A TEXTURAL/MINERALOGICAL GRADIENT WITHIN VITROPHYRIC MARE BASALT NORTHWEST AFRICA (NWA) 8632

Chi Pui Tang[1,2], Krista Sawchuk[2] and Paul H. Warren[2], [1]Lunar and Planetary Science Laboratory, Macau Univ. Sci. and Technology, Macau, cptang@must.edu.mo, [2]Earth, Planet. & Space Sci., UCLA, Los Angeles, CA 90095, USA.

The 24-gram meteorite Northwest Africa (NWA) 8632 has been described as a rare lunar vitrophyric basalt devoid of plagioclase [1,2]. For most of the rock's volume, this characterization is valid. The rock consists of early phenocrysts of olivine with microphenocrysts of Cr-spinel, a later generation of pyroxene (px) phenocrysts, and a groundmass of (partially devitrified) aluminous glass with minor ilmenite, and no plagioclase (plag). However, we have found that a corner of rock has a holocrystalline texture, where the groundmass, instead of being dominantly glass, is dominated by roughly equal proportions of plag and px (caveat: we say "holocrystalline" and "plag" in reference to the original rock; launch off the Moon may have altered the plag to maskelynite). Px within the holocrystalline zone is compositionally distinctive.

The plag-rich zone occupies one corner, accounting for ~10% of our 155 mm^2 thin section (manifestly from the same rhomb-shaped slab as the sample studied by [2]). Fig. 1 shows a backscattered electron (BSE) image of typical plag-zone groundmass. The dominant groundmass phases are plag and px, clustered into sheaf-like bunches of elongate, subparallel to slightly radiating platy crystals, with typically about 10 grains of each (plag and px) per sheaf. Directional crystallization within the sheafs was influenced by surrounding phenocrysts, but sheaf orientations are near-random; they seldom pass through large phenocrysts and show little or no long-distance foliation.

Groundmass grain sizes for plag are up to 130×12 μm (px is similar), although conceivably long grains in BSE are not single crystals. Grain sizes generally decrease with distance away from the tip of the plag-rich corner, and give way to glass at about 4-5 mm. In the x-ray map (Fig. 2) the upper left corner is near the outer boundary of the plag-rich zone.

Pyroxene major-element compositions are shown in Fig. 3. In the plag-free vitrophyric portion of the rock px compositions are restricted to moderate *mg* and moderate-to-high Wo. Pyroxene in the plag-rich zone is more diverse, as the groundmass px is distinctly Fe-rich and Ca-poor (some of the lowest-Ca, highest-Fs "pyroxene" is conceivably pyroxferroite). ***The FeO that*** (unlike MgO) ***remained largely still in melt and quenched into glass in the vitrophyric zone, instead yielded high-Fs px in the holocrystalline zone***. The plag-rich zone's pyroxenes also show less development of compositions near Fs50Wo30, which formed in the vitrophyric zone by late plag-absent extensions onto rims of phenocrysts.

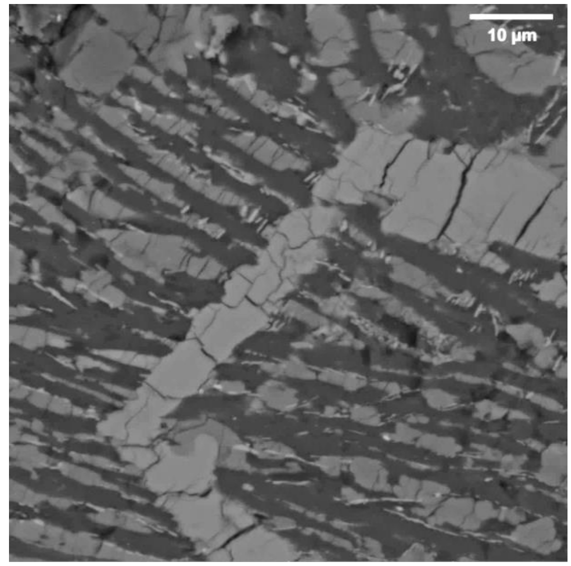

Fig. 1. BSE image of groundmass in plag-rich zone of NWA 8632. Major phases in order of increasing brightness: plag, px, and (a single Π–shaped grain) Fe-rich olivine. Minor phases, near-white and dark grey, are ilmenite and silica.

