

CRYSTALLIZATION HISTORY OF MARTIAN METEORITE NORTHWEST AFRICA 13227: A NEW OLIVINE GABBROIC SHERGOTTITE. S. Benaroya¹, J. Gross^{1,2,3,4}, P. Burger¹, S. A. Eckley^{5,6}; ¹Dept. of Earth & Planetary Science, Rutgers University, Piscataway, NJ 08854 (sb1541@scarletmail.rutgers.edu); ²NASA, Johnson Space Center, Houston, TX, 77058, ³Dept. of Earth & Planetary Sciences, American Museum of Natural History, New York, NY 10024; ⁴Lunar and Planetary Institute, Houston, TX 77058; ⁵Jackson School of Geosciences, University of Texas at Austin, Austin TX, 78712; ⁶Jacobs Technology, Johnson Space Center, Houston, TX 77058.

Introduction: Martian meteorites are the only samples available on Earth to study Mars. The majority of martian meteorites are igneous in origin, and understanding their formation can provide insight into mantle and crust composition and differentiation [1]. Shergottites comprise the majority (~83%) of the martian meteorite collection and are classified based on mineralogy and texture into four subgroups: basaltic, olivine-phyric, gabbroic, and poikilitic (previously lherzolitic) [2-5]. Gabbroic and poikilitic shergottites are intrusive rocks that crystallized at depth, and thus, can provide information into the composition of the deep crust and upper mantle. Although intrusive rocks should be dominant on Mars [6], only two gabbroic shergottites have been extensively studied: Northwest Africa (NWA) 7320 [5] and NWA 6963 [4], and both have little to no olivine present. NWA 13227 may have special significance among the gabbroic samples because it contains significant amounts of olivine. Another recently discovered gabbroic shergottite NWA 11509, also contains olivine in similar quantities to NWA 13227 [7]. Here, we present preliminary data on petrography, mineral chemistry, and X-ray computed tomography (XCT) to constrain various aspects of its petrologic history, including conditions of crystallization and crystallization sequence.

Sample & Methods: NWA 13227 was purchased in 2019 and classified as an olivine gabbroic shergottite [8]. Qualitative backscattered-electron (BSE) images and X-ray elemental maps, as well as quantitative point analyses on a thick section of NWA 13227, were obtained using the JEOL JXA-8200 Superprobe at Rutgers University. X-ray computed tomography was carried out at the Astromaterials XCT-lab at NASA Johnson Space Center using the Nikon XTH 320 micro- X-ray Computed Tomography (XCT) scanner. Imaging of the samples was done using a 180kV nano-focus transmission source at 90 kV and 2.0 W.

Petrography and Mineralogy: NWA 13227 consists of large pyroxene and olivine grains, set in a matrix of smaller olivine grains, along with small pyroxene grains, lath-like maskelynite, and accessory phases of spinel, ilmenite, phosphates, and FeS (Fig.1). The volume proportion of minerals was estimated based on the 3D XCT images (26.30 mm³ and 59.60 mm³, with voxel sizes of 4.09 µm and 5.54µm, respectively) and are: 61-64% pyroxene; 17-20 % olivine; 17-18 % maskelynite; and ~1 % accessory phases.

Pyroxene: Pyroxene phenocrysts are euhedral to subhedral with lengths between 500 µm - 5 mm.

Oscillatory zoning of Mg, Fe, and Ca is observed (Fig. 1C). Cores are low-Ca pyroxene with an average composition of En₆₇Fs₂₇Wo₆, Mg and Fe content decrease slightly while Ca increases (avg. En₄₉Fs₂₂Wo₂₉). The rim compositions increase in Mg and Fe and decrease in Ca (avg. En₅₁Fs₃₆Wo₁₃) (Fig. 2). The pyroxene in the matrix are smaller and some display long, spinifex-like, lath textures (Fig. 1B,C). Compositionally, they overlap with the rim compositions of the larger pyroxene grains and have an average composition of En₅₀Fs₃₄Wo₁₆.

