GRANULITE CLASTS OF INTERMEDIATE MG* IN LUNAR METEORITE ALHA 81005: CHEMICAL COMPOSITIONS AND ORIGINS. K.E. Rahilly[1] and A.H. Treiman[2], [1]Smith College, 7 College Lane, Northampton, MA 01063, krahilly#email.smith.edu, [2]Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058, treiman#lpi.usra.edu

Lunar highland meteorites contain fragments of metamorphic granulites with a wide range of Mg* (molar Mg/(Mg+Fe)) [1], between that of Mg-suite plutonics and magnesian anorthositic granulites (MAG), and those of ferroan anorthosites (FAN), Figure 1 [2,3]. The intermediate-Mg* granulites have been inferred (explicitly or implicitly) to represent mixtures of FAN and MAG or Mg-suite rocks. To test this inference, we analyzed granulite clasts in lunar meteorite ALHA 81005, which include MAG, FAN composition, and those of intermediate Mg*. Most of the intermediate-Mg* granulites cannot be simple binary mixtures of MAG and one FAN composition. Thus, the intermediate-Mg* granulites probably formed from several precursor materials, and likely by several mechanisms, including solid-state diffusion.

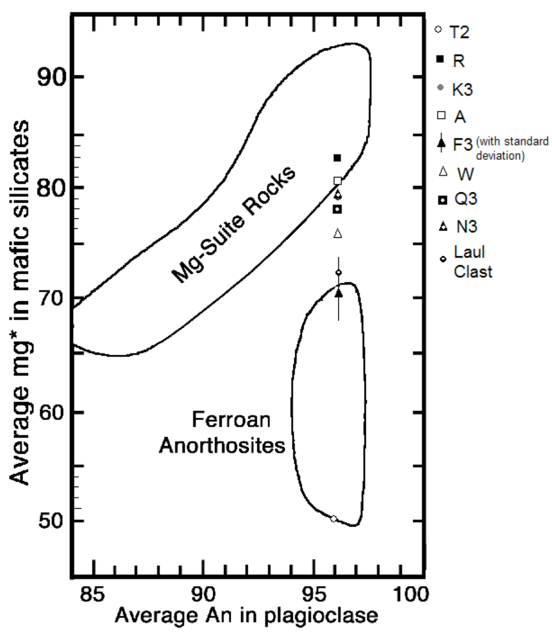

Figure 1. An-Mg* for Mg-granulitic clasts analyzed here, and one from *Laul et al.* [10].

Sample and Methods: Meteorite ALHA 81005 is a regolith breccia from the lunar highlands [4-6]. Its clasts include granulites, FAN, mare basalts, impact melts, and impact glasses. We analyzed granulite clasts in thin section ,9 [4].

We obtained mineral analyses and x-ray maps for eight fine-grained, granulite clasts. Compositions of mafic minerals in the clasts were obtained with the SX100 EMP at JSC and the JEOL 733 (focused beam, 10-40 nA, 15kV accelerating potential) at the University of Houston. Standards included well-characterized natural and synthetic materials; analyses were with a. Plagioclase analyses are pending. BSE images (Fig. 2) and elemental maps were obtained with the SX 100 and a JEOL FEGSEM at JSC.

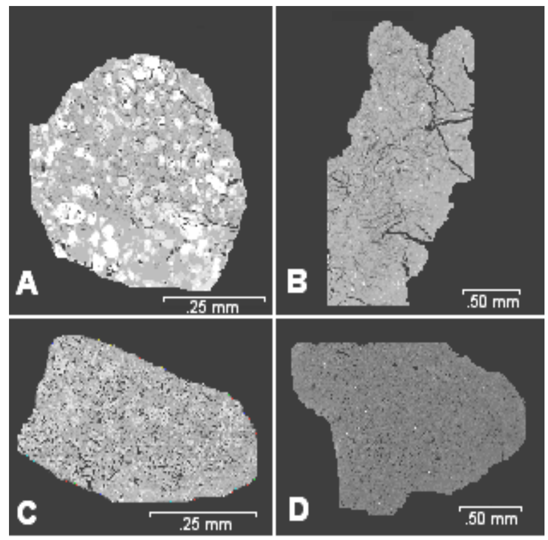

Figure 2. BSE images of four granulite clasts. Darkest gray is plagioclase; intermediate grays are pyroxenes; lightest shades are olivine. (A) Clast F3, with Fe-rich rim and darker Mg-rich core. (B) Clast T2. (C) Clast W. (D) Clast R.

Mineral proportions in each clast were obtained from the X-ray maps, using the histogram functions of the program ImageJ and the classification routines in the program MultiSpec® [7-9]. The bulk chemistry of each clast was calculated from mineral analyses, proportions, and densities (for An96 plagioclase).

