COSMOGENIC RECORDS IN 18 ORDINARY CHONDRITES FROM THE DAR AL GANI REGION, LIBYA: I NOBLE GASES.

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Introduction: In the last decade thousands of meteorites have been recovered from hot deserts in the Sahara and Oman. One of the main meteorite concentration surfaces in the Sahara is the Dar al Gani plateau in Libya, which covers a total area of ~8000 km^2. More than 1000 meteorites have been reported from this area. The geological setting, meteorite pairings and the meteorite density of the Dar al Gani (DaG) field are described in more detail in [1].

In this work we report concentrations of the noble gas isotopes of He, Ne, Ar as well as ^{84}Kr and ^{132}Xe in 18 DaG meteorites. In a separate paper we will report the cosmogenic radionuclides [2]. We discuss the thermal history and cosmic-ray exposure (CRE) history of these meteorites, and evaluate the effects of the hot desert environment on the noble gas record.

Samples: We selected 13 H-chondrites, 4 L-chondrites and 1 LL-chondrite for noble gas and radionuclide analyses. Only one of these meteorites belongs to a shower, whereas two others belong to two different meteorite pairs [1]. The weathering grade ranges from W1 (DaG 062/908) to W5 for DaG 388, the shock grade from S1 (DaG 907) to S4 (DaG 908).

Experimental procedures and results: Concentrations and isotopic ratios of He, Ne and Ar were measured in chips of ~100 mg at the MPI, as described in [3]. The measured noble gas concentrations, given in Table 1, are a mixture of trapped components, a radiogenic component and a cosmogenic component, which will be discussed separately.

Trapped noble gases. Most samples contain significant amounts of trapped Ne, Ar, Kr and Xe, which generally increase from weathering grade 1 to 4, most notably for ^{84}Kr and ^{132}Xe. The ratio of trapped ^{132}Xe/^{84}Kr ranges from 0.1-0.4, which is much closer to the value of 0.073 in water (at 0 °C) than to the average planetary value of ~1.7 [4]. These two observations and the lack of ^{4}He concentrations >2 x 10^{-5} cm^3 STP/g indicate that the majority of the trapped noble gases is atmospheric. We therefore assume a ^{20}Ne/^{22}Ne ratio of 9.8 and a ^{36}Ar/^{38}Ar ratio of 5.32 for the trapped Ne and Ar components [3].

Radiogenic noble gases. The concentrations of radiogenic ^{4}He are deduced from the measured ^{4}He concentration by subtracting the cosmogenic component, assuming $(^{4}He/^{3}He)_c$=6 [5]. The concentrations of radiogenic ^{40}Ar are deduced from the measured ^{40}Ar concentration by subtracting a trapped atmospheric component, assuming $(^{40}Ar/^{36}Ar)_{tr}$ = 250±50 [6]. Radiogenic ^{4}He ranges from 0.03–1.80 x 10^{-5} cm^3 STP/g, whereas radiogenic ^{40}Ar ranges from 0.2–6.0 x 10^{-5} cm^3 STP/g. The radiogenic ^{4}He and ^{40}Ar concentrations seem to correlate with shock stage, with consistently high values for samples with S1-S2 and lower values for samples with S3-S4, consistent with previous observations [7]. Surprisingly, none of the five samples with low radiogenic ^{40}Ar (below 4.0 x 10^{-5} cm^3 STP/g), are L-chondrites.

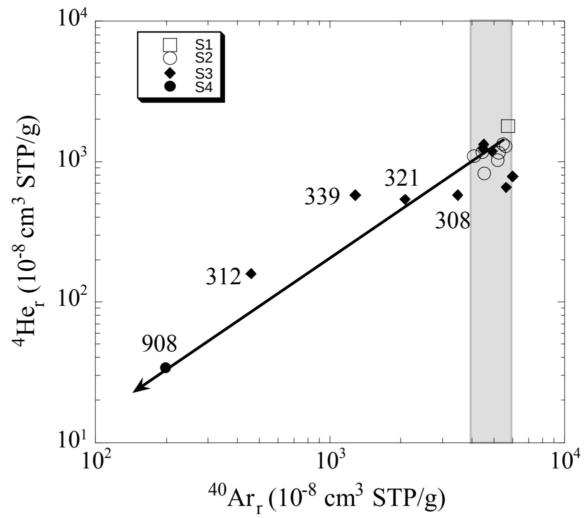

Fig. 1. Correlation of radiogenic ^{4}He and ^{40}Ar with shock stage. Most DaG samples with S3 and S4 show significant losses of radiogenic gases.

