

PETROLOGY AND GEOCHEMISTRY OF NORTHWEST AFRICA 11044, A NEW ENRICHED LOW-AL SHERGOTTITE. A. B. Love¹, S. J. Singletary², and S. Huang³ ¹Department of Geological and Environmental Sciences, Appalachian State University, Boone, NC 28608 (loveab@appstate.edu), ²Science Dept., Robeson Community College, Lumberton, NC 28360 (ssingletary@robeson.edu), ³Dept. of Geoscience, University of Nevada, Las Vegas, NV 89154 (shichun.huang@unlv.edu).

Introduction: Petrographic, mineral compositional, and whole rock geochemical analysis of two slightly weathered stones weighing 95.3 and 9.4 grams recovered from the Moroccan Sahara in 2016 (NWA 11044) determined they belong to the low-Al group of enriched basaltic shergottites. We present preliminary results of Northwest Africa 11044 in this report. We compare it to other known low-Al shergottites [1]. Radiogenic study is currently under way.

Analytical Methods: Two polished thin sections from NWA 11044 were examined using Optical Light Microscopy, SEM, and EPMA. Optical petrography was performed within the Department of Geological and Environmental Sciences and backscattered electron (BSE) images were collected using the JEOL ITS300 SEM in the Dewel Microscopy Facility at Appalachian State University (ASU). Quantitative analyses were performed on the Cameca SX-100 housed within Earth and Planetary Sciences at the University of Tennessee. Accelerating voltage of 15kV and a 30nA beam current were used to analyze major and minor elements for silicate phases, and Si, S, Fe, Co, Ni, P, Mg, Al, Ti were determined for oxide and sulfide phases.

Bulk composition was measured using the Thermofisher iCAPTM Qc ICP-MS at the University of Nevada Las Vegas. BHVO-1, BCR-1 and AGV-1 were used to construct calibration curve, and BHVO-2 was analyzed unknown.

Petrography: Similar to Shergotty and Zagami [2], NWA11044 is an ophitic-textured basaltic shergottite, composed of 65% euhedral-subhedral prismatic twinned pyroxene, 26% lath-shaped plagioclase (based on composition) that has been transformed to maskelynite, 4% mesostasis, 2.5% Ti-magnetite and ilmenite, 2% merrillite and Cl-apatite, and accessory pyrrhotite and rare baddeleyite occurring interstitial to pyroxene and maskelynite. NWA11044 has been affected by shock metamorphism and, in addition to maskelynite, shows fractured pyroxenes, and melt pools and veins. Pyroxenes show complex zonation, seen in other basaltic shergottites [2-4], with Mg-rich pigeonite (avg. $\text{Fs}_{31}\text{Wo}_{14}\text{Mg}\#64$) and augite cores (avg. $\text{Fs}_{23}\text{Wo}_{34}\text{Mg}\#66$) mantled by sub-calcic augite (avg. $\text{Fs}_{54}\text{Wo}_{24}\text{Mg}\#29$) and surrounded by late-stage ferropigeonite rims (avg. $\text{Fs}_{61}\text{Wo}_{16}\text{Mg}\#28$). Mg-pigeonite cores have irregular-shaped margins and are surrounded by an augite mantle and ferropigeonite rim. Pyroxenes show a

general trend towards Fe-enrichment, and pyroxene cores have distinct Ti/Al ratios from ferropigeonite rims (0.13 and 0.62, respectively). Maskelynite is zoned with Ca-rich cores. Ti-magnetite contains ilmenite exsolution lamellae. Late-stage merrillite is the primary phosphate and is crosscut by Fe-Ti oxides. Two and rare three-phase symplectites composed of fayalite, silica and Ca-clinopyroxene occur on the boundary between ferropigeonite rims and merrillite.

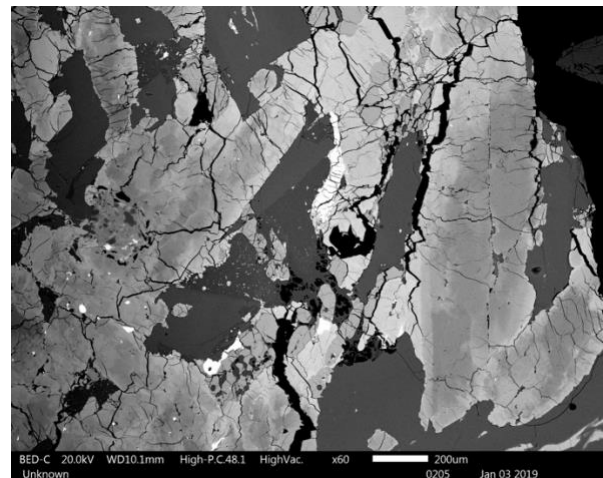


Figure 1. Backscattered electron image showing chaotic zonation in NWA11044 pyroxenes.

Bulk Composition: A ~60 mg rock chip of NWA11044 was dissolved and analyzed by ICP-MS for major and trace elements. The sample is an enriched shergottite with a Mg# of 22.8, and has a CI-normalized REE pattern parallel to other low-Al enriched basaltic shergottites (Shergotty, Zagami, NWA480, NWA856, NWA5298, NWA8657, NWA 8679, NWA 5214[2-10]). Compared to other low-Al basalts, NWA 11044 has higher Na and P, lower abundances of the compatible elements such as Mg, Cr, and Ni, and distinct enrichments of the incompatible elements such as Th, Zr, Hf.

