Torfajökull 2005 – seismic project

I Scientific report

II Technical report

Heidi Soosalu
Robert S. White

Bullard Laboratories
Department of Earth Sciences
University of Cambridge

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I Scientific report

Abstract

Torfajökull is a rhyolitic volcano with a prominent caldera and vigorous geothermal activity, located in south Iceland. We operated a 30-station network of broadband Güralp 6TD seismometers inside and around the Torfajökull caldera from mid-June until early October 2005. As a result an excellent dataset with 98.8% recovery was obtained. The main focus of the project was low-frequency earthquakes, which occur in the southern part of the caldera. Intriguing data on these events were recorded, for the first time also with stations very close to their origin. An ample dataset was gathered on high-frequency earthquakes, which occur principally in the western part of the caldera, in close connection to geothermal activity.

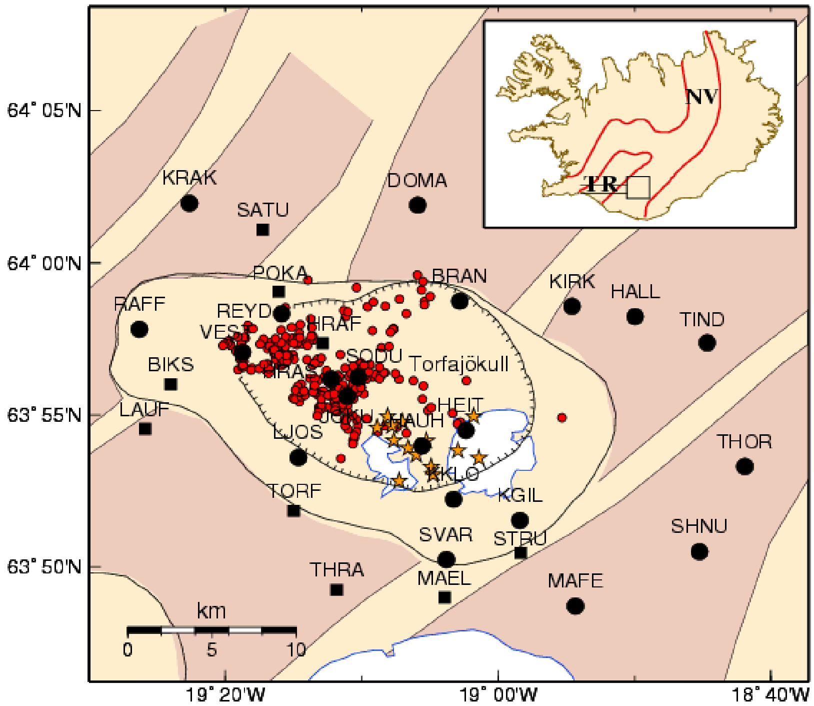

Figure 1. The location of Torfajökull within the southern end of the Icelandic Neovolcanic Zone (NV). TR stands for the transform zone. The central volcano of Torfajökull is outlined and its caldera hatched, areas of eruptive fissure swarms are shaded. White areas are glaciers. The 2005 seismic network is shown with black squares (2002 sites re-occupied) and black dots (new sites). Red dots denote the approximately 800 high-frequency earthquakes located by Fiona Campbell and Nick Borner. Orange stars show the low-frequency earthquakes located so far.

Geological and seismic background

Torfajökull in south Iceland is a large rhyolitic volcano massif, rising about 500 m above the surrounding basaltic landscape, 450 km^2 in area. It is the largest silicic centre in Iceland, with a 12-km-diameter caldera and an outstanding high-temperature geothermal field. It is located in the neovolcanic zone, at a junction where the eastern rift zone and a transform zone meet the intraplate volcanic flank zone of south Iceland (Fig. 1). During the last 1100 years there have been two eruptions in the Torfajökull area, the latest at the end of the 15th century.

Torfajökull is a source of persistent small-scale seismicity, with two types of events being observed. High-frequency earthquakes (Fig. 2) are located mainly in the western part of the caldera and low-frequency earthquakes (Fig 3.) cluster in the south. High-frequency earthquakes occur typically in swarms and are small in size (magnitude < 3). They have been interpreted to be related to hydrothermal cooling of a magma body (Soosalu and Einarsson 1997). Low-frequency earthquakes are also small in size (magnitude < 2), and have a frequency content of typically 1-3 Hz. Their phases are emergent and precise locations thus hard to obtain.

The 2005 Torfajökull seismic project is a continuation of a 20-station survey made in 2002 (Soosalu 2003). The main objective of the new project was to gain better understanding of the nature of the low-frequency seismicity with a more dense network of more sites in closer vicinity to the source of the seismicity. As a by-project a large number of high-frequency earthquakes was recorded, and a few teleseismic events were detected, useful for receiver function studies of crustal structure in the Torfajökull area.

