Evolution of Trapped vs. Main Liquids during Crystallization of Northwest Africa 773 Olivine Cumulate.

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Introduction:

The Northwest Africa 773 clan of meteorites (NWA 773, NWA 2700, NWA 2727, NWA 2977, NWA 3160, NWA 3333) consists of brecciated and unbrecciated lunar meteorites with a characteristic olivine gabbro cumulate lithology and other mafic rocks [1-4]. Much of NWA 773 consists of a large clast of the olivine cumulate (Fig. 1). Textures, zoning trends in pyroxene, and similar Ba-enrichments in K-feldspar indicate that many clasts in the breccia come from the same olivine cumulate lithology and later magmatic differentiates [5,6]. This "main trend" of magmatic differentiation is recorded by variations in pyroxene from Mg-rich low- and high-Ca pyroxenes to more hedenbergitic compositions and a co-varying increase in Ti# (Ti/(Ti+Cr); see [5,6] and Fig. 2). In contrast, pyroxenes within the large olivine cumulate clast show a wide variation in Ti#, but nearly constant Fe# (Fe/(Mg+Fe)).

The main goal of this project is to establish whether compositional variations of pyroxene within the olivine cumulate can be correlated with texture to help interpret the origin of this trend. Incompatible element-rich, intercumulate pockets, with K,Ba-feldspar, have been noted in the olivine cumulate clast [5,6]. In this study, we ask whether the Ti# of pyroxene in the olivine cumulate increases with proximity toward the intercumulate pockets. In general, we find that this pattern is true and that plagioclase feldspar becomes more Ab-rich with proximity to the pockets. These compositional variations suggest that the intercumulate pockets formed during magmatic differentiation within the olivine cumulate; however, the difference between the "pocket trend" (increase in Ti# with little change in Fe#) vs. the "main trend" (increase in both Ti# and Fe#) indicates that the pockets were isolated from the main body of liquid during crystallization of the olivine cumulate and subsequent differentiates.

Analytical Methods:

Our main observations and analyses are based on one thin section of NWA 773 on loan to Waseda University from Southwest Meteorite Laboratory (courtesy of M. Killgore). We have compared textures and mineral compositions with other members of the NWA 773 clan, including NWA 2727 in our collection and NWA 2977 through the courtesy of H. Nagaoka. An elemental map of the olivine cumulate clast was made using a JEOL JXA-8900 electron microprobe (EPMA) at Waseda University in order to identify K-rich pockets. After five pockets were identified (Fig. 1), pyroxene and plagioclase feldspar analyses were collected along traverses toward the incompatible pockets. Lengths of the traverses varied from 150 to 500 µm. Quantitative analyses were collected by wavelength dispersive spectroscopy using silicate and oxide standards under the following conditions: 15 kV; 20 nA; focused beam scanning at 100,000X (effective spot size near 1 to 2 µm for most silicates).

In addition to analyses near the pockets, we also analyzed pyroxene in: (1) a clast with alternating pyroxene/feldspar groundmass ("straw-texture") and pyroxene phenocrysts (2) a clast similar to the large olivine cumulate, but with more chromite; (3) a clast with wide Fe/Mg zoning as indicated by back-scattered electron (BSE) imaging. The straw-textured clast appears texturally distinct from the olivine cumulate and differentiates, and pyroxene was analyzed to determine whether it is compositionally distinct from main trend pyroxenes. The chromite-rich clast was analyzed to determine whether it represents a more primitive (lower Fe#) rock than the large olivine cumulate clast. The zoned clast was analyzed to determine how much of the main trend pyroxene variation could be preserved in a single clast.

Results and Discussion:

Pocket Trend. Of nine traverses in pyroxene, eight showed increasing Ti# with proximity to K,Ba-rich feldspar in incompatible pockets (Fig. 3). Fe# was nearly constant in all nine traverses. Of seven traverses in plagioclase, four showed decreases in An-content (increases in Ab) with proximity toward the pockets. These results support the interpretation that the pockets originated by in situ magmatic differentiation, isolated from the main body of fractionating liquid.

Breccia Clasts 1, 2, 3. (1) Groundmass pyroxene from the straw-textured clast may be less Ca-rich than main-trend pyroxene (Fig. 2). Ti-enriched margins of phenocrysts from the straw-textured clast are intermediate in Fe# between the pocket and main trend pyroxenes. (2) High- and low-Ca pyroxenes from the chromite-rich clast are slightly Mg-rich compared to the large olivine cumulate clasts, and are interpreted as more primitive crystals of the main trend (Fig. 2). (3) Pyroxene from the zoned clast encompasses most of the Ti# and Fe# variation of the main trend (Fig. 2).

References:

[1] Bunch et al. (2006) *LPSC 37,* #1375. [2] Jolliff et al. (2007) *LPSC 38,* #1489. [3] Zhang et al. (2010) *MaPS 44,* p. 1929-1947. [4] Nagaoka et al. (2011) *LPSC 42,* #1864. [5] Fagan et al. (2003) *MaPS 38,* p. 529-554. [6] Jolliff et al. (2003) *GCA 67,* p. 4857-4879.

