LV-2016-103

Landsvirkjun

Krafla – Well K-41

Phase 2: Drilling for Production Casing from 293 m down to 1039 m Depth

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ÍSOR
ÍSLENSKAR ORKURANNSÓKNIR

ÍSOR-2016/057
Project no.: 16-0147

September 2016

Key page

Landsvirkjun

LV report no.:	LV-2016-103	**Date:**	September 2016
Pages: 99	**Copies:** 7	**Distribution:**	☒ **On www.lv.is** ☒ **Open** ☐ **Limited until**
Title:	Krafla – Well K-41. Phase 2: Drilling for Production Casing from 293 m down to 1039 m Depth.		
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Prepared for:	Landsvirkjun		
Co operators:			

Abstract:

Well K-41 is a directionally drilled production well for the Krafla power plant. It is sited on the same drill pad as wells KJ-15, KJ-32 and KJ-33. The well pad is west of Hveragil, and the aim of the drilling was to penetrate purported fractures associated with the Hveragil fracture zone and in the Vesturhlíðar area further east. This report addresses the drilling history and data acquisition of the 2nd 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. K-41 was pre-drilled with a 21" drill bit for 18⅝" surface casing to 100 m and with 17½" drill bit for 13⅜" anchor casing down to 292.5m. The 2nd phase was drilled with 12" bit for 9⅝" casing to 1039 m. The stratigraphy of phases 0–2 in well K-41 is composed of basaltic lava flows and hyaloclastite formations, including basaltic breccias, tuffs and pillow basalts. Intrusives become more common below 880 m. The grade of alteration is generally low or moderate in the upper part of the well, but increases markedly below 500 m. Solid Epidote appears at 638 m. At 1000 m the main alteration minerals are quartz, epidote, wollastonite and clays. A loss zone was cut at 547 m depth, in the middle of a basaltic breccia unit and required a cement plug before drilling deeper.

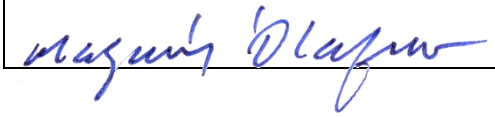
Key words:

Krafla, well K-41, geothermal field, high temperature, Power generation, brine, steam, geological log, feed zones, Sleipnir, Landsvirkjun, Iceland Drilling, ÍSOR

UWI (Unique Well Id): B60411

ISBN no:

Approved by Landsvirkjun's project manager

Project manager's signature	Reviewed by
	Benedikt Steingrímsson

Ágrip

Hola K-41 er stefnuboruð vinnsluhola fyrir orkuverið í Kröflu. Holan er á sama borplani og holur KJ-15, KJ-32 og KJ-33. Borplanið er vestur af Hveragili og markmið borunarinnar er að bora í gegnum sprungur sem tengjast sprungukerfinu í Hveragili og Vesturhlíðum lengra til austurs. Þessi skýrsla lýsir borsögunni, borgögnum og gagnavinnslu 2. áfanga. 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 sem og borholumælingum 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. K-41 var forboruð með 21" borkrónu fyrir 18⅝" yfirborðsfóðringu niður að 100 m, með 17½" krónu fyrir 13⅜" öryggisfóðringu niður í 293,5 m og með 12" krónu fyrir 9⅝" vinnslufóðringu niður á 1039 m dýpi. Jarðlögin í forborun, 1. og 2. áfanga holu K-41 samanstanda af hraunlögum og móbergi (túff, breksíur og bólstraberg). Innskot verða algengari neðan 880 m. Ummyndunarstig er lágt eða meðalmikið í efri lögum en eykst talsvert neðan 500 m. Epidót kemur inn á 638 m dýpi. Á 1000 m dýpi eru helstu ummyndunarsteindirnar kvars, epidót, wollastónít og leir. Æð var skorin í 547 m, í miðju breksíulagi, og þurfti að steypa til þess að unnt væri að halda áfram.

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1 Introduction

Drilling of well K-41 in the Krafla geothermal field was conducted by Iceland Drilling (Jarðboranir) for Landsvirkjun. Well K-41 is drilled from the same well pad as the 2097 m deep KJ-15 drilled in 1980 (Gautason et al., 2016), the 1875 m deep KJ-32 drilled in 1998 (Guðmundsson et al., 1998) and the 2011 m deep KJ-33 drilled in 1999 (Guðmundsson et al., 1999). The wells are located west of the Hveragil gully. Well KJ-15 is vertical but the others are directionally drilled, KJ-32 towards "north" but KJ-33 towards northeast and KJ-41 towards east-northeast into Vesturhlíðar production field in Krafla (Figure 2 and Table 1). The direction of K-41 will be 70° (Thordarson, 2015b) and the well will be drilled to at least 1700 m MD (Thordarson, 2015a). The trajectory of K-41 is planned to find permeability connected to fractures under explosion craters and CO_2 flux anomaly from the soil in Vesturhlíðar of Krafla (Mortensen, 2013). The well is planned to be at good distance from existing wells, such as KT-40, KJ-34 and KJ-20. The well will, however, not be drilled too far east under Krafla mountain and not much deeper than 2000 m to avoid HCl-rich and corrosive fluids (Mortensen, 2013).

Table 1. *Further details of K-41. Coordinates are in ISNET93.*

Well name	Well ID	East (X)	North (Y)	h.a.s.l (m)	Planned depth (m)
K-41	58041	602984	580998	571	1700–2000

To reach the target zones the direction of the well was set at 70 ± 5° and the inclination at 35 ± 3° in the upper part of the well, with more relaxed deviation limits below the MD where the motor and MWD tool will be removed from the BHA (i.e. 70° ± 12°: inclination 35 ± 5°. The kick-off was planned 20 m below the anchor casing, at 310 m. The angle built up was planned to be 2,5°/30 m with the final inclination of 35°

Figure 1. *Picture showing the Krafla cooling towers in the foreground and the Sleipnir rig drilling well K-41 in the background.*

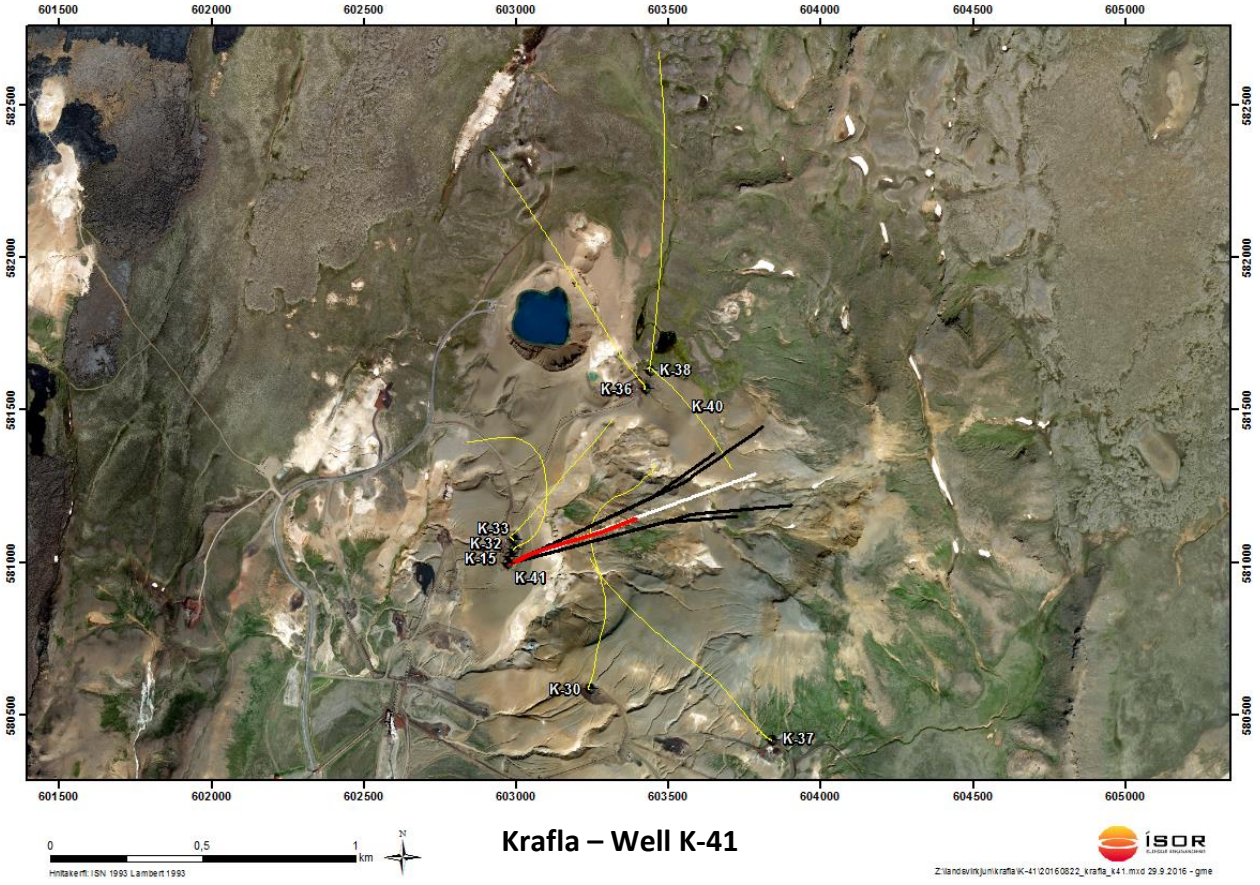


Figure 2. *Location and trajectory of well K-41 in Krafla.*

Depths in this report refer to measured depth (MD) relative to Sleipnir´s rig floor (5.64 m above ground level), except if otherwise is 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 surveying and geothermal consulting.

