Petrology and Olivine Fabric of Lodranite NWA 2235.

Masahiro Yasutake[1], Akira Yamaguchi[2,3].
[1]Grad. Sch. of Science, Kyoto University, [2]SOKENDAI (The Graduate University for Advanced Studies), [3]National Institute of Polar Research, Japan.

Introduction

Acapulcoite-lodranite clan (AL-clan) is a suite of meteorites classified into primitive achondrites. AL-clan shows various differentiation stages, and it consists mainly of two sub-types, acapulcoites and lodranites. Acapulcoites have fine-grained texture, chondritic modal abundance, and chondritic bulk chemical compositions [1,2]. It is widely accepted that acapulcoites suffered low degree of partial melting ~1-4 vol%. Lodranites have coarse-grained texture, modal abundance poor in troilite, plagioclase, and/or augite, and differentiated bulk chemical compositions [1,2]. Most lodranites are thought to be residual rocks after limited partial melting <15 vol% [1]. On the other hand, recent studies of unusual lodranites and numerical modeling imply that acapulcoite-lodranite parent body (ALPB) suffered a large degree of melting [3,4,5]. If it is the case, the formation of the magma chamber is the possible scenario, and some lodranites could preserve the clues in olivine fabric such as the case of ureilites [6].

NWA 2235 is a lodranite with oxygen isotope composition ($\delta^{17}O$ = 1.62, $\delta^{18}O$ = 4.94) and mineral chemical compositions similar to other lodranites [7]. However, NWA 2235 has unusual features that are the presence of large augite, a poikilitic texture, and the presence of glass inclusions, and LREE enriched bulk chemical composition [7,8]. These features raise a hypothesis that NWA 2235 suffered different igneous processes to other common lodranites. We revisited the petrology and investigated olivine fabric of NWA 2235 to better understand the igneous history of ALPB.

Sample and Methods

One polished thin section of NWA 2235 was investigated at National Institute of Polar Research, Japan. The texture of the section was observed by an optical microscope and a FE-SEM (JEOL JSM7100F) equipped with EDS (Oxford instruments AZtec Energy). Compositions of minerals were determined by using an EPMA (JEOL JXA8200). Modal abundance was estimated from X-ray elemental maps obtained by SEM-EDS. The orientation of olivine crystals was investigated by using an EBSD detector (Oxford instruments AZtec HKL). Obtained orientation data was analyzed by Oxford instruments Channel 5 software. We set the space group of olivine as *Pbnm*.

Results

NWA 2235 has a coarse-grained texture (~300 μm) consisting mainly of olivine (54 vol%, Fo88), low-Ca pyroxene (27 vol%, Wo2.3En85), augite (6.8 vol%, Wo45En50), kamacite (8.1 vol%), and minor chromite (2.5 vol%) and troilite (1.0 vol%). Plagioclase is absent in the section we studied. Low-Ca pyroxene and/or augite compose poikilitic textures and enclose olivine, kamacite, chromite crystals (Fig. 1a, b). Two olivine crystals contain glass inclusions. Lineation texture of olivine crystal is obvious in the section (Fig. 1c). Olivine LPO has a concentration of [010] with point maxima (maximum multiples of uniform distribution (MUD) = 3.2) (Fig. 1d). The direction of [010] point maxima is nearly normal to the lineation texture. Olivine [100] and [001] of NWA 2235 forms a girdle on the plane normal to the [010] point maxima. The pattern of [100] is unclear compared to other axes.

The formation temperature was estimated by pyroxene thermometer by [9,10]. The equilibrium temperature was estimated to be ~960 °C from the compositions of low-Ca pyroxene and ~1000 °C from the compositions of augite. The equilibrium temperature of olivine and chromite was estimated to be ~810 °C [11].

Discussion

The coarse-grained texture, chemical compositions of olivine and low-Ca pyroxene, and modal abundance except for the abundance of augite resemble those of other lodranites (Fo85-97, Wo2.5-3.9En82-95) [1]. These results favor that NWA 2235 is a lodranite. Oxygen isotope composition of NWA 2235 [7] supports this hypothesis.

On the other hand, the development of olivine fabric, the poikilitic texture, the presence of inclusions are not common features among lodranites [1,12]. The olivine fabric of NWA 2235 is similar to the other achondrites such as ureilites or terrestrial igneous rocks [e.g. 6,13,14]. This type of fabric is thought to be the result of the accumulation of olivine crystals with flattened (010) plane in the magma chamber without strong laminar flow [6,14]. Therefore, NWA 2235 might be suffered accumulation process. If this is the case, we can explain other unusual features. The poikilitic texture could be interpreted as the result that intercumulus melts rich in low-Ca pyroxene and augite components were trapped during accumulation of olivine crystals. The glass inclusions in olivine might be trapped during the crystal growth of olivine. The accumulation processes could account for the LREE enriched bulk chemical composition obtained by [8]. Although the thermal history is hard to estimate precisely, the absence of pigeonite and equilibrium temperatures indicate that NWA 2235 did not suffer rapid cooling at high temperature.

We propose that NWA 2235 is a cumulate rock. AL-clan includes cumulate rocks in addition to residual rocks as the case of ureilites [15]. We also propose that the magma chamber in the ALPB was without strong laminar flow. On the other hand, the size of the magma chamber and location in the ALPB were not identified.

