**PETROGRAPHIC AND GEOCHEMICAL ANALYSIS OF FELDSPATHIC LUNAR METEORITE SHIŞR 161.**
A. B. Foreman[1], R. L. Korotev[1], R. A. Zeigler[1], A. Wittmann[2], D. A. Kring[2], A. J. Irving[3], and S. M. Kuehner[3], [1]Department of Earth & Planetary Sciences, Washington University, Saint Louis, MO 63130; [2]Lunar and Planetary Institute, Houston, TX; [3]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA; Andrewforeman@levee.wustl.edu

**Introduction:** Shişr 161 is a 57.2-gram lunar meteorite collected from the al Shişr niyabat in the Dhofar governorate of Oman in January 2008. Initial geochemical analysis of this feldspathic regolith breccia suggested a lunar meteorite compositionally similar to the granulitic breccias NWA 3163/4483/4881 [1,2] in being moderately mafic, for a nominally feldspathic breccia, and low in incompatible elements. As regolith breccias often contain lithologies in addition to granulitic breccia, we decided further investigation of Shişr 161 was warranted. Our study was designed to 1) provide a petrographic and geochemical description of Shişr 161, 2) determine the similarity of the bulk composition of the meteorite compared to the granulitic clasts, and 3) identify and characterize the mafic components in Shişr 161.

**Methods:** We divided our 294-mg bulk sample into 10 subsamples (~30 mg each) and analyzed each by INAA (instrumental neutron activation analysis) to determine trace-element abundances (Table 1). Two INAA subsamples were fused into glass beads and analyzed by EPMA (electron probe microanalysis) to determine the major-element composition. The petrography of Shişr 161 was determined using a combination of EPMA, and transmitted- and reflected-light microscopy on a thin section (area = 4.8 cm$^2$). Mineral compositions were determined in >250-um clasts in thin section at WU [3]. Melt clasts and spherules were petrographically characterized in ~100 µm thick sections at LPI prior to Ar-Ar analyses of their ages.

**Table 1.** Bulk composition of Shişr 161

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 44.2 | Sc | 13.1 | Eu | 0.639 | | |
| $TiO_2$ | 0.21 | Co | 16.8 | Tb | 0.153 | | |
| $Al_2O_3$ | 25.2 | Ni | 88 | Yb | 0.68 | | |
| $Cr_2O_3$ | 0.16 | Sr | 1100 | Lu | 0.099 | | |
| FeO | 5.94 | Zr | <50 | Hf | 0.45 | | |
| MnO | 0.09 | Ba | 273 | Ta | 0.06 | | |
| MgO | 8.17 | La | 1.19 | Ir | 2.6 | | |
| CaO | 15.0 | Ce | 3.2 | Au | <4 | | |
| $Na_2O$ | 0.32 | Nd | 1.9 | Th | 0.16 | | |
| $K_2O$ | 0.04 | Sm | 0.642 | U | 0.22 | | |
| $P_2O_5$ | 0.03 | Oxides in wt%, others in µg/g, except Au and Ir in ng/g. | | | | | |
| sum | 99.4 | | | | | | |

**Petrography:** Shişr 161 (Figs. 1,2) is composed of a variety of lithic clasts (up to 7 mm) and angular to sub-rounded mineral clasts (≤0.4 mm) set in a fine-grained dark brown fragmented matrix with very minor glass veins. The mineral clasts are predominantly olivine, plagioclase, orthopyroxene, augite, and pigeonite. Relative clast percentages include: 8% feldspathic granulitic breccias (clasts 5 and 54 in Fig. 1), 4% noritic mafics (clast 23), and 3% fragmental breccias (clast 1). Rare clasts of mare basalt were also identified. A large vein of crystallized melt is present and is part of clast 54 (Fig. 2). Sparse melt spherules and rare