The planned design of well K-41 (Figure 3) and the division of the drilling into section was as follows:

- Phase 0: Pre-drilling for the surface casing with 21" drill bit to ~90 m depth. Cased with 18⅝". (Was drilled to 100 m and the casing landed at 99.7 m)
- Phase 1: Drilling for the anchor casing with 17½" drill bit down to ~290 m depth. Cased with 13⅜". (Was drilled to 293.5 m and the casing landed at 292.5 m)
- Phase 2: Drilling for the production casing with 12¼" drill bit down to ~1100 m depth. Cased with 9⅝". (Was drilled to 1039 m and the casing landed at 1031 m)
- Phase 3: Drilling of the production part with 8½" drill bit to 1700–2000 m depth, cased with 7" perforated liner.

This report presents the geological part of the drilling, including e.g. lithology, alteration and feed points, as well as the geophysical logging of the well. The report is structured into the following chapters: the *first chapter* gives an introduction. *The second chapter* reports on the drilling operations during drilling of phase 2. *The third* describes the geological strata and alteration, observed by the on-site geologist, and openings in the well. *The fourth chapter* includes the wireline loggings of phase 2, carried out by ÍSOR´s logging engineers.

The aim of this report is to document the geological- and geophysical part from the drilling of phase 2 in K-41, and present all the data collected and provide data interpretations. Appendix B contains all daily reports written by the borehole geologist during drilling operations, presenting preliminary results.

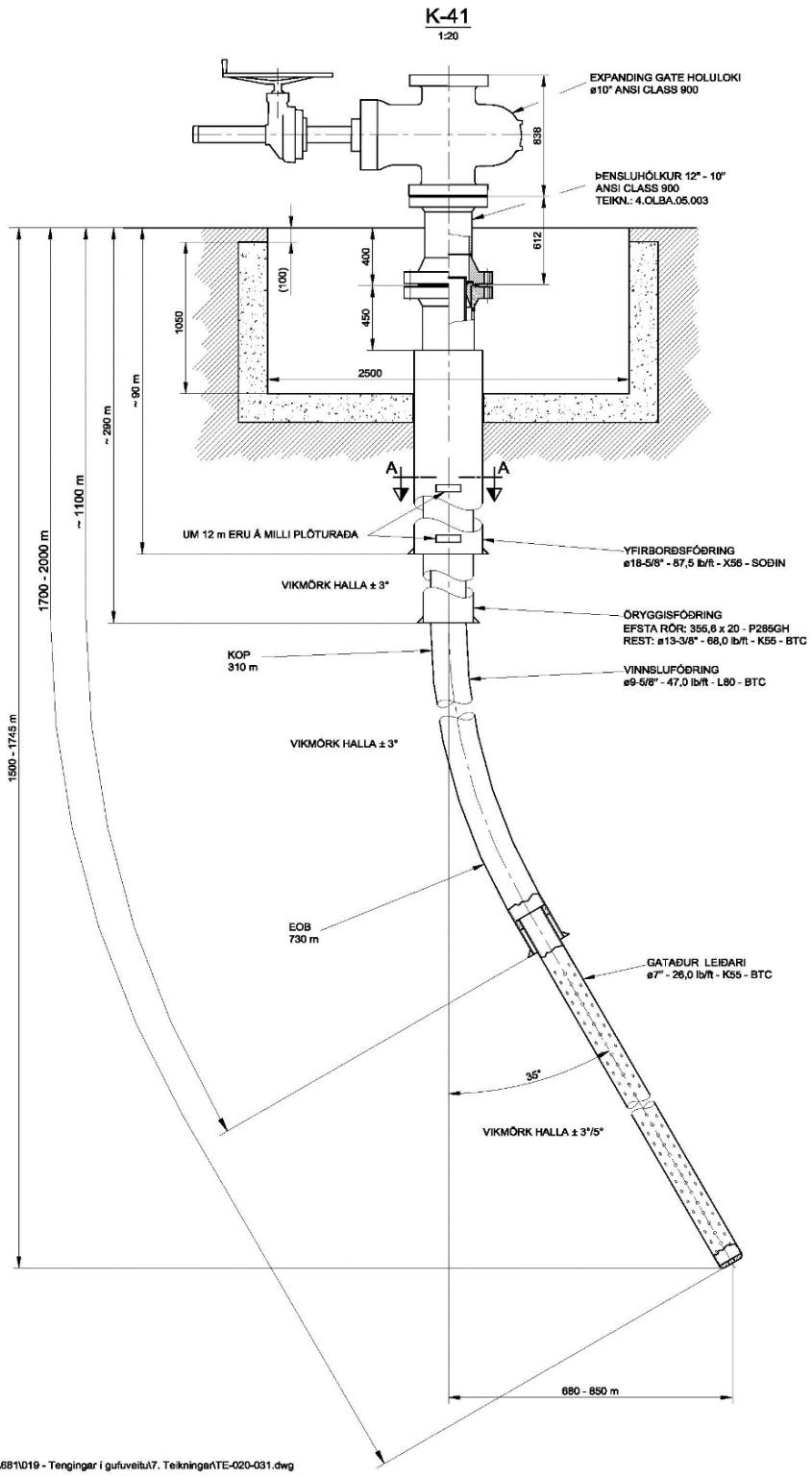


Figure 3. *Well design of K-41.*

2 Drilling operations

2.1 Overview

The drilling with 12¼" bit for the production casing , from 293,5 m to 1039,7 m, took nine days (Table 2). Drilling started on August 2nd (workday 14) and reach the final depth on August 109th (workday 22). The well was drilled using rotary mud drilling method with a 12¼" tri-cone bit. A 9⅝" production casing was run down to 1031 m on August 15th (workday 27). The BHA used for the drilling of Phase 2 including the MWD tools shown in Figure 4.

Due to significant circulation losses, a cementing job was carried out at 566 m depth during August 4th to the 6th. The cementing job was completed in two attempts, since there were still losses after the first cement job.

On August 10th (workday 22), following several mechanical issues were encountered, the drill string got stuck. It was freed one day later, with ample circulation of soda and water to dissolve the clays obstructing the drillstring. It was decided to pull out of the hole on the 12th of August and set the production casing after running geophysical logs.

For cementing the production casing, 40 m^3 of cement slurry were used, the cement was pumped on August the 15th.

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

Rig operations of phase two started on August 1st 2016 by setting up and testing the blow-out preventers at 30 bar pressure for 15 min. Afterwards, the BHA (including motor and MWD), with a 12¼" drill bit was run in hole. The average rate of penetration (ROP) during drilling of phase 2 was 6.7 m/h with approximately 50–60 L/s mud circulation whereas the stand-pipe pressure ranged between 70 and 110 bar. The directional drilling started at the kick off point (KOP) at about 310 m with the aim of steering the well towards ENE (70°). Drilling operations proceeded with severe complications due to circulation losses in the well starting at 545 m, causing 2 cement jobs during drilling of phase 2. At 1039,7 m the drill string got stuck in the well for 2 days (August 10th to August 12th, 2016) following a several mechanical problems, including problems with the mud pumps and one incident involving the hydraulic pump.

