COMPLEX PETROGENESIS OF DIOGENITES ON VESTA REVEALED BY THE TROILITE-ORTHOPYROXENE INTERGROWTH IN HED METEORITES. A. C. Zhang[1], Y. F. Bu[1], R. L. Pang[1], N. Sakamoto[2], H. Yurimoto[2,3], L. H. Chen[1], and R. C. Wang[1], [1]School of Earth Sciences and Engineering, Nanjing University, China (aczhang@nju.edu.cn); [2]Isotope Imaging Laboratory, Creative Research Institution Sousei, Hokkaido University, Japan; [3]Department of Natural History Sciences, Hokkaido University, Japan.

Introduction: Diogenites are a group of achondrites that consist mainly of orthopyroxene and olivine with various proportions. It was thought that diogenites are cumulates directly crystallized from the magma ocean of Vesta [1–3]. However, a few recent investigations argued that some of the diogenites could have originated from melting of the magma-ocean cumulates [4–6]. Based on the magma ocean model for Vesta, olivine-rich diogenites are expected to be present at the two south-pole basins on Vesta where the lower crust or upper mantle of Vesta should have been exposed to the surface. However, previous investigations found no olivine-rich diogenites there based on the Dawn VIR mapping spectrometer, leading to a conclusion that the magma ocean model might not be straightforwardly applicable to Vesta [7].

Troilite-orthopyroxene intergrowth has been described as rare fragments in a few howardite and diogenite meteorites [8–10]. It was proposed having formed by reaction between olivine and fluid [8]. However, two recent investigations suggested that the troilite-orthopyroxene intergrowth probably have formed via shock-induced localized melting and rapid crystallization of diogenite with the presence of troilite [9-10]. Recently, we observed abundant fragments of the troilite-orthopyroxene intergrowth in a brecciated diogenite NWA 7183 and some of them are included in diogenitic orthopyroxene. Here, we report the petrography and mineral chemistry of the troilite-orthopyroxene intergrowth and discuss its origin and implications for the complex petrogenesis of diogenites on Vesta.

Results: The majority of troilite-orthopyroxene intergrowth fragments in NWA 7183 are composed of troilite and orthopyroxene (Opx-I) with minor, fine-grained olivine and chromite included in orthopyroxene (Fig. 1). In other fragments, olivine occurs as coarse-grained, irregular grains and two groups of troilite-orthopyroxene intergrowth are observed (Fig. 2). In one group, the orthopyroxene is similar in size to Opx-I in the intergrowth without coarse-grained olivine. In the other group, the orthopyroxene (Opx-II) and associated troilite are more fine-grained in size than those in the first group. Two fragments of the intergrowth are included in diogenitic orthopyroxene, with curved boundaries (Fig. 2).

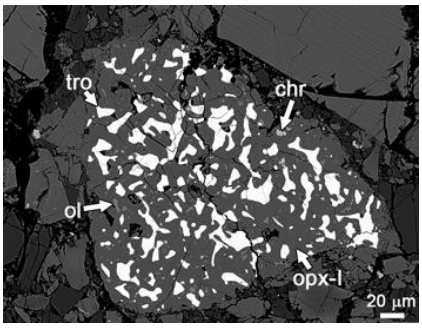

Fig. 1. A fragment of troilite-orthopyroxene intergrowth with fine-grained inclusions of olivine and chromite.

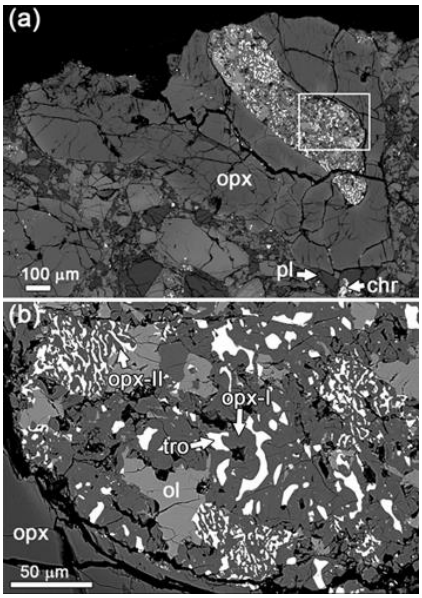

Fig. 2. A fragment of troilite-orthopyroxene intergrowth included in diogenitic orthopyroxene. The fragment contains two groups of intergrowth and irregular, coarse-grained olivine.

The majority of diogenitic orthopyroxene ($En_{68.8–75.9}Fs_{22.1–28.4}Wo_{2.1–4.1}$) in NWA 7183 is chemically similar to typical diogenitic orthopyroxene in the literature [11]. However, a few grains of diogenite orthopyroxene have Fe-rich rims ($En_{55.7–64.0}Fs_{33.5–42.5}Wo_{1.7–4.1}$). The contents of minor elements (Ti, Al, and Cr) in the diogenitic orthopyroxene are also comparable to those reported in the literature (Fig. 3). The Opx-I in troilite-orthopyroxene intergrowth has a composition of $En_{54.9–62.6}Fs_{37.0–43.9}Wo_{0.9–1.5}$. Their Al, Cr, and Ti concentrations are much lower than those in diogenitic orthopyroxene in NWA 7183 (Fig. 3). The

Opx-II in the intergrowth contains even lower Fs and Wo components ($En_{61.0–64.3}Fs_{35.1–38.4}Wo_{0.5–0.7}$). Meanwhile, the concentrations of Al, Cr, and Ti in Opx-II are close to or below their detection limits (Fig. 3).

