

PETROLOGIC INVESTIGATION OF OLIVINE PHYRIC DEPLETED SHERGOTTITES NORTHWEST AFRICA 2046 AND NORTHWEST AFRICA 6162. S. E. Suarez¹, S. Ramsey², A. Udry², M. Righter¹, T.J. Lapen¹ and A.J. Irving³ ¹Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX (sesuare2@central.uh.edu), ²Department of Geoscience, University of Nevada at Las Vegas, Las Vegas, NV ³Department of Earth and Space Sciences, University of Washington, Seattle, WA.

Introduction: Shergottites, the most abundant class of martian meteorites, are mafic to ultramafic igneous rocks that have a wide range of crystallization ages that span over 2 billion years [1]. Their mineralogy, textures, trace element and radiogenic isotope compositions can provide information about early planetary differentiation, evolution of mantle reservoirs, and magmatic processes that occur in the crust and upper mantle [2].

Shergottites are classified petrographically as basaltic, olivine-phyric, gabbroic, and poikilitic based on mineralogy and texture and classified geochemically as enriched, intermediate, or depleted with respect to incompatible/compatible trace element ratios and mantle source compositions [2]. Olivine-phyric shergottites are characterized by olivine megacrysts set in a fine-grained groundmass composed of pyroxene, maskelynite, olivine, and minor phases including chromite, phosphate, ulvöspinel, and ilmenite [3]. At least 16 olivine-phyric shergottites that are derived from incompatible trace element depleted sources share a 1.1 Ma ejection age [1] and possibly originated from the Tooting crater [4].

Northwest Africa (NWA) 6162 is characterized as an olivine-phyric depleted shergottite [5] that was found in 2010 near Lbirat, Morocco. Northwest Africa 2046 is categorized as a olivine-orthopyroxene-phyric shergottite [6] that was found in near Labkhbi, Algeria in 2003. In this study we report element maps, major and minor element compositions of phases including pyroxene, olivine, chromite, and source isotope data for each specimen. Based on these data, we present constraints on the petrogenetic histories of these specimens and compare them with other olivine-phyric shergottites that did and did not share a common ejection event.

Methods: Polished thin sections of NWA 6162 and NWA 2046 were prepared for this study. A JEOL 7600F analytical field-emission SEM was used to obtain elemental maps for initial characterization at NASA Johnson Space Center (Fig. 1), followed by quantitative spot analyses using a JEOL JXA-8900 EPMA at the University of Nevada, Las Vegas. Operating conditions of the EPMA were an accelerating potential of 15 kV, beam current of 20 nA and beam diameter of 1 μ m.

Bulk rock powders of NWA 6162 and NWA 2046 were analyzed for Lu-Hf and Sm-Nd isotopes by a NuPlasma II multiple-collector inductively-coupled

plasma mass spectrometer at the University of Houston following procedures and operating conditions outlined in [1] and references therein.

