Cruise report

R/V Dröfn

June/July 2004

(Photo: M. Schnese)

Dalvik - Polar circle - Siglufjördur

C. Riedel
University of Hamburg

Cruise report

R.V. Dröfn   Last cruise

Embarkation dates: **28/06/04– 08/07/04**
(afterwards transfer to Reykjavik)
Report phase: **25/06/04 – 08/07/04**

Subject of research: **Earthquake studies in North Iceland**

Institute: Institut für Geophysik
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Chief Scientist: Dr. C. Riedel

Number of scientific crew members: 8

Project: **„Tjörnes Fracture Zone Seismic Tomography Experiment“**
(TJOSTE 2004) – part of the NICExperiment,
DFG-project Da 478/13-1, Ri 1220/2-1

Contents:

1. Crew, list and affiliation

Position	Name	Affiliation
Chief Scientist	Carsten Riedel	Inst. für Geophysik Hamburg
Scientists	Rolf Herber	Inst. für Geophysik Hamburg
	Martin Hensch	Inst. für Geophysik Hamburg
	Michael Schnese	Inst. für Geophysik Hamburg
	Marcus Thölen	Inst. für Geophysik Hamburg
	Josef Holmjarn	Vedurstofa Islands
Technicians	Andrei Martinienko	GeoPro
	Alexandre Jelnikov	GeoPro
Scientific support onshore	Ragnar Stefanson	Vedurstofa Islands

Figure 1: The Hamburg scientific crew (M. Hensch, R. Herber, M. Schnese, C. Riedel and M. Thölen from left to right).

2. Introduction

Geophysics enjoys a long history at Hamburg and in early times people involved in earthquake research at the observatory became interested in North Iceland, the target area for this survey. Thoroddsen (1925) mentioned that in 1908, the Hamburg seismic station, a Wiechert instrument, registered an event of intensity 3 on the Mercalli scale near Akureyri (Fig. 1) shortly before 6 h on the 26th of December. However, this is not visible on the stored carbon copies of 1908 at the observatory in Harburg.

This event, as we know today, probably occurred in a 120 km wide belt joining two segments of the mid ocean ridge system, Kolbeinsey Ridge in the north and the North Volcanic Zone of Iceland in the south. Frequent seismicity (Rögnvaldsson et al., 1998), recent ultramafic volcanism (Devey et al., pers. comm.) and gas venting (Botz et al., 1999) go along with this unique geodynamic situation, which was first described as a transform zone by Sykes et al. (1967) and is actually situated between the Iceland plume and an ultra-slow spreading ridge. It is nowadays known as the Tjörnes Fracture Zone (TFZ), see Fig. 2.

From time to time seismicity endangers the life conditions of man, their cattle and infrastructure in the TFZ. The last disastrous (local earthquake magnitude 6.4) event happened in 1934 around Dalvik (Thorarinsson, 1937) and was described by a Mercalli scale intensity of 10 - houses broke down and many men were injured between Hofsos on Skagafjördur and Akureyri, the secret capital of the icelandic north.

Although stress is usually transferred from ridge movement to the transform zone, most of the faulting near the surface occurs in north-west orientation (Riedel et al., 2000), thus, they represent so called Riedel faults of the shearing system. *b*-values indicate that fluid movement plays a vital role for the rupture of these faults (Riedel et al., 2003).

Both its unique geodynamic situation and hazard assessment make this area a prime target for seismic observations. The permanent icelandic SIL network has operated 13 3-component-stations with 20 s sensors from Lennartz in the icelandic north (Fig. 3). Their setup, however, suffers from a major disadvantage. Since most of the events in the TFZ occur offshore and their seismic stations are mainly operating on the icelandic mainland, an expansion towards the offshore part using ocean bottom seismometers (OBS) appears to be logical.

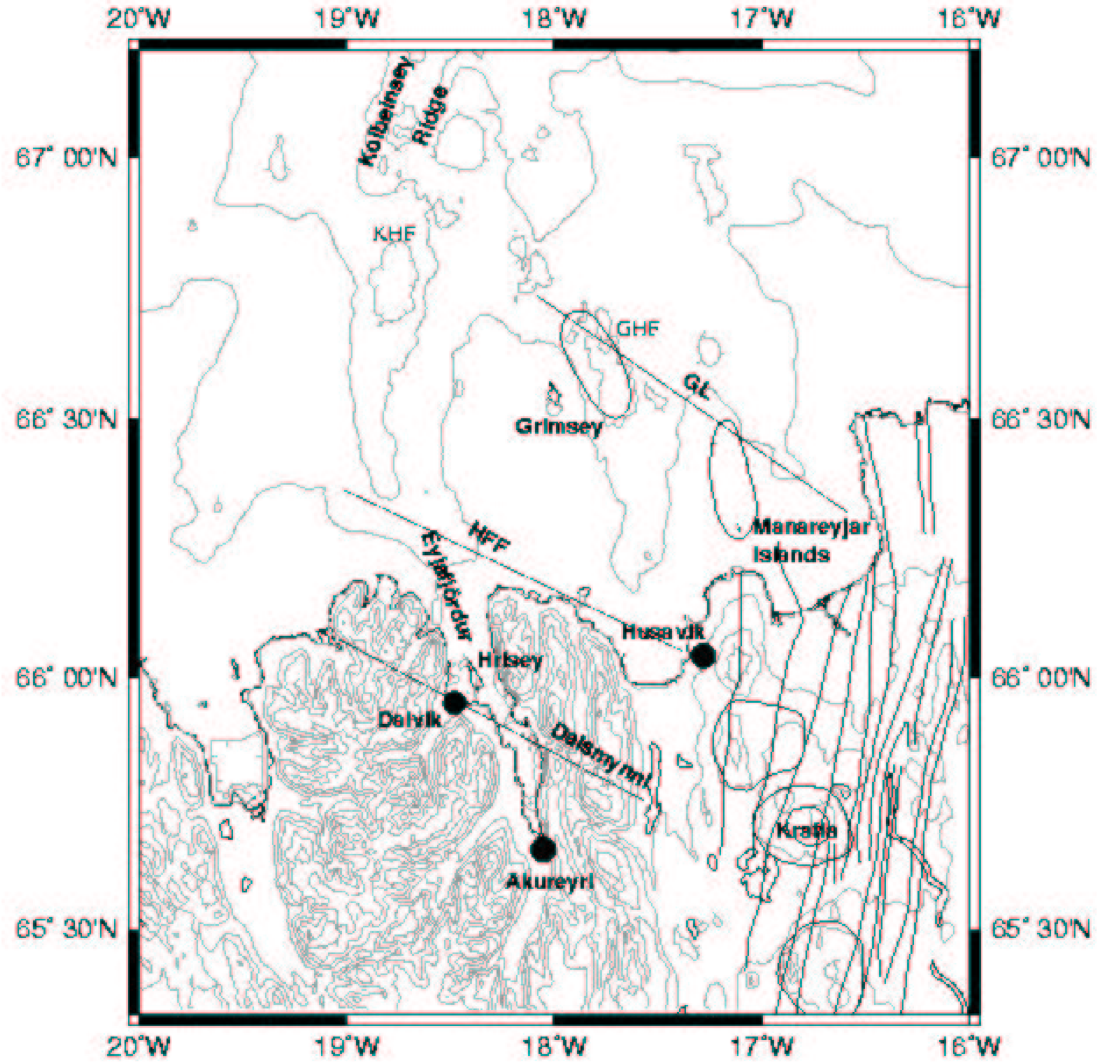

Figure 2: The topography/bathymetry (in grey contours) of the Tjörnes Fracture Zone is shown on the map. Geographic names of interest and the three most important towns, Akureyri, Husavik and Dalvik have been marked. The hydrothermal field at the islands Kolbeinsey (KHF) and Grimsey (GHF) are also marked. Seismicity is focussed along 2 seismic lineaments offshore, the Grimsey Lineament (GL) and the Husavik-Flatey fault (HFF), and a virtual lineament through the town of Dalvik and Dalsmynni valley, often termed the Dalvik lineament.

3. Research program

In a common approach with the meteorological office in Iceland the University of Hamburg installed a temporary seismic network offshore North Iceland and tested both the temporary setup and the permanent SIL setup of the meteorological office by dynamite explosions during the cruise of R/V Dröfn. At the same time the land network was expanded by further stations from the University of Uppsala (Sweden). This combined approach is called NICE (North Iceland Experiment). Between end of June 2004 and mid September 2004 the NICE experiment will register local earthquakes on 38 3-component stations (see Fig.3). Data exchange will happen in a later phase after recovery of the stations which is not part of this cruise.

