Memo

Rockslide in Askja, July 21 2014 - Preliminary results of observations

Jón Kristinn Helgason, Sveinn Brynjólfsson, Tómas Jóhannesson, Kristín S. Vogfjörð and Harpa Grímsdóttir; Icelandic Meteorological Office (IMO). Ásta Rut Hjartardóttir, Þorsteinn Sæmundsson, Ármann Höskuldsson, Freysteinn Sigmundsson and Hannah Reynolds; University of Iceland

5.8.2014

In the evening of 21 July 2014, a large rockslide occurred in Askja, which descended into the caldera lake (Lake Öskjuvatn). The slide was released from the southeastern caldera wall in an area called "Suðurbotnar". It is one of the largest known rockslides since the settlement of Iceland. The slide covered most of the Suðurbotnahraun lava field and it reached the Kvíslahraun lava, but the eruptive fissure of the Suðurbotnahraun lava is beside the rockslide and therefore intact. The slide triggered a tsunami in the lake that washed up on the lakeshores all around the lake, reaching up to 20–30 m elevation above the water level and even higher in places. The wave travelled farthest around 400 m (horizontally) into the flatland SE of the crater Víti. It was fortunate that the rockslide occurred late at night and nobody was close to the water, otherwise it would have been extremely hazardous. A few hours earlier, tens of people were at the lakeshore who might not have been able to escape the tsunami.

The rockslide appeared as shallow tremor on IMO seismographs near Askja and the data show that the slide was released at around 23:24. The slide created seismic waves that travelled around most of Iceland in roughly one minute. The waves were picked up by most of the IMO seismic network; signals were clearest at the nearest stations, but only the lowest frequencies were picked up at seismometers farthest away.

There were no eyewitness to the slide, but members of a search and rescue team saw a white plume rise up above Askja at 23:27. The steam plume was created when the slide exposed shallow geothermal areas in the release area. In addition, a dust cloud created by the rock slide may have contributed to the plume.

The release area of the rockslide is approximately 800 m wide and 350 m above the lake surface. It may have been a "rotational slide movement", which means that the failure surface of the slide is concave. The volume of the slide is roughly estimated 30–50 million m^3, however, the estimation may change when further measurements and analyses have been carried out, especially on the part that is in the lake and regarding the depth of the sliding surface. If the bottom of the slide reaches below the lake bottom, the total volume of material that moved may be a lot more.

The water level of Öskjuvatn lake rose 1–2 m after the rockslide. The rise of the water level will be measured precisely because it gives information on the volume of the slide. Bubbles and muddy plumes were noticed in Víti after the slide, most likely due to subsurface inflow of water after the water level rose in Öskjuvatn.

Askja consists of 3–4 calderas. The youngest one hosts Lake Öskjuvatn and was formed over a period of 30 years after an eruption in 1875. Before that, Öskjuvatn did not exist and, therefore, the rims of the caldera are geologically a very young area. Such slopes are more unstable than slopes in older landscape. It is clear from geological evidence that rockslides similar to the one that fell in July 2014 have been released before from the rims of Askja, although people have not noticed them.

Further rockslides in Askja should, therefore, be expected within the next years, decades or centuries. Consequently, travel near the lake is associated with a certain risk. A person by the lake that notices a landslide should move immediately up the hill and away from the lake. It takes a tsunami wave about 1–2 minutes to travel across the lake and sound takes about 10 sec to cover that distance. Thus, people have a very short time to escape if a big rockslide is released from the other side of the lake. A large rockslide is needed to cause a tsunami of a similar size as the one in July 2014, smaller slides may cause smaller waves and a small slide would hardly cause any wave, even though the noise may be considerable.

Photographs from the rockslide area indicate that considerable movement had started before the slide was released. Slow movement in the bedrock seems to have accelerated in the summer of 2014. There was deep snow in the mountains and fairly warm weather before the slide occurred. Percolating water from the melting snow might, thus, have increased the rate of movement. Seismic data indicate that a sudden movement occurred around 40 minutes before the slide, but at 23:24 the failure point was reached and the rockslide was released.

It is important to observe the rockslide in detail with the goal of using the results to detect and monitor unstable areas, both within Askja as well as in other areas where people may be endangered by rockslides and tsunamis. During the next weeks and months, further measurements and analyses will be carried out, adding to the results and making them more precise. Below are photographs, maps and graphs that show the main results of measurements and analyses that are available, now two weeks after the event.

- Width of fracture line: 800 m
- Vertical drop: 350 m
- Runout length beyond the lake shore: ~1000 m
- Volume: ~30–50 million m^3
- Estimated duration of the slide: 20 seconds according to seismographs
- Travel time of tsunami across the lake: 1–2 minutes

Figures

Figure 1. The rockslide area four hours before the slide occurred. The outline of the slide is indicated in the picture. Photo: Ármann Höskuldsson 21.7.2014. Drawing: Jón Kristinn Helgason.

