CLAST POPULATION AND CHEMICAL BULK COMPOSITION OF THE DHOFAR 018 HOWARDITE.

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Introduction: Dhofar 018 is a new howardite found in Oman on January 17, 2000. Twelve fragments totaling 833 g were collected [1]. We report here first data on clast population and major and trace element chemistry of the meteorite. In bulk composition, Dhofar 018 is similar to Binda and Pavlovka. A specialty of Dhofar 018 is the presence of a variety of xenoliths, such as CM and LL chondrites and an aubrite, and of peculiar metal-sulfide objects.

Results: Dhofar 018 is a polymict breccia consisting of lithic clasts (6.8 vol%) and mineral fragments (53 vol%) embedded in a fine-grained clastic matrix (40.2 vol%). The lithic clasts are more than 0.2 mm in size and presented mainly by eucrites, orthopyroxenites and breccias. Accessory constituents of the lithic clast population are glasses, chondrule-like objects, fayalite-clinopyroxene-silica and metal-sulfide objects, carbonaceous and ordinary chondrites, and an aubrite-like rock. Impact melt veins, up to 0.1 mm thick, cut the matrix and follow clast boundaries. Abundant cracks filled with Ca-carbonate, celestine and barite are present indicating significant terrestrial contamination.

Eucrites comprise 50 % of the lithic clast population. They are mainly ophitic, coarse- to fine-grained rocks consisting of plagioclase (An82-95) and low-Ca pyroxene (En22-69;Wo2-4), containing augite lamellae, in the proportion of 40:50. Accessories are silica, troilite, chromite, ilmenite and Ni-poor metal.

Orthopyroxenites comprise 40 % of the lithic clasts and can be subdivided into coarse-grained equigranular rocks and porphyritic rocks. The coarse-grained rocks (grain size of 500 - 1000 µm) consist mainly of orthopyroxene (En65-75 Wo1-4) with minor olivine (Fo73-85) and rare plagioclase (An90). Occasionally olivine and pyroxene grain boundaries are decorated with high-Ca pyroxene-chromite symplectites, which are similar to those described from lunar rocks [2]. The coarse-grained rocks can be classified as olivine diogenites. In contrast to the eucrites the diogenites contain pyroxene that is more magnesian than En65. The porphyritic orthopyroxenites are composed mostly of skeletal orthopyroxene crystals (En55-73Wo1-4) embedded into fine-grained or microcrystalline pyroxene-plagioclase groundmass. Minor olivine (Fo60-85) is commonly present.

Breccia clasts consist of mineral fragments of pyroxene (En65-91Wo1-48), plagioclase (An75-92) embedded into a microcrystalline or glassy matrix. Rare olivine fragments (Fo70-75) are also present. One breccia clast consists of mineral fragments set within a troilite matrix.

The most abundant discrete **mineral fragments** are pyroxene (En20-80;Wo1-48), plagioclase (An76-97), and olivine (Fo73-Fo87). There are also rare fragments of silica, troilite, chromite, ilmenite and metal. The proportion of eucritic pyroxene to plagioclase clasts is 61:39, that of eucritic (En<65) to diogenitic (En>65) pyroxene fragments (by number) is 78:22. Olivine fragments are about 1/3 as abundant as diogenitic pyroxene fragments. Plagioclase tends to be more abundant among the small grains of the mineral fragments as compared to the coarser ones.

Glass clasts and droplets are rare. They are transparent and light- to dark-brown. Some of them are devitrified or contain phenocrysts of olivine and pyroxene.

Fayalite-clinopyroxene-silica objects consist of fine-grained graphic symplectites or equigranular intergrowths of these phases. Pyroxenes are ferroaugite, ferrosalite or hedenbergite. Olivine varies from Fa89 to Fa95. The clasts have bulk compositions which project close to the field of the pyroxene instability on the Di-Hd-En-Fs diagram. This lithology is similar to one that was described from lunar basalts [e.g., 3] and lunar meteorites [4, 5].

Chondrule-like objects, 200-800 µm in size, consist of parallel aligned skeletal olivines (Fo65) and an interstitial glass.

Metal-sulfide clasts. Two unique metal-sulfide clasts, about 150 µm in size, were found. The clasts consist of eutectic intergrowths of FeNi metal and troilite. The metal/troilite volume ratio in the intergrowths is about 1.5. The Ni content of the troilite varies from 0.1 to 0.7 wt%. The metal contains about 6-7 wt% Ni. The sulfide-metal intergrowths are similar in texture and composition to those described from ordinary chondrites [6] and from experimentally shocked chondrite samples [7]. It is possible that these objects have a foreign origin and were derived from ordinary chondrite matter.

