GEOCHEMISTRY OF INTERMEDIATE OLIVINE-PHYRIC SHERGOTTITE NORTHWEST AFRICA 6234.

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Introduction: The SNC meteorites are our only samples from Mars and are, therefore, the key source of information regarding its igneous history and geochemical evolution [e.g., 1, 2]. Shergottites, which form the largest sub-group of the SNC meteorites, provide some of the most significant insights into the igneous history of Mars due in part to their petrological and geochemical diversity. Among petrological divisions of shergottites the olivine (ol)-phyric shergottites [3] are extremely useful in extending our knowledge of the interior of Mars, because they have many primitive characteristics. Here we present major- and trace-element geochemistry, Li isotope composition and abundance, and Re-Os isotope and highly-siderophile element abundance data for the ol-phyric shergottite NorthWest Africa 6234 (NWA 6234).

Meteorite NWA 6234 was found in 2009 at an undisclosed location in Mali and purchased by an anonymous collector in February 2010. It was a 55.7 g partly fusion-crusted stone. It is thought to have experienced a moderate shock stage and limited weathering. For this study, we purchased a 3.3 gram slice of the meteorite from Marmet Meteorites, and confirmed that it matched the description of NWA 6234 [4, 5].

Previous Work. NWA 6234 is thought to be paired with stones NWA 2990, 5960, and 6710 [5]. To date, work has focused mainly on NWA 2990 [4, 6-8]. Based on the original bulk chemical analyses NWA 2990 was suggested to represent a magma composition, consistent with its fine grained texture [7]. This original bulk composition is much more evolved than NWA 5789 and Yamato 980459, two meteorites that are thought to represent mantle-derived melts [9, 10]. This suggests that NWA 2990 (and its paired stones, NWA 6234, 5960, and 6710) are unique stones that may represent either: (1) a fractionated melt and not a primitive mantle derived melt, or (2) a melt from a reservoir with high Fe/Mg in the martian mantle. However, recent work on NWA 6234 (including the work presented here) has suggested that preliminary data on NWA 2990 may not be representative [4].

Results: The bulk chemical composition of NWA 6234 is fairly typical of martian meteorite basalts. NWA 6234 is an Al-poor, Fe- and Mg-rich picrite rock, with 17.1 wt. % MgO. The rare earth element (REE) pattern of NWA 6234 is characterized by having similar relative and absolute abundances of the middle- and heavy REE (MREE and HREE, respectively) to enriched ol-phyric shergottites such as LAR 06319, NWA 1068, and Dhofar 378, but relatively depleted abundances of light REE (La-Nd). This LREE depletion is similar to ol-phyric shergottites such as Dhofar 019, Yamato 980459, DaG476, and SaU 005/094 (**Figure 1**). The measured δ^7Li value of NWA 6234 is +3.2±1‰ and the Li concentration is 2.9 ppm. These measurements are consistent with previous bulk rock measurements of δ^7Li values of martian meteorites, which have mostly fallen within the range of +3.6 to +5.2‰ and 1.8 to 12.2 ppm [11, 12]. The chondrite-normalized HSE pattern for NWA 6234 is characterized by high (Pt, Pd, Re)/(Os, Ir, Ru), similar to the patterns observed for some ol-phyric and basaltic shergottites [13], and for terrestrial intraplate basalts [e.g., 14]. The measured $^{187}Os/^{188}Os$ ratio of NWA 6234 (0.1367) is similar to that measured for NWA 2990 (0.1387) and lies within the range of $^{187}Os/^{188}Os$ measured previously for ol-phyric shergottites (0.1277-0.1481; [13]).

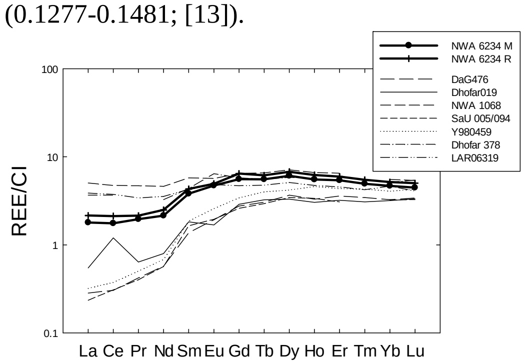

Fig 1. REE normalized to CI chondrites [15] for NWA 6234 compared to olivine-phyric shergottites.

