CATHODOLUMINESCENCE OBSERVATIONS OF *IN SITU* AQUEOUS DESTRUCTION OF CHONDRULES IN THE MURCHISON CM CHONDRITE. Derek W.G. Sears, Paul H. Benoit, Lu Jie and Andrew S.R. Sears. Cosmochemistry Group, University of Arkansas, Fayetteville, AR 72701.

A low-power cathodoluminescence (CL) mosaic of a 1x2 cm section of the Murchison CM chondrite contains chondrules of two types, one containing olivines with red CL, and thought to be the equivalent of group A chondrules of Sears et al. (1992), and one without observable CL, probably equivalent of their group B chondrules. Both types of chondrule contain dust mantles with a characteristic uniform red CL due to very fine-grained forsterites, but the mantles of group A chondrules have complex internal structure and are much thicker than the relatively thin rims on group B chondrules. The variety of internal textures and the progressive integration of the objects with the surrounding matrix suggests to us that these features are large group A chondrules in the process of being destroyed by aqueous alteration. Prior to aqueous alteration, group A chondrules in CM chondrites were larger than group B chondrules, which is contrary to the situation in ordinary chondrites and were apparently destroyed more rapidly than group B chondrules by aqueous alteration.

Introduction. Aqueous alteration played an important part in the history of CI and CM chondrites affecting most of the minerals present and probably lowering the bulk Fe/Si of the matrix and the decreasing the chondrule/matrix ratio[1-3]. Most of the aqueous alteration clearly occurred on the parent body [4,5], although there have been some recent suggestions that minor alteration occurred prior to accretion, perhaps in the nebula. Similar to the matrix, although perhaps slightly more coarse-grained, are fine-grained rims around chondrules (sometimes termed "dust mantles", "halos", "accretionary rims")[4,6,7], which are widely thought to be the result of the accretion of nebular dust prior to the aggregation of the meteorite. Being dependent on both texture and composition, low-powered CL mosaics enable a novel and widescale assessment of the mineralogical and textural properties of meteorites[9,10] which is complementary to the other techniques. Like many little-metamorphosed chondrites, the CL properties of Murchison are dominated by the distribution and grain size of forsterites (generally ≤ 5 μm in size and <3 mol% FeO, since higher levels quench the CL), although occasionally calcic glasses cause regions of yellow CL.

Two groups of chondrules. The CL reveals essentially two kinds of chondrule in Murchison. About 35% (by number) consist of circular or elliptical objects with no CL and which stand out sharply against the profusion of fine-grained forsterite grains in their dust mantles and matrix. Purely on the basis of CL, these appear to be the equivalents of the group B chondrules observed in type 3 ordinary chondrites[11,12]. The remaining chondrules are large objects which display varying degrees of integration with the matrix. They contain forsterites which are sometimes large ($\sim 100 \mu$m) and euhedral, and sometimes of moderate size (say, 10-50μm), with bright red CL indicative of <2wt% FeO and are often surrounded by areas of dark red CL indicative of 2-4wt% FeO. We suspect that this is due to the original igneous zoning. In that they contain essentially Fe-free olivine, these chondrules resemble the group A chondrules of ordinary chondrites, differing only in the frequent absence of a Ca-rich mesostases of bright yellow CL. The destruction of chondrule mesostasis and its conversion to phyllosilicates ("spinach") has often been observed [e.g.13], and we suggest that the loss of CL reflects this process. Thus we suggest that these chondrules are the aqueously altered equivalents of group A chondrules[11,12].

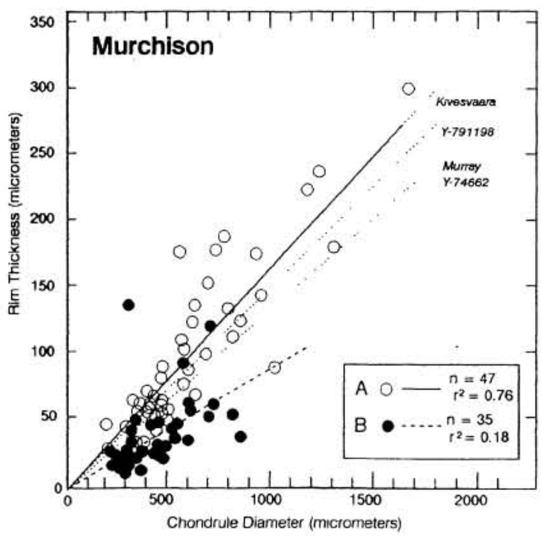

Fig. 1. Plot of chondrule 'rim' thickness against the diameter of the chondrule being 'rimmed' as measured in mosaics of the cathodoluminescence (the data points, 'group A' are those which show CL, i.e. contain Fe-free olivine, and 'group B' without CL, i.e. >2wt% FeO in the olivine). The dotted lines refer to data from BSE images for four CM chondrites[6].

