

CRYSTAL-LIQUID DENSITY INVERSIONS IN HIGH-TiO₂ LUNAR BASALT

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The sinking and floating spheres technique has been previously used to determine the high-pressure compressibility of komatiite and peridotite liquids [1, 2, 3]. From these studies crystal-liquid density inversions are predicted to exist during deep-Earth melting. Recently we have extended investigations on high-pressure density inversions to the magmatic differentiation of the Moon.

Sampled pristine lunar glasses have high FeO contents (16-25 wt%) and up to 16.4 wt% TiO₂, resulting in comparatively dense liquids. We examined the possibility that Fe,Ti-rich magmas could have been neutrally buoyant in the lunar mantle at relatively modest pressures [4]. These density relationships would have important implications for magma mobility and for the evolution of the lunar interior [5]. To determine the depth at which Fe,Ti-rich magma would become denser than the lunar mantle, the density of a silicate liquid with Apollo 14 black glass composition (TiO₂=16.4 wt%) has been measured at high pressure using the sinking and floating spheres technique.

Experiments have been performed along the liquidus (1415-2065°C) of Apollo 14 black glass at 1.0-10.0 GPa in piston-cylinder and multi-anvil devices. The density of the liquid has been narrowly bracketed at two pressures using crystalline marker buoys (see figure 1). Olivine (Fo_{84.3}) is neutrally buoyant at 1.5 GPa, 1435°C, and garnet (Py₇₀Al₁₇Gr₁₃) is neutrally buoyant at 5.5 GPa, 1800°C. Further constraints on the liquid compression curve are from flotation of San Carlos olivine (Fo₉₀) at 1.0 GPa and sinking of garnets (Py₆₃Al₂₈Gr₈, Py₆₂Al₃₆Gr₃) and synthetic corundum at 9 and 10 GPa. Presently we are attempting to achieve an additional bracket of the liquid density by floating Py₆₃Al₂₈Gr₈ garnet in the range 10-12 GPa. The 1-bar liquid reference density was calculated from Lange and Carmichael [6]. Preliminary results indicate that the bulk modulus of high-TiO₂ basalt is significantly lower than other ultrabasic liquids measured by this technique, suggesting a dependence of silicate liquid compressibility on composition. We calculate a Birch-Murnaghan $K_T=15.2$ GPa with $dK/dP=4.7$ for the molten Apollo 14 black glass. This compares with $K_T=26.0$ GPa and $dK/dP=4.25$ for an Archean komatiite [1].

High-TiO₂ lunar glasses have been proposed as some of the most primitive melts of the Moon's mantle [7]. Phase equilibria indicate that they may be derived from the olivine-orthopyroxene cotectic at 400-500 km depth (2.0-2.5 GPa). Fe-Mg distribution coefficients (K_D) ranging from 0.24-0.28, yield calculated liquidus olivines (Fo_{79.9-77.6}) and orthopyroxenes (En_{81.5-77.6}) that may have been in equilibrium with Apollo 14 black glass. At liquidus conditions, density inversions should occur at 0.4-0.7 and 2.0-2.4 GPa for the orthopyroxenes and olivines, respectively (see figure 2). Hence molten Apollo 14 black glass should be denser than an olivine+orthopyroxene cotectic residue at the 400-500 km proposed depth of origin. Diapiric genesis for high-TiO₂ lunar basalts, as envisaged by Hess [5], may be required to explain the eruption of these magmas.

References

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