PARENTAL MAGMAS OF THE NAKHLITES RE-EXAMINED. Ralph P. Harvey and Hany Y. McSween Jr., Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410 USA.

The nakhlite meteorites (Nakhla, Governador Valadares and Lafayette) are medium-grained augite-olivine cumulates such as might be found in differentiated shallow intrusions. They are members of the SNC group whose parent body is thought to be Mars; therefore, unravelling the petrogenesis of the nakhlites may also provide clues to martian igneous processes. Unfortunately, the cumulate nature of the nakhlites makes calculating parental magma compositions difficult [1-3]. However, large olivine grains in all three nakhlites, and in particular Governador Valadares, often contain partially crystallized melt inclusions that presumably are representative of an early or intermediate liquid coexisting with the cumulus phases. This study represents a summary of our continued analyses of magmatic inclusions in Nakhla and Governador Valadares, and a correction to our previously published parental liquids [1].

Typical melt inclusions within nakhlite olivine are sub-rounded and between 50 and 200 μm in diameter. Most inclusions consist predominantly of augite and an interstitial Si-rich glass (58-72% SiO₂). Other phases include an Fe-Ti oxide (either Ti-magnetite or ilmenite, or both), and minor Fe-sulfides, chlor-apatite, kaersutitic amphibole and hercynitic spinel [1]. Unlike the mesostasis of the nakhlites, these inclusions do not contain feldspar. With the exception of the Fe-Ti oxide, which occurs in all studied inclusions, the abundance and composition of minor phases appears to vary dramatically from inclusion to inclusion.

The inclusions exhibit two distinct textures. In roughly half of the observed inclusions, augite has nucleated on the surrounding olivine walls and formed needle- and blade-like crystals pointing inward, with glass occurring interstitially and the Ti-Fe phase occurring as a palisade of small euhedral grains at the inclusion's outer rim. The other inclusions are essentially single large augite crystals, mantled by a small meniscus of Si-rich glass and a few larger crystals of a Ti-Fe phase. We attribute this dichotomy of textures to the occasional enclosure of cumulus augite nuclei, producing a single large augite grain rather than many smaller grains. Since it is likely that the inclusions with the radiating texture closed earlier (they contain a larger proportion of melt and did not trap already-crystallized augite) we have chosen two such inclusions (GV1 from Governador Valadares and NK3 from Nakhla) from which to reconstruct the parental magma.

Olivine and augite were the first phases to crystallize from the nakhlite parent magma [4,5]. Given that the inclusions studied were centered within olivine grains, we assume that a mixture of the enclosing olivine (which plated out on the walls enclosing the initial liquid) and the inclusion phases represents the parental magma. Parental magma compositions were calculated using a system of linear mass-balance equations that were then solved by regression methods using both exact and inexact constraints [6,7]. The primary phases used in the regression were olivine, augite, Ti-magnetite or ilmenite, and the inclusion glass, with minor phases included when present. The results of previous experimental studies of SNC meteorites [2,6] allowed the use of measured partition coefficients for several major oxides as partial constraints to some calculations. The most important constraint was that the FeO/MgO of the liquid be as close to equilibrium with the cores of cumulus augite as possible (wt. FeO/MgO approaching 4.84). The equations were weighted to give a high relative importance to the mass-balance of the equations and to keep the proportion of minor phases low. A systematic series of initial solutions was then introduced and the linear regression performed to produce a variety of possible parental liquids. Following the regression, possible parent compositions were selected that were cosaturated with olivine and augite, as shown by their position on Fig. 1A. This yielded a set of 8-10 parental compositions (shaded area of Fig. 1B) from which we chose the 3 with the lowest residual (difference between the regression-calculated parent composition and that calculated from the regression-calculated mode) and averaged them to produce our preferred composition. These parent compositions differ significantly from our earlier published values [1] that suffered from erroneous and inappropriate weights. Our new preferred compositions for GV1 and NK3 parent liquids are shown in Table 1 and Fig 1B.
The compositions GV1 and NK3 are reasonably similar to each other, the primary difference being the higher Ti and alkali content of GV1. This higher alkali and Ti content is also supported by the observed presence of kaersutite in this inclusion. Our calculated nakhlite compositions for both inclusions contain higher levels of alkali and Ti than those previously published [2,3] for two reasons. Most important is that the inclusions are inherently richer in these oxides, as exhibited by the ubiquitous presence of Ti-Fe oxides and the high alkali content of both the glass and minor phases. Secondly, the constraint that the parent FeO/MgO be in equilibrium with cumulus augite and the Ti-Fe oxide be kept low requires a fair proportion of glass (which has FeO/MgO around 5) for mass balance; i.e., the glass present in the inclusions has nearly the right FeO/MgO ratio, and thus makes up a relatively high proportion of the calculated mode.

The parental liquid compositions derived from melt inclusions GV1 and NK3 are different from previously published parents for Nakhla but are remarkably similar to several published Chassigny and Shergotty parent compositions (Fig. 1B). If magmatic inclusions faithfully record parental liquids, all three types of SNC meteorites may have formed from magmas more similar in composition than has previously been supposed.