Felispathic Lunar Meteorite Graves Nunataks 06157, A Magnesian Piece of the Lunar Highlands
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**Introduction:** To date, 49 feldspathic lunar meteorites (FLMs) have been recovered, likely representing a minimum of 35 different sample locations in the lunar highlands. The compositional variability among FLMs far exceeds the variability observed among highland samples in the Apollo and Luna sample suites [1]. Here we will discuss in detail one of the compositional end members of the FLM suite, Graves Nunataks (GRA) 06157, which was collected by the 2006-2007 ANSMET field team [2]. At 0.79 g, GRA 06157 is the smallest lunar meteorite so far recovered. Despite its small size, its highly feldspathic and highly magnesian composition are intriguing (Fig. 1). Although preliminary bulk compositions have been reported, thus far no petrographic descriptions are in the literature [3]. Here we expand upon the bulk compositional data, including major-element compositions, and provide a detailed petrographic description of GRA 06157.

**Methods:** Trace-element compositions were determined by INAA (instrumental neutron activation analysis) on 57 mg of GRA 06157. Major-element compositions were determined by electron probe microanalysis (EPMA) of fused beads (FB) prepared from the INAA samples [4]. Petrography was determined using back-scattered electron (BSE) images, elemental x-ray maps, and quantitative EMPA on polished thin section GRA 06157,8 (~10 mm\(^2\); Fig. 2).

**Petrography:** GRA 06157 is a glassy-matrix regolith breccia containing abundant lithic and mineral clasts and a few small impact spherules (Fig. 2 blue). All of the lithic clasts identified are granulite clasts. The mineral clast population is dominated by plagioclase, pyroxene, and olivine, with trace amounts of FeTiCr oxides, FeNi metal, and FeS. The meteorite has a discontinuous vesicular fusion crust on three sides.

The most abundant type of lithic clast is highly feldspathic granulate (>90% plagioclase) consisting of large plagioclase grains, up to 1 mm in their longest dimension, that contain tiny rounded inclusions of pyroxene, almost always less than 2 \(\mu m\) wide. All granulite clasts have highly calcic plagioclase (An\(94-97\)). Rarely there are strings of larger pyroxene grains (up to 
\(\sim 20 \mu m\) wide) present along the borders of some plagioclase grains (Fig. 2 green). Augite is the dominant pyroxene (En\(46\)Wo\(42\)Fs\(12\); Fig. 3), with rare occurrences of hypersthene (En\(45\)Wo\(40\)Fs\(15\)); there is no compositional difference between the different size pyroxenes. Minor olivine grains also occur, with a relatively wide range in compositions (Fo\(60-78\)). There are also troctolitic granulite clasts, including the largest lithic clast in the section (\(\sim 1.5 \times 1.5 \mu m\); Fig. 2 magenta). They contain up to 50% magnesian olivine (Fo\(78\)), <5% magnesian augite (En\(53\)Wo\(37\)Fs\(10\)), <5% near end member magnesian spinel (mgl' = 83; 1.7 wt% Cr\(_2\)O\(_3\)), and trace amounts of bronzite (En\(77\)Wo\(3\)Fs\(20\)). A few small (~150 \(\mu m\)) mafic granulate clasts (plagioclase is <20% by mode) are compositionally similar to the more feldspathic granulite clasts (Fig. 2 orange), albeit with more ferroan pyroxene compositions (En\(90\)Wo\(42\)Fs\(10\), En\(55\)Wo\(37\)Fs\(43\)).

![Figure 1: Al\(_2\)O\(_3\) vs. mgl' for 72 of 78 known lunar meteorites. Data from FB-EPMA at Washington University.](https://ntrs.nasa.gov/search.jsp?R=20120011725)
**Discussion:** On the basis of significant differences in mg', siderophile-element concentrations, and clast populations, GRA 06157 is not paired with any other FLM. The high Mg' of GRA 06157 is due to the overall magnesian nature of its clasts, in particular the presence of the highly magnesian spinel-bearing troctolitic granulite clasts and forsterite mineral clasts. The presence of spherules makes GRA 06157, by definition, a regolith breccia (this is also supported by the presence of a vesicular fusion crust). The paucity of impact spherules or glass clasts of any kind, coupled with low siderophile concentrations suggests it represents an immature regolith. Low concentrations of incompatible elements commonly associated with KREEP suggests that its provenance was distant from the Procellarum KREEP Terrane. Finally, the presence of a likely pyroclastic spherule indicates there is at least a minor basaltic component in GRA 06157. The absence of lithic basalt clasts, the coarse-grained nature of the pyroxene exsolution, and the overall magnesian nature of the sample suggest that the basaltic component is minor.


**Figure 2:** BSE images (grey scale) and an RGB elemental x-ray map of lunar meteorite GRA 06157. The scale bar applies only to the main image.

**Figure 3:** Pyroxene and olivine compositions in GRA 06157 mineral clasts (MC, grey) and lithic clasts (LC, blue,cyan). Different symbols in the same color represent different clasts.