MARTIAN METEORITE RAIN 2021: PETROLOGY AND BULK ELEMENTAL COMPOSITION OF MORE SHERGOTTITES AND NAKHLITES.

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Introduction: The number of unpaired Martian meteorites continues to increase at the rate of at least 15 per year. Since our 2020 report [1], 20 more distinct specimens (including two new nakhlites) have been recovered or provided for scientific studies, making the present total 159, of which 141 are various sorts of shergottites with differing textures and bulk compositions.

Nakhlites NWA 13368 and NWA 13669: The recovery of these two specimens brings the total number of unpaired nakhlites to 13. We have described NWA 13368 and its potassic chlorohastingsite amphibole elsewhere [2, 3]. NWA 13669 (139.2 grams) is composed predominantly of zoned augite ($Fs_{22.8\text{-}27.8}Wo_{39.5\text{-}40.5}$, FeO/MnO = 31-35; rim $Fs_{37.6}Wo_{34.9}$), olivine ($Fa_{72.3\text{-}74.5}$, FeO/MnO = 47-48) and zoned pigeonite ($Fs_{56.4\text{-}62.8}Wo_{11.6\text{-}6.5}$, FeO/MnO = 34-35) with ferrosilite rims ($Fs_{70.9}Wo_{3.0}$), plus accessory birefringent plagioclase ($An_{34.3\text{-}37.2}Or_{3.3\text{-}3.0}$), titanomagnetite, chlorapatite, pyrrhotite and interstitial mesostasis (K-rich glass with microlites of pigeonite). Olivine grains contain thin veinlets of Fe-rich "iddingsitic" material (see Figure 1), which judging from low oxide sums is hydroxylated.

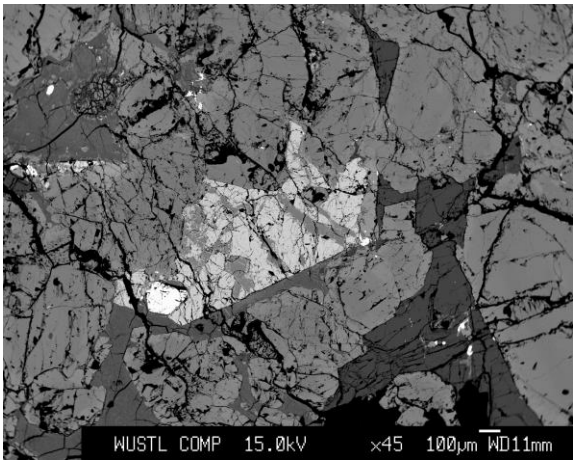

Figure 1. *BSE image of NWA 13669. Note the "iddingsite" veinlets in olivine (center), plagioclase (darkest gray) and titanomagnetite (largest bright grain).*

Enriched Mafic Aphyric Shergottites: Enriched mafic aphyric shergottites (generally like Shergotty, but varying in grainsize from fine-intergranular to diabasic) continue to be the most common specimens recovered. Most are likely pairings to NWA 12262 and NWA 12269, but two specimens from Libya (NEA 009, NEA 011) may be distinct examples. All of these specimens are characterized by strongly zoned clinopyroxene and lath-like maskelynite grains plus accessory Fe-Ti oxides, phosphates, alkali feldspar and FeS (see Figure 2).

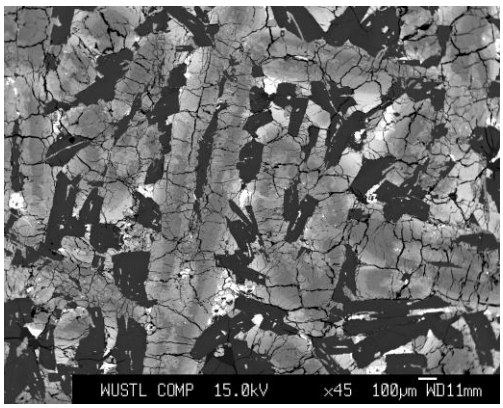

Figure 2. *BSE image of aphyric shergiottite NEA 011*

Mafic Gabbroic Shergottites NWA 13227, NWA 13440, NWA 13467 and NWA 13474: Since last year five different gabbroic or microgabbroic specimens with equigranular textures but varying grainsizes have been studied. NWA 13227 is olivine-bearing and exhibits the same distinctive sheaf-like habit of maskelynite grains shown by olivine-free specimens NWA 10761, NWA 11300 and NWA 12323 (see Figure 3a and [4]). All four of these specimens have intermediate ITE (incompatible trace element) signatures, but we cannot imagine the correlation with maskelynite habit to be anything other than fortuitous. NWA 13467 and NWA 13474 are also olivine-bearing with a different maskelynite habit (see Figure 3b).

Poikilitic Shergottite NWA 13276: This specimen (paired with NWA 13250 and several others) consists of oikocrysts of compositionally-zoned pyroxene ($Fs_{21.5\text{-}30.0}Wo_{3.4\text{-}14.0}$,; $Fs_{15.5\text{-}18.5}Wo_{27.6\text{-}36.7}$; FeO/MnO = 23-32) enclosing chadacrysts of shock-darkened olivine ($Fa_{33.1\text{-}37.1}$, FeO/MnO = 46-53) and interstitial equigranular regions composed of the same phases plus lath-like maskelynite ($An_{57.5\text{-}59.5}Or_{1.6\text{-}0.9}$) and accessory Ti-poor chromite, Ti-chromite, ilmenite, merrillite, pyrrhotite, pentlandite and baddeleyite (see Figure 4).

