PETROLOGY OF PRIMITIVE OLIVINE-ORTHOPYROXENE-PHYRIC SHERGOTTITES NWA 2046 AND NWA 1195: ANALOGIES WITH TERRESTRIAL BONINITES AND IMPLICATIONS FOR PARTIAL MELTING OF HYDROUS MARTIAN MANTLE

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Introduction: Research on Martian meteorites has led to the recognition of several shergottite subgroups, namely the relatively evolved basaltic shergottites, the lherzolitic shergottites, and the more primitive olivine-phyric shergottites. NWA 1195 had been classified as an olivine-phyric shergottite [1], but the discovery in 2003 of the 30th known Martian meteorite near Lakhbi, Algeria (provisional number NWA 2046) has led to the realization that both of these Mg-rich samples (containing preferentially aligned, prismatic phenocrysts of orthopyroxene in addition to olivine) properly belong to a separate shergottite subgroup.

Olivine-Orthopyroxene-Phyric Shergottite NWA 2046: This 63 gram ellipsoidal stone has a thin weathering rind (Figures 1, 2), but the fresh interior consists of euhedral to subhedral olivine phenocrysts (up to 2.2 mm long; some in clusters, and strongly zoned from $Fa_{15.7}$ cores to $Fa_{47.9}$ rims) and prismatic low-Ca pyroxene phenocrysts (up to 2.1 mm long) in a finer grained groundmass composed mainly of intergrown pigeonite ($Fs_{30-40}Wo_{6.5-13}$) and maskelynite ($An_{74.4}Or_{0.1}$ cores to $An_{62.3}Or_{1.1}$ rims), see Figures 3, 4. There is a prominent preferred orientation of both orthopyroxene and olivine phenocrysts, suggesting either magmatic flow and/or crystal accumulation, probably within a subsurface dike-like conduit. Additional groundmass phases are smaller olivine grains (Fa_{48-58}), Ti-chromite, chromite, ilmenite, Cr-ulvospinel, pyrrhotite, merrillite, chlorapatite, and minor fayalite (as rims on groundmass pigeonite in contact with ilmenite or pyrrhotite). The low-Ca pyroxene phenocrysts have large, irregularly-shaped cores of orthopyroxene ($Fs_{17.7-20}Wo_{2.5}$, with ~0.05 wt.% TiO_2 and ~0.6 wt.% Al_2O_3) mantled by pigeonite and augite (Figures 3, 5). Trapped melt pockets within olivine phenocrysts consist of aluminous diopside, another Mg-Al-Ca-Fe-bearing silicate (possibly amphibole), pleonaste, chromite, merrillite and glass (Figure 6). Olivine cores in NWA 2046 are almost as magnesian as those (Fa_{14}) in Antarctic olivine-phyric shergottite Y 980459 [2]. Although orthopyroxene does not form phenocrysts in Y 980459, the quench-textured orthopyroxenes are as Mg-rich as the cores in NWA 2046. Olivine core compositions imply that the Mg/(Mg+Fe) of the parent magmas of NWA 2046 and Y 980459 were 0.64 and 0.67, respectively.

Figure 1 Side view of NWA 2046

Figure 2 Cross-sectional view (width = 30 mm)

Olivine-Orthopyroxene-Phyric Shergottite NWA 1195: Initial studies [1] revealed the presence of euhedral olivine phenocrysts zoned from cores of Fa_{19} to rims of Fa_{40}, and orthopyroxene cores as magnesian as $Fs_{23}Wo_4$ within pigeonite grains. Additional studies now demonstrate that the prismatic orthopyroxene cores actually are phenocrysts (as magnesian as $Fs_{17.1}Wo_{1.8}$) preferentially aligned parallel to the long dimension of this unusually elongated stone. This had not been recognized initially, because all slices and two thin sections were oriented perpendicular to the long axis of the stone. Compared with NWA 2046, NWA 1195 has a coarser groundmass, smaller orthopyroxene phenocrysts, and less extreme compositional zoning in olivine phenocrysts - all suggestive of a slower cooling rate than for NWA 2046 - and a lower Mg/(Mg+Fe) of the parent magma (0.59). Although slightly more evolved, NWA 1195 also should be termed an olivine-orthopyroxene-phyric shergottite.

