**PETROGRAPHY AND PAIRING RELATIONSHIPS OF LUNAR METEORITES SAYH AL UHAYMIR 449 AND DHOFAR 925, 960, AND 961.**
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**Introduction:** Lunar meteorites Dhofar 925 (49g), Dhofar 960 (35g), and Dhofar 961 (22g) were collected together in Oman in 2003. They were classified as paired based on their find locations and their initial petrographic descriptions [1-2]. Bulk chemical analyses show that although Dhofar 925 and 960 are identical in composition, and they are different from Dhofar 961, which is more mafic and incompatible element trace (ITE) rich [3-4]. More recently, lunar meteorite SaU (Sayh al Uhaymir) 449 (16.5g) was also collected in Oman, approximately 100 km from the Dhofar 961 clan. The bulk composition of SaU 449 is indistinguishable from Dhofar 925 and 960 [3-4], and the petrographic description is broadly similar as well [5]. We present here a petrographic study of SaU 449, Dhofar 925, Dhofar 960, and Dhofar 961, and assess whether the Dhofar stones are truly paired as well as whether SaU 449 is likewise paired.

**Samples:** We studied the polished end of the Dhofar 961 main mass (150 $mm^2$) and thick sections of Dhofar 961 (64 $mm^2$), Dhofar 960 (18 $mm^2$), Dhofar 925 (11 $mm^2$), and SaU 449 (14 $mm^2$).

**Petrography:** All four stones are glassy-matrix regolith breccias (a few impact spherules were found) containing large impact-melt breccia (IMB) clasts. The regolith breccias are very immature, bordering on fragmental, and contain abundant mineral and lithic clasts. Shock-melt veins occur in all stones, typically at the edges of the large IMB clasts. Terrestrial alteration products are pervasive in all sections, with fractures filled with carbonate ($CaCO_3$), sulfates (principally Ca and Sr, rarely Ba and Pb), and Fe-oxides. Fe,Ni metal grains are typically large (up to ~1 mm) and rimmed by Fe-oxides, Fe-oxyhydroxides, and/or siderite.

Mineral and lithic clast components within the regolith breccia areas of different stones are similar in both texture and composition, varying only in relative abundance. Plagioclase is the most abundant mineral clast, followed by pyroxene and then olivine in all sections. Trace amounts of silica, glass, ilmenite, chromite, and Cr-ulvöspinel clasts are also observed. Plagioclase has a restricted compositional range ($An_{88-98}$), whereas pyroxene and olivine show a considerable range in composition (Figs. 1,2). Some 350 lithic clasts were analyzed and are classified into the following groups: granulite/plutonic, anorthositic granulite, crystalline basalt, quenched basalt, unequilibrated "igneous", equilibrated "igneous", impact-melt, and IMB (Table 1). These lithic clast groupings are based on similarities in texture and mineral composition (Fig. 3).

**Table 1: Lithic clast abundance in different sections**

| Clast Type | 961mm | 961 | 960 | 925 | 449 |
|---|---|---|---|---|---|
| Anorthositic Granulite | 2 | 4 | 6 | 4 | 4 |
| Granulite/Plutonic main | 8 | 14 | 8 | 12 | 11 |
| Granulite/Plutonic ungr. | 2 | 4 | 1 | 1 | 2 |
| Crystalline Basalt | 12 | 1 | 1 | 6 | 3 |
| Quenched Basalt | 8 | 10 | 3 | 2 | 4 |
| Equilibrated igneous | 12 | 30 | 15 | 10 | 30 |
| Unequilibrated igneous | 8 | 12 | 4 | 0 | 3 |
| Impact-melt | 4 | 8 | 2 | 3 | 2 |
| Incompat.-rich IMB | 3 | 2 | 1 | 0 | 0 |
| Incompat.-poor IMB | 11 | 15 | 10 | 12 | 21 |
| Total lithic clasts classified | 70 | 100 | 51 | 50 | 80 |
| Regolith breccia area | 40% | 25% | 22% | 65% | 50% |
| Incompat.-rich IMB area | 50% | 60% | 3% | - | - |
| Incompat.-poor IMB area | 10% | 15% | 75% | 35% | 50% |

Number of lithic clasts of each type found in different thick sections and the main mass (mm) of Dhofar 925, 960, 961 and SaU 449. Modal abundance of the regolith breccia and principal IMB types also listed.

