LV-2016-107

Landsvirkjun

Þeistareykir – Well ÞG-11

Phase 3: Drilling for the Production Section for a 7" Liner from 802 m to 2224 m Depth

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ÍSOR
ÍSLENSKAR ORKURANNSÓKNIR

ÍSOR-2016/065

Project no.: 16-0110

October 2016

Key page

LV report no.: LV-2016-107

Date: October 2016

Pages: 145

Copies: 8

Distribution:
☒ On www.lv.is
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☐ Limited until

Title: Þeistareykir – Well ÞG-11. Phase 3: Drilling for the Production Section for a 7" Liner from 802 m to 2224 m Depth

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Prepared for: Landsvirkjun

Co operators:

Abstract: Well ÞG-11 is a directionally drilled production well for the Þeistareykir power plant. It is sited on the same drill pad as well ÞG-9. The well is located approximately 600 m north of Mt. Bæjarfjall and the aim of the drilling was to penetrate fractures north of, and under, Mt. Bæjarfjall. This report addresses the drilling history and data acquisition of the 3rd phase. This includes subsurface mapping of the lithology and alteration in the well based on drill-cuttings, estimating subsurface temperatures from key alteration minerals and relating drill-data and geophysical logs of lithology to constrain formation boundaries and identify potential aquifers. ÞG-11 was pre-drilled with a 21" drill bit for an 18⅝" surface casing to 94.3 m, with a 17½" drill bit for a 13⅜" anchor casing down to 304 m and with a 12" bit for a 9⅝" production casing to 802 m using the rig Sleipnir. Then the rig Óðinn drilled with an 8½" bit for the 7" liner. The stratigraphy of phases 0–3 in well ÞG-11 is composed of basaltic lava flows and hyaloclastite formations, including basaltic breccias, tuffs and pillow basalts. Intrusives are seen below 400 meters but are rather rare and of limited thickness in the well. The gamma ray log indicates ~40 m of felsic rock just below 1000 m, which is considered on grounds of the resistivity log to be intrusive. This would be the first detection of felsic intrusion in Þeistareykir and will be inspected further. The grade of alteration is generally high. From 802 to 2224 m the main alteration minerals are clays, quartz, epidote, prehnite, wollastonite and rare actinolite. Loss circulation started being observed at 1318 m and varied through the well. Sustained full circulation losses started at 2130 m in a fine grains basaltic flow formation down to the final depth of the well at 2224 m.

Key words:

Þeistareykir, well ÞG-11, geothermal area, high temperature, wellbore, steam mining, geological strata, feed zones, wireline logging, Sleipnir.

UWI (Unique Well Id): B60411

ISBN no.:

Approved by Landsvirkjun's project manager

Project manager's signature	Reviewed by
Magnús Ólafsson	Benedikt Steingrímsson

Ágrip

Hola ÞG-11 er stefnuboruð vinnsluhola fyrir Þeistareykjavirkjun. Holan er á sama borplani og hola ÞG-9. Borplanið er um 600 m norður af Bæjarfjalli og markmið borunarinnar er að bora í gegnum sprungur sem tengjast sprungukerfinu undir Bæjarfjalli. Þessi skýrsla lýsir borsögu, borgögnum og gagnavinnslu 3. áfanga holu ÞG-11. Með svarfskoðun á borstað er gerð grein fyrir jarðlögum og ummyndun bergs með tilliti til ummyndunarsteinda sem gefa upplýsingar um berghita. Ennfremur er gefið yfirlit um borgögn úr sjálfvirku skráningarkerfi Sleipnis og Óðins sem og borholumælingar sem gerðar voru á meðan borverkinu stóð. Öll þessi gögn eru notuð til frekari túlkunar, m.a. til þess að greina jarðlagamót og hugsanlegar æðar í holunni. Borinn Sleipnir forboraði holu ÞG-11 með 21" borkrónu fyrir 18⅝" yfirborðsfóðringu niður í 94,3 m, með 17½" krónu fyrir 13⅝" öryggisfóðringu niður á 304 m dýpi og með 12" krónu fyrir 9⅝" vinnslufóðringu niður í 802 m. Óðinn tók þá við og boraði með 8½" krónu fyrir 7" leiðara. Jarðfræðin í forborun, 1., 2. og 3. áfanga sýnir að jarðlögin í holu ÞG-11 eru að mestu samansett úr basalthraunlögum og móbergsmyndunum (túff, breksíur og bólstraberg). Innskot má sjá neðan 400 m en þau eru sjaldgæf of þunn. Ummyndunarstig er alla jafna hátt. Á 802–2224 m dýpi eru helstu ummyndunarsteindir leir, kvars, epidót, prehnít og wollastónít, og á stöku stað má sjá aktínólít. Skoltap kom fram í 1318 m og var mismikið alla holuna eftir það. Algert skoltap byrjaði í 2130 m í fínkorna basalthraunlagi og náði skoltapið niður á lokadýpi holunnar sem er 2224 m.

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1 Introduction

Drilling of well ÞG-11 in the Þeistareykir geothermal field was conducted by Iceland Drilling (Jarðboranir) for Landsvirkjun. ÞG-11 was drilled from the same well pad, i.e. well pad B, as the vertical, 2194 m deep well ÞG-9 (Figure 1). The wells are located approximately 600 m north of Bæjarfjall (Table 1), at 350 m a.s.l. (Mortensen, et al., 2013). The planned depth of well ÞG-11 was 2000–2500 m. The well was to be directionally drilled towards south, and the main aim of the drilling was to intersect the permeability and heat related to fractures north of Mt. Bæjarfjall (see Khodayar et al., 2016, Mortensen, 2012).

Table 1. *Geographical position of well ÞG-11. Coordinates are in ISNET93.*

Well name	Well ID	East (X)	North (Y)	Elevation (m a.s.l.)	Planned depth
		(m)	(m)		(m)
ÞG-11	60411	593436	599582	350	2500

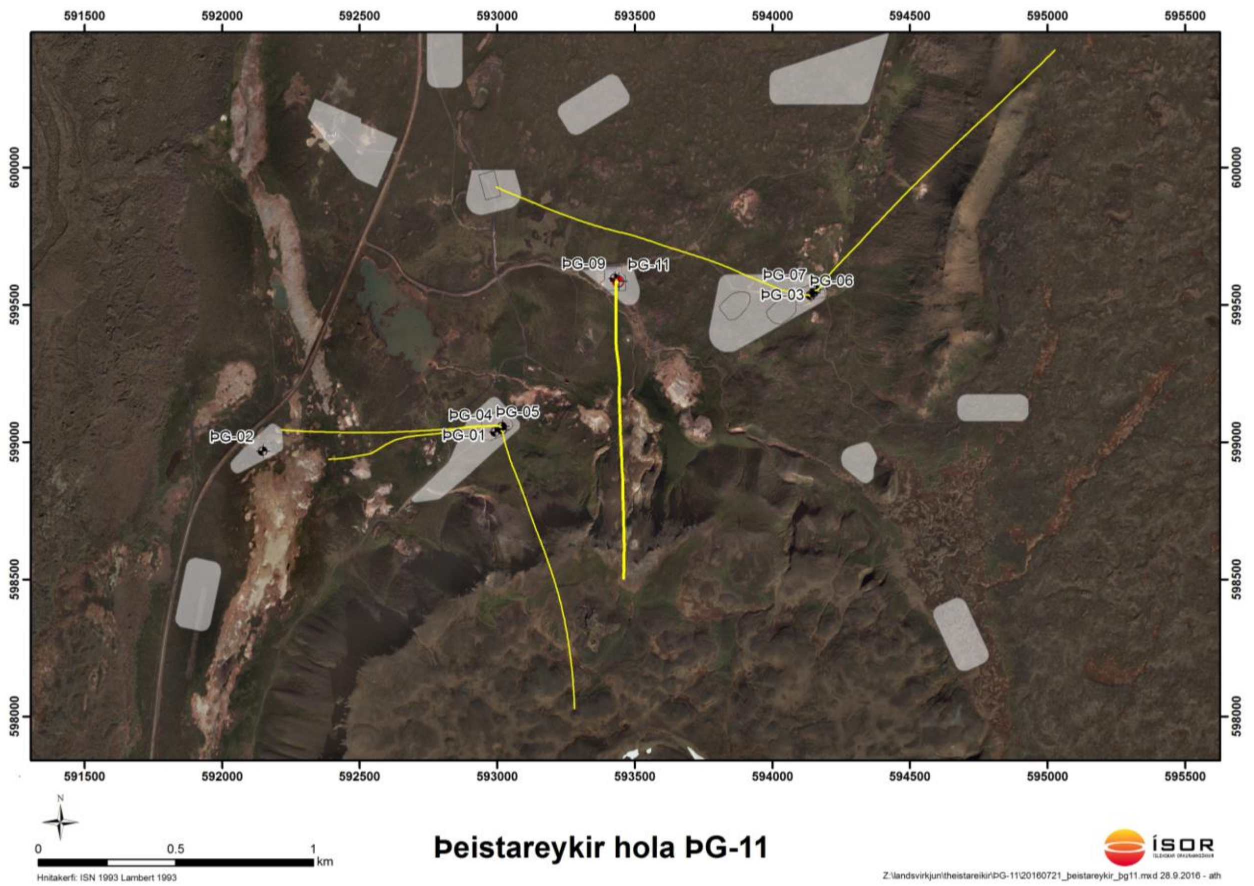


Figure 1. *Location and l actual trajectory of ÞG-11 in Þeistareykir. The well pads are shown as light grey patches*

The planned design of well ÞG-11 (Figure 2) was as follows:

- Phase 0: Pre-drilling for an 18⅝" surface casing with 21" drill bit to approximately 100 m depth (was drilled to 94.3 m, casing set to 91.5 m)
- Phase 1: Drilling for a 13⅝" anchor casing with 17 ½" drill bit down to ~ 300 m depth (was drilled to 304 m, casing set to 302.5 m)
- Phase 2: Drilling for a 9⅝" production casing with 12" drill bit down to ~ 800 m depth (was drilled to 802 m, casing set to 801.7 m)
- Phase 3: Drilling for a 7" perforated liner with 8 ½" drill bit to 2000–2500 m depth (was drilled to 2124 m, casing set to 2209,5 m)

A summary of the drill rigs used to drill well ÞG-11 and the final well design are shown in Table 2
To reach the target zones the direction of the well was set at 180 ±5° relative to true North with an inclination 40±3° from vertical within the depth range 320 m to 1600 m (MD). Below 1600 m (MD) greater deviations in direction and inclination are tolerated i.e. ±15° on direction and 40±12° on inclination (Figure 3). The kick-off was planned 20 m below the anchor casing, at 320 m depth. The angle build-up rate was planned to be 3°/30 m with the final inclination of 40° from vertical. The build-up should be completed before reaching 800 m (MD).

Phase 3 of ÞG-11 was drilled by the drill-rig Óðinn. Sleipnir drilled phases 0 to 2. Drilling of previous phases were described in a separate report (Guðjónsdóttir et al., 2016a, b). Depths in this report refer to measured depth (MD) relative to Óðinn´s rig floor, 6,80 m above ground level, except otherwise stated.

The drilling contractor, Iceland Drilling (Jarðboranir), carried out the drilling operations with Landsvirkjun supervising the work. Iceland GeoSurvey (ÍSOR) managed cutting inspection, well logging, gyro surveys and geothermal consulting.

This report presents the geological part of the drilling, including lithology, alteration and a list of feed points. Also, results of the well loggings carried out during phase 3 are presented. Appendix A contains the daily reports written by the on-site borehole geologist during drilling operations, presenting preliminary results.

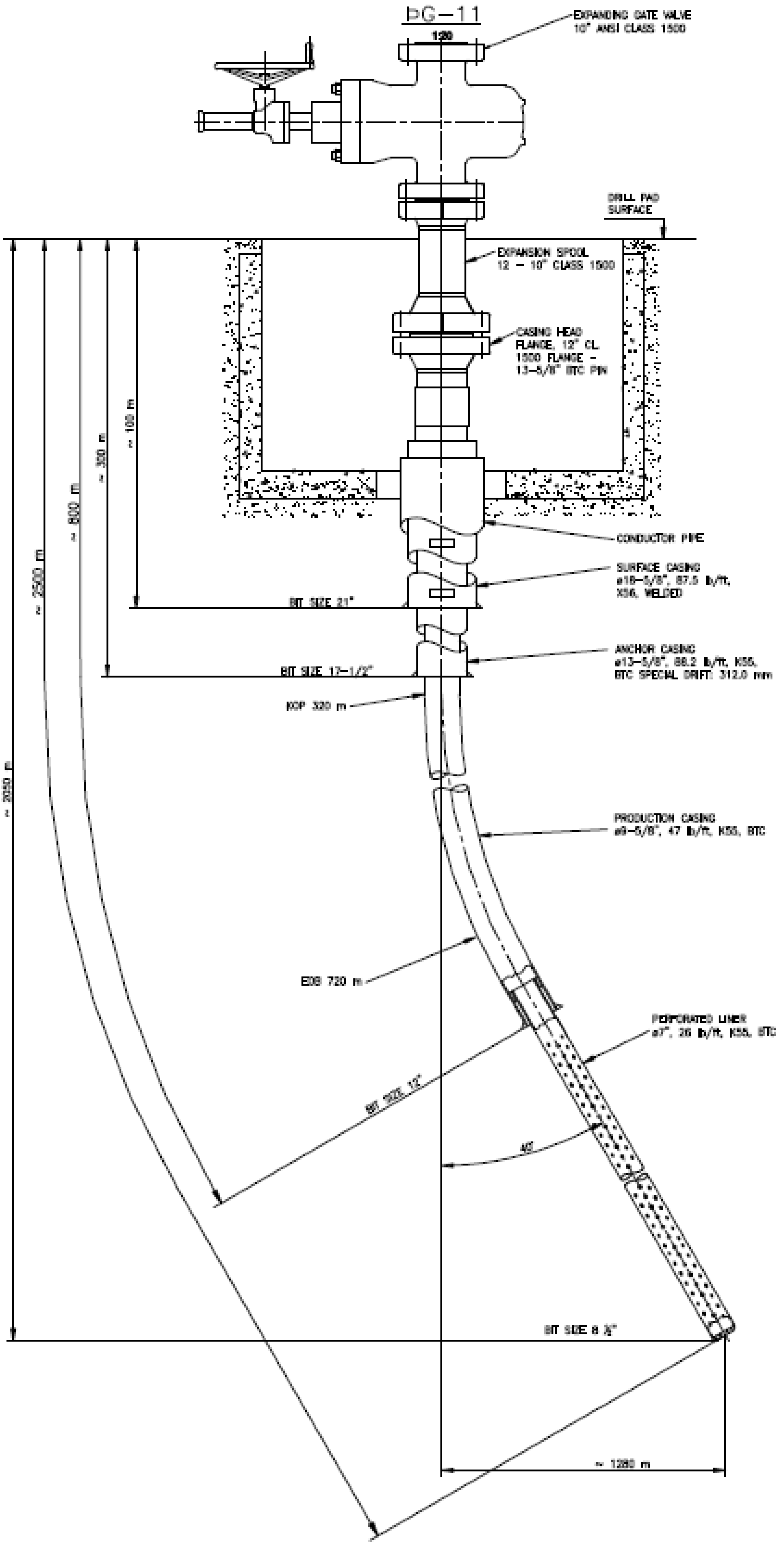


Figure 2. *Well design of well ÞG-11 (actual depth numbers are shown in table 2).*

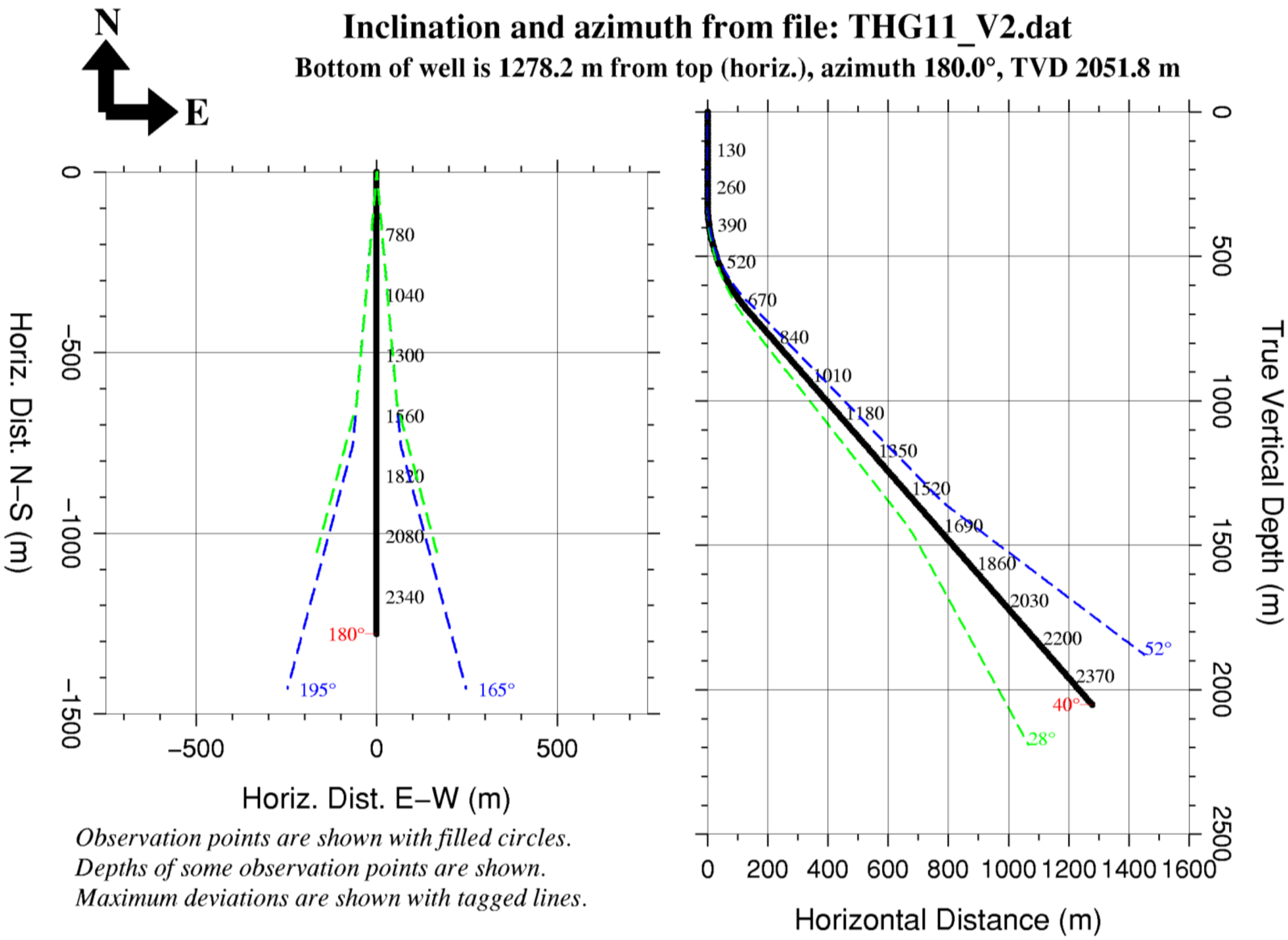


Figure 3. *Cross section and birds-eye-view of the planned trajectory of well ÞG-11 with allowable deviation indicated (Thordarson, 2016).*

2 Drilling operations

2.1 Overview

Drilling operations on well ÞG-11 are divided into four separate phases (0 to 3), see table 2. Drilling operations of phase 3 are described below. Following completion of the 2nd phase of ÞG-11 at 802 m depth, on June 14th 2016, the drill rig, Sleipnir, was moved to well-pad A to commence drilling of well ÞG-10. The work of Sleipnir in well ÞG-11 took 36 workdays

After two days of preparations, drilling started on the 3rd workday of Óðinn on July 7th 2016. The drilling activities lasted 13 days, from the 7th of July to the 19th both days included (see Figure 4 and Table 3). During this time interval there was no drilling on July 13th where the string was pulled out of the well to replace the bit and remove the motor and MWD from the BHA. Rate of penetration were generally high to begin with but slowed as the well got deeper (Figure 4), circulation loss increased, and problems with getting rid of cuttings and keeping torque within reasonable limits increased. After testing and logging the well, the 7" liner was run into the well to 2209.5 m and the well was closed on July 24th just before midnight. The work of Óðinn in well ÞG-11 took 20 workdays and 56 workdays for both rigs on the well from start to completion.

Table 2. *Drilling and casing depths of phases 0–3 in well ÞG-11.*

Drill-Rig	Phase	Drill bit	Depth (m)	Depth Reference	Casing width	Casing Depth
Sleipnir	0	21"	94.3	Sleipnir RF*	18⅝"	91.5
Sleipnir	1	17 ½"	304	Sleipnir RF*	13⅜"	302.5
Sleipnir	2	12"	802	Sleipnir RF*	9⅝"	801.7
Óðinn	3	8½"	2112	Óðinn RF*	7"	2209.5

** RF = rig floor. Sleipnir´s rig floor is 5.64 m above ground level. Óðinn´s rig floor 6.80 m above ground level.*

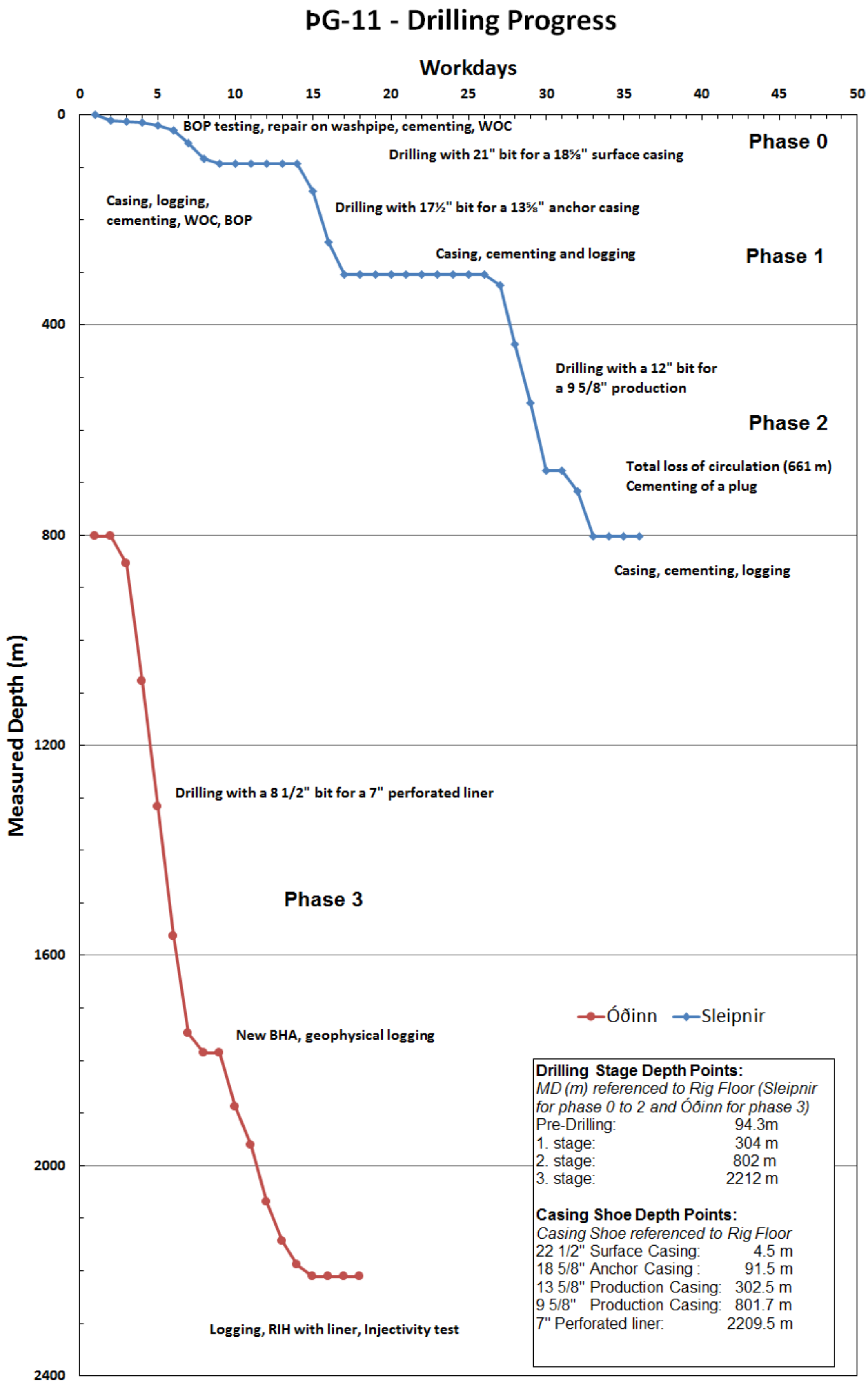


Figure 4. *Drilling progress in well ÞG-11.*

Table 3. *Summary of drilling activities for phase 3 in well ÞG-11.*

Date	Workday Óðinn	Section drilled	Hours drilling	Average ROP (m/hr)	Depth (m) at 24:00
05.07.2016	1	0	0	0	803
06.07.2016	2	0	0	0	803
07.07.2016	3	53	6.80	7.8	855
08.07.2016	4	223	20.75	10.7	1078
09.07.2016	5	240	20.00	12.0	1318
10.07.2016	6	245	23.25	10.5	1563
11.07.2016	7	185	20.50	9.0	1748
12.07.2016	8	37	5.00	7.4	1785
13.07.2016	9	0	0.00	0	1785
14.07.2016	10	104	22.50	4.6	1889
15.07.2016	11	72	16.50	4.4	1961
16.07.2016	12	109	22.75	4.8	2070
17.07.2016	13	73	15.25	4.8	2143
18.07.2016	14	46	12.00	3.8	2189
19.07.2016	15	35	8.75	4.0	2224 (corrected 2212 m)

2.2 Drilling for the 7" perforated liner - phase 3

Drill-rig Óðinn arrived at Húsavík on June 16th 2016. Transportation of the rig to well-pad B at Þeistareykir commenced on the 19th of June. During the following ten days the crew worked on rigging-up. From the 1st to the 5th of July the blow out preventers (BOP´s) were installed and the flow-line connected. The BOP stack was pressure tested, from 06:00 to 14:00, on the 5th of July. A minor pressure drop was observed, i.e. 1 bar in 10 min, for each of the three Blow Out Preventer (the annular, pipe-ram and the blind-ram). The bolts had to be tightened further to fix this issue.

Later the same day (July 5th) a string for cooling the well was run in. In the uppermost 130 m the return temperature was in range of 27–30°C but below that it was 43–52°C. The string was run down to 785.6 m (where the top of the float collar was found). While the well was being cooled the crew worked on tightening the bolts connecting the Blow Out Preventer to the flange.

At 17:00 on July 6th the crew started to pull the string out, which was finished at 21:00. Running a bottom hole assembly with an 8½" bit, a mud motor and a MWD in the hole started at midnight (Figure 5). At noon on the 7th of July the cement was drilled out and at 15:30 drilling in formation commenced at 803 m depth. At 20:00 preparations for the first gyro-survey in this section started. The survey was carried out from 21:30–23:00 that evening. Because of high temperature in the well, only one gyro reading was obtained, at 811 m depth. An inclination of 43.53° and an azimuth of 183.5° were measured which was close to the design of the well. A complete listing of gyro-results is presented in chapter 4.

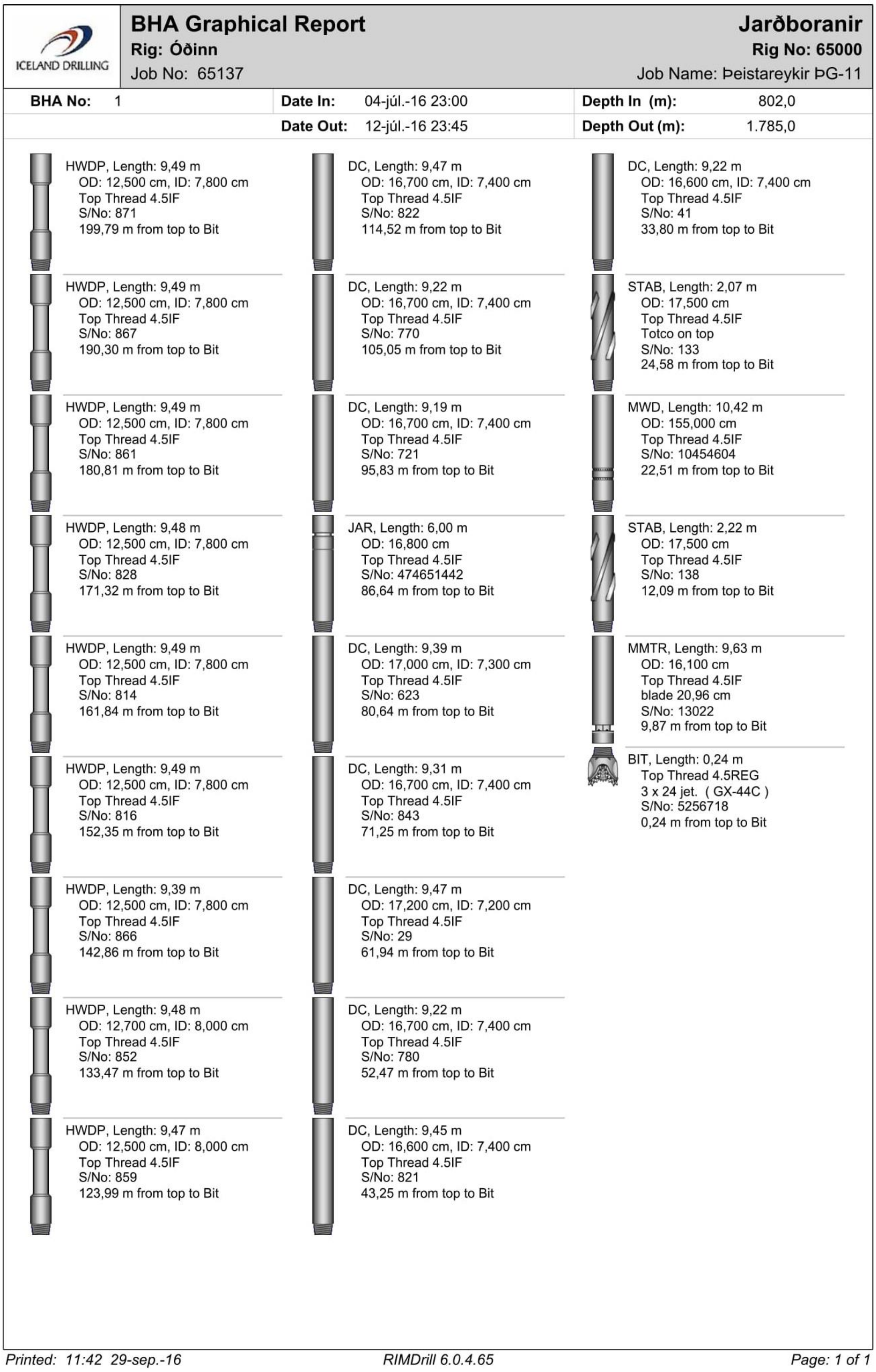
Drilling went smoothly the 8th of July, with an average rate of penetration of 10.7 m/hr (see Table 2). No circulation losses were observed. Polymers were injected after each single. At dinner time, ÍSOR´s logging engineers performed another gyro survey down to 983 m. Drilling was then continued with water circulation of 40 L/s.

Drilling progressed at rapid speeds on the 8th,, 9th and 10th of July, with more than 200 m of hole made each day (Table 2). Polymer pills were injected into the well after each single. At 1202 m depth, on the 9th of July, the well was circulated before running a gyro survey. After ÍSOR´s logging engineers had completed the survey, a circulation loss of 14 L/s was measured. Drilling continued and the circulation loss increased to 17–20 L/s at 1250–1318 m depth.

Drilling was almost continuous through the 10th of July, with average rate of penetration of 10.5 m/hr. Two polymer pills were injected after each single. Circulation loss ranged from 9–18 L/s during drilling. The following morning, 11th of July, circulation losses were down to 6 L/s. Drilling continued to 1681 m at 11:30, on the 11th of July (Workday 7). Then the well was circulated clean and a gyro survey performed by ÍSOR´s logging engineers. The logging was completed at 15:00. Drilling then continued down to 1748 m at midnight. Two polymer pills were injected after drilling each single. Water circulation was 40 L/s.

Drilling was ongoing during the night of the 12th of July down to 1785 meters (MD) where it was decided to pull out the drill string and replace the drill bit. Circulation loss at that time was ~21 L/s.

During the pull out, the pipe handler failed, but was repaired 4 hours later. At 17:50 circulation loss was measured at the pumps and turned out to be around 39 L/s. The pull out was complete just before midnight and the drill bit was in fairly good conditions (Figure 6). ÍSOR´s logging engineers started logging with the acoustic televiewer, the temperature probe and caliper tool. The temperature log showed signs of feed zones at ~1630 m and ~1700 m depth. The caliper log showed several washouts, variable in size, in the well (see Chapter 4).


BHA Graphical Report — Jarðboranir

ICELAND DRILLING

Rig: Óðinn — Rig No: 65000

Job No: 65137 — Job Name: Þeistareykir ÞG-11

BHA No:	1	**Date In:**	04-júl.-16 23:00	**Depth In (m):**	802,0
		Date Out:	12-júl.-16 23:45	**Depth Out (m):**	1.785,0

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 871
199,79 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 867
190,30 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 861
180,81 m from top to Bit

HWDP, Length: 9,48 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 828
171,32 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 814
161,84 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 816
152,35 m from top to Bit

HWDP, Length: 9,39 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 866
142,86 m from top to Bit

HWDP, Length: 9,48 m
OD: 12,700 cm, ID: 8,000 cm
Top Thread 4.5IF
S/No: 852
133,47 m from top to Bit

HWDP, Length: 9,47 m
OD: 12,500 cm, ID: 8,000 cm
Top Thread 4.5IF
S/No: 859
123,99 m from top to Bit

DC, Length: 9,47 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 822
114,52 m from top to Bit

DC, Length: 9,22 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 770
105,05 m from top to Bit

DC, Length: 9,19 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 721
95,83 m from top to Bit

JAR, Length: 6,00 m
OD: 16,800 cm
Top Thread 4.5IF
S/No: 474651442
86,64 m from top to Bit

DC, Length: 9,39 m
OD: 17,000 cm, ID: 7,300 cm
Top Thread 4.5IF
S/No: 623
80,64 m from top to Bit

DC, Length: 9,31 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 843
71,25 m from top to Bit

DC, Length: 9,47 m
OD: 17,200 cm, ID: 7,200 cm
Top Thread 4.5IF
S/No: 29
61,94 m from top to Bit

DC, Length: 9,22 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 780
52,47 m from top to Bit

DC, Length: 9,45 m
OD: 16,600 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 821
43,25 m from top to Bit

DC, Length: 9,22 m
OD: 16,600 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 41
33,80 m from top to Bit

STAB, Length: 2,07 m
OD: 17,500 cm
Top Thread 4.5IF
Totco on top
S/No: 133
24,58 m from top to Bit

MWD, Length: 10,42 m
OD: 155,000 cm
Top Thread 4.5IF
S/No: 10454604
22,51 m from top to Bit

STAB, Length: 2,22 m
OD: 17,500 cm
Top Thread 4.5IF
S/No: 138
12,09 m from top to Bit

MMTR, Length: 9,63 m
OD: 16,100 cm
Top Thread 4.5IF
blade 20,96 cm
S/No: 13022
9,87 m from top to Bit

BIT, Length: 0,24 m
Top Thread 4.5REG
3 x 24 jet. (GX-44C)
S/No: 5256718
0,24 m from top to Bit

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Figure 5. *Bottom hole assembly graphical report with 8 ½″ drill bit used from 802 to 1785 m.*

Figure 6. *8½" drill bit pulled out of the well on July 12th.*

After the logging was completed the drilling crew started to run in with a new bottom hole assembly, with an 8½" drill bit, but without motor and MWD (Figure 7). Initially the crew pumped cold water on the string after every third single during the run in. From 1685 m the well was cooled after each single. Just before midnight, on the 13th of July (Workday 9), the bit tagged bottom of hole and no deposits were noticed at the bottom.

For the next three days drilling continued at a steady pace with average rates of penetration between 4 and 5 m/hr (Table 3). Drilling was then stopped in the morning on the 15th at 1921 m depth to conduct a gyro-run. Logging began just before 11:00. The gyro survey showed that the well was basically right on track down to 1890 m. The drilling crew then did some maintenance work on the pumps and then drilling commenced at ~14:00.

Circulation losses were measured at 5:50 and 7:36 in morning of the 16th of July. The results were 24 L/s and 29 L/s respectively.

Drilling progressed at a moderate but steady speed on the 17th of July. In the afternoon the well was cleaned for a gyro. The depth of the well was at this time was 2143 m. However, the crew was not happy with the cleaning of the well. A decision was made to pull out partially to bring the bit to 1200 meters (MD) and let the cuttings in the well settle and then run in hole again and check for bottom fill.

Subsequently the crew ran back in hole, with 14 L/s on kill line and 5 L/s on string. A 4 m bottom fill was detected. Two singles were removed and the inclination of the lowermost part of the well determined with an inclination tool in the early morning of July 18th. The results (discussed in Chapter 4) showed that the well has kept the planned inclination.

Drilling progressed at a slow but steady rate in the afternoon and evening of July 18th (see Figure 8). Early the following morning drilling stopped due to maintenance work on the kelly-hose. Drilling continued on the 19th.

The status of the well was discussed at a project meeting on Tuesday morning on the 19th of July. A power outage was planned in the Þeistareykir area at 23:00 that evening. This could adversely affect pumping of cold water to the rig. Emergency power units were expected to deliver a maximum of 30–40 L/s to the rig. It was clear therefore that as a precautionary measure the crew should pull the bit back, preferably all the way up into the casing. However, in light of the circumstances (i.e. condition of well) a decision was made to pull out completely and RIH with a temperature tool, the acoustic televiewer and lithology logging tools. A decision on whether to continue drilling could then be made on the basis of a new temperature log which should be very informative.

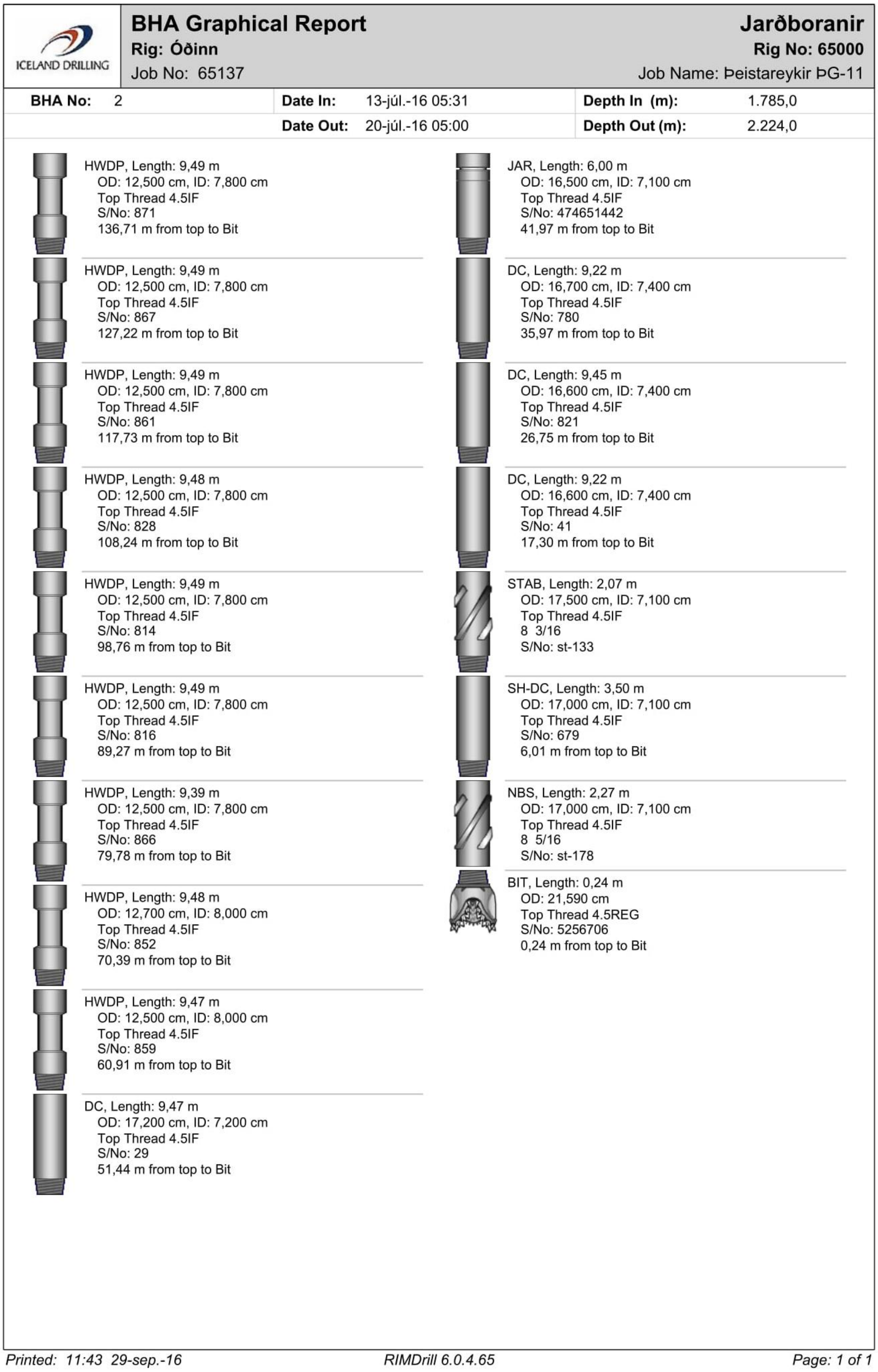
Drilling stopped at 2224.1 m at 11:00 on the 19th of July (Workday 15). Water was then circulated and the well cleaned for 4 hours. Prior to pulling the string out, a polymer pill was injected. POOH started at 15:00. During the power outage, the back-up power units for the pumps that deliver cold water to the rig did not operate as planned and the rig's water reserves were used to finish pulling out of the hole. The operations were stopped at 3:00 in the morning of July 20th due to water shortage at the rig and resumed at 4:00 once the water supply was restored. Once the drilling assembly was out of the hole, the string for logging was run in hole.

The logging string couldn't go deeper than 2212 m due to an unknown obstruction in the wellbore. An unsuccessful attempt to flush away the possible bottom fill were carried out by pumping 30 L/s. It was concluded that the well total depth is 2212 m and not 2224 m as previously reported, probably due to an error in the drill-string counting.

In the evening of July 20th, the gyro tool was also run down the hole and shows consistent results with the well plan. A temperature survey was completed while pumping 11 L/s and indicates a cooling at the bottom, but the heat up rate did not change with increasing injection from 11 to 30 L/s. On July 21st, ÍSOR logging engineer carried out the conventional open hole logging including temperature, gyro, caliper, televiewer, neutron-neutron, natural gamma and resistivity logs (results and interpretation are presented in the wire-line logging chapter 4).

On July 23rd, the 7" liner was run into the hole until about midnight. The liner went down to 2209.5 m and is hanging at 761.4 m. Information on the liner is published in tables 9 and 10.

Conventional injection test started later shortly after midnight 24th of July. day. This time a PTS tool was used, so data on not only temperature and pressure were measured during the test but also flow data registered by the spinner unit in the tool. The injection test was completed in the afternoon and then pumping in the well was stopped and the master valve shut-in. That marks the completion of the drilling of well ÞG-11 on the 20th workdays of Óðinn on the phase 3 and 36 working days of Sleipnir on phases 0 to 2. In total the drilling work took 56 workdays for the two drilling rigs.



ICELAND DRILLING	**BHA Graphical Report**	**Jarðboranir**
	Rig: Óðinn	**Rig No: 65000**
	Job No: 65137	Job Name: Þeistareykir ÞG-11

BHA No:	2	**Date In:**	13-júl.-16 05:31	**Depth In (m):**	1.785,0
		Date Out:	20-júl.-16 05:00	**Depth Out (m):**	2.224,0

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 871
136,71 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 867
127,22 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 861
117,73 m from top to Bit

HWDP, Length: 9,48 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 828
108,24 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 814
98,76 m from top to Bit

HWDP, Length: 9,49 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 816
89,27 m from top to Bit

HWDP, Length: 9,39 m
OD: 12,500 cm, ID: 7,800 cm
Top Thread 4.5IF
S/No: 866
79,78 m from top to Bit

HWDP, Length: 9,48 m
OD: 12,700 cm, ID: 8,000 cm
Top Thread 4.5IF
S/No: 852
70,39 m from top to Bit

HWDP, Length: 9,47 m
OD: 12,500 cm, ID: 8,000 cm
Top Thread 4.5IF
S/No: 859
60,91 m from top to Bit

DC, Length: 9,47 m
OD: 17,200 cm, ID: 7,200 cm
Top Thread 4.5IF
S/No: 29
51,44 m from top to Bit

JAR, Length: 6,00 m
OD: 16,500 cm, ID: 7,100 cm
Top Thread 4.5IF
S/No: 474651442
41,97 m from top to Bit

DC, Length: 9,22 m
OD: 16,700 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 780
35,97 m from top to Bit

DC, Length: 9,45 m
OD: 16,600 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 821
26,75 m from top to Bit

DC, Length: 9,22 m
OD: 16,600 cm, ID: 7,400 cm
Top Thread 4.5IF
S/No: 41
17,30 m from top to Bit

STAB, Length: 2,07 m
OD: 17,500 cm, ID: 7,100 cm
Top Thread 4.5IF
8 3/16
S/No: st-133

SH-DC, Length: 3,50 m
OD: 17,000 cm, ID: 7,100 cm
Top Thread 4.5IF
S/No: 679
6,01 m from top to Bit

NBS, Length: 2,27 m
OD: 17,000 cm, ID: 7,100 cm
Top Thread 4.5IF
8 5/16
S/No: st-178

BIT, Length: 0,24 m
OD: 21,590 cm
Top Thread 4.5REG
S/No: 5256706
0,24 m from top to Bit

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Figure 7. *Bottom hole assembly graphical report with 8½" Drill bit used from 1785 to 2224 m*

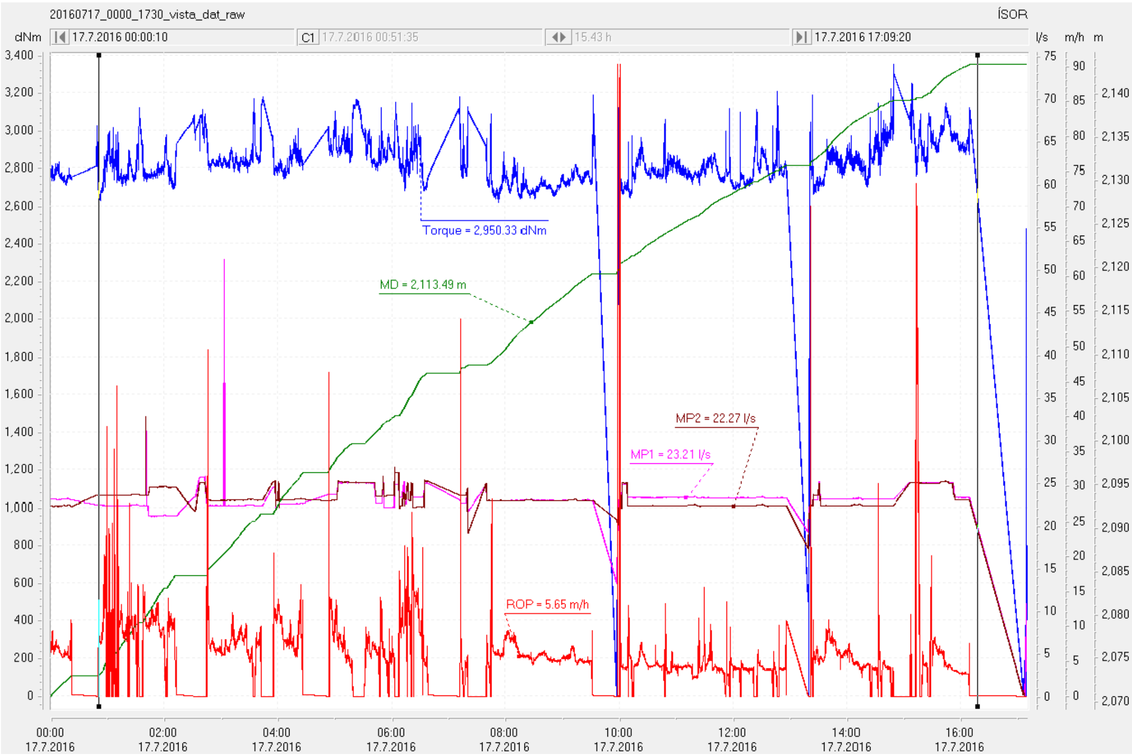

Figure 8. *Key parameters during drilling July 18th.*

ICELAND DRILLING	**Casing Information Report** **Rig: Óðinn** Job No: 65137	**Jarðboranir** **Rig No: 65000** Job Name: Þeistareykir ÞG-11

Casing Information

Run Date/Time:	23-júl.-16 17:30		
		Leak Off Test (kg/cu m):	
Well Section:		**String Type:**	LINER
String Top MD (m):	761,4	**String Top TVD (m):**	
Casing Shoe MD (m):	2.209,5	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	17,78	**String Nominal ID (cm):**	
Bit Diameter (cm):		**Avg. Open Hole Diam. (cm):**	
Centralizers: No:		**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 24-júl.-16 06:54		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
62	JOINT	691,320	17,78	15,94	26,0	K-55	BUTT	
1	JOINT	10,990	17,78	15,94	26,0	K-55	BUTT	
10	JOINT	113,420	17,78	15,94	26,0	K-55	BUTT	
2	JOINT	22,250	17,78	15,94	26,0	K-55	BUTT	
52	JOINT	587,480	17,78	15,94	26,0	K-55	BUTT	
2	JOINT	22,600	17,78	15,94	26,0	K-55	BUTT	
Totals: 129		1.448,060						

Figure 9. *Casing information report for the 7″ liner in well ÞG-11.*

	Casing Tally Run Report	Jarðboranir
ICELAND DRILLING	Rig: Óðinn	Rig No: 65000
	Job No: 65137	Job Name: Þeistareykir ÞG-11

String Nominal OD (cm): 17,78 String Type: LINER

Items Run:	129	Length Run:	1.448,060	Top Depth:	761,440
Items Excluded:	0	Length Excluded:	0,000	Bottom Depth:	2.209,500
Items Tallied:	129	Length All Items:	1.448,060	Cut Off Length:	0,000

