

MARTIAN WATER IN THE IMPACT MELTS IN EETA 79001. Yang Chen¹, Yang Liu¹, Yunbin Guan², John M. Eiler², Chi Ma², George R. Rossman². ¹Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA; ²Geol. & Planet. Sci., California Institute of Technology, Pasadena, CA 91125, USA. (Email: Yang.Chen@jpl.nasa.gov).

Introduction: EETA 79001 is a particularly interesting martian meteorite because the impact melts in it contain noble gas signatures indicative of martian origin [1]. The noble gases were initially thought to be from martian atmosphere [1] and later revised to be from martian aqueous solution [2]. In either scenario, the impact melts acquired the noble gases could also have acquired martian H₂O. If this H₂O source exchanged hydrogen isotopes with recent martian atmosphere, it should have elevated deuterium content similar to the present martian surface values of 3900-7000 ‰ in δD [3] considering the young crystallization and cosmic-ray exposure ages of this meteorite [4]. However, previous studies on the impact melts in EETA 79001 yielded relatively low δD values of 1454-2900 ‰ [5,6]. Here we report new data on the impact melts in EETA 79001 and show that the H₂O source acquired by EETA 79001 had high δD values within the range of recent martian atmosphere.

Samples and Methods: We studied four impact melt pockets, one melt vein, and many maskelynites in three sections: EETA 79001,524, 715, and 717. Sample 524 is a polished section from Lithology A. Sample 715 and 717 are from Lithology C (“Bravo”, >1 cm impact pockets), and three pieces were prepared and mounted in indium. All impact melts and veins contain crystals and vesicles: the ones in 524 contain large olivines, pyroxenes and maskelynites surrounded by fine-crystalline devitrified glass, whereas those in 715 and 717 are mostly fine-crystalline (Fig 1). We focused our analyses on the fine-crystalline regions and avoided the large olivines and pyroxenes. For maskelynite, we analyzed some that are far away from impact melts and some fully enclosed in impact melts.

The major-element compositions were analyzed with an electron microprobe and energy-dispersive spectroscopy on a scanning electron microscope. The volatiles (H₂O analyzed as OH, F, Cl, P, and S) were analyzed with secondary ion mass spectrometry (SIMS). Natural and synthetic glasses were used as standards. The 2 σ errors based on the reproducibility of the standards are 10% for H₂O, P, and S, and 6 % for F and Cl. The detection limits are 5 ppm for H₂O, 0.3 ppm for F, 0.2 ppm for Cl and P, and 0.1 ppm for S. Hydrogen isotopes were analyzed in separated SIMS sessions and reported as δD values relative to Vienna Standard Mean Ocean Water. The measured D/H values in the impact melts and maskelynites were

corrected by the instrument mass fractionation factor of 1.016 (α) based on glass standards. The 2 σ errors for δD values are 47-168 ‰, depending on the H₂O concentration.

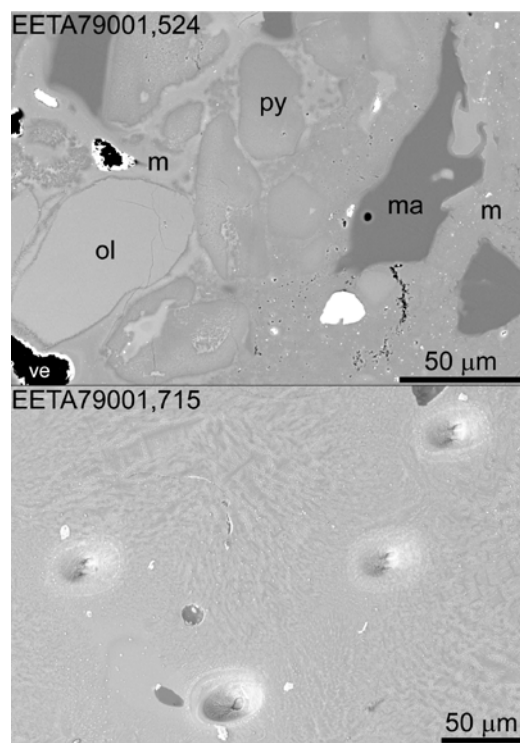


Figure 1. Back-scattered electron images of the impact melts, showing the different textures. *ol*-olivine; *py*-pyroxene; *ma*-maskelynite; *m*-melt; *ve*-vesicle.

Results: Major-element compositions of the impact melts are basaltic and fall within a small range. The impact melts in 524 have more SiO₂, Al₂O₃, CaO and Na₂O but less MgO than those in 715 and 717. The maskelynites in all samples are An₅₄₋₆₀Ab₄₄₋₃₄.

The impact melt pockets contain 125-638 ppm H₂O, 9.3-13.5 ppm F, 32-53 ppm Cl, 1278-2545 ppm P, and 1737-2702 ppm S. H₂O shows the largest variation among the volatiles but does not show any correlation with the other volatiles. The δD values are 3368-4639 ‰ and not correlated with concentrations of H₂O or other volatiles (Fig 2). The only notable correlations are among F, Cl, and P (F+Cl vs. P in Fig 3).

Maskelynites contain up to 97 ppm H₂O, 0.64 ppm F, 4.5 ppm Cl, and 3.1 ppm S. The δD values in maskelynites are 1604-3938 ‰ and negatively corre-

lated with $1/H_2O$ (Fig 2). The maskelynites enclosed in impact melts have higher volatile concentrations and δD values than those far away from impact melts.

