FORMATION AND EMPLACEMENT OF MARTIAN POIKILITIC SHERGOTTITES

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Poikilitic shergottites: Poikilitic shergottites make up >20% of the current martian meteorite collection, with a total of 27 samples. These meteorites are intrusive gabbroic and lherzolitic rocks and represent igneous materials recording important processes in the martian crust. Poikilitic shergottites originate from enriched [high bulk $(La/Yb)_{CI}$ ratios, high $^{87}Sr/^{86}Sr$ and $^{187}Os/^{188}Os$, and low εNd and εHf] [e.g., 1-10] to intermediate [moderate bulk $(La/Yb)_{CI}$ ratios, $^{87}Sr/^{86}Sr$, $^{187}Os/^{188}Os$, εNd, and εHf compared with martian shergottites as a whole] sources [e.g., 1-9]. No depleted poikilitic shergottites have been identified yet. Poikilitic shergottites show a characteristic bimodal texture representing polybaric crystallization from the crust/mantle boundary (early stage) to hypabyssal (late stage) depths, which allows examination of parental magma evolution from the interior of Mars to the surface [9]. Here we present a comprehensive study of the largest suite of poikilitic shergottites to date to better constrain their formation, emplacement, and links with the other shergottites. We measured bulk rock major and trace element compositions, mineral major element compositions, oxygen fugacity (fO_2) values, crystallization temperatures, and quantitative textural analyses on eleven samples (Northwest Africa – NWA – 7755, NWA 7397, NWA 4468, NWA 10169, Allan Hills – ALHA – 77005, Lewis Cliff – LEW – 88516, Roberts Massif – RBT – 04261/2, and four newly recovered samples: NWA 11065, NWA 11043, NWA 10961, and NWA 10618).

Results and discussions:

Source of poikilitic shergottites. Bulk rock $(La/Yb)_{CI}$ allows determination of shergottite source compositions, with enriched shergottites distinguished by $(La/Yb)_{CI}$ values ≥0.8 and intermediate shergottites $(La/Yb)_{CI}$ values between 0.30–0.50 [e.g., 2, 3, 8–12]. Northwest Africa 11043 originated from a light rare earth element (LREE)-enriched mantle source (the greatest $(La/Yb)_{CI}$ value of our samples = 1.54), whereas the newly recovered NWA 10961 and NWA 11065 sampled an intermediate source. The bulk Zr/Y-Nb/Y and $^{187}Os/^{188}Os$ composition of NWA 11043 falls within the fields of intermediate shergottites [13, 14].

Oxygen fugacities. We calculated fO_2 for the different poikilitic shergottites using the olivine-pyroxene-spinel oxybarometer and we observe consistent increases in fO_2 from early-stage to late-stage textures ranging from 1.2 to 2.0 log units below the Quartz-Fayalite-Magnetite (QFM) buffer for enriched poikilitic shergottites, and 2.0 to 2.9 log units for intermediate poikilitic shergottites. The fO_2 increase indicates that degassing was likely an important process in the formation of poikilitic shergottites, similar to olivine-phyric shergottites [15]. In addition, we do not observe correlation between fO_2 and LREE enrichment, although it was previously suggested to represent different shergottite reservoirs [16]. Thus, fO_2 is not a reliable tool to distinguish shergottite sources.

Emplacement of poikilitic shergottites. Crystal size distribution (CSD) analyses of the olivine population show similar patterns for all poikilitic shergottites, including olivine accumulation, indicating similar emplacement processes for all of these rocks. Using a combination of geochemical, mineralogical, and quantitative textural data, we suggest that the enriched poikilitic shergottites were emplaced in various shallow sills and at different geographical locations compared with of intermediate poikilitic shergottites. In addition, the Ti/Al of poikilitic pyroxenes are relatively similar for all poikilitic shergottites, suggesting that early mineral assemblages formed at the crust/mantle boundary of Mars. Thus, the presence of at least two magmatic chambers at these depths on Mars, possibly resulting in formation of the different enriched and intermediate shergottites, is likely [15].

References: [1] Lin (2013) *Meteoritics & Planet. Sci.* 48:1572–1589. [2] Lodders (1998) *Meteoritics & Planet. Sci.* 33. [3] McSween et al. (2015) *Am. Min.* 100:2380–2395. [4] Mikouchi and Kurihara (2008) *Polar Science* 2: 175–194. [5] Lin et al. (2005) *Meteorit. Planet. Sci.* 40:1599–1619. [6] Usui (2010) *GCA* 74:7283–7306. [7] Walton et al. (2012) *Meteorit. Planet. Sci.* 47:1449–1474. [8] Combs et al. (2018) *LPSC XLIX*, Abstract #2083. [9] Howarth et al. (2014) *Meteorit. Planet. Sci.* 49:812–830. [10] Tait and Day (2018) *EPSL* 494:99-108. [11] Barrat et al. (2002a) *Meteorit. Planet. Sci.* 37:487–499. [12] Filiberto et al. (2012) *Meteorit. Planet. Sci.* 47:1256–1273. [13] Day et al. (2018) *Nat. Comm.* 9:4799. [14] Paquet et al. (2019) *LPSC L*, Abstract #1456. [15] Herd (2019) *LPSC L*, Abstract #2746. [16] Castle and Herd (2018) *Meteorit. Planet. Sci.* 53:1341–1363.