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
1	129	JOINT	0,280	2.209,220	2.209,500	17,78 x 15,94 K-55 BUTT	Sleppistykki		
2	128	JOINT	11,470	2.197,750	2.209,220	17,78 x 15,94 K-55 BUTT	Heilt rör		
3	127	JOINT	11,590	2.186,160	2.197,750	17,78 x 15,94 K-55 BUTT	Heilt rör		
4	126	JOINT	11,590	2.174,570	2.186,160	17,78 x 15,94 K-55 BUTT			
5	125	JOINT	11,480	2.163,090	2.174,570	17,78 x 15,94 K-55 BUTT			
6	124	JOINT	11,580	2.151,510	2.163,090	17,78 x 15,94 K-55 BUTT			
7	123	JOINT	11,150	2.140,360	2.151,510	17,78 x 15,94 K-55 BUTT			
8	122	JOINT	11,350	2.129,010	2.140,360	17,78 x 15,94 K-55 BUTT			
9	121	JOINT	11,140	2.117,870	2.129,010	17,78 x 15,94 K-55 BUTT			
10	120	JOINT	11,300	2.106,570	2.117,870	17,78 x 15,94 K-55 BUTT			
11	119	JOINT	11,280	2.095,290	2.106,570	17,78 x 15,94 K-55 BUTT			
12	118	JOINT	11,350	2.083,940	2.095,290	17,78 x 15,94 K-55 BUTT			
13	117	JOINT	10,900	2.073,040	2.083,940	17,78 x 15,94 K-55 BUTT			
14	116	JOINT	11,600	2.061,440	2.073,040	17,78 x 15,94 K-55 BUTT			
15	115	JOINT	10,940	2.050,500	2.061,440	17,78 x 15,94 K-55 BUTT			
16	114	JOINT	11,350	2.039,150	2.050,500	17,78 x 15,94 K-55 BUTT			
17	113	JOINT	11,130	2.028,020	2.039,150	17,78 x 15,94 K-55 BUTT			
18	112	JOINT	11,130	2.016,890	2.028,020	17,78 x 15,94 K-55 BUTT			
19	111	JOINT	11,690	2.005,200	2.016,890	17,78 x 15,94 K-55 BUTT			
20	110	JOINT	11,390	1.993,810	2.005,200	17,78 x 15,94 K-55 BUTT			
21	109	JOINT	11,270	1.982,540	1.993,810	17,78 x 15,94 K-55 BUTT			
22	108	JOINT	11,510	1.971,030	1.982,540	17,78 x 15,94 K-55 BUTT			
23	107	JOINT	11,600	1.959,430	1.971,030	17,78 x 15,94 K-55 BUTT			
24	106	JOINT	10,980	1.948,450	1.959,430	17,78 x 15,94 K-55 BUTT			
25	105	JOINT	11,290	1.937,160	1.948,450	17,78 x 15,94 K-55 BUTT			
26	104	JOINT	11,580	1.925,580	1.937,160	17,78 x 15,94 K-55 BUTT			
27	103	JOINT	11,120	1.914,460	1.925,580	17,78 x 15,94 K-55 BUTT			
28	102	JOINT	11,360	1.903,100	1.914,460	17,78 x 15,94 K-55 BUTT			
29	101	JOINT	11,100	1.892,000	1.903,100	17,78 x 15,94 K-55 BUTT			
30	100	JOINT	11,410	1.880,590	1.892,000	17,78 x 15,94 K-55 BUTT			
31	99	JOINT	11,520	1.869,070	1.880,590	17,78 x 15,94 K-55 BUTT			
32	98	JOINT	11,290	1.857,780	1.869,070	17,78 x 15,94 K-55 BUTT			
33	97	JOINT	11,290	1.846,490	1.857,780	17,78 x 15,94 K-55 BUTT			
34	96	JOINT	11,600	1.834,890	1.846,490	17,78 x 15,94 K-55 BUTT			
35	95	JOINT	11,290	1.823,600	1.834,890	17,78 x 15,94 K-55 BUTT			
36	94	JOINT	11,290	1.812,310	1.823,600	17,78 x 15,94 K-55 BUTT			
37	93	JOINT	11,560	1.800,750	1.812,310	17,78 x 15,94 K-55 BUTT			
38	92	JOINT	11,100	1.789,650	1.800,750	17,78 x 15,94 K-55 BUTT			
39	91	JOINT	11,290	1.778,360	1.789,650	17,78 x 15,94 K-55 BUTT			
40	90	JOINT	11,410	1.766,950	1.778,360	17,78 x 15,94 K-55 BUTT			
41	89	JOINT	11,330	1.755,620	1.766,950	17,78 x 15,94 K-55 BUTT			

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Figure 10. *Detailed Casing report for the 7" liner in well ÞG-11.*

	Casing Tally Run Report **Rig: Óðinn** Job No: 65137	**Jarðboranir** **Rig No: 65000** Job Name: Þeistareykir ÞG-11
ICELAND DRILLING		

String Nominal OD (cm): 17,78 **String Type: LINER**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
42	88	JOINT	11,510	1.744,110	1.755,620	17,78 x 15,94 K-55 BUTT			
43	87	JOINT	11,150	1.732,960	1.744,110	17,78 x 15,94 K-55 BUTT			
44	86	JOINT	11,390	1.721,570	1.732,960	17,78 x 15,94 K-55 BUTT			
45	85	JOINT	11,600	1.709,970	1.721,570	17,78 x 15,94 K-55 BUTT			
46	84	JOINT	11,600	1.698,370	1.709,970	17,78 x 15,94 K-55 BUTT			
47	83	JOINT	11,270	1.687,100	1.698,370	17,78 x 15,94 K-55 BUTT			
48	82	JOINT	11,590	1.675,510	1.687,100	17,78 x 15,94 K-55 BUTT			
49	81	JOINT	11,070	1.664,440	1.675,510	17,78 x 15,94 K-55 BUTT			
50	80	JOINT	11,150	1.653,290	1.664,440	17,78 x 15,94 K-55 BUTT			
51	79	JOINT	11,380	1.641,910	1.653,290	17,78 x 15,94 K-55 BUTT			
52	78	JOINT	11,350	1.630,560	1.641,910	17,78 x 15,94 K-55 BUTT			
53	77	JOINT	11,250	1.619,310	1.630,560	17,78 x 15,94 K-55 BUTT			
54	76	JOINT	11,290	1.608,020	1.619,310	17,78 x 15,94 K-55 BUTT			
55	75	JOINT	11,220	1.596,800	1.608,020	17,78 x 15,94 K-55 BUTT			
56	74	JOINT	11,400	1.585,400	1.596,800	17,78 x 15,94 K-55 BUTT			
57	73	JOINT	11,210	1.574,190	1.585,400	17,78 x 15,94 K-55 BUTT			
58	72	JOINT	11,310	1.562,880	1.574,190	17,78 x 15,94 K-55 BUTT			
59	71	JOINT	11,310	1.551,570	1.562,880	17,78 x 15,94 K-55 BUTT			
60	70	JOINT	11,090	1.540,480	1.551,570	17,78 x 15,94 K-55 BUTT			
61	69	JOINT	10,880	1.529,600	1.540,480	17,78 x 15,94 K-55 BUTT			
62	68	JOINT	11,420	1.518,180	1.529,600	17,78 x 15,94 K-55 BUTT			
63	67	JOINT	10,990	1.507,190	1.518,180	17,78 x 15,94 K-55 BUTT			
64	66	JOINT	11,490	1.495,700	1.507,190	17,78 x 15,94 K-55 BUTT			
65	65	JOINT	11,380	1.484,320	1.495,700	17,78 x 15,94 K-55 BUTT			
66	64	JOINT	11,390	1.472,930	1.484,320	17,78 x 15,94 K-55 BUTT			
67	63	JOINT	11,470	1.461,460	1.472,930	17,78 x 15,94 K-55 BUTT			
68	62	JOINT	11,140	1.450,320	1.461,460	17,78 x 15,94 K-55 BUTT			
69	61	JOINT	10,860	1.439,460	1.450,320	17,78 x 15,94 K-55 BUTT			
70	60	JOINT	11,560	1.427,900	1.439,460	17,78 x 15,94 K-55 BUTT			
71	59	JOINT	11,470	1.416,430	1.427,900	17,78 x 15,94 K-55 BUTT			
72	58	JOINT	11,190	1.405,240	1.416,430	17,78 x 15,94 K-55 BUTT			
73	57	JOINT	11,470	1.393,770	1.405,240	17,78 x 15,94 K-55 BUTT			
74	56	JOINT	11,080	1.382,690	1.393,770	17,78 x 15,94 K-55 BUTT			
75	55	JOINT	11,170	1.371,520	1.382,690	17,78 x 15,94 K-55 BUTT			
76	54	JOINT	11,280	1.360,240	1.371,520	17,78 x 15,94 K-55 BUTT			
77	53	JOINT	11,270	1.348,970	1.360,240	17,78 x 15,94 K-55 BUTT			
78	52	JOINT	11,570	1.337,400	1.348,970	17,78 x 15,94 K-55 BUTT			
79	51	JOINT	11,410	1.325,990	1.337,400	17,78 x 15,94 K-55 BUTT			
80	50	JOINT	10,830	1.315,160	1.325,990	17,78 x 15,94 K-55 BUTT			
81	49	JOINT	11,310	1.303,850	1.315,160	17,78 x 15,94 K-55 BUTT			
82	48	JOINT	11,070	1.292,780	1.303,850	17,78 x 15,94 K-55 BUTT			
83	47	JOINT	11,270	1.281,510	1.292,780	17,78 x 15,94 K-55 BUTT			
84	46	JOINT	11,080	1.270,430	1.281,510	17,78 x 15,94 K-55 BUTT			
85	45	JOINT	11,480	1.258,950	1.270,430	17,78 x 15,94 K-55 BUTT			

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Figure 10. *(Cont.) Detailed Casing report for the 7″ liner in well ÞG-11.*

	Casing Tally Run Report **Rig: Óðinn** Job No: 65137	**Jarðboranir** **Rig No: 65000** Job Name: Þeistareykir ÞG-11
ICELAND DRILLING		

String Nominal OD (cm): 17,78 **String Type: LINER**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
86	44	JOINT	11,330	1.247,620	1.258,950	17,78 x 15,94 K-55 BUTT			
87	43	JOINT	11,590	1.236,030	1.247,620	17,78 x 15,94 K-55 BUTT			
88	42	JOINT	11,370	1.224,660	1.236,030	17,78 x 15,94 K-55 BUTT			
89	41	JOINT	11,580	1.213,080	1.224,660	17,78 x 15,94 K-55 BUTT			
90	40	JOINT	11,270	1.201,810	1.213,080	17,78 x 15,94 K-55 BUTT			
91	39	JOINT	11,310	1.190,500	1.201,810	17,78 x 15,94 K-55 BUTT			
92	38	JOINT	11,370	1.179,130	1.190,500	17,78 x 15,94 K-55 BUTT			
93	37	JOINT	11,380	1.167,750	1.179,130	17,78 x 15,94 K-55 BUTT			
94	36	JOINT	11,430	1.156,320	1.167,750	17,78 x 15,94 K-55 BUTT			
95	35	JOINT	11,290	1.145,030	1.156,320	17,78 x 15,94 K-55 BUTT			
96	34	JOINT	11,290	1.133,740	1.145,030	17,78 x 15,94 K-55 BUTT			
97	33	JOINT	11,460	1.122,280	1.133,740	17,78 x 15,94 K-55 BUTT			
98	32	JOINT	11,110	1.111,170	1.122,280	17,78 x 15,94 K-55 BUTT			
99	31	JOINT	11,000	1.100,170	1.111,170	17,78 x 15,94 K-55 BUTT			
100	30	JOINT	11,020	1.089,150	1.100,170	17,78 x 15,94 K-55 BUTT			
101	29	JOINT	11,590	1.077,560	1.089,150	17,78 x 15,94 K-55 BUTT			
102	28	JOINT	11,290	1.066,270	1.077,560	17,78 x 15,94 K-55 BUTT			
103	27	JOINT	11,290	1.054,980	1.066,270	17,78 x 15,94 K-55 BUTT			
104	26	JOINT	11,160	1.043,820	1.054,980	17,78 x 15,94 K-55 BUTT			
105	25	JOINT	11,390	1.032,430	1.043,820	17,78 x 15,94 K-55 BUTT			
106	24	JOINT	11,520	1.020,910	1.032,430	17,78 x 15,94 K-55 BUTT			
107	23	JOINT	11,350	1.009,560	1.020,910	17,78 x 15,94 K-55 BUTT			
108	22	JOINT	11,070	998,490	1.009,560	17,78 x 15,94 K-55 BUTT			
109	21	JOINT	11,250	987,240	998,490	17,78 x 15,94 K-55 BUTT			
110	20	JOINT	11,390	975,850	987,240	17,78 x 15,94 K-55 BUTT			
111	19	JOINT	10,850	965,000	975,850	17,78 x 15,94 K-55 BUTT			
112	18	JOINT	10,970	954,030	965,000	17,78 x 15,94 K-55 BUTT			
113	17	JOINT	11,250	942,780	954,030	17,78 x 15,94 K-55 BUTT			
114	16	JOINT	11,520	931,260	942,780	17,78 x 15,94 K-55 BUTT			
115	15	JOINT	11,420	919,840	931,260	17,78 x 15,94 K-55 BUTT			
116	14	JOINT	11,370	908,470	919,840	17,78 x 15,94 K-55 BUTT			
117	13	JOINT	11,080	897,390	908,470	17,78 x 15,94 K-55 BUTT			
118	12	JOINT	11,330	886,060	897,390	17,78 x 15,94 K-55 BUTT			
119	11	JOINT	11,250	874,810	886,060	17,78 x 15,94 K-55 BUTT			
120	10	JOINT	10,980	863,830	874,810	17,78 x 15,94 K-55 BUTT			
121	9	JOINT	11,400	852,430	863,830	17,78 x 15,94 K-55 BUTT			
122	8	JOINT	11,390	841,040	852,430	17,78 x 15,94 K-55 BUTT			
123	7	JOINT	11,170	829,870	841,040	17,78 x 15,94 K-55 BUTT			
124	6	JOINT	11,510	818,360	829,870	17,78 x 15,94 K-55 BUTT			
125	5	JOINT	11,270	807,090	818,360	17,78 x 15,94 K-55 BUTT			
126	4	JOINT	11,470	795,620	807,090	17,78 x 15,94 K-55 BUTT			
127	3	JOINT	11,580	784,040	795,620	17,78 x 15,94 K-55 BUTT			
128	2	JOINT	11,310	772,730	784,040	17,78 x 15,94 K-55 BUTT			
129	1	JOINT	11,290	761,440	772,730	17,78 x 15,94 K-55 BUTT	Skór á þessu röri		

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Figure 10. *(Cont.) Detailed Casing report for the 7" liner in well ÞG-11.*

3 Lithology, alteration, intrusions and circulation losses

During drilling of the 3rd phase of well ÞG-11, the drilling crew members collected cutting samples at two meter intervals. However, early in phase 3, some samples were not collected for an unknown reason. Depth values of the samples refer to the rig floor of Óðinn (6.80 m above ground level). The samples were collected in 150 ml plastic containers. ÍSOR's borehole geologists analysed the cutting samples on site during drilling and determined the lithology and the alteration mineral assemblages with the aid of a binocular microscope. Additionally, the main drilling parameters from the automatic data acquisition system of Óðinn were collected.

The lithology of the third phase of well is described below and shown in Figures 11–18. The first three figures are photographs of alteration minerals then in Figure 14, the legend for the following figures is shown. Figure 15 shows the drilling data from the drill rig Óðinn and lithology of well ÞG-11 during the third phase. Several problems were noticed with the drilling data uploaded from the rig; the weight on bit values varies greatly between negative values as low as -50 tons to high positive values up to 50 tons. These values for the weight on bit are unrealistic and might be linked to the electrical problems encountered at the rig during the drilling of phase 3, consequently the weight on bit curve is not included in the log. Also, from the beginning of the phase, at 803 m to about 1678 m, corresponding to July 7th to 11th, the rig was recording the drilling parameters with a depth that didn't match the actual depth of the bit, the gap varies between 70 and 116 m and was irregular so it cannot be fixed later on. The problem was reported by the ÍSOR wellsite geologist to the drilling supervisor who contacted the drilling crew to fix the error. On July 11th, at about 11:05, the well depth in the system was corrected by adding about 116 meters (from 1562.86 to 1678.81 m) to fit the actual well depth. This is the reason why no drilling data is shown in Figure 15 down to 1678 m.

Figures 16 shows the lithology of the third phase with an abbreviated description of the main geological units. Figure 17 shows the stratigraphic column and the distribution of alteration minerals encountered. Finally, Figure 18 compares the lithology in ÞG-11 with the lithology in well ÞG-9. Additional information on the lithology are obtained from the geophysical well logs (see Figure 21 in chapter 4).

3.1 Lithology of phase 3

The lithology of well ÞG-11 is consistent with the general geology of the Þeistareykir geothermal area; constituted of an alternation of hyaloclastite formations like basaltic tuff, breccia and glassy basalt, intersected with thin layers of altered fine to medium grained basaltic flow and a few possible intrusions of fine to medium grained fresh basaltic rocks. Exceptional for the lithology in this well compared to other Þeistareykir wells is a 40 m thick silicic unit seen in the gamma log at 1000 m. This is the first time a silicic unit is encountered in a well at Þeistareykir. Silicic rocks are rare in the Þeistareykir area and the volcanic system has not developed a caldera (caldera formation is often associated with explosive rhyolitic eruptions). However, Mælifell, a subglacial unit located a few kilometers to the west of the main geothermal field, is composed of rhyolitic material.

The cuttings were originally described as "white dense tuff" based on their color and appearance. The cuttings do contain a considerable amount of transparent and semi-transparent feldspar crystals which are indicative of the formations silicic nature. The formation is probably an intrusion and in keeping with the tradition from Krafla it could be classified as "granophyre." A proper name, based on e.g. the IUGS classification scheme, for this formation will have to wait for thin-sections analysis

The cuttings that were brought to the surface from below 1800 m (MD) were very fine grained. There was clear evidence of mixing in the cuttings and in addition to mixing, it seemed that some sorting, according to grain size was occurring in the water column as well. This leads to diffuse contacts between formations and can result in incorrect interpretation of the stratigraphic column. This can be corrected to some extent by geophysical logs.

The results of the drill-cutting inspection from 804–2224 m in ÞG-11 are shown below (final depth of the well was later corrected to 2212 m):

803–814 m NO CUTTINGS

814–820 m FINE-MEDIUM GRAINED BASALT

Slightly tuff mixed. Dense grains with clinopyroxene and plagioclase in groundmass. Epidote growing on quartz in a pore. This formation could possibly be a pillow basalt.

820–826 m GLASSY BASALT

Increase in crystalline epidote and euhedral quartz crystals. Occasional sediment grains with fine and green groundmass. Also, partly crystalline grains with glassy groundmass. Quite cement mixed.

826–830 m BASALTIC BRECCIA

Abundant of euhedral quartz in pores. Increase in tuff grains.

830–832 m NO CUTTINGS

832–836 m BASALTIC BRECCIA

Partly crystalline basalt and tuff grains.

836–838 m FINE-MEDIUM GRAINED BASALT

Mostly well crystalline grains with quartz and coarse grained clay in pores. Rather dense formation, with clinopyroxene and plagioclase in groundmass. Tuff mixed in (highly altered).

838–840 m CEMENT

840–854 m BASALTIC BRECCIA

Clay and quartz in pores. Increase in green tuff grains. Also found fine grained basalt grains with no phenocrysts. Abundant of tuff down the formation.

854–858 m CEMENT

858–872 m BASALTIC BRECCIA

Green tuff and reddish basalt grains. Dense formation with no epidote in the uppermost sample. Voids filled with clay and quartz/silica, Increase in pyrite in the lower most part of the formation.

872–878 m BASALTIC TUFF

Mostly green and highly altered tuff grains. Increase in epidote.

878–892 m BASALTIC BRECCIA

Porphyritic free dark colored basalt with green tuff grains. Voids filled with clay and pyrite. Well crystallized epidote and quartz crystals.

892–916 m BASALTIC TUFF

Almost only tuff grains with green appearances. High amount of epidote. Reddish tuff grains mixed in.

916–922 m GLASSY BASALT

Partly crystalline basalt with pores filled with clay and quartz. Tuff mixed in.

922–928 m FINE-MEDIUM GRAINED BASALT

Highly altered basalt. High amount of calcite. Dense grains with clay as pore fillings.

928–936 m NO CUTTINGS

936–938 m FINE-MEDIUM GRAINED BASALT

Dense and greenish/grayish grains.

938–940 m NO CUTTINGS

940–942 m GLASSY BASALT

Fine grained basalt grains with clay in pores. Abundant of epidote. Could be a lava formation.

942–944 m NO CUTTINGS

944–946 m GLASSY BASALT

Same as above

946–948 m NO CUTTINGS

948–950 m GLASSY BASALT

Same as above. Quite possibly a continuous formation from 938 or 940 m depth down to 958 m depth. The cuttings are very similar in the samples that were recovered from this interval. Sampling in this interval was discontinuous unfortunately, but there are no obvious changes in the lithological logs that suggest formation changes in this depth interval.

950–956 m NO CUTTINGS

956–958 m GLASSY BASALT

Same as above with abundant epidote.

958–960 m BASALTIC BRECCIA

Dense basalt grains, with fractures filled with epidote and quartz? Tuff mixed in.

960–968 m NO CUTTINGS

968–970 m FINE-MEDIUM GRAINED BASALT

Dense and light colored fine grained basalt. Various alteration between grains. Quartz and epidote in pores.

970–974 m NO CUTTINGS

974–976 m FINE-MEDIUM GRAINED BASALT

Fractured and dense basalt. Not porphyritic. Epidote and quartz in voids.

976–978 m NO CUTTINGS

978–1002 m FINE-MEDIUM GRAINED BASALT

Dark and fresh basalt grains (50%). The other 50% is green and highly altered basalt/tuff grains. Possibly intrusion is being penetrated.

1002–1006 m GLASSY BASALT

Less of intrusion like grains.

1006–1010 m NO CUTTINGS

1010–1018 m BASALTIC BRECCIA

White dense tuff grains with epidote in groundmass, slightly plagioclase-porphyriticok. Dense and fresh basalt grains mixed in. With reference to geophysical logs this unit is probably the upper part of an approximately 40 m thick unit of silicic intrusion.

1018–1020 m NO CUTTINGS

1020–1022 m BASALTIC BRECCIA

1022–1058 m BASALTIC TUFF

White and light-greyish cutting grains are dominant. Mixed within the cuttings are grey-greenish tuff grains, glassy basalt, fresh basalt grains and pinkish porous grains, possibly sediment or tuff. Abundant of quartz and epidote, and epidote increases downward. Increase in the gamma ray log suggests that the well intersects felsic rock at 1000–1035 m depth. The cuttings from 1022–1058 m are considered most likely to be from felsic rock but as definite determination of these cuttings is difficult through a binocular microscope, further analysis (i.e. chemical analysis and/or inspection of thin sections) is required.

1058–1068 m BASALTIC BRECCIA

Very few dark basalt grains. Altered grains slightly porous with fillings as above. Abundance of epidote.

1068–1070 m FINE-MEDIUM GRAINED BASALT

Light colored basalt. Very fine cuttings. Some amount of tuff mixed in. Most likely lava formation.

1070–1084 m BASALTIC BRECCIA

Grains again white in color with epidote and green clay in groundmass. Broken fragments from the drill bit mixed in. Grains become reddish downwards the formation.

1084–1122 m BASALTIC TUFF

Epidote almost 1/3 of the samples. Mostly white and green tuff grains and occasionally crystallized basalt is observed. The cuttings are very fine grained.

1122–1174 m BASALTIC BRECCIA

Fine grained basalt in a matrix of highly altered tuff and epidote crystals. Generally, rather tuff rich breccia with high amount of alteration minerals (clay, epidote, quartz, wollastonite and prehnite).

1174–1182 m GLASSY BASALT

Very fine cuttings with light colored fine grained basalt, glassy basalt and tuff grains.

1182–1210 m BASALTIC BRECCIA

More tuff grains than above. Plenty of alteration minerals like wollastonite and epidote. Very fine grained cuttings, light in color. Tuff grains white and green. Becomes very tuff rich at intervals.

1210–1234 m BASALTIC TUFF

Homogenous whitish tuff formation. Abundant of epidote. Few dark and fine grained basalt grains. Grains with plagioclase needles.

1234–1240 m BASALTIC BRECCIA

1240–1254 m BASALTIC TUFF

Some amount of basalt fragments, but still mostly tuff grains. White and green with pores filled with coarse grained clay and epidote. Some fragments from the drill bit.

1254–1268 m BASALTIC BRECCIA

Still abundance of epidote. Plagioclase in the groundmass as plagioclase-needles in partly crystalline and tuff grains.

1268–1270 m NO CUTTINGS

1270–1300 m BASALTIC BRECCIA

Green and white tuff grains with pores filled with epidote, clay, quartz and plagioclase in groundmass. Brownish fine grained basalt grains mixed in as well as some partly crystalline grains. Becomes very tuff rich at intervals.

1300–1306 m BASALTIC TUFF

Less of crystalline basalt grains.

1306–1322 m BASALTIC BRECCIA

Matrix of tuff, glassy basalt and crystalline grains. Clay and epidote in pores.

1322–1336 m GLASSY BASALT

Abundance of fine crystallized basalt grains, but still mixed with greenish tuff grains. Possibly a pillow basalt.

1336–1338 m NO CUTTINGS

No cuttings sampled

1338–1370 m BASALTIC BRECCIA

Tuff grains, some with plagioclase in groundmass, mixed with crystalline basalt. Pores are filled, mostly with clay. Not as abundant of epidote as above, but still plenty. Euhedral quartz. Some grains slightly fractured with white/clear fillings.

1370–1376 m GLASSY BASALT

More of reddish basalt grains with plagioclase in groundmass. As well as light colored basalt grains. Less tuff grains than above.

1376–1386 m BASALTIC BRECCIA

Clay and epidote in pores.

1386–1398 m GLASSY BASALT

Mostly crystalline-and partly crystalline basalt with plagioclase needles.

1398–1424 m BASALTIC BRECCIA

Very fine cuttings, mixed with crystalline basalt, green tuff and partly crystalline basalt (glassy). Abundant of epidote.

1424–1428 m FINE-MEDIUM GRAINED BASALT

Very fine cuttings with fine grained and well crystallized basalt. Still a few grains with glass in the groundmass. Decrease in epidote. Some tuff grains from above mixed in.

1428–1434 m BASALTIC BRECCIA

Mostly glass rich grains and tuff. Some crystallized grains from above.

1434–1452 m GLASSY BASALT

A lot of fine grained light grey basalt grains. Possibly intrusion. White and green glass rich grains with plagioclase in groundmass.

1452–1466 m FINE-MEDIUM GRAINED BASALT

Very fine cuttings. Highly altered basalt. Some tuff grains mixed in. Possibly a pillow basalt formation. Abundant of epidote. Alteration minerals mostly epidote, clay, quartz and wollastonite.

1466–1474 m BASALTIC BRECCIA

Mostly white and green tuff grains. Epidote and coarse grained clay in groundmass. Few well crystallized basalt grains.

1474–1478 m GLASSY BASALT

Epidote rich mixture of tuff and crystallized or partly crystallized grains.

1478–1484 m BASALTIC TUFF

Plenty of well crystallized epidote. Some crystallized rock fragments.

1484–1494 m BASALTIC BRECCIA

More of crystallized rock fragments, but still tuff rich. Plagioclase and glass in the groundmass of partly crystalline grains.

1494–1542 m BASALTIC TUFF

Thick formation of basaltic tuff. Plenty of epidote and slightly various amount of crystallized rock fragments. Mostly white and green tuff grains, highly altered. In some cases, the tuff is totally white. Plagioclase needles often seen in the groundmass.

1542–1564 m BASALTIC BRECCIA

Partly crystallized grains with glass and plagioclase needles in the groundmass. Very similar to what was seen above, Very tuff rich and epidote rich. Could be the same tuff formation as above.

1564–1596 m GLASSY BASALT

Dark and glassy grains, some with pl-needles. Some tuff grains with clay and epidote in pores. High amount of epidote. Cuttings often very fine grained and mixed. Various amount of crystalline grains.

1596–1608 m FINE-MEDIUM GRAINED BASALT

Altered fine to medium grained basalt mixed with grains with glass rich groundmass. Could be pillow basalt formation, or just mixed cuttings. High abundance of epidote. Well crystallized grains often partly transparent with magnetite in the groundmass. Highly altered.

1608–1616 m GLASSY BASALT

Slight increase in tuff from above. Well crystallized grains with clinopyroxene crystals and pyroxen altered to chlorite. Some grains very fine grained and dark grey in color.

1616–1620 m FINE-MEDIUM GRAINED BASALT

More of the crystallized grains from above. Could be a scoria formation due to the amount of glass rich grains.

1620–1630 m GLASSY BASALT

Glass rich grains 50% crystallized grains 50%

1630–1656 m BASALTIC BRECCIA

Lesser amount of fine grained basalt grains than above. Pyroxene seen altered into chlorite. Plagioclase needles in the groundmass. Still high abundance of epidote. White and green tuff grains and glass rich grains. Variable amounts of tuff in the samples. Pores filled with clay, epidote and quartz.

1656–1692 m GLASSY BASALT

Very fine cuttings. Mixture of fine crystallized basalt, white and green glass rich grains and dark grains with glassy groundmass. Abundant of epidote.

1692–1714 m FINE-MEDIUM GRAINED BASALT

Mostly light colored fine crystallized basalt, some plagioclase phorphyric and with magnetite in the groundmass. Clinopyroxenes mostly altered to chlorite. Still some green and white tuff grains. Most likely a lava formation. Decrease in epidote.

1714–1728 m GLASSY BASALT

An increase in the amount of glass-rich grains. No clear formation boundaries.

1728–1742 m FINE-MEDIUM GRAINED BASALT

Similar to the upper lava formation.

1742–1750 m GLASSY BASALT

Mixture of light grey fine grained basalt and green glassy grains/tuff.

1750–1784 m FINE-MEDIUM GRAINED BASALT

Still some glass rich grains wit plagioclase needles. But mostly light colored fine crystallized basalt grains. Wollastonite and epidote the main alteration minerals.

1784–1788 m BASALTIC BRECCIA

1788–1810 m NO CUTTINGS

No samples were retrieved due to circulation losses between 1788–1822 m.

1810–1820 FINE-MEDIUM GRAINED BASALT

Transparent, white and greenish fine grained basalt. Magnetite seen in the groundmass. Epidote color and very few epidote crystals. Relatively small amounts of alteration minerals such as epidote, quartz, clay and wollastonite. No pore fillings observed and the grains do not appear to be fractured. Fragments from the drill bits seen in the cuttings. Minor amounts of chalcopyrite.

1820–1866 m BASALTIC BRECCIA

Greenish and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. glassy basalt and tuff. Slightly more crystallized basalt grains mixed in around 1860 m depth. Wollastonite occurs regularly. Minor sulfites both pyrite and probably pyrrhotite.

1866–1870 m: BASALTIC TUFF

Greenish, yellow and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. tuff. "Polka dot" grains with white circular spots probably vesicle fillings, fairly common.

1870–1916 m: FINE-MEDIUM GRAINED BASALT

This depth interval is characterized by a greater proportion of altered fine-grained basalts mixed with tuff and originally glassy basalt grains. Formation boundaries are not sharp. From 1910 to 1918 and at 1926 to 1928 the formation may be classified as a breccia. It should be noted that there is considerable mixing apparent in the cuttings and additionally there is some sorting according to grains size during transport to the surface.

A modest peak in both resistivity- and neutron log is probably an indication of fairly well crystallized basalt rather than an intrusion.

1916–1924 m: NO CUTTINGS

1924–1936 m: BASALTIC BRECCIA

Similar to the breccia above. Yellowish, light green and white grains most prominent. Mixed in with fine-grained greyish basalt. Epidote, and quartz along with chlorite and wollastonite are the most prominent alterations minerals. Several examples of wollastonite precipitating after epidote and/or quartz.

1936–1942 m: FINE-MEDIUM GRAINED BASALT

This depth interval is characterized by a greater proportion of altered fine-grained basalts mixed with tuff and originally glassy basalt grains. Again formation boundaries are not sharp.

1942–1948 m: BASALTIC BRECCIA

Similar to the breccia above. Yellowish, light green and white grains most prominent. Mixed in with fine-grained greyish basalt. Epidote, and quartz along with chlorite and wollastonite continue to be the most prominent alterations minerals.

1948–1964 m: FINE-MEDIUM GRAINED BASALT

Altered medium to coarse grained basalt. Difficult to assign original rock type with certainty. Cuttings are fine-grained, single crystal grains are common. Alteration minerals as before in addition there are minor amounts of pyrite and possibly pyrrhotite

1964–1982 m: BASALTIC BRECCIA

Again very similar to the breccia above. Light yellowish, green and whitish colors dominate. Epidote, and quartz along with chlorite and wollastonite continue to be the most common alterations minerals. Delicate wollastonite crystals are more common in samples that are affected by polymer pills.

1982–2008 m: FINE-MEDIUM GRAINED BASALT

Fine-medium grained basalt grey to grey-green basalt fragments. Plagioclase is very common probably fragments of phenocrysts from a plagioclase porphyritic lava sequence. Alteration minerals are mainly epidote, chlorite, quartz and wollastonite as before. A trace of calcite appears at 2004 m sulfides (pyrite) were identified in small amounts in a couple of samples.

2008–2018 m: BASALTIC BRECCIA

Greenish and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. glassy basalt and tuff. Mixed with slightly more crystallized basalt grains. Alteration minerals as before. Trace of calcite and pyrite in sample from 2028 m.

2018–2066 m: MEDIUM-COARSE GRAINED BASALT

Greyish looking medium to coarse grained basalt. Not as altered as the formations above. This is either a sequence of thick lava-flows or possibly intrusions. Particularly the depth interval from 2048 to 2058 is a possible intrusion, also around 2072 m. Alteration minerals as before. Trace of pyrite in a few samples.

2066–2072 m: BASALTIC BRECCIA

Similar to the breccia above. Typically, the cuttings are very fine grained. A high proportion of the grains are individual fragments of alteration minerals and sometimes primary minerals.

2072–2078 m: MEDIUM-COARSE GRAINED BASALT

Very similar to the unit described above. (2030 – 2078 m).

2078–2084 m: BASALTIC BRECCIA

Again very fine cuttings. The apparent alternating layers of breccia and crystallized basalt may be an artifact of grain size sorting in the water-column in the well.

2084–2096 m: MEDIUM-COARSE GRAINED BASALT

Similar to the unit described above. Either very thick flows (less permeable and therefore less altered or possibly intrusions.

096–2118 m: ALTERNATING BASALTIC BRECCIA AND MEDIUM GRAINED BASALT

Only a few cutting samples were obtained in this interval. Apparently breccia is alternate with medium to coarse grained basalts.

2118–2212 m: NO CUTTINGS

No cuttings below 2118 m (MD).

3.2 Intrusions

Only a few intrusions and possible intrusions were encountered during the drilling of this phase of well ÞG-11. The first intrusion in phase 3 was identified at 978–986 m (MD), it consists of a dark fine grains basalt with low alteration. Another intrusion was then clearly observed at 1000–1002 m (MD) where the cuttings mostly consisted of dark and fresh, fine grained dark basalt. A greater depth, several fragments of intrusive basaltic rocks were noticed in the cuttings mixed with other lithology, at 1436–1440 m and below 2000 m at 2048–2060 and 2070–2076 m. Between 2100 and 2106 m, a medium to coarse basaltic unit could be a thick lava flow or an intrusion. The neutron-neutron response is uniform for all the well and does not indicate highly dense intrusions.

3.3 Alteration

The most common high temperature alteration minerals in phase 3 of ÞG-11, are quartz (180°C), epidote (230°C), coarse grained clay/chlorite (230°C) and below 970 m prehnite (240°C), wollastonite (260°C) and actinolite (280°C) were noticed. Calcite is absent below 980 m, except for sporadic occurrences 1066–1074 m. Based on the disappearance of calcite and vast amount of epidote along with the high temperature minerals wollastonite and prehnite, the estimated rock temperature in the well is at least 280°C below ~1000 m (MD). Figures 11–13 show examples of alteration minerals (coarse grained clay, epidote and wollastonite) seen in the drill cuttings in ÞG-11.

Pyrite was found in various amounts down to approximately 1100 m, where it almost disappeared from the cuttings, but is still seen occasionally in very low amounts down the well.

To summarize: Quartz, epidote and coarse grained clay are seen continuously in almost every sample in phase 3. Wollastonite and prehnite are found repeatedly, but are not as continuous as quartz, epidote and clay. Actinolite was found in a few samples from 1594 m depth (MD), indicating formation temperatures around or higher than 280 °C.

Prior to the drilling of ÞG-11, it was expected, based on the other wells, that the formation temperature would more or less follow the boiling point depth curve to bottom. The alteration mineral assembly seen in the drill cuttings supports that hypothesis.

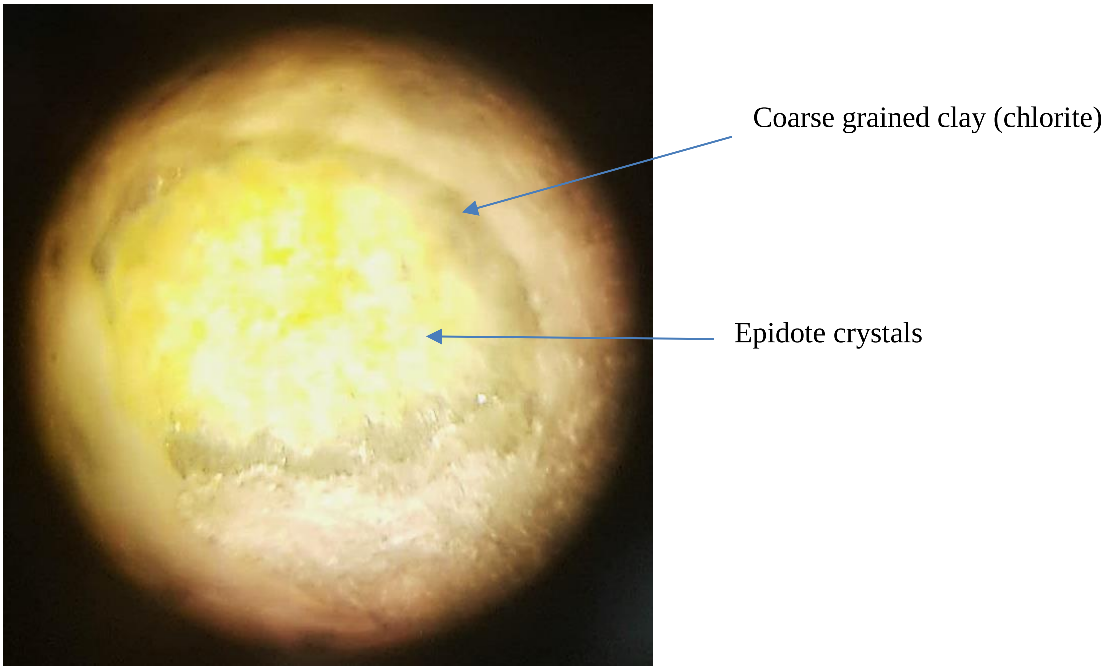

Figure 11. *Pore filling. Rim of coarse grained clay, with epidote crystals in the middle.*

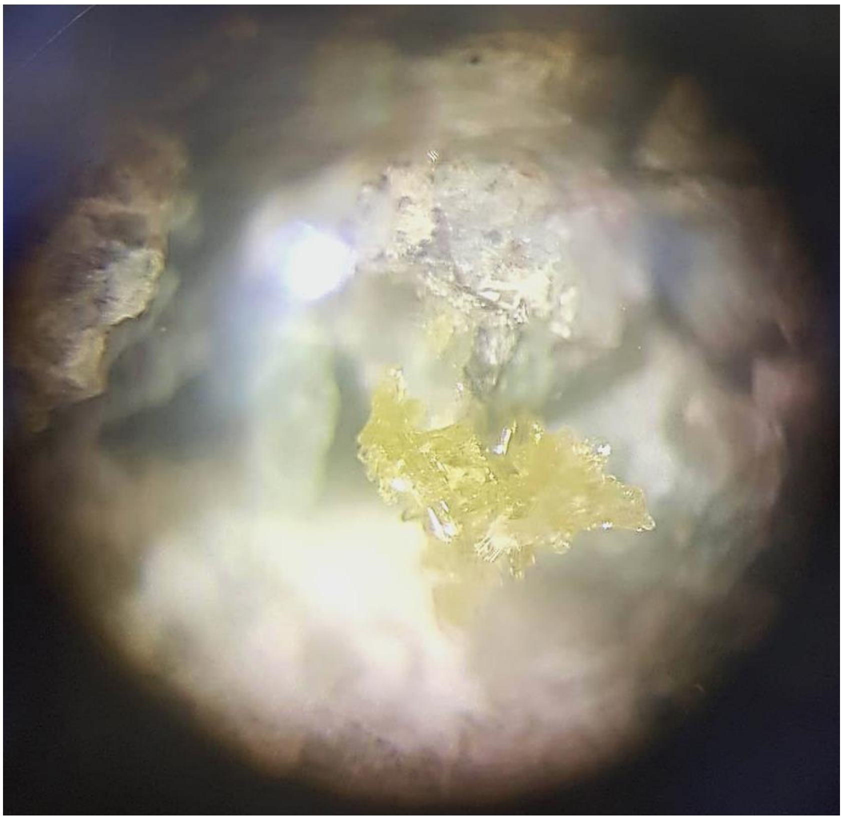

Figure 12. *Well shaped epidote crystal seen in the binocular microscope*

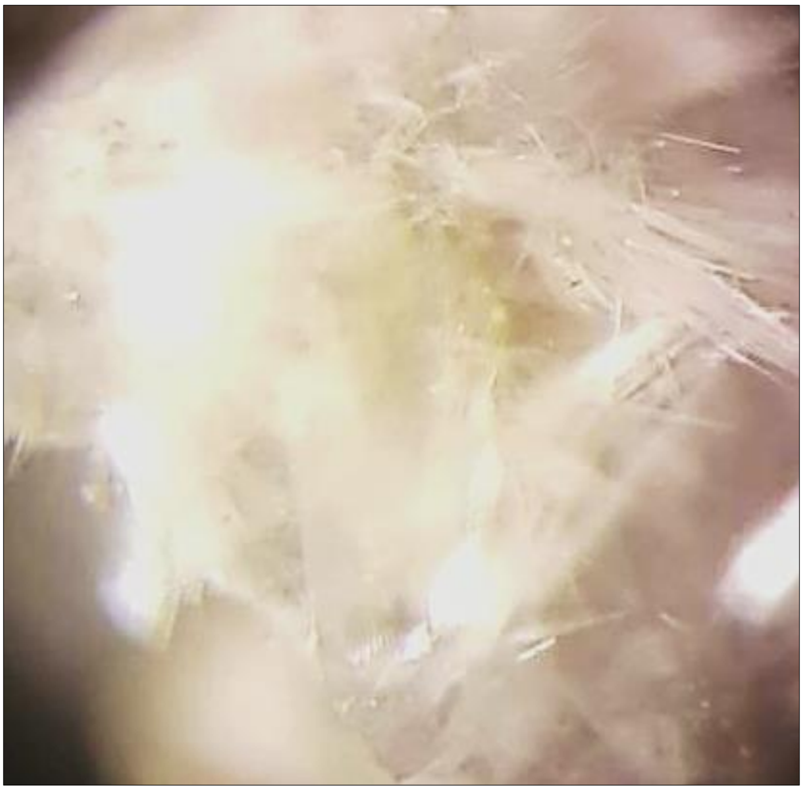

Figure 13. *Wollastonite needles seen in the binocular microscope.*

3.4 Circulation losses during drilling

The evolution of circulation losses in well ÞG-11 is shown in Table 4. First circulation losses occurred at about 1318 m depth and were evaluated to 17–20 L/s, they stayed quite steady down to about 1354 m where they were about 18 L/s and then started to decrease to about 7 L/s at 1443 m and stabilized at about 9 L/s from 1552 m.

Around 1634 m, the losses were only 6 L/s but started increasing gradually to 14 l/s in the 1700´s. While changes drill bit at 1785 m the well opened and the loss increased to 39 l/s which was the about the capacity of the water supply (~43 l/s). The loss decreased when drilling resumed but returns from the well were very sporadic between 1785 and 2130 m and losses stayed high, and several intervals of full losses occurred until continuous total loss started at 2130 m and stayed down to the bottom of the well. At around the same depth, several intrusions of fine grains basalt were noted by the wellsite geologist (2048–2060, 2070–2076 and 2100–2106 m) and could be linked to these major loss circulation zones.

Table 4. *Circulation losses during drilling of phase 3 of ÞG-11.*

Date	depth (m)	Loss circulation (L/s)	Comment
9.7.2016	1318	17-20	
10.7.2016	1354	18	
10.7.2016	1443	7	Losses gradually decrease
10.7.2016	1472	8	
10.7.2016	1552	9	Losses stabilized at 9 L/s
10.7.2016	1563	9	
11.7.2016	1609	9	
11.7.2016	1634	6	Loss zones between 1630 and 1700 shown on temperature log run on 11.07.2016
11.7.2016	1710	13	
11.7.2016	1729	14	
11.7.2016	1748	14	Start increasing
12.7.2016	1785	39	First full losses
16.7.2016	2048	22	Occasional returns
16.7.2016	2070	36	Occasional returns
17.7.2016	2139	43	Total loss from 2130 m to total depth at 2224 m