Figure 2. A photograph taken three days after the rockslide. The outline of the slide is indicated in the picture. Photo and drawing: Jón Kristinn Helgason, 24.7.2014.

Figure 3. A photograph taken at 23:27 close to Herðubreiðartögl on July 21, 2014, showing a plume above Askja. The plume disappeared shortly after. Photo: Kolbeinn Helgi Gíslason from the Icelandic Search and Rescue.

Figure 4. Bubbles and muddy material rising up in Víti after the slide, most likely groundwater flow resulting from the rising water level in Askja. Photo: Ármann Höskuldsson.

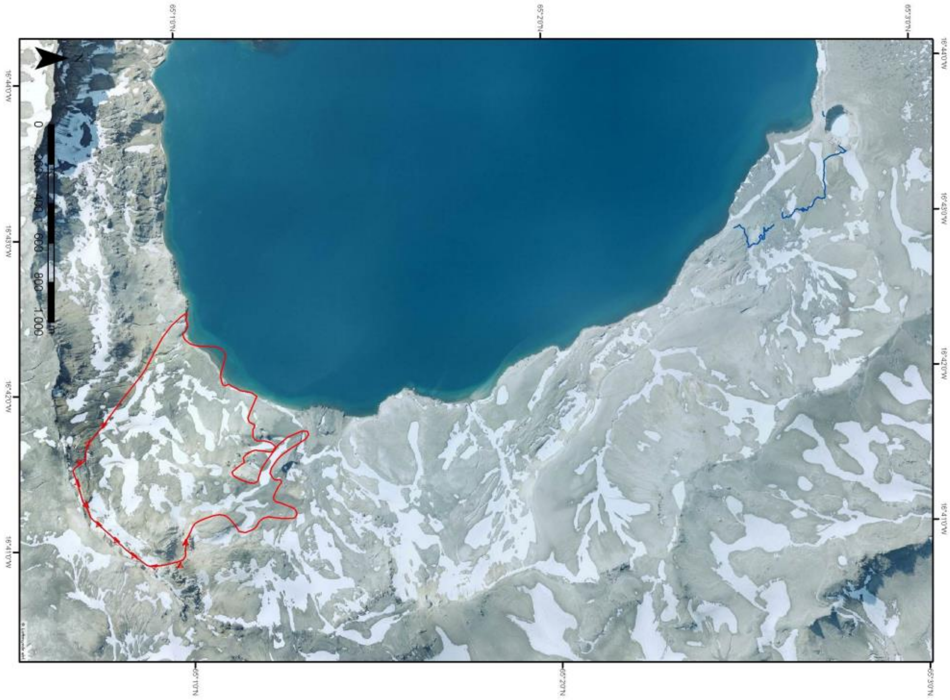

Figure 5. Outlines of the rockslide and GPS outlines of the tsunami wave close to Víti. Drawing: Sveinn Brynjólfsson.

Figure 6. Runup marks of tsunami waves by Víti. Photo: Jara Fatima, 24.7.2014.

Figure 7. 4–6 m high erosion bank by the coast created by backflow of water from the flatland SE of Víti. Photo: Sveinn Brynjólfsson, 24.7.2014.

