CHARACTERISTICS OF ACCRETIONARY DARK RIMS IN CARBONACEOUS CHONDRITES


Chondrules, inclusions, and fragments, rimmed by dark fine-grained material occur in most types of chondritic meteorites (CV3, CO3, CM2, type 3 ordinary chondrites) and have been described by many authors (e.g. 1-6). According to their chemistry and textures, these rims have been widely accepted as material that has been formed in the solar nebula and has coated chondrite components prior to the formation of the chondritic parent bodies.

In order to characterize and classify the textures and chemistry of these accretionary rims from different types of chondritic meteorites, 15 carbonaceous chondrites have been investigated by scanning electron microscopy and the electron microprobe. The investigated meteorites belong to the CV3 (Leoville, Efremovka), to the CO3 (Ornans, ALHA 77007, Y-81020) and to the CM2 chondrites (Cold Bokkeveld, Murchison, Murray, ALHA 83100, Y-74662, Y-791198, Y-793221, Kivesvaara, Haripura, Essebi). All meteorites exhibit components that are surrounded by accretionary rims, typical examples are demonstrated in Figs.1 and 2. Fig.1 shows an accretionary zoned olivine, the CM2 chondrite Y-74662, Fig.2 shows an olivine chondrule in the CO3 chondrite ALHA 77007, both completely enclosed by rim material.

RIM CHARACTERISTICS: The most characteristic property of the accretionary rims is their dark to opaque appearance in thin sections of usual thickness. This feature is due to the very fine grain size (<1 micron) of the rim groundmass in connection with the uniform distribution of opaque minerals. In general, the rim material is finer grained than the matrix material, especially regarding the opaque phases. The chemical compositions of rims are similar to the matrix chemistry of the host meteorites. The composition of 2 accretionary rims surrounding olivine fragments in the CM2 chondrite Y-74662 is shown in a Si-Mg-Fe-plot (Figs.3A, 3B; microprobe analyses, focussed beam). The observed chemical variation follows the trend for CM2-matrix (7). Obviously these rims consist of Fe-rich serpentine and PCP-material, a mixture of cronstedtite and tochilinite, corresponding to the CM2 matrix mineralogy (8,9). Fig.3C demonstrates the chemical variation of 2 rims around olivine chondrules in the CO3 chondrite ALHA 77007. These rims consist mainly of fine-grained serpentine material with compositions between olivine and pyroxene of intermediate compositions, but also coarser grained olivine, pyroxene and Ni-poor Fe-metal occur (see also Fig.3C). The coarser grain size in the rims of this meteorite type accounts for the wider range of variation in comparison with CM2 rims. The chemistry and mineralogy of CV3 rims is similar to that of CO3 rims.

Accretionary rims consist of several layers of two or more components in the chemistry and/or the grain size have been observed in most of the investigated CM2 samples. In many cases the inner rim layers are partly abraded to the degree that remnants of inner rim material are preserved in embayments of the rimmed interior which was coated by new rim material later on. In the different meteorites either all rimmed components exhibit stratified rim material or all components are surrounded by unstratified rim material. The outer shape of the rim layers is always very smooth and rounded, absolutely independent of the shape of the interior (Fig.1). The CM2’s Essebi and ALHA 83100 are exceptional, because they exhibit brecciation features, and parts of rim material around many components are broken or completely lost.

An important fact is the observation, that rim fabrics always closely resemble the fabric of the matrix of the host meteorite. Accretionary zoned olivine, the Allende meteorite, for example, exhibit a porous texture of euhedral silicate grains similar to Allende matrix outline, on contrast to Efremovka, where the rim material as well as the matrix material consists of dense aggregated and irregularly shaped silicate material. The characteristic texture of rimmed components remains unaffected by in-situ shock compaction of the meteorite, as visible in the shocked CM2 chondrite Y-74662 (Fig.1).

CONCLUSIONS:

1.) The described rims cannot represent reaction zones between meteorite matrix and the rimmed components, because the rim chemistry is independent of the interior, and the boundaries between interior, rims, and matrix are always very sharp.

2.) No magmatic crystallization textures have been observed in any accretionary rim. Accretionary rims seem to be the result of an accretion process, where fine grained dust particles adhered to the surfaces of all kinds of chondrite components, prior to the formation of the parent bodies. A possible mechanism could be the sticking of very fine grained dust on the surface of matrix passing dense dust clouds, perhaps close to gravitational centers. The sticking process could be supported by the electrostatical charging of the dust particles or Van der Waals forces that lead to dust lumps and could ease the adhesion process.

3.) The textural similarity of these rims, even in different chondritic subgroups, leads to the conclusion that they have been formed basically by the same process. This process seems to be ubiquitous in the accretion history of all types of chondritic bodies, since the different chondritic subgroups obviously originate from different parent bodies (as indicated by oxygen isotope ratios). Furthermore the large number of chondritic meteorites containing rimmed components and the high frequency of this components in each of these meteorites support the ubiquity of the rim-forming process.

4.) The striking similarity between the chemistry and textures of the accretionary rims and the matrix of the host meteorite could be explained by the following model. The rim forming process took place close to the dust-rich environment of the accreting parent bodies. The finest grained dust portion adhered to the surface of chondrules, inclusions and fragments that passed the dust-rich regions while they were accelerated by the gravitational field of the protoplanet and then be explained by the successive adhesion of material by the passage of components through different dust regions around different or the same body(ies).

5.) Chondrites showing undisturbed accretionary textures over a range of a few centimeters ore more, cannot be interpreted as regolith breccias, but as coarse grained fragmental breccias or accretionary breccias. An intensive regolith gardening surely would have destroyed the delicate rim structures because of the weak bonding (2) between rims and rimmed interior.

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Fig. 1: Asymmetrically zoned olivine fragment surrounded by an accretionary rim (Y-74662 CM2)

Fig. 2: Olivine chondrule surrounded by an accretionary rim (ALHA 77307 CO3)

Fig. 3: Si-Mg-Fe ratios (wt.%) of rim material in Y-74662 (CM2) and ALHA 77307 (CO3)

PCP = poorly characterized phase; Toch. = tochilinite; Cron. = cronstedtite; solid lines after (7)