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Laboratory volcano geodesy

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Magma transport in volcanic plumbing systems induces surface deformation, which can be monitored by geodetic techniques, such as GPS and InSAR. These geodetic signals are commonly analyzed through geodetic models in order to constrain the shape of, and the pressure in, magma plumbing systems. These models, however, suffer critical limitations: (1) the modelled magma conduit shapes cannot be compared with the real conduits, so the geodetic models cannot be tested nor validated; (2) the modelled conduits only exhibit shapes that are too simplistic; (3) most geodetic models only account for elasticity of the host rock, whereas substantial plastic deformation is known to occur. To overcome these limitations, one needs to use a physical system, in which (1) both surface deformation and the shape of, and pressure in, the underlying conduit are known, and (2) the mechanical properties of the host material are controlled and well known.

In this contribution, we present novel quantitative laboratory results of shallow magma emplacement. Fine-grained silica flour represents the brittle crust, and low viscosity vegetable oil is an analogue for the magma. The melting temperature of the oil is 31 °C; the oil solidifies in the models after the end of the experiments. At the time of injection the oil temperature is 50 °C. The oil is pumped from a reservoir using a volumetric pump into the silica flour through a circular inlet at the bottom of a 40x40 cm square box. The silica flour is cohesive, such that oil intrudes it by fracturing it, and produces typical sheet intrusions (dykes, cone sheets, etc.). During oil intrusion, the model surface deforms, mostly by doming. These movements are measured by an advanced photogrammetry method, which uses 4 synchronized fixed cameras that periodically image the surface of the model from different angles. We apply particle tracking method to compute the 3D ground deformation pattern through time. After solidification of the oil, the intrusion can be excavated and photographed from several angles to compute its 3D shape with the same photogrammetry method. Then, the surface deformation pattern can be directly compared with the shape of underlying intrusion. This quantitative dataset is essential to quantitatively test and validate classical volcano geodetic models.