RARE EARTH ELEMENT SYSTEMATICS OF FINE-GRAINED CALCIUM-ALUMINIUM-RICH INCLUSIONS AND AMOEBOID OLIVINE AGGREGATES FROM EFREMOVKA (CV3). S. S. Russell[1], A. N. Krot[2], T. E. Jeffries[1], and A. A. Ulyanov[3] [1]Dept. Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD, UK (sarr@nhm.ac.uk) [2]Hawai'i Institute of Geophysics and Planetology, School of Ocean and Earth Science and Technology, Universitry of Hawai'i at Manoa, Honolulu, HI 96822, USA. [3]M.V. Lomonosov Moscow State University, Moscow 117999, Russia.

Introduction: Many components of chondrites have experienced melting prior to their incorporation into the chondrite parent body. Important exceptions include fine-grained spinel-rich calcium aluminium-rich inclusions (CAIs), and amoeboid olivine aggregates (AOAs). Both of these groups of objects have 'fluffy' textures and are aggregates of small, irregularly-shaped grains, thus they may represent pristine condensates from the early solar system. Our aims were to study the trace element characteristics of condensed components and to compare and contrast two groups of objects (AOAs and CAIs) that have different bulk chemistries, in order to compare their origins.

Previous studies of REEs in fine grained CAIs and AOAs have focused on inclusions from the oxidized CV3 chondrite Allende [1, 2] that experienced late-stage metasomatic alteration [3]. In order to minimize effects of secondary alteration, we selected inclusions from the reduced CV3 chondrite Efremovka meteorite, that is less altered than Allende [3].

Techniques: Samples were measured using a quadropole-based LA-ICP-MS. Spot sizes of 50-100 µm were used, which is larger than the average grain size of the inclusions. Thus, we acquired data on the bulk composition of these objects.

Samples: We studied four fine-grained CAIs from Efremovka: E42, E49, E51, and E67. These CAIs are mineralogically-zoned with a core rich in spinel, anorthite and diopside, and a mantle rich in melilite. E49 is a compound object that contains a region texturally and mineralogically similar to compact type A CAIs. The mineralogy and petrology of these CAIs are decribed in detail in [4]. One CAI, E68, is considered separately from the other CAIs. E68 is coarser- grained than fine-grained CAIs and is richer in hibonite that the other CAIs. Six AOAs (five from section E68, and one from E51) were also analysed.

Results and Discussion:

Fine grained CAIs: Results for the fine-grained inclusions are shown in Figs. 1-4. Each of the fine-grained CAIs exhibited Type II REE patterns at least in part, in line with previous studies of fine-grained inclusions [3, 5]. This REE pattern probably form by condensation of a gas depleted in refractory REEs [6]. REEs are typically present at levels of around 10×CI. There are subtle, but real, differences in the REE patterns observed between the inclusions. They show differences in the degree of LREE/HREE fractionation: Ce/Er varies between 6 (in E42) and 36 (in E51). E49 (Fig. 1) is composed of two different domains. The main part of the CAI has a Group II pattern, and the CAI also contains a compact melilite-rich region (mantle 2) that has an unfractionated pattern, as previously reported [5], suggesting it is a compound CAI.

For the non-compound CAIs, no differences were observed between any of the layers within the CAIs, reinforcing the suggestion by Krot and co-workers that the mantles form by gas-solid reactions at relatively low temperatures [4].

Medium-grained CAI: The core of E68 has a Group III REE pattern, with highly variable REE abundances, from 10×CI to 300×CI. Depletions in Eu and Yb imply the inclusion has experienced an intense heating event that allowed these elements to evaporate [6]. The mantle of the CAI has a smaller depletion in Eu and Yb than most core measurements, with REE abundances of ~20×CI. The variability observed between measurements may be a sampling artifact, since E68 has a grain size comparable to the diameter of the laser pit. The measurements with the most pronounced Eu and Yb depletions appear to be associated with hibonite, and since this pattern is associated with evaporation rather than condensation, the hibonite in E68 may be relict.

AOAs: REEs in AOAs were present at levels similar to those observed in fine grained CAIs, around 5 to 10×CI, and are typically unfractionated. One AOA in E68 (AOA5) has a "Type VI" pattern (characterized by positive enrichments in Eu and Yb), which must have formed by condensation of material that had previously evaporated from a solid. It is complementary to the Group III pattern of, for example, E68.

Conclusions: Fine-grained CAIs and AOAs condensed from reservoirs that were similarly enriched in ^{16}O [7]. However, REE patterns are clearly distinguishable between these different types of refractory objects. This suggests that they cannot have formed from exactly the same reservoir, but may have condensed in different places or times within the ^{16}O-rich gaseous reservoir(s). The compound CAI E49 demonstrates that the objects may have moved between regions of distinctive REEs. AOAs are likely to be intermediate between fine-grained inclusions and chondrules, as like chondrules they tend to have unfractionated REE pat-

terns, although their overall REE abundance is higher than in most chondrules [8].

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