

INTERNAL WORKINGS OF SHOCK MELTING: VIEWS FROM THE FRIST X-RAY COMPUTED TOMOGRAPHY (XCT) OF THE TISSINT METEORITE. Yang Liu^{1,*}, ¹Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA. *yang.liu@jpl.nasa.gov.

Introduction: Impact melt pockets are rounded to irregular regions of shock-generated melts (now glass or partial glass, e.g., Fig. 1) that are common in shergottites (e.g., [1-4]). These melt pockets formed rapidly inside the meteorites by the impacts on Mars that excavated and launched these rocks from (sub)surface. The sources of the melts and formational mechanisms have not been agreed upon, although shock experiments and modeling demonstrated that impact melts form readily under moderate shock conditions in powder or vesicle-bearing rocks, easier than those in dense rocks under the same shock conditions (e.g., [5-8]).

The 3D textural relationship between impact melt pockets and the host rocks has never been examined in Martian meteorites. The Tissint meteorite contains large glassy melt pockets [9], making it an excellent specimen to study the texture of impact melt pockets *in situ*. Here I present the first internal view of impact melt pockets in the Tissint meteorite from non-destructive XCT scans, and discuss the implications of the observations on the formation of the impact melt pockets in the Tissint.

Method: I used a piece of the Tissint meteorite with a triangular prism shape (3 cm sides for the triangle base and ~1 cm thick), which is mostly covered by a fusion crust (Fig. 2). The XCT scans were collected using the Xradia microXCT at the UTCT facility in the University of Texas, Austin with a 90 kV voltage and a 10 W power.

Results: A total of 1691 slices was reconstructed from the raw sinograms, and each slice contains a voxel size of 17.15 μm (Fig. 3). A cut-off movie was generated from these reconstructed slices. The similar grayscale between melt (glass), pyroxene, and Mg-rich olivine present a challenge to reconstruct a 3D view of the interior. Manual processing of these images are being performed to highlight the impact melt pockets and associated fractures and mineral phases.

Several interesting features are readily visible from the cut-off movie of the Tissint piece (e.g., Fig. 3). First, this Tissint piece contains abundant (~34), rounded, impact melt pockets with a diameter of >140 μm . The largest pocket reaches ~5 mm in diameter. These melt pockets occur randomly in the sample, and are not preferentially located near the edge of the piece. Second, all impact melt pockets contain irregular shaped voids in the middle of the glass regions. In some cases, small rounded bubbles also occur near the edge of the pockets (Figs. 1 and 3). Third, all pockets

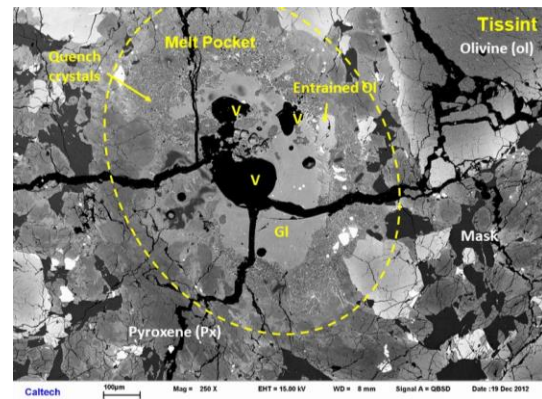


Figure 1. Example of an impact melt pocket in a polished section of the Tissint meteorite (sample used in [4, 9]), outlined by a dashed curve. From inside out, the impact pocket contains irregular voids (V), glass (Gl), and a crystal-rich zone at the contact with un-melted rock. Mask: maskelynite. Scale bar is 100 μm .



Figure 2. Different views of the Tissint piece used for the XCT scan. The arrow shows the direction of XCT slices.

are associated with clusters of fractures. Moreover, larger pockets are associated with ring fractures in the rock matrix, which follow the contour of the pockets. For the largest pocket, there are two layers of ring fractures. Additionally, minerals inside the ring fractures are stretched with a preferred orientation converging to the melt pockets. Fourth, there are no melt veins connecting different melt pockets.

Discussion: Our results provide insights on the formation of impact melt pockets and their volatile sources in shergottites.

