THE PLAGIOCLASE-BEARING POIKILITIC SHERGOTTITE NORTHWEST AFRICA 12241, A NOT-SO SHOCKED MARTIAN METEORITE. A. Udry[1], A. Ostwald[1], G. H. Howarth[2], M. Paquet[3], L. V. Forman[4], J. M. D. Day[3], and A. Taylor[1], [1]Department of Geosciences, University of Nevada Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 890154 (arya.udry@unlv.edu), [2]Department of Geological Sciences, University of Cape Town, Rondebosch 7701, South Africa, [3]Scripps Institution of Oceanography, University of California San Diego, La Jolla CA 92093-0244, [4]Space Science & Technology Centre Curtin University, GPO Box U1987, Perth, Western Australia 6845, Australia.

Introduction: Poikilitic shergottites are gabbroic/lherzolitic lithologies and currently consist of 30 paired groups [e.g., 1–6]. They have a bimodal texture that provides insight into magmatic processes from the crust-mantle boundary to the shallow crust [2]. Here we examine the newly recovered sample Northwest Africa (NWA) 12241, which was classified as an olivine gabbro in the Meteoritical Bulletin. This meteorite is one of the few martian shergottites that contains plagioclase, and not solely the high pressure phase maskelynite. The NWA 12241 meteorite also has all of the textural and geochemical characteristics of an 'intermediate' poikilitic shergottite.

Methods: We conducted quantitative textural analyses, bulk major and trace composition analyses, and mineral major element analyses following the same procedure and in the same laboratories as [2]. Electron Backscatter Diffraction (EBSD) analyses were conducted at the John de Laeter Centre at Curtin University, Western Australia. We collected high resolution maps of plagioclase grains to understand the crystallinity of this phase. These data were obtained using step sizes of 0.1–0.5 µm.

Results and Discussion: *Mineralogy and petrogenesis of NWA 12241*. Northwest Africa 12241 has a bimodal texture, similar to other poikilitic shergottites [2], characterized by an early-stage poikilitic texture of pyroxene oikocrysts and olivine and chromite chadacrysts, and a later-stage non-poikilitic texture, including olivine, pyroxene, plagioclase, chromite, merrillite, ilmenite, and sulfides (mostly pyrrhotite). The modal abundances of all phases are similar to those of other poikilitic shergottites [2]. Pyroxene oikocrysts have low-Ca cores with contrasting high-Ca rims. Low-Ca poikilitic pyroxenes cores have compositions of $En_{55–70}Fs_{25–27}Wo_{5–18}$, while high-Ca poikilitic pyroxene rims have compositions of $En_{44–54}Fs_{17–20}Wo_{26-39}$. Non-poikilitic pyroxenes are also present as distinct grains; they are richer in Ca and poorer in Mg than pyroxene oikocrysts, with compositions of $En_{51}Fs_{11}Wo_{37}$ to $En_{64}Fs_{26}Wo_{10}$. Olivine chadacrysts within pyroxene oikocrysts have compositions of $Fo_{64–67}$ and non-poikilitic olivine have compositions of $Fo_{60–67}$. Northwest Africa 12241 contains lath-shaped plagioclase grains (up to ~ 750 µm in length) that exhibit undulose extinction and polysynthetic twinnings. Birefringent and amorphous plagioclase has stoichiometric compositions (5 cations based on 8 O) of $An_{53–59}Ab_{46–40}Or_{2–1}$. While most plagioclase grains are entirely birefringent, sharp transitions from birefringent to isotropic are seen in some plagioclase grains. Amorphous plagioclase identified in NWA 12241 is not defined as maskelynite as compositional analyses were stoichiometric. Mineral compositions in NWA 12241 and other intermediate poikilitic shergottites are similar in both poikilitic and non-poikilitic textures [2–6].

Olivine-pyroxene-spinel oxybarometry and olivine-spinel geothermometry calculations were conducted on both poikilitic and non-poikilitic textures in eight mineral assemblages [7, 8, http://melts.ofm-research.org/CORBA_CTserver/Olv_Spn_Opx/index.php]. Oxygen fugacities (fO_2) range from –4.3 to –3.6 relative to the Fayalite-Magnetite-Quartz (FMQ) buffer for poikilitic textures and from FMQ –3.2 to –1.7 for non-poikilitic texture. These oxygen fugacities are similar to those of the intermediate poikilitic shergottites Lewis Cliff (LEW) 88516 and Allan Hills (ALH) 77005 with increasing fO_2 from poikilitic to non-poikilitic textures.

