A PETROLOGICAL AND GEOCHEMICAL ANALYSIS OF LUNAR FELDSPATHIC METEORITE Dhofar 910.

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Introduction: Dhofar 910 is a lunar feldspathic breccia and was found as a brownish gray stone of 174 g in Oman [1]. These petrographic and compositional similarities may indicate a possible source-pairing relationship between Dhofar 910 and Dhofar 081, 280, and 1224. However, Dhofar 910 is more feldspathic and poorer in ITEs than other paired meteorites [2]. Here we present preliminary results on mineralogies, petrography and shock metamorphism of Dhofar 910.

Sample and Methods: Analysis of Dhofar 910 were performed on a polished thin section about 1.3 × 2.1 cm. Petrographic characterization was performed using a FEI Nova NanoSEM 450 scanning electron microscope (SEM) with X-Max^{N}50 electron dispersive spectrometer (EDS). Montaged backscattered electron (BSE) image (Figure 1a) and elemental map (Figure 1b) were processed using the ImageJ software package [3]. The typical conditions were ~15 kV and a current of ~300 mA. Semiquantitative analysis of mineral phases were analyzed via EDS with a 15 kV accelerating voltage, a beam current of 20 nA, and a focused beam diameter of 4 μm.

Petrography and Mineral Chemistry:

Troctolitic anorthosite clast. The anorthosite clast (Figure 2a) is 1.5 × 0.5 mm in size and consists of 70 vol.% plagioclase and 30% vol.% olivine with minor accessory minerals Al-Ti-chromite and ilmenite. Olivine grains exhibit limited chemical composition ($Fo_{72.6\sim74}$) (Figure 3) and are enclosed in the plagioclase. Plagioclase grains are euhedral to subhedral, exhibiting high-Ca composition ($An_{95.2-97}Ab_{3.4-4.8}$). Based on Mg# VS. An value plot, this clast may be analogous to Apollo Mg-suite lithologies (Figure 4).

Noritic anorthosite clast. A 0.6 × 1.2 mm sized noritic anorthosite clast (Figure 2b) with an igneous texture contains highly anorthositic plagioclase ($An_{96.1-96.6}Ab_{3.4-3.9}$) and subhedral orthopyroxene (Mg# ~ 62.0-73.4, $En_{58.0-60.7}Fs_{25.6-35.6}Wo_{3.4-7.9}$) (Figure 3). The plagioclase grains usually exhibit fractures from cores to rims. Difference from plagioclase, pyroxene have a few cracks without zoned compositional variation. The accessory minerals are composed of Al-chromite, ilmenite and Fe-sulfide. Interestingly, olivine grains are not identified in this clast. Petrographically and compositionally, noritic anorthosite clast is similar to Apollo FAN suite lithologies (Figure 4), indicating the sourced highland rocks.

Anorthosite clast. Anorthosite plagioclase (>90 vol.%) is dominant in this clast (3 × 2.5 mm) (Figure 2c). Mafic minerals have euhedral to subhedral pyroxene and subhedral to anhedral olivine grains. The largest pyroxene is 250 μm in size with orthopyroxene being the modally most abundant species with lesser amounts of augite. Chemical compositions of pyroxene are $En_{36.8-64.7}Fs_{22.7-37.3}Wo_{2.6-40.5}$ with a range of Mg# (61.0-70.9). Olivine grains have limited chemical composition ($Fo_{69.2-77.3}$) (Figure 3). The chemical compositional variations of the same olivine grains are negligible, while different samples have inhomogeneous composition. The Al-chromite, troilite and ilmenite as accessory minerals have been identified. Chemically and texturally, anorthosite clast is derived from highland rocks, analogous to FAN suite rocks (Figure 4).

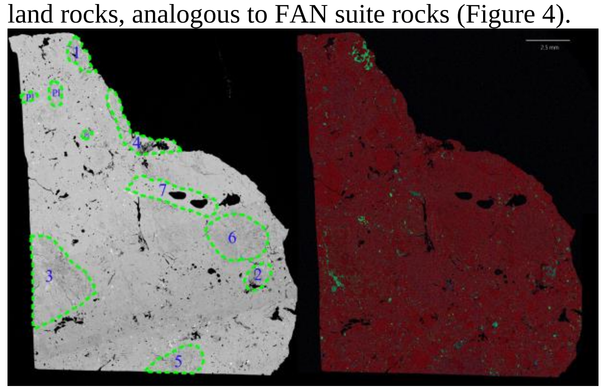

Figure 1. a) BSE mosaic image of Dhofar 910 thin section labeled with 7 lithic clasts. 1 is *troctolitic anorthosite clast*. 2 is *noritic anorthosite clast*. 3 and 4 are *anorthosite clasts*. 5, 6 and 7 are *impact melt breccia clasts*. Pl represents *plagioclase*. b) False-color elemental map of Dhofar 910 where colors correspond to: Al=red, Mg=green, Fe=blue.

Impact melt breccia clasts. There are a variety of texturally diverse impact melt breccia clasts (Figure 2d and 2e). The largest is a 2 × 1 mm feldspathic fragments with a anorthosite composition (based on CIPW) composed of calcic plagioclase ($An_{95.9-97.1}Ab_{2.9-4.1}$), subhedral pyroxene (Mg#: 50.7-77.1; $En_{45.4-62.6}Fs_{13.5-46.9}Wo_{5-41.2}$), subhedral to anhedral olivine grains ($Fo_{52.4-75.9}$) (Figure 3), and minor amounts of ilmenite and troilite. Furthermore, one glassy impact melt clast (Figure 2e) have a heterogenous texture with the average bulk composition of 1.83±0.65 wt.% MgO, 32.91 ±0.32 wt.% Al_2O_3, 44.67±0.6 wt.% SiO_2, 18.33±0.54 wt.% CaO, 2.11±0.64 wt.% FeO, containing several maskelynite ($An_{95.8-96.2}Ab_{3.8-4.2}$) fragments.

