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Deep Geothermal Prospecting, Phase II test survey report

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DEEP GEOTHERMAL PROSPECTING, PHASE II
TEST SURVEY REPORT

1. INTRODUCTION

The aim of the Deep Geothermal Prospecting (DGP) project is to develop and test resistivity methods for deep geothermal prospecting and mapping of deep (1-5 km) geothermal resources, outside known shallow geothermal systems. The project is a multi national cooperation, which was initiated by Orkustofnun in Iceland. The non-Icelandic participants are: The international Institute for Geothermal Research in Pisa, Italy; the University of Frankfurt, Germany; Uppsala University, Sweeden; the University of Edinburgh, Scotland and the University of Cologne, Germany.

The project is divided into three phases, scheduled for three years. The first phase, scheduled from July 1999 to June 2000, comprises numerical model studies to estimate the resolution of different electrical exploration methods in the depth range of 1-5 km. The second phase is scheduled form April to September 2000. It consists of a test survey where different electrical methods will be tested in a multi-method survey in the volcanic zone of Iceland, on a profile along the road in Þrengsli, west of the Hengill and Skálafell area. The third phase, scheduled for September 2000 to December 2001, consist of data processing and interpretation of the survey data and over all evaluation of the tested methods.

This report describes the work performed and the data acquisition in the multi-method field test in the second part of the project. The test survey was designed to test different electro-magnetic methods and in the same time map the low resistivity cap connecting two known geothermal system; both the depth to the top of the cap and its thickness. The test survey was, for practical reasons, divided into two field missions; a shallow standard central-loop TEM resistivity survey and a multi-method deep survey.

2. THE SURVEY AREA

The site for the test survey was chosen along the road in Þrengsli in southwest Iceland. The survey area is on the axis of active tectonics and volcanism between the Hengill-Olkelduhals volcanic complex and the Brennisteinsfjoll geothermal system towards the south-west. The Hengill-Olkelduhals geothermal area is a surface manifestation of a large geothermal system. The uppermost part of the system has been mapped in some details by Schlumberger and central-loop TEM-soundings, to the depth of about 1 km. The Brennisteinsfjoll geothermal system, a shallow geothermal system with only minor surface manifestations, has also been mapped to the depth of about 1 km by central-loop TEM-soundings.

The volcanic zone between these two geothermal systems hosts many volcanos, with the most recent eruption about one thousand years ago. No geothermal activity is visible at the surface and parts of the area have been surveyed by scattered Schlumberger and central-loop TEM-soundings, showing no sign of geothermal activity in the uppermost kilometer. The volcanic history of the area on the other hand strongly suggest that heat sources and geothermal potential is to be found at depth.

This test site is chosen because:

- The survey area is known to have cold rocks with high resistivity to a depth of about 1 km and the volcanic history indicates heat sources at depth. A relatively clear and unambiguous resistivity anomaly with a low resistivity layer, in the temperature range of about 100 to 230°C, is therefore expected at depth.
- The resistivity structure (the geometry of the low resistivity cap) of the geothermal systems neighboring the survey area has been mapped in some detail. This provides boundary conditions for the interpretation of the survey data.
- The survey area is not inhabited but is relatively close to the City of Reykjavik with necessary service facilities.

3. MEETINGS

A meeting was held in the DGP project on June 17-19, in Frankfurt, Germany. All partners in the group were represented, except for the University of Edinburgh. Graham Dawes, from the University of Edinburgh, was, however, consulted by telephone and e-mail. Apart from discussing the result of the first phase of the project, the meeting was devoted to the discussion and detailed planning of the field test in the second phase.

It was decided to focus the the deep multi-method survey on an about 15km long profile along the road through Þrengsli, from Svínahraun in the north, and towards the road crossing, north of Þorlákshöfn, in the south. This profile runs nearly perpendicular to the suspected connection between the shallow geothermal systems to the NE and SW. The distance between stations along the profile should preferably be about 500m. Controlled source signals (CSMT,TEM and DC) should be recorded at each station during that day and natural source signals (MT) during night.

One of the findings of the model calculations in the first phase was that grounded dipoles couple more strongly to the suspected target than loop sources. It was further more found that, for the TEM, dipoles parallel to the connection couple more strongly than dipoles perpendicular to it. For the TEM and DC, the main emphasis should therefore be put on EW grounded dipole sources, but two perpendicular source dipoles are needed for the CSMT. It was considered important to use more than one source location. It was therefore decided to aim at three different source locations; one to the north of the profile, one close to the centre, and one to the south. Orkustofnun was to arrange that the source dipoles should be ready before the field mission started.

Instrumentation and technical details were discussed thoroughly. It was decided that the University of Edinburgh should provide two complete SPAM sets (including magnetic sensors), the university of Frankfurt would likewise two SPAM sets, Uppsala University would provide Metronix recording system and Metronix transmitter and that the University of Cologne would provide a high power Zonge transmitter. It was therefore planned to have five receiver systems for simultaneous data recording and two transmitters. It was planed to have the Metronix transmitter permanently stationed at the central source site and that the Zonge transmitter would be operated at the source sites to the north and to the south of the profile.