Minnisblað

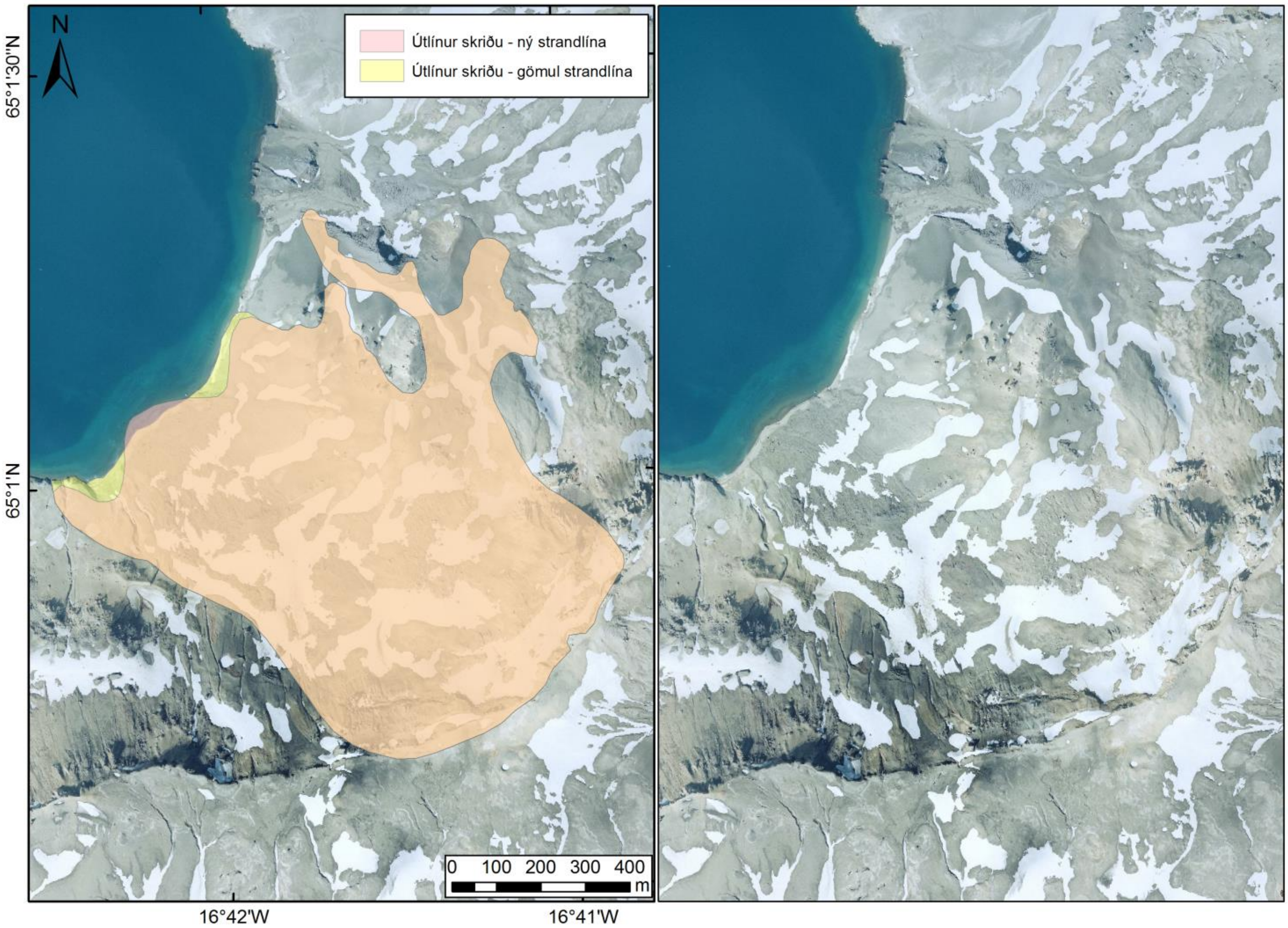

Figure 8. Right: An areal photo of the rockslide area in Suðurbotnar. There is evidence of older movement which is probably an old rockslide. Left: The outline of the rockslide. The lake shore has retreated in places (yellow areas), the displacement being up to 50 m. Around the middle of the deposit, the edge seems to have advanced (purple area). Background: Loftmyndir ehf. Analyses: Ásta Rut Hjartardóttir and Þorsteinn Sæmundsson.