The granulite/plutonic group of lithic clasts exhibits a range in textures from relict igneous (gabbronorite) to brecciated granulite. Despite the range in textures the group has uniform mineral compositions and assemblages consisting of calcic plagioclase ($An_{95-97}$), two or three pyroxenes (hypersthene>augite>pigeonite), and minor olivine grains ($Fo_{70-75}$). Pyroxene (Fig. 4) is sometimes exsolved, with hypersthene and augite hosting thin pigeonite lamellae (1 μm). Modal abundances vary considerably among different clasts within the group (10-90 % plagioclase), but the group as a whole has a mode of ~75% plagioclase, 15-20% hypersthene, 5-10% augite, ~5% olivine, with minor pigeonite and trace chromite. A few lithic clasts have similar textures as the "main" group of granulite/plutonic clasts, but more ferroan mafic mineral compositions. The anorthositic granulite group consists of clasts dominated by plagioclase (90-95%), with small rounded olivine grains (5-10%) and trace amounts of low-Ca pyroxene and chromite. Mineral compositions are typically more calcic ($An_{96-98}$) and magnesian ($Fo_{76-81}$) than the main granulite/plutonic group.

Within each section, clasts of crystalline basalt are found. Although the details vary slightly, collectively the basalt clasts have a mode of 60-70% zoned pyroxene, 30-35% plagioclase, ~5% olivine, with minor or trace amounts of silica, ilmenite, Cr-ulvöspinel, and troilite. Plagioclase is calcic and not strongly zoned ($An_{90-96}$), whereas the pyroxene is strongly zoned from cores of magnesian calcic pigeonite to rims approaching pyroxferroite or (rarely) ferroaugite. Olivine ($Fo_{45-60}$) typically occurs as small partially resorbed grains mantled by pyroxene. Several small basaltic clasts have quenched textures containing pyroxene and aluminous glass. The unequilibrated igneous clasts have subophitic or intersertal textures with strongly zoned pyroxene and elongate plagioclase laths. Minor differences in mineral chemistry (mainly pyroxene; Fig. 3) distinguish this group from the crystalline basalt group. The largest group of clasts, the equilibrated igneous group, consists of clasts with equilibrated mineral compositions. Mineral assemblages are relatively constant, with pigeonite and plagioclase dominant, minor olivine and augite, and trace amounts of Fe,Ti,Cr oxides and troilite. Textures vary widely and include ophitic, sub-ophitic, intergranular, and (rarely) granulitic. No clasts or FeNi metal are observed. The impact-melt clasts have a matrix of finely intergrown plagioclase and mafic glass. These clasts contain metal and are too feldspathic to represent igneous melt compositions. There are a large number of small IMB clasts within the regolith breccia similar in texture and composition to the larger IMB clasts (see below).

The principal difference among the stones lies in the compositions of the impact-melt breccias. A relatively ITE-rich mafic IMB dominates in Dhofar 961 (Table 1), is a minor component in Dhofar 960, and is not observed in our small samples of Dhofar 925 and SaU 449. This ITE-rich IMB has few plagioclase clasts and a crystalline matrix dominated by zoned pyroxene and plagioclase, with small phenocrysts (and variable proportions) of olivine, and small ITE-rich mesostasis areas (see [6-7] for more details). The dominant IMB clasts in the Dhofar 925/960 and SaU 449 stones have a different texture (plagioclase clasts and a matrix of plagioclase laths and mafic glass), are less mafic, and have lower ITE concentrations.

**Pairing:** Similarities in lithic clast populations, especially the presence of the ITE-rich IMB clasts in both Dhofar 961 and 960 indicates that despite bulk compositional differences Dhofar 925, 960, and 961 are paired. Similarities in lithic clast populations and major- and trace-element composition strongly suggest that SaU 449 is also paired (or at least source-crater paired) with this group.