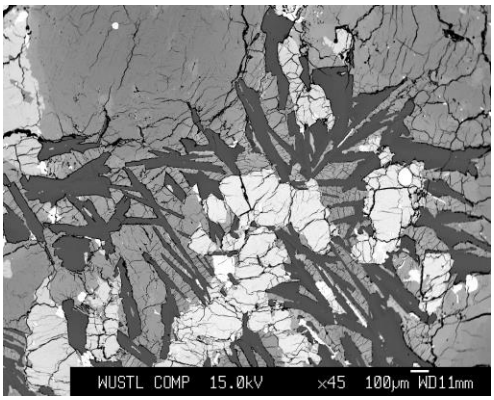

Figure 3. *BSE images of NWA 13227 (above) and NWA 13474 (below). Note the melt inclusions within olivine surrounded by subradial re-expansion cracks*

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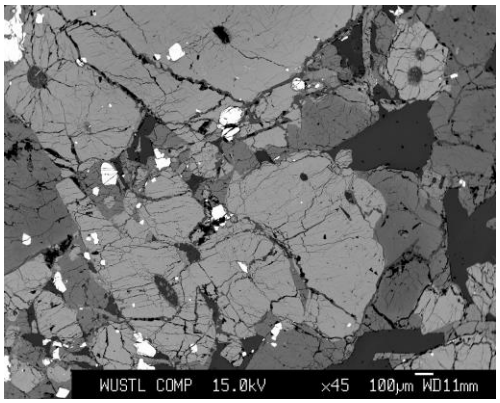

Figure 4. *pXPL image of NWA 13276. FOV =10 mm.*

Olivine-Phyric Shergottites (*including Northeast Africa 015 with secondary halite*): At least five different olivine-phyric specimens were recovered in northern Africa during 2020, but apart from a pairing to Rafsa 001 only NEA 015 has been formally classified. The latter 632 gram fusion-crusted specimen is notable for the pervasive presence of minor secondary (probably terrestrial) halite associated with calcite and gypsum in microfractures within pyroxene (see Figure 5).

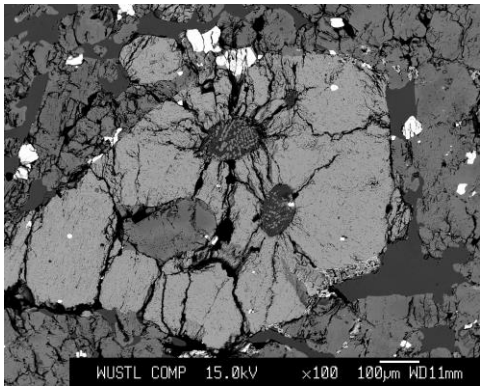

Figure 5. *BSE image of NEA 015, showing melt inclusions in an olivine phenocryst. Halite (light gray) is visible at upper right within pyroxene (medium gray).*

A Persistent ITE Trichotomy: Representative bulk rock powders have been analyzed for major and trace elements by ICP-OES and ICP-MS. In Figure 6 we have summarized the REE patterns for **90** analyzed shergottites, which still fall into ***three*** distinct groups (with only a few exceptions such as NWA 4480 and NWA 11509). We interpret this persistent trichotomy in ITE (and related radiogenic isotopic compositions) to imply that most young (<2.4 Ga) Martian plume magmas were sourced from three separate mantle domains, that experienced no convective intermixing since very ancient planet-scale differentiation events.

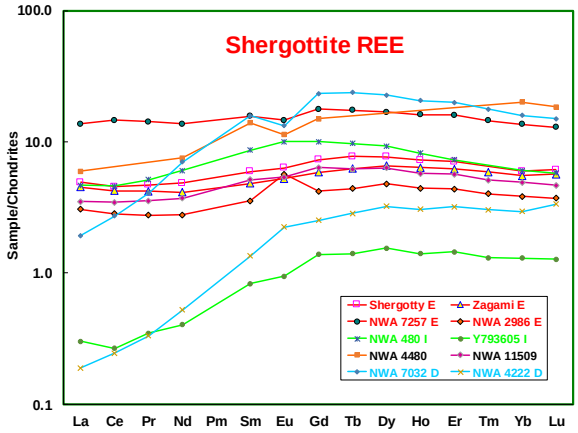

Figure 6. *Chondrite-normalized REE plot for whole rock shergottites emphasizing the abundance ranges for the three major incompatible trace element groups (*D = *depleted*, I = *intermediate*, E = *enriched)*

References: [1] Irving A. *et al*. (2020) *LPS* **LI**, #2459 [2] Carpenter P. and Irving A. (2020) *Fall AGU Mtg.*, #V012-01 [3] Carpenter P. *et al.* (2021) *LPS* **LII**, this conference [4] Stephen N. and Irving A. (2021) *LPS* **LII**, this conference.

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