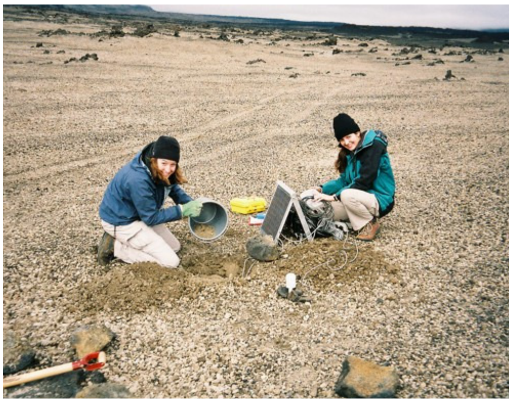
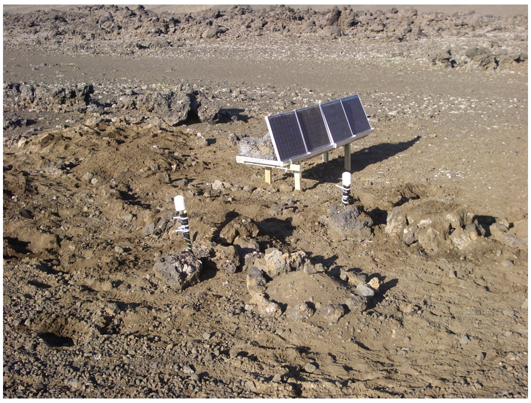
Askja 2007 Seismic Project
Scientific Report
(with Appendices: Station descriptions)

NERC GEF Loan : 842





Janet Key
Heidi Soosalu
Robert S. White

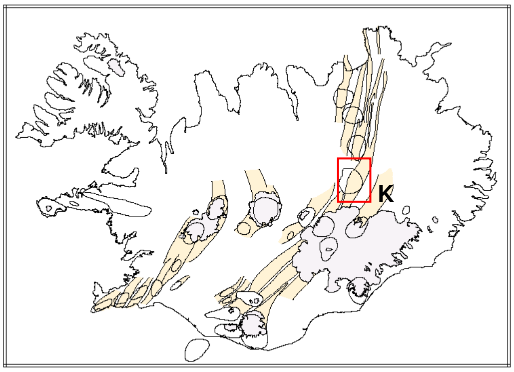
Bullard Laboratories
Department of Earth Sciences
University of Cambridge

May 2008

Askja 2007 Seismic Project

Abstract

The Askja region is located on the mid-Atlantic spreading boundary in central Iceland. The study area includes the Askja caldera and the mountains Herðubreið and Herðubreiðartögl which are part of the larger Askja volcanic system. During a two month deployment in summer 2006 over 1800 earthquakes were detected in the region including 100 previously unwitnessed lower-crustal earthquakes. A new deployment of 22 Güralp 6TDs was conducted during July and August 2007 specifically designed to target these deeper events. Over 250 lower-crustal Askja events were recorded, more than double the number seen in 2006. Shallow earthquakes in the 2 – 5 km depth range within the caldera appear to delineate the upper edge of a magma chamber. In February 2007 a new region of lower-crustal seismic activity began below Upptyppingar mountain in the Kverkfjöll volcanic system, just 20 km E of Askja. One of our stations was directly above much of this activity and detailed relocations have been performed combining data from our network and the permanent Icelandic network; revealing short term clusters of ~10-100 events that are grouped very tightly horizontally and migrate vertically.



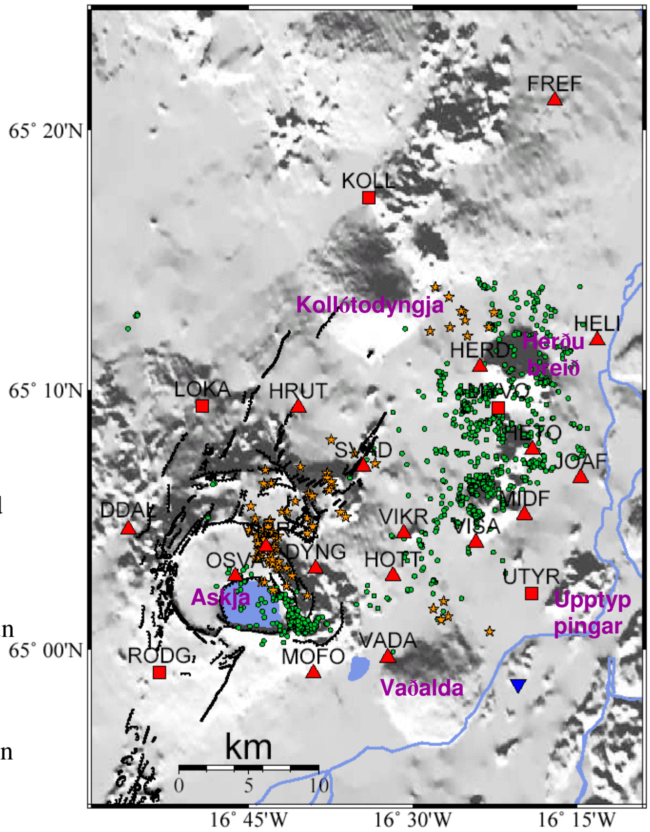


Figure 1. a) Red box shows the location of the Askja region within the Northern volcanic zone of Iceland. The central volcanoes of the volcanic systems are circled and their fissure swarms are shaded orange. K shows Kverkfjöll volcanic system. Ice caps are shaded grey. **b)** Red triangles are stations that were occupied July-August 2007, red squares are stations that were left in place to run through the winter, blue inverted triangle is station of the permanent seismic network run by the Icelandic Meteorological Office. Earthquakes from the 2006 deployment are plotted, green circles show earthquakes less than 10 km depth and yellow stars for those deeper. Rivers and lakes are identified in blue. Mapped faults and fissures outlined in black. Place names mentioned in text are labelled in purple.

