THE 100TH MARTIAN METEORITE KSAR GHILANE 002 (KG 002): NOBLE GASES AND RADIONUCLIDES POINT TO A STRONG RELATIONSHIP WITH LOS ANGELES.
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Introduction: Ksar Ghilane 002 (KG 002) is the 100th Martian meteorite to be catalogued by the Meteoritical Bulletin, and the first to be recovered from Tunisia (January, 2010). The single stone, weighing 538 g, is a coarse-grained basaltic shergottite that shows remarkable petrological and compositional similarities with evolved shergottite Los Angeles [1,2].

By performing noble gas and radionuclide analysis on KG 002, we aim to contribute further in determining the extent of its similarity with Los Angeles. In particular, we investigate the potential for a launch-pairing of these two meteorites by comparison of cosmic ray exposure (CRE) ages, where preferred CRE ages for Los Angeles of 3.10 ± 0.70 and 3.35 ± 0.30 Ma have been previously suggested [3,4].

Methodology: A 67.53 mg bulk fragment of KG 002 was analysed for all noble gases (He, Ne, Ar, Kr and Xe) using an MAP 215-50 noble gas mass spectrometer at MPIC, Mainz. Gases were extracted in steps at 600, 1000 and 1800 ºC. A 177.44 mg bulk fragment of KG 002 was used for long-lived radionuclide analysis, using the separation procedure described by [5]. The light radionuclides ^{10}Be and ^{26}Al were analysed at the accelerator mass spectrometry (AMS) system DREAMS at Dresden, while ^{53}Mn was analysed at the GAMS facility at TU Munich.

Results: Our results for the noble gases He, Ne and Ar, and our radionuclide data are summarised in Tables 1 and 2, respectively. Also listed for comparison are literature data for Los Angeles [4,6-8]. Whilst, for calculation of CRE ages, we assumed all ^{3}He to be cosmogenic, cosmogenic $^{21}Ne_c$ and trapped $^{20}Ne_t$ were obtained assuming trapped neon to have Earth atmospheric (EA) composition [9] and a cosmogenic $(^{20}Ne/^{22}Ne)_c$ ratio of 0.83 e.g. [10]. For the calculation of $^{38}Ar_c$ and $^{36}Ar_t$, we assumed trapped Ar to have EA composition [11] and a cosmogenic $(^{38}Ar/^{36}Ar)_c$ ratio of ~1.5 [12].

Concentrations: We observe slight differences in concentrations of (mostly) radiogenic ^{4}He and ^{40}Ar, as well as trapped $^{20}Ne_t$ and $^{36}Ar_t$, for Los Angeles and KG 002 (Table 1). However, the most startling feature is the near-identical concentrations of cosmogenic ^{3}He, $^{21}Ne_c$, $^{38}Ar_c$ and ^{10}Be (Tables 1-2). Such similarities may be expected in (chemically similar) samples that have experienced similar cosmogenic exposure conditions. This may provide a hint for a launch-pair.

CRE ages: We have calculated CRE ages for KG 002 using two different methods: 1) The empirical model of $^{22}Ne/^{21}Ne$-corrected production rates [14,15] using our noble gas data; 2) The Monte-Carlo model of depth- and radius-dependent production rates [16] using both radionuclide and noble gas data. Both methods use major and trace element data for KG 002 from [1] (for major elements, average of two analyses).

Using method 1) with the cosmogenic concentrations given in Table 1, we obtain T_3 (^{3}He), T_{21} (^{21}Ne), and T_{38} (^{38}Ar) ages of 1.97 ± 0.06, 4.42 ± 0.11 and 2.90 ± 0.29 Ma respectively. The calculated errors take into account uncertainties in concentrations of cosmogenic nuclides as well as in the shielding parameter, but not in chemical composition. Our T_{38} age is similar to the preferred Los Angeles CRE age of 3.1-3.4 Ma reported by [3,4]. In addition, [4] and [6] report T_3, T_{21} and T_{38} ages for Los Angeles of ~1.35-1.9, 3.13-3.6 and 3.23-2.8 Ma, respectively. The T_3 ages are low compared to the T_{21} and T_{38} ages: a feature we also observe for KG 002. Note that in order to derive the T_{21} value [6] corrected their $^{21}Ne_c$ for production from Na and then calculated an age of 3.6 Ma using the $(^{22}Ne/^{21}Ne)_c$ ratio of ~1.163 from their highest temperature release (1600 ºC), as it should be the least ef-

Table 1: Total noble gas (NG) concentrations and ratios for KG 002 and Los Angeles. t = trapped, c = cosmogenic.

