FINE-GRAINED CAIs IN EFREMOVKA AND LEOVILLE: IN-SITU LAYER GROWTH AND CONFIRMATION OF A LINK TO RIMS ON COARSE-GRAINED CAIs; A. Ruzicka and W.V. Boynton, University of Arizona, Tucson, AZ 85721, USA.

Fine-grained CAIs (here defined as spinel- or melilite-bearing "Ca- and Al-rich" inclusions that have a characteristic grain size of <50 μm) in the Efremovka and Leoville (CV3) chondrites were studied using SEM, microprobe, and optical techniques to provide a basis of comparison to well-studied inclusions in Allende and other chondrites [1-5]. CAIs in Vigarano, Leoville, and Efremovka were less affected by low-temperature alteration than CAIs in other chondrites [6,7], but to date little work has been performed on fine-grained CAIs in these meteorites. Our results 1) confirm that fine-grained CAI in Efremovka and Leoville largely escaped low-temperature alteration; 2) suggest that some (but probably not all) of these inclusions are aggregates with various proportions of olivine (ol) and layered objects with "refractory" (mainly Al-rich) cores; 3) suggest that all of the inclusions experienced high-temperature metamorphism that enabled clinopyroxene (cpx) layers to grow at least partly *in situ* (after inclusion formation); and 4) indicate that fine-grained CAIs are very similar and probably genetically related to rim layers on coarse-grained CAIs.

INCLUSION COMPONENTS. All fine-grained CAIs in Efremovka and Leoville contain subrounded to sinuous to convolute layered objects that have "refractory" cores (typically 5-100 μm wide) rich in either spinel (sp; Mg/(Mg+Fe) ~0.90-1.0), melilite (mel; $Åk_{3-40}$), or fassaite (Tpx) + anorthite (anor; An_{95-100}). Sp-cored objects are surrounded (from cores outward) by successive layers of mel or anor, cpx, and sometimes ol; mel-cored objects are surrounded by successive layers of anor, cpx, and sometimes ol; and Tpx- and anor-cored objects are surrounded by successive layers of cpx and sometimes ol. These layers are monomineralic, except for anor layers around mel-bearing cores, which appear to grade into the cores, and except for ol layers, which are sometimes intergrown with a small amount of cpx and Ca-rich feldspathic material. Cpx layers are mainly composed of Al-diopside (Al-diop), although diopside, augite, and Tpx are also present. The cpx layers are often (but not always) zoned with decreasing Ti and Al away from the cores, especially when Tpx is present in the latter. The other major lithology sometimes present in fine-grained CAI is composed mainly of zoned ol (Fa_{0-35}) grains 1-10 μm across and accessory Ca-rich feldspathic material, cpx, and metal. Low-temperature alteration products that are usually common in CAIs [8] are rare in these inclusions, although a small amount of nephelinitic material is often associated with anor.

FORMATION BY AGGREGATION. That most of the fine-grained CAIs formed by aggregation (in agreement with [1-5]) is suggested by 1) the irregular, often "clumpy", form of the CAIs; 2) the relatively high porosities of the inclusions (ranging from ≤1 to ~10%, defining areas that are filled with matrix-like material to be "pores"); 3) the tendency for matrix-filled pores and cracks to occur roughly equidistant to adjacent layered objects and between layered objects and ol-rich areas (which suggests that the various core objects and ol-rich areas formed independently of one another); and 4) the presence of layers in the CAIs, which are unlike what one would expect for igneous crystallization. The textures are best explained by the accumulation of ol grains and refractory objects into porous aggregates.

IN-SITU GROWTH OF LAYERS. Internal layers comprise between 5-75 vol% of fine-grained inclusions. Although some layer growth may have occurred around refractory core objects prior to their becoming incorporated in the inclusions, there is good evidence that some layers, especially cpx (Al-diop) layers, grew *in situ* following inclusion assembly. This evidence includes: 1) the physical continuity of cpx layers, which often form an interconnected "groundmass" around refractory core objects; 2) the tendency for cpx layers to fill even the most irregularly-shaped interstices between adjacent core objects; 3) the occasional uniform crystallographic orientation of cpx layers, either locally, or as in one case, throughout the entire inclusion; and 4) the tendency for cpx layers to have smooth, systematic variations in composition (often with Ti and Al decreasing away from core objects), with no chemical discontinuities evident. *In-situ* growth could have occurred either by condensation in void spaces between adjacent refractory objects or by metamorphism and metasomatism (coupled diffusion and reaction). We believe that growth during metamorphism (possibly in an open-system) is more likely than condensation, because the layers tend to be massive, compact, and relatively non-porous. The importance of metamorphism in the formation of at least one other well-studied, fine-grained CAI in Efremovka was also emphasized by [6].

LINKS TO RIMS ON COARSE-GRAINED CAIs. Ever since layers associated with CAIs were first systematically described [1], it has been recognized that fine-grained CAIs seem to consist of the same materials as rims on coarse-grained CAIs. Based on our data for relatively unaltered CAIs in Efremovka, Leoville, and Vigarano, this apparent link is confirmed. Compositions of various minerals in fine-grained CAIs are similar to their

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counterparts in rim layers on coarse-grained CAIs, and the bulk compositions of fine-grained CAIs and rims on coarse-grained CAIs overlap. Moreover, fine-grained CAIs and rims on coarse-grained CAIs have similar layer sequences, allowing the components of fine-grained CAI to be correlated with various portions of rims on coarse-grained CAIs (Table 1). Sp-rich cores and mel-bearing cores of layered objects in fine-grained CAIs appear to correspond to the sp-rich rim layer and the interiors of coarse-grained CAIs, respectively, while the ol-rich lithology or the ol layer in fine-grained CAIs appears to correspond to the ol-rich rim layer on coarse-grained CAIs (Table 1). The ol-rich layer on coarse CAIs consists in part of zoned grains that pre-existed rim formation [8], and these grains are very similar in size and composition to zoned ol grains in the ol-rich lithology of fine-grained CAIs. Tpx- and anor-rich cores in fine-grained CAIs may correspond to a variant of the contact between the mel/anor and Tpx layers in rims around coarse-grained CAIs. In addition to structural and chemical similarities between fine-grained CAIs and coarse-grained CAI rims, the latter sometimes contain outward-extending, bulbous "rim protrusions" that appear to be equivalent to fine-grained CAIs. Rim protrusions contain one to two dozen concentrically layered objects (most commonly containing cores of Tpx + anor, but also containing cores of sp or mel). Concentric cpx layers in the protrusions typically grade into planar cpx layers on the surfaces of the coarse-grained CAIs, implying that the concentric layers of fine-grained inclusions and the planar layers of coarse-grained inclusions formed at the same time and in the same way.

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Table 1. Idealized correlated stratigraphy of layered objects in CAIs.

OBJECT	Interior						Exterior
coarse-grained CAIs [8]	mel-rich	sp-rich layer	mel/anor layer	Tpx layer	Al-diop layer	± ol-rich layer	matrix
mel-bearing cores in fine-grained CAIs	mel-bearing cores		anor layer (grades into core)		cpx layer (mainly Al-diop)	± ol layer	± matrix in pores or ol grains
sp-rich cores in fine-grained CAIs		sp-rich cores	mel or anor layer		cpx layer (mainly Al-diop)	± ol layer	± matrix in pores or ol grains
Tpx + anor cores in fine-grained CAIs				? Tpx + anor cores	cpx layer (mainly Al-diop)	± ol layer	± matrix in pores or ol grains