It was decided that for the TEM and DC recording, the transmitters should transmit 0.25Hz (4s period) full duty square wave signal and that 500 periods (1000 transients) should be recorded at each station for processing and stacking. For the CSMT, the transmitters should transmit full duty square wave at eight frequencies (1,2,4,8,16,32,64 and 128Hz) and that about 1000 periods of each frequency should be recorded for stacking.

Uppsala University would provided high precision GPS clock for controlling the transmitter frequencies for the CSMT and with programmable time scheduler for different frequencies. The University of Edinburgh would provide GPS clock for controlling the transmitters at 0.25Hz for TEM and DC recoding, allowing synchronization with GPS time stamped data recording. (It turned out later, however, that the Metronix recording system does not time stamp the recorded time series with GPS time. The GPS clock in the system is only used to control the sampling frequency. This implied that the Metronix system could not be used for TEM and DC recording.)

In order to be able to use remote reference data processing techniques, the recording systems should not all be operated at neighboring sites on the profile, but simultaneous recoding should be performed with systems separated by about 5km distance. The data recording should start with recording systems at the north end and at the centre of the profile and then progress towards south (alternatively with three systems in the north and two in the south; and two in the north and three in the south).

It was decided at the meeting in Frankfurt that the multi-method deep survey should take place from September 4 to September 16. Prior to the arrival of the non-Icelandic participants, Orkustofnun should have made all necessary arrangements, such as clearing equipment through customs, preparing the source dipoles and selecting sites for data recording.

4. CENTRAL-LOOP TEM-SURVEY

The shallow central-loop TEM resistivity survey was carried out to map the near surface resistivity structure (depths < 1 km). This is needed to resolve static shift problems in the MT and DC data in the deep survey. The shallow survey was scheduled for the early spring of 2000 and was carried out by Orkustofnun. In late winter, the survey area is covered with snow and easily accessible by snow-mobiles, which greatly speeds up the field operation.

The survey was carried out using TEM67 transmitter and PROTEM digital receiver form Geonics Ltd. The source was a half duty square wave current transmitted into a 300m x 300m square loop. The transient response was measured in 30 time gates during current off periods. The time gates are logarithmically distributed from 87 μs and up to 87 ms after the current turn-off.

The survey plan was to make soundings on three profiles, one WSW-ENE oriented, connecting the existing central-loop surveys in the Brennisteinsfjoll area and in the Hengill-Hellisheidi area and two N-S oriented profiles, along the road in Threngsli and about 3km west of the road.

4.1 Field work

The field work started in February 2000. The central-loop TEM sounding survey for the DGP was performed in conjunction with commercial geothermal exploration surveys on Hellisheidi, south of mount Hengill and in Graendalur, north of Hveragerdi. This offered more flexibility in choosing survey area according to whether conditions. The soundings were performed by two specialists from Orkustofnun, using two snow mobiles.

In the winter months, the main emphasis was put on soundings in areas which are not accessible by vehicles on a snow less ground, that is, the WSW-ENE profile and the N-S profile west of the road in Threngsli. The soundings on the N-S profile along the road were performed in July and August, by a field crew of summer students.

A total of 30 soundings were performed specifically for the DGP projectis, but nearby sounings from earlyer geothermal exploration projects are also available. Figure-1 shows the location of these soundings, as well as near by soundings in the Brennisteinsfjoll area in the SW and Hellisheidi-Hengill area in NE. Some of the central-loop TEM data (data recorded from February to April) have already been processed and run through preliminary interpretation. The data from last summer have not jet been processed.