Minnisblað

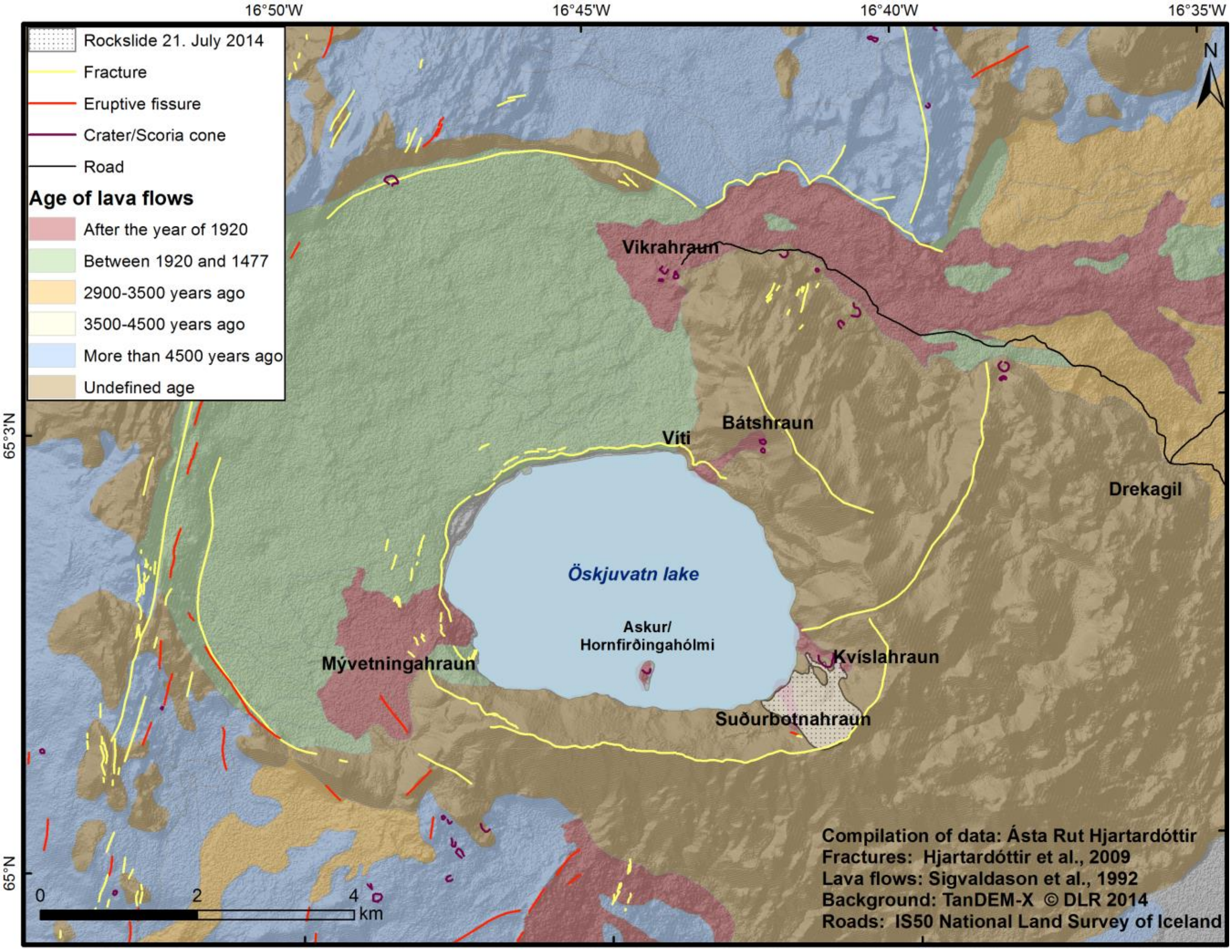

Figure 9. Geological map showing the outline of the rockslide, as well as eruptive fissures and the age of lava flows in the area.

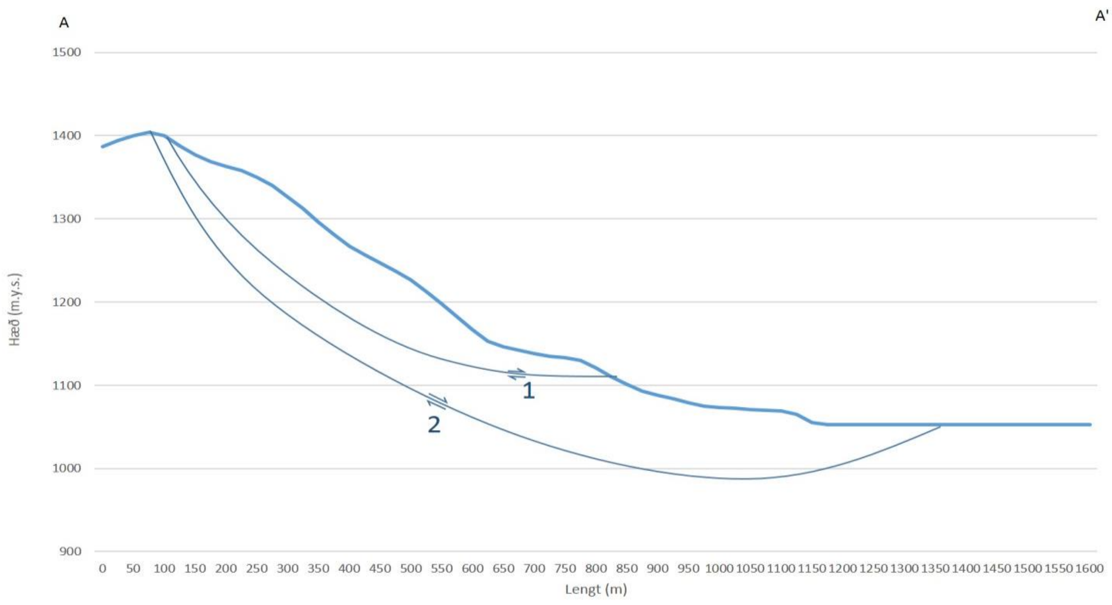

Figure 10. Schematic drawing of possible failure surfaces of the rockslide. In case 1, the rockslide is mainly released from the upper part of the hillside, it fallw down and partly goes into the water. In case 2, the ailure surface reaches down below the lake bottom and in that case the total volume of material that is activated by the slide could be greater. Further explanation of case 2 is in the next figure. Drawing: Jón Kristinn Helgason.

