

NOBLE GAS COSMIC RAY EXPOSURE AGES FOR FIVE SHERGOTTITES AND EVIDENCE FOR TRAPPED MARTIAN ATMOSPHERE IN TISSINT. L. Huber¹, A.J. Irving², C. Maden¹ and R. Wieler¹, ¹Dept. of Earth Sciences, ETH Zürich, CH-8092 Zürich, Switzerland (liliane.huber@erdw.ethz.ch), ²Dept. of Earth and Space Sciences, University of Washington, Seattle, WA, USA.

Introduction: New Martian meteorites are found quite frequently, with ten new hot desert finds and one fall in 2011 and 2012 alone, bringing the total number of unpaired specimens to 68. Cosmic-ray exposure ages can help constrain their recent history and possibly identify launch- or fall-pairings. Here we discuss the cosmic ray exposure histories of five recently-discovered Martian meteorites based on ³He, ²¹Ne and ³⁸Ar, and we report Kr and Xe data for Tissint glass.

Samples: NWA 7032 is a depleted permafic microgabbroic shergottite, and NWA 7042 is an intermediate permafic intersertal shergottite [1] (both found in 2011). NWA 7257 (also found in 2011) is an enriched mafic shergottite similar to Shergotty [2]. Tissint (which fell in July, 2011) is a depleted permafic olivine-phyric shergottite [3]. Two samples of Tissint were measured, one sample rich in interior shock-produced glass and a bulk sample lacking glass. NWA 7397 (found in 2012) is an enriched permafic poikilitic shergottite, similar to NWA 4468 and RBT 04261/2. Petrologic data are given in [4], and a thin section optical image is presented in Figure 1.

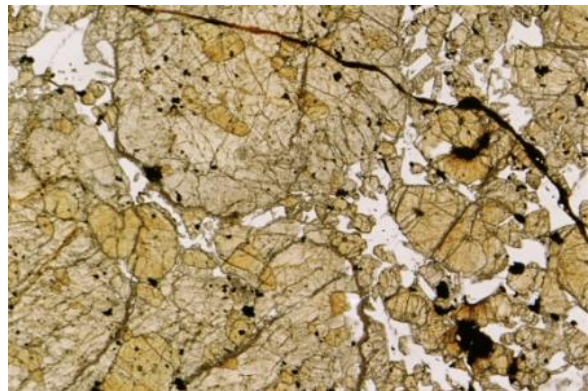


Figure 1: Plane polarized light image of NWA 7397, showing its poikilitic texture with chadacrysts of olivine enclosed within pyroxene oikocrysts. White areas are maskelynite and black areas are oxides/pyrrhotite and shock glass veinlets. Width = 9 mm. Photo by T. Bunch.

Analytical Procedures: Chips of about 50-75 mg without fusion crust were wrapped in aluminum foil, loaded in the furnace storage volume and preheated in UHV for 24h at 120°C. Noble gases were extracted by heating the sample to 1700°C for 30 min. Gases were cleaned by various ZrTi getters and separated into

three fractions (HeNe, Ar, KrXe), which were analyzed in two sector field mass spectrometers.

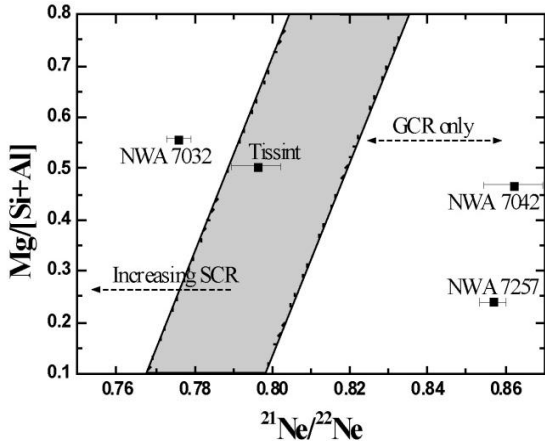


Figure 2: Adapted from [5] shows that NWA 7032 and possibly Tissint seem to be affected by SCR. NWA 7397 plots off scale and to the right, and like NWA 7042 and NWA 7257 has not seen SCR.

Exposure ages: The cosmic ray exposure ages are all calculated using the procedure described in [6,7]. Before calculating the exposure ages it is important to determine whether shergottites show evidence of solar cosmic ray exposure (SCR) [5]. Figure 2 shows that NWA 7032 very likely and Tissint possibly contain SCR-Ne. NWA 7397 plots off scale to the right and like NWA 7042 and NWA 7257 has not seen any SCR.

The ²¹Ne/²²Ne ratio is used as a proxy for the shielding. Since this ratio is influenced by SCR a general ²¹Ne/²²Ne ratio of 0.83 was assumed for NWA 7032. For Tissint we used the measured ²¹Ne/²²Ne for the shielding correction.

Table 1: Exposure ages (in million years) of five shergottites based on cosmogenic ³He, ²¹Ne and ³⁸Ar.