Discussion: The δD values in the impact melts in this study are much higher than those from [5] and [6], although the H_2O concentrations are in the same range. The impact melts in [6] are clearly different from the ones reported here: they are fully enclosed in maskelynites and have higher Al_2O_3 concentrations (~22 wt%). The lower δD data in [6] could reflect mixing of maskelynite and other igneous minerals that have low δD values but higher H_2O concentrations. Details on the texture and chemistry of the impact melts in [5] are not available, but the fact that their δD values are between this study and [6] suggests mixing between the two different types of impact melts.

The high δD values in the impact melt pockets are consistent with a H_2O source that exchanged hydrogen isotopes with recent martian atmosphere, likely existed on or near martian surface. This source could also have introduced the martian noble gases to the impact melts. The presence of a high- δD surface or near surface H_2O source is consistent with the observation in the impact melt in Tissint, a shergottite of a similar ejection age [7]. The 3368-4639 ‰ variation in δD is non-negligible, suggesting that either this source has heterogeneous δD values, or there is another low- δD source.

Besides the H_2O in exchange with martian atmosphere, apatite could also be a high- δD H_2O source for impact melts [6,8]. The role of apatite in EETA 79001 is difficult to infer based on hydrogen isotopes because there is no reliable data. Boctor et al. [5] reported 146 ‰ δD in one apatite in EETA 79001, but suspected that this value may be affected by surrounding silicates. The correlation between (F+Cl) and P suggests that apatite contributed to the impact melts in EETA 79001. However, apatite cannot be the only H_2O source, because the OH/P molar ratios in the impact melts are from 0.3 to 1.1, higher than that in apatites.

The negative correlation between δD and $1/H_2O$ in maskelynites (Fig. 2) indicates that there is a low- δD source represented in maskelynites far away from impact melts. The negative correlation argues against terrestrial contamination and dehydration fractionation. This source is possibly martian magmatic H_2O with low δD values stored in nominally anhydrous minerals, similar to Tissint [7]. This low- δD magmatic source could have contributed to the impact melts as well. However, the lack of correlation between H_2O concentrations and δD values in the impact melts hinders further inferences.

In summary, we interpret three volatile sources in the impact melts and maskelynites in EETA 79001: H_2O in exchange with martian atmosphere, magmatic volatiles in apatite, and magmatic H_2O in nominally anhydrous minerals. We do not observe the low- δD surface source in [6]. It is possible that different impact melts sampled the H_2O sources differently.

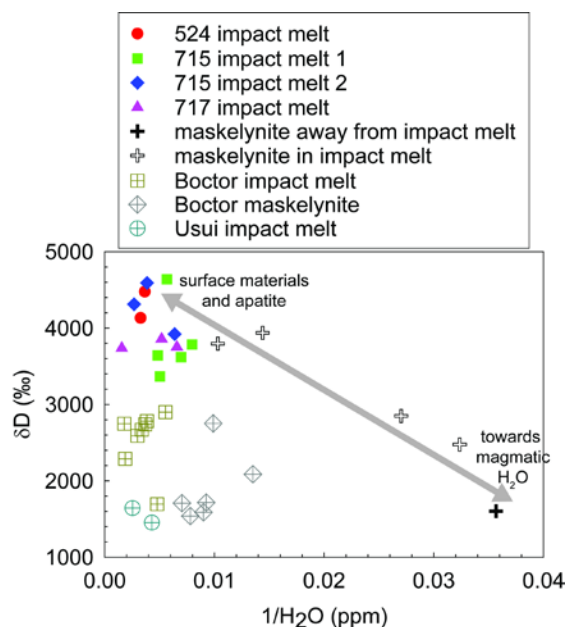


Figure 2. H_2O concentration and hydrogen isotope of the impact melts and maskelynites in EETA 79001.

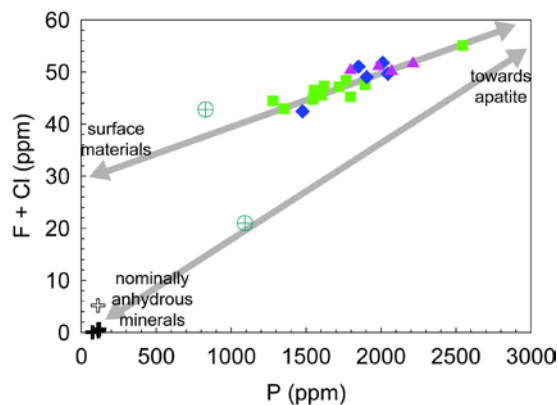


Figure 3. Positive correlation between $F+Cl$ and P . The symbols are the same as in Fig 2.

References: [1] Bogard D.D. & Johnson P. (1983) *Sci.*, 221, 651-654. [2] Bogard D.D. & Garrison D.H. (1998) *GCA*, 62, 1829-1835. [3] Leshin L.A. et al. (2013) *Sci.* 341, 1238937. [4] Nyquist L.E. et al. (2001) *Chronol. Evol. Mars*, 96, 105-164. [5] Boctor N.Z. et al. (2003) *GCA*, 67, 3971-3989. [6] Usui T. et al. (2015) *EPSL*, 410, 140-151. [7] Chen Y. et al. (2014) 45th *LPSC*, Abstr. # 2425. [8] Greenwood J.P. et al. (2008) *GRL*, 35, L05203.