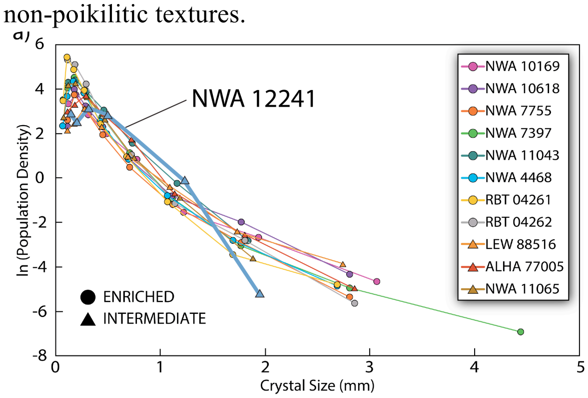

Fig. 1: Crystal Size Distribution plot comparing NWA 12241 of all poikilitic shergottites from [2]. Circle = enriched, triangle = intermediate shergottites.

Oxygen fugacities and mineral compositions of NWA 12241 imply that it had a similar petrogenesis to the other intermediate and enriched poikilitic shergottites, with initial formation of poikilitic textures at crust-mantle boundary depths and subsequent formation of non-poikilitic textures during ascent [2–4]. The change from poikilitic to non-poikilitic texture formation is accompanied by degassing and/or autoxidation as evident from the increase of melt fO_2.

Emplacement of NWA 12241. Quantitative textural analyses were conducted on the olivine population (n = 664) in poikilitic and non-poikilitic zones of NWA 12241. The resultant Crystal Size Distribution (CSD) plot has a negative and concave-up overall slope of –3.54 ± 0.16 mm^{-1} and intercept of 4.42 ± 0.11, with steeper slope for poikilitic olivine (–3.84 versus –3.51 mm^{-1}) (Fig. 1). The CSD data have similar best-fit ratios and olivine grain sizes to poikilitic shergottites, with CSD slopes most similar to the enriched poikilitic shergottite NWA 10169 [2].

Parental melt compositions. Northwest Africa 12241 has bulk Mg# of 62, and major element compositions that are similar to other poikilitic shergottites [2, 6]. The bulk $(La/Yb)_{CI}$ of NWA 12241 is 0.66 and its rare earth element (REE) pattern exhibits enrichment in La (Fig. 2), likely due to terrestrial contamination [9]. Northwest Africa 12241 has V/Sc (8.3), Nb/Y (0.09), and Zr/Y (2.9), similar to most intermediate shergottites [9]. Based on its trace element composition, NWA 12241 is an intermediate poikilitic shergottite (Fig. 2) [2], as also suggested by previously reported ε_{Nd} and ε_{Hf} compositions measured by [10].

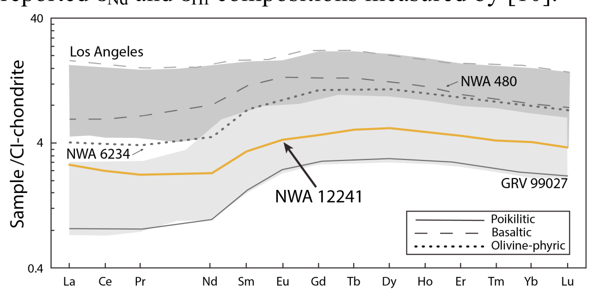

Fig. 2: CI-normalized REE patterns of NWA 12241 compared to other poikilitic shergottite. Dark grey envelope = enriched poikilitic shergottites and light grey envelope = intermediate poikilitic shergottites. See [2] for references.

Shock history of NWA 12241. The studied thin sections of NWA 12241 do not contain strong evidence for shock metamorphism: no shock melt and no olivine darkening were seen. We observed birefringent, and isotropic and amorphous plagioclase in NWA 12241: amorphization was unevenly distributed throughout plagioclase grains (Fig. 3). To date, plagioclase has not been reported in poikilitic shergottites other than the depleted poikilitic shergottite Asuka (A) 12325 [11, 12]. Birefringent plagioclase and amorphous plagioclase have also been found in the augite-rich depleted shergottites NWA 8159 and NWA 7635 [13, 14]. Plagioclase was also identified in the olivine-phyric shergottites NWA 4480 (intermediate) and NWA 10146 (depleted) [15, 16].

