COSMOGENIC RADIONUCLIDES IN MARTIAN METEORITES: THE TISSINT CASE.

P. P. Povinec[1], L. Ferrière[2], A. J. T. Jull[3,4], C. Koeberl[2,5], A. Kováčik[1,6] and I. Sýkora[1], [1]Dept. of Nuclear Physics and Biophysics, Comenius University, 84248 Bratislava, Slovakia (pavel.povinec@uniba.sk), [2]Natural History Museum, 1010 Vienna, Austria, [3]Dept. of Geosciences, University of Arizona, Tucson, AZ 85721, USA, [4]ICER, Institute for Nuclear Research, Hungarian Academy of Sciences, 4026 Debrecen, Hungary, [5]Dept. of Lithospheric Research, University of Vienna, 1090 Vienna, Austria, [6]MicroStep-MIS, s.r.o., 84104 Bratislava, Slovakia.

Introduction: Tissint is a Martian meteorite which fell on July 18, 2011 in Morocco. It has been classified as a depleted permafic olivine-phyric shergottite [1]. The total recovered mass is of at least 12 kg. Tissint probably experienced multiple shock events, producing shock-melt veins and pockets and abundant fractures [2]. Cosmogenic radionuclides found in meteorites are products of interactions of cosmic-ray particles with their bodies. They have been widely used to study the origin of meteorites, their orbital history, and cosmic-ray exposure ages. We focused on cosmogenic radionuclides with half-lives from about one year to 0.7 Myr (^{54}Mn, ^{22}Na, ^{60}Co, ^{14}C, and ^{26}Al). The aim has been to determine the diameter and cosmic-ray exposure age of the Tissint meteoroid.

Results: Two fragments of the Tissint meteorite with masses of 37.7 and 908.7 g (samples NHMV-N9412 and NHMV-N9388, respectively) were analyzed by gamma-spectrometry in the low-background laboratory of the Comenius University in Bratislava [3]. For the ^{14}C analyses, a small sample of 188 mg was selected for AMS measurements, which were carried out on a 3 MV AMS machine at the University of Arizona. The ^{14}C measurements gave a result of 42.6±0.4 dpm/kg and the extraction procedure is given in [4]. The average activities of ^{22}Na and ^{26}Al measured in 37.7 g and 908.7 fragments are 65.4±4.6 and 36.9±3.1 dpm/kg, respectively. The ^{22}Na/^{26}Al activity ratio for the bigger sample measured with better precision is 1.89±0.05, what is higher than the value expected for H chondrites (1.5) due to an unsaturated production of ^{26}Al, caused by its short cosmic-ray exposure age. In terms of ^{60}Co activity, only the detection limit of <0.2 dpm/kg can be reported.

Pre-atmospheric radius (PAR): ^{60}Co has usually been used as a depth indicator for fragments within the meteoroid body, as well as for the estimation of its PAR [5, 6]. The absence of ^{60}Co in the analyzed fragments indicates either a small concentration of the target isotope (^{59}Co) in the meteorite, and/or its small PAR. The cobalt concentration was measured to be 58 ppm [1], which is lower by a factor of 10 when compared to H chondrites. Using the measured ^{60}Co limit (<0.2 dpm/kg), we may estimate the PAR of the Tissint meteorite (following [5, 6]) to be <20 cm. Another method to estimate the PAR is based on ^{26}Al, as its production rate with depth in small meteorites has a steep rise [5, 6]. Following a similar comparison as we did for ^{60}Co, the Tissint PAR estimated using the ^{26}Al method is 20±3 cm. The ^{14}C results are also consistent with this size estimate. The mass of the meteoroid would be then 100±15 kg (using an average measured density of 3 g/cm^3).

Cosmic-ray exposure age (CRE): We can estimate the cosmic-ray exposure age of the Tissint meteorite using the ^{26}Al method described by Herzog [7]. Although we have only ^{26}Al measurements in two fragments with unknown depth in the meteoroid, at least for the large fragment, because of its size (and a small radius of the meteorite), we can expect its position to have been close to the meteoroid surface. The CRE exposure age calculated by using the ^{26}Al method is 0.9 ±0.3 Myr. Our estimation agrees with the CRE age of 0.7±0.3 Myr, calculated using the method based on stable isotopes ^{3}He, ^{21}Ne, and ^{38}Ar [1], as well as with result based on the ^{10}Be method 1.10±0.15 Myr [8]. These estimations are consistent with CRE ages of similar Martian meteorites (EETA79001, DaG 476, DaG 735, NWA 1195, NWA 2046, NWA 2626, NWA 4925, NWA 5789, SaU 005, and Yamato 980459), which have an average CRE age of 1.05±0.10 Myr [8]. From these estimations we may conclude that Tissint was ejected from Mars in the same impact event as other shergottites, although these small objects reached Earth at different times.

Acknowledgement: Support provided by the Slovak Science and Grant Agency VEGA (project no. 1/0891/17) is highly appreciated.

References: [1] Chennaoui Aoudjehane H. et al. (2012) *Science* 338:785–788. [2] Baziotis I. P. et al. (2013) *Nature Communications* 4:1404 doi: 10.1038/ncomms2414. [3] Povinec P. P. et al. (2016) *Journal of Radioanalytical and Nuclear Chemistry* 307:2403–2407. [4] Jull A. J. T. et al. (2010) *Meteoritics and Planetary Science* 45:1271–1283. [5] Povinec P. P. et al. (2015) *Meteoritics and Planetary Science* 50:880–892. [6] Povinec P. P. et al. (2015) *Meteoritics and Planetary Science* 50:273–286. [7] Herzog G. F. (2005) Cosmic-ray exposure ages of meteorites. In Davis A. M. (ed.) *Meteorites, Planets, and Comets.* Elsevier, p 347–380. [8] Nishiizumi K. et al. (2012) *Meteoritics and Planetary Science* #5349.