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Onset of the Bardarbunga 2014-2015 caldera collapse: Role of magma buoyancy and lubricated caldera faults

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We evaluate the factors contributing to the onset of the 2 km3 gradual caldera collapse at Bárðarbunga volcano in Iceland in 2014-2015. After an initial phase, the process has been modelled with pressure from a subsiding piston (minus friction) driving magma out of a source. The inferred overpressure to drive the flow after the onset of the piston collapse is on the order of 2 MPa. With such low driving pressure, the question arises why the piston collapse began. In addition to size and geometry of the magma body, as well as pressure gradient from topography, we suggest that magma buoyancy is a critical factor: magma density was about 2700 kg/m3, and thus less dense than surrounding crust at the inferred depth of prior magma storage (6-12 km) of around 2900-3000 kg/m3. We suggest to explore the following scenario of events: (i) prior to onset of activity magma had gradually accumulated in a source with volume $\geq$ 2 km3 within viscoelastic crust, with overpressure on the order of the tensile strength of the crust, or about 2 MPa. This pressure could have, to a large degree, resulted from buoyancy pressure at the roof of the magma source (density difference × thickness of magma body × g). Failure occurred on 16 August following subtle pressure increase in the source in the preceding months. (ii) Vertical rise (eventually for about 3 km) of magma occurred through crust that was denser than the magma, up towards the level of neutral buoyancy. Increase in overpressure from the original source to the top of a continuous magma column above may have been significant (density difference × height of magma path × g, or about 9 MPa). (iii) Initial flow of magma into a lateral dyke was driven by the combined pressure effects from (i) and (ii). As this pressure is substantially larger than needed to drive the flow according to the piston model, the pressure could drop significantly in the feeding source, while still ensuring sufficient pressure to drive lateral flow in the dyke. Caldera collapse could thus be stimulated. Onset of the piston collapse and slip on caldera faults began a few days after flow into the dyke (frequent M>5 caldera earthquakes began on 23 August), after a sufficiently large volume of magma had been injected into the dyke. In addition, we suggest reduction of friction on the caldera boundaries could have played a role. Initial upflow path may have been located on the deeper level of the eastern part of caldera boundary, which was relatively aseismic during the caldera collapse. Preceding the Gjálp eruption in 1996, different parts of the caldera boundary may have been lubricated or weakened during fracturing or the formation of ring dyke complex as witnessed by propagation of seismicity from a similar location in the NE corner of the caldera, and following the rim towards west and then south along the eastern rim. If sufficiently thick, its deeper parts may have remained weak in 2014.