LV-2016-104

Landsvirkjun

Þeistareykir – Well ÞG-12

Phase 2: Drilling for Production Casing

from 300 m down to 806 m Depth

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ÍSOR

ÍSLENSKAR ORKURANNSÓKNIR

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Title: Þeistareykir – Well ÞG-12. Phase 2: Drilling for Production Casing from 300 m down to 806 m Depth.

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Abstract: Well ÞG-12 is a directionally drilled production well for the Þeistareykir power plant. It is sited on the same drill pad as wells ÞG-3, ÞG-6 and ÞG-7. The well is located approximately 600 m north of Mt. Bæjarfjall and west of Mt. Ketilfjall. The aim of the drilling was to penetrate a purported fracture systems north of, and under, Mt. Bæjarfjall. This report addresses the drilling history and data acquisition of the 2nd phase. ÞG-12 was pre-drilled with 21" drill bit for 18⅝" surface casing to 116.6 m. Drilling continued with a 17½" drill bit for a 13⅜" anchor casing, down to 292.2 m and then with a 12¼" drill bit for a 9⅝" production casing to 802 m. The stratigraphy of phase 2 in well ÞG-12 is composed mostly of hyaloclastite formations, including basaltic breccias, tuffs and pillow basalts. Also minor amounts of lava flows may be present. Several intrusions were noted. The abundance of intrusives increases below 600 m depth. The grade of alteration is generally high. The appearance of epidote is noted at 358 m and below 410 m it becomes common. Wollastonite is found at 770 m.

Key words:

Þeistareykir, well ÞG-12, geothermal area, high temperature, wellbore, steam mining, geological strata, feed zones, wireline logging, Óðinn, Landsvirkjun, ÍSOR

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Ágrip

Hola ÞG-12 er stefnuboruð vinnsluhola fyrir raforkuverið á Þeistareykjum. Hún er staðsett á framlengdu borplani C, um það bil 600 metra norðan við Bæjarfjall, vestur af Ketilfjalli. Fyrir voru á plani C holur ÞG-3, ÞG-6 og ÞG-7. Lagt var upp með að skera þekkt sprungukerfi norðan við Bæjarfjall með það að markmiði að fá sem mestan hita og lekt í holuna eins og mögulegt væri. Þessi skýrsla fjallar um borsögu og gagnaöflun 2. áfanga holunnar. Þar með er talin kortlagning jarðlagasúlunnar og ummyndunarsteinda, sem greind var út frá borsvarfi sem kom upp með skolvökvanum. Einnig er hér átt við jarðeðlisfræðilegar mælingar sem gerðar voru á meðan borverkinu stóð. ÞG-12 var forboruð með 21" krónu fyrir 18⅝" yfirborðsfóðringu niður á 120 m dýpi. Borun var haldið áfram með 17½" krónu niður á 300 m dýpi og 13⅝" öryggisfóðring sett niður. Því næst var borað fyrir 9⅝" vinnslufóðringu með 12¼" krónu niður á 802 m dýpi. Jarðlagasúlan í þessum áfanga einkennist aðallega af móbergsmyndunum, s.s. breksíu, túffi og bólstrabergi, en einnig varð vart við þunn hraunlög og innskot. Fjöldi innskota eykst neðan við 600 m dýpi. Ummyndun bergsins er almennt mikil. Kristallað epidót sást fyrst á 358 m dýpi og verður algengt neðan við 410 m. Wollastónít kemur inn á 770 m dýpi.

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1 Introduction

Drilling of well ÞG-12 in the Þeistareykir geothermal field was conducted by Iceland Drilling (Jarðboranir) for Landsvirkjun. ÞG-12 is drilled from an extended drillpad C. The production wells ÞG-3 (2659 m deep), ÞG-6 (2799 m deep) and ÞG-7 (2509 m deep) are located on the same drillpad approximately 150 m ENE of well ÞG-12. Drillpad C is located under the slopes of Mt. Ketilfjall, by the road to Bóndhólsskarð pass (Figures 1 and 2).

Exploration drilling for electrical power production in the Þeistareykir geothermal area were first carried out in 2002. The area is thought to be one of three largest geothermal areas in northeastern Iceland. The surface manifestations cover an area of 11 km^2 and TEM resistance measurements in the bedrock, conducted in 2006, indicate the size of 45 km^2 (Karlsdóttir et al., 2006).

The geothermal system is located within the active Þeistareykir volcanic system. The fissure swarm, which is about 5 km wide and 50–60 km long, with its southern end in the Mývatn area and its northern end in sea off Kelduhverfi. The most recent volcanic activity, the formation of the Þeistareykjahraun lava, date to c. 2400 BP (Sæmundsson et al., 2012). The surface manifestations are most abundant in three areas 1) by the southwestern slopes of Mt. Ketilfjall, 2) In the northern slopes of Mt. Bæjarfjall and 3) in southern Tjarnarás (Figure 1).

The planned depth of well ÞG-12 is 2000–2500 m. The well is directionally drilled towards southwest, with the aim of intersecting the permeability and heat anomaly related to the fracture system north of, and under, Mt. Bæjarfjall (see Khodayar et al., 2016; Mortensen, 2012).

Table 1. *Geographical position of well ÞG-12. Coordinates are in ISNET93.*

Well name	Well ID	East (X) (m)	North (Y) (m)	Elevation (m a.s.l.)	Planned depth (m)
ÞG-12	60412	593912	599461	350	2500

The planned design of well ÞG-12 (Figure 3) is as follows:

- Phase 0: Pre-drilling for the surface casing with 21" drill bit to approximately 110 m depth. Cased with 18⅝" pipes.
- Phase 1: Drilling for the anchor casing with 17½" drill bit down to ~ 300 m depth. Cased with 13⅜".
- Phase 2: Drilling for the production casing with 12" drill bit down to ~ 800 m depth. Cased with 9⅝".
- Phase 3: Drilling of the production part with 8½" drill bit to 2500 m depth, cased with 7" perforated liner.

To reach the target zones the direction of the well was set at 235°±5°relative to true North, with an inclination 30°±3° from the vertical within the depth range 400 m to 1600 m (MD). Below 1600 m (MD) greater deviations in direction and inclination are tolerated i.e. ±15° for direction and ±12° for inclination (Figure 4). The kick-off was planned c. 20 m below the anchor casing, at 320 m depth. The angle build-up rate was planned to be 2.5°/30 m with the final inclination of 30° from the vertical, to be completed before 660 m (MD). 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 monitoring the work. Iceland GeoSurvey (ÍSOR) managed cutting inspection, geophysical logging, gyro surveys and geothermal consulting. The drill rig Óðinn started the predrilling (Phase 0) of ÞG-12 on August 6th with a 21" drill bit for 18⅝" surface casing. Phase 0 was completed on August 18th at 120 m depth. The drill rig Óðinn continued drilling Phase 1 with a 17½" drill bit to 300 m for the 13⅝" anchor casing which was cemented to 292.2 m.

This report presents progress of the drilling during phase 2 and the exploration work carried out, including lithology, alteration and feed point locations, as well as the wireline logging done in the well during this phase. The report is divided into four main chapters. The *first chapter* gives an introduction. *The second chapter* reports on the drilling operations during drilling. *The third chapter* describes the geological strata, geothermal alteration and loss zones/aquifers in the well. *The fourth chapter* includes the wireline loggings carried out by ÍSOR´s logging engineers.

The aim of the report is to document the geological- and geophysical part from the drilling of phase 2 in ÞG-12, and present all the data collected and provide data interpretations. Appendix B contains all daily reports written by the on-site geologist during drilling operations, presenting preliminary results.

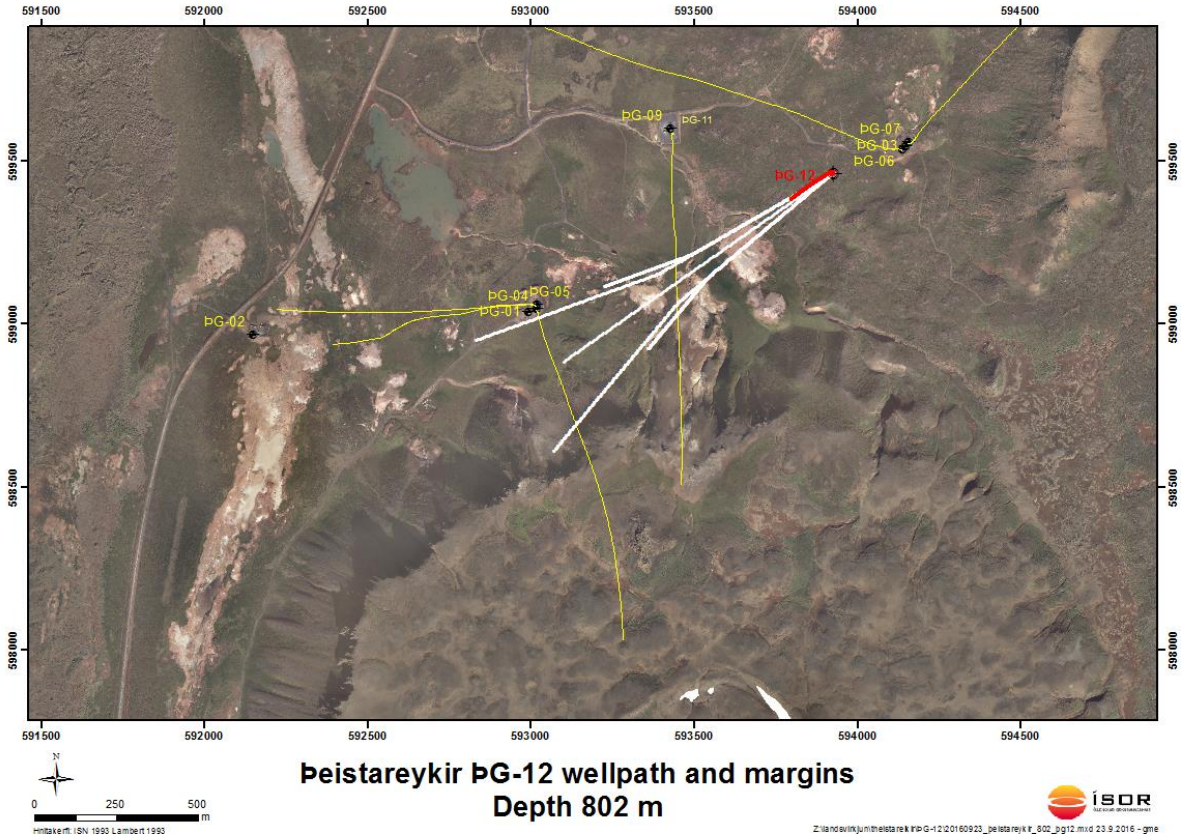


Figure 1. *Aerial photograph of Þeistareykir. Location of current drillpads and production wells and their trace in the Þeistareykir geothermal field. The red line represents the trace of well ÞG-12 to 806.0 m depth (end of phase 2).*

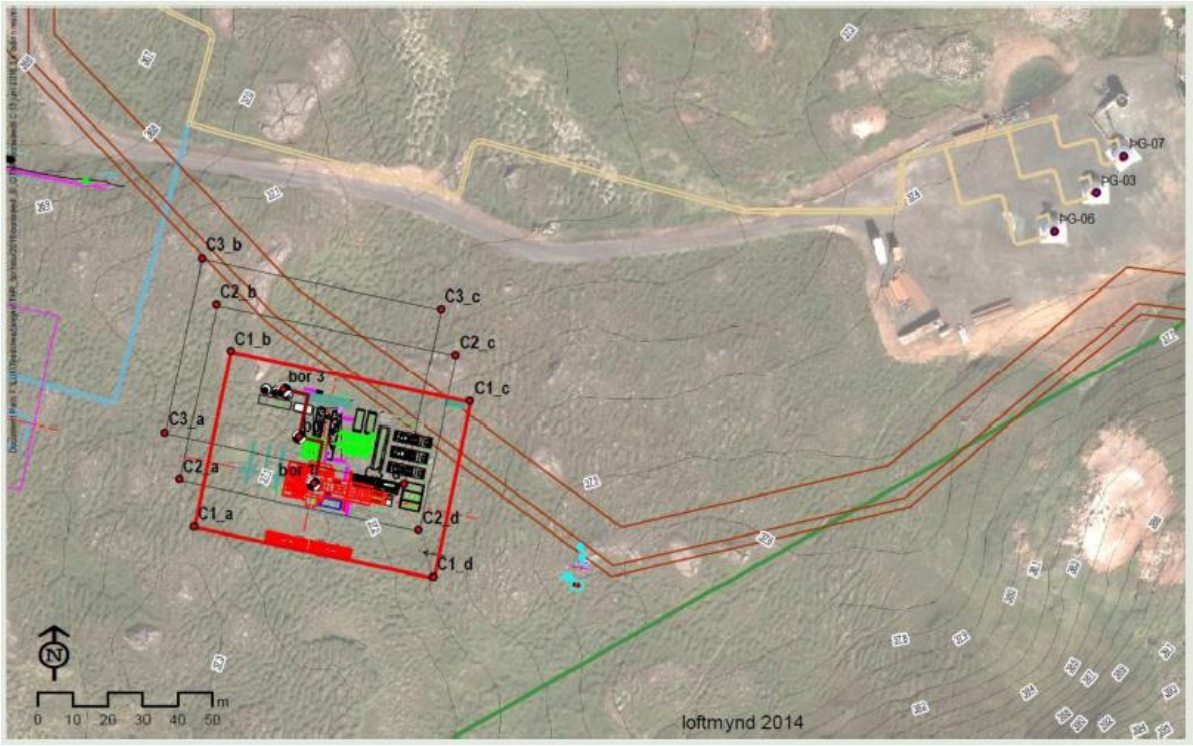


Figure 2. *Location of wellpad C (upper right corner) and its extension towards WSW where well ÞG-12 is located.*

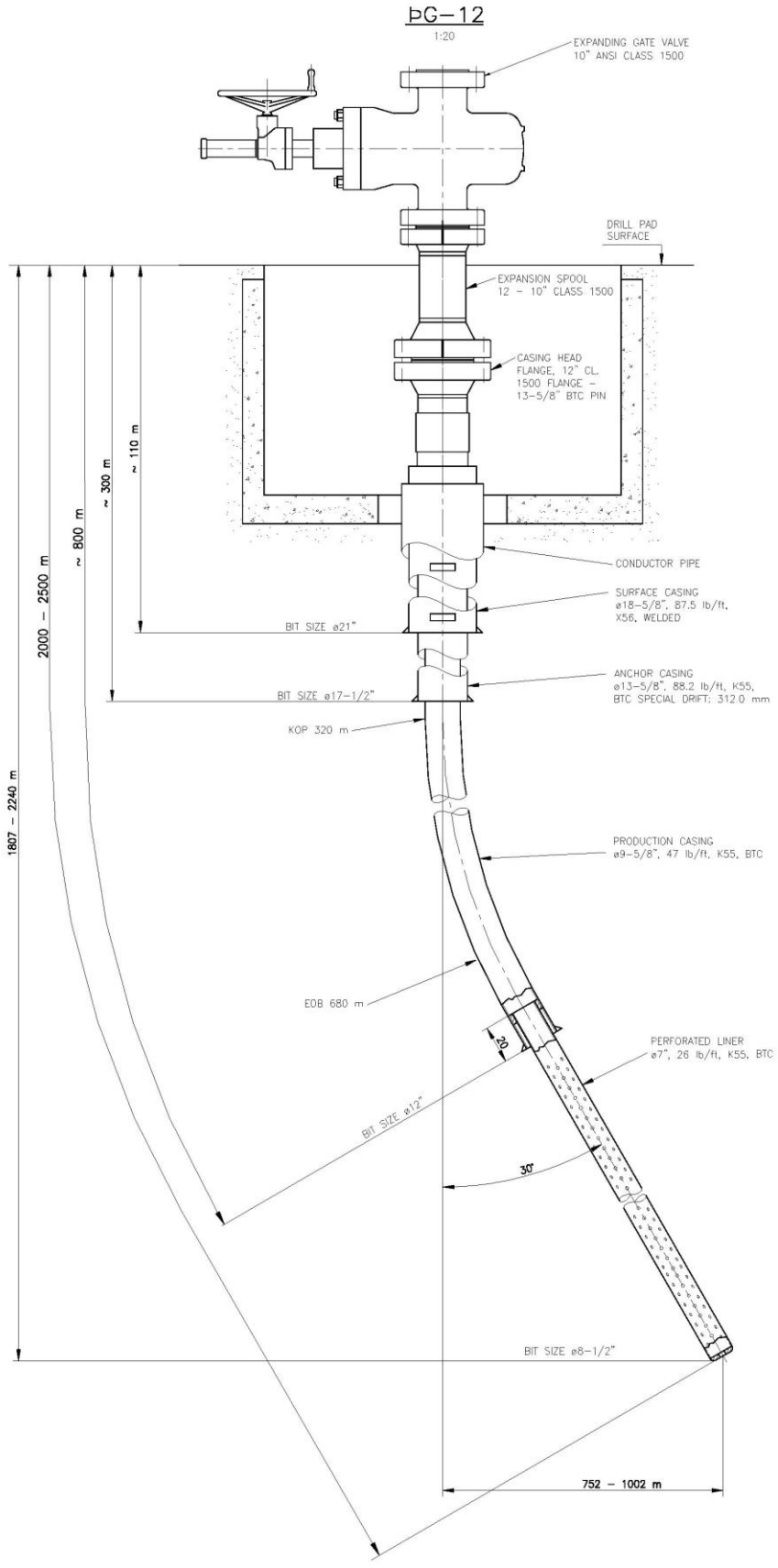


Figure 3. *Well design of ÞG-12.*

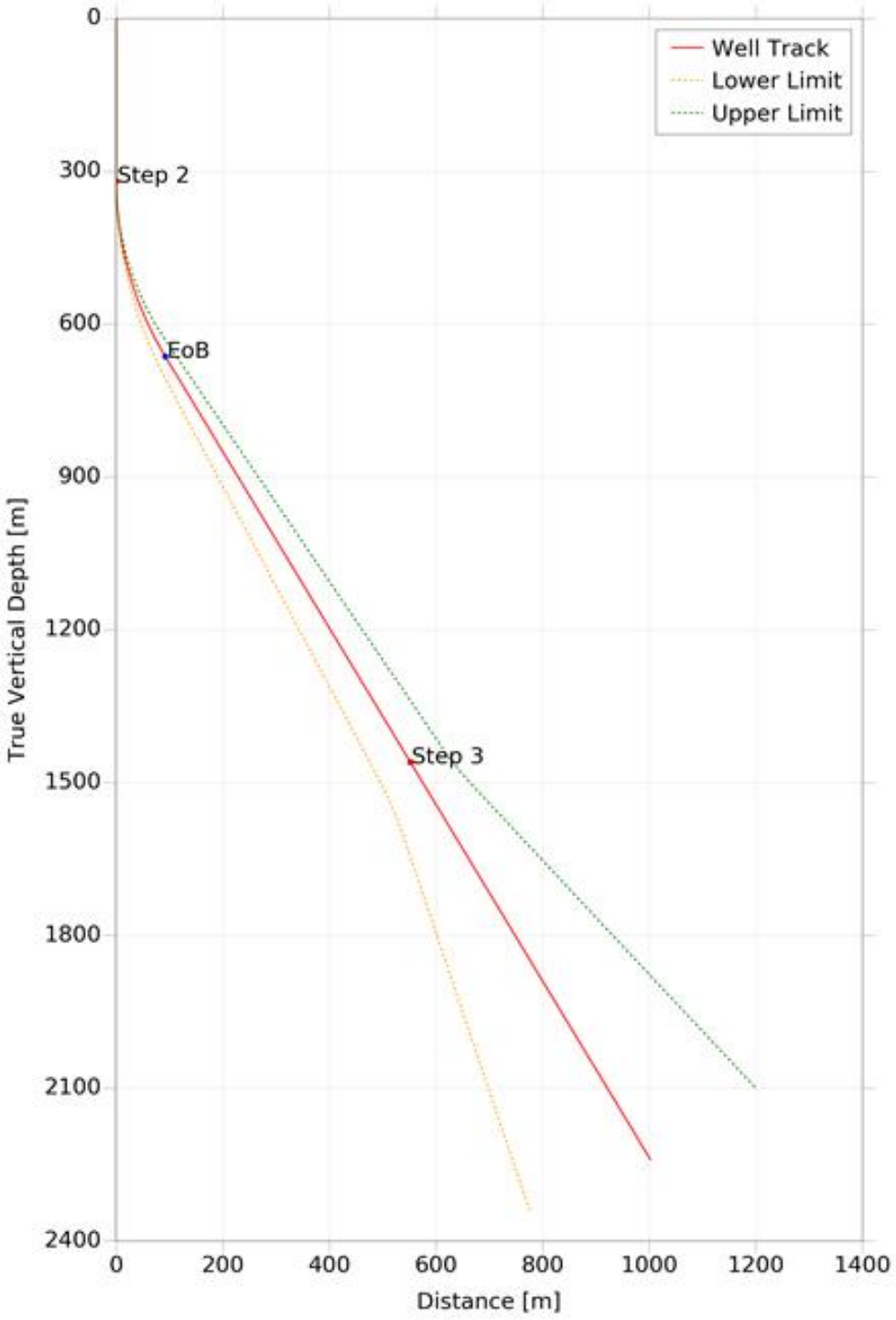


Figure 4. *Cross section of the planned trajectory of well ÞG-12 with allowable deviation indicated.*

2 Drilling operations

2.1 Overview

Drilling of well ÞG-12 with the rig Óðinn started on the 6th of August 2016. Predrilling was completed on 18th of August at 120 m with a cemented surface casing to 116.6 m. Phase 1 was complete 25th of August 2016 (workday 21) when the 13⅝" anchor casing was run down and cemented to 292.2 m depth.

Preparation for Phase 2 started on 25th of August by setting up the Master valve, blow out preventers (BOP's) and the flow line and then testing the BOP's. The drilling crew started RIH the bottom hole assembly with the 12" drill bit in the morning on the 27th of August 2016 (workday 24). Drilling into formation started at 300 m the same day. No loss of circulation was noted during the drilling of phase 2. Drilling was terminated at 806 m depth on the 31st of August 2016 (workday 28). The production casing was then cemented and several temperature logs were run into the hole as well as Gamma, Resistivity, Neutron-Neutron and CBL logs (cement bond).

An overview of the first three drilling phases and details of the casing depths are shown in Table 2. Figure 5 and Table 3 shows the drilling progress of well ÞG-12 during drilling to 806 m.

Table 2. *Drilling and casing depths in well ÞG-12.*

Drill-Rig	Phase	Drill bit	Depth (m)	Depth Reference	Casing Type	Casing Depth (m)
Óðinn	0	21"	120	Óðinn RF*	18⅝"	116.6
Óðinn	1	17½"	300	Óðinn RF*	13⅜"	292.2
Óðinn	2	12"	806	Óðinn RF*	9⅝"	802.0

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

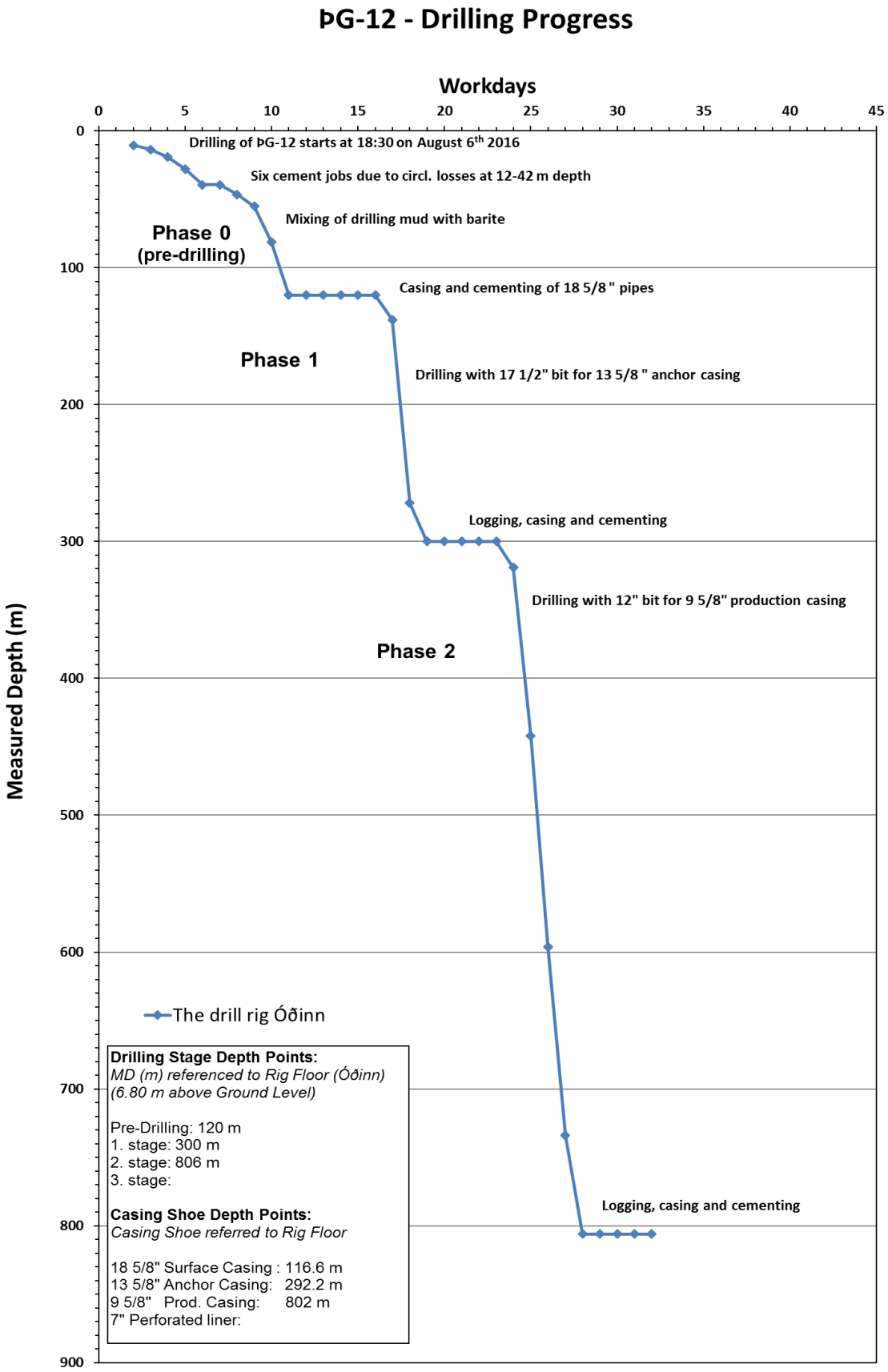


Figure 5. *Drilling progress of well ÞG-12, phases 0–2.*

2.2 Drilling for the production casing (9⅝") - Phase 2

Drilling operations of phase 2 started on August 25th by mantling up and testing the blow-out preventers by applying a pressure of 30 bar for 10 min. The BOPs passed the tests, no leakage were observed.