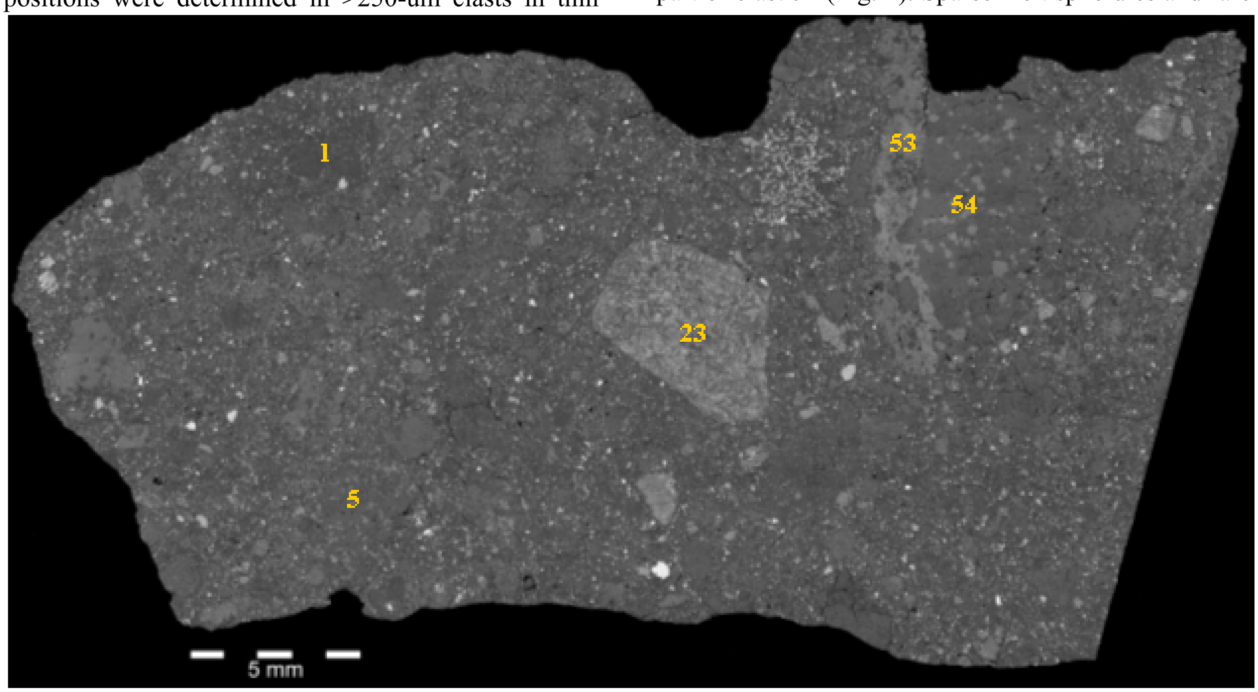


**Figure 1.** Back-scattered electron (BSE) photomosaic of Shişr 161 thin section.

clasts of crystallized impact melt also occur. The section contains trace amounts of FeNi metal as discrete grains within lithic clasts and in the matrix, consistent with the low concentrations of Ni and Ir (Table 1).

*Clast 1, Fragmental-breccia*. This clast contains 0.3–0.4-mm sub-clasts of moderately fractured plagioclase ($An_{96.6}Or_{0.4}$), olivine ($Fo_{61-65}$), augite ($Fs_{16.4-16.9}Wo_{38.9-39.8}$), and orthopyroxene ($Fs_{32-36}Wo_{0.2-3.6}$) set in a fine-grained light-brown/gray matrix. Though virtually indistinguishable from the main thin section in BSE, this clast does appear lighter under plane polarized light, possibly due to a coarser-grained matrix than the rest of the section. Though spherules and impact melt breccias were not identified in this clast, the load is similar in every other respect to that of the main section.

*Clast 23, Noritic mafic clast*. This clast is moderately fractured with a spherulitic texture, dominated by lath-shaped plagioclase ($An_{95-97}Or_{0.2-0.5}$) and orthopyroxene ($Fs_{42-47}Wo_{2.5-3.9}$) and minor amounts of augite ($Fs_{15-27}Wo_{31-42}$) and ilmenite.

*Clasts 5 and 54, Feldspathic granulitic breccias*. These breccias are moderately to highly fractured with granoblastic olivine ($Fo_{63-79}$, commonly anhedral and equant, with boundaries forming 120º triple junctions), poikiloblastic pyroxenes and accessory ilmenite and chromite set in a plagioclase ($An_{95-98}Or_{0.0-0.3}$) matrix.

*Crystallized melt vein, 53*. This melt vein contains rapidly cooled glass of pyroxene-like composition ($Fs_{35}Wo_4$) with interspersed clasts of highly fractured plagioclase ($An_{95-97}Or_{0.1-0.6}$).

*Melt clasts in thick section.* Three of the melt clasts identified are feldspathic (22–28 wt% $Al_2O_3$), while one, a spherule, has a KREEP-affinity (19 wt% $Al_2O_3$, 0.58 wt% $K_2O$, and 0.35 wt% $P_2O_5$).

