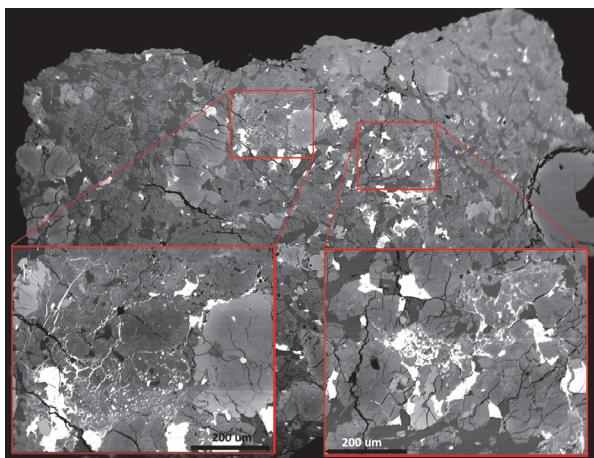


**TRACE ELEMENT AND PB ISOTOPE GEOCHEMISTRY OF TISSINT IMPACT MELT GLASS AND SULFIDE REVEAL NO CONTAMINATION BY MARTIAN SOIL.** T. J. Lapen<sup>1</sup>, S. E. Suarez<sup>1</sup>, M. Righter<sup>1</sup>, A. J. Irving<sup>2</sup>, K. Righter<sup>3</sup>, <sup>1</sup>Dept. Earth and Atm. Sci., University of Houston, Houston, TX ([tjlapen@uh.edu](mailto:tjlapen@uh.edu)), <sup>2</sup>Department of Earth and Space Sciences, University of Washington, Seattle WA, <sup>3</sup>NASA Johnson Space Center, Houston, TX.

**Introduction:** Shergottite meteorites typically contain melt pockets and veins that formed during the impact-ejection event. The impact glass within shergottites EETA 79001 and Tissint have been hypothesized to contain martian soil components incorporated during the shock event [e.g., 1,2], but this hypothesis has been debated [3]. In general, the predicted signatures of a soil component would include enrichment in S [1], incompatible trace elements, such as light rare earth elements (REE), Ba, Th [1,2], more radiogenic Sr, Pb, and Os, and less radiogenic Nd and Hf isotopic compositions. Despite the clear evidence for Mars atmospheric components in impact glass, incorporation of a crustal component has been difficult to definitively test. Evidence for radiogenic Sr and Pb isotopic compositions in dilute HCl/HBr washes of Tissint samples [e.g., 4,5] suggests either a terrestrial (unlikely) or martian component hosting the labile Sr and Pb, but the distribution of these components is unclear.

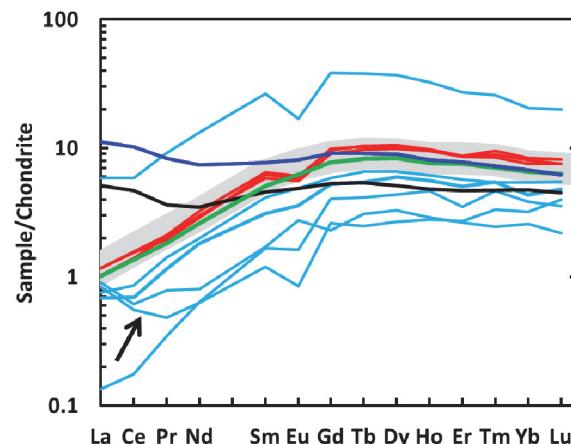


**Figure 1.** SEM-BSE images of the analyzed fragment. The bright phases are pyrrhotite (as intact grains and as veins and droplets), large phenocrysts are olivine, light grey areas associated with sulfide veins and areas without distinct igneous textures are impact glass, light and dark gray grains in the groundmass are pyroxene and maskelynite, respectively.

In this study, a 1.5 x 2.0 mm impact glass and sulfide-rich fragment of Tissint (Fig. 1; Sample TS2 [6]) was analyzed in situ for REE and highly siderophile element (HSE) concentrations and Pb isotopic compositions. The data are used to assess whether the sul-

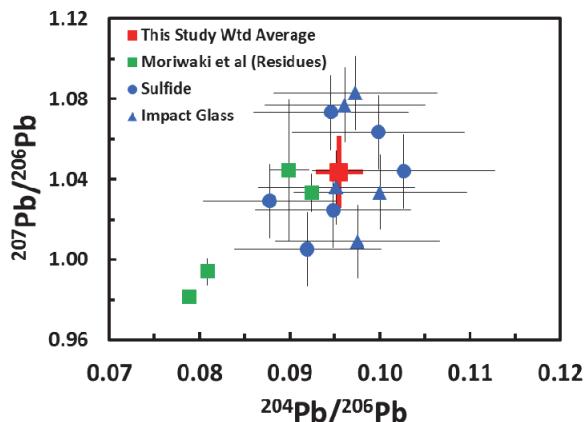
fide-rich impact melt glass in Tissint contains any detectable exogenous components.

**Methods:** The fragment of Tissint was polished to expose impact melt glass, associated sulfide minerals, and relict igneous phases. The areas were imaged and mapped by SEM BSE followed by laser ablation analysis using a Photon Machines *Excite* coupled to a Varian 810 quadrupole ICPMS at UH. Each spot analysis was conducted with 65-85 μm in diameter laser beam at 10-25 Hz repetition rates, a fluence of 4 J/cm<sup>2</sup>, 30s on-peak blank, 30s ablation time. Operating conditions of the samples were exactly matched to the standards for each analysis. Calibration standards include NIST 612 glass (Pb isotopes), BHVO-2G (REE concentrations), and the HOBA meteorite (HSE concentrations). External standards were BHVO-2G (Pb), BIR-1G (REE), and Filomena (HSE). Pb isotopes were corrected for the <sup>204</sup>Hg isobar in the instrument blank and Hg in the standards by monitoring <sup>201</sup>Hg and <sup>202</sup>Hg; other Pb data reduction methods follow [7]. Trace element concentrations were processed using the *Glitter* program.