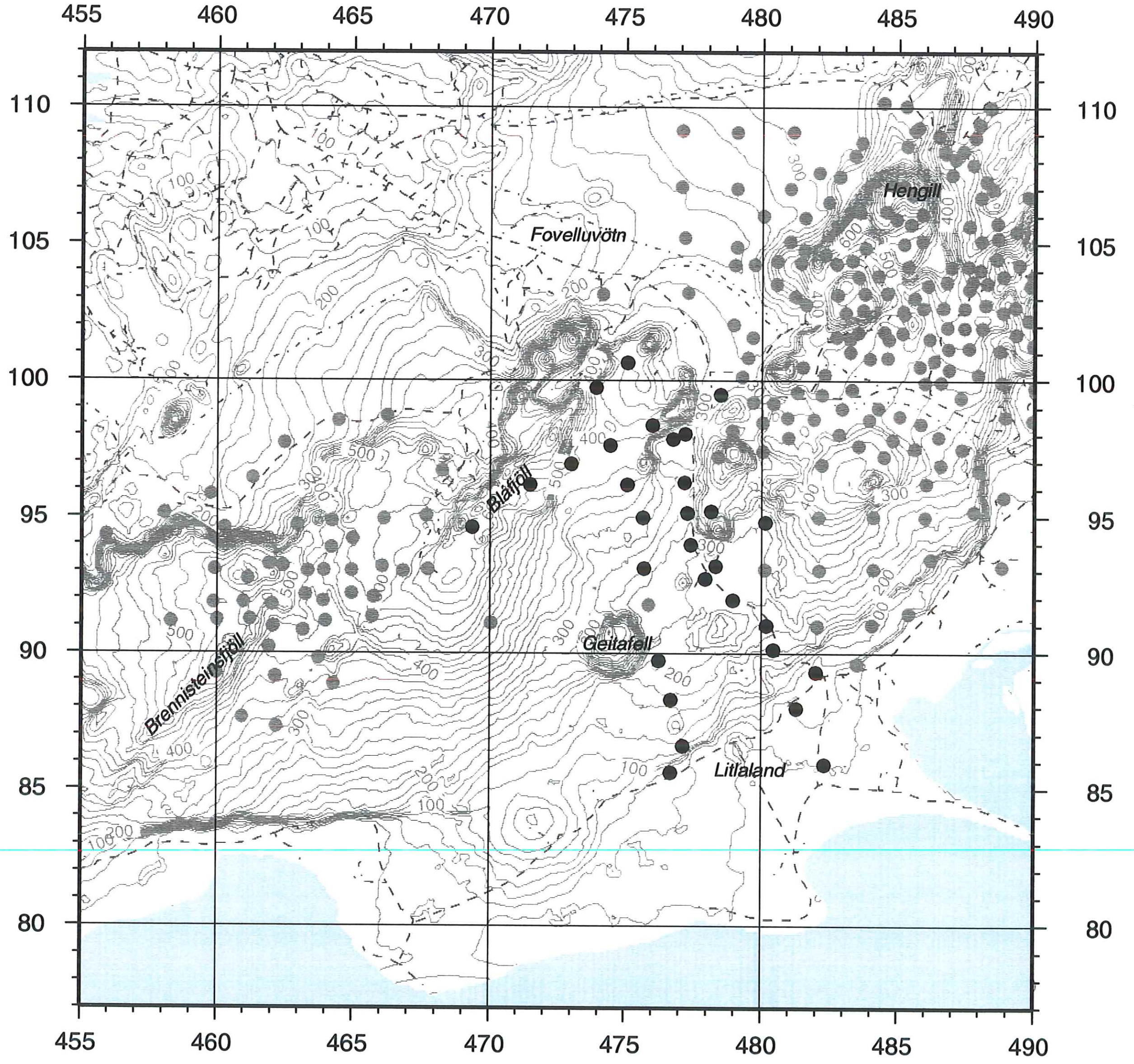

Figure-1. Location of TEM-soundings made for the DGP project (black dots) and TEM-soundings at nearby geothermal systems (gray dots). Roads are shown by dashed lines and axis anotation are UTM units in km.

5. THE MULTI METHOD SURVEY

The deep multi-method survey was designed to test all the electro-magnetic methods considered in the project (MT, CSMT, TEM and DC) in a single survey. The natural source MT signal was to be recorded during nights. The controlled source methods (CSMT, TEM and DC) were to be applied during the day, using a high power transmitter to transmit current into perpendicular grounded dipoles at different locations. The transmitter, and the receiver units would be synchronized by high precision crystal or GPS clocks.

5.1 Preparation

Prior to the survey, 22 measuring sites were chosen along the road through Threngsli, with about 500m between sites. They are numbered, from north to south, as site DGP-00, in Svinahraun about 1km north of Lambafell, and up to site DGP-21, about 0.5km north of the road crossing north of Thorlakshofn. Some care had to be exercised in choosing sites in order to ensure sufficiently good ground contact for the electrodes of the electric field receiving dipoles as well as the possibility to dig down the magnetic sensor coils. This could be achieved in most cases, except at site DGP-02, east of Lambafell, which had to be abandoned.

5.2 Preparation of sources

The original plan was to record controlled source signals for three different source locations, one to the north of the profile, one close to the centre, and one to the south of the profile. It was decided, at the meeting on June 17-19 in Frankfurt, that source dipoles, as well as electric and magnetic field sensor should be oriented parallel and perpendicular to magnetic north, which in the survey area is about 20° west of north. It was further discussed that the perpendicular dipoles at each transmitter site, should be about 1km long and preferably make a regular cross.

The preparation of the source dipoles started in early August. Fóvelluvötn at Sandskeið was chosen for the source to the north of the profile and a place near the farm Litlaland to the south of the profile. Þufnavellir, east of mount Geitafell, were chosen as source location near the centre of the profile. It turned out to be quite difficult to achieve good ground contact and favorable places, preferably with thick and wet soil, had to be chosen for the grounding electrodes. In order to select as good places as possible for the grounding electrodes, the source dipoles to the ends of the survey profile were laid such that they make an L, instead of a cross. The source dipoles at Þúfnavellir, near the centre of the profile, were, however, laid in a cross.

As a first attempt, grounding electrodes were made using sixteen 1m long steel rods with the diameter of 16mm. The steel rods were completely submerged in holes filled with NaCL mixed bentonite, arranged in a regular square pattern with 1m between rods. The grounded electrodes of the dipoles were connected by a 6 and in some cases 4 quadrat coper cable. The steel rods did not give satisfactory results because the resistance of the dipoles was typically some hundreds of Ohms. The maximum output voltage of the more powerful of the two transmitters, to be used in the survey, is 1000V and the goal was to be able to transmit 10-20A. The resistance of the dipoles had therefore to be reduced to lower than 100Ω.