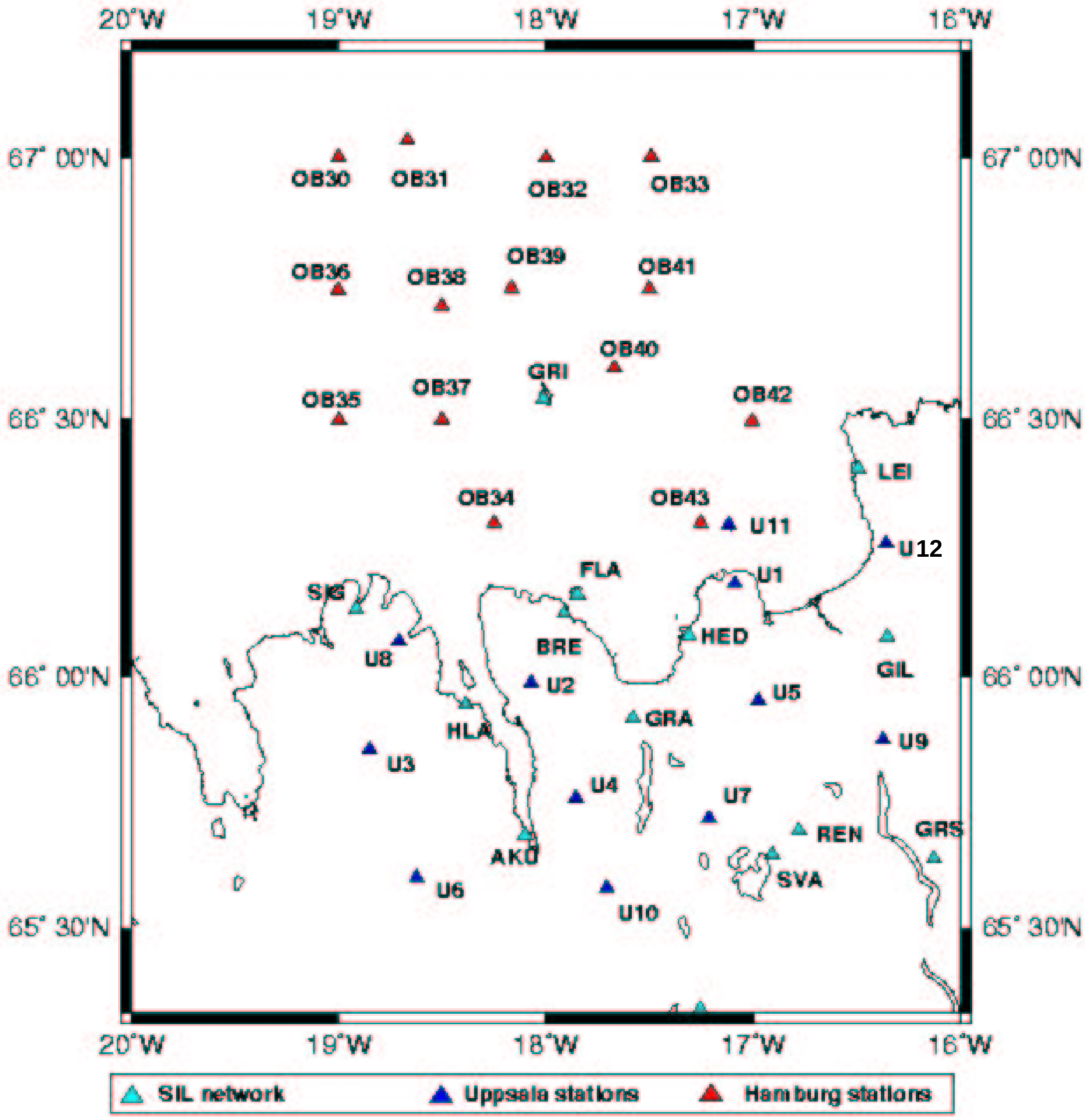

Figure 3: The station setup for the whole NICE experiment, this cruise report only deals with the deployment of the OB stations of Hamburg.

The deployment of 14 ocean bottom (OB) stations and the firing of 16 shots will be documented on the following pages as well as any technical requirement stemming from observations during the deployment phase on the Dröfn and in the cooperation with the land crew.

4 of the OB stations are ocean bottom hydrophones from the University of Hamburg (OB30-OB33) and 10 of the OB stations are ocean bottom seismometer/hydrophon combinations from the company GeoPro (OB34-OB43).

Before deploying the stations, an acoustic releaser testframe was used for the first time and valuable information for an improvement of its design was gained.

Further more, simple geological work was performed on the island of Hrisey in Eyjafjördur (Fig. 2) and echo sounder lines were recorded between Dalvik, Hrisey and Dalsmynni valley in Eyjafjördur.

4. Cruise diary and technical report

25/06/04 Arrival of the scientific crew from the University of Hamburg in Dalvik after 6 hours drive by rental car from Keflavik via Hvalfjördur tunnel, ring road and short stop at Grabrokarhraun. Accomodation in „Guesthouse Dalvik“ owned by Julius Snorrison.

26/06/04 **<u>Preparation (day I)</u>**

The container is easily spotted in the tiny harbour of Dalvik. However, after deinstallation of the customs seal it is necessary to install a lock instead. Since no such lock was packed it is bought at a price of 895 icelandic crowns (ISK) which is pretty expensive. Such things should be bought in advance and carried to the survey location.

The first workshop hall that we get from a guy called Sigurdur Marinosson is a little chaotic but big enough. However, from what Carsten can interpret of his icelandic talk he wants to organize a new hall which is better suited.

M. Hensch and R. Herber prepare the anchors. They make a special knot (Fig. 4) into the iron wire around the steelen O-Ring which will finally be tied to the acoustic releaser. The end of the wire will be tied by screwed wire fixers called „Frösche“ in german.

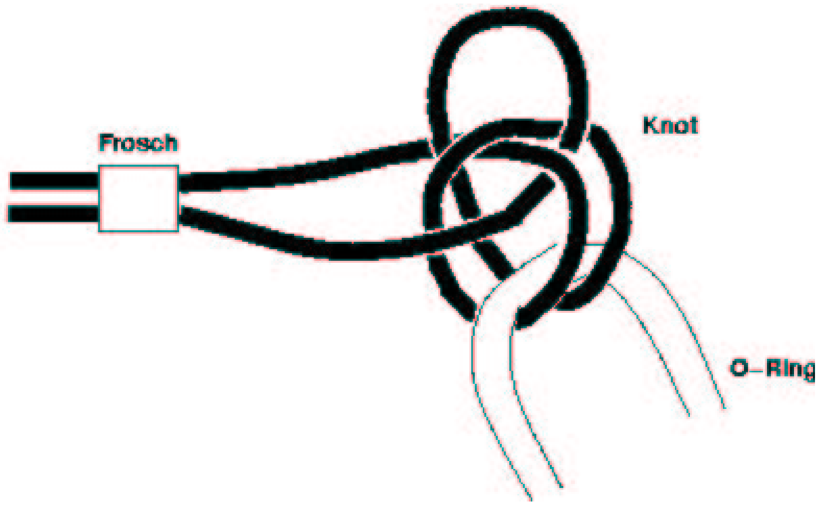

Figure 4: The Anchors were tied with iron wire (about 5 mm thick) in a knot and a screwed wire fixer called „Frosch“ to the anchor on the one side and to an O-Ring on the other, which will later connect to the acoustic releaser .

C. Riedel, M. Schnese and M. Thölen inspect the pressure cylinders after transport and equip them with the necessary batteries. The test of the pressure cylinders reveals that a cable is missing which connects GEOLON and PC via a serial cable. Cables should be marked particularly in coming cruise so that the exact location in the aluminium boxes is known beforehand and transport is secured. The manual does not state via simple connection or a crosslink cable is necessary, but trial and error results in the definition as found in Fig. 5. It does only work when all 4 cables are connected. There is no redundancy.

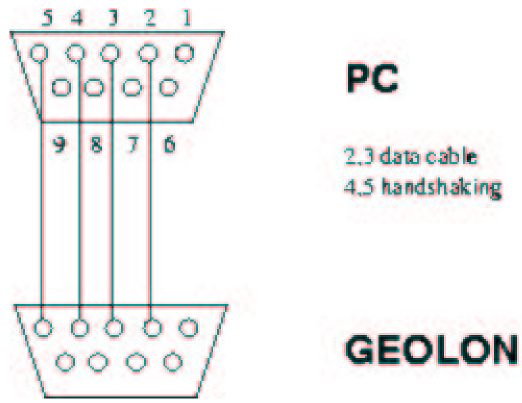

Figure 5: The PC-GEOLON serial link needs ports 2, 3, 4 and 5 to allow data transfer between them.

In the following, M. Hensch and R. Herber perform similar tests on the acoustic releasers. M. Hensch states that the modes of the releasers are different as this is marked on one of the releasers. The MORS releasers are operated in water by an onboard pinger tool which operates in 2 modes. Most of the Hamburg releasers are the same mode, but the mode is noteworthy for all to be sure which mode to use for releasing the stations after use and not leaving them on the seafloor for ever.

Everyone is reminded first by R. Herber then by C. Riedel that polydessicant dry bags should be put into each of the acoustic releasers and pressure cylinders.

Finally, after Marcus soldered the linking cable between PC and GEOLON, the GEOLONs can be tested. C. Riedel uses his own laptop, a Sony Vaio PCG 801 running under Windows 98, to connect to the GEOLON via the sendcom.exe software (MSDOS version). The station „Denmark (DK)“, which is going to be OB 30, works. The numbers of the deployments will start with 30 to ensure that no station of the Iceland survey can be mixed up with other earlier survey which run under single numbers, 10s or 20s.

M.Hensch explains that it is necessary to check the settings in the GEOLONs after the registration has been started to ensure that the capacity of storage remaining on the flash disks is really decreasing, i.e. data are recorded. In our sample, this takes about 5 minutes to be visualized for the case of 1 hydrophone connected to a GEOLON.

Further more we notice that one of two sealing rings is missing in one of the red pressure cylinders , that we called „Göteborg“, which is installed at position OB33, however according to R. Herber it should be okay without.

Further notes on the single ocean bottom stations are registered on the OBH station form in the Appendix.

We realize that it is essential to have a local partner in logistical issues, there is a small problem with the language. Contrary to the overall opinion, not all the icelanders are capable of speaking more languages than their mother tongue. So Ragnar Stefanson or Julius Snorrison need to deal with Sigurdur Marinosson about the location of the workshop. Sigurdur explains that the container will be moved during the night to the new place and the key will be handed over at 8:00 h.

In the evening the technicians from GeoPro turn up and contact Ragnar before contacting Carsten. They live in the same place for the preparation phase. A shipyard from Akureyri which was welding their anchors has told them that they deliver the anchors in time on Sunday (27/06) morning. M. Hensch will show them the way to the hall if the shipyard people arrive.

At the end of the day the 4 OBH pressure cylinders are equipped and programmed, the anchors are connected by a wire and the acoustic releasers are ready to be deployed. It took about 5 hours with 5 people because of the small problems described. All things are packed into the container and will be moved although they have already been programmed.

27/06/04 **Preparation (day II)**

In the morning information is exchanged. The anchors for GeoPro will arrive between 9 h and 10 h according to GeoPro. The people from the shipyard never arrive at Akureyri. Because of the short time available the technician have come by plane to Akureyri and need to return to Reykjavik on the 4th of July, which seems to be a rather short time.

At 8h in the morning S. Marinosson hands overs the key of the empty Eimskip customs store to C. Riedel. This is going to be a very spacious new workshop. The container was moved to a place directly outside the hall and provides a good overview of the harbour. It is only about 200 m away from the old place.

Around 9.45 h preparation of the instruments continues. The external hydrophone in a bombshell, that we call „fish“, which shall provide us with the precise shot timing during explosions is tested by R. Herber and M. Thölen.

The external hydrophone is not working like that because the amplifying circuit is damaged. So the plan comes up to use a SEND preamplifier instead. However, although the manual is in the documentation box, it does not mention the usage of its pins. This should be the case for the next survey ! So the hydrophone signal amplitude is tested and it is decided to use the hydrophone without amplifier and directly connect it to a datalogger. Next problem: The datalogger, an additional Methusalem station from SEND, was also left at home. So C. Riedel contacts A. Tryggvason in order to borrow an EarthData logger for the 2 days when active sources will be used. A. Tryggvason agrees to the plan.

