the evidence suggests that chondrules initially accreted under warm conditions, and that the chondrule and chondrite formation environments were dynamically active.

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