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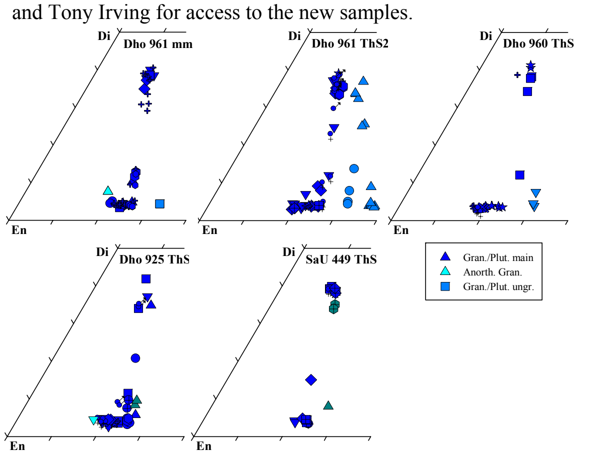


**Fig. 4**. Pyroxene compositions in granulite/plutonic clasts in all five sections studied. Different symbols are different clasts.

**References:** [1] Russell S. S. et al. (2004) *MAPS 39,* A215-A272. [2] Russell S. S. et al. (2005) *MAPS 40,* A201-263. [3] Korotev R. L. et al. (2009) *MAPS 44*, 1287–1322. [4] Korotev R. L. et al., this conference. [5] Connolly H. C. Jr. (2007) *MAPS 43,* 571-632. [6] Jolliff B. L. et al. (2007) *MAPS,* abstract #5311. [7] Jolliff B. L. et al. (2008) *LPS 39,* abstract #2519.

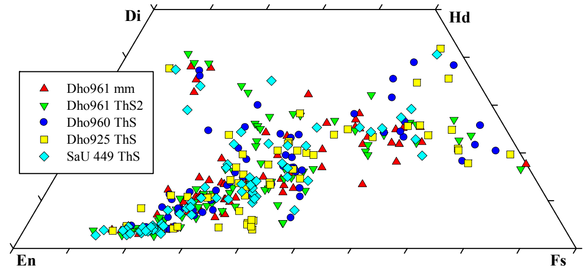


**Figure 1**. Pyroxene quadrangle showing pyroxene mineral clast compositions in Dhofar 925/960/961 and SaU 449.

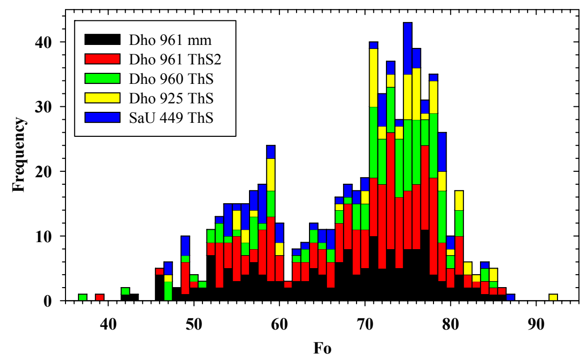


**Figure 2**. Olivine histogram for mineral clast compositions in Dhofar 925/960/961 and SaU 449. A few values present at low Fo values (<20) not shown here.

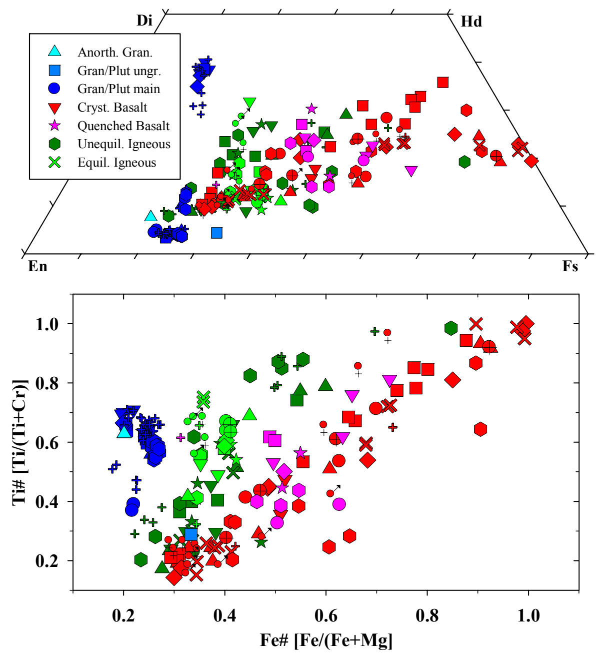


**Figure 3**. Pyroxene compositions in lithic clasts in the main mass of Dhofar 961. Different colors are different clast types, different symbols within a color are individual clasts.