C. Riedel connects the gel batteries of the Uppsala group to the battery charger from Hamburg. Most of them are not fully charged. The pole connectors of the ELV charging instrument are too small for typical car battery poles. So R. Herber drills holes into the poles and fixes small screws. We realize that we did not bring drilling utensils and borrow them from instruments on site. We also forgot to bring a pipe-wrench (Rohrzange) that we borrow, as well, which we need for the installation of instruments onto the frame. However, in future surveys all these things should be packed into the toolbox !

Batteries can be charged by a tenth of their capacity according to R. Herber. So the 74Ah batteries can usually be charged with 7.4 A. The ELV charger only allows much less. M. Thölen recognizes that this might result from the electronic regulation, which is essential for some kind of batteries. We choose to charge the batteries on channel 1 and 3, because on 2 and 4 it does not work while 1 and 3 are running. The parameters we choose for the gel batteries are:

Type of Battery: „Blei“
Charging current: max. 2 A (ch. 1) and max. 0.5 A (ch. 3)
Capacity: 74 Ah

We try to charge 2 batteries parallel on one channel. That does not work very well, because it is impossible to select 24 V instead of 12 V. The charged batteries are numbered on silver tape and their voltage goes up to more than 15 V in some cases.

Both, M. Hensch and M. Schnese connect the pressure cylinders to the GFK frames, by pure plastic cable ties from Fischer, which can hold up to 113 kg. These cable ties are underlain by hard gum belts. In order not to confuse cables the cylinders are mounted in the way that the hydrophone plug is on the right side, which is the opposite side from the pinger/hydrophone of the acoustic releaser (Fig. 6).

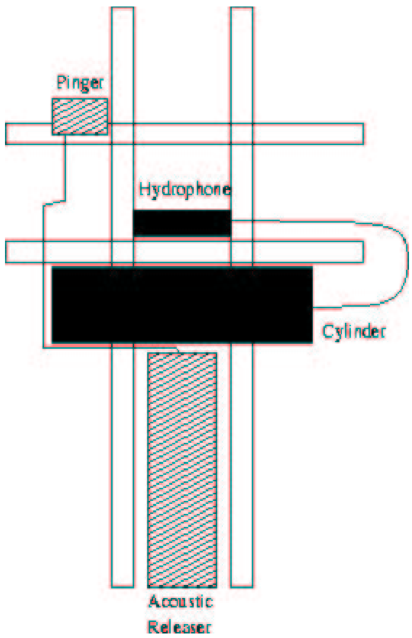

Figure 6: The montage of instruments on the OBH frame.

Until 10.50 h the shipyard from Akureyri has not delivered the anchors for GeoPro and the preparation for GeoPro instruments has not started. They inform C. Riedel that they will need about 2 days for preparing the instruments, so they should be finished by Tuesday (29/06) morning.

Because R. Herber does not trust in the plastic cable ties, 6 mm polyethylen rope is used to fix the pressure cylinders further. The rope is fixed with a palsteg on the one side and two half hitches (halbe Schläge) on the other.

All underwater plugs are finally sealed against corrosion with contact spray. When C. Riedel tries to use grease around the plugs to seal it even more R. Herber reminds him that the contact spray will be sufficient. So he agrees to deploy them this way.

According to captain Ragnar, the Dröfn will leave Akureyri at 23 h and will be in Dalvik in the morning. The anchors for the GeoPro instruments will be on board.

At 13:25 h we are finished with all the preparations for the deployment of OBH stations and the acoustic releaser test. So we drive to a meeting with Ragnar Stefanson in his house at Svafadardalur. We return with the information that there is a new exhibiton on the Dalvik earthquake in town from 1934. Ragnar thinks that the presence of hydrothermalism and recent volcanism along the Grimsey lineament are indicators for more fluids along this part of the TFZ than along the Husavik Flatey fault. They should evolve when there is an extension component to the shearing in the subsurface so they imply pull-apart basins and thus book-shelf faulting like in the south of Iceland. The observations during the Dalvik earthquake presented in the local museum indicate a similar thing for the Dalvik lineament which to Ragnar's opinion is only the southern end of the book shelf faulting induced by shearing along the Husavik Flatey fault. Of course, all these are only models and more data and discussions are needed.

In the evening A. Tryggvason and colleagues arrive in Reykjavik. He is going to work with K. Tryggvason from Akureyri who wrote a paper about the icelandic mantle plume with Ragnar some time ago. They are going to come to Dalvik late Monday.

After the meeting R. Herber and C. Riedel discuss the plan for the dynamite shooting at the end of the cruise internally. The idea is depicted in figure 7. The external hydrophone is connected by a cable to a GPS updated datalogger. Dynamite will be ignited by a simple shotbox (from Hamburg and clad in black leather) which can discharge up to 2 kV via a cable. Once exploded the signal will travel to the external hydrophone and we know the shot time and location up to a resolution of the sample rate (100 Hz) and some tens of meters (distance between shot and hydrophone). By creating an offset section of the shots we might even find a better solution.

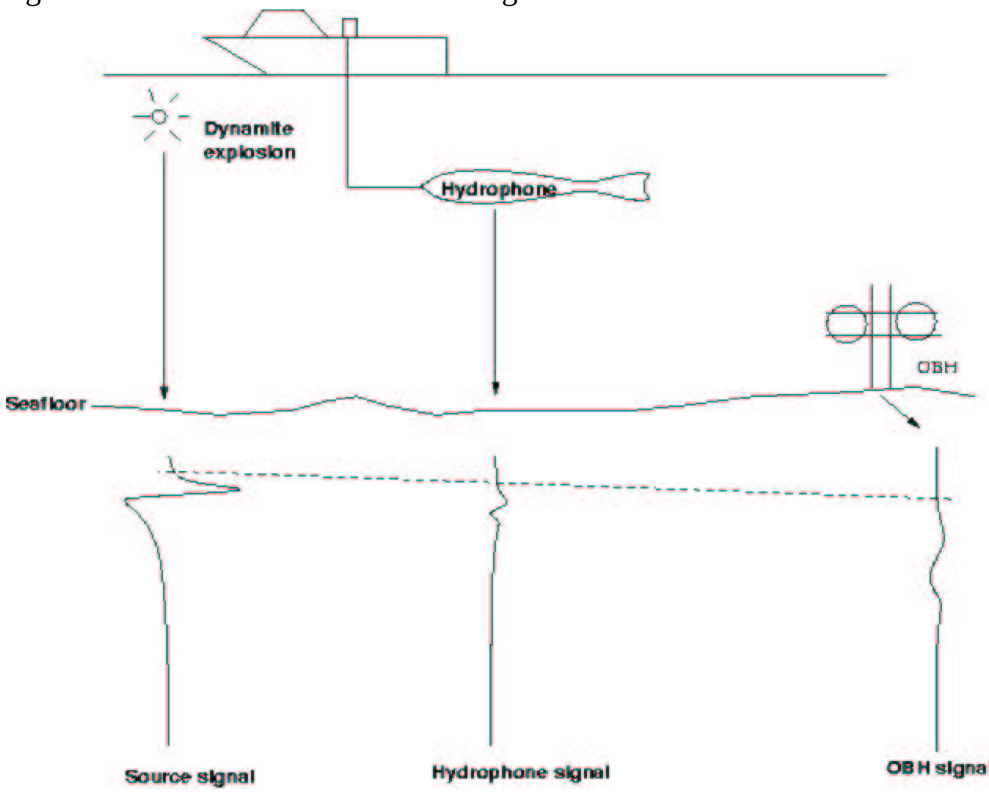

Figure 7: By detecting the first break on the hydrophone „fish“ next to the ship and on the OBHs it should easy to find the precise source time and location. The first break on the „fish“ itself is already a good approximation for the kind of passive seismological studies we pursue.

The schedule for Monday is fixed and thus another small ignorance is noted. We did not bring a printer, so it might not be possibe to print cruise commands for the captain so that he knows where he should take the ship.

28/06/04 **Preparation (day III)**

The research vessel Dröfn arrives during the night and C. Riedel and M. Thölen inspect it just before 8h in the morning. 5 beds for researchers are available on the 26 m long ship. They are on the lowest level next to one toilet in the stern of the vessel. In the central level the kitchen is located and above is the command centre. Everybody who wants to enter the ship normally has to enter through this room. The deck is about 14 m long and offers sufficient space for our instruments. The crane can lift far more than we need and far higher than we need. The captain asks us whether we have sea charts of the region, however, they did not arrive in time, but have arrived at the time of writing and will be available for the recovery cruise.
Afterwards the Dröfn needs to change its place in the harbour because a huge container ship will arrive soon.

R. Herber and M. Hensch finish the anchors since they forgot to tie the wires to the actual anchor weights. Finally, they equip flash beacons and transmitters with baby cell batteries while M. Thölen reassembles the toolbox.

M.Schnese hands over the rental car to the rental company in Akureyri.

C. Riedel instructs the GeoPro technicians where to deploy their instruments, they need at least 36 h. Afterwards he discusses with J. Holmjarn on the telephone about the explosives and his arrival.

The whole scientific crew moves the Hamburg OBH frames and the acoustic releasers to the outside and at around 9:30 h, after the navigator of the Dröfn called Samskip, they help us with their lifters to carry our equipment on board the Dröfn. When the frames have landed on the Dröfn, the crew of the ship unpacks them and unfortunately cuts some of the expensive cable ties around the pressure cylinders – namely the station OB31, because they think they are packaging. So they have to be reinstalled till tomorrow. The boatsman mentions that the sharp steel disc behind the GFK frame might cut the cable ties and this was the original reason, but that seems to be far fetched.

Cruise (Part 1)

At 10:15h the crew of the day embarks on the Dröfn (C. Riedel, M. Thölen, M. Hensch and R. Herber) for the acoustic releaser test just offshore Olafsfjördur where the fjords drops to seafloor depths around 200 m.
The new acoustic releaser test frame is equipped with the 5 releasers during the cruise. They do not fit into the frame without gum strips about 3 mm thick on one side of the releaser.
The releasers are first tested in air, when their hooks are attached to the springs on the bottom of the test frame. The pinger of „Hafnarfjördur“ reacts only after 3

unsuccessful tries, probably because it is running under „Mode B“.

The pingers of „Hvidesande“ and „Longyearbyen“ do not fit onto the test frame, because the hole in their cover are differently sorted than the wholes in the other releasers. M. Hensch thinks their holes are just in the center between the other locations of holes. So these pingers are only fixed with one screw, which is apparently sufficient. Nothing is lost during the test.
On top, „Hvidesande“ does not react to the MORS board unit in air, so we swap its hydrophone with another instruments and, finally, it works. So the hydrophone seems to be broken. We attach the old hydrophone for the test in water.