The presence of birefringent plagioclase with intermediate chemistry indicated that NWA 12241 underwent an ejection event involving shock pressures <23 GPa [13]. However, maskelynite may not be a reliable indicator of peak shock pressures as amorphization can be heterogeneous within samples [17]. This is the case for NWA 12241: amorphization occurred at pressures between 8 GPa and 11 GPa and 17.6 GPa for anorthite with strain rate at 10^{-3} s^{-1}. Additionally, maskelynite can retain crystallinity up to pressures of 45 GPa [18]. Similar plagioclase textures and crystallinity are observed in NWA 8159, which has estimated shock pressures between 15 and 23 GPa [13]. Thus, NWA 12241 also likely underwent shock pressures of 15–23 GPa. Poikilitic shergottites exhibit a large range of shock metamorphism, from NWA 12241 to highly shocked meteorites, such as NWA 4797 and NWA 6342, which have possibly undergone shock pressures of 75–90 GPa [19, 20].

Conclusions: The bulk and mineral compositions and bimodal texture of NWA 12241 indicate that it was formed and emplaced similarly to the other poikilitic shergottites. However, the presence of birefringent plagioclase suggests that this meteorite may have originated from a different ejection event than most other shergottites, similar to the depleted poikilitic shergottite A 12325 [12]. Thus, this meteorite samples a new location at the martian surface.

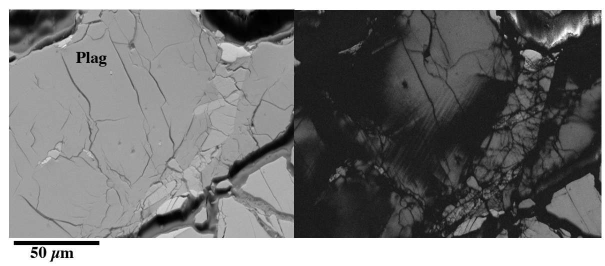

Figure 3: EBSD analyses of a plagioclase grain shown as: (left) a forescatter electron image and (right) a band contrast (BC) Where bright regions yield good quality EBSD patterns (i.e., crystalline and black regions yield no EBSD patterns (i.e., amorphous).

References: [1] Udry et al. (2020) *JGR :Planets*, doi:10.1029/2020JE006523. [2] Rahib et al. (2019) *GCA*, **266**, 463–496. [3] Combs et al. (2019) *GCA*, **266**, 435–462. [4] Howarth et al. (2014) *Meteoritics & Planet. Sci.*, **49**, 812–830. [5] Lin (2013) *Meteoritics & Planet. Sci.*, **48**, 1572–1589. [6] Usui (2010) *GCA*, **74**, 7283–7306. [7] Sack and Ghiorso (1989) *Contrib. Miner. Petrol.,* **102**, 41–68. [8] Sack and Ghiorso (1991) *Am. Mineral.*, **76**, 827–847. [9] Crozaz et al. (2003) GCA, **67**, 4727–4741. [10] Lapen et al. (2019) *LPSC XLX*, Abstract #2605. [11] Debaille et al. (2019) *10th Symposium on Polar Science*, Abstract #0219. [12] Takenouchi et al. (2019) *10th Symposium on Polar Science*, Abstract #0089. [13] Herd et al. (2017) *GCA*, **218**, 1–26. [14] Lapen et al. (2017) Science Advances, 3: e1600922. [15] Irving et al. (2016) *LPSC XLVII*, Abstract #2330. [16] Walton et al. (2016) *LPSC XLVII*, Abstract #1639. [17] Sims et al. (2019) *EPSL*, **507**, 166–174. [18] Ostertag (1983) *JGR*, **88**, B364–B376. [19] Kizovski et al. (2019) *Meteoritics & Planet. Sci.,* **54**, *768–784.* [20] Walton et al. (2012) *Meteoritics & Planet. Sci.,* **47**, 1449–1474.