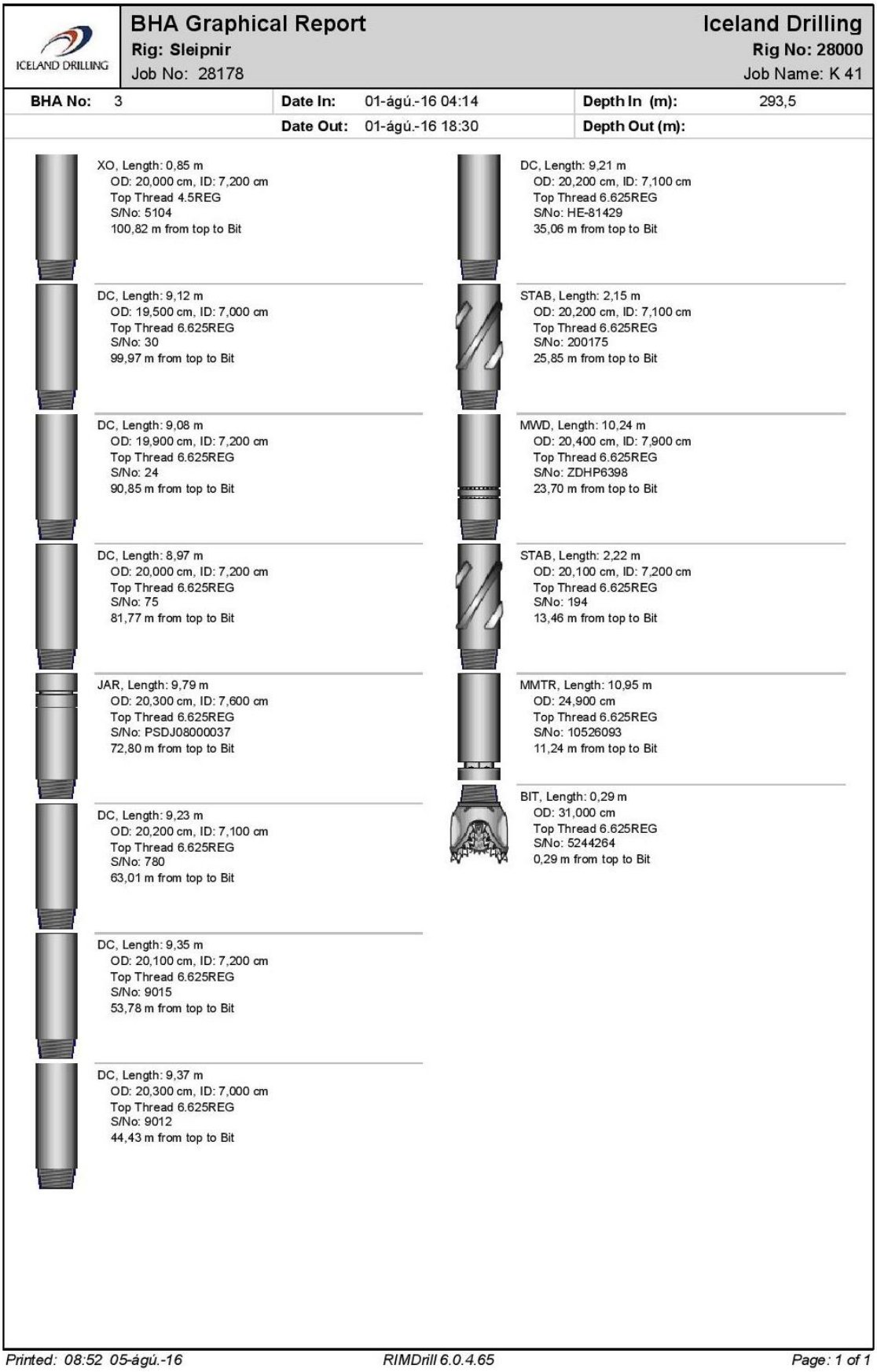


Figure 4. *BHA graphical report for Phase 2 drilling of K-41.*

Table 2. *Drilling progress Phase 2 Drilling with 12¼" drill bit for 9⅝" production casing*

Date	Work Day	Stage	Drill Time (hours)	Drilled Section in formation (m)	ROP (m/hour)	Total depth at 24:00 (m)
1.8.2016	13	2	0	0	0	300
2.8.2016	14	2	16.50	64	4.3	364
3.8.2016	15	2	18.75	124	6.6	488
4.8.2016	16	2	10.50	78	7.4	566
5.8.2016	17	2	0.00	0	0.0	566
6.8.2016	18	2	2.00	19	9.5	585
7.8.2016	19	2	21.25	163	7.7	748
8.8.2016	20	2	20.75	162	7.8	910
9.8.2016	21	2	3.00	26	8.7	936
10.8.2016	22	2	18.00	103	5.7	1039
11.8.2016	23	2	0.00	0	0.0	1039

At 8:00 on the 2nd of August, the drill bit reached the cement float collar at a depth of 268 m inside the 13⅜" anchor casing. Drilling into formation commenced at a depth of 293,5 m. Drilling continued until 12:00 when the depth of the kick-off point at 310 m was reached.

Drilling was stopped at 310 m and a gyro survey was performed from surface to 275 m, yielding an inclination of 0.27° at 273 m and azimuth of 204.2°. Drilling with the motor and MWD included in the BHA commenced again from 310 m as the angle build-up started and continued to 386 m on August 3rd when it was stopped in order to run a new gyro survey. This survey measured an inclination of 3.66° at 347 m with an azimuth of 69,8°.

Drilling continued and reached 451 m in the evening of August 3rd, and a new gyro survey measured inclination of 9.49° at 413 m with an azimuth of 65,3°.

On August 4th, a considerable circulation losses were measured between 547 and 566 m depth, ranging from 20 L/s at 547 m to 12.5 L/s at 566 m. Consequently, the drilling was stopped at 10:30 and it was decided to cement the bottom of the well to plug the losses. Before cementing, a temperature tool was run into the hole after pulling the drill string out of the hole. The cement string was then run into the well and a gyro survey was run into it measuring an inclination of 21.75° at 557 m and azimuth of 61.8°. A volume of 10.4 m^3 of cement slurry was injected into the string at 500 m followed by 4 m^3 of water. Once the cement was cured, circulation losses of 18 L/s were measured and a new temperature log was run by ÍSOR logging engineers on August 5th at 21:00. A second cementing job was then necessary, and a volume of 6.6 m^3 of cement slurry was injected at 370 m followed by 3.1 m^3 of water.

After the cement was cured, the bottom hole-assembly and the drill string was put back in the well and drilling through the cement started at 357 m at 4:20 on August 6th. Formation was reached at 21:00 on that day, with measured circulation losses about 3–4 L/s at 565 m.

Drilling through formation continued until August 9th, down to 926 m, at 2:00, when a leak appeared in the stand pipe and repair was necessary. During the drilling of those 361 m, two gyro survey were completed by ÍSOR logging engineers, at 651 m on August 7th, with an

inclination of 2913° and azimuth of 716°. The second measurement was done on August 8th at 13:00, at 803 m the inclination is 35.25° and the azimuth 72.7°.

After repair of the standpipe, drilling continued from 926 to 1034 m on August 10th at 14:00, when failure of one of the mud pump occurred. Drilling continued from 21:00 to 1039 m, stopped by failure of one hydraulic pump. Following this failure, the drill string got stuck, it was necessary to circulate soda and water for about 24 hours to dissolve the clays and finally release the drill string. Losses were then measured at 20 L/s. The drilling string was freed in the morning of August 12th and was then pulled pull out of the hole. The plan was to change the drill bit and continue drilling, but then it was decided to stop the drilling and complete phase 2. The geophysical logging was started after midnight August 13th (Workday 25) and was finished in the afternoon.

The 9⅝" production casing was then run in the hole down to 1031 m. Cementing of the casing was after midnight August 15th. A total volume of 55 m^3 of cement slurry was used (5 m^3 through the cement string, cleaned with 5.3 m^3 of water, and then 48 m^3 through the kill line into the annulus and finally filed up with 2 m^3). The cementing and casing information are shown in Figure 5 and Figure 6 as well as Table 3 (note that the casing shoe was first considered at 1036 m and the depth was then corrected to 1031 m). Figure 7 shows the drilling progress of well K-41 for phases 0 to 2.