Name	***Serial Number***	***Instru-ment***	***Ping-Code***	***Release Code***
Hafnarfjördur	196	OB31	B486 + B494	B489 (Mode B)
Hvidesande	772	-	4821	4822 (Mode A)
Longyearbyen	172	OB32	9311 + 9394	9314 (Mode A)
Karlstad	195	OB33	B481 + B494	B474 (Mode A)
Hamburg	535	OB30	6B31 + 6B94	6B34 (Mode A)

Table 1: Acoustic releaser codes and modes.

At 11:20 h the ship stops and the test frame is attached to the crane of the Dröfn with a rope and shackles (Fig. 8). The rope and shackles should be part of our instrumentation but are not so we borrow them from the ship's crew.

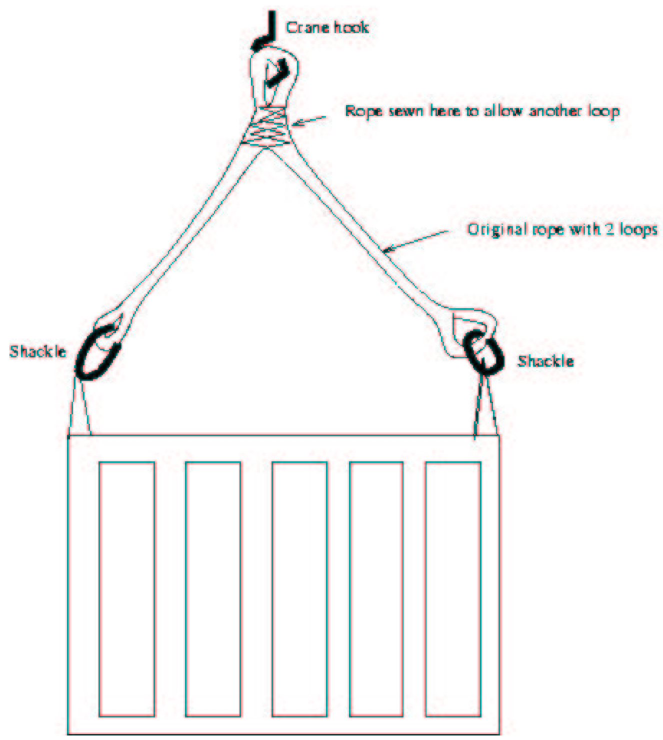

Figure 8: The test frame was fixed to the crane by a rope with 2 loops that was sewn in the middle to form another loop. The loops were fixed by shackles to the frame.

The frame is lowered into the water at the backside of the ship. The frame's weight is too light and exhibits very sharp corners, so it oscillates trongly on the crane, cuts into the ship's side and cannot be lowered into the water at the first two tries. It needs to be rounded off and dampened by some gum material or something similar so that it cannot rest fixed at the ship's side. Finally, at 12:02h, we succeed in getting the frame into the water after many contacts with the ship.

The test frame is lowered to a depth of 199 m, which according to the captain is 10 m above the seafloor. The acoustic releasers are tested for ping and release. Each result is given in Table 2 and Table 3.

Name	***Display after ping command***	***Display after release command***
Hafnarfjördur	1243 m RANGE	212 m RANGE
Hvidesande	618 m RANGE	289 m RANGE
Longyearbyen	195 m RANGE (on 2nd try)	197 m RANGE
Karlstad	197 m RANGE (on 3rd try)	196 m RANGE (on 2nd try)
Hamburg	196 m RANGE	197 m RANGE

Table 2: Results on display after ping and release command. The ping command in the old releasers does not work very well.

Name	***Hook opened***	***Still pinging ?***
Hafnarfjördur	X	X
Hvidesande	-	-
Longyearbyen	X	-
Karlstad	X	-
Hamburg	X	X

Table 3: Results when test frame was up on deck again.

At 12:45 h the winch gets the frame up again. At 13 h the frame is on board and the Dröfn returns to Dalvik. During the cruise those pingers of the releasers that are still pinging (Table 3) are switched off. The pinger off codes are essential and must be noted, as well. R. Herber tries to reduce the voltage loss by dismounting the pinger cable at the pinger plug of the releasers and gets a small electric shock because of the salt water. Only small currents flow through the cable, but anybody should be careful when dismounting these cables while the instruments are pinging. Best to dry the cables first !

Because „Hvidesande“ did not open the hook C.Riedel decides to use „Hamburg“ instead and connect it to the OBH frame for the station „Denmark (DK)“ at OB30.

At 14:23 h the Dröfn stops at the quay in the harbour of Dalvik again.

C. Riedel notifies the captain that the ship should be sailing towards Kolbeinsey at 4.00 h in the night. The captain will be watching weather conditions and inform the

scientific crew.
In the harbour, the acoustic releasers are dismounted from the test frame (M. Hensch and R. Herber) and tied to the OBH frames by cable ties (C. Riedel and M. Thölen). The gum strips prepared to use around the releasers are too thick to be used all around the releaser. So a small part is only used one side of the releaser to fix it to the frame in a tight fashion.

M. Schnese is informed via SMS and arrives a short time afterwards at the quay to help mounting the releasers. He did not have to pay more for the rental car for handing it in at Akureyri, the total gasoline costs for the drive from Keflavik to Akureyri via Dalvik was 4500 ISK, the bus from Akureyri to Dalvik was 650 ISK.

C. Riedel proposes to use tape as a third security for tieing the pressure cylinders to the frames, but R. Herber and M. Thölen think that this is nonsense from an engineering point of view, so C. Riedel decides to leave it like that.

Luckily there is a computer and a printer on board so that a detailed cruise plan can be written and handed over to the captain and the navigator.

In order to test whether the releaser lost too much energy during their 30 min ping phase, the releaser „Hamburg“ is reopened. However, it is still charged with 9.43 V in contrast to 9.63 V before use. This is still more than 9 V and should be sufficient for our task. So „Hafnarfjördur“ is not reopened.

Flash beacons and radio transmitters are finally attached to the frames by M. Hensch and M. Schnese. The radio frequencies are listed in Table 4.

Name	***Frequency***	***Mode***
Thorlakshöfn	159.48 MHz	B
Bergen	160.725 MHz	C
Öland	159.48 MHz	B
Grönland	159.48 MHz	B

Table 4: Radio frequencies of NOVATECH transmitters.

C. Riedel prepares the cruise plan for captain and GeoPro. At 16:50 h all preparations are finished.

Because of the construction of NOVATECH flash beacons and radio transmitters is is not trivial to determine their voltage. So these gaps can vanish from the OBH station form. But there should be a place where the test of function is performed and must be signed by the operator.

C. Riedel discusses with J. Holmjarn the details for the use of explosives on the last part of the cruise. The final method will be stated in that part of the cruise report. We need floats and buoys for the shooting that we do not have and R.Stefanson is trying to organize them during the next few days. C. Riedel orders 400 kg dynamite via the expert Josef, which is 16 shots a 25 kg – following R. Herber's opinion that this is enough to image the basement.

C. Riedel and A. Martinienko set the date for the GeoPro deployment to the 01/07/04.

29/06/04 **Cruise (Part 2)**

The plan for the day is to deploy all the 4 stations of Hamburg University at places where the slope of the sea bottom is not higher than 20°, so on a distance of 100 m, the echo sounding should not vary more than 26 ms.
R. Herber will be responsible for the final deployment, M. Hensch should swith on flash beacons and transmitters (that point is missing on the station forms), M. Thölen should keep the anchor wires fixed by a rope. When the instrument is lowered into the water, R. Herber will release it once the buoyant glass bowls touchs the sea surface.. M. Schnese and C. Riedel will document and watch from the bridge.

Practice looks different since the crew is faced with 4 people seasick (C. Riedel, M. Schnese, M. Thölen and M. Hensch), shortly after Dröfn leaves the port at 4:00 h in the morning.

The ship crew tries to lift the OBH overboard at the rear end of the ship. But this does not work at a wind speed of 4-5 on the Beaufort scale, so R. Herber und M. Hensch instruct them to use the left rear side of the ship. The radio transmitter is not brilliantly fixed in the OBH because of a construction problem of the frame. So the transmitter slides down some centimeters, because there is no metal piece or screw which keeps it upright in a tight position.

The first OBH deployed is OB33 at 11.00h. M. Thölen opens the hooks of the acoustic releasers by using the MORS board unit for radio communication, closes them again and ties the O-Ring of the anchors inside. Afterwards he switches on the transmitters and flash beacon and finally lifts the anchors on the railing. R. Herber ties the OBH to the crane with a stick on a rope knotted as in Fig. 9 and when the crane lifts the OBH to more than 2m height and turns over the railing, M. Hensch drops the anchor into the sea.

When the second OBH (OB32) is lifted overboard at 12.37 h above an area called „Paradisarhola“, all people but C. Riedel are working again. M. Schnese is documenting the process on the bridge, so that all times and locations noted in this report originate from this documentation. The location of the OBHs are printed in the appendix.

The other two Hamburg OBHs (OB31 and OB30) are deployed at 14:25 h next to Kolbeinsey Hydrothermal Field and at 15:10 h at the outermost northwestern position of the network. The full crew is now working again, although sea sickness still takes its toll, particularly when the ship returns to the harbour of Dalvik, rolling as a reaction to wind from the side.

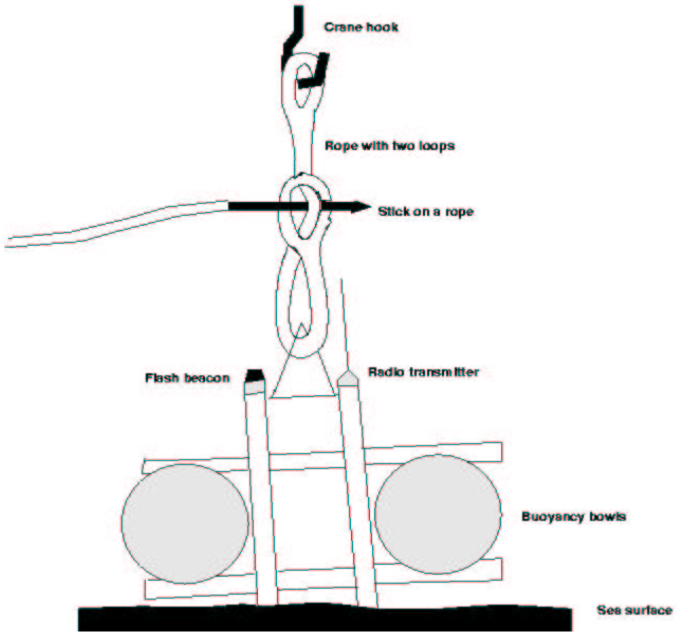

Figure 9: Knotted by a stick, the OBH is lifted overboard. When the buoyancy bowls touch the surface of the sea, the stick is drawn out and the OBH sinks.

