A LIQUIDUS GEOTHERMOMETER FOR SNC, LUNAR, AND EUCRITIC MAGMAS. J.H. Jones, SR, NASA/JSC, Houston, TX 77058 (jjones2@ems.jsc.nasa.gov).

Two very useful pieces of information about a basalt are its liquidus temperature and liquid line of descent. To determine these, experiments are performed at various temperatures on the composition of interest between the solidus and liquidus. There are numerous examples of such experiments in the literature.

Figure 1

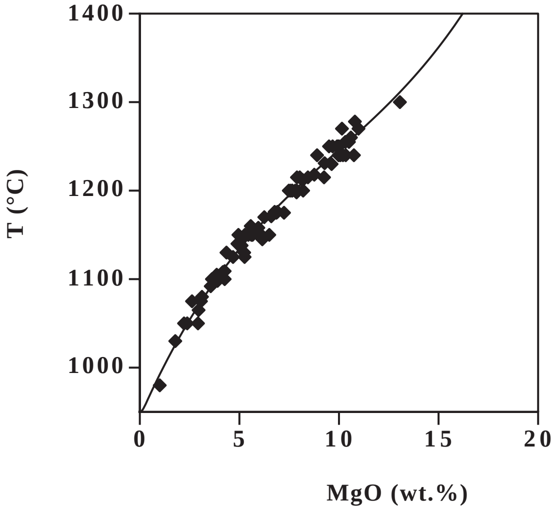


Figure 1 summarizes of 82 such experiments for SNC compositions using a T vs. MgO diagram, where T is the temperature of the experiment and MgO is the magnesia content of the glass quenched from that temperature [1-8]. All of these experiments were performed at one bar pressure and most were performed near the FMQ oxygen buffer. The data define a smooth trend and have been fitted with a third order polynomial. The data are well fit by the equation

$$T = 948.5 + 48.59\,\text{MgO} - 2.771\,(\text{MgO})^2 + 0.0882\,(\text{MgO})^3 \qquad (1)$$

The correlation coefficient (r^2) of the fit is quite good (0.98), and the fit has a standard error of about ±10°C. While this degree of accuracy may not be sufficient for all purposes, it appears that the regression of Figure 1 yields a very reasonable estimate of liquidus temperature for martian magmas.

Figure 2

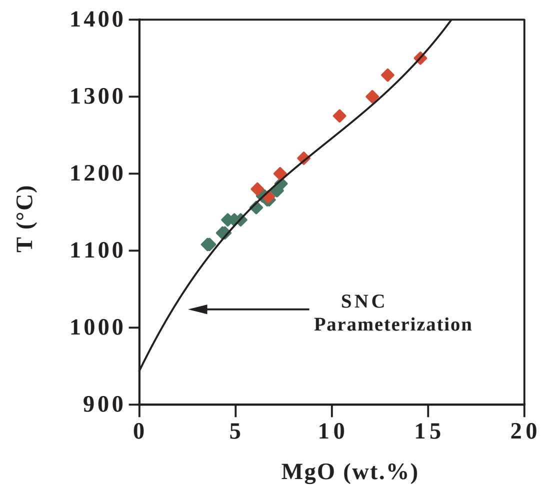
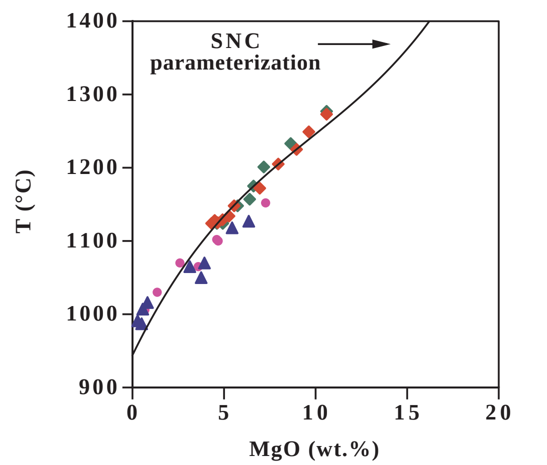


Figure 3

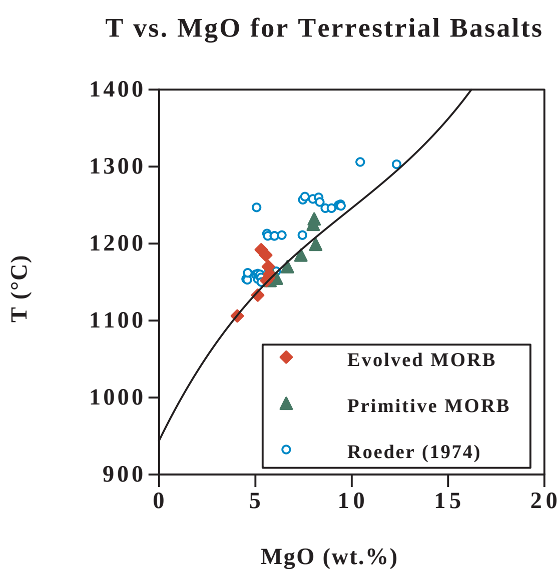


Surprisingly, the fit for the SNC experiments also gives reasonable estimates of liquidus temperatures for eucritic liquids and lunar mare basalts. Figures 2 and 3 show data from eucritic and lunar experimental glasses, respectively, and compare them to the regression for martian compositions given above. In Figure 2 the green symbols are the eucrite experiments of [9] and the red symbols are the St. Severin partial melting experiments of [10]. In Figure 3 the red and green symbols are, respectively, the

