THE PARENTAL MAGMAS OF THE SNC METEORITES. John Longhi & Vivian Pan, Dept. Geology & Geophysics, Yale University, New Haven, CT 06511

Most SNC (Shergottites, Nakhlites, Chassigny) meteorites are igneous cumulates or partial cumulates (1), so the bulk compositions of their parental magmatic liquids cannot be simply measured. Parental magma compostions provide important constraints on lines of descent, possible assimilation, source region composition, and depth of melting, so it is vital to determine these compositions as accurately as possible. Several calculations of SNC parental magma composition already have been made e.g., Shergotty (2), EETA79001A (3), and Nakhla (4). In this paper we provide original estimates of the parental magma compositions of Chassigny and the xenocryst assemblage in EETA79001A plus an alternate to the composition for Nakhla proposed by (4). We have derived these compositions from a combination of data from new melting experiments, calculations of equilibrium crystallization by the method of (5), and reconstruction of liquid composition from mineral compositions and partition coefficients.

Shergottites: Stolper & McSween (2) determined the parental magma composition of Shergotty through melting experiments. The relatively low value of Mg'=0.32 ($MgO/(MgO + FeO_T)$) for this composition plus the absence of olivine in the meteorite itself suggest that Shergotty crystallized from a fractionated magma. EETA79001A contains a few percent magnesian olivine and orthopyroxene xenocrysts enveloped in a fine-grained matrix generally similar to that of Shergotty, but containing pigeonites with slightly less calcic and more magnesian core compositions. The composition of the EETA79001A matrix less the xenocrysts, as determined by (3), is given in Table 1. We have calculated the equilibrium crystallization path of the matrix composition and find olivine (Mg'=0.82) on the liquidus at 1356°C, followed by pigeonite at 1233°C (Wo_9En_{68}). The calculated pigeonite is similar to the most magnesian cores observed in the groundmass and the calculated coexisting olivine (Mg'=0.73) is within the range of olivine compositions reported in the zoned rims of the xenocrysts. Thus the groundmass composition appears to be close to that of quenched liquid, and this liquid is somewhat more primitive than the Shergotty parent.

Calculated crystallization of the EETA79001A bulk composition shows olivine (Mg'=0.83) on the liquidus, joined by pigeonite (Wo_8En_{71}) at 1257°C (Mg'(ol)=0.76); augite ($Wo_{41}En_{45}$) joins pigeonite (Wo_9En_{68}) and olivine (Mg'=0.74) at 1228°C. A melting experiment at 1240°C on a synthetic EETA79001A bulk glass at the QFM oxygen buffer produced coexisting olivine (Mg'=0.76) and pigeonite (Wo_4En_{75}). These results indicate that the anhedral orthopyroxene ($Wo_{2.5-2.7}En_{80-82}$) megacrysts did not crystallize from the EETA79001A bulk composition at low pressure. We have employed crystal/liquid partition coefficients from the 1240°C run and other coefficients taken from related experimental data (6) plus the constraint of coexisting olivine and orthopyroxene at low pressure to estimate the composition of the liquid in equilibrium with the EETA79001A xenocryst assemblage. Given that the size and compositions of the EETA79001A xenocrysts are similar to those of the indigenous minerals in ALHA77005 (7), this preliminary liquid composition is also parental to ALHA77005.

Nakhla: Treiman (4) modeled the bulk composition of Nakhla as a mixture of cumulus augite, cumulus olivine, and trapped liquid. He determined a range of liquid compositions (A - D in Fig. 1b) by varying the proportions of cumulus crystals and trapped liquid. Our calculations confirmed by experiments show all of these compositions to have olivine alone on the liquidus. More importantly, the array of aug(+ol)-liquid tielines in Fig. 1b suggest that the average cumulus augite in Nakhla would coexist with a low-Al liquid with lower Wo content than compositions A - D even after sufficient olivine crystallized to saturate them with augite. Accordingly, we have calculated an alternative parental magma composition for Nakhla by multiplying partition coefficients derived from the augite-liquid pair (open circles) illustrated in Fig. 1b, times the cumulus augite composition and then adjusting the SiO_2 concentration so that the liquid composition lies approximately on the olivine/augite liquidus surface. This parental magma composition is illustrated in Fig. 1b (N). We note that the bulk analysis of Nakhla reported by (8) lies much closer to our inferred augite-liquid tieline than does the average analysis employed by (4).

