DHOFAR 304, 305, 306 AND 307: NEW LUNAR HIGHLAND METEORITES FROM OMAN

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Introduction: Several lunar highland meteorites were found in the Dhofar region of Oman. Here we report the first data on the petrography and mineralogy of four new lunar stones, Dhofar 304, 305, 306 and 307. Dh-304 was found close to Dh-025 and 301, whereas Dh-305, 306 and 307 were recovered nearby Dh-081, 280, 302 and 303. The new meteorites are moderately weathered, impact-melt breccias. No KREEP or mare components are present in the rocks. Dh-304 may be paired with Dh-025 and 301. Dh-305, 306, and 307 are probably paired with Dh-302 and 303, but Dh-302 and 305 could represent different meteorite falls. However, these meteorites are definitely not related to Dh 081 and 280.

Dhofar 304 is a brownish-gray, moderately weathered stone weighing 10 g. This is an impact-melt breccia in which mineral fragments and lithic clasts are embedded in a fine-grained impact-melt matrix. The lithic-clast population is dominated by impact-melt breccias, but possible igneous rocks and granulites are present too. The rocks have mostly anorthositic and gabbro-norithic compositions. Mineral chemistries are: An_{93-98}, olivine Fo_{62-89}, clinopyroxene $Wo_{5-41}En_{39-78}$, orthopyroxene $Wo_{3-5}En_{44-80}$. Accessory minerals are Ti-rich chromite, Cr-pleonaste, ilmenite (7-8 wt.% MgO), troilite, and FeNi metal (7.8 wt.% Ni and 0.6 wt.% Co). Composition of the impact-melt matrix is SiO_2 45.0, TiO_2 0.34, Al_2O_3 25.3, Cr_2O_3 0.17, FeO 5.71, MnO 0.12, MgO 7.09, CaO 14.8, Na_2O 0.37, K_2O 0.04, and P_2O_5 0.07 (wt%). In the An-MG# graph (Fig. 1) most of lithic clasts and mineral plot within the gap between HMS and FAN, but some are Mg-rich.

Dhofar 305 is a light-gray, moderately weathered stone weighing 7 g. This is an impact-melt breccia consisting of mineral fragments and lithic clasts set within a fine-grained, well-crystallized, impact-melt matrix. Clasts of impact-melt breccias are most common; granulites and possible igneous rocks are rare and most have anorthositic and troctolitic compositions. Most minerals show large variations in composition: feldspar An_{88-97}, olivine Fo_{45-89}, clinopyroxene $Wo_{5-47}En_{30-80}$, orthopyroxene $Wo_{1-5}En_{37-85}$. Accessories are Ti-rich chromite, Cr-pleonaste, ilmenite (1-8 wt.% MgO), armalcolite, troilite, and FeNi metal (17-32 wt.% Ni and 1.3-2.3 wt.% Co). Composition of the impact-melt matrix is SiO_2 43.9, TiO_2 0.16, Al_2O_3 28.5, Cr_2O_3 0.10, FeO 3.69, MnO 0.07, MgO 6.08, CaO 15.9, Na_2O 0.36, K_2O 0.02, and P_2O_5 0.04 (wt%). Two clasts of olivine pyroxenite were found. They consist of low-Ca pyroxene (Wo_{2-8}, En_{70-75}) with minor olivine (Fo_{74-75}), and plagioclase (An_{90-96}). This meteorite is distinctly polymict and contains both FAN and HMS components. However, the majority of the lithic clasts reside within the gap between these two lithologic groups (Fig. 2). Mineral fragments are more variable in composition.

Dhofar 306 is a light-gray, moderately weathered stone weighing 2.6 g. This is an impact-melt breccia composed of mineral fragments and lithic clasts cemented by a fine-grained, impact-melt matrix. The clast population is dominated by impact-melt breccias, but granulites and cataclastic igneous rocks of anorthositic, troctolitic, and noritic compositions are also present. Devitrified glass fragments occur as well. Mafic mineral fragments show large compositional ranges: olivine Fo_{49-94}, clinopyroxene $Wo_{5-45}En_{25-77}$, orthopyroxene $Wo_{2-5}En_{48-85}$, but feldspar composition (An_{94-98}) is restricted. Aaccessory phases include Ti-rich chromite, Cr-pleonaste, ilmenite (3-7 wt.% MgO), armalcolite, silica, Ca-phosphate, troilite, and FeNi metal (7-68 wt.% Ni and 0.3-3.4 wt.% Co). Composition of the impact-melt matrix is SiO_2 44.0, TiO_2 0.15, Al_2O_3 27.2, Cr_2O_3 0.12, FeO 4.00, MnO 0.05, MgO 7.55, CaO 15.5, Na_2O 0.33, K_2O 0.04, and P_2O_5 0.07 (wt%). Most of Dh-306 clasts plot compactly into the gap between FAN and HMS groups (Fig. 3)