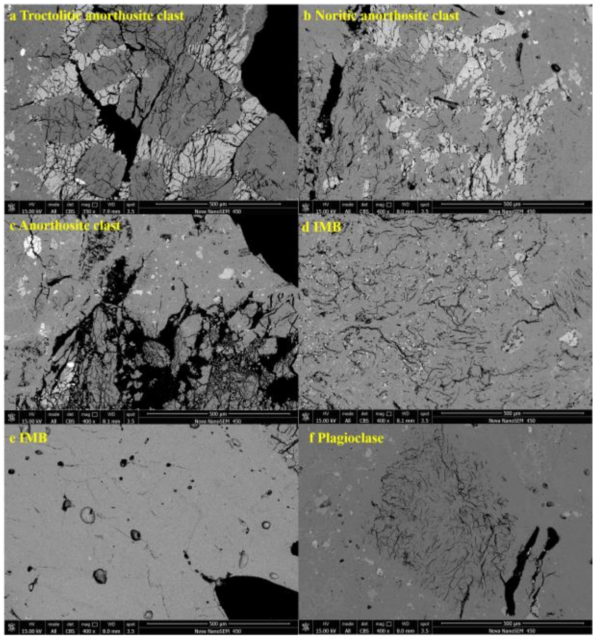

Figure 2. BSE images of clasts in Dhofar 910. a) Troctolitic anorthosite clast. b) Noritic anorthosite clast. c) Anorthosite clast. d-e) IMB represents impact melt breccia clast. f) Plagioclase in the matrix.

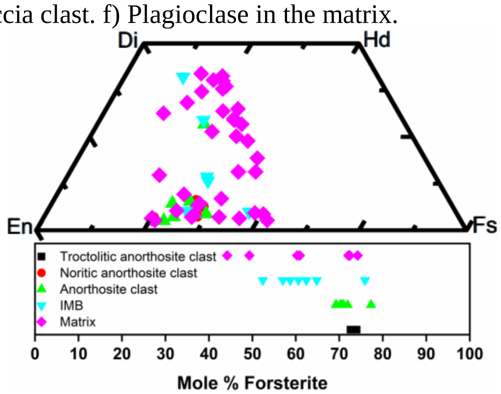

Figure 3. Mineral compositions of pyroxene/olivine.

Mineral Fragments and Matrix. The matrix of Dhofar 910 consists mostly of individual mineral fragments. The silicate minerals (i.e., plagioclase, pyroxene, olivine, Figure 2f) are main phases with angular to subrounded in shape, while the nonsilicate phases (e.g., FeNi metal, chromite, ilmenite and troilite) are less common. Pyroxene fragments usually have a large compositional range ($En_{35.9-71.5}Fs_{14.0-52.4}Wo_{2.7-42.0}$, Mg# 46.1-79.6). Olivine show similar mineral composition with moderate Mg content ($Fo_{44.2-74.2}$). Plagioclase in the matrix are calcic ($An_{95.0-96.9}Ab_{3.1-5.0}$) (Figure 3).

Shock metamorphism. In Dhofar 910 all clasts are shocked to almost the same degree indicating that shock metamorphism affected all components of the polymict breccia homogeneously. Characteristic shock features include intergranular recrystallization, strong fracturing and mosaicism in plagioclase, mostly irregular fractures in olivine and pyroxene as well as impact melting. Maskelynite is present, indicating moderate shock pressure of <25 GPa. Shock experiments on chondritic powder and on regolith analogs showed intergranular melts begin to form at about 20 GPa [4]. Since small amount of intergranular melts and maskelynite are present, an equilibration shock pressures of 20-25 GPa is estimated for the main shock event in Dhofar 910.

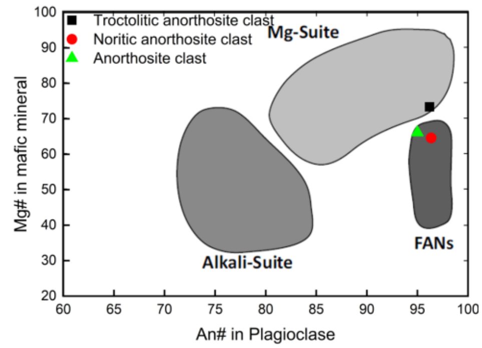

Figure 4. Mg# in mafic mineral versus An content in plagioclase plot of anorthosite clasts in Dhofar 910.

Discussion: Dhofar 910 shows close similarities to feldspathic fragmental breccia collected by Apollo 16 due to low abundance of mafic components and KREEP-poor lithologies. However, the absent of granulitic lithologies in Dhofar 910 and chemical signatures in mineral are indicative of a derivation from a primarily FAN-rich terrain with a few HMS constituents where it was removed from appreciable HMS and KREEP influences, remote from the KREEP-bearing lithologies of the near side of the Moon. Further, it is evident that FAN and HMS magmatism may be global events [5]. Based on low concentrations of ITE [1], the role of KREEP of HMS magmatism in far side may have less signatures than on the nearside. It supports the observation that KREEP is restricted to the western regions of the near side.

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