Carbonaceous chondrite clasts are from 50 to 500 µm in size. They are consist mainly of phyllosilicate matrix containing µm-sized grains of olivine (Fo46-98) and orthopyroxene (En49-94) as well as intergrowths of troilite, pyrrhotite and magnetite. Accessories are schreibersite, chromite, Mg,Al-spinel, a P,Cr-rich Fe,Ni sulfide, a Ni,Mn,Fe,Cr sulfide, and an unknown Fe,Mn silicate. The carbonaceous chondrite clasts are similar to those described from other howardites [e.g., 8, 9] and should be classified as fragments of CM carbonaceous chondrites.

An aubrite clast is about 800 µm long and consists mainly of pure enstatite (En97-98Wo1-2) and minor Na-rich plagioclase (Ab53–Ab80) and Ca-rich pyroxene (En41Wo56). Occasionally Ti-Cr-Mn-rich troilite is present. In most cases enstatite forms equigranular masses of anhedral grains. However, sometimes there are also present aggregates of randomly oriented, well-shaped prismatic enstatite crystals of 20-200 µm size. Plagioclase and clinopyroxene are mainly located between enstatite grains but clinopyroxene is also present as inclusions within enstatite. Troilite is included in enstatite and plagioclase or located at grain boundaries. It has variable contents of Ti, Cr and Mn. One sulfide inclusion in enstatite is similar in composition to Cr-rich violarite ($FeNi_2S_4$). The inclusion is partly replaced by rust containing significant amounts of potassium. The unique enstatite rock clast is the first finding of an aubrite-like rock in a howardite breccia.

A LL chondrite clast of about 400 µm size consists of olivine (Fo73-74), Na-rich plagioclase (Ab73-83) and orthopyroxene (En76-77 Wo2) Kamacite and troilite are also present. Plagioclase forms irregular intergrowths with olivine and small globular inclusions in kamacite. No compositional zoning of the silicate grains was detected. The mineral abundances and the mineral compositions of this clast correspond well to those of ordinary chondrites of the LL type [10]. This is a first possible ordinary chondrite rock fragment in a howardite breccia.

Bulk composition. The bulk chemical composition of 1 g sample as determined by wet chemistry, atomic absorption, XRF and INAA methods (analysts L.D. Barsukova and D.J. Sapozhnikov) is given in the Table. The composition of Dhofar 018 is similar to that of other howardites. The XFe/CaO ratio of Dhofar 018 (Fig) is close to those in Binda and Pavlovka [11] and indicates that these howardites should contain approximately equal proportions of eucritic and diogenitic components. High Ir and Ni contents and the Ir/Ni ratio indicate the presence of a primitive chondritic component. Relatively high abundances of Ba and Sr appear to be the result of terrestrial contamination. Consequently, concentrations of some other elements (e.g., K, Se) could also be more or less terrestrially modified

Summary: Dhofar 018 is a typical howardite that consists mainly of eucrite and diogenite lithologies. The diogenite constituent is richer in olivine as compared to that of other howardites. In bulk chemistry Dhofar 018 is similar to Binda and Pavlovka. A large variety of foreign components are present in Dhofar 018, some of which were not known to occur in howardites so far. Beside the common CM chondrite fragments, fragments of ordinary chondrite and aubrite composition were identified.

Table: Bulk chemical major (wt%) and trace element (ppm) composition of Dhofar 018.

Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Cr_2O_3	MnO
0.35	15.97	8.32	47.81	0.06	6.94	0.45	0.545	0.485
FeO	NiO	2O5	Fe su	H2C	otal			
6.47	.035	).07	1.28	).06	8.83			
La	Ce	Nd	Sm	Eu	Yb	Cr	Co	Ni
2.46	5.97	3.98	1.24	).23	).94	3297	19	240
Se	Hf	Th	Ba	Sr	Zr	Ir		
).53	0.2	).45	330	540	60	.009		

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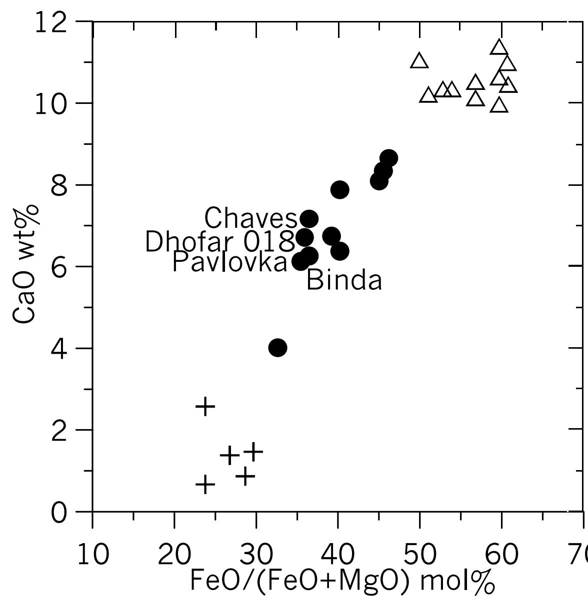

Fig.: CaO (wt%) – FeO/(FeO+MgO) (mol%) plot of Dhofar 018 bulk composition compared to other meteorites (data from [11]). • – howardites, + – diogenites, Δ – eucrites.