

Shock features in a Martian meteorite, Tissint

MIYAHARA, Masaaki^{1*}; OHTANI, Eiji²; EL GORESY, Ahmed³; GILLET, Philippe⁴

¹DEPSS, Graduate School of Science, Hiroshima Univ., ²Institute of Mineralogy, Petrology and Economic Geology, Graduate School of Science, Tohoku Uni., ³BGI, ⁴EPFL

Tissint is the fifth fall Martian meteorite collected in Morocco on 2011 [1]. The nomination of a fall Martian meteorite is since 1962. Tissint will bring new clues for Martian evolution because it is less contaminated with terrestrial materials. Tissint is a member of shergottite. Many shergottites experienced a heavy shock event on Mars [e.g., Ref. 2]. We expected that Tissint should be also heavily shocked. A high-pressure polymorph is one of clear evidences for such a dynamic event. Accordingly, we described shock features, especially a high-pressure polymorph by FEG-SEM, EMPA, Raman spectroscopy and FIB-TEM techniques to clarify shock history recorded in Tissint.

We prepared several petrographic thin sections of Tissint for this study. EMPA analysis show that Tissint studied here consists mainly of olivine (Fa₁₈₋₆₆), pigeonite or augite (En₄₃₋₆₂Fs₂₃₋₃₇Wo₁₀₋₃₄) and labradoritic feldspar (An₆₂₋₆₆Ab₃₄₋₃₇Or₀₋₁). There are many melt-pockets, which is suggestive of a heavy shock event. FEG-SEM and FIB-TEM observations show that olivine grains entrained in the melt-pockets dissociated into silicate-perovskite (now almost amorphous or poorly-crystallized) and magnesiowustite, which is found in a Martian meteorite DaG 735 for the first time [3]. Silicate-perovskite and magnesiowustite show equigranular texture and less than ~100 nm in dimension. We also identified ringwoodite lamella in some olivine grains adjacent to the melt-pockets. TEM images show that ringwoodite has a dimension of less than ~500 nm. Raman spectroscopy analysis indicates that most feldspar now transforms into maskelynite. Jadeite-like crystals appear in some feldspar grain adjacent to the melt-pockets.

Considering the dissociation reaction of olivine into silicate-perovskite and magnesiowustite, shock pressure condition recorded in Tissint is beyond ~23 GPa based on phase diagram deduced from static synthetic experiments [4]. Phase transformation from olivine to ringwoodite also occurs besides the olivine dissociation reaction. Phase transformation from olivine to ringwoodite occurs instead of olivine dissociation reaction with decreasing temperature but under same pressure condition [5], which is due to thermal gradient in the olivine grains adjacent to the melt-pockets although pressure condition should be almost homogeneous. The nucleation and grain growth of a high-pressure polymorph is kinetically controlled. Baziotis et al. (2013)[6] propose that Tissint experienced the largest impact event among known Martian meteorites because ringwoodite appear to be a huge single crystal based on their SEM observations. However, our TEM images clearly depict that ringwoodite is a fine-grained grain assemblage, suggesting that it is unlikely that Tissint experienced the largest impact event.

References

- [1] Chennaoui Aoudjehane H. et al. Tissint Martian Meteorite: A fresh look at the interior, surface, and atmosphere of Mars. *Science* 338, 785-788 (2012).
- [2] El Goresy A. et al. Shock-induced deformation of Shergottites: Shock-pressures and perturbations of magmatic ages on Mars. *Geochim.Cosmochim.Acta* 101, 233-262 (2013).
- [3] Miyahara M. et al. Natural dissociation of olivine to (Mg,Fe)SiO₃ perovskite and magnesiowustite in a shocked Martian meteorite. *Proc.Nat.Acad.Sci.U.S.A.* 108, 5999-6003 (2011).
- [4] Presnall D.C. Phase diagrams of Earth-Forming Minerals. 248-268, in *Mineral Physics & Crystallography, A Handbook of Physical Constants*, T. J. Ahrens ed., AGU, Washington D. C (1995).
- [5] Akaogi M. et al. Low-temperature heat capacities, entropies and enthalpies of Mg₂SiO₄ polymorphs, and a?b?c and post-spinel phase relations at high pressure. *Phys.Chem.Minerals* 34, 169-183 (2007).
- [6] Baziotis I.P. et al. The Tissint Martian meteorite as evidence for the largest impact excavation. *Nat.Commun.*, doi: 10.1038/ncomms2414 (2013).

Keywords: Tissint, Martian meteorite, Shock, High-pressure polymorph