On August 27th a BHA for the drilling of phase 2 of ÞG-12 was RIH. The BHA was composed of the following components: A 12" bit-a steerable motor- stabilizer- MWD NaviTrak-sub-stabilizer-5x drill collars-jar-3x drill collars-sub x/o- drill pipes. The graphical report for the BHA is shown in Figure 6. According to the well design the azimuth of the well was going to be towards SW (i.e. 235°) in direction to the north slopes of Mt. Bæjarfjall. The KOP was planned at 320 m depth and EOB at 680 m. The build-up rate was planned to be 2.5°/30 m until an inclination of 30° was reached. During RIH a circulation with water was applied as the well was rather hot, as indicated by a temperature log from the 26th of August (see Chapter 4).

The float collar was reached at 256.3 m depth and drilled through until reaching the formation at 300 m at 9:00 pm on the August 27th.

The KOP of the well was at 320 m. A 2:30 am in the morning of August 28th, the logging engineers from ISOR ran their gyro instrument in the hole for establishing the starting point of the directional drilling. At 291 m an inclination of 2.3° and azimuth of 33.4° was measured. Drilling was then ongoing until reaching 806 m, the final depth for the drilling of phase 2, in the morning on August 31st (on workday 28). During the drilling of phase 2 several gyro surveys where completed, summarized in (table 9 in Chapter 4). During drilling of phase 2 ROP was rather high, between 6.7 and 7.2 m/hour, the WOB was generally between 3 and 10 tons and the pump rate about 50–55 L/s.

No major issues were encountered during the drilling of phase 2 but on September 1st, during the temperature logging by the ISOR logging team before running the production casing in the hole, the tool got stuck in a thick mud at 570 m depth and 1000 kg had to be applied to pull it out of the hole. Consequently, the additional logging that was planned was cancelled, including caliper, resistivity and NN-Gamma.

At 10:00 on September 1st the Jarðborarnir rig crew started RIH the 9⅝" production casing while regularly pumping water through the casing head due to the thick mud in the well. Below 450 m the work continued even slower as it was necessary to circulate water after each pipe. The casing job finished at 6:00 on the 2nd of September. The depth of the casing shoe was set at 802.0 m (see Table 4).

Before the cementing of the casing, the well was cooled down by circulating water mixed with 150 kg of soda, using the rig pump for 7.5 hours first and then the cementing unit for 30 minutes. The cementing started on 2nd September at 22:10 when 31 m^3 of cement was pumped down the cementing string and through the float collar at 778 m, followed by a displacement water of 7.5 m^3. The cement was recovered at surface, but 30 minutes after the cement job 1 m^3 of cement was used to fill up the annulus. The cementing report is published in Table 5. After waiting on cement (WOC) for about 6 hours, the ISOR logging engineers arrived at the drilling site to run a temperature log followed by a CBL log 10 hours after cementing. Due to a poor cement bonding, additional WOC was necessary and a second CBL log was run later in the afternoon on the 3rd of September 18 hours after the cementing.

In the evening on the 3rd of September, on workday 31 of Óðinn, the lower Annular BOP was nippled down and the casing cut. In the morning on September 4th the BOP stack was taken down and the top of the casing cut to a desired height, i.e. 10 cm above the flange. This marks the end of drilling phase 2 of ÞG-12 (workday 32).

Table 3. *Drilling progress of the drilling phase 2 carried out by Óðinn. Depths are relative to the rig-floor of Óðinn (6.80 m above the ground).*

Day/workday	Drilled Section (m)	Drill Time (h)	ROP (m/h)	Total Depth at 24:00 (m)
27.8.2016/24	19.0	3.00	6.33	319.0
28.8.2016/25	123.0	18.00	6.83	442.0
29.8.2016/26	154.0	21.25	7.25	596.0
30.8.2016/27	138.0	19.50	7.08	734.0
31.8.2016/28	72.0	10.80	6.67	806.0
Total	**506.0**	**56.00**	**6.83**	**806.0**

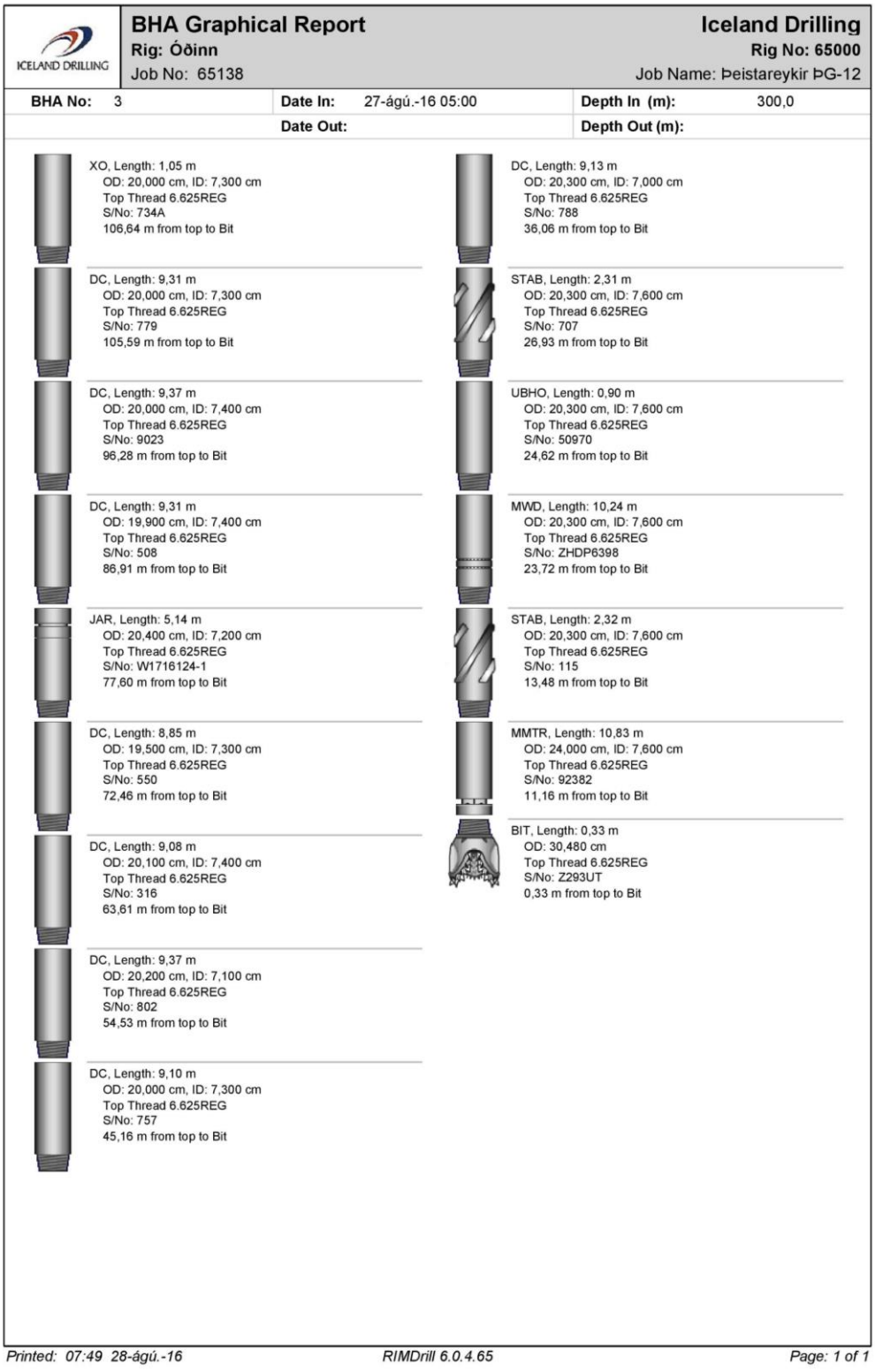


Figure 6. *BHA graphical report for phase 2 of well ÞG-12.*

Table 4. *Casing report for production casing in ÞG-12.*

ICELAND DRILLING	**Casing Information Report**	**Iceland Drilling**
	Rig: Óðinn	**Rig No: 65000**
	Job No: 65138	Job Name: Þeistareykir ÞG-12

Casing Information			
Run Date/Time:	02-sep.-16 06:00		
		Leak Off Test (kg/cu m):	
Well Section:	INT3	**String Type:**	FULL
String Top MD (m):	0,0	**String Top TVD (m):**	
Casing Shoe MD (m):	801,5	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	24,45	**String Nominal ID (cm):**	22,05
Bit Diameter (cm):	30,48	**Avg. Open Hole Diam. (cm):**	30,48
Centralizers: No:	61	**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 03-sep.-16 01:25		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
1	SHOE	0,540				K-55	BUTT	
2	JOINT	23,290	24,45	22,05	47,0	K-55	BUTT	
1	FLOAT	0,510				K-55	BUTT	
67	JOINT	777,700	24,45	22,05	47,0	K-55	BUTT	
Totals: 71		802,040						

Table 5. *Cementing report for production casing in ÞG-12.*

ICELAND DRILLING	**Cementing Report**	**Iceland Drilling**
	Rig: Óðinn	**Rig No: 65000**
	Job No: 65138	Job Name: Þeistareykir ÞG-12

Cement Job Information			
Start Date/Time:	02-sep.-16 22:10	**Well Bore:**	Original Well Bore
Job Type:	PRIMARY	**String OD (cm):**	24,45
Well Section:	INT3	**String Type:**	FULL
Cementing Co:	JARDB	**Cementing Engineer:**	Arnar Freyr

Primary Job Detail

	Volume (cu m)	Pump Time	Rate (cu.m./min)	Pressure (bar)
Conditioning Data:				
Cement Data:	31,0	40	0,8	
Displacement Data:	7,5	10	0,8	
Calc. Displacement Vol:	7,5			

☐ **Batch Mix?**	☐ **Bump Plug?**	**Bump Pressure:**	
Returns to Surface: FULL	☐ **Reciprocate Pipe?**	☑ **Cement at Surface?**	
Calc Top of Cement (m):	**Excess (%):**	**Avg. Hole Size (cm):**	30,48

Slurry Information

Type	Density	Yield	Sacks	Volume	Rate	Additives
LEAD	1.700,00			31,0	0,8	
TAIL	1.700,00			1,0	0,5	

Post Job Information

Liner Top Test (kg/cu m):		**Job Success?**	Yes
Actual Top of Cmt (m):		**CBL Bond Quality:**	
Misc. Comments:	9 5/8" Fóðringar steyping		

3 Lithology, alteration, intrusions and circulation losses

The crew of Óðinn collected cutting samples at two metres interval during the drilling of phase 2 of well ÞG-12. 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. During drilling the ÍSOR's borehole geologists inspected the cutting samples and determined the lithology and the alteration mineral assemblage with the aid of a binocular microscope. Additionally, data from the drill-rig data acquisition system, including the main drilling parameters, were collected and also information on losses of circulation. The description of the lithology is given below and graphical presentation of lithology and alteration is shown on Figures 7, 9, 10 and 11. Legend for the graphs is shown on Figure 8.

296–304 m: FINE-MEDIUM GRAINED BASALT

Fresh and fine grained basalt. Moderately oxidized. Clay is abundant in pores. The color of the rock is green, grey and dark grey.

304–310 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, with a high grade of alteration. Non-porphyritic.

310–318 m: BASALTIC BRECCIA

Mixed cuttings, mostly composed of fragments from pillow lava. Mostly fine crystalline basalt with a glassy groundmass. Non-porphyritic as above.

318–366 m: BASALTIC BRECCIA

Most likely pillow lava breccia. Composed of fine crystalline basalt with a glassy groundmass, non-porphyritic. Somewhat fractured. White and translucent precipitations are abundant. Large greenish glass fragments are admixed in the cuttings.

366–382 m: GLASSY BASALT

Fine crystalline non-porphyritic basalt admixed with some green glass fragments. The formation is considerably fractured. Calcite and pyrite are common.

382–406 m: BASALTIC BRECCIA

Pillow lava breccia. Fine crystalline basalt with glassy groundmass. Non-porphyritic. Considerably fractured. Green fine-crystalline clay and quartz are common. Highly altered at intervals, whitish in color. Traces of epidote are found at 358 m.

406–440 m: GLASSY BASALT

Rather porous fine grained crystalline basalt, feldspar porphyritic. Greenish glass fragments are admixed. Rock crystals are common in voids. The upper part is greenish in color but at 414 m it changes to grayish brown. Epidote becomes rather common from below 410 m.

440–444 m: BASALTIC BRECCIA

A thin layer of breccia between units of pillow basalt.

444–480 m: GLASSY BASALT

Similar pillow basalt as above, gray greenish in color and rather porous. Some minor amount of plagioclase phenocrysts are seen.

480–482 m: BASALTIC BRECCIA

A thin layer of breccia between glassy basalt and possibly a unit of lava flows below.

482–496 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, feldspar porphyritic. No glass fragments are seen in the cuttings. Possibly lava flows. Gray-whitish in color. Pyrite is abundant.

496–512 m: GLASSY BASALT

Fine grained plagioclase porphyritic glassy basalt, gray whitish to gray greenish in color. Glass fragments are rather common. Some intrusive rock may be present at 498 m and 508 m depth, where fragments of dark gray rather fresh rock are seen.

512–516 m: BASALTIC BRECCIA

Very mixed cuttings, mostly composed of various types of fine crystalline basalt and pieces of green glass.

516–530 m: GLASSY BASALT

Fine grained, gray-greenish, basalt. Plagioclase porphyritic. Fragments of glass are common, green to brownish in color. Minor oxidation is present. Pillow lava.

530–546 m: GLASSY BASALT

At 530 m there is a color changes in the pillow lava formation, below it becomes darker in color, dark brownish. Also the rock becomes coarser. Epidote is common.

546–554 m: BASALTIC BRECCIA

Mixed cutting, mostly composed of various types of crystalline basalt and glass fragments. Pillow lava breccia.

554–596 m: GLASSY BASALT

Very altered fine crystalline basalt with glassy groundmass. Plagioclase porphyritic. Rather fractured. No epidote is seen. At 570 m the basalt becomes somewhat coarser and darker in color. The rock is greenish-brown in color. Plagioclase porphyritic.

596–602 m: MEDIUM-COARSE GRAINED BASALT

Medium grained crystalline basalt. Not as altered as above. Plagioclase porphyritic. Dense rock non-porous. Most likely intrusive rock.

602–608 m: GLASSY BASALT

Same glassy basalt as at 554–570 m depth, fine grained plagioclase porphyritic. Very altered.

608–620 m: MEDIUM-COARSE GRAINED BASALT

Medium grained moderately altered basalt as above, intrusive rock.

620–640 m: FINE-MEDIUM GRAINED BASALT

Gray brownish fine crystalline basalt. Plagioclase porphyritic. Very few glass fragments are found. Possibly lava flows rather than pillow basalt. Rather homogenous formation.

640–660 m: BASALTIC BRECCIA

Mixed cuttings, composed of various types of crystalline basalt and glass fragments.

660–676 m: GLASSY BASALT

More homogenous formation than above. Fine grained light brownish crystalline basalt. Plagioclase porphyritic. Green glass fragments are admixed. Epidote is abundant.

676–692 m: MEDIUM-COARSE GRAINED BASALT

Medium grained crystalline basalt, plagioclase porphyritic (dolerite). Greenish brown in color. Intrusive dike. Not as altered as the rock above and below.

692–710 m: BASALTIC BRECCIA

Pillow lava breccia, composed of fine crystalline basalt with glassy groundmass and blue-green glass fragments admixed. Calcite disappears and pyrite is scarce. Quartz, epidote and prehnite are seen as fracture fillings.

710–716 m: MEDIUM-COARSE GRAINED BASALT

An intrusive dike of medium grained basalt (dolerite) as above.

716–736 m: BASALTIC BRECCIA

Pillow lava breccia at 716–726 m but below that the breccia becomes mixed with light green moderately coarse primary tuff. Calcite appears again in the cuttings. The formation is considerably fractured.

736–746 m: BASALTIC TUFF

Light green coarse primary tuff, light grayish and very altered. The tuff becomes finer downwards and mixed with crystalline basalt. Calcite is abundant.

746–750 m: BASALTIC BRECCIA

A thin layer of basaltic breccia

750–766 m: FINE-MEDIUM GRAINED BASALT

An intrusion of fine grained dark colored basalt. Plagioclase porphyritic. Less altered than the surrounding rock.

766–782 m: BASALTIC BRECCIA

A pillow lava breccia. Composed of fine crystalline basalt and green glass fragments. Calcite disappears and wollastonite is found. The epidote is well crystallized. Some dark colored intrusive rock is seen at the base of this unit.

782–788 m: FINE-MEDIUM GRAINED BASALT

An intrusion of fine dark colored basalt. Very dense and non-porphyritic rock. No calcite is found.

788–806 m: BASALTIC BRECCIA

A greenish basaltic breccia. Composed of crystalline basalt and green glass fragments. Wollastonite is rather common.

ÍSOR ICELAND GEOSURVEY

Þeistareykir

1.09.2016

Location:	Þeistareykir	*Drill rig:*	Óðinn	*Drilling fluid:*	Mud	*UWI:*	60412
Well:	ÞG-12	*Depth interval:*	0 -800 m	*Work phase:*	Phase 1-2	*Geologists:*	BP

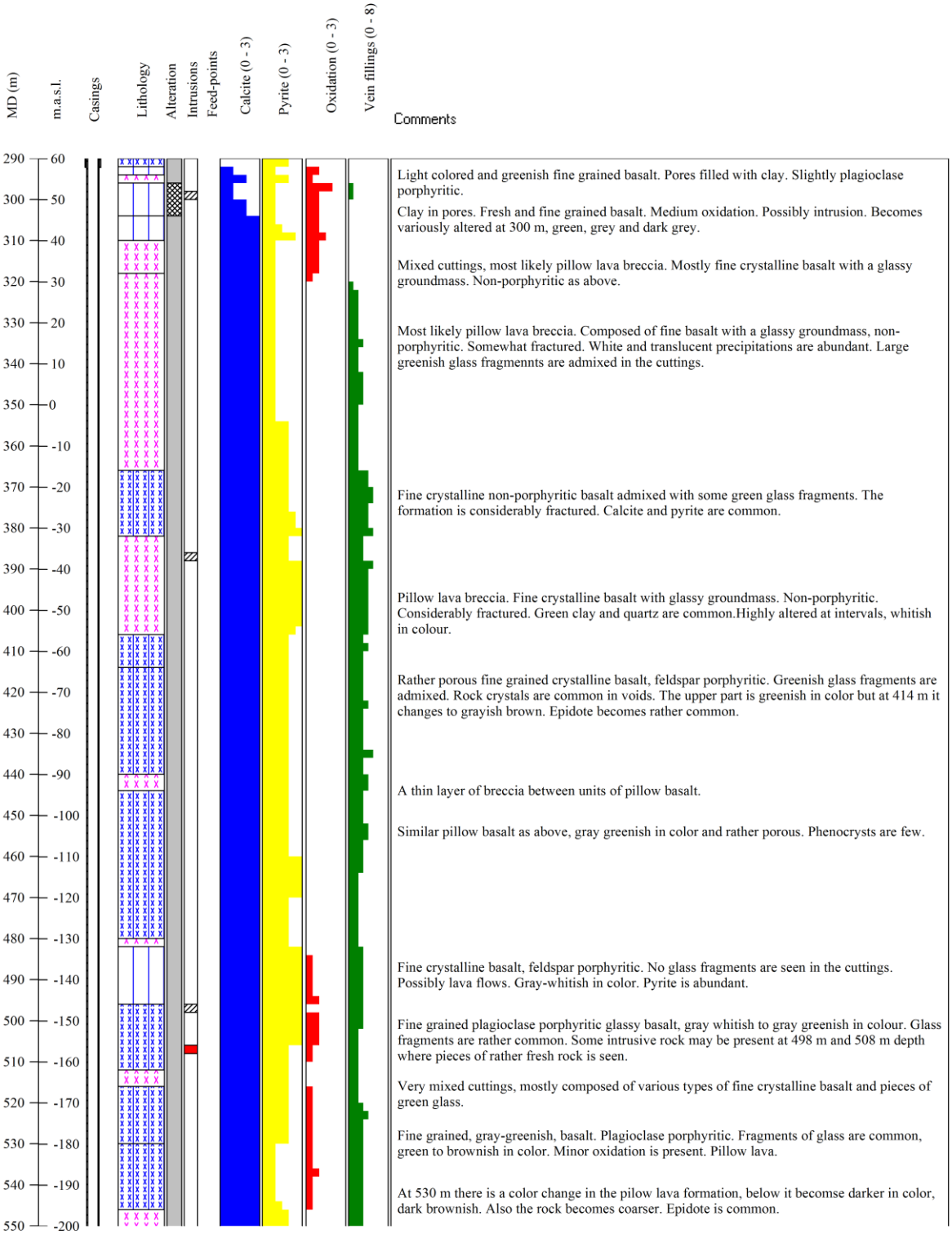


Figure 7. *Lithology and alteration of ÞG-12, from surface to 806 m.*

ÍSOR ICELAND GEOSURVEY

Þeistareykir 1.09.2016

Location:	Þeistareykir	*Drill rig:*	Óðinn	*Drilling fluid:*	Mud	*UWI:*	60412
Well:	ÞG-12	*Depth interval:*	0 -800 m	*Work phase:*	Phase 1-2	*Geologists:*	BP