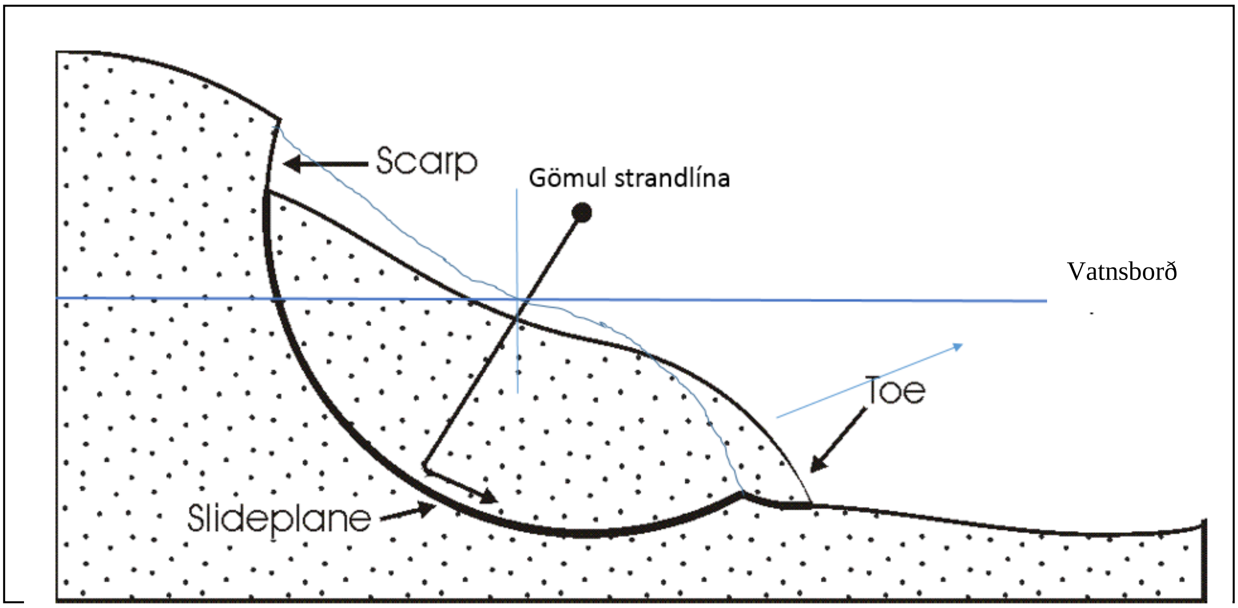

Figure 11. The movement in the rockslide may have been a “rotational”, meaning that the failure surface is concave. The axis of rotation could be beyond the current coast line, as the figure shows. Adaptation of drawing: Þorsteinn Sæmundsson.

Minnisblað

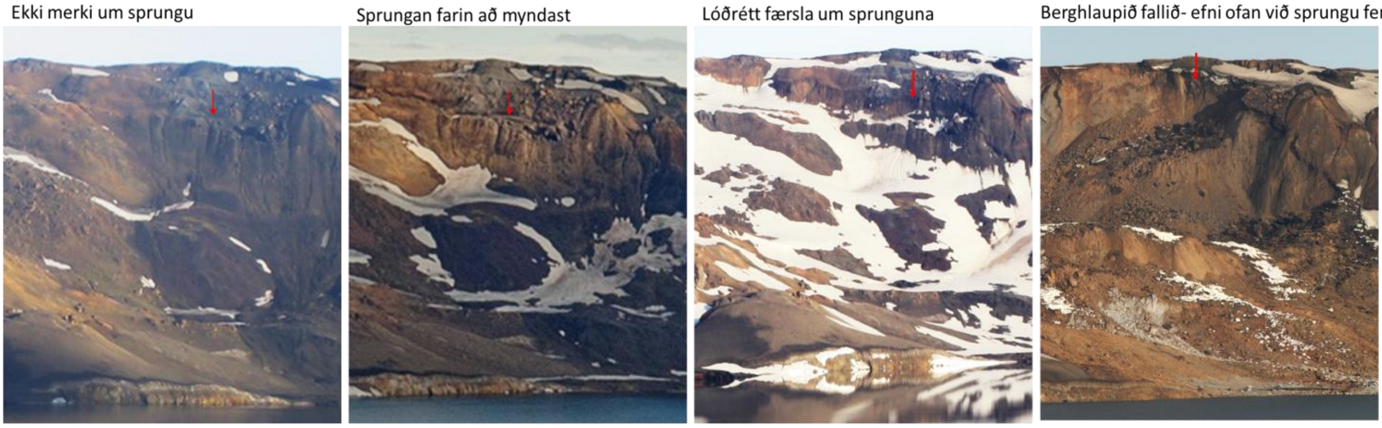

Figure 12. On a photograph from 2003 there is little or no evidence of the fracture, however, in 2011 a clear fracture can be seen. Shortly before the rockslide, the material below the fracture seems to have sunk considerably. The crown of the rockslide is just above the fracture. Compiled by Jón Kristinn Helgason.

