PETROGRAPHY AND MINERAL CHEMISTRY OF THE NEW ENRICHED LHERZOLITIC SHERGOTTITE NORTHWEST AFRICA 10169. L. M. Combs[1], A. Udry[1] and J. M. D. Day[2], [1]Department of Geoscience, University of Nevada Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154-4010. [combsl1@unlv.nevada.edu]. [2]Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0244.

Introduction: Shergottites are the most common martian meteorite type, and are divided into three major groups: basaltic, olivine-phyric, and lherzolitic [1-2]. Shergottites can be further classified, based on their degree of relative Light Rare Earth Element (LREE) enrichment, into three different classes: 'enriched', 'intermediate', and 'depleted'. Other significant variations within these groups include fO_2 (oxygen fugacity), trace element and isotope geochemistry [1].

The meteorite Northwest Africa (NWA) 10169 was found in the Laayoune region of the Western Sahara and has been classified as a lherzolitic shergottite. Lherzolitic shergottites are the most primitive of the three types of shergottites, with the highest bulk Mg#'s [$100*Mg^{2+}/(Mg^{2+}+Fe^{2+})$] and the highest modal abundance of olivine (40-60%) [1]. Unlike the basaltic and olivine-phyric shergottites, which are interpreted to be extrusive igneous rocks, lherzolitic shergottites are likely cumulate, and display a bimodal texture composed of both poikilitic and nonpoikilitic regions [2].

Until quite recently, the only known lherzolitic shergottites have been geochemically classified as intermediate, with respect to their REE compositions [3]. In the past few years, relatively 'enriched' lherzolitic shergottites have been recovered, and appear to be geochemically similar to the enriched basaltic and olivine-phyric shergottites [4, 5].

Here, we examine the lherzolitic shergottite, NWA 10169, reporting petrography, as well as the major, minor, and REE chemistry of mineral phases.

Methods: This study utilizes data gathered from two thin sections cut from the main sample of NWA 10169. A *JEOL 8900* SuperProbe electron microprobe was used at UNLV to perform *in situ* major and minor elemental analyses, obtain backscatter electron (BSE) images, and create elemental X-ray maps (Fig. 1). The beam size used was 5µm, while the beam current and accelerating voltage were 20nA and 15kV, respectively. The beam current was decreased to 10nA for maskelynite and glass analyses. The X-ray maps produced were analyzed with the software *ImageJ* in order to determine modal abundances. Both thin sections were analyzed using a *New Wave Research* UP213 (213 nm) laser-ablation system coupled to a *ThermoScientific* iCAPq ICP-MS at SIO, to obtain *in situ* trace element compositions of pyroxene, olivine, maskelynite, and merrilite, with spot-sizes ranging from 50 to 100 µm.