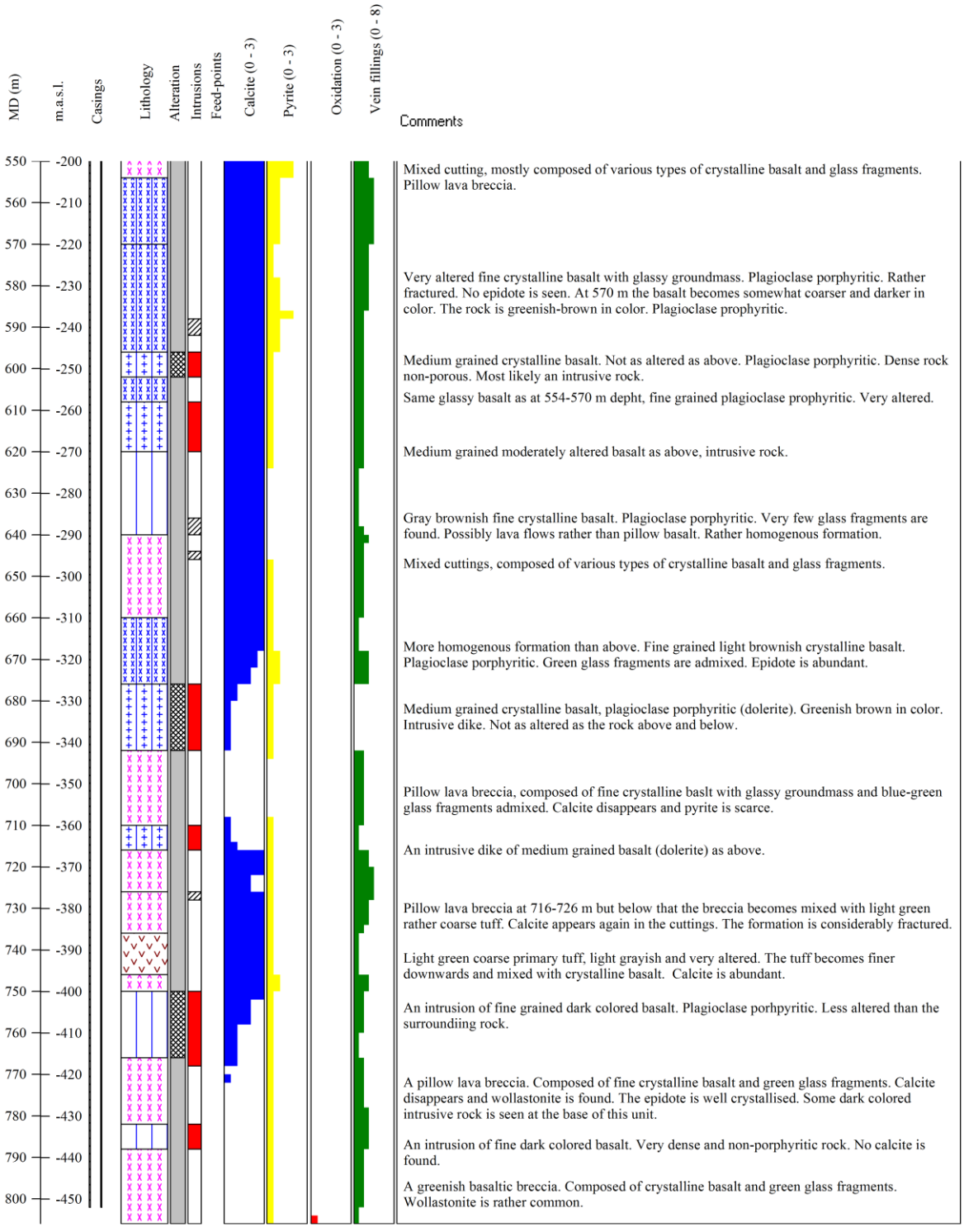


Figure 7. *(Cont.) Lithology and alteration of ÞG-12, from surface to 806 m.*

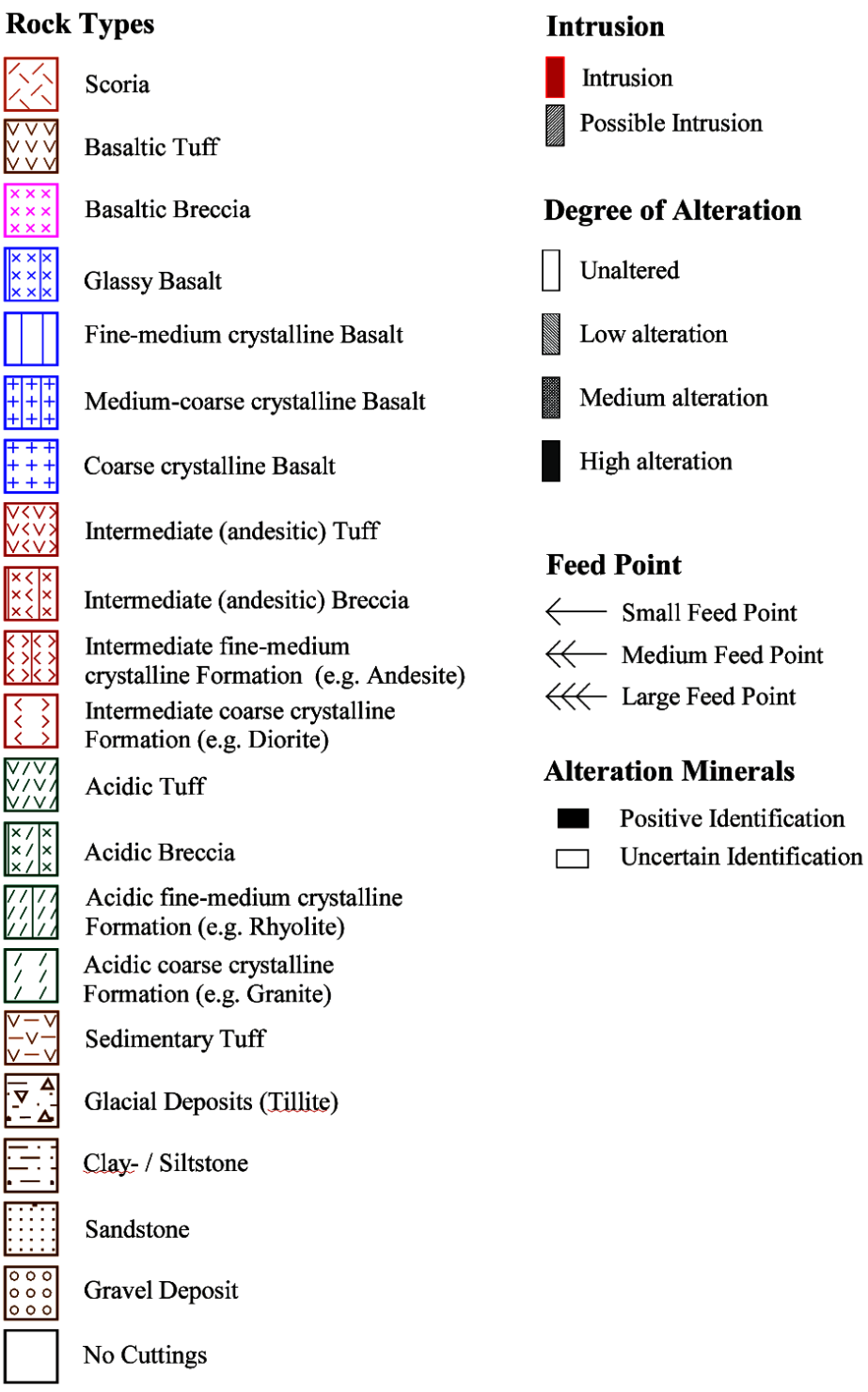


Figure 8. *Lithology legend for Figure 7, 9, 10 and 11.*

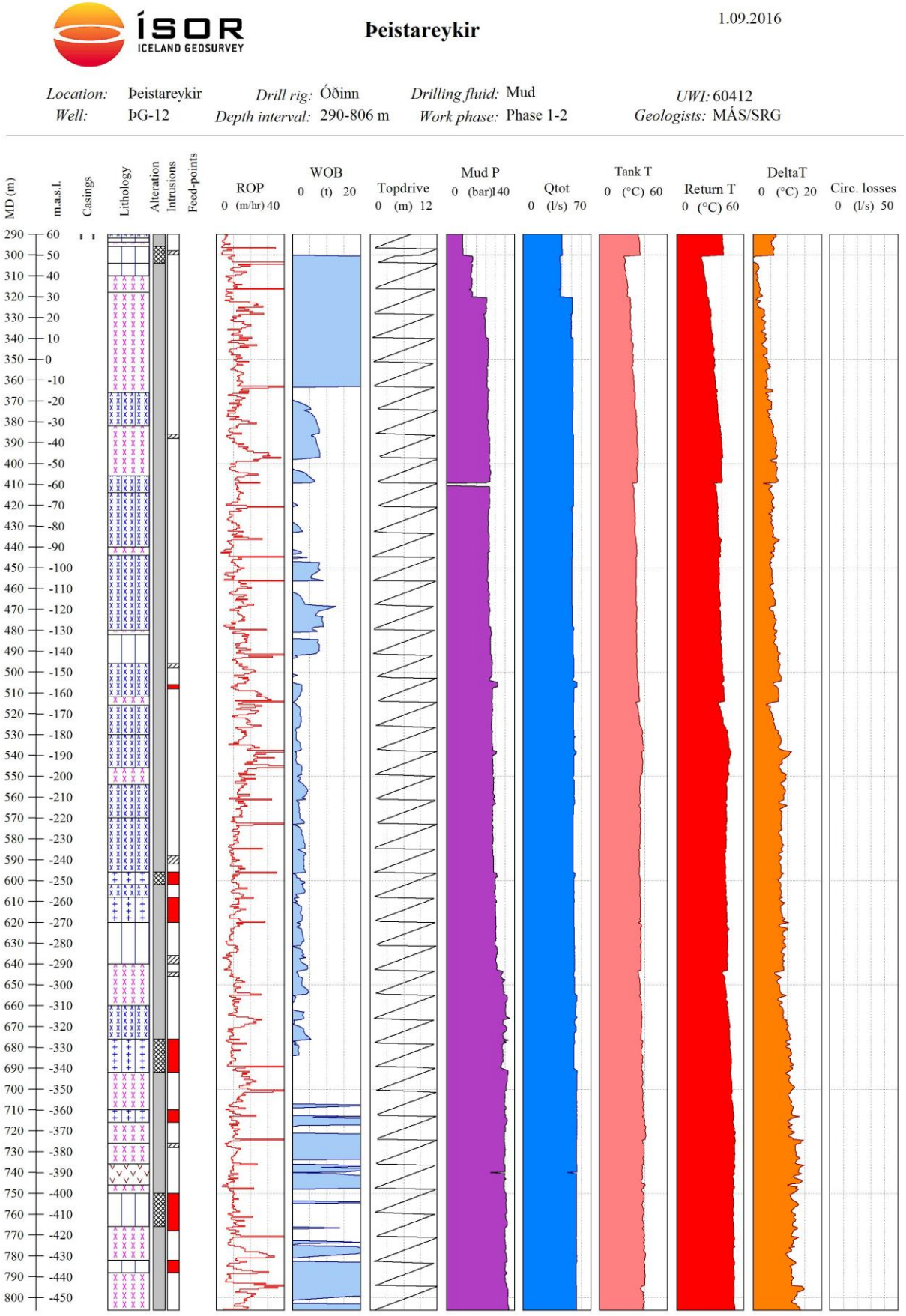


Figure 9. *Lithology and drilling data in well ÞG-12 from 290 to 806 m.*

3.1 Intrusions

Indications of several intrusions and possible intrusions were observed in the drill cuttings during drilling of phase 2. Table 6 gives an overview of the intrusions observed in well ÞG-12. Intrusions become rather common below c. 590 m in ÞG-12. Compared to the other wells on pad C, intrusions seem to be more abundant in ÞG-12 (Figure 10).

Table 6. *Intrusions in ÞG-12 at 290–806 m depth.*

Depth interval (m)	Type	Remarks
386-388	Possible intrusion	Intrusive veins
496-498	Possible intrusion	Intrusive veins
506-508	Intrusion	Intrusive veins
588-592	Possible intrusion	Intrusive veins
596-602	Intrusion	Medium grained crystalline basalt. Moderately altered. Plagioclase porphyritic
608-620	Intrusion	Medium grained moderately altered basalt
636-640	Possible intrusion	Intrusive veins
644-646	Possible intrusion	Intrusive veins
676-692	Intrusion	Medium grained crystalline basalt (dolerite), plagioclase porphyritic
710-716	Intrusion	An intrusive dike of medium grained basalt (dolerite)
726-728	Possible intrusion	Intrusive veins
750-768	Intrusion	Fine grained dark colored basalt, plagioclase porphyritic
782-788	Intrusion	Fine dark colored basalt, dense and non-porphyritic

3.2 Alteration

Figure 10 shows the main alteration mineral distribution in well ÞG-12 from 290 to 806 m depth. In the uppermost part, from 304 m to ca. 460 m the main alteration minerals are clays (fine to coarse grained), quartz and wairakite. Epidote appears at 358 m and becomes rather common below 410 m depth. For comparison epidote was found at 366 m in ÞG-7, 386 m in ÞG-11 and at 324 m in ÞG-9. In ÞG-9 epidote did not become common until below 420 m (Mortenson et al., 2011; Harðarson et al., 2013). At around 500 m depth prehnite appears. At similar depth the clays become more coarsely crystallized than above. Calcite is abundant from 300 to 670 m depth. Below 770 m no calcite is found in the cuttings (no responses to acid tests). At similar depth wollastonite appears in the cuttings indicating a formation temperature of about 300 °C. Pyrite is generally common down to 550 m but is only found in minor amounts below that.

At intervals the formation is moderately fractured but generally fractures are not common.

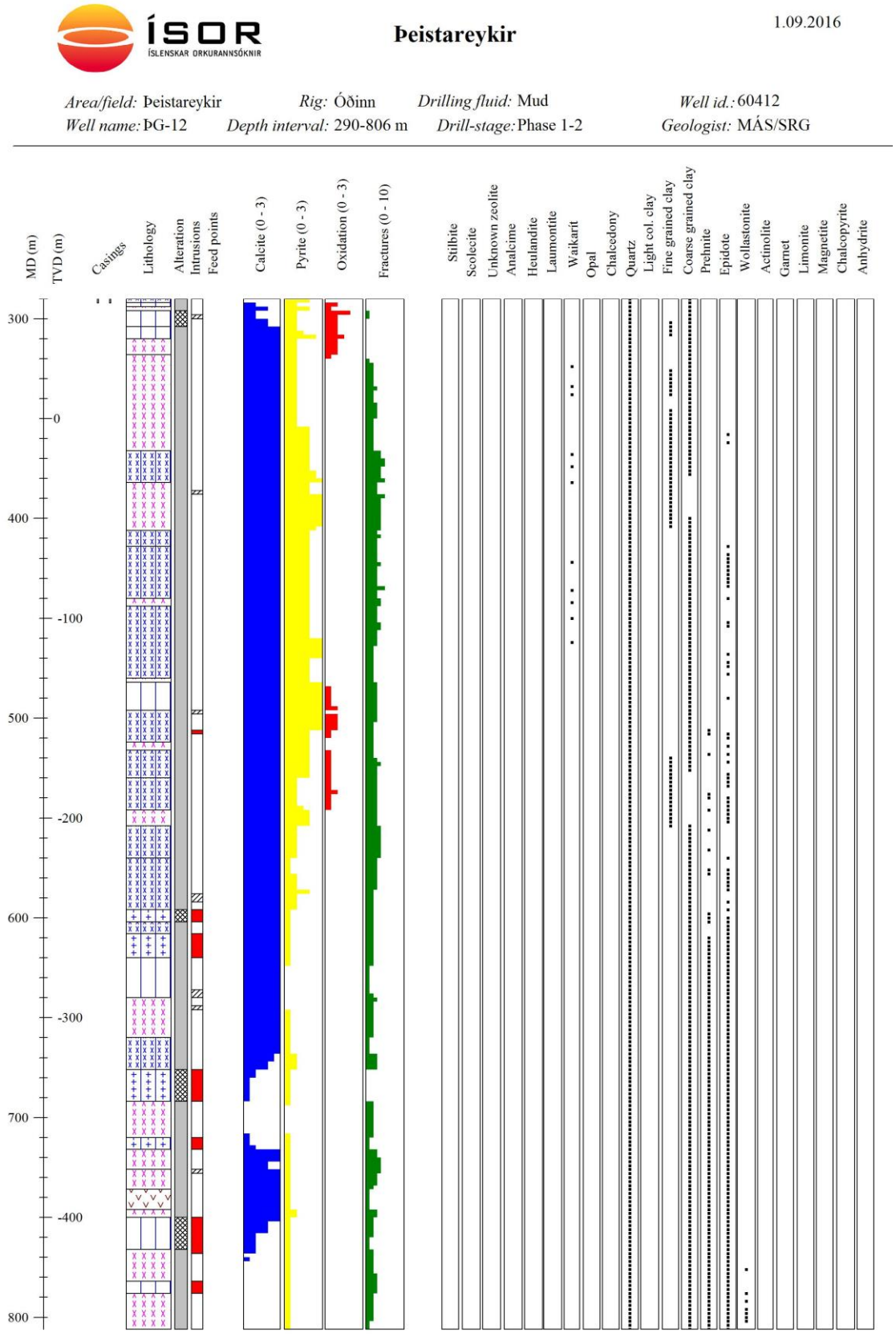


Figure 10. *A summary of the alteration minerals found in ÞG-12 during drilling of phase 2.*

3.3 Circulation losses during drilling of phase 2

No circulation loss was observed during the drilling of phase 2.

3.4 Comparison of wells located on well pad C

Figure 11 shows the lithologies of the wells located on well pad C, i.e. wells ÞG-7, ÞG-3, ÞG-6 and ÞG-12. In ÞG-12 the formation is characterized by hyaloclastite, mostly basaltic breccia and glassy basalt (pillow lava). Just one layer of basaltic tuff was identified, at 736–746 m depth. Three units of possible basaltic lava flows were found. In all the other wells located on well pad C the formation of phase 2 was composed mostly of basaltic breccia, glassy basalt and some tuff. Basaltic tuff seems to be more abundant in the other wells, esp. ÞG-3 and ÞG-6, than in ÞG-12. In all the wells a tuff layer/layers are found at 700–780 m depth that might represent the same layer.

In ÞG-12 intrusions are more common than in the other well.

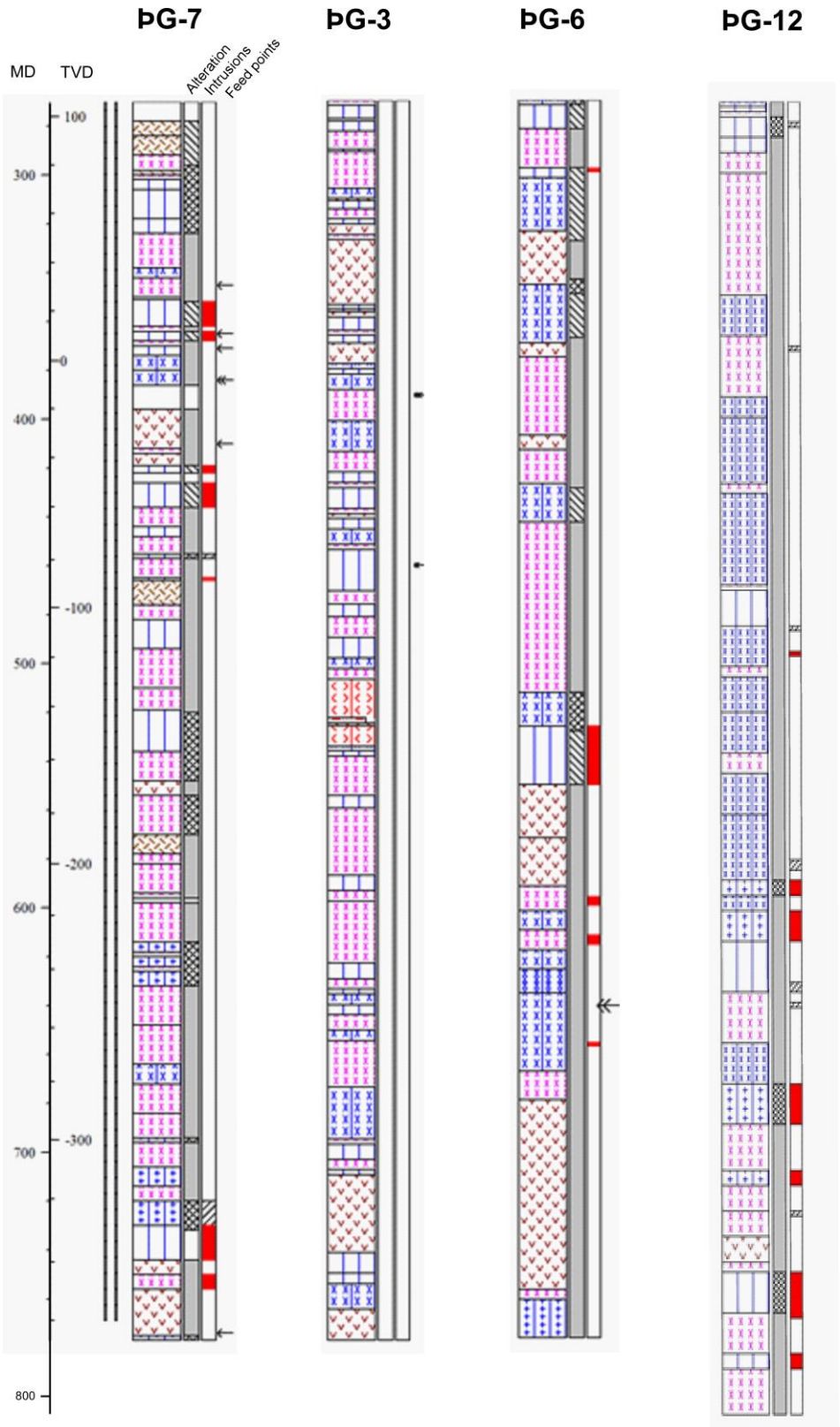


Figure 11. *Comparison of the lithology in the wells ÞG-7, ÞG-3, ÞG-6 and ÞG-12 located on pad C (modified from Mortensen et al., 2011).*

4 Wireline logging

Wireline logging in phase 2 of well ÞG-12 can be divided into 3 types.

- Gyro surveys to measure inclination and azimuth with depth in order to monitor the directional drilling (angle build-up and direction).
- Temperature log to check the warm-up rate inside the well and to locate loss zones if they occur.
- Cement Bond Logs and temperature logs after cementing of casings to evaluate the quality of the casing cementing.

In this chapter the logging activity and the logging results for the drilling of well ÞG-12 for the 9⅝" production casing (drilling of phase 2) are introduced and discussed. Overview of the wireline loggings is shown in Table 7.

Table 7. *Geophysical logs in phase 2 of ÞG-12.*

Date	Time	Log type	Depth (m)	Purpose	Q [l/s]	Remarks
26.8.2016	13:38-13:47	Temperature	5-200	Temperature for BHA	0	Tool max temp 150°C reached @ 200 m.
28.8.2016	03:06-03:38	Gyro	50-288	Motor-tool face	0	Surveys @ 288, 250, 200, 150, 100 and 50m.
28.8.2016	17:28-17:50	Gyro	280-367	Incl. & azimuth	0	Surveys @ 367, 340, 310, 288 and 280m.
29.8.2016	11:58-12:24	Gyro	367-470	Incl. & azimuth	0	Surveys @367, 370, 400, 430, 460 and 470m.
30.8.2016	09:15-09:41	Gyro	460-600	Incl. & azimuth		Surveys @ 460, 470, 500, 530, 560, 590 and 600m.
1.9.2016	00:41-01:18	Temperature	0-570	Temp / feed point location	0	Tool hung up at 570 m.
3.9.2016	04:40-05:07	Temperature	5-777	Temperature	0	4 hours after cement job.
3.9.2016	09:03-09:55	CBL	5-775	Cement Bond	0	10 hours after cement job.
3.9.2016	10:21-10:44	Temperature	7-775	Temperature	0	11 hours after cement job.
3.9.2016	16:16-16:36	Temperature	10-645	Temperature	0	17 hours after cement job, tool max temp reached @ 645m.
3.9.2016	17:12-17:36	CBL	29-523	Cement Bond	0	18 hours after cement job.

Before RIH of a new BHA, including a mud motor and a MWD for the drilling of phase 2, ISOR logging engineers carried out temperature logging August 26th (Figure 14). Drilling of phase 2 started August 27th with drilling in the cement float collar at 256 m depth. The first Gyro log for motor orientation was run when drilling depth was 320 m, which is the kick-off point (KOP). A total of four Gyro runs were performed in phase 2. Production casing (9⅝") depth was reached at 806 m on Wednesday, August 31st. When POOH was finished it was planned to carry out geophysical logging including temperature, caliper, resistivity and NN-Gamma logs. When temperature log was abandoned when the tool hung up in thick mud at 570 m and 1000 kg pull was needed to get the tool free. Further logging was therefore cancelled because the thick mud in the well.

Two temperature log and cement bond logs were performed after cementing of the production casing. Table 7 shows an overview of all logs performed during phase 2 in well ÞG-12.

Gyro surveys

Table 8 shows the design parameters for the directional drilling of well ÞG-12 including kick-off-point (KOP), angle build-up (AB), inclination and azimuth. To reach the target zones the direction of the well was set at 235 ±5° and inclination 30 ±3° (320–800 MD). Logging engineers from ÍSOR carried out four gyro surveys in phase 2 of well ÞG-12 and the corresponding depth intervals are listed in Table 9.

Table 8. *Target for inclination and azimuth in well ÞG-12.*

Azimuth	KOP	AB	Inclination	Target
235°	320 m	2,5°/30 m	30°	2000-2500 m (MD)

The first Gyro survey was conducted on August 28th for the depth interval down to 288 m when the motor "tool face" was logged. The second gyro survey was conducted for depths 280 m – 367 m. For the reminder of the drilling job, two more gyro surveys were run in phase 2 to measure the inclination and the azimuth of the well. The last gyro survey in phase 2 was run on August 30th when drilled depth was 643 m and the well was logged down to 600 m depth. In Table 10 the combined results of the Gyro surveys in ÞG-12 are presented, including derived parameters. Figure 12 shows the calculated well path from the measured inclination and azimuth data together with the designed well path and corresponding deviation limits.

Figure 12 shows at 600 m depth the well path is outside deviation limits. The results show that the inclination at 600 m depth is 24.05° and the azimuth 234.0°.

