Exposure Histories of Yamato Shergottites. K. Nishiizumi[1] and M. W. Caffee[2], [1]Space Sciences Laboratory, University of California, Berkeley, CA 94720-7650, USA, [2]Department of Physics, Purdue University, West Lafayette, IN 47907-1396, USA.

Introduction:

Cosmogenic nuclide studies of Martian meteorites have contributed significantly to our understanding of these objects. Uisng a combination of cosmogenic stable- and radionuclides, it is possible to determine many important properties about these meteorites. Most lunar meteorites have complex cosmic ray exposure histories, having been exposed both at some depth on the lunar surface (2π irradiation) before their ejection and as small bodies in space (4π irradiation) during transport from the Moon to the Earth. On the other hand, we have not yet observed clear evidence of complex exposure history for Martian meteorites. These exposures are followed by residence on Earth's surface, a time commonly referred to as the terrestrial ages. In addition to their complement of galactic cosmic ray (GCR) produced nuclides, some Martian and lunar meteorites contain nuclides produced by solar cosmic rays (SCR). Unraveling the complex history of these objects requires the measurement of at least four cosmogenic nuclides. The specific goals of these measurements are to constrain or set limits on the following shielding or exposure parameters: (1) the depth of the sample at the time of ejection from the Mars; (2) the transit time (4π exposure age) from ejection off the Martian surface to the time of capture by the Earth; and (3) the terrestrial residence time. The sum of the transit time and residence time yields an ejection age. Information about the orbital evolution of Martian meteorites is obtained by comparing a spectrum of measured transit times to model predictions.

We report here results of three or four cosmogenic radionuclides: ^{10}Be (half-life = 1.36 Myr), ^{26}Al (0.705 Myr), ^{36}Cl (0.30 Myr), and ^{41}Ca (0.104 Myr) in Yamato (Y) lherzolitic shergottites, Y 793605, 984028, 000027, and 000097 and depleted olivine-phyric shergottite Y 980459. Partial results of Y 980459 were reported earlier [1].

Experimental Procedures and Results:

We received exterior and interior chips from each shergottite in order to investigate SCR effects. Exterior chips were further divided and identified by distance from the surface of the fusion crust. Each sample was then dissolved in an HF-HNO_3 mixture along with Be and Cl carriers. The chemical compositions of Mg, Al, Ca, Mn, Fe, Co, and Ni in aliquot of samples were measured by atomic absorption spectrometry or ICP-OES. The results are shown in Table 1, along with distance form the fusion crust. The ^{10}Be, ^{26}Al, and ^{36}Cl AMS measurements were performed at PRIME Lab, Purdue University. The AMS measurements in Y-980459 were performed at Lawrence Livermore National Laboratory and partially reported earlier [1]. The results of cosmogenic nuclide concentrations (±1σ) are shown in Table 2.

Discussion:

***Yamato 980459**:* The depleted olivine-phyric shergottite Y 980459 is paired with Y 980497. They are both covered by fusion crust; the combined recovered mass is 91 g. A higher concentration of ^{26}Al in the near-surface sample indicates that the meteorite contains SCR produced ^{26}Al. This meteorite experienced low ablation during atmospheric entry. The pre-atmospheric radius is estimated to be less than 5 cm, similar to NWA 5789 [2]. The exposure age of Y 980497 is calculated to be 1.0±0.2 Myr, based on the ^{10}Be concentration. The terrestrial age of Y 980497 is 60±60 kyr. The terrestrial ages for depleted olivine-phyric shergottites span a wide range (11 - 450 kyr). Within this range there is a cluster comprised of the DaG 476-1051 pairs, NWA 1195, 2046, 2626, 4925, 5789, and SaU 005-150 pairs [2], The ejection age of Y 980459 fits into this cluster at 1.1±0.1 Myr,. The radionuclide ages are significantly shorter than the ^{21}Ne exposure age of 2.1-2.5 Myr [3] indicating either the presence of SCR-produced ^{21}Ne or a significant pre-exposure on the parent body.