Finally, the crane lowers the OBH to the sea surface until half of the buoyant glass bowls are drowned before R. Herber draws out the stick on a rope and the OBH sinks with about 1-2 meter per second which is close to their terminal fall velocity.

At 22:30 h the ship returns to Dalvik.

Because of the sea sickness, C. Riedel decides to hand over the responsibility for the GeoPro cruise on 01/07/2004 to R. Herber and he is okay with that decision.

30/06/04 **Preparation (day IV)**

GeoPro technicians decide that they cannot be ready before the 1st of July. So the whole day can be spent for the preparation of the GeoPro instruments and the preparation of the dynamite shooting.

J. Holmjarn tells the crew that he is going to bring his winch with 300 m elastic cable and he is going to hand over the bill to the Christel, the secretary of the department in Hamburg. He also needs a lot of 6 mm polyethylen rope and C. Riedel says he can provide it.

A. Tryggvason needs the help of M. Hensch and M. Schnese to deploy some land stations. During the day they deploy a land station close to a water fall in Olafsfjördur and they inspect the potential to deploy another station in Svafadardalur, however, do not succeed in finding one. Later, R.Stefanson tells C. Riedel, that valleys are generally bad positions for land stations in the north of Iceland because of the frequent tillites and gravel which are too loose for a good coupling to the seismometer.

M. Thölen and C. Riedel are preparing the EarthData logger for use with the external hydrophone.

In the late morning there is a discussion with EIMSKIP on the use of the storing and working place, which is their empty customs store. It has to be cleared on the 01/07 in order to avoid further costs. They declare the container as „EMPTY“. G. Gudjonsson, the agent in Reykjavik, and Julius from EIMSKIP in Dalvik will decide how to transport and store things in Akureyri for September without adding extra costs.

C. Riedel, M. Thölen and R. Herber are invited to inspect the local exhibition on the Dalvik earthquake in 1934 where they also present the present survey to the local public. The danger of earthquakes in the area is not so well known, although the old reports describe in very colorful icelandic language what happened in 1934. A typical case for the Icelanders must be the 9 year old girl who is surprised that a bucket full of skyr is flying through the room. R. Stefanson installed a 3 component seismometer writing on drums in the museum.

Although the EarthData manual does not indicate a GND-pin and does not indicate that it might not need one, C. Riedel and M. Thölen test the equipment with a serial cable connection to the SONY VAIO laptop computer described earlier. They select station no. 3168, and a battery not fully charged is used. At first, only ACQ and PC are flashing with light, but, finally, the ACQ and GPS diodes are flashing rhythmically and PC is dark again. To connect to the PC the EarthData logger has to be „Flushed“ by pressing the green button, disconnected from power and restarted.

A Hyperterminal is opened up on the laptop in Windows 98 and the connection is established using RS 232 – 9600 Baud – 8 bits, no parity bit and 1 start bit (saved as file „ED“ on laptop). The screen popping up is first full of MODEM AT commands, before a typical LINUX screen appears and the computer can be accessed using either „user“ as login and password or „root“ as login and password. By using vi, M. Thölen sets the parameter „channel_0_format“ in /config/recorder.ini to ASCII.

The usage of the auxiliary channels is limited to a sample rate of 1 Hz, so it is not used and the parameters are left on ASCII for channel 1 and MSeed for the other channel, so that both kinds of data can be created depending on where the cables are linked. The connectors are displayed in Fig. 10.

In the evening A. Tryggvason is reminded to get the land stations out of the storage house so that only the following things remain in Dalvik: 1 EarthData (no. 3168) logger plus antenna, 1 Lennartz seismometer, 1 sensor cable, 1 battery cable for two car batteries.

An oscilloscope is unpacked from one of the boxes to take it to Germany for another cruise.

The rest of the equipment which will not be used anymore is packed into the according boxes and sealed with plastic foil from EIMSKIP on palettes.

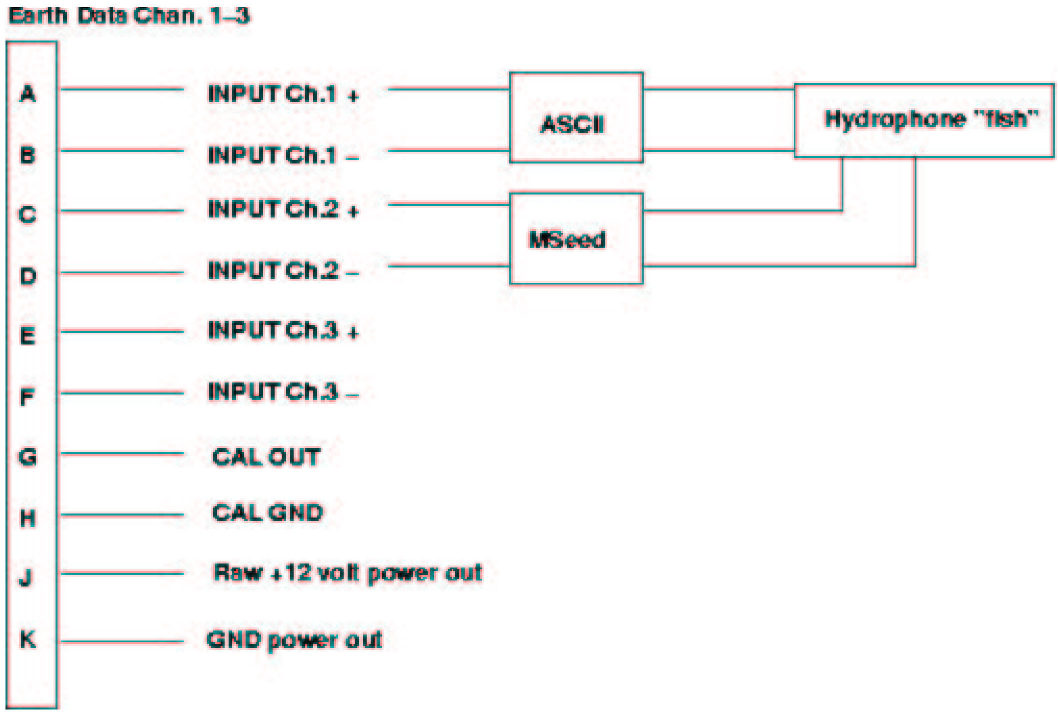

Figure 10: Connection to Earth Data Ch. 1-3 connector, a typical military sensor plug, after our programming with vi can either be done on Channel 1 as ASCII data or Channel 2 as MSeed. During explosions we actually used Channel 2.

A. Martinienko informs C. Riedel that all GeoPro stations will be programmed to start registering data at 0.00 h on the 05/07/04.

01/07/04 **Preparation (day V)**

Instead of 8.00 h as planned by SAMSKIP, some lifters from EIMSKIP arrive at 9.00h to take the GeoPro stations onboard the Dröfn.

The land crew, M. Schnese, M. Thölen and M. Hensch, in structed to wrap all the boxes in the EIMSKIP customs store into plastic foils and place it on palettes.

The cable for the connection between EarthData logger and Hydrophone is tested by using the computer and a serial connection. Unfortunately, it is not possible to visualize the signal of the hydrophone on the EarthData system, so by connecting it to the ASCII channel on pin A and B and observing the deviations from the bias value stored on channel 1 - by using an editor or the „less"-command - , M. Thölen can only make a crude estimate if the system is working in conjunction. However, he decides that the system delivers a signal, so that it can be used on board.

C. Riedel is meeting with R. Stefanson and B. Gautason in the Nordurorka building in Akureyri during the morning. B. Gautason is a scientist from ISOR, the new icelandic research organization for geosciences. He is a geologist and interested in results of Poseidon cruise 252. R.Stefanson mentions that he is going to be the head of a new research institute which is going to be opened up in Akureyri soon.

J. Holmjarn and C. Riedel discuss the explosions on the telephone. J. Holmjarn is organizing the transport of the explosives on the 05/07/04. He is still looking for floats and hands over the details to C. Riedel who again explains R.Stefanson what he needs. The Dröfn does not provide such floats.

After returning C. Riedel inspects the customs store and wraps the plastic foils around the palettes, because they are still standing free. Afterwards , the key of the customs store is handed over to EIMSKIP again. Unfortunately, C. Riedel forgot to get the 6 mm polyethylen rope. EIMSKIP is already closed when he notices, so that there is a need to return the following day.

The equipment of A. Tryggvason which was borrowed for use during the explosions is carried to the guesthouse by aid of J. Snorrison.

The experiment is much faster than thought, so that flights for two members of the crew are rebooked. Staying overnight in Iceland is much more expensive than paying more to leave earlier.

Cruise (Part 3)

The scientifc crew for this part consists of A. Martinienko and A. Jelnikov under the supervision of R. Herber. A. Martinienko, the captain and R. Herber were instructed by C. Riedel where to deploy the stations and what name to use.

The vessel starts at 9.30 h towards the position of OB34. During the cruise A. Martinienko and A. Jelnikov prepare two stations so that at 12:45 h when the ship arrives on position the first one is ready to be deployed. The second one, OB 43, is deployed 3 h later at 15:40 h.
At this point in time A. Martinienko and A. Jelnikov develop symptoms of sea sickness and in agreement with R. Herber and the captain they decide to perform further instrument preparations inside the harbour of Husavik, so the ship sails to Husavik, where it is lying along the quayside during the whole night, because the preparation phase for the instruments is not finished earlier.

02/07/04 **Preparation (day VI)**

First thing in the morning C. Riedel can access the 6 mm polyethylene rope. Later on C. Riedel informs R.Stefanson about the prospective shotpoints for the dynamite so that the ministry of fisheries can warn other ships in the region to keep the distance.

Probably, a first big earthquake has been registered on the OBH stations (OB30 to OB33), because there was a quake in Myrdalsjökull (Mag > 4).

A. Tryggvason informs the crew that M. Schnese and M. Hensch will be needed for installing a station near Dettifoss on the following day.

Cruise (Part 3 – continued)

The ship leaves Husavik at 04.00 h and during the course of the day the crew is successful in deploying all the remaining OB positions (see Table 5).