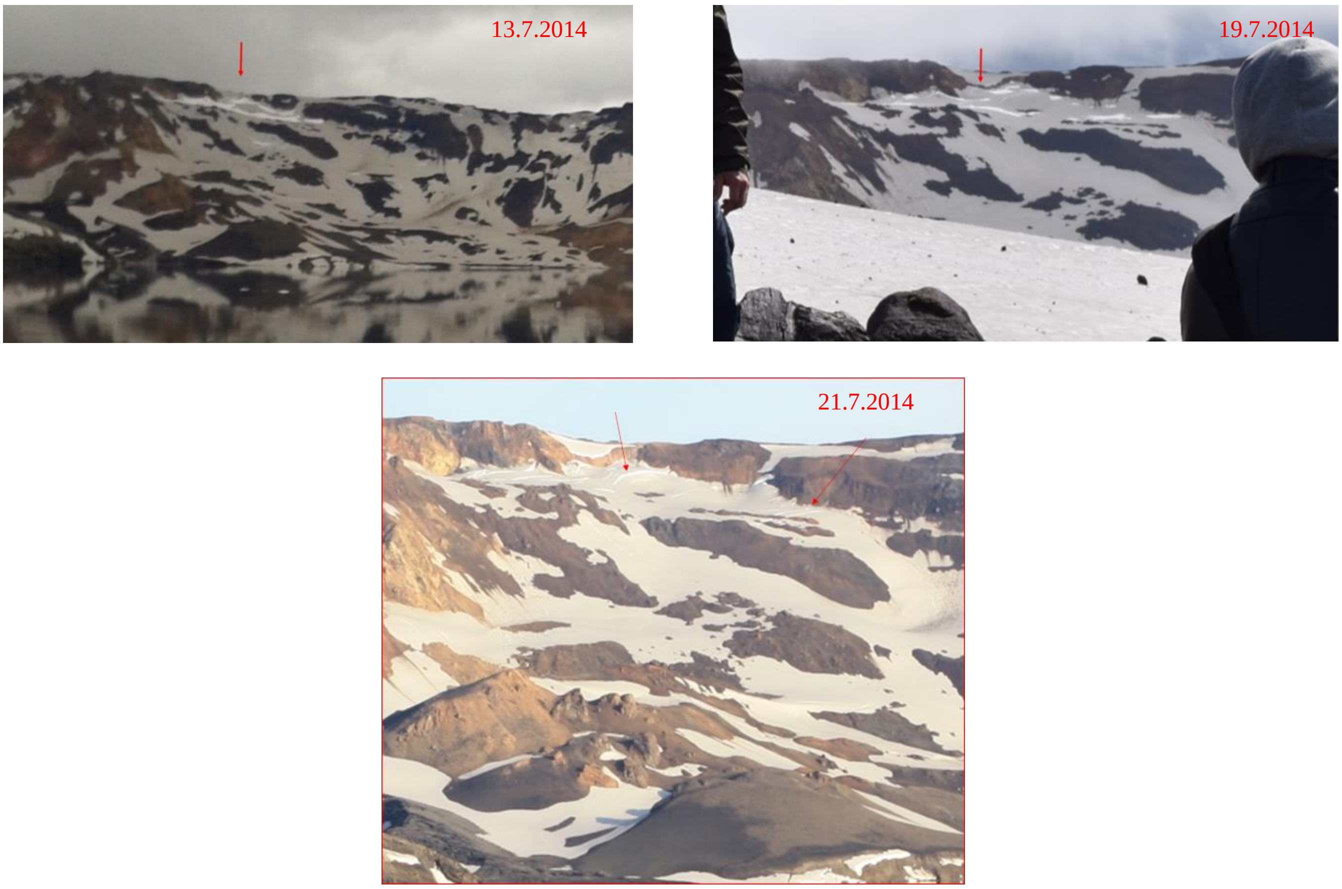

Figure 13. Fractures in the snow could be seen days before the rockslide, and apparently some vertical movement. The upper pictures were taken by the guide Kristinn Ingi Pétursson, and the lower picture by Ármann Höskuldsson 4 hours before the slide. Compiled by Jón Kristinn Helgason.

