Adventures in Rheology

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Most geological processes involve heat and/or mass transfer, driven by gradients in temperature and/or gravitational potential. The rate of mass transfer (deformation), whether of solid crust thickened in orogenic belts, or of liquid rock erupted from volcanoes, depends strongly on the material composition, and its temperature. Liquids often behave in a simple “Newtonian” fashion, with a constant ratio of stress to strain rate, known as viscosity. The rheology of mushes and 3-phase lavas (crystals, bubbles and melt) also depends on strain rate, and often on finite strain, potentially leading to complex time-dependent behavior. Here I discuss a few examples of the rheological and thermal measurements that will be possible in the new experimental petrology laboratory and their applications. These include: (i) Combining observations of active flow emplacement with rheological studies to improve flow laws used in forecasting lava flow hazards (e.g. Kilauea, USA; Piton de la Fournaise, Réunion); (ii) Integrating field and laboratory studies of previously emplaced lava flows, to estimate the emplacement timescale of individual flow units (e.g. Cima, CA; Obsidian Dome, CA); (iii) Analog laboratory studies of lavas on other planets to help to elucidate processes on other bodies in the solar system (e.g. flood basalts on Mercury; impact melt sheets on the Moon; cryolavas erupted from ice-covered ocean worlds such as Europa and Enceladus); (iv) Laboratory studies of space dust analogs. The condensation temperature of disorganized (“amorphous”) dust grains is either above or below their glass transition temperature. If formed above the glass transition, these grains can crystallize, producing strong peaks in infrared spectra. Studies of terrestrial volcanism are often adventures in their own right, while studies of extraterrestrial processes often allow exploration of uncharted areas of pressure-temperature-composition space. Interested students can join me in some of these adventures by taking an upper-level class in “Rheology of Earth Materials” in 2020-2021.