**FELDSPATHIC GRANULITE CLASTS IN LUNAR METEORITE SHIŞR 161 – CUMULATES FROM A DIFFERENTIATED BASIN MELT SHEET ?** A. Wittmann[1], R. L. Korotev[1], B. L. Jolliff[1]. [1]Department of Earth & Planetary Sciences, Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130, wittmann@levee.wustl.edu.

**Introduction:** Lunar regolith breccia Shişr 161 has a feldspathic, magnesian character [1,2], normatively an anorthositic norite. Its bulk rock composition is unusual in being at the mafic end of the range (Mg# 71) but having low concentrations of incompatible elements, e.g., 0.16 ppm Th, precluding the presence of a significant KREEP component. Siderophile-element abundances are low for a regolith breccia, e.g. 2.6 ppb Ir, indicating only minor meteoritic contamination. In order to trace the origin of its magnesian feldspathic affinity, we did modal recombination of the major clast components in Shişr 161 and report the results here.

**Samples and Methods:** In a 550-mm$^2$ thin section of the 57-g meteorite, the 60 largest clasts were petrographically characterized. EMPA analyses of the major and minor constituent phases of these analyses was then used to conduct modal recombination after the component proportions in the respective clasts had been determined by image analysis of BSE images.

**Results:** Only 8 clasts are larger than 3 mm in length. Clasts > ~150 µm in size amount to 24% of the thin section area (TSA). Major clast components are single-crystal clasts and polymict breccias (3% TSA), a 6.2 mm long very-low-Ti pigeonite basalt clast (3% TSA), vitrophyres and glasses (6% TSA), hornfelsic clasts (<1% TSA), and crystallized impact-melt clasts (12% TSA). Crystallized impact-melt clasts include types with ferroan affinities that are mostly very fine grained (average grain sizes <0.03 mm), and typically more coarsely crystallized clasts (average grain sizes ~0.05–0.35 mm) with cumulate textures and magnesian affinities ([3]; Fig. 1a). A subset of crystallized melt clasts and most cumulate clasts have affinities towards magnesian anorthositic granulites (Fig. 1b). Two cumulate clasts and a fraction of crystallized melt clasts could be mixtures of ferroan anorthositic (FAn) and mare lithologies. One clast is an aluminous VLT basalt.

Two-pyroxene thermochemical modeling determined equilibration temperatures of 850 to 1100°C for pyroxene pairs in crystallized and cumulate melt clasts.

Fe-Ni metal particles in the cumulate melt particles mostly follow the 20:1 Ni/Co ratio of chondrites and most of them have Ni abundances >35 wt%.

**Discussion:** How did the cumulate-textured impact-melt clasts of Shişr 161 form ? Compared with model compositions of the lunar crust [6], both the bulk rock composition and the modal mineralogy of

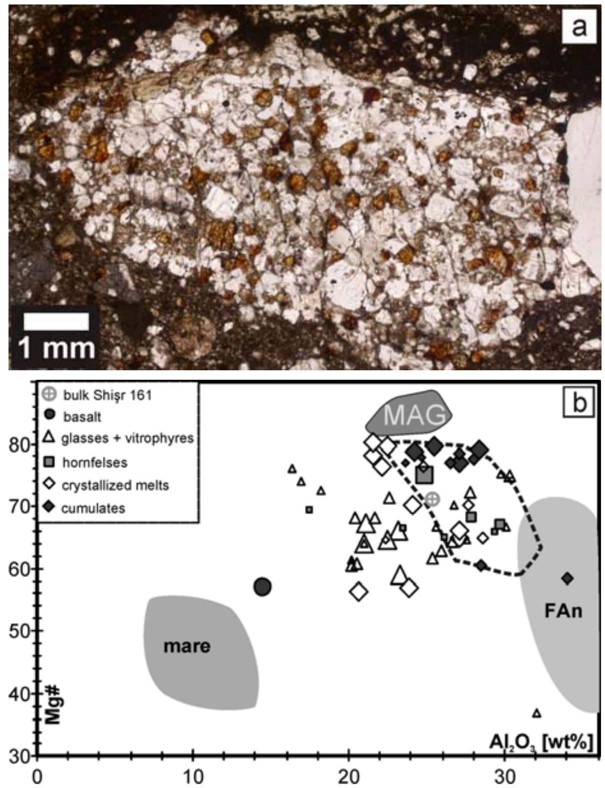


*Fig. 1. a) Feldspathic cumulate clast in Shişr 161. Clear plagioclase and brown olivine form a cumulate texture with interstitial grey pyroxene; plane polarized light micrograph; b) $Al_2O_3$ (wt%) versus Mg# (mole % Mg/(Mg+Fe)*100) of Shişr 161 clasts; diagram modified after [4]). Large symbols for clasts >1 mm$^2$, medium symbols for clasts 1-0.5 mm$^2$, and small symbols for clasts <0.5 mm$^2$. Dashed outline indicates field for the composition of 36 feldspathic lunar meteorites that have FeO abundances <7 wt%. Field for magnesian anorthositic granulites (MAG) after [5].*

