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Detailed Raman Spectroscopic Study of the Tissint Meteorite: Extraordinary Occurrence of High Pressure Polymorphs in a Single Fresh Piece of Martian Shergottite

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A recent (July 2011) witnessed fall of a Martian Shergottite, Tissint, has generated great excitement for its pristine nature and its great scientific potential owing to its minimum terrestrial contamination. In recent work, using detailed petrography, electron microprobe method, micro-Raman Spectroscopy on serial sections, we investigated the presence of high-pressure (Hi-P) polymorphs occurring in impact-melt pockets throughout our 10 gm sample. Based upon the static and dynamic phase experimentation, we reconstructed the P-T-t conditions for the formation of these many polymorphs (Baziotis et al., 2012, Nature Comm.).

Tissint is an olivine-phyric shergottite, with large olivine grains ($<$1 mm) in a fine-grained groundmass of pyroxenes, plagioclase, oxides, and phosphates. The large olivine grains contain central regions ($\sim$0.6 mm) displaying a nearly uniform composition of Fo_{80}, with rims of 50-100 μm ranging from Fo_{77} to Fo_{35}. Micro-inclusions of Fe-Ti-Cr oxides are ubiquitous in olivine grains. Some groundmass pyroxenes ($<$0.3 mm) consist of orthopyroxene-rich cores ($Wo_{0-4}En_{71-69}$), but are mainly pigeonites ($Wo_{6-14}En_{67-50}$) with subcalic augites ($Wo_{13-26}En_{37-38}$). Augite with high CaO contents ($Wo_{34-40}En_{47-46}$) occurs in some interstitial regions. Plagioclase (An_{60-66}) has been converted to maskelynite. Chromite grains, with a characteristic cracked texture, typically contain gradational chromian ulvöspinel rims. Ilmenite was also observed as individual grains in groundmass, as well as thin exsolution lamellae in ulvöspinel. Widespread phosphate grains have a uniform merrillite composition and represent the major REE host phase.

The shock history of Tissint has been reconstructed based upon the presence and texture of Hi-P polymorphs in numerous impact melt pockets and melt veins. The analyzed Tissint sample has concentrated a unique assemblage of polymorphs, not seen in other Martian shergottites: (1) it contains near all previously described polymorphs in a single sample; and (2) it possesses the largest ringwoodite grain (75 $\times$ 140 μm) seen in meteorites. In particular, the Hi-P minerals observed with micro-Raman Spectroscopy in Tissint include ringwoodite, vitrified perovskite, akimotoite, majorite, lingunite, tuite, stishovite, maskelynite, and pyroxene glass. The P-T conditions of the shock were estimated from the presence of former-perovskite and the absence of lingunite decomposition products (calcium ferrite-type $NaAlSiO_4$+ stishovite); the P-T was $\sim$25 GPa and $\sim$2000 $^{\circ}$C, with localized shock reaching 40 GPa and $>>$2000 $^{\circ}$C. Furthermore, the large size of ringwoodite in Tissint likely reflects prolonged shock durations. After heating, rapid cooling was achieved in $\sim$50 ms for the center of the melt pocket and $\sim$20 ms for the rim of the pocket, rendering conditions capable of preserving the high-P minerals observed.