NG	KG 002	Los Angeles [4]	Los Angeles [4]	Los Angeles [6]
^{3}He	3.16(10)	1.69(10)	2.64(15)	3.14
^{4}He	21.49(86)	21.80(70)	29.50(1.00)	69.70
$^{20}Ne_t$	10.50(2.21)	78(7)	62(5)	97.9
$^{21}Ne_c$	60.46(1.17)	62(5)	59(2)	59.2
^{22}Ne	78.30(1.39)	94.30(6.10)	82.24(4.61)	86.2
$^{20}Ne/^{22}Ne$	0.953(8)	1.58(8)	1.52(7)	1.87
$^{21}Ne/^{22}Ne$	0.773(5)	0.690(38)	0.704(30)	0.69
$(^{22}Ne/^{21}Ne)_c$	1.277(9)	1.35(7)	1.33(6)	1.288(5)
$^{36}Ar_t$	12.57(1.56)	63(5)	59(2)	31.7#
$^{38}Ar_c$	49.10(4.89)	49.8(3.0)	50.1(2.5)	45.1#
^{40}Ar	222.7(19.8)	386(10)	340(8)	298.0

^{3-4}He, ^{40}Ar in 10^{-8} ccSTP/g, $^{20-22}Ne$ and $^{36-38}Ar$ in 10^{-10} ccSTP/g.

Table 2: Cosmogenic radionuclide (RN) data for KG 002 and Los Angeles.

RN	KG 002	Los Angeles [7]	Los Angeles [7]	Los Angeles [7]	Los Angeles [8]
^{10}Be	18.27(35)	18.4(4)	19.5(4)	18.4(3)	17.6(5)#
^{26}Al	116.1(1.9)	95.5(2.4)	103.0(3.8)	89.6(3.0)	77.7(3.7)
^{53}Mn	300(64)	-	-	-	251(14)

^{10}Be & ^{26}Al in dpm/kg, ^{53}Mn in dpm/kg Fe. # = renormalised by factor of 1.045 for direct comparison between PRIMElab and DREAMS [13].

fected by production on Na. Later, [4] followed the same approach, arriving at a T_{21} age of 3.15 Ma.

If we perform a similar correction based on an estimated 4.4% Na contribution to $^{21}Ne_c$ (calculated for a typical $^{21}Ne_c$ production rate for Na [16] and Na content of ~1.6 % [1]), and use our 1800 °C step for the $(^{22}Ne/^{21}Ne)_c$ shielding parameter (1.161 ± 0.012), we obtain a T_{21} age of 3.44 ± 0.11 Ma. This value is close to the (presumably more reliable) T_{38} age of 2.90 ± 0.29 Ma. Together, this may suggest an ejection event at ~3.0 Ma.

Using method 2), Figure 1 shows a comparison of ^{10}Be and ^{26}Al activities expected for CRE ages in the range 2.8-3.7 Ma and for saturation compared with the measured values. While a pre-atmospheric radius of ≤ 25 cm can be excluded based on the $(^{22}Ne/^{21}Ne)_c$ ratio of 1.277 ± 0.009 (Fig. 2), the radionuclide data allow us to exclude very large radii (Fig. 1). The best match is for the investigated sample originating from a position near the centre of a 35-65 cm radius meteoroid. The data do not overlap with the calculated saturation activities of ^{10}Be and ^{26}Al, suggesting a shorter CRE than necessary for ^{10}Be saturation. This is in agreement with the T_{38} age of ~2.9 Ma, for which the ^{26}Al activity is near saturation (94.2 %), whereas ^{10}Be is undersaturated. Overall, the data allow for a simple one-stage travel history through space before entering the Earth's atmosphere. The investigated sample was probably from a shielded position near the centre, excluding SCR-induced nuclear reaction products as inferred for other Martian shergottites.

The CRE ages of KG 002 from methods 1 and 2 agree well with the ages calculated for Los Angeles: 3.0 ± 0.4 and 3.3 Ma from ^{10}Be and 2.8-3.1 Ma from several noble gases [3,7-8]. However, we can exclude a common travel of both KG 002 and Los Angeles in a single meteoroid, as previous data for Los Angeles deduced a meteoroid radius of 20-40 cm [7]. Thus, a conjoint ejection event on Mars is a possibility, but individual exposure of both meteoroids is required.