Dhofar 307 is a light-gray, moderately weathered stone weighing 50 g. This is also an impact-melt breccia, similar in structure to Dh-305 but dominated by a fine-grained impact-melt matrix. Rare clasts of anorthositic, troctolitic, and gabbro-noritic compositions and mineral fragments were also found. Glass veins are common. Mineral phases have large compositional ranges: feldspar An_{90-98}, olivine Fo_{39-94}, clinopyroxene $Wo_{6-46}En_{39-73}$, orthopyroxene $Wo_{1-4}En_{46-89}$. Accessory minerals are Ti-rich chromite, Cr-pleonaste, ilmenite (2-6 wt.% MgO), armalcolite, troilite, and FeNi metal (8-49 wt.% Ni and 0.3-2.0 wt.% Co). Composition of the glass veins is SiO_2 43.8, TiO_2 0.09, Al_2O_3 30.8, Cr_2O_3 0.09, FeO 2.58, MnO 0.05, MgO 4.06, CaO 17.3, Na_2O 0.36, K_2O 0.01, and P_2O_5 0.02 (wt%). The characteristic feature of Dh-307 is the presence of rare dunitic fragments. Two dunitic clasts, which were identified, consist of olivine (Fo_{65-71}) with minor pyroxene ($Wo_{3-34}En_{49-73}$), plagioclase (An_{95}) and troilite. The majority of mineral compositions are situated within the FAN-HMS gap (Fig. 4).

Discussion: The new meteorites are highland impact-melt breccias. No KREEP and mare components were found in the rocks. All of them are moderately weathered: calcite, gypsum, celestite, barite, and Fe hydroxides are present.

In mineral chemistry and matrix composition (Fig. 1) Dh-304 is very similar to Dh-025 and 301, which were found nearby [1]. Therefore, the meteorites may be paired. Dh-305, 306 and 307 were discovered closely to Dh-081, 280, 302, and 303. Dh 081 and 280 are similar in composition and weathering grade [2]. The meteorites may be paired and are completely different from others collected nearby, which are higher in MG# and more weathered. Therefore, Dh-302, 303, 305, 306 and 307 may have resulted from another lunar meteorite shower.

Dh-302 is characterized by the presence of KREEP and mare basalt components [3], which were not recognized in the other meteorites. Dh-303 shows a distinct conglomeratic texture and contains a large, primary troctolite and a significant number of MG#-rich mafic grains [3]. Dh-305 and 307 are close to Dh-303 in matrix and mineral chemistry. Mafic phases of Dh-305 and 307 are very variable in composition (Figs. 2,4). There is certainly HMS material in the meteorites. However, Dh-305 contains several HMS clasts with Ca-rich plagioclase, which are absent in Dh-307. In addition, there are olivine pyroxenites in Dh-305, whereas Dh-307 contains dunite fragments. Trace-element data support the enrichment of Dh-305 in a pyroxene-bearing component and point to a higher degree of weathering of the rock [4]. A significant feature of Dh-306 is the distinct bimodal distribution of MG# values of mafic phases. The HMS component is abundant in Dh-306 and its matrix is enriched in MG#.

It is possible that these differences are not significant and can be related to heterogeneity of a lunar meteorite body. However Dh-302 and Dh-305 appear to be sufficiently different from others and could represent different meteorite falls.

Summary: Based on texture and mineral chemistry, we conclude that: (1) Dh-025, 301, and 304 are probably paired; (2) Dh-081 and 280 may also be paired and are different from other lunar stones collected nearby; (3) Dh-302, 303, 305, 306 and 307 are probably paired, but Dh-302 and 305 could be produced by other meteorite falls.

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References: [1] Cahill J.T. et al. (2001) *LPSC, 32rd*, #1840. [2] Cahill J.T. et al. (2002) *LPSC, 33rd*, #1351. [3] Nazarov M.A. et al. (2002) *LPSC, 33rd*, #1293. [4] Nazarov M.A. et al. (2003) *LPSC, 34th* This volume.