Geological and Seismic Background

The Askja volcanic system is one of several *en echelon* volcanic systems that make up the northern segment of the mid-Atlantic plate boundary in Iceland (Figure 1a). The Askja volcanic massif is a large nested caldera formed by several large eruptions and is the central volcano of the Askja system. Subsidence following the most recent major eruption in 1875 AD formed the caldera lake Öskjuvatn. Geodetic modelling suggests that there is a dual magma chamber system at Askja, with one centred at ~3 km depth and the second larger one at a depth of ~16 km (Sturkell et al, 2006). The mountains Herðubreið and Herðubreiðartögl are part of the Askja system and are located to the NE of the caldera (Figure 1b). They were formed as a result of subglacial eruptions during the last Ice Age but are currently volcanically quiescent and very few signs of fissuring can be found around them (Hjartardóttir et al, 2008). Despite the lack of surface features related to faulting, these two mountains have been persistently seismically active, with typical earthquake magnitudes of < 3 (IMO). In the summer of 2006 we conducted a two month long deployment of 20 Güralp 6TDs, focusing on the Herðubreið area (Soosalu and White, 2007), following a successful three week pilot study with 5 stations in August 2005.

Over 1800 earthquakes were detected, mainly located in a conspicuous belt of upper crustal seismicity (2 – 7 km depth) extending northeast from the Askja caldera to Herðubreið and Herðubreiðartögl (Figure 1b). Unexpectedly lower crustal events in the depth range 17 – 25 km were also detected, mainly located at the northern boundary of the caldera (Figure 1b). These events have distinctive emergent onsets, typically with lower frequency contents than the shallow earthquakes. It is suggested that these deep events are the result of melt movements, where locally high strain rates caused by propagating dykes allow brittle failure to occur within the normally hot and ductile lower crust. In order to be able to investigate these deep events more thoroughly a second major seismic survey of the Askja region was conducted in summer of 2007.

In February 2007 intense seismic activity began below Upptyppingar, a mountain 20 km to the east of Askja, at the extreme northern end of the Kverkfjöll volcanic system (Figure 1). Our Askja 2007 network was fortuitously well positioned to capture this activity as the Icelandic Meteorological Offices' permanent seismic network (known as SIL) has no stations to the NW of Upptyppingar in close proximity to the activity.

Fieldwork procedure

The field season in the Askja region is limited to the summer months due to the high latitude of 65° and altitudes of 500-1200 metres a.s.l. Depending on snow conditions each year the mountain roads in the area are opened in late-June or early-July and are accessible only by 4WD vehicles. The roads are closed due to snow cover as early as late-August or early-September. There are two mountain huts within the field area, manned by rangers from late-June to the end of August. The deployment began on the 2nd of July and was finished on 7th July and the pick up trip was completed between the 25th and 29th of August. As the field area is over 100 km away from inhabited areas, for safety reasons we only operated at times when rangers were present and aware of our locations and actions.

The seismic network consisted of 22 broadband Güralp 6TD seismometers (Figure 1b). Thirteen were provided by SEIS-UK and another nine by Cambridge University. Each of them had an individual GPS clock and for a power source, a battery of varying size depending on location, together with a 20 W solar panel. As we only had 20 panels and 22 sites, JOAF and MOFO were powered by batteries alone. The majority of the stations reoccupied sites from the 2006 deployment, but coverage to the west of Askja and within the caldera itself was improved. The sites were chosen as a compromise between optimal coverage and accessibility in the challenging terrain of the region. A station could be deployed typically within an hour. Most of the sensors were buried in a plastic bin bag in sand or pumice depending on the local ground conditions. At two sites (HERD and SVAD) there were good exposures of flat pahoehoe lava, and the sensors were levelled directly on it, covered with a bucket with a cairn built around for protection. Although these sites suffered higher long-wavelength background noise, after filtering these sites were very good. At the site DYNG the instrument was placed in an unused seismometer vault belonging to the Icelandic Meteorological Office, so the instrument was levelled directly on the concrete plinth within the vault.

All of the sensors were aligned to N21E on the assumption that this was grid north, however we have subsequently found out that was actually N15E in the Askja region during summer 2007. As the magnetic north can move quite rapidly in Iceland it is recommended that the correct value is checked in the University of Iceland almanac each year. The sampling rate was set to 100 samples-per-second with the GPS clock run in continuous mode. The breakout box and cable ends were placed in a plastic sandwich box with holes made for the cables, and the box was either placed in the same bag with the battery or wrapped in a plastic bag and buried underground. The 3 or 4 GB memory of the sensors was sufficient for the ~50-day long recording period and no service trip was needed before the pick-up of the instruments. The majority of the instruments were downloaded onto Lacie disks before being dug up; however MIDF and MYVO could not be downloaded either in situ or later at the mountain hut.

During the pick-up trip ten instruments were set up at five sites (KOLL, MYVO, UTYR, RODG and LOKA) in order to run a test network through the winter. As the instruments had a memory of 4 GB a pair of seismometers was used at each site, with one set in individual mode and the other in continuous mode so that we would have a capacity for 8 GB of data. The sampling rate was reduced to 40 samples-per-second to reduce memory requirements. Each seismometer was connected to two batteries in parallel, totalling at least 160 Ah and then connected to two 20 W solar panels. The four solar panels at each site were mounted on a wooden stand (see cover photo), raising them off the ground to reduce the chance of them being covered with snow. The wooden frame was limited in height and the whole stand was weighted down with lava boulders encased in chicken mesh to prevent it being knocked over by the high winds the region experiences in the winter. The GPS clocks were also mounted on metal poles to elevate them above snow cover. All of the batteries for the two instruments were buried in a single pit with a combination of polystyrene sheets and roofing insulation lining the edges to try to prevent them from cracking in the freezing temperatures. A single site could be assembled in 3 hours. These stations will be serviced in July 2008.

Recorded Data

Data recovery for the days that the instruments were operational was 100% at all stations except JOAF, MIDF, MOFO and VIBR (Table 1). The data were downloaded from the lacie disks and converted to miniseed following the detailed instructions provided by SEIS-UK (www.le.ac.uk/seis-uk/Manuals6T.htm).