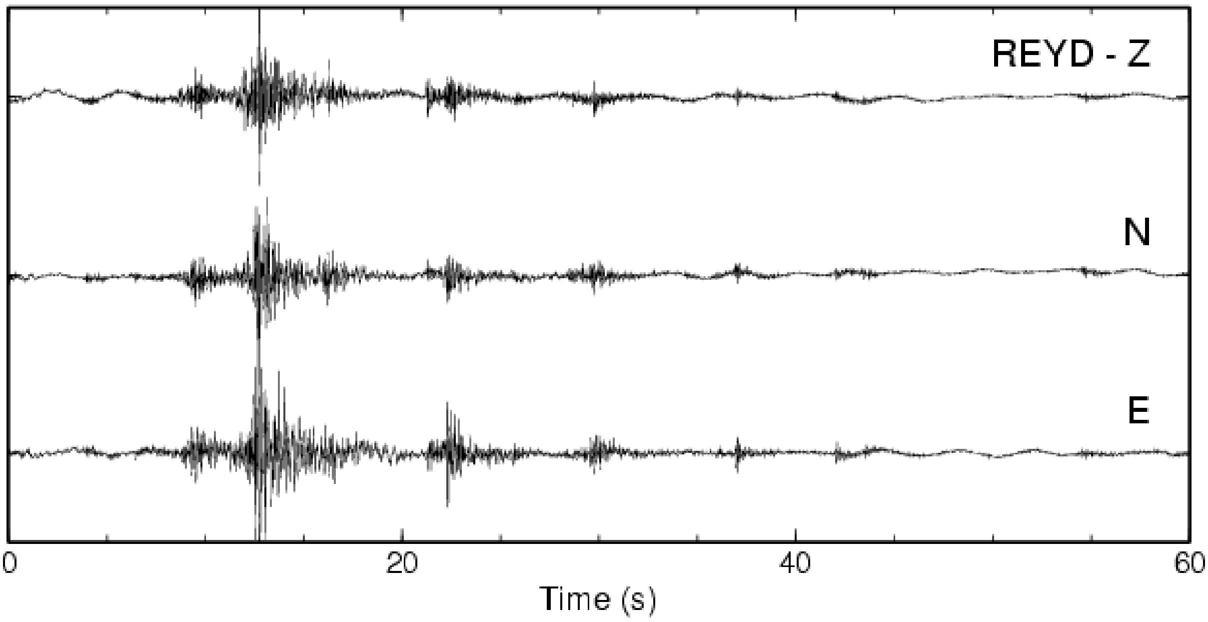

Figure 2. An example of a swarm of high-frequency earthquakes in the western part of Torfajökull, recorded by the station REYD. All the three components have the same arbitrary scale and no filtering is applied.

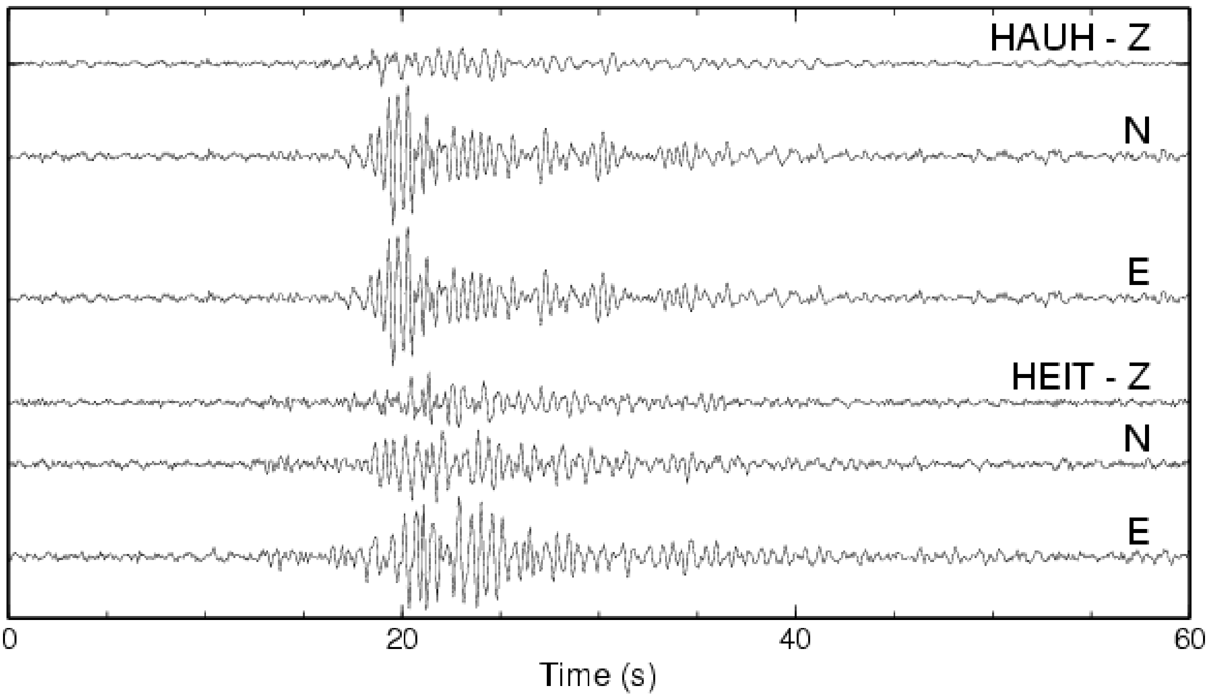

Figure 3. A low-frequency earthquake recorded by the stations HAUH and HEIT. All the traces have the same arbitrary scale and are bandpass filtered 0.8-8 Hz. The length of the records is the same 60 seconds as in Fig. 2.

Field installations of the Torfajökull 2005 seismic project

The instrumentation of the network consisted of thirty broadband Güralp 6TD seismometers borrowed from SEIS-UK. They were used with individual GPS clocks and the power source was an 80 Ah battery together with a solar panel. The terrain in the Torfajökull area is rough and challenging. Getting to the sites involves driving on steep slopes and crossing rivers by fords. The sites were chosen by optimizing between accessibility and vicinity to the active areas. It was possible to drive with 4WD cars to most of the sites, and the two sites closest to the area of low-frequency earthquakes were reached by helicopter transport. The deployment was done during the latter half of June and pick-up during end-September to mid-October.

The network was serviced and data downloaded once, at the beginning of August. As the time between visits was rather long and the seismometers had 3 or 4 Gbyte memory, the sampling rate was set to 50 samples per second to avoid data being written over. To save batteries, the GPSs were not set to continuous mode, but to one-hour-cycles.

