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Experimental constraints on silicic magma storage at Hekla volcano (Iceland) and potential implications for pre-eruptive deformation

Gregor Weber (1,2) and Jonathan Castro (2)

(1) Department of Earth Sciences, University of Geneva, Geneva, Switzerland (gregor.weber@unige.ch), (2) Institute for Geosciences, Johannes Gutenberg-University, Mainz, Germany

Understanding the conditions that culminate in explosive eruptions of silicic magma is important for volcanic hazards mitigation. However, geological records of volcanoes typically show a wide range of eruptive behaviour and magnitude for individual eruptive centres. In order to evaluate future scenarios of eruption precursors, namely pre-eruptive deformation, magmatic system variables for different eruption types need to be constrained. Here we use experimental petrology and microanalysis of plagioclase crystals to clarify the P-T-x state under which rhyodacitic melts accumulated prior to Hekla Volcano's H3 eruption; the largest Holocene Plinian eruption in Iceland. Cobalt-buffered, H_2O-saturated phase equilibrium experiments reproduce the natural H3 pumice phenocryst assemblage (pl>fa+cpx>ilm+mt>ap+zrc) and glass chemistry, at 850±15°C and PH_2O of 130 to 175 MPa, implying shallow crustal magma storage between 5 and 6.6 km. The systematics of FeO and anorthite (CaAl2Si2O8) content in plagioclase reveal that thermal gradients were more important than compositional mixing or mingling within this magma reservoir. As these findings indicate magma storage much shallower than is currently thought of Hekla's mafic system, we use the constrained storage depth combined with deformation modelling to help forecast surface uplift patterns that could stem from the input of magma in reservoirs at different depth prior to an eruption. Using finite element modelling, we show that the vertical surface displacements for silicic magma accumulation sourced from about 6 km depths could potentially be more focussed than those observed in recent mafic events, which are fed from a lower crustal storage zone. Our results show how petrological reconstruction of magmatic system variables can link signs of pre-eruptive geophysical unrest to magmatic processes occurring in reservoirs at shallow depths. This will enhance our abilities to use deformation measurements (e.g. InSAR and GPS) in tandem with petrological studies to constrain potential precursors to volcanic eruptions.