Time of deployment	***Station***
06:15 h	OB42
08:05 h	OB40
09:12 h	OB41
11:00 h	OB39
12:04 h	OB38
13:25 h	OB36
15:02 h	OB35
16:22 h	OB37

Table 5: Times of deployment during the course of the day.

A problem occurs when the 13^{th} ocean bottom station, OB35, is deployed. The anchors falls off and the OBS is drifting on the sea surface. It turns out to be a slight problem to recover the stations and deploy it again. Because of the way the OBS is built, it can only be recovered when ropes on both side are tugged by hooks. However, on the rocking sea surface that is not easily arranged. A further problem is the construction of the anchor and the frame. The frame consists of a single PVC board about 1 cm thick. Two floating bowls rest on its two ends and draw it upwards by buoyancy, while the anchor is fixed in the middle and draws it downwards, therefore pressing it into a V-Shape (see Fig. 11), which might have a bad influence on the coupling to the ground, because the whole frame can oscillate.

After all stations have been deployed, the captain R. Hermansson sends the position to the radio for fisheries so that all positions are published in their radio news. Within one nautical mile they are presented as danger area for the nets of the fishermen. Hopefully, this is sufficient in this region of intense crab and shell fishing to avoid destruction of the stations.

At 20:30 h, R/V Dröfn returns to Dalvik.

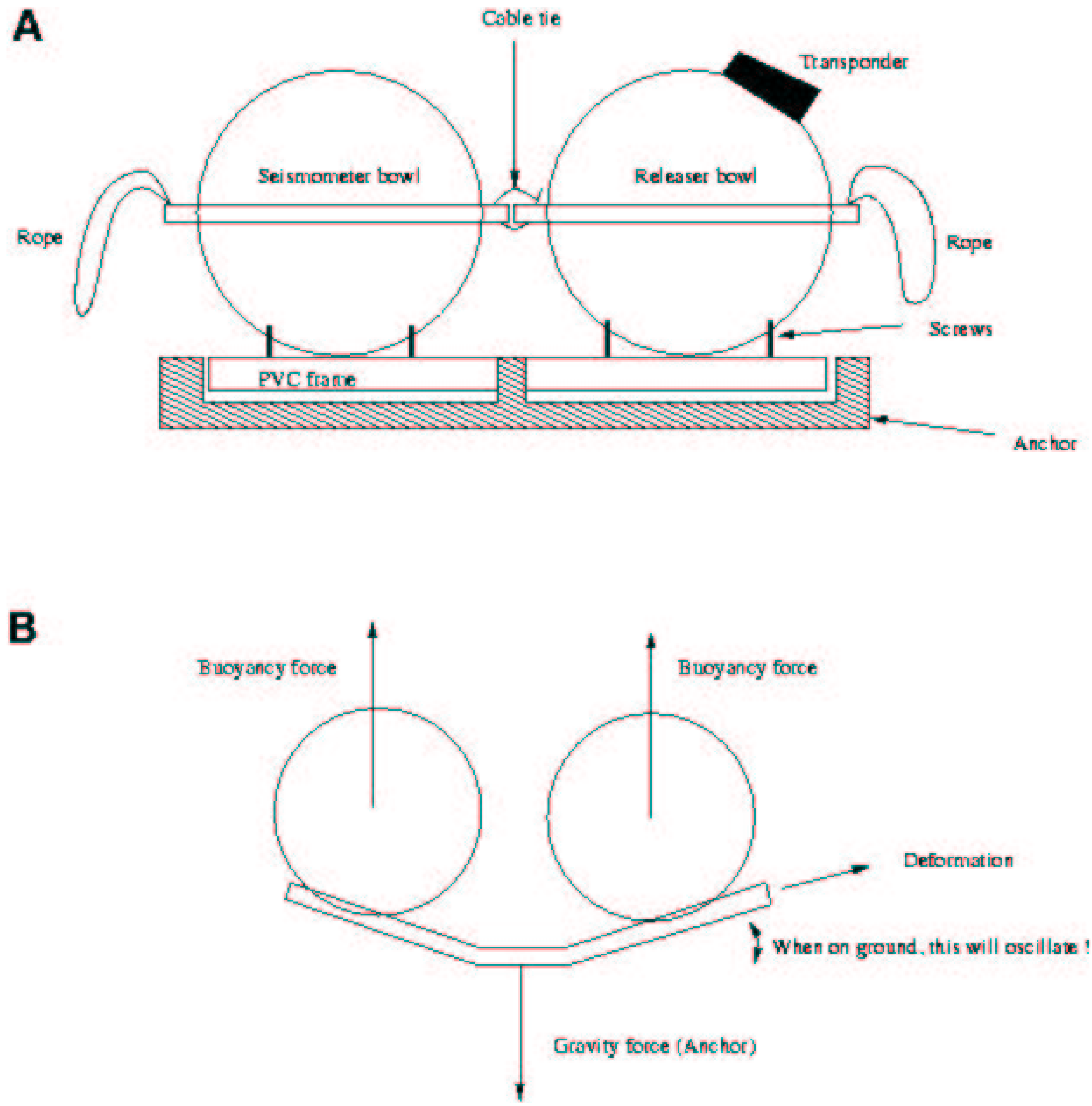

Figure 11: A) shows the construction of the double bowl OBS from GeoPro, while B) shows the potential problem resulting from this construction when drowned in the sea or hanging loose in air, because the ropes at the side will impose similar forces to the buoyancy of the bowls.

03/07/04 **Cruise (part 4)**

R/V Dröfn leaves Dalvik at 10:00 h with 5 knots. The schedule for the day consists of profiling the seafloor by the onboard ELAC LAZ 4400 echo sounder. The profile coordinates are given in Table 6.

We observed that the structure is generally getting complexer towards the southern end of the profiles towards Dalsymynni valley. Gas venting cannot be discovered because the frequencies of the echo sounder (dual frequency 24 kHz and 30 kHz) are optimized for fish finding and the icelandic waters of the north are full of fish. Some unique structures tower above the environment, in particular near Brimnes close to the western shore of the fjord. No unequivocal signs for faulting are visible on the sea bottom.

Line No.	***North***	***West***	***Line No.***
1	65°55.15	18°26.43	
	65°57.67	18°25.01	**2**
3	65°58.43	18°25.1	
	65°58.46	18°23.61	**4**
5	65°57.70	18°23.45	
	65°57.66	18°20.32	**6**
7	65°56.18	18°17.51	
	65°54.895	18°16.024	**8**
9	65°55.097	18°13.03	
	65°58.61	18°55.88	

Table 6: Corner points of echo sounder profiles registered in Eyjafjördur between Dalvik and Dalsmynni.

After the echo sounding R/V Dröfn sets out for a visual inspection around Hrisey Island, which is recorded as a movie on mini DV. The north of the island is overprinted by dikes, in particular a major one that runs north-south and creates shallow waters north of the island before popping up over the sea surface again in a place called Hrolfsker. The north of the island is covered by clastic material, probably pyroclastic or tillites. The whole structure could represent an ancient fissure zone dotted by cinder cone structures. Remnants of the feeding dike structures are also visible northwest of the harbour of Hrisey. The dikes we find are easily 4 to 5 m thick in diameter and have been intruded more than once, which is typical for such an elongated fissure zone.

So, at 15:00 h, the ship lands in Hrisey harbour. C. Riedel and M. Thölen approach the dikes near the harbour which intrude into flood basalts. Dikes and flood basalts alike are penetrated by numerous veins, which have opened in the direction Dalsmynni-Karlsaradalur (near Dalvik) or precisely orthogonal, which is roughly the main direction of the dikes. The minerals in the veins are white and are ball-shaped with single spikes inside, probably a kind of zeolith.

At 17:15 h the Dröfn leaves Hrisey and shortly afterwards, at 18:00 h, returns to Dalvik.

During the echo sounding survey, M. Schnese and M. Hensch, helped K. Tryggvason to install the land station near Dettifoss (U9 on Fig. 3).

04/07/02 Work rests on this day and the ship is lying in the harbour, because the scientific crew is waiting for the dynamite to arrive. In the morning R.Stefanson arrives with the necessary floats for the active part of the experiment that he got from Saeplast in Dalvik.

05/07/02 **Cruise (part 5)**

At 8:00 h the dynamite (Poladyn from Krumski Mlyn) arrives as 22.8 kg packets in the harbour and is transported into the ship, when shortly afterwards, J. Holmjarn arrives, who is the dynamite expert for the next part of the cruise. R. Herber and J. Holmjarn exchange ideas on the explosions and J. Holmjarn is instructed how to use the shotbox that the crew brought from Hamburg.

R. Herber and M. Thölen leave the ship and at 8:57 h the ship sail away from the harbour of Dalvik. People on board are C. Riedel, J. Holmjarn, M. Hensch and M. Schnese. The captain notifies us that we will need 2 h sailing before we can proceed with the 1st explosion. C. Riedel plans to perform the 1st explosion in the mouth of the fjord to see if all the equipment works and if something can go wrong. The locations of all shots are displayed in the appendix.

The sea is very calm during the whole day, the sun is shining and many whales follow our trail.

C. Riedel connects all the necessary cables between the hydrophone fish, the GPS antenna and the EarthData logger, while M. Hensch connects the power. The hydrophone fish is connected to Channel 2 via pin C and D. The EarthData logger is working throughout the whole cruise and is updating GPS location and time permanently, so that the hydrophone fish is always connected to a GPS clock.

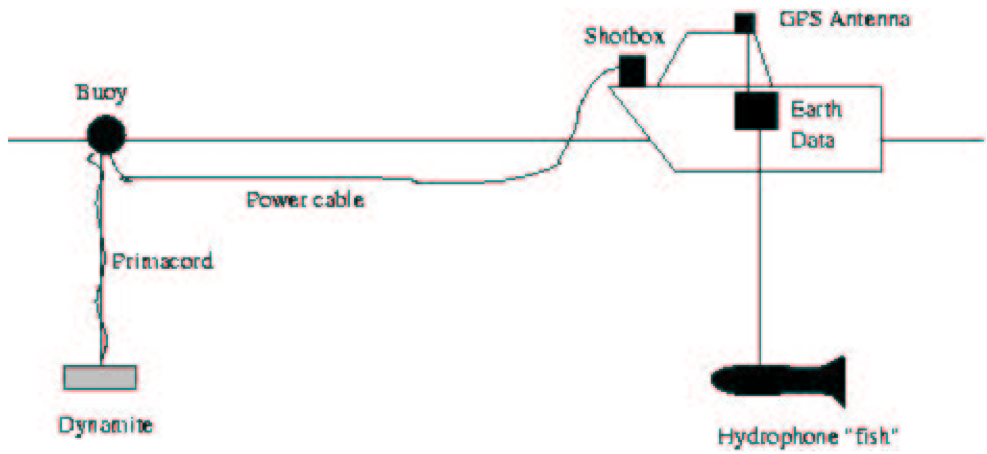

*Figure 12: S*hot setup for the explosion by J. Holmjarn. Loose hanging primacord links the dynamite and a power cable. The EarthData logger registers the signal from the hydrophone „fish“ and is triggered by GPS signal through the antenna.

