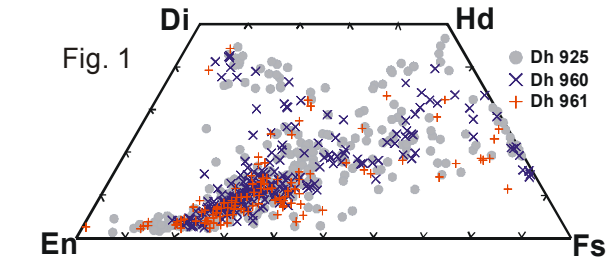
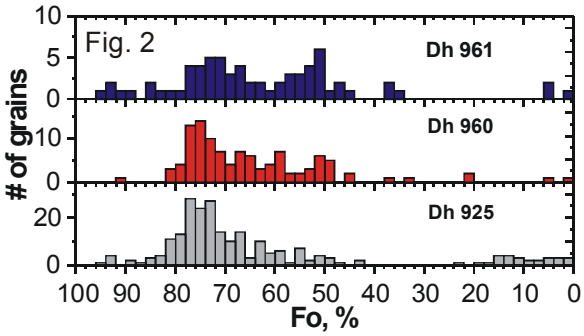
NEW LUNAR METEORITES FROM OMAN: DHOFAR 925, 960 AND 961 S. I. Demidova[1], M. A. Nazarov[1], G. Kurat[2,3], F. Brandstätter[2], T. Ntaflos[3] [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Kosygin St. 19, Moscow 119991, Russia, demidova@geokhi.ru; [2]Naturhistorisches Museum, Burgring 7, A-1010 Vienna, Austria; [3]Department of Geological Sciences, University of Vienna, Althanstr. 14, A-1090 Vienna, Austria

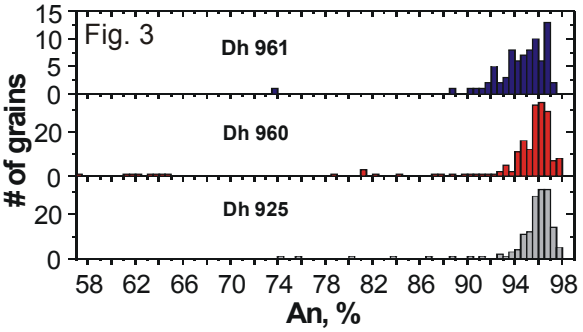
Introduction: New lunar meteorites have been recently discovered in the Dhofar region of Oman (Dhofar 925, 960 and 961). The stones were found in close proximity to each other and they are very similar in lithology, mineral chemistry and degree of weathering and, therefore, they must be paired. These are the first Dhofar lunar meteorites, which contain both highland and mare material as well as a KREEP component. The stones were found close to Dhofar 489, which differs from them in some features. Here we report first data on petrography, mineralogy and chemistry of the new meteorites.

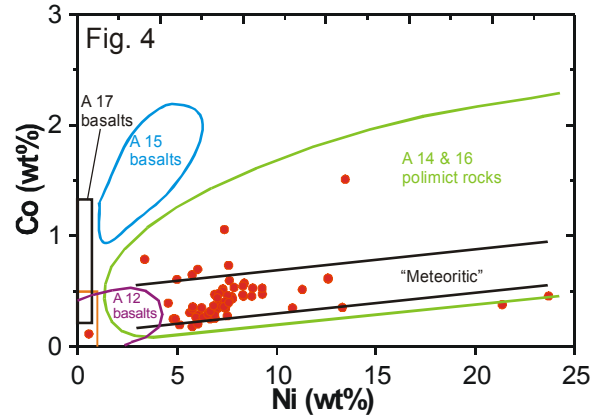
Results: Dhofar 925, 960 and 961 are impact melt breccias with abundant mineral fragments and lithic clasts which are embedded into a fine-grained impact melt matrix. In some areas the meteorites have a fragmental breccia texture. Glass veins and fragments of different composition are common and, therefore, the meteorites have characteristics of regolith breccias [1]. The stones are moderately weathered: calcite, gypsum, celestite, barite, smectite and Fe-hydroxides are present in cracks.

In mineral chemistry, the meteorites are indistinguishable from each other. Pyroxenes are pigeonites and minor augites varying in MG# from 99 up to Fe-rich augite as well as pyroxferroite $En_{0.1\text{-}97}Wo_{1\text{-}47}$ (Fig.1). Olivine ranges from Fo_{95} to $Fo_{0.5}$ (Fig 2). In Dhofar 961 olivine compositions have a bimodal distribution; with the Fe-rich olivine cluster being related to KREEPy rocks. Plagioclase shows huge variations in composition $An_{57\text{-}98}Or_{0\text{-}5.7}$ (Fig 3). All meteorites contain a population of Na-bearing plagioclases. Dhofar 960 contains the Na-richest plagioclase (labrador $An_{57\text{-}65}$), which is present in an alkali gabbro-anorthositic clast and among mineral fragments. Such Na-rich plagioclases were reported from some anorthositic gabbro breccias and low-K Fra Mauro rocks [2] as well as in some lunar meteorites (QUE 94281, Yamato 791197, Yamato 983885, PCA 02007). Accessory minerals are ulvöspinel, Cr-rich ulvöspinel, Ti-rich chromite, Al-rich chromite, pleonaste, ilmenite (0.4-7.5 wt% MgO), silica, troilite, K-Ba feldspar, whitlockite, apatite, baddeleyite, zircon, Zr-armalcolite, monazite, tranquillityite and zirconolite. In contrast to other lunar meteorites Dhofar 925, 960 and 961 are extremely enriched in FeNi metal (0.6-24 wt% Ni; 0.1-1.5 wt% Co), most of which has meteoritic composition (Fig 4).