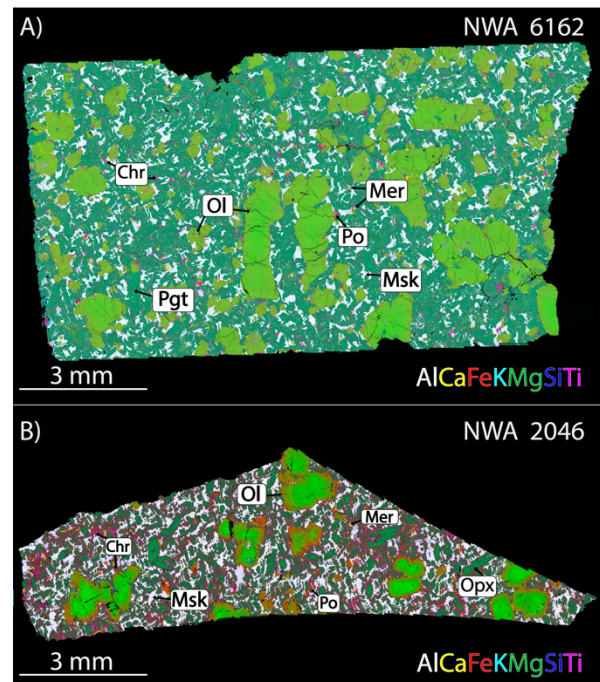


Figure 1. Composite X-ray elemental map (Al = white, Ca = yellow, Fe = red, K = cyan, Mg = green, Si = blue, Ti = pink) of A) NWA 6162 and B) NWA 2046. Chr = Chromite, Msk = Maskelynite, Mer = Merrillite, Ol = Olivine, Opx = Orthopyroxene, Pgt = Pigeonite, Po = Pyrrhotite

Results: The Hf and Nd isotope data of the whole rocks are +49.2 and +41.0 for NWA 6162 (Fig. 3), respectively. Isotope data for NWA 2046 is forthcoming, but trace element compositions indicate it is derived from a depleted source. NWA 2046 has 176Hf/177Hf ratio of 0.284107 (eHf = +47.1) which plots on the established fields for depleted shergottites. Mineral compositions of pyroxene and olivine measured are shown in Figure 2.

Northwest Africa 6162 contains olivine zoned from core to rim (Fo_{64.6-72.4}) up to 3 mm in the long dimension, augite grains (En_{46-51.8}Wo_{31.2-37.5}Fs_{15.5-18.4}) that are as large as 0.1 mm and average 0.05 mm, pigeonite grains (En_{62.2-70.1}Wo_{5.9-11.4}Fs_{22.2}) that are up to 0.8 mm and average 0.5 mm, and maskelynite (An_{52.4-66.8}Ab_{32.9-46.9}Or_{0.17-0.76}) up to 0.3 mm and average 0.1

mm. NWA 2046 contains olivine ($\text{Fo}_{46.9-83.4}$) up to 2.2 mm in the long dimension and average 1 mm, pyroxene phenocrysts ($\text{En}_{38.7-79.7}$ $\text{Wo}_{2.2-35.1}$ $\text{Fs}_{17.9-48.5}$) that are as large as 1.5 mm and matrix pyroxene average 0.5 mm, and maskelynite ($\text{An}_{55.2-66.8}$ $\text{Ab}_{33-44.1}$ $\text{Or}_{0.08-0.87}$) up to 1 mm and average 0.5 mm.

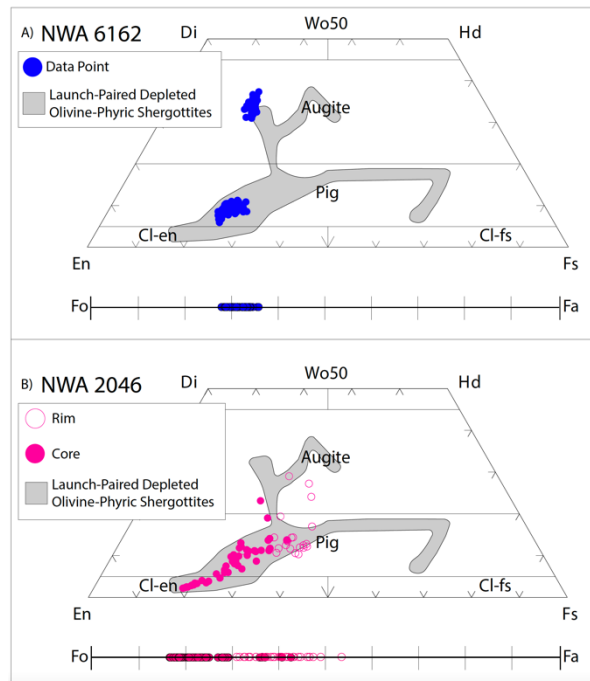


Figure 2. Pyroxene quadrilateral and olivine major element compositions for A) NWA 6162, and B) NWA 2046. Compositions overlay with launch paired depleted olivine-phyric shergottites from [7,10,11,12,13]

Discussion: The isotopic compositions of bulk rock and major element compositions of phases are all consistent with parental melt for NWA 6162 and NWA 2046 derived from mantle sources depleted in incompatible elements (Fig. 3).