15555 and 15065 experiments of [11], the blue symbols are from the residual melt and immiscible liquid study of [12], and the magenta symbols are the 70017 high-Ti basalt experiments of [13]. These comparisons are hardly exhaustive, but illustrate the general similarity of liquidus temperatures at a given MgO content for martian, lunar, and asteroidal basalts. Of course, there is no need to use the SNC regression for these other bodies. For example, a regression could be performed that used only lunar compositions. The experiments of Figures 2 and 3 are again at one bar pressure and were typically performed at or below the IW oxygen buffer. This difference in fo_2 between the SNC experiments and the others appears to not have had a great effect.

Another parameter that does not seem to be important is alumina content. A similarity between lunar mare basalts and SNC meteorites is that they were both derived from depleted source regions and have relatively low Al_2O_3 contents. However, this is not true for eucrites and chondrite partial melts [10]. Eucrites and eucritic melts of chondrites have nearly chondritic Ca/Al ratios and elevated Al_2O_3 contents compared to most SNC's and mare basalts. It therefore appears that the general method of using MgO content to estimate one-bar liquidus temperature has some general applicability.

Figure 4



However, this applicability is not universal. Figure 4 shows that experiments on terrestrial basalts [14,15] often plot above the regression of Figure 1 and application of equation (1) to terrestrial basalts would tend to underestimate liquidus temperature. Two MORB compositions have liquidi above the SNC regression but evolve to the SNC trend and then follow it [14]. The classic FeO activity experiments of Roeder [15] fall on or above the SNC trend which appears to act as a high-MgO bound.

One possibility for why terrestrial compositions behave differently is because of the higher Mg# of the Earth relative to the Moon, Mars, and Eucrite Parent Body. At a given MgO content, basalts from these other bodies will have similar Mg#'s, whereas terrestrial basalts will have higher Mg#. This explanation may be partially true, but it fails to predict the MORB liquid line of descent of Figure 4. Evolved terrestrial basalts have lower Mg#'s but should still have higher Mg#'s than comparably evolved SNC's.

A more likely explanation involves another commonality between SNC, lunar, and eucrite compositions — low alkali contents. It seems plausible that the SNC regression represents the low-alkali boundary for liquid lines of descent. The Roeder experiments support this view. The modest changes in liquid MgO contents at a given temperature are accompanied by large changes in FeO. And FeO anti-correlates with total alkalis in this suite of experiments. Higher alkali concentrations increase the activity coefficients of FeO and MgO in the silicate liquid, expanding the olivine stability field [15]. And on a diagram such as Figure 4, liquidus temperatures could be elevated with respect to alkali free systems.

Therefore, somewhat surprisingly, it appears that, to predict the liquidus temperature of many planetary basalts, it is only necessary to know the MgO content of that basalt. Further, because many of these basalts have FeO contents of ~18-20 wt.%, it may be possible to estimate liquidi from the compositions of olivine and/or pyroxene cores and knowledge of the proper K_D(Fe/Mg).

References: [1] Stolper E.M. and McSween H.Y. Jr. (1979) *GCA* **43**, 1475-1498. [2] Longhi J. and Pan V. (1989) *Proc. Lunar Planet. Sci Conf. 19th*, 451-464. [3] McKay G.A. et al. (1986) *GCA* **50**, 927-937. [4] Minitti M. and Rutherford M.J. (2000) *GCA* **64**, 2535-2547. [5] Dann J.C. et al. (2001) *MAPS* **36**, 793-806. [6] McCoy T.J. and Lofgren G. E. (1999) *EPSL* **173**, 397-411. [7] Wasylenki L.E. et al., unpublished. [8] Herd C.D.K et al. (2002) *MAPS* **37**, 987-1000. [9] Stolper E.M. (1977) *GCA* **41**, 587-611. [10] Jurewicz A.J.G. (1995) *GCA* **59**, 391-408. [11] Walker D. et al. (1977) *Proc. Lunar Sci. Conf. 8th*, 1521-1547. [12] Hess P.C. et al. (1975) *Proc. Lunar Sci. Conf. 6th*, 895-909. [13] Rutherford M.J. et al. (1974) *Proc. Lunar Sci. Conf. 5th*, 569-583. [14] Walker D. et al. (1979) *Cont. Min. Pet.* **70**, 111-125. [15] Roeder P.L. (1974) *EPSL* **23**, 397-410.