Understanding the flow-to-fracture transition of volcanic fluids through analogy experiments

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How flowing magma breaks like a solid is a fundamental problem that has been investigated for decades. This talk introduces the recent multi-disciplinary project on the flow and fracture of complex fluids, consisting of experimental, theoretical, and numerical approaches. In volcanology, the glass transition is considered to appear at high strain rates and control the brittle fracture of magma. In physics, on the other hand, the glass transition is more frequently associated with the appearance of yield strength at low strain rates. The project aims to bridge this discrepancy and establish the fracture mechanics for complex fluids.
We experimentally show the contrasting flow/fracture behaviors of Maxwell-type viscoelastic fluid, Bingham-type yield-strength fluid, Newtonian viscous fluids, and those with solid particles. The experiments include bubble growth and fracture within and at the surface of the fluids, flow and fracture around a cylinder, and flow and rupture of fluid films under extension. We emphasize that the observation of elasticity at small strain is not sufficient to infer that fluid can generate brittle fractures.
We also develop a numerical method to simulate the flow and fracture of Maxwell-type viscoelastic fluids, combining the finite element methods and phase field algorithm. The simulations reproduce the essential features of some experiments and indicate that inhomogeneity is essential for initiating fracture in fluids.
When complex fluids are concerned, it is not straightforward to scale the laboratory phenomena to the natural volcanic systems. However, we demonstrate that a deep understanding of experimental phenomena can improve our understanding of how volcanic systems work by considering the physical and/or mathematical analogy. We name these approaches analogy experiments.