NOBLE GAS, ^{26}Al, ^{10}Be, AND ^{14}C CONCENTRATIONS AND TRACK DENSITIES OF BUR GHELUAI: EVIDENCE FOR A TWO-STAGE EXPOSURE HISTORY; R. Wieler and P. Signer (ETH-Zurich, NO C61, CH-8092 Zurich, Switzerland) A.J.T. Jull (NSF Facility for Radioisotope Analysis, Univ. Arizona, Tucson, AZ) P. Pellas (Museum d'Histoire Naturelle, 61 Rue Buffon, 75005, Paris, France) C. Tuniz (Istituto di Fisica, Universita degli Studi, Trieste, Italy), A. Maras (Dip. Scienze della Terra, Sez. Mineralog. Cristallog., Univ. la Sapienza, Rome, Italy), D. Fink, J. Klein, and R. Middleton (Dept. Phys., Univ. Pennsylvania, Philadelphia, PA) G.F. Herzog and S. Vogt (Dept. Chemistry, Rutgers Univ., New Brunswick, NJ).

Meteorites that have short conventional exposure ages and show signs of brecciation may be especially good places to search for evidence for multi-stage irradiations [1]. Bur Gheluai, an H5 fall, is a meteorite of this kind. Aylmer et al. [2] presented the ^{26}Al and ^{10}Be concentrations of 7 samples from Bur Gheluai. The variations, >50% for each isotope, proved that the meteoroid was large - at least 50 cm in radius - but left open the possibility of a two-stage irradiation. To learn more about the exposure history we re-sampled at the Museo di Mineralogia, Univ. Roma 6 specimens analyzed previously [2] and obtained material from two others. Table 1 gives results for cosmogenic noble gases and for ^{14}C, ^{26}Al, and ^{10}Be. The various experimental methods used are described in references [3-7].

Noble gases - 1) The cosmogenic ^{21}Ne concentrations (10^{-8} cm^3 STP/g) of the 8 samples range from 0.24 in T6 to 0.72 in T4, nearly a factor of three; the ^3He_c and $^{38}Ar_c$ concentrations vary by a factor of two. Confirmed variations of this magnitude are rare for stone meteorites. 2) The sample with the lowest ^{21}Ne content, T6, has a $^{22}Ne/^{21}Ne$ ratio (R) consistent with just a few cm of shielding; R in the other 7 samples is consistent with shielding depths of 20 cm or so. While we would expect near-surface samples to have somewhat lower production rates (P), a threefold increase in P_{21} from surface to interior cannot be explained by current models of a one-stage irradiation [e.g., 8,9]. 3) We have not so far found solar gases in Bur Gheluai. A few samples have $^{20}Ne/^{22}Ne$ ratios as high as 2.5, but these values probably reflect minor contamination of the gas extraction system. Our search for solar gas will continue in samples with light-dark structure.

Tracks - Olivine crystals in sample T6 have a GCR track density of $(4.9\pm1.0)\times10^4$ tr/cm^2. From this result and various estimates of meteoroid size and exposure age we infer a shielding depth for T6 of 5-6 cm (see [10]); a correction for the different track recording efficiencies of olivines and pyroxenes has been included. A depth of 5-6 cm is also deduced from the $^{22}Ne/^{21}Ne$ ratio [8] assuming a one-stage exposure. Tracks and noble gases together suggest that T6 acquired all or most of its cosmogenic noble gases during its last exposure stage. Sample T4 is essentially devoid of tracks, implying a shielding depth of > 20 cm.

^{26}Al and ^{10}Be - The new determinations generally agree well with the old. The ^{10}Be and ^{26}Al activities increase by about 50% overall, from 6 to 9 and 27 to 38 dpm/kg, respectively; both activities correlate with the ^{21}Ne concentrations as one might expect if shielding were responsible. Best-fit lines show, however, that the relative increase in ^{21}Ne is substantially larger than that for either ^{26}Al or ^{10}Be (Fig. 1). This observation contradicts our expectation for a one-stage irradiation: P_{10}/P_{21} is nearly constant in chondrites of various size [8A]; according to model calculations [8,9], both P_{10}/P_{21} and P_{26}/P_{21} vary much less than our observed $^{10}Be/^{21}Ne$ and $^{26}Al/^{21}Ne$ ratios.

^{14}C - The average value of P_{14} for a chondrite is about 44 dpm/kg [11]. The observed ^{14}C activities range from about 20 to 30 dpm/kg. As P_{14} should behave similarly to P_{21} [9,12], the structure shown in Figure 1 suggests that Bur Gheluai must have undergone irradiation in two or more stages, consistent with the conclusion reached above from the noble gas data.

