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Basaltic magmas at high pressures and the origin of the lithosphere-asthenosphere boundary

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Basaltic lavas rise buoyantly from the Earth's mantle to form the oceanic crust, and are an important source of terrestrial volcanism. The density and viscosity of basaltic magmas moderates igneous processes ranging from volcanic activity to fractionation, and is intimately linked to its atomic structure. Here we show that basaltic magmas undergo rapid densification with increasing pressure and exhibit a viscosity minimum near 4 GPa, correlated with an increase in coordination number for Si^{4+} and Al^{3+} cations. Magma mobility- the ratio of the melt-solid density contrast to the magma viscosity- exhibits a peak at 120-150 km depth that is up to an order of magnitude greater than values in the shallower lithosphere and deeper mantle. Thus the driving force for melt separation in Earth's asthenosphere diminishes as melts ascend, which could lead to excessive melt accumulation at depths of 80-100 km, providing a simple explanation for the occurrence of a seismically-observed Gutenberg discontinuity.

Keywords: basalt, magma, high pressure, density, viscosity, structure