Geophysical Research Abstracts
Vol. 17, EGU2015-10753-2, 2015
EGU General Assembly 2015

Subglacial melting associated with activity at Bárdarbunga volcano, Iceland, explored using numerical reservoir simulations

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Increased seismic activity was observed within the caldera of Bárdarbunga, a central volcano beneath Vatnajökull glacier, on 16 August 2014. The seismicity traced the path of a lateral dyke, initially propagating to the south east of the volcano, before changing course and continuing beyond the northern extent of the glacier. A short fissure eruption occurred at the site of the Holuhraun lavas on 29 August, lasting for approximately 5 hours and producing less than 1 million cubic meters of lava, before recommencing in earnest on 31 August with the large effusive eruption, which is still ongoing at the time of writing. The glacier surface has been monitored aerially since the onset of heightened seismic activity, and the caldera and dyke propagation path surveyed using radar profiling.

Ice cauldrons are shallow depressions which form on the glacier surface due to basal melting, as a manifestation of heat flux from below; the melting ice acts as a calorimeter, allowing estimations of heat flux magnitude to be made. Several cauldrons were observed outside the caldera, two to the south east of Bárdarbunga, and three located above the path of the dyke under the Dyngjujökull outlet glacier. The cauldrons range in volume from approximately 0.001 km^3 to 0.02 km^3. We present time series data of the development and evolution of these cauldrons, with estimates of the heat flux magnitudes involved.

The nature of the heat source required to generate the aforementioned cauldrons is not obvious and two scenarios are explored: 1) small subglacial eruptions; or 2) increased geothermal activity induced by the dyke intrusion. We investigate these scenarios using analytical and finite element modelling, considering the surface heat flux produced, and timescales and spatial extent of associated surface anomalies. A range of permeabilities has been explored. It is found that an intrusion of a dyke or sill into rocks where the groundwater is near or at the boiling point curve can cause rapid increase in geothermal activity. However, a shallow intrusion into a cold groundwater reservoir will have a very muted thermal response even when an intrusion stops within a few tens of meters from the surface. Thus, our results indicate that minor subglacial eruptions, similar or slightly larger than the small eruption north of the glacier on the 29 August, are the most plausible explanation for the formation of the ice cauldrons observed. These results have implications for the understanding and interpretation of thermal signals observed at ice-covered volcanoes, highlighting the importance of reservoir/bedrock thermal state prior to intrusion.