J. Holmjarn's shot setup is displayed in Fig. 12. He is rolling a primacord cable around one of the dynamite columns, which are only going to ignite if the speed of ignition is higher than 5500 m/s. Polyethylen rope is wrapped around the box of dynamite and is hanging on a float. The primacord cable is also connected to a detonator hanging on the float, but in such a way, that it cannot tear apart, i.e. it is hanging loosely. The detonator will only ignite is it gets a discharge of more than 70 V. So it is connected by an ordinary power cable (300 m long) to the black Hamburg shotbox described earlier, which can provide up to 2 kV. For security reasons, the shotbox is only connected when the dynamite has reached its final location. This final location is always in front of the ship, because the front side of the ship is the most stable part. In the case of 22.8 kg shots the distance is about 100 m, in the case of a double portion (45.6 kg) it is 180 m. The depth of the shots is 19 m, although it was planned to use 15 m. This shot depth kills most of the „bubble noise“ originating from the oscillation of the explosion bubble in water, because it penetrates through the sea-air interface and the gas is released into the air instead of rising upwards through the water column and sending out signals. The problem in using shallower depths is the high loss of energy to the open air.

Once the dynamite box is lowered into the water on the left side of the ship, the hydrophone fish is lowered into the water on the right side of the ship, so that they cannot float into one another. Sometimes the hydrophone hits the shipside, because it is quite heavy for lowering down manually. This might create a further signal and must be carefully inspected when reading the data.

At 11:08 h the first explosion takes place near the mouth of Olafsfjördur, however farther outside than the acoustic releaser test. When the dynamite is ignited, a bubble is approaching the surface, penetrates the sea-air boundary and a fountain of water rises to about 10 m height. A white foam line spreads from the point where the bubble first penetrated the surface and spreads out radially, so that a boiling sea surface can be observed with a radius of a about 15 m. Boiling takes place, when the pressure release at the free surface cannot be compensated beyond the pressure of air and thus the energy is released in heating up the water spontaneously and transforming it from fluid into gas.

All explosions during the day ignite at the first possible option. The 8th shot is the 1st of two pssible 45.6 kg shots. At double distance the observations looks very similar to the smaller shot. The 2nd bigger shot is the last shot (SP12) of the day.

At 23h, a break is imposed by the captain, because his crew needs a rest, so that the remaining explosions will be carried out the day after.

06/07/04 **<u>Cruise (part 5 – continued)</u>**

The sky has become grey during the night and the waves are getting higher due to a wind speed 5 on the Beaufort scale.

After breakfast a first dynamite explosion is scheduled. In contrast to the day before, this shot no. 13 failed at the 1st possibility. So we observe our first misfire. Only the primacord ignited, so a new connection is established and a 2nd try is performed, which is successful.

The last 2 shots are only situated at 10 m depth because the primacord cable has shrunk much more than anticipated and there is no more cable left.

At 14:37 h M. Hensch flushes the EarthData logger which is followingly dismounted.

At 16:10 h the ship returns to Dalvik and the floats are handed back to Saeplast. Further more, R.Stefanson agrees to store 1 aluminium box, the hydrophone fish, 200 m rope, nearly 200 m polyethylen rope and 3 security helmets for the next cruise in September.

The full land station including EarthData logger and serial cable connection is handed to R. Stefanson, as well, who will be taking it to A. Tryggvason and onto the Manareyjar island, where the last station (U11) is going to be installed during the night. The configuration files were not changed so that the disk is still registering data as ASCII. An SMS tells A. Tryggvason not to delete any of the data recorded on the disk. J. Holmjarn leaves the ship in Dalvik.

At 18:30 h the ship leaves Dalvik again towards Akureyri, the final port of call for this cruise.

At 21:00 h the ship arrives in Akureyri.

07/07/02 At 07:30 h the scientific crew leaves the ship, rents a car and is on its way back to Reykjavik. In the afternoon the ship leaves Akureyri towards Siglufjördur.

08/07/02 Transfer of the ship to Reykjavik.

5. Scientific equipment

Technical details of the scientific equipment are described in further reports. It is important to note the instruments we deployed. On locations OB30 to OB33 we used the Hamburg-type ocean bottom hydrophones (OBH on Fig. 13) with

Figure 13: The Hamburg type OBH with two glass bowl covered by orange plastic, which are mounted on a GFK frame. The datalogger is stored in the red pressure cylinder made of aluminium. The silver aluminium housing covers the hydrophone.

Geolon dataloggers, the exact specifications of the deployed instruments is noted in the Appendix. These stations use MORS OCEANO acoustic releasers, their release codes are also noted in the Appendix.

The echo sounding survey was performed using an ELAC LAZ 4400 single beam echo-sounder with double frequeny capability at 24kHZ and 30 kHz.

On locations OB34 to OB42 we used GeoPro double bowl seismometers with a hydrophone and Sedis III dataloggers. Further informaton on these stations are given in detail by the company GeoPro. The acoustic release codes are not documented here, since they are part of the GeoPro responsibility.

For the explosions we used poladyn from Kruspki Mlyn and primacord cable (Fig. 14).

Figure 14: This is 22.8 kg box of poladyn from Kruspki Mlyn.

6. Preliminary results

First of all, as stated in the diary, all seismometers were successfully deployed and no problems occurred. A small problem, concerning the coupling and recovery of the Geopro stations, was noticed. But in a similar fashion, the design of the Hamburg OBHs shows some minor points which can be improved.

The acoustic releaser test frame was used for the 1st time in a ocean bottom seismometer survey and its application turned out to be crucial, because one of the acoustic releasers brought to Iceland did not work. The design of the test frame, however, shows the typical errors of new designs and and has to be adjusted for use in a marine environment, i.e. robustness and sheltering needs to be added. Also the drill holes for the pinger/hydrophone of the releasers needs to be adapted to fit to all the hydrophones. At least two different options occur in the MORS production.
It is probably of use to some metascience, that both the 13th shot and the 13th ocean bottom instrument deployment were accompanied by problems.

The main results, however, were created by G. Gudmundsson from Vedurstofa Islands, who located our shots by the permanent SIL network and gave us the locations during a meeting on the 07/07/2004 in Reykjavik. 3 shots were automatically registered, SP 1, 2 and 16, the rest was manually put into the system and located. The coordinates of the locations are stated in Tab. 7.

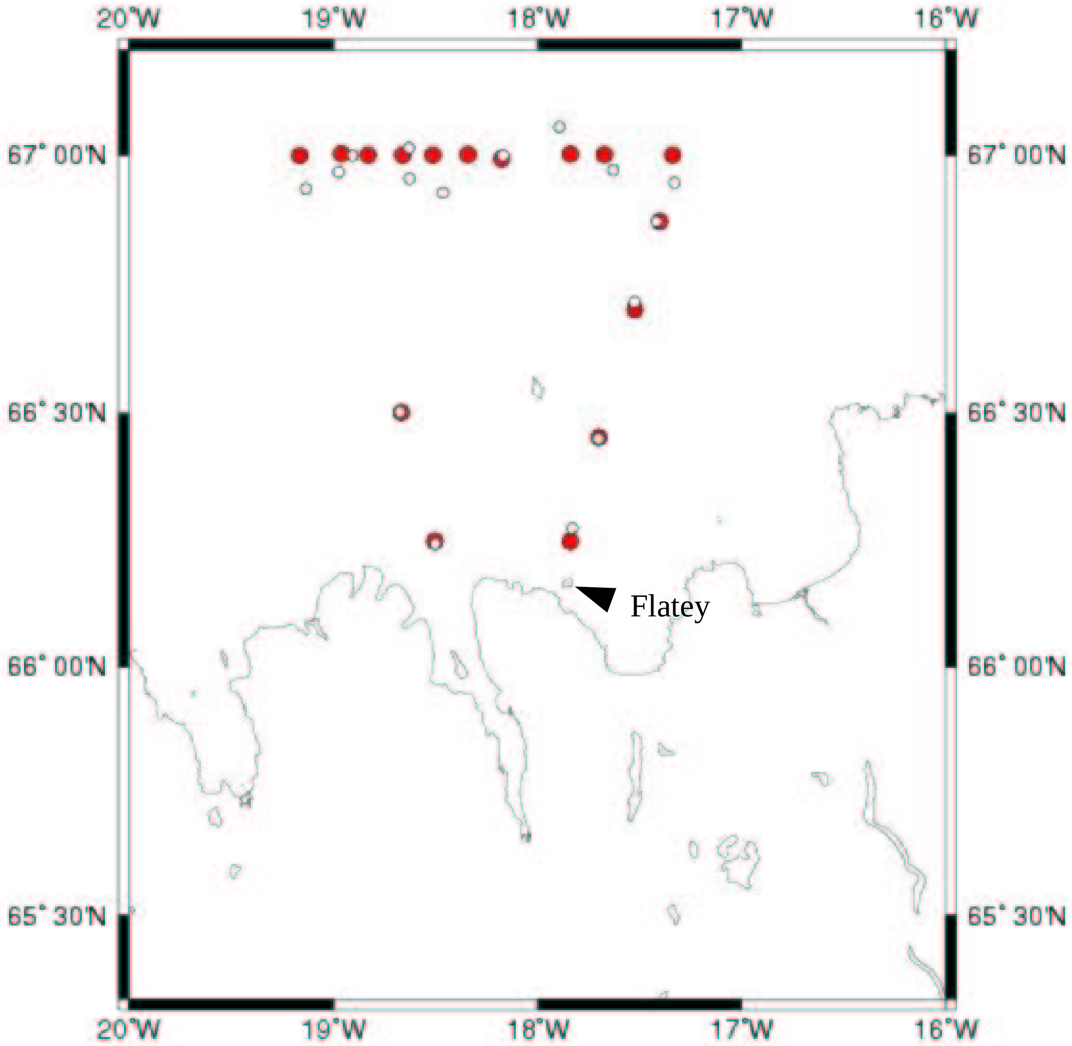

Figure 15: shows the locations of the shots as red circles and the virtual positions of the shots located by the SIL network as small white circles.

