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Aqueous Alteration in CM meteorites

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Introduction: Kamacite grains can be converted into tochilinite, a serpentine phyllosilicate, if exposed to sulfurated water [1]. We evaluated the conversion of kamacite to tochilinite of metal assemblages in CM chondrites in order to determine the extent of aqueous alteration for these meteorites.

Method: We established a relative indicator of aqueous alteration for CM meteorites by measuring the thickness of tochilinite rims around exposed kamacite grains and correlated it with other indicators of aqueous alteration, the Fe^{3+}/(2-Si) ratio [2] and the scale suggested by Rubin [3]. The original size and shape of kamacite blebs, both in chondrules and isolated matrix grains, can usually be identified even if the entire grain has been converted into tochilinite.

We require that the kamacite grains be in physical contact with the matrix and not embayed by coherent minerals. We assume the matrix is porous enough to provide no protection from any aqueous alteration processes; however, an embayed kamacite grain would not be exposed to the same amount of water, and thus, not be altered at the same rate.

We assign an index of alteration based on the thickness of the tochilinite rim based on five categories with 0 for no alteration and 4 when the tochilinite rim is 20 microns or greater. Fully altered kamacite grains will only set a lower bound for alteration.

We looked at thin sections of Murchison, Cold Bokkeveld, Bells and Nogoya, and two thin sections of Murray using both optical petrologic microscope and a Cameca SX-50 microprobe.

Results: Murray has several 10 to 80 micron kamacite spheres that have seen no or almost no alteration. However, it also has large regions in where the kamacite grains have been fully altered, or if the grain is large, have 20+ um rims. Murchison and Bells have similar alteration patterns.

Our sample of Nogoya is well altered, matching the suggested alteration index by [2] and [3]. Cold Bokkeveld is clearly a breccia with its primary component's kamacite grains fully or almost fully altered. However, there is a single distinct clast that has kamacite grains with rims of only 10 microns.

Discussion: CM meteorites that have been slightly altered, such as Murray and Murchison, 2.5, do not have a homogenous level of alteration. Over short distances, less than one millimeter, there are large variations in the thicknesses of the tochilinite rims. CM meteorites that have seen extensive alteration, such as Cold Bokkeveld, 2.2 and Nogoya, 2.2, have very little variation in alteration spatially.

One suggestion is that the different alteration regions could be different clasts of breccia since CM meteorites are frequently brecciated [3]. This would require that alteration occurred before brecciation, which is useful in determining the timing of early solar system events. An alternative explanation is that the amount of water available to alter the meteorites varied over short distances meaning alteration was a water-limited environment.

References:

[1] Tomeoka, L. and Buseck, P. R. 1985. Geochimica et Cosmochimica Acta 49:2149-2163. [2] Browning, L. B., McSween, H. Y., Zolensky, M. E. 1996. Geochimica et Cosmochimica Acta 60:2621-2633. [3] Rubin, A. E. et al. 2007. Geochimica et Cosmochimica Acta 71:2361-2382. ers.