Table 1. The volume of data gathered

Site	°N	°W	Alt (m)	Installed	Pick-up	Operation (days)	Days of data	Recovery (%)
LAUF	63.90916	19.43146	658	9-Jun	5-Oct	117.95	117.95	100
BIKS	63.94943	19.41237	779	9-Jun	5-Oct	117.90	117.90	100
RAFF	63.96364	19.43877	911	9-Jun	5-Oct	117.86	117.86	100
KRAK	64.03248	19.37757	682	10-Jun	5-Oct	117.06	117.06	100
SATU	63.01809	19.28747	671	10-Jun	4-Oct	116.18	116.18	100
DOMA	64.03158	19.09841	652	10-Jun	4-Oct	116.18	116.18	100
BRAN	63.97903	19.04707	620	10-Jun	4-Oct	116.07	116.07	100
POKA	63.98442	19.26821	917	11-Jun	5-Oct	116.09	116.09	~100
HRAF	63.95618	19.21494	897	11-Jun	5-Oct	116.08	109.08	94
REYD	63.97201	19.26449	917	11-Jun	5-Oct	116.03	116.03	100
VEST	63.95115	19.31254	872	11-Jun	5-Oct	115.74	115.74	100
SODU	63.93718	19.17151	1078	14-Jun	19-Oct	127.09	127.09	100
HRAS	63.93641	19.20482	1018	14-Jun	5-Oct	113.03	113.03	~100
JOKU	63.92701	19.18447	1109	14-Jun	19-Oct	126.95	126.95	100
TORF	63.86405	19.24982	547	15-Jun	7-Oct	113.96	113.96	100
LJOS	63.89330	19.24454	697	15-Jun	7-Oct	113.86	113.86	100
MAEL	63.81640	19.01667	619	15-Jun	6-Oct	113.09	88.44	~78
KGIL	63.85869	18.97325	603	15-Jun	6-Oct	112.98	112.98	100
STRU	63.84095	18.97253	576	15-Jun	6-Oct	112.91	107.31	95
THRA	63.82057	19.19711	580	16-Jun	6-Oct	112.32	112.32	100
SVAR	63.83705	19.06336	605	16-Jun	7-Oct	112.98	112.98	~100
KKLO	63.87033	19.05419	655	16-Jun	7-Oct	112.93	112.93	~100
MAFE	63.81170	18.90571	552	16-Jun	6-Oct	111.97	111.97	100
HALL	63.97064	18.83239	601	20-Jun	6-Oct	107.78	107.78	~100
KIRK	63.97617	18.90944	605	20-Jun	6-Oct	107.70	105.20	~98
TIND	63.95618	18.74455	682	21-Jun	6-Oct	107.06	107.06	100
THOR	63.88849	18.69845	490	21-Jun	6-Oct	107.03	107.03	100
SHNU	63.84140	18.75374	591	21-Jun	6-Oct	107.00	107.00	100
HAUH	63.89973	19.09278	963	22-Jun	20-Oct	120.10	120.10	100
HEIT	63.90829	19.03936	971	22-Jun	20-Oct	120.05	120.05	100

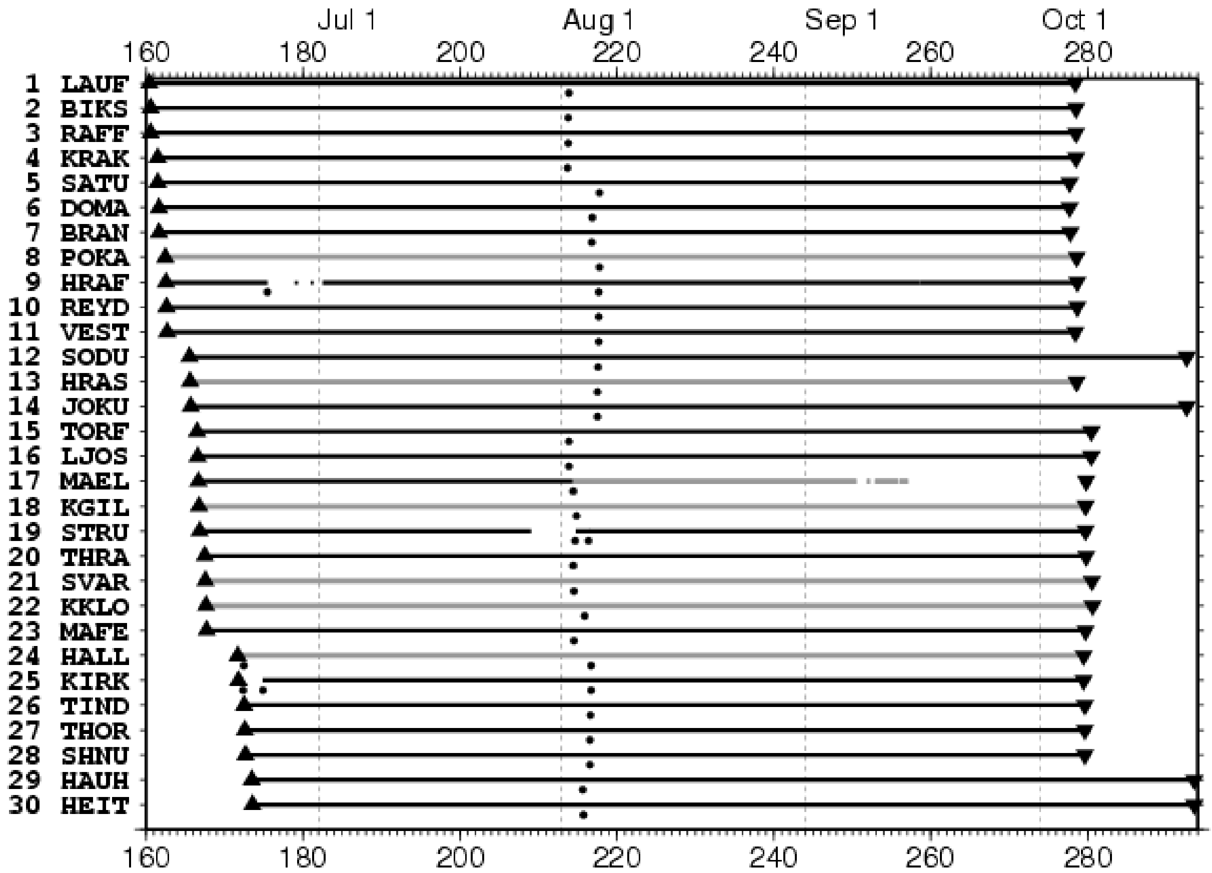

Figure 4. The station operation chart. A triangle shows the installation time of a station and an inverted triangle the pick-up. Solid thick line shows the times when data were gathered at the station, black when GPS was working normally, grey when a faulty GPS produced patchy data. Dashed line represents sporadic data. Dots under each line are site checks.