Results: The eight granulites from thin section ALHA 81005,9, and one clast from *Laul et al.* [10], include MAG, FAN, and intermediate-Mg* compositions. Clast T2 (Fig. 2-B) has Mg* of 50.5, and > 90% plagioclase (=> Al_2O_3 = 32.4% wt) -- typical of normal FAN. Clasts A and R (Fig. 1-D) are MAG (Mg* = 80.5 and 82.9 respectively; Fig. 3), and are comparable to MAG clasts reported by [5,11,12]. Clast A contains a small proportion of Al-Cr spinel, as do some MAG in this and other lunar highland meteorites [11,12].

The other five granulites have intermediate-Mg* compositions (Figs. 1,3). Clasts K3 and N3 are nearly identical, with Mg*s of ~78.8, and Al_2O_3 = 21.5% wt. Clast Q3 has the same Mg* as K3 and N3 (78), but is richer in plagioclase. Clast F3 (Fig. 1-A) is texturally like the other granulites, but olivine in its center is more magnesian than that in its rim (Mg* = 73.5 ± 3.5 vs. 68.7 ± 2.5). Clast W (Fig. 1-C) contains 30% Al-Cr spinel, 48% plagioclase, and olivine with Mg* = 75.5. The *Laul et al.* [10] clast is "white" with Mg*=72 and Al_2O_3 = 25.9% wt.

Discussion: To test the idea that intermediate-Mg* granulites represent mixtures of MAG and FAN, we plotted their compositions in Fig. 3 of Mg* versus bulk Al_2O_3 content. On that diagram, mixtures of MAG and FAN mark out hyperbolae between the end-member compositions; and Fe-Mg diffusion changes Mg* without changing Al_2O_3 much. Igneous processes (accumulation, fractionation) can produce trends in several directions – as an example, Figure 3 shows some Stillwater anorthosites [13]. Figure 3 shows that the compositions of granulites in ALH 81005 cannot be explained by a single process (e.g., mixing). Clast Q3's composition is the only one fully consistent with simple mixing, as it falls near mixing lines between MAG and typical FAN (clast T2 & Dho081 bulk). Clasts R, A, and the Laul clast could represent a mixing line between MAG and a ferroan troctolite or norite (not an anorthosite); such lithologies are not reported in ALHA 81005, but are in other lunar samples [14,15]. Clasts F3, N3, and K3 could represent MAG that partially exchanged Fe/Mg with a ferroan reservoir (shock melt?). Clast W, being rich in Al-spinel, cannot be a simple mixture of FAN and MAG (neither contain significant Al-spinel); its origin requires some sort of igneous processing.

Conclusions: Intermediate-Mg* granulites from ALHA81005,9 do not form a simple mixing trend between MAG (or Mg-suite plutonic rock) and a known FAN composition. Clast Q3 is consistent with that simple model, and many clasts could represent mixtures of MAG and other anorthositic materials (not now known as individual rocks). But, clasts F3 and W clearly show that all intermediate-composition granulites cannot be simple mixtures of MAG and FAN rocks.

Results here on intermediate-Mg* granulites need to be extended, both as revisits to Apollo samples and as studies of other lunar highland meteorites. These results will help elucidate the constituents of the lunar crust and surface – whether the anorthositic materials in hand were present during formation of the granulites – and whether (and how) the highlands crust sampled by the Apollo missions differs from that sampled by the lunar meteorites.

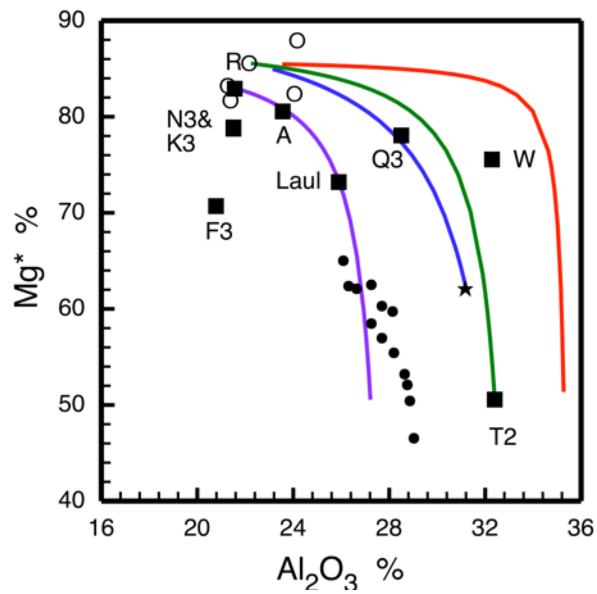

Figure 3. Bulk compositions of granulite clasts here and from Laul [10] (squares), and MAG from [11,12] (open circles). Mixing lines between MAGs and: the Dho081 anorthosite meteorite (blue line & star); Apollo anorthosite 60025 (red line [15]); clast T2 (green); and a ferroan anorthositic troctolite/norite (purple). Filled circles are anorthosites from the Stillwater complex, MT [13].

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