Analogies with Boninites: Reflectance spectra of rocks at the Viking landing sites [3] gave the first indication that surface Martian lavas are more like terrestrial andesites than basalts. This was supported by X-ray spectral analysis of the distinctly gray rocks at the Pathfinder landing site [4], which have bulk SiO_2 contents of 56 ± 3 wt.%, inviting comparisons with both andesites and icelandites [4], despite their much lower average Al_2O_3 contents of 10 ± 1 wt.%. Similar-looking gray rocks also are present at the Spirit landing site. A good analog for the most primitive Martian rocks may be terrestrial boninites, which are olivine-low Ca pyroxene-phyric lavas with relatively high SiO_2 (~56 wt.%) and MgO (up to 15 wt.%), yet relatively low TiO_2 (~0.2 wt.%), Al_2O_3 (~10 wt.%) and CaO (~5 wt.%).

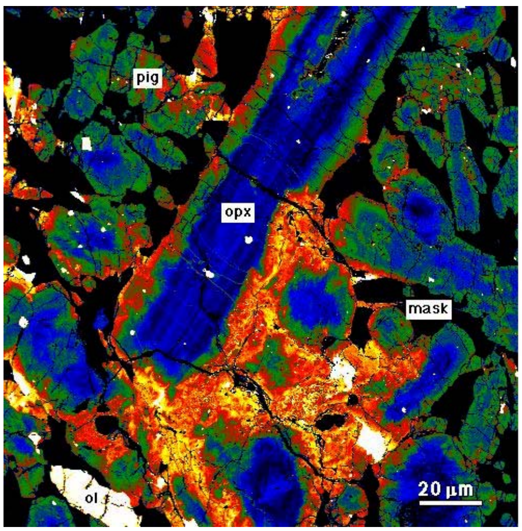


Figure 3 Prismatic orthopyroxene phenocryst

Partial Melting of Hydrous Martian Mantle: On Earth primitive boninitic magmas are believed to be produced by melting of hydrated, depleted sub-arc peridotite by rising mantle plumes [5]. Even without subduction, any mechanism that introduces water into harzburgitic peridotite could generate primitive boninitic or shergottitic magmas, and there is evidence [6] implying an important role for water in shergottite magma genesis. Although direct addition of hydrous mantle fluids into overlying infertile peridotite is a possibility, this would require production of adequate amounts of such fluids within the Martian interior as recently as 575-165 Ma ago. An alternative is a two-stage model beginning with ancient production of a hydrated peridotite containing serpentine, talc and amphiboles, followed by dehydration partial melting triggered thermally by younger upwelling mantle plumes. The olivine-free basaltic shergottites then may represent liquids that have evolved from such primitive magmas.

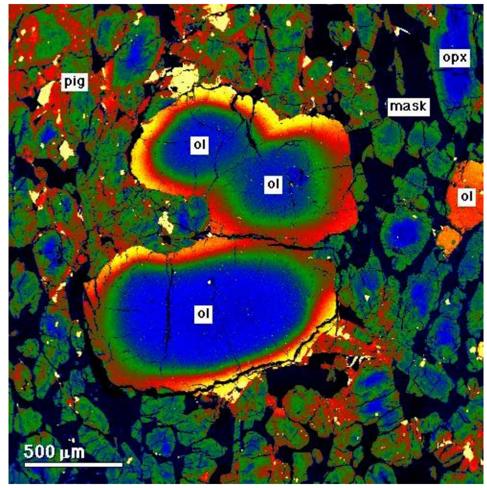
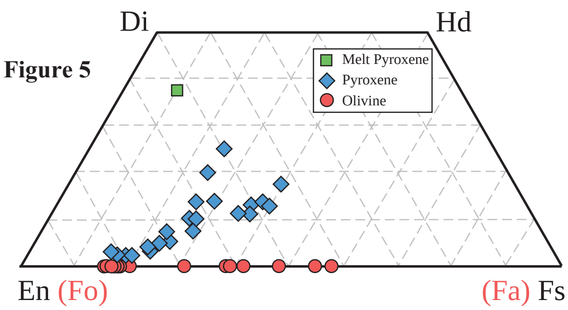


Figure 4 Zoned olivine phenocrysts

Figure 5


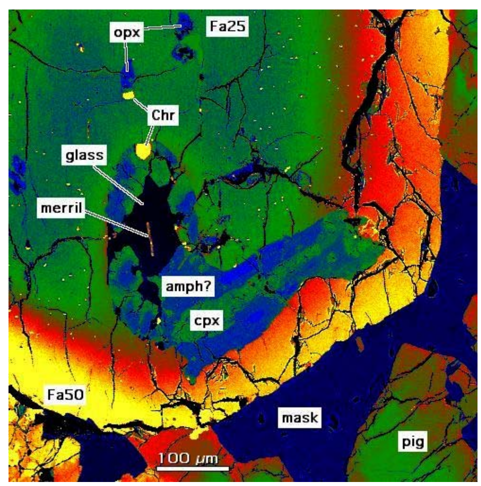


Figure 6 Trapped melt pocket in olivine

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