The data gathered

The data recovery was excellent, altogether 98.8% (Table 1 and Fig. 4). Only one instrument (MAEL) got out of order towards the end of the measuring period. One station (STRU) had a faulty solar panel regulator, but only some five days of data before the service trip were lost because of this problem. The station HRAF was working during the days 182-258 as an experimental station of the national seismic network run by the Icelandic Meteorological Office. There are some small data gaps around this period because of installation work.

Unfortunately, seven of the GPSs were discovered to be faulty after returning from the field. Because their internal battery was not working properly, they did not remember leap seconds. Every time such a GPS started its hourly search of satellites, it initially recorded data 13 seconds too late before catching up with the satellites. This lead to production of numerous short files with a too late timing. However, these data are useful, if the timing is corrected with -13 seconds. In the future, we strongly recommend always to use continuous GPS to avoid any problems like this. The power consumption of a continuous GPS does not appear to be markedly higher than of a one-hour-cycle GPS.

The data were processed following the SEIS-UK instructions described in fieldwork and data treatment reports provided by them. The original Güralp raw format was converted to mseed. Back-up copies were made on DVD discs of both the formats. Mseed format data are also stored by SEIS-UK and in the IRIS database with the network code YA of the year 2005.

Preliminary results

The level of the low-frequency earthquake seismicity was rather modest throughout the measuring period. Prior experience from stations at distances of 7-8 km and more was that the signals are emergent and precise phase picking is laborious and time-consuming. P-wave arrivals are particularly small and obscure, S-wave arrivals are more distinct (Soosalu et al. 2006). This appears to be the case also when these signals are recorded by seismic stations at close vicinity (the stations HAUH, HEIT, KKLO, see Fig. 1). The frequency content from close-by observations is the same 1-3 Hz, as previously observed. Only occasionally impulsive P-wave onsets and higher frequencies are observed at the closest sites. A crude event location list is under construction. More sophisticated locating analysis using the waveforms will be done based on this event list. In general, these earthquakes cluster in the area where the geothermal fields have hottest temperatures within Torfajökull (> 340° C), according to chemical analysis of steam and water samples (Bjarnason and Ólafsson 2000).

The high-frequency seismicity was exceptionally abundant during the summer of 2005, and several hundreds of earthquakes, up to magnitude 3.1 were detected and located very precisely. The majority of this activity occurred in the western part of the Torfajökull caldera at depths of 1-5 km, correlating well with the locations of geothermal fields that have recently been mapped in great detail (Sæmundsson and Friðleifsson 2001). This dataset supports the interpretation of a geothermally cooling magma chamber suggested by Soosalu and Einarsson (1997). A small cluster of high-frequency earthquakes were also detected in an unexpected location in the vicinity of the station HEIT in the eastern part of the caldera.

Formerly unknown persistent activity of minor low-frequency earthquakes in the vicinity of the station HEIT was discovered. Typically these signals are short in duration and large at HEIT records, are visible at HAUH but are beyond detectability at other sites. Presumably they are shallow events related to geothermal activity there.

Presentations, publications and research in progress

The first results of the Torfajökull 2005 campaign have been presented at the meeting of the Volcanic and Magmatic Studies Group in the U.K.:

Campbell, Fiona, M., Robert S. White & Heidi Soosalu (2006). High-frequency microseismicity at the Torfajökull volcano, South Iceland. Volcanic & Magmatic Studies Group, 40th Anniversary Meeting, Leeds, U.K., 4-6 January, 2006, p. 42-43.

Soosalu, Heidi, Robert S. White, Fiona Campbell & Páll Einarsson (2006). Low-frequency earthquakes at the Tofajökull volcano, Iceland – evidence for a cryptodome? Volcanic & Magmatic Studies Group, 40th Anniversary Meeting, Leeds, U.K., 4-6 January, 2006, p. 31-32.

More presentations based on the Torfajökull data will be given in forthcoming relevant meetings. The high-frequency earthquake dataset has formed the material of two final year undergraduate student projects at the University of Cambridge, the first half by Fiona Campbell in 2005 and the latter half by Nick Borner in 2006. A summarizing article will be written based on the whole high-frequency earthquake dataset. Heidi Soosalu is at the moment analysing the low-frequency earthquakes, which will provide material for another article. Julian Drew, a Cambridge PhD student, is using the high-frequency earthquakes for developing and testing an automatic event detection tool. Kristín Jónsdóttir, a PhD student at the Uppsala University, is using our recordings as additional data for her tomographic study on the neighbouring Katla volcano.

Acknowledgements

Haukur Brynjólfsson and Halldór Ólafsson from the Institute of Earth Sciences of the University of Iceland were the priceless field experts in the challenging Icelandic terrain and weather conditions. Anna Horleston from SEIS-UK, Fiona Campbell, Marie Keiding, Auli Mikkola and Sarah White were hard-working and careful field assistants. Alex Brisbourne from SEIS-UK advised in every data treatment problem that showed up. Jósef Hólmjárn from the Icelandic Meteorological Office did the installations at the station HRAF to turn it to an experimental national network station. The National Energy Authority of Iceland, Orkustofnun and the Icelandic Power Company, Landsvirkjun are thanked for generous financial support for the fieldwork. Without the help of the helicopter team of the Icelandic Coast Guard the deployment of our two key stations HAUH and HEIT had been impossible.

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Soosalu, H. and P. Einarsson (1997). Seismicity around the Hekla and Torfajökull volcanoes, Iceland, during a volcanically quiet period, 1991-1995. *Bulletin of Volcanology* 59: 36-48.

Soosalu, H., R. Lippitsch and P. Einarsson (2006). Low-frequency earthquakes at the Torfajökull volcano, south Iceland. *Journal of Volcanology and Geothermal Research* 153, 187-199.