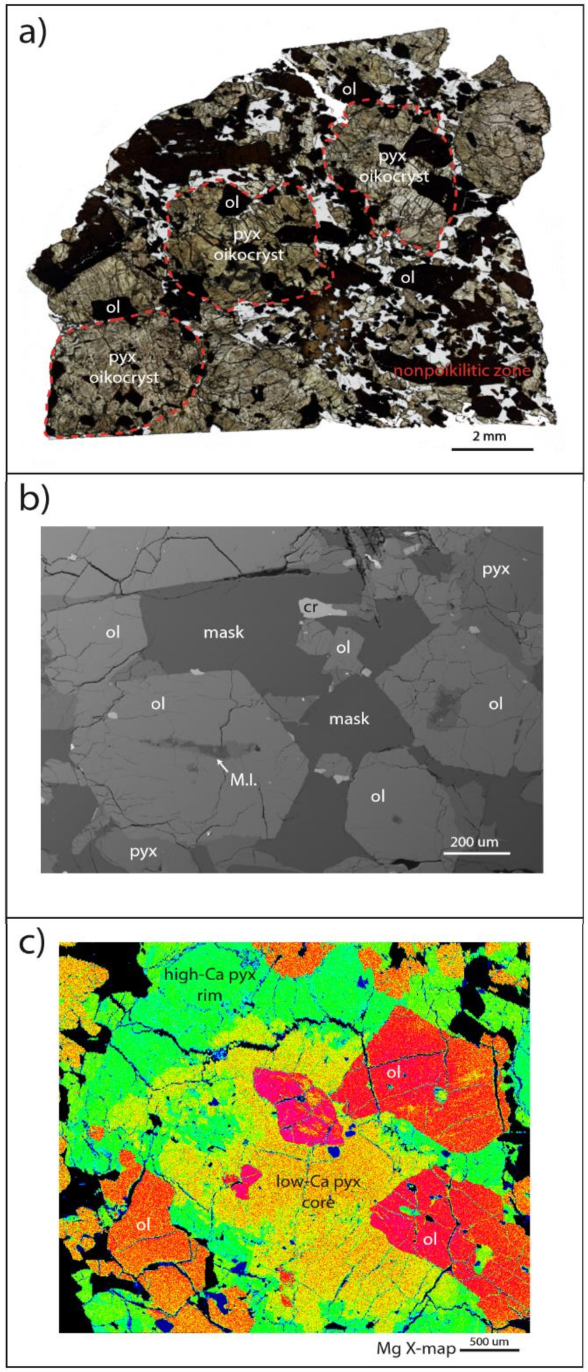

Figure 1. a) PPL mosaic map of a thin section of NWA 10169 showing a bimodal texture; b) BSE image of euhedral, nonpoikilitic olivine; c) Mgkα map of a pyroxene oikocryst.

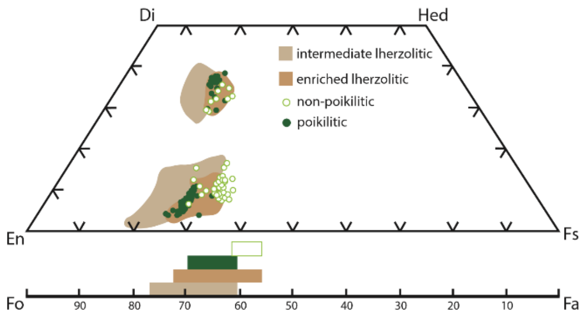

Figure 2. Pyroxene quadrilateral showing relation between low-Ca and high-Ca pyroxenes from NWA 10169, as well as pyroxene compositions of intermediate and enriched lherzolitic shergottites. Similar relationships are shown with olivine data from NWA 10169. Pyroxene and olivine fields from [4, 5, 6].

Petrography: NWA 10169 displays a bimodal texture, with both poikilitic and nonpoikilitic regions (Fig. 1), and contains (in modal %) olivine (37%), low-Ca pyroxene (34%), high-Ca pyroxene (12%), maskelynite (15%), Fe-oxides (2%), and trace amounts of phosphates and sulfides. The poikilitic zone is characterized by large (up to 4mm) anhedral pyroxene oikocrysts, displaying low-Ca cores and high-Ca rims. These pyroxene oikocrysts contain subhedral olivine chadacrysts (Fig. 1). The olivine and pyroxene in this zone often completely or partially enclose euhedral chromite grains. The nonpoikilitic zone is characterized by an assemblage of maskelynite, anhedral to subhedral pyroxene, subhedral to euhedral olivine, and andhedral, highly fractured merrilite. Minor phases include pyrrhotite, ilmenite, and apatite.