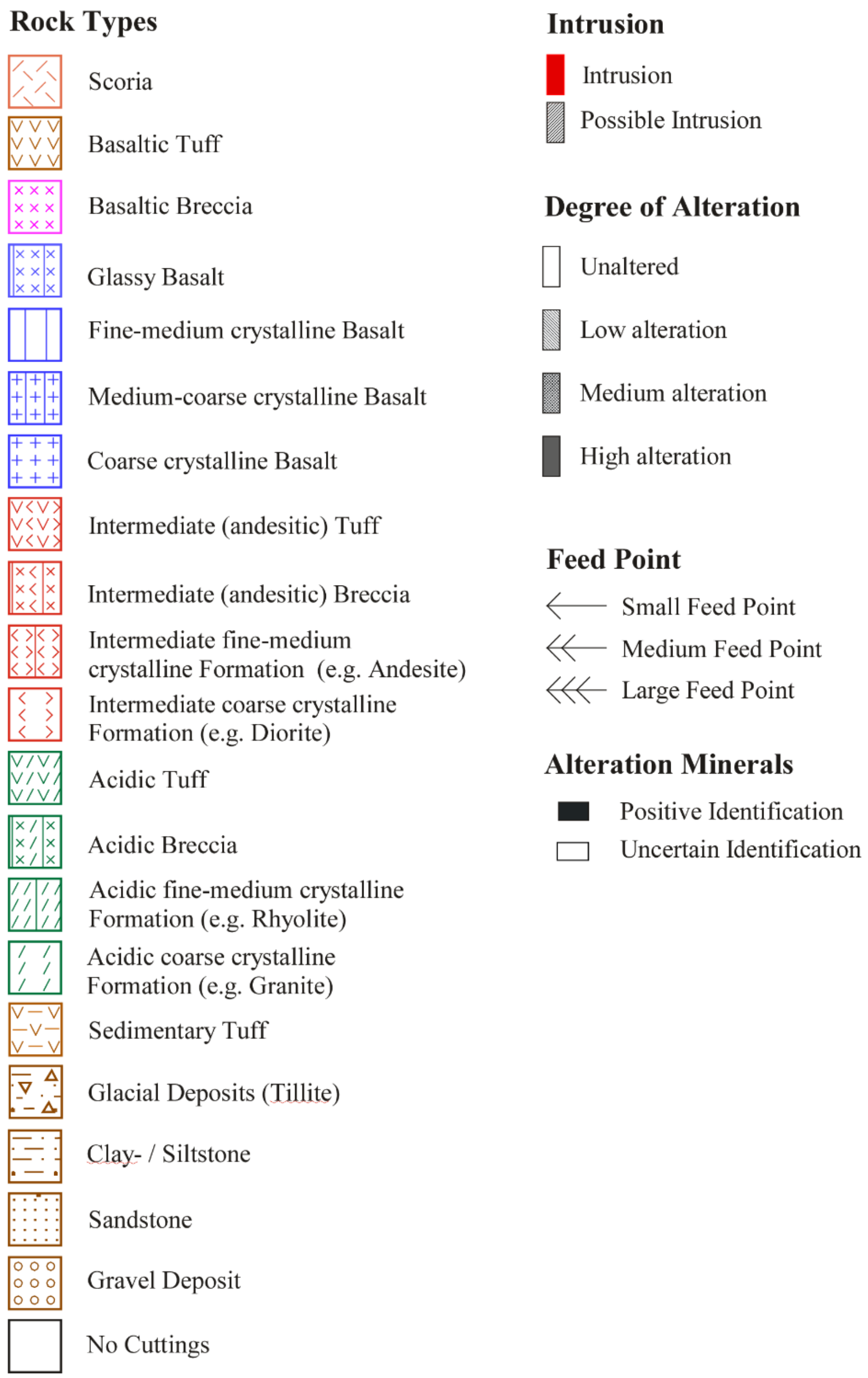

Figure 14. *Legend for Figures 15 to 18.*

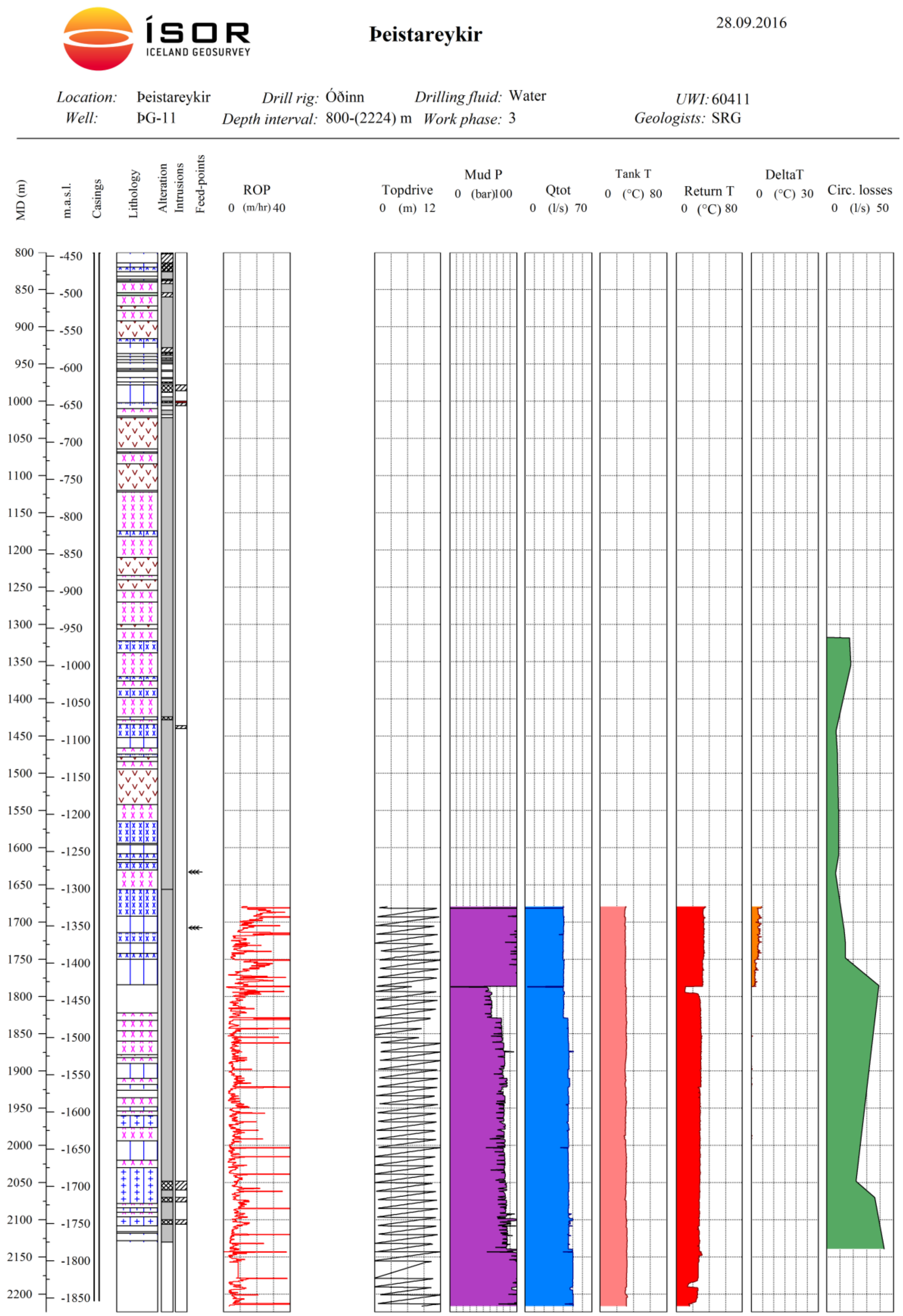

Figure 15. *Lithology and drilling data from 800 to 2224 m in ÞG-11.*

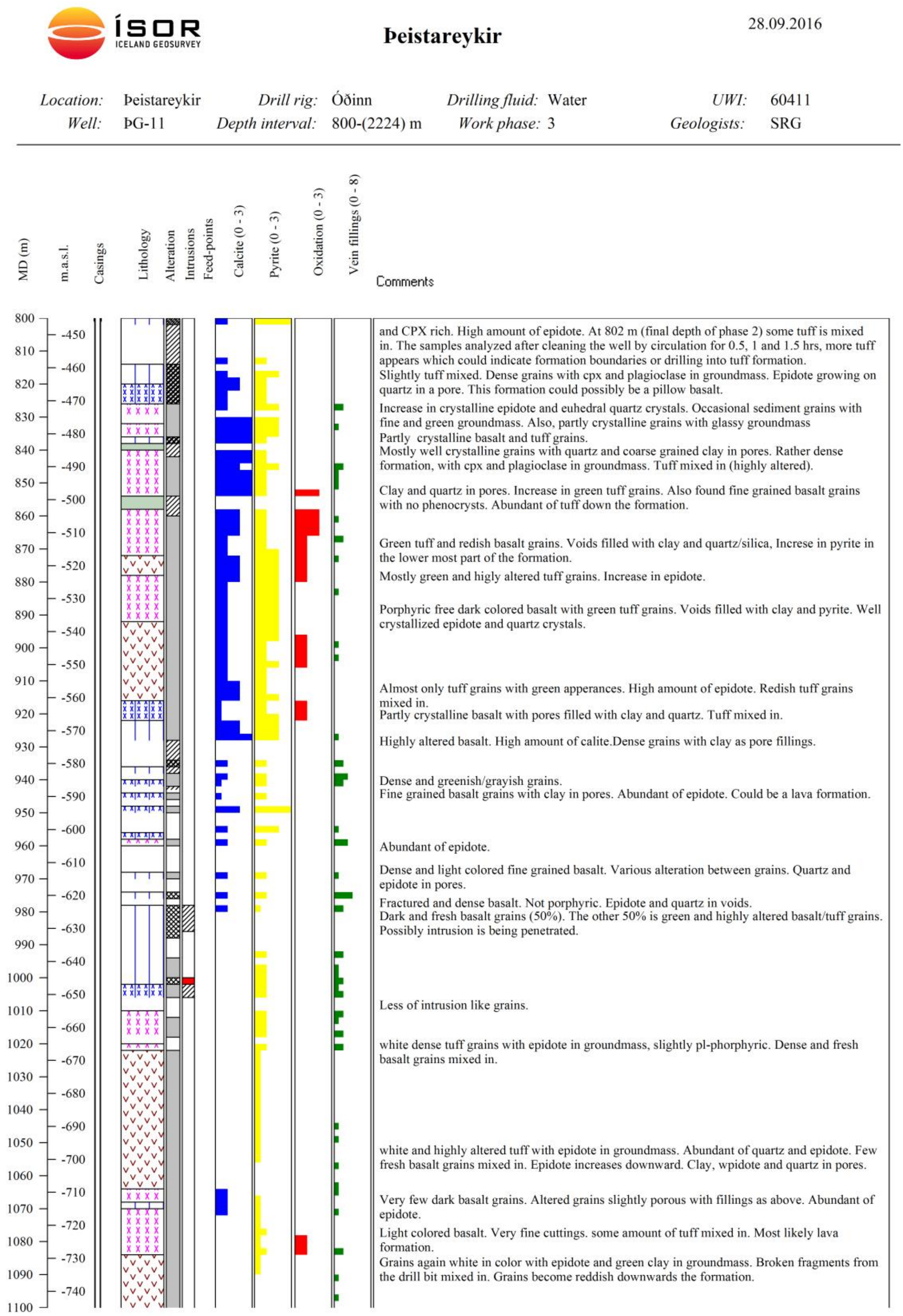

Figure 16. *Lithology and descriptions from 800 to 2224 m in ÞG-11.*

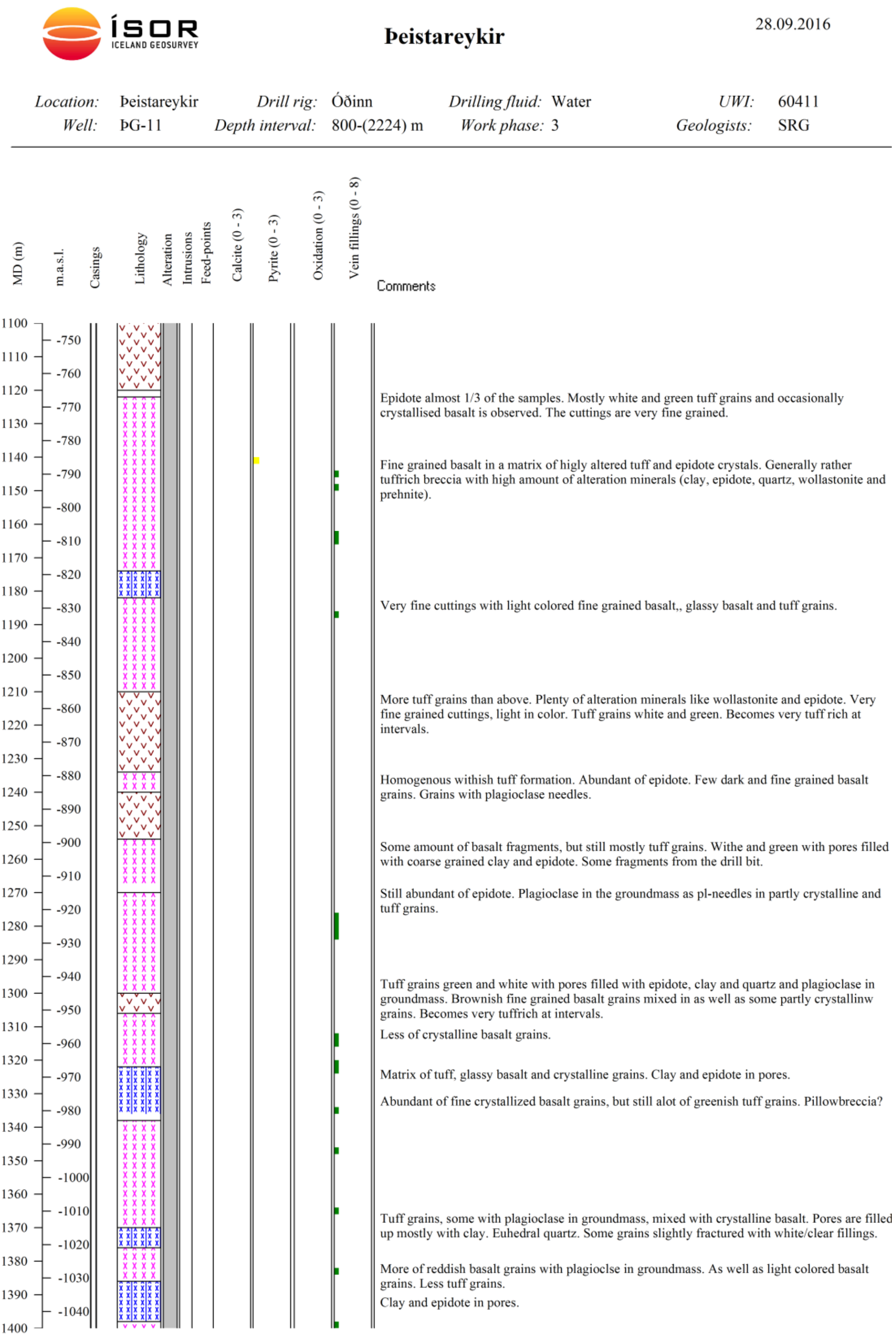

Figure 16. *(Cont.) Lithology and descriptions from 800 to 2224 m in ÞG-11.*

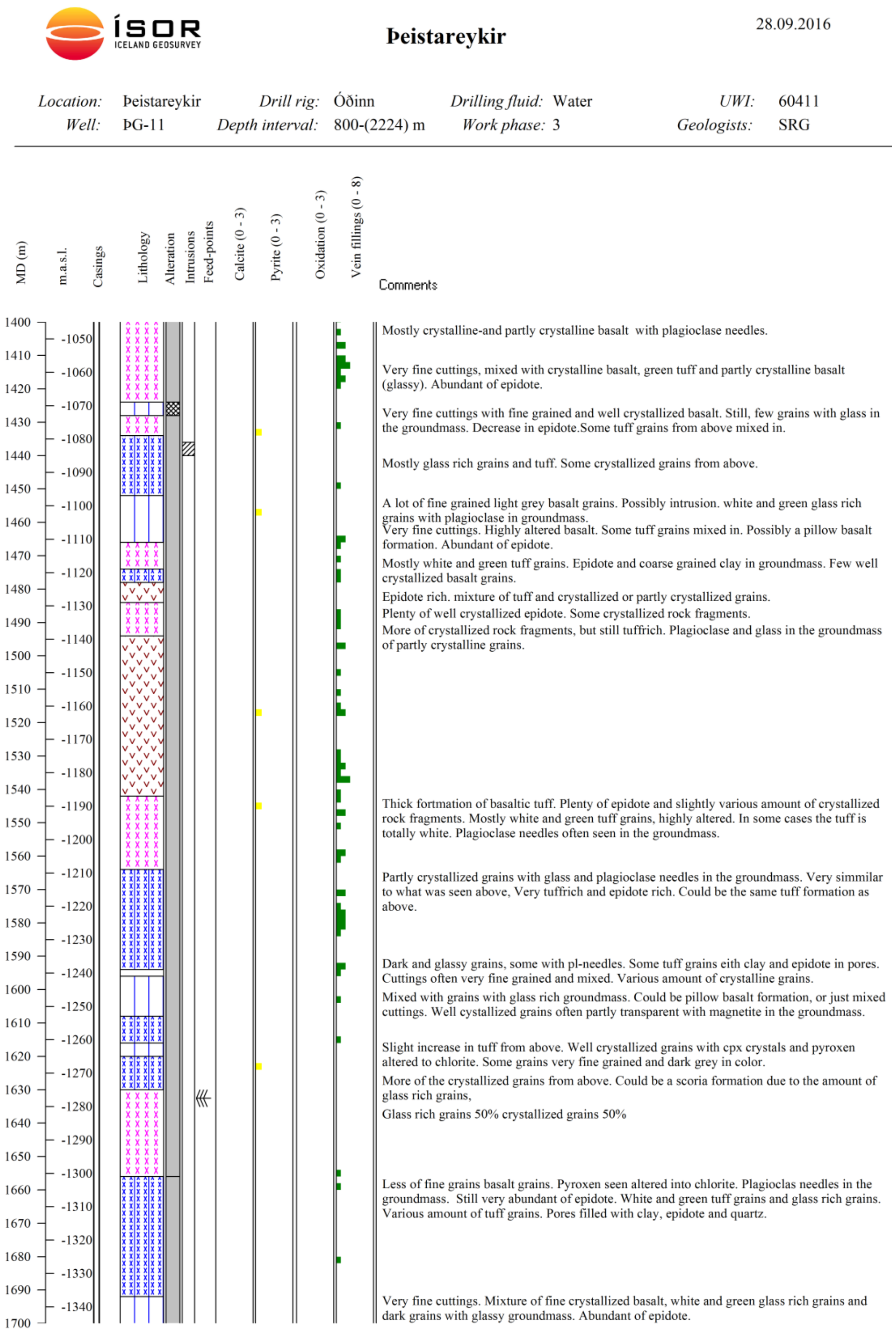

Figure 16. *(Cont.) Lithology and descriptions from 800 to 2224 m in ÞG-11.*

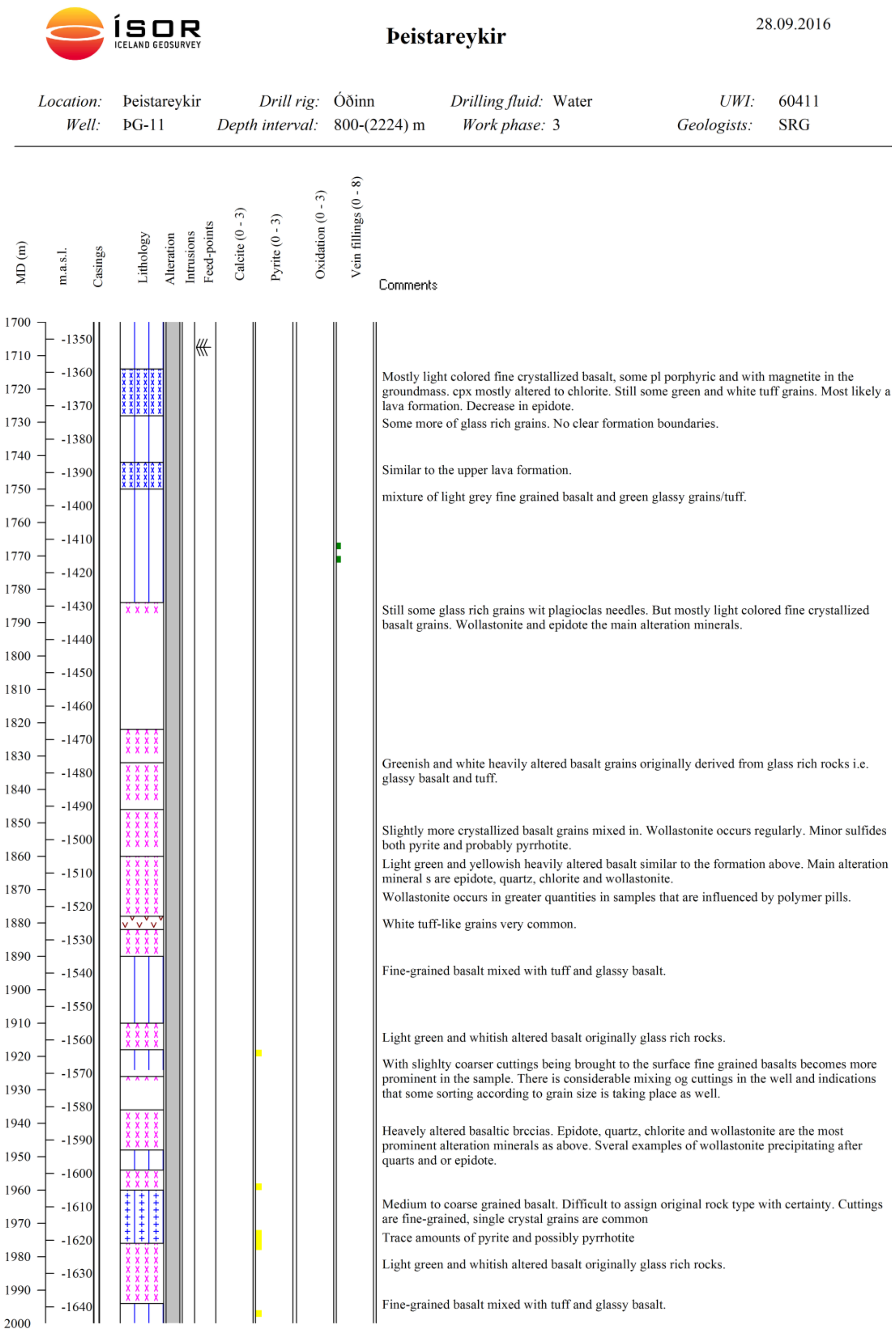

Figure 16. *(Cont.) Lithology and descriptions from 800 to 2224 m in ÞG-11.*

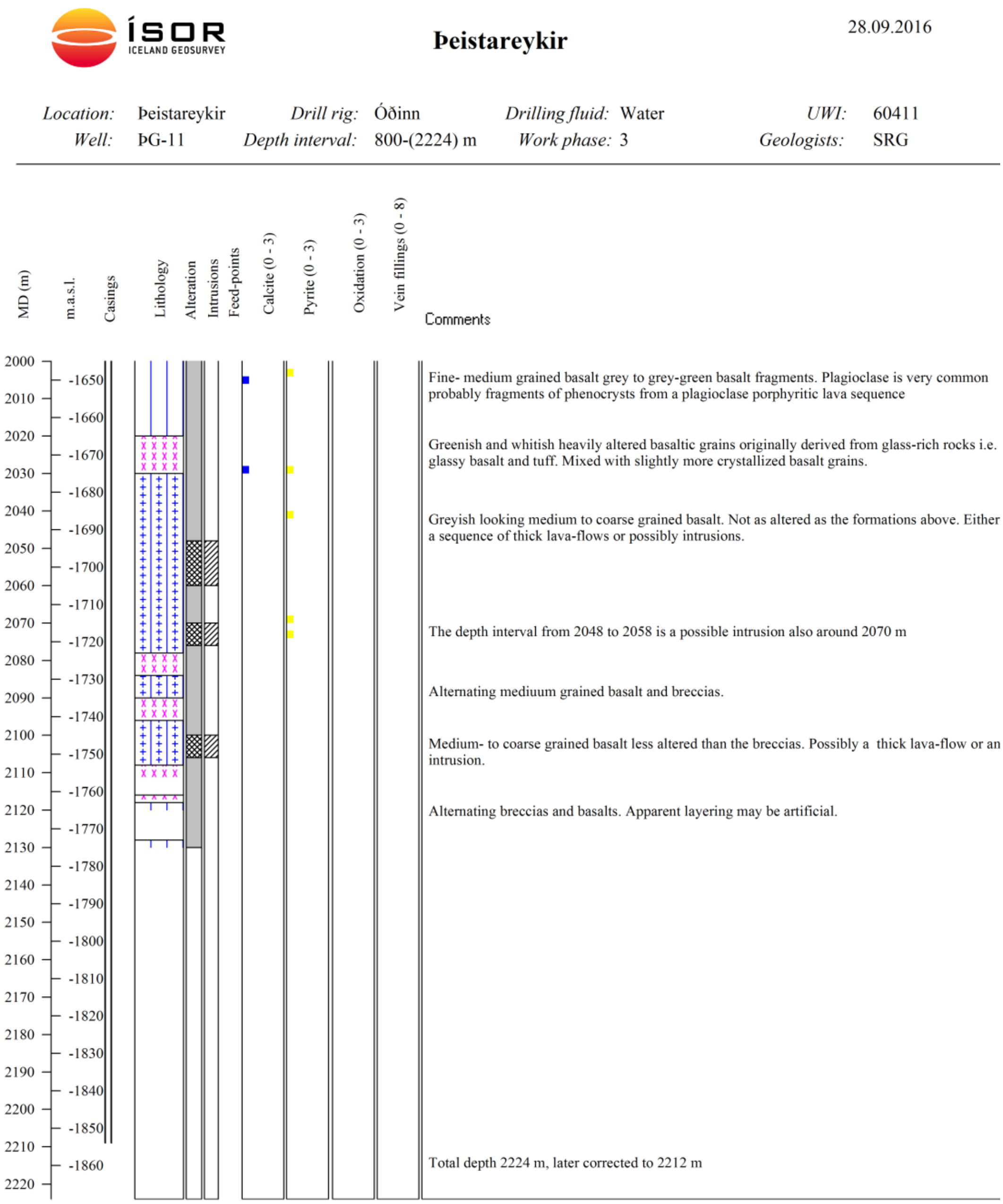

Figure 16. *(Cont.) Lithology and descriptions from 800 to 2224 m in ÞG-11.*

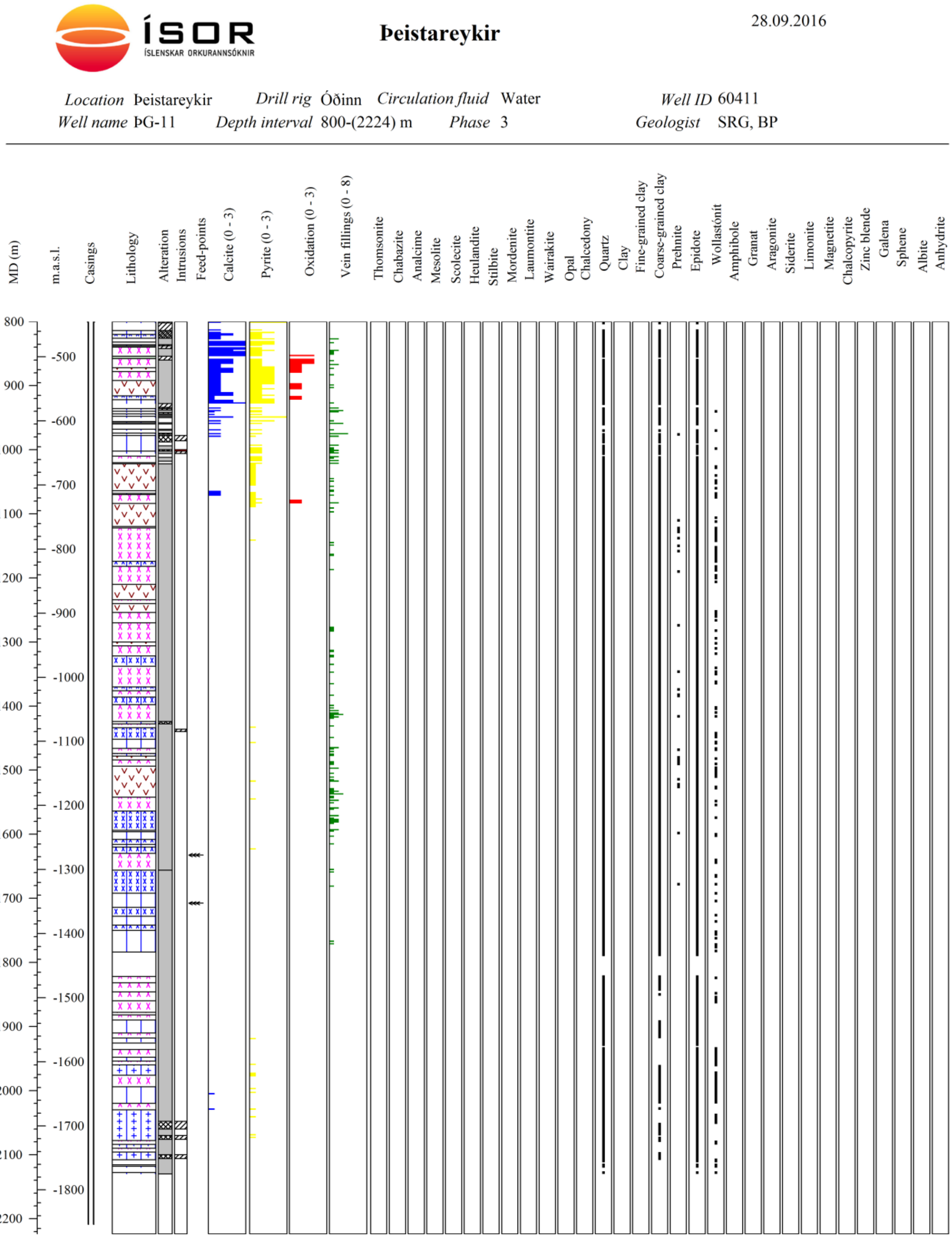

Figure 17. *Alteration minerals for phase 3 in ÞG-11.*

3.5 Comparison with well ÞG-9

Correlation of the lithological units between wells ÞG-11 and ÞG-9 for phase 3 is more complex than for the previous phases given the ÞG-11 is directionally drilled toward the south whereas ÞG-9 is a vertical well. Consequently, the distance between the two wells is increasing with depth and the measured depths in both wells doesn't correspond to the same vertical depth. Comparison must be done using the true vertical depth of ÞG-11 calculated using the results of the gyro survey. The measured depth of 800 m in well ÞG-11 corresponds to a depth of about 450 m in well ÞG-9.

Several lithological segments could be correlated between the two wells (Figure 18):

- Both wells are mostly composed of hyaloclastite formation, alternating between basaltic breccia, basalt tuffs and glassy basalt formations,
- Some intrusive rocks are found between 900 and 1000 m (true depth ~550 to 650 m) in ÞG-11 and could correspond to the intrusive rocks encountered between 700 and 800 m in well ÞG-9 (described as intrusive in ÞG-9),
- Basaltic flows found in ÞG-11 from 1692 to 1788 m (true depth ~1340 to 1430 m) seem to match with basaltic flows described in well ÞG-9 from 1256 to 1440 m,
- Same for the basaltic flow from 1994 to 2130 m in well ÞG-11 (true depth ~1640 to 1770 m) with the basaltic flow in well ÞG-9 from 1670 to 1768 m, which also include intrusive basaltic rocks intervals in both wells.

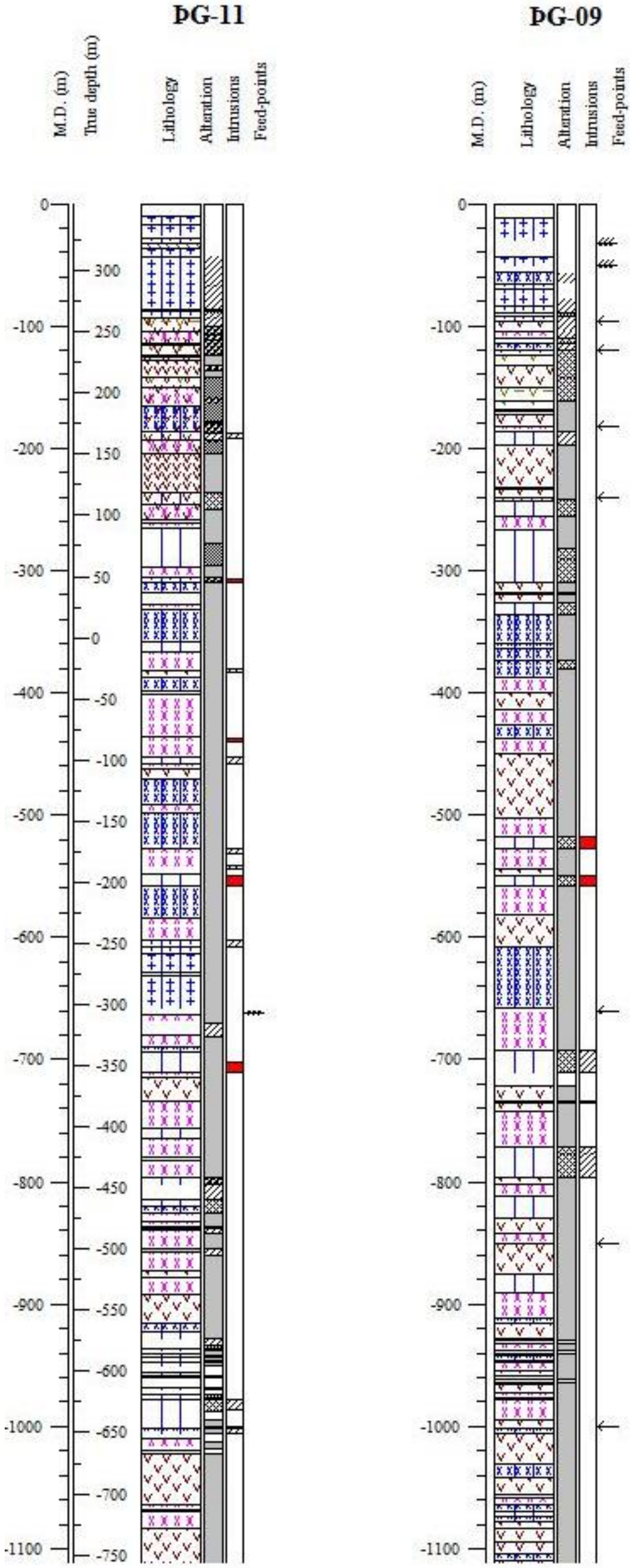

Figure 18. *Comparison of the lithology of wells ÞG-11 and ÞG-9*

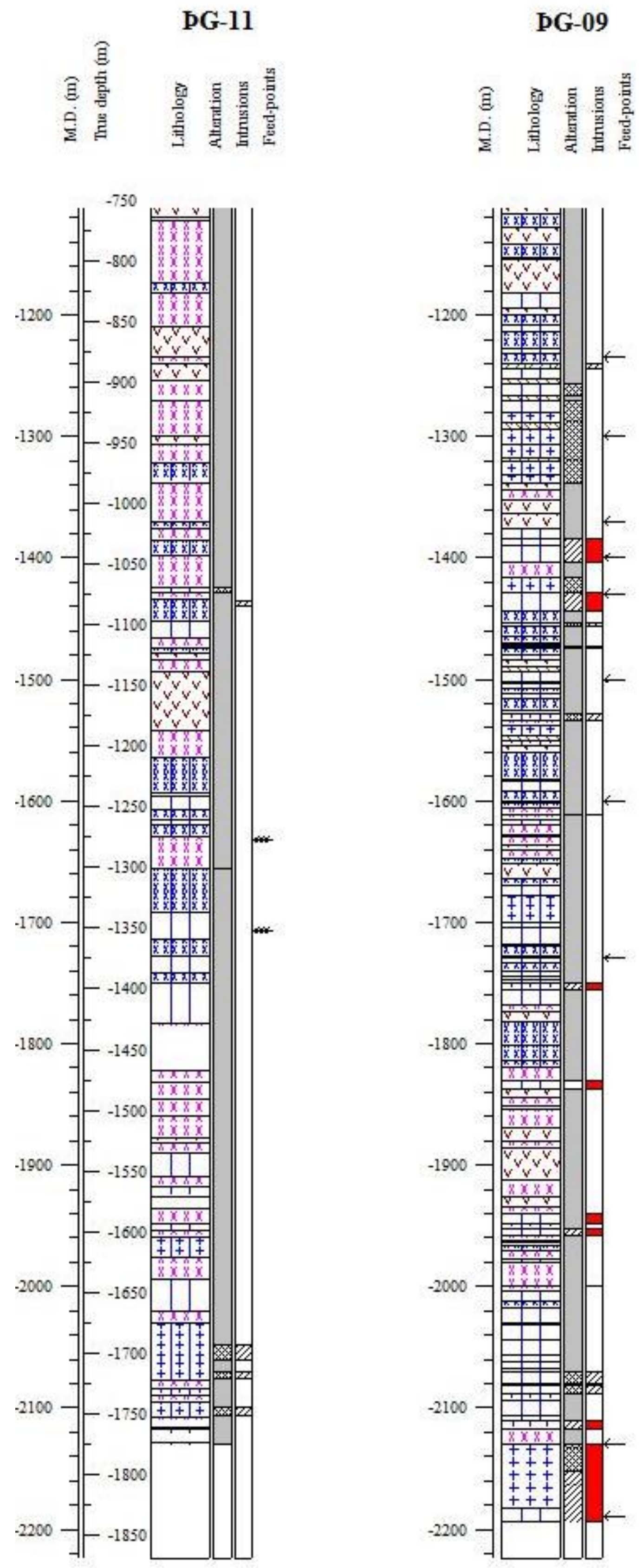

Figure 18. *(Cont.) Comparison of the lithology of wells ÞG-11 and ÞG-9*

4 Wireline logging

Wireline logging in the 3rd phase of drilling may be categorized as follow:

- Gyro logs to measure azimuth and inclination in order to check if the well path is within acceptable limits.
- Temperature log in open hole in order to map its temperature profile and locate feed zones. The temperature conditions in the well also decides if other geophysical logs can be conducted, depending on the maximum temperature limits of the various logging tools.
- Caliper log to map the well's shape, i.e. cavities and possible obstacles inside the well that require further reaming. In addition, the caliper log gives a good reference for the interpretation of televiewer data.
- Lithological logs to get physical information on the formations that the well intersects. This includes resistivity logs, neutron-neutron response and natural gamma radiation.
- Acoustic televiewer log in order to map the fracture structure of the well and determine fault direction (strike) and inclination (dip) mainly aimed at open zones.
- Flow measurements with spinner in order to locate feed zones of the production part of the well and estimate flow in or out of the feed zones.
- Multi-rate injection test in order to obtain permeability information. Also, to get information on reservoir and well properties that govern the flow towards and into the well.

In this chapter the logging activity and the logging results for the drilling of the production part of well ÞG-11 are introduced and discussed except the acoustic televiewer data, which will be processed and reported in a stand-alone report. Overview of the wireline logs carried out in phase 3 is shown in Table 5.

Table 5. *Overview of wireline logging in drilling phase 3 of well ÞG-11.*

Date	Time	Log type	Depth [m]	Purpose	Q [L/s]	Remarks
04-JÚL-16	23:00-23:30	Temperature	0-772	Temperature	0	Heating up since 13th of June when the production casing was cemented.
04-JÚL-16	23:00-23:30	Pressure	0-772	Pressure	0	Heating up since 13th of June when the production casing was cemented.
07-JÚL-16	21:39-23:05	Gyro	811-811	Azimuth and Inclination	-15	Single recording at 811 m.
08-JÚL-16	18:13-19:20	Gyro	640-984	Azimuth and Inclination	-16	Single shots at 983, 940, 890, 840, 740 and 690 m. Injection stopped during log.
09-JÚL-16	12:19-12:28	Gyro	983-1165	Azimuth and Inclination	-16	Single shots at 1162, 1130, 1080, 1030 and 983 m.
11-JÚL-16	13:06-14:36	Gyro	1130-1641	Azimuth and Inclination	-16	Single shot at 1641, 1600, 1550, 1450, 1350, 1250 and 1130 m.
13-JÚL-16	00:46-01:38	Temperature	2-1778	Temperature	-13	Tool hung up at 1778 m.
13-JÚL-16	03:22-04:36	Caliper, Y	740-1751	Well diameter	-13	
13-JÚL-16	03:22-04:36	Caliper, X	740-1751	Well diameter	-13	
13-JÚL-16	07:12-11:42	Televiewer	764-1401	Fractures	-13	Two recordings in high lateral resolution: 1401 m to 1225 m and 1230 m to 764 m. Tool hung up at 1401 m.
15-JÚL-16	10:44-12:45	Gyro	1600-1892	Azimuth and Inclination	-29	Single shots at 30 m interval from 1892 to 1600 m.
18-JÚL-16	07:36-07:46	Inclination	1850-2116	Inclination	-30	Single shots from 1850 m to 2116 m.

Table 5. *(Cont.)*

Date	Time	Log type	Depth [m]	Purpose	Q [L/s]	Remarks
20-JÚL-16	19:30-20:48	Temperature	0-2191	Temperature-loss zones	-11	Inside drill string. Injection on kill line.
20-JÚL-16	20:50-22:13	Temperature	2190-2190	Temperature	-30	30 L/s from 20:52, T_{start}=53°C T_{end}=60°C, 11,4 L/s at 21:53. 5 L/s on DS at 21:53.
20-JÚL-16	22:14-23:05	Temperature	10-2189	Temperature	-16	Inside drill string with injection. Temperature log before gyro
21-JÚL-16	01:48-03:36	Gyro	2187-30	Azimuth and Inclination	-30	25 L/s on kill line. Continuously sampled, uploaded with 1 m interval.
21-JÚL-16	14:48-15:11	Temperature	0-750	Temperature-loss zones	0 (-15)	Unexpected heating inside casing. The log stopped and injection rate increased in order to cool the well. No water was injected!!
21-JÚL-16	15:11-16:00	Temperature	750-750	Heat-up	-35	Injection rate changed from 0 to 35 L/s.
21-JÚL-16	16:00-17:04	Temperature	750-2210	Temperature-loss zones	-35	35 L/s put on at 15:18 Temperature from 96 to 35°C.
21-JÚL-16	17:25-17:34	Temperature	2100-2210	Temperature-loss zones	-40	Injection rate changed from 35 to 40 L/s at 17:09.
21-JÚL-16	17:35-18:40	Temperature	25-2210	Temperature-loss zones	-40	
21-JÚL-16	19:54-21:45	Caliper, X	750-2208	Well diameter	-41	Measurements adjusted to casing ID (220.5 mm for 9 5/8 in of K55).
21-JÚL-16	19:54-21:45	Caliper, Y	750-2208	Well diameter	-41	Measurements adjusted to casing ID (220.5 mm for 9 5/8 in of K55).
22-JÚL-16	00:42-06:00	Televiewer	1350-2208	Fractures	-41	4 mm vertical resolution, 144 samples/circ. Max caliper set to 13 in.
22-JÚL-16	09:17-11:40	Neutron	773-2211	Lithology	-40	
22-JÚL-16	09:17-11:40	Gamma	772-2210	Lithology	-40	
22-JÚL-16	14:14-15:05	Resistivity 16"	789-2209	Lithology	-40	61V; 0,88mA in wet green field, SP offset changed to 123 @ 1795 m. Mud-tank conductivity 190 µS/cm @ 24.5°C
22-JÚL-16	14:14-15:05	Resistivity 64"	788-2207	Lithology	-40	--- ditto ---
22-JÚL-16	14:14-15:05	SP	800-2208	Lithology	-40	--- ditto ---
24-JÚL-16	02:30-03:22	Temperature	0-2200	Injection test	0 (-14.9)	
24-JÚL-16	02:30-03:22	Pressure	0-2200	Injection test	0 (-14.9)	
24-JÚL-16	02:30-03:22	Flow	0-2200	Injection test	0 (-14.9)	Tool speed +45 m/min.
24-JÚL-16	03:55-04:22	Flow	730-2200	Injection test	0 (-14.9)	Tool speed +55 m/min.
24-JÚL-16	04:22-04:49	Flow	730-2200	Injection test	0 (-14.9)	Tool speed -55 m/min.
24-JÚL-16	04:49-05:12	Flow	730-2200	Injection test	0 (-14.9)	Tool speed +65 m/min.
24-JÚL-16	05:12-05:35	Flow	730-2200	Injection test	0 (-14.9)	Tool speed -65 m/min.
24-JÚL-16	05:35-05:48	Flow	730-1780	Injection test	0 (-14.9)	Tool speed +75 m/min.
24-JÚL-16	05:48-12:26	Temperature	1780-1780	Injection test		Injection rate changed: 0 L/s to 23.9 L/s at 06:00 23.9 L/s to 36.2 L/s at 08:20 36.2 L/s to 19.4 L/s kl 10:08. Rapid changes in injection rate secured
24-JÚL-16	05:48-12:26	Pressure	1780-1780	Injection test		--- ditto ---
24-JÚL-16	05:48-12:26	Flow	1780-1780	Injection test		--- ditto ---
24-JÚL-16	12:36-12:48	Flow	730-1780	Injection test	-19.5	Tool speed -80 m/min.
24-JÚL-16	12:49-13:16	Temperature	730-2200	Injection test	-19.5	
24-JÚL-16	12:49-13:16	Pressure	730-2200	Injection test	-19.5	
24-JÚL-16	12:49-13:16	Flow	730-2200	Injection test	-19.5	Tool speed +55 m/ min.
24-JÚL-16	12:49-13:16	Temperature	730-2200	Injection test	-19.5	
24-JÚL-16	12:49-13:16	Pressure	730-2200	Injection test	-19.5	
24-JÚL-16	13:16-13:43	Flow	730-2200	Injection test	-19.5	Tool speed -55 m/min.
24-JÚL-16	13:43-14:06	Flow	730-2200	Injection test	-19.5	Tool speed +65 m/min.
24-JÚL-16	14:06-14:29	Flow	730-2200	Injection test	-19.5	Tool speed -65 m/min.
24-JÚL-16	14:30-14:50	Flow	730-2200	Injection test	-19.5	Tool speed +75 m/min.
24-JÚL-16	14:50-15:20	Flow	0-2200	Injection test	-19.5	Tool speed -75 m/min.

Drilling of the 3rd phase of well ÞG-11 started on 7th of July and finished on July 19th. Before the drilling of the production part of the well commenced, the water inside the closed casing had been heating since the production casing was cemented on June 13th or for 3 weeks. Therefore, a temperature profile was measured in order to obtain an estimate of the formation temperature profile of the well down to the production casing depth. This profile is shown in Figure 19 together with the well´s saturation temperature calculated from the measured pressure. The temperature is close to boiling from 100 m depth to bottom (772 m) and supports that the formation temperature in this area follows the boiling point curve as other wells in the vicinity of ÞG-11 have shown.

During the drilling phase, five gyro logs were conducted and one inclination log after the MWD tool had been removed from the BHA. As usual, when the drilling of the well was finished a final gyro log was measured in order to map the well's actual path.

After pulling out the drill string after drilling to the final depth of 2212 m a temperature log was conducted prior to further logging. For the planned logging program, an injection rate of 15 l/s was expected. Running the temperature tool down the hole the log showed high temperature gradient as the temperature was about 20°C at surface and almost 100°C at 750 m. This high gradient indicates that no water at all was actually flowing down the well despite the flow meter on the pump 15 l/s. The drillers could not explain this but when the pumps were set to 35 l/s water flowed down the well and cooled it. Then, ÍSOR's logging crew could continue their work. The temperature profiles confirming this are shown in Figure 20 and the rest of the logging program was performed with 35 l/s pumping into the well. Following logs were caliper, acoustic televiewer, neutron-neutron response, natural gamma radiation, and resistivity.

After the 7" perforated liner had been run in hole a multi-rate injection test was conducted and together with that a flow measure with a spinner was also conducted.

Figure 20 shows temperature logs from 21st of July in combination with lithological logs and from 24th of July in combination with the well completion test. The temperature profile logged at 16:00 on July 21st shows small inflow effects at 1016 m and clear outflow zones are at 2081 m and 2117 m. In order to confirm if there was flow beyond 2117 m or not, the injection rate was increased to 40 l/s and the temperature was logged again from 2100 m, it started at 17:25 and is shown in Figure 20. The clear cooling of the well from 2117 m depth and down to bottom of the hole confirms that there is a permeable zone at BOH.

At the beginning of the well completion test an injection rate of 15 l/s was requested from the drilling crew. The first temperature profile logged showed rapid heating and a high temperature gradient inside the production casing. When the tool entered open hole the temperature got stable and from 1045 m depth there is almost isothermal condition in the well down to 2217 m where the temperature increases a little. At the moment when this temperature profile was logged, with no water injected into the well, the lowered pressure and water table at ~250 m, the inflow at 105–1020 m increased and governed the temperature there below, i.e. the inflow there exited the well some part at 2117 m and some part at BOH. The temperature profile logged under 19.5 l/s injection rate on July 24th follows the same in/out-flow pattern described above.

A summation of the feed zones seen in the temperature logs in phase 3 (Figures 20 and 21) and the spinner logs, discussed later, are shown in Table 6. The loss of circulation measurement (Table 4) were also looked at.

Table 6. *Feed zones in phase 3 seen in temperature and spinner logs as well as circulation losses during drilling.*

Depth [m]	Description	Comments regarding the localization of the feed zones
930	Small	Seen in temperature logs with no injection
980	Small	Seen in temperature logs with no injection
1020	Intermediate	Seen in many temperature logs and spinner logs.
1050	Small	Seen in temperature logs with no injection.
1130	Small	Seen in temperature logs with no injection.
1220	Small	Seen in temperature logs with no injection.
1270	Small	First loss of circulation, 17-20 l/s, was observed at1318 m. This is probably the first LOC measurement and the loss therefore the sum of the losses of the feed zones above.
1480	Small	Seen in temperature logs with no injection.
1620-1640	Intermediate	Seen in temperature log 13th of July and more T-logs.
1700	Small	Seen in temperature log 13th of July and more T-logs.
2080-2120	Large	Seen in temperature logs and spinner logs.
BOH	Small	Seem to have opened at the end of the drilling operation. Seen in temperature logs and spinner logs.

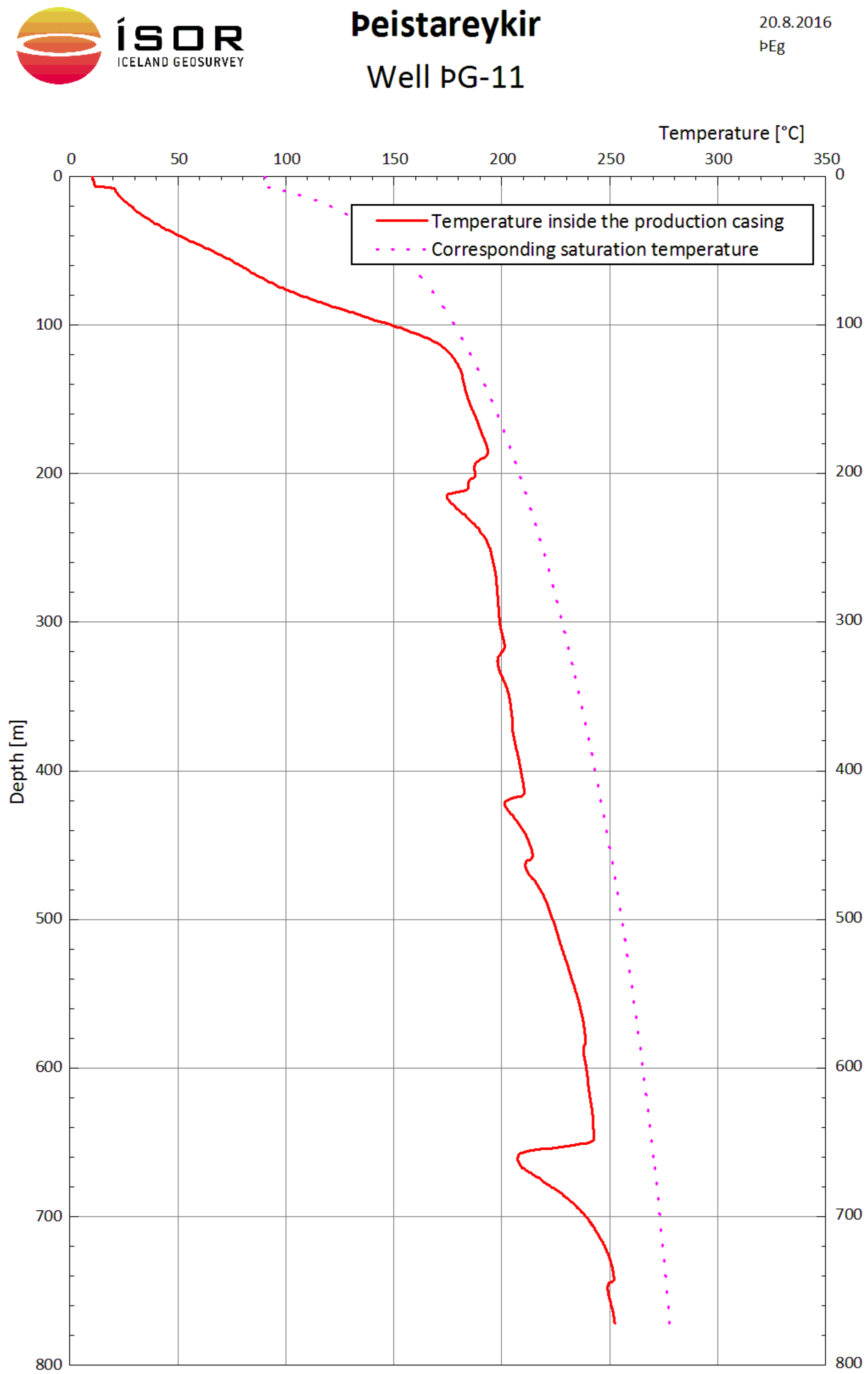

Figure 19. *Measured temperature and corresponding saturation temperature inside the production casing after 21day of heating.*

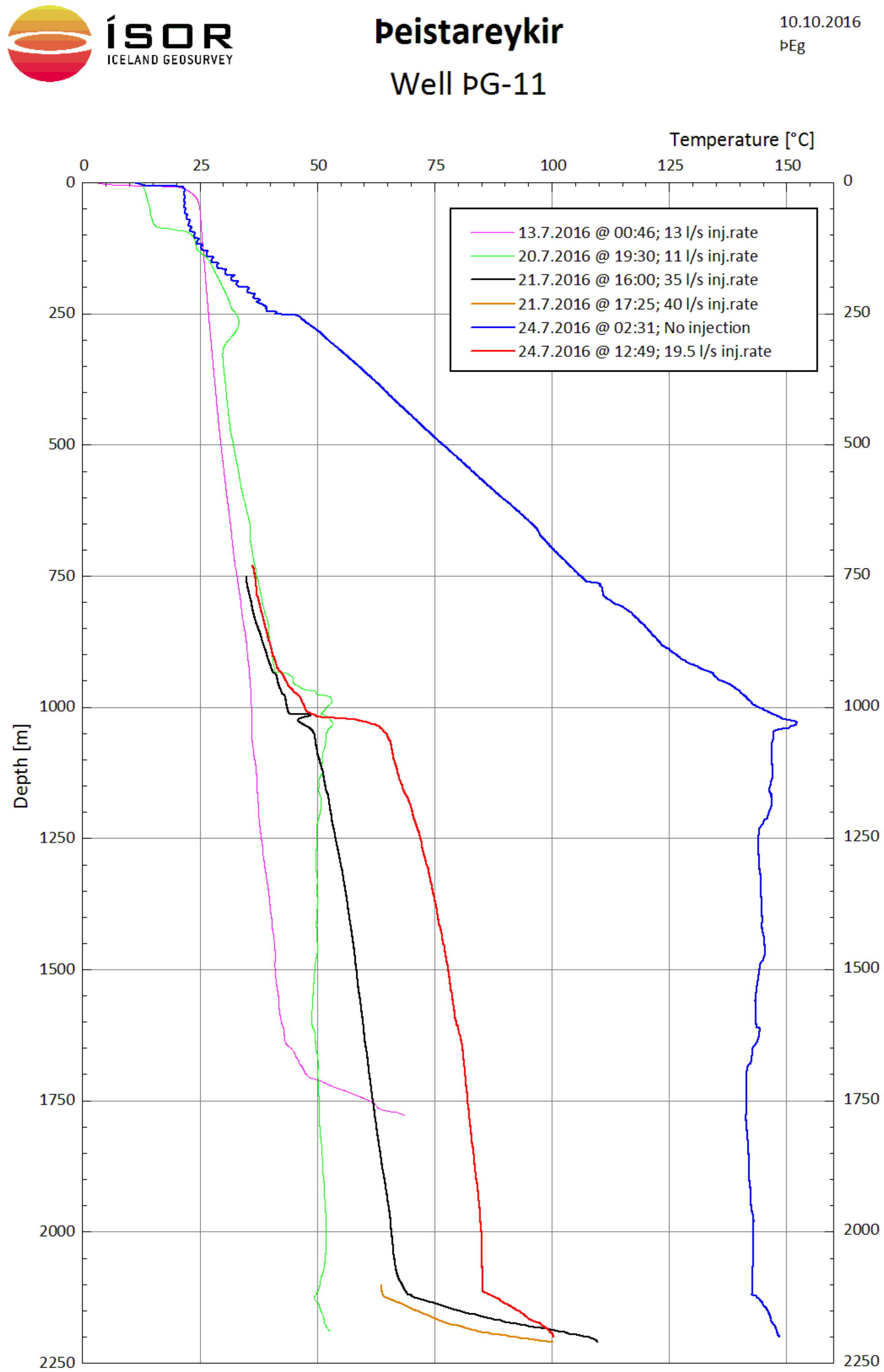

Figure 20. *Temperature logs, both prior to the lithological logging program and in the well completion test. Various temperature profiles at different flow conditions in the well give information on feed zones*

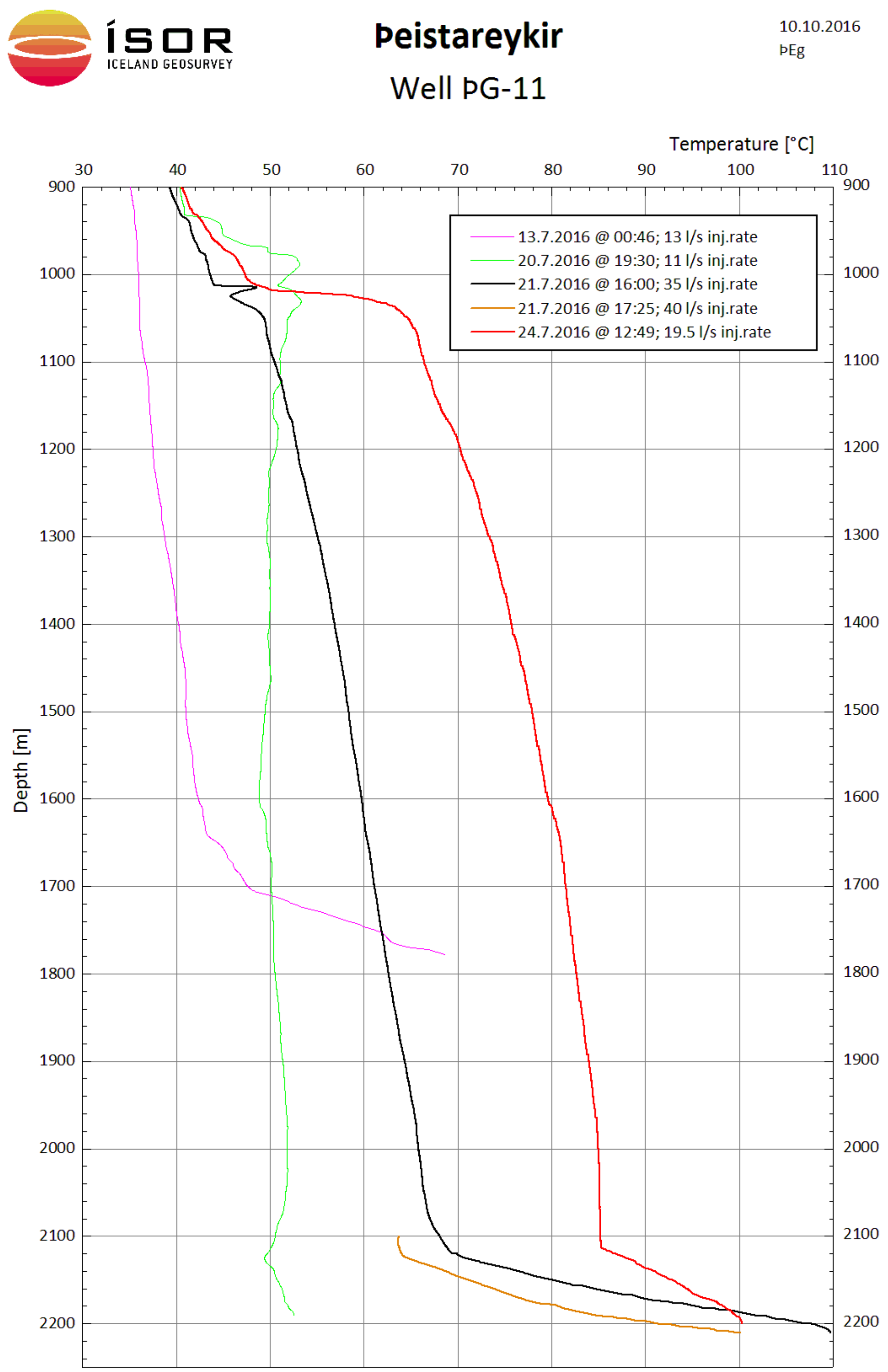

Figure 21. *The same temperature profiles as in Figure 20 zoomed in for closer inspection of feed zones.*

4.1 Lithological logs

The lithological logs started with the temperature log described in previous paragraph. The logging started at 14:48 on July 21st and it was finished at 15:05 on July 22nd. Overview of the temperature, caliper, neutron-neutron, natural gamma and the resistivity is shown in Figure 22.