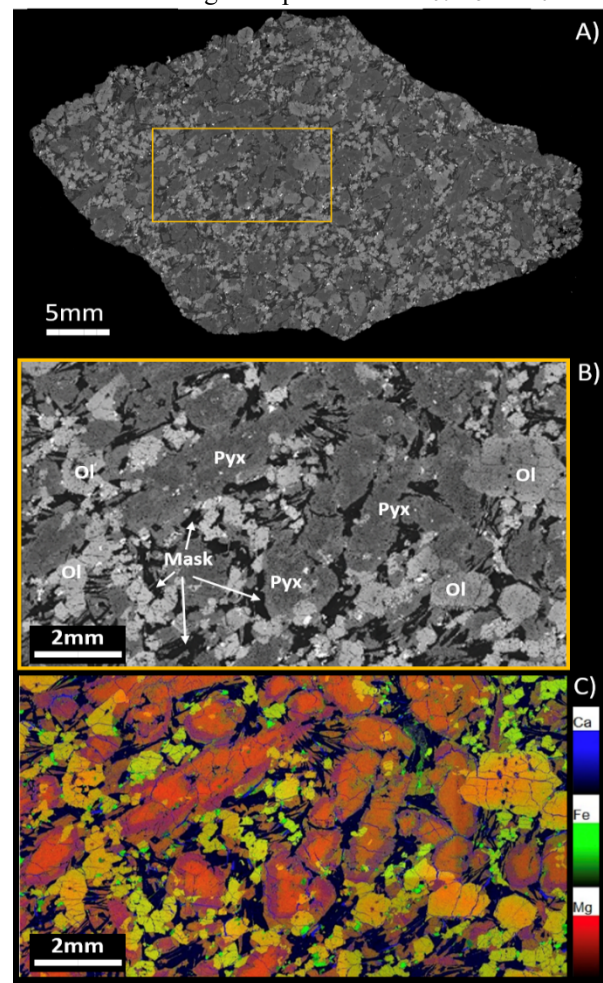


Figure 1: A) Back-scattered electron (BSE) image of NWA 13227. B) Close-up BSE image of the yellow outlined inset in A). C) Composite elemental X-ray map of Mg(red) Fe(green) Ca(blue) of the inset shown in A). Ol = olivine, Pyx = pyroxene, Mask = maskelynite

Olivine: Large olivine grains are euhedral to subhedral with sizes up to 2 mm. They often contain melt inclusions. The cores of these larger grains are Mg-rich with a Fo content ranging from Fo₇₀ to Fo₆₁ which decreases to Fo₆₁₋₅₇ towards the rim. Matrix olivine are subhedral to anhedral and smaller in size, ranging on average from 100 to 800µm in size. The composition of the matrix olivine grains range from Fo₅₈ to Fo₄₅. Some olivine grains are present as inclusions within the pyroxene cores and mantles.

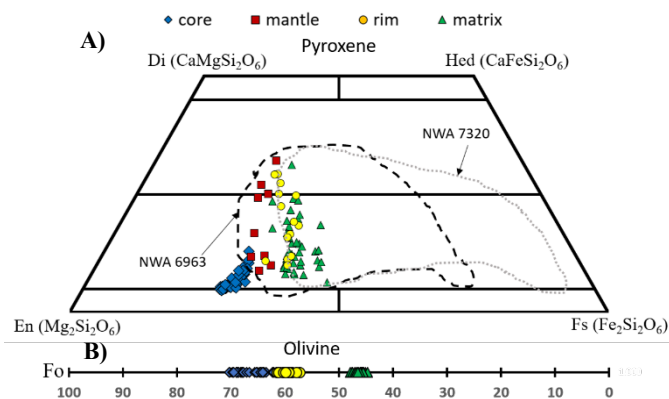


Figure 2: Pyroxene quadrilateral (A) and olivine Fo content (B) of NWA 13227. Dashed line in (A) represents pyroxene compositions of NWA 6963 [3]; gray dotted line represent NWA 7320 [4].

Maskelynite: Maskelynite is present as lath-like grains in the matrix, with average sizes of ~600 µm, with some grains up to 2.5 mm in size. The composition ranges from An₅₅Ab₄₃Or₂ to An₃₇Ab₅₈Or₅.

Other phases: Small (50-200µm), euhedral chromite grains are present as inclusion in olivine rim areas, as are small (~50-100µm) Fe-Ti oxides. Subhedral to anhedral magnetite and ilmenite grains are present in the matrix and range in size from 30µm up to 250µm. Phosphates and FeS are present in the matrix.