Lithologies: Based on mineralogy and mineral chemistry at least five different lithologies are distinguishable in Dhofar 925, 960 and 961. Typical highland material is represented by anorthositic, troctolitic, noritic and gabbro-noritic rocks most of which have the mineral chemistry of the FAN suite or fill the gap

between FAN and HMS rocks. They are characterized by Ca-rich plagioclase An_{95-98} and Mg-rich mafic phases (MG# ~ 68-84).

Clasts of VLT basalts have ophitic texture and show a wide range of major mineral composition. However, plagioclase is mainly An_{94-97}, pyroxenes are richer in Fe as compared to those of highland rocks and show a huge compositional range of $En_{0-72}Wo_{6-41}$ (MG# 0-77). Olivines clusters mainly around Fo_{60-69}.

KREEPy rocks have basaltic, gabbro-noritic, gabbro-anorthositic, gabbro-troctolitic and anorthositic compositions. They are characterized by Na-bearing plagioclase (mainly An_{92-96}) and Fe-rich olivine (mostly Fo_{49-59}). Pyroxene is highly variable in composition (MG# ~ 50-70). Besides that, the characteristic minor phases are K-rich glassy mesostasis, K-Ba feldspar, whitlockite, apatite, baddeleyite and Zr-armalcolite. Some of the rocks have primary igneous texture. Similar rocks named alkali were found among Apollo 12 and 14 rocks [e.g., 3] and recently in the lunar meteorite Yamato 983885 [4,5].

Fe-rich rocks consist of fayalite, Fe-rich augite, hedenbergite, ilmenite and silica. This association was described in mare basalts and it is thought to be crystallized stably from late-stage Fe-enriched portions of mare basalt melts [2]. However, Dhofar 925, 960 and 961 contain Fe-rich pyroxenes and pyroxferroite as well, which are believed to be crystallized metastably [2].

Rare granitic fragments (30-250 μm in size) consist of K-feldspar ($An_{1-10}Or_{85-89}$), silica and K,Al,Si-rich mesostasis with minor Ca-rich and Ca-poor pyroxene ($En_{40}Wo_{20}$, $En_{41}Wo_6$ respectively), plagioclase ($An_{74-94}Or_{0.9-1.5}$), ilmenite, whitlockite, apatite, baddeleyite, monazite, zircon and tranquillityite (Fig. 5).

A fragment (11 μm in size) of a perfectly stoichiometric tschermakite composition was found in Dhofar 925. However, low refractive indeces show that it should be a glass fragment.

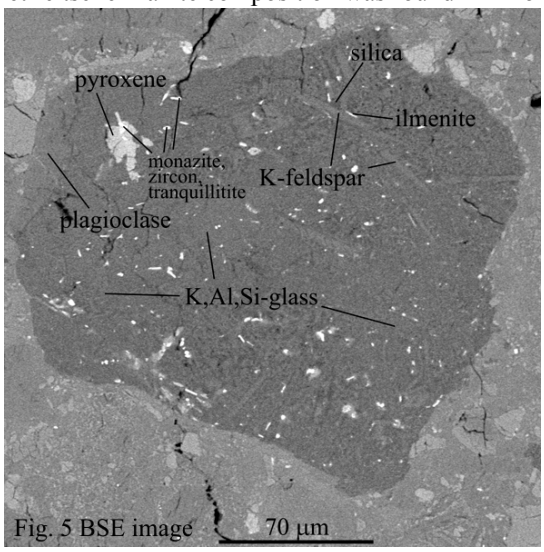


Fig. 5 BSE image

Bulk chemistry: Dhofar 925 has an intermediate composition between highland and mare rocks similar to LKFM breccias of Apollo 14 and 16 [6]. However, in contrast to LKFM rocks Dhofar 925 is depleted in REEs (10xCI) and does not show any Eu anomaly. In spite of the clear petrographic evidence for the presence of KREEP in Dhofar 925 there is no enrichment in KREEP elements in the meteorite. As compared to highland rocks, Dhofar 925 is enriched in Sc (25 ppm) that is consistent with the presence of mare basalts. The Ir content is the highest among all lunar meteorites (22,6 ppb) and indicates the presence of a significant meteoritic component. In bulk chemistry, Dhofar 925 is most similar to the Yamato 983885 mixed meteorite [5,7], but the latter is richer in Th [5]. Ba and Sr contents (105 and 630 ppm, respectively) of Dhofar 925 are relatively high and close to those in Dhofar 307,309,310,311 and 730. This indicates that Dhofar 925 has a significant terrestrial age [8].

Discussion: Based on petrography, mineralogy and chemistry Dhofar 925, 960 and 961 must be classified as mixed lunar meteorites. The stones are very similar to each other in composition and definitely paired. The meteorites were found close to Dhofar 489 but the stones are very different in composition from that of Dhofar 489, which does not contain any mare basalt material [9]. However, Dhofar 489 may represent a highland fragment of the Dhofar 925, 960 and 961 meteorite shower. In chemistry and lithological composition Dhofar 925, 960 and 961 are remarkably similar to Yamato 983885, which contains both highland rocks and VLT basalts as well as rare KREEPy rocks. Therefore, it is possible that the meteorites may be launch paired. The meteorites could originate from the northwestern part of the nearside, which is thought to be enriched in KREEP material.

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