Bulk Composition Discrepancy: The bulk composition of NWA 6234 has significantly higher FeO and MgO and significantly lower SiO_2, Al_2O_3 and CaO compared to that reported by [6] for the presumably paired meteorite NWA 2990. It was hypothesized that the reported NWA 2990 composition represents a sample with an unrepresentatively low proportion of olivine phenocrysts [4]. To test this, we used a simple mass balance calculation to compare the composition of NWA 6234 to mixtures of the reported NWA 2990 composition and that of phenocryst olivine [4-6]. To produce the NWA 6234 bulk composition, ~30-40 wt% olivine of Fo_{74} or Fo_{68} must be added to the published NWA 2990 bulk composition. This is significantly more olivine than seen in most ol-phyric shergottites [e.g., 3, 7] and implies that the compositional differences between these two meteorites are not caused by underrepresentation of the abundance of olivine phenocrysts. It remains possible that NWA 2990 and NWA 6234 are not paired, but their similarity in $^{187}Os/^{188}Os$ and HSE abundances suggest a close relationship.

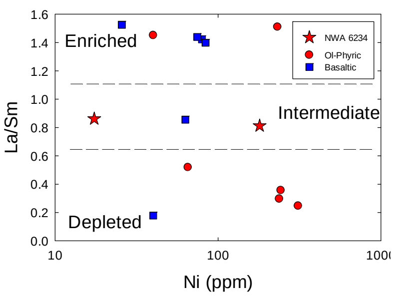

Fig 2. La/Sm vs. Ni for NWA 6234 compared with ol-phyric and basaltic shergottites showing the differences between enriched, depleted and intermediate compositions (modified from [16]).

Discussion: Basaltic shergottites are typically categorized as either enriched or depleted in rare earth elements (REE) [e.g., 16, 17, 18]. NWA 6234 falls into an intermediate category **(Fig 2)**. No other ol-phyric shergottite falls into this category; however, basaltic shergottite NWA 480 has a similarly intermediate composition. This suggests a unique source region for NWA 6234 that has similarities to the source region of NWA 480 but has not been previously sampled by other ol-phyric shergottites. Given the overall similarity of HSE CI-chondrite normalized patterns for NWA 6234 with other intermediate MgO shergottites (e.g., EETA 79001; **Fig 3**), we argue that NWA 6234 and paired 2990/5960/6710 may represent a new grouping of intermediate shergottites; an important series of rocks in understanding the cause of enrichment and depletion in shergottites.

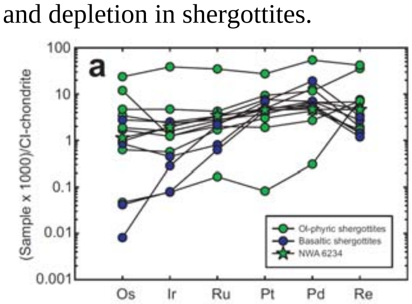

Figure 3. Chondrite-normalized HSE patterns for NWA 6234, basaltic and ol-phyric shergottites. Basaltic and ol-phyric shergottite data is from [13].

The whole-rock abundance and isotopic composition of Li in NWA 6234 are within uncertainties of the composition of other martian meteorites, including basaltic shergottites [11, 12]. The similarity of δ^7Li of NWA 6234 to the other shergottites is likely not coincidental and may suggest that the shergottites' mantle sources have similar δ^7Li (approximately the +4‰ inferred for the inner solar system) [11,12]. If so, the Li isotopic composition of the martian mantle must have been immune to the processes that caused extreme fractionation in other isotopic systems, including Rb-Sr, Sm-Nd, Lu-Hf, and Re-Os [13, 16-18]. On the other hand, the similarity may suggest similar martian post-magmatic alteration, as suggested for Os isotope ratios in some other martian meteorites [19, 20].

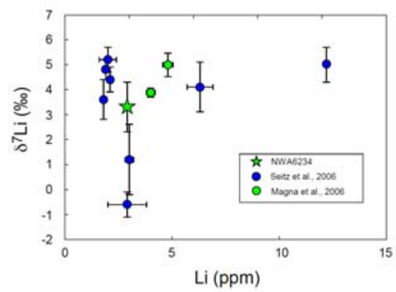

Fig. 4 Li concentration and isotope composition for NWA 6234 compared with other martian meteorites [11,12].

Conclusions: From its major and trace element budget NWA 6234 is is an ol-phyric shergottite with trace element characteristics similar to basaltic shergottite NWA 480 and isotopic characteristics similar to ol-phyric shergottite NWA 2990. In terms of REE, it (along with its putative paired stones) is neither enriched or depleted and thus is distinct from any other ol-phyric shergottite. This suggests a unique source region for NWA 6234, which has trace element and isotopic similarities to the source region of NWA 480, but has not been previously taped by other ol-phyric shergottites.

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