Chassigny: We have employed a technique similar to that applied to Nakhla to calculate a parental magma composition for Chassigny (Ch in Fig. 1a and 1b). Based on the higher Al_2O_3 concentrations in Chassigny augite (9), Ch is considerably higher in Al_2O_3 than N.

Discussion: We anticipate further refinements of the calculated parental magma compositions of Nakhla, Chassigny, and the EETA79001A xenocryst assemblage as more experimental data become available. In the meantime, some generalizations appear secure. The SNC parental magmas (PM) define an array of low-Al basalts with a spread in wollastonite (Wo) component. The low-Al is reflected in the late crystallization of plagioclase, whereas the variable Wo controls the nature of the first pyroxene to crystallize -- augite for Nakhla and Chassigny, pigeonite for the more primitive shergottites. In terms of the Ol projection (Fig. 1b), the spread in SNC PM compositions is similar to that observed in terrestrial basaltic komatiites, although the basaltic komatiites typically have lower concentrations of alkalies and higher Mg', as might be expected from cosmochemical models of the terrestrial and martian mantles (e.g., 10).

If, as is widely accepted, the SNC's come from Mars, then some additional observations are in order. Fig. 1a illustrates the ol/low-Ca pyx boundary (dash-dot line) at 23 kb as fixed by the martian minimum melt composition as determined by (11). No reasonable fractionation scheme will produce the SNC PM's by differentiation of the minimum melt composition, which implies that the SNC

PM's were derived from primary magmas produced either during high degrees of partial melting or from small degrees of partial melting of sources depleted in Al. In either case neither garnet nor aluminous spinel was a residual phase.

To illustrate the relation between parental magma and possible primary magma, we have calculated olivine addition paths (the reverse of fractional crystallization) to the SNC PM's (dashed lines in Fig. 1a). Where the composition of the olivine has Mg' in the range of 0.74-0.79 (the estimated range of the martian mantle from 10), we have drawn the curves as solid lines. Keeping in mind probable increases in Mg' as a result of high degrees of partial melting or depletion of the source, we observe that the SNC PM's (except E_x) could have been derived from more primitive magmas produced by melting at pressures of 20 kb or more in the martian interior.

REFERENCES

(1) McSween H.Y. (1985) Revs. Geophys., 23, 391-416. (2) Stolper E.M. and H.Y. McSween (1979) Geochim. Cosmochim. Acta 43, 1475-1498. (3) McSween H.Y. and E. Jarosewich (1983) Geochim. Cosmochim. Acta 47, 1501-1513. (4) Treiman A.H. (1986) Geochim. Cosmochim. Acta 50, 1061-1070. (5) Longhi J. and V. Pan (1988a) Proc. Lunar Planet. Sci. Conf. 18th, in press. (6) Longhi J. and V. Pan (1988b) J. Petrol., in press. (7) McSween H.Y., L.A. Taylor, and E.M. Stolper (1983) Science 204, 1201-1203. (8) Dreibus G. et al. (1982) Lunar Planet. Sci. 13, 186-187. (9) Floran R.J. et al (1978) Geochim. Cosmochim. Acta 42, 1213-1229. (10) BVSP (1981) Pergamon, New York. (11) Bertke C.M. and J.R. Holloway (1988) Proc. Lunar Planet. Sci. Conf. 18th, in press.

