PETROLOGY AND GECHEMISTRY OF THE ENRICHED POIKILITIC SHERGOTTITE NORTHWEST AFRICA 10169: INSIGHT INTO THE MARTIAN INTERIOR. L. M. Combs, A. Udry, G. H. Howarth, T. J. Lapen, M. Righter, J. Gross, J. M. D. Day, and R. R. Rahib. 1Department of Geoscience, University of Nevada Las Vegas, 4505 S. Maryland Pkwy, Las Vegas NV 89154-4010 (combsl1@unlv.nevada.edu), 2Department of Geology, University of Georgia, Athens GA 30602-2501, 3Department of Geosciences, University of Houston, Houston TX 77204-5007, 4Department of Earth & Planetary Sciences, Rutgers University, Piscataway NJ 08854, 5Scripps Institution of Oceanography, University of California San Diego, La Jolla CA 92093-0244.

Introduction: Shergottites are the most abundant group of martian meteorites, and are divided into basaltic, olivine-phyric, poikilitic, and gabbroic petrologic types. [e.g., 1, 2]. Shergottites are also divided into three geochemical groups (enriched, intermediate, and depleted) based upon their relative light rare earth element (LREE) enrichment, and source 143Nd and 176Hf compositions [e.g., 1, 3]. These variations have arisen through the sampling of distinct geochemical reservoirs, whose origins and locations remain controversial [e.g., 4, 5]. The crystallization ages of the shergottites, dated using the Sm-Nd, Lu-Hf, and Rb-Sr isotope systems, mainly range from ~150-574 Ma [e.g., 6, 7, 8], with two meteorites as old as ~2.4 Ga [9, 10]. Here we present new major, minor and trace element compositions; oxygen fugacity (fO2), temperature and pressure calculations; and Lu-Hf ages and isotopic composition of Northwest Africa (NWA) 10169. NWA 10169 is a poikilitic shergottite that was found in the Laayoune region of Western Sahara in 2015. Our data indicate that NWA 10169 is a new member of the enriched shergottites.

Figure 1. The measured bulk REE profile of NWA 10169 in comparison to previously studied shergottites. Figure modified from [11]; and references therein.

Analytical Techniques: Major, minor, and trace element in situ compositional analyses were performed using the JEOL JXA-8900 electron microprobe (EMP) at UNLV, and the New Wave Research UP213 (213mm) solid-state laser ablation system coupled to a ThermoScientific iCAP Qc ICP-MS at the Scripps Institution of Oceanography (SIO). Bulk major, minor, and trace element compositions were obtained on a second ThermoScientific iCAP Qc ICP-MS housed at SIO.

Lu-Hf Crystallization Age Dating. A ~1 g sample of NWA 10169 was crushed in a clean agate mortar and pestle. A pyroxene fraction was hand-picked from the powder; while spinel, and maskelynite-rich fractions were isolated through density separation, using thallium malonate (~4.36 g/cc) and lithium metatungstate (~2.75 g/cc), respectively. The mineral separates, a bulk <45 μm sample, and a bulk (minus separates) sample were dissolved through microwave digestion, then 4-stage column chemistry was performed, isolating Lu and Hf. All samples were analyzed using a Nu Instruments NPlasma II MC-ICP-MS at the University of Houston.