Table 9. *Gyro surveys carried out in phase 2 of well ÞG-12.*

Date	Depth interval (m)	Tool
28.8.2016	50-288	SPT 45
28.8.2016	280-367	SPT 1414
29.8.2016	367-470	SPT 1414
30.8.2016	460-600	SPT 1414

Table 10. *Inclination, azimuth and derived parameters for well ÞG-12.*

Measured Depth [m]	Inclination [°]	Azimuth [°]	Horizontal displacement [m]	TVD [m]	ISNET93 Coordinates		
					East [m]	North [m]	Elevation [m]
0	0.00	0.0	0	0	593923.0	599459.0	350
50	0.13	234.8	0	50	593922.9	599459.0	300
100	0.08	4.4	0	100	593922.9	599459.0	250
150	0.58	27.3	0	150	593923.0	599459.2	200
200	1.87	20.5	1	200	593923.4	599460.2	150
250	2.46	32.2	3	250	593924.3	599461.9	100
280	2.24	19.2	4	280	593924.8	599463.0	70
288	2.51	27.0	5	288	593924.9	599463.3	62
310	2.32	17.4	6	310	593925.3	599464.2	40
340	1.37	315.4	6	340	593925.2	599465.0	10
370	3.39	261.5	6	370	593924.1	599465.1	-20
400	6.15	245.9	6	400	593921.8	599464.3	-50
430	8.81	244.7	6	430	593918.2	599462.7	-80
460	11.85	238.8	10	459	593913.5	599460.1	-109
470	12.72	237.2	11	469	593911.7	599459.0	-119
500	14.80	235.1	18	498	593905.8	599455.0	-148
510	15.83	235.6	20	508	593903.6	599453.5	-158
540	18.42	236.1	29	536	593896.3	599448.5	-186
570	20.82	235.7	39	564	593888.0	599442.9	-214
600	24.05	234.0	50	592	593878.6	599436.3	-242

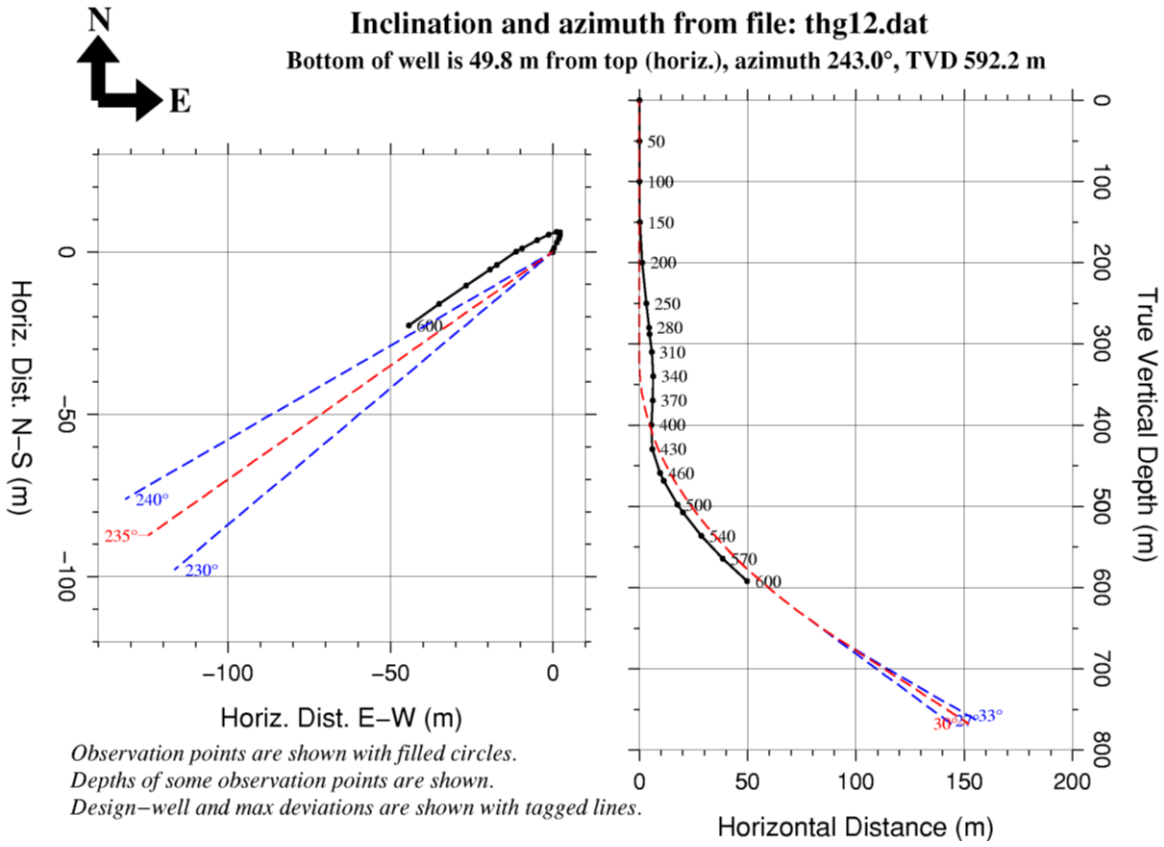


Figure 12. *Calculated well path from the measured inclination and azimuth data together with the designed well path and corresponding deviation limits.*

Temperature and Cement bond logs

Before RIH of a new BHA, including a mud motor and a MWD for the drilling of phase 2, ISOR logging engineers carried out temperature logging August 26th. Figure 14 shows the results of the temperature log (red profile). The logging tool was run down with no cooling and at 200 m depth the temperature reached 150°C which is the maximum temperature for the temperature instrument used. Therefore, logging was stopped.

Production casing (9⅝") depth was reached at 806 m on Wednesday, August 31st. After the well was circulated and cleaned for two hours. POOH started and was finished close to midnight September 1st. Early morning September 1st the ISOR logging engineers started their logging program and as no loss of circulation had been reported no water was pumped on the well. At first the temperature tool was run in the hole. At 570 m depth temperature tool stopped in a thick mud and did not go deeper. When pulling it back a 1000 kg force had to be applied to get it out, which is much more than normal. When at surface a thick layer of clay was found covering the heat sensor (Figure 13). The temperature log is shown in Figure 14 (blue curve). The maximum temperature measured was 91°, but rose to 114° before pulling out the hole. Because of the mud in the well insulates the sensor and the log does therefore not reflect the actual temperature around ÞG-12. Further logging that was planned, including caliper, resistivity and NN-Gamma, were cancelled because of the thick mud.

The cementing of the 9⅝" production casing was finished September 2nd at ≈ 23:00. In total, 32 m³ of cement were used. ÍSOR´s logging engineers started temperature and CBL logging early

morning September 3rd. The temperature log was performed first and the results can be seen in Figure 14 (orange curve). The temperature rises with depth with a small temperature peak just below 200 m indicating feed zone (over pressured?) outside the anchor casing at that depth. Other indications of permeability are not seen in the log and the highest temperature measured was 115°C, just above the float collar at 777 m depth.
The CBL log was carried out approximately 10 hours after cementing (Figure 15 and Figure 16) and revealed that cement was behind the casing at all depths. The log shows moderate cement bond down to 100 m, and then very poor bonding down to 500 and finally good cement bond below 540 m down to the float collar. After the CBL log was completed ÍSOR´s logging engineers started another temperature log about 11 hours after cementing was finished (Figure 14, magenta curve). The log is similar the previous log but the temperature had increased by about 25°C with highest temperature measured was 144°C, at the float collar
After the temperature log was completed it was decided to WOC longer and run a new temperature and CBL later in the afternoon.

A temperature log followed by new CBL log started at 16:00 and was finished around 18:00. September 3rd. The temperature profile is shown on Figure 14 (green curve). It is similar to previous logs but about 20°C hotter. The temperature reached 150°C at 645m depth which is the maximum temperature for the temperature instrument used. Therefore, logging was stopped.

The 2nd CBL log was conducted at ~17:15 in the afternoon September 3rd, approximately 18 hours after cementing. Logging was stopped at 523 m depth since the temperature threshold of the CBL tool is 140°C (Figure 17 and Figure 18). This log shows only minor improvement of the cement bond from the previous log and still poor bonding between the cement and the 9⅝" casing at long ranges between places with good bonding.

Figure 13. *The temperature logging tool at surface after logging September 1st with the heat sensor covered by mud.*

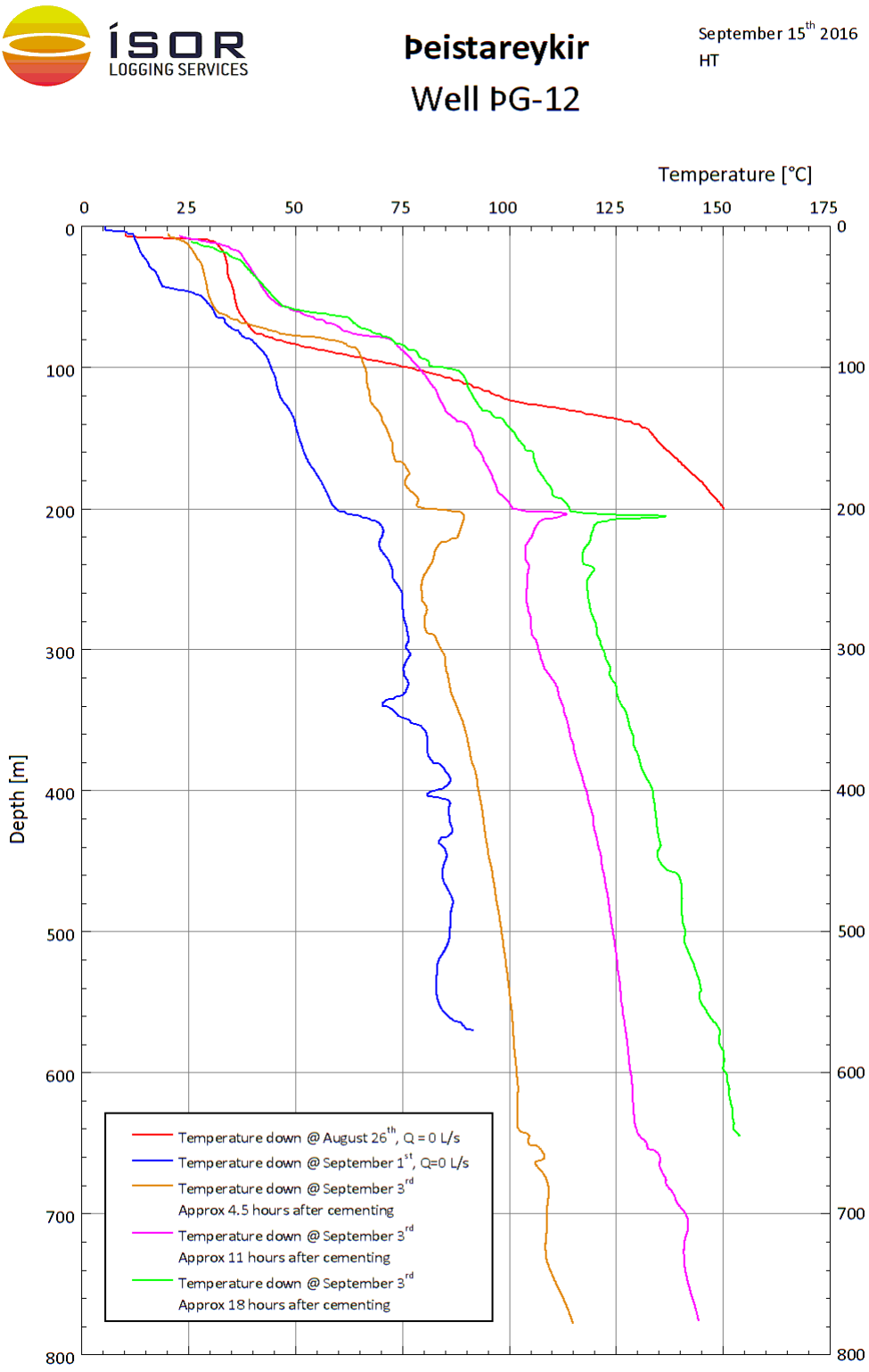


Figure 14. *Temperature log compilation for phase 2 of well ÞG-12.*

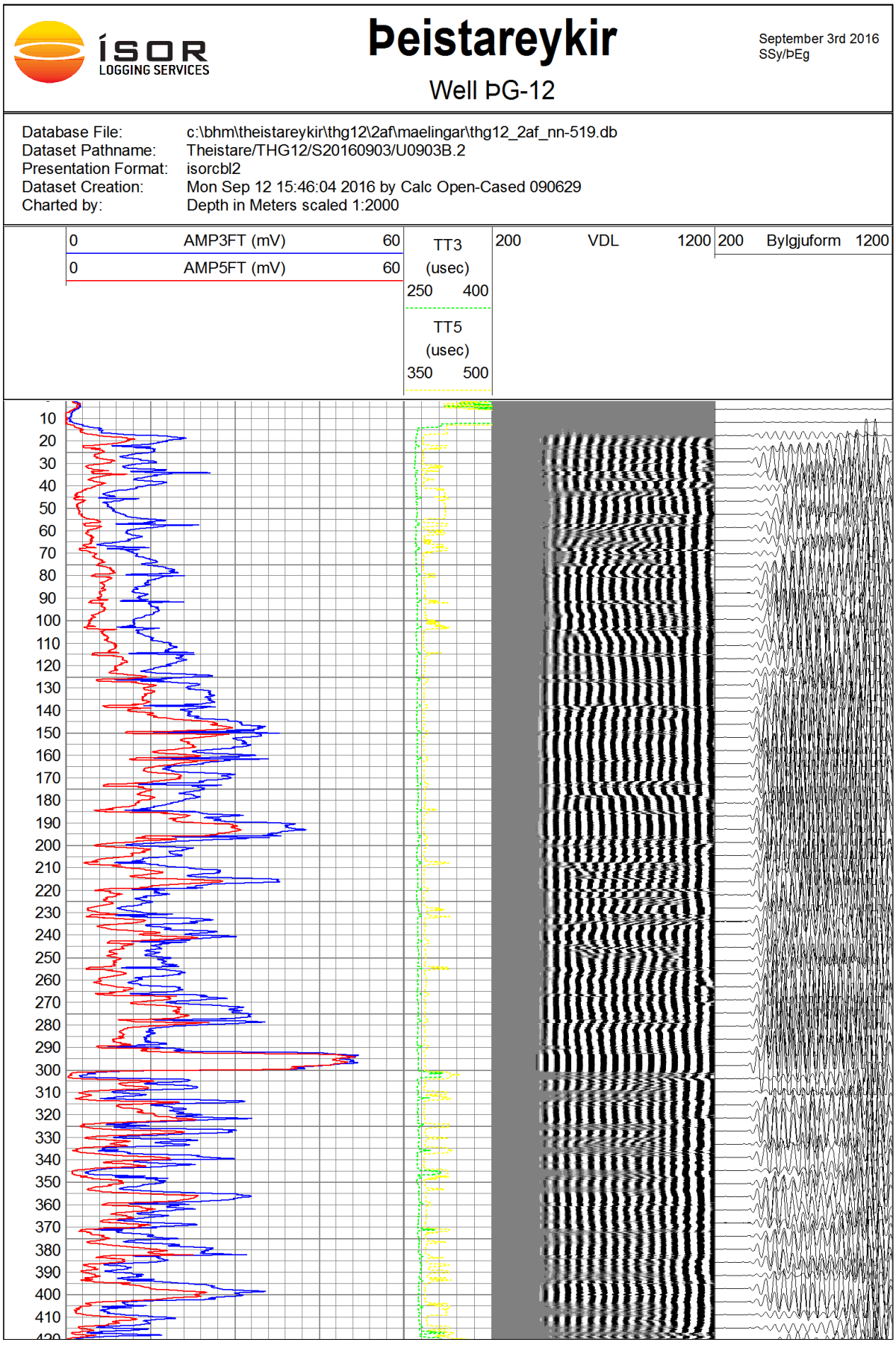


Figure 15. *Cement Bond Log – Production casing, ~10 hours after cementing.*

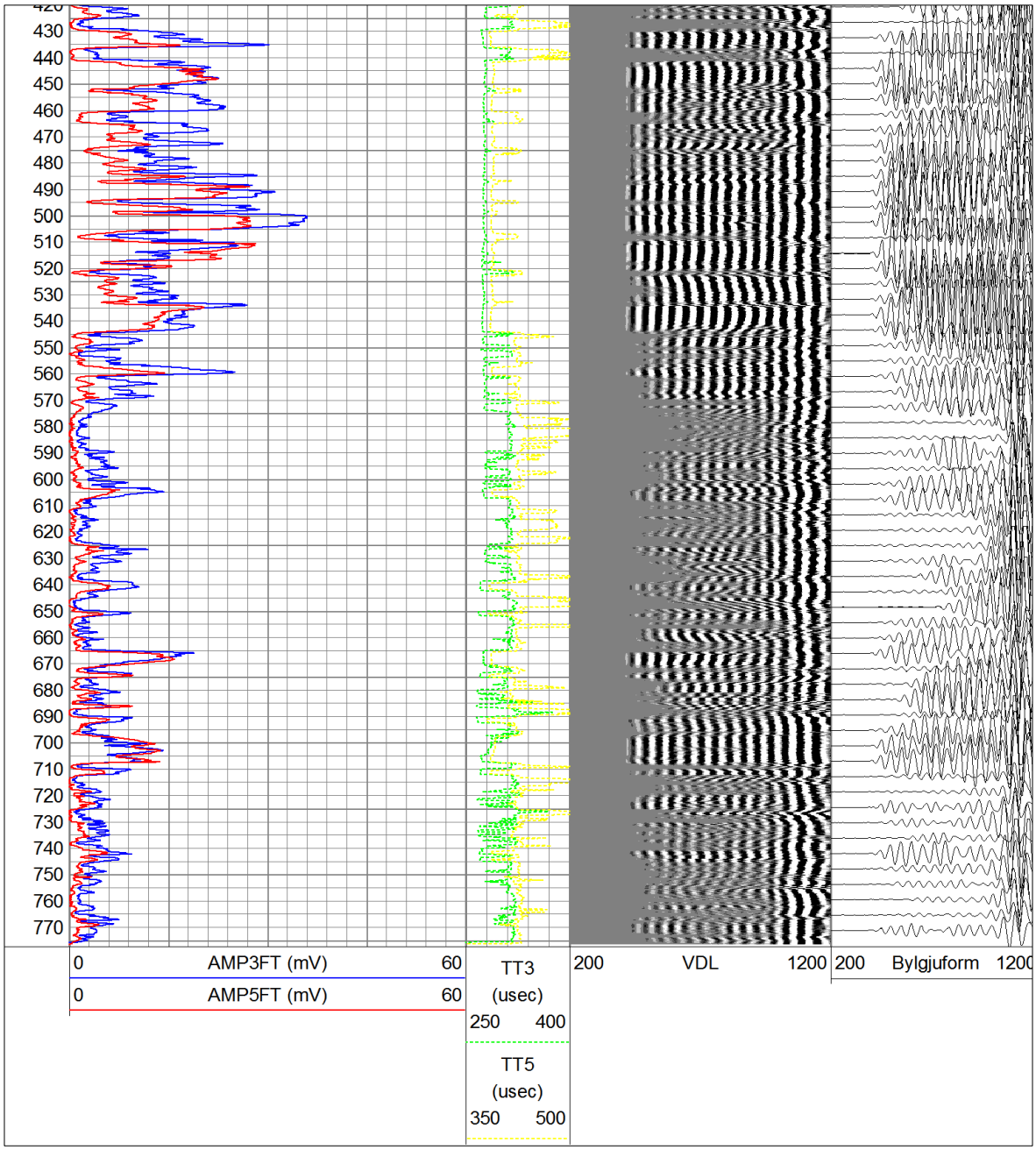


Figure 16. *Cement Bond Log – Production casing, ~10 hours after cementing.*

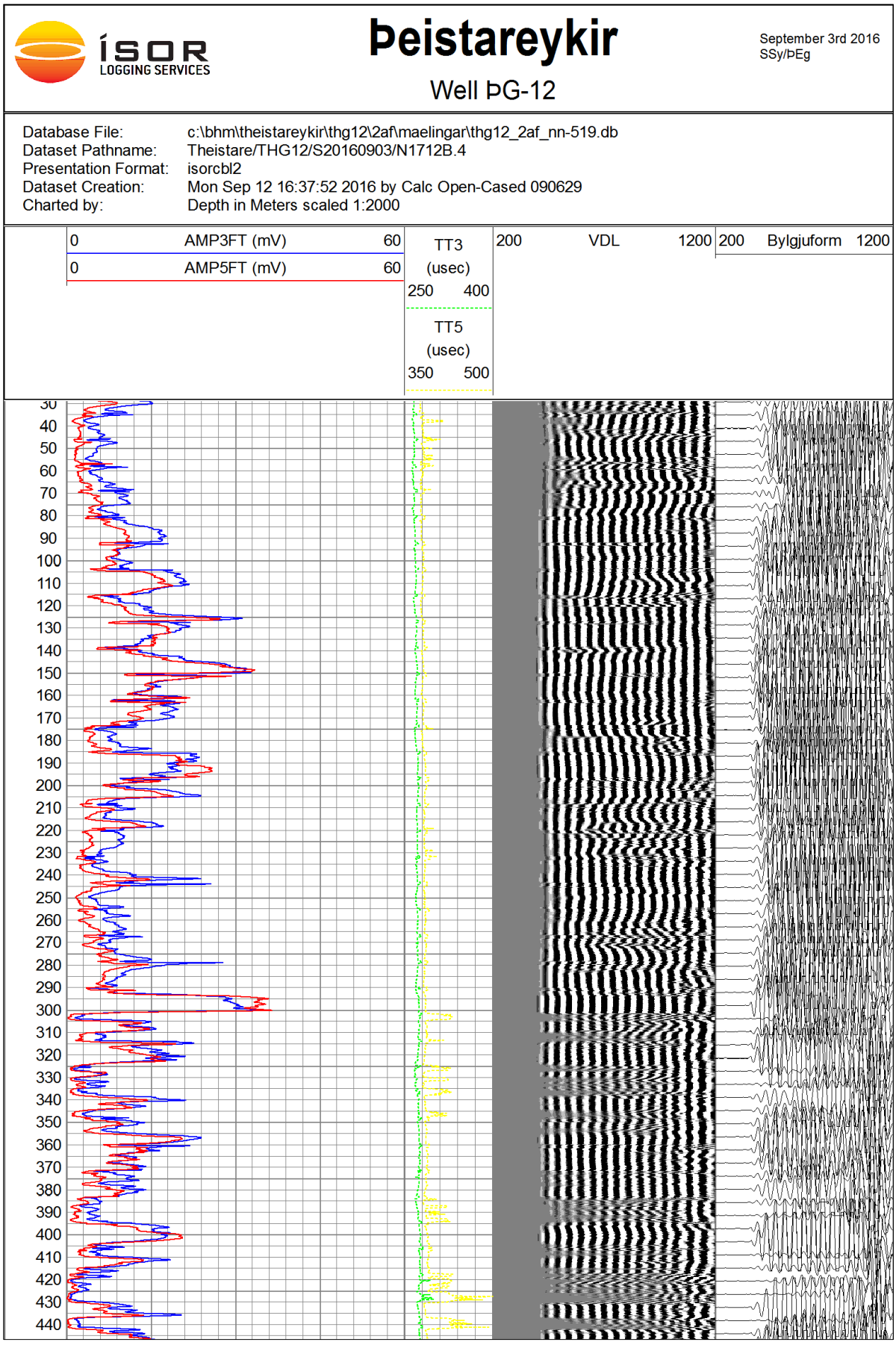


Figure 17. *Cement Bond Log – Production casing, ~18 hours after cementing.*

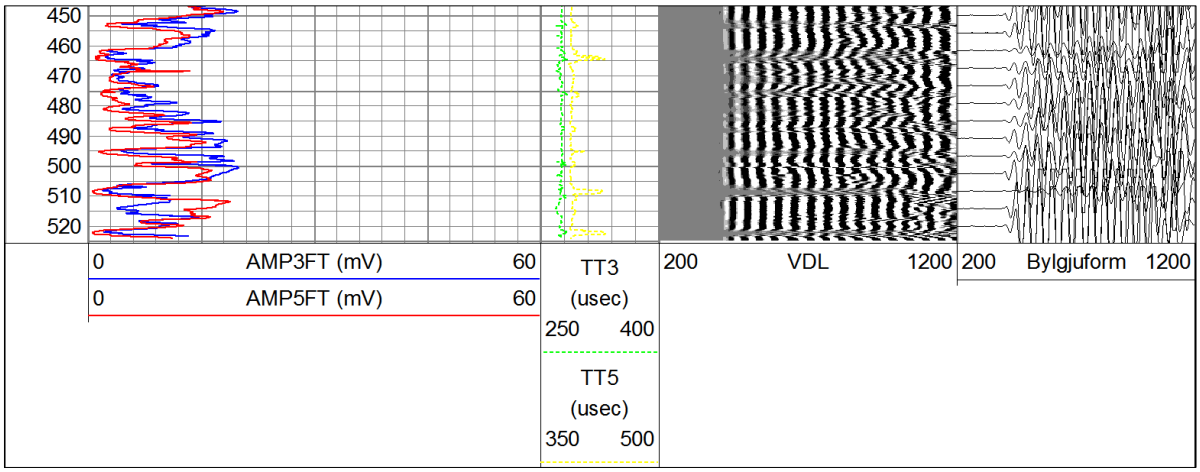


Figure 18. *Cement Bond Log – Production casing, ~18 hours after cementing.*

5 References

Harðarson, B. S, Ingólfsson, H., Stefánsson, H. Ö., Tryggvason, H. and Egilson, Þ. (2013). *Þeistareykir – Hola ÞG-9. 2. áfangi: Jarðlög og mælingar. Borun fyrir vinnslufóðringu frá 310 m í 828 m dýpi.* Iceland GeoSurvey, report, ÍSOR-2013/004, 25 pp.

Khodayar, M., Kristinsson, S.G., and Karlsdóttir, R. (2016). *Structural Drilling Targets from Platforms A, B, and F at Þeistareykir. Northern Zone and Tjörnes Fracture Zone*. Iceland GeoSurvey, report, ÍSOR-2016/030. 24 pp.