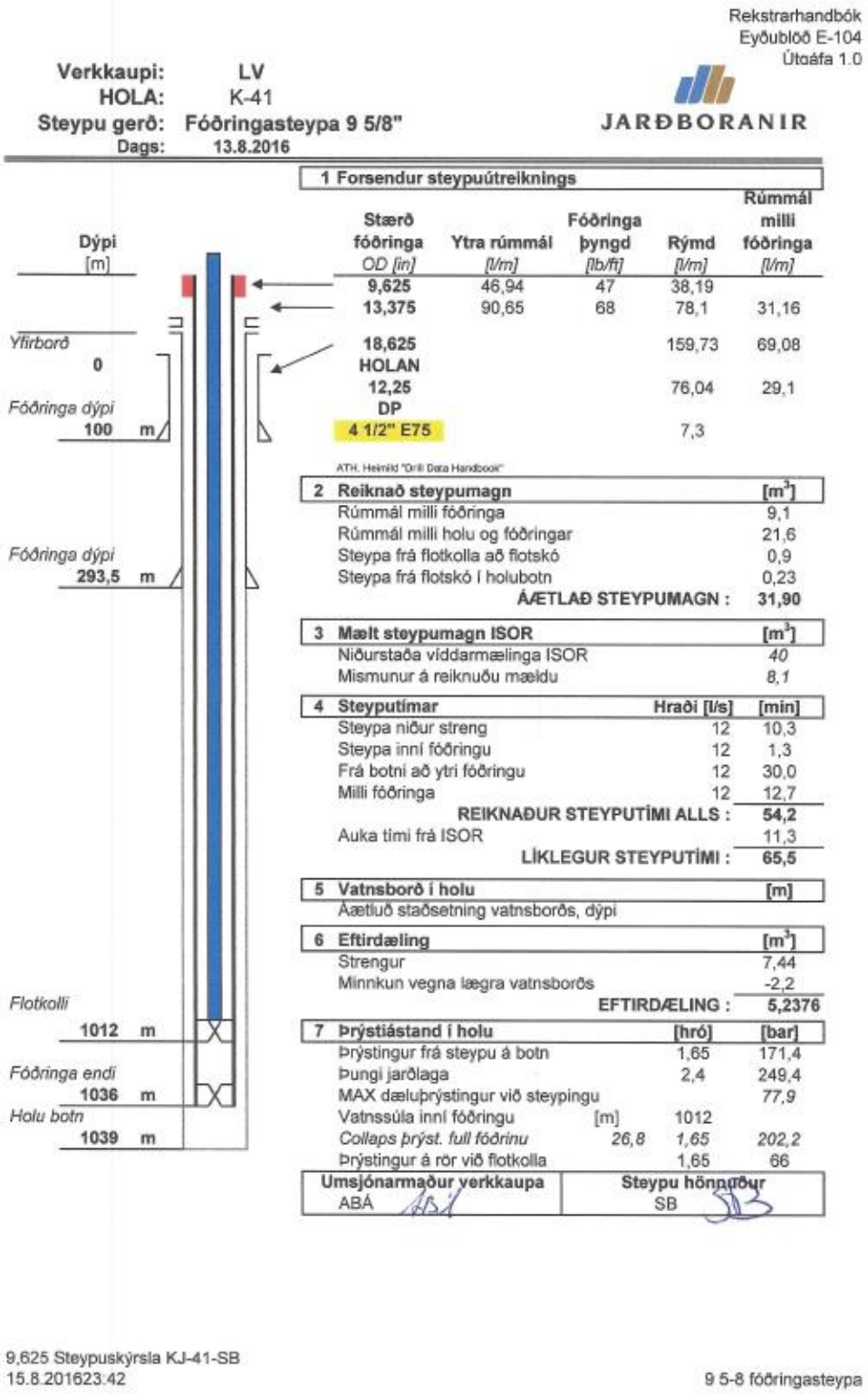
Table 3. *Contractors casing information report.*

ICELAND DRILLING	**Casing Information Report**		**Iceland Drilling**
	Rig: Sleipnir		**Rig No: 28000**
	Job No: 28178		Job Name: K 41

Casing Information			
Run Date/Time:	14-ágú.-16 00:00		
		Leak Off Test (kg/cu m):	
Well Section:	INT2	**String Type:**	FULL
String Top MD (m):	5,6	**String Top TVD (m):**	
Casing Shoe MD (m):	1.036,1	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	24,45	**String Nominal ID (cm):**	22,66
Bit Diameter (cm):	31,11	**Avg. Open Hole Diam. (cm):**	31,11
Centralizers: No:	72	**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 15-ágú.-16 01:39 leið rétt dýpi flotkolli 1009 m skór 1031 m.		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
1	SHOE	0,570	24,45	22,66		K-55	BUTT	
2	JOINT	22,980	24,45	22,66	17,3	K-55	BUTT	
1	FLOAT	0,540	24,45	22,66		K-55	BUTT	
90	JOINT	1.016,670	24,45	22,66	17,3	K-55	BUTT	
Totals: 94		1.040,760						



Rekstrarhandbók
Eyðublöð E-104
Útgáfa 1.0

Verkkaupi: LV
HOLA: K-41
Steypu gerð: Fóðringasteypa 9 5/8"
Dags: 13.8.2016

JARÐBORANIR

1 Forsendur steypuútreiknings

Dýpi [m]	Stærð fóðringa OD [in]	Ytra rúmmál [l/m]	Fóðringa þyngd [lb/ft]	Rýmd [l/m]	Rúmmál milli fóðringa [l/m]
	9,625	46,94	47	38,19	
	13,375	90,65	68	78,1	31,16
Yfirborð 0	18,625			159,73	69,08
	HOLAN				
	12,25			76,04	29,1
Fóðringa dýpi 100 m	DP				
	4 1/2" E75			7,3	

ATH. Heimild "Drill Data Handbook"

2 Reiknað steypumagn	[m³]
Rúmmál milli fóðringa	9,1
Rúmmál milli holu og fóðringar	21,6
Steypa frá flotkolla að flotskó	0,9
Steypa frá flotskó í holubotn	0,23
ÁÆTLAÐ STEYPUMAGN :	**31,90**

3 Mælt steypumagn ISOR	[m³]
Niðurstaða víddarmælinga ISOR	*40*
Mismunur á reiknuðu mældu	*8,1*

4 Steyputímar	Hraði [l/s]	[min]
Steypa niður streng	12	10,3
Steypa inní fóðringu	12	1,3
Frá botni að ytri fóðringu	12	30,0
Milli fóðringa	12	12,7
REIKNAÐUR STEYPUTÍMI ALLS :		**54,2**
Auka tími frá ISOR		11,3
LÍKLEGUR STEYPUTÍMI :		**65,5**

5 Vatnsborð í holu	[m]
Áætluð staðsetning vatnsborðs, dýpi	

6 Eftirdæling	[m³]
Strengur	7,44
Minnkun vegna lægra vatnsborðs	-2,2
EFTIRDÆLING :	**5,2376**

7 Þrýstiástand í holu		[hró]	[bar]
Þrýstingur frá steypu á botn		1,65	171,4
Þungi jarðlaga		2,4	249,4
MAX dæluþrýstingur við steypingu			*77,9*
Vatnssúla inní fóðringu	[m]	1012	
Collaps þrýst. full fóðrinu	*26,8*	*1,65*	*202,2*
Þrýstingur á rör við flotkolla		1,65	66

Umsjónarmaður verkkaupa	Steypu hönnuður
ABÁ	SB

Flotkolli 1012 m
Fóðringa endi 1036 m
Holu botn 1039 m

9,625 Steypuskýrsla KJ-41-SB
15.8.201623:42

9 5-8 fóðringasteypa

Figure 5. *Contractor's casing report (note: corrected casing shoe depth is 1031 m).*

Rekstrarhandbók
Eyðublöð E-104
Útgáfa 1.0

Verkkaupi: LV
HOLA: K-41
Steypu gerð: Fóðringarsteypa 9 5/8"
Dags: 13.8.2016

JARÐBORANIR

Aðstæður í holunni:

Leki er í holunni á 1000m dýpi. Og hún kælir sig þangað niður. Samkvæmt viddarmæling má gera ráð fyrir 40m3 en vegna leka má gera ráð fyrir meira magni. Og líklega fleiri en einni steypingu. Einsog fyrr sagði þá er hitinn niður í 1000m ekki mikill eða um 30°.

Steypu aðferð:

Steypt verður í gegnum streng reiknuðu rúmmáli shoetrack, og rýmdar frá botni holu og að leka. Eða um 5 m3. Á meðan við steypum í gegnum streng skal hafa 15l/s dælingu á killine til að halda æðinni opinni. Borari getur byrjað að taka upp steypustreng.
Síðan verður byrjað að steypa í gegnum killine því magni sem vídarmæling segir til um að viðbættu 25%. Blanda skal vel af Mica flakes í steypuna 2 pokar 1m3. Eftir þetta er steypt ofan á í 10m3 skömmtum þar til steypa kemur til yfirborðs. **Ekkert vatn má koma nálægt fóðringunni á milli steypinga.**

Steypu niðurstaða:

Steypt var úr 5 m3 í gegnum streng og svo eftirdælt með 5,2m3. Síðan var steypt utan á 48m3. Við fengum steypu upp í síðustu rúmmetrunum biðum í hálftíma og steyptum ofan á 2m3. Og steypa náði upp til yfirborðs. Success. Við settum 20 poka af MicaCoarse í fyrstu 10m3.Einnig höfðum við meiri eðliþyngd í steypu fyrstu 20 m3. Meðalþyngd steypu var 1,72. Íóðað var á steypu 4 tímum síðar og var steypa upp við CHF.