Torfajökull 2005 – seismic project
II Technical report

The field installations and site visits

Torfajökull is located in highland desert with no or very little vegetation. The ground conditions are typically lava blocks and loose volcanic material, mainly pumice or ash. In some areas the bedrock substance is hyaloclastite. We aimed for finding solid ground, either a large lava block or hyaloclastite for the sensor. In one case the instrument was buried in loose riverbed gravel. The instrumentation consisted of a Güralp 6TD broadband seismometer, which contains both the sensor and the digitizer, a breakout box, firewire cable for downloading, other necessary cables, a GPS clock with a mounting stick, a solar panel and a battery (Fig. 5). The used firmware version of the 6TDs was 131 J.

The installation took normally about an hour for a two to four persons team. The typical procedure was to dig a hole through the loose surface material until solid rock was reached, lay a ceramic plate on the rock with quick-setting cement and place the sensor on it (Fig. 6). The north arrow was always put to point to geographical north (N21°E), except at some sites, where it was discovered to be erroneously set a few degrees off (see Appendix). A plastic bucket was placed over the sensor and it covered with blocks of rock, ash and sand (Fig. 6). Typically the top of the bucket was covered with about 10-20 cm of material. In some cases the instrument could not be dug in the ground but was placed under a bucket and covered with a cairn. This did not turn out to be a very good solution, as these stations were prone to temperature changes and to wind, and the data were often noisy.

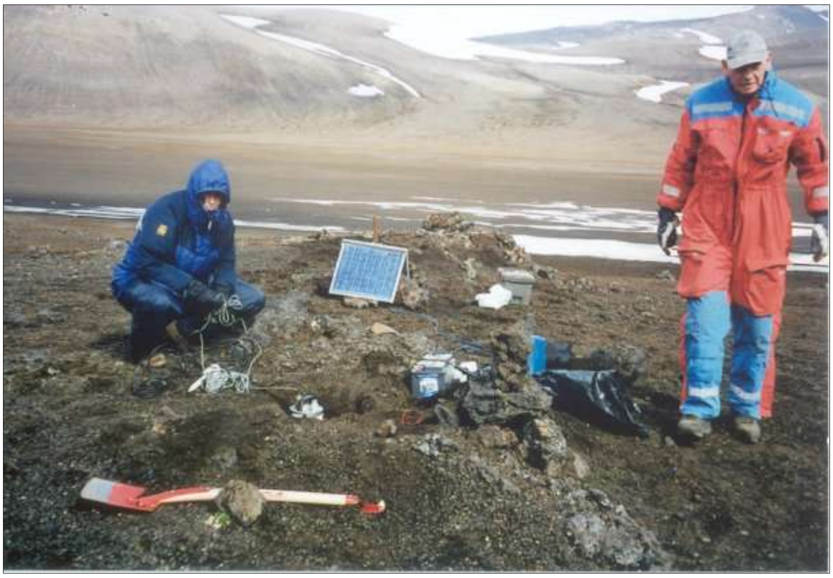

Figure 5. An example of a typical installation, at the station LAUF.

The geographical coordinates of the stations were defined by a hand-held GPS. The location was checked again during every visit, and the final coordinates used for the sites are the averages of the readings. For sites that were re-occupied after the 2002 project, the same coordinates were used as in 2002. The breakout box and the cable ends were placed in a plastic sandwich box with small holes made for the cables, which was wrapped in a plastic bag and buried underground. Lack of vegetation was an advantage for the GPS clocks, and the sites had good and unhindered visibility to the sky. A GPS lock was normally gained within minutes.

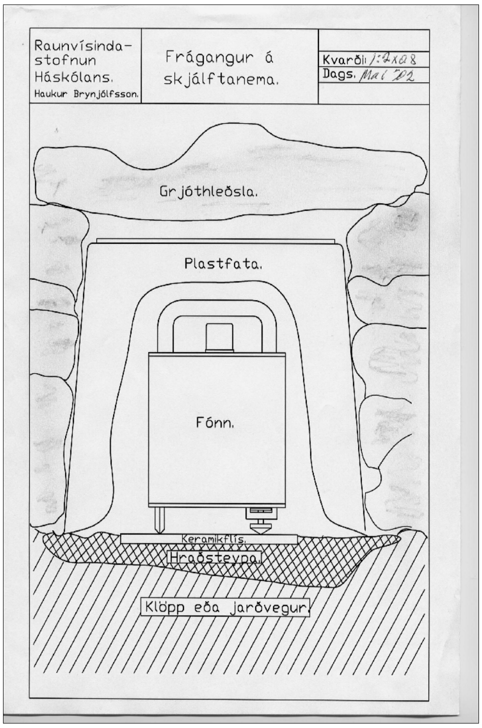

Figure 6. A schematic picture of a seismometer installation, drawn by Haukur Brynjólfsson.

The weather in Iceland can be very stormy even in summer, and strong winds blow across the barren landscape of the Torfajökull area. For that reason the solar panel installations were made robust; metal bars were drilled into solid blocks of lava and the panels attached to them. There was no problem of placing the solar panels directly on the ground as there is plenty of light in the Icelandic highland during the summer season. The panels were put as far as possible from the sensors to prevent wind noise. For the same reason, all the cables were dug in the ground whenever possible. The power source of the stations was a 12 V, 80 Ah battery connected to the solar panel. This battery-panel combination provided power without trouble throughout the deployment period until the short autumn days of October when the stations were picked up, and no data gaps because of power failure occurred (except at the site STRU, caused by a faulty solar panel regulator, see Appendix). In fact, most of the batteries were measured to have high voltages (typically 12.5-13 V) during the pick-up.

All the installation, site check, and pick-up visits were documented on field forms. A laptop computer was used during the huddle test, but in the field the computer connection was always made with a palm computer with a waterproof cover. We checked the sensor number, battery voltage, in some cases also solar panel current, correctness of GPS timing and GPS cycle (one hour), mass positions and sample rates (50 sps). A stomp test was made to check the appearance of the seismograms. Downloading was done using a palm computer and an external Lacie disk attached to the sensor with a firewire cable. To save time during the pick-up tour in wintry conditions, no downloading was done in the field, but in the lab afterwards.