Table 1. The volume of raw data gathered, note that volumes of raw data from MIDF and MYVO are unknown as these sites were downloaded by Güralp.

Site	ºN	ºE	Alt (m)	2007 Installed	2007 Picked Up	Days deployed	Days of data	Rec-overy (%)	Raw data (MB)	Mseed data (GB)
DDAL	65.07739	-16.93341	801	04-Jul	26-Aug	53.05	53.05	100	2789	2.4
DYNG	65.05191	-16.64809	957	03-Jul	29-Aug	56.72	56.72	100	2983	2.5
FREF	65.35190	-16.28355	533	06-Jul	27-Aug	51.78	51.78	100	2728	1.8
HELI	65.19875	-16.21843	491	06-Jul	25-Aug	49.67	49.67	100	2589	1.9
HERD	65.18157	-16.39731	686	03-Jul	28-Aug	56.04	56.04	100	2748	2.0
HETO	65.12872	-16.31695	582	03-Jul	27-Aug	54.75	54.75	100	2354	1.7
HOTT	65.04748	-16.52985	718	03-Jul	25-Aug	53.26	53.26	100	2882	2.6
HRUT	65.15576	-16.67443	701	04-Jul	26-Aug	53.01	53.01	100	2424	1.8
JOAF	65.11055	-16.24406	548	05-Jul	25-Aug	50.83	20.78	41	1096	1.0
KOLL	65.29024	-16.56726	593	06-Jul	27-Aug	52.06	52.06	100	2443	2.0
LOKA	65.15699	-16.82042	734	04-Jul	26-Aug	53.00	53.00	100	2586	2.1
MIDF	65.08676	-16.32961	572	05-Jul	25-Aug	50.90	33.28	65	?	1.4
MOFO	64.98440	-16.65119	702	04-Jul	28-Aug	54.98	39.91	73	2101	1.8
MYVO	65.15550	-16.36895	639	03-Jul	28-Aug	56.06	56.06	100	?	1.7
OSVA	65.04696	-16.77066	1130	05-Jul	25-Aug	51.24	51.24	100	2565	2.1
RODG	64.98513	-16.88639	1022	04-Jul	26-Aug	53.01	53.01	100	2466	2.0
SVAD	65.11746	-16.57498	680	04-Jul	26-Aug	53.02	53.02	100	2519	1.9
UTYR	65.03605	-16.31867	623	02-Jul	29-Aug	57.89	57.89	100	2460	1.9
VADA	64.99487	-16.53817	673	03-Jul	28-Aug	56.11	56.11	100	2538	1.9
VIBR	65.06619	-16.73256	1110	05-Jul	29-Aug	54.98	50.16	91	2670	2.2
VIKR	65.07474	-16.51347	718	02-Jul	26-Aug	54.57	54.57	100	2732	2.2
VISA	65.06901	-16.40369	640	03-Jul	25-Aug	53.18	53.18	100	2490	2.0

Eighteen of the twenty-two sensors operated completely correctly throughout the campaign. The two instruments without solar panels (JOAF and MOFO) were only operational for 21 and 40 days respectively. A third instrument, MIDF, stopped recording at midnight on the 8th of August. Despite the fact that it had a solar panel, reboot messages in the log suggest that this was probably caused by insufficient power. This instrument was also one of the two that had to be sent to Güralp for downloading. The data from RODG is chopped into numerous very small bits from 12:10 on 5th July to 19:28 on 6th July but there are no gaps; this is likely to be because of a faulty chip in the memory. Some sensors (HELI, HOTT, MIDF, UTYR and VISA) located near to the main tracks are occasionally affected by traffic noise. The two stations within the caldera (VIBR and OSVA) have quite poor signal to noise ratios, probably because of voids within the caldera fill.

Preliminary Results and Interpretations

We have gathered a large data set of local seismicity of over 3000 earthquakes (Figure 2). The dataset is dominated by the new activity beneath Upptyppingar, with the SIL network recording 1785 events during the deployment period (IMO). The hypocentres of both the shallow earthquakes around Herðubreið and Askja and the deep Askja earthquakes are consistent with those detected in 2006 (Figures 1 and 2).

