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Structure and dynamics of surface uplift induced by incremental sill emplacement

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Ground deformation commonly heralds eruptions at active volcanoes, providing real-time insight into the location and geometry of subsurface intrusions that are critical to volcanic hazard assessment. To constrain the evolution of ground deformation beyond dynamic events captured by geodetic data, we examine the structural and extrusive history of the Alu dome, Ethiopia. Surface uplift and subsidence in 2008, recorded by InSAR during a nearby eruption, demonstrates that Alu is actively deforming; these ground deformation patterns were attributed to deformation of a shield volcano above a tabular sill. We contend that Alu is actually a forced fold developed above an incrementally emplaced saucer-shaped sill, which fed surrounding lava flows and spatter cones, because: (1) there is no central vent or evidence of construction from lava flow build-up, meaning Alu is not a shield volcano; (2) surrounding lava flows deflect around Alu, indicating that it had a topographic expression prior to their extrusion; (3) the boundary of Alu directly overlies the lateral termination of a sill modelled from ground deformation data, similar to sill-fold relationships observed elsewhere; (4) the normal faults that cross-cut Alu are compatible with outer-arc extension during doming; (5) the disposition of lava flows radiating from Alu and emanating from vents and/or spatter cones distributed around the periphery of the dome is consistent with their being fed by a saucer-shaped sill; and (6) the scale and timespan of ground deformation during the 2008 eruption suggests that Alu may have formed through the incremental injection of distinct magma pulses. Whilst the size and shape of Alu resembles that of a laccolith, we show that forced folds above sills and laccoliths are commonly indistinguishable. Intrusion geometries interpreted from the topographic expression of long-lived magma bodies, like those modelled from geodetic data, are therefore non-unique. Through integrating geodetic data and structural mapping, we show that ground deformation at Alu-Dalafilla in 2008 and observed using InSAR, capture the first, real-time evidence for dynamic forced folding above a saucer-shaped sill.