DISCUSSION - For simplicity we will assume a two-stage exposure with spherical geometry. These assumptions and our track and ^{21}Ne data then require that Bur Gheluai's second stage lasted long enough to saturate ^{14}C. The observed range of ^{14}C activities suggests that the meteoroid's radius (**R**) during the second stage lay between ~150 and 500 cm.

EXPOSURE HISTORY OF BUR GHELUAI: Wieler, R. et al.

Table 1. Cosmogenic nuclide concentrations[1] in Bur Gheluai.

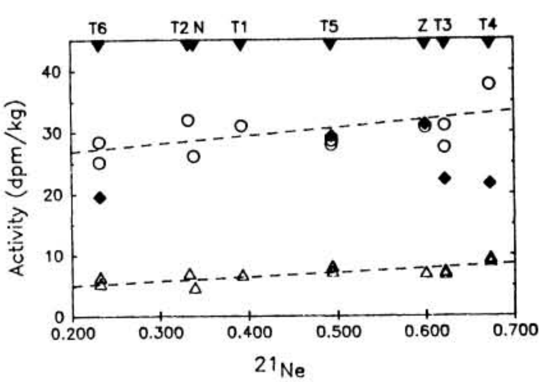
Sample[2]	^{3}He	^{21}Ne[3]	$22/21_c$[4]	$^{38}Ar_c$[5]	^{14}C	^{26}Al	^{10}Be
T1	1.27	0.393	1.082	0.046		31.0[6]	6.7[6]
	1.35	0.394		0.053			
T2	0.945	0.335		0.044		32.0[6]	7.0[6]
T3	2.04	0.624		0.072	22.2±0.7	27.4	6.9
	2.05	0.631	(1.053)	0.071		31.0[6]	7.3[6]
T4	2.23	0.674	(1.065)	0.083	21.5±0.7		9.4
	2.25	0.683	1.067	0.080		37.6[6]	8.9[6]
T5	1.32	0.502		0.054	29.3±0.8	27.9	8.1
	1.29	0.484	1.067	0.056		28.6[6]	7.3[6]
T6	1.20	0.233		0.041	19.5±1.4	25.1	6.4
	1.23	0.247	(1.125)	0.038		28.4[6]	5.4[6]
	1.22	0.239	1.142	0.035			
T7	1.49	0.441	1.073	0.050			
N778	1.26	0.340		0.044		26.1[6]	4.7[6]
Z	1.96	0.603	1.050	0.071	31.2±0.8	30.7	7.0
	1.98	0.608	1.062	0.072			

Notes: 1) Gas concentrations in 10^{-8} cm^3 STP/g; 1-σ error ~ 4%. Radionuclides in dpm/kg; 1-σ error for ^{26}Al and ^{10}Be ~ 8%. 2) Typical masses for gas analysis, 200 mg; for cosmogenic nuclides, 100 mg. 3) ^{21}Ne~$^{21}Ne_c$ because trapped gas corrections are small. 4) Reported only when uncertainty introduced by unknown composition of trapped component is less than 0.4% (less than 1% for values in parentheses). 5) $^{38}Ar_c$=calculated with canonical $(36/38)_c$=0.65. 6) Ref. 2. 7) T2 contained fusion crust; low ^{3}He/^{21}Ne probably indicates ^{3}He loss.

The ^{21}Ne and ^{14}C concentrations of the sample T6 may place an upper limit on t_2. With P_{21} set as $(^{14}C/P_{14-m})xP_{21-m}$, ($P_{14-m}$ = 44 dpm/kg [11]; P_{21-m} = 0.33/Ma [13]) we obtain t_2 < 1.6 Ma. The model of [8] gives t_2 < 1.4-1.7 Ma for 150 < $\mathbf{R}_2$ < 500 cm. Turning now to the first stage, T4 has the highest ^{21}Ne content but a ^{14}C content approximately equal to that of T6. Accordingly, if T4 and T6 have equal ^{21}Ne contributions from the second stage, then T4 would have > 0.48 units of ^{21}Ne from the first stage. According [8], t_1 should exceed 3 Ma.

In summary, Bur Gheluai experienced a two- (or multi-) stage exposure. The short duration of our model second stage implies that the concentrations of ^{26}Al and ^{10}Be "remember" the first irradiation. This result underscores the need for care in selecting the meteorites used to deduce noble gas production rates from cosmogenic radionuclide data [1].

Figure 1. ^{14}C (♦), ^{26}Al (O), and ^{10}Be (Δ) *vs.* ^{21}Ne.



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