Mineralogy and petrology of Y002712 shergottite. T. Mikouchi, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.

Introduction:

Japanese Antarctic Research Expedition (JARE) has carried out meteorite search in many seasons and recovered more than 17,000 meteorites that are now stored and curated at NIPR. The NIPR meteorite collection includes several shergottites and nakhlites, all found in Yamato Mountains. These rare planetary meteorites have provided crucial information about the igneous evolution and aqueous alteration of the planet Mars [e.g., 1,2]. Recently, finding of a new 72.93 g shergottite Y002712 (with a paired sample, Y002192: 32.07 g) was announced by [3] and here I report its mineralogy and petrology to compare it with other shergottites in order to better understand variation of Martian igneous activity and shock history found for basaltic shergottites.

Sample and Methods:

A thin section of Y002712 (*ca*. 15 x 7 mm) was kindly provided by NIPR (Y002712,51-2). The section was first carefully observed by optical microscope and then FEG-SEM equipped with EDS and EBSD detectors (Hitachi S-4500) was used to observe minute textures and identify species of crystalline phases. Mineral compositions were analyzed with JEOL JXA-8900L electron microprobe by using well-characterized natural and synthetic standards.

Results:

Petrography

Y002712 shows a medium-grained equigranular texture with evidence of strong shock metamorphism (Fig. 1). Major minerals are 70% clinopyroxenes (43% augite and 27% pigeonite) and 29% plagioclase (completely transformed to maskelynite) with accessory Ca phosphates, ulvöspinel, ilmenite, Fe sulfide and Si-K-rich glass. Most clinopyroxene grains are subrounded in shape usually ~0.1-0.5 mm in diameter. Augite and pigeonite are present as individual grains, but often complexly associated with each other (Fig. 2). Polysynthetic twinning of pyroxene is common, which was probably caused by shock. Both clinopyroxenes show a fine exsolution feature with submicron size lamellae. Maskelynite is interstitial to pyroxene and shows typical smooth appearance. The size range (~0.1-1 mm) is greater than that of pyroxene. Ulvöspinel and ilmenite co-exist, suggesting an exsolution relationship.

Mineral chemistry

Clinopyroxenes show chemical zoning in Fe-Mg, but Ca abundance is generally constant in each grain (Figs. 2 and 3). The compositional ranges of augite and pigeonite are $En_{45}Wo_{35}$-$En_{35}Wo_{33}$ and $En_{58}Wo_{11}$-$En_{40}Wo_{13}$, respectively. Al_2O_3 and TiO_2 in augite are 1.0-1.5 wt% and 0.2-0.7 wt% whereas pigeonite has lower Al_2O_3 (0.6-0.8 wt%) and TiO_2 (0.1-0.6 wt%). Most maskelynites are homogeneous, but some show asymmetric chemical zoning ($An_{59}Or_1$ to $An_{41}Or_3$). It contains 0.4-0.7 wt% FeO. Ulvöspinel has 69 wt% FeO, 2 wt% Al_2O_3, 22 wt% TiO_2 and 1.5 wt% Cr_2O_3. Ilmenite contains ~1.5 wt% MgO. The equilibration temperature and oxygen fugacity using these Fe-Ti oxides compositions give 780 ^{o}C and logfO_2=IW+1.5 (Total P = 1 atm) [4].

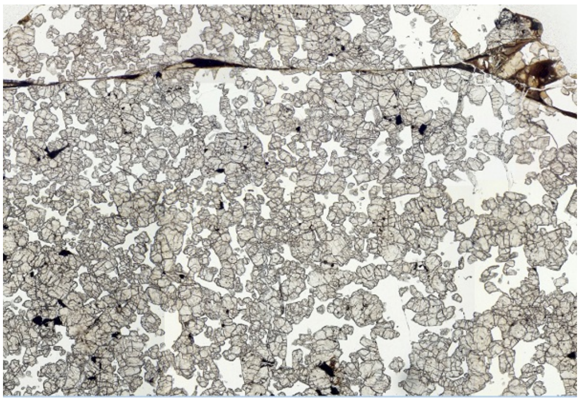

Fig. 1. Optical photomicrograph of Y002712 (plane-polarized light), showing the presence of abundant small pyroxene with interstitial maskelynite. The width of the image is *ca*. 4.5 mm.

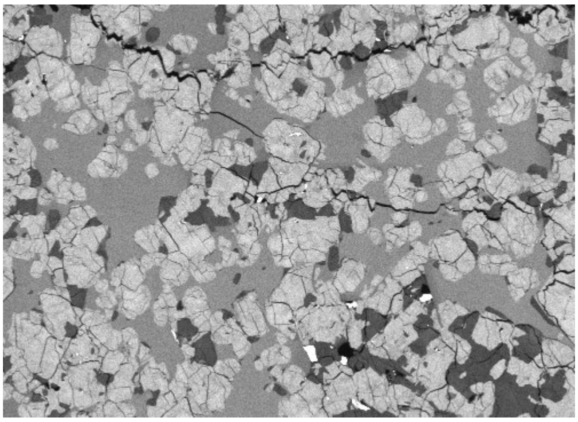

Fig. 2. Ca distribution map of Y007212. Abundant bright phases are augite. Medium-grey is maskelynite. Dark grey is pigeonite. The width of the image is 1.5 mm.

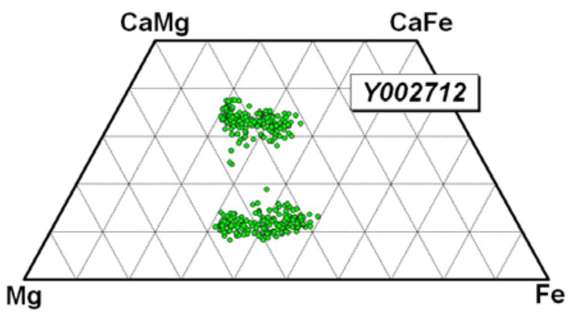

Fig. 3. Pyroxene quadrilateral of Y002712.

