RARE EARTH ELEMENT DISTRIBUTION IN A COMPLEX TYPE B1 ALLENDE INCLUSION, AN ION MICROPROBE STUDY; Glenn J. MacPherson*, Ghislaine Crozaz** and Laura L. Lundberg**, *Dept of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560, **McDonnell Center for the Space Sciences and Earth and Planetary Sciences Department, Washington University, St Louis, MO 63130.

USNM 5241 is a complex type B1 inclusion (radius ~0.8cm), described in detail by El Goresy et al. [1], that is notable for the large Fremdling "Willy" contained within it [2]. The inclusion consists of a melilite mantle (0.2cm thick) surrounding a core of fassaite (~80%) + melilite (~5%) + spinel (~ 10%) + anorthite (≤5%). Within the core are spinel-free islands of fassaite + melilite + rare anorthite that are interpreted by [1] to be xenoliths.

We measured rare earth element (REE) concentrations in individual melilite and fassaite crystals in the core and the mantle, as well as in the spinel-free islands, in order to shed further light on the origin of this interesting object.

Melilite in the mantle has a flat REE pattern close to the rim of the inclusion, but becomes progressively fractionated in light REE (LREE) over heavy REE (HREE) with increasing distance from the rim. The absolute abundances are ~15XC1 for rim melilite; in inner mantle melilites, they are HREE <10XC1 and LREE ~15XC1. All patterns show a large positive Eu anomaly. Absolute concentrations of the LREE remain roughly constant across the width of the mantle. Small, irregularly shaped, fassaite inclusions within mantle melilite show fractionated REE patterns (La/Tm~0.2XC1) with absolute concentrations of 10XC1 for the LREE and marked negative Eu anomalies. Melilite in the spinel-rich core of 5241 is markedly depleted in REE concentrations relative to the melilite in the mantle, by a factor of approximately 2, and with a strong positive Eu anomaly. Fassaite in the core is similar in absolute REE concentrations to fassaite inclusions within mantle melilite, with an enrichment of ~10XCI and a La/Tm ratio of ~0.2. Melilite in the spinel-free islands is distinctly different from melilite elsewhere in 5241: it is very depleted in REE relative to both the core and mantle melilite; concentrations are only 1 to 5XC1 and the pattern is flat with a positive Eu anomaly. Fassaite in the islands shows strong zoning of REE, with the Ti-rich cores being depleted by a factor of 4 to 5 relative to the Ti-poor rims. The fassaite REE patterns are fractionated and depleted in LREE by approximately 3 to 4 times relative to HREE, and show strong negative Eu anomalies. Absolute concentrations in the islands fassaite centers are 5 to 10XC1 for LREE and ~30XC1 for HREE; concentrations in their rims are 15 to 30XC1 for LREE and 80 to 140XC1 for HREE.

The REE data strongly indicate that the spinel-free islands are not in equilibrium with the melt from which the core solidified, and are consistent with the idea [1] that the islands are xenoliths that were accidentally trapped prior to solidification of the melt. The REE data do not by themselves rule out the possibility that the islands are unmelted relicts of the preexisting solids from which the melt may have been derived, although their lack of spinel is inconsistent with this hypothesis. The question of the origin of the melilite mantle is not clearly resolvable at this time. The progressive inward fractionation of melilite REE in the mantle is indicative of the beginning of pyroxene co-crystallization with melilite, as the melilite grew inward, consistent with the presence of minor pyroxene inclusions in the mantle melilite. Although this suggests that the mantle is indeed the first crystallizing fraction of the same liquid that ultimately formed the core, we cannot rule out the model of [1] that a later liquid (after coating the surface of the already solidified core) experienced partial equilibration with the pyroxene of the core. However, the nearly constant levels of LREE in the mantle melilite are incompatible with simple progressive crystallization inwards of an homogeneous melt, regardless of whether that melt was a separate late addition to the outside of the already solidified core [1] or whether it was simply the early solidifying fraction of a single melt that eventually formed the core as well [3, 4]. Moreover, the markedly lower REE levels of the core melilite relative to the mantle melilite show that the two could not have crystallized from an homogeneous melt. Rayleigh fractionation crystallization models, using modal proportions of the phases in the mantle and core and taking into account the compositional dependence of melilite REE partition coefficients [5], require that the interior liquid must have been depleted in REE relative to the outermost mantle by the time the core solidified. Since the mineral/liquid partition coefficients of all the phases present (particularly melilite) are less than unity, this depletion can not have been produced by any fractional crystallization process. The model of [1] can be reconciled with this observation by invoking partial fusion of the xenoliths within the interior. In this case, the only component that could have melted to any degree was the REE-depleted melilite, as the fassaite in the xenoliths is at least as enriched in REE as the bulk core and therefore would not have diluted the overall REE concentration. However, phases in multi-component systems melt in their eutectic proportions; since the eutectic composition of a melilite/fassaite solid is closer to the fassaite composition than to that of melilite [4], a considerable proportion of fassaite in the xenoliths would have experienced melting along with the melilite. Therefore, resorption of the xenoliths does not appear to be a satisfactory explanation for the low REE abundances of core melilite.

An alternative model that is consistent with all the observations is that of a single molten droplet (+xenoliths) that experienced volatilization of Mg and Si from its surface, thus establishing by difference a negative gradient of REE and other refractory element concentrations inward towards the core. Progressive inward crystallization had to occur within a sufficiently short timescale to prevent complete re-equilibration of the zoned liquid droplet. A consequence of this model is that it requires the heating process to have occurred within a relatively short timescale, in particular ruling out the possibility of a very high regional gas temperature within the nebula. A local and transient heating process is indicated.

REFERENCES:

[1] El Goresy A. et al. (1985) Geochim. Cosmochim. Acta **49**, 2433;
[2] Armstrong J. T. et al. (1985) Geochim. Cosmochim. Acta **49**, 1001;
[3] MacPherson G. and Grossman L. (1981) Earth Planet. Sci. Lett. **52**, 16;
[4] Stolper E. (1982) Geochim. Cosmochim. Acta **46**, 2159;
[5] Nagasawa H. et al. (1980) Earth Planet. Sci. Lett. **46**, 431.