Seinni steypa:

Umsjónarmaður verkkaupa	Steypu hönnuður
ABÁ	SB

9,625 Steypuskýrsla KJ-41-SB
16.8.201600:07

9 5-8 steypulýsing

Figure 6. *Contractor's casing report (continued).*

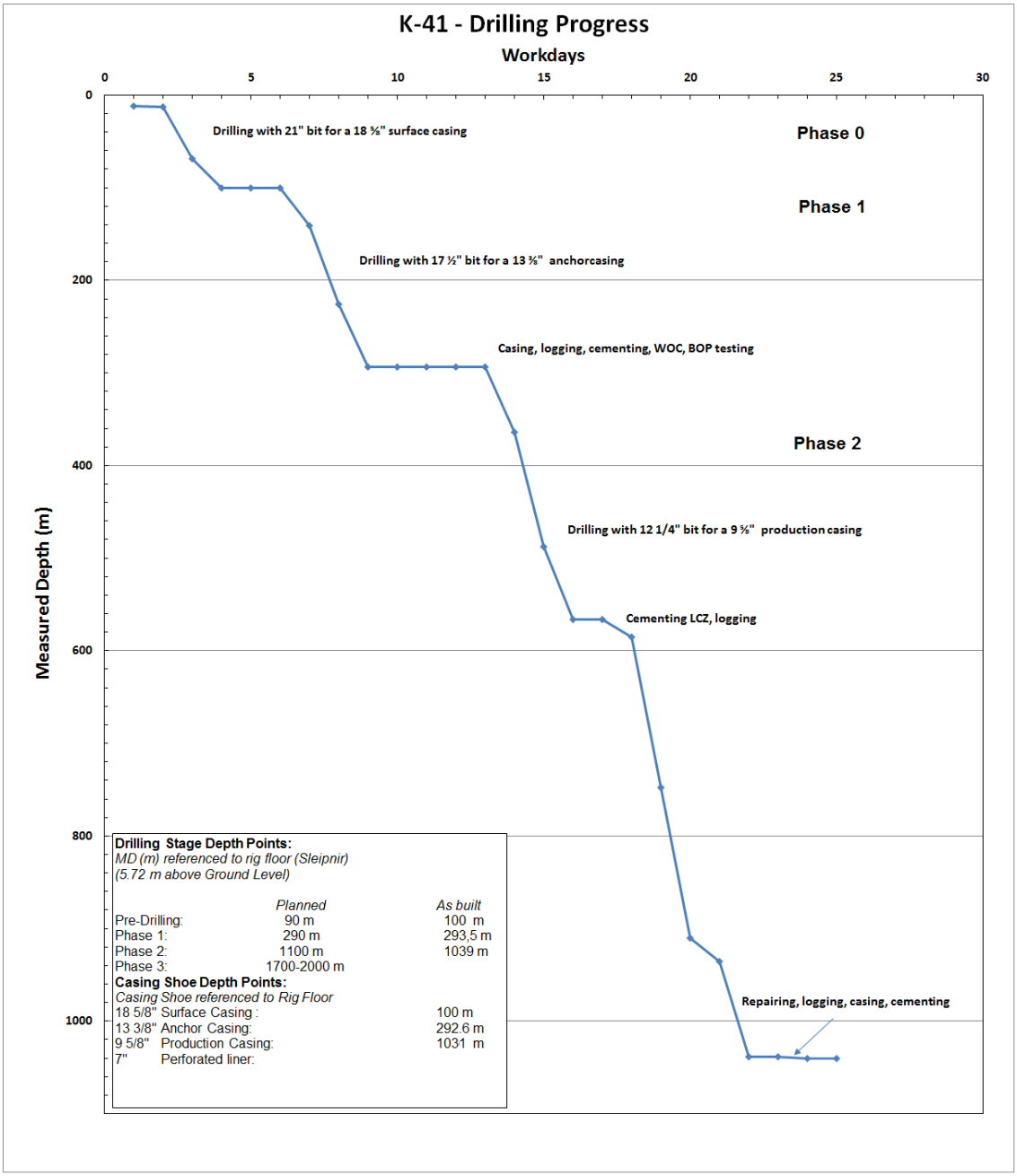


Figure 7. *Drilling progress of Phases 0, 1 and 2 of well K-41.*

3 Lithology, alteration, intrusions and circulation losses

The drilling crew collected cutting samples at two meters interval during the drilling of phases 2 in well K-41. Depth values of the samples are in reference to the rig floor of Sleipnir (5.64 m above ground level). The samples were collected in 150 ml plastic containers. ÍSOR's borehole geologists analyzed the cutting samples on site during drilling of phase 2 and determined the lithology and the alteration mineral assemblage through the aid of a binocular microscope. Additional data on the main drilling parameters from the drill rig data system were collected,

wire-line logs as well as measured circulation losses were compared with the lithological units drilled trough.

Figure 8 shows the drilling data from the drill rig Sleipnir and lithology of well K-41 during phase 2. From the figure we can see how the rate of penetration is generally higher during the drilling through basaltic breccias and basaltic tuffaceous formations than when drilling through crystalline units constituted of basaltic lava unit or intrusive rock. Secondary minerals, typical of high temperature geothermal reservoir, were seen in the cuttings during the drilling of phase 2, such as epidote, wollastonite and wairakite (Figure 13).

3.1 Lithology of phase 2 from 293.5 to 1039 m

The lithology of drilling phase 2 can be divided in 4 major formations (Figures 9, 10 and 11). The upper boundary of the uppermost unit is at ~200 m depth (within phase 1) and the lower boundary is at 487 m. It consists primarily of thick basaltic flows, from fine to coarse grained. Alteration of the basalts is light to moderate. A thin intrusion of olivine-tholeiite is found at the base of this unit (from 487 to 489 m). Judging from the lithological logs other intrusions may be inferred around 300 m depth but unfortunately no cuttings are available. From 489 m to 698 m the well cuts through a hyaloclastite unit composed of (alternating) basaltic breccias and tuffs units, with few fragments of basalt. The basalt fragments may be from thin intrusions in the hyaloclastite formation or possibly derived from pillow basalt lavas. The third sequence is mostly composed by fine to medium grained basalt, light to moderately altered, intercalated with a few thin units of basaltic breccia or tuff. The last sequence is dominated by intrusions of a fine grain basalt down to 1038 m. The intrusion took place in a tuffaceous formation which is often mixed in the cuttings in various proportions with the fragments of intrusive basalt. Judging from the geophysical logs the thickness of the intrusives may be overestimated in the cuttings and conversely the thickness of the tuff they intrude may be underestimated.

Lava formation (~200–489 m):

294–316 m: NO CUTTINGS (no cuttings were taken by the rig crew)

316–320 m: BASALTIC BRECCIA

Beige-green color tuffaceous fragments, light alteration, aggregates of fine and coarse grained clay, mixed with fine grained basaltic fragments.

320–375 m: MEDIUM-COARSE GRAINED BASALT

Medium to coarse grained basalt, grey color, vesicles filled with radial crystals of coarse grained clay, green color, rare pyrite and calcite, presence of quartz.

375–383 m: MEDIUM-COARSE GRAINED BASALT / INTRUSIVE ROCK

Olivine-tholeiite intrusion, medium-coarse grained, black color, lightly altered. Rare pyrite, veining and light oxidation. Mixed with altered basalt similar to above.

383–388 m: MEDIUM-COARSE GRAINED BASALT

Medium to coarse grained basalt, grey in color, vesicles filled with radial crystals of coarse grained clay, green color, rare pyrite and calcite, presence of quartz. Few fragments of intrusive olivine-tholeiite.

388–406 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basalt, medium to dark grey in color, light to moderate alteration, trace of pyrite, presence of fine and coarse grained clay, mostly in vesicles and fractures, associated with quartz and pyrite. Presence of laumontite at 404 m.

406–410 m: BASALTIC BRECCIA

Mix of lithological units, fragments of fine grained altered basalt and brecciated fragments appear. Presence of few crystals of epidote, associated with quartz.

410–487 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basalt, medium to dark grey in color with light to moderate alteration. Traces of pyrite are found, presence of fine and coarse grained clay, mostly in vesicles and fractures, associated with quartz and pyrite. Few sections are slightly more altered and contain more pyrite. Rare presence of laumontite crystals and amorphous silica.

487–489 m: MEDIUM-COARSE GRAINED BASALT / INTRUSIVE ROCK

Olivine-tholeiite intrusion, medium-coarse grained, black color, lightly altered. Rare pyrite, veining and light oxidation.

Hyaloclastite formation (489–698 m):

489–498 m: BASALTIC BRECCIA

Basaltic breccia, white greenish color, fine tuff grains mixed with basaltic fragments, light alteration, noticeable pyrite associated with quartz and calcite in fracture veining. Presence of oxidized fragments.

498–504 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basalt, grey color, light alteration. Clay filled vesicles are present, along with quartz and calcite.

