

DEPTHS OF MARE SOURCE-REGIONS: LIMITS IMPOSED BY BUOYANCY-DRIVEN MELT SEGREGATION. J. W. Delano; Dept. of Geological Sciences, State University of New York; Albany, NY 12222

The depths within the Moon from which mare basaltic liquids were derived by partial melting remains a topic of enduring interest and controversy. Numerous petrologic investigations [e.g. 1-4] have estimated the pressures and temperatures at which mare compositions become multiply saturated on their liquidii. Based upon the demonstrable success of using this approach on terrestrial basalts, the assumption of multiple saturation has been consistently applied to lunar rocks since return of the first samples in 1969. A persuasive test of this critical assumption for the Moon has proven elusive until now.

In a landmark publication, Stolper et al. [5] proposed that olivine may float in basic magmas at sufficiently high pressures in the Earth's upper mantle. Under those circumstances, the magma would be denser than the solid residuum and would sink, rather than rise. Other investigators [6-9] have provided important additional constraints on the likelihood of this process occurring in the Earth. The minimum pressure now thought to be needed for this phenomenon is ≥ 80 kbars [e.g. 6].

Although the maximum pressure achieved in the Moon is only about 47 kbars, the compositional range of mantle-derived magmas on the Moon is so extreme [e.g. factor of 60 range in Ti; 10] that some magmas might become denser than their olivine residua at only modest pressures. Lange and Carmichael [6] have recently published experimentally derived values for the partial molar volumes of major-element oxides as functions of temperature and pressure. These parameters have been applied to the published compositions of primary mare magmas [i.e. pristine glasses; 10] in order to estimate the densities of those liquids over a plausible range of pressure and temperature in the Moon. It has been found that some high-Ti magmas may sink, as suspected earlier by another investigator [P.C. Hess, pers. comm., 1983].

Liquidus temperatures of lunar magmas at P=0: The liquidus temperatures of the twenty-five, high-Mg magmas represented by the pristine glasses were inferred using the temperature dependence of the MgO partition coefficient between olivine and liquid (Figure). The experimental data are from low- and high-Ti mare compositions [1, 11-14]. Note that this partition coefficient is not demonstrably affected by Ti-abundance and hence can be applied to all of the glass compositions to acquire estimates for their liquidus temperatures at zero-pressure. A similar approach was used by Stolper and Walker [15] in their study of terrestrial basalts. Note that the lunar data (Figure) are different from the familiar relationship originally reported by Roeder [16] for terrestrial basalts. In addition, an Fe/Mg distribution coefficient (K_D) between olivine and liquid was used that conformed to the following empirical relationship: $K_D = 0.333 - 0.0071$ (mole % TiO_2 in melt). The dependence of this value on pressure and temperature is assumed to be small within the ranges of interest [e.g. 17].

Estimated densities of melts and olivines: The melt densities were calculated using the partial molar volumes of the major element oxides with their pressure- and temperature-derivatives [6]. Olivine densities in equilibrium with each of the twenty-five magmas [10] were estimated using the third-order Birch-Murnaghan equation of state. Thermodynamic parameters of olivine are from [18-20] listed in [6].

Preliminary implications:

- (a) Magmas with ≥ 16 mole % TiO_2 can not be erupted onto the lunar surface, either hydrostatically or by buoyancy forces. If the Moon produced such mare compositions, they would have sunk for all mantle pressures. The most titaniferous of the pristine glasses (i.e. 13 mole % TiO_2) is close to that stated limit.
- (b) The geochemical consequences of redistributing Ti and large ion lithophile elements within the Moon's interior by the sinking of dense ultramafic melts may be important for understanding assimilative interactions during mare petrogenesis [e.g. 21].
- (c) Based solely on buoyancy considerations, observed high-Ti magmas (10–13 mole % TiO_2) were derived from source-regions at depths < 400 km. This constraint may supersede all estimates previously derived by experimental petrology implying depths ≥ 400 km [e.g. 1–3, 10].

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