CHONDRITE ACCRETION WITHIN HOURS TO A FEW DAYS AFTER CHONDRULE FORMATION ? TEXTURAL EVIDENCE FROM UOC´S Knut Metzler, Institut für Planetologie, Wilhelm-Klemm-Strasse 10, 48149 Münster, Germany. Email: knut.metzler@uni-muenster.de

Introduction: The formation processes of chondrules are highly debated and the period between chondrule formation and chondrite accretion is poorly constrained. The investigation of some barely considered textures in unequilibrated ordinary chondrites (UOC´s) can possibly help to better understand chondrule formation processes and to set limits on the above time span. These textures, characterized by deformed and mutually indented chondrules (Fig. 1), have been sporadically described in the literature and interpreted as the result of hot chondrule accretion [e.g. 1-5].

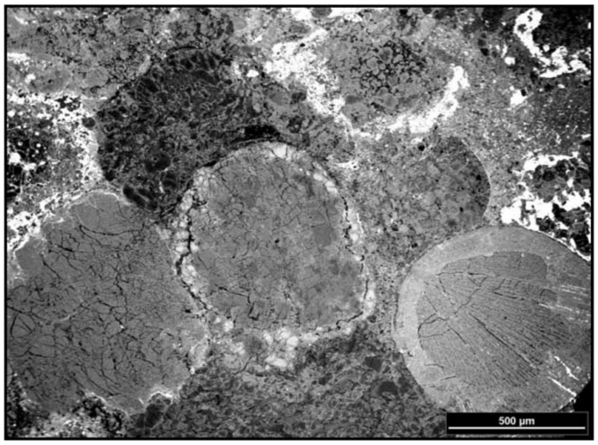

Fig.1: Deformed and mutually indented chondrules in a cluster chondrite clast in the LL chondrite NWA 5205. SEM-BSE image

Textural setting of deformed and indented chondrules: I found that these textures are restricted to specific chondritic lithologies which I termed “cluster chondrites” [6]. They occur in the shape of clasts (chondritic rock fragments; Fig.2) in many brecciated UOC´s. Most cluster chondrite clasts are in the size range between 2 and 10 mm, but can reach sizes up to 10 cm. I investigated thin sections from 55 UOC´s and found that 21 (38%) of these meteorites contain cluster chondrite clasts.

Characteristics of cluster chondrite clasts: These clasts occur in all UOC groups (H, L, LL) and share the following characteristics:

- Close-fit textures, where many chondrules are plastically deformed and mutually indented
- Coexistence of rigid and plastically deformed chondrules
- Most chondrules are intact, only few chondrules are fragmented
- Low amounts of fine-grained interchondrule matrix
- Several chondrules exhibit fine-grained accretionary rims

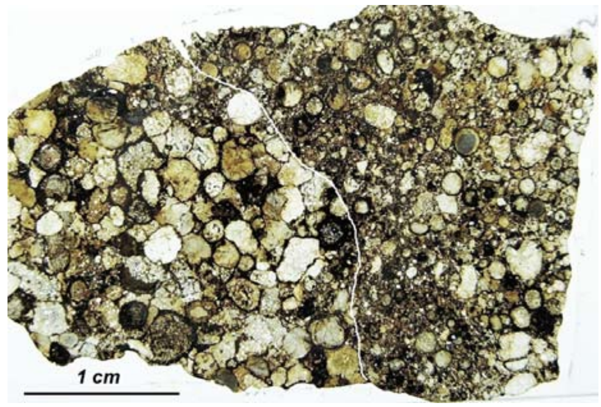

Fig.2: Cluster chondrite clast of petrologic type 3.7 (left of white line) in the LL chondrite NWA 5205. The right part represents the clastic matrix of this brecciated meteorite. Polished thin section, transmitted light

Evidence for effective chondrule size sorting: Several cluster chondrite clasts show a high degree of chondrule size sorting. The LL chondrite NWA 5205 contains clasts of very different mean chondrule sizes (Fig.3) which show chondrule size distributions that are atypical for UOC´s. Obviously, effective size sorting processes, possibly chondrule-gas interactions, led to separation / concentration of large and small chondrules prior to accretion.

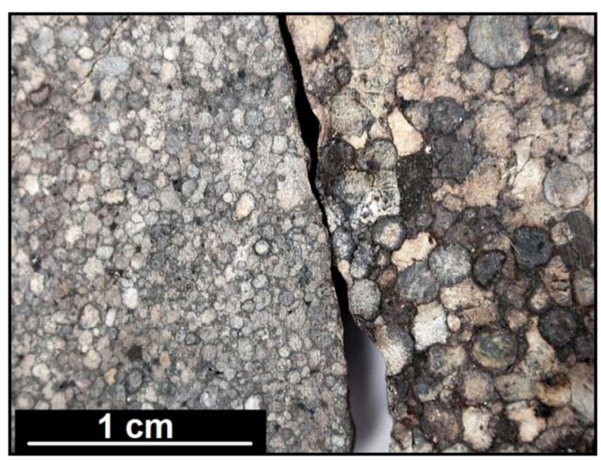

Fig.3: Two cluster chondrite clasts with distinctly different chondrule size distributions from the LL chondrite NWA 5205. Polished cut faces. (Image courtesy by P. Marmet, Bern, Switzerland)

Degree of chondrule deformation: The degree of chondrule deformation was measured for 188 chondrules in 3 cluster chondrite clasts from 3 brecciated UOC´s (NWA 869, L3-6; NWA 1756, LL3.10; NWA 5205, LL3.2). I defined this parameter as the ratio of the measured chondrule perimeter and the calculated circle perimeter of the corresponding chondrule area in a thin section. A characteristic inverse correlation between the apparent size (area) of chondrules and their degree of deformation has been observed, where large deformed chondrules are underrepresented (e.g. Fig.4, bottom). For comparison, 53 chondrules from the LL3.6 chondrite NWA 4572 were measured in the same way (Fig. 4, top) and in this case no correlation is found [6].