**Geochemistry:** With "only" 70% normative plagioclase, the meteorite has a composition at the mafic (Fe- and Sc-rich) end of the range of those feldspathic lunar meteorites that are not significantly "contaminated" by mare basalt. Compared to most other feldspathic lunar meteorites, concentrations of incompatible elements are low [2]. Sm/Sc, for example, is 0.049, slightly lower than the plutonic anorthositic norite of Apollo 16 sample 67513 (0.057; [4]). Thus, there is little or no KREEP component (typical Sm/Sc: 2–3) in the breccia. In this regard Shişr 161 is similar only to granulitic breccia NWA 3163/4483/4881; mean Sm/Sc = 0.040) and NEA 001 (Sm/Sc = 0.063) among lunar meteorites [2]. Concentrations of siderophile elements are at the low-end of the range for feldspathic lunar meteorites (88 ppm Ni), suggesting that the meteorite is composed of immature regolith [5]. Like other meteorites from Oman, Shişr 161 is significantly contaminated with Ba and especially Sr (1100 µg/g) from terrestrial alteration.

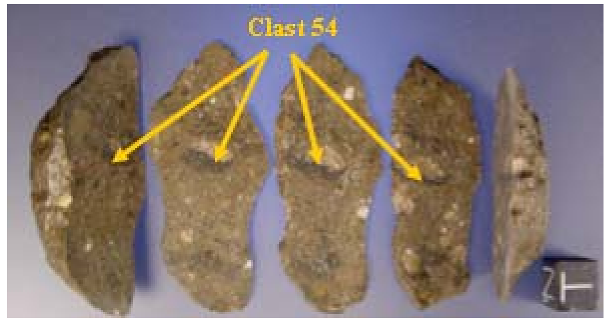


**Figure 2**. Slices of Shişr 161 with Clast 54 labeled for reference. 1-cm cube for scale. Main photo courtesy of Greg Hupé and Phil Mani.

With a bulk *Mg´* of 71 (molar Mg/[Mg+Fe]), Shişr 161 is more magnesian than most ferroan anorthosites and most other feldspathic lunar meteorites. The high *Mg´* is likely attributable to the granulite component as these are the most magnesian lithologies that we have found in the meteorite (*Mg´* = 63–78). The Shişr 161 granulites are also more magnesian than NWA 3163/4483/4881 (*Mg´* = 62) and in that regard are more similar to granulitic breccia Dhofar 733 (*Mg'* = 74) than to the NWA pairs. The plagioclase compositions of the Shişr 161 granulites, however, are not nearly as sodic as in Dhofar 733 [6] and suggest these granulites derived from a separate location.

**Discussion:** Shişr 161 derives from an unknown location in the feldspathic highlands, one that is minimally contaminated with KREEP. Like some other feldspathic lunar meteorites, it contains nonmare clasts of both ferroan and magnesian provenance [7–9] in addition to rare mare clastic material. The feldspathic granulitic breccias derived from a metamorphosed subregolith troctolitic anorthosite, but one more magnesian than that of the NWA 3163/4483/4881 pairs. As in some other feldspathic lunar meteorites, we do not observe clasts of highly feldspathic ferroan anorthosite such as that characteristic of the Apollo 16 site. The "maficness" (29 normative percent pyroxene + olivine + ilmenite) of the breccia occurs mainly because the meteorite is composed of anorthositic norites, troctolites, noritic and troctolitic anorthosites, and their brecciated derivatives.

**Acknowledgements:** This work was funded by NASA grant NNG04GG10G (Korotev).

**References:** [1] Irving A. J. et al. (2006) *LPSC37*, [2] Korotev R. L. et al., this conf. #1365. [3] Zeigler R. A. et al. (2005) *M&PS* **40**, 1073–1102. [4] Jolliff B. L. and Haskin L. A. (1995) *GCA* **59**, 2345–2374. [5] Korotev R. L. et al. (2006) *GCA* **70**, 5935–5956. [6] Foreman A. B. et al. (2007) *LPSC38*, #1853. [7] Goodrich C.A.et al (1984) *PLSC15*, C87–C94. [8] Maloy A.K. et al. (2004) *LPSC35*, #1159; [9] Maloy A.K. et al. (2005) MetSoc 68, #5278.