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Linking spatial and temporal variations in shear stress within a volcanic conduit to observed deformation and seismicity

Luke Marsden, Jurgen Neuberg, and Mark Thomas
Institute of Geophysics and Tectonics, University of Leeds, Leeds, UK (eelhm@leeds.ac.uk)

During the 2013-4 eruptive activity at Tungurahua volcano, Ecuador, Vulcanian explosions were often associated with a significant decrease in tilt up to around 200 μrad and an increase in low-frequency seismicity. Attempts to link the significant near-field deformation observed at Tungurahua and other silicic volcanoes to realistic pressure variations in the upper part of the edifice require the source to be excessively large or the edifice to be unreasonably weak. Additionally, it is difficult to explain why the tilt, and therefore the pressure, should decrease leading up to a major explosion. Therefore, an alternative explanation is required. As magma ascends through a volcanic conduit, it exerts shear stress at the conduit walls that pulls up the surrounding edifice. Studies have shown that a shear stress of around 20 MPa is sufficient to explain the tilt variations observed. However, whether such shear stresses are achieved in nature is so far unclear. Here, we perform flow modelling using COMSOL Multiphysics to assess how shear stress varies both spatially and through time in a volcanic conduit. Depth-variant shear stress profiles at the conduit-edifice boundary are output from the flow modelling and used to drive deformation models. From this it can be determined whether sufficient shear stress to explain the deformation observed at silicic volcanoes can be achieved through the ascent of magma. Additionally, the flow modelling will provide information on where in the conduit the critical shear stress required for brittle failure of magma is reached, thereby linking the low-frequency seismicity to the deformation. Processes such as shear thinning, shear heating and the development of a thermal boundary layer are likely to significantly influence the viscosity, strain rate, and therefore the shear stress close to the conduit wall, and consequently, the deformation observed at the surface.