LATE-STAGE CRYSTALLIZATION PRODUCTS IN NWA 773 GROUP LUNAR METEORITES.
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Introduction: Many clasts in lunar meteorite Northwest Africa 773 and related meteorites can be linked together to illustrate stages of igneous evolution of a mafic magmatic system on the Moon [1-4]. Among the most distinctive rock-types in this set are olivine cumulate gabbros (OC) and fayalite-hedenbergite-silica symplectites [1-3]. These rocks originate from early and late stages, respectively, of magmatic evolution. However, in addition to the symplectites, a variety of domains with high Fe/(Fe+Mg) or enrichments in incompatible elements suggesting late-stage crystallization are present. In this study, we document several types of late-stage lithologies in NWA 773 group lunar meteorites and speculate on late-stages of magmatic evolution.

Methods: Late-stage crystallizing domains were identified in one polished thin section (PTS) of NWA 773 (on loan from M. Killgore of University of Arizona) and one PTS of NWA 2727 (Waseda University sample). The samples were studied using standard petrography, back-scattered electron (BSE) images and X-ray elemental maps. The elemental maps were critical for identifying high SiO_2, K_2O and/or Fe/(Fe+Mg) signatures of late-crystallizing assemblages. BSE images, X-ray maps and quantitative elemental analyses of minerals and glass were collected using a JEOL JXA-8900 electron microprobe at Waseda University. Quantitative analyses were collected by wavelength dispersive spectroscopy using well-characterized oxide and silicate standards at 15 kV and 20 nA. Incident beam spot sizes were one or two µm for most analyses of minerals and for glasses in fine inclusions. Larger spot sizes (7x5 µm) were used for some analyses of glass ± fine minerals in melt inclusions.

Late-stage rocks: *Symplectites.* The symplectites consist mostly of fine-grained (generally ≤4 µm across) intricately interwoven blebs of fayalitic olivine (Fa_{95}), hedenbergitic pyroxene ($Wo_{38}Fs_{53}$) and silica (Fig. 1). Detailed modes based on BSE images show that typical symplectites are similar to or somewhat pyroxene-rich compared to the idealized modes that would result from pyroxferroite breakdown. Some symplectite-like lithologies consist of multiple pyroxene-hosted inclusions of silica+olivine. Coarse-grained fayalitic olivine or hedenbergitic pyroxene may occur adjacent to symplectite domains; both sharp and gradational boundaries (with pyroxene riddled with curved inclusions of silica+olivine) occur. Coarse-grained feldspar ($An_{75}Or_4$) and Ca-phosphates are present in some symplectites. Most of the symplectites probably formed by breakdown of pyroxferroite in pyroxene-rich domains, leading to the variable excesses in mode of pyroxene.

Symplectites with glass inclusions. Some symplectites show variations in texture from the typical 3-phase symplectite to pyroxene-poor, olivine-rich domains. This olivine hosts multiple amoeboid inclusions of feldspathic glass ± fine elongate silica. The occurrence of feldspathic glass in these domains implies formation by direct quenching of silicate liquid without intervening pyroxferroite.

K,Ba-feldspar-bearing rocks. Coarse-grained (non-symplectic) Fe-rich olivine ± pyroxene occur with K,Ba-feldspar, feldspathic glass and silica in these clasts (Fig. 2). BaO-content in feldspar ranges up to 8.5 wt%. Ca-phosphates, ilmenite, troilite, ±baddeleyite also may be present.

K,Ba-feldspar also occurs in intercumulus domains of the olivine cumulate gabbro (Fig. 3). These domains are bordered by olivine and pyroxenes with compositions typical of the gabbro. Ca-phosphates, troilite and ilmenite coexist with the alkali feldspar (1 to 4 wt% BaO) in these domains.

Aphyric melt inclusions. Two types of melt inclusions occur in olivine. One type is characterized by dendritic pyroxene and appears to be primary. The other type is typically aphyric (though minor crystals may be present), and SiO_2-rich (as high as 90 wt% SiO_2). The pyroxene-phyric inclusions have been identified only in OC olivine, whereas aphyric inclusions occur in OC olivine, where they appear to be secondary, and fayalitic olivine, where they may be primary.

Late-stage crystallization: Fractional crystallization of olivine and pyroxene led to enrichments in incompatible K and Ba, among other elements, in intercumulate domains of the OC. This enrichment occurred without significant fractionation of Fe/(Fe+Mg). The residual intercumulus pockets were isolated from the main body of liquid, which subsequently fractionated to form liquid high in K_2O, BaO and Fe/(Fe+Mg). Crystallization of this liquid formed the K,Ba-feldspar-bearing clasts.