The caliper log shows traditional elliptical shape of the slanted well's cross section down to 1720 m but there below the well is circular. No major cavities were detected.

No high resistivity zones are measured in the well. Also, almost no sharp anomalies are detected that would represent contrasts in alteration except at 1060 m depth. However, from 920 m down to 1080 m the character of the resistivity log is a bit different from the rest of the log, showing higher resistivity than seen as the general trend in this log.

The neutron-neutron response is uniform for all of the well, no indication of highly dense intrusions. Note the small anomaly at 1060 m that coincides with an anomaly in resistivity.

Even though the neutron-neutron response and the resistivity log show little signs of anomalies they can be used to correlate the cutting analysis where cuttings are available.

Anomalies are seen in the natural gamma radiation log. The main anomaly is seen from 1000 to 1040 m, suggesting an acidic intrusion at this depth interval. The first analysis of the drill cuttings suggested fine grained tuffs, of basaltic origin but further studies done after the gamma log do not exclude acidic origin. This is then the first sign of acidic intrusion seen in Þeistareykir well. This depth interval also shows some irregularities in the resistivity. According to the temperature log, there is a feed zone at about 1020 m depth and there is also a change in the SP values indicating change in fluid flow character. Other locations where the gamma shows higher radiation are at: 1140, 1163, 1197, 1245, 1316–1333, 1536, 1651, 1682–1694, 1735, 1986–1998, 2010, 2039–2051, 2064, 2079–2087, 2094, 2155, 2178 and 2202 m depth, these anomalies are, however, thinner and smaller than the anomaly at 1000–1040 m.

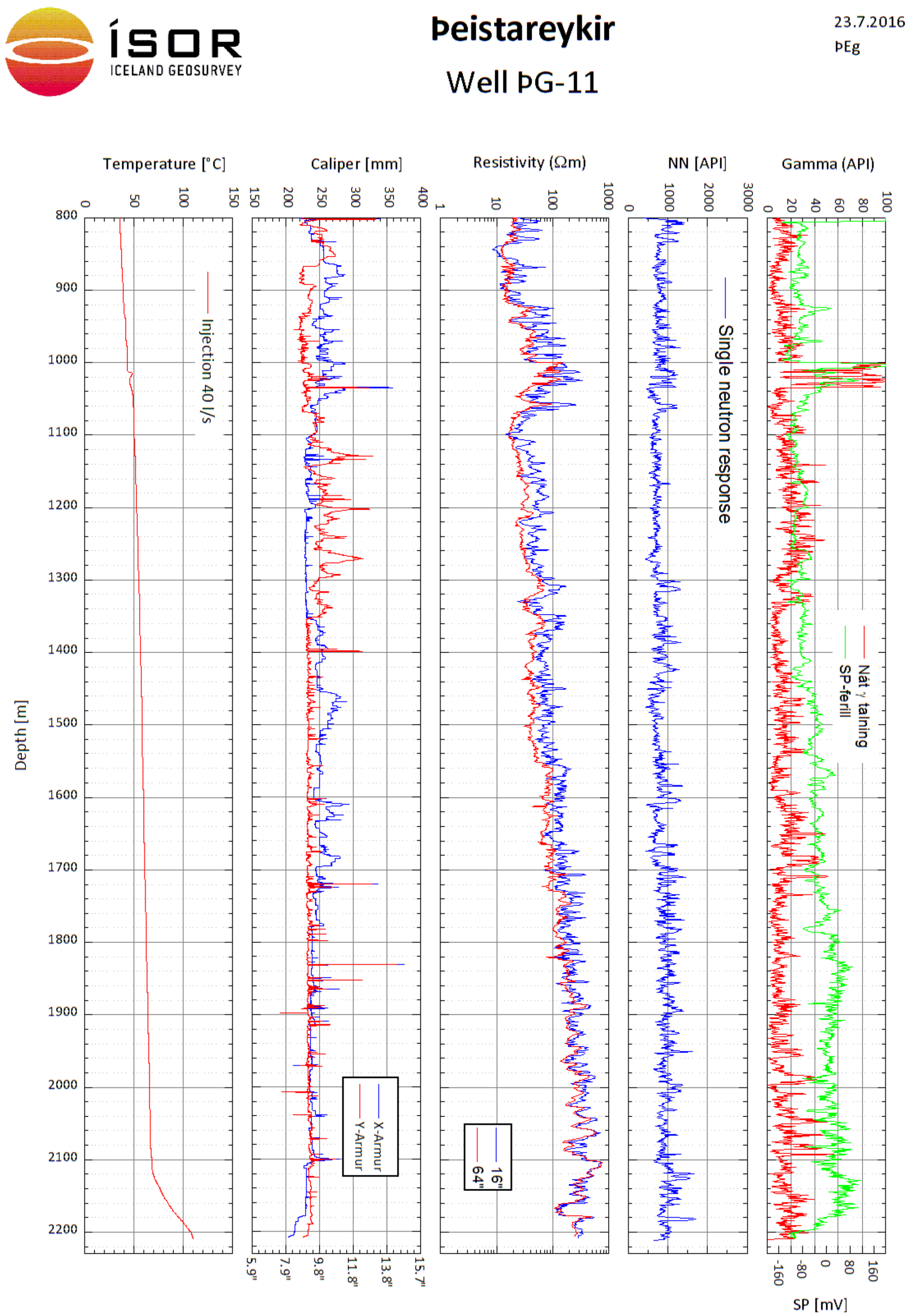

Figure 22. *Overview of temperature, caliper and lithological logs.*

4.2 Gyro logs and well path

As seen in Table 5, five single shot gyro logs were conducted, during the 3rd phase of drilling of well ÞG-11, one inclination log and a final continuous reading gyro log. Table 7 contains the results for the final log sampled at 30 m intervals. Figure 23 shows the measured azimuth and inclination during all drilling phases of the well and it also shows the continuous log values as solid lines. Figure 24 shows how well the true vertical depth and corresponding horizontal displacement of the well path follows the designed well path. As it turns out, the maximum deviation from the designed well path is within 30 m.

Table 7. *The measured azimuth and inclination together with calculated East and North coordinates of the well path, True Vertical depth and horizontal displacement of the well path relative to its well head.*

MD [m]	Incl [°]	Azim [°]	East [m]	North [m]	TVD [m]	Horizontal displacement [m]
0	0	0	0	0	0	0
30.0	0.17	301.01	0.0	-0.1	30.0	0.1
60.0	0.20	149.28	0.0	-0.1	60.0	0.1
90.0	0.41	205.77	0.0	-0.2	90.0	0.2
120.0	0.34	190.53	-0.1	-0.4	120.0	0.4
150.0	0.50	312.31	-0.2	-0.4	150.0	0.4
180.0	0.78	330.02	-0.4	-0.1	180.0	0.4
210.0	1.33	309.77	-0.7	0.3	210.0	0.8
240.0	1.42	306.97	-1.3	0.7	240.0	1.5
270.0	2.03	309.04	-2.0	1.3	270.0	2.4
300.0	1.99	309.02	-2.8	1.9	299.9	3.4
330.0	1.79	296.90	-3.7	2.5	329.9	4.4
360.0	1.75	207.91	-4.3	2.3	359.9	4.8
390.0	4.43	172.09	-4.3	0.7	389.9	4.4
420.0	7.49	179.75	-4.2	-2.4	419.7	4.8
450.0	10.52	180.18	-4.2	-7.1	449.3	8.2
480.0	13.68	179.12	-4.1	-13.4	478.6	14.0
510.0	17.10	179.84	-4.1	-21.3	507.5	21.7
540.0	21.14	179.11	-4.0	-31.1	535.9	31.4
570.0	24.19	179.94	-3.9	-42.7	563.5	42.9
600.0	28.06	180.45	-3.9	-55.9	590.5	56.0
630.0	31.74	180.65	-4.1	-70.8	616.5	71.0
660.0	34.72	180.83	-4.3	-87.3	641.5	87.4
690.0	36.88	180.62	-4.5	-104.8	665.9	104.9
720.0	40.52	179.99	-4.6	-123.6	689.3	123.7
750.0	42.41	179.57	-4.5	-143.4	711.8	143.5
780.0	42.69	179.72	-4.4	-163.7	733.9	163.8
810.0	43.55	179.91	-4.3	-184.2	755.8	184.3
840.0	43.00	180.11	-4.3	-204.8	777.6	204.8
870.0	41.54	177.65	-3.9	-225.0	799.8	225.0
900.0	40.58	175.06	-2.7	-244.6	822.4	244.6
930.0	40.96	172.20	-0.5	-264.1	845.1	264.1
960.0	40.84	172.62	2.1	-283.5	867.8	283.6
990.0	40.40	173.13	4.5	-302.9	890.6	303.0
1020.0	40.42	173.81	6.7	-322.3	913.4	322.3
1050.0	39.71	178.56	8.0	-341.5	936.4	341.6
1080.0	39.63	180.61	8.1	-360.6	959.5	360.7
1110.0	39.76	180.83	7.9	-379.8	982.6	379.9
1140.0	40.99	180.87	7.6	-399.2	1005.4	399.3
1170.0	41.26	179.60	7.5	-419.0	1028.0	419.0
1200.0	41.30	179.51	7.7	-438.8	1050.6	438.8
1230.0	40.67	177.59	8.2	-458.4	1073.2	458.5
1260.0	40.04	177.55	9.0	-477.8	1096.1	477.9
1290.0	40.18	177.61	9.8	-497.1	1119.0	497.2

Table 7. *(Cont.)*

MD [m]	Incl [°]	Azim [°]	East [m]	North [m]	TVD [m]	Horizontal displacement [m]
1320.0	40.09	177.97	10.6	-516.5	1141.9	516.6
1350.0	40.31	178.12	11.2	-535.8	1164.9	535.9
1380.0	40.87	177.03	12.1	-555.3	1187.6	555.4
1410.0	41.59	176.89	13.1	-575.1	1210.2	575.2
1440.0	41.47	176.91	14.2	-594.9	1232.7	595.1
1470.0	40.72	177.75	15.1	-614.6	1255.3	614.8
1500.0	40.60	178.02	15.8	-634.2	1278.0	634.4
1530.0	40.69	178.47	16.4	-653.7	1300.8	653.9
1560.0	41.26	177.04	17.2	-673.3	1323.4	673.6
1590.0	40.86	176.08	18.4	-693.0	1346.1	693.3
1620.0	41.19	177.37	19.5	-712.7	1368.7	712.9
1650.0	40.80	178.15	20.3	-732.3	1391.3	732.6
1680.0	40.28	179.26	20.7	-751.8	1414.1	752.1
1710.0	40.85	179.23	21.0	-771.3	1436.9	771.6
1740.0	41.05	179.62	21.2	-791.0	1459.6	791.3
1770.0	40.49	177.87	21.6	-810.6	1482.3	810.9
1800.0	40.26	178.42	22.2	-830.0	1505.1	830.3
1830.0	40.30	178.23	22.8	-849.4	1528.0	849.7
1860.0	39.95	178.38	23.4	-868.7	1551.0	869.0
1890.0	39.77	178.20	23.9	-887.9	1574.0	888.3
1920.0	40.31	178.34	24.5	-907.2	1597.0	907.6
1950.0	39.75	178.90	25.0	-926.5	1619.9	926.8
1980.0	39.65	179.44	25.3	-945.7	1643.0	946.0
2010.0	39.80	180.19	25.3	-964.8	1666.1	965.2
2040.0	39.99	180.09	25.3	-984.1	1689.1	984.4
2070.0	40.18	180.39	25.2	-1003.4	1712.1	1003.7
2100.0	40.51	181.23	24.9	-1022.8	1734.9	1023.1
2130.0	40.48	181.58	24.4	-1042.3	1757.7	1042.6
2160.0	39.93	181.87	23.9	-1061.7	1780.7	1061.9
2186.8	39.73	182.43	23.2	-1078.8	1801.2	1079.0

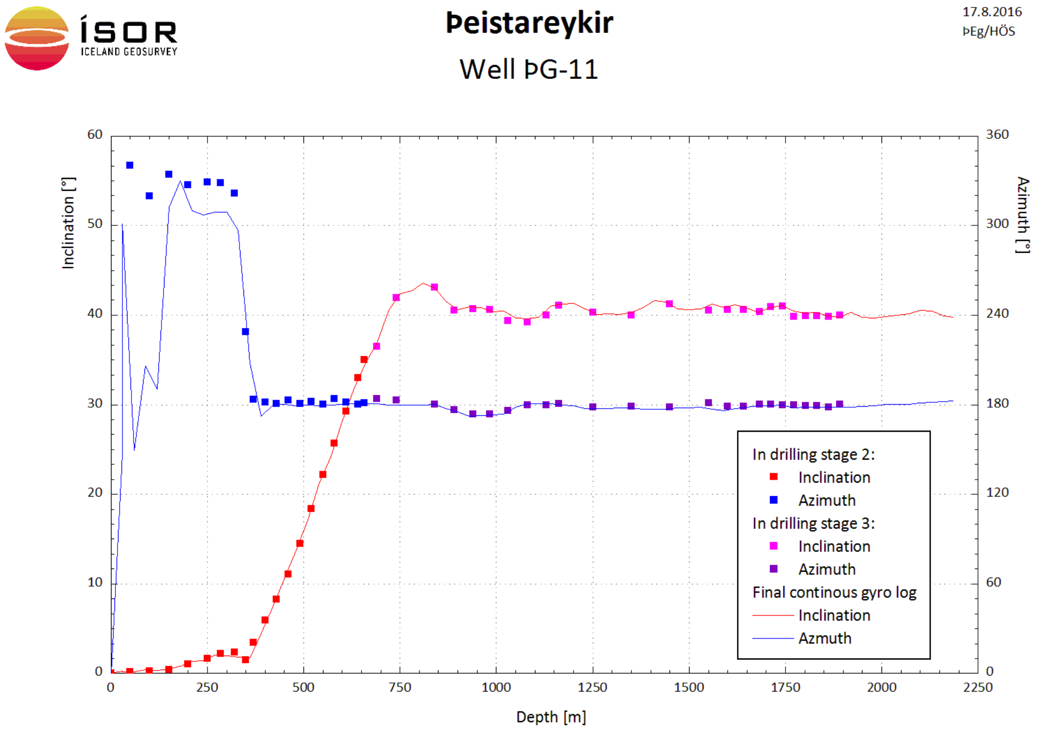

Figure 23. *Measured azimuth and inclination of the well path for well ÞG-11.*

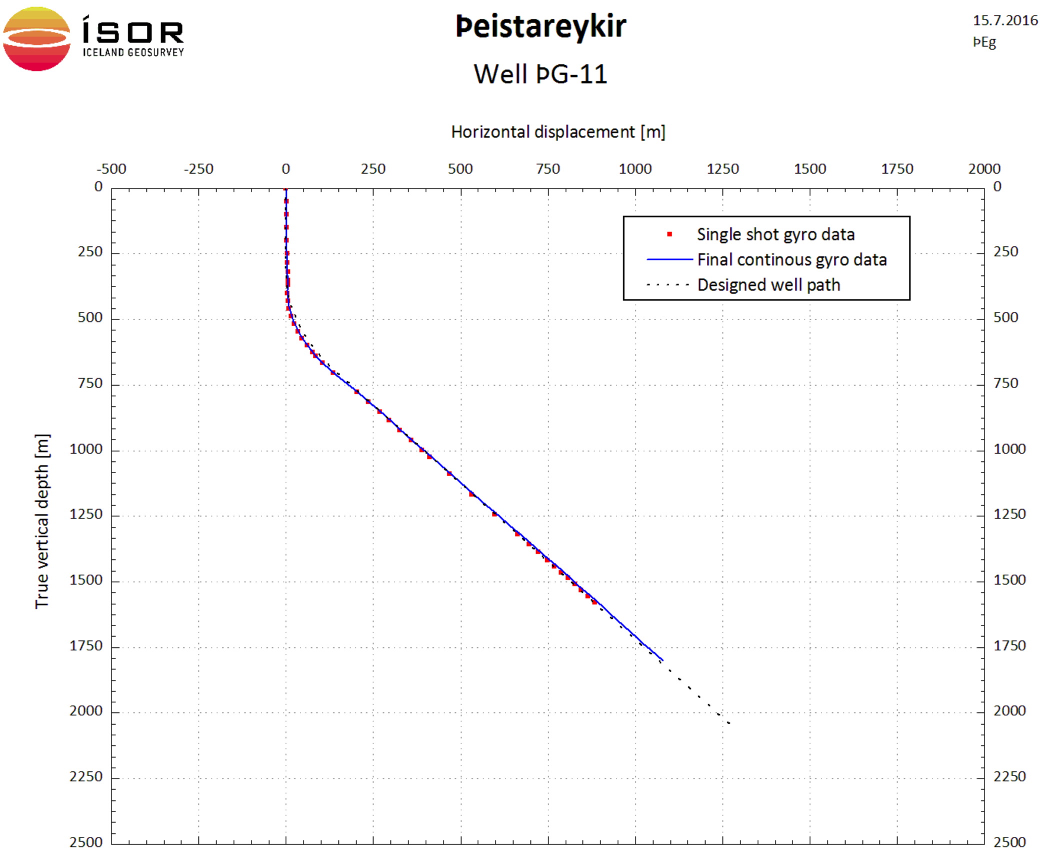

Figure 24. *The actual well path is very close to the designed one as azimuth and inclination of the well consistently fulfilled the designed criteria.*

4.3 Flow measurements with spinner

Flow measurements were conducted in well ÞG-11 in combination with the conventional multi-rate injection test. It was decided to make three runs at six different tool speeds of the whole production part of the well for two different injection rates. Before the logging started, the ÍSOR's logging crew was told that 15 l/s injection rate was applied to the well. It was, however, found out after the logging started, that no water was actually being pumped into the well. The same unexplained problem occurred when the logging program after drilling was completed. This means that the first spinner logs and the temperature and pressure logs prior to the multi-rate injection test were done with zero injection instead of 15 l/s. The spinner logs, which were conducted after the step rate test were carried out with 19.6 l/s injection rate. An overview of the spinner runs is given in where a positive tool speed is for running down hole and negative up hole.

Table 8. *An overview of the spinner runs in the flow test.*

Trip [m]	Injection [L/s]	Tool speed [m/min]
0-2200	0	+45
2200-730	0	-45
730-2200-730	0	+/- 55
730-2200-730	0	+/- 65
730-1780	0	+80
1780-730	-19.6	-80
730-2200-730	-19.6	+/- 55
730-2200-730	-19.6	+/- 65
730-2200-0	-19.6	+/- 75

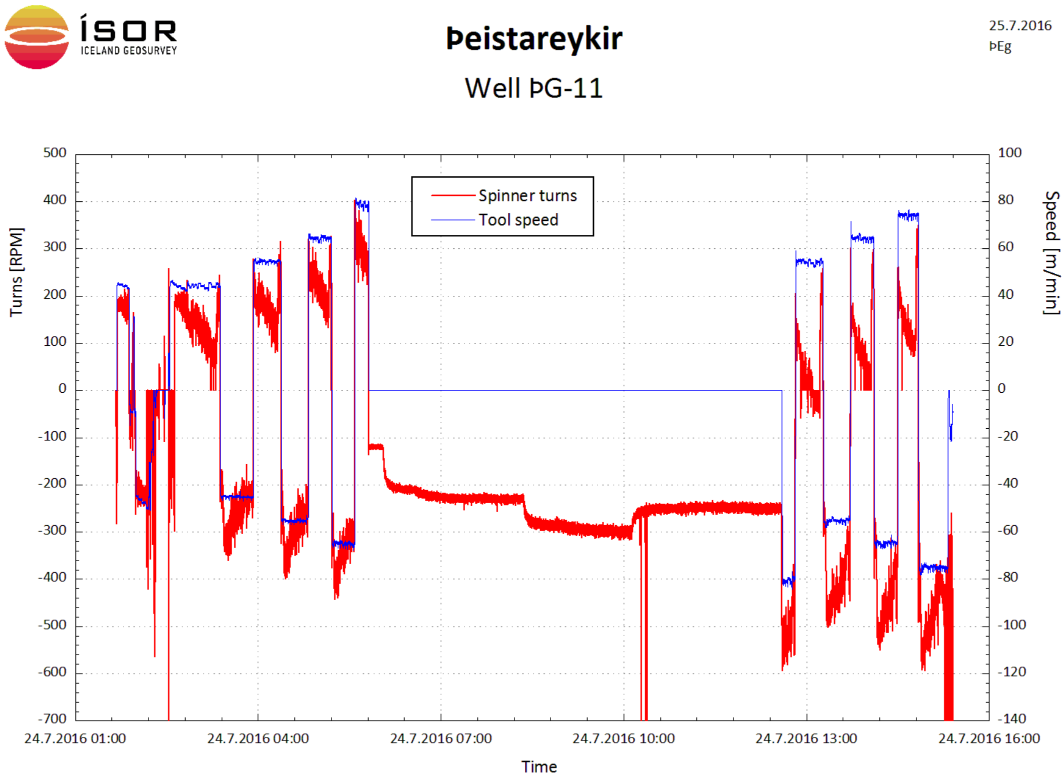

Figure 25. *Overview of the spinner logs and the logging speed of the tool during the whole multi-rate injection test.*

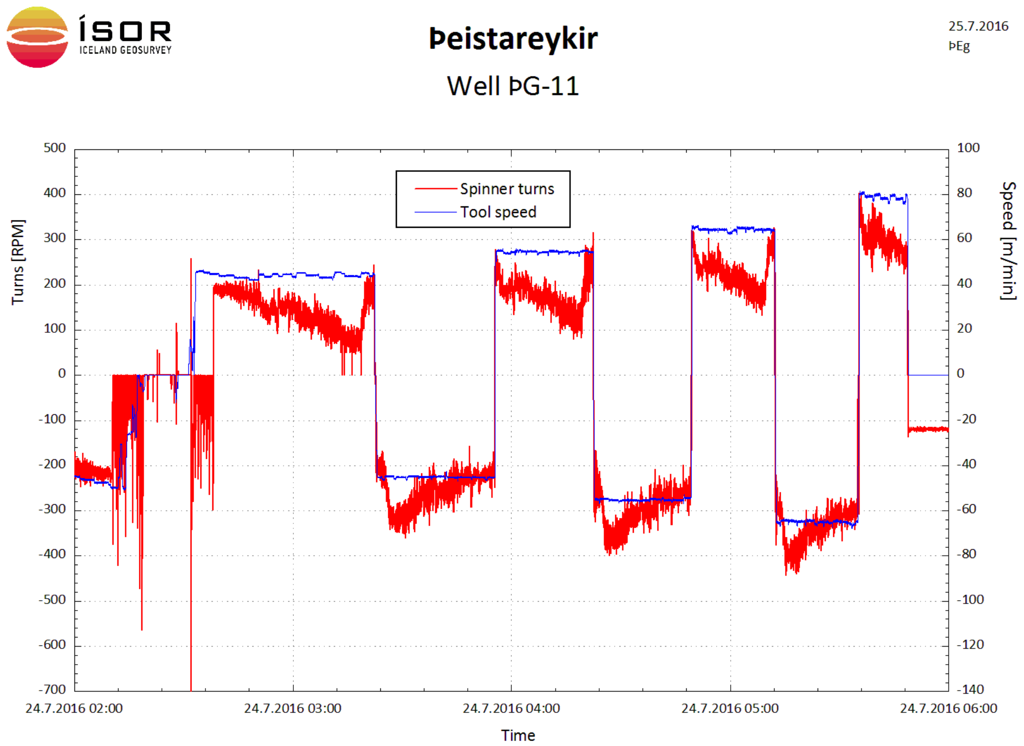

Figure 26. *Overview of the spinner log conducted with zero injection rate prior to the multi-rate injection test.*

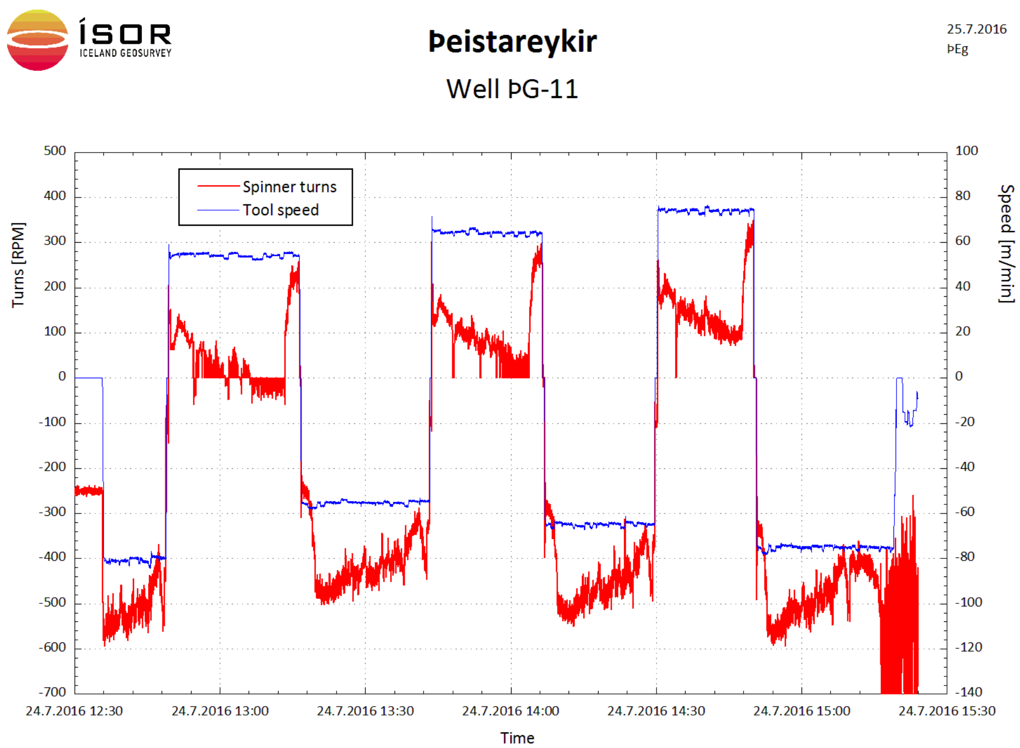

Figure 27. *Overview of the spinner logs conducted with 19.6 L/s injection rate during the final step of the injection test.*

Overview of the spinner measurements with time is shown in Figures 25–27. Figure 28 shows the spinner logs with depth when there was no water injected at well head. It shows clear inflow of liquid at 1020 m. Figure 29 shows the spinner logs with depth when the injection rate at well head was 19.6 l/s. Also here is a sign of inflow at 1020 m depth. From 1200 m to 2000 m depth there is a sign of increased fluid speed which is connected to slightly decreasing width of the well as can be seen in Figure 22. However, below 2000 m depth the decreasing fluid speed is because of fluid exiting the well. Figure 30 focuses on the depth interval 2000–2200 m, and we conclude that the main loss zone in the well is from 2025 m to 2105 m.

A precise way to calculate fluid speed from a spinner log is to make so called cross plots. These are based on measuring the spinner turns at certain locations at different tool speeds (Grant and Bixley, 2011). Figures 31–34 show cross plots for different locations in the well. Figure 31 shows a cross plot at 745 m and an intended 15 l/s injection, but the zero fluid velocity makes it clear from the plot that the intended 15 l/s injection of water did not take place. A cross plot at the same depth, 745 m, but with 19.6 l/s injection rate shows fluid speed of 24 m/min inside the production casing. It is stated above, that the main loss zone in well ÞG-11, is from 2025 m down to 2105 m. Figure 33 shows a cross plot at 1950 m under 19.6 L/s injection rate. The fluid speed at 1950 m is ~56m/min whereas the cross plot in Figure 34 shows that the fluid speed at 2160 m depth is ~6 m/min. This confirms the interpretation of the temperature logs, that only a small amount of the injected water flows beyond 2105 m exiting the well at bottom.

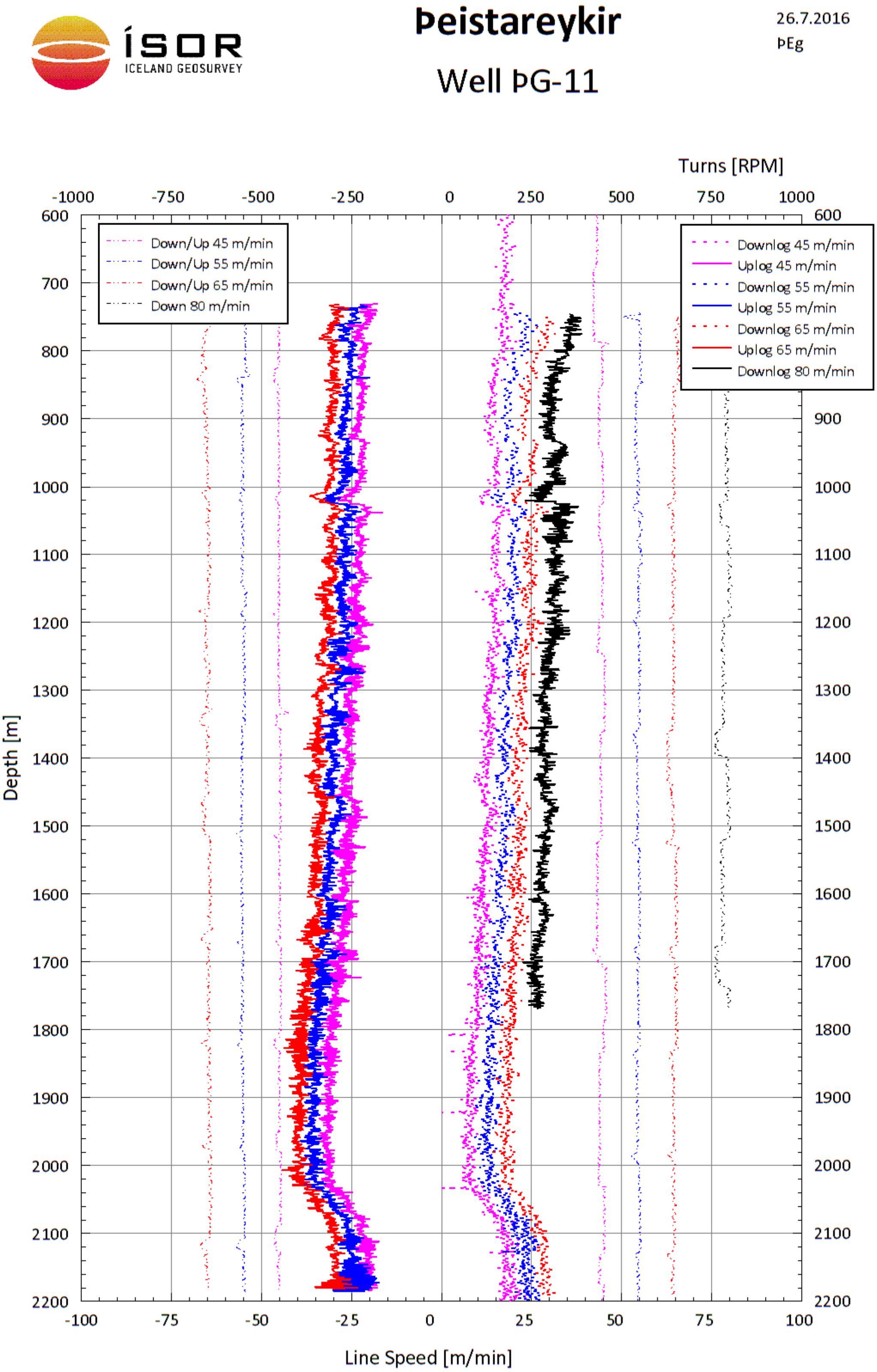

Figure 28. *Overview of the spinner logs and tool speeds with zero injection rate.*

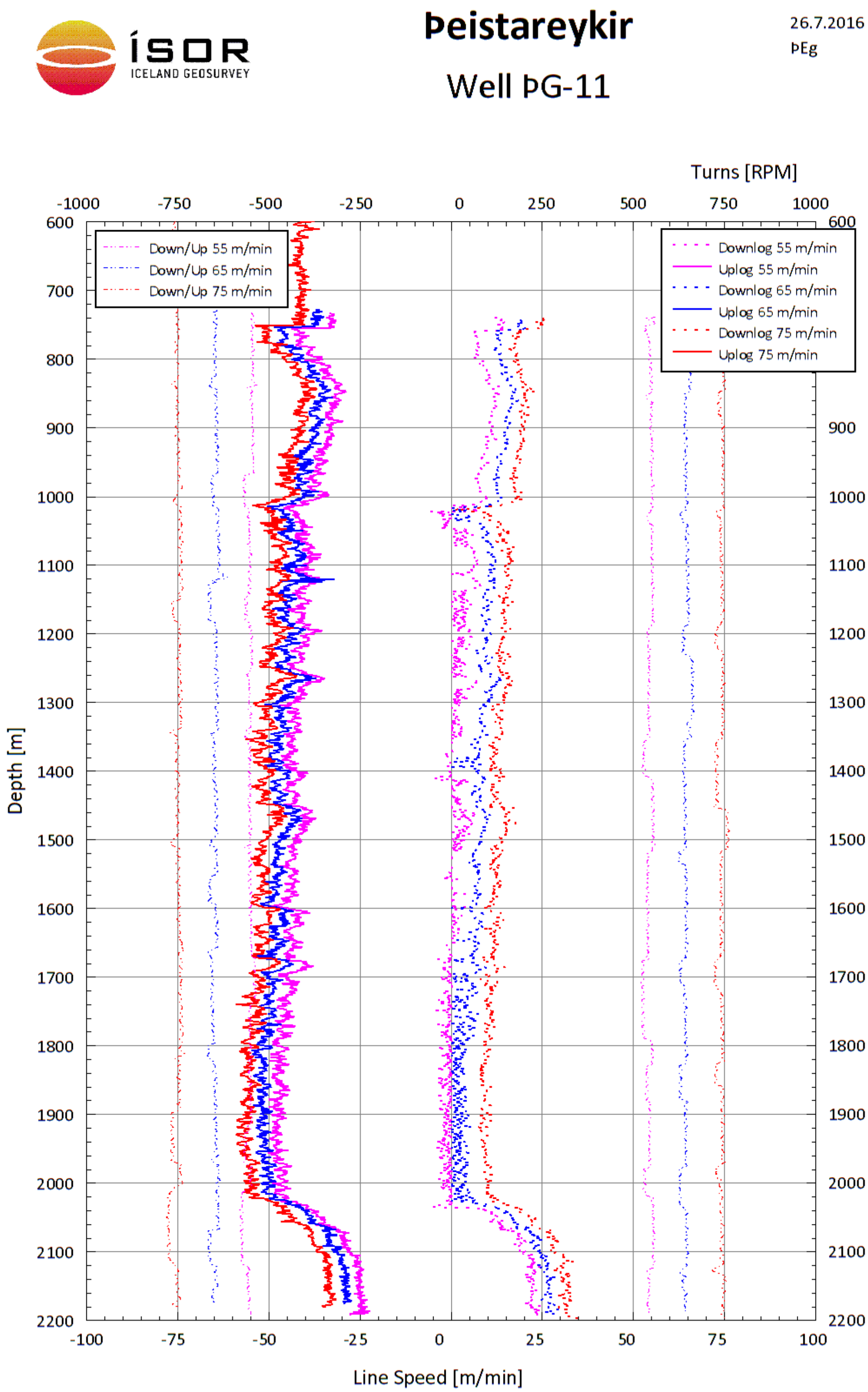

Figure 29. *Overview of the spinner logs and tool speed with 19.6 L/s injection rate.*

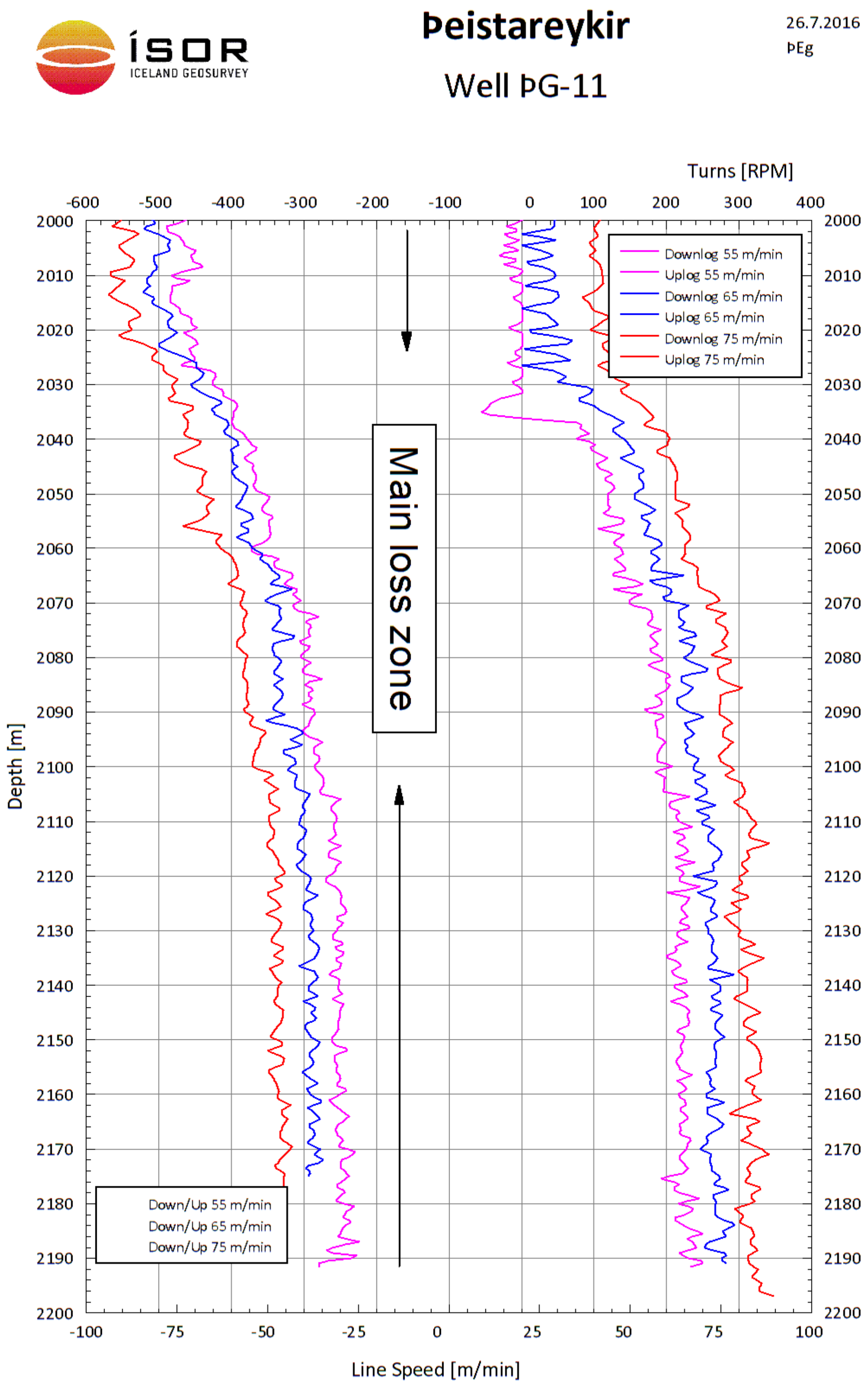

Figure 30. *The spinner log with 19.6 L/s injection rate shows that the main feed zone area is from 2015 m to 2105 m depth in well ÞG-11.*

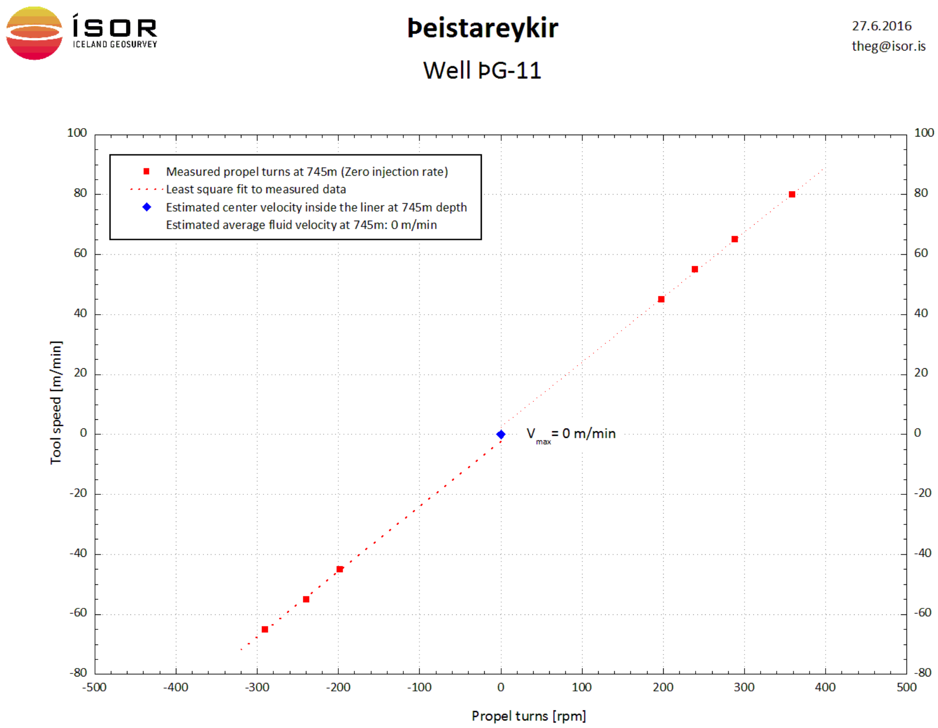

Figure 31. *Cross-plot of the spinner log at 745 m confirms that no water was injected into the well in the beginning of the multi rate injection test when pumping rate meters at Óðinn drill rig showed 15 L/s.*

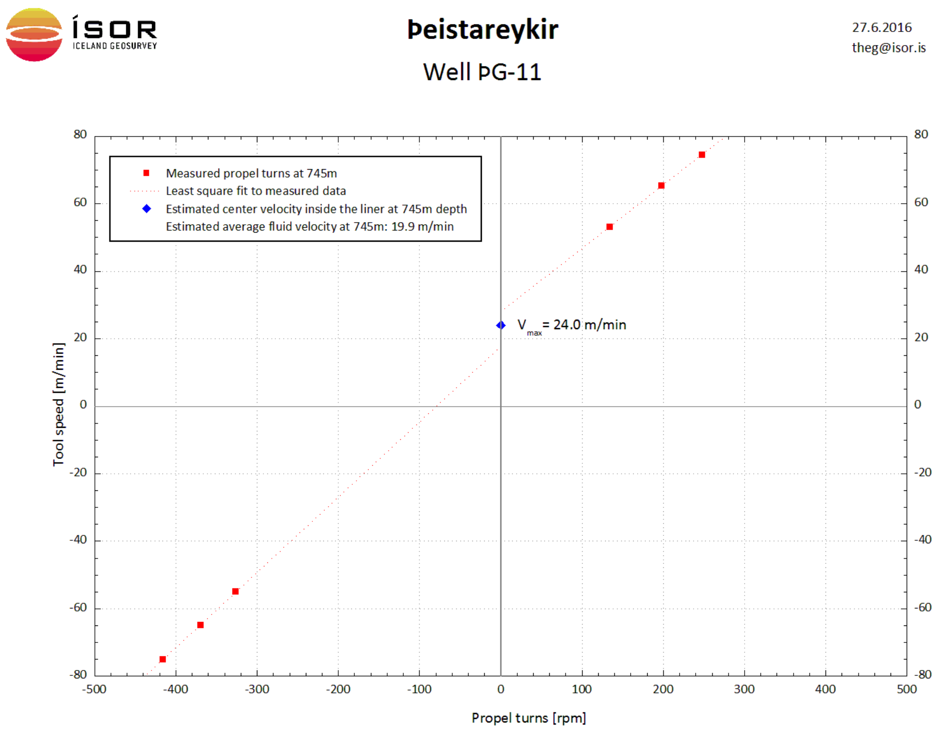

Figure 32. *Cross-plot of the spinner log at 745 m shows a fluid center speed of 24 m/min inside the production casing with 19.6 L/s injection rate at surface.*

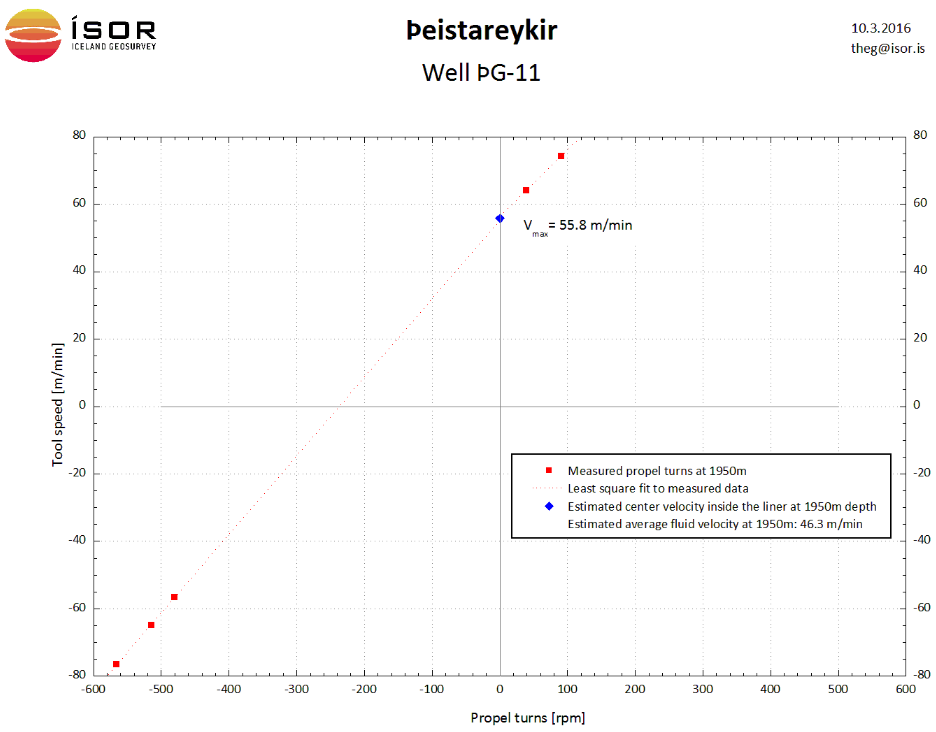

Figure 33. *Cross-plot of the spinner log at 1950 m shows a fluid center speed of ~56 m/min with 19.6 L/s injection rate at surface.*

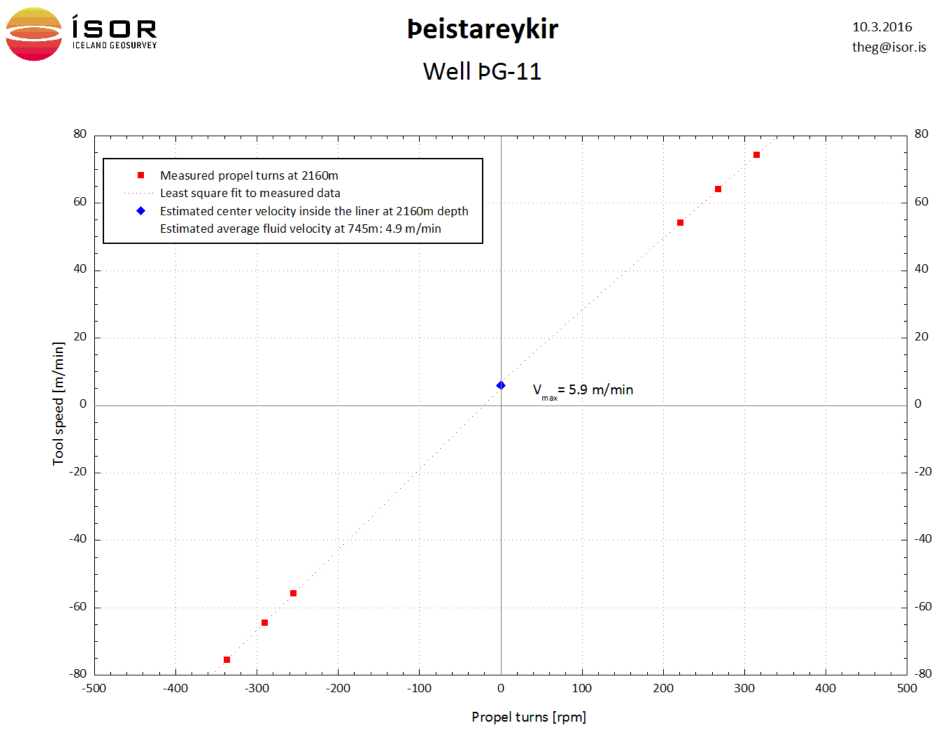

Figure 34. *Cross-plot of the spinner log at 2160 m shows a fluid center speed of ~6 m/min with 19.6 L/s injection rate at surface.*

4.4 Multi-rate injection test and its analysis

The last phase of the well completion studies was the injectivity test which was conducted according to the completion program consisting of multi-rate injection. The PTS tool was expected to run in hole under 15 l/s injection down to 1780 m depth according to estimated loss zone area. However, no injection took place. The injectivity test consisted of three steps and an overview of the applied injection rates and the measured pressure response is shown in Figure 35. In Figure 36 the injection rate is plotted against equilibrium pressure at the end of each step. As seen in the figure, data points are well connected with a least squares linear fit with regression consistency of R^2=0.9998 with the initial injection rate as zero. The line's slope, 5.3 (L/s)/bar, represents the well's injectivity index which should refer as fair permeability. Before the injectivity test was conducted the well was regarded to be in total loss of circulation. Figure 35 shows that the measured pressure data at 1780 m is of moderate to good quality, indicating a geothermal reservoir with constant pressure boundaries. Moreover, the pressure in each step reaches equilibrium in a relatively short time. Even though cautions about air drag were taken prior to the injectivity test to avoid perturbations that might affect the well equilibrium, it turned out that the well was not completely stable during the multi rate injection test, mainly appearing in the 2^{nd} step.