To improve the ground contact, a 30m long 16 quadrat grounding copper wire was dug down, to the depth of about 0.5m, in a spiral with about 1m between windings. To increase the effective contact surface, about 0.1m^2 sheets of normal household aluminum foil were attached, side by side, to the copper wire, and every thing submerged in NaCl mixed bentonite. This reduced the resistance of the grounded dipoles considerably especially at Fovelluvötnn in the north. The resistance of the dipoles at Litlaland was further decreased by using a 300m deep casing of a nearby well as the corner electrode of the L shaped dipole configuration. In order to do so, the N-S dipole was no longer along magnetic north.

Table-1 lists information on the transmitter dipoles; UTM (zone 27W, Hjörsey dataum) coordinates of the grounded electrodes, dipole lengths and resistance.

Dipole	Electr.1 (UTM coord)	Electr.2 (UTM coord)	L(m)	R(Ω)
Fóvelluvötn N-S	(7472335,7104405)	(7472161,7105279)	891	110
Fóvelluvötn E-W	(7472335,7104405)	(7473254,7104591)	937	88
Þúfnavellir N-S	(7476143,7091207)	(7475910,7092005)	831	418
Þúfnavellir E-W	(7475370,7091835)	(7476366,7092114)	1034	364
Litlaland N-S	(7479814,7086844)	(7479826,7087406)	980	64
Litlaland E-W	(7479814,7086844)	(7479030,7086547)	980	120

Table-1. Dipoles set up for the DGP, Coordinates of electrodes, dipole length (L), direction (Dir in ° rel. to magnetic north) and resistance (R).

5.3 Participants

Participant in the multi-method field test came from all the Universities and institutions of the DGP consortium. Table-2 lists the participants in the data recording.

Participant	Institution
Graham Dawes	Univ. of Edinburgh
Val Valiant	Univ. of Edinburgh
Lars Dynesius	Uppsala University
Behrooz Bsokour	Uppsala University
Reiner Bergers	Univ. of Cologne
Adele Manzela	Int. Inst. of Geoth. Res., Italy
Reiner Rosberg	Univ. of Frankfurt
Hjálmar Eysteinsson	Orkustofnun
Knútur Árnason	Orkustofnun
Ingvar Þ. Magnússon	Orkustofnun

Table-2. Participnats in the field work.

In addition to the above listed personnel, specialist and the summer student field crew from Orkustofnun worked on the preparation of dipole sources, site preparation and other tasks relating to the field mission.

5.4 Equipment

The equipment used in the field work was supplied by the participants. Table-3 list the main items provided by the various participants:

Institution	Items
Univ. of Edinburgh	2 SPAM recording systems with sensors. GPS clock for controlling transmitters at 0.25Hz (TEM and DC). Laptop computers.
Univ. of Frankfurt	2 SPAM recording systems with sensors. Laptop computer.
Uppsala University	Metronix recording system with sensors. Metronix transmitter with generator. GPS clock for controlling transmitters at 2-128Hz (CSMT). Field vehicle.
Univ. of Cologne	Zonge transmitter (30kW,1000V) and generator.
Orkustofnun	5 field vehicles. Portable telephones and radios. laptop computers. Tents Facilities for storage and repair of equipments.

Table-3. Equipment provided by individual partners.

All the equipments were shipped to Iceland at the end of August. Staff from Orkustofnun cleared customs and all the equipments were at Orkustofnun's offices before the foreign participants arrived. All shipped equipments were ensured by a total-risk insurance during shipping and use in Iceland. Shipping costs and insurance fees were payed form the DGP budget.

5.5 Field procedure and data acquisition

When most of the foreign participants had arrive, a short visit was payed to the survey site on September 3, to take a look at the local conditions. On the morning of September 4 a meeting was held at Orkustofnun for discussions and detailed planing of the field work.

At that meeting, it became clear that the Metronix recording system does not time stamp the recorded time series and hence could not be used to record TEM and DC data, where synchronization in time with the transmitter is essential. Due to the high resistance of the dipoles at the central source station at Þúfnavellir, it was further decided that Metronix transmitter, which has the maximum output voltage of 500V, should not be used, but only the Zonge transmitter which can supply output voltage up to 1000V.

As stated earlier, controlled source signal were to to be recorded during daytime and MT during the night. A time schedule was set up for the transmission at different frequencies and source orientations. Due to the long recording time needed to record 1000 transients for the TEM (about 60 min.), it was decided, in order to speed the data collection, that TEM should only be recorded for E-W oriented dipoles. In order to have at least 1000 periods for each frequency for the CSMT, the programmable GPS clock, controlling the CSMT transmission, was programmed to let the transmitter step through frequencies such that 1Hz is on for 21 minutes, 2Hz for 11 minutes and the higher frequencies (4,8,16,32,64 and 128) for 6 minutes. The total frequency sweep therefore took 67 minutes. In order to get 1000 TEM transients, the source was to be operated at 0.25Hz for about 60 minutes. The following time schedule was therefore used for the source:

CSMT frequency sequence in N-S dipole	67 min.
Time gap	5 min.
CSMT frequency sequence in E-W dipole	67 min.
Time gap	10 min.
TEM and DC transmission in E-W dipole	60 min.
Total time	209 min.

Table-4. Time schedule for source transmission.