Mortensen, A. K. (2012). *Þeistareykir. Tillögur um staðsetningu borholna í jarðhitakerfinu á Þeistareykjum 2012.* Iceland GeoSurvey, report, ÍSOR-2012/043, 36 pp.

Mortensen, A. K., Tryggvason, H., Jónsson, S.S., Árnadóttir, S., Egilson, Þ., Jónasson, H., Sveinbjörnsson, S., Vilhjálmsson, S. and Kristinsson, B. (2011). *Þeistareykir – Hola ÞG-7. 2. áfangi: Jarðlög og mælingar. Borun fyrir vinnslufóðringu í 776 m dýpi.* Iceland GeoSurvey, report, ÍSOR-2011/061, 39 pp.

Sæmundsson, K., Sigurgeirsson. M.Á. and Grönvold, K. (2012). *Þeistareykir. Jarðfræðirannsóknir 2011*. Iceland GeoSurvey, report, ÍSOR-2012/024, 61 pp.

Appendix A

9⅝" production casing report

Appendix B

Daily reports

ÍSOR ICELAND GEOSURVEY	ÞG-12	Saturday 27th of August 2016 Workday #24 of Óðinn

Þeistareykir	**Report for workday #23** Preliminary results	Phase 2 ($9^5/_8$" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/SSy, HeI (E-mail: mas@isor.is)

Last casing size:	$13^3/_8$"	Depth at 24:00.	300 m	Hole made last 24 hrs. :	- m
Last casing depth:	292.2 m	Depth at 8:00.	300 m	Drilling time:	- hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	- m/hr

Drilling operation

Yesterday morning the crew of Óðinn worked on nippling-up the BOP stack. At 1:45 until 3:15 pm a temperature logging was carried out by the ISOR logging engineers. After that the crew finished installation of the BOP's and the flow-line. At 10 pm preparations for pressure test started. The pressured tests of the blow out preventers were carried out during last night. All the BOP's passed the tests, no leakages were observed.

This morning a BHA for the drilling of phase 2 of ÞG-12 is being RIH. The BHA is composed of the following components: A 12" bit-a steerable motor- stabilizer- MWD NaviTrak-sub-stabilizer-5x drill collars-jar-3x drill collars-sub x/o- drill pipes. According to the well design the azimuth of the well is going to be towards SW (i.e. 235°) in direction to the north side of Mt. Bæjarfjall. The KOP is planned at 320 m depth and EOB at 680 m. The build-up rate will be 2.5°/30 m until an inclination of 30° is reached.

Figure 1 shows the results of the temperature logging from yesterday. The logging tool was run down to 200 m. At that depth the temperature reached 150 °C (which is the upper temp. limit of the instrument used). At 300 m depth a temperature in range of 170-180 °C might be expected.

Drilling in cement should start in the afternoon today.

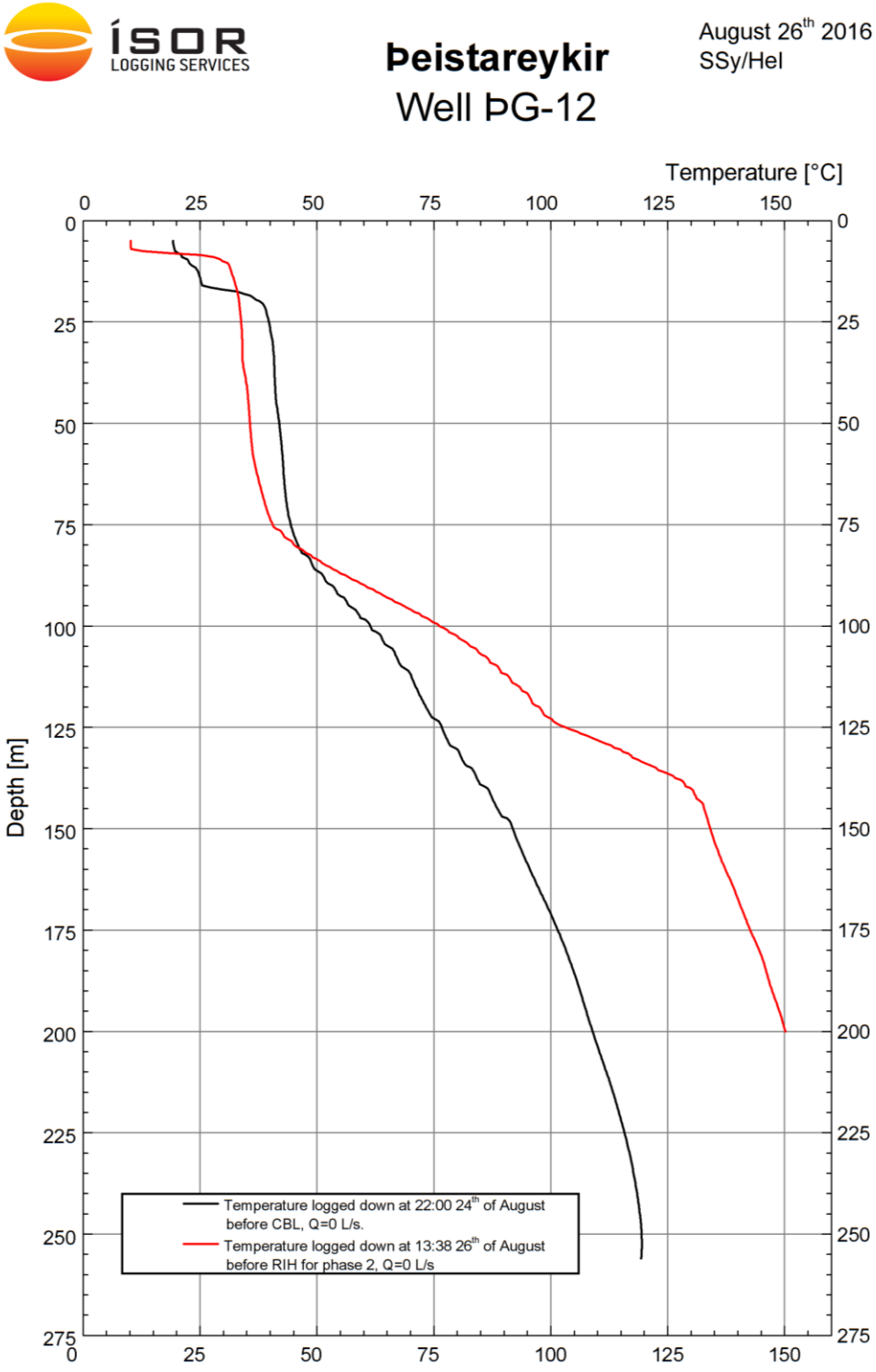


Figure 1. *Temperature logs from the 24th and 26th of August.*

Þeistareykir	**Report for workday #24** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/HÖS, HI (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	319 m	Hole made last 24 hrs. :	19 m
Last casing depth:	292.2 m	Depth at 8:00.	347 m	Drilling time:	3 hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	6.3 m/hr

Drilling operation

Early in the morning yesterday the blow-out preventers were pressure tested, by applying 30 bar for 10 min. All of them passed the test. RIH of a new BHA, including a mud motor and a MWD, started at 5 am (Figure 1). During RIH a pumping of water was applied as the well was rather hot, as indicated by a temperature log from the 26th of August.

At 11 am RIH of the drill rods started. At 199 m depth the well was circulated for a half an hour (with 36 l/s of water). The maximum temperature of the circulation outflow reached 47 °C. Then RIH continued. The float collar was reached at 256.3 m depth. At 2:45 pm there was a power outage in the rig (Bentec system) for two hours. At 4:45 the engineers of Óðinn managed to fix this malfunction and drilling resumed. At 9 pm last night the formation was reached at 300 m depth. Before further drilling the circulation fluid was changed from water to mud. At midnight the depth of the well was 319 m.

The KOP of the well was at 320 m. A 2:30 am this morning the logging engineers from ISOR ran their gyro instrument in the hole for establishing the starting point of the directional drilling. At 291 m an inclination of 2.3° and azimuth of 33.4° was measured. A gyro survey is planned at about 400 m depth of the well, which will be reached sometime in the afternoon.

Geology

At present, at around 350 m depth, the formation is composed of highly altered breccia. The main alteration minerals are green fine crystalline clay, quartz and wairakite.

The cuttings sampled during last night are being inspected.

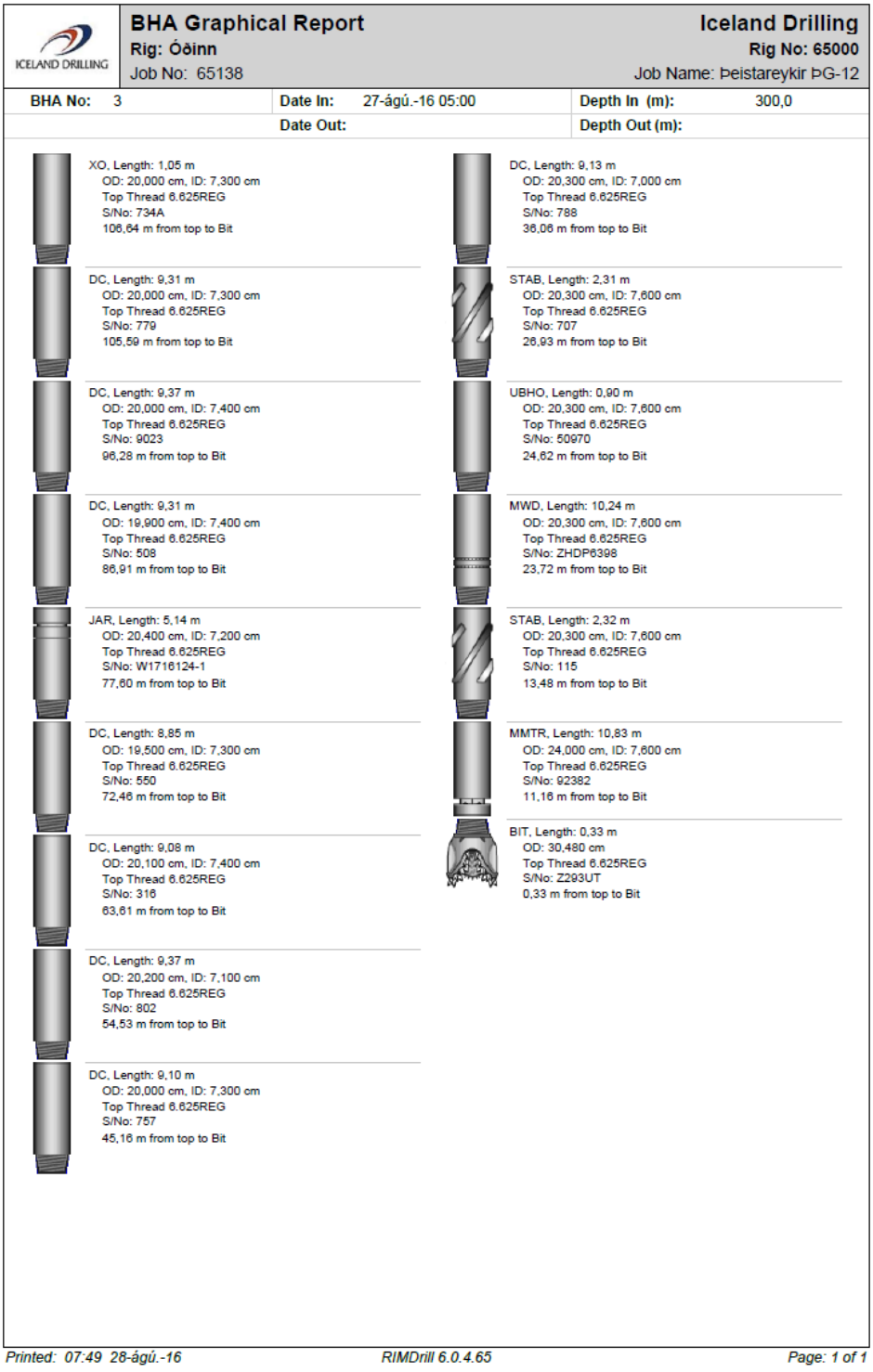


Figure 1. *The BHA for drilling of phase 2 of well ÞG-12.*

ÍSOR ICELAND GEOSURVEY	ÞG-12	Monday 29th of August 2016 Workday #26 of Óðinn

Þeistareykir	**Report for workday #25** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/HT, HI (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	442 m	Hole made last 24 hrs. :	123 m
Last casing depth:	292.2 m	Depth at 8:00.	492 m	Drilling time:	18 hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	6.8 m/hr

Drilling operation

Since 3:30 am yesterday morning, after the gyro measurement at 320 m, drilling was going fine. ROP remained rather high during the day, about 7 m/hour on average. Mostly sliding was applied but occasionally the string was rotated for a short while. WOB was in range of 4-8 ton and the pumping rate about 50 l/s. No loss of circulation has been noted so far.

In the afternoon yesterday, at 5 pm, a gyro survey was carried out by the ISOR logging engineers. The results show an inclination of 2.97° and an azimuth of 270° at 367 m depth. Another gyro survey is planned this morning at about 500 m depth.

Geology

At present cuttings from 300-402 m have been inspected (Figure 1). The formation is composed of basaltic lavas at 296-310 m but below that it is composed of hyaloclastite, basaltic breccia and glassy basalt. The grade of alteration is generally high. The most common alteration minerals are fine-crystalline green clay, quartz, calcite and wairakite. Pyrite is also rather abundant.

296-304 m: FINE-MEDIUM GRAINED BASALT

Fresh and fine grained basalt. Moderately oxidized. Clay is abundant in pores. The color is green, grey and dark grey.

304-310 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, with a high grade of alteration. Non-porphyritic.

310-318 m: BASALTIC BRECCIA

Mixed cuttings, mostly composed of fragments from pillow lava. Mostly fine crystalline basalt with a glassy groundmass. Non-porphyritic as above.

318-366 m: BASALTIC BRECCIA

Most likely pillow lava breccia. Composed of fine basalt with a glassy groundmass, non-porphyritic. Somewhat fractured. White and translucent precipitations are abundant. Large greenish glass fragments are admixed in the cuttings.

366-382 m: GLASSY BASALT

Fine crystalline non-porphyritic basalt admixed with some green glass fragments. The formation is considerably fractured. Calcite and pyrite are common.

382-402 m: BASALTIC BRECCIA

Pillow lava breccia. Fine crystalline basalt with glassy groundmass. Non-porphyritic. Considerably fractured. Green fine-crystalline clay and quartz are common. Highly altered at intervals, whitish in color.

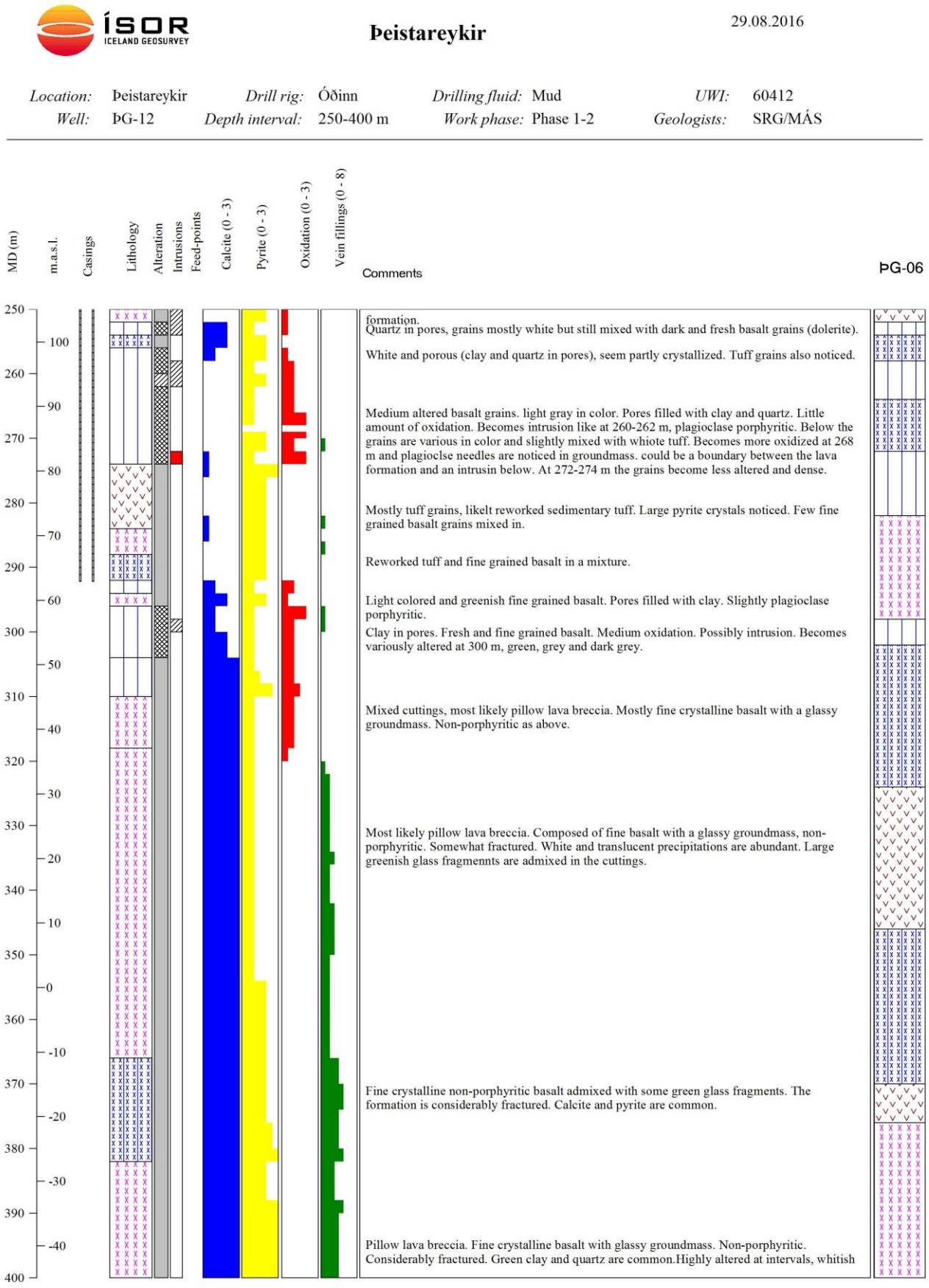


Figure 1. *Lithology column from ÞG-12 from 250-400 m depth. Well ÞG-06 is shown for comparison.*

ÍSOR ICELAND GEOSURVEY	ÞG-12	Tuesday 30th of August 2016 Workday #27 of Óðinn

Þeistareykir	**Report for workday #26** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/HI, HeI (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	596 m	Hole made last 24 hrs. :	154 m
Last casing depth:	292.2 m	Depth at 8:00.	642 m	Drilling time:	21.2 hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	7.2 m/hr

Drilling operation

Yesterday drilling was going fine with an average ROP of 7.2 m/hour. Between 11 am -1 pm a gyro survey was carried out by the ISOR logging engineers. The results are shown in Table 1 below. At 470 m depth an inclination of 12.7° have been gained and the azimuth is close to the planned one, which is 235°. This morning an another gyro survey will be conducted.

According to readings from the MWD instrument the inclination at 637 m depth is 24.9°.

No losses of circulation have been noted so far during drilling.

Table 1. *Gyro survey from August 29th 2016.*

Depth, m	Inclination, °	Azimuth, °
367	2.72	270.02
370	3.39	261.45
400	6.15	245.87
430	8.81	244.65
460	11.85	238.80
470	12.72	237.17

Geology

At present cuttings from 300-516 m have been inspected (Figure 1). As before the formation is composed of hyaloclastites, mostly basaltic breccia and glassy basalt. The grade of alteration is high. The most common alteration minerals are fine- coarse crystalline green clay, quartz, calcite, pyrite and wairakite. Below c. 410 m epidote is becoming rather common.

296-304 m: FINE-MEDIUM GRAINED BASALT

Fresh and fine grained basalt. Moderately oxidized. Clay is abundant in pores. The color is green, grey and dark grey.

304-310 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, with a high grade of alteration. Non-porphyritic.

310-318 m: BASALTIC BRECCIA

Mixed cuttings, mostly composed of fragments from pillow lava. Mostly fine crystalline basalt with a glassy groundmass. Non-porphyritic as above.

318-366 m: BASALTIC BRECCIA

Most likely pillow lava breccia. Composed of fine basalt with a glassy groundmass, non-porphyritic. Somewhat fractured. White and translucent precipitations are abundant. Large greenish glass fragments are admixed in the cuttings.

366-382 m: GLASSY BASALT

Fine crystalline non-porphyritic basalt admixed with some green glass fragments. The formation is considerably fractured. Calcite and pyrite are common.

382-406 m: BASALTIC BRECCIA

Pillow lava breccia. Fine crystalline basalt with glassy groundmass. Non-porphyritic. Considerably fractured. Green fine-crystalline clay and quartz are common. Highly altered at intervals, whitish in color.

406-440 m: GLASSY BASALT

Rather porous fine grained crystalline basalt, feldspar porphyritic. Greenish glass fragments are admixed. Rock crystals are common in voids. The upper part is greenish in color but at 414 m it changes to grayish brown. Epidote becomes rather common from below 410 m.

440-444 m: BASALTIC BRECCIA

A thin layer of breccia between units of pillow basalt.

444-480 m: GLASSY BASALT

Similar pillow basalt as above, gray greenish in color and rather porous. Some minor amount of plagioclase phenocrysts are seen.

480-482 m: BASALTIC BRECCIA

A thin layer of breccia between glassy basalt and possibly lava flows below.

482-496 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, feldspar porphyritic. No glass fragments are seen in the cuttings. Possibly lava flows. Gray-whitish in color. Pyrite is abundant.

496-512 m: GLASSY BASALT

Fine grained plagioclase porphyritic glassy basalt, gray whitish to gray greenish in color. Glass fragments are rather common. Some intrusive rock may be present at 498 m and 508 m depth, where fragments of dark gray rather fresh rock are seen.

512-516 m: BASALTIC BRECCIA

Very mixed cuttings, mostly composed of various types of fine crystalline basalt and pieces of green glass.

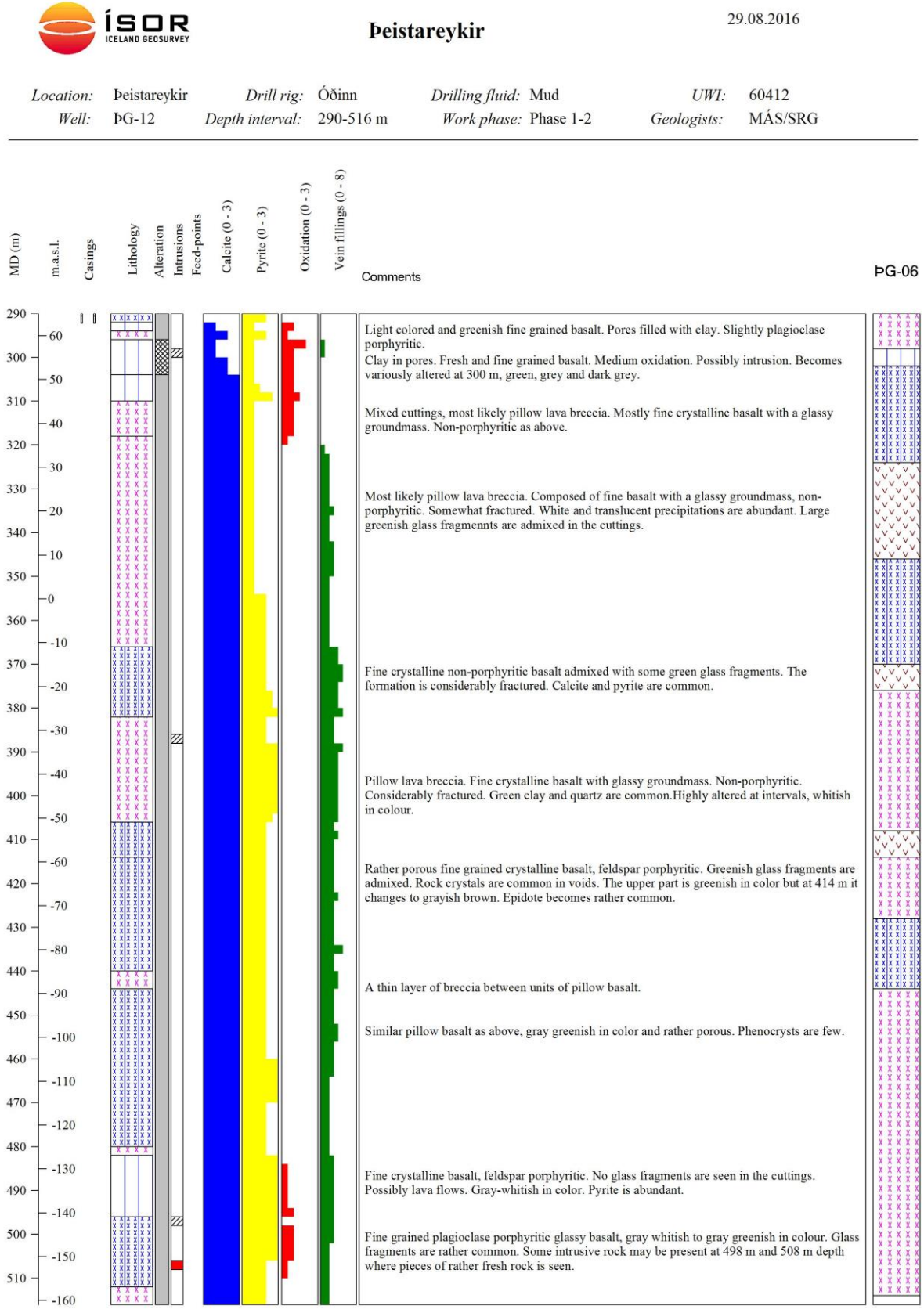


Figure 1. *Lithology column from ÞG-12 from 290-516 m depth. Well ÞG-06 is shown for comparison.*

ÍSOR ICELAND GEOSURVEY

ÞG-12

Wednesday
31st of August 2016
Workday #28 of Óðinn

Þeistareykir	**Report for workday #27** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/HT, HeI (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	734 m	Hole made last 24 hrs. :	138 m
Last casing depth:	292.2 m	Depth at 8:00.	782 m	Drilling time:	19.5 hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	7.1 m/hr

Drilling operation

Yesterday drilling was going fine with an average ROP of 7.1 m/hour. Pump rate has been 52-55 l/s and WOB in range of 3-10 ton. Between 7:30 -10 am a gyro survey was carried out by the ISOR logging engineers. The results are shown in Table 1 below. At 590 m depth an inclination of 23.1° and azimuth of 236.2° was measured. According to readings from the MWD instrument this morning the inclination at 754 m depth is 29.8° and the inclination 238°.