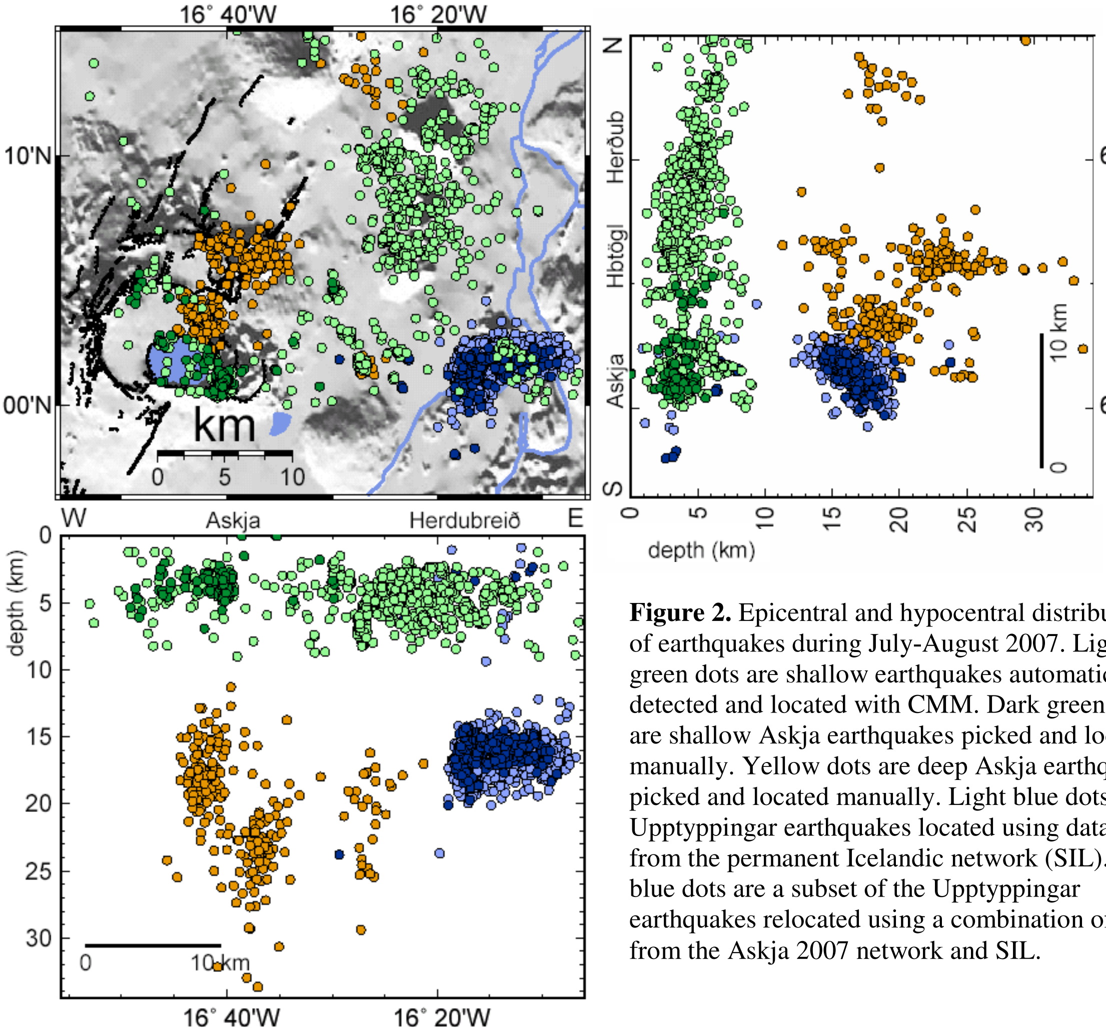


Figure 2. Epicentral and hypocentral distribution of earthquakes during July-August 2007. Light green dots are shallow earthquakes automatically detected and located with CMM. Dark green dots are shallow Askja earthquakes picked and located manually. Yellow dots are deep Askja earthquakes picked and located manually. Light blue dots are Upptyppingar earthquakes located using data only from the permanent Icelandic network (SIL). Dark blue dots are a subset of the Upptyppingar earthquakes relocated using a combination of data from the Askja 2007 network and SIL.

Approximately 800 shallow earthquakes have been automatically detected and located around Herðubreið and Askja using Coalescence Microseismic Mapping (CMM), a new algorithm developed at University of Cambridge by Julian Drew. Some 100 of these events around the Askja caldera have been manually picked and located and cluster in a depth range of 2 – 5 km (Figure 2). The majority of the events are located in the SE corner of the caldera which correlates with sites of known geothermal activity. The lower cut off in seismicity forms a dome shape across the caldera, proposed to represent the brittle-ductile transition above the upper magma chamber. This seismically defined magma chamber is located 2.4 km deeper and 3.4 km to the SE of the geodetically proposed upper magma chamber (Sturkell et al., 2006), and is much smaller in volume. Ray tracing techniques show significant S-wave attenuation in this region, supporting the presence of partial melts (Coffin, 2008). Although the focal mechanisms produced for these earthquakes show no clear pattern, a density plot of their T-axes shows alignment with the regional stress field caused by plate spreading.

Using data from both our network and the SIL stations, relocations were performed for 273 of the Upptyppingar earthquakes (Figure 2) (Nowacki, 2008). The majority of events are between 14 and 20 km deep, tending to shallow to the north. Short-term clusters of ~10–100 events are grouped tightly horizontally and migrate vertically with time. They usually have clear impulsive P- and S-arrivals and a broad range of frequencies between 2 and 20 Hz (Figure 3). Over 70 very well constrained focal mechanisms are consistent with reverse-, normal- and strike-slip faulting and show an enigmatic pattern of

T-axes oriented either vertically or NNW. Changes from one orientation to another can occur over timescales of less than a week. This flipping between horizontal and vertical axes; normal and reverse mechanisms respectively indicates that for traditional brittle dip-slip faulting, the two lesser principle stresses are oriented vertically and along ~155º, and are approximately equal in magnitude; thus small local deviations in stress may cause a ~90º change in the T-axis of the focal mechanisms.