	T(²¹ Ne)	T(³⁸ Ar)	T(³ He)	²² Ne/ ²¹ Ne
NWA 7032	2.7	1.9	2.3	1.29
NWA 7042	2.8	1.6	2.4	1.16
NWA 7257	3.1	2.5	2.5	1.17
Tissint Bulk	1.1	1.0	1.1	1.26
NWA 7397	1.9	2.2	1.4	1.00

Exposure ages are given in Table 1. These values include production corrections as described in [6,7] based on analyzed bulk compositions (given in Table 2

below). We have not attempted to subtract the SCR-Ne contribution for NWA 7032. Indeed, the ^{21}Ne age of NWA 7032 is somewhat higher than its ^3He and ^{38}Ar ages. However, this is also the case for NWA 7042 and NWA 7257, and it is thus unclear whether SCR-Ne is the culprit for the difference between the ^{21}Ne age of this meteorite and its ^3He and ^{38}Ar ages. It is generally accepted that the ^{21}Ne is the best proxy for exposure ages of all three light noble gases, since Ca (the main producer of Ar) can be unevenly distributed, and $^3\text{He}/^3\text{H}$ can be lost during meteoroid travel around the sun. Because production rates are distinctly dependent on the accuracy of the models as described in [8], differences among adopted He, Ne, and Ar ages are common. All exposure ages determined in this study are below 4 Ma and agree therefore with the ages determined for the majority of the shergottites measured until now [9-13]. The noble gas-derived exposure age for Tissint also agrees exactly with the ^{10}Be age [14] and is also within uncertainties of the age reported in [15]. Therefore, the meteorites studied here likely were ejected from Mars in events already known from previous shergottite studies. Taking into account other literature data [e.g. 9-13], we tentatively conclude that three ejection events would suffice to produce all the shergottites which show less than 5 Ma of exposure.

Kr and Xe results for Tissint: Tissint contains fairly abundant small pockets of shock-produced glass (see Figure 3) that might contain Martian atmospheric gases. Of the two measured samples of Tissint, the one rich in glass plots distinctly closer to the Mars atmosphere composition than the bulk sample in Figure 4, implying that Tissint glass contains Kr and Xe from the Martian atmosphere. The data points for the other shergottite samples studied here fall near the lower end of the range for shergottite bulk samples observed previously.



Figure 3: Shock-produced interior glass pockets (black) in a Tissint stone. Photo © S. Ralew.

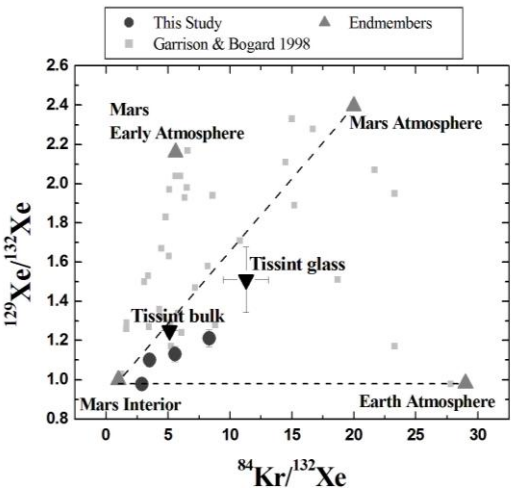


Figure 4: $^{129}\text{Xe}/^{132}\text{Xe}$ versus $^{84}\text{Kr}/^{132}\text{Xe}$ for Martian meteorites. Mars interior point is from Chassigny; literature data from [16].

Table 2: Bulk major element compositions (determined by XRF at Washington State University)

	Tissint	NWA 7032	NWA 7042	NWA 7257	NWA 7397
SiO ₂	43.97	36.59	42.38	47.36	42.27
TiO ₂	0.60	0.97	0.79	1.36	0.55
Cr ₂ O ₃	0.81	0.40	0.70	0.24	0.78
Al ₂ O ₃	4.95	4.93	5.12	4.78	3.70
FeO	22.28	29.21	22.93	23.25	27.12
MnO	0.52	0.53	0.53	0.59	0.50
MgO	19.44	18.30	17.51	9.82	18.81
CaO	6.30	6.43	8.30	9.83	4.99
Na ₂ O	0.64	0.78	0.80	1.03	0.26
K ₂ O	0.03	0.03	0.08	0.23	0.09
P ₂ O ₅	0.47	1.85	0.88	1.52	0.94
Sum	100.00	100.00	100.00	100.00	100.00

References: [1] Irving A. J. et al. 2012. LPS XLIII, Abstract #2510. [2] Irving A. J. al. 2012 MAPS (*MetSoc75 abstracts*) Abstract #5367. [3] Irving A. J. et al. 2012 LPS XLIII Abstract #2496. [4] Meteorit. Bulletin 101 2013 (*classification of NWA 7397*). [5] Garrison D. H. et al. (1995) Meteoritics 30, 738. [6] Eugster O. and Michel T. (1995) Geochim. Cosmochim. Acta 59, 177. [7] Eugster O. et al. (1997) Geochim. Cosmochim. Acta 61, 2749 [8] Huber et al. 2012 LPS XLIII, Abstract #1408. [9] Nyquist L.E. et al. 2001 Chronology and evolution of Mars 96 105-164 [10] Eugster O. et al 2002. MAPS 37, 1345 [11] Christen et al 2005 Antarct. Meteorite Res. 18, 117. [12] Nishiizumi et al. 2010 LPS XLI Abstract #2276. [13] Nishiizumi et al. 2011LPS XLII Abstract #2371. [14] Nishiizumi K. et al. (2012), MAPS 47S1, #5349. [15] Chennaoui H. et al. 2012, Science 338, 785 [16] Garrison D.H. and Bogard, D.D. (1998) MAPS 33, 721