After the meeting, the equipments were prepared for field operation. The field operation started on September 6. The first task was to set up a SPAM recording system close to one of the sources (N-S dipole at Fóvelluvötn) and record signals in order to determine the system response corresponding to the square wave current form. The square wave system response is needed for processing the TEM data. Since TEM data would not be recorded by the Metronix system, no system response was needed for that.

When the recording systems had been set up, in the afternoon on Sept. 6 and the morning of Sept. 7, problems started to show up in the SPAM systems, especially in those from the University of Frankfurt. A considerable amount of time was spent on fixing these problems and the result was that only three of the SPAM systems were used for the data recording and one was abandoned. Due to these delays, it was decided that the central source at Þúfnavellir would not be used, in order to safe time.

A routine data collection started in the evening of Sept. 7 and continued to the morning of Sept. 14. MT was recorded at night. During the day, the Zonge transmitter transmitted signal for CSMT and TEM-DC, both at Fóvelluvötn, in the north, and Litlaland in the south. The transmission was performed after a predefined time schedule described above, and each transmission session took about 4 hours. The field work coordinator was in telephone and radio contact with the operators at all sites and the operator of the transmitter. When the recording systems at all four sites were ready for recording, the coordinator decide a start time of the transmission sequence and informed the operators at the receiver sites.

When controlled source data (CSMT and TEM-DC) had been recorded, for both source locations, as well as MT, the recording systems were moved to the next sites. In the data recording, two receivers were on the northern half of the profile and two on the southern half, progressively moved from north to south. The distance between the receivers on the northern and southern part was always grater than 5km. As mentioned earlier, such a simultaneous recording at separated stations can be used for noise rejection (remote reference technique).

Data were recorded at 21 stations, labeled from DGP-00 through DGP-21, except for DGP-02, which had to be abandoned, because a proper ground contact for the electrodes of the E-filed receiver dipoles could not be obtained at that site. The receiver site locations are given in UTM (zone 27W, Hjorsey datum) coordinates in Table-5 and are shown, as well as the source dipoles used, on Figure-2.

Station	E-coordinate (UTM)	N-coordinate (UTM)	Elevation (m)
DGP-00	7477516.	7101488.	290
DGP-01	7477585.	7099940.	295
DGP-03	7477945.	7099044.	275
DGP-04	7477218.	7098208.	265
DGP-05	7477672.	7097703.	270
DGP-06	7477693.	7096982.	270
DGP-07	7477379.	7096495.	270
DGP-08	7477487.	7095688.	260
DGP-09	7477299.	7095129.	250
DGP-10	7477370.	7094588.	230
DGP-11	7477706.	7093917.	220
DGP-12	7477814.	7093466.	210
DGP-13	7477757.	7092929.	210
DGP-14	7478279.	7092389.	210
DGP-15	7478820.	7091980.	210
DGP-16	7479496.	7091870.	205
DGP-17	7480036.	7091475.	195
DGP-18	7480374.	7091020.	190
DGP-19	7480682.	7090528.	170
DGP-20	7480676.	7090028.	140
DGP-21	7481769.	7089718.	80

Table-5. UTM coordinates and elevation of stations.