From information of loss of circulation and available temperature profiles it was decided to locate the P/T tool at 1780 m depth for the injectivity test. The injectivity test was performed in following order:

Initial injection rate	0 L/s		
Step 1	24.9 L/s	for	02:19
Step 2	36.2 L/s	for	01:41
Step 3	19.6 L/s	for	02:28

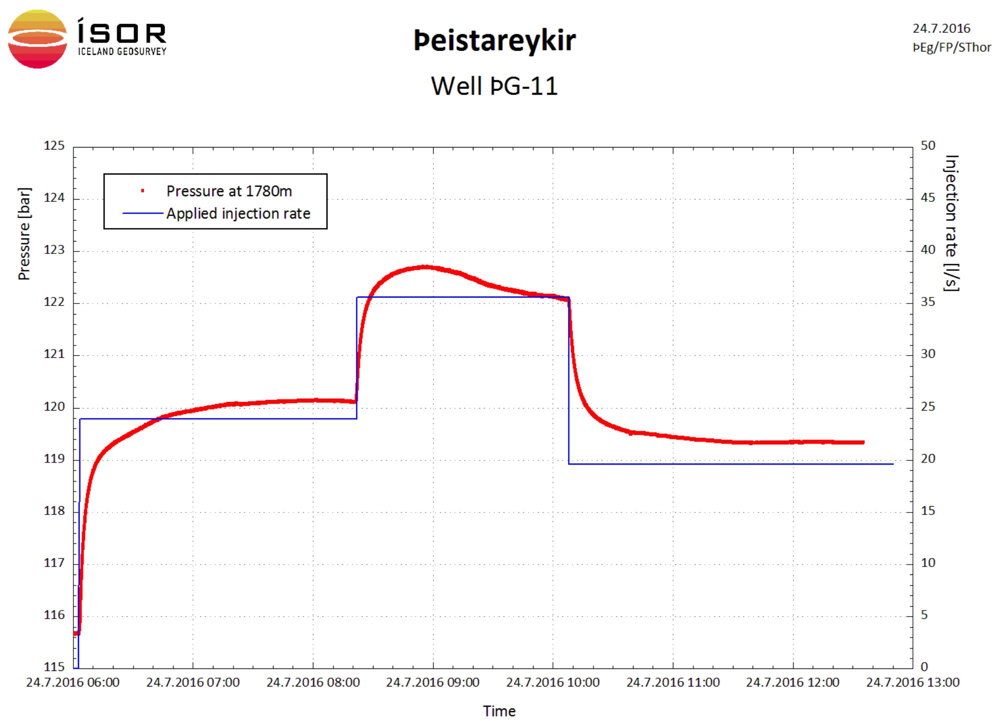

Figure 35. *test July 24th. Measured pressure at 1780 m and applied injection rate.*

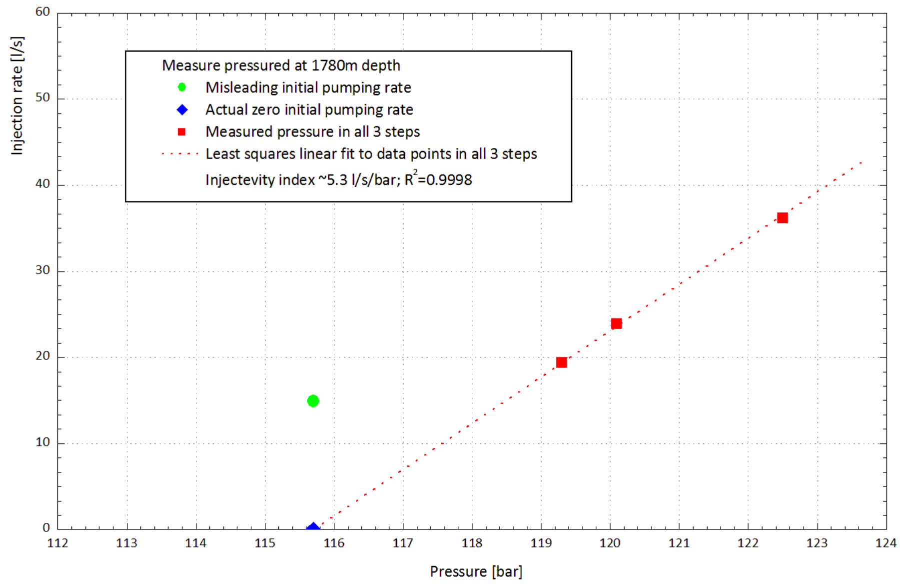

Figure 36. *The injection/pressure steps correlate to each other with constant injection/pressure relation of 5.3 (L/s)/bar.*

4.4.1 Well testing analysis and modelling

In an injection test the pressure response is recorded with time after the injection rate is changed suddenly. The pressure response is then compared to the computed response of a model with certain properties that are considered to have similar physical properties as the well and the reservoir it is drilled into. The models at hand depend on various reservoir properties. These model parameters are varied and justified until a good match is obtained between the calculated model response and the actual pressure response measured in the well. The model parameters that give the best fit determine the value of the well and reservoir parameters. This modelling approach is called inverse modelling. This includes some uncertainty but with additional information on the known geology based on cutting analysis and loss zones in the well this uncertainty can be reduced. The computer program, WellTester (Júlíusson et al., 2007), was used for the modelling of the injection test data from well ÞG-11. WellTester's algorithm is based on the well-known Theis's approach of the pressure diffusion equation for horizontal, isotropic reservoir and laminar flow that follows Darcy's law (Grant and Bixley, 2011). Non-linear regression analysis is used to determine the reservoir properties of the model that gives the best fit between data points and the model's response to the given change in injection. The results are presented both in tables and figures produced by the program.

4.4.2 Initial parameters

For interpretation of the injection test certain initial parameters for the well and the reservoir are requested. These are; the wellbore radius, accurate values of reservoir temperature, reservoir pressure, rock porosity, fluid dynamic viscosity and compressibility. Other parameters are not necessary for reliable results of the modelling procedure. However, the better the parameter determination is, the better is the possibility to obtain accurate values of derived properties such as reservoir thickness and reservoir permeability. Initial parameters used for the data interpretation are listed in Table 9.

Table 9. *An overview of initial wellbore and reservoir parameters used for interpreting the injection test results.*

Property (symbol)	Value	Unit
Estimated reservoir temperature (T_{est})	~280	°C
Estimated reservoir pressure (P_{est})	~120	bar
Wellbore radius (r_w)	0.11	m
Porosity (ϕ)	0.08	-
Dynamic fluid viscosity (μ)	$9.5 \cdot 10^{-5}$	Pa·s
Fluid compressibility (c_w)	$2.0 \cdot 10^{-9}$	Pa^{-1}
Rock compressibility (c_r)	$2.4 \cdot 10^{-11}$	Pa^{-1}
Total compressibility (c_t)	$1.8 \cdot 10^{-10}$	Pa^{-1}

4.4.3 Model type and model properties

Analyzing the injection test data seems to indicate that a dual porosity model is the most appropriate one, especially when it comes to fitting the time derivative response. The following model calculations are, therefore, based on a dual porosity model. This means that a secondary permeability, i.e. permeability based on fractures and/or faults in the rock formations, plays an important role in the reservoir mechanism. The well and reservoir model types used for the data analysis are listed in Table 10.

Table 10. *An overview of wellbore and reservoir model type used for the injection test performed in well ÞG-11.*

Well and reservoir model type	
Reservoir	Dual porosity
Boundary	Constant pressure
Well type	Constant skin
Wellbore storage	Constant wellbore storage

The dual porosity model property refers to distinguishing the thermal reservoir into both a rock matrix that stores most of the fluid mass inside the reservoir, and a fracture system through which the reservoir fluid is transferred between different parts of it. The most important property for estimating in what sense the reservoir is dual porosity, i.e. to what extent is the reservoir storage determined by fracture activity, is the storativity ratio

$$\omega = \frac{\phi_f c_{tf}}{\phi_f c_{tf} + \phi_m c_{tm}}$$

where φ denotes porosity and c_t denotes total compressibility. The subscripts *f* and *m* refer to fractures and rock matrix. Note that the storativity ratio, which takes values between 0 and 1, increases as the porosity is more determined by fracture activity. The less this ratio becomes, the more of the reservoir fluid storativity occurs in the rock matrix. Another ratio, the transmissivity ratio, is defined for dual porosity reservoirs as

$$\lambda = \alpha \frac{k_m}{k_f} r_w^2$$

The transmissivity ratio connects the fissure permeability (k_f) to matrix permeability (k_m) and it gets less as the relative fissure permeability is increased. r_w is the wellbore radius and α is a coefficient that relates fissure connection to the rock matrix (Horne, 1995).

4.4.4 Modelling results for the ÞG-11 injection test

In following sub-chapters, the interpretation results of each injection step are shown with one table and four figures. The table shows values of the well and reservoir properties obtained with the model calculations, i.e. the table lists the actual results of the injection test for the current injection step. The first figure shows the measured pressure and the injection rate during the corresponding injection step. The second figure shows both the pressure change and the logarithmic derivative $\left(\frac{\partial P}{\partial \ln t} = t \cdot \frac{\partial P}{\partial t}\right)$ (Horne, 1995) of the observed pressure on a logarithmic scale for both time and pressure for a dual porosity reservoir. This graph shows how well the observed data are fitted and the logarithmic time derivative indicates how well the model type used for the interpretation suits the observed data. The third figure shows the model fit of the data with a logarithmic time scale and a linear pressure scale and the fourth figure shows on a linear scale how the model response fits the observed pressure on a linear scale.

The obtained model properties of transmissivity and storativity can be used to estimate effective permeability and reservoir thickness for known porosity in the well's vicinity and estimated rock and fluid compressibility (Grant and Bixley, 2011). However, it should be noted that the compressibility values depend on the reservoir state, i.e. temperature and pressure, so the estimated derived parameter values generally depend on properties that are only roughly known. The formulae for the reservoir permeability is $k = \frac{T}{S} \cdot \mu \cdot c_t$ and for reservoir thickness $h = \frac{S}{c_t}$.

The estimated skin effect is an important well property determined from a pressure response at the wellbore's boundary. A negative skin effect is a measure of good permeability between the wellbore wall and the neighbour formation matrix or connecting fissure (Horne, 1995). In case of well damages, possibly caused by cuttings sitting in permeable zones, the calculated skin effect turns into positive values.

As mentioned above, the two ratio reservoir properties, transmissivity ratio and storativity ratio should reflect the dual porosity activity in the model. Therefore, they will be discussed for each step of the injection test in order to estimate the validity of choosing the dual porosity model of the interpretation program.

4.4.5 ÞG-11 Injection test: Step1 (0 L/s to ~25 L/s)

The first step of the injection test was to change the injection rate from 0 L/s to 23.9 L/s. The initial pressure was 115.7 bar and the equilibrium pressure was 120.1 bar. Figure 37 shows the pressure measured at 1780 m during the first step change of the multirate injection test.

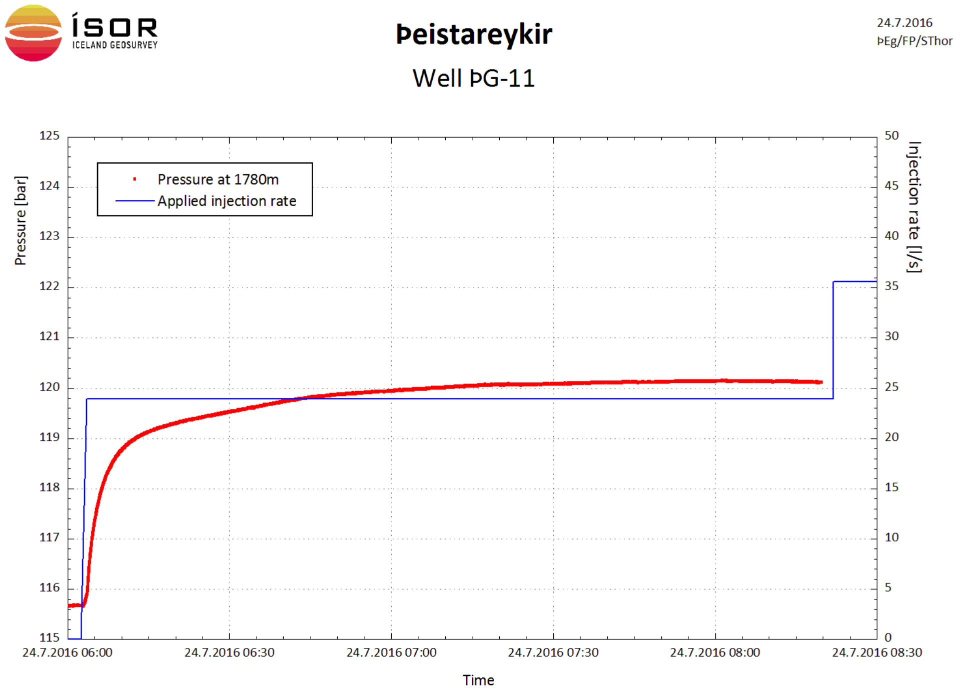

Figure 37. *Pressure response at 1780 m to change in injection rate from zero to 23.9 L/s.*

Table 11. *Modelled well- and reservoir parameters for constant pressures boundaries from the pressure recorded in Step 1 of the injectivity test.*

Reservoir/Well properties	Value	Standard Deviation	Unit
Transmissivity (T)	2.9	$2.0 \cdot 10^{-3}$	10^{-8} m³/(Pa s)
Storativity (S)	5.6	$2.0 \cdot 10^{-2}$	10^{-8} m/Pa
Response distance (r_e)	60.0	0.2	m
Skin factor (s)	-3	-	
Wellbore storage (C)	1.3	$2.3 \cdot 10^{-3}$	10^{-5} m³/Pa
Transmissivity ratio (λ)	3.0	$1.0 \cdot 10^{-2}$	10^{-5}
Storativity ratio (ω)	7.3	$4.0 \cdot 10^{-1}$	10^{-5}
Reservoir Thickness (h)	90	-	m
Injectivity Index (II)	5.6	-	(L/s)/bar
Effective Permeability (k)	30	-	10^{-15} m²

As seen in Figures 38–40 the obtained parameters for a dual porosity model listed in Table 11 give a good fit to the observed data after the first two minutes and the model is reliable for calculating the pressure response for any change in injection rate. The dual porosity model also simulates the time derivative of the pressure adequately which gives a good confidence of choosing secondary permeability as an important reservoir property.

For this step the skin effect of -3.0 represents a good coupling of the well to the formation. Even though we see clear signs of dual porosity behaviour in the model calculation, the storativity ratio, $\omega \approx 7 \cdot 10^{-5}$, indicates a relatively high matrix porosity which also is the case for the transmissivity ratio, $\lambda \approx 3 \cdot 10^{-5}$ (Horne, 1995).

From the reservoir properties listed in Table 11 and the reservoir parameters listed in Table 9, the estimated reservoir thickness is $h \approx 90\ m$ which leads to reservoir permeability of $k \approx 30\ mD$. Compared to general permeability of geothermal fields, reservoir permeability of 30 milli-Darcy, is above moderate (Axelsson, 2004).

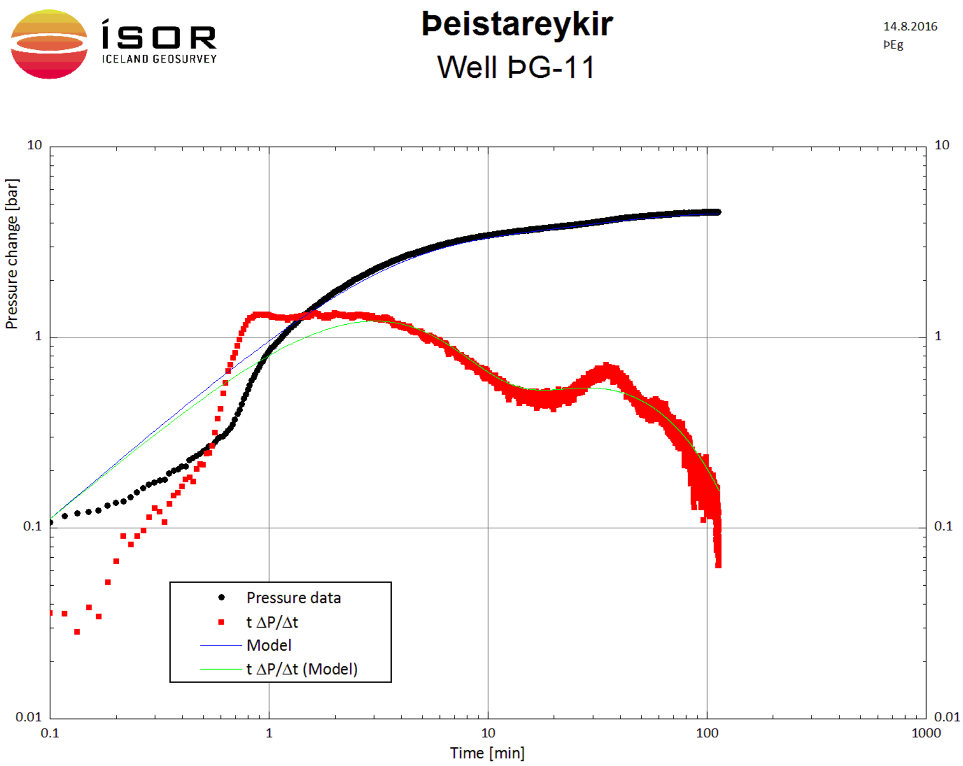

Figure 38. *Modelling results for step 1 on a logarithmic scale for both the pressure change and the time derivative of the pressure data.*

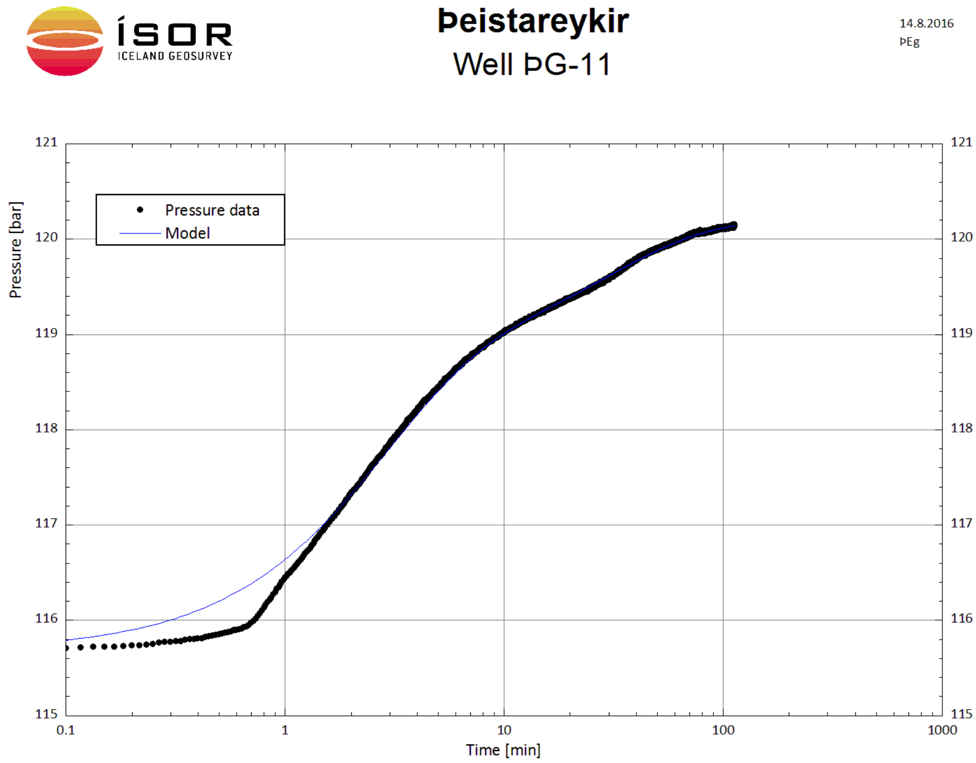

Figure 39. *Modelling results for step 1 on a logarithmic scale for the time and on a linear scale for the pressure data.*

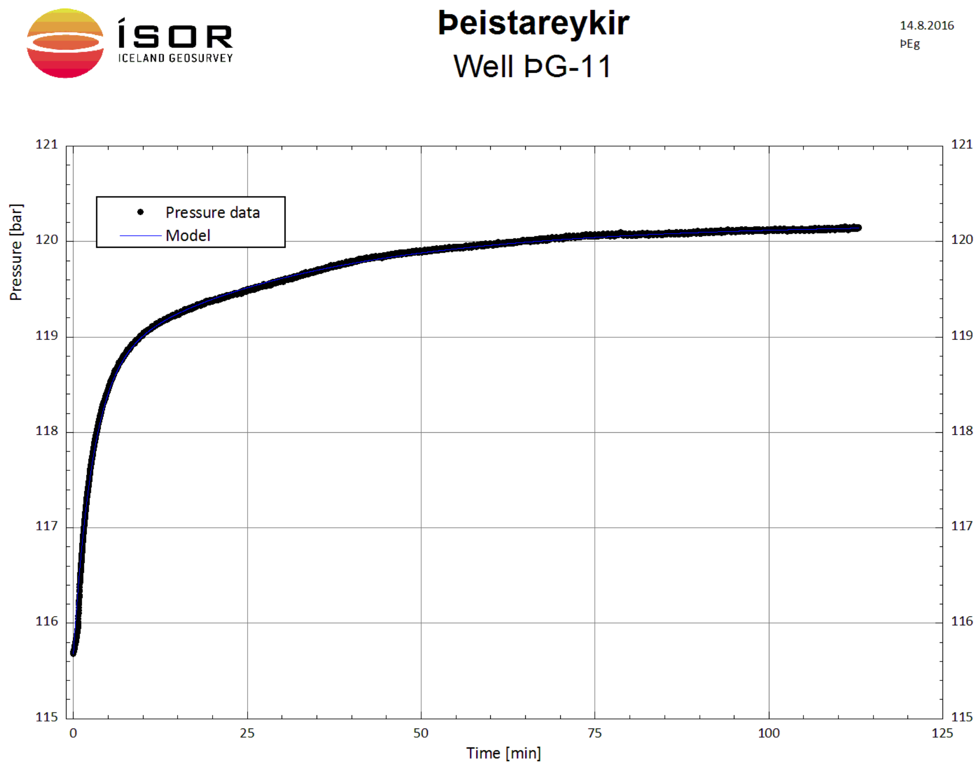

Figure 40. *Modelling results for step 1 on a linear scale for both time and pressure data.*

4.4.6 Step 2

The second step of the injection test was to change the injection rate from 23.9 L/s to 36.2 L/s. The initial pressure was 120.1 bar and the estimated equilibrium pressure was 122.5 bar which was reached after only about 30 minutes, see Figure 41. After that the pressure starts to decrease, most likely affected by air that was dragged into the well with the water injection.

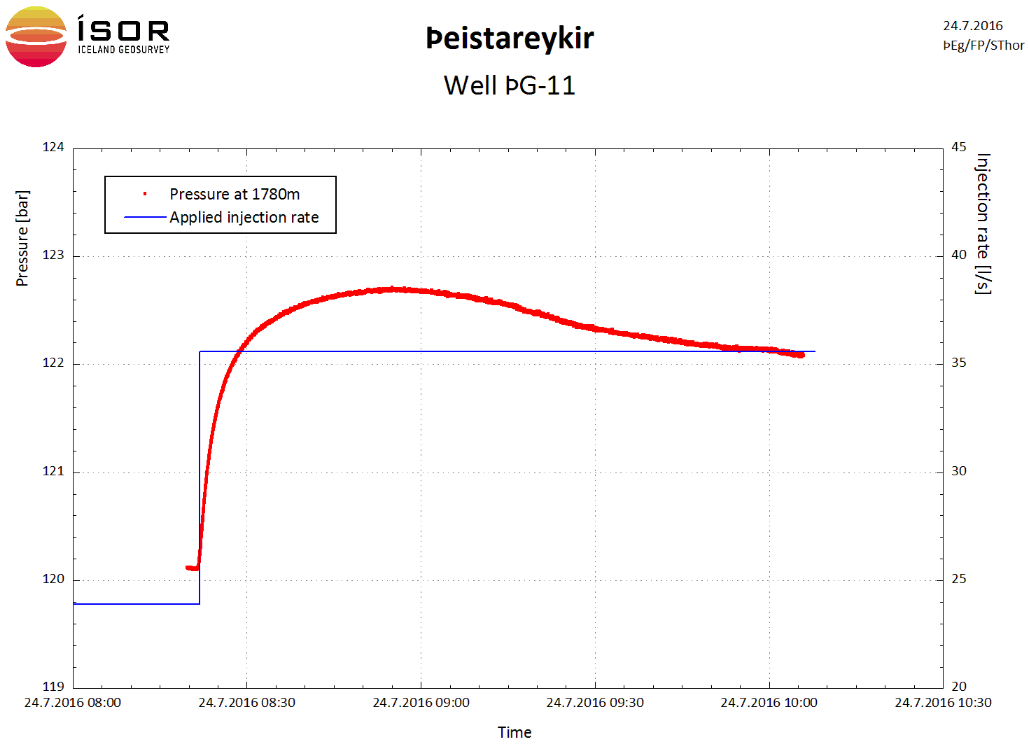

Figure 41. *Pressure response at 1780 m to change in injection rate from 23.9 L/s to 35.6 L/s.*

Table 12. *Modelled well- and reservoir parameters for constant pressures boundaries from the pressure recorded in Step 2 of the injectivity test.*

Parameter	Value	Standard Deviation	Unit
Transmissivity (T)	1.7	$3{\cdot}10^{-3}$	10^{-8} m³/(Pa s)
Storativity (S)	0.9	$2{\cdot}10^{-2}$	10^{-8} m/Pa
Response distance (r_e)	60	0	m
Skin factor (s)	-3	0	
Wellbore storage (C)	0.8	$2{\cdot}10^{-3}$	10^{-5} m³/Pa
Transmissivity ratio (λ)	3.3	$3{\cdot}10^{-2}$	10^{-5}
Storativity ratio (ω)	84	1	10^{-5}
Reservoir Thickness (h)	50		m
Effective Permeability (k)	31		10^{-15} m²
Injectivity Index (II)	3.7		(L/s)/bar

As seen in Figures 42–44 the obtained parameters for a dual porosity model listed in Table 12 give a good fit to the observed data after the first two minutes and the model is reliable for calculating the pressure response for any change in injection rate. The dual porosity model also simulates the time derivative of the pressure data considerably well which gives a good confidence of choosing secondary permeability as an important reservoir property.

For this step the skin effect of -3.0 represents a good coupling of the well to the formation. Even though we see clear signs of dual porosity behaviour in the model calculation the storativity ratio, $\omega \approx 8 \cdot 10^{-4}$, indicates a relatively high matrix porosity, which also is the case for the transmissivity ratio, $\lambda \approx 3 \cdot 10^{-5}$ (Horne, 1995).

From the reservoir properties listed in Table 12 and the reservoir parameters listed in Table 9, the reservoir thickness is $h \approx 50\,m$ which leads to reservoir permeability of $k \approx 31\,mD$. Compared to general permeability of geothermal fields, reservoir permeability of 30 milli-Darcy, is above moderate (Axelsson, 2004).

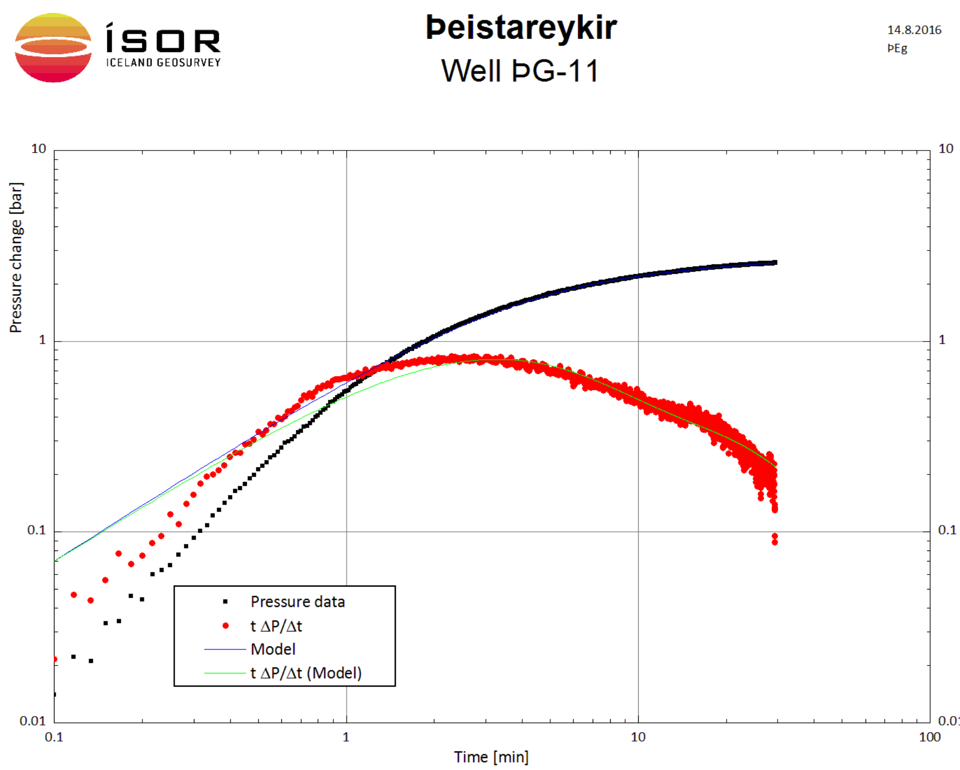

Figure 42. *Modelling results for step 2 on logarithmic scale for both the pressure change and the time derivative of the pressure data.*

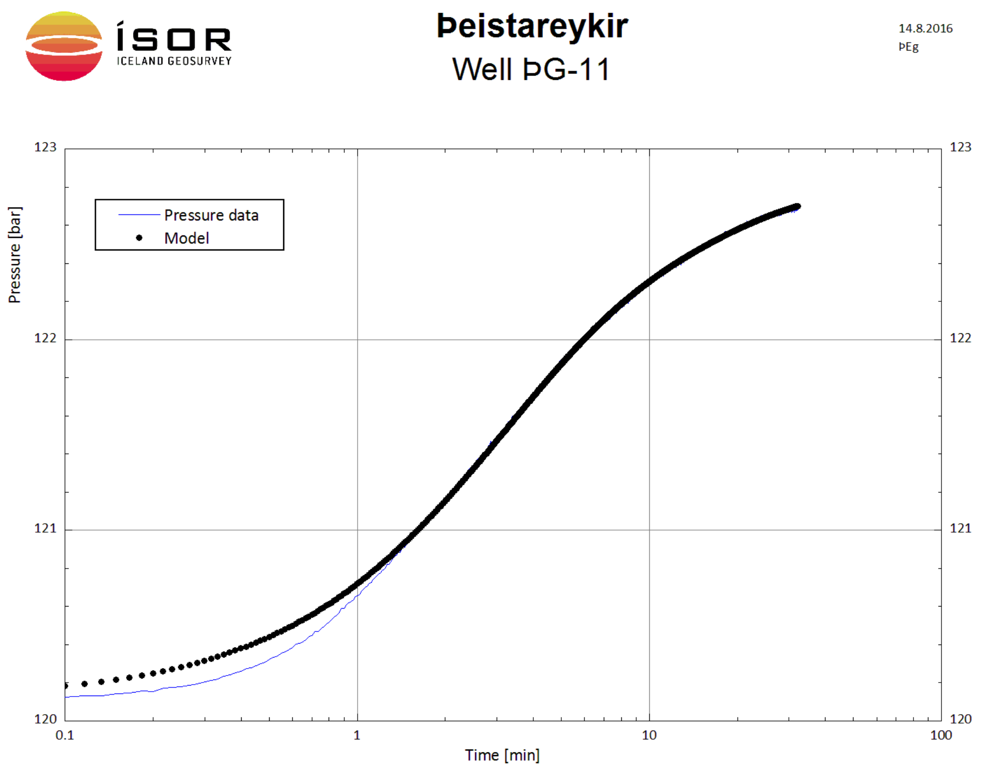

Figure 43. *Modelling results for step 2 on a logarithmic scale for the time and on a linear scale for the pressure data.*

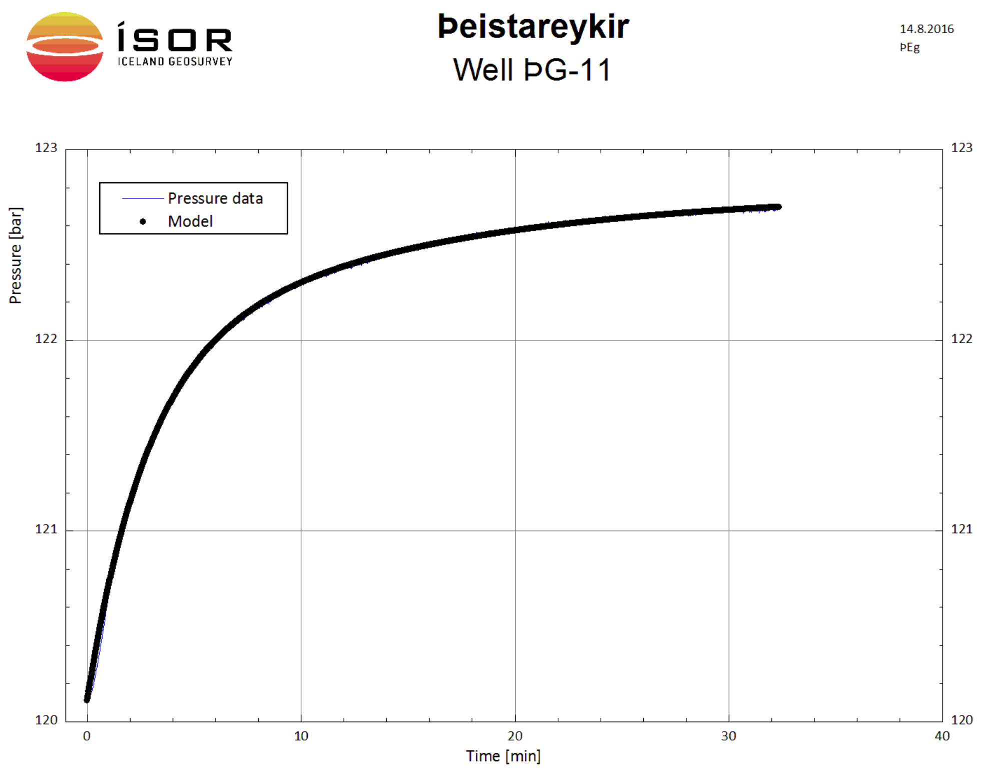

Figure 44. *Modelling results for step 2 on linear scale for both time and pressure data.*

4.4.7 Step 3

The third step of the injection test was to change the injection rate from 36.2 L/s to 19.4 L/s. The initial pressure was 122.5 bar and the estimated equilibrium pressure was 119.3 bar (see Figure 45).

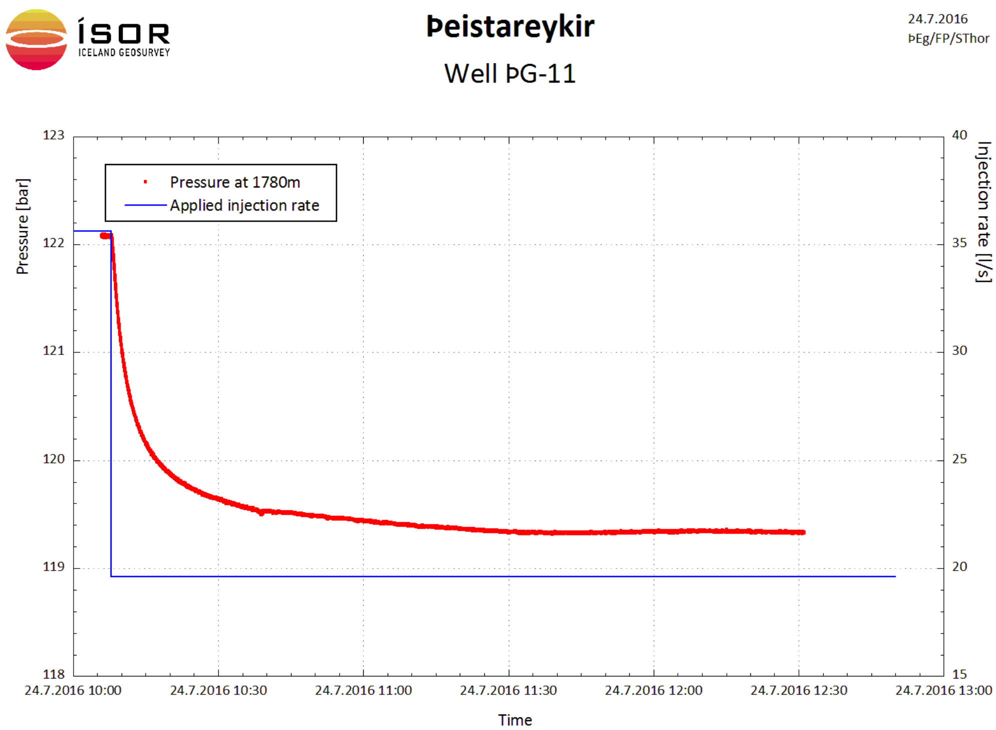

Figure 45. *Pressure response at 1780 m to change in injection rate from 35.6 L/s to 19.6 L/s.*

Table 13. *Modelled well- and reservoir parameters for constant pressures boundaries from the pressure recorded in Step 3 of the injectivity test.*

Parameter	Value	Standard Deviation	Unit
Transmissivity (T)	3.9	$4 \cdot 10^{-4}$	10^{-8} m³/(Pa s)
Storativity (S)	4.0	$7 \cdot 10^{-3}$	10^{-8} m/Pa
Response distance (r_e)	70	0	m
Skin factor (s)	-2.5	0	
Wellbore storage (C)	1.5	$2 \cdot 10^{-3}$	10^{-5} m³/Pa
Transmissivity ratio (λ)	2	$5 \cdot 10^{-3}$	10^{-5}
Storativity ratio (ω)	96	0.3	10^{-5}
Reservoir Thickness (h)	90		m
Effective Permeability (k)	32		10^{-15} m²
Injectivity Index (II)	6.1		(L/s)/bar

As seen in Figures 46–48 the obtained parameters for a dual porosity model listed in Table 13 give a good fit to the observed data from the first minute of the test and the model is reliable for calculating the pressure response forny change in injection rate. The dual porosity model also simulates the time derivative of the pressure data considerably well which gives a good confidence of choosing secondary permeability as an important reservoir property.

For this step the skin effect of -2.5 represents a good coupling of the well to the formation. Even though we see clear sign of dual porosity behaviour in the model calculation the storativity ratio, $\omega \approx 1 \cdot 10^{-3}$, indicates a relatively high matrix porosity, which also is the case for the transmissivity ratio, $\lambda \approx 2 \cdot 10^{-5}$ (Horne, 1995).

From the reservoir properties listed in Table 13 and the reservoir parameters listed in Table 9, the reservoir thickness is $h \approx 90\,m$ which leads to reservoir permeability of $k \approx 32\,mD$. Compared to general permeability of geothermal fields, reservoir permeability of 30 milli-Darcy, is above moderate (Axelsson, 2004).

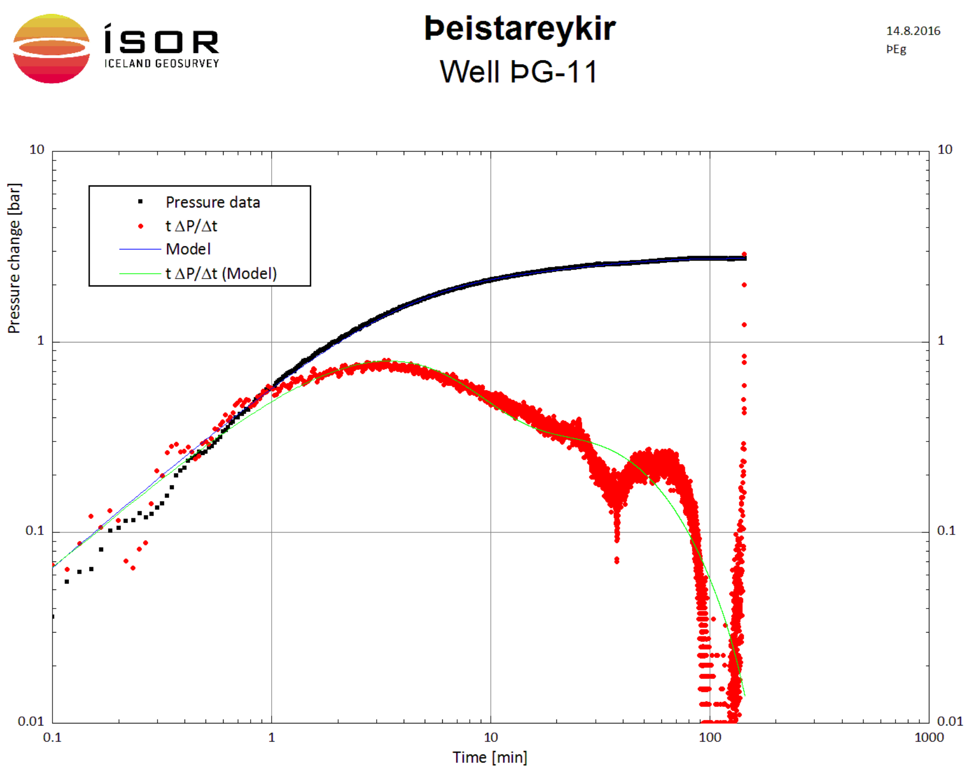

Figure 46. *Modelling results for step 3 on logarithmic scale for both the pressure change and the time derivative of the pressure data.*

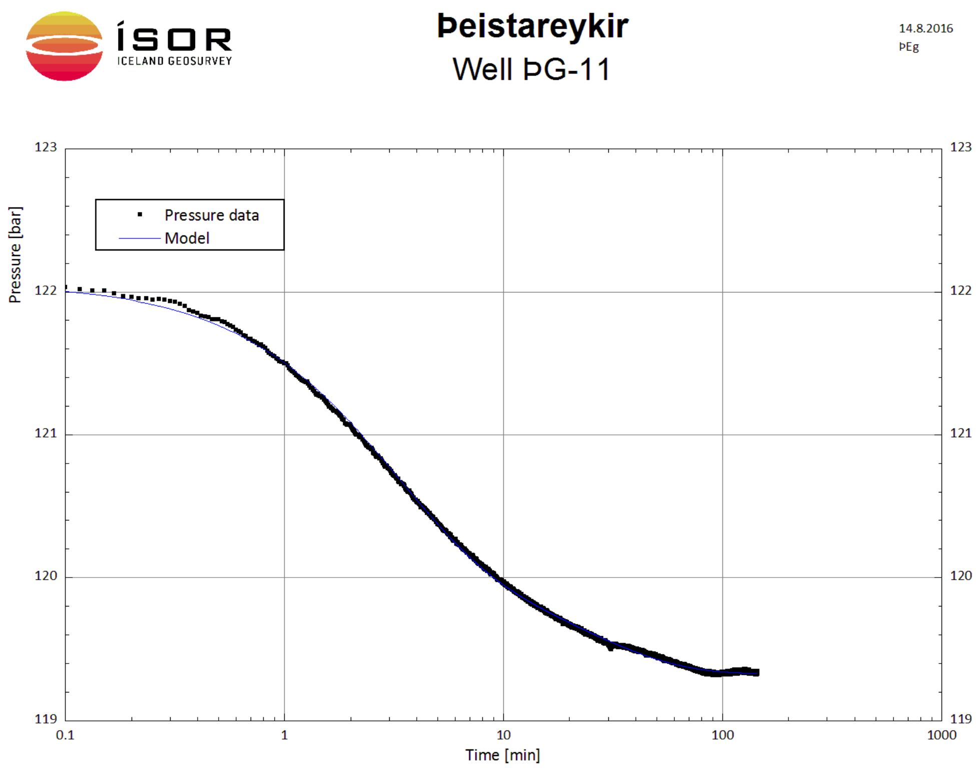

Figure 47. *Modelling results for step 3 on a logarithmic scale for the time and on a linear scale for the pressure data.*

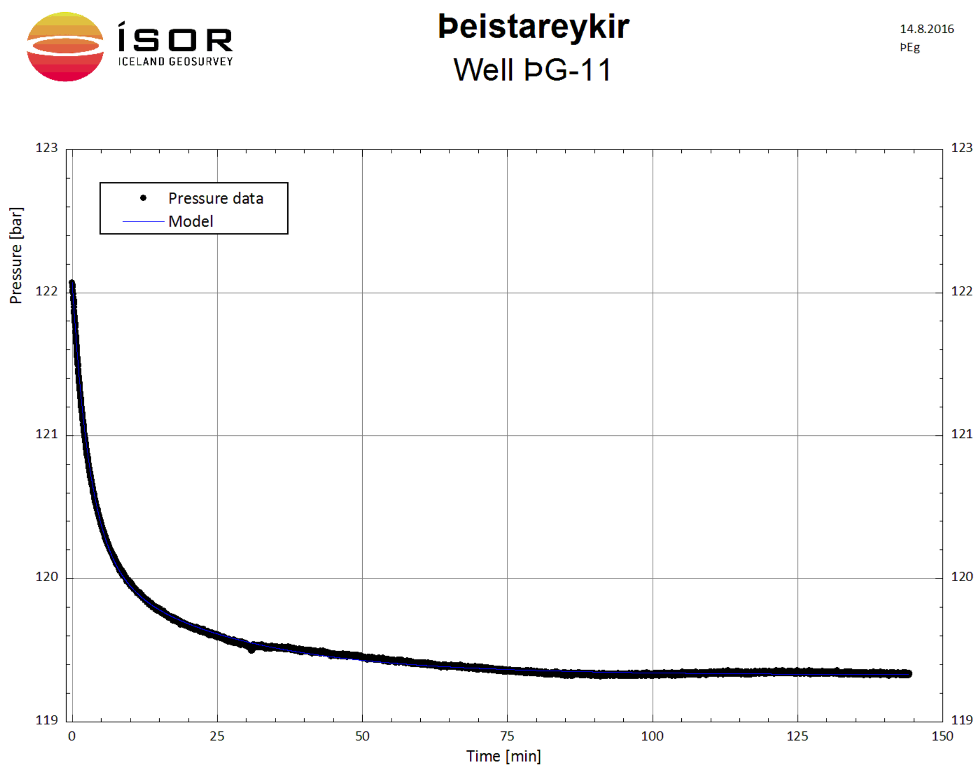

Figure 48. *Modelling results for step 3 on a linear scale for both time and pressure data.*

Table 14. *Summary of injection test results for the 3 steps.*

Reservoir/Well properties	Step 1	Step 2	Step 3
Transmissivity [10^{-8} m^3/(Pa s)]	2.9	1.7	3.9
Storativity [10^{-8} m/Pa]	5.6	0.9	4.0
Response distance [m]	60.0	60	70
Skin factor [-]	-3	-3	-2.5
Wellbore storage [10^{-5} m^3/Pa]	1.3	0.8	1.5
Transmissivity ratio [10^{-5}]	3.0	3.3	2.0
Storativity ratio [10^{-5}]	7.3	84	96
Reservoir Thickness	90	50	90
Injectivity Index [(L/s)/bar]	5.6	3.7	6.1
Effective Permeability [10^{-15} m^2]	30	31	32

The general result of the simple modelling is that for each of the step rate changes, each property is well determined, i.e. low standard deviation. However, they distinguish a bit between individual ones. The estimated reservoir thickness is about 90 m with a consequent reservoir permeability of 30 mD, which is a moderate value for a geothermal reservoir. The 90 m estimate of the reservoir thickness is supported by the spinner log, see Figure 29.

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Appendix:

Daily reports

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Wednesday** **6th of July 2016** Workday #2 of Óðinn

Þeistareykir	**Report #34** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**MÁS, RSÁ** **(E-mail: mas@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**802 m**	**Hole made last 24 hrs. :**	**- m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**802 m**	**Drilling time:**	**- hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**0 l/s**	**Average ROP:**	**- m/hr**

Drilling operation

Drilling of the first three phases (i.e. phases 0 to 2) of ÞG-11 was carried out with Sleipnir. On June 14th drilling operations of the 2nd phase of ÞG-11 finished as the top of the production casing was cut to a desired height.

On the 16th of June the rig Óðinn arrived at Husavik by ship and on the 19th of June transportation of the rig to Þeistareykir, wellpad A, started. During the next ten days the crew worked on rigging-up. From the 1st to 5th of July the BOP stack was installed and the flow-line connected. At 6 am until 2 pm yesterday the BOP´s were pressure tested (by applying 30 bar for 10 min.). A minor pressure drop was observed, i.e. 1 bar in 10 min, for each of the three BOP´s (the annular, pipe-ram and the blind-ram). For fixing that the bolts had to be tightened further. At 10:30 pm yesterday a string for cooling the well was RIH. According to a temperature logging carried out at 11 pm on the 4th of July the maximum temperature in the well was close to 250 °C (Figure 1).

At present, at 3 pm on July 6th, the well is being circulated with water in order to cool it before running a drill-string with a motor and MWD in the well. At the same time the crew is tightening the bolts connecting the BOB stack to the flange.

