

Two models that could explain the similarity in rim and interior siderophile (and chalcophile) patterns are (1) chondrules and rims formed at about the same time from local nebular precursors that varied with time and place; or (2) rim siderophiles were part of the chondrule when it formed and migrated to the surface as a low-temperature metal-sulfide melt. Because siderophile patterns show large differences — larger than anticipated for fine-grained nebular matter — we find the first model to be less plausible. If the second model is correct, we expect rims to be enriched in metal and sulfide relative to the fine-grained interchondrule matrix.

We find moderate surface enrichments of K, Zn and As in most chondrules, an indication that some volatilization of these elements occurred while the chondrule was hot. However, these surface enhancements are small relative to the total volatile budget. Our earlier conclusion that the bulk of chondrule volatiles resides in the interiors remains valid.

PHYLLOSILICATE INSIDE AMOEBOID OLIVINE AGGREGATES IN ALLENDE

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In an SEM study of Al-rich inclusions inside amoeboid olivine aggregates in Allende, we demonstrated (Hashimoto and Grossman, 1984) increasing alteration intensity from inclusions with cavity-free, melilite-bearing cores to cavity-rich, fine-grained inclusions and determined the relative resistance to secondary alteration of primary phases. We have now found evidence for an additional alteration reaction, conversion of fassaite into fine-grained, ragged material.

Viewed in backscattered electrons, the ragged material is porous and frequently has the appearance of a bundled haystack in which sub-parallel strands are each 0.1-0.3 μm thick and 1-2 μm long. It occurs in the inner fassaite layer of the clinopyroxene rims of relatively lightly altered Al-rich inclusions and in place of that layer in relatively heavily altered inclusions. In the cores of some inclusions, the ragged material fills interstices between spinel grains often attached to fassaite grains with highly irregular surfaces on their other sides. The cores of other inclusions are composed entirely of islands of highly irregular spinel embedded in a matrix of the ragged material. These observations suggest that fassaite and, in some cases, spinel are replaced by this material.

Ion microprobe analyses of the ragged material show the presence of water. X-ray diffraction of samples relatively enriched in this material indicates the presence of olivine, diopside, feldspathoids and spinel and yields several unidentified lines. One, at 10 \AA , suggests the presence of mica and another, at 7 \AA , the presence of a chlorite or serpentine mineral.

The ragged material is rich in Mg, Al and Si, always contains ≥ 1 wt % each of Na_2O and K_2O , and is highly variable in Fe and Ti contents. The latter feature is due to variable amounts of finely disseminated ilmenite. The maximum possible ilmenite contribution was subtracted from the FeO and TiO_2 contents before calculating a chemical formula on the basis of 22 oxygens for each of 47 spot analyses. Twenty analyses fall within the range of total K + Na + Ca and the range of total octahedral cations characteristic of mica from metamorphic rocks, 1.65-2.00 and 5.6-6.0, resp. With a mean atomic Fe/Mg ratio of 0.035 and a mean Na/K ratio of 2.9, this phase is Na-rich phlogopite. Eighteen of the remaining analyses have Na + K + Ca between 1.05 and 1.72 and octahedral cation sums between 6.1 and 6.5. These analyses are entirely consistent with mixtures of Na-rich phlogopite with 20-59% chlorite or Al-lizardite in which the octahedral cation sum ranges from 2.56 to 3.11 per seven oxygen atoms. The ragged material has a very similar composition to that

of HAP from Mokoia (Cohen *et al.*, 1983), a phase that also has a 10 Å interlayer spacing (Tomeoka and Buseck, 1986). The relative proportions of Ca + Mg + Fe:Al:Si span the same range in the ragged material and the fassaite of Al-rich inclusions, again suggesting replacement of the latter by the former. Addition of Na₂O, K₂O, H₂O and FeO was accompanied by replacement of CaO by MgO to transform fassaite into ragged material + ilmenite.

Phyllosilicate alteration products in Al-rich inclusions encased in thick, massive, phyllosilicate-free olivine mantles pose a potential problem for the origin of amoeboid olivine aggregates. Thermodynamic calculations suggest, however, that, at solar nebular water fugacities, hydration of olivine to form serpentine would only occur at $T < 274^\circ\text{K}$, hydration of fassaite to Na-phlogopite is possible at 470°K , and retrograde alteration of Na-phlogopite to chlorite is possible at 328°K . Thus, Na-phlogopite could have formed by reaction of solar nebular water vapor with fassaite, and chlorite could have formed from Na-phlogopite without serpentinization of olivine if $274 < T < 328^\circ\text{K}$.

Cohen, R.E. *et al.*, 1983. *GCA* **47**, 1739.

Hashimoto, A. and L. Grossman, 1984. *Meteoritics* **19**, 234.

Tomeoka, K. and P.R. Buseck, 1986. *LPS XVII*, 899.

METAMORPHISM VERSUS AQUEOUS ALTERATION IN TYPE 3.0-3.3 ORDINARY CHONDRITES

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There is considerable evidence that the type 3.0-3.2 ordinary chondrites differ in some fundamental way from the higher petrologic types. Since the properties that distinguish the type 3.3 from the higher types is due to different levels of metamorphism, it has been commonly assumed that the types 3.0-3.2 are the least metamorphosed ordinary chondrites known, and thus the "most primitive" (Sears *et al.*, 1980). Type 3.0-3.2 chondrites have the lowest TL sensitivities and do not lie on the TL sensitivity vs. peak temperature and peak width trends displayed by the higher types (Sears *et al.*, 1982; Sears and Weeks, 1983). They also have unique cathodoluminescence (CL) properties as minerals other than feldspar, which is the dominant phosphor in type > 3.3 , are the major sources of CL, and TL, in these lower petrologic type meteorites (DeHart and Sears, 1986). Semarkona shows much evidence for aqueous alteration (Hutchison *et al.*, 1985); stepwise heating releases water of unusual isotopic composition (McNaughton *et al.*, 1983), the matrix contains lines of calcite and some chondrules have been attacked to produce a material which give low sums upon electron microprobe analysis. We report here on a series of hydrothermal annealing experiments which demonstrate that the type < 3.3 ordinary chondrites may have been subject to aqueous alteration, while the higher types have suffered only metamorphism.

Semarkona (3.0), Allan Hills A77214 (3.4), Sharps (3.4) and Dhajala (3.8) were annealed at $450\text{-}900^\circ\text{C}$ for 10-500 h, at pressures of 0.77-1.0 kbar (Lofgren, 1971; Lofgren *et al.*, 1985; Guimon *et al.*, 1986a, 1986b). Various amounts of water and sodium disilicate were added to catalyze the devitrification process thought to be responsible for the metamorphism-induced TL increase. We found that low temperatures and short annealing times produced a decrease in TL sensitivity, while longer annealing times and higher temperatures produced an increase in TL sensitivity. The decrease occurred in samples with no sodium disilicate added, and we assume that it is due solely to the presence of water and the heating. The times and temperatures at which these changes occurred varied from sample to sample, but the decrease was greater for the samples with higher pre-annealing