Shock melt vein

A black shock melt vein (~0.2 mm wide) is cutting through the thin section (Fig. 1). It connects to shock melt pockets with brown color. Most areas of the vein are composed of ~1-2 μm polycrystalline aggregates that are similar to high-pressure polymorphs found in shocked meteorites [e.g., 5] (Fig. 4). There are no vesicles around these polycrystalline areas. SEM-EBSD analysis of these tiny phases gives sharp Kikuchi bands that match with the calculated patterns using a majorite structure.

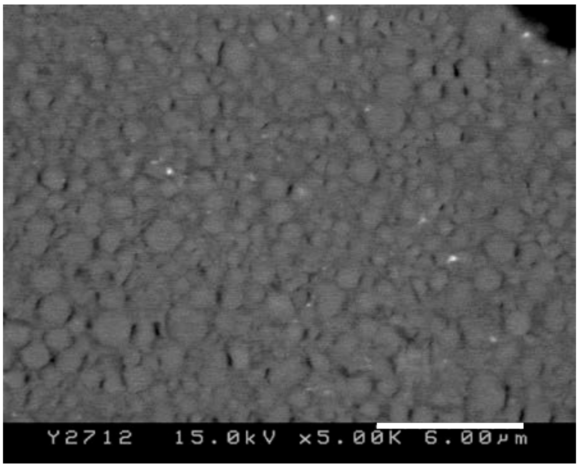

Fig. 4. Back-scattered electron image of a shock melt vein in Y002712, showing the presence of 1-2 μm aggregates of majorite. Scale bar is 6 μm.

Discussion and Conclusion:

Y002712 (and possibly Y002192) is a new shergottite different from any other known Japanese Antarctic Martian meteorites, ruling out pairing with others. Its texture mainly composed of pyroxene and maskelynite (without olivine) leads its classification to a “basaltic shergottite” or “diabasic shergottite” such as Zagami [6], which has not been found in the Japanese Antarctic meteorite collection. The pyroxene grain sizes of Y002712 are smaller than those in Zagami and other basltic shergottites. Also, subrounded shape of pyroxene in Y002712 is slightly different from elongated pyroxenes in these basaltic shergottites (though 3-D observation is necessary). The texture is rather similar to highly-equilibrated eucrite(-like) meteorites Ibitira and EET 90020 [7,8]. However, the presence of chemical zoning and a near submicron-scale exsolution texture indicate that its cooling history was rather rapid and similar to other basaltic shergottites.

Like most of basaltic shergottites, high abundance of pyroxene relative to plagioclase suggests that it is a pyroxene cumulate rock. High proportion of augite relative to pigeonite is unusual in basaltic shergottites and selective accumulation of augite in a magma chamber is considered.

It is of great interest which geochemical group this new shergottite belongs to. Although this study deals with only mineralogical work and trace element chemistry of Y002712 is not performed, one can judge geochemical grouping by using K_2O and Na_2O contents of plagioclase and the bulk Al_2O_3 composition that are correlated with the bulk La/Yb ratio [9]. For the bulk Al content, I can employ an average Al content of the fusion crust (4.7 wt% Al_2O_3). However, K/Na ratio of maskelynite in Y002712 shows a large variation. Ca-rich maskelynite has a low estimated La/Yb, corresponding to a depleted group while Na-rich maskelynite is in the range of an enriched group. It is further required whether such a large variation is found from maskelynite in other basaltic shergottites, but this may suggest increase of fO_2 during crystallization as found in some shergottites [10]. The estimated $\log fO_2$ of IW+1.5 is fairly low and similar to those of depleted shergottites. Since Fe-Ti oxides used for oxybarometer are late-crystallization phases, they record redox information of the late stage of crystallization, which is not consistent with the geochemical grouping estimated from the maskelynite composition. Bulk REE analysis is required to confirm geochemical grouping of Y002712 and its relationship to redox states.

The presence of majorite is rare in Martian meteorites because of their unique post-shock history distinct from shocked chondrites [11]. Y002712 must have experienced a fast-quenching post-shock P-T history similar to Tissint olivine-phyric shergottite which contains several high-pressure polymorphs [12]. We interpret the absence of high-pressure polymorphs in most shergottites due to long thermal annealing after strong shock [9]. More detailed analysis (e.g., FIB-TEM) is required to see the spatial distribution of majorite and the presence of other high-pressure phases.

References:

[1] Mikouchi T. et al. (2004) *Antarct. Meteorite Res., 17*, 13-34. [2] Hicks L. J. et al. (2014) *GCA, 136*, 194-210. [3] Yamaguchi A. et al. (2015) *Meteorite Newsletter, 24*, 1-20. [4] Sauerzapf U. et al. (2008) *J. of Petrol.*, 49, 1161-1185. [5] Xie Z. et al. (2006) *GCA, 70*, 504-515. [6] McCoy T. J. et al. (1992) *GCA, 56*, 3571-3582. [7] Yamaguchi A. et al. (2001) *GCA, 65*, 3577–3599. [8] Mittlefehldt D. W. (2003) *Meteorit. & Planet. Sci.*, 40, 665–677. [9] Karner J. M. et al. (2009) *LPS XL*, Abstract #1327. [10] Peslier A. H. et al. (2010) *GCA, 74*, 4543-4576. [11] Takenouchi A. et al. (2015) *LPS XLVI*, Abstract #1650. [12] Walton E. L. et al. (2014) *GCA, 140*, 334-348.