TRACE ELEMENT GEOCHEMISTRY OF NEW NAKHLITES FROM THE ANTARCTIC AND THE SAHARAN DESERT: FURTHER CONSTRAINTS ON NAKHLITE PETROGENESIS ON MARS.

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Introduction: Although numerous new meteorites of purported martian origin have been found in recent years, most of these have been classified as belonging to the shergottite type. In fact, of the approximately two dozen meteorites thought to have originated on Mars, ~70% are shergottite basalts. Therefore, the recent finds of two paired nakhlites from the Antarctic (Y000593 and Y000749) [1] and another two from the Sahara (NWA 817 and NWA 998) [2, 3] have doubled the number of martian pyroxenites available for study. Previously known nakhlites (Nakhla, Governador Valadares and Lafayette) are virtually identical in terms of their petrologic and geochemical characteristics (e.g., [4, 5]) and, thus, constraints on the petrogenesis of new and potentially diverse members of the nakhlite class are anticipated to provide new insights into the magmatic history of Mars. Towards this goal, we have made an investigation of the trace element systematics in each of these new nakhlites. Results of our work on NWA 817 were presented earlier [6]; here we report new ion microprobe trace element data for the paired Y000593/749 nakhlites and the NWA 998 Saharan nakhlite.

Analytical Techniques: Polished thin sections of each of the samples studied here were initially characterized with the University of Chicago JEOL JEM-5800LV scanning electron microprobe. Subsequently, the concentrations of selected trace and minor elements (including the rare earths) were measured in individual minerals using the Washington University Cameca IMS-3f ion microprobe.

Results and Discussion: As is the case for non-desert nakhlites, the whole rock REE budgets of Y000593/749 and NWA 998 appear to be dominated by apatite, even though this mineral is present in only trace modal abundances in each of these rocks. In the nakhlites, this mineral typically has a LREE-enriched pattern that mimics that of the whole rock (Fig. 1). (It is noted here that although whole rock REE abundances have not been reported so far for NWA 998, the whole rock REE patterns of Y000593 and Nakhla are similar [7].) As previously discussed for the non-desert nakhlites [5], this characteristic suggests closed system fractional crystallization of the parent melt of each of the nakhlites.

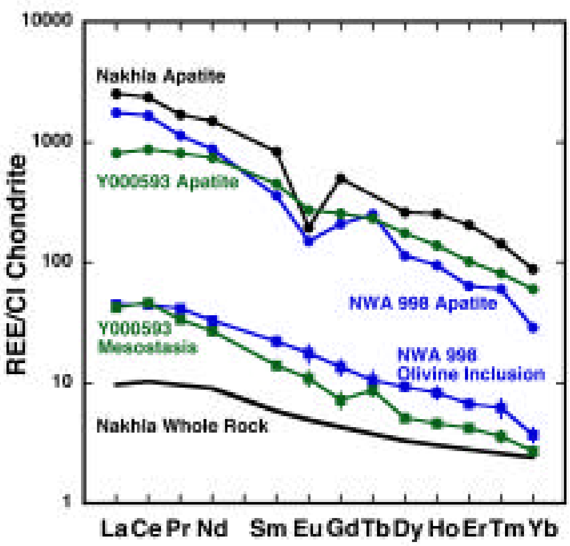

Figure 1. Representative REE abundances in apatites of Y000593 and NWA 998; apatite [5] and whole rock [9] data for Nakhla are shown for comparison. Also shown are REE concentrations in mesostasis of Y000593 and in a magmatic inclusion in an olivine of NWA 998.

Figure 1 also shows REE abundances in the mesostasis of Y000593 and in a glassy magmatic inclusion of NWA 998. Both have similar LREE-enriched patterns even though each represents a different stage in the evolution of their respective parent melt (with the magmatic inclusion in olivine representing an early stage, and the mesostasis a late stage). The almost identical REE patterns suggest that the Y000593 and NWA 998 parent melts not only had LREE-enriched patterns but also may have originated from partial melting of a similar source. However, the fact that they also have comparable absolute REE concentrations (although having formed at very different stages in the evolution of their parent melts) indicates that the parent melt of Y000593 was much less evolved and had lower REE concentrations than that of NWA 998.

REE patterns of plagioclases in the nakhlites studied here differ significantly in their absolute concentrations (La ~6-13×CI in Y000593/749 and ~1-3×CI in NWA 998) and sizes of Eu anomalies (Eu/Eu* ~5 in Y000593/749 and ~60 in NWA 998) (Fig. 2). Olivines in Y000593/749 and NWA 998 are characterized by HREE-enriched patterns (Fig. 2); the upturn in the

NWA 998 LREE pattern may be due to addition of LREE during terrestrial alteration.

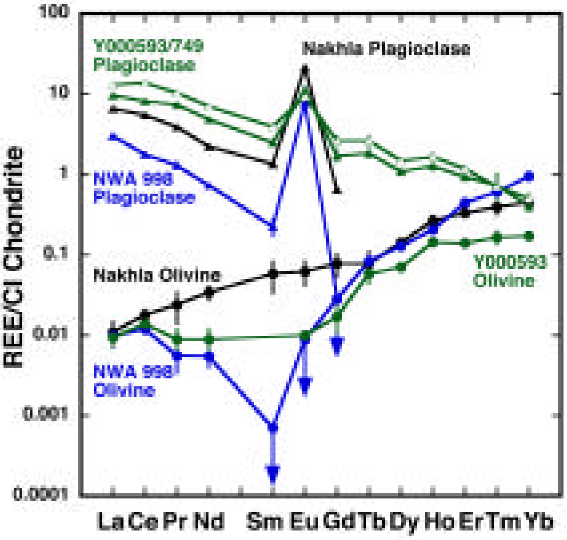

Figure 2. Representative REE abundances in plagioclases and olivines of Y000593 (solid symbols), Y000749 (open symbols) and NWA 998. Nakhla data [5] are shown for comparison. Downward pointing arrows indicate upper limits.