Minnisblað

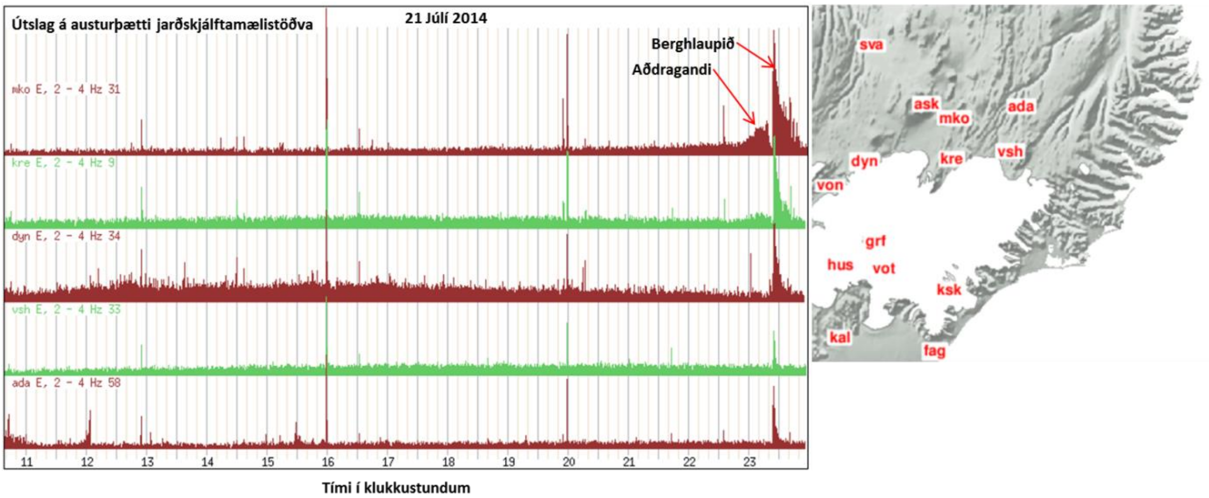

Figure 14. The plot shows the amplitude of the east-west component of nearby seismometers, at Mókollar (mko), Krepputunga (kre), Dyngjuháls (dyn), Vestari-Sauðahnjúkar (vsh) and Aðalból (ada). The station locations are shown on a map to the right together with the location of Askja (ask). The time period shown is from 10:40 am on July 21 till midnight. Earthquakes registered at the seismometers are seen as higher amplitude peaks or pulses above the environmental noise, for example at 4 pm and some at around 8 pm. These earthquakes are very shallow and are most likely occurring within and at the bottom of the slide itself. The largest events are at 3:59 pm, magnitude 2.1 and at 7:59 pm, magnitude 1.7. The landslide itself is seen as higher amplitude pulse at 11:24 pm which decays slowly in about 20 minutes, but most of the energy is released during the first 2 minutes. It seems from the seismic records that the landslide had a precursor about 40 minutes before the main event, or at around 10:40 pm. Continuous seismic tremor in certain frequency bands can be seen in at station mko and is less obvious at station kre. This tremor possibly indicates that part of the landslide had started to creep. Drawing: Kristín S. Vogfjörð.

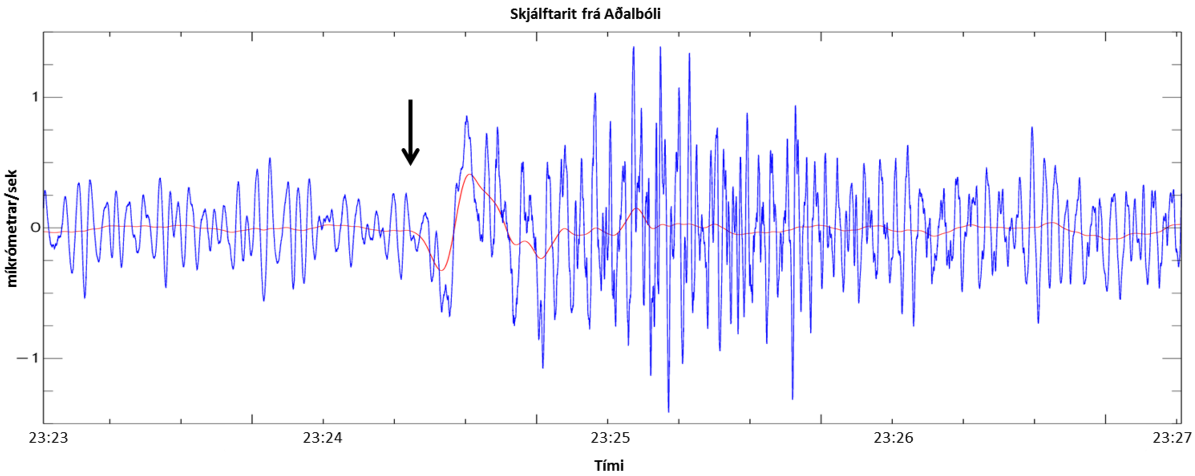

Figure 15. Seismic records (east–west component) (blue) from 11:23–11:27 pm from the station at Aðalból (ada), at approximately 32 km distance from Askja. The arrow shows the arrival time of the first wave to the station, but the highest amplitude signal was measured approximately 1 minute later, with velocity 1,5 micrometers/second and main frequency ~1 Hz. The red seismic trace on top shows the lower frequency content of the wave, with main frequency around 0.05 Hz. This low frequency was even measured in the southwestern part of Iceland at a roughly 230 km distance. It probably indicates the main mass movement in the landslide. Drawing: Kristín S. Vogfjörð.