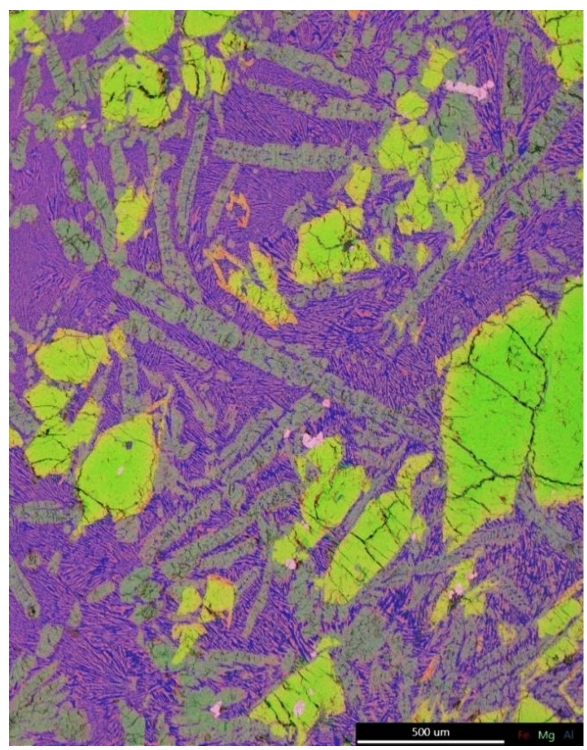

Fig. 2. SEM x-ray map of typical plag-rich portion of NWA 8632. Phenocryst phases are olivine (green except for orange Fe-rich rims), px (grey) and smaller Cr-spinel (pink). Dominant groundmass phases are plag (indigo blue) and px. Texture trends toward vitrophyric in "northwest" of this field.

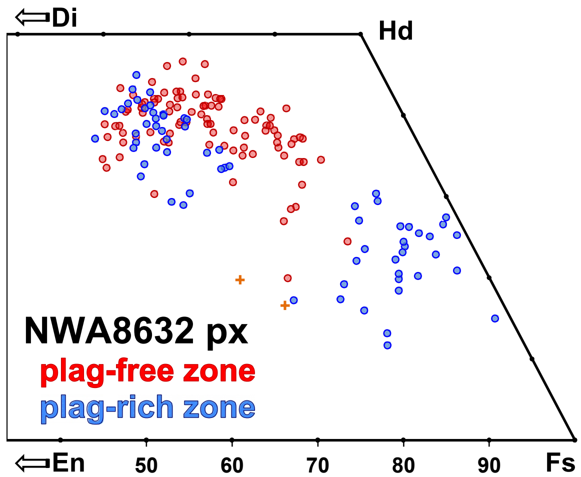

Fig. 3. Pyroxene quadrilateral (truncated) for NWA 8632.

Pyroxene minor-element compositions also show effects of cocrystallizing plag. In the absence of plag (vitrophyric zone), minor elements became enriched in late, relatively low-*mg* px. A similar pattern occurs in the analogously plag-free Apollo-15 vitrophyre 15597 [3,4]. The anticorrelation between *mg* and Al (mirrored by Ti) is striking. To allay concern that the trend might be a trivial side-effect of major-element variation, Fig. 4 shows instead the similar pattern from Al/Ca. In the plag-rich zone, the groundmass px shows Al/Ca lower by a factor of close to 5 in relation to the low-*mg* end of the vitrophyric anticorrelation trend. ***The Al that partitioned mainly between melt (glass) and late px in the vitrophyric zone was instead incorporated into plag in the holocrystalline zone***.

