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THE NAKHLA PARENT MELT: REE PARTITION COEFFICIENTS AND CLUES TO MAJOR ELEMENT COMPOSITION. G. McKay (SN2, NASA-JSC, Houston, TX,77058) L. Le, and J. Wagstaff (Lockheed ESCO, 2400 NASA Rd. 1, Houston, TX 77058)

Introduction. Nakhla is one of the SNC meteorites, generally believed to be of Martian origin. It is a medium-grained augite-olivine cumulate with a variolitic groundmass of sodic plagioclase, alkali feldspar, and Fe-rich pyroxenes and olivine [e.g., 1]. One of the major tasks in deciphering Nakhla's petrogenesis is determining the composition of its parent melt. Gaining an understanding of the composition and petrogenesis of this parent melt may help unravel Nakhla's relationship to the other SNCs, and provide clues to Martian petrogenesis in general. Our experimental partitioning studies provide new information that helps constrain both the major and trace element composition of the Nakhla parent melt.

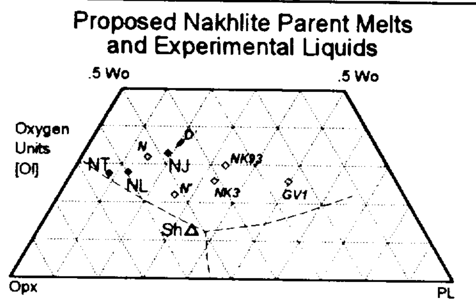

Fig. 1. Projection from Ol showing our quenched melt compositions (NT,NL,NJ), the Shergotty analog melt for which we previously measured DREE (Sh), and proposed nakhlite parent melt compositions N [4], NK3 and GV1 [5], NK93 and N' [6], and D' [1 & pers. comm.]. Multiple saturation curves are after Longhi and Pan [4]. The starting compositions for our experiments are based on Longhi & Pan's composition N (our NL), an abandoned Tennessee composition α (our NT) and a variation of Treiman's now-abandoned composition *D'* (our NJ).

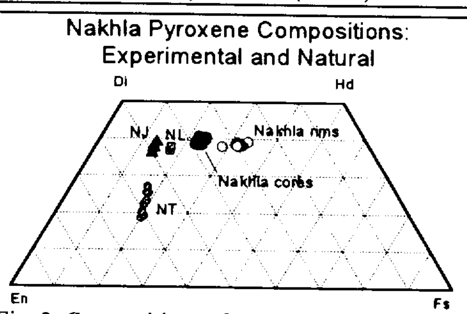

Fig. 2. Compositions of synthetic pyroxenes and Nakhla cores and rims. The same standards and analytical conditions were used for both natural and synthetic samples.

Can we use Shergotty partition coefficients for Nakhla? One approach to determining parent melt composition is to invert the trace element abundances of cumulus minerals. Earlier, we applied this approach to Shergotty pyroxenes [2] with good results. Success depends on accurate partition coefficients. For our Shergotty study, we used REE partition coefficients that we had previously measured for an analog Shergotty parent melt [3]. Because of the similarity in pyroxene compositions, it is tempting to apply those D values to Nakhla. However, partition coefficients depend on many factors, including melt composition. Although pyroxene compositions of Nakhla and Shergotty are similar, the melt compositions may not be.

Proposed Nakhlite parent melts have a wide range of compositions (and have been a real moving target over the last two years). Some recent ones are shown in Fig. 1. Most differ substantially from the Shergotty melt we studied earlier (Sh, Fig. 1). For example, composition N of Longhi and Pan [4] is much lower in Al than Sh, while all compositions are higher in Wo. It is important to determine whether D values for these other melts differ significantly from the Shergotty values.

To address this issue, and to help evaluate whether low- or high-Al parent compositions are more consistent with Nakhla mineral compositions, we are studying partitioning and phase relations for three synthetic compositions, NL, NT, and NJ (Fig. 1). Using these synthetic mixes as starting compositions, we measured REE partition coefficients between liquidus augite and coexisting melt. Charges were doped with 0.5-2% REE oxide, held on Pt wire loops in gas mixing (CO/CO_2) furnaces for four days at 1200°C - 1230°C at QFM. Quenched charges were analyzed with the JSC electron microprobe, along with pyroxenes from Nakhla, to facilitate direct comparison. We reported results for NT last year. This year, we have completed our study of NL and NJ.

Experimental Results. Quenched charges contain glass and a few % augite. Pyroxene compositions are shown in Fig. 2. As in our earlier Shergotty experiments, synthetic NT augite has nearly constant Fe/Mg but is zoned in Wo content. NL and NJ augites are much more homogeneous in major elements, and show a comparable range to Nakhla cores.

Both synthetic pyroxenes and Nakhla cores show significant zoning in minor elements, particularly Al and Ti (Fig. 3) and Cr (not shown). All NL and NT pyroxenes are lower in Al than any Nakhla analyses. However, about half the NJ pyroxenes have Al contents that overlap the low

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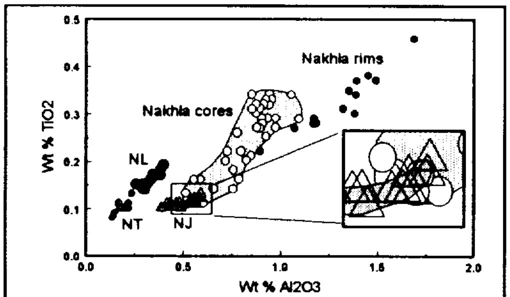

Fig. 3. Al and Ti in synthetic pyroxenes and Nakhla cores and rims. Inset shows enlargement of area in rectangle. NJ pyroxenes (dk gray field) overlap the most Al- and Ti-poor Nakhla cores (lt gray field), but are less Al-rich than majority of Nakhla cores.