504–566 m: BASALTIC BRECCIA

Basaltic breccia, similar to the previous one, green white color, locally pinkish, fine grains of tuffaceous material, mixed with altered basaltic fragments. Presence of pyrite and rare fracture fillings (clay, quartz, calcite). Wairakite crystals are identified at 546 m depth for the first time (Figure 13).

566–574 m: NO CUTTINGS (only cement fragments after cementing loss circulation zone)

574–584 m: BASALTIC TUFF

White-greenish color, fine grains from tuff formation with light alteration, common to abundant disseminated cubic pyrite, rare quartz and calcite. Few fragments with greenish color, probably chlorite. Few fragments show quartz veining.

584–646 m: BASALTIC BRECCIA

White-greenish tuff fragments, fine grained, with disseminated and aggregates of cubic pyrite mixed with fragments of lightly altered fine to medium grained basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include chlorite, quartz (rarely fully developed crystals). Few crystals of epidote were identified at the bottom of the formation, starting from 638 meters.

646–672 m: BASALTIC TUFF

White to greenish and grey colored tuff fragments, fine grained, abundant crystals of cubic pyrite disseminated and in aggregates, locally oxidized fragments. Presence of epidote become more frequent after 674 m and is associated with a higher quantity of quartz, probably linked to veining.

672–698 m: BASALTIC BRECCIA

White-greenish tuff fragments, fine grained, with disseminated and aggregates of cubic pyrite mixed with fragments of lightly altered fine to medium grained basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include chlorite, quartz. A thin basaltic intrusion is possible at about 688m, manifested by the presence of few dark grey, not altered, medium grained fragments of basalt.

Lava formation (698–936 m):

698–738 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basaltic formation, light to medium alteration, greenish-grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include chlorite, quartz, common pyrite and epidote (now solid presence).

738–748 m: BASALTIC BRECCIA

White-greenish fine grained tuff fragments, with disseminated aggregates of cubic pyrite mixed with fragments of lightly altered fine to medium grained basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include chlorite and quartz.

748–764 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basaltic formation, light to medium alteration, greenish grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include chlorite, quartz, commonly pyrite and epidote.

764–776 m: BASALTIC TUFF

White greenish to grey coloured fine grained tuff fragments, with abundant crystals of cubic pyrite, disseminated and in aggregates. Locally oxidized fragments.

776–838 m: FINE-MEDIUM GRAINED BASALT

Light to moderately altered fine to medium grained basalt, dark grey in color with a crystalline appearance, locally with a greenish color due to chlorite. Secondary minerals include chlorite, quartz and epidote. From 790 to 798 m, more oxidation is noted in veins, with quartz, calcite and pyrite.

838–854 m: BASALTIC BRECCIA

White-greenish tuff fragments, fine grained with disseminated cubic pyrite mixed with fragments of lightly altered fine to medium grained basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include chlorite, quartz. Oxidation is high at in the top part of the formation.

854–870 m: FINE-MEDIUM GRAINED BASALT

Light to moderately altered fine to medium grained basalt, dark grey color with a crystalline appearance, locally with a greenish color due to chlorite. Secondary minerals include chlorite, quartz and epidote.

870–876 m: BASALTIC BRECCIA

White-greenish fine grained tuff fragments, with disseminated cubic pyrite mixed with fragments of lightly altered fine to medium grains basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include chlorite, quartz, but with lower quantity of calcite.

876–880 m: BASALTIC TUFF

White greenish, grey coloured tuff fragments, with locally oxidized fragments. Rich in epidote. Few fragments of basaltic rocks.

880–888 m: FINE-MEDIUM GRAINED BASALT / INTRUSIVE ROCK

Dark grey to black, fine grained intrusive basalt, not altered. Presence of pyrite and epidote related to few fragments of tuff like above.

888–920 m: FINE-MEDIUM GRAINED BASALT

Fine to medium grained basaltic formation, light to medium alteration, greenish-grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include chlorite, quartz, common pyrite and epidote. Calcite disappears at about 902–904 m.

920–936 m: BASALTIC TUFF

White greenish to grey coloured fine grained tuff fragments, with abundant crystals of cubic pyrite disseminated and in aggregates. Locally oxidized fragments. Between 928 and 932 m is an abundance of pyrite crystals.

Intrusives (936–1038 m):

936 –980 m: FINE-MEDIUM GRAINED BASALT / INTRUSIVE ROCK

Fine grained basaltic intrusion, no alteration, dark grey to black in color. Few cubic crystals of pyrite and some sections are mixed with tuff fragments similar to the one described above which are associated with secondary minerals such as chlorite, pyrite, epidote and wollastonite.

980–1002 m: BASALTIC TUFF

White, greenish-grey coloured tuff fragments, fine grained with abundant crystals of cubic pyrite disseminated and in aggregates. Locally oxidized fragments. Secondary minerals include chlorite, epidote and wollastonite. Between 982 and 988 m, there are still fragments of intrusive basalt similar to the formation above. A fragments at 996 m shows epidote overgrown with calcite (Figure 14), indicating cooling in the geothermal system..

1002–1038 m: FINE-MEDIUM GRAINED BASALT / INTRUSIVE ROCK

Fine to medium grained basaltic intrusion with no notable alteration. Dark-grey to black color. Few cubic crystals of pyrite and some sections are mixed with tuff fragments similar to the one described above which are associated with secondary minerals such as chlorite, pyrite and epidote.

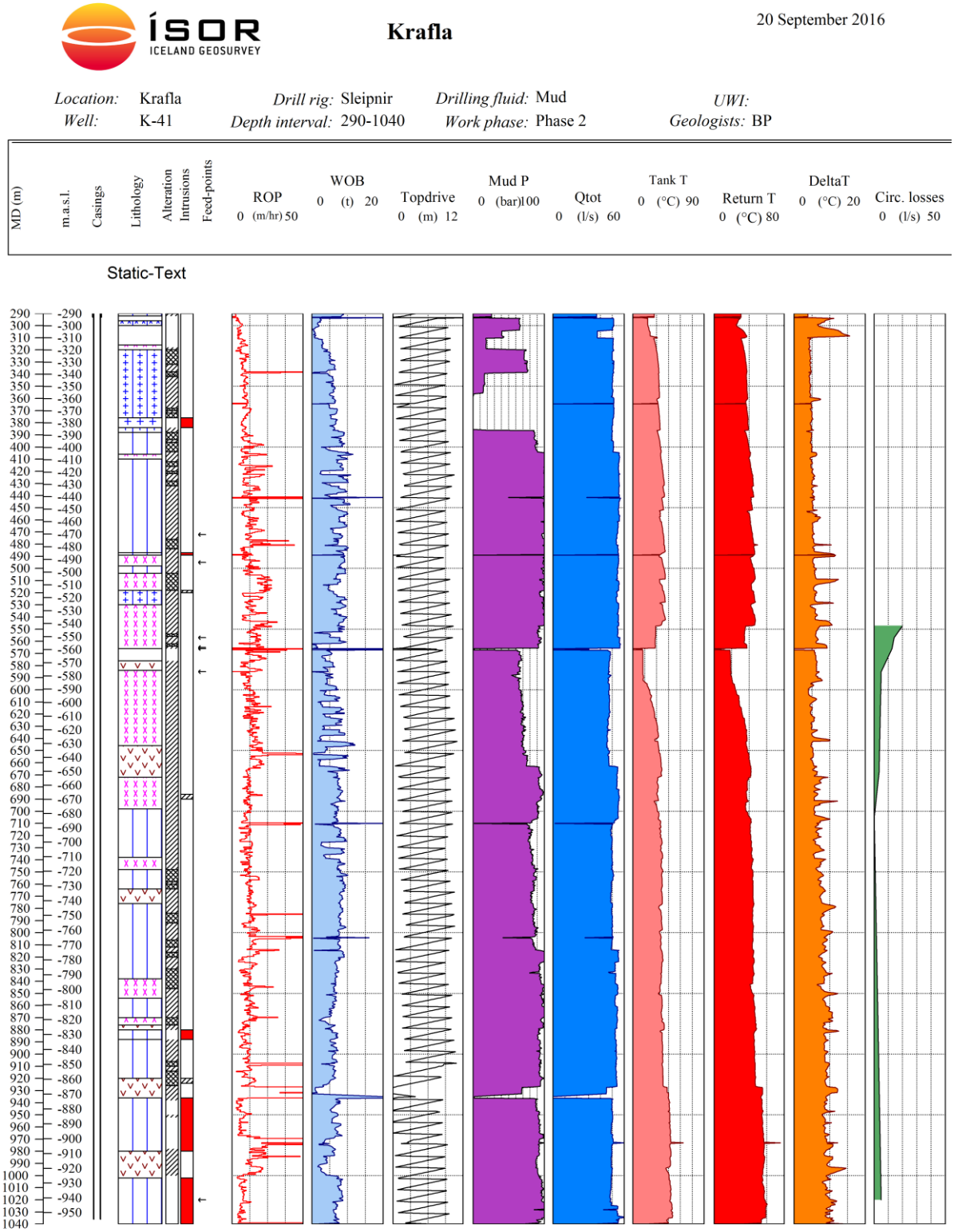


Figure 8. *Lithology and drilling data recorded during the drilling of well K-41, Phase 2.*

