NOBLE GASES IN THREE LUNAR METEORITES FROM OMAN.
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Introduction: During recent years 14 lunar meteorites have been recovered from the Antarctic or from hot deserts. Recently, three small lunar meteorites have been found in Oman: Dhofar 025, an anorthositic regolith breccia, Dhofar 026, an anothositic crystalline melt breccia [1], and Dhofar 081, classified as a feldspatic fragmental highland breccia [2]. The first two meteorites were found about 20 km apart from each other. The find location of Dhofar 081 is more than 200 km away from the other two lunar meteorites.

We have measured the noble gases in samples of all three meteorites to obtain information on a possible pairing, on the trapped noble gas component and on the irradiation history of this lunar material. Measured concentrations and isotopic composition of noble gases in bulk samples as well as the sum of temperature steps of a Dhofar 025 sample are given in Tab.1.

Dhofar	025		026	081	
[mg]	65.1*	105.3	50.0*	100.7	20.6
^{3}He	4.78	2.84	0.02	1.69	
^{4}He/^{3}He	24.3	12.9	4272	185.8	
^{20}Ne	200	117	2.85	153.7	181.0
^{20}Ne/^{22}Ne	9.35	9.44	10.40	5.79	6.15
^{21}Ne/^{22}Ne	0.178	0.186	0.039	0.446	0.423
^{36}Ar	386.0	509.0	8.70	244.1	320.0
^{36}Ar/^{38}Ar	6.06	4.94	5.15	3.59	3.67
^{40}Ar/^{36}Ar	68.9	52.1	280.5	13.6	13.6
^{84}Kr	0.554	0.327	0.090	0.234	0.258
^{132}Xe	0.064	0.038		0.030	0.037
^{21}Ne$_{c}$	3.3	2.0	0.002	11.5	12.0
^{38}Ar$_{c}$	4.3	8.4	0.06	25.3	30.8

* sum of several temperature steps

Tab.1: Concentration (in 10^{-8}cm^{3}STP/g) and isotopic composition of noble gases in lunar meteorites from Oman. Included are also cosmogenic ^{21}Ne and ^{38}Ar.

The measured noble gases in these samples is a mixture of different components. We will discuss here the trapped solar component, the cosmogenic gases and possible atmospheric adsorbed contributions.

Discussion: The solar wind is the principle source of noble gases in lunar regolith material. Mature soils contain very large concentrations of solar He and Ne. Smaller amounts occur in immature soils that have been not exposed to the solar wind to attain high concentrations. Lunar breccias as well as lunar meteorites may have lost noble gases due to thermal effects, which may occur during breccia formation or during launch off the lunar surface.

Fig.1 shows a comparison of the concentrations of solar gases in all three Dhofar finds with other lunar meteorites.

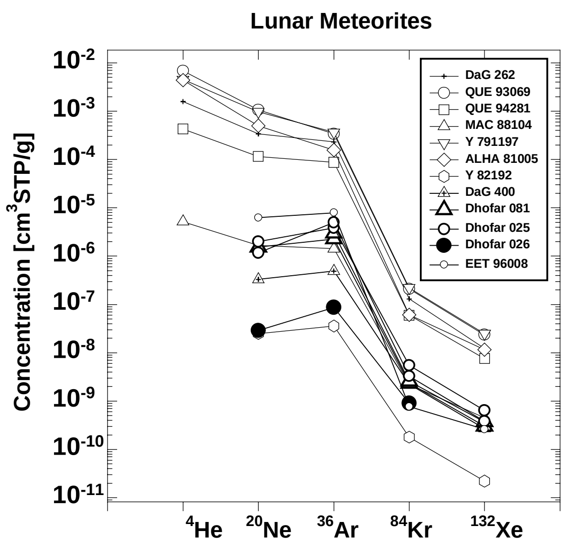

Fig.1: Elemental abundances of solar noble gases in lunar meteorites. For references see [3].

The concentrations of ^{4}He in the Dhofar meteorites is rather low and within the range of expected radiogenic He. For these meteorites we have plotted only the concentrations of ^{20}Ne, ^{36}Ar, ^{84}Kr, and ^{132}Xe.

Dhofar 025 and 081 do not show the typical abundance pattern of lunar anorthositic breccias like QUE 93069. Their solar gas concentrations are smaller by about two orders of magnitude and can be compared with those of MAC 88104 [4]. Dhofar 026 has even less solar gases. Its elemental abundance pattern is similar to that of Yamato 82192 [5]. With respect to solar gases these meteorites appear to be very immature compared to typical lunar soils. However, some lunar highland breccias from Apollo 16 contain similar amounts of trapped solar gases [6].

The original abundance pattern of solar gases is influenced by later thermal metamorphism. For meteorites found in hot deserts adsorbed gases from the terrestrial atmosphere are accumulated in weathering products. Such influences can be detected in a 3-isotope plot for neon which is given in Fig.2.