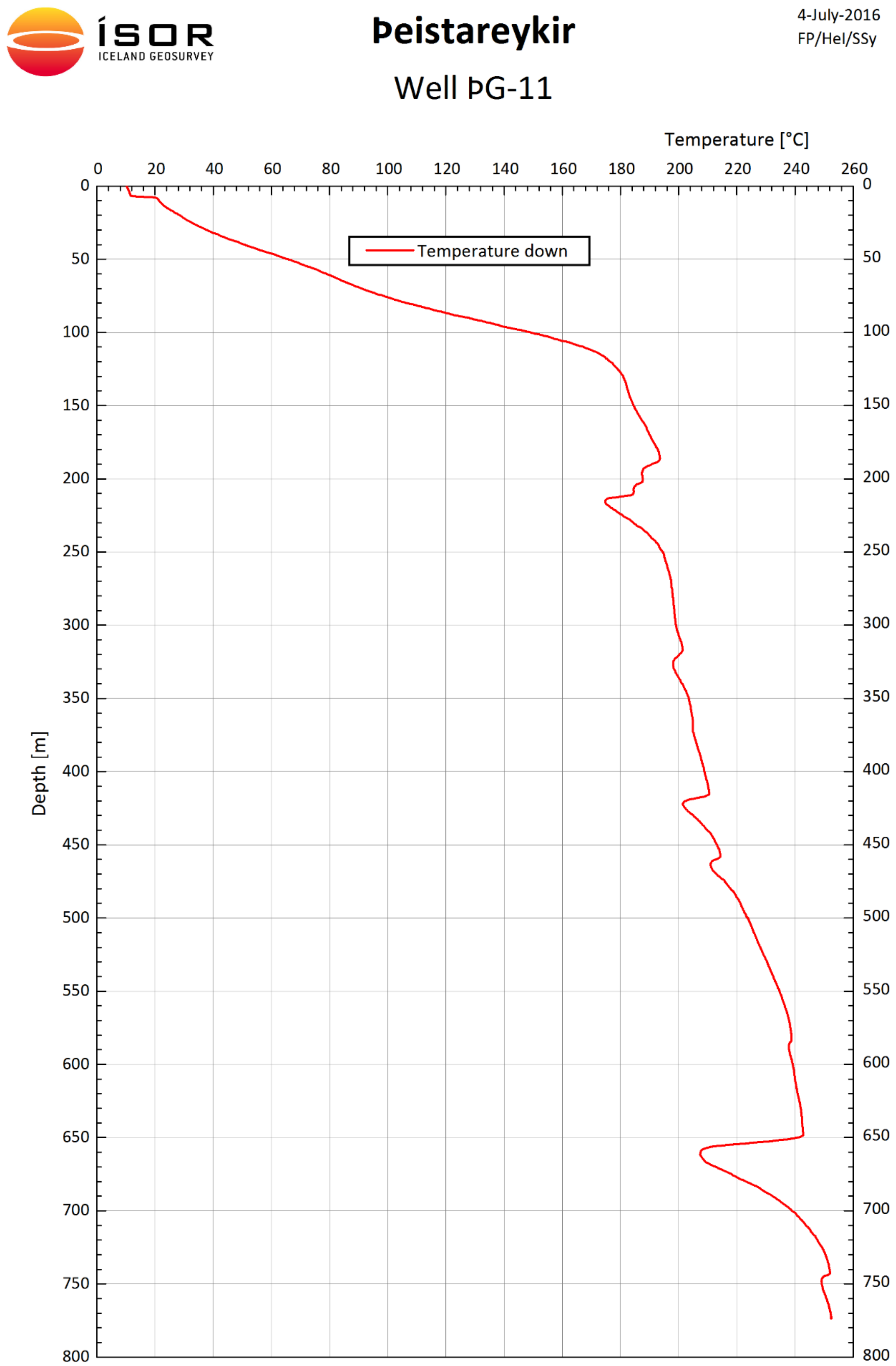

Figure 1. *Temperature log from ÞG-11 from inside the production casing, 4th of July 2016. Logging interval was 0-772 m.*

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Thursday** **7th of July 2016** Workday #3 of Óðinn

Þeistareykir	**Report #35** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**MÁS, RSÁ** **(E-mail: mas@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**802 m**	**Hole made last 24 hrs. :**	**- m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**802 m**	**Drilling time:**	**- hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**0 l/s**	**Average ROP:**	**- m/hr**

Drilling operation

Yesterday morning until 10 am a cooling string was RIH down to 785.6 m (where the top of the float collar was found). In the uppermost 130 m the return temperature was in range of 27-30 °C but below that it was 43-52 °C. At the bottom (i.e. 785 m) a pumping of 30 l/s was applied. At 5 pm the crew started to POOH which was finished at 9 pm. Then preparation for running a BHA with an 8½" bit, a mud motor and a MWD in the hole started. RIH started at midnight. At noon today the cement was drilled out and now at 3:30 pm drilling in formation is about to start at 804 m.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Friday** **8th of July 2016** Workday #4 of Óðinn

Þeistareykir	**Report #36** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	MÁS, RSÁ/SSy, FP, HeI (E-mail: mas@isor.is)

Last casing size:	9 ⅝" (production casing)	**Depth at 24 hrs.**	855 m	**Hole made last 24 hrs. :**	53 m
Last casing depth:	801.7 m	**Depth at 8 hrs.**	932 m	**Drilling time:**	6.8 hrs.
Drilling fluid:	Water	**Circulation losses at 8 hrs.**	0 l/s	**Average ROP:**	7.8 m/hr

Drilling operation

Yesterday morning the BHA with a motor and MWD was run slowly in the hole. Pumping was applied after every single during RIH. At 1:35 pm drilling in cement (i.e. top of float-collar) started and at 3 pm drilling in formation started at 804 m. A polymer pill was pumped down after drilling of every single. At 8 pm preparations for a gyro survey started. The survey was carried out at 9:30-11 pm. Because of a high temperature in the well only one gyro reading was obtained, at 811 m depth. An inclination of 43.53° and an azimuth of 183.5° were obtained which is close to the design of the well.

Geology

Preliminary inspection of cuttings from around 928 m show that the it is mostly composed of fine crystalline basalt with some greenish glass and tuff fragments admixed. The rock is highly altered. The main alteration minerals are quartz, epidote and fine crystalline green clay.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Saturday** **9th of July 2016** Workday #5 of Óðinn

Þeistareykir	**Report #37** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, HeI** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**1078 m**	**Hole made last 24 hrs. :**	**223 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1166 m**	**Drilling time:**	**20.75 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**0 l/s**	**Average ROP:**	**10.7 m/hr**

Drilling operation

Drilling went smoothly the 7th of July, with average ROP of 10.7 m/hr. No circulation losses were observed. Polymer was injected after each single. At 16:30 the well was circulated and 2 polymer pills injected. ÍSOR´s logging engineers performed a gyro survey down to 983 m between 18:15 and 19:45. Drilling was then continued with water pumping of 40 l/s.

Geology

Samples down to 980 m have been analyzed. They mostly compose of different hyaloclastite formations. A possible intrusion was seen at the bottom with dark and fresh basalt with low alteration. Figure 1 shows the description of each unit with alteration and amount of calcite/pyrite/oxidation/vein fillings. The most common alteration minerals are quartz, epidote, coarse grained clay and below 970 m prenhnite and wollastonite were noticed. Samples from 814-980 are described to further details hereunder:

814-820 m FINE-MEDIUM GRAINED BASALT

> Slightly tuff mixed. Dense grains with cpx and plagioclase in groundmass. Epidote growing on quartz in a pore. This formation could possibly be a pillow basalt.

820-826 m GLASSY BASALT

> Increase in crystalline epidote and euhedral quartz crystals. Occasional sediment grains with fine and green groundmass. Also, partly crystalline grains with glassy groundmass. Quite cement mixed.

826-830 m BASALTIC BRECCIA

> Abundant of euhedral quartz in pores. Increase in tuff grains.

830-832 m NO CUTTINGS

832-836 m BASALTIC BRECCIA

Partly crystalline basalt and tuff grains.

836-838 m FINE-MEDIUM GRAINED BASALT

Mostly well crystalline grains with quartz and coarse grained clay in pores. Rather dense formation, with cpx and plagioclase in groundmass. Tuff mixed in (highly altered).

838-840 m CEMENT

Cement

840-854 m BASALTIC BRECCIA

Clay and quartz in pores. Increase in green tuff grains. Also found fine grained basalt grains with no phenocrysts. Abundant of tuff down the formation.

854-858 m CEMENT

Cement

858-872 m BASALTIC BRECCIA

Green tuff and reddish basalt grains. Dense formation with no epidote in the uppermost sample. Voids filled with clay and quartz/silica, Increse in pyrite in the lower most part of the formation.

872-878 m BASALTIC TUFF

Mostly green and highly altered tuff grains. Increase in epidote.

878-892 m BASALTIC BRECCIA

Porphyric free dark colored basalt with green tuff grains. Voids filled with clay and pyrite. Well crystallized epidote and quartz crystals.

892-916 m BASALTIC TUFF

Almost only tuff grains with green appearances. High amount of epidote. Reddish tuff grains mixed in.

916-922 m GLASSY BASALT

Partly crystalline basalt with pores filled with clay and quartz. Tuff mixed in.

922-928 m FINE-MEDIUM GRAINED BASALT

Highly altered basalt. High amount of calcite. Dense grains with clay as pore fillings.

928-936 m NO CUTTINGS

No cuttings sampled

936-938 m FINE-MEDIUM GRAINED BASALT

Dense and greenish/grayish grains.

938-940 m NO CUTTINGS

No cuttings sampled

940-942 m GLASSY BASALT

Fine grained basalt grains with clay in pores. Abundant of epidote. Could be a lava formation.

942-944 m NO CUTTINGS

No cuttings sampled.

944-946 m GLASSY BASALT

946-948 m NO CUTTINGS

No cuttings sampled

948-950 m GLASSY BASALT

950-956 m NO CUTTINGS

No cuttings sampled

956-958 m GLASSY BASALT

Abundant of epidote.

958-958 NO CUTTINGS

No cuttings sampled

958-960 m BASALTIC BRECCIA

Dense basalt grains, with fractures filled with epidote and quartz? Tuff mixed in.

960-968 m NO CUTTINGS

No cuttings sampled

968-970 m FINE-MEDIUM GRAINED BASALT

Dense and light colored fine grained basalt. Various alteration between grains. Quartz and epidote in pores.

970-974 m NO CUTTINGS

No cuttings sampled

974-976 m FINE-MEDIUM GRAINED BASALT

Fractured and dense basalt. Not porphyric. Epidote and quartz in voids.

976-978 m NO CUTTINGS

No cuttings sampled

978-980 m FINE-MEDIUM GRAINED BASALT

Dark and fresh basalt grains (50%). The other 50% is green and highly altered basalt/tuff grains. Possibly intrusion is being penetrated.

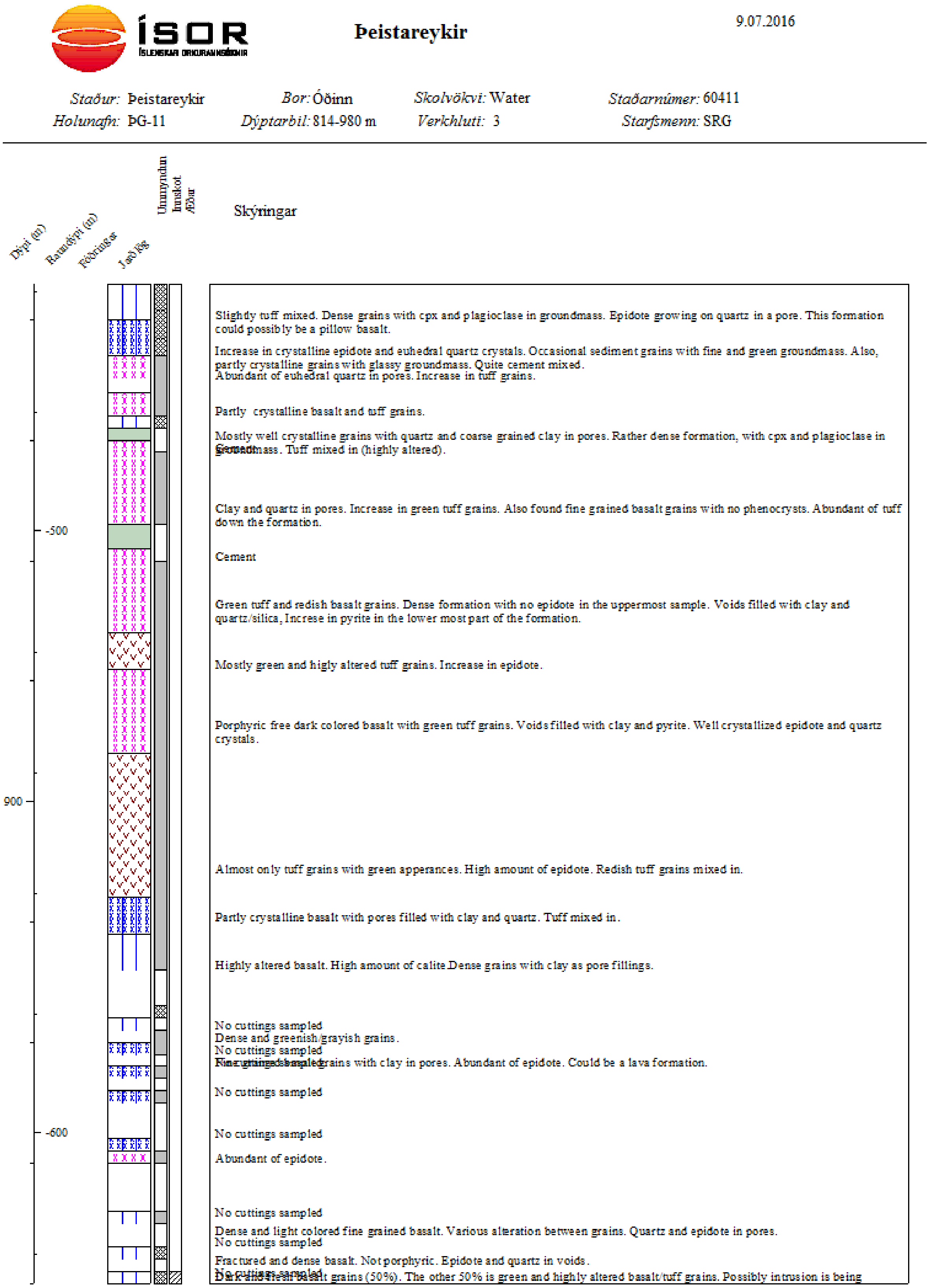

Figure 1. Description of lithology from 814-980 m

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Sunday** **10th of July 2016** Workday #6 of Óðinn

Þeistareykir	**Report #38** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, HeI** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**1318 m**	**Hole made last 24 hrs. :**	**240 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1422 m**	**Drilling time:**	**20 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**17-20 l/s**	**Average ROP:**	**12 m/hr**

Drilling operation

Drilling was very fast the 8th of July, with average ROP of 12 m/hr. Polymer pills were injected into the well after each single. At 1202 m the well was circulated before a gyro survey. After ÍSOR´s logging engineers had completed the survey, circulation losses were measured 14 l/s. The results of the gyro survey are shown in table 1. Drilling was then continued and circulation losses increased to 17-20 l/s at depth 1250-1318 m. The container for the on-site geologist was transported from well pad A (ÞG-10) to well pad B (ÞG-11) around 14:00. Currently at 08:30 the 10th of July, drilling is ongoing. Figure 1 shows the drilling activity in ÞG-11.

Table 1. *Azimuth measured in degrees and referenced to local grid*
Inclination measured from vertical

Time	MD[m]	Inclination	Azimuth
12:48	1162.00	41.11	180.5
12:51	1130.00	40.04	180.0
12:57	1080.00	39.18	179.7
13:01	1030.00	39.42	175.9
13:06	983.00	40.39	174.5

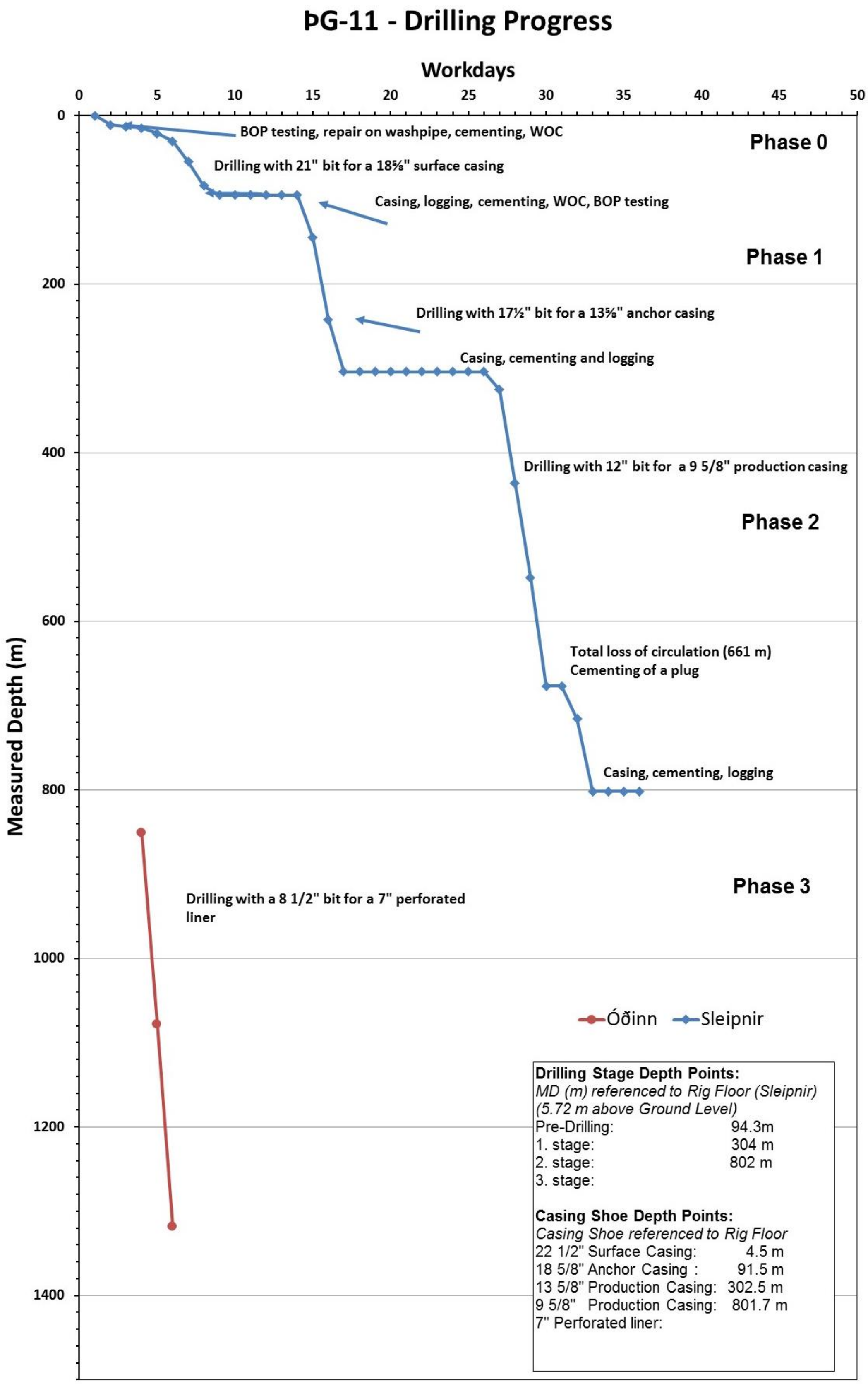

Figure 1. Drilling progress of ÞG-11. Red line = Óðinn, blue line = Sleipnir.

Geology

Samples down to 1166 m have been analyzed. They mostly compose of different hyaloclastite formations, but with intervals of fine to medium grained basalt units. A possible intrusion was seen at 978-986 m with dark and fresh basalt grains with low alteration. An intrusion was then clearly observed at 1000-1002 m where the cuttings mostly consisted of dark and fresh, fine grained basalt. Figure 2 shows the alteration mineral assembly from 800-1166 m. High temperature minerals like epidote, quartz, wollastonite and prehnite are found in abundance, especially in the lower part of this section. Calcite disappears below 980 m, but I found in small portion at 1066-1074 m. Based on the disappearance of calcite and vast amount of epidote along with the high temperature minerals wollastonite and prehnite, the estimated rock temperature in the well could be around 250 °C. Figures 3-5 show examples of alteration minerals (coarse grained clay, epidote and wollastonite) seen in the drill cuttings in ÞG-11. Samples from 1002-1166 are described to further details hereunder:

1002-1006 m GLASSY BASALT

Less of intrusion like grains.

1006-1110 m NO CUTTINGS

No cuttings sampled

1010-1018 m BASALTIC BRECCIA

White dense tuff grains with epidote in groundmass, slightly pl-phorphyric. Dense and fresh basalt grains mixed in.

1018-1020 m NO CUTTINGS

No cuttings sampled

1020-1022 m BASALTIC BRECCIA

1022-1064 m BASALTIC TUFF

White and highly altered tuff with epidote in groundmass. Abundant of quartz and epidote. Few fresh basalt grains mixed in. Epidote increases downward. Clay, epidote and quartz in pores.

1064-1068 m BASALTIC BRECCIA

Very few dark basalt grains. Altered grains slightly porous with fillings as above. Abundant of epidote.

1068-1070 m FINE-MEDIUM GRAINED BASALT

Light colored basalt. Very fine cuttings. some amount of tuff mixed in. Most likely lava formation.

1070-1084 m BASALTIC BRECCIA

Grains again white in color with epidote and green clay in groundmass. Broken fragments from the drill bit mixed in. Grains become reddish downwards the formation.

1084-1120 m BASALTIC TUFF

Epidote almost 1/3 of the samples. Mostly white and green tuff grains and occasionally crystallized basalt is observed. The cuttings are very fine grained.

1122-1166 m BASALTIC BRECCIA

Fine grained basalt in a matrix of highly altered tuff and epidote crystals. Generally, rather tuff rich breccia with high amount of alteration minerals (clay, epidote, quartz, wollastonite and prehnite).

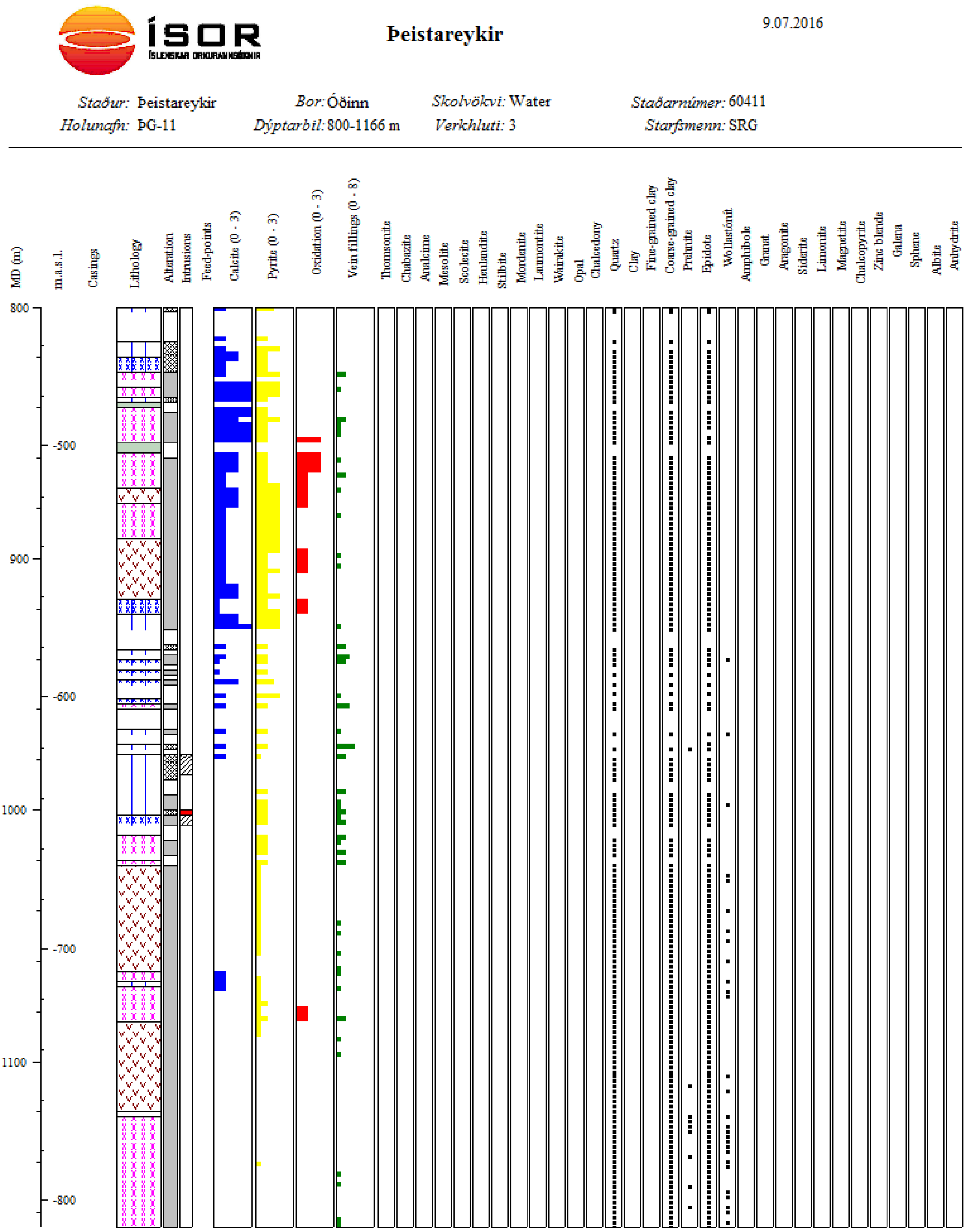

Figure 2. Alteration minerals from 800-1166 m in well ÞG-11.

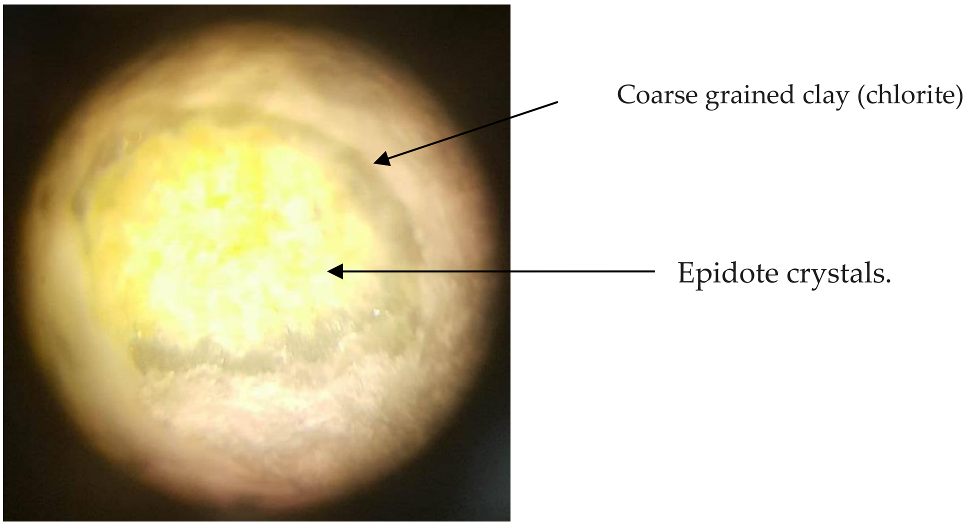

Figure 3. Pore filling. Rim of coarse grained clay, with epidote crystals in the middle.

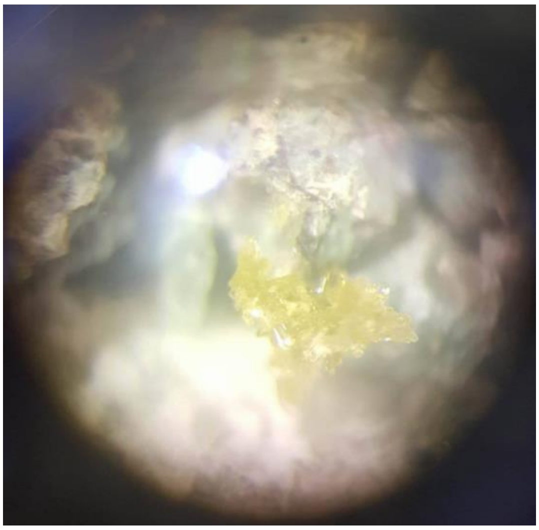

Figure 4. Well shaped epidote crystal.

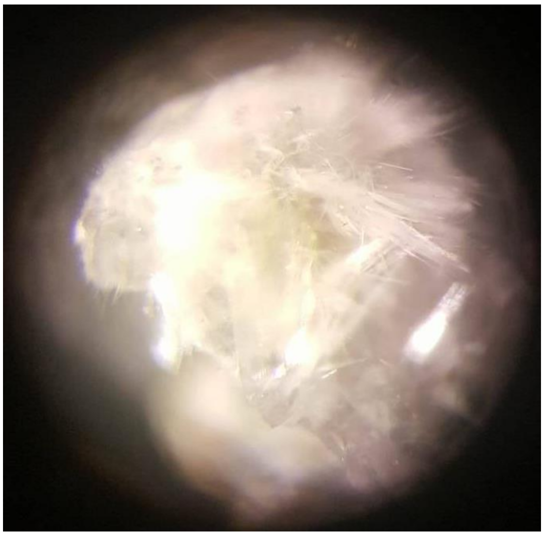

Figure 5. Wollastonite needles.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Monday** **11th of July 2016** Workday #7 of Óðinn

Þeistareykir	**Report #39** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, HeI** (E-mail: srg@isor.is)

Last casing size:	**9 ⅝"** (production casing)	**Depth at 24 hrs.**	**1563 m**	**Hole made last 24 hrs. :**	**245 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1659 m**	**Drilling time:**	**23.25 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**6 l/s**	**Average ROP:**	**10.5 m/hr**

Drilling operation

Drilling was almost continuous the 10th of July, with average ROP of 10.5 m/hr. Two polymer pills were injected after each single. Circulation losses ranged from 9-18 l/s. Drilling was stopped at 23:15 to circulate the well. Currently at 09:45 the 11th of July, drilling is ongoing and 6 l/s losses, with the plan to carry out a gyro survey after drilling the next single.

Geology

Samples down to 1412 m have been analyzed and mostly consist of basaltic breccia, tuff and pillow basalt formations.

1070-1084 m BASALTIC BRECCIA

> Grains again white in color with epidote and green clay in groundmass. Broken fragments from the drill bit mixed in. Grains become reddish downwards the formation.

1084-1120 m BASALTIC TUFF

> Epidote almost 1/3 of the samples. Mostly white and green tuff grains and occasionally crystallized basalt is observed. The cuttings are very fine grained.

1122-1174 m BASALTIC BRECCIA

> Fine grained basalt in a matrix of highly altered tuff and epidote crystals. Generally, rather tuff rich breccia with high amount of alteration minerals (clay, epidote, quartz, wollastonite and prehnite).

1174-1182 m GLASSY BASALT

> Very fine cuttings with light colored fine grained basalt, glassy basalt and tuff grains.

1182-1210 m BASALTIC BRECCIA

More tuff grains than above. Plenty of alteration minerals like wollastonite and epidote. Very fine grained cuttings, light in color. Tuff grains white and green. Becomes very tuff rich at intervals.

1210-1234 m BASALTIC TUFF

Homogenous whitish tuff formation. Abundant of epidote. Few dark and fine grained basalt grains. Grains with plagioclase needles.

1234-1240 m BASALTIC BRECCIA

1240-1254 m BASALTIC TUFF

Some amount of basalt fragments, but still mostly tuff grains. Withe and green with pores filled with coarse grained clay and epidote. Some fragments from the drill bit.

1254-1268 m BASALTIC BRECCIA

Still abundant of epidote. Plagioclase in the groundmass as pl-needles in partly crystalline and tuff grains.

1268-1270 m NO CUTTINGS

No cuttings sampled.

1270-1300 m BASALTIC BRECCIA

Tuff grains green and white with pores filled with epidote, clay and quartz and plagioclase in groundmass. Brownish fine grained basalt grains mixed in as well as some partly crystalline grains. Becomes very tuff rich at intervals.

1300-1306 m BASALTIC TUFF

Less of crystalline basalt grains.

1306-1322 m BASALTIC BRECCIA

Matrix of tuff, glassy basalt and crystalline grains. Clay and epidote in pores.

1322-1336 m GLASSY BASALT

Abundant of fine crystallized basalt grains, but still a lot of greenish tuff grains. Pillow breccia?

1336-1338 m NO CUTTINGS

No cuttings sampled

1338-1370 m BASALTIC BRECCIA

Tuff grains, some with plagioclase in groundmass, mixed with crystalline basalt. Pores are filled up mostly with clay. Not as abundant of epidote as above, but still plenty. Euhedral quartz. Some grains slightly fractured with white/clear fillings.

1370-1376 m GLASSY BASALT

More of reddish basalt grains with plagioclase in groundmass. As well as light colored basalt grains. Less tuff grains.

1376-1386 m BASALTIC BRECCIA: Clay and epidote in pores.

1386-1398 m GLASSY BASALT: Mostly crystalline-and partly crystalline basalt with plagioclase needles.

1398-1412 m BASALTIC BRECCIA: Very fine cuttings, mixed with crystalline basalt, green tuff and partly crystalline basalt (glassy). Abundant of epidote.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Tuesday** **12th of July 2016** Workday #8 of Óðinn

Þeistareykir	**Report #40** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, HeI** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**1748 m**	**Hole made last 24 hrs. :**	**185 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1785 m**	**Drilling time:**	**20.5 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**21 l/s**	**Average ROP:**	**9 m/hr**

Drilling operation

Drilling was ongoing until 11:30 the 11th of July, depth 1681 m. Then the well was circulated clean and a gyro survey performed by ÍSOR´s logging engineers. The measurement was complete at 15:00. Drilling was continued down to 1748 m at midnight. Two polymer pills were injected after drilling each single. Water pumping was 40 l/s. Currently at 09:00 the 12th of July, POOH is in operation and the drill bit will be replaced and temperature and televiewer logging will be conducted. Table 1 shows the results of the gyro survey. Figure 1 shows the drilling progress of well ÞG-11. Table 2 shows measured circulation losses during drilling of phase 3.

Table 1, Gyro survey down to 1641m

Time	MD (m)	inclination	azimuth
13:44	1641	40.63	179.0
13:47	1600	40.64	178.7
13:52	1550	40.47	181.2
14:00	1450	41.20	178.4
14:04	1350	39.96	178.7
14:10	1250	40.32	178.3
14:15	1130	39.96	180.4

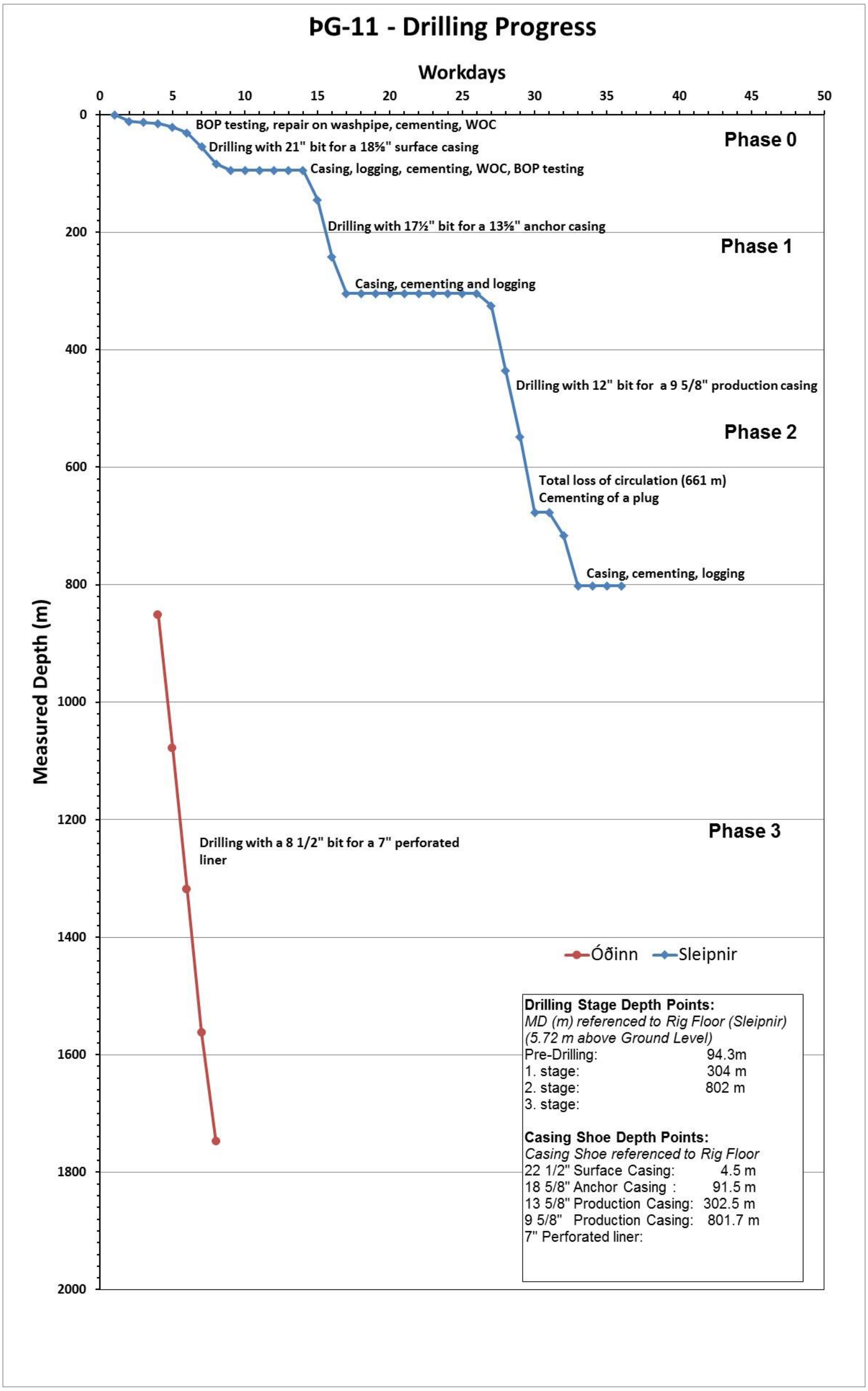

Figure 1. Drilling progress of ÞG-11

Table 2. Circulation losses during drilling of phase 3.

3. Stage

dd.mm.yyyy	depth (m)	Circ. Loss (l/s)
9.7.2016	1318	17-20
10.7.2016	1354	18
10.7.2016	1443	7
10.7.2016	1472	8
10.7.2016	1552	9
10.7.2016	1563	9
11.7.2016	1609	9
11.7.2016	1634	6
11.7.2016	1710	13
11.7.2016	1729	14
11.7.2016	1748	14

Geology

Samples down to 1656 m have been analyzed and mostly consist of basaltic breccia, tuff and pillow basalt formations intersected by thin formations of basaltic lava.

1424-1428 m FINE-MEDIUM GRAINED BASALT

Very fine cuttings with fine grained and well crystallized basalt. Still, few grains with glass in the groundmass. Decrease in epidote. Some tuff grains from above mixed in.

1428-1434 m BASALTIC BRECCIA

Mostly glass rich grains and tuff. Some crystallized grains from above.

1434-1452 m GLASSY BASALT

A lot of fine grained light grey basalt grains. Possibly intrusion. white and green glass rich grains with plagioclase in groundmass.

1452-1466 m FINE-MEDIUM GRAINED BASALT

Very fine cuttings. Highly altered basalt. Some tuff grains mixed in. Possibly a pillow basalt formation. Abundant of epidote. Alteration minerals mostly epidote, clay, quartz and wollastonite.

1466-1474 m BASALTIC BRECCIA

Mostly white and green tuff grains. Epidote and coarse grained clay in groundmass. Few well crystallized basalt grains.

1474-1478 m GLASSY BASALT

Epidote rich. mixture of tuff and crystallized or partly crystallized grains.

1478-1484 m BASALTIC TUFF

Plenty of well crystallized epidote. Some crystallized rock fragments.

1484-1494 m BASALTIC BRECCIA

More of crystallized rock fragments, but still tuff rich. Plagioclase and glass in the groundmass of partly crystalline grains.

1494-1542 m BASALTIC TUFF

Thick formation of basaltic tuff. Plenty of epidote and slightly various amount of crystallized rock fragments. Mostly white and green tuff grains, highly altered. In some cases, the tuff is totally white. Plagioclase needles often seen in the groundmass.

1542-1564 m BASALTIC BRECCIA

Partly crystallized grains with glass and plagioclase needles in the groundmass. Very similar to what was seen above, Very tuff rich and epidote rich. Could be the same tuff formation as above.

1564-1594 m GLASSY BASALT

Dark and glassy grains, some with pl-needles. Some tuff grains with clay and epidote in pores. High amount of epidote. Cuttings often very fine grained and mixed. Various amount of crystalline grains.

1596-1608 m FINE-MEDIUM GRAINED BASALT

Slight mixed with grains with glass rich groundmass. Could be pillow basalt formation, or just mixed cuttings. high amount of epidote. Well crystallized grains often partly transparent with magnetite in the groundmass. Highly altered.

1608-1616 m GLASSY BASALT

Slight increase in tuff from above. Well crystallized grains with cpx crystals and pyroxen altered to chlorite. Some grains very fine grained and dark grey in color.

1616-1620 m FINE-MEDIUM GRAINED BASALT

More of the crystallized grains from above. Could be a scoria formation due to the amount of glass rich grains.

1620-1630 m GLASSY BASALT

Glass rich grains 50% crystallized grains 50%

1630-1656 m BASALTIC BRECCIA

Less of fine grains basalt grains. Pyroxen seen altered into chlorite. Plagioclase needles in the groundmass. Still very abundant of epidote. White and green tuff grains and glass rich grains. Various amount of tuff grains. Pores filled with clay, epidote and quartz.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Tuesday** **12th of July 2016** Workday #8 of Óðinn

Þeistareykir	**Report #41** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, M** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**1788 m**	**Hole made last 24 hrs. :**	**40 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1788 m**	**Drilling time:**	**5 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**39 l/s**	**Average ROP:**	**8 m/hr**

Drilling operation

Drilling was ongoing the 13th of July down to 1785 m depth, where the string was POOH. Circulation losses at that time were 21 l/s. The pipe handler failed at 14:30, but was repaired 4 hours later. At 17:50 circulation losses were measured at the pumps and turned out to be around 39 l/s. POOH was complete at 23:45 and ÍSOR´s logging engineers started logging televiewer, temperature and caliper. The results of the temperature measurements are shown in figure 1. According to the figure, there are signs of loss zones at 1630 m and 1700 m. At that depth intervals, circulation losses were measured 6 and 14 l/s, respectively. Figure 2 shows the drill bit that was POOH, and was in fairly good conditions, according to Baker, and could have been used for some while longer.

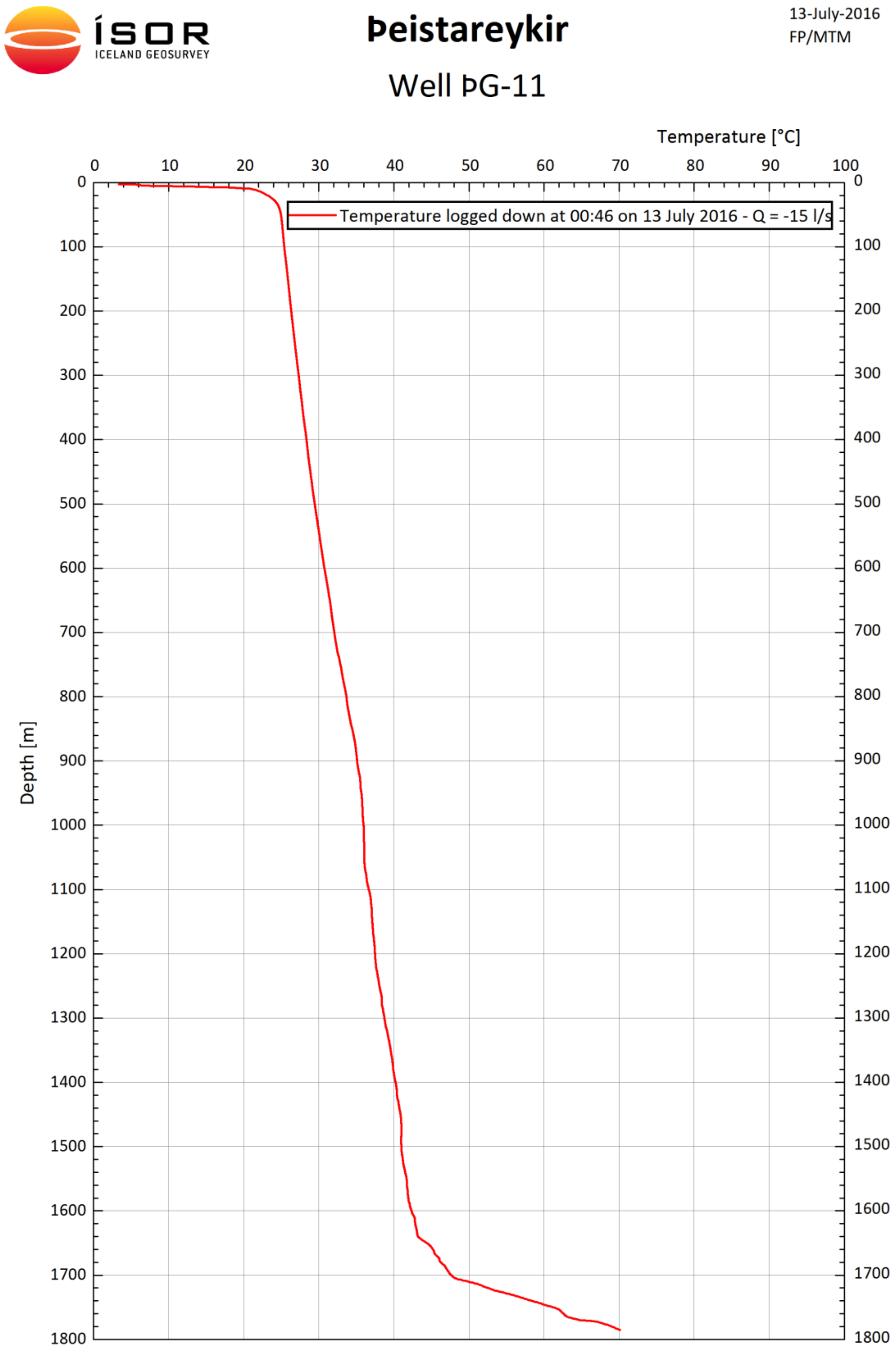

Figure 1. Temperature measurement in an open hole.

Figure 2. The drill bit that was POOH.

Geology

Samples down to 1784 m have been analyzed and consists of glassy basalt/breccia, intersected by fine to medium grained basalt formations.

1656-1692 m GLASSY BASALT

Very fine cuttings. Mixture of fine crystallized basalt, white and green glass rich grains and dark grains with glassy groundmass. Abundant of epidote.

1692-1714 m FINE-MEDIUM GRAINED BASALT

Mostly light colored fine crystallized basalt, some pl phorphyric and with magnetite in the groundmass. cpx mostly altered to chlorite. Still some green and white tuff grains. Most likely a lava formation. Decrease in epidote.

1714-1728 m GLASSY BASALT

Some more of glass rich grains. No clear formation boundaries.

1728-1742 m FINE-MEDIUM GRAINED BASALT

Similar to the upper lava formation.

1742-1750 m GLASSY BASALT

mixture of light grey fine grained basalt and green glassy grains/tuff.

1750-1784 m FINE-MEDIUM GRAINED BASALT

Still some glass rich grains wit plagioclase needles. But mostly light colored fine crystallized basalt grains. Wollastonite and epidote the main alteration minerals.

Figure 3 shows the lithology and alteration mineral assembly in ÞG-11 from 800-1784 m. The lithology of ÞG-09 is shown as well, for comparison. Quartz, epidote and coarse grained clay are seen continuously in every sample down the well. Wollastonite and prehnite are found repeatedly, but not as continuous as quartz, epidote and clay. Actinolite is found in one sample at 1594 m, indicating rock temperature around 300 °C. Pyrite and calcite are not seen below ˜1100 m. The lithology in wells ÞG-11 and 09 are quite consistent. Hyaloclastite formations like basaltic tuff, breccia and glassy basalt are dominant, intersected with thin layers of fine- to medium grained basalt units.

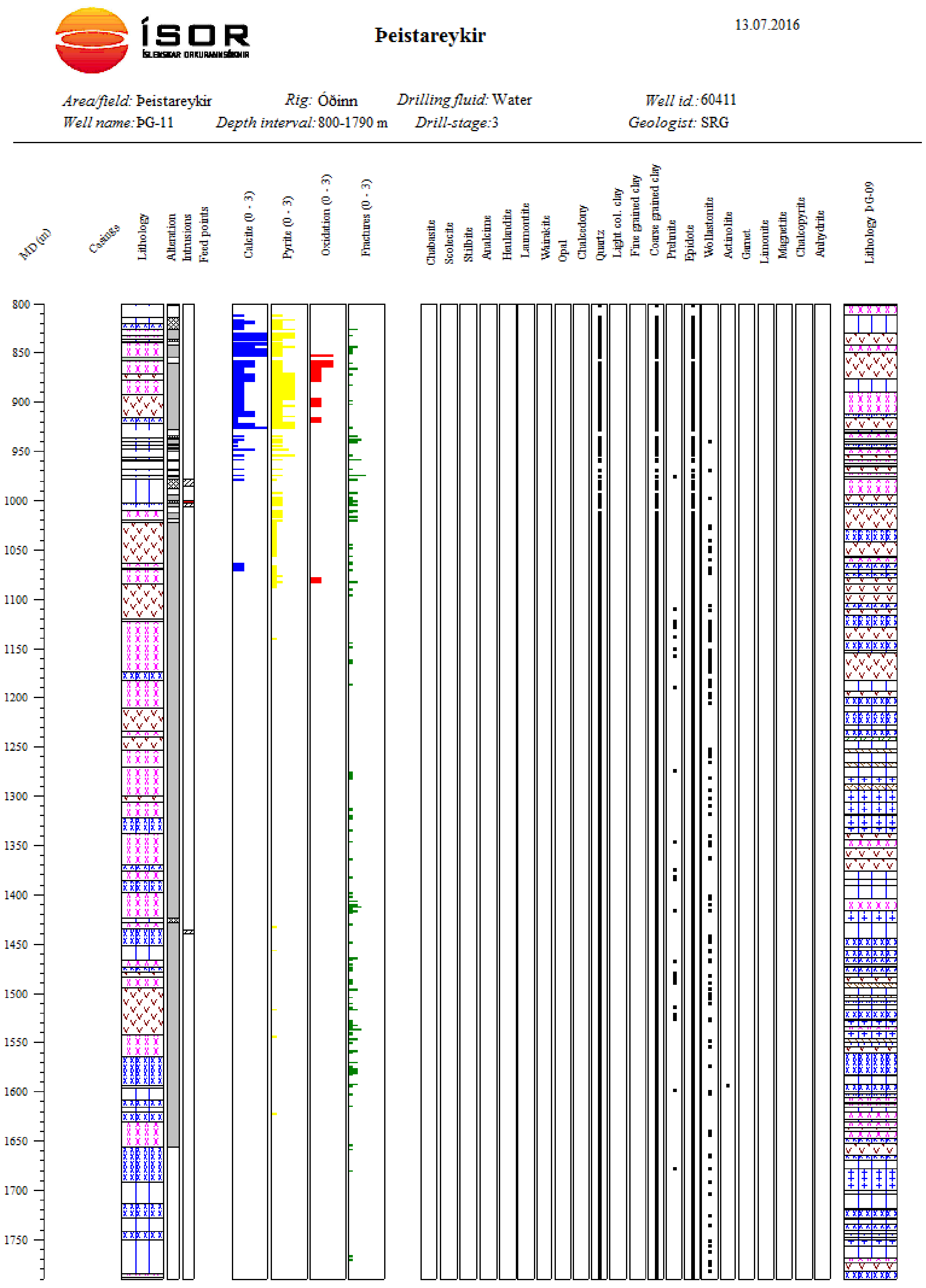

Figure 3. The lithology and alteration minerals in ÞG-11 from 800-1780 m. For comparison the lithology of well ÞG-09 is shown.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Thursday** **14th of July 2016** Workday #10 of Óðinn

Þeistareykir	**Report #42** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, M** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝" (production casing)**	**Depth at 24 hrs.**	**1788 m**	**Hole made last 24 hrs. :**	**- m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1832 m**	**Drilling time:**	**- hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**~39 l/s**	**Average ROP:**	**- m/hr**

Drilling operation

Temperature, caliper and televiewer measurements were carried out by ÍSOR´s logging engineers from 00:15-12:30. BHA without motor and mwd and with an 8 ½" drill bit started at 15:45. Around midnight this process, with three polymer pills injected after each single, was finished and no bottom hole deposit noticed. Currently at 09:00 the 14th of July, drilling is ongoing with little return of the drilling fluid. Figure 1 shows the measured diameter of the well. It shows several washouts, variable in size, that occur in the well, e.g at 800, 890-910, 1030, 1430, 1470 and 1720 m depth.