Data downloading to the computer and data processing

SEIS-UK provided a Linux computer with detailed software instructions and manuals for data processing after the field downloading. The Lacie disk was connected to the computer and the raw data, in the Güralp compressed format (gcf), were read in. For the download of each Lacie the procedure chops the raw data in chunks of 1 Gbyte, named e.g. lacie_051024_2049_01.dd (the download was done on the 24th of October, 2005 and the Lacie serial number is 2049). One such file may contain data from several stations.

The raw data files were converted to miniseed format. As a result the data are written in one-hour-long files, each channel in its own file. The data are stored in day directories, with names like G2002.195, and the files have names such as GCF.2002:195:00:49:37.6104Z2.m (6104 is the sensor serial number, Z the component and 2 stands for the 50 sps channel). The conversion also produced log files, which document the operation and timing of the GPS clocks. The log files include information such as GPS synchronizing times, offset and drift, number of satellites seen and site location. These files were renamed in an informative manner, for example HRAF.6098.240702.log (site.sensor-number.downloading-date.log). In the end a dataless seed volume was constructed, containing the network, instrument and operation time information. The mseed data are stored both at SEIS-UK and in the international Iris data centre.

The dataset: problems and comments

The measuring period for each station is shown in the Table 1 and in Fig. 4 of the Scientific report section. A detailed description of each station, including the location, site conditions, instrumentation serial numbers, the exact dates of the operation period and possible remarks, can be found in the Appendix.

In general, the Torfajökull 2005 network worked fine and data recovery was very good, 98.8%. However, the usability of data from a few sites (HALL, HRAS, KGIL, KKLO, SVAR, POKA, and MAEL after the service trip) was deteriorated because of faulty GPS clocks. Their internal batteries were not working and as a consequence these clocks did not have a memory of leap seconds. In the start of each hourly satellite connection these stations initially had a 13 seconds too late timing until they were synchronised with the satellites and the time jumped to the real one. As a result the data from these stations are chopped into awkwardly numerous files: short patches with too early timing and long patches with correct timing. This also caused small data gaps between the both types of files. The too late files are usable, if the readings are corrected with -13 seconds. In the future, we recommend to use only continuous GPS to avoid an unfortunate nuisance like this.

Another leap second was untimely added on the 4th of August because of a bug in the GPS software. This leap second was meant to be appended first in the end of the year 2005. Each GPS of each station did this jump individually at some point in the early morning of the 4th of August. However, this error is now corrected by Alex Brisbourne at SEIS-UK, and the Torfajökull 2005 data stored at SEIS-UK and in the Iris data centre have correct timing throughout.

Appendix: Description of the operation of the seismograph stations of the Torfajökull network

1. **LAUF** – Laufahraun (63.90916 °N, 19.43146 °W, 658 m) – re-occupied site from 2002
Installed 160 – 9.6. 10:46
Site check 213 – 1.8. 20:35
Pick-up 278 – 5.10. 09:36
117.95139/117.95139 days of data, recovery 100 %
Sensor 6179 , grid north N21E, GPS G3841
Ground: lava, cement & ceramic plate, ash-sand
Burial material: bucket, rocks, ash-sand

2. **BIKS** – Bikslétta (63.94943 °N, 19.41237 °W, 779 m**)** – re-occupied site from 2002
Installed 160 – 9.6. 13:38
Site check 213 – 1.8. 19:40
Pick-up 278 – 5.10. 11:21
117.90486/117.90486 days of data, recovery 100 %
Sensor 6207, grid north N21E, GPS G3747
Ground: lava, cement & ceramic plate, ash-sand
Burial material: bucket, rocks, ash-sand

3. **RAFF** – Rauðfossafjöll (63.96364 °N, 19.43877 °W, 911 m)
Installed 160 – 9.6. 15:01
Site check 213 – 1.8. 18:45
Pick-up 278 – 5.10. 11:46
117.86459/117.86459 days of data, recovery 100 %
Sensor 6056, NOT grid north but N31E, GPS G4136
Ground: hyaloclastite cliff, cement & ceramic plate
Burial material: bucket, cairn

4. **KRAK** – Krakatindur (64.03248 °N, 19.37757 °W, 682 m)
Installed 161 – 10.6. 11:11
Site check 213 – 1.8. 17:00
Pick-up 278 – 5.10. 12:41
117.06250/117.06250 days of data, recovery 100 %
Sensor 6123, NOT grid north but N15E, GPS G3746
Ground: lava, pumice, sand, cement & ceramic plate
Burial material: bucket, cairn

5. **SATU** – Sátubarm (64.01809 °N, 19.28747 °W, 671 m) – re-occupied site from 2002
Installed 161 – 10.6. 12:10
Site check 217 – 5.8. 18:50
Pick-up 277 – 4.10. 16:33
116.18264/116.18264 days of data, recovery 100 %
Sensor 6117, grid north N21E, GPS G3840
Ground: lava, scoria, cement & ceramic plate
Burial material: bucket, lava blocks, scoria

6. **DOMA** – Dómadalur (64.03158 °N, 19.09841 °W, 652 m)
Installed 161 – 10.6. 14:37
Site check 216 – 4.8. 20:30
Pick-up 277 – 4.10. 17:27
116.18264/116.11805 days of data, recovery 100 %
Sensor 6204, grid north N21E, GPS G3825
Ground: lava, sand, cement & ceramic plate
Burial material: bucket, cairn
Remarks: traffic noise from the mountain track is rather disturbing during the daytime

7. **BRAN** – Brandsgil (63.97903 °N, 19.04707 °W, 620 m)
Installed 161 – 10.6. 16:24
Site check 216 – 4.8. 19:15
Pick-up 277 – 4.10. 18:11
116.07431/116.07431 days of data, recovery 100 %
Sensor 6016, NOT grid north N33E, GPS G3875
Ground: sand, riverbed gravel
Burial material: sand, gravel