Augites of Y00593/749 and NWA 998 have the concave-downward patterns that are characteristic of high-Ca pyroxenes in the nakhlites (Fig. 3). NWA 998 is unusual among nakhlites in having magmatic low-Ca pyroxene [3]. This mineral has a V-shaped REE pattern suggestive of the addition of LREE due to terrestrial alteration. Similar evidence of LREE enrichment is commonly observed in meteorites recovered from hot deserts [8].

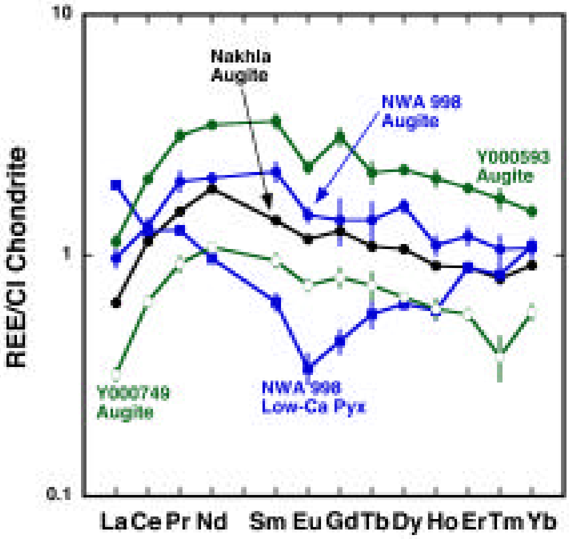

Figure 3. Representative REE abundances in pyroxenes of Y000593 (solid symbols), Y000749 (open symbols) and NWA 998. Data for Nakhla [5] are shown for comparison.

As is the case for the previously studied nakhlites [5, 6], pyroxenes in Y000593/749 and NWA 998 are extensively zoned in terms of trace and minor element concentrations. Additionally, as can be seen in the plot of Y versus Ti abundances (Fig. 4), augites of Y000593/749 and NWA 998 fall along the same trend as that defined by augites in NWA 817 and the non-desert nakhlites. However, the ranges of trace and minor element compositions in each nakhlite are somewhat different. In particular, among all the nakhlites, augites of Y000593/749 have some of the lowest incompatible element abundances, whereas those of NWA 817 have the highest concentrations of such elements (Fig. 4). This is consistent with the suggestion (also inferred from REE abundances in the mesostasis) that the Y000593/749 parent melt has the least evolved composition among the nakhlite parent melts.

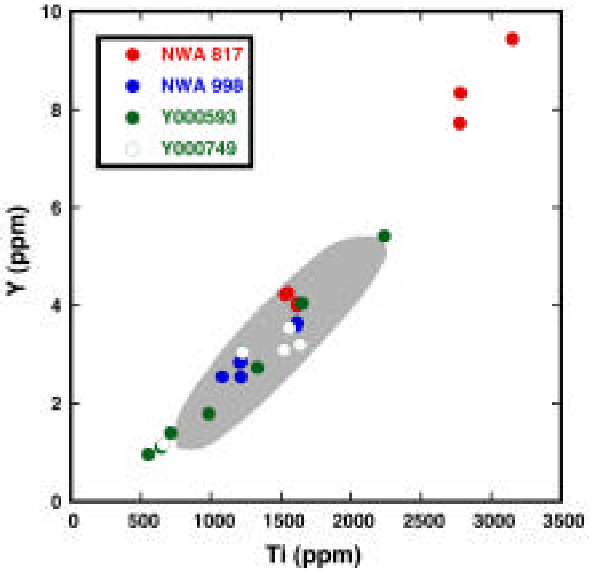

Figure 4. Y versus Ti concentrations in augites of Y000593 (solid symbols), Y000749 (open symbols) and NWA 998. Also shown are data for NWA 817 augites [6]. Range of compositions in augites of non-desert nakhlites [5] are shown as the shaded area.

In conclusion, the data reported here show that the new Antarctic and Saharan nakhlites appear to be petrogenetically related to the non-desert nakhlites and likely originated from similar sources in the martian mantle. Nevertheless, the new nakhlites also show clear differences that suggest that their parent melts were fractionated to different degrees prior to crystallization.

References: [1] Imae N. et al. (2002) *LPS XXXIII,* Abstract #1483. [2] Sautter V. et al. (2002) *EPSL, 195,* 223. [3] Irving A. J. et al. (2002) *MAPS, 37,* A70 . [4] Harvey R. P. and McSween H. Y., Jr. (1992) *GCA, 56,* 1655. [5] Wadhwa M. and Crozaz G. (1995) *GCA, 59,* 3629. [6] Wadhwa M., Barrat J. A. and Crozaz G. (2001) *MAPS, 36,* A217-A218. [7] Nakamura N. et al. (2002) *Antarct. Meteorites XXVII,* 112. [8] Crozaz G., Floss C. and Wadhwa M. (2003) *GCA,* submitted. [9] Nakamura et al. (1982) *GCA, 46,* 1555.