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The transport properties of mafic melt at extreme conditions: Insights into the dynamics of the magma ocean

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The transport properties such as diffusion and viscosity of magma influence their mobility in the present-day Earth. In the early history of the Earth, the crystallization of the magma ocean is likely to have also been influenced by these transport properties. Despite a cubical parameter influencing magma dynamics in the present day and early earth, the pressure-dependence behavior of viscosity at high pressure remains poorly constrained. To address this issue, we have used first-principles molecular dynamics simulations of basaltic melt. We find that under compression, viscosity first decreases and then increases with minima in the pressure dependence of viscosity at ~6 GPa. At pressures relevant to the lower mantle, the melt viscosity increases upon compression. And this pressure dependence of viscosity at these lower mantle pressures remains true for all the isotherms explored in this study. However, elevated temperatures of the magma ocean translate to low viscosities ranging between 0.01 and 0.03 Pa.s implying that the crystallization of the magma ocean is likely to have been completed within a few million years. The crystallization of the magma ocean is also likely to be fractional, i.e., the chemical heterogeneity observed in the present-day mantle is likely to have been generated during the early crystallization of the magma ocean.