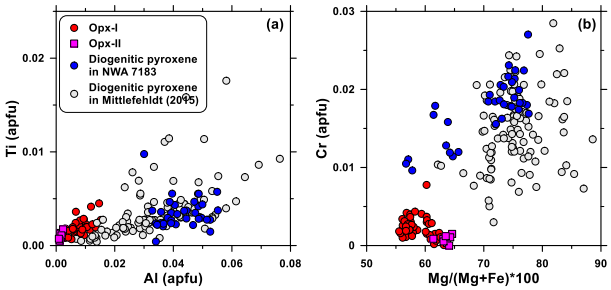

Fig. 3. Chemical compositions of Ti, Al, and Cr in low-Ca pyroxene from diogenitic clasts and the troilite-orthopyroxene intergrowth.

Rounded olivine grains included in two diogenitic orthopyroxene grains have different chemical compositions (Mg#=54.0–69.9). Their contents of Cr_2O_3, Al_2O_3 and TiO_2 are very low. All the olivine grains in troilite-orthopyroxene intergrowth are Fe-rich (Mg#=39.4–53.3). The Cr_2O_3, Al_2O_3 and TiO_2 contents of olivine in the troilite-orthopyroxene intergrowths also very low. The chromite in troilite-orthopyroxene intergrowths is Al-rich with low ulvöspinel components ($Chr_{64.7–72.7}Spl_{21.2–25.0}Usp_{3.3–6.2}$), generally similar to that from diogenitic clasts [11]. However, they are Fe-richer (Mg#=5.1–6.6) than diogenitic chromite (Mg#=7.7–31.7) in the literature [11].

Discussion: (1) ***Post-crystallization Fe-Mg interdiffusion.*** Ref. 11 compiled the chemical features of minerals in HED meteorites. Compared with those in diogenites, some of the orthopyroxene, olivine, and chromite in NWA 7183 are Fe-enriched. Troilite-orthopyroxene intergrowth has also been described in the literature [8–10]. The silicate minerals in troilite-orthopyroxene intergrowth, including those in this study, show various Mg# values. Because the olivine, chromite, and diogenitic orthopyroxene in NWA 7183 have minor element compositions identical to those compiled by Ref. 11, we suggest that their Fe-enrichment to various extents was due to post-crystallization Fe-Mg interdiffusion on the parent body.

(2) ***Origin of the troilite-orthopyroxene intergrowth in HED meteorites***. Two groups of troilite-orthopyroxene intergrowth were observed in this study. They have various grain sizes and compositions of Ca, Cr, Al, and Ti, indicating that they could have formed through different processes. Based on the textural relationship between the troilite-orthopyroxene intergrowth and olivine and the depletion of Cr, Al, and Ti in Opx-I and Opx-II to various extents, we suggest that the two types of orthopyroxene in troilite-orthopyroxene intergrowth formed through replacing olivine by S-rich melts and vapors, respectively. This process is similar to those proposed by Refs. 12–13. The precursor lithology of the troilite-orthopyroxene intergrowth could be olivine-rich diogenites.

(3) ***Complex petrogenesis of diogenites***. The inclusion of troilite-orthopyroxene intergrowth in a few diogenitic clasts indicates that formation of the host diogenitic clasts should postdate the formation of troilite-orthopyroxene intergrowth, no matter whether the troilite-orthopyroxene intergrowth was trapped as a melt or a solid. As discussed above, the troilite-orthopyroxene intergrowth is the product of replacement of olivine-rich lithology by S-rich melts and vapors, it is unlikely that the host diogenites are cumulate directly crystallized from the magma ocean on Vesta. Instead, they probably originated from melting of the magma-ocean cumulates as suggested by Refs. 4–6.

(4) ***Implications for the absence of olivine at Vestan south-pole basins***. Based on the current study, the olivine grains in olivine-rich diogenites have been metasomatized into orthopyroxene through reactions with both S-rich melts and vapors, probably due to hypervelocity impact events. If this process occurred widely at the south-pole basins of Vesta, some of the olivine grains might have been metasomatized into orthopyroxene. This would lead to low olivine/orthopyroxene ratios at the surface and make olivine difficult to be detected with the VIS mapping spectrometer. If this is the case, olivine-rich rocks could have been exposed to the surface when the south-pole basins formed and then were metasomatized by late S-rich melts or vapors during the long-term (1–2 Gyr) exposure history of south-pole basins [14]. In summary, sulfide metasomatism can account for the absence of olivine at the south-pole basins of Vesta and the magma-ocean model is still applicable to the early differentiation of Vesta.

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