NEW MINERALS FROM A NEW LUNAR METEORITE, DHOFAR 280.

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Introduction: Dhofar 280 (Dh-280) is a new lunar meteorite found in the Dhofar region of Oman in April, 2001. It is classified as fragmental breccia [1]. The rock consists of several impact-melt and lithic clasts of different sizes and compositions. The largest clast (~2cm) is a regolith breccia that itself contains several different clasts. Other smaller clasts in Dh-280 are of variable-size range (0.5 to 5 mm) and mainly consist of angular feldspathic fragments, as well as chips of olivine and pyroxene. Petrographically pristine-textured troctolitic fragments also occur. Some clasts possess a haystack texture, indicative of impact-melt crystallization. The matrix consists mainly of impact-melt glass and fine-grained mineral fragments. Accessory minerals include ilmenite, Ti-rich chromite, troilite, and FeNi metal. In the regolith- breccia clast, some of the small (e.g. 5-10 μm) opaque minerals optically appear to be FeNi metal with a slight tarnish. On closer inspection with electron microprobe (EMP), these grains are "iron-silicides", consisting of *three distinct new mineral phases -- FeSi, Fe_2Si, $FeSi_2$* (Table 1).

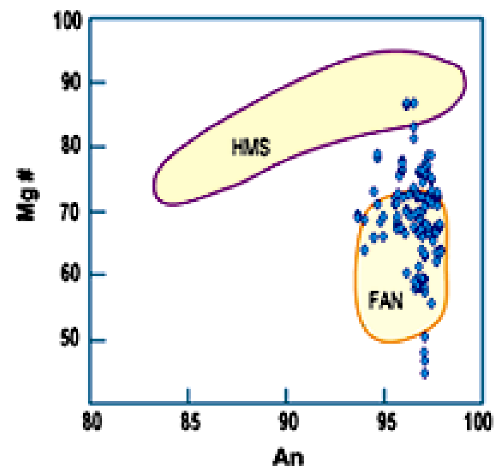
Table 1. EMP Data of New Fe-Si Phases.

Wt %	FeSi	Fe2Si	FeSi2
Fe	65.87	75.45	50.26
Si	31.13	19.12	46.20
Co	0.16	0.13	0.05
Ni	1.27	3.05	0.45
S	0.01	0.01	0.01
P	0.30	1.27	1.45
Ti	0.02	0.00	0.00
Cr	0.21	0.35	0.02
Total	99.0	99.39	98.64
At. %	FeSi	Fe2Si	FeSi2
Fe	50.70	63.30	34.55
Si	47.65	31.90	63.15
Co	0.12	0.11	0.03
Ni	0.93	2.44	0.30
S	0.01	0.02	0.01
P	0.42	1.93	1.78
Ti	0.02	0.00	0.00
Cr	0.17	0.31	0.16
Total	100.0	100.0	100.0

Lastly, although Dh-280 and Dh-081 were found about 200 m apart in Oman and contain similar clast populations [2], they are probably not paired.

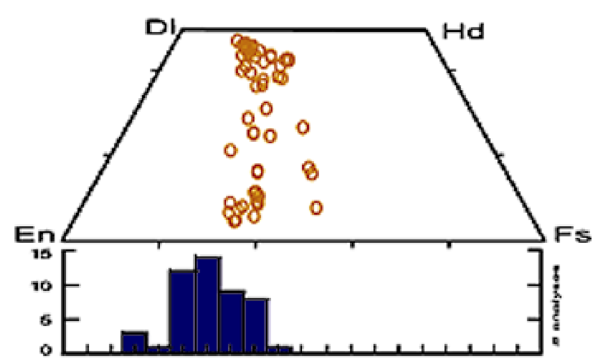
Petrography and Mineral Chemistry: Dhofar-280 is a fragmental highland breccia with well-preserved primary igneous clasts and negligible terrestrial alteration (e.g., calcite, Fe-stain on Ol).

