EGU General Assembly 2025

EGU25-5227, updated on 12 May 2025
https://doi.org/10.5194/egusphere-egu25-5227
EGU General Assembly 2025

Influence of rheology on lava flow dynamics inferred from numerical modeling

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Using numerical modelling, we study the influence of lava rheology (described by Newtonian, Bingham or Herschel-Bulkley fluids) on lava flow advancement and flow morphology. Numerical simulations were conducted using a three-dimensional fluid dynamics model as well as a depth-averaged model based on the shallow water approximation. In the case of isothermal flow models, we have shown that the increased yield strength significantly influences lava flow morphology by restricting flow advance and promoting upward growth of lava flows. In the case of temperature-dependent rheological models, the Newtonian and Bingham fluids demonstrate similar lava flow morphologies and thickness distributions. The viscosity values in both cases vary from about $10^{2.7}$ – 10^{6} Pa s across the central part of the lava flow to about 10^{12} Pa s near the lava flow margins. The Herschel-Bulkley model exhibits the viscosity values of 10^{9} Pa swithin the flow and reaches the highest viscosity values, up to 10^{16} Pa s along the lava flow margins resulting in the shortest lava flow. We simulate the emplacement of a natural lava flow using observational data from the December 2015 eruption at Mount Etna. All thermal rheological models approximate the real lava flow width accurately, with the Newtonian model providing the best match for flow extent and developing the same morphological features as the real lava emplacement. While the Herschel-Bulkley model shows a slight deviation in the lava flow length, the Bingham model fits well the main flow branch, with minor divergence in the upper branches.