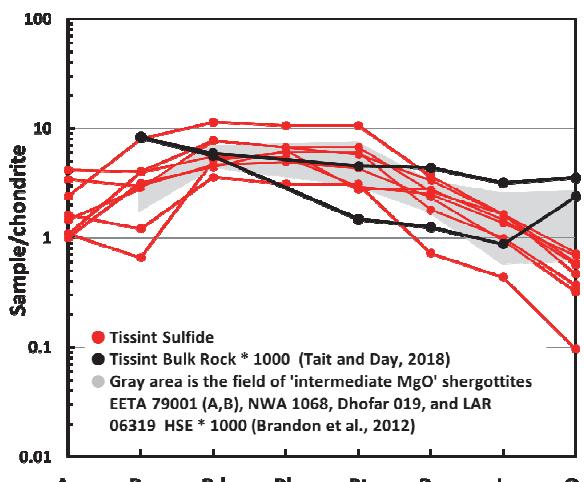
**Figure 2.** Chondrite-normalized REE for Tissint whole rock (light grey) [3,8], impact glass (green [3]; black [2]; red, this study), ‘groundmass’ (dark blue) [2], sulfide and sulfide + glass (light blue, this study). Arrow points to LREE enrichment for some analyses.

**Results:** The REE and HSE concentrations of the external standards match literature data. The REE concentrations of Tissint glass, sulfide, and mixtures are summarized in Fig. 2.



**Figure 3.** Measured Pb isotopic compositions of sulfide and impact glass. Weighted average based on the 11 blue data points. All errors are 2SD. Green data from [5].

The measured Pb isotopic compositions of BHVO-2G, which had similar concentrations of Pb (1.7 ppm) as the sulfide and impact glass, yielded  $^{206}\text{Pb}/^{204}\text{Pb} = 18.92 \pm 0.47$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 15.77 \pm 0.48$ ,  $^{208}\text{Pb}/^{204}\text{Pb} = 38.87 \pm 1.10$ , and  $^{207}\text{Pb}/^{206}\text{Pb} = 0.8335 \pm 0.0092$  ( $n=10$ ; 2SD), identical to the accepted *GeoReM* values with uncertainty. Pb isotopic compositions of samples are summarized in Fig. 3; all data yielded a weighted average of  $^{206}\text{Pb}/^{204}\text{Pb} = 10.42 \pm 0.30$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 10.88 \pm 0.30$ ,  $^{208}\text{Pb}/^{204}\text{Pb} = 29.46 \pm 0.93$ ,  $^{207}\text{Pb}/^{206}\text{Pb} = 1.043 \pm 0.018$  ( $n=11$ ).



**Figure 4.** HSE data of Tissint sulfides (Red) compared to 1000 times the concentrations of Tissint bulk rock (black) [9] and the field of 'intermediate MgO' shergottites [10].

The HSE data are summarized in Fig. 4 and the concentration patterns are compared to Tissint whole rock and HSE concentrations of 'intermediate MgO' shergottite whole rocks [10].

**Discussion and conclusions:** The REE data of the impact melt glass (red, Fig. 2) are identical to the bulk rock and impact glass of [3] except that our sample contains a negative Eu anomaly. Pure sulfide minerals are very low in REE (should be below detection), therefore the REE in the sulfide analyses likely include phosphate and glass based on P and Si measured during laser analysis. Some of the sulfide rich material shows an enrichment in LREE, similar but less in magnitude to that observed by [2].

The Pb isotopes are nearly identical to the least radiogenic values measured by [5], which are thought to reflect the mantle source compositions. This includes the two LREE-enriched analyses (Fig. 2). These values represent some of the least radiogenic Pb for any shergottite with the exception of NWA 7635 [11]. The  $^{238}\text{U}/^{204}\text{Pb}$  ratio for the glass and sulfides average  $0.1 \pm 0.1$  (1SD), so no age correction is necessary. Given the very high sensitivity of these unradiogenic Pb isotopic compositions to contamination, the Pb in the sulfide and impact glass show no evidence for contamination of enriched material, terrestrial or martian.

The HSE data of the sulfides show a pattern consistent with HSE fractionation [9,10,12]. The range in HSE concentrations is not correlated to Si (dilution), so it appears that this is the natural variation of the grains. The patterns and HSE ratios are consistent with patterns of 'intermediate MgO' shergottites [10] ( $\text{MgO}$  14-17 Wt%; Tissint has 17.5 Wt%  $\text{MgO}$ ), while the Tissint whole rocks show some variability, but a less fractionated patterns [9]. It is likely that there is considerable variability in HSE distribution in Tissint [e.g., 12], but in the area studied here, the patterns are very consistent. Overall, there is nothing in the HSE data to suggest exogenous components in the sulfide.

In summary, in situ analyses of Tissint impact glass and associated sulfide material contains no evidence for exogenous materials. The host of labile radiogenic Pb and Sr [4-6] is unrelated to the impact melt glasses and instead are likely related to mineral film coatings, and at least for labile Sr, is likely related to nearby depleted shergottite rock units on Mars [6].

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