No losses of circulation have been noted so far during drilling. This morning at 10:45 am the final depth of phase 2 was reached at 806 m. At that depth the formation is composed of a basaltic breccia. After cleaning the well, a gyro survey is planned.

Table 1.

Gyro survey from August 29th 2016.

Depth, m	Inclination, °	Azimuth, °
367	2.72	270.02
370	3.39	261.45
400	6.15	245.87
430	8.81	244.65
460	11.85	238.80
470	12.72	237.17

Gyro survey from August 30th 2016.

Depth, m	Inclination, °	Azimuth, °
460	11.64	240.22
470	12.53	239.06
500	14.63	238.21
530	17.42	237.05
560	19.93	238.66
590	23.14	236.18
600	24.31	240.22

Geology

At present cuttings down to 650 m have been inspected (Figure 1). As before the formation is mostly composed of mostly basaltic breccia and glassy basalt. Possible lava piles are found at two intervals at 482 and 620 m. Intrusive rock becomes more common below 590 m. The grade of alteration is high. The most common alteration minerals below 600 m are fine- coarse crystalline green clay, quartz, calcite, epidote and prehnite. Pyrite is only found in minor amounts below 600 m.

296-304 m: FINE-MEDIUM GRAINED BASALT

Fresh and fine grained basalt. Moderately oxidized. Clay is abundant in pores. The color is green, grey and dark grey.

304-310 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, with a high grade of alteration. Non-porphyritic.

310-318 m: BASALTIC BRECCIA

Mixed cuttings, mostly composed of fragments from pillow lava. Mostly fine crystalline basalt with a glassy groundmass. Non-porphyritic as above.

318-366 m: BASALTIC BRECCIA

Most likely pillow lava breccia. Composed of fine basalt with a glassy groundmass, non-porphyritic. Somewhat fractured. White and translucent precipitations are abundant. Large greenish glass fragments are admixed in the cuttings.

366-382 m: GLASSY BASALT

Fine crystalline non-porphyritic basalt admixed with some green glass fragments. The formation is considerably fractured. Calcite and pyrite are common.

382-406 m: BASALTIC BRECCIA

Pillow lava breccia. Fine crystalline basalt with glassy groundmass. Non-porphyritic. Considerably fractured. Green fine-crystalline clay and quartz are common. Highly altered at intervals, whitish in color.

406-440 m: GLASSY BASALT

Rather porous fine grained crystalline basalt, feldspar porphyritic. Greenish glass fragments are admixed. Rock crystals are common in voids. The upper part is greenish in color but at 414 m it changes to grayish brown. Epidote becomes rather common from below 410 m.

440-444 m: BASALTIC BRECCIA

A thin layer of breccia between units of pillow basalt.

444-480 m: GLASSY BASALT

Similar pillow basalt as above, gray greenish in color and rather porous. Some minor amount of plagioclase phenocrysts are seen.

480-482 m: BASALTIC BRECCIA

A thin layer of breccia between glassy basalt and possibly lava flows below.

482-496 m: FINE-MEDIUM GRAINED BASALT

Fine crystalline basalt, feldspar porphyritic. No glass fragments are seen in the cuttings. Possibly lava flows. Gray-whitish in color. Pyrite is abundant.

496-512 m: GLASSY BASALT

Fine grained plagioclase porphyritic glassy basalt, gray whitish to gray greenish in color. Glass fragments are rather common. Some intrusive rock may be present at 498 m and 508 m depth, where fragments of dark gray rather fresh rock are seen.

512-516 m: BASALTIC BRECCIA

Very mixed cuttings, mostly composed of various types of fine crystalline basalt and pieces of green glass.

516-530 m: GLASSY BASALT

Fine grained, gray-greenish, basalt. Plagioclase porphyritic. Fragments of glass are common, green to brownish in color. Minor oxidation is present. Pillow lava.

530-546 m: GLASSY BASALT

At 530 m there is a color change in the pillow lava formation, below it becomes darker in color, dark brownish. Also the rock becomes coarser. Epidote is common.

546-554 m: BASALTIC BRECCIA

Mixed cutting, mostly composed of various types of crystalline basalt and glass fragments. Pillow lava breccia.

554-596 m: GLASSY BASALT

Very altered fine crystalline basalt with glassy groundmass. Plagioclase porphyritic. Rather fractured. No epidote is seen. At 570 m the basalt becomes somewhat coarser and darker in color. The rock is greenish-brown in color. Plagioclase porphyritic.

596-602 m: MEDIUM-COARSE GRAINED BASALT

Medium grained crystalline basalt. Not as altered as above. Plagioclase porphyritic. Dense rock non-porous. Most likely an intrusive rock.

602-608 m: GLASSY BASALT

Same glassy basalt as at 554-570 m depth, fine grained plagioclase porphyritic. Very altered.

608-620 m: MEDIUM-COARSE GRAINED BASALT

Medium grained moderately altered basalt as above, intrusive rock.

620-640 m: FINE-MEDIUM GRAINED BASALT

Gray brownish fine crystalline basalt. Plagioclase porphyritic. Very few glass fragments are found. Possibly lava flows rather than pillow basalt. Rather homogenous formation.

640-650 m: BASALTIC BRECCIA

Mixed cuttings, composed of various types of crystalline basalt and glass fragments.

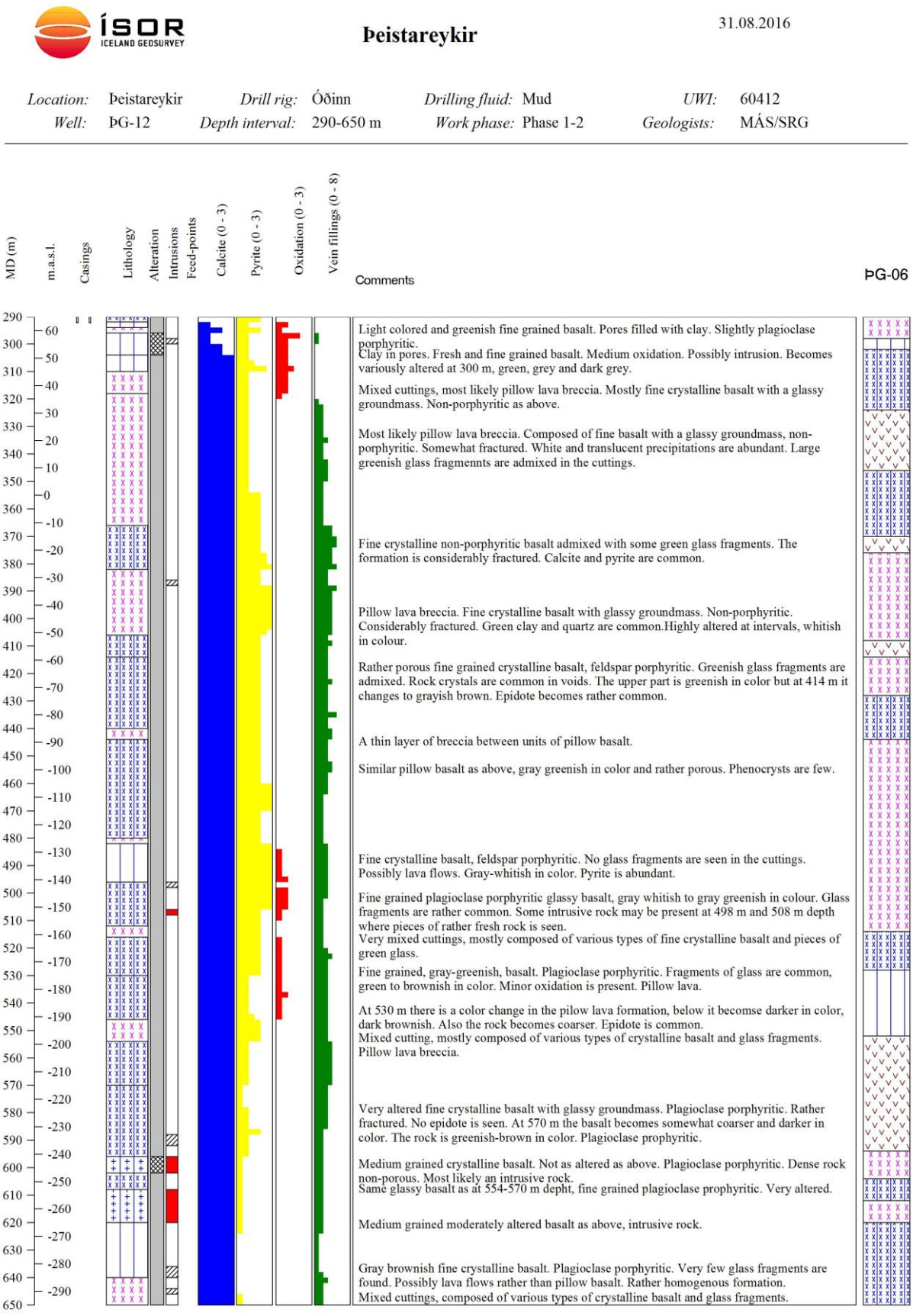


Figure 1. *Lithology column from ÞG-12 from 290-650 m depth. Well ÞG-06 is shown for comparison.*

ÍSOR ICELAND GEOSURVEY	ÞG-12	Thursday 1st of September 2016 Workday #29 of Óðinn

Þeistareykir	**Report for workday #28** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS/HÖS, HI, HeI (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	806 m	Hole made last 24 hrs. :	72 m
Last casing depth:	292.2 m	Depth at 8:00.	806 m	Drilling time:	10.8 hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	6.7 m/hr

Drilling operation

Yesterday drilling was going fine with an average ROP of 6.7 m/hour. The pump rate was 55 l/s and WOB in range of 3-10 ton. At 10:45 am the final depth of phase 2 was reached at 806 m. After that the well was circulated and cleaned for two hours. POOH started at 1 pm and finished close to midnight. Then preparations for well logging started. After midnight the ISOR logging engineers started on their logging program. At first the temperature tool was run in the hole. At 570 m depth it stopped in a thick mud and did not go deeper. When pulling it back a 1000 kg force had to be applied. When at surface a thick layer of clay was found covering the heat sensor (Figure 1). The temperature log is shown in Figure 2. The maximum temperature measured was 91°, but rose to 114° before pulling out the hole. Because of the mud in the well the log does not indicate the formation temperature around ÞG-12. Further logging that was planned, including caliper, resistivity and NN-Gamma, were cancelled.

At present the crew of Óðinn is running the 9⅝" production casing in the well. On Figure 3 the location and direction of ÞG-12 is shown based on gyro surveys down to 600 m depth.

Figure 1. *The temperature logging tool at surface after use, with the heat sensor covered by mud.*

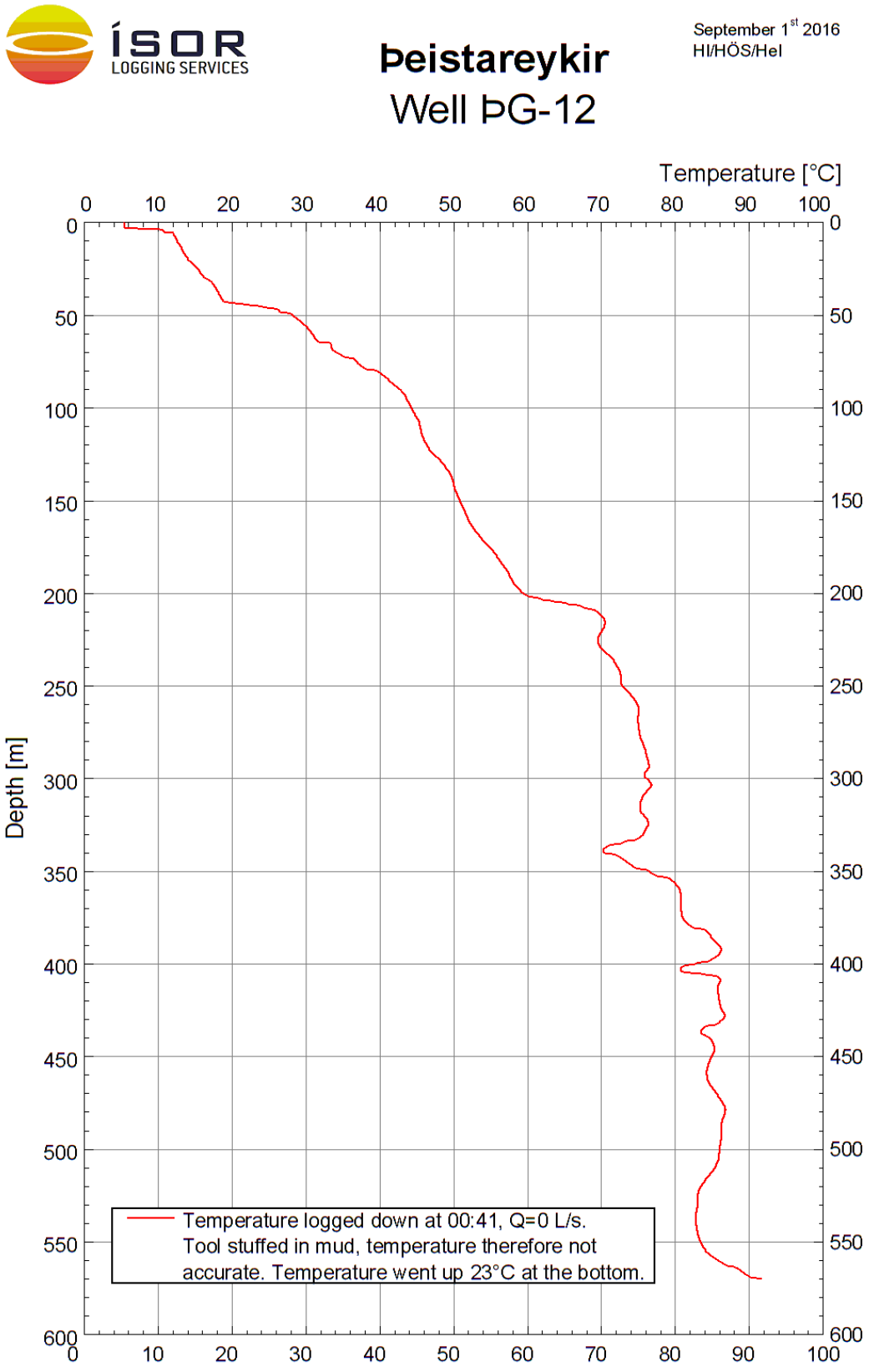


Figure 2. *Results from the logging last night, on the 1st of September.*

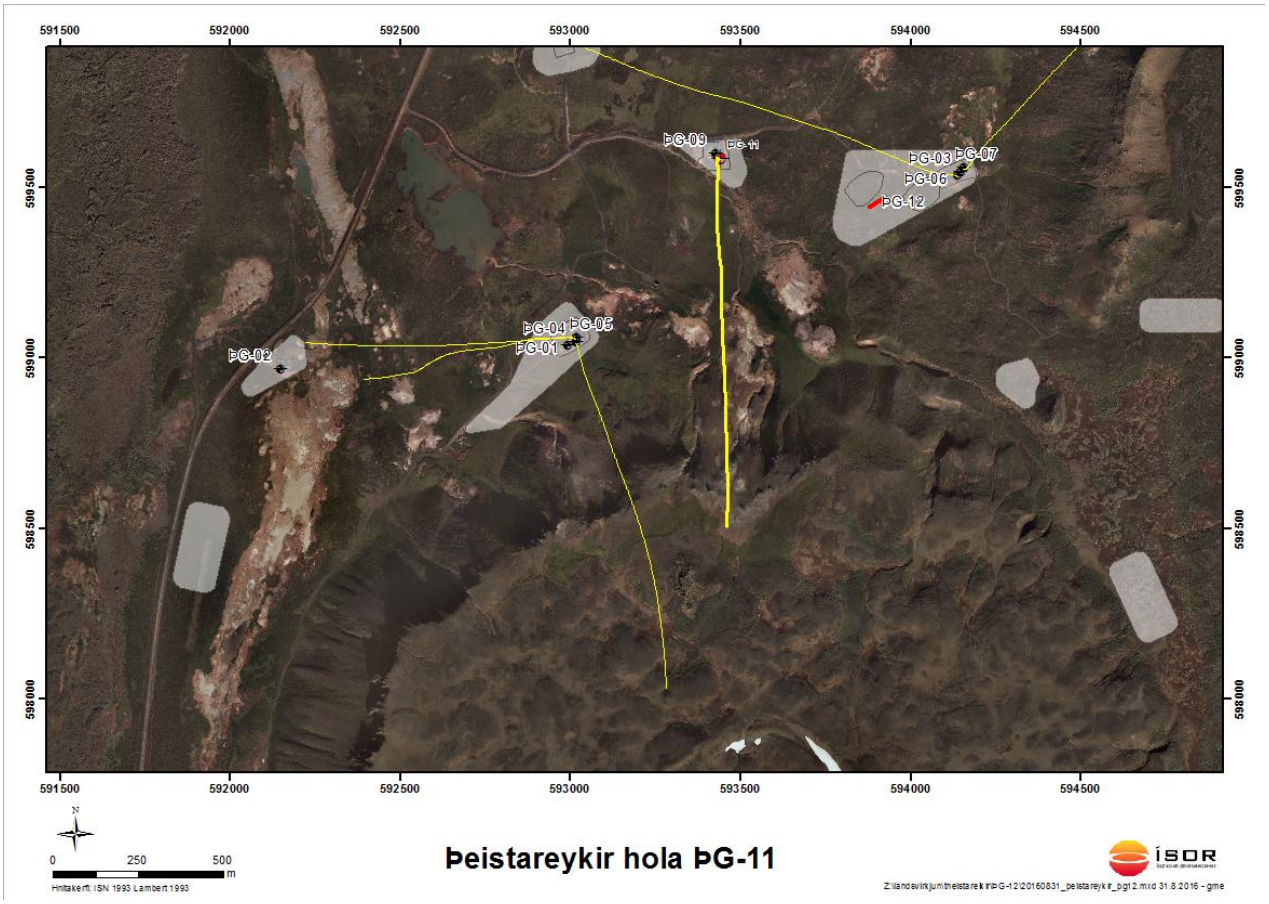


Figure 3. *The location and direction of ÞG-12 based on gyro surveys (red line).*

Geology

All cuttings down to 806 m have been inspected (Figure 4). From 300 to 806 m the formation is composed of hyaloclastites (tuff formation), basaltic breccia, glassy basalt and some minor tuff. Possible lava piles are found at two intervals, at 482 and 620 m. Intrusive rock becomes rather common below 590 m. Three dolerite intrusions were found, at 608, 676 and 710 m depth, 6 to 16 m thick. The grade of alteration is generally high. The most common alteration minerals below 600 m are coarse crystalline green clay, quartz, calcite, epidote and prehnite. Wollastonite was identified in the lowermost part of the well, at 770-806 m. At the same interval almost no calcite was found. The alteration mineral assemblage indicates a formation temperature of about 300°C below 770 m depth.

496-512 m: GLASSY BASALT

Fine grained plagioclase porphyritic glassy basalt, gray whitish to gray greenish in color. Glass fragments are rather common. Some intrusive rock may be present at 498 m and 508 m depth, where fragments of dark gray rather fresh rock are seen.

512-516 m: BASALTIC BRECCIA

Very mixed cuttings, mostly composed of various types of fine crystalline basalt and pieces of green glass.

516-530 m: GLASSY BASALT

Fine grained, gray-greenish, basalt. Plagioclase porphyritic. Fragments of glass are common, green to brownish in color. Minor oxidation is present. Pillow lava.

530-546 m: GLASSY BASALT

At 530 m there is a color change in the pillow lava formation, below it becomes darker in color, dark brownish. Also the rock becomes coarser. Epidote is common.

546-554 m: BASALTIC BRECCIA

Mixed cutting, mostly composed of various types of crystalline basalt and glass fragments. Pillow lava breccia.

554-596 m: GLASSY BASALT

Very altered fine crystalline basalt with glassy groundmass. Plagioclase porphyritic. Rather fractured. No epidote is seen. At 570 m the basalt becomes somewhat coarser and darker in color. The rock is greenish-brown in color. Plagioclase porphyritic.

596-602 m: MEDIUM-COARSE GRAINED BASALT

Medium grained crystalline basalt. Not as altered as above. Plagioclase porphyritic. Dense rock non-porous. Most likely an intrusive rock.

602-608 m: GLASSY BASALT

Same glassy basalt as at 554-570 m depth, fine grained plagioclase porphyritic. Very altered.

608-620 m: MEDIUM-COARSE GRAINED BASALT

Medium grained moderately altered basalt as above, intrusive rock.

620-640 m: FINE-MEDIUM GRAINED BASALT

Gray brownish fine crystalline basalt. Plagioclase porphyritic. Very few glass fragments are found. Possibly lava flows rather than pillow basalt. Rather homogenous formation.

640-660 m: BASALTIC BRECCIA

Mixed cuttings, composed of various types of crystalline basalt and glass fragments.

660-676 m: GLASSY BASALT

More homogenous formation than above. Fine grained light brownish crystalline basalt. Plagioclase porphyritic. Green glass fragments are admixed. Epidote is abundant.

676-692 m: MEDIUM-COARSE GRAINED BASALT

Medium grained crystalline basalt, plagioclase porphyritic (dolerite). Greenish brown in color. Intrusive dike. Not as altered as the rock above and below.

692-710 m: BASALTIC BRECCIA

Pillow lava breccia, composed of fine crystalline basalt with glassy groundmass and blue-green glass fragments admixed. Calcite disappears and pyrite is scarce. Quartz, epidote and prehnite are seen as fracture fillings.

710-716 m: MEDIUM-COARSE GRAINED BASALT

An intrusive dike of medium grained basalt (dolerite) as above.

716-736 m: BASALTIC BRECCIA

Pillow lava breccia at 716-726 m but below that the breccia becomes mixed with light green moderately coarse primary tuff. Calcite appears again in the cuttings. The formation is considerably fractured.

736-746 m: BASALTIC TUFF

Light green coarse primary tuff, light grayish and very altered. The tuff becomes finer downwards and mixed with crystalline basalt. Calcite is abundant.

746-750 m: BASALTIC BRECCIA

A thin layer of basaltic breccia

750-766 m: FINE-MEDIUM GRAINED BASALT

An intrusion of fine grained dark colored basalt. Plagioclase porphyritic. Less altered than the surrounding rock.

766-782 m: BASALTIC BRECCIA

A pillow lava breccia. Composed of fine crystalline basalt and green glass fragments. Calcite disappears and wollastonite is found. The epidote is well crystallized. Some dark colored intrusive rock is seen at the base of this unit.

782-788 m: FINE-MEDIUM GRAINED BASALT

An intrusion of fine dark colored basalt. Very dense and non-porphyritic rock. No calcite is found.

788-806 m: BASALTIC BRECCIA

A greenish basaltic breccia. Composed of crystalline basalt and green glass fragments. Wollastonite is rather common.