Location:	Krafla	*Drill rig:*	Sleipnir	*Drilling fluid:*	Mud	*UWI:*	
Well:	K-41	*Depth interval:*	290-1040	*Work phase:*	Phase 2	*Geologists:*	BP

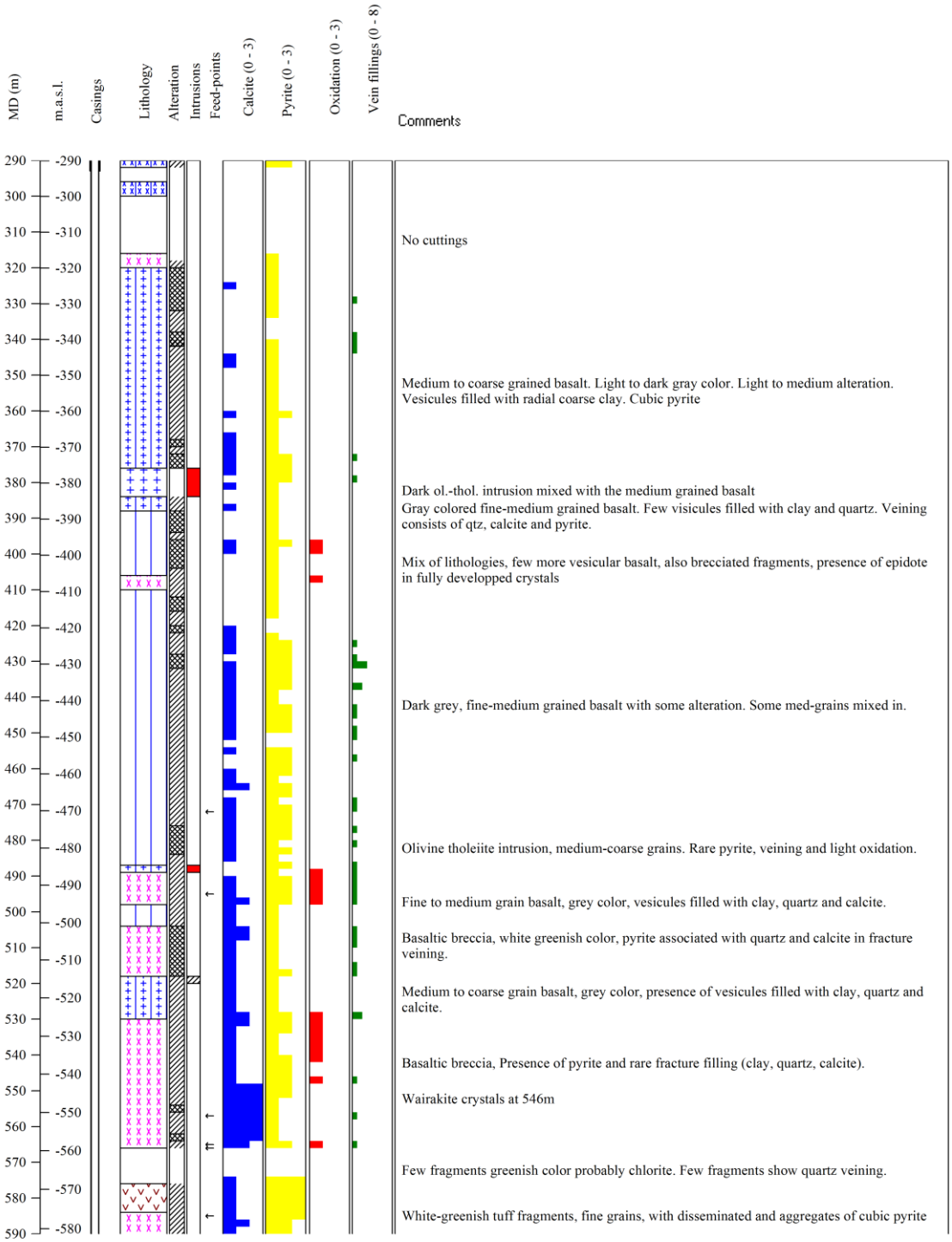


Figure 9. *Lithology, alteration and description of lithology in well K-41 from 290 to 590 m.*

Location:	Krafla	*Drill rig:*	Sleipnir	*Drilling fluid:*	Mud	*UWI:*	
Well:	K-41	*Depth interval:*	290-1040	*Work phase:*	Phase 2	*Geologists:*	BP

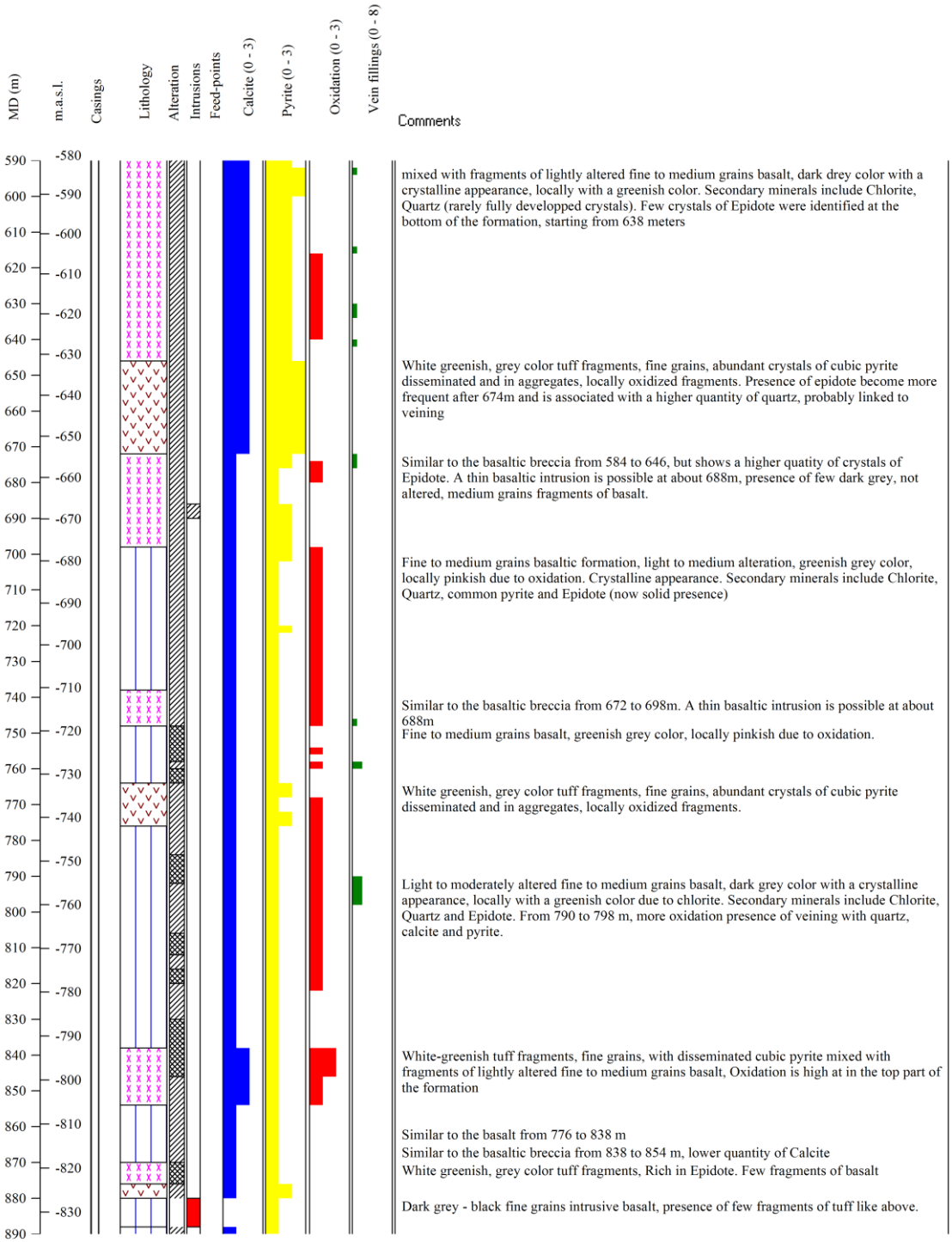


Figure 10. *Lithology, alteration and description of lithology in well K-41 from 590 to 890 m.*

Location:	Krafla	*Drill rig:*	Sleipnir	*Drilling fluid:*	Mud	*UWI:*	
Well:	K-41	*Depth interval:*	290-1040	*Work phase:*	Phase 2	*Geologists:*	BP

