Complicated shock metamorphism deducing from shocked olivine in Tissint. M. Miyahara[1], E. Ohtani[2], S. Ozawa[2], A. El Goresy[3], Ph. Gillet[4], [1]Hiroshima Univ., Japan, [2]Tohoku Univ., Japan, [3]Bayreuth Univ., Germany, [4]Ecole Polytechnique Fédérale de Lausanne, Switzerland.

Introduction:

Most Martian meteorites were heavily shocked on the Mars or when they were launched from the Mars. Accordingly, a shock feature in a Martian meteorite is clue for interpreting impact history on the Mars and its delivery process to the Earth. One of important and intriguing shock features in a Martian meteorite is a high-pressure polymorph. Varied high-pressure polymorphs have been found from many Martian meteorites. Several previous studies estimated the magnitude of impact events using a high-pressure polymorph inventory, kinetics or diffusion coefficients [e.g., 1-3]. A high-pressure polymorph in a shocked Martian meteorite itself also attracts colleagues who are working on planetary interiors because these high-pressure polymorphs are expected to exist in the deep planet interiors.

Tissint is the fifth fall Martian meteorite collected in Morocco on 2011 [4]. The nomination of a fall Martian meteorite is since 1962. This is a very unique opportunity to investigate a shock feature, especially a high-pressure polymorph because Tissint is less contaminated with a terrestrial material. In this study, we especially focused on the high-pressure polymorph of olivine in Tissint to clarify the impact magnitude and its formation process.

Experimental methods:

We prepared several petrographic thin sections of Tissint for this study. Subsequently, we described its shock feature, especially the high-pressure polymorph of the thin sections using a FEG-SEM, EMPA, laser micro-Raman spectroscopy, FIB-TEM and STEM-EDS techniques.

Results and discussion:

Tissint is a member of shergottite. EMPA analyses indicate that Tissint studied here consists mainly of olivine (Fa_{18-66}), pigeonite or augite ($Fs_{23-37}En_{43-62}Wo_{10-34}$) and labradoritic feldspar ($An_{62-66}Ab_{34-37}Or_{0-1}$). We found many melt-pockets in the thin sections. Raman spectroscopy analyses indicate that most feldspar now transform into maskelynite. These features suggest a heavy impact event.

Olivine grains among the melt-pockets occur as a phenocryst and are embed in a groundmass consisting mainly of pyroxene and feldspar. Lamellar texture appears in olivine grains adjacent to the melt-pockets. Raman spectroscopy analyses indicate that the lamellae are ringwoodite (γ-Mg_2SiO_4). Some lamellae are ahrensite (γ-Fe_2SiO_4) [5] based on their chemical compositions. Not only lamellar ahrensite but also granular ahrensite occur. With decreasing a distance from the melt-pocket, granular ahrensite becomes dominant instead of lamellar ahrensite. This distribution feature is also observed in olivine grain adjacent to the shock-melt vein of ordinary chondrite [6]. The two different phase transformation textures originate from two different phase transformation mechanisms. Accordingly, two different phase transformation mechanisms from olivine to ringwoodite and/or ahrensite work simultaneously, which is probably due to a different thermal history depending on a distance from the melt-pocket. The granular ahrensite is up to about one micro meter in size based on TEM observations, which is coarser than ringwoodite (< about 300 nm) in ordinary chondrite [6]. The differences on size between ahrensite in Tissint and ringwoodite in ordinary chondrite may come from the different magnitude of impact or different kinetics between ringwoodite and ahrensite. It is speculated that Tissint experienced the largest impact event among known Martian meteorites because ringwoodite appear to be a huge single crystal based on SEM observations [7]. However, our TEM observations prove that ringwoodite and ahrensite in Tissint are polycrystalline assemblages. Walton et al. (2014) [8] also observed ringwoodite and ahrensite in Tissint with a TEM and proposed that there is no clear evidence for such a huge impact event. Our TEM observations support their conclusion.

Some olivine grains entrained in the melt-pockets show a dissociation texture. The dissociation texture also occurs next to the granular ahrensite assemblages. Dissociated olivine into silicate-perovskite (now almost amorphous or poorly-crystallized) + magnesiowüstite was found in a Martian meteorite DaG 735 [1]. Equigranular and lamellar textures were observed in the dissociated olivine of DaG 735. On the other hand, the olivine dissociation texture in Tissint is different from those of DaG 735, and does not coincide with a dissociation texture recovered from a synthetic high-pressure experiment. Three different phases occur in the dissociated olivine grains. The first phase is magnesiowüstite based on electron diffraction patterns and STEM-EDS analyses. The second phase is a poorly crystallized material with a $(Mg,Fe)SiO_3$ composition. Although the poorly crystallized material with a $(Mg,Fe)SiO_3$ composition may vitrified silicate-perovskite (now called bridgmanite)[9], now we cannot find clear evidence for it. The magnesiowüstite and poorly crystallized material with a $(Mg,Fe)SiO_3$ composition have a granular texture. Lamellar texture was not observed in Tissint. The third phase is residual olivine or isolated ahrensite, indicating that the dissociation reaction initiates not only from olivine but also from ahrensite.

Phase transformations from olivine to ringwoodite or ahrensite and from olivine or ahrensite to magnesiowüstite + a poorly crystallized material with a $(Mg,Fe)SiO_3$ composition simultaneously occurs in Tissint, which would be due to differences on thermal history and the chemical composition of original olivine.

Summary:

We identified ringwoodite, ahrensite and dissociated olivine in and around the melt-pockets of Tissint. The ringwoodite and ahrensite are fine-grained polycrystalline assemblages, which does not support the largest impact event hypothesis. High-pressure polymorphs of olivine and their formation processes indicate that the shock metamorphism phenomenon in Tissint is complex compared with other Martian meteorites.

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