Figure 1. Bi-mineralic clasts in Dh-280



The An content of plagioclase feldspars from several clasts show a restricted range of An 94-98, typical of highland breccias. As shown in Figure 1, the majority of the feldspar and mafic minerals plot either in the FAN region or in the gap between the FAN and HMS groups. Only one olivine-bearing clast plots (2 sets of analyses) in the HMS field. The Fo contents of olivines vary from 55-87 (Fig. 2); the Mg# of pyroxene grains varies from 44-80. As shown in Figure 2, Dh-280 pyroxenes follow a trend typical for lunar highland rocks. Glass compositions consist of both aluminous and ma-

Figure 2. Olivines and pyroxenes in Dh-280



fic components, with Mg# of the latter varying between 60 to 75. Chromite and ilmenite grains occur throughout the sample. Chromite compositions are unusually rich in Ti (16 wt% TiO_2) and follow the chromite-ulvöspinel trend typical for lunar spinels.

Ilmenites are relatively high in their MgO content (4.5wt% MgO).

New Mineral Phases: Grains of three new Fe-Si phases (Table 1) from 2-30 µm in size were discovered in the regolith-breccia clast in Dh-280. This clast also contains numerous small (0.5-10 µm) FeNi metal grains, similar to an agglutinitic-glass-rich soil. We present here the first-reported occurrence of Fe-Si phases in lunar rocks, namely FeSi, Fe_2Si and $FeSi_2$ (Table 1). The only other Fe-Si minerals reported are suessite, Fe_3Si, as described from an ureilite [3] and perryite, $(Ni,Fe)_5(Si,P)_2$, in enstatite achondrites [4]. Figure 3 shows x-ray elemental maps of one such Fe-Si grain. In general, more than 95 wt% of this mineral is composed of Fe and Si with only minor amounts of Ni P, and Cr. In addition, x-ray maps reveal hotspots of Ti- and P-rich areas in this grain (4.6 and 15 wt%, resp.). Characterization and formal description of these new minerals are in progress.

Presence of these Fe-Si minerals in Dh-280 indicates extreme reducing conditions, whether on the Moon or on an asteroid. If from a meteorite, these phases may have an origin similar to that postulated by [3,4]. Inasmuch as they do occur in a fragmental lunar breccia, such an extra-lunar origin is distinctly possible. BUT, it is important to note that the Fe-Si phases in Dh-280 only occur in the lunar regolith-breccia clast that has not undergone extensive high-temperature metamorphism, as witnessed by the abundant minute Fe-metal grains (<1-2 µm). One possible scenario for the indigenous lunar formation of these phases involves the melting and vaporization of lunar soil by micro-meteorite impact. In fact, Dikov et al. [6] first reported atomic-size particles of elemental Fe, Si, and Ti on the surfaces of soil grains. As well demonstrated by Keller and McKay [5], the surfaces of many, if not most, lunar-soil particles consist of thin (0.1-0.5 µm) patinas and rims of silica-rich glass containing abundant nanophase-size Fe^0 metal. Most of this nanophase Fe^0 is from the vaporization of FeO and SiO_2 from impact-melted soil. The FeO in the vapor further dissociates to Fe^0 and O, and the Fe^0 is condensed onto the soil particles. Little consideration of the role of SiO_2 in the vapor-phase has been made. We suggest that the SiO_2 in the vapor dissociates further to SiO^{2+} and Si^0. It is thermodynamically possible that *the Fe^0 in the vapor combines with various proportions of Si^0, also in the vapor, and condenses as small Fe-Si grains.*. If these Fe-Si phases are the result of impact-produced vaporization of lunar soil components, *it is predicted that many of the small, micron-sized Fe^0 metal grains occurring in lunar soil may well contain Si^0 and Fe-Si phases.*

Discussion: D-280 is a new lunar meteorite consisting of a highland fragmental breccia, with numerous clasts, including at least one regolith breccia. The Mg# vs AN plot for bimineralic clasts seems to suggest the possibility of the lunar farside as the source region of this meteorite. The overall mineralogy and petrography of Dhofar-280 is very similar to Dhofar-081 [2], and it may be possible that these two meteorites are paired. However, the presence of the new mineral phases of iron-silicides have not been reported form Dhofar-081, but it is possible that due to the small size and similar appearance, in reflected light, of FeNi metal and the iron-silicides, these new mineral phases may have been missed in previous studies.

References: [1] Nazarov (2001) Met Bull, No. 85, A295; [2] Cahill et al. (2001) Met Soc., v.36, 9; [3] Keil et al. (1982) Amer. Mineral. 67; [4] Wasson & Wai (1970) GCA 34; [5] Keller & McKay (1997) GCA; [6] Dikov et al. (1978) PLSC 9th.

Figure 3. X-ray Elemental Maps of New Fe-Si Phases in Dh-280.