EXOGENIC (?) CLASTS IN LL4 CHONDRITE MILLER RANGE (MIL) 15285.

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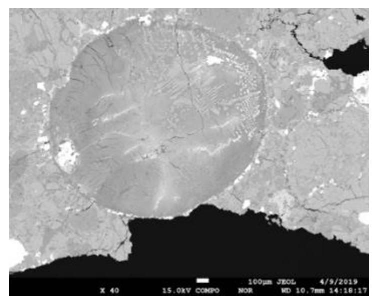
Introduction: While most chondrites contain one or more unusual chondrules or mineral fragments, these particles typically experienced a similar history of formation, accretion and metamorphism as other chondrules or fragments in the same meteorite. An example of such a clast can be found in LL6 Miller Range (MIL) 07065, where a mm-sized, hemispheric barred spinel occurs in a chondrule which has experienced similar metamorphism and is of similar size as other chondrules in the same meteorite [1]. In contrast, a newly identified LL4 chondrite, MIL 15285, contains a number of chondrules and clasts that appear to have experienced a distinct history from the remainder of the meteorite, suggesting the possibility that these are exogenic in origin and that the meteorite may be a regolith breccia.

Host/Mineralogy: The LL4 chondrite host material is only modestly weathered and/or shocked. Two thin sections (,2 and ,3) were made of this meteorite and both were used in the classification. This meteorite contains a wide array of chondrule sizes, ranging from 0.2 to multiple mm in diameter. Chondrules are compound (with one unique barred olivine chondrule inside of a barred/porphyritic chondrule), barred olivine, porphyritic olivine, porphyritic olivine and pyroxene, and radial pyroxene. Matrix includes fragments/grains of olivine, pyroxene and feldspar. Some chondrules retain glassy mesostases. Generally, olivines range from Fa_{27-30} and pyroxenes are $Fs_{22-24}Wo_{0.5-2.0}$. Feldspars within the meteorite range from $An_{63-88}Or_{0.8-1.1}$ (see below).

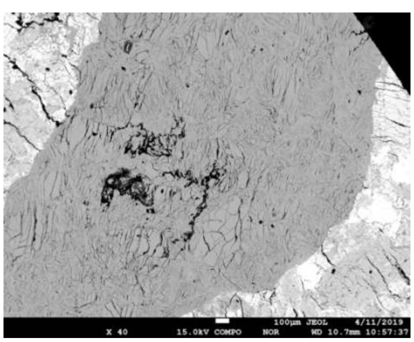
Unique Clasts: Within this meteorite are found three notable particles.

Olivine Chondrule?: The first is a large (~3 mm diameter), polycrystalline olivine chondrule or grain, with a radiating texture that also includes embedded olivine grains. This olivine is generally the same composition as the rest of the host LL chondrite but with a slightly more variable composition (Fa_{25-30}).

Glassy Spherule: This 2 mm diameter glass sphere contains skeletal, cruciform dendrites of what appear to be chromite-rich spinel set in a microcrystalline mesostasis of Al-rich glass. The spinel only occupies a few percent of the entire spherule (Fig 1). The composition of this particle is not at all similar to the bulk chondrite. It may have been created through impact, but is an unusually high in CaO, TiO_2, Cr_2O_3, Al_2O_3, and Na_2O, and unusually low in FeO, SiO_2, and dramatically lower in MgO compared to bulk LL chondrites. Therefore, this clast is not likely a product of the bulk melting of the host chondrite.



Feldspar Grain: Most intriguing in the meteorite is what appears to be a single, large (2.4 x 3.5 mm) feldspar grain (Fig. 2) that is fractured and sheared, exhibiting multiple offsets. The composition of this grain is dominantly $An_{63}Or_{0.8}$ with two analyses at $An_{70}Or_{0.6}$. This composition is different than those seen in the chondrule feldspars ($An_{88-90}Or_{0.5-1.1}$). As with the glass spherule described above, the composition of this clast is inconsistent with that of the host LL chondrite and is significantly more calcic. When compared to other types of meteorite feldspar, this grain is also more calcic than other equilibrated chondrites including ordinary and enstatite chondrites, but is within the broad range observed for equilibrated CK chondrites [2]. However, the large size of this grain is not generally observed in chondrites, suggesting a possible origin from a differentiated body. This grain is less calcic than lunar feldspars [3] or angrites [4]. The grain is less sodic than aubrites, brachinites and the GRA 06128/129 pair [4, 5]. The composition is similar to those observed in HED meteorites, although slightly more sodic [4], and is also within the range of Martian meteorites [6], although this grain is not maskelynitized, as is typically seen in Martian meteorites.



Future work: Additional studies of this meteorite could include measurement of solar wind implanted gases to test whether it is a regolith breccia, age dating of the feldspar grain, and oxygen isotopes of the grain to determine its parent body.

References: [1] Corrigan et al. (2016) *Meteoritics & Planetary Science* 51, #6479. [2] Brearley and Jones (1998) *Planetary Materials*, MSA 36, 3. [3] Papike et al. (1998) *Planetary Materials*, MSA 36, 5. [4] Mittlefehldt (1998) *Planetary Materials*, MSA 36, 4. [5] Day et al. (2012) *GCA* 81, 94-128. [6] McSween and Treiman (1998) *Planetary Materials*, MSA 36, 6.