The irregular voids in the interior of every pocket are likely residual pore space from incomplete collapse of pre-impact vesicles. They differ from spherical ones

that are typical from volatile outgassing. Moreover, profile analysis of volatiles near these voids was inconsistent with outgassing [4]. Residual vesicles are also reported in other shergottites in 2D observations (e.g., [1,2]). Thus, impact melt pockets of $>140\ \mu\text{m}$ diameters in shergottites represent locations of pre-impact vesicles. A further implication is that pre-impact rocks for the impact-melt-pocket-bearing shergottites were likely crystallized from volatile-rich melts.

It has been recognized that impact melt pockets are enriched in volatiles compared to the surrounding rocks (e.g., [4, 10-17]). Different volatile sources have been proposed, including 1) direct implantation of Martian atmosphere based on noble gas studies [11-13]; 2) infusion of Martian regolith based on excess sulfur abundances [15-17]; 3) subsurface water/ice [14], and 4) subsurface alteration products in pre-existing vesicles [4,10]. The impact melt pockets often contain much larger H/C ratios than expected from the Martian atmosphere, which suggests that Martian atmosphere is not directly implanted nor it is the sole source for the volatiles in melt pockets [4,10]. Subsurface water or ice is also not the sole source because the measured water contents are lower than the expected values if the source is solely water/ice [10]. Impact melt pockets contain high concentrations of S, similar or higher than observed H. Early model for the regolith infusion [15] proposed that the regolith was injected into the rock during impact. This model is not supported by 3D observations in this study. There are no connections among melt pockets through melt veins. A revision of the regolith infusion model proposed that regolith is attached to vesicles when the rocks reside on or near the surface [17]. However, how regolith gets

inside the isolated vesicles inside the rock cannot be simply explained by regolith attachment. As point out by Rao et al [17], regolith and subsurface alteration hypotheses are not be mutually exclusive. It is possible that either some melt pockets were derived from vesicles near the surface [17], or the subsurface fluid may have carried a small amount of regolith [17], or the subsurface fluid is salt rich via its interaction with surface soil or crustal rocks [4,10]. The important message here is that impact melt pockets in Martian meteorites provide the best, if not only, means to study the surface or subsurface fluids at different times and locations, before we can collect, analyze, or return subsurface samples from Mars.

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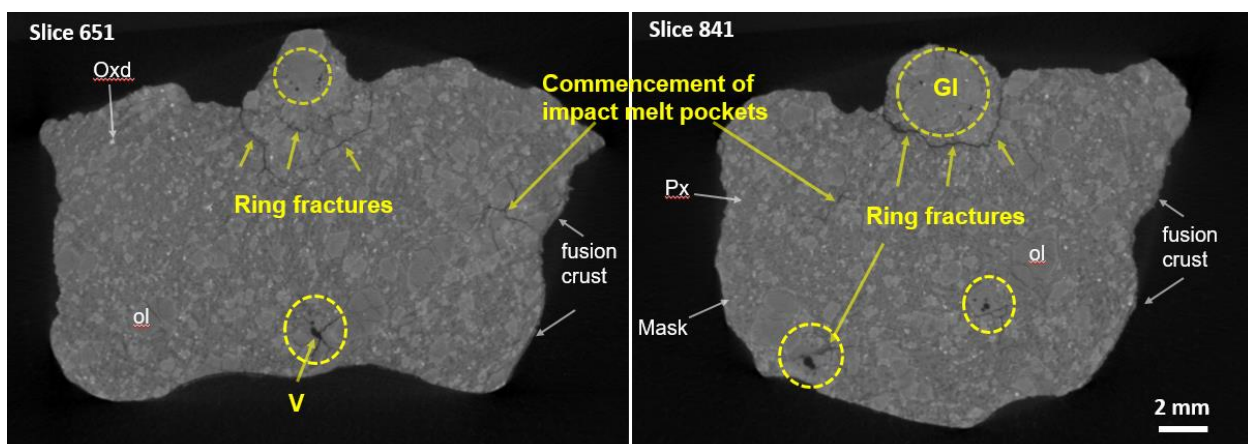


Figure 3. Two CT slices of the Tissint meteorite that are $\sim 3.3\ \text{mm}$ apart. The largest melt pocket in this piece is present at the top in both slices. Dashed circles outline the melt pockets in these slices. Oxd: oxides. [Cut-off video will be present at the conference].