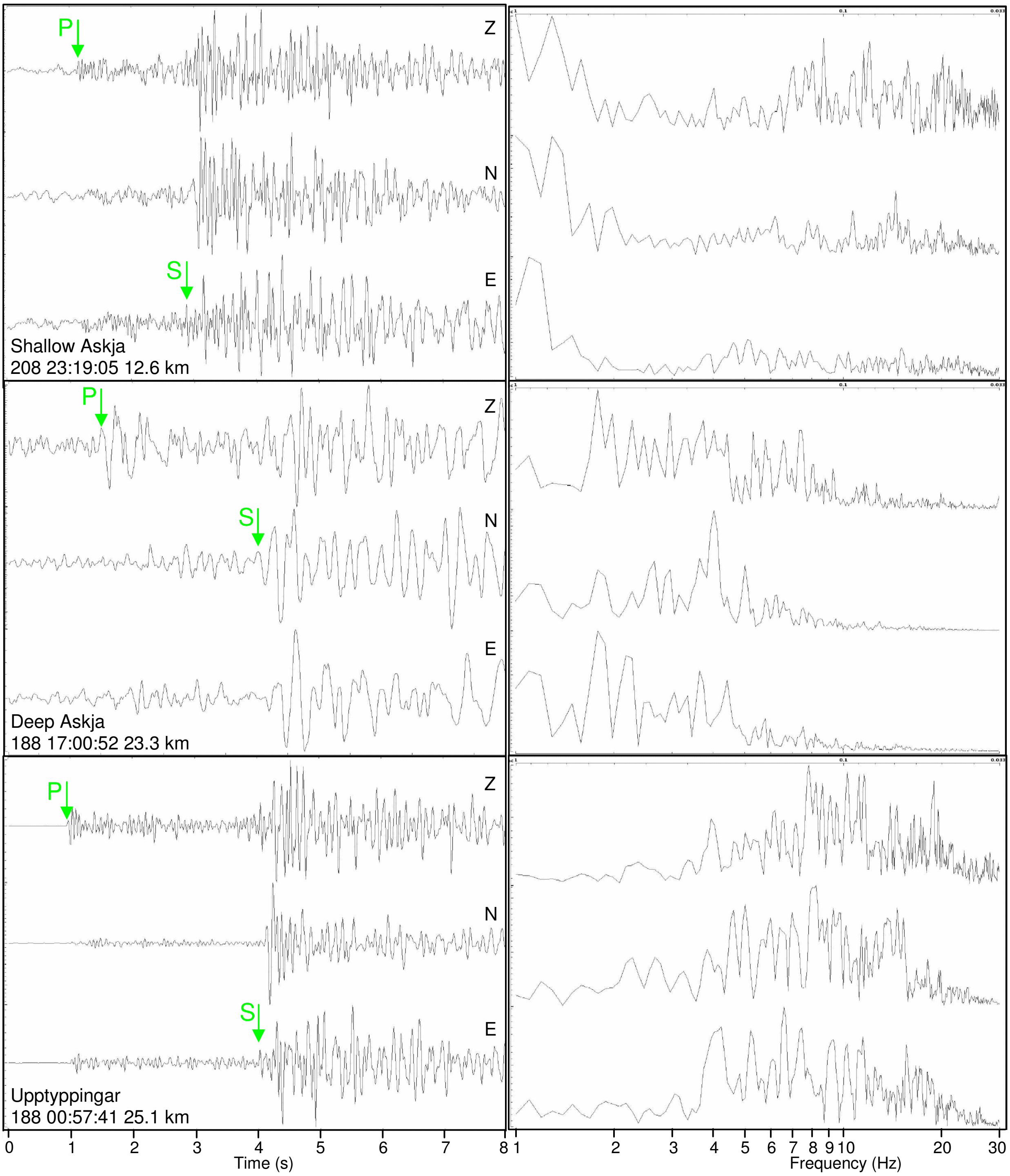


Figure 3. Seismograms from the station SVAD, 8s long windows with a 1.5 – 20 Hz filter applied, from a shallow Askja, deep Askja and Upptyppingar event respectively. The Julian day, origin time and hypocentral distance from earthquake to SVAD are given in bottom left corner. Spectrograms are shown for each of the events with no filter applied, over the range of frequencies 1 to 30 Hz. The shallow Askja event has mainly high frequencies in the range 7 – 30 Hz, the deep Askja event has mainly low frequencies 1.5 – 8 Hz and the Upptyppingar event has a broad range of frequencies from 2 – 20 Hz. The large-amplitude low-frequency signal seen in the shallow Askja spectrogram is part of the 1 Hz background noise present on all seismograms but is seen here because the earthquake is smaller in amplitude than the other two.

There were ~ 250 of the deep Askja earthquakes picked from the 2007 data set, over double the number observed for the same time period with a comparable network in 2006 (Soosalu and White, 2007). These lower-crustal events around Askja are distinctly different to those at Upptyppingar as they have emergent onsets and a much narrower and lower frequency range (Figure 3). It is almost impossible to produce focal mechanisms for these events as they are generally both emergent and small in amplitude and therefore impossible to see in the unfiltered data, preventing phase picks. They are mainly located within a depth range of 12 – 28 km, with some deeper events down to 34 km. The locations of these earthquakes are remarkably similar to those observed in 2006, falling into three distinct clusters: the largest in a SW-NE trending belt on the northern boundary of the caldera; the second between Herðubreið and Kollóttadyngja, on the same NE trend as the main cluster; and a third halfway between the Askja and Kverkfjöll volcanic systems (Figure 2). The main cluster is located immediately north of the geodetically proposed deeper magma chamber and is interestingly beneath the site of the most recent minor eruption in 1961. Within this main cluster there appears to be two sub-clusters: the majority of events within the caldera are in the depth range 15 – 22 km and those outside the caldera 20 – 28 km. This deepening away to the NE is consistent with geodetic and gravimetric observations (de Zeeuw-van Dalfsen et al., 2005; Sturkell et al., 2006) suggesting magma drainage away from the Askja plumbing system.

Presentations, Publications and Further Research

Waveform relocation techniques will be applied to both the lower-crustal Askja and Upptyppingar earthquakes to investigate relationships between events and any temporal or spatial patterns that emerge. We currently have 9 instruments in the field and will be returning in July 2008 to service them and install a 25 station network for the summer from which 15 instruments will be left in place over winter 2008/2009. These 15 instruments each have a 16 GB memory preventing the need for more than one instrument at each site. This will give 2.5 years of continuous data from the region with which to fully study both the Askja and Upptyppingar activity.

<u>Publication in International Refereed Journal</u>

Soosalu, H., Key, J. White, R. S., Knox, C., Einarsson, P. & Jakobsdóttir, S. S., Lower-crustal earthquakes caused by magma movement beneath Askja volcano on the north Iceland rift. *Bull. Volc.,* in press.

<u>Presentations at International Meetings</u>

Soosalu, H., C. Knox, R.S. White, P. Einarsson, S.S. Jakobsdóttir & E. Sturkell (2007). Seismicity at the Askja volcano and its surroundings, north Iceland. Volcanic & Magmatic Studies Group, Winter Meeting, Oxford, U.K., p. 27-28.

Knox, C., H. Soosalu, R.S. White & S.S. Jakobsdóttir (2007). Earthquakes at Herdubreid on the north Iceland plate boundary: tectonic or magmatic? Volcanic & Magmatic Studies Group, Winter Meeting, Oxford, U.K., 4-5 January, 2007, p. 55.