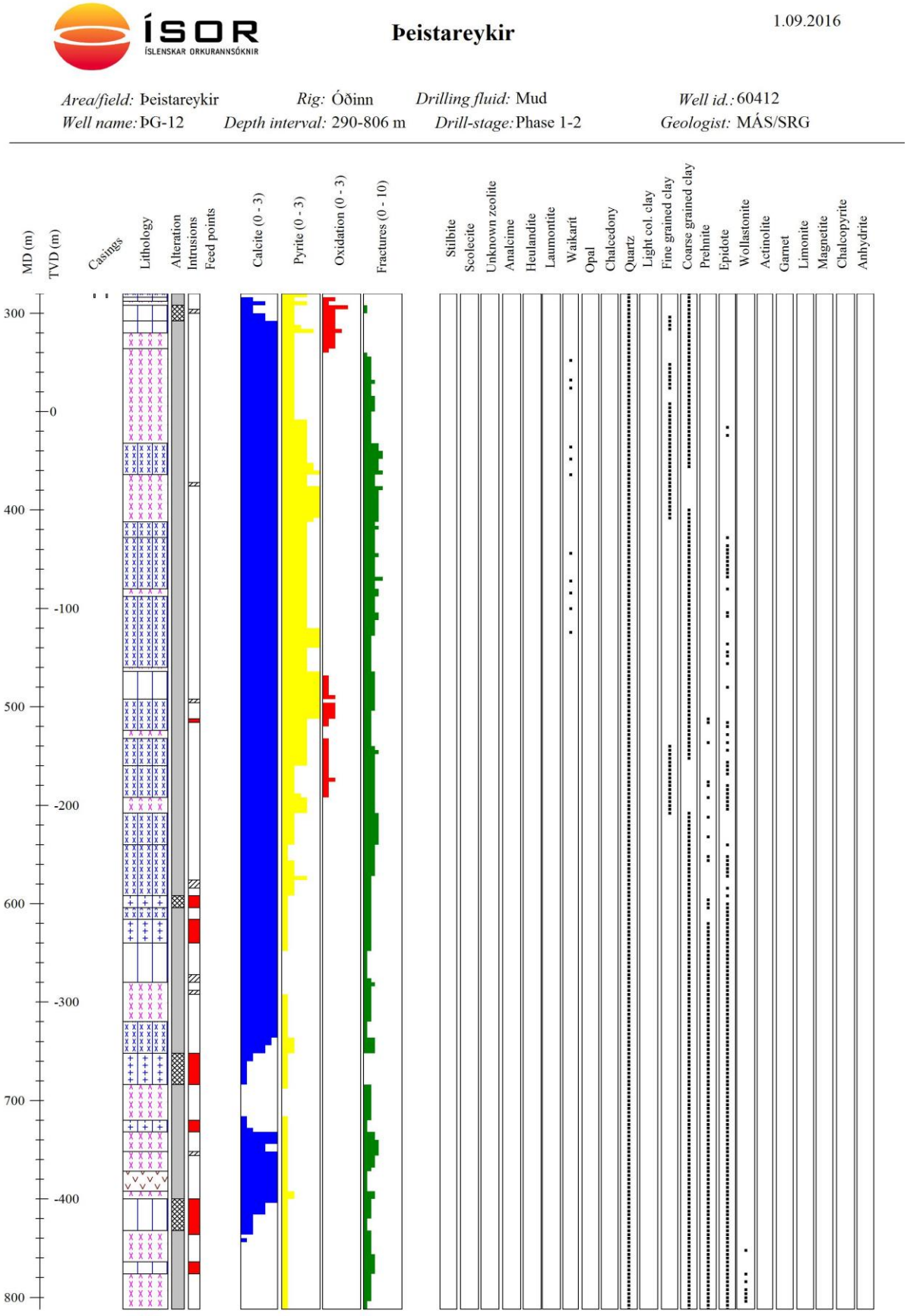


Figure 4. *Lithology and alteration in ÞG-12 from 290-806 m depth.*

ÍSOR ICELAND GEOSURVEY

ÞG-12

Friday
2nd of September 2016
Workday #30 of Óðinn

Þeistareykir	**Report for workday #29** Preliminary results	Phase 2 (9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	MÁS (E-mail: mas@isor.is)

Last casing size:	13⅝"	Depth at 24:00.	806 m	Hole made last 24 hrs. :	m
Last casing depth:	292.2 m	Depth at 8:00.	806 m	Drilling time:	hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	m/hr

Drilling operation

At 3 am yesterday morning, after the temperature logging of ISOR, preparations for running the 9⅝" production casing in the well started. At 10 am the first pipe was RIH. Because of the mud still present in the well a water was regularly pumped through the casing head. Below 450 m depth pumping was applied after installation of every pipe (which is c. 11.6 m long). The maximum temperature of the return water measured about 60 °C. This morning at about 7 am the casing job finished. The depth of the casing shoe is 802 m (casing report is not available yet). Soon preparations for cementing will start. Cementing of the production casing will be carried out in the afternoon.

The drilling progress of ÞG-12 until present is shown in Figure 1.

Geology

Lithology and drilling data from the data acquisition system of Óðinn is shown in Figure 2 below.

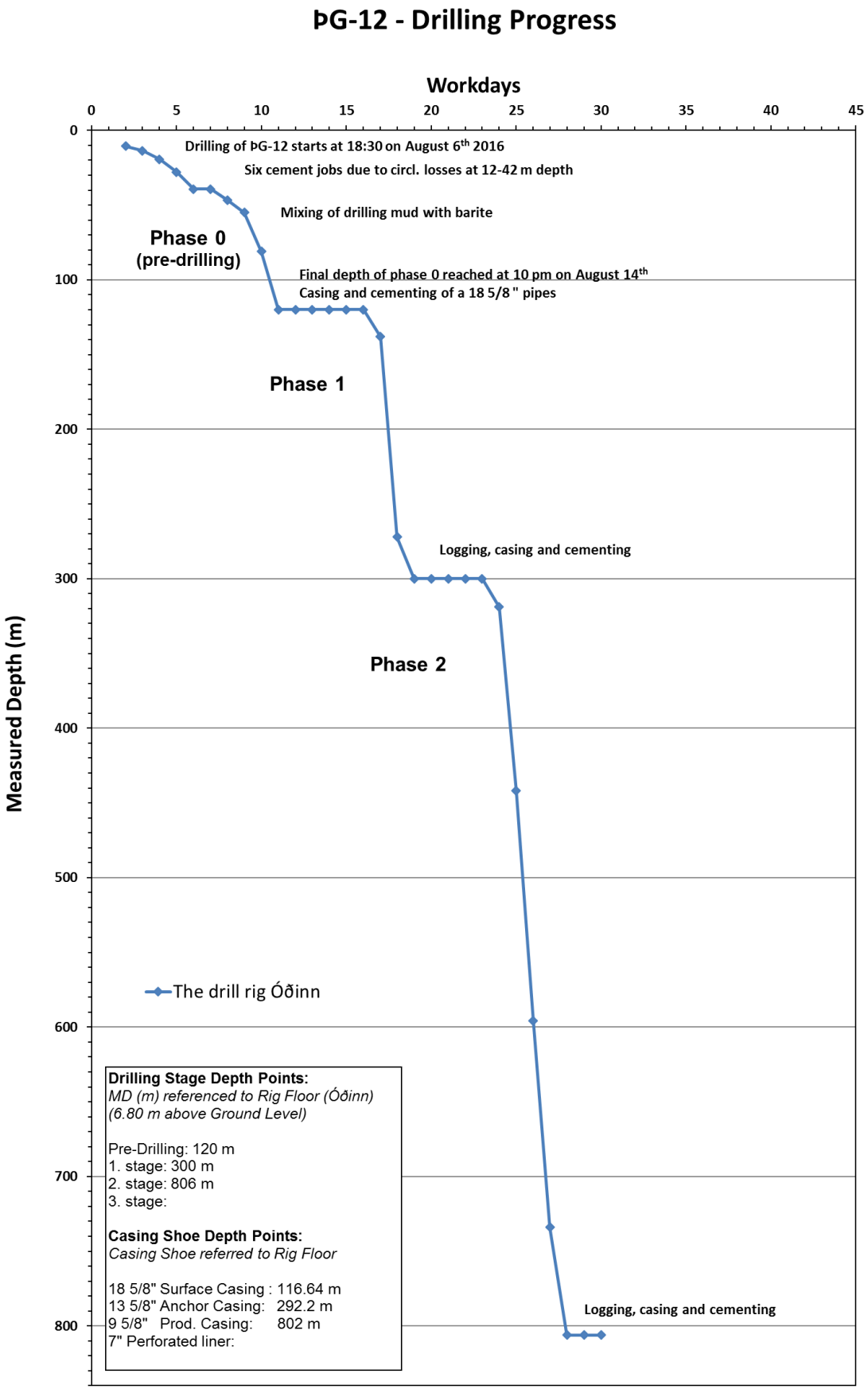


Figure 1. *Drilling progress of ÞG-12 until present.*

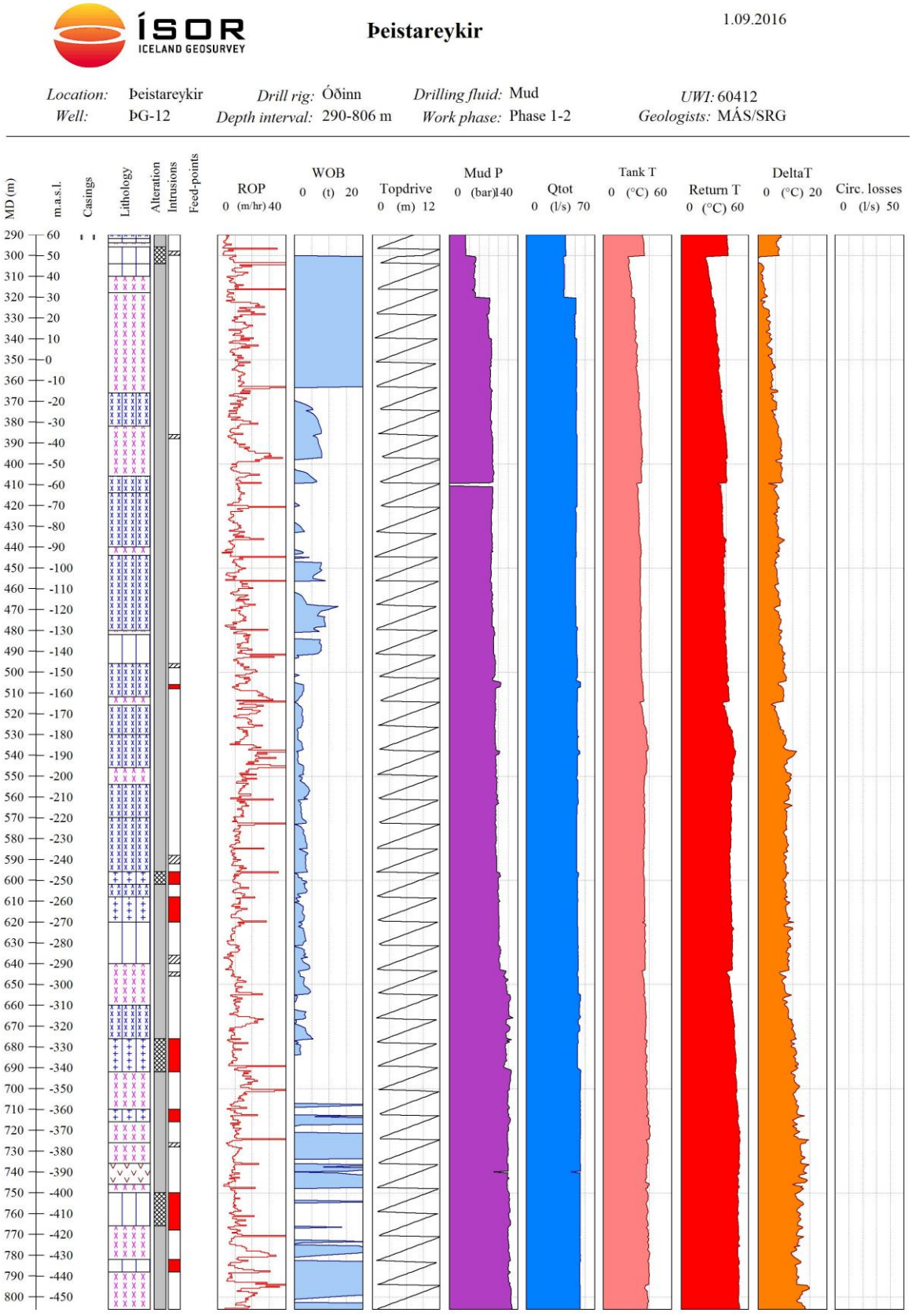


Figure 2. *Lithology and drilling data from Óðinn, drilling phase 2 of ÞG-12.*

ÍSOR ICELAND GEOSURVEY	ÞG-12	Saturday 3nd of September 2016 Workday #31 of Óðinn

+	**Report for workday #30** Preliminary results	Phase 2 ($9^5/_8$" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	BP (E-mail: b@isor.is)

Last casing size:	$9^5/_8$"	Depth at 24:00.	806 m	Hole made last 24 hrs. :	m
Last casing depth:	802 m	Depth at 8:00.	806 m	Drilling time:	hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	m/hr

Drilling operation

Once the production casing was set, laying at 802 m (see casing report Figure 1), the rig crew started RIH the cementing string at 9:30 and finished at 14:00. Before the cement job, the well was cooled down by circulating water mixed with 150 kg of soda, first using the rig pump from 14:00 to 21:30 and then using the cementing unit for 30 minutes. As a results, the temperature went down from 91,4°C to 40,4°C.

The cementing job started at 22:00, 31 m^3 of cement were injected in the well at 778 m followed by 7,5 m^3 of water. An additional cubic meter of cement was injected 30 minutes later. The cementing report can be seen on figure 2

Most on the night was spent WOC while POOH the cement string. At 4:00 am the ISOR logging engineers arrived at the drilling site to run a temperature log followed by a CBL log and a second temperature log afterward. Surveying ended at 11:30 and results for the temperature logs run this morning, before and after the CBL are shown on Figure 3.

The CBL log was run about 9 hours after cementing (Figure 4), it shows that the cement bond is good below 540 m but above that depth it is poor. It is planned to WOC until 16:00 today, and the ISOR logging team will then run a new CBL log down to about 540 m to check the cement bond.

ICELAND DRILLING

Casing Information Report
Rig: Óðinn
Job No: 65138

Iceland Drilling
Rig No: 65000
Job Name: Þeistareykir ÞG-12

Casing Information

Run Date/Time:	02-sep.-16 06:00		
		Leak Off Test (kg/cu m):	
Well Section:	INT3	**String Type:**	FULL
String Top MD (m):	0,0	**String Top TVD (m):**	
Casing Shoe MD (m):	801,5	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	24,45	**String Nominal ID (cm):**	22,05
Bit Diameter (cm):	30,48	**Avg. Open Hole Diam. (cm):**	30,48
Centralizers: No:	61	**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 03-sep.-16 01:25		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
1	SHOE	0,540				K-55	BUTT	
2	JOINT	23,290	24,45	22,05	47,0	K-55	BUTT	
1	FLOAT	0,510				K-55	BUTT	
67	JOINT	777,700	24,45	22,05	47,0	K-55	BUTT	
Totals: 71		802,040						

Figure 1. *Casing information report for 9⅝" production casing*

ICELAND DRILLING

Cementing Report
Rig: Óðinn
Job No: 65138

Iceland Drilling
Rig No: 65000
Job Name: Þeistareykir ÞG-12

Cement Job Information

Start Date/Time:	02-sep.-16 22:10	**Well Bore:**	Original Well Bore
Job Type:	PRIMARY	**String OD (cm):**	24,45
Well Section:	INT3	**String Type:**	FULL
Cementing Co:	JARDB	**Cementing Engineer:**	Arnar Freyr

Primary Job Detail

	Volume (cu m)	Pump Time	Rate (cu.m./min)	Pressure (bar)
Conditioning Data:				
Cement Data:	31,0	40	0,8	
Displacement Data:	7,5	10	0,8	
Calc. Displacement Vol:	7,5			

☐ **Batch Mix?**	☐ **Bump Plug?**	**Bump Pressure:**	
Returns to Surface: FULL	☐ **Reciprocate Pipe?**	☑ **Cement at Surface?**	
Calc Top of Cement (m):	**Excess (%):**	**Avg. Hole Size (cm):**	30,48

Slurry Information

Type	Density	Yield	Sacks	Volume	Rate	Additives
LEAD	1.700,00			31,0	0,8	
TAIL	1.700,00			1,0	0,5	

Post Job Information

Liner Top Test (kg/cu m):		**Job Success?**	Yes
Actual Top of Cmt (m):		**CBL Bond Quality:**	
Misc. Comments:	9 5/8" Fóðringar steyping		

Figure 2. *Cementing report for casing 9⅝", Phase 2*

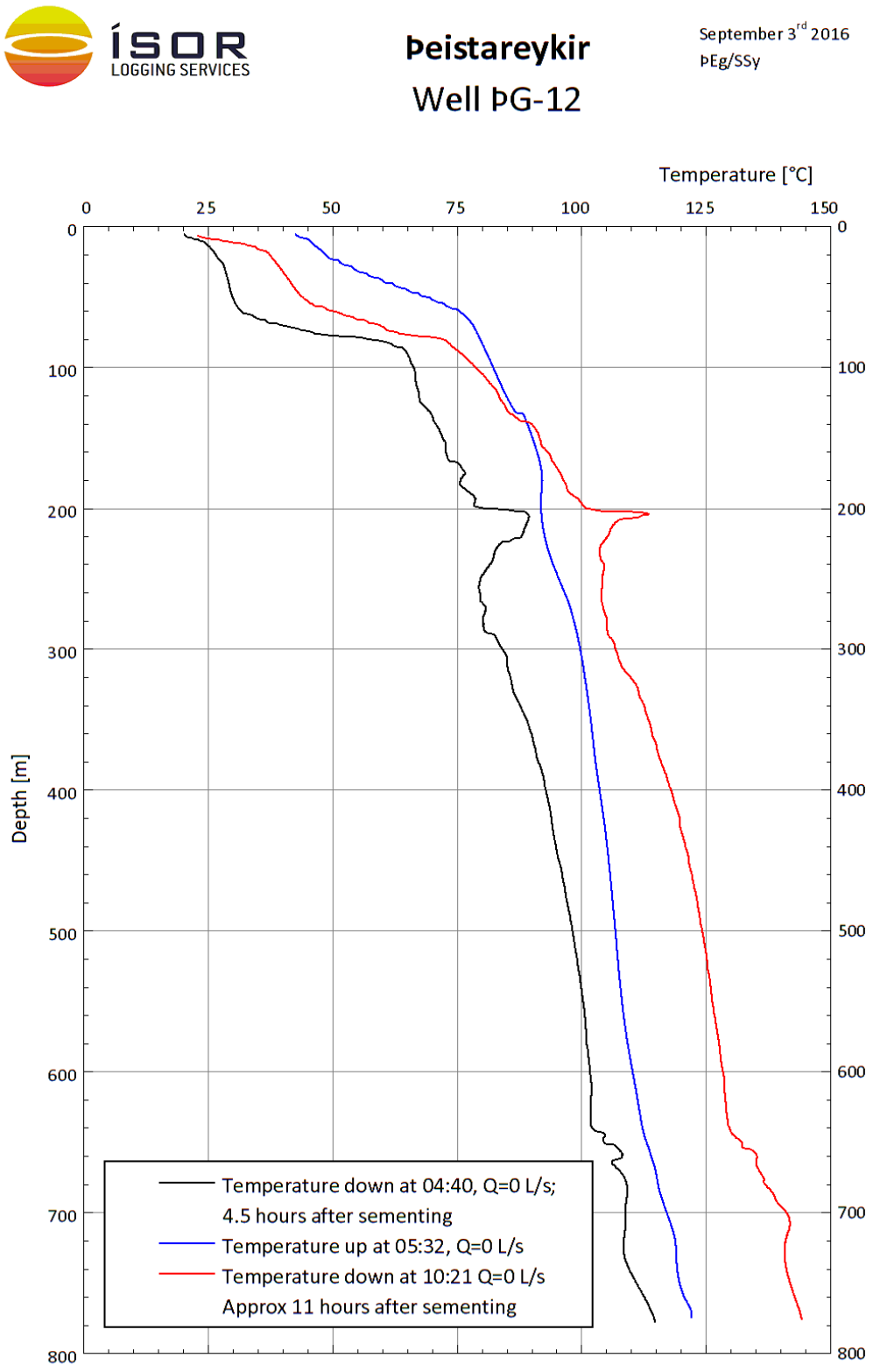
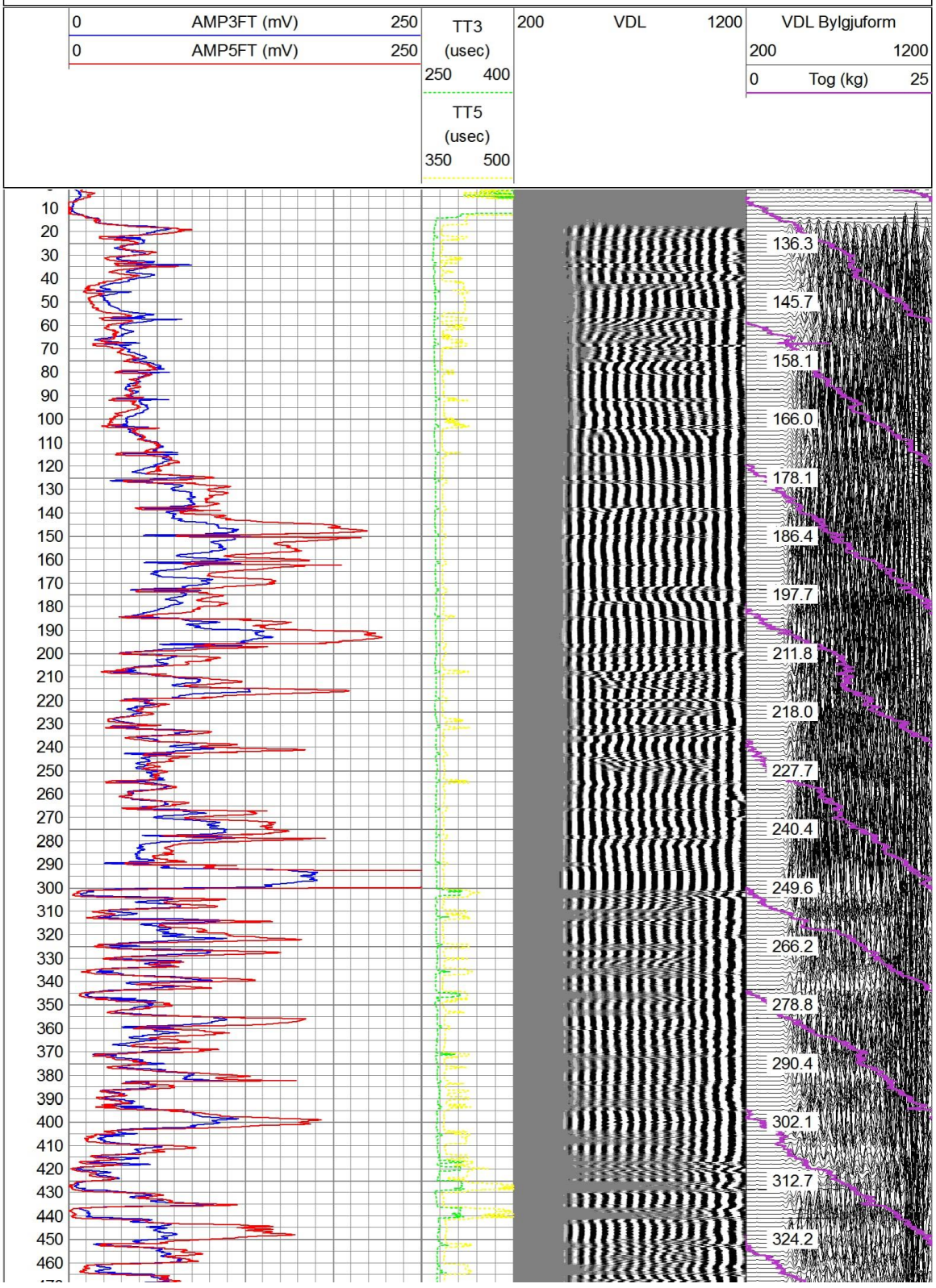


Figure 3. *Temperature logs run after cementing of production casing (before and after CBL log)*

Database File:	c:\bhm\theistareykir\thg12\2af\maelingar\thg12_2af_nn-519.db
Dataset Pathname:	Theistare/THG12/S20160903/U0903B
Presentation Format:	isorcbl2
Dataset Creation:	Sat Sep 03 09:04:09 2016 by Log Open-Cased 090629
Charted by:	Depth in Meters scaled 1:2000



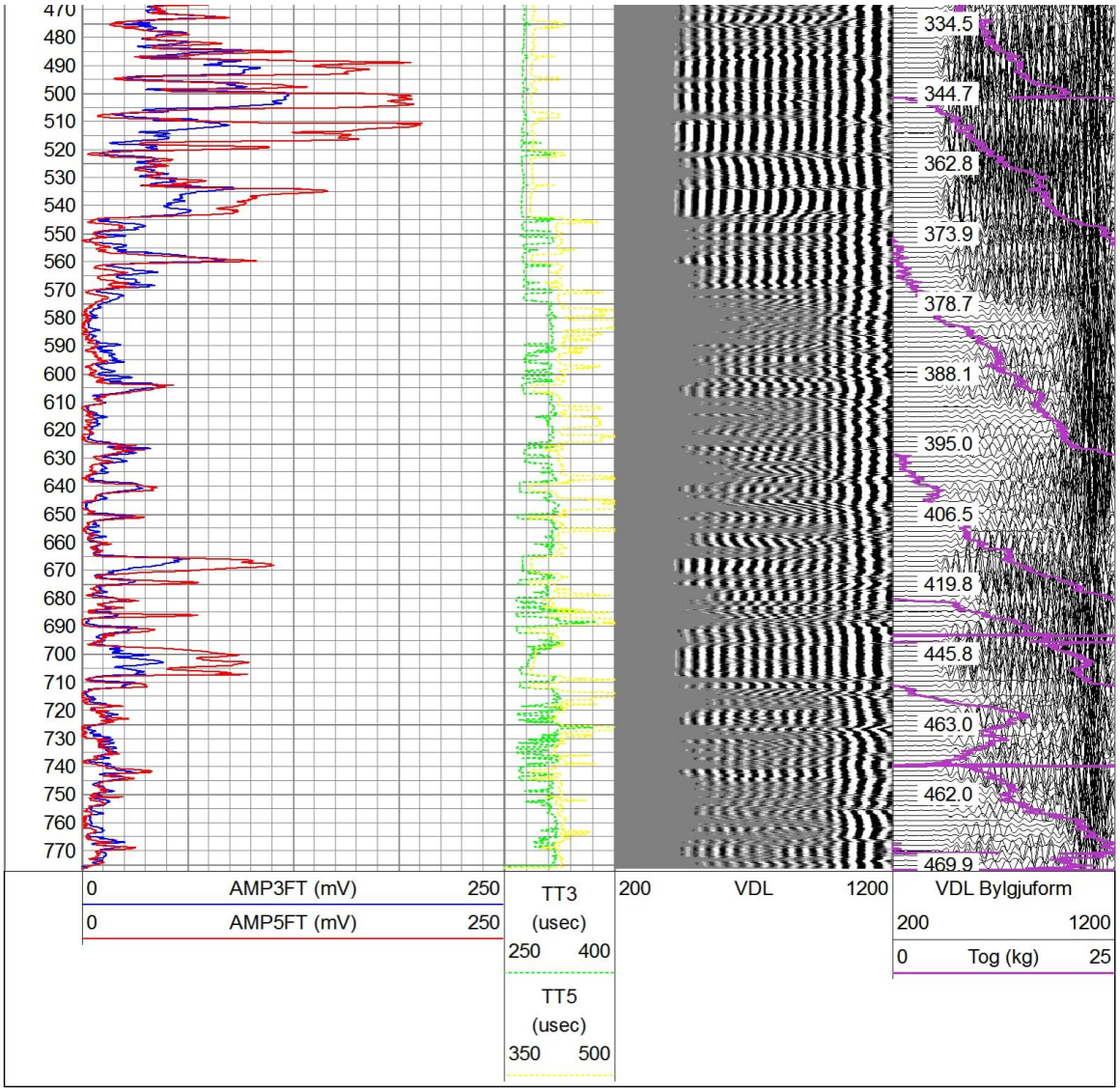


Figure 4. Low res. *CBL log run about 9hours after cementing of production casing (High resolution data available on LV SharePoint)*

Report for workday #31
Preliminary results

Phase 2
(9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	ÞEg (E-mail: bpoux@isor.is)

Last casing size:	9⅝"	Depth at 24:00.	806 m	Hole made last 24 hrs. :	m
Last casing depth:	802 m	Depth at 8:00.	806 m	Drilling time:	hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	m/hr

Drilling operation

After the CBL log completed in the morning, it was decided to WOC longer and run a new CBL later in the afternoon.