The px (both zones) shows a typical mare-basaltic trend [5] of anticorrelation between *mg* and the ratio "*ti*" [=molar Ti/(Cr+Ti)]. The *mg* = 50 intercept of this trend at *ti* ~ 0.78 implies [5] an initial magma TiO_2 content of ~ 3.4 wt%, high in comparison with a bulk analysis (from only 64 mg) result of 2.5 wt% [1]. However, "initial" in the case of an olivine-phyric rock may best be viewed as representing the magma at onset of *ti*-*mg* fractionation, i.e., px crystallization.

The plag is so fine-grained, microinclusion-rich, and, we suspect, shocked-altered (maskelynite?) that measuring it for composition or Raman spectroscopy is difficult. It appears to be almost Raman-inert and susceptible to EPMA beam damage (loss of Na and K). But a broadly defocused beam is not an option. A set of 42 mildly defocused analyses using current at 1.5-2 nA yield average An85 with a range of 81-88; adding (correcting?) sufficient Na and K, in their as-measured ratio, to yield ideal plag stoichiometry might shift the average to An79 and range to 74-83. In any event, the plag Na/Ca ratio is not unusual for a mare basalt.

X-ray spectra acquired by EDS rastering over different large regions within the thin section show that the textural/mineralogical heterogeneity in this rock is ***not*** an effect of compositional disparity (higher Al_2O_3) in the plag-rich corner. Nor is the holocrystalline plag-rich corner much poorer or richer in phenocrysts than the rest of NWA 8632. The heterogeneity is more likely a result of slower cooling (greater distance from the lava margin) in the plag-rich corner.

The closest precedent for NWA 8632 among lunar basalts is the 14-gram rocklet 12024,15 [6], which completely lacks plag and even px large enough for good analysis by EPMA, and yet shows textural heterogeneity and other evidence [7] of origin at a lava's outer margin. Another Apollo 12 vitrophyre, the 192-gram 12015, also shows subtle internal heterogeneity [3]. But NWA 8632 is unique as a sample with an internal gradient from vitrophyric to plag-rich.

References: [1] Korotev R. L. et al. (2015) *Lun. Planet. Sci*. 46, abstr. #1195. [2] Cato M. J. et al. (2016) *Lun. Planet. Sci.* 47, abstr. #2751. [3] Baldridge W. S. et al. (1979) *Proc. Lun. Planet. Sci. Conf.* 10, 141-179. [4] Grove T. L. and Bence A. E. (1977) *Proc. Lun. Sci. Conf.* 8, 1549-1579. [5] Arai T. and Warren P. H. (1996) *Meteor. Planet. Sci*. 31, 877-892. [6] Warren P. H. and Jerde E. A. (1990) *Lun. Planet. Sci*. 21, abstr. #1657. [7] Marvin U. B. (1978) *Apollo 12 Coarse Fines (2-10): Sample Locations, Description, and Inventory*, NASA JSC 14434.

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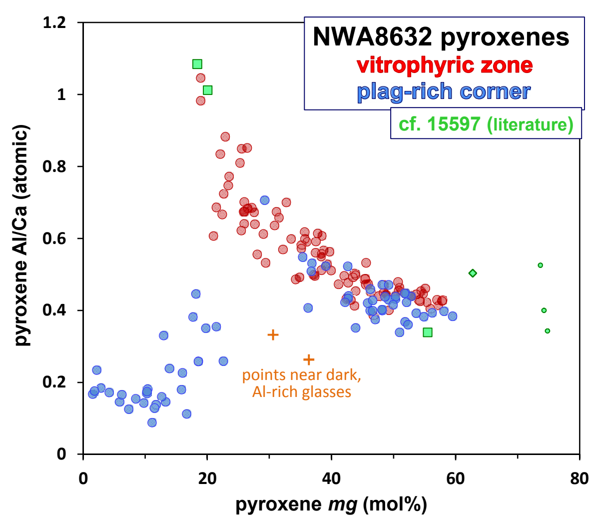

Fig. 4. Pyroxene Al/Ca systematics, with vitrophyre 15597 [3] for comparison. For 15597, data from low-Ca px are shown with smaller symbols; high-Ca px analyses, shown with full-sized symbols, are most relevant to NWA 8632.