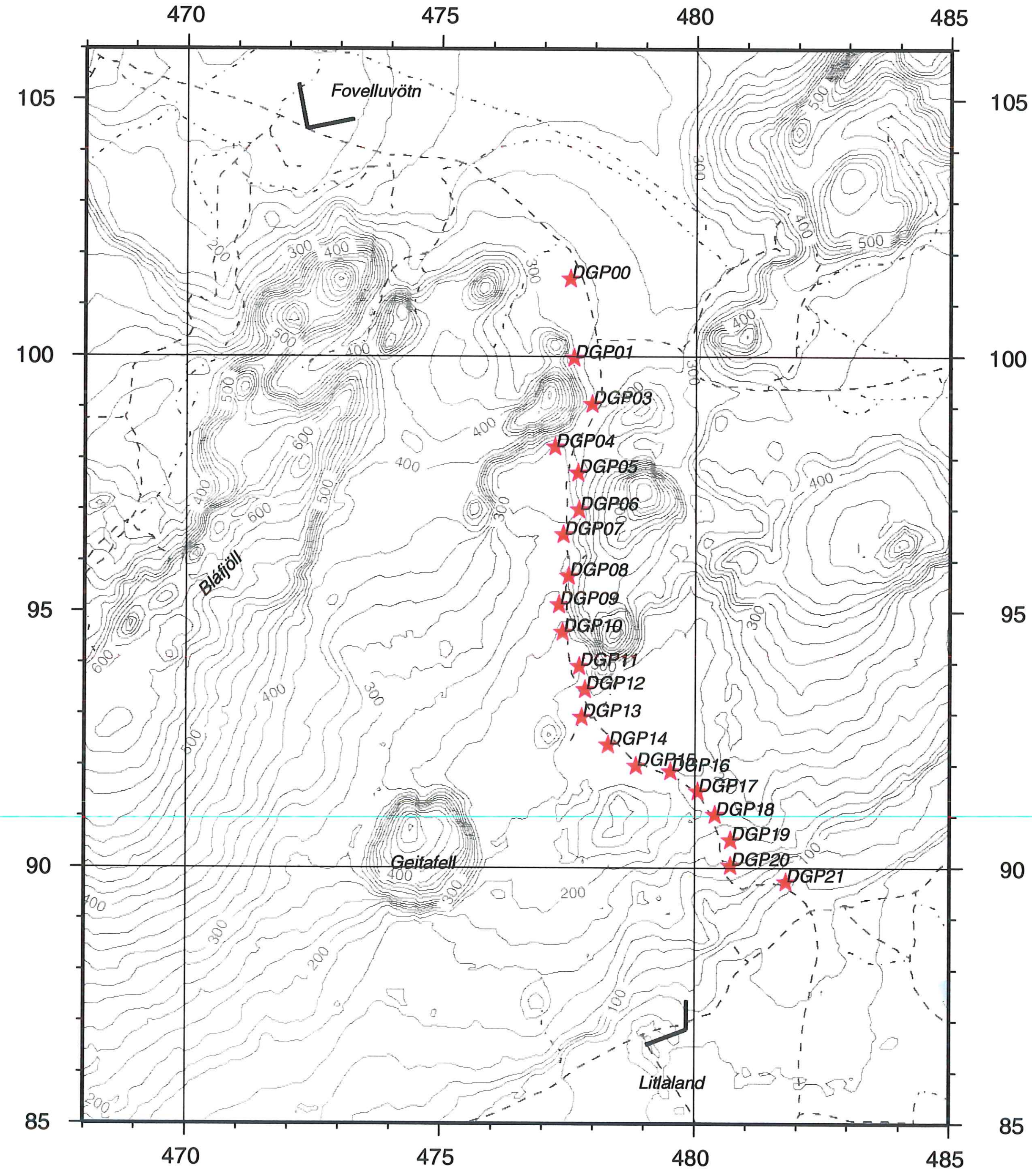

Figure-2. Location of the DGP recording sites and transmitter dipoels.

At each receiver site, two perpendicular grounded dipoles were set up and carefully oriented along magnetic N-S and E-W for measuring the electric field components. Non polarizing grounding electrodes were used and placed in small holes. Bentonite was used to improve ground contact. Three magnetic induction coils were dug down, two along magnetic N-S and E-W and one vertical for measuring the horizontal and vertical magnetic field variations. For the MT and CSMT, all five components (three magnetic- and two electric-field components) were measured, but for the TEM (0.25Hz controlled source) only four components were recorded, i.e. three components of the magnetic field and the E-W component of the electric field, parallel to the source dipole.

The progress of the field work is summarized in Table-6. The table lists the dates, source dipole in use, the type of transmitted/recorded signal, the on time of the transmitter, the transmitted current. In labeling the dipoles, FV stands for Fóvelluvötn to the north and LL stands for Litlaland to the south of the profile. CSMT stands for Controlled source MT recording with the transmitter sweeping through 1 to 128Hz and TEM for Transient- and DC-recording with the transmitter running continuously at 0.25Hz. MT stands for natural source signal recording with the source off. The listed current values are amplitudes of the transmitted square wave (peak to peak values are two times higher). The table also lists which sites are occupied by which recording system at different times. SPAM1 and SPAM2 are systems from the University of Edinburgh and SPAM3 is from the University of Frankfurt.

Table-7 summarizes the coverage of the profile with different methods and different source locations. The table shows that MT was recorded at all stations, CSMT with source at Litlaland is missing at DGP-00, CSMT with source at Fóvelluvötn is missing at DGP-14, and TEM is missing at six stations for each source location (this is mainly because the Metronix system is not able to record TEM).

Date	Dipole	Type	Time	Current(A)	SPAM1	SPAM2	SPAM3	Metronix
7.-8.9.		MT			03	04		01
7.9.	LL-NS	CSMT	18:40-19:50	15.01	03	04	13	01
8.9.	LL-EW	CSMT	11:50-12:57	6.50	03	04	13	01
8.9.	LL-EW	TEM	14:30-15:35	6.51	03	04	13	
8.9.	FV-NS	CSMT	17:00-18:10	8.50	03	04	13	01
8.9.	FV-EW	CSMT	18:30-19:37	11.01	03	04	13	01
8.-9.9.		MT					13	
9.9.	FV-EW	TEM	12:00-13:10	11.02	03	04	13	
9.9.	FV-NS	CSMT	17:00-18:08	8.50	06	05	15	16
9.9.	FV-EW	CSMT	18:12-19:16	11.01	06	05	15	16
9.9.	FV-EW	TEM	19:40-20:42	11.00	06	05	15	
9.-10.9.		MT			06	05	15	16
10.9.	LL-NS	CSMT	11:45-12:52	9.51	06	05	15	16
10.9.	LL-EW	CSMT	12:57-14:04	8.01	06	05	15	16
10.9.	LL-EW	TEM	14:14-15:45	8.01	06	05	15	
10.9.	LL-NS	CSMT	16:15-17:22	12.01			14	
10.9.	LL-EW	CSMT	17:31-18:38	7.52			14	
10.9.	LL-EW	TEM	18:55-19:46	8.02			14	
10.-11.9.		MT			18	07	14	08
11.9.	LL-NS	CSMT	11:10-12:17	18.02	18	07	17	08
11.9.	LL-EW	CSMT	12:22-13:29	8.01	18	07	17	08
11.9.	LL-EW	TEM	13:39-14:44	8.01	18	07	17	
11.9.	FV-NS	CSMT	15:50-16:57	8.50	18	07	17	08
11.9.	FV-EW	CSMT	17:02-18:09	11.00	18	07	17	08
11.9.	FV-EW	TEM	18:24-19:40	11.00	18	07	17	
11.-12.9.		MT				07	17	08
12.-13.9.		MT			10		20	19
13.9.	LL-NS	CSMT	11:05-12:12	18.00	10	09	20	19
13.9.	LL-EW	CSMT	12:17-13:24	8.00	10	09	20	19
13.9.	LL-EW	TEM	13:39-14:39	8.00	10	09	20	
13.9.	FV-NS	CSMT	15:45-16:52	8.50	10	09	20	19
13.9.	FV-EW	CSMT	16:57-18:04	11.00	10	09	20	19
13.9.	FV-EW	TEM	18:19-19:19	12.00	10	09	20	
13.-14.9.		MT			11	09		21
14.9.	LL-NS	CSMT	11:40-12:47	19.52	11		12	21
14.9.	LL-EW	CSMT	12:52-13:59	8.52	11		12	21
14.9.	LL-EW	TEM	14:18-15:20	8.52	11		12	
14.9.	FV-NS	CSMT	16:20-17:27	9.50	11	00	12	21
14.9.	FV-EW	CSMT	17:32-18:39	12.00	11	00	12	21
14.9.	FV-EW	TEM	19:26-20:30	12.00	11	00	12	
14.-15.9.		MT			11	00	12	21

