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Reawakening of Öræfajökull volcano monitored using a multidisciplinary approach

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Öræfajökull is a stratovolcano in SE Iceland overlain by Vatnajökull ice cap. It is the highest peak of Iceland (2110 m). The volcano has steep slopes towards west, south and east and encompasses an oval caldera with a diameter of 3.5-5 km. It is responsible for two eruptions during the past 1000 years, in 1362 and 1727–28. Because of low seismic activity and the comparatively few eruptions in the last millennium, Öræfajökull has not been considered highly active. Extensive monitoring infrastructure has therefore not been operated around the volcano before 2017.

The eruption in 1362 was a major Plinian eruption, destroying the nearby inhabited area by pyroclastic flows, massive tephra fallout, ballistics and volcanogenic floods. The eruption spread tephra over E-Iceland as well as Greenland, Ireland and Norway. The 1727 eruption was a VEI3–4 flank eruption but nevertheless had major effects on the closest farms, with earthquakes, floods and tephra fallout. Since modern volcano monitoring started in Iceland a few decades ago, the volcano has been rather quiet with on average 8 earthquakes per year of magnitudes 1 to 3.

In 2016 the seismicity increased slightly and in 2017, during the summer months and from September onwards, the seismicity intensified, with tens of earthquakes monthly. In November 2017, circular crevasses were discovered signifying the subsidence of the ice surface in a 1-km wide cauldron near the center of the caldera, indicating rapid melting of the glacier from below, however without any signs of volcanic tremor. At the same time, gas smell was reported from the main outlet river, Kvíá, draining the caldera. The ice-cauldron deepened to 17 m in just over 2 weeks, and in the middle of December 2017, the depth at the center had increased to 23 m. These changes reveal the reawakening of a subglacial geothermal area covered with up to 500 m thick ice.

Geochemical analysis shows a 5–7% ratio of geothermal water in Kvíá river, which is consistent with the volume of geothermal water required to melt the amount of ice corresponding to the volume of the ice cauldron. This indicates that high-temperature geothermal water (>250°C) is likely being discharged to the bedrock surface (at the base of the glacier). Signs of increased geothermal activity elsewhere in the caldera are suspected (January 2018). Deformation data show subtle signs of inflation of the volcano, indicating an intrusion of magma prior to the unrest in the fall 2017.

We present an overview of monitoring the reawakening of Öræfajökull volcano combining geophysical and geochemical instruments. We show the results of earthquake monitoring and the evolution of seismicity, including temporal changes of seismic velocity, InSAR and GPS measurements, including modelling of a minor crustal intrusion, results of gas-, geochemical- and hydrological measurements in the outlet rivers, air-borne radar altimetry profiling to map the evolution of ice-cauldrons and satellite images to monitor glacier-surface changes.