Shişr 161 suggest a lower crustal origin for most of the material that constitutes this immature regolith breccia (Table 1). Thus, the cumulate melt particles likely were part of a melt volume that formed as a result of impact melting of a significant portion of the Feldspathic Highlands Terrane's (FHT) lower crust. The average thickness of the FHT crust is taken to be ~50 km [8]. In order to excavate material from the bottom of the FHT crust, an impact with a minimum transient-cavity diameter of ~500 km is required [9], a premise only fulfilled by 6 impact basins on the Moon [10]. However, because the melt zone in a large crater reaches much deeper than the excavation zone, it is

Table 1. Model crustal provenances of normative lithologies in Shisr 161.

| Rock type and assumed vol% plagioclase | modal abundance (%) | | | | number of clasts |
|---|---|---|---|---|---|
| | Upper Crust | Lower Crust | Most Mafic Lower Crust | Shisr 161 clasts | |
| anorthosite (95±5) | 38.3 | 22.1 | 0 | 2.2 | 9 |
| GNTA1 (87.5±2.5)* | 34.3 | 17.6 | 4.2 | 2.3 | 11 |
| GNTA2 (82.5±2.5)* | 16.2 | 24.2 | 17.2 | 27.5 | 12 |
| **sum (90±10)** | **88.8** | **63.9** | **21.4** | **32.0** | **32** |
| anorthositic gabbro (70±10) | 2.7 | 1.5 | 4.2 | 0.0 | 0 |
| anorthositic gabbro-norite (70±10) | 2.9 | 4.6 | 7.5 | 0.0 | 0 |
| anorthositic norite (70±10) | 3 | 15.4 | 29.7 | 35.7 | 35 |
| anorthositic troctolite (70±10) | 1.6 | 1.5 | 0 | 16.0 | 14 |
| **sum (70±10)** | **10.2** | **23** | **41.4** | **51.7** | **48** |
| gabbro (50±10) | 0.5 | 1.5 | 4.2 | 0.0 | 0 |
| gabbro-norite (50±10) | 0 | 6.1 | 17.2 | 1.7 | 1 |
| norite (50±10) | 0 | 5.6 | 15.8 | 14.2 | 7 |
| troctolite (50±10) | 0.4 | 0 | 0 | 0.0 | 2 |
| **sum (50±10)** | **0.9** | **13.2** | **37.2** | **16.0** | **10** |
| other (px, ol, GASP) | n.a. | n.a. | n.a. | 0.4 | 7 |
| bulk plagioclase | 87.4±4.3 | 79.0±5.8 | 65.4±8.4 | 71.0/75.6§ | n.a. |

*GNTA is defined as "Mafic+Anorthosite" [7], note that [6] called "GNTA1" "An2" and "GNTA2" "GNTA";

§normative plagioclase abundance as a relative proportion of clasts / normative plagioclase abundance from whole rock chemistry.

more likely that deep seated material is sampled as impact melt near the Moon's surface [11].

In order to generate impact melt from the lowermost crust of the FHT, a basin-size crater with a minimum transient cavity diameter of ~90 km is required [10-11]. Furthermore, such an impact is expected to form a voluminous impact melt sheet. For example, 320 km Schrödinger basin likely has a melt sheet >3.5 km thick [11], which is comparable to the differentiated melt sheet of the Sudbury impact structure. Schrödinger's melt zone also may have begun to exceed the ~70 km depth of it's ~210 km diameter transient cavity [11].

Initially, such an impact homogenized portions of the crust. After thermal equilibration of the superheated impact melt with unmelted debris, fractional crystallization that is inferred from cumulate textures [3] may have produced magnesian and ferroan anorthosite melt rocks [11,12]. Possibly, parts of this crater were subsequently flooded with mare basalts. A later, mid-size impact that produced an excavation cavity with a diameter on the order of 10 km into this basalt-capped, differentiated melt sheet would have been sufficient to excavate fragments of these melt rocks from a few kilometers depth into a proximal ejecta blanket. This ejecta would be composed of a mixture of regolith components, basalt fragments, thermally metamorphosed and partly melted fallback breccia [13], surficial, more rapidly chilled portions of the melt sheet, and deeper seated, magnesian and ferroan cumulate melt rocks, a good approximation of the clast components in Shişr 161 (Fig. 1b).

Other lunar feldspathic meteorites with magnesian character and some Apollo samples contain possibly similar cumulates, e.g., magnesian anorthosites in Dho 489 [14], magnesian granulites in ALHA 81005 and Dho 309 [5-15], and clasts in 60035 [16-17]. In contrast, [16] conclude that such "lunar granulitic impactites", interpreted as poikilitic and hornfelsic melt rocks by these authors, could be generated in lunar impact craters 30-90 km in diameter. However, the high number of craters with such sizes on the Moon fails to explain the ancient ages of these "granulitic impactites" [18] that are mostly restricted to the basin-forming epoch of the Moon before 3.6 Ga [17]. Therefore, their ancient ages and lower crustal affinities may rather indicate relation to the impact melt sheets of very large craters of the Moon's basin forming epoch.

**Conclusions:** The magnesian anorthositic character of feldspathic regolith breccia Shişr 161 is mainly derived from crystallized impact melt rock clasts, incuding such with cumulate textures. These lithologies are texturally similar to "granulites" and "granulitic breccias" with poikilitic textures. These have previously been identified as melt rocks [16;19] and were linked to very large, ancient impacts [e.g., 17]. We entertain the hypothesis that some of these rocks sample differentiated melt sheets of lunar impact basins.

**Acknowledgment:** This work was funded by NASA grant NNX11AJ66G.

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