8. **POKA** – Pokahryggur (63.98442 °N, 19.26821 °W, 917 m) – re-occupied site from 2002
Installed 162 – 11.6. 11:40
Site check 217 – 5.8. 17:55
Pick-up 278 – 5.10. 13:51
116.09097/116.09097 days of data, recovery 100 %
Sensor 6158, NOT grid north but N27E, GPS G3753
Ground: hyaloclastite, cement & ceramic plate, ash-sand, pumice
Burial material: bucket, hyaloclastite blocks, ash-sand
Remarks: faulty GPS

9. **HRAF** – Hrafntinnuhraun (63.95618°N, 19.21494°W, 897 m) – re-occupied site from 2002
Installed 162 – 11.6. 13:29
Site checks 175 – 24.6. 12:00; 217 – 5.8. 15:50
Pick-up 278 – 5.10. 15:21
Data gap 175 – 24.6. 12:02 to 179 – 28.6., Sporadic data 179 – 28.6. to 181 – 30.6.
109.08125/116.07777 days of data, recovery 93.97 %
Sensor 6019, grid north N21E, GPS G3877
Ground: obsidian, ash-sand, scoria, cement & ceramic plate
Burial material: bucket, obsidian blocks, ash-sand
Remarks: operated as a part of the Icelandic national network (SIL) during the days 182-258, 1.7.-15.9. (with the sampling rate of 100 sps),
occasional traffic noise (the track inside the caldera had been moved closer to the site after 2002)

10. **REYD** – Reykjadalir (63.97201 °N, 19.26449 °W, 917 m)
Installed 162 – 11.6. 15:19
Site check 217 – 5.8. 17:25
Pick-up 278 – 5.10. 15:58
116.02709/116.02709 days of data, recovery 100 %
Sensor 6078, grid north N21E, GPS G3830
Ground: hyaloclastite, scoria, cement & ceramic plate
Burial material: bucket, cairn

11. **VEST** – Vesturdalir (63.95115 °N, 19.31254 °W, 872 m)
Installed 162 – 11.6. 16:55
Site check 217 – 5.8. 16:35
Pick-up 278 – 5.10. 10:43
115.74167/115.74167 days of data, recovery 100 %
Sensor 6057, grid north N21E, GPS G3816
Ground: obsidian lava, pumice, scoria, cement & ceramic plate
Burial material: bucket, cairn

12. **SODU** – Söðull (63.93718 °N, 19.17151 °W, 1078 m)
Installed 165 – 14.6. 12:37
Site check 217 – 5.8. 14:20
Pick-up 292 – 19.10. 14:40
127.08542/127.08542 days of data, recovery 100 %
Sensor 6132, NOT grid north but N26E, GPS G3821
Ground: obsidian lava, cement & ceramic plate on an obsidian block
Burial material: bucket, cairn

13. **HRAS** – Hrafntinnusker (63.93641 °N, 19.20482 °W, 1018 m)
Installed 165 – 14.6. 14:10
Site check 217 – 5.8. 11:55
Pick-up 278 – 5.10. 14:54
113.03055/113.03055 days of data, recovery 100 %
Sensor 6113, NOT grid north but N28E, GPS G3788
Ground: obsidian lava, pumice, ash-sand, cement & ceramic plate
Burial material: bucket, cairn
Remarks: faulty GPS clock, very patchy data, the same locations as of the GPS point HRAS

14. **JOKU** – Jökulhaus (63.92701 °N, 19.18447 °W, 1109 m)
Installed 165 – 14.6. 16:26
Site check 217 – 5.8. 13:30
Pick-up 292 – 19.10. 15:16
126.95139/126.95139 days of data, recovery 100 %
Sensor 6047, grid north N21E, GPS G3842
Ground: obsidian lava, pumice, sand, cement & ceramic plate
Burial material: bucket, cairn

15. **TORF** – Torfatindar (63.86405 °N, 19.24982 °W, 547 m) – re-occupied site from 2002
Installed 166 – 15.6. 12:21
Site check 213 – 1.8. 22:20
Pick-up 280 – 7.10. 11:29
113.96389/113.96389 days of data, recovery 100 %
Sensor 6048, grid north N21E, GPS G3896
Ground: hyaloclastite, ash-sand, rocks, cement & ceramic plate
Burial material: bucket, rocks, ash-sand

16. **LJOS** – Ljósá (63.89330 °N, 19.24454 °W, 697 m)
Installed 166 – 15.6. 14:21
Site check 213 – 1.8. 21:35
Pick-up 280 – 7.10. 10:55
113.85694/113.85694 days of data, recovery 100 %
Sensor 6120, grid north N21E, GPS G4240
Ground: rocks, gravel, sand, cement & ceramic plate
Burial material: bucket, rocks, sand

17. **MAEL** – Mælifellssandur (63.81643 °N, 19.06538 °W, 621 m) – re-occupied site from 2002
Installed 166 – 15.6. 16:29
Site check 214 – 2.8. 11:35
Pick-up 279 – 6.10. 18:40
Data gaps 250 – 7.9. 14:00 to 251 – 8.9. 19:24; 252 – 9.9. 06:32 to 252 – 9.9. 20:54; 255 – 12.9. 20:11 to 256 – 13.9. 01:02; 257 – 14.9. 03:43 to pick-up
88.44235/113.09097 days of data, recovery 78.20 %
Sensor 6128, grid north N21E, GPS G3828
Ground: lava, ash-sand, cement & ceramic plate
Burial material: bucket, lava blocks, ash-sand
Remarks: faulty GPS clock, became a problem after the site check (before it the GPS was working continuously)

18. **KGIL** – Krókagil (63.85869 °N, 18.97325 °W, 603 m)
Installed 166 – 15.6. 18:11
Site check 214 – 2.8. 20:00
Pick-up 279 – 6.10. 17:44
112.98125/112.98125 days of data, recovery 100 %
Sensor 6146, NOT grid north but N27E, GPS G4960
Ground: hyaloclastite, sand, gravel, cement & ceramic plate
Burial material: bucket, hyaloclastite blocks, sand
Remarks: faulty GPS clock