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References: [1] Llorca J. et al. (subm.) *MAPS*. [2] Roszjar J. et al. (2012) *LPSC XLIII, this conf*. [3] Terribilini, D. et al. (2000) *MAPS*, 35:A155-A156. [4] Eugster, O. et al. (2002) *MAPS*, 37:1345-1360. [5] Merchel S. and Herpers U. (1999) *Radiochim. Acta*, 84:215-219. [6] Garrison, D.H. and Bogard, D.D. (2000) *MAPS*, 35:A58. [7] Nishiizumi K. et al. (2000) *MAPS*, 35:A120. [8] Berezhnoy A. A. et al. (2010) *MAPS*, 45:A13. [9] Eberhardt P. et al. (1965) *Zeitschr. Naturforsch.* A 20:623-624. [10] Garrison D.H. et al. (1995) *Meteoritics* 30:738-747. [11] Lee J.-Y. et al. (2006) *GCA* 70:4507-4512. [12] Wieler R. (2002) Reviews in Min. and Geochem. 47:125-170. [13] Merchel S. et al. (subm.) *Nucl. Instr. Meth. Phys. Res. B*. [14] Eugster O. et al. (1997) *GCA* 61:2749-2757. [15] Eugster O. and Michel T. (1995) *GCA* 59:177-199. [16] Leya I. and Masarik J. (2009) *MAPS* 44:1061-1086.

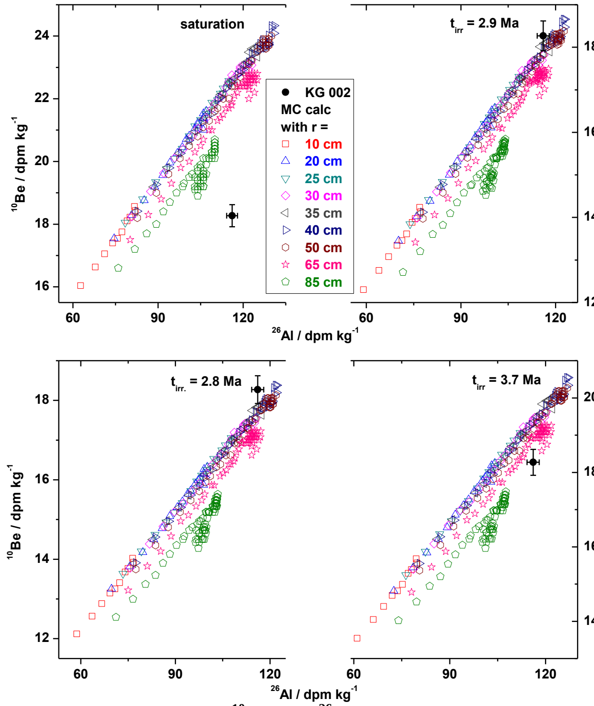

Figure 1: Experimental ^{10}Be and ^{26}Al activities of KG 002 in comparison to predictions for saturation and three different CRE ages (2.8, 2.9 and 3.7 Ma). Predicitions are based on Monte-Carlo-calculated depth- and radius-dependent production rates [16] and chemical composition from [1].

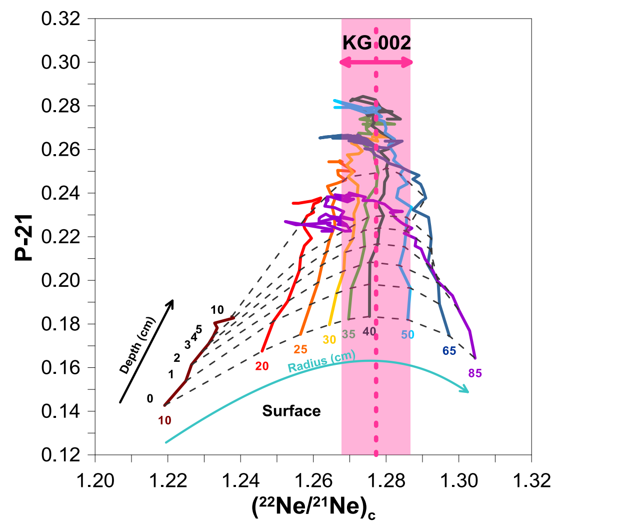

Figure 2: Plot of Cosmogenic ^{21}Ne production rate P-21 vs. cosmogenic $(^{22}Ne/^{21}Ne)_c$ based on the Monte-carlo model by [16] and element abundances from [1]. Coloured full lines = potential pre-atmospheric radii. Dashed black lines = depth within a sample of such radius. The pink band is the total measured $(^{22}Ne/^{21}Ne)_c$ for KG 002 (Table 1). A pre-atmospheric radius of ≤ 25cm can be excluded.