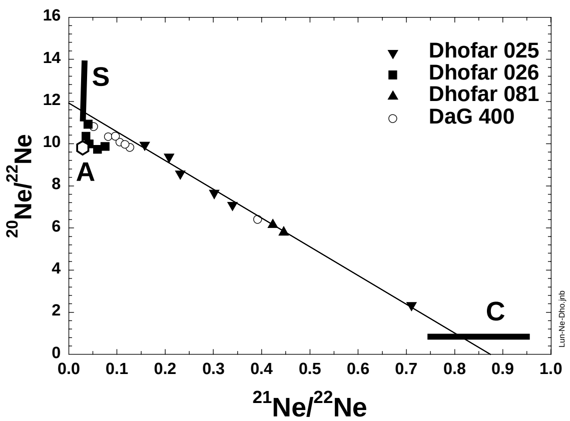

Fig.2: Neon-3-isotope plot with data of the three lunar Dhofar meteorites and, for comparison, Dar al Gani (DaG) 400 [7]. Indicated are the neon composition of the terrestrial atmosphere (A), and the ranges of the solar (S) and cosmogenic (C) compositions. The line through the Dhofar 025 and 081 data demonstrates a mixture of solar and cosmogenic gas.

The fit through the Dhofar 025 data indicates a trapped component with an isotopic composition similar to solar energetic particles (SEP). This may be explained by the loss of solar wind particles. These less energetic ions are more easily removed than SEP gases from the material by thermal events. Also, the bulk measurements on Dhofar 081 plot on the Dhofar 025 line and those of Dar al Gani 400 are close to this line.

For Dhofar 026, the sample with less trapped gases, all data points of temperature steps plot close to the atmospheric neon point (Fig.2). A contamination with terrestrial atmospheric neon seems to explain these data best. Adsorption of terrestrial gases is a common observation for meteorite finds from hot deserts [8]. This is also seen in the isotopic composition of Ar. Fig.3 shows the $^{40}Ar/^{38}Ar$ ratios in temperature steps of Dhofar 025 and 026. With the exception of the last temperature steps the values for Dhofar 026 are close to values of the terrestrial atmosphere. Dhofar 025, however, has much lower $^{40}Ar/^{38}Ar$ ratios, which are typical for lunar soils.

It is not possible to decompose He in these lunar meteorites into trapped, cosmogenic, and radiogenic components. However, ^{3}He is largely of cosmogenic origin but possibly influenced by thermal effects. Cosmogenic ^{21}Ne is calculated assuming a trapped $^{22}Ne/^{21}Ne$ = 32 and a cosmogenic value of 1.2. Cosmogenic Ar is derived assuming $^{36}Ar/^{38}Ar$ = 5.32 and 0.67 for trapped and cosmogenic gases, respectively. Results are given in Tab.1.

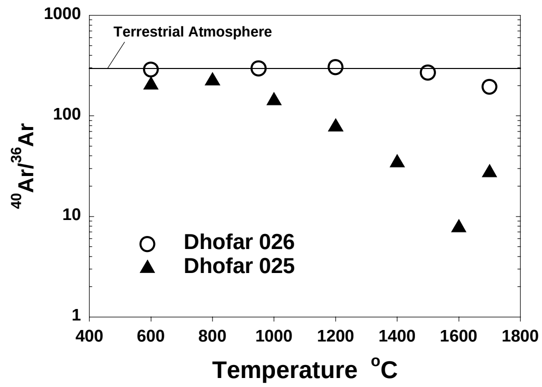

Fig.3: Isotopic composition of Ar in Dhofar 025 and 026.

For Dhofar 025 the cosmogenic isotopic composition of Kr and Xe is also deduced from the stepwise heating experiment.

The cosmogenic ^{21}Ne and ^{38}Ar concentrations of Dhofar 025 and Dhofar 081 is comparable to those of other lunar meteorites (e.g. MAC88104 [4]). They represent the sum of production in the lunar regolith and during the flight as a meteoroid. A deciphering of these irradiation steps is not possible without further studies, especially of cosmogenic radionuclides. However, the different amounts of cosmogenic gases indicate that these meteorites are not paired.

Dhofar 026 has extremely low cosmogenic gas concentrations, which limit the transfer time between Moon and Earth. Assuming a 4π-production rate of $0.2x10^{-8}cm^3$ $^{21}Ne/Ma$ the measured concentration would indicate a maximum transfer time of the order of 10^4 years.

References: [1] Grossman J.N. (2000) *Meteoritics & Planet. Sci., 35*, A199-A225. [2] Greshake A. et al. (2001) *Meteoritics & Planet. Sci., 36*, (in press) [3] Schultz L. and Franke L. (2000) Noble Gas Compilation, *MPI Mainz.* [4] Eugster O. et al. (1991) *Geochim. Cosmochim. Acta 55*, 3139-3148. [5] Eugster O. and Niedermann S. (1988) *Earth Planet Sci. Lett. 89*, 15-27. [6] Heiken G.H. et al (1991) *Lunar Scource Book*, Cambridge Univ. Press. [7] Scherer et al. (1998) *Meteoritics & Planet. Sci., 33*, A135-A136. [8] Scherer et al. (1994) In: *Noble Gas Geochemistry and Cosmochemistry*, 43-53.