Discussion: NWA 13227 and NWA 11509 represent the only gabbroic shergottites that contains significant amounts of olivine (17-20 vol% and 17.1 vol%, respectively). By comparison, NWA 6963 and NWA 7320 only contain olivine as an accessory phase [4,5]. While the modal mineral abundance of NWA 13227 and NWA 11509 is similar with respect to olivine and plagioclase (NWA 13227: 17-20 vol% olivine, 17-18 vol% maskelynite; NWA 11509: 20.1 vol% plagioclase, 17.1 vol% olivine [7]), NWA 13227 contains ~10 vol% more pyroxene. Further, NWA 11509 has been extensively shocked and contains 11 vol% vesicles as well as recrystallized plagioclase and olivine aggregates in the matrix [7]. No such shock features have been observed in NWA 13227.

Crystallization history of NWA 13227: Olivine and pyroxene were the first phases to crystallize and core compositions are in Fe-Mg equilibrium (Fig. 2). The

Ti/Al ratio (Fig. 3A) suggests that NWA 13227 almost fully crystallized somewhere in the lower crust/upper mantle, which is supported by the coarse grained nature of the sample. The Ti/Al ratio of the rim and matrix pyroxene indicates that the sample crystallized under lower pressure towards the end of the crystallization sequence. The sharp increase in Ti/Al ratio in lower pyroxene with decreasing Mg# (<64) (Fig. 3B) indicates the onset of plagioclase crystallization after pyroxene mantles crystallized, modifying the Ti/Al ratio in the evolving melt and subsequent crystallizing pyroxene rim compositions. This observation is consistent with the finer grained matrix.

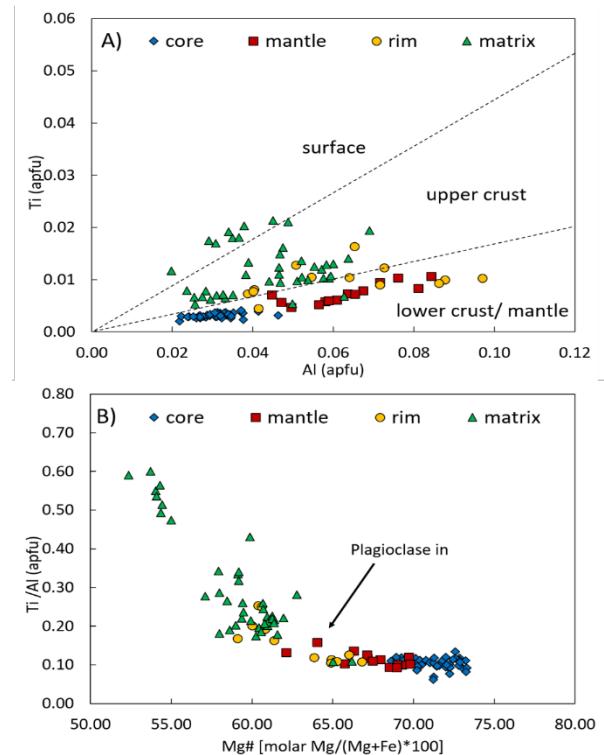


Figure 3: A) Al vs. Ti (apfu) for pyroxene analyses. B) Mg# vs. Ti/Al ratio in pyroxenes. The figure illustrates the onset of plagioclase crystallization.

Conclusions: NWA 13227 appears to be the most primitive gabbroic shergottite to date and could possibly represent a magmatic cumulate. We expect to obtain a more complete understanding of the crystallization history of NWA 13227 by measuring bulk chemistry including REE, as well as carrying out fO₂ calculations, and obtaining more detailed zoning profiles for olivine and pyroxene.

References: [1] Udry et al. (2020) *JGR-Planets*, doi.org/10.1029/2020JE006523 [2] Bridges & Warren (2006) *J. Geo. Society*, 163, 229 – 251. [3] Goodrich (2002) *MAPS*, 37, B31-B34. [4] Filiberto et al. (2018) *JGR-Planets*, 123, 1823-1841. [5] Udry et al. (2017) *GCA*, 204, 1-18. [6] Filiberto et al. (2014) *Am. Min.* 99, 601-601. [7] Irving et al. (2018) 49th LPSC #2279. [8] Meteoritical Bulletin, no. 109 (2020).