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Quantifying basaltic magma flow rates in the East Pacific Rise from magnetotelluric observations

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Volcanic eruptions across the Earth are dominated by basaltic lava, broadly characterized by 45 to 52 weight % (wt%) SiO_2. More than half of the Earth's magma budget is thought to be produced in the mantle below mid-oceanic ridge spreading centers. Along these ridges, the magmatism produces new oceanic crust, which, due to its higher density compared to the mantle, helps to drive subduction and hence plate tectonics. Mid-oceanic ridge magmatism also fuels differentiation of the Earth by extracting trace chemical components which are incompatible in the source melting regions of the mantle. The flow rate of basaltic magma controls the refueling rate of volcanic magma chambers, and hence potential for eruption, but also chemical differentiation between the mantle and crust. Geophysical methods, such as seismic wave or magnetotelluric soundings, allow us to detect the magma at depth and hence study its flow. However, these techniques cannot determine the viscosity of the magma which controls its flow rate. Magnetotelluric soundings are, however, sensitive to the electrical conductivity of the magma. Einstein's Kinetic Theory of Heat predicts that the viscosity and electrical conductivity of magma are inversely related through their respective connections to the diffusion of charged ions in the melt. In this study, we experimentally constrain the relationship between these two fundamental transport properties of basaltic magma at conditions relevant to the crust and upper mantle. As a case example for quantifying basaltic magma flow rates from magnetotelluric data, we applied this relationship to the East Pacific Rise (EPR) mid-oceanic spreading center. Our relationship indicates that porous melt flow in the EPR mantle is < 10 m per day, in good agreement with other evidence from geochemical and geodynamic studies.