

RARE EARTH ELEMENTS IN A HIBONITE-RICH ALLENDE FINE-GRAINED INCLUSION; Andrew M. Davis¹ and Glenn J. MacPherson². ¹James Franck Institute, University of Chicago, Chicago, IL 60637. ²Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, D. C. 20560.

Allende inclusions 3529-40 was one of a number of inclusions whose petrography and bulk chemical compositions were studied by Mason and Taylor [1]. It has a group II REE pattern and is the most aluminum rich of the group II inclusions in that study, containing 52.35 wt% Al₂O₃. Reexamination of some thin sections of inclusions studied by Mason and Taylor revealed that 3529-40 is extraordinarily rich in hibonite. Since the hibonite is relatively coarse-grained in this inclusion, we have initiated an ion microprobe study of the distribution of the REE within 3529-40.

3529-40 is a fairly large inclusion. The portion represented in thin section is 1.2 cm long and 0.3 cm wide. The interior of 3529-40 contains abundant elongated hibonite 10 to 50 μm across. Many of these grains have rims of spinel speckled with submicron perovskite grains. Nepheline and sodalite are quite abundant in voids between the hibonite grains. Other abundant alteration phases are hedenbergite and kirschsteinite. The outer portion of the inclusion has an amoeboid texture, with spinel grains surrounded by diopside rims and interstitial hedenbergite. Nepheline and sodalite are common in voids.

Hibonite is uniformly low in magnesium and titanium, with 0.5 wt% MgO and 1.1 wt% TiO₂. It usually contains 0.15-0.30 wt% FeO. No zoning in hibonite composition was observed. Spinel is generally rather iron-rich, with 6 wt% FeO in cores and up to 10 wt% FeO in rims. Kirschsteinite is essentially stoichiometric CaFeSiO₄ with 0.4 wt % MnO.

A preliminary investigation of the magnesium isotopic composition of hibonite in this inclusion shows that δ²⁶Mg is correlated with ²⁷Al/²⁴Mg, consistent with an initial ²⁶Al/²⁷Al ratio of 5x10⁻⁵.

Hibonite in 3529-40 has the characteristics of that from group II inclusions. It has C1 chondrite-normalized enrichment factors of 70-170 for LREE, 5-8 for Eu, 70-90 for Tm and 1-30 for the remaining heavy REE and Y. In group II REE patterns, Tm has the same enrichment factor as the LREE. Hibonite in refractory inclusions often shows the effects of partitioning of REE with other phases, such that it is depleted in heavy relative to light REE. In group I inclusions, the effects of this partitioning are easy to see, but in group II inclusions, the group II characteristic is overprinted on the partitioning effects. The Tm/LREE ratio in hibonite from group II inclusions can be used to assess the degree of REE partitioning with other phases. The REE patterns of hibonite-rich portions of 3529-40 all have group II characteristics, but variable degrees of fractionation due to partitioning. Most are relatively unfractionated and show much less fractionation than hibonites from Murchison and Murray [2,3].

The degree of fractionation among the heavy REE in group II REE patterns provides an indication of the temperature at which the removal of the refractory heavy REE took place [4]. The REE patterns of hibonite-rich areas have a remarkably uniform degree of fractionation among the HREE, indicating that they condensed from a common reservoir. Most hibonite grains from Murchison show the effects of partitioning with other phases. This is believed to have been caused by cocondensation of hibonite with perovskite or zirconium oxide [3]. The fact that hibonite in 3529-40 is relatively unfractionated indicates that it condensed when no other REE carriers were present. Yttrium has an ionic radius between those of Dy and Ho. In hibonite which has partitioned REE with other phases, Y usually has an enrichment factor intermediate between those of Dy and Ho. Y is substantially more refractory than Dy and Ho and nearly as refractory as Lu. The abundance of Y in 3529-40 hibonite reflects this—in these grains Y has an enrichment factor similar to that of Lu, indicating that its concentration is controlled by volatility rather than ionic radius.

Group II REE patterns are believed to have formed by condensation from a gas from which the most refractory REE have been removed in a prior condensation episode [4,5]. Condensation calculations done using ideal solid solution of REE into hibonite can match most of the characteristics of group II REE patterns, but remove a substantial fraction of Tm in the first condensation step. This leads to REE patterns with much smaller Tm anomalies than are observed. In order for Tm to have a volatility similar to that of the LREE, the host phase in the first condensation step must favor light over heavy REE. Hibonite is the best candidate, because it has a high condensation temperature and strongly favors light over heavy REE in partitioning. Modeling group II inclusions with nonideal solid solution into hibonite matches observed patterns quite well. In order for hibonite to condense from the gas remaining after an episode of hibonite condensation, only a small fraction of hibonite must be removed in the early condensation step.

Allende inclusion 3529-40 appears to contain hibonite grains that have condensed from a reservoir from which the most refractory REE have been removed in an earlier event involving condensation of a small amount of hibonite. Hibonite appears to be the only primary mineral in this inclusion and it has been partially replaced with spinel and perovskite. A relatively short time must have elapsed between the two condensation episodes, because hibonite in 3529-40 has a calculated initial $^{26}\text{Al}/^{27}\text{Al}$ value similar to that found in many coarse-grained Allende inclusions.

REFERENCES: [1] Mason B. and Taylor S. R. (1982) *Smithson. Contrib. Earth Sci.* No. 25. [2] Fahey A. J. *et al.* (1987) *GCA* **51**, 329. [3] Hinton R. W. *et al.* (1988) *GCA* **52**, in press. [4] Davis A. M. and Grossman L. (1979) *GCA* **43**, 1611. [5] Boynton W. V. (1975) *GCA* **39**, 569.