Textural and chemical data of pyroxenes from NWA 2046 and NWA 6162 suggest they have distinct thermal histories. NWA 2046 is composed of orthopyroxene and pigeonite that is chemically zoned and show increases in Ca from core to rim (Figs. 1, 2). These pyroxenes have a preferred orientation, potentially due to flow [5]. The compositional trend of NWA 2046 pyroxene has been observed in other launch paired olivine-phyric shergottites (Dar al Gani 476, NWA 1195, Sayh al Uhaymir (SaU) 005, and Yamato 980459) and is thought to be caused by delayed nucleation of plagioclase [6]. It is implied that NWA 2046 and previously studied launch paired depleted olivine-phyric shergottites formed in an environment that cooled quickly enough to persevere compositional zoning in olivine and pyroxene. NWA 6162,

on the other hand, contains distinct augite grains that occur as irregular patches within and on pigeonite grains. Unlike NWA 2046, the pyroxene compositions show distinct groupings between pigeonite and augite. It is suggested that NWA 6162 differs from NWA 2046 and formed in a more slowly cooled environment based on the presence of what could be exsolved pyroxenes and re-equilibrated olivine megacrysts. The two pyroxene thermometer [8] yields an Fe-Mg equilibration temperature of 1080 ± 50 °C.

Textural and mineral chemical differences between NWA 6162 and NWA 2046 highlight the potential diversity of emplacement environments recorded in the igneous pile. The apparently more slowly cooled NWA 6162 and its cumulate texture may suggest this specimen may be derived from a sill or thick flow. Despite having an olivine-phyric texture, pyroxene and olivine compositions of NWA 6162 are similar to enriched poikilitic shergottites [9], but tend to be more homogeneous. Pyroxene compositions from NWA 2046 are consistent with other launch paired olivine-phyric shergottites including NWA 5789 [10]. Flow textures may indicate surface or intrusive flow alignment of pyroxene.

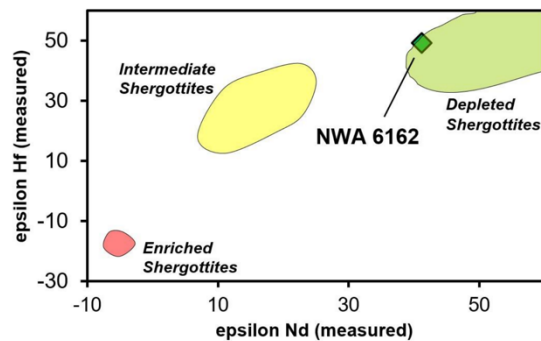


Figure 3. Nd and Hf data for whole rock of NWA 6162 compared to literature compilations [1].

References: [1] Lapen T. J. et al. (2017) *Science Advances*, 3, e1600922. [2] Udry et al. (2020) *Journal of Geophys. Research: Planets* 125, 12, e2020JE006523 [3] Goodrich C. A. (2002) *Meteoritics & Planet. Sci.*, 37, B31–B34. [4] Lagain et al. (2021) *Nature Communications*, 12, 6352. [5] Kuehner S. M. et al. (2011) LPS XLII, Abstract #1610. [6] Irving et al. (2004) LPS XXXV, Abstract #1444 [7] Papike et al. 2009 *Geochim. Cosmochim. Acta* 73, 7443–7485. [8] Brey and Kohler (1990) *Journal of Petrology*, 31, 6, 1353–1378. [9] Rahib et al. (2019) *Geochim. et Cosmo. Acta* 266, 463–496. [10] Gross et al. (2011) *Meteoritics & Planet. Sci.*, 46, 1, 116–133. [11] Balta et al. (2014) *Meteoritics & Planet. Sci.*, 50, 1, 63–85 [12] Usui et al. (2008) *Geochim. et Cosmo. Acta* 72, 1711–1730 [13] Zipfel et al. (2000) *Meteoritics & Planet. Sci.*, 35, 1, 95–106.