A temperature log followed by new CBL log started at 16:00 and was finished around 18:00. The temperature profile is shown on Figure 1, compiled with the results of the other temperature logs of earlier in the morning. This last log corresponds approximatively to 18 hours after the cementing job, temperature values are high; above 150°C below 600 meters.

As seen in Figure 1 there is a high heat-up rate inside the well. It is, however, a little risk of boiling conditions inside the well. The estimated pressure at 100 m after 24 hours of heating is no less than 9.5 bar-a which corresponds to over 184°C for the water to boil. With that information IDC's tool pusher on duty let his workers take down the flow line and start working on well head without risk of having hot water coming from the casing.

The 2nd CBL log conducted at ~17:15 in the afternoon could only be taken down to 640 m depth since the temperature threshold of the CBL tool is 140°C. This log still shows poor bonding between the cement and the 9⅝" casing at long ranges between places with good bonding. The first wavelet-amplitude was calibrated at 29 m depth in the well. However, the cement bonding there was better than at many other locations in the well. This means that the amplitude data must be rescaled for the 51 mV-API value that represents a CBL amplitude reference for 9⅝" casing.

During the night, the flow-line was taken down and the casing was cut off at the expansion sleeve. A new expansion sleeve was installed in the morning. The Master valve and BOP will be installed during the day and RIH should start in the night or early morning.

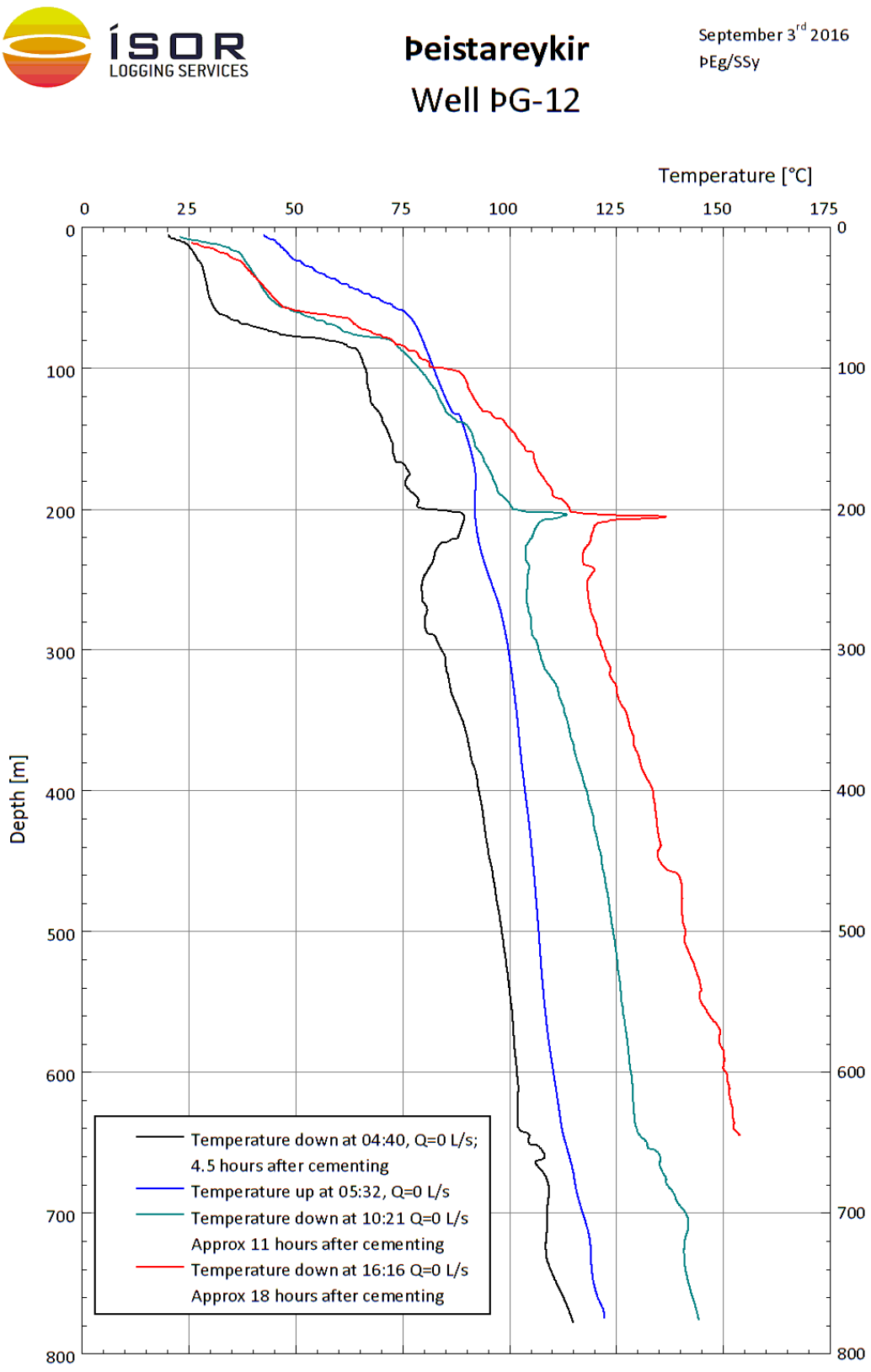
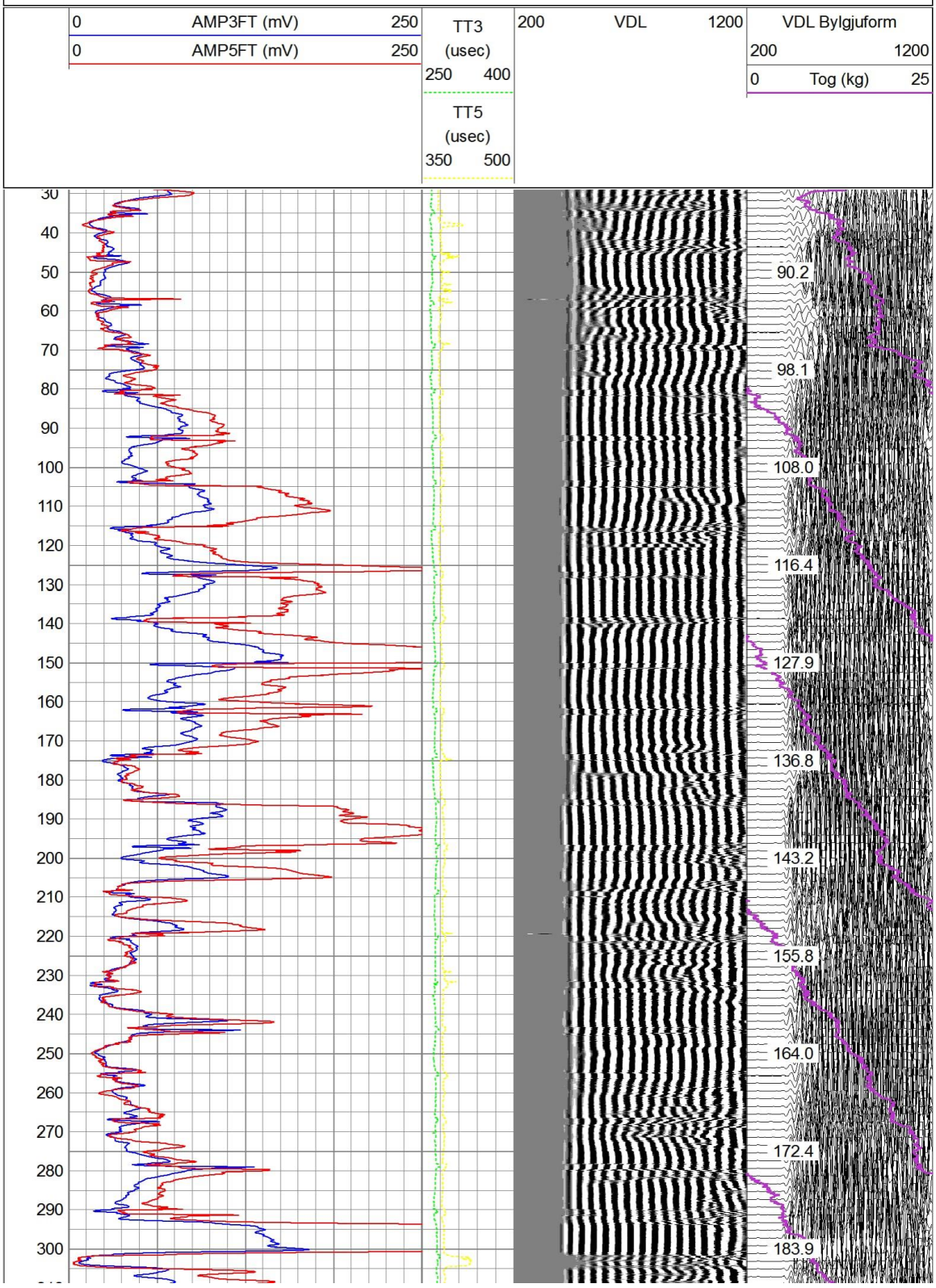


Figure 1. *Compiled temperature logs run in the 9⅝" production casing after cementing*

Database File:	c:\bhm\theistareykir\thg12\2af\maelingar\thg12_2af_nn-519.db
Dataset Pathname:	Theistare/THG12/S20160903/N1712B
Presentation Format:	isorcbl2
Dataset Creation:	Sat Sep 03 17:12:28 2016 by Log Open-Cased 090629
Charted by:	Depth in Meters scaled 1:1200



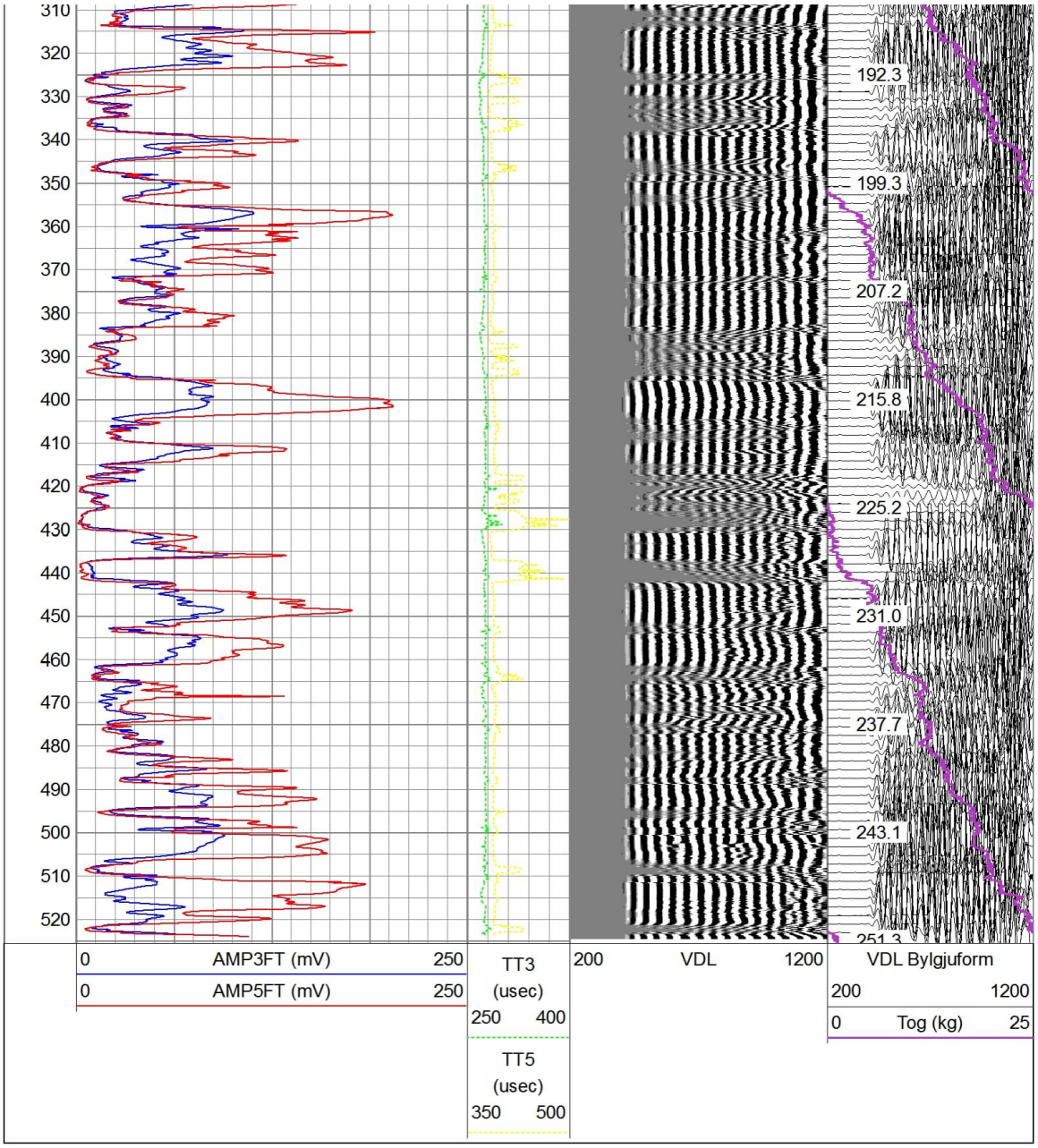


Figure 2. *Low res. CBL log run about 18hours after cementing of production casing (High resolution data available on LV SharePoint)*

ÍSOR ICELAND GEOSURVEY

ÞG-12

Monday
5th of September 2016
Workday #32 of Óðinn

Report for workday #31
Preliminary results

Phase 2
(9⅝" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	ÞG-12	*Drill-Rig:*	Óðinn
Well-Id:	60412	*Geologist/Geophysicist:*	BP (E-mail: bpoux@isor.is)

Last casing size:	9⅝"	Depth at 24:00.	806 m	Hole made last 24 hrs. :	m
Last casing depth:	802 m	Depth at 8:00.	806 m	Drilling time:	hrs.
Drilling fluid:	Mud/water	Circulation losses at 8:00	0 L/s	Average ROP:	m/hr

Drilling operation

After cutting the production casing, the extension sleeve was added as well as the Master valve, the BOP and the flow line. This operation took most of the day and a big part of the night. This morning, the rig crew in RIH the drilling string without the MWD motor and using an old bit. In order to cool down the hole, fresh water will be circulated between each drill string until temperature cools down. Once the cement has been drilled, the drill string will be POOH to set up a new BHA with the MWD motor and a new bit.

Figure 1 shows a comparison of the lithology and loss circulation zones of well ÞG-12 and the other wells drilled in the same area: ÞG-06 and ÞG-09 (see Figure 2 for well traces)

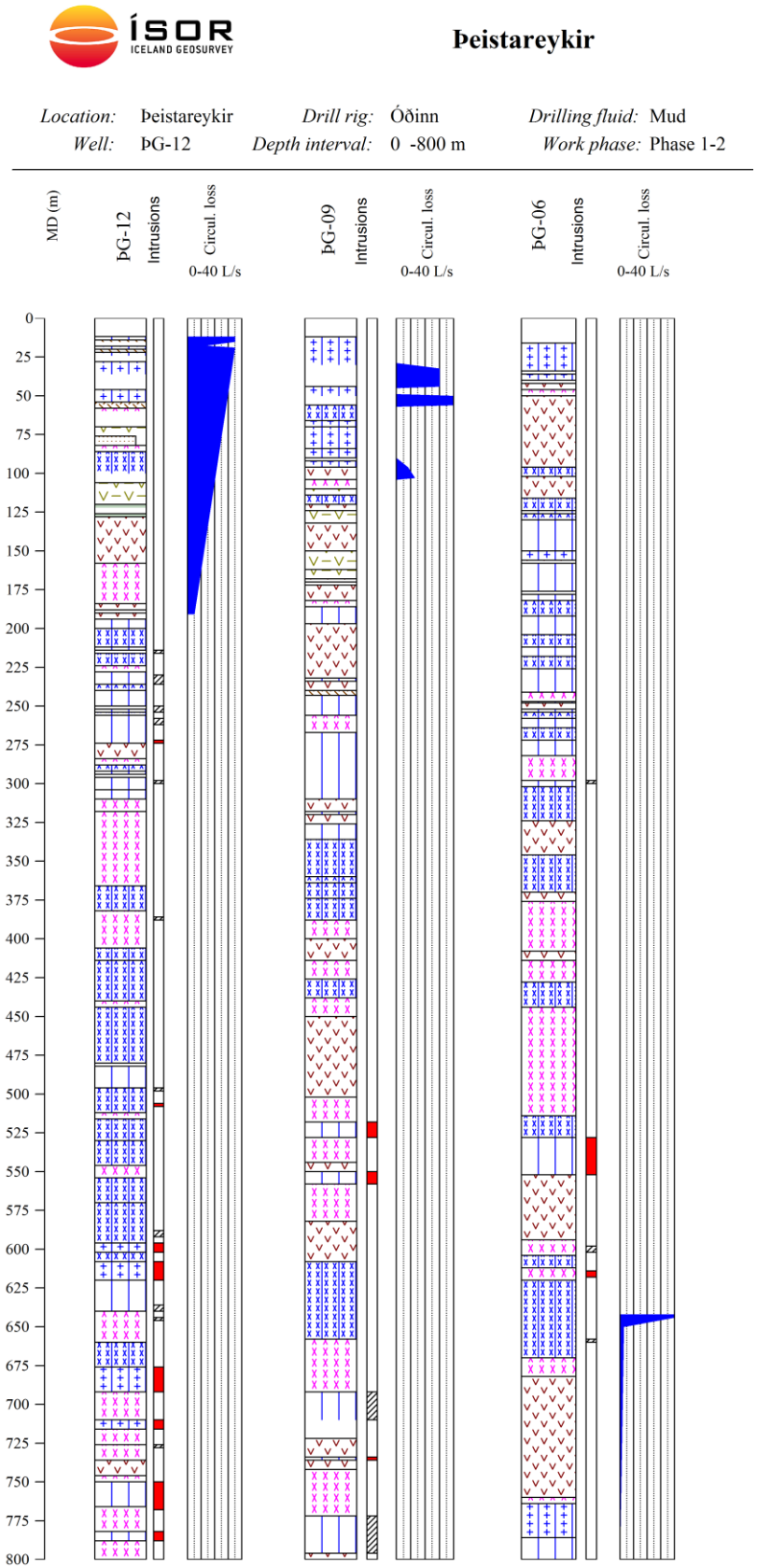


Figure 1. *Lithology logs and loss circulation zones from 0 to 800m for wells ÞG-12, ÞG-09 and ÞG-06*

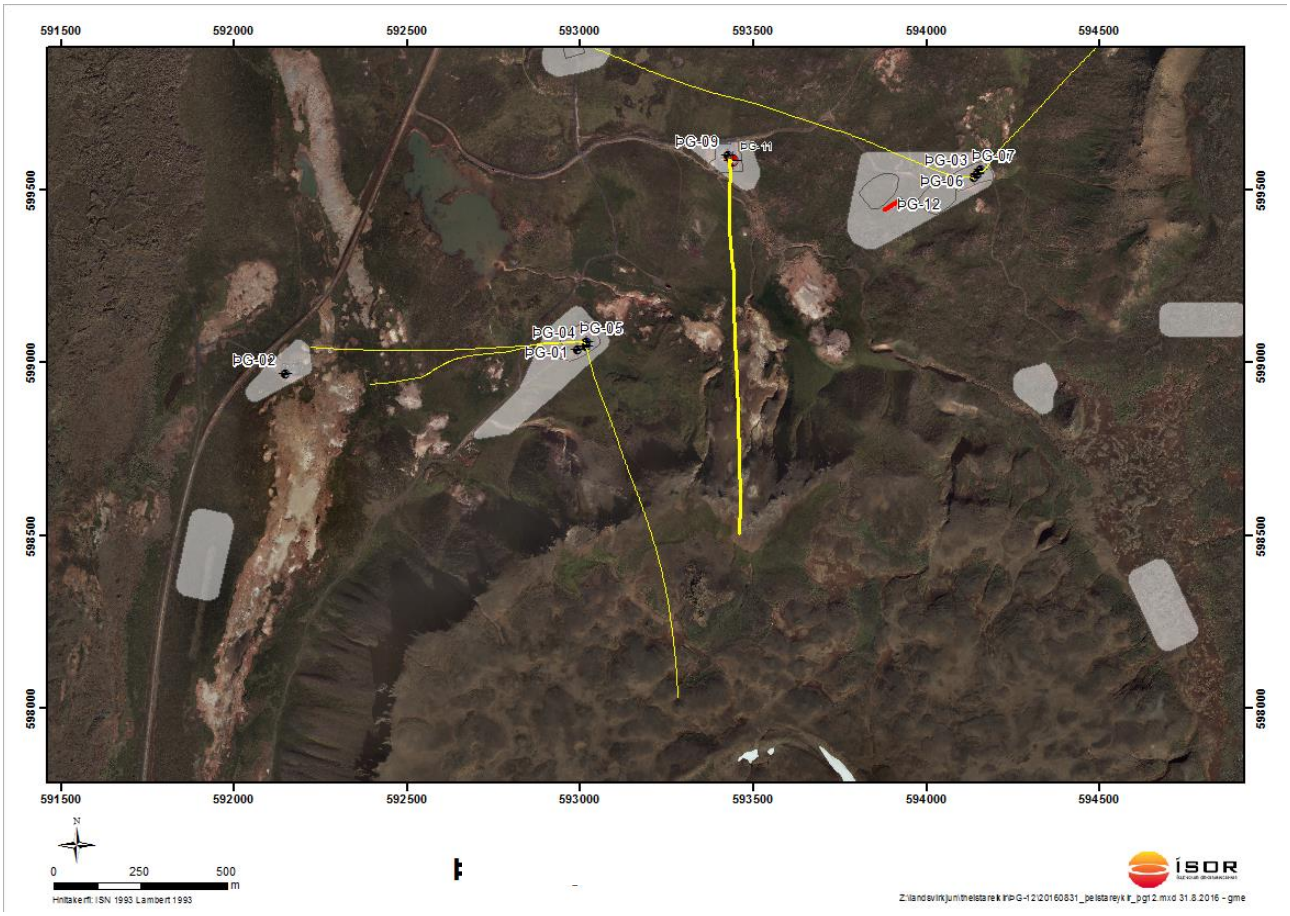


Figure 2. *Well location and traces for ÞG-12 (in red) and nearby wells (in yellow)*

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Prentað efni