Table-6. Overview of the progress of field work.

Station	MT	CSMT-LL	CSMT-FV	TEM-LL	TEM-FV
DGP-00	X		X		X
DGP-01	X	X	X		
DGP-03	X	X	X	X	X
DGP-04	X	X	X	X	X
DGP-05	X	X	X	X	X
DGP-06	X	X	X	X	X
DGP-07	X	X	X	X	X
DGP-08	X	X	X		
DGP-09	X	X	X	X	X
DGP-10	X	X	X	X	X
DGP-11	X	X	X	X	X
DGP-12	X	X	X	X	X
DGP-13	X	X	X	X	X
DGP-14	X	X		X	
DGP-15	X	X	X	X	X
DGP-16	X	X	X		
DGP-17	X	X	X	X	X
DGP-18	X	X	X	X	X
DGP-19	X	X	X		
DGP-20	X	X	X	X	X
DGP-21	X	X	X		

Table-7. Coverage of profile with different methods.

5.6 Data quality control

Data quality check was performed in the field during recording of MT and CSMT data. The MT and CSMT recording was done in time windows and after each window, the time series for all the recorded components were Fourier-transformed. The power spectra and impedance tensor elements from the time windows were stacked and could be observed and stored to disk file. The impedance tensor elements were observed to check the quality of the MT data. The power spectra were observed to check the data quality of the recorded CSMT data for different transmitted frequencies.