Petrogenesis: The complexly zoned pyroxenes, Ni content and disequilibrium between pyroxene and discrepancies in bulk and pyroxene Mg #'s indicate that this sample was derived from a fractionated magma source that initially crystallized olivine and was subsequently separated from that magma. Two-pyroxene thermometry [11] of augite and pigeonite

cores yields an initial crystallization temperature of 1150° C. Ragged boundaries on pigeonite cores and fractionated olivine suggest the magma was separated from its source prior to continued crystallization which produced augite mantles and ferropigeonite rims. Increased Ti/Al and Cr/Mg# ratios in pyroxenes suggest plagioclase and Ti-magnetite co-crystallized subsequent to the pyroxene cores (~ Mg# 57). Drop in Ca during plagioclase crystallization resulted in crystallization of Fe-rich ferropigeonite rims. Compositions of merrillite support co-crystallization with plagioclase and pyroxene [12]. The occurrence of merrillite and Ti-magnetite within ferropigeonite rims supports co-crystallization of these phases. Si-Al-rich mesostasis occurs as the final product of cooling of NWA11044.

Comparison with other low-Al basalts: Treiman and Filiberto [1] recognized basaltic shergottites could be divided into groups based upon their Al concentrations, Fe/Mg ratio, and Th abundances, all of which are related by igneous processes [1]. NWA11044 has 4.18 wt% Al, which classifies it as a low-Al shergottite. With the exception of its modal abundance of mesostasis, NWA11044 shares petrographic (modal mineralogy, texture and grainsize) similarities with other low-Al shergottites. NWA11044 has one of the lower Mg#'s of this group, and the highest incompatible element abundances only after NWA 5214. NWA11044 is also enriched in Ba, La, Sr, Ce and U, however these are known weathering proxies [13] and may be related to terrestrial weathering effects. Additional data from NWA11044 and more recent finds, NWA 8657, NWA 8769 and NWA5214, extend the known range of incompatible element abundances for the low-Al shergottites [1]. The source of incompatible element enrichment within NWA11044 has yet to be identified as it contains comparable modal abundances of minerals phases to most other low-Al shergottites. The Th-Lu, Th-Hf trends do not go through origins, so that they cannot be fractionation trends. Mixing and variation of degree of partial melting may also play a role. These findings provide additional evidence in support of mixing between distinct REE sources within the martian mantle.

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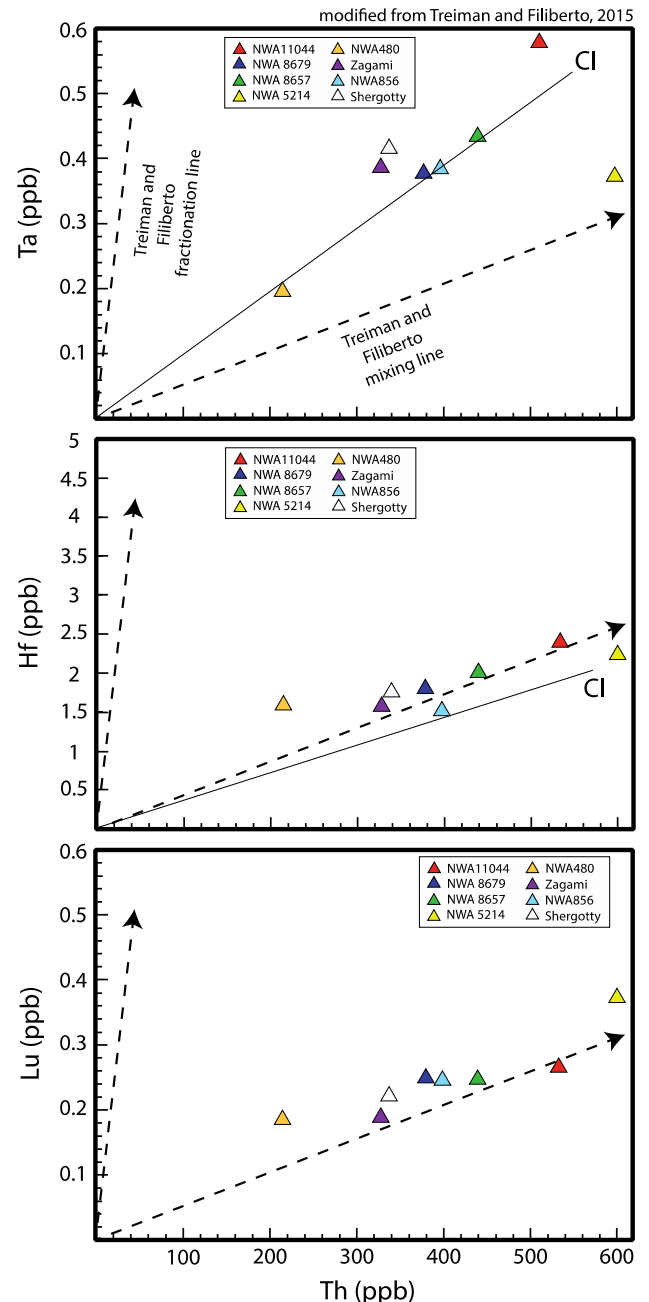


Figure 2. REE plots of bulk compositions showing the range of incompatible element composition for low-Al shergottites. Modified from Treiman and Filiberto, 2015.