Cosmogenic noble gases. We determined the concentrations of cosmogenic ^{3}He, ^{21}Ne, ^{22}Ne and ^{38}Ar as in [3]. In many DaG samples, the concentration of cosmogenic ^{38}Ar is difficult to determine due to large amounts of trapped Ar: in a few cases the cosmogenic ^{38}Ar component is less than 10% of the total ^{38}Ar. The concentration of cosmogenic ^{21}Ne is much more reliable, because the amount of trapped ^{21}Ne is usually negligible (<1%). However, for samples with large amounts of trapped Ne, the cosmogenic ^{22}Ne/^{21}Ne ratio, which is used as a shielding parameter, becomes less reliable. Three DaG samples show highly elevated ^{20}Ne/^{22}Ne ratios of 3.5-4.5 relative to a typical ^{20}Ne/^{22}Ne ratio of ~0.84 for cosmogenic Ne. For these samples we adopted a ^{22}Ne/^{21}Ne ratio of 1.11, corresponding to average shielding (Table 1).

Exposure ages. We calculated the CRE ages from the cosmogenic ^{3}He, ^{21}Ne and ^{38}Ar concentrations and production rate methods which use the ^{22}Ne/^{21}Ne ratio as a shielding parameter [8]. The ^{21}Ne ages show typical values for ordinary chondrite in the range from ~1 Myr to over 40 Myr. Surprisingly, only one of the 13 DaG H-chondrites shows a CRE age coinciding with the main cluster at 7 Myr, whereas 8 meteorites show exposure ages ≤ 5 Myr and two coincide with the peak at ~30 Myr. This is partly due to the selection of samples, which was done using cosmogenic gases to avoid pairing. It is also likely that some of the low CRE ages were underestimated, since many samples show $^{22}Ne/^{21}Ne$ ratios <1.10. At these high shielding conditions, the simple relationship between the ^{21}Ne production rate and the $^{22}Ne/^{21}Ne$ ratio is not valid, resulting in an overestimation of the production rate for very large objects. In order to obtain reliable ages, we will calculate $^{10}Be/^{21}Ne$ ages for these samples [2].

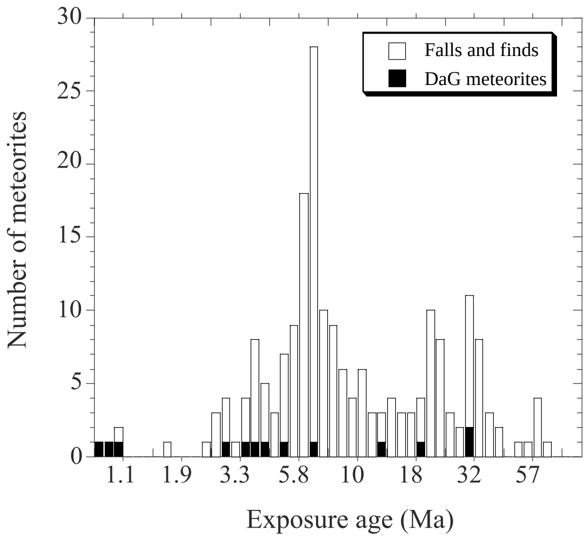

Fig. 2. CRE ages of 13 H-chondrites from the DaG region compared to those of 190 falls and finds [9].

The ^{3}He ages show generally good agreement (within 20%) with the ^{21}Ne ages, even for meteorites of weathering grade W4 and W5. This implies that moderate weathering in hot deserts does not lead to significant loss of cosmogenic ^{3}He. Nevertheless, six samples show ^{3}He ages significantly lower than the corresponding ^{21}Ne ages. For one or two samples with large amounts of trapped Ne, this is mainly due to the uncertainty in the $^{22}Ne/^{21}Ne$ ratio, which strongly affects the ^{21}Ne production rate and thus the ^{21}Ne age. However, for four other samples (DaG 308, 321, 339 and 908), the low ^{3}He ages correlate with loss of radiogenic gases. This correlation suggests that cosmogenic ^{3}He and radiogenic ^{4}He and ^{40}Ar were lost either by shock heating during impact on the parent body or by solar heating in space. The first scenario requires a previous CRE on the parent body. Results of cosmogenic radionuclide measurements indicate that DaG 908 had such a complex exposure history [2], whereas for the other samples with low cosmogenic ^{3}He, losses are most likely due to solar heating.