Petrography and Mineral Chemistry: NWA 10169 exhibits the characteristic bimodal texture observed in the poikilitic shergottites. The namesake poikilitic texture manifests as large (up to 4 mm), anhedral pyroxene oikocrysts, enclosing anhedral olivine (100-800 μm) and anhedral to subhedral chromite (25-100 μm) chadacrysts. The pyroxene oikocrysts show sharp compositional boundaries from pigeonite cores (Wo37En68Fs57) and mantles (Wo6En60Fs14), to augite rims (Wo32En06Fs18). Olivine chadacrysts range from Fo68 to Fo61 from the cores to the rims of the oikocrysts. Chromite chadacrysts have uniform compositions of Cr27Mg33Mn0.6Spin0.3Ulv0.1. Interstitial to the poikilitic textures, is a relatively more equigranular assemblage of subhedral pyroxene (500-1000 μm), subhedral to euhedral olivine (~800 μm), and plagioclase that has been completely shocked to maskelynite (500-100 μm). Anhedral spinel (up to 300 μm) are commonly enclosed by olivine, and there are minor phosphates, pyrrhotite, and ilmenite present. This texture is heretofore referred to as non-poikilitic. Non-poikilitic pyroxene exists as discrete grains of pigeonite (Wo10En89Fs13) and augite (Wo30En77Fs20). Non-poikilitic pyroxene also shows significantly higher concentrations of incompatible elements (Ti, Y, Zr) than poikilitic pyroxene. Non-poikilitic olivine is more Fe-rich (Fo60) than the olivine chadacrysts. Maskelynite in the non-poikilitic texture range from An86 to An93, and show positive Eu anomalies [Eu/Eu* = 3.4]. Spinel in the non-poikilitic textures are more Ti-rich (Ch3.3Mg1.5Spin0.4Ulv0.1) than the poikilitic chromite. Merrilite in NWA 10169, though only
in trace amounts, exert an important control on the bulk REE composition with La ~555xCI.

**Geochemical Classification:** Bulk REE concentrations of NWA 10169, normalized to CI, show a relatively flat, LREE enriched ([La/Yb]CI = 1.18) profile (Fig. 1). The profile has a similar pattern to previously studied enriched poikilitic shergottites [11-13], and shows one of the highest REE-enrichments in the shergottite suite. This observation, along with the textural and compositional characteristics of NWA 10169 has led to its classification as a new member of the geochemically enriched poikilitic shergottites.

**Conditions of Formation:** The positive correlation between pressure and Ti/Al ratios in pyroxene has been experimentally calibrated for martian meteorites [15, 16], and has been used to estimate pressures of pyroxene oikocryst formation in enriched poikilitic shergottites [11]. Pyroxene Ti/Al ratios in NWA 10169 suggest pressures of >9 kbar during oikocryst formation. The non-poikilitic texture likely crystallized at shallower depths, as the relatively finer and more equigranular texture is consistent with faster cooling at lower pressures. Subsolidus equilibration temperature and fO2 were calculated for both the poikilitic and non-poikilitic textures using the olivine-pyroxene-spinel oxygeobarometer and olivine-spinel geothermometer [17]. The poikilitic texture yielded a temperature of 994 ± 22°C and a log fO2 of FMQ -2.50 ± 0.38, while the non-poikilitic texture yielded a temperature of 803 ± 66°C and a log fO2 of FMQ -1.08 ± 0.15 (Fig. 2). The compositional differences between the poikilitic and non-poikilitic textures, and these results, suggest a formation consistent with the polybaric crystallization model proposed by [11]; in which the poikilitic texture likely formed at depth, under more reducing conditions and pressures >9 kbar, and following magma ascent, the non-poikilitic texture began to form at shallower depths and under more oxidizing conditions.

**Lu-Hf Age and Source Composition:** A 5 point Lu-Hf isochron yielded a crystallization age of 167 ± 31 Ma (2σ, MSWD = 1.4) for NWA 10169, and a derived initial 176Hf/177Hf of 0.282186 ± 0.000011 (Fig. 3). The crystallization age lies between the youngest (~150 Ma) and oldest (~225 Ma) enriched poikilitic shergottites, NWA 4468 [18] and RBT 04262 [19], respectively. The calculated source 176Lu/177Hf of 0.02748 ± 0.00037 is identical to the calculated sources of NWA 4468 and RBT 04262, basaltic shergottites Shergotty and Zagami, and olivine-phyric shergottite LAR06319, suggesting a shared mantle source for this group of enriched shergottites.