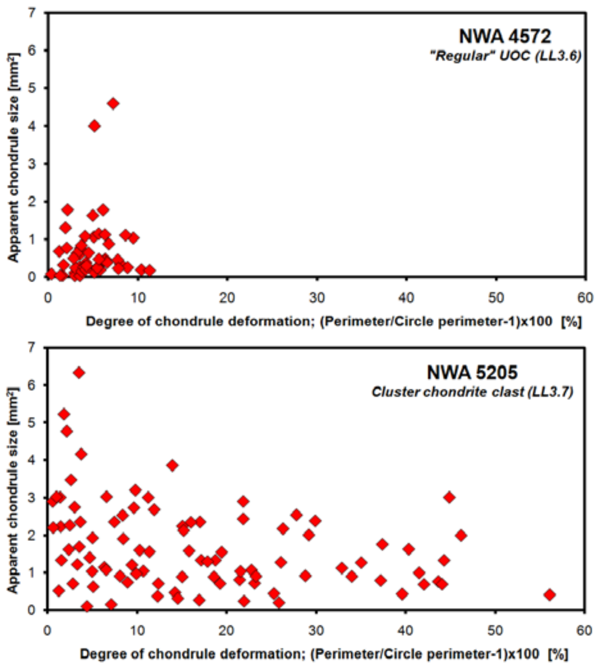

Fig.4: Apparent chondrule sizes (in thin sections) vs. their degree of deformation. The "regular" LL3.6 chondrite NWA 4572 (top), which is free of cluster chondrite clasts, shows a restricted range of chondrule deformations. A cluster chondrite clast with large chondrules (compare Fig.3, right) from NWA 5205 (bottom) shows a wide range of chondrule deformations and a "deficit" of strongly deformed large chondrules.

Chondrite accretion within hours to a few days after chondrule formation: From experimental reproduction of chondrule textures we can conclude that the cooling rates of chondrules were on the order of 5 to 3000 k/hr [e.g.7,8]. For this reason the textures of cluster chondrites may be interpreted such that hot and hence plastic chondrules accreted together with rigid chondrules within hours to a few days after formation of the deformed chondrules. This process was obviously followed by instantaneous compaction and lithification. This is in contrast to current views that chondrules were already solidified prior to accretion [6].

Survival of presolar silicates - rapid cooling after accretion: First investigations by Nano-SIMS ion probe at MPIC (Mainz) [9] revealed three presolar grains in a cluster chondrite clast from NWA 1756 (LL3.1). These grains (2 silicates, 1 Al-oxide) are located in the fine-grained matrix portion between deformed chondrules. The survival of presolar silicates points to a rapid cooling after cluster chondrite formation, because those grains are sensitive to heating [e.g.10].

Original dimensions of cluster chondrite bodies: The original dimensions of the source rocks of cluster chondrite clasts are unknown. They must have been larger than the largest observed clast, i.e. > 10 cm (NWA 5205). The maximum observable clast size is obviously confined by the size of the corresponding meteorite. Possibly entire planetesimals consisted of those rocks prior to their disruption and comminution.

Conclusions:

- A certain fraction of UOC material accreted while many chondrules were hot and deformable.
- Cluster chondrites are the products of this process. They formed by concentration, collision and instantaneous compaction of hot and plastic chondrules together with rigid chondrules within hours to a few days after chondrule forming events. Hence, cluster chondrites can be interpreted as primary accretionary rocks.
- Cluster chondrite clasts are remnants (rock fragments) of these primary accretionary rocks.
- The ubiquitous occurrence of cluster chondrite clasts in the investigated UOC´s could mean that the process of hot chondrule accretion was widespread in the protoplanetary disk.
- In the case of cluster chondrites chondrule forming heating events and the accretion of chondritic bodies (> 10 cm) were closely linked in time and space.

References: [1] Hutchison R. and Bevan A.W.R. (1983) In *Chondrules and Their Origins*, 162-179. [2] Taylor G.J et al. (1983) In *Chondrules and Their Origins*, 262-278. [3] Holmén B.A. and Wood J.A. (1986) *Meteoritics*, *21*, 399. [4] Hutchison R. 1996. *LPSC XXVII*, 579. [5] Zanda B. 2004. *EPSL*, *224*, 1-17. [6] Metzler K. (2011) *Meteoritics & Planet. Sci.*, *74*, 5178.pdf. [7] Hewins R.H. (1983) In *Chondrules and Their Origins*, 122-133. [8] Desch S.J. and Conolly H.D. (2002) *Meteoritics & Planet. Sci. 37*, 183-207. [9] Leitner J. (2011) Pers. comm.. [10] Nguyen A.N. et al. (2007) *Astrophys. J. 656*, 1223-1240.