TRACE ELEMENTS IN PETROGRAPHICALLY DISTINCT COMPONENTS OF ALLENDE INCLUSIONS.

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Fine-grained inclusions have been the subject of considerable interest since the discovery (1) that they contain highly fractionated, group II REE patterns. Thermodynamic calculations (2,3) indicate that a high-temperature component was removed from the solar nebular gas prior to condensation of these inclusions, and that it was highly enriched in refractory heavy REE relative to light REE and Tm compared to Cl chondrites. It has also been suggested (1,3) that another component, a so-called flat component, uniformly enriched in refractory elements relative to Cl's and perhaps identical to coarse-grained inclusions, has been added to the fractionated component. In an ongoing search for petrographic evidence for the flat component, we analyzed three samples from a single, large (>1 cm) fine-grained inclusion, Al4S6: one from an interior pink region, one from an interior purple zone and a third from an exterior white rim. These were excavated from the slab surface exposure of the inclusion whose mirror image on an adjoining slab was made into a polished thin section and studied by SEM. The pink zone, corresponding to Zone A in (4), is porous and contains Fe-bearing spinel, grossular and minor anorthite and Al-bearing clinopyroxene, all of which are sometimes enclosed by nepheline or sodalite. Perovskite ($\lesssim$3 μm) is found inside spinel. The purple zone, also part of Zone A (4), contains perovskite-bearing spinel grains that are enclosed by anorthite that is, in turn, enclosed by Al-diopside bands that often line irregular cavities which sometimes contain feldspathoids. The white rim, probably a mixture of Zones B and C (4), is andradite-, nepheline- and spinel-rich and contains minor Fe-bearing olivine. All three have group II REE patterns with light REE enrichments of ~15 for the purple zone, ~23 for the pink and ~50 for the rim. The Cl-normalized Sm/Lu ratios are 10 ± 1, 15 ± 5 and 3 ± 1, respectively. Calculations identical to those in (3) suggest that both the purple and pink regions contain nearly the same amounts of the flat REE component, 8.3 and 7.4%, respectively, while the rim contains much more, at least 50%. Tanaka and Masuda (1) also found an enrichment of flat component in the rim relative to the core of their fine-grained inclusion. Enrichment of the flat REE component in exterior rims of fine-grained inclusions may be the result of preferential introduction of this component into the outer parts of these inclusions during the extensive open-system alteration process envisioned in (4). Because the rim contains more Ir, 75 ppb, than the purple zone, 28 ppb, and less than the pink zone, 771 ppb, refractory siderophiles vary independently, at least in part, from the proportions of the REE components.

Bulk samples of two other fine-grained inclusions, F-9 and F-13, which have been studied by SEM were also analyzed for trace elements. Both have typical group II REE patterns with light REE uniformly enriched 5-8 times in F-9 and 14-17 times in F-13 with respect to Cl's. The major difference between the two REE patterns is the high Cl-normalized Sm/Lu ratio of 91 ± 17 in F-13 compared to 21 ± 5 for F-9. Thermodynamic calculations identical to those in (3) show that the REE in F-13 can be modelled as being composed entirely of the fractionated component with <0.05% of the flat component, while F-9 contains 1.5% of the flat component. No significant difference in refractory siderophile contents was seen between the two inclusions.

Both inclusions contain abundant, fine-grained, loosely-packed assemblages of feldspathoids, grossular and Al-, Fe-bearing clinopyroxene with spinel being the only surviving primary phase. If, as suggested above, the flat REE component is concentrated in outer rim layers of fine-grained inclusions, the pink and purple interior zones of Al4S6 would be expected to contain a smaller amount of this component than the more representative bulk samples of F-9 and F-13 but, in fact, the reverse is true. Perhaps the flat component is concentrated only in the outermost rim and none of these samples contain such material. The amount of this component present in the core of a fine-grained inclusion may depend on such things as the identity and porosity of the precursor assemblage.

Two samples were taken from the slab surface exposure of a large, fluffy Type A inclusion, A18S7, whose mirror image on an adjoining slab was made into a polished thin section, TS52F1, and studied by SEM. The interior sample, composed of large, relatively unaltered, gehlenitic melilite which poikilitically encloses spinel and perovskite, is uniformly enriched in both refractory lithophiles and refractory siderophiles by a factor of 20 ± 4, like many other Allende coarse-grained inclusions. The other sample, removed from a large pocket of fine-grained alteration products just inside the Wark-Lovering rim, is composed of spinel, grossular, hedenbergite, nepheline, anorthite and minor amounts of perovskite and Ti-pyroxene. While refractory lithophiles, including Ce, Sm and Yb, are uniformly enriched by a factor of ∿10 compared to Cl chondrites, refractory siderophiles are spectacularly depleted relative to them, the Ir enrichment factor being only 0.4. Although this may simply reflect an original, inhomogeneous distribution of refractory siderophiles within the primary assemblage, the possibility must be entertained that loss of siderophiles may accompany the advanced stages of alteration of coarse-grained inclusions.

Petrographic studies of amoeboid olivine aggregates (AOA) show that they consist of altered refractory inclusions that have been enclosed by and mixed with olivine (5,6). Many AOA are uniformly enriched in refractory elements relative to Cl chondrites but, in accord with petrographic work, the mean enrichment factor is much less than that for pure Allende coarse-grained inclusions, ∿4 vs 17.8 (7). In order to see if refractory element levels in AOA are correlated with the abundances of refractory inclusions from one aggregate to another, we analyzed two AOA, F-1 and F-5, for which we have performed detailed SEM-petrographic studies. Relative to Cl chondrites, the mean enrichment factors for refractory lithophiles and refractory siderophiles are 2.56 ± .46 and 1.33 ± .41, respectively, in F-5 and 1.58 ± .44 and 0.80 ± .24, respectively, in F-1. Although both AOA contain lower than average levels of refractory elements, the higher concentrations in F-5 compared to F-1 are definitely reflected in their petrographic properties. F-5 contains abundant, relatively unaltered, melilite-, spinel-, perovskite-bearing inclusions, some of which reach 300 μm in size. F-1 contains far fewer refractory inclusions, and these are more heavily altered and much smaller on average.

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