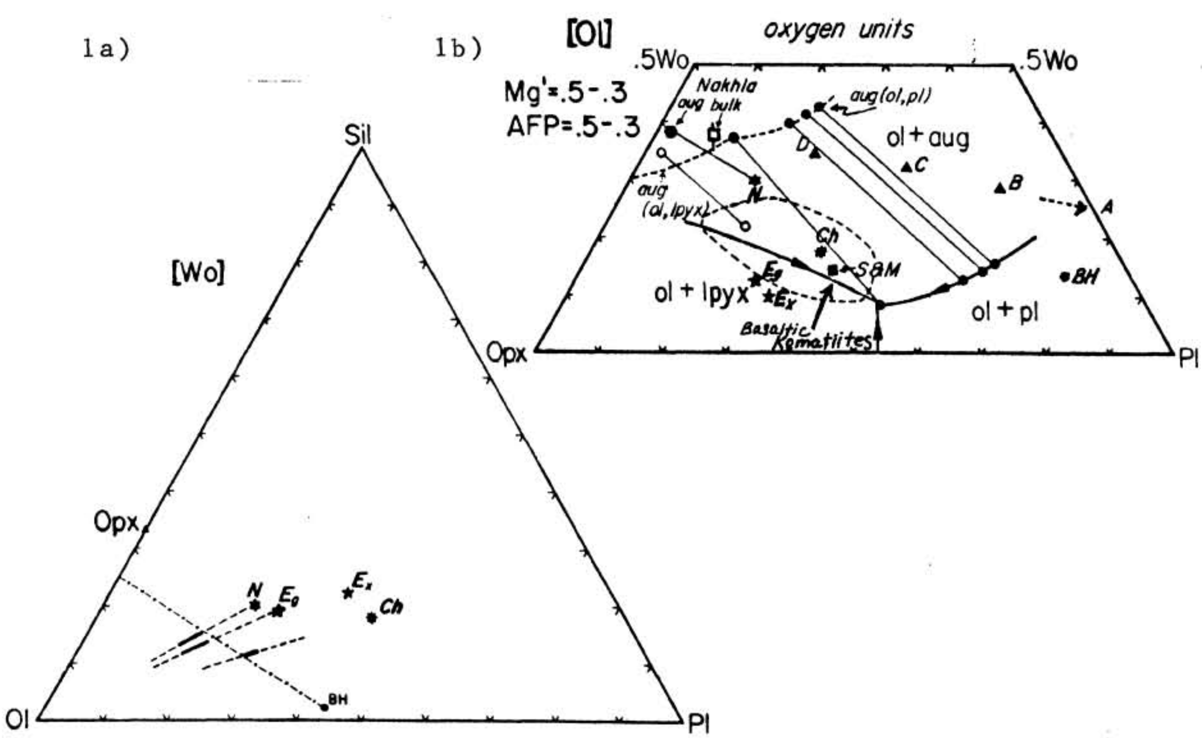

FIGURE CAPTIONS

Fig. 1 Projections of mineral, liquid, and rock compositions in the Ol-Pl-Wo-SiO_2 system.
a) Projection from Wo component. Calculated parental magma compositions: Nakhla (N), Chassigny (Ch), EETA79001A groundmass (E_g - ref. 3) and xenocryst assemblage (E_x). Dashed lines indicate olivine addition; solid segments indicate portions of olivine addition where Mg'(ol)=0.74-0.79. BH is 23 kb martian minimum melt composition after (11). Dash-dot line is approximate position of the ol/low-Ca pyx liquidus boundary at 23 kb.
b) Projection from Ol component. Liquidus boundaries and limits of augite solid solution are appropriate for SNC compositions (Mg'(liq)=0.5-0.3; normative alkali feldspar, AFP=0.5-0.3) taken from present study (open circles) and from Walker et al. (1979, Contrib. Mineral. Petrol. 70, 111-125, filled circles) Parental magma compositions as in Fig. 1a, plus Shergotty PM (S&M) from (2) and Nakhla PM range (A - D) from (4). Average Nakhla cumulus augite and bulk compositions from (4); line through bulk composition indicates range of individual analyses. Closed dashed curve indicates range of terrestrial basaltic komatiite compositions from (10).