When comparing the positions located by the SIL network with original data (Fig. 15), it is easily visible that the data gets worse the further one gets to the north. Since location erros usually get better the smaller the azimnuthal gap is, adding the data from our temporary network must result in far better comparisons. It is of further notice that north of Flatey, where a preliminary 3D tomography (Riedel et al., submitted) showed a velocity anomaly, the location of the shot is really bad. This can only be improved by using a joint determination method for subsurface velocity and location of the shots.

SP	*North*	*West*	*Depth*	*Recording stations*	*Remarks*
1	66.24487	18.50166	135	10	Fixed depth, automatically located
2	66.50322	18.67402	71	12	automatically located
3	66.93497	19.13564	135	5	Fixed depth
4	66.96687	18.97578	135	6	Fixed depth
5	66.99916	18.90736	135	5	Fixed depth
6	66.95510	18.62684	135	5	Fixed depth
7	67.01324	18.62983	135	8	Fixed depth
8	66.92776	18.46234	135	7	Fixed depth
9	66.99919	18.16788	135	6	Fixed depth
10	67.05346	17.89343	135	8	Fixed depth
11	66.97047	17.62988	144	6	
12	66.94646	17.32912	135	7	Fixed depth
13	66.87239	17.41750	135	7	Fixed depth
14	66.71701	17.52660	135	9	Fixed depth
15	66.45084	17.70062	135	9	Fixed depth
16	66.27518	17.83099	135	9	automatically located

Table 7: Positions of shotpoints as located by the SIL network and the number of stations that recorded the events.

The echo-sounding gave an overview of the structure in Eyjafjördur, which is rather complex southeast of Hrisey, but very flat west and north of it. A typical complex morphology is depicted in Fig. 16, which shows the structure direclty offshore Brimsnes.

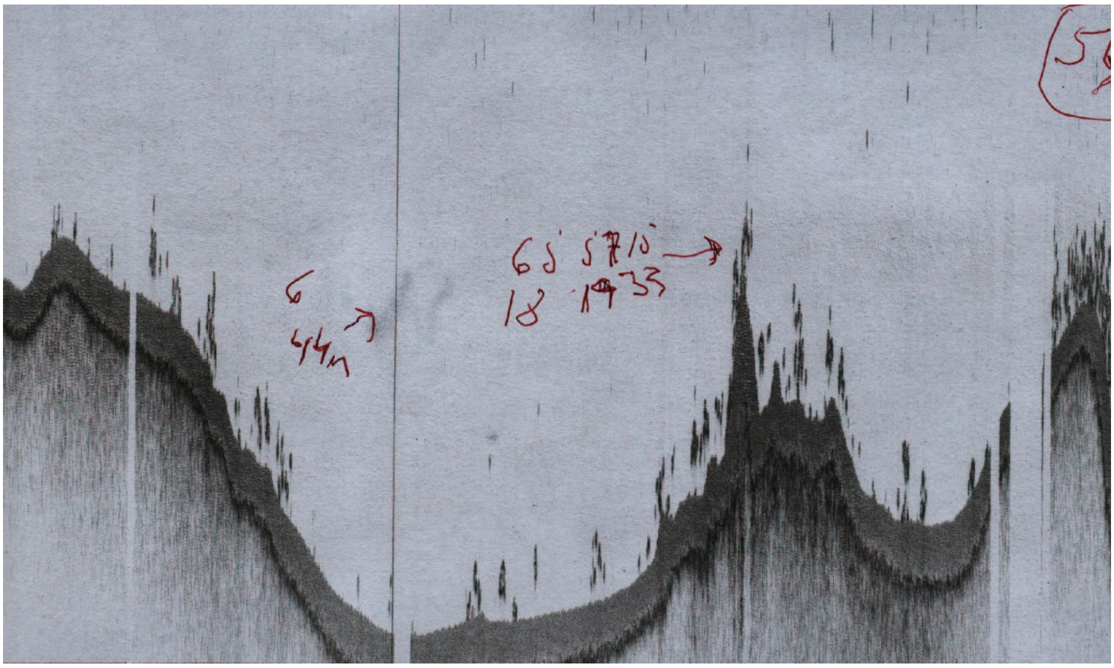

Figure 16: The bottom morphology in Eyjafjördur is shown between 15 and 60 m water depth just offshore Brimsnes. A detailed analysis is beyond the results of this report.

7. Appendix

In this appendix we list the ocean bottom station protocols and charts and coordinates of stations and shots.

Ocean Bottom instrument positions

Name	*North*	*West*	*Depth* *from echo sounder*
OB30	67°00.09	19°00.01	521 m
OB31	67°01.984	18°40.175	264 m
OB32	66°59.976	17°59.896	447 m
OB33	67°00.12	17°29.48	279 m
OB34	66°18.00	18°15.00	120 m
OB35	66°29.96	18°59.98	380 m
OB36	66°44.983	19°00.23	345 m
OB37	66°30.033	18°30.127	193 m
OB38	66°43.07	18°30.08	296 m
OB39	66°45.12	18°10.01	427 m
OB40	66°35.993	17°40.125	395 m
OB41	66°45.09	17°30.02	279 m
OB42	66°29.86	17°00.156	238 m
OB43	66°18.005	17°15.035	155 m

Table A1: Positions of the OBHs (OB30-OB33) and OBSes (OB34-OB43).

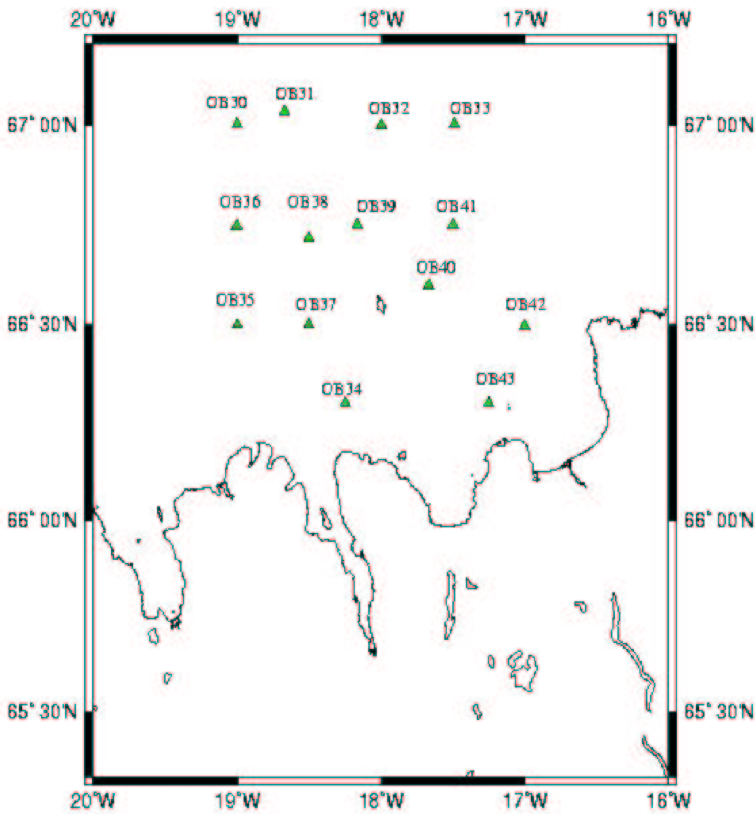

Figure A1: Map of ocean bottom instrument positions. The yellow triangles mark the stations.

Shot times and positions

SP	*GPS Time*	*North*	*West*	*Bottom depth*	*Further remarks*
1	11:01	66°14.96	18°30.16	341 m	100 m offset, 22.8 kg
2	12:57:13	66°30.10	18°40.14	273 m	„
3	16:36:34	66°59.94	19°09.91	453 m	„
4	17:19:25	67°00.13	18°57.64	442 m	„
5	17:47:17	67°00.02	18°49.84	208 m	„
6	18:22:28	67°00.02	18°39.63	305 m	„
7	18:55:00	67°00.00	18°30.67	?	„
8	19:30:21	67°00.03	18°20.40	206 m	180 m offset, 45.6 kg
9	20:08:06	66°59.57	18°10.52	?	100 m offset, 22.8 kg
10	21:08:12	67°00.09	17°50.42	424 m	„
11	21:44:00	67°00.06	17°40.30	334 m	„
12	22:41:10	67°00.00	17°20.31	206 m	180 m offset, 45.6 kg
13	08:36:06	66°52.34	17°24.01	257 m	„
14	09:54:02	66°42.12	17°31.35	?	„
15	11:45:40	66°27.19	17°41.89	358 m	„„ Shot depth 10 m
16	13:18:18	66°14.97	17°50.34	?	„„ „

Table A2: The shot times and positions of the dynamite explosions are printed in the table above. SP is short for Shotpoint. Bottom depth is echo sounder depth.

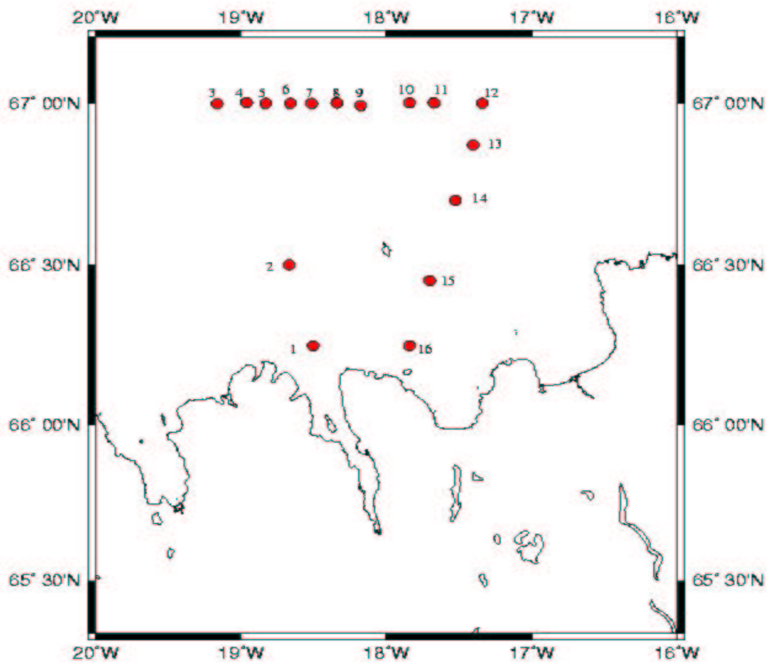

Figure A2: A map of all the shots documented in Table A2.

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