PETROGENESIS AND ISOTOPE SYSTEMATICS OF AUGITE-RICH MARTIAN METEORITE NORTHWEST AFRICA (NWA) 13467

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Introduction: Martian meteorites are dominated by shergottites, mafic to ultramafic lithologies formed at or near the martian surface from ~2400 Ma to 150 Ma [1]. Shergottites may be classified by igneous texture or incompatible trace element (ITE) and isotopic compositions, reflecting derivation from ITE enriched (La/Yb_{CI} >0.8), intermediate (La/Yb_{CI} 0.3 to 0.8), or depleted (La/Yb_{CI} <0.3) mantle sources. Two recently described augite-rich specimens, Northwest Africa (NWA) 7635 and NWA 8159, share comparable source compositions, cosmic ray exposure and igneous crystallization ages, and evidence for interactions with similarly ITE depleted sulphide material [2-5]. These samples likely reflect early Amazonian magmatism of the same, long-lived (> 2 Gyr) volcanic edifice as depleted shergottites [2]. Investigation of such lithologies therefore allows greater understanding of the long-term evolution of martian crust and mantle reservoirs. Here, we report petrological and isotopic characteristics of augite-rich basalt NWA 13467. The studied sample possesses petrographic and chemical similarities to NWA 7635 and NWA 8159 [2-5], but also contains petrological characteristics that highlight a distinct late magmatic and subsolidus petrogenesis.

Results: *Petrology:* NWA 13467 is dominated by augite (~40 %), plagioclase (~42 %; now diaplectic glass) and fayalitic olivine (Ol; ~12 %). Pigeonite is completely absent. Minor phases include ilmenite, titanomagnetite, magnetite, orthopyroxene, apatite, pyrrhotite, and chromite. Augite compositions are evolved (Mg# ≤58), with complex zonation that initially trend towards Ca-poor and Fe-rich compositions. Below Mg# 30, augite interstitial to plagioclase and augite rims record an abrupt transition to increasingly Ca-rich compositions. Augite cores (Mg# 58-42) and olivine cores (Mg# 45-34) are not in Mg-Fe equilibrium; further evidence of olivine disequilibrium includes ubiquitous orthopyroxene-magnetite symplectites and low, but variable Fe-Mg thermometry temperatures of 506-670 °C for olivine-chromite pairs. Oxide compositions are diverse, ranging from Fe^{3+}-poor chromite to near-pure magnetite.

Trace element and isotope compositions: Trace element systematics of major mineral phases are light rare earth element (LREE) depleted, with a minor positive slope in heavy REE shown by Dy/Lu_{CI} ratios of ~0.8. LA-ICP-MS data demonstrate olivine are notably poor in Ni and Co, with concentrations of < 20 ppm and < 72 ppm, respectively. Whole rock (WR) data reveal highly radiogenic present-day εHf of +186.

Discussion: NWA 13467 mineral compositions indicate a protracted magmatic history; Ti-Al systematics [6] of augite cores indicate initial crystallization at depth, before emplacement at or near the martian surface. Petrographic and geochemical characteristics, including orthopyroxene-magnetite symplectites formed by subsolidus or peritectic oxidation of olivine, suggest late-stage oxidation of NWA 13467 from ~IW +2 (semi-quantitative chromite V/(Cr+Al) oxybarometer [7]) to at or near ~FMQ. Textural evidence coupled with unusually low (e.g., [8]) Ol-chromite Fe-Mg thermometry temperatures indicates oxidation may have occurred under subsolidus conditions (< 500 °C), potentially reflecting low temperature crustal processes and/or interaction with crustal fluids at or near the martian surface

NWA 13467 possesses numerous chemical characteristics that are unlike late Amazonian shergottites, but remarkably similar to ~2400 Ma augite-rich basalts NWA 7635 and NWA 8159. Petrological similarities to NWA 7635 and NWA 8159 include the absence of pigeonite, evolved augite compositions, the presence of orthopyroxene-magnetite symplectites, and indistinguishable olivine trace element systematics [2-5]. Furthermore, the radiogenic Hf isotope composition of NWA 13467 WR is directly comparable to NWA 7635 (εHf 179 [2]), rather than 587-327 Ma late Amazonian depleted shergottites. However, despite such similarities to previously described augite-rich basalts, differing modal proportions and bulk igneous textures, the presence of accessory phases absent in both NWA 7635 and NWA 8159, and distinct compositions of late-formed augite indicate a discrete petrogenesis of NWA 13467, at least in the latter stages of crystallization. We therefore suggest that NWA 13467 is unlikely to be derived from the same igneous unit as either NWA 7635 or NWA 8159, precluding a pairing with either stone. Thus, NWA 13467 represents an important sample for investigation of martian high- and low-temperature processes; ongoing isotopic measurements will employ Sm-Nd, Lu-Hf, and U-Pb isotope systematics to confirm or preclude a genetic link to NWA 7635 and NWA 8159, determine the crystallization age, and better understand the low-temperature processes recorded in NWA 13467.

References: [1] Udry A. *et al.* (2020) *JGR: Planets* 125: e2020JE00652. [2] Lapen, T. J. *et al.* (2017) *Science Advances, 3:* e1600922. [3] Herd, C. D. K. *et al.* (2017) *Geochimica et Cosmochimica Acta,* 218: 1-26. [4] Shearer C. K. *et al.* (2018) *Geochimica et Cosmochimica Acta* 258: 242–257. [5] Humayun, M. *et al.* (2021) *LPSC 52,* Abstract# 1390. [6] Filiberto *et al.* (2010) *Meteoritics and Planetary Science* 45: 1258–1270. [7] Papike, J. J. (2004) *American Mineralogist* 89: 1557–1560. [8] Roeder et al. (1979) *Contributions to Mineralogy and Petrology* 68: 325-334.