Comparisons of the features around group A and group B chondrules. The major distinction between the fine-grained circular features around group A chondrules and the fine grained rims around group B chondrules is their thickness. The thickness of the fine-grained diffuse 'rim-like' features around group A chondrules is much greater than the group B rims (Fig. 1). It is also apparent from Fig. 1 that group A chondrules tend to be larger than group B chondrules in Murchison, whereas in the Semarkona (type 3.0) ordinary chondrite, the reverse is true. Rims on chondrules in four CM chondrites have thicknesses up to $\sim 250\,\mu m$ on ~ 1.4 mm diameter chondrules[6], so that the thickness-diameter trends are comparable to those of the present group A chondrules. In comparison, the thickness/diameter ratio of the rims on B chondrules is significantly smaller than that of group A chondrules and they are apparently not represented in Metzler *et al.*'s data determined from mosaics of BSE images, although 35% of the chondrules in Murchison are group B. Apparently, group B chondrules and their mantles have been largely unsampled in previous studies, perhaps because they do not stand out as well as the group A chondrules in BSE images.

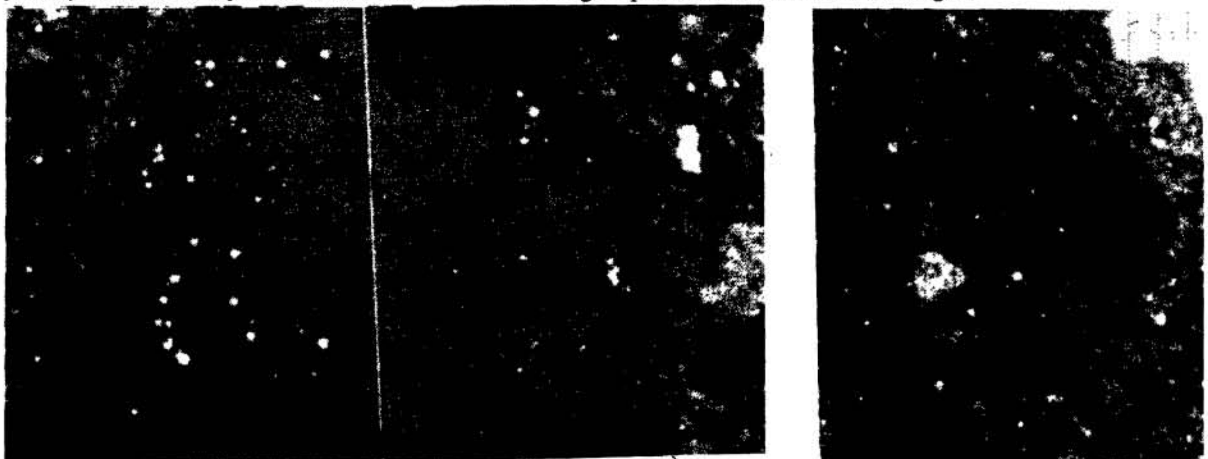

Fig. 2. Photograph of the cathodoluminescence of group A (left) and group B (right) chondrules in Murchison. White and light grays are areas of red CL produced by forsterite, darker gray is olivine with $\geq$2wt% FeO. Both chondrules contain thin rims, but in the case of the group A chondrule there is also a mantle extending further into the chondrule of lower grain density. (1 cm is 200 μm).

All chondrules in Murchison have a group B-like rim of bright red, low-Fe olivine but, in the case of the group A chondrules, this rim forms the outermost shell of the mantle (Fig. 2). The thickness of these outermost rims appear to follow the group B trend (Fig. 1) and their outlines in section are usually circular. The contact between the mantle and the object being mantled in group A chondrules, on the other hand, is often highly irregular with numerous embayments (Fig. 2) and, furthermore, their outermost rim is often somewhat more diffuse than the rims of group B chondrules such that group A chondrules often appear to be intergrown with the matrix.

Discussion. There are clearly differences between the mantles of group A and B chondrules in Murchison. It is possible that these differences reflect differences in the dust accretion history of the two groups, accretion of nebular dust often being discussed as an origin for chondrule mantles[4,7,8]. However, we would suggest that the mantle is the product of *in situ* aqueous alteration. The textures observed in CL images of group A chondrules are more suggestive of an aqueous alteration front than they are of pristine mantled chondrules. In this case, the differences in the mantles on A and B chondrules are related to differences in alteration susceptability and hence to differences in chondrule group chemistry[11,12]. If this is the case, we are observing the process described by McSween[1] and Tomeoka and Buseck[2] whereby chondrules are destroyed by aqueous alteration and the alteration products added to the matrix.

Summary of observations. (i) Murchison contains two groups of chondrules (A and B, 65 and 35% n/n, respectively) which are analogous to those of the primitive ordinary chondrites, (ii) unlike the ordinary chondritic chondrules, A chondrules tend to be larger than B chondrules, (iii) all Murchison chondrules have a thin mantle containing brightly luminescent Fe-poor olivine, but (iv) only the A chondrules have complex thick mantles similar to those described by Metzler *et al.* (1992).

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