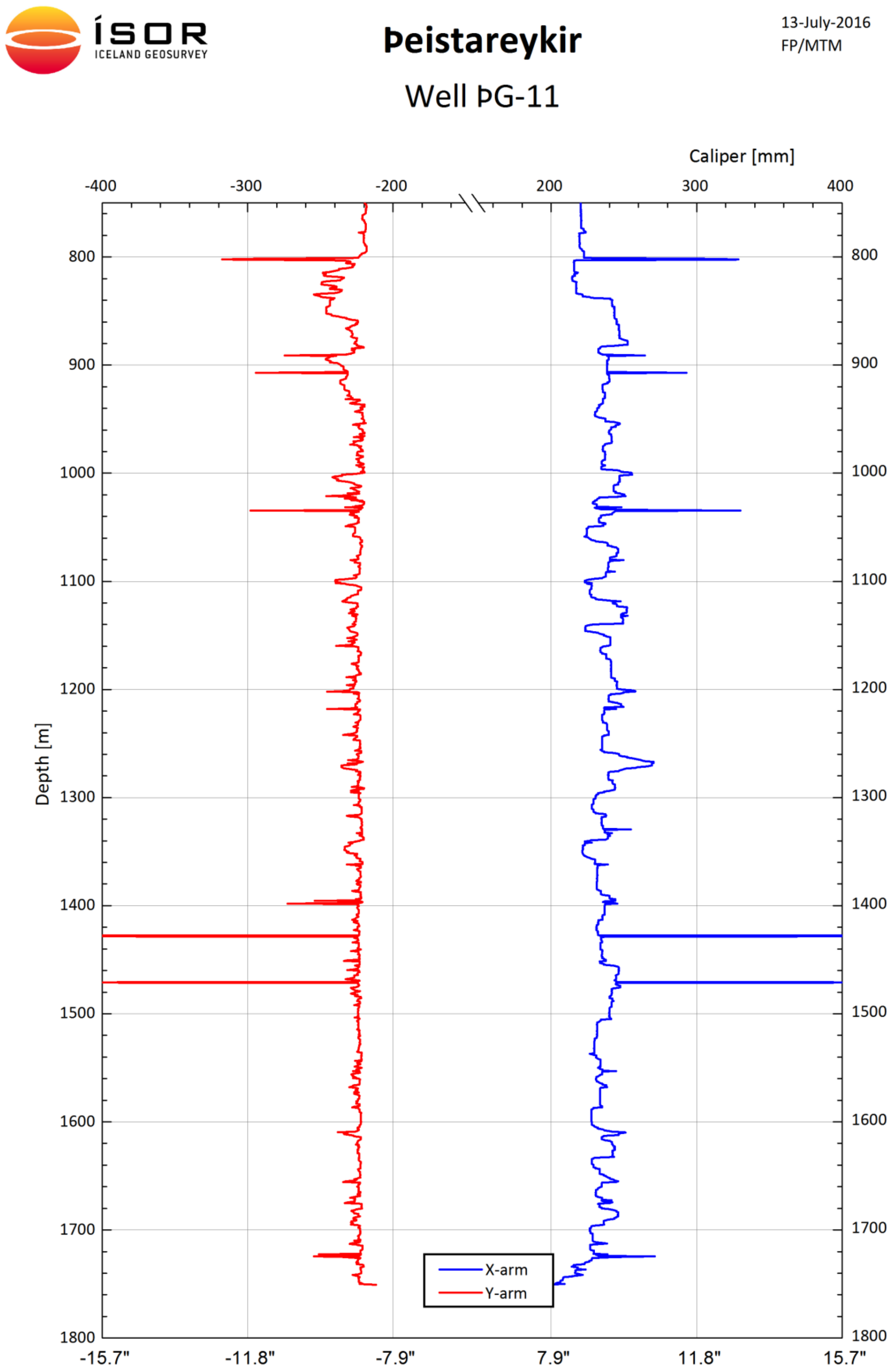

Figure 1. Caliper log in open well.

Geology

No samples were retrieved due to circulation losses between 1788-1822 m.

Samples from 1822-1828 m have been analyzed.

1822-1828 FINE-MEDIUM GRAINED BASALT

> Transparent, white and greenish fine grained basalt. Magnetite seen in the groundmass. Epidote color and very few epidote crystals. Little amount of alteration minerals such as epidote, quartz, clay and wollastonite. No pore fillings and the grains are not fractured. Fragments from the drill bits seen in the cuttings. Little amount of chalcopyrite.

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	**Friday** **15th of July 2016** Workday #11 of Óðinn

Þeistareykir	**Report #43** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**SRG, FP, M** **(E-mail: srg@isor.is)**

Last casing size:	**9 ⅝"** **(production casing)**	**Depth at 24 hrs.**	**1889 m**	**Hole made last 24 hrs. :**	**101 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1921 m**	**Drilling time:**	**22.5 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**? l/s**	**Average ROP:**	**4.5 m/hr**

Drilling operation

Yesterday, drilling was conducted from 1788-1842 m with two polymer pills injected after drilling each single. Drilling was then stopped around noon to clean out cuttings from the well. A pill was pumped in and following that the string was rotated rapidly (70 rpm) to try to amplify current velocity and maintain cuttings in suspension. Following this procedure, the torque was somewhat reduced and drilling continued with the occasional pill being injected into the well. Currently, at 08:00 the 15th of July, ÍSOR´s logging engineers are preparing for a gyro survey. Circulation losses have not been measured this morning, but cuttings were retrieved from the well during the night shift. Figure 1 shows the drilling progress, so far, in well ÞG-11.

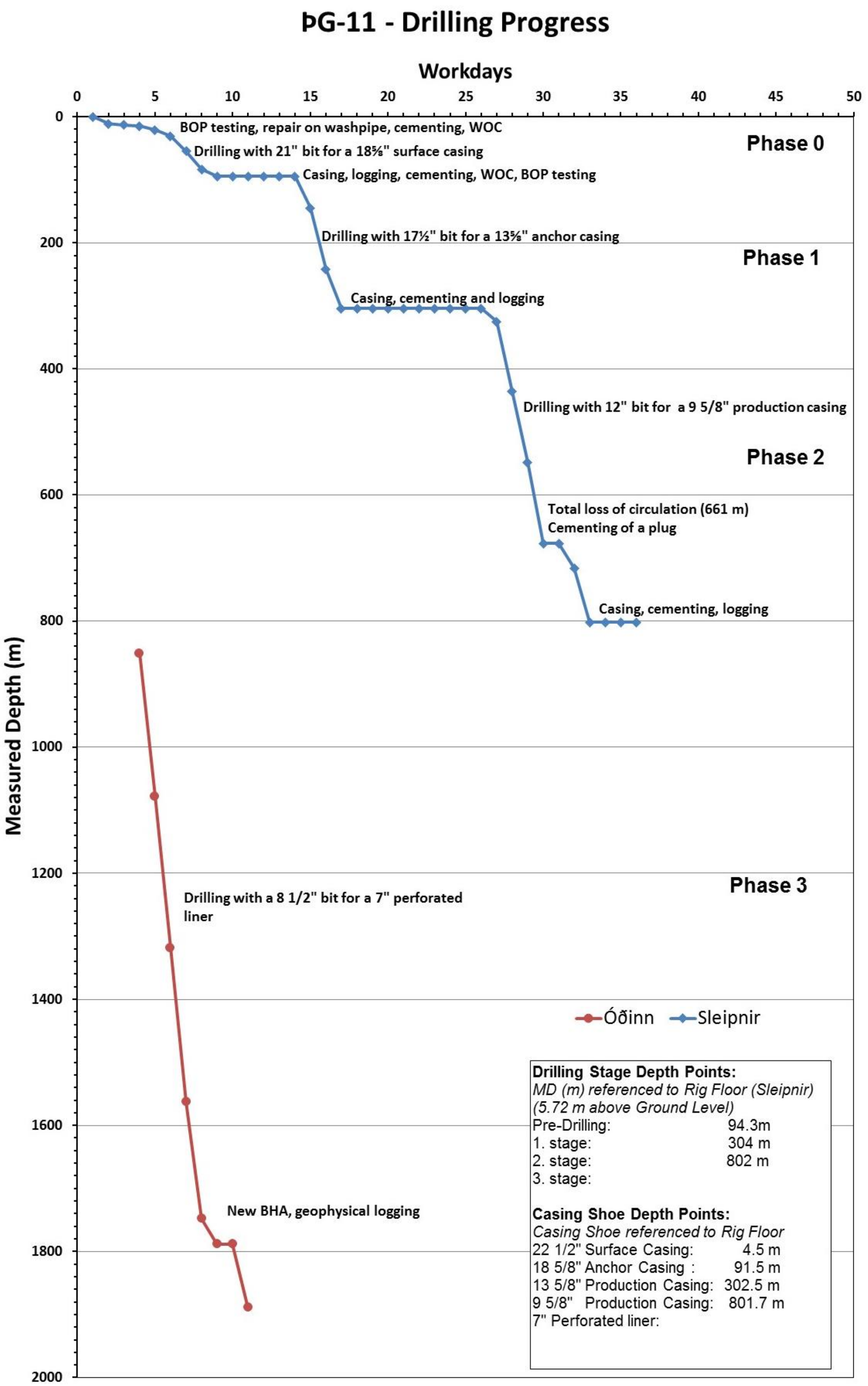

Figure 1. Drilling progress in well ÞG-11.

	ÞG-11	Saturday 16th of July 2016 Workday #12 of Óðinn
Þeistareykir	**Report #44** **Preliminary results**	**Phase 3** **(7" perforated liner)**

Operator:	**Landsvirkjun**	*Drilling Company:*	**Iceland Drilling Company**
Well Name:	**ÞG-11**	*Drill-Rig:*	**Óðinn**
Well-Id:	**60411**	*Geologist/Geophysicist:*	**BG, ÞEg, HÖS** **(E-mail: bg@isor.is)**

Last casing size:	**9 ⅝" (production casing)**	**Depth at 24 hrs.**	**1961 m**	**Hole made last 24 hrs. :**	**72 m**
Last casing depth:	**801.7 m**	**Depth at 8 hrs.**	**1999 m**	**Drilling time:**	**16.5 hrs.**
Drilling fluid:	**Water**	**Circulation losses at 8 hrs.**	**~24 l/s**	**Average ROP:**	**4.4 m/hr**

Drilling operation

Yesterday morning the loggers conducted a gyro-run (Table 1). MD at that time was 1921 m. Logging began just before 11:00. The well is basically right on track down to 1890 m. Logging was completed at 12:45.

Table 1. *Results of yesterday's gyro-run.*

Time	MD [m]	Inclination	Azimuth
11:26	1892	40.02	180.3
11:33	1862	39.77	178.5
11:39	1832	39.90	179.5
11:45	1802	39.94	179.3
11:48	1772	39.82	179.7
11:54	1742	41.04	179.7
11:59	1712	40.94	180.4
12:05	1682	40.41	180.2
12:11	1641	41.25	180.9

The crew then did some maintenance work on the pumps and then drilling commenced at ~14:00. Drilling continued with 4 to 5 tons WOB and an ROP of no more than 10 m/h. Polymer pills were injected twice per single.

Circulation losses were measured at 5:50 and 7:36 this morning and were 24 L/s and 29 L/s respectively.

A compilation of all gyro-data to date is presented in table 2 and displayed graphically in Figs. 1 and 2. The well trajectory is projected onto the Earth´s surface in Fig. 3. In Fig. 2 several structural targets are indicated with red dots. The two main permeability zones in the well are indicated with blue dots. The permeability zones are inferred from a recent temperature profile (see Daily Report #41). Additional aquifers and permeability zones may potentially be identified during logging and well testing after drilling is completed.

Borvakt

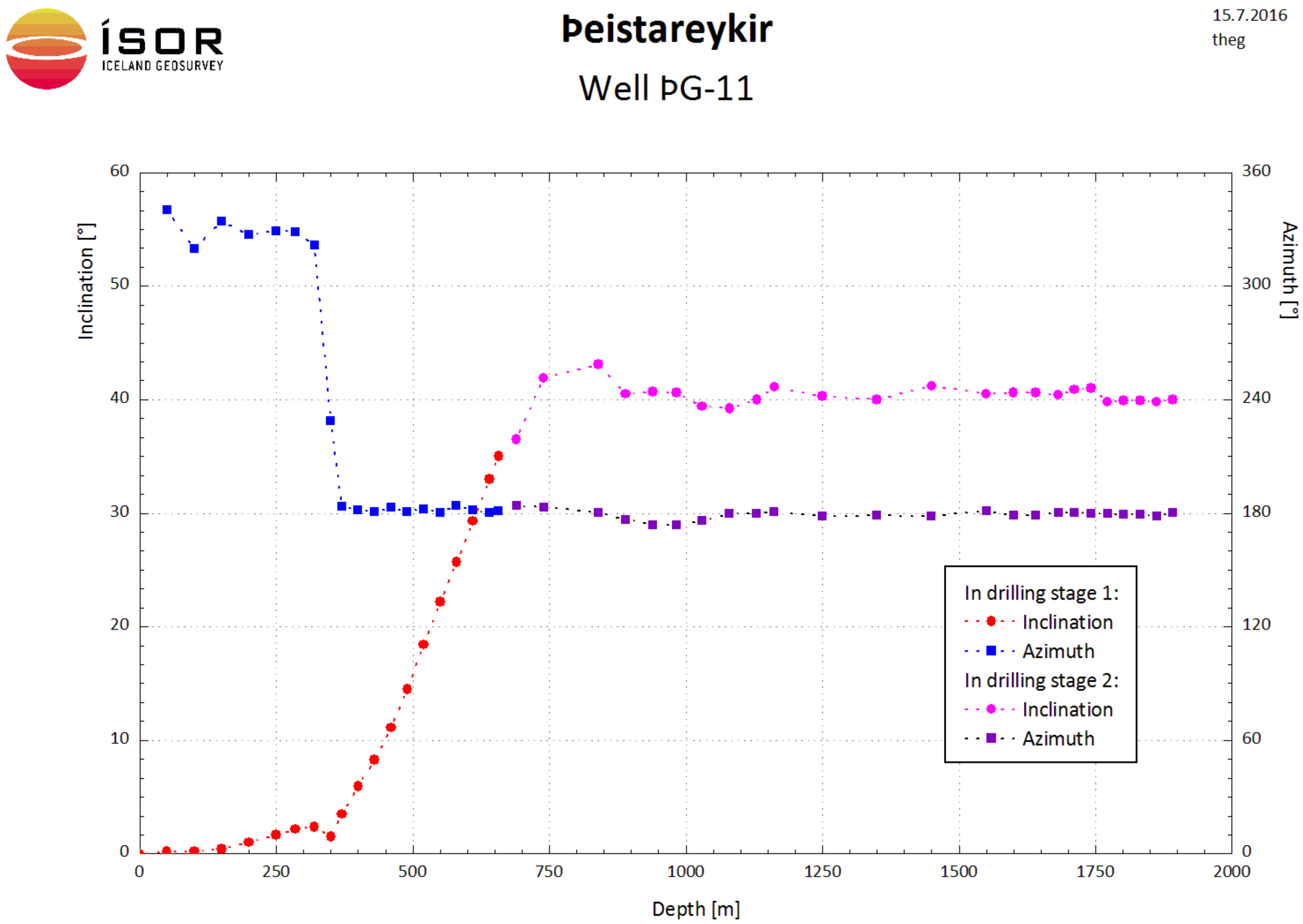

Figure 1. *Inclination [°] (left) and Azimuth [°] plotted against depth (MD) in well (m).*

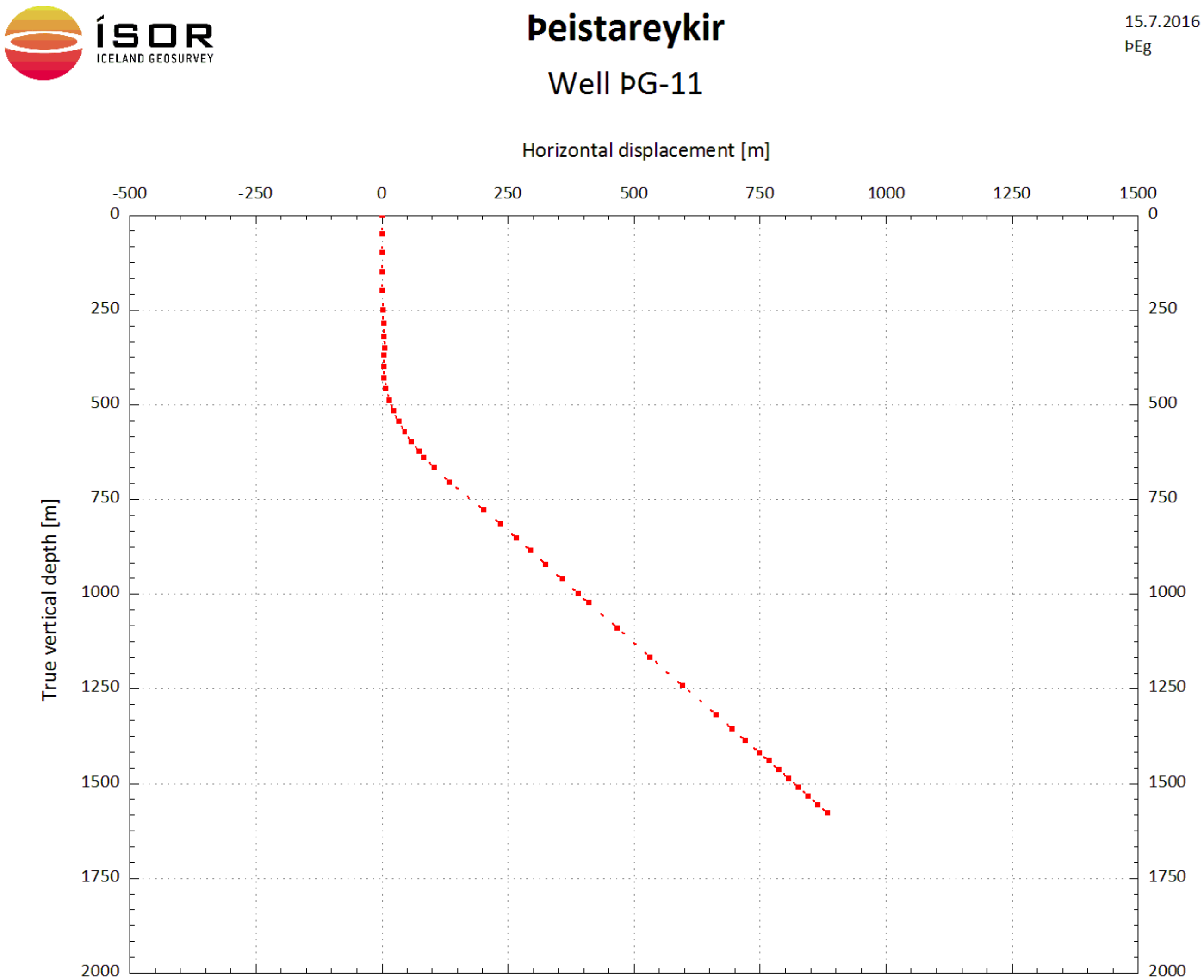

Figure 2. *Well trajectory in a N-S cross section. Red dots represent data-points.*

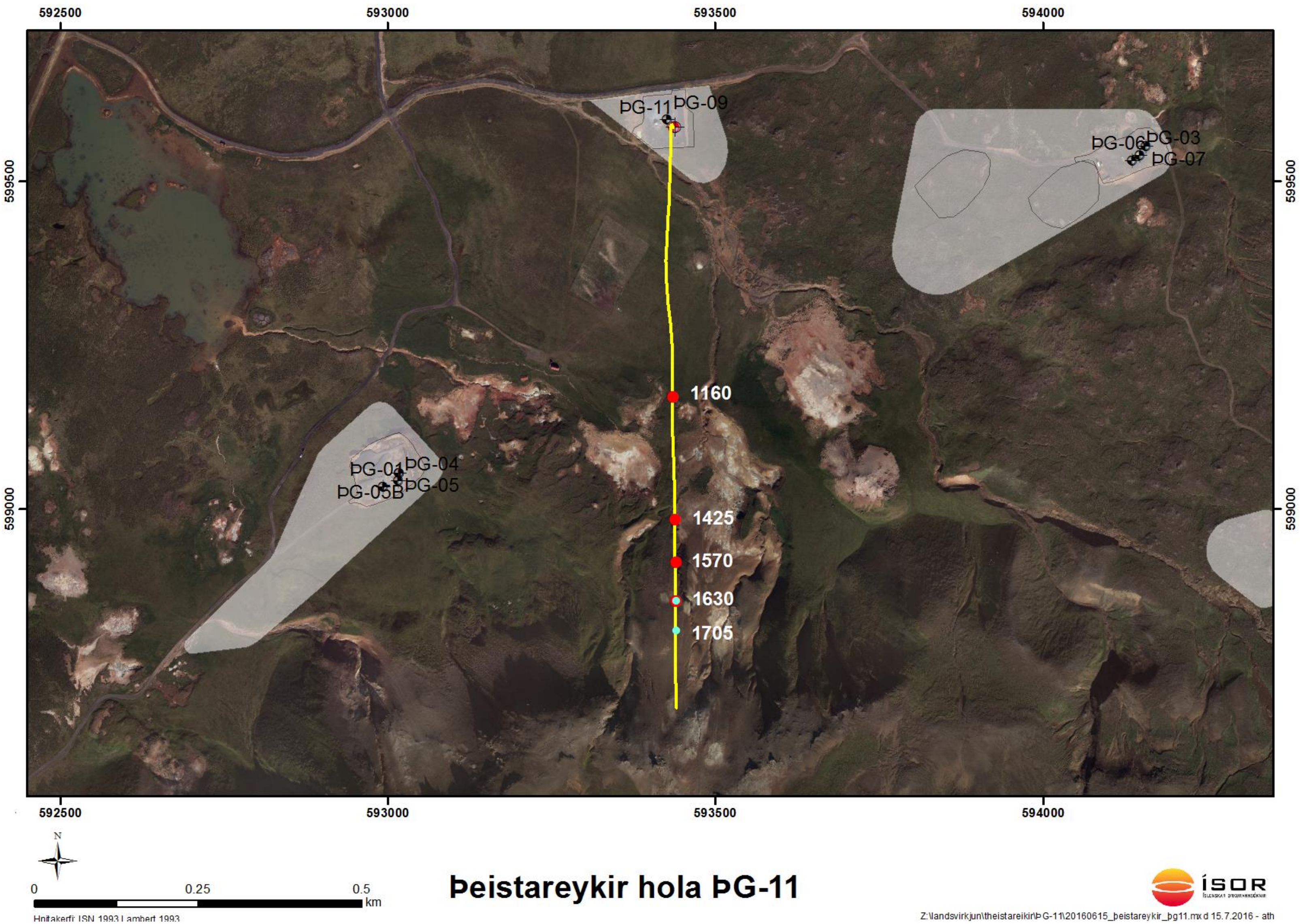

Figure 3. *Well trajectory projected onto the Earth's surface. Red dots indicate structural targets. Blue dots show main permeability zones estimated from temperature.*

Table 2. *Compilation of all gyro-data to date.*

MD(m)	Inclination	Azimuth
0	0	0
50	0.18	340.4
100	0.23	319.6
150	0.41	334.3
200	1.02	327.0
250	1.66	329.2
285	2.17	328.7
320	2.35	321.7
350	1.52	228.9
370	3.48	183.3
400	5.95	181.7
430	8.27	180.7
460	11.1	183.0
490	14.5	180.9
520	18.4	182.1
550	22.2	180.4
580	25.7	184.0
610	29.3	181.5
640	33.0	180.2
657	35.0	181.1
690	36.5	183.9
740	41.9	183.1
840	43.1	180.4
890	40.5	176.7
940	40.7	173.9
983	40.6	173.9
1030	39.4	175.9
1080	39.2	179.7
1130	40.0	180.0
1162	41.1	180.5
1250	40.3	178.3
1350	40.0	178.7
1450	41.2	178.4
1550	40.5	181.2
1600	40.6	178.7
1641	40.6	179.0
1682	40.4	180.2
1712	40.9	180.4
1742	41.0	179.7
1772	39.8	179.7
1802	39.9	179.3
1832	39.9	179.5
1862	39.8	178.5
1892	40.0	180.3

ÍSOR ICELAND GEOSURVEY	ÞG-11	Sunday 17th of July 2016 Workday #13 of Óðinn

Þeistareykir	Report #45 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	BG, ÞEg, HÖS (E-mail: bg@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24 hrs.	2070 m	Hole made last 24 hrs. :	109 m
Last casing depth:	801.7 m	Depth at 8 hrs.	2110 m	Drilling time:	22.75 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	~28 l/s	Average ROP:	4.8 m/hr

Drilling operation

Drilling has progressed at a moderate but steady speed. WOB is kept at 5-6 tons with and RPM of ~55. Two polymer pills are injected per single. The time it takes for the drilling fluid to return to surface after each single addition is increasing and this morning it is up to about 8 minutes according to the tool pusher. Cuttings are being returned to surface, they are however, very fine grained.

Hole made since the last gyro is approaching 200 m and a gyro will probably be run sometime in the afternoon or evening.

Geology

The cuttings that are brought to the surface are very fine grained. There is evidence of mixing in the cuttings and in addition to mixing, it seems clear that some sorting, according to grain size is occurring in the water column as well. This leads to diffuse contacts between formations and can result in incorrect interpretation of the stratigraphic column. The stratigraphic column presented in Fig. 1 is a preliminary interpretation. it will be revised with reference to the geophysical well-logs.

1832-1878 m: Basaltic breccias

Greenish and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. glassy basalt and tuff. Slightly more crystallized basalt grains mixed in around 1860 m depth. Wollastonite occurs regularly. Minor sulfides both pyrite and probably pyrrhotite.

1878-1882 m: Basaltic tuff

Greenish, yellow and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. tuff. "Polka dot" grains with white circular spots porbably vesicle fillings, fairly common.

1882-1890 m: Basaltic breccias

Similar to the breccias above. Light green, yellowish and white grains most prominent. Mixed in with fine-grained greyish basalt. Epidote, and quartz along with chlorite and wollastonite are the most prominent alterations minerals.

1882-1928 m: Fine- medium grained basalts

This depth interval is characterized by a greater proportion of altered fine-grained basalts mixed with tuff and originally glassy basalt grains. Formation boundaries are not sharp. From 1910 to 1918 and at 1926 to 1928 the formation is classified as a breccia. It should be noted that there is considerable mixing apparent in the cuttings and additionally there is some sorting according to grains size during transport to the surface.

1828-1936 m: No cuttings

1936-1948 m: Basaltic breccias

Similar to the breccias above. Yellowish, light green and white grains most prominent. Mixed in with fine-grained greyish basalt. Epidote, and quartz along with chlorite and wollastonite are the most prominent alterations minerals. Several examples of wollastonite precipitating after epidote and/or quartz.

1948-1954 m: Fine- medium grained basalts

This depth interval is characterized by a greater proportion of altered fine-grained basalts mixed with tuff and originally glassy basalt grains. Again formation boundaries are not sharp. Due to processes in the well (mixing of lithologies and sorting according to grain size) the stratigraphic column presented here is tentative. It will be revised when lithology logs are available

1954-1960 m: Basaltic breccias

Similar to the breccias above. Yellowish, light green and white grains most prominent. Mixed in with fine-grained greyish basalt. Epidote, and quartz along with chlorite and wollastonite continue to be the most prominent alterations minerals.

1960-1976 m: Fine- medium grained basalts

Altered medium to coarse grained basalt. Difficult to assign original rock type with certainty. Cuttings are fine-grained, single crystal grains are common. Alteration minerals as before in addition there are minor amounts of pyrite and possibly pyrrhotite

1976-1994 m: Basaltic breccias

Again very similar to the breccias above. Light yellowish, green and whitish colors dominate. Epidote, and quartz along with chlorite and wollastonite continue to be the most common alterations minerals. Delicate wollastonite crystals are more common in samples that are affected by polymer pills.

Borvakt

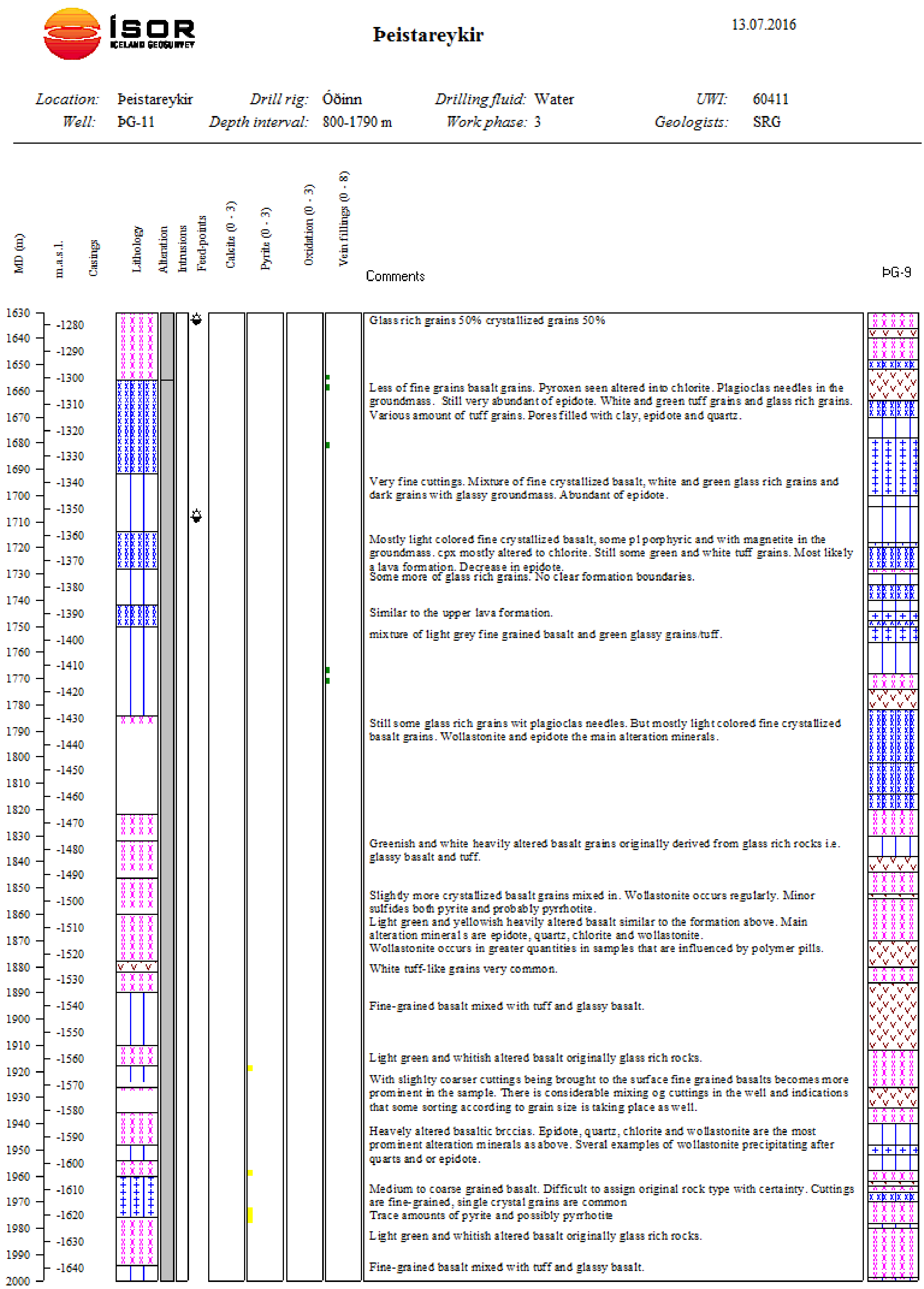

Figure 1. *Lithology and lithological descriptions down to 2000 m (MD).*

ÍSOR ICELAND GEOSURVEY	# ÞG-11	Monday 18th of July 2016 Workday #14 of Óðinn

Þeistareykir	Report #46 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	BG, ÞEg, HÖS (E-mail: bg@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24 hrs.	2143 m	Hole made last 24 hrs. :	73 m
Last casing depth:	801.7 m	Depth at 8 hrs.	2143 m	Drilling time:	15.25 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 43 l/s	Average ROP:	4.8 m/hr

Drilling operation

Drilling progressed at moderate speed yesterday. The plan was to run a gyro when 200 m of whole had been made since Fridays gyro-run. The contractors crew drilled until just past 16:00 yesterday and started to clean the well with polymer pills and prepared to break out two singles prior to the logging run. MD at this time was 2143. However, the crew was not happy with the cleaning of the well. A decision was made to pull out partially bit inside casing and let the well settle and then RIH again and check for botnfall.

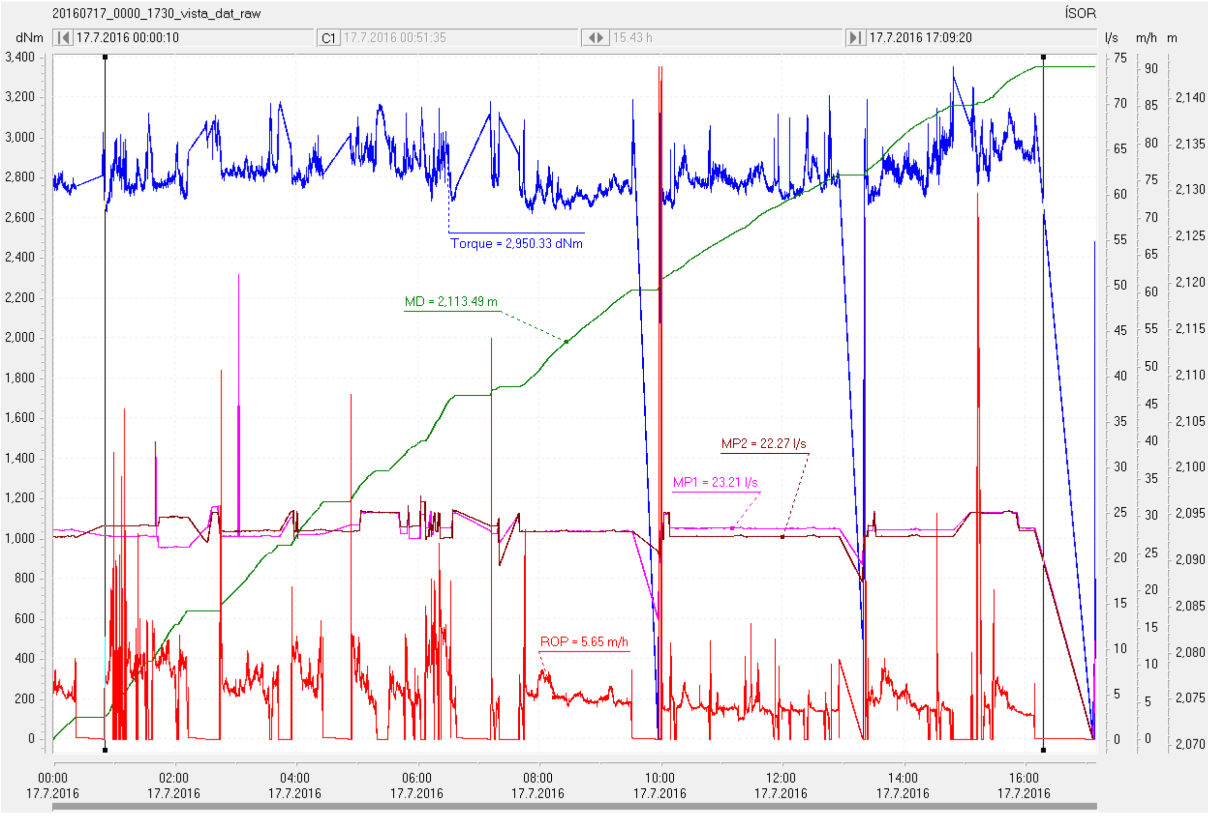

Figure 1. *Drilling progress yesterday from midnight until ~16:00.*

In Fig 1. it can be seen that torque was kept at around 2800-3000 dNm for most of the drilling. ROP's were apparently slightly higher during the night shift (e.g. from 01:00 to 02:00).

Table 1. *Inclination of well ÞG-11 as logged 18.07.2016*

Inclinometer
Date: 18.7.2016
Device Number: 8
Crew: HOS/ThEg
Operator: HOS/ThEg
Well Number: Thg11
Field: Theistareykir
Client: JB
Well Depth: 2143

Description:

Inclination measured from vertical
Length measured in meters

Time	Depth	Inclination (from Vert)
7:35:39	2116	41.1
7:37:45	2100	40.3
7:38:47	2070	40.1
7:40:28	2000	39.5
7:42:19	1950	39.7
7:44:18	1900	40.1
7:45:48	1850	40.2

Below 2110 m MD cuttings were only sporadically returned to the surface and no cuttings were returned below 2130 m MD. Circulation losses were measured at 2139 m MD (~15:00) and were in excess of 43 L/s at that time.

After pulling the bit back to ~12 m MD and waiting while cuttings in the well settled to bottom the crew went back to bottom and found 4 m of accumulated cuttings at the bottom. Two singles were subsequently broken out and then an inclination tool was run into the well. Early this morning inclination of the lowermost part of the well was logged. Results are given in table 1.

Following the logging the crew did some maintenance work on the pumps and then started drilling again shortly before 11:00 AM.

Þorvakt

ÍSOR ICELAND GEOSURVEY	# ÞG-11	Tuesday 19th of July 2016 Workday #15 of Óðinn

Þeistareykir	Report #47 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	BG, ÞEg, HÖS (E-mail: bg@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	2189 m	Hole made last 24 hrs. :	46 m
Last casing depth:	801.7 m	Depth at 7:30.	2214 m	Drilling time:	12 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	~50 L/s	Average ROP:	3.8 m/hr

Drilling operation

Drilling progressed at a slow but steady rate yesterday afternoon and last night. The hole is reamed after each single with high rpm's. Early this morning drilling stopped due to maintenance work on the "kelly-hose." Torque has been maintained around 3000 dNm during the night. Progress of drilling is shown in Fig. 1. There are not any clear indications of new aquifers being added.

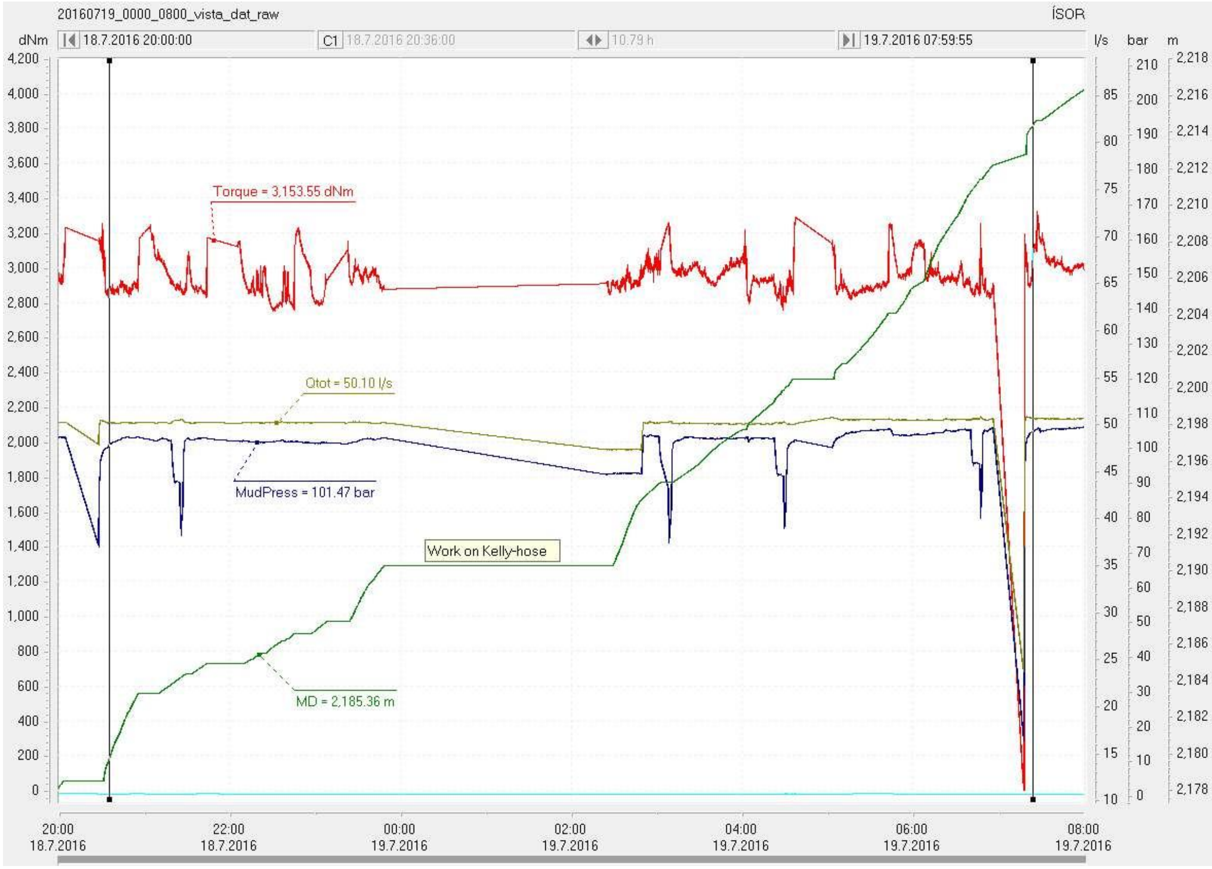

Figure 2. *Pumping, standpipe pressure, torque and MD for the drilling last night. Polymer pills show up as rapid decline in stand-pipe pressure.*

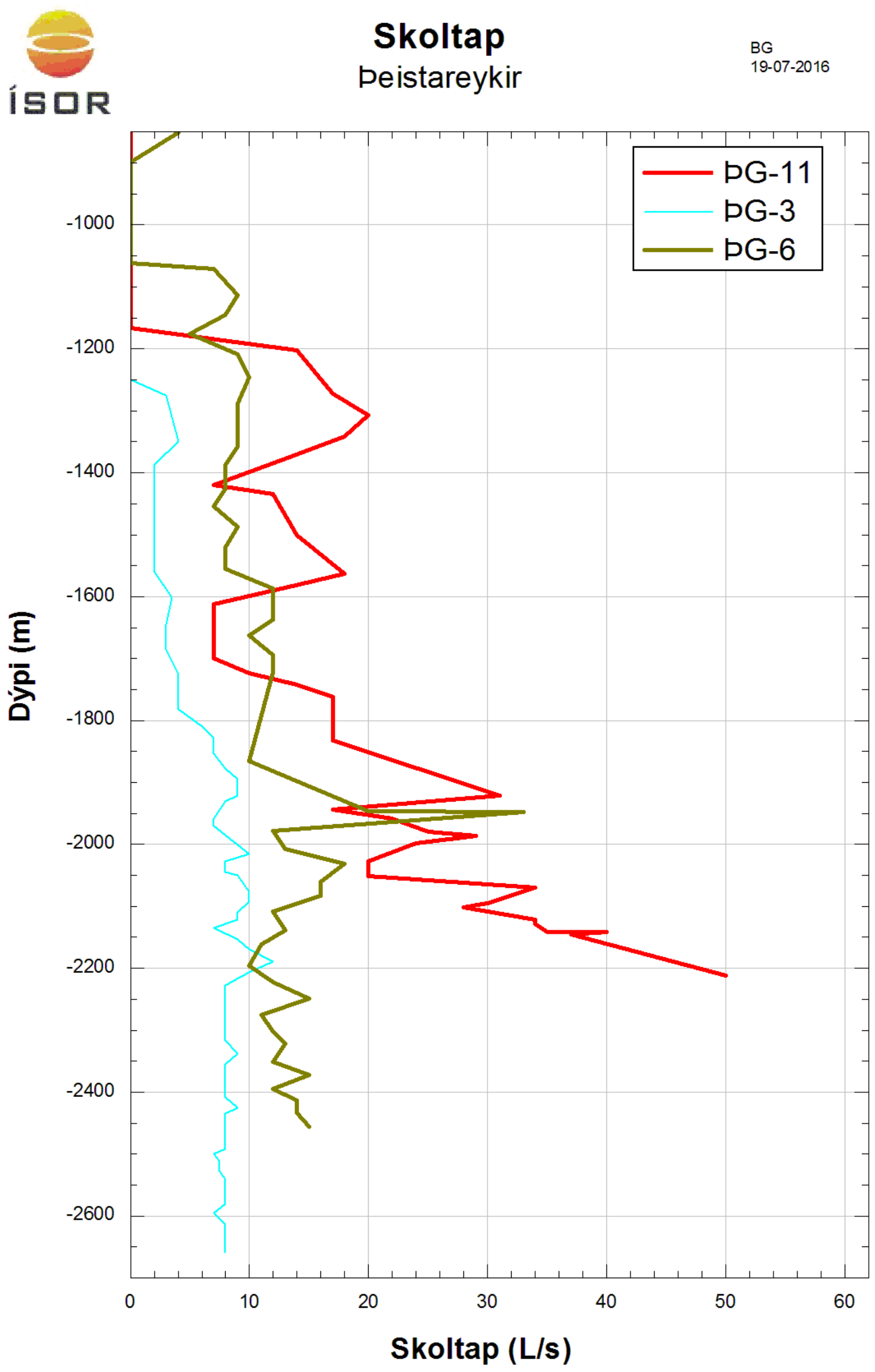

Figure 2. *Loss of circulation (skoltap) plotted vs. depth in meters (MD) for the production section. Circulation loss data from ÞG-3 and ÞG-6 on platform C are shown for comparison.*

Circulation losses have been increasing steadily and have been close to 50 L/s since 04:00 this morning. Typically, the well will be close to full at the end of each single at a pumping rate of approximately 50 L/s. Circulation losses plotted as a function of depth (MD m). For comparison data from two wells on platform C are shown on Fig. 1 as well.

Geology

No cuttings have been returned to surface since MD 2130 m. The stratigraphic column down to 2130 m (MD) is presented in Fig. 3. The alteration minerals indicate temperatures around 280-300°C. The well possibly cuts through some intrusions between 2000 and 2100 m depth.

1994-2020 m: Fine- medium grained basalts

Fine- medium grained basalt grey to grey-green basalt fragments. Plagioclase is very common probably fragments of phenocrysts from a plagioclase porphyritic lava sequence. Alteration minerals are mainly epidote, chlorite, quartz and wollastonite as before. A trace of calcite appears at 2004 m sulfides (pyrite) were identified in small amounts in a couple of samples.

2020-2030 m: Basaltic breccias

Greenish and whitish heavily altered basaltic grains originally derived from glass-rich rocks i.e. glassy basalt and tuff. Mixed with slightly more crystallized basalt grains. Alteration minerals as before. Trace of calcite and pyrite in sample from 2028 m.

2030-2078 m: Medium- to coarse grained basalts

Greyish looking medium to coarse grained basalt. Not as altered as the formations above. Either a sequence of thick lava-flows or possibly intrusions. Particularly the depth interval from 2048 to 2058 is a possible intrusion, also around 2072 m. Alteration minerals as before. Trace of pyrite in a few samples.

2078-2084 m: Basaltic breccias

Similar to the breccia above. Typically the cuttings are very fine grained. A high proportion of the grains are individual fragments of alteration minerals and sometimes primary minerals.

2084-2090 m: Medium- to coarse grained basalts

Very similar to the unit described above. (2030 – 2078 m).

2090-2096 m: Basaltic breccias

Again very fine cuttings. The apparent alternating layers of breccia and crystallized basalt may be an artifact of grain size sorting in the water column in the well.

2096-2108 m: Medium- to coarse grained basalts

Similar to the unit described above. Either very thick flows (less permeable and therefore less altered or possibly intrusions.

2108-2130 m: Alternating basaltic breccias and medium grained basalt

Below2108 only a few samples have been obtained. Apparently breccias alternate with medium to coarse grained basalts. No cuttings below 2130 m (MD).