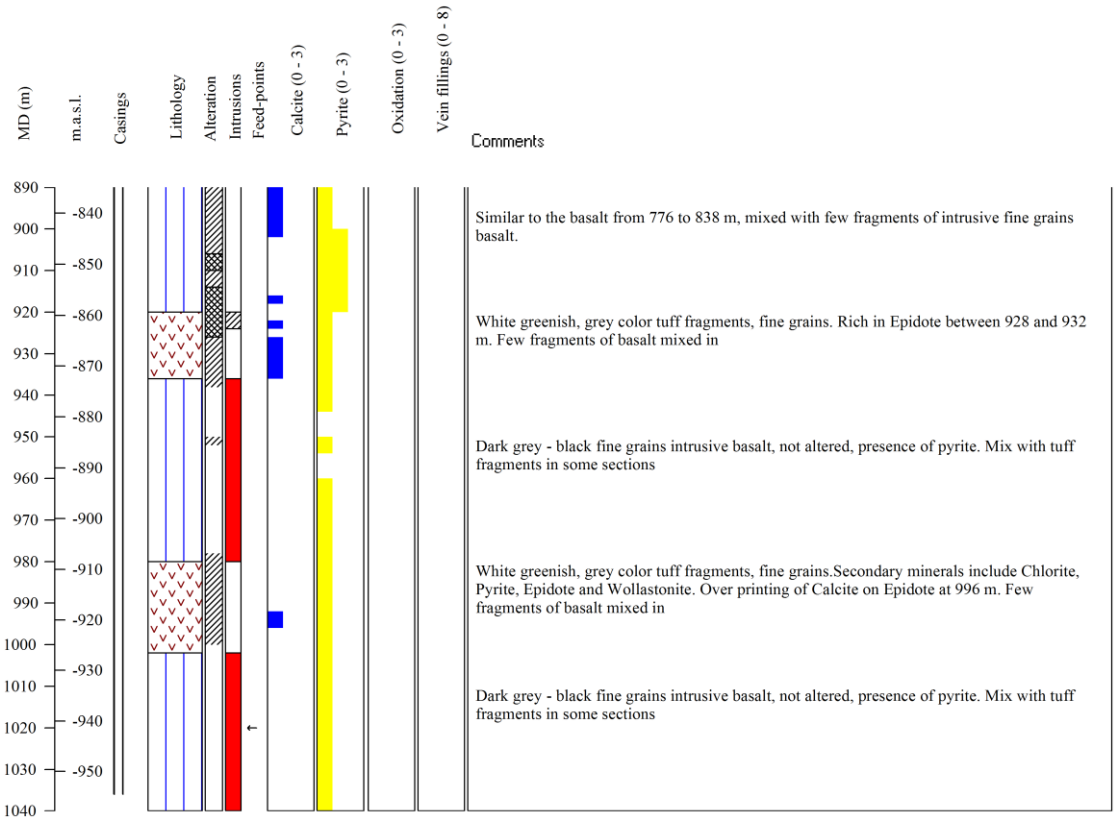


Figure 11. *Lithology, alteration and description of lithology in well K-41 from 890 to 1040 m.*

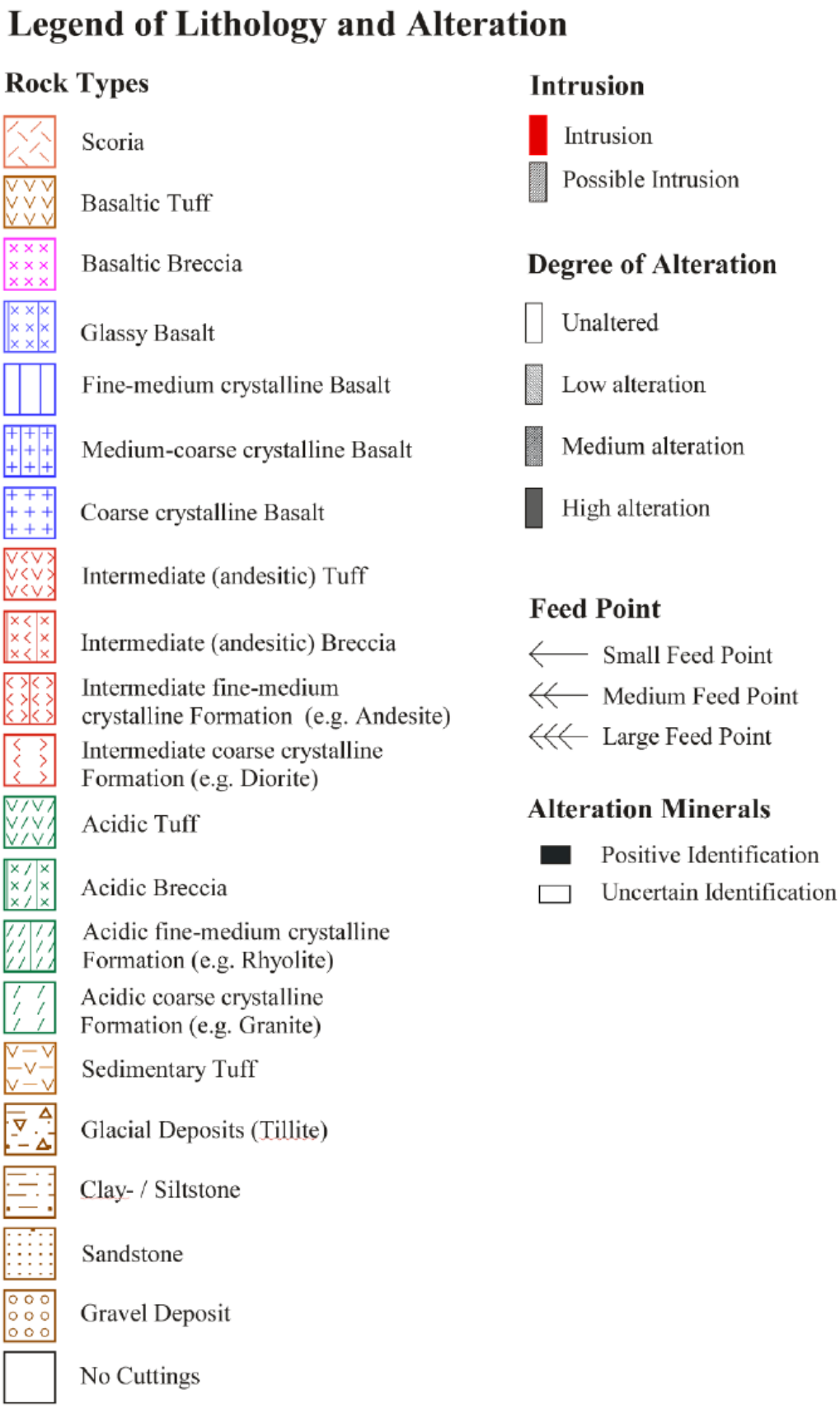


Figure 12. *Lithology legend for Figures 8 to 10 and 13 and 14.*

3.2 Intrusions

Only few small intrusions were encountered in the well during phase 2 before reaching the depth of 936 m. The first one was an olivine-tholeiite, from 375 to 383 m. A similar one was found from 487 to 489 m. However, from 936 m, several thick basaltic intrusive units were encountered (note that a thin intrusion, with similar lithology was encountered from 880 to 888 m). The bottom of the production casing in setting in intrusive basaltic formation.

3.3 Alteration

Low-temperature minerals, like fine-grained clay and zeolites occur at shallower levels, whereas high-temperature minerals, like epidote, wairakite or wollastonite appear at deeper levels in the well. The production casing is extending to 1031 m and based on the mineral assembly it extends well into the geothermal reservoir, with abundance of epidote (>230–250°C) noticed in cutting samples at that depth (Figure 15). Epidote was first observed at 406 m depth in very small quantity for a few meters, whereas below 638 m epidote was frequently observed in the majority of the cutting samples. Wairakite was first observed at 546 m (Figure 13) depth and wollastonite was observed in several samples from 976 m. Calcite was present in almost every sample down to 936 m, then it was only observed in a few samples and in smaller quantity. Pyrite was present through the whole section drilled for phase 2, at the beginning mostly small crystals disseminated and sometimes in the veins associated with calcite and quartz, but deeper, some fully developed cubic crystals started to appear gradually. The quantity of pyrite crystals is usually higher in the tuff and breccia lithologies than in the basaltic flows.

In the Krafla geothermal system, it has been observed in other wells that a colder aquifer might be present above the hot temperature resource. In order to identify the zone of cold fluids, a particular attention was given to the secondary mineralogy; the presence of Calcite over-printing the crystals of Epidote like it was found at 996 m are clues indicating such character-istics (Figure 14).