Heidi Soosalu, Steinunn S. Jakobsdóttir, Robert S. White, Clare Knox & Páll Einarsson (2007). Lower-crustal earthquakes at the divergent plate boundary of north Iceland near Askja, *Geoscience Society of Iceland,* Spring meeting 2007, p.37.

Soosalu, H., R.S. White, C. Knox, S.S. Jakobsdóttir & P. Einarsson (2007). Discovery of lower-crustal earthquakes down to ~30 km depth near the Askja volcano in north Iceland. *The 38th Nordic Seismology Seminar*, Helsinki, Finland, 13-15 Jun, 2007. 2 pp.

Soosalu, H., R.S. White, C. Knox, P. Einarsson & S.S. Jakobsdóttir (2007). Waveforms of lower-crustal earthquakes near the Askja volcano at the north Iceland divergent plate boundary. *European Seismological Commission workshop, Seismic phenomena associated with volcanic activity*, Nesjavellir, Iceland, 9-16 Sep, 2007. 1 p.

H. Soosalu, R. S. White, A. J. Key, C. Knox, P. Einarsson & S. S. Jakobsdottir (2008). Lower-crustal earthquakes reflect magma movements beneath the north Iceland rift near Askja, European Geoscience Union, Vienna, April 2008, EAGE2008-A-07323.

White, R. S. (2008). Geophysical Mapping of Melt Storage Beneath Rifts, IAVCEI, Reykjavik, August 2008 [invited talk].

H. Soosalu, R.S. White, J. Key, P. Einarsson, S.S. Jakobsdóttir (2008). Magma movement at the roots of Askja volcano, Iceland, indicated by lower-crustal seismicity, IAVCEI, Reykjavik, August 2008.

Key, J., H. Soosalu, R.S. White, J.E. Drew, A.J. Nowacki, M.R. Coffin, P. Einarsson and S.S. Jakobsdóttir. Crustal seismicity beneath Askja volcano, central Iceland, reflecting plate tectonics and melt movement, IAVCEI, Reykjavik August 2008.

Soosalu, H., J. Key, R.S. White, P. Einarsson & S.S. Jakobsdóttir (2008). Mid-Atlantic rift volcano Askja in Iceland: seismic observations. ESC workshop, Seismic phenomena associated with volcanic activity, León, Nicaragua, 21-27 September, 2008.

Key, J., H. Soosalu, R.S. White, J. Drew, P. Einarsson & S.S. Jakobsdóttir (2008). Deep crustal seismicity beneath Askja volcano, central Iceland: interpretations and future work. ESC workshop, Seismic phenomena associated with volcanic activity, León, Nicaragua, 21-27 September, 2008.

MSci Theses, University of Cambridge

Knox, Clare, 2007, Earthquakes near Askja on the north Iceland plate boundary.

Coffin, Michael, 2008, Shallow Seismicity at Askja, central Iceland.

Nowacki, Andy, 2008, Accurate location of previously unwitnessed swarms of microseismic activity beneath Upptyppingar, central Iceland.

Reports

Soosalu, H. and White, R. S., 2007. Herðubreið 2006 – seismic project, Scientific report. Available at: http://gef.nerc.ac.uk/documents/publications/822.pdf

Acknowledgements

Thirteen of the seismometers were loaned from SEIS-UK. The SEIS-UK staff, Alex Brisbourne, David Hawthorn and Anna Horleston provided prompt and professional help during all the phases of the project, and David is particularly thanked for participating in fieldwork. The rangers at the mountain huts of Dreki and Herðubreiðarlindir, are thanked for their assistance, friendliness and hospitality during our stays in the field area. Erik Sturkell provided valuable logistical assistance and advice, and fed the fieldworkers with delicious dinners on the way out to and back from the highland. Jennifer Eccles, Juan Carlos Molina Santana, Mike Coffin and Andy Nowacki were proficient and pleasant fieldworkers and Mike Coffin and Andy Nowacki processed the shallow Askja and Upptyppingar data respectively. Julian Drew is also thanked for the CMM algorithm and for the time and effort spent working with this data set.

References

Hjartardóttir, Á. R., Einarsson, P., Sigurdsson, H., 2008. Structure of the northern fissure swarm of the Askja volcanic system in the volcanic zone of Northern Iceland: Uneven distribution of fractures in space and time. From Hjartardóttir, Á. R. The fissure swarm of the Askja volcano. Master of Geophysics Thesis, University of Iceland.

IMO. Icelandic Meteorological Office seismic database: www.vedur.is

Sturkell, E., Sigmundsson, F., and Slunga, R., 2006. 1983-2003 decaying rate of deflation at Askja caldera: Pressure decrease in extensive magma plumbing system at a spreading plate boundary, Bulletin of Volcanology, 68, 727-735.

de Zeeuw-van Dalfsen, E., Rymer H., Williams-Jones, G., Sturkell, E., and Sigmundsson, F., 2005. Net gravity decrease at Askja volcano, Iceland: constraints on processes responsible for continuous caldera deformation, 1988-2003. Journal of Volcanology and Geothermal Research, 139, 227-239.

Appendix 1
Detailed information on the stations of the summer 2007 Askja network

1. **UTYR** – Upptyppingar 2 (65.03605°N, 16.31867°W, 623 m) **–** relocated 2006 site UPTY
Sensor 6359 (Cambridge), set to N21E but correct grid north is N15E, GPS 4269
Installed 183 (2nd July) 18:07
Pick-up 241 (29th August) 15:35
57.89/57.89 days of data, recovered 100%
Ground: pumice, sand, lava blocks
Burial material: sand, pumice
Notes: doesn't always pick up Upptyppingar events, sometimes badly affected by high-frequency noise, possibly rock falls from Upptyppingar mountain

2. **VIKR** – Vikrafell (65.07474°N, 16.51347°W, 718 m) – reoccupied 2006 site
Sensor 6037 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 4142
Installed 183 (2nd July) 20:02
Pick-up 238 (26th August) 09:39
54.57/54.57 days of data, recovery 100%
Ground: pumice, sand
Burial material: pumice, sand