19. **STRU** – Strútur (63.84095 °N, 18.97253 °W, 576 m) – re-occupied site from 2002
Installed 166 – 15.6. 19:20
Site-checks 214 – 2.8.17:20; 216 – 4.8. 10:45
Pick-up 279 – 6.10 17:16
Data gap 209 – 28.7. 03:32 to 214 – 4.8. 10:45
107.30555/112.91388 days of data, recovery 95.03 %
Sensor 6203, grid north N21E, GPS G3883
Ground: hyaloclastite, soil, scoria, ash, cement & ceramic plate
Burial material: bucket, rocks, ash, soil
Remarks: solar panel regulator not working, emergency fixing (lost only few days of data)

20. **THRA** – Þrætutangir (63.82057 °N, 19.19711 °W, 580 m) – re-occupied site from 2002
Installed 167 – 16.6. 11:27
Site check 214 – 2.8. 10:55
Pick-up 279 – 6.10. 19:13
112.32361/112.32361 days of data, recovery 100 %
Sensor 6201, grid north N21E, GPS G3816
Ground: lava, sand, cement & ceramic plate
Burial material: bucket, rocks, sand

21. **SVAR** – Svartaklof (63.83705 °N, 19.06336 °W, 605 m)
Installed 167 – 16.6. 13:25
Site check 214 – 2.8. 12:30
Pick-up 280 – 7.10. 12:54
112.97847/112.97847 days of data, recovery 100 %
Sensor 6014, grid north N21E, GPS G3755
Ground: hyaloclastite, gravel, cement & ceramic plate
Burial material: bucket, cairn
Remarks: faulty GPS clock, rather/very patchy dataset

22. **KKLO** – Kaldaklof (63.87033 °N, 19.05419 °W, 655 m)
Installed 167 – 16.6. 15:33
Site check 215 – 3.8. 21:20
Pick-up 280 – 7.10. 13:47
112.92639/112.92639 days of data, recovery 100 %
Sensor 6036, NOT grid north but N35E, GPS G3774
Ground: hyaloclastite, river gravel, cement & ceramic plate
Burial material: bucket, cairn
Remarks: faulty GPS clock

23. **MAFE** – Mælifell (63.81170 °N, 18.90571 °W, 552 m)
Installed 167 – 16.6. 17:33
Site check 214 – 2.8. 13:45
Pick-up 279 – 6.10. 16:44
111.96597/111.96597 days of data, recovery 100 %
Sensor 6110, NOT grid north but N31E, GPS G4141
Ground: hyaloclastite, cement & ceramic plate
Burial material: bucket, cairn

24. **HALL** – Halldórsfell (63.97064 °N, 18.83239 °W, 601 m)
Installed 171 – 20.6. 16:59
Site checks 172 – 21.6. 10:50; 216 4.8. 16:55
Pick-up 279 – 6.10. 11:38
107.77708/107.77708 days of data, recovery 100 %
Sensor 6163, grid north N21E, GPS G3085
Ground: hyaloclastite, rocks, sand, cement & ceramic plate
Burial material: bucket, cairn
Remarks: faulty GPS clock

25. **KIRK** – Kirkjufellsvatn (63.97617 °N, 18.90944 °W, 605 m)
Installed 171 – 20.6. 18:17
Site checks 172 – 21.6. 10:00; 174 – 23.6. 22:10; 216 – 4.8. 17:40
Pick-up 279 – 6.10. 11:03
Data gap 172 – 21.6. 10:27 to 174 – 23.6. 22:25
105.20000/107.69861 days of data, recovery 97.68 %
Sensor 6145, grid north N21E, GPS G3879
Ground: hyaloclastite, cement & ceramic plate
Burial material: bucket, cairn
Remarks: had to be unplugged between the days 172-174 because of cable problems

26. **TIND** – Tindafjöll (63.95618 °N, 18.74455 °W, 682 m)
Installed 172 – 21.6. 13:03
Site check 216 – 4.8. 15:30
Pick-up 279 – 6.10. 14:31
107.06111/107.06111 days of data, recovery 100 %
Sensor 6090, grid north N21E, GPS G3822
Ground: hyaloclastite, cement & ceramic plate
Burial material: bucket, cairn

27. **THOR** – Þorsteinsgil (63.88849 °N, 18.69845 °W, 490 m)
Installed 172 – 21.6. 14:49
Site check 216 – 4.8. 13:40
Pick-up 279 – 6.10. 15:25
107.02500/107.02500 days of data, recovery 100 %
Sensor 6167, grid north N21E, GPS G3823
Ground: lava, scoria, moss, cement & ceramic plate
Burial material: bucket, lava blocks, scoria

28. **SHNU** – Svartahnúksfjöll (63.84140 °N, 18.75374 °W, 591 m)
Installed 172 – 21.6. 15:53
Site check 216 – 4.8. 13:00
Pick-up 279 – 6.10. 15:56
107.00208/107.00208 days of data, recovery 100 %
Sensor 6045, grid north N21E, GPS G3865
Ground: hyaloclastite, cement & ceramic plate
Burial material: bucket, cairn

29. **HAUH** – Háuhverir (63.89973 °N, 19.09278 °W, 963 m)
Installed 173 – 22.6. 11:45
Site check 215 – 3.8. 15:15
Pick-up 293 – 20.10. 14:07
120.09861/120.09861 days of data, recovery 100 %
Sensor 6074, grid north N21E, GPS G3834
Ground: hyaloclastite, pumice, sand, cement & ceramic plate
Burial material: bucket, cairn

30. **HEIT –** Heitaklof (63.90829 °N, 19.03936 °W, 971 m)
Installed 173 – 22.6. 13:04
Site check 215 – 3.8. 17:45
Pick-up 293 – 20.10. 14:17
120.05070/120.05070 days of data, recovery 100 %
Sensor 6089, grid north N21E, GPS G3844
Ground: hyaloclastite, pumice, sand, cement & ceramic plate
Burial material: bucket, cairn