Borvakt

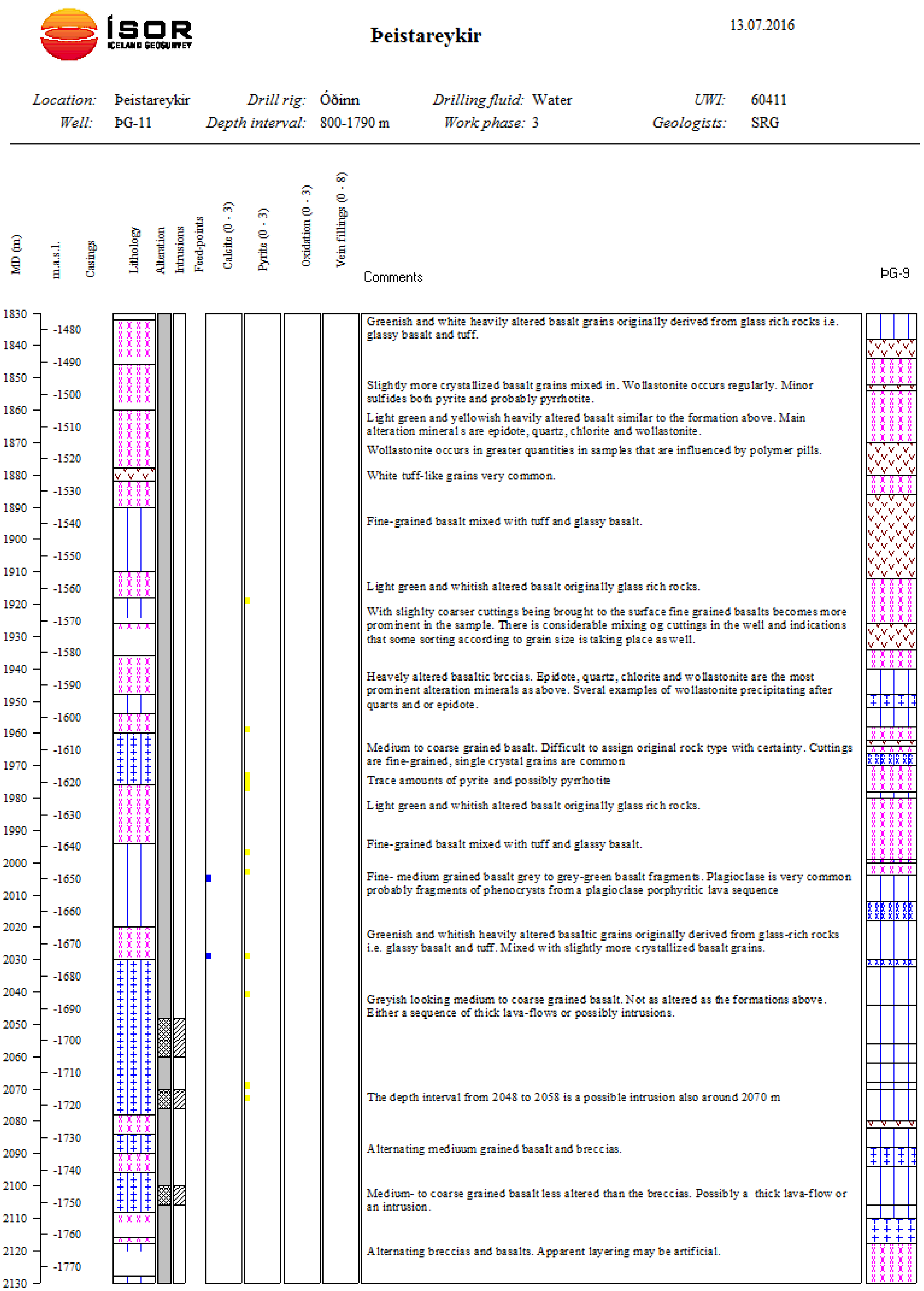

Figure 3. *Stratigraphy of the lowermost 300 m represented by cuttings from well ÞG-11.*

ÍSOR ICELAND GEOSURVEY	# ÞG-11	Wednesday 20th of July 2016 Workday #16 of Óðinn

Þeistareykir	Report #48 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	BG, RSÁ, ÞEg, HÖS (E-mail: bg@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	2224 m	Hole made last 24 hrs. :	35 m
Last casing depth:	801.7 m	Depth at 7:30.	2224 m	Drilling time:	8,75 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	4.0 m/hr

Drilling operation

Drilling continued yesterday morning at a slow but steady pace. As before two polymer pills are injected for every single. The well was reamed after every single with high rpm's. A decision was made to stop drilling at 2224,1 m at 11:00 AM. Water was then circulated and the well cleaned for 4 hrs. Prior to POOH a polymer pill was injected. POOH started at 15:00.

A planned power outage in the Þeistareykir area came into effect at 23:00 hrs. last night. Unfortunately, backup power-units for the pumps that deliver cold water to the rig did not operate as planned.

The rig used its own water reserves and continued POOH until 03:00 this morning but had to stop at that time due to water shortages. POOH continued from 04:00 after the water supply had been restored. After POOH was completed the crew started RIH with a logging-string.

The following plan was discussed and agreed upon at a project meeting yesterday.

i)	POOH	
ii)	RIH with logging string	24 hrs
iii)	Temperature and gyro	8 hrs
iv)	POOH	8 hrs
v)	Logging incl. televiewer	24 hrs
vi)	RIH with liner	24 hrs
vii)	Injection testing with spinner	24 hrs

The total time for items i) and ii) is ~24 hrs. and that should be completed around mid-day today. All time allotments are approximate and subject to change. It should be noted that the plan may be revised, e.g. after logging temperature and gyro.

Borvakt

ÍSOR ICELAND GEOSURVEY	# ÞG-11	Thursday 21st of July 2016 Workday #17 of Óðinn

Þeistareykir	Report #49 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	RSÁ, ÞEg, HÖS (E-mail: rsa@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	(2224) m	Hole made last 24 hrs. :	0 m
Last casing depth:	801.7 m	Depth at 7:30.	(2224) m	Drilling time:	0 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	- m/hr

Drilling operation

As stated in an earlier report, a planned power outage in Þeistareykir area came into effect at 23:00 Tuesday night. Due to some issues with backup power, cooling water was not pumped to the drillsite. The rig therefore used its own water reserves until 3:00 AM at which point POOH was suspended. POOH continued after the rig started receiving water again at 4:00 AM. At 06:00 POOH was completed and the crew started RIH with a logging string.

The logging string surprisingly stopped at 2212 m (MD). Attempts to flush away what was believed to be bottom fill in the well by increasing pumping to 30 l/s did not prove successful. It is now believed that a mistake must have been made in tallying singles in the drill-string during drilling and that the well is 2212 m deep not 2224 as previously reported.

Yesterday evening a temperature and gyro surveys were carried out (Figures 1-5). A temperature log inside drill pipes with 11 l/s injection on annulus indicates at first that the well is cooling at the bottom (Figure 1). However, the heat up rate did not change with increasing injection from 11 l/s to 30 l/s (Figure 2). Possibly there is an opening at a cooling point at 2125 m. The most active part of the well is probably at 1640-1710 m, but before the survey the well was cooled through the string and it is possible that the cooling liquid went up the annulus and out of the well. Inflow can be seen at 935-970 m (Figure 1).

The gyro survey is consistent with previous surveys and shows that the well is on track (Figures 3-5).

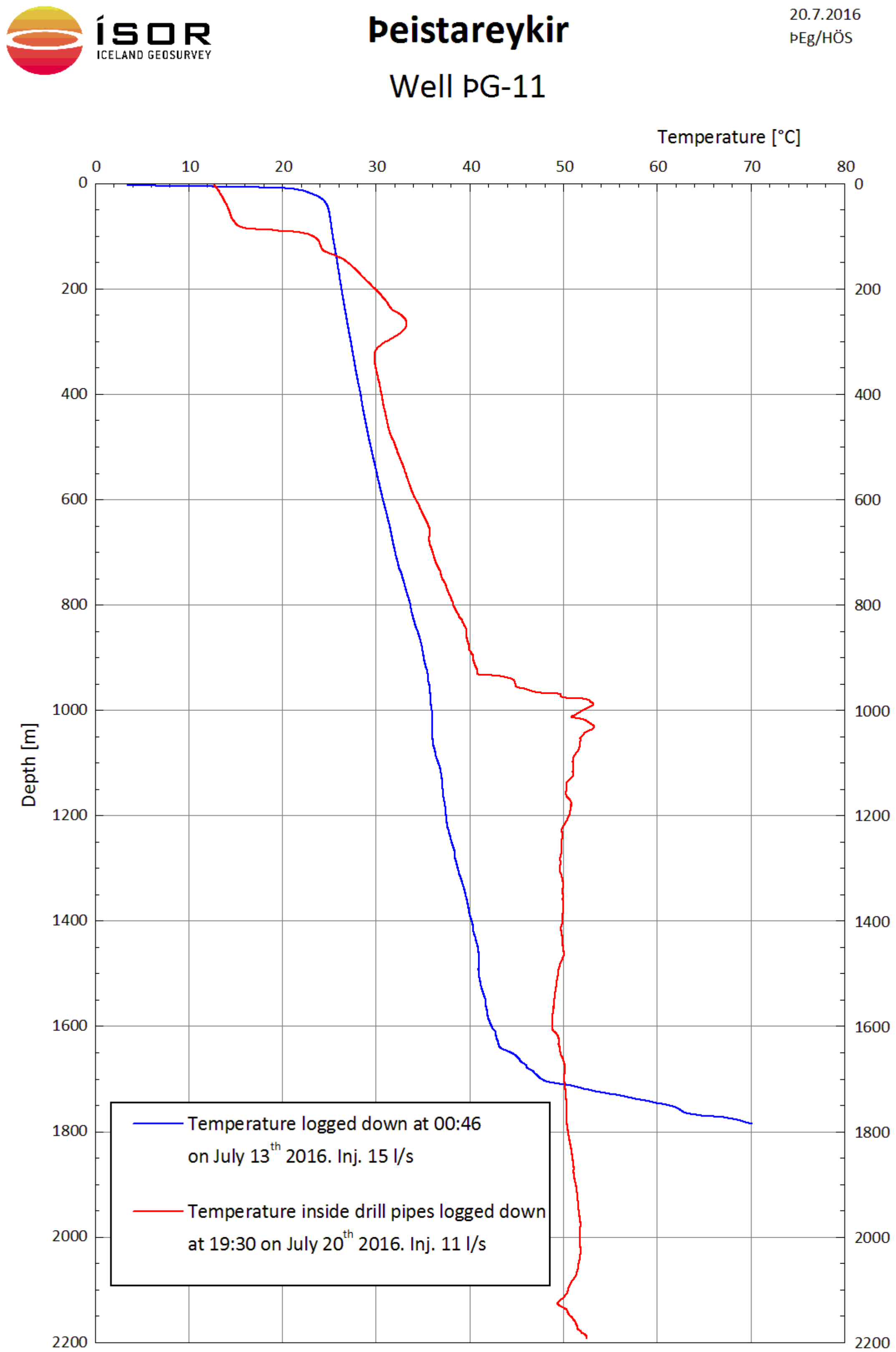

Figure 1. Temperature log in well ÞG-11.

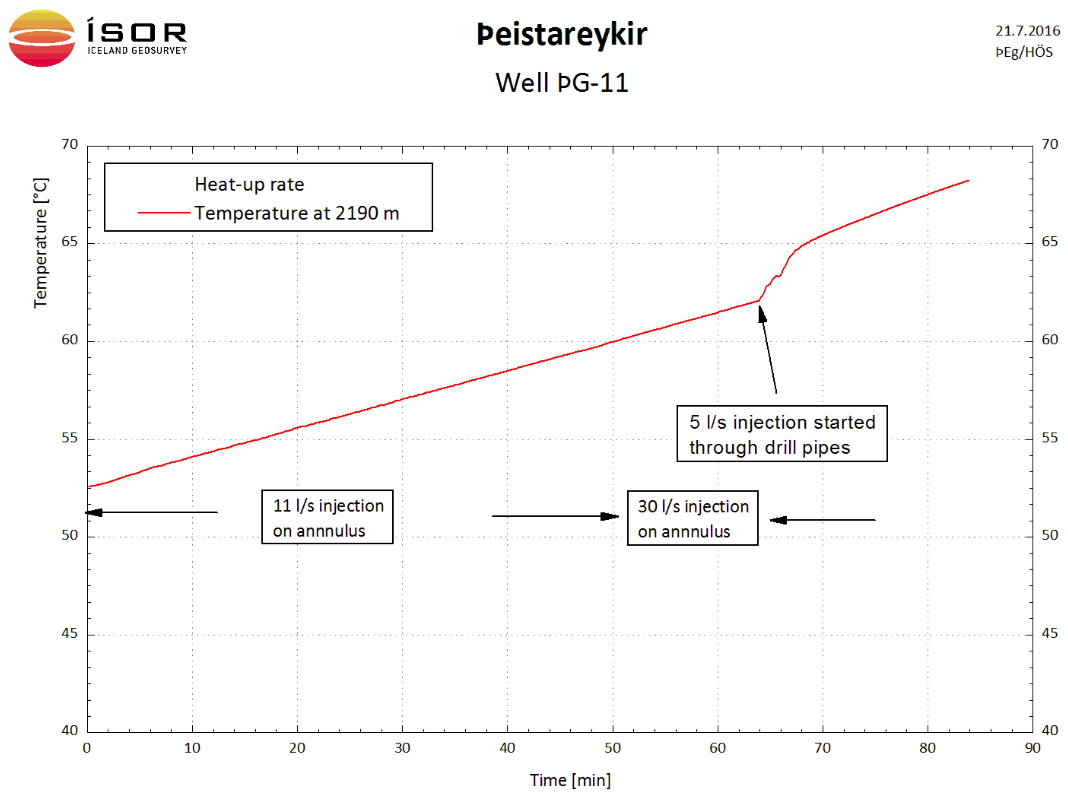

Figure 2. Heat up rate with changing of injection from 11 l/s to 30 l/s.

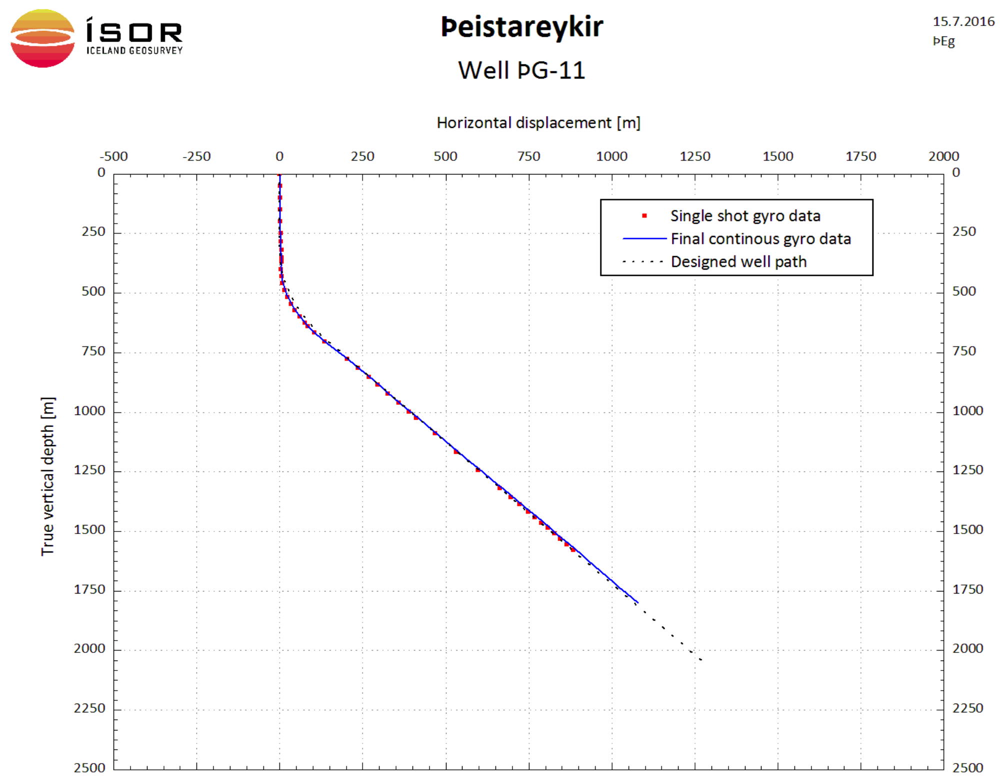

Figure 3. Gyro survey showing the well is on track.

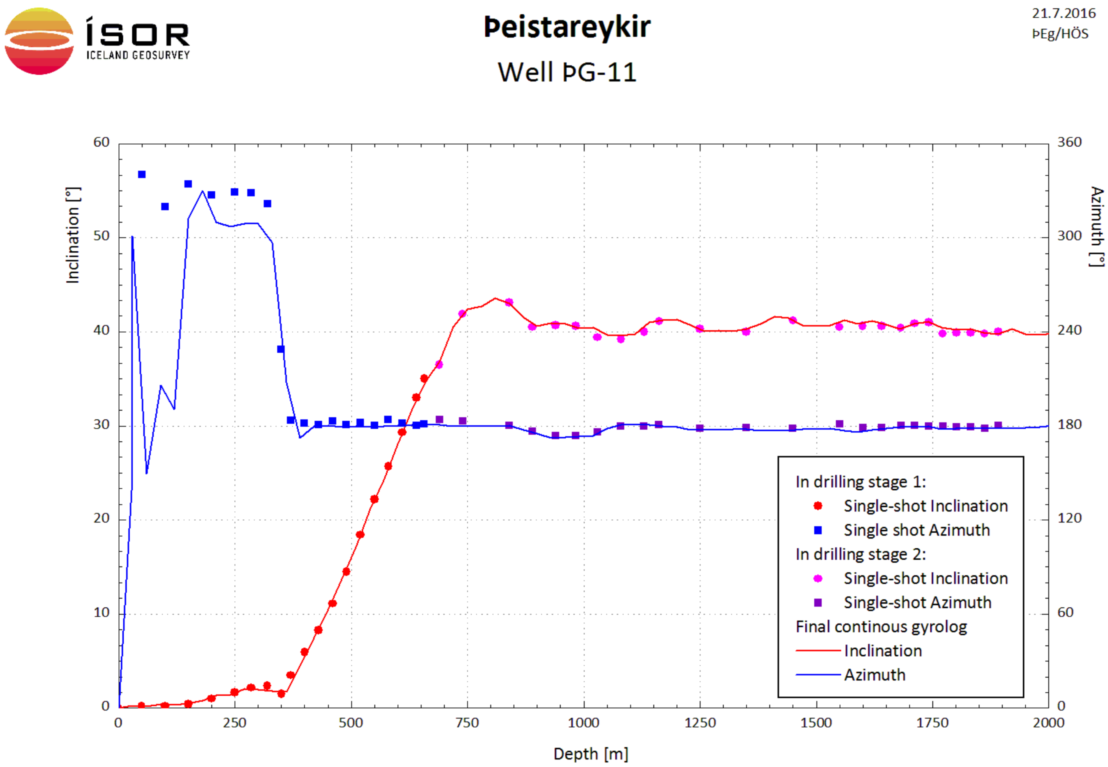

Figure 4. Gyro survey showing inclination and azimuth.

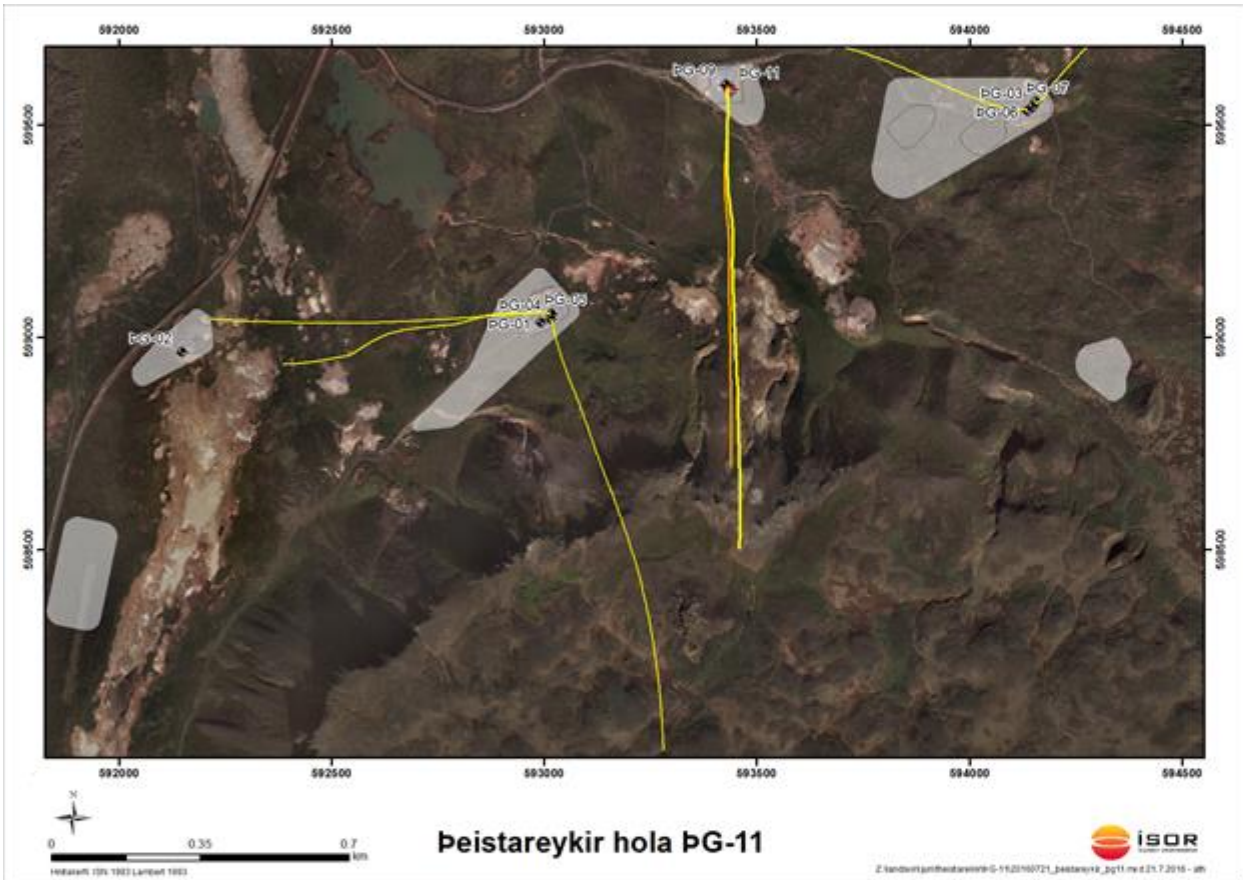

Figure 5. Well path according to gyro surveys. The yellow path shows the continuous survey and the orange shows single-shot measurements.

The following plan is ongoing. At the moment the logging string is being POOH and soon after, logging in open hole will be carried out.

i)	POOH	
ii)	RIH with logging string	24 hrs
iii)	Temperature and gyro	8 hrs
iv)	POOH	8 hrs
v)	Logging incl. televiewer	24 hrs
vi)	RIH with liner	24 hrs
vii)	Injection testing with spinner	24 hrs

Borvakt

	ÞG-11	Friday 22nd of July 2016 Workday #18 of Óðinn
Þeistareykir	Report #50 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	RSÁ, ÞEg, HÖS, STh, FP (E-mail: rsa@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	(2224) m	Hole made last 24 hrs. :	0 m
Last casing depth:	801.7 m	Depth at 7:30.	(2224) m	Drilling time:	0 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	- m/hr

Drilling operation

Yesterday, ÍSOR's logging engineers took over the rig and carried out measurements, starting with gyro survey. After that, the logging string was POOH and the conventional open hole logging program started with a temperature log at 14:45. After that a caliper log was done, then televiewer, neutron-neutron and natural gamma which is currently running. The last run will be the resistivity log. Measurements are expected to be finished in the afternoon.

Figure 1 shows three temperature logs. The first (green) is the temperature profile logged inside the drill string with ~11 l/s on annulus and static water inside the pipes. That profile definitely shows cooling of the well to BOH but further interpretation was not unique since circulation water was injected through the drill pipes for 2-3 hours. The temperature profile in open hole with 35 l/s injection rate (red) shows inflow in the region from ~930 m-1050 m but from there down to 2120 m there is a slow and even increase in temperature. At 2080 m there is an outflow zone and another at ~2125 m. There is, however, water passing 2150 m and it exits the well below 2210 m depth were all the logging tools have stopped.

The 3rd temperature profile in Figure 1 (blue) was measured in order to confirm the water flow passing 2125 m by measuring the response to increased injection rate. With 40 l/s injection rate, definite cooling takes place proofing that there is an outflow zone close to BOH. This also confirmed that the temperature inside the well is within temperature limits for all the tools planned for the logging program.

Figure 2 shows the caliper log. Neither obstacles nor major cavities are detected. Also, there is not much sign of elliptical shape of the well's cross section. During the televiewer log conducted on July 13th the tool stopped at ~1400 m depth. When the televiewer tool was RIH this morning there were some problems exceeding that point but fortunately the tool passed that point after repeated attempts. Figure 3 shows a clear fracture at BOH.

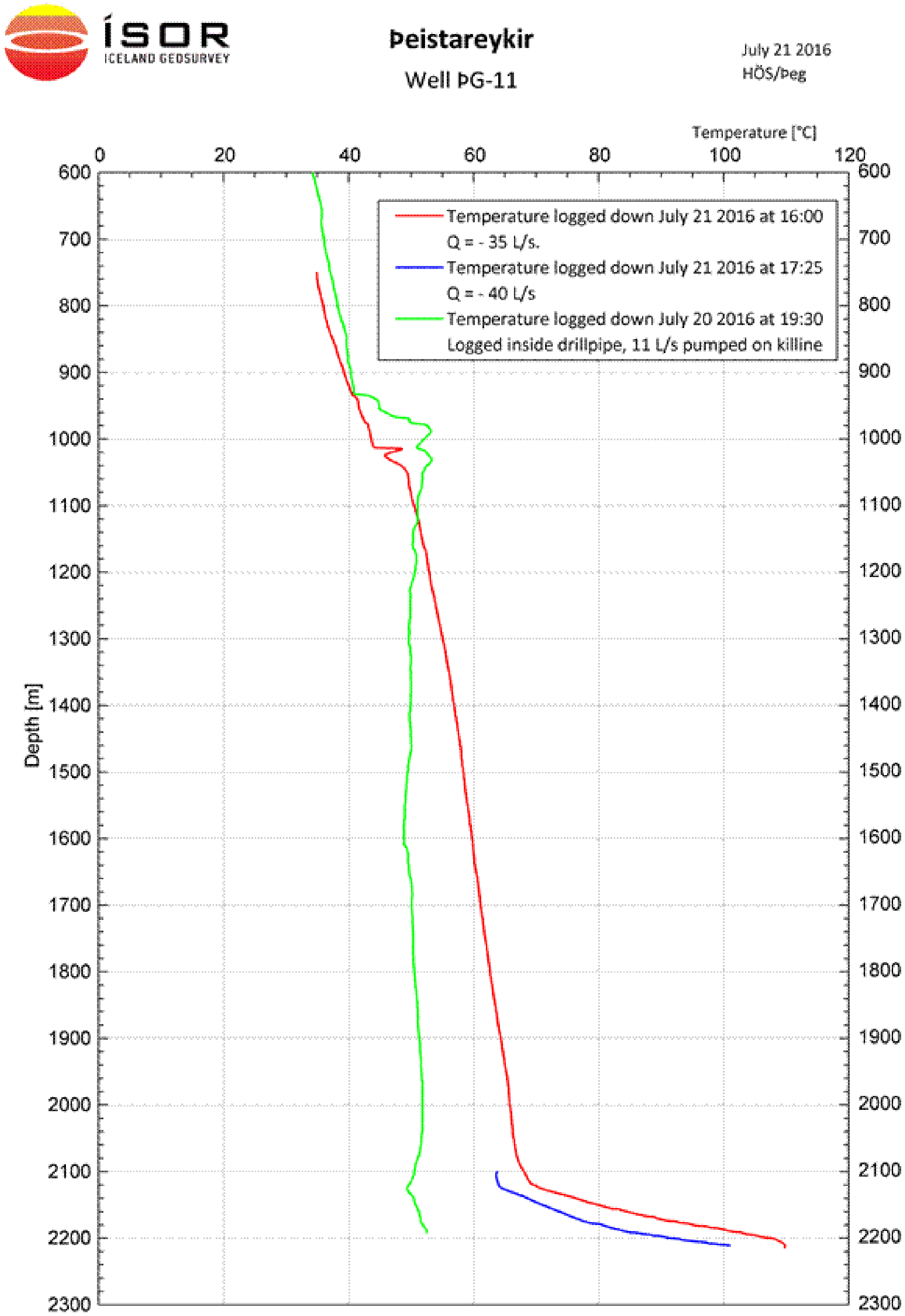

Figure 1. Temperature log in well ÞG-11.

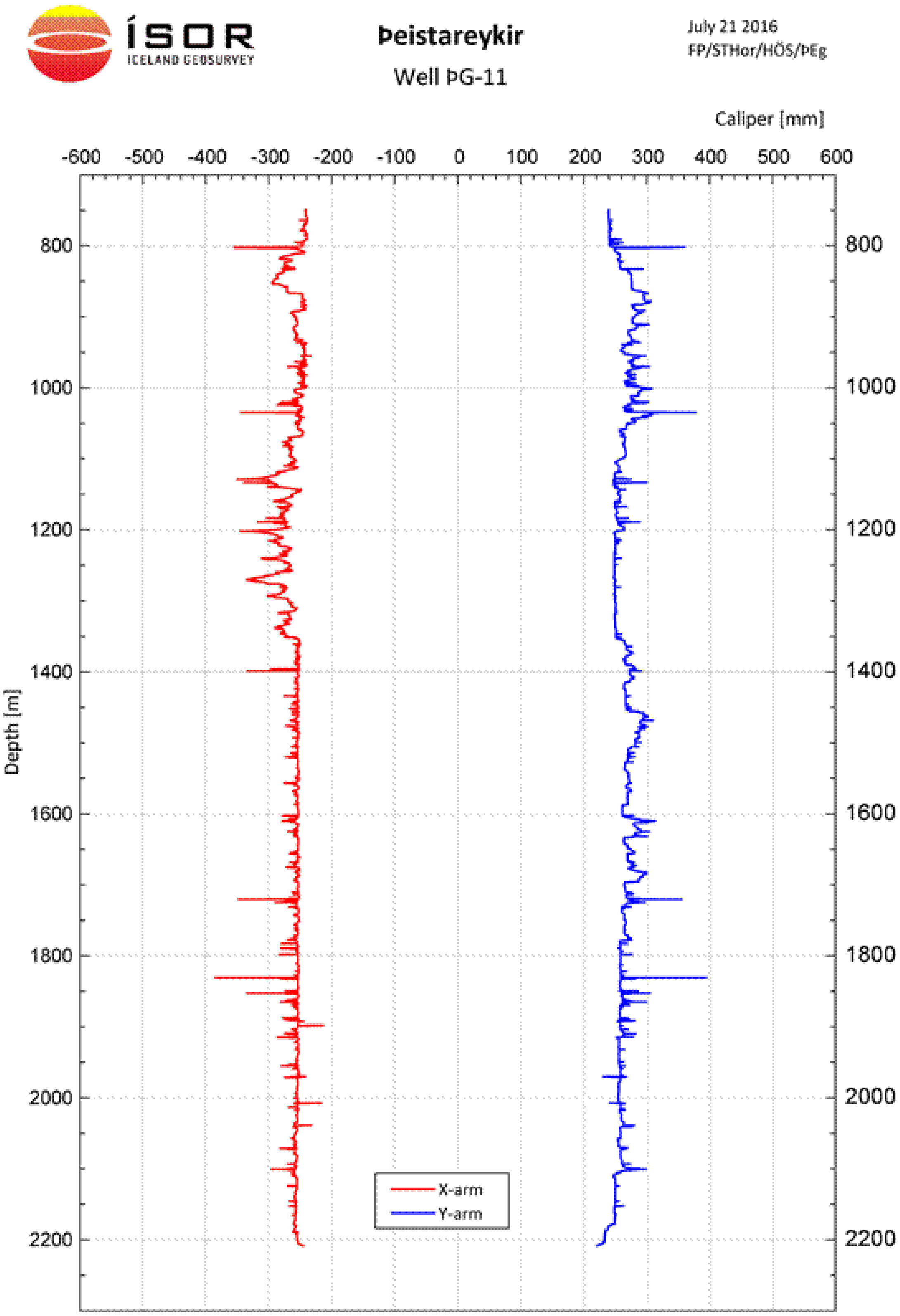

Figure 2. Caliper log for well ÞG-11

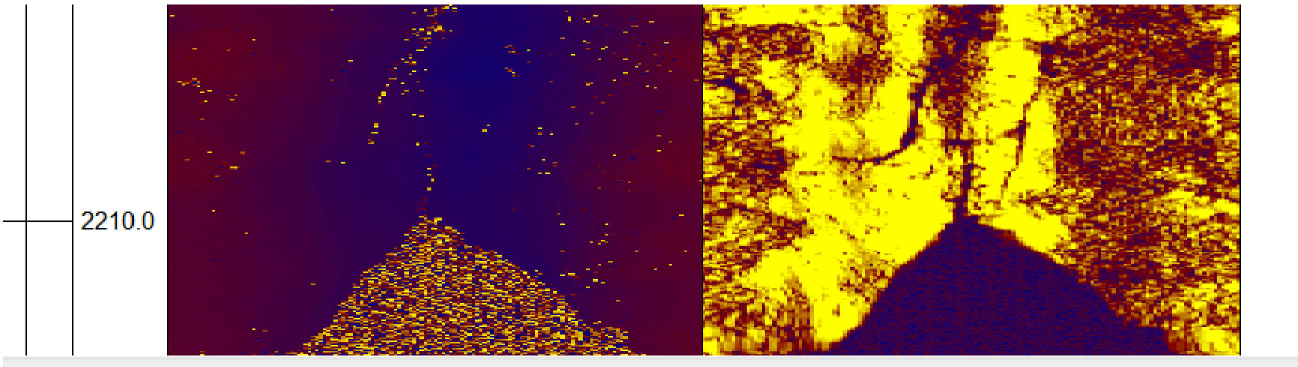

Figure 3. The figure show a screenshot of the televiewer log at BOH where there is a clear wide fracture.

The following plan is ongoing. At the moment logging is being conducted and will finish this afternoon.

~~i)~~	~~POOH~~	
~~ii)~~	~~RIH with logging string~~	~~24 hrs~~
~~iii)~~	~~Temperature and gyro~~	~~8 hrs~~
~~iv)~~	~~POOH~~	~~8 hrs~~
v)	Logging incl. televiewer	24 hrs (ongoing)
vi)	RIH with liner	24 hrs
vii)	Injection testing with spinner	24 hrs

Borvakt

ÍSOR ICELAND GEOSURVEY	**ÞG-11**	Saturday 23rd of July 2016 Workday #19 of Óðinn

Þeistareykir	Report #51 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	RSÁ, SThor, FP (E-mail: rsa@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	(2224) m	Hole made last 24 hrs. :	0 m
Last casing depth:	801.7 m	Depth at 7:30.	(2224) m	Drilling time:	0 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	- m/hr

Drilling operation

After drilling stopped, ÍSOR's logging engineers have been carrying out measurements of the well. After the televiewer was finished yesterday morning, neutron-neutron, natural gamma and resistivity measurements took place. Results can be seen in figure 1 with the latest temperature log.

As can be seen on the caliper log, no obstacles or major cavities were detected and there is not much sign of elliptical shape.

The following plan is ongoing. At the moment logging is being conducted and will finish this afternoon.

~~i)~~	~~POOH~~	
~~ii)~~	~~RIH with logging string~~	~~24 hrs~~
~~iii)~~	~~Temperature and gyro~~	~~8 hrs~~
~~iv)~~	~~POOH~~	~~8 hrs~~
v)	~~Logging incl. televiewer~~	~~24 hrs~~
vi)	RIH with liner	24 hrs (ongoing)
vii)	Injection testing with spinner	24 hrs

Borvakt

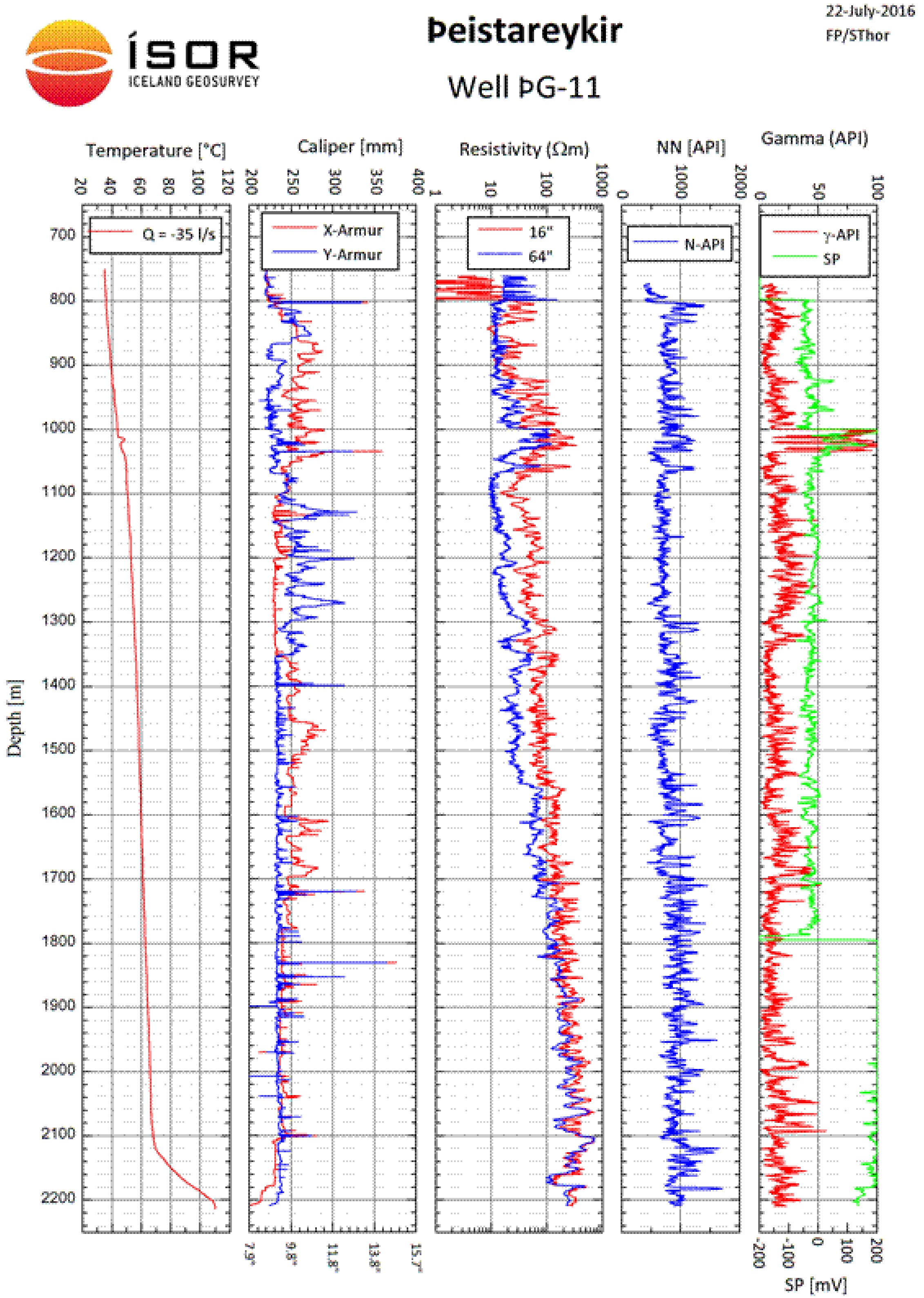

Figure 1. *Logs from well ÞG-11. From the left; temperature, caliper, resistivity, neutron-neutron and natural gamma.*

	ÞG-11	Sunday 24th of July 2016 Workday #20 of Óðinn

Þeistareykir	Report #52 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	RSÁ, SThor, FP, ÞEg (E-mail: rsa@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	2224 m	Hole made last 24 hrs. :	0 m
Last casing depth:	801.7 m	Depth at 7:30.	2224 m	Drilling time:	0 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	- m/hr

Drilling operation

Yesterday, 7" liner was RIH and was completed around midnight last night. The liner stopped at 2209 m and was left at 761 m. Some issues with the pipe robot caused delays for few hours but the injection test with spinner started at 2:30 AM this morning. The injection test should finish in the late afternoon.

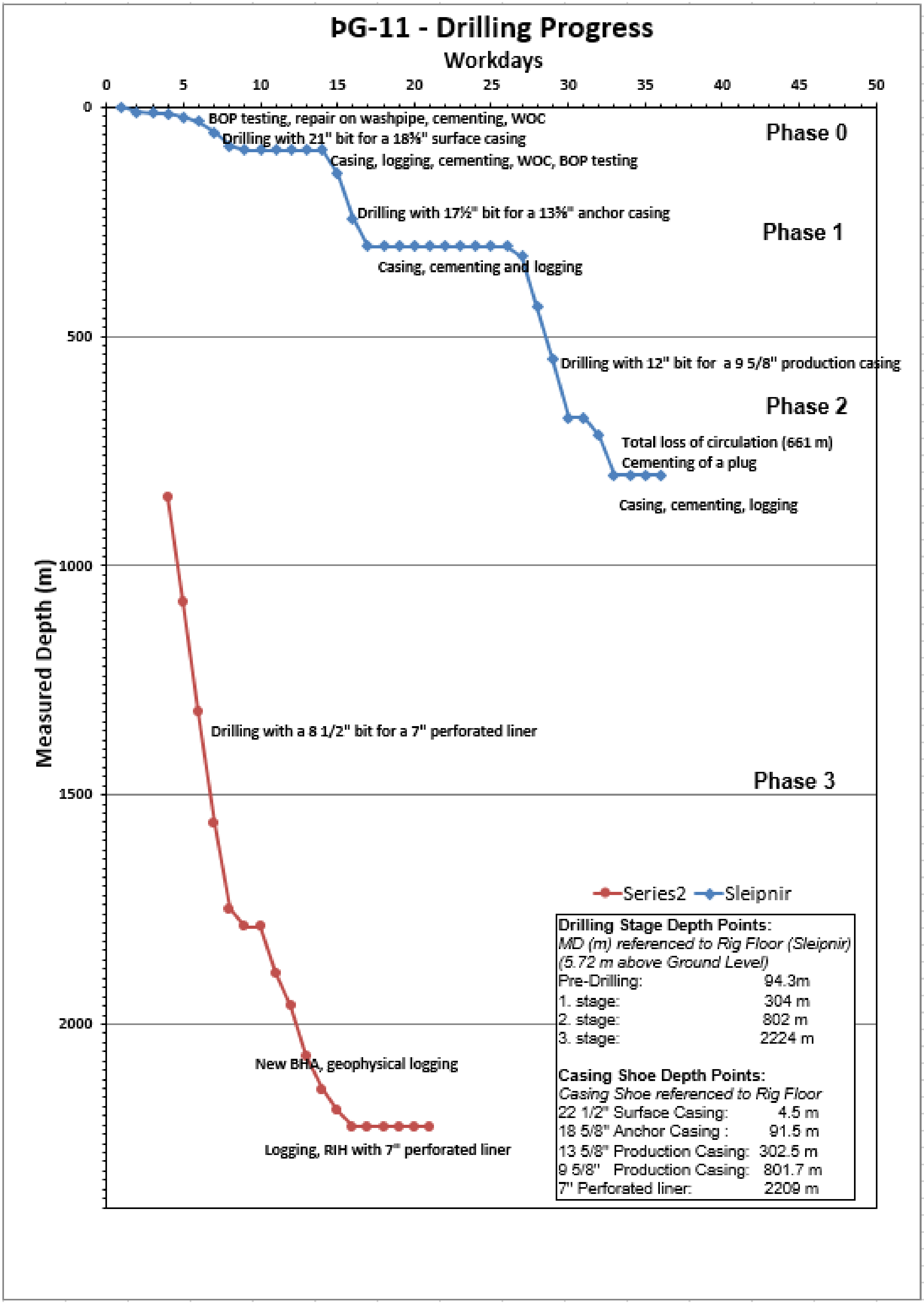

Figure 1. Drilling progress of ÞG-11.

Figure 2. ÍSOR´s logging engineers, Sigvaldi and Friðgeir, preparing for the injection test.

Figure 3. The weather at the beginning of the week was fantastic (left) but for the last few days it has been quite cloudy (right).

The following plan is ongoing. At the moment injection test is being conducted and will finish this afternoon.

~~i)~~	~~POOH~~	
~~ii)~~	~~RIH with logging string~~	~~24 hrs~~
~~iii)~~	~~Temperature and gyro~~	~~8 hrs~~
~~iv)~~	~~POOH~~	~~8 hrs~~
~~v)~~	~~Logging incl. televiewer~~	~~24 hrs~~
~~vi)~~	~~RIH with liner~~	~~24 hrs~~
vii)	Injection testing with spinner	24 hrs (ongoing)

Borvakt

ÍSOR ICELAND GEOSURVEY	ÞG-11	Monday 24th of July 2016 Workday #20 of Óðinn

Þeistareykir	Report #53 Preliminary results	Phase 3 (7" perforated liner)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-11	*Drill-Rig:*	Óðinn
Well-Id:	60411	*Geologist/Geophysicist:*	RSÁ, SThor, FP, ÞEg (E-mail: rsa@isor.is)

Last casing size:	9 ⅝" (prod. casing)	Depth at 24;00.	2224 m	Hole made last 24 hrs. :	0 m
Last casing depth:	801.7 m	Depth at 7:30.	2224 m	Drilling time:	0 hrs.
Drilling fluid:	Water	Circulation losses at 6.00	> 50 L/s	Average ROP:	- m/hr

Drilling operation

After the liner had been RIH, ÍSOR's logging engineers started their tests at 2:30 am. Figure 1 shows four temperature profiles down the well. The red and blue profiles show the temperature measured earlier this week. The pink profile is one that was logged at 2:30 am, before the injection test, and the green one is the newest profile, logged after the injection test.

Figure 2 shows preliminary results from the injection test measured at 1780 m MD (KT10-XT). The KT10-XT instrument is temperature sensitive, but these results indicate an injection index of around 5 (l/s)/bar for the last two steps.

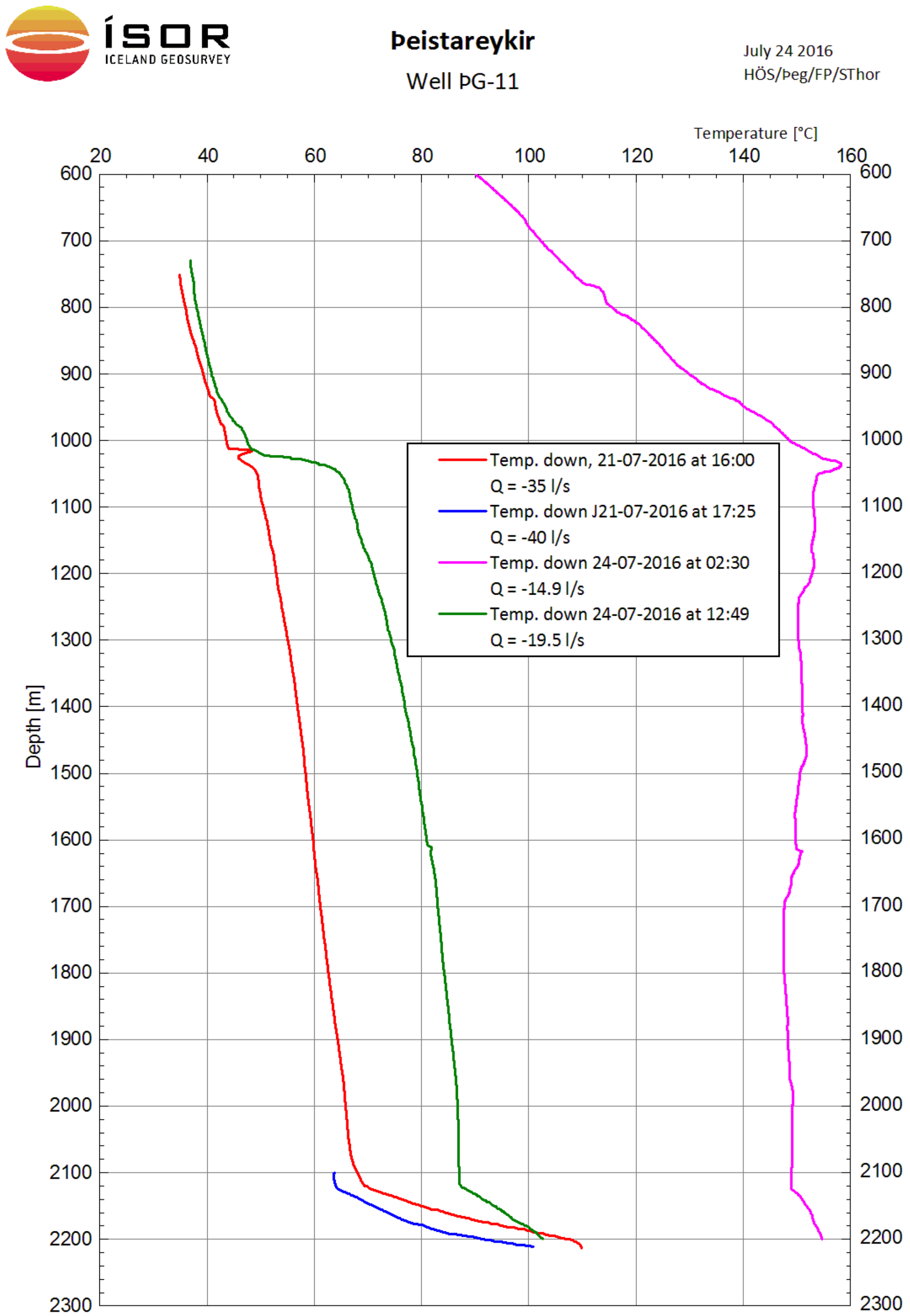

Figure 1. Temperature profiles logged July 21st and July 24th.

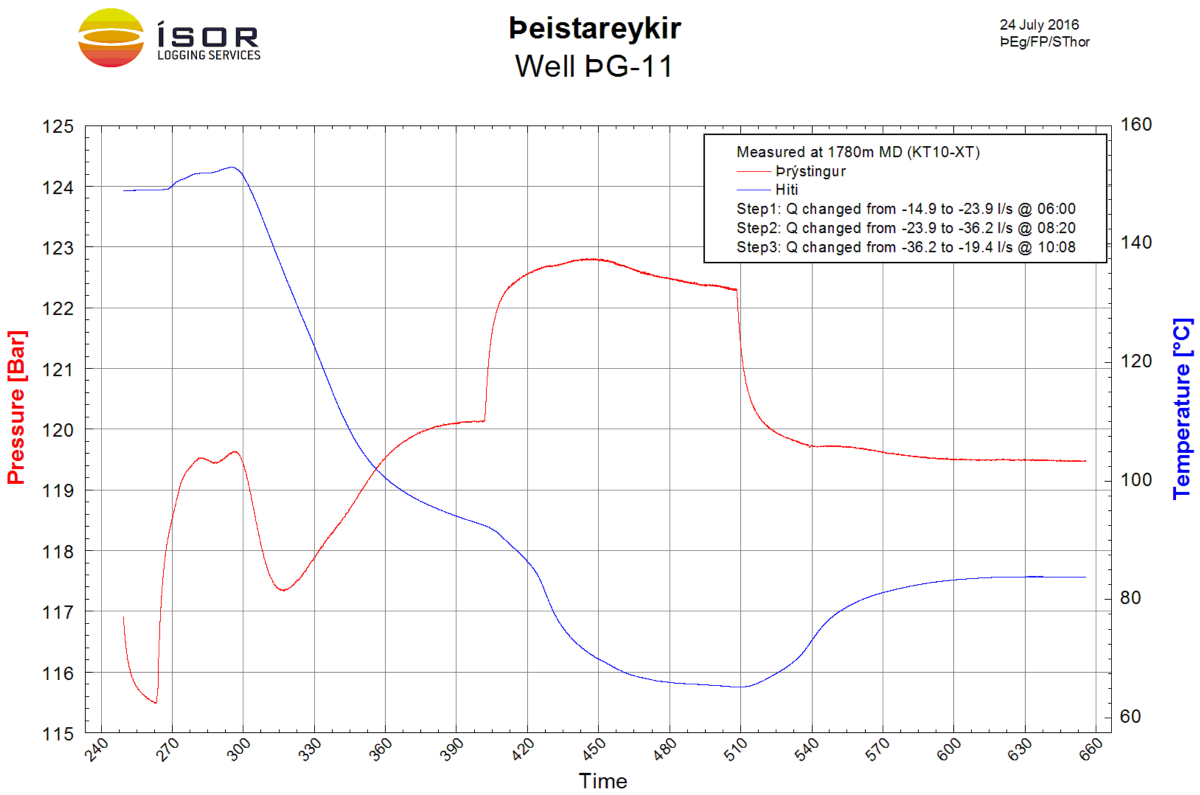

Figure 2. Results from injection test

The following plan is now finished.

~~i) POOH~~
~~ii) RIH with logging string 24 hrs~~
~~iii) Temperature and gyro 8 hrs~~
~~iv) POOH 8 hrs~~
~~v) Logging incl. televiewer 24 hrs~~
~~vi) RIH with liner 24 hrs~~
~~vii) Injection testing with spinner 24 hrs~~

Borvakt

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