The evolution and timing of symplectite-bearing clasts and aphyric melt inclusions are uncertain. Most of these rocks are not K,Ba-rich. They might have formed after fractionation of K and Ba by crystallization of feldspar. Alternatively, silicate liquid immiscibility may have played a role in evolution of these late-stage lithologies.

References: [1] Fagan T.J. et al. (2003) *MaPS 38,* 529-554. [2] Jolliff B.L. et al. (2003) *GCA 67, 4857-4879*. [3] Zeigler R.A. et al. (2007) *LPS XXXVIII,* #2109. [4] Jolliff B.L. et al. (2007) *LPS XXXVIII,* #1489.

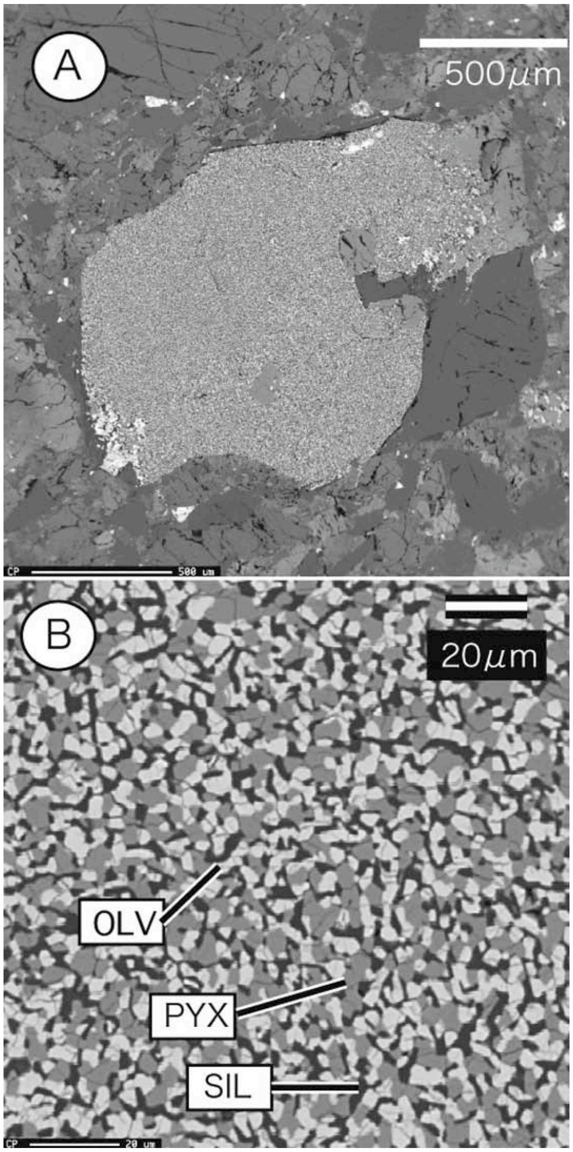

Fig. 1. BSE images of symplectite clast (A) and detail of symplectite texture (B). Abbreviations for this and other figures: OLV = olivine; PYX = pyroxene; SIL = silica; CAP = Ca-phosphate; CPX = high-Ca pyroxene; FGL = feldspathic glass; ILM = ilmenite; KBF = K,Ba-feldspar; MPX = low-Ca pyroxene; PLG = plagioclase feldspar; TRO = troilite.

Fig. 3.→ BSE image (A) and X-ray elemental map (B) of intercumulus domain in olivine cumulate. Red = K, Green = Ca and B = Al Kα X-rays.

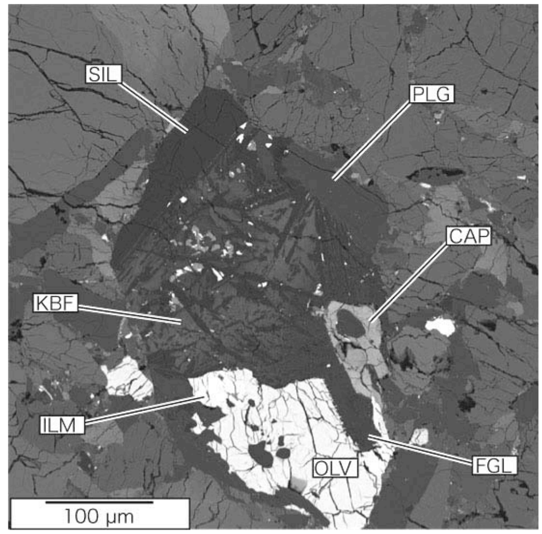

Fig. 2. BSE image of K,Ba-feldspar-bearing clast.