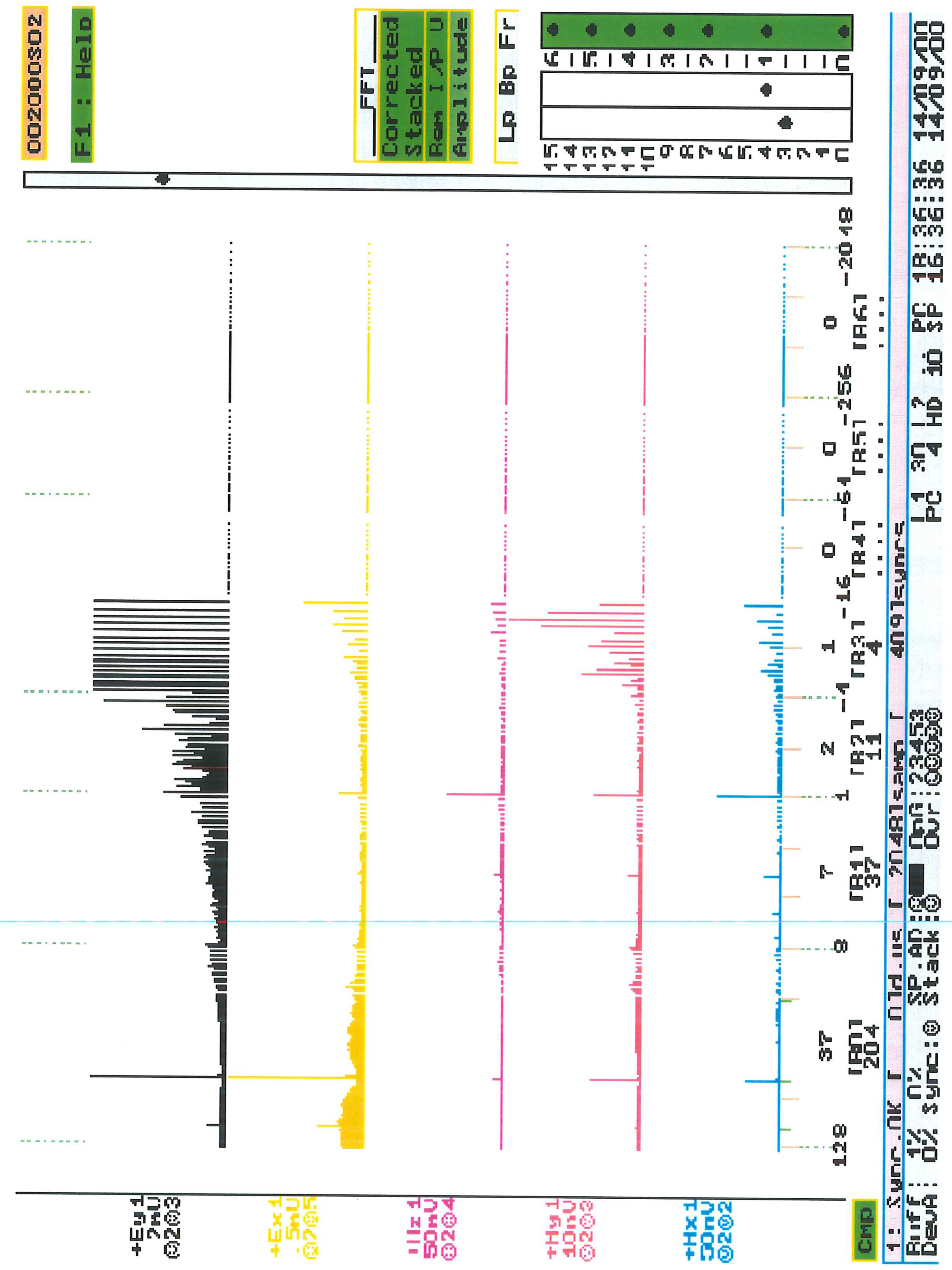

Figure-3. Power spectra of CSMT recording at site DGP-00. 1Hz transmittd at Fóvelluvötn.

Figure-3 shows an example of such a power spectra of data recorded at site DGP-00 while 1Hz signal is transmitted into the E-W dipole at Fóvelluvötn. The figure shows (from top to bottom) the power spectra for the E-W (Ey) and N-S (Ex) components of the electric field and the vertical (Hz), E-W (Hy) and N-S (Hx) components of the magnetic field. The frequency decreases (and the period increases), on a logarithmic scale, from left to right. The frequency/period values are labeled (according to the convention for MT) as frequency, for frequency values higher than 1Hz and as period for values lower then 1Hz (with a minus sign in front). The highest recorded frequency is 128Hz (to the far left) and the lowest recorded frequency is 1/16Hz (period of 16s; the right end of the x-axis is at the period of 2048s).

All the spectra show a clear peak at 50Hz (to the left on the figure) due to noise from nearby power lines. The 50Hz signal is so strong that it gets through, even though 50Hz analog notch filters were used. The spectra also show a clear peak at 1Hz, showing that the signal from the source is well above the noise, except for the the N-S component of the electric field (Ey). The figure actually shows the spectra after a short recording time. Only to recordings have been stacked in the period range form 1 to 4s and only one in the range from 4 to 16s (the number of stacked values in different frequency ranges is listed in the top row below the x-axis). Longer stacking will give better signal to noise ration at 1Hz.

Data quality check, similar to the one described above, was not possible for the TEM recording. The reason for this is that in this case, the the recording systems were run in a "continuous" recording mode at 4kHz sampling frequency, which did not allow any real time data processing. A true continuous recording was actually not possible at such a high sampling frequency and data were sampled in internal memory in 32s time windows followed by 16s for storing data on internal disk.

Phase distortion by analog filters can pose a problem when recording TEM data. Therefore 50Hz notch filters were not applied and the time series contain the full 50Hz noise which will be removed by digital filtering in the data processing. Due to the strong 50Hz signal, the transients were not clearly observed in the time series. A clear spectral peak of the 1Hz signal in the CSMT recording was, however, assumed to guarantee that stacking of 1000 transients of the 0.25Hz signal in the TEM recording would result in a good signal to noise ratio.

5.7 Data storage and distribution

While recording, the data were stored on internal hard disks of the recording systems. As these were filled, data were dumped, in the field, either to internal hard disks in laptop PCs or external portable hard disks. The data were then transfered to the main frames at Orkustofnun and backed up. The data have been organized into a directory structure and will be written to CD-roms, one copy for each institution that participating in the project. The total amount of data collected in the field test is a little more than 8Gb.

6. PLANS FOR DATA PROCESSING AND INTERPRETATION

The processing and interpretation of the collected data is the task of the third phase of the project. It will be distributed among the partners in the project. MT data will be processed and interpreted by th University of Frankfurt, the Internat. Inst. of Geoth. Res. in Pisa and Orkustofnun. CSMT data will be processed and interpreted at Uppsala University and Orkustofnun, and TEM data will be processed and interpreted by the University of Cologne and at Orkustofnun. The final step will be a joint interpretation and evaluation of the performance of the different methodes, which is the main purpose of the project.

The field survey described in this report in somewhat unique, in the sense that it tests many different electro-magnetic exploration methods in a single survey. This has not been done before, as far as the participants of the DGP project know. The survey data will therefore probably be of interest to other people working with electro-magnetic methods and after the project is completed, the data will be made generally available for those who are interested.