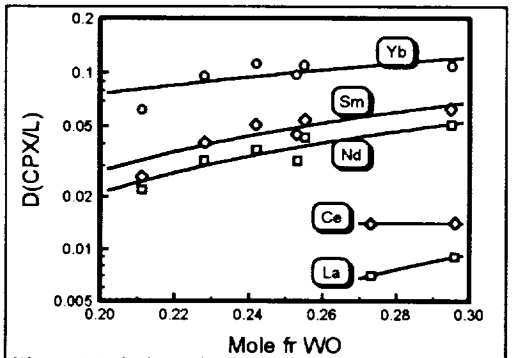

Fig. 4. Variation of D_{REE} with Wo content for NT pyroxenes. We observed a similar correlation with Wo in the Shergotty system [1].

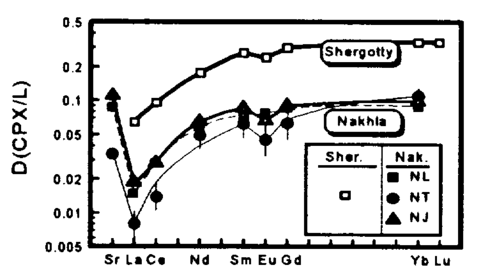

Fig. 5. REE distribution coefficients for clinopyroxenes in the Nakhla system, compared with Ds for pyroxenes of similar Wo in the Shergotty system [3]. Values for Nakhla composition NT are interpolated to Wo_{29} pyroxene, while values for NL and NJ are averages of >30 analyses (Wo_{43}) from several replicate runs. Shergotty patterns were calculated using equations in [3]. Shergotty values are significantly higher than those for Nakhla. Values for NT, NL, and NJ are quite similar, despite large differences in phase composition.

range of the Nakhla cores. This suggests that the Nakhla parent melt may have been similar in Al content to our NJ composition, while the more Al-rich parent melts in Fig. 1 *may* produce pyroxenes that are too Al-rich to match the Nakhla cores. This idea should be tested with further experiments.

As with our Shergotty experiments, we see correlations between D values and Wo content for the NT experiments (Fig. 4). To facilitate comparison with our Shergotty results, we use such correlations to interpolate D values for NT pyroxenes of Wo_{30}, the most Wo-rich NT pyroxenes. Fig. 5 compares D patterns for all our synthetic Nakhla pyroxenes (Wo_{30} NT values plus average values from NL and NJ pyroxenes of $Wo_{\sim 40}$) with a pattern from our Shergotty study extrapolated to Wo_{40} [3].

Discussion. Our new results on the NL and NJ compositions confirm our conclusion from last year based mainly on NT experiments: The Shergotty partition coefficients are higher than those for the Al-poor Nakhla starting compositions by factors of ~5. Thus, if Nakhla cumulus augites formed from a low-Al melt, use of the Shergotty D values to invert the augite REE contents will yield melt abundances that are several times too low. Moreover, the experimental Nakhla values are more than 10x lower than those which Nakamura *et al.* calculated for Nakhla clinopyroxene [8].

Note that D_{Sr} for NL and NJ is significantly higher than D_{Sm} or D_{Gd}, so that there is an apparent positive Sr anomaly, in contrast to the negative Eu anomaly. Although Sr analyses are difficult because of interferences, we have checked our analyses very carefully. Moreover the concentrations in these samples are fairly high, yielding reasonably good peak/bkg. Hence, we believe the positive Sr anomalies are probably not artifacts, but instead reflect real differences in the partitioning behavior of Eu^{2+} and Sr. Note also data are lacking for elements between Gd and Yb. We drew in smooth curves, but have no actual knowledge of how far up those curves might really go.

The major element composition of the Nakhla parent melt remains ambiguous. Our results point towards a composition of moderately low Al (Fig. 3), but experiments should be performed on more Al-rich compositions such as NK3 or NK93 (Fig. 1). Over the limited range of Al in our experiments, there appears to be only minor variation of D_{REE} other than that correlated with pyroxene Wo content. Finally, our synthetic pyroxenes have higher Mg/Fe than Nakhla cores (Fig 2). We have observed no significant effect of Mg/Fe on partition coefficients, although there may be a minor effect. Despite ambiguities in Al and differences in Mg/Fe, we believe that use of the partition coefficients in Fig. 5 will not lead to serious errors in estimating the REE content of the Nakhla parent melt.

References: [1] Treiman (1986) GCA 50, 1061. [2] Lundberg et al. (1983) GCA 52, 2147. [3] McKay et al. (1986) GCA 50, 927. [4] Longhi and Pan (1989) PLPSC 19, 451. [5] Harvey and McSween (1991) EPSL 111, 467. [6] Treiman (1993) GCA (submitted). [7] Treiman (1990) PLPSC 20, 273. [8] Nakamura *et al.* (1982) GCA 46, 1555.