Mineral chemistry: The pyroxene oikocrysts in NWA 10169 have core compositions of $Wo_6En_{68}Fs_{27}$, compositions of $Wo_9En_{64}Fs_{27}$ in the area between the cores and rims, and rims of oikocrysts are high-Ca pyroxene ($Wo_{35}En_{47}Fs_{18}$). In the nonpoikilitic zone, NWA 10169 contains discrete grains of both low-Ca pyroxene ($Wo_{10}En_{59}Fs_{31}$) and high-Ca pyroxene ($Wo_{33}En_{47}Fs_{20}$) (Fig. 2). NWA 10169 pyroxene have similar compositions to previously studied enriched lherzolitic shergottites (Fig. 2). Low-Ca pyroxenes from NWA 10169 have low REE abundances, but similar chondrite-normalized REE patterns to high-Ca pyroxenes. In detail, however, low-Ca pyroxenes are slightly more LREE-depleted [$(La/Lu)_{CI}$ ~0.06] than the high-Ca pyroxenes [$(La/Lu)_{CI}$ ~0.1]. In general, the pyroxene oikocryst cores have a greater REE depletion than the oikocryst rims and the nonpoikilitic pyroxenes (Fig. 3). Olivine chadacrysts in the poikilitic zone vary from Fo_{68} in the cores of the pyroxene oikocrysts, to Fo_{61} at the rims. Olivine in the nonpoikilitic zone is more fayalitic ($Fo_{59.5}$). Olivine REE contents are close to the detection limit. Maskelynite is only present in the nonpoikilitic zone, and exists in both high-anorthite ($An_{51.2}$) and low-anorthite phases ($An_{36.4}$). The maskelynites have relatively LREE enriched [$(La/Lu)_{CI}$ ~1.6] CI-chondrite normalized profiles, and display distinct positive Eu anomalies (Fig. 3). Merrillite has the highest amount of REE in NWA 10169 (La ~555xCI) and displays a slight negative Eu anomaly (Fig. 3).

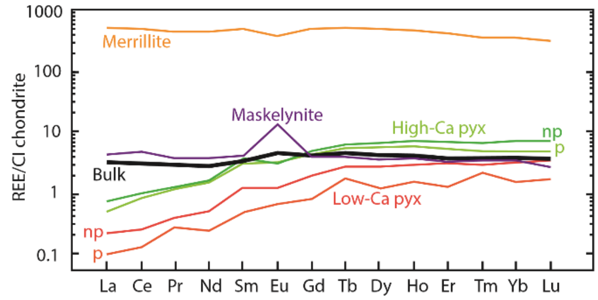

Figure 3. REE profiles normalized to CI for both the bulk rock (calculated) and major mineral phases of NWA 10169.

Discussion: In NWA 10169, the poikilitic zone formed at the earliest-stage of crystallization of the parent melt, and thus represents the most primitive (highest Mg#) composition. By contrast, olivine and pyroxene Mg#'s are lower in the nonpoikilitic zone, reflecting fractional crystallization in the parent melt. Given the incorporation of the olivine and Cr-spinel within pyroxene oikocrysts, the apparent crystallization sequence follows Cr-spinel ≥ olivine ≥ low-Ca pyroxene > high-Ca pyroxene > plagioclase > phosphate; a typical crystallization sequence for lherozolitic shergottites.

The bulk rock REE profile was calculated using modal abundances (Fig. 3). The relatively flat bulk REE profile of NWA 10169 (La/Lu = 0.87) suggests that this lherzolitic shergottite is enriched. In addition, the pyroxene and olivine compositions fit within the more Fe-rich enriched lherzolitic shergottite fields (Fig. 2). The textural characteristics, mineral composition, and bulk REE composition are similar to the enriched lherzolitic shergottites NWA 7397, Grove Mountains (GRV) 020090 and Robert Massif (RBT) 04261/2 [4, 5, 6]. The similarities between NWA 10169 and the enriched lherzolitic shergottites indicate that it is an enriched lherzolitic shergottite.

References: [1] Bridges J. C. and Warren P. H. (2006) *Contributions to Mineralogy and Petrology, 107*, 27-40. [2] Goodrich, C. A. (2002) *Meteoritics & Planet. Sci., 37,* B31-B34. [3] Hsu, W. et al. (2004) *Meteoritics & Planet. Sci., 39*, 701-709. [4] Usui, T. et al. (2010) *Geochimica et Cosmochimica Acta, 74,* 7283-7306. [5] Howarth, G. H. et al. (2014) *Meteoritics & Planet. Sci., 49*, 1812-1830. [6] Bingkui, M. et al. (2004) *Acta Geologica Sinica*, 78, 1034-1041.