Y 793605, 984028, 000027, and 000097: Five (excluding YA1075) lherzolitic shergottites were found from the Yamato Mountain icefield. Among them Y 000027, 000047, and 000097 are proposed as paired; there are 3 Yamato lherzolitic shergottites. Cosmogenic nuclide concentrations in Y 000027 and 000097 are nearly identical and support pairing. The recovered masses of all Yamato lherzolitic shergottites are small (5 - 24 g) and they have a fusion crust. Unlike Y 980459, there is no ^{26}Al excess (no SCR effect) in any of samples. The ablation depth of these is more than a few cm. None of these meteorites has as small a preatmospheric size as Y 980459. Although cosmogenic nuclide concentrations in three lherzolitic shergottites are significantly different, the nuclide concentration ratios, such as ^{26}Al/^{10}Be or ^{36}Cl/^{10}Be in the 3 meteorites are nearly identical. These differences are due to different shielding conditions in a meteoroid(s) with same exposure age. The cosmogenic nuclide measurements indicate these 3 meteorites are part of the same fall. The terrestrial ages of these 3 meteorites are 35±35 kyr. Noble gas exposure ages of Y 793605 are 5.1-5.8 Myr [4] and 4.4 Myr [5] and that of Y 000027 and 000097 are 4.6±1.5 Myr [6].

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References:

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Table 1. Chemical compositions in 5 Yamato shergottites.

Yamato	Distance from FC (mm)	Mass (mg)	Mg (%)	Al (%)	Ca (%)	Mn (ppm)	Fe (%)	Co (ppm)	Ni (ppm)
984028,73	0 – 1	52.1	16.30	1.34	2.41	3590	16.93	120	410
984028,71	interior	54.9	15.79	1.27	2.78	3470	14.74	80	280
793605,77	0 – 2	22.0	13.68	1.86	2.50	3570	14.71	80	330
793605	interior	64.3	15.13	1.92	2.49	3750	15.85	90	330
000097,94	0 – 2	66.2	15.56	1.42	3.11	3630	16.91	80	300
000097,93	3 – 4	41.0	15.95	0.58	2.31	3550	14.64	70	280
000027,73	3 – 4	54.5	14.31	1.87	2.85	3470	17.06	90	290
980459,58	0 – 2	40.1	11.47	2.08	5.02	3320	13.31	60	190
980459,58	2 – 4	44.6	12.66	1.90	4.83	3290	13.32	70	250
980459,58	4 – 6	39.6	12.61	2.13	4.65	3290	13.34	70	270
980459,56	interior	99.8	10.62	2.60	5.36	3270	13.28	60	170

Table 2. Cosmogenic radionuclide concentrations in 5 Yamato shergottites.

Yamato	Distance from FC (mm)	^{10}Be (dpm/kg)	^{26}Al (dpm/kg)	^{36}Cl (dpm/kg)	^{36}Cl (dpm /Fe+8Ca+16K)	^{41}Ca (dpm/kg)	^{41}Ca (dpm/kgCa)
984028,73	0 - 1	15.06±0.44	41.7±1.5	6.66±0.14	17.96±0.37		
984028,71	interior	14.63±0.44	46.9±2.2	7.21±0.15	19.11±0.39		
793605,77	0 - 2	17.08±0.27	50.3±1.6	7.70±0.12	20.73±0.32		
793605	interior	17.78±0.47	51.5±2.0	7.90±0.20	21.58±0.55		
000097,94	0 - 2	18.69±0.25	53.2±2.2	9.10±0.38	21.15±0.88		
000097,93	3 - 4	18.25±0.32	55.1±2.0	7.42±0.18	22.15±0.53		
000027,73	3 - 4	18.15±0.24	54.4±2.7	9.29±0.40	22.70±0.98		
980459,58	0 - 2	7.25±0.13	65.2±1.2	8.56±0.15	15.75±0.28	3.54±0.58	71 ±12
980459,58	2 - 4	6.85±0.20	58.6±1.1	7.74±0.13	14.74±0.25	4.14±0.76	86 ±16
980459,58	4 - 6	7.26±0.19	55.9±1.0	7.77±0.22	15.17±0.43	2.89±0.81	62±18
980459,56	interior	7.29±0.11	57.5±1.0	8.50±0.11	14.87±0.20	4.92±0.70	92±13