3. **VADA** – Vaðalda (64.99487°N, 16.53817°W, 673 m) – reoccupied 2006 site
Sensor 6098 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3741
Installed 184 (3rd July) 08:50
Pick-up 240 (28th August) 11:22
56.11/56.11 days of data, recovered 100%
Ground: sand, pumice, lava blocks
Burial material: sand

4. **HOTT** – Höttur (65.04748°N, 16.52985°W, 718 m) – reoccupied 2006 site
Sensor 6096 (Cambridge), set to N21E but correct grid north is N15E, GPS 4208
Installed 184 (3rd July) 10:19
Pick-up 237 (25th August) 16:29
53.26/53.26 days of data, recovery 100%
Ground: pumice, sand
Burial material: pumice, sand
Notes: occasional traffic noise

5. **VISA** – Vikursandur (65.06901°N, 16.40369°W, 640 m) – reoccupied 2006 site
Sensor 6211 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 4217
Installed 184 (3rd July) 11:21
Pick-up 237 (25th August) 15:44
53.18/53.18 days of data
Ground: sand, pumice, lava boulders
Burial material: sand, pumice

6. **HERD** – Herðubreið (65.18157 °N, 16.39730 °W, 688 m) – reoccupied 2006 site
Sensor 6046 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3742
Installed 184 (3rd July) 13:56
Pick-up 240 (28th August) 14:53
56.04/56.04 days of data, recovery 100%
Ground: pahoehoe lava, sand
Burial material: levelled on flat lava, covered with bucket, cairn of lava blocks and sand

7. **MYVO** – Mývatnsöræfi (65.15550°N, 16.36895°W, 639 m) – reoccupied 2006 site
Sensor 6360 (Cambridge), set to N21E but correct grid north is N15E, GPS 4255
Installed 184 (3rd July) 15:00
Pick-up 240 (28th August) 16:20
56.06/56.06 days of data, recovery 100%
Ground: sand, lava
Burial material: sand

8. **HETO** – Herðubreiðartögl (65.12872°N, 16.31695°W, 582 m) – reoccupied 2006 site
Sensor 6192 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3874
Installed 184 (3rd July) 16:02
Pick-up 239 (27th August) 10:09
54.75/54.75 days of data, recovery 100%
Ground: lava, pumice, sand, lava slabs
Burial material: sand, pumice

9. **DYNG** – Dyngja (65.05191°N, 16.64809°W, 957m) – reoccupied 2006 site
Sensor 6305 (Cambridge), set to N21E but correct grid north is N15E, GPS 6305
Installed 184 (3rd July) 18:43
Pick-up 241 (29th August) 11:53
56.72/56.72 days of data, recovery 100%
Ground: vault with concrete bottom, built on a hyaloclastite ridge
Burial material: vault

10. **SVAD** – Svartadyngja (65.11746°N, 16.57498°W, 680 m) – reoccupied 2006 site
Sensor 6021 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3866
Installed 185 (4th July) 10:17
Pick-up 238 (26th August) 10:46
53.02/53.02 days of data, recovered 100%
Ground: pahoehoe lava, sand
Burial material: levelled on flat lava, covered with bucket, cairn of lava blocks and sand

11. **HRUT** – Hrútur (65.15576°N, 16.67443°W, 701 m) – reoccupied 2006 site
Sensor 6024 (Cambridge), set to N21E but correct grid north is N15E, GPS 4193
Installed 185 (4th July) 11:28
Pick-up 238 (26th August) 11:39
53.01/53.01 days of data, recovery 100%
Ground: sand, pahoehoe lave
Burial Method: sand
Notes: can be poor at detecting higher frequencies and often long reverberations

12. **LOKA** – Lokatindur (65.15699°N, 16.82042°W, 734 m)
Sensor 6026 (Cambridge), set to N21E but correct grid north is N15E, GPS 3807
Installed 185 (4th July) 13:38
Pick-up 238 (26th August) 13:42
53.00/53.00 days of data, recovery 100%
Ground: sand, pahoehoe lava
Burial material: sand

13. **DDAL** – Dyngjufjalladalur (65.07739°N, 16.9334°W, 801m)
Sensor 6214 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3839
Installed 185 (4th July) 15:57
Pick-up 238 (26th August) 17:05
53.05/53.05 days of data, recovery 100%
Ground: sand, small rocks
Burial material: sand

14. **RODG** – Roðgúll (64.98513°N, 16.88639°W, 1022 m) – reoccupied 2006 site
Sensor 6010 (Cambridge), set to N21E but correct grid north is N15E, GPS 4157
Installed 185 (4th July) 18:26
Pick-up 238 (26th August) 18:35
Data (all channels) chopped in numerous very small bits but no gaps:
186:12:10:51.84 to 187:19:28:20.00
53.01/53.01 days of data, recovered 100%
Ground: sand, lava blocks
Burial material: sand

15. **MOFO** – Móflöt 2 (64.98449 °N, 16.64970 °W, 699 m) – relocated 2006 site MOFL
Sensor 6065 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3894
Installed 185 (4th July) 20:29
Stopped working 225 (13th August) 18:22
Pick-up 240 (28th August) 10:20
39.91/54.58 days of data, recovery 73%
Ground: sand, gravel
Burial material: sand, gravel
Notes: no solar panel so stopped working when battery ran out of power

16. **VIBR** – Vikraborgir 2 (65.06619°N, 16.73256°W, 1110 m) – relocated 2006 site VIBO
Sensor 6084 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3884
Installed 186 (5th July) 11:04
Pick-up 241 (29th August) 10:41
Gaps 231:22:13:06.89 to 233:07:55:36.00; 234:04:59:48.77 to 234:09:53:21.00
50.16/54.98 days of data, recovery 91%
Ground: scoria
Burial material: gravel and pebble sized scoria
Notes: lots of noise and generally long reverberations, probably as a result of ground conditions within caldera

17. **OSVA** – Öskjuvatn (65.04696°N, 16.77066°W, 1130 m)
Sensor 6058 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 2472
Installed 186 (5th July) 13:13
Pick-up 237 (25th August) 19:03
51.24/51.24 days of data, recovery 100%
Ground: lava, pumice
Burial material: pumice
Notes: sometimes long reverberations and sometimes apparently delayed, possibly because of large voids within the lava and pumice infill in caldera.