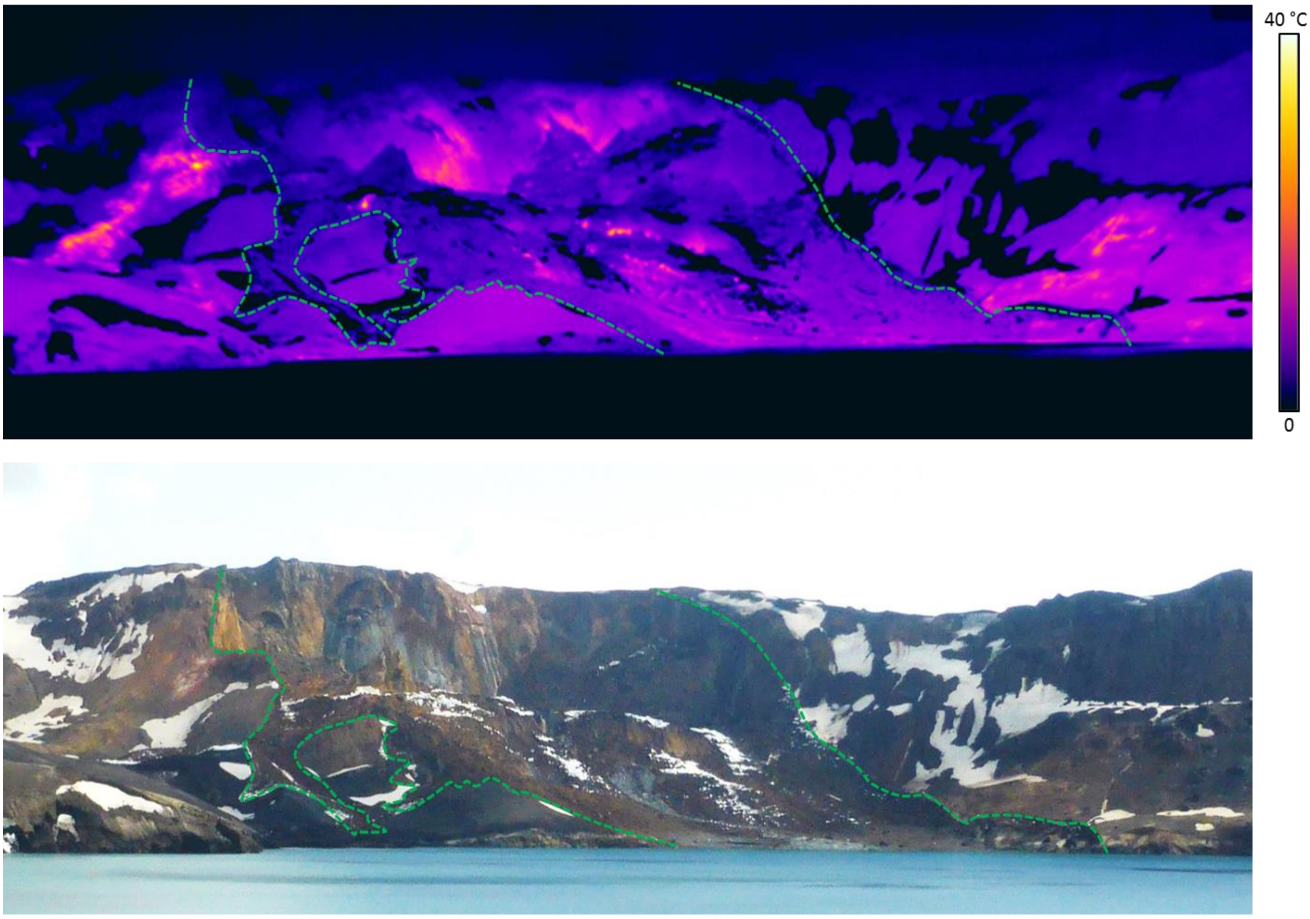

Figure 16. Thermal image (upper) and photograph (lower) of the rockslide area taken near Víti at the north side of Öskjuvatn. The thermal image was taken with a FLIR P660 infrared camera. Hot patches are visible in the scarp, corresponding to the most hydrothermally altered material. The scale bar shows the temperatures represented in the thermal image in degrees centigrade. The dashed green lines trace the outline of the rockslide. Pictures: Hannah Reynolds.