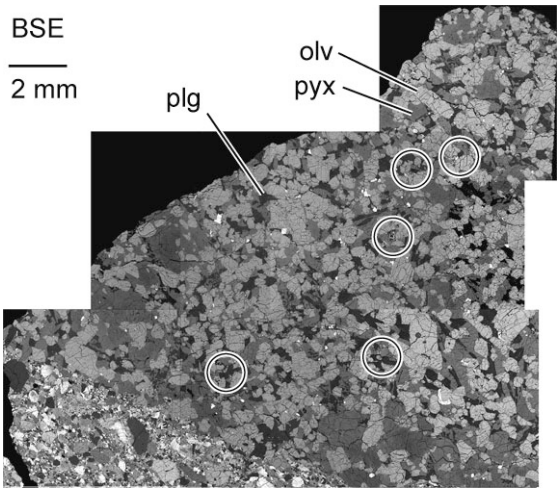

Figure 1. BSE image of large olivine cumulate clast in NWA 773. Some breccia texture present at lower left. Locations of incompatible pockets shown by circles. Abbreviations: olv = olivine; plg = plagioclase feldspar; pyx = pyroxene.

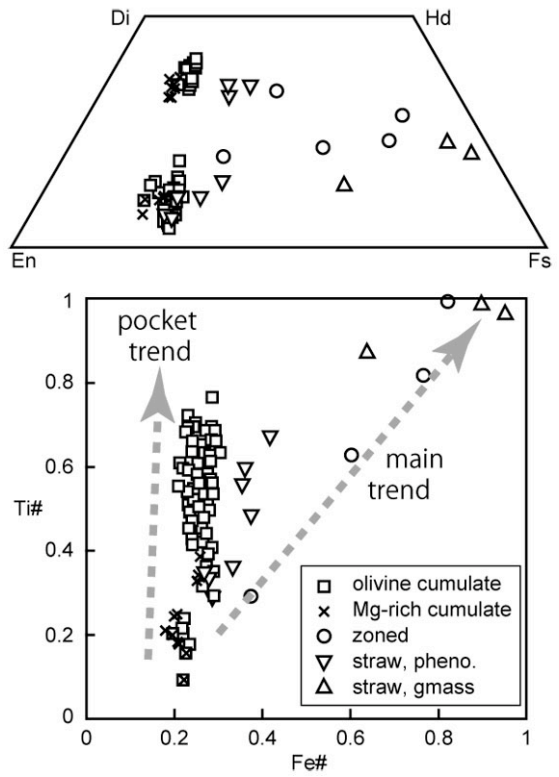

Figure 2. Compositions of pyroxenes from clasts in NWA 773 in pyroxene quadrilateral (above) and Ti# (molar Ti/(Ti+Cr)) vs. Fe# (molar Fe/(Mg+Fe)) (below). Pocket trend (offset to show analyses) is within the large olivine cumulate clast; main trend is from cumulate and differentiates in the breccia [5,6]. Olivine cumulate is one large clast of the olivine cumulate lithology; Mg-rich cumulate is similar in texture, but enriched in chromite; zoned clast has zoned pyroxene; both phenocryst and groundmass pyroxenes were analyzed in the straw-textured clast.

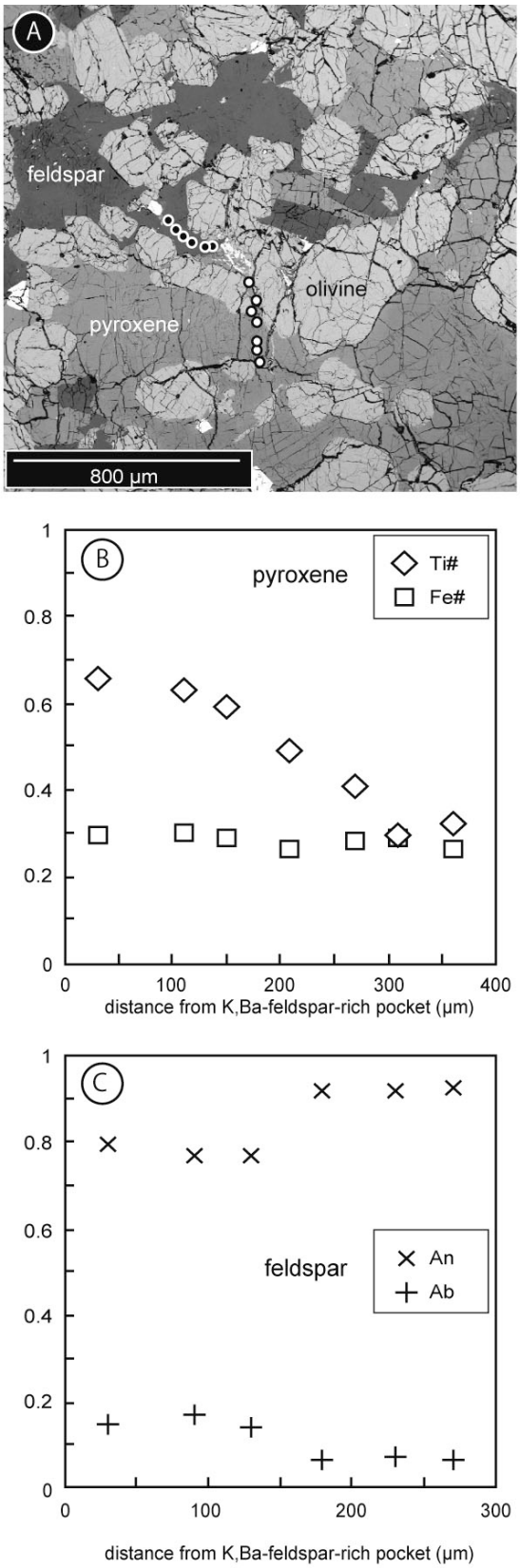

Figure 3. (A) BSE image of incompatible pocket 2, with dots showing locations of EPMA. (B and C) Pyroxene and plagioclase feldspar compositions on traverses toward incompatible pocket 2.