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In-situ viscosity measurements of active lava

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Lava viscosity have predominantly been constrained from analyzing flow dynamics and measuring re-melted rocks in the laboratory. Laboratory viscometers have been used extensively to establish the viscosity-temperature relationship of lava at super and subliquidus conditions (900-1400°C). Laboratory measurements are well-constrained in temperature, shear rate, and oxygen fugacity but are unable to fully reproduce the complexities and dynamics of the natural emplacement environment (predominantly due to the inability to retain bubbles over experimentally relevant timescales). In situ viscosity measurements of lava in its natural state, during active flow emplacement, have been an underutilized method largely due to a lack of reliable field instruments but also due to the hazardous volcanic environments. Yet, it is the only method able to capture natural lava's multiphase rheology and map the rheological properties along lava flows that is needed to validate and implement accurate lava flow properties in numerical modeling efforts for hazard assessment.

Here we present two new field viscometers: a lava penetrometer (Harris et al. 2024) and a rotational viscometer (Chevrel et al. 2023). The lava penetrometer is able to measure a force of 10 to 500 N, and has been calibrated for a viscosity range of ~10^2 to 10^5 Pa s. The rotational viscometer covers a wide range of stress (30 to 3870 Pa) and strain rate (0.1–28 s^{-1}), and, with that, viscosity range of 10 to 10^3 Pa s. Both instruments are designed to be easy to operate, highly mobile, and capable of measuring multiphase lavas temperature up to 1200°C. These instruments were deployed during the 2023 Litli Hrútur eruption, Iceland, generating the first in-situ rheological map along a complete lava flow. Viscosity measurements were combined with temperature measurement and sampling for textural characterization. The resulting data represent an extensive contribution to the very limited database of natural lava viscosity.

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