18. **MIDF** – Miðfell (65.08676°N, 16.32961°W, 572 m) – reoccupied 2006 site
Sensor 6075 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 4134
Installed 186 (5th July) 17:25
Stopped working 220 (8th August) 00:09
Pick-up 237 (25th August) 15:00
33.28/50.90 days of data, recovery 65%
Ground: pumice, sand, lava
Burial material: sand, pumice
Note: reboot messages in the log suggest early failure was probably due to insufficient power, even though this instrument had a solar panel

19. **JOAF** – Jökulsá á fjöllum 2 (65.11055°N, 16.24406°W, 548 m) – relocated 2006 site JAAF
Sensor 6111 (SEIS-UK), set to N21E but correct grid north is N15E, GPS 3817
Installed 186 (5th July) 18:17
Stopped recording 207 (26th July) 13:03
Pick-up 237 (25th August) 14:15
20.75/50.83 days of data, recovery 41%
Ground: sand, gravel, lava pebbles
Burial material: sand
Notes: no solar panel and faulty battery suspected to be reason for such early failure

20. **KOLL** – Kollóttadyngja (65.29024°N, 16.56726°W, 593 m)
Sensor 6173 (Cambridge), set to N21E but correct grid north is N15E, GPS 4186
Installed 187 (6th July) 14:36
Pick-up 239 (27th August) 16:00
52.06/52.06 days of data, recovery 100%
Ground: gravel, sand, lava
Burial material: sand

21. **FREF** – Fremstafell (65.35190°N, 16.28355°W, 533m) – reoccupied 2006 site
Sensor 6150 (Cambridge), set to N21E but correct grid north is N15E, GPS 3880
Installed 187 (6th July) 18:46
Pick-up 239 (27th August) 13:29
51.78/51.78 days of data, recovery 100%
Ground: soil, gravel, sand, hyloclastite
Burial Material: soil, sand, gravel

22. **HELI** – Herðubreiðarlindir (65.19875°N, 16.21843°W, 491 m) – reoccupied 2006 site
Sensor 6106 (Cambridge), set to N21E but correct grid north is N15E, GPS 3772
Installed 187 (6th July) 20:40
Pick-up 237 (25th August) 12:51
49.67/49.67 days of data, recovery 100%
Ground: sand, gravel
Burial material: sand, gravel

Appendix 2
Deployment information for the stations of the winter 2007-08 Askja network
To be serviced in July 2008

1. **LOKA** – Lokatindur (65.15699°N, 16.82042°W, 734 m)
Autumn instrument: Sensor 6024 (Cambridge – 4 GB), GPS 4193, two 80 Ah batteries, two 20 W solar panels, set to write-once mode, sampling rate 40s/s
Winter instrument: Sensor 6024 (Cambridge – 4 GB), GPS 3807, 80 Ah and 120 Ah batteries, two 20 W solar panels, set to duplicate mode, sampling rate 40 s/s
Installed 238 (26th August) 16:20
Ground: sand, pahoehoe lava
Burial material: sand

2. **RODG** – Roðgúll (64.98513°N, 16.88639°W, 1022 m)
Autumn instrument: Sensor 6096 (Cambridge – 4 GB), GPS 4208, two 80 Ah batteries, two 20 W solar panels, set to write-once mode, sampling rate 40 s/s
Winter instrument: Sensor 6010 (Cambridge – 4 GB), GPS 4157, 80 Ah and 120 Ah batteries, two 20 W solar panels, set to duplicate mode, sampling rate 40 s/s
Note: Sensor 6010 is the one with the possibly faulty chip causing data to be chopped into little pieces.
Installed 238 (26th August) 20:35
Ground: sand, lava blocks
Burial material: sand

3. **KOLL** – Kollóttadyngja (65.29024°N, 16.56726°W, 593 m)
Autumn instrument: Sensor 6150 (Cambridge – 4 GB), GPS ?, two 80 Ah batteries, two 20 W solar panels, set to write-once mode, sampling rate 40 s/s
Winter instrument: Sensor 6173 (Cambridge – 4 GB), GPS 4186, 80 Ah and two 60 Ah batteries, two 20 W solar panels, set to duplicate mode, sampling rate 40 s/s
Installed 239 (27th August) 17:50
Ground: gravel, sand, lava
Burial material: sand

4. **MYVO** – Mývatnsöræfi (65.15550°N, 16.36895°W, 639 m)
Autumn instrument: Sensor 6106 (SEIS-UK – 4 GB), GPS 3747, two 80 Ah batteries, two 20 W solar panels, set to write-once mode, sampling rate 40 s/s
Winter instrument: Sensor 6098 (SEIS-UK – 3 GB), GPS 3741, two 80 Ah batteries, two 20 W solar panels, set to duplicate mode, sampling rate 40 s/s
Installed 240 (28th August) 18:50
Ground: sand, lava
Burial material: sand

5. **UTYR** – Upptyppingar (65.03605°N, 16.31867°W, 623 m)
Autumn instrument: Sensor 6305 (Cambridge – 4 GB), GPS 4187, 80 Ah and two 60 Ah batteries, two 20 W solar panels, set to write-once mode, sampling rate 40 s/s
Winter instrument: Sensor 6359 (Cambridge – 4 GB), GPS 4269, 80 Ah and 120 Ah batteries, two 20 W solar panels, set to duplicate mode, sampling rate 40 s/s
Installed 241 (29th August) 18:25
Ground: pumice, sand, lava blocks
Burial material: sand, pumice

6. **DYNG** – Dyngja (65.05191°N, 16.64809°W, 957m)
Cambridge Instrument
Installed September 2007
Operated by Icelandic Meteorological Office as temporary SIL network station