References

[1] Keil K. and McCoy T. (2018) Chem. Erde, 78, 153-203. [2] Patzer A. et al. (2002) MAPS, 39, 61-85. [3] Folco L. et al. (2006) MAPS, 41, 1183-1198 [4] Yasutake M. and Yamaguchi A. (2017) Polar Sci., 14, 49-59. [5] Neumann W. et al. (2018) Icarus, 311, 146-169. [6] Berkley J. And Keil. K. (1981) Am. Mineral., 66, 1233-1236. [7] Yamaguchi A. et al. (2006) abst. 69th Met. Soc., A192. [8] Hidaka Y. et al. (2012) abst. 43th LPSC, #1785. [9] Lindsley D. H. (1983) Am. Mineral., 68, 477-493. [10] Nakamuta. Y. et al. (2017) MAPS, 52, 511-521. [11] Wlotzka F. (2004) MAPS, 40, 1973-1702. [12] Yasutake M. and Yamaguchi A. (2015) abst. 38th symp. on Antarct. Meteorites. [13] Hasegawa H. et al. (2017) abst. 47th LPSC, #2131. [14] Benn K. and Allard B. (1989) J. Petrol., 30, 925-946. [15] Goodrich C. A. et al. (2004) Chem. Erde, 64, 283-327.

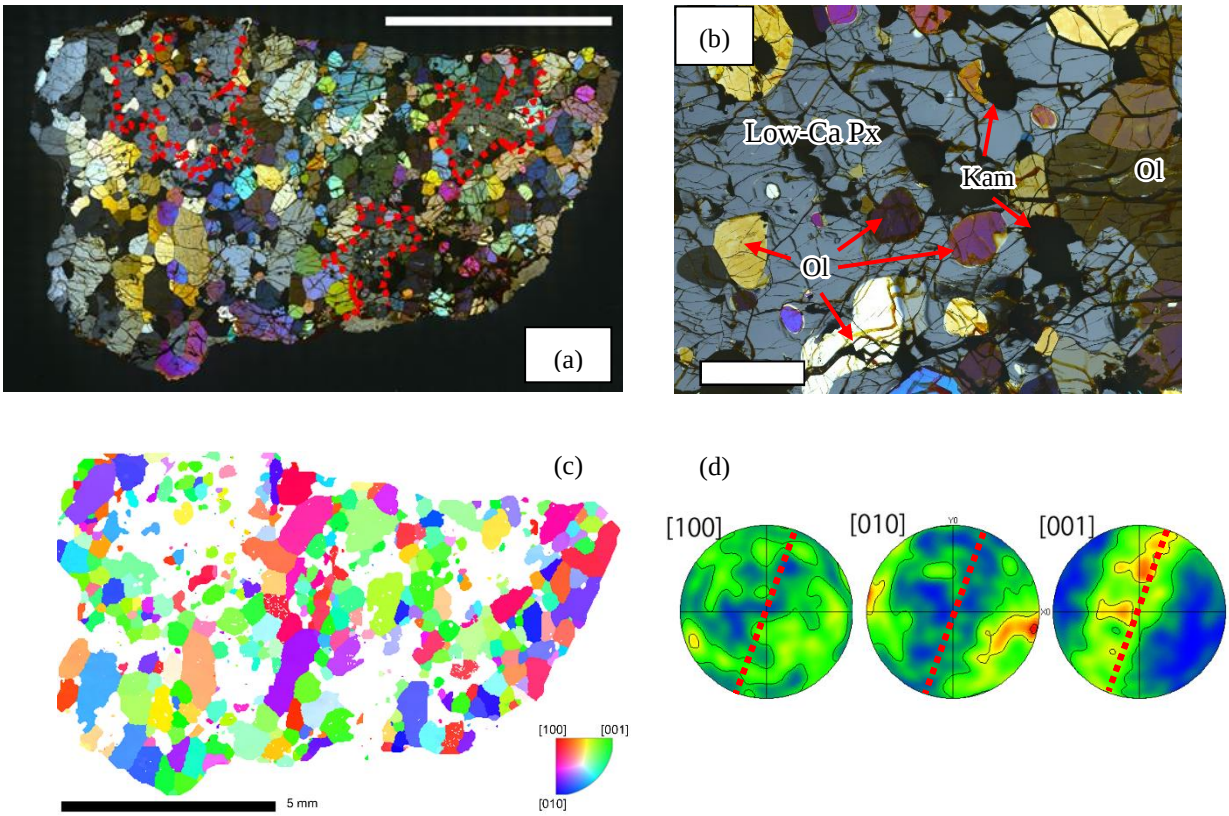

Fig.1. (a) Photomicrograph of whole section of NWA 2235 under crossed polarized light. Poikilitic textures are shown in dotted lines. Scale bar = 5 mm. (b) Photomicrograph of poikilitic texture in upper-left of (a). A large low-Ca pyroxene crystal (grey) encloses olivine and kamacite grains (yellow to purple). Low-Ca Px; low-Ca pyroxene, Ol; olivine, Kam; kamacite. Scale bar = 0.5 mm. (c) Orientation map of olivine crystals. Olivine crystals are colored by the axis that direct normal direction to the section plane. The axis corresponding to the color is shown in the sector. Linear texture of olivine crystals (upper right to lower left) is obvious. Scale bar = 5 mm. (d) Pole figure of olivine. Dotted lines indicate rough direction of the lineation texture. The data is contoured by MUD and lines show intervals of 1 MUD.