Conclusions: The 18 meteorites studied represent 18 individual falls. The trapped noble gases are dominated by atmospheric gases, which increase with the degree of weathering, especially for Kr and Xe. Five of the samples show significant losses of radiogenic ^{4}He and ^{40}Ar, which correlate with shock effects rather than with terrestrial weathering. Eight of the 13 H-chondrites show CRE ages below 5 Myr, whereas only one coincides with the peak at ~7 Myr. The low CRE ages may be an artifact of the high shielding in many samples as judged from the low $^{22}Ne/^{21}Ne$ ratios. Loss of cosmogenic ^{3}He in six samples is not due to weathering but to solar heating or impact-related heating.

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Table 1. Noble gas concentrations (10^{-8} cm^3 STP/g) and ^{3}He, ^{21}Ne and ^{38}Ar exposure ages (in Myr) of 18 DaG meteorites.

DaG	Class	^{3}He	^{4}He	^{20}Ne	^{21}Ne	^{22}Ne	^{36}Ar	^{38}Ar	^{40}Ar	$^{3}He/^{21}Ne$	$^{22}Ne/^{21}Ne$	T3	T21	T38
304	H6,S3,W4	1.07	789	2.34	0.33	0.53	16.47	3.16	9577	3.20	1.11	0.7	1.1	1.5
308	H6,S3,W2	2.92	595	2.31	1.17	1.35	6.50	1.36	5093	2.49	1.041	*1.8*	2.8	3.2
311	H6,S3,W3	6.92	1220	2.61	1.63	1.76	3.37	0.79	6174	4.26	1.044	4.2	3.7	3.7
312	H6,S3,W2	40.19	400	8.83	9.35	10.49	1.98	1.31	774	4.30	1.121	25.0	31.8	25.2
321	H5,S3,W3	5.73	571	4.32	2.29	2.72	1.49	0.49	2420	2.50	1.091	*3.5*	6.8	5.3
322	H4,S2,W2	30.42	1332	4.75	4.05	5.01	5.78	1.67	6548	7.51	1.221	19.4	19.6	18.7
336	H5/6,S2,W4	5.33	1317	1.43	0.95	1.13	6.51	1.33	7196	5.62	1.138	3.3	3.5	2.9
339	H5,S3,W3	3.29	596	8.83	1.57	2.45	5.64	1.23	2656	2.10	1.11	*2.0*	5.0	4.5
343	H4,S2,W4	6.51	1358	1.07	0.81	1.07	4.41	0.93	6700	8.00	1.288	4.2	4.4	3.9
388	H5/6,S2,W5	44.6	1429	10.51	11.41	12.31	2.74	1.55	4929	3.89	1.077	27.3	31.5	26.0
904	H6,S2,W3	1.14	834	0.36	0.39	0.41	1.17	0.24	4815	2.95	1.075	*0.7*	1.0	0.5
907	H6,S1,W3	22.66	1919	4.27	4.61	5.03	1.75	0.90	6051	4.92	1.090	14.0	13.6	14.6
908	H6,S4,W1	0.22	36	2.05	0.27	0.48	5.26	1.00	1512	0.80	1.11	*0.1*	0.9	0.8
330	L5,S2,W3	12.52	1098	2.47	2.52	2.91	12.73	2.29	8380	4.96	1.154	7.9	9.1	-
341	L6,S3,W3	17.71	761	3.07	3.33	3.85	2.45	0.78	6169	5.33	1.157	11.1	12.1	9.8
342	L5-6,S2,W3	58.20	1437	15.69	17.10	18.31	3.80	2.06	4784	3.40	1.069	35.7	41.9	36.1
906	L6,S3,W2	8.30	1374	1.85	0.87	1.22	6.25	1.25	6048	9.54	1.296	5.4	4.8	3.0
062	LL5-6,S3,W1	19.58	1350	3.40	3.60	4.09	2.05	0.86	6007	5.45	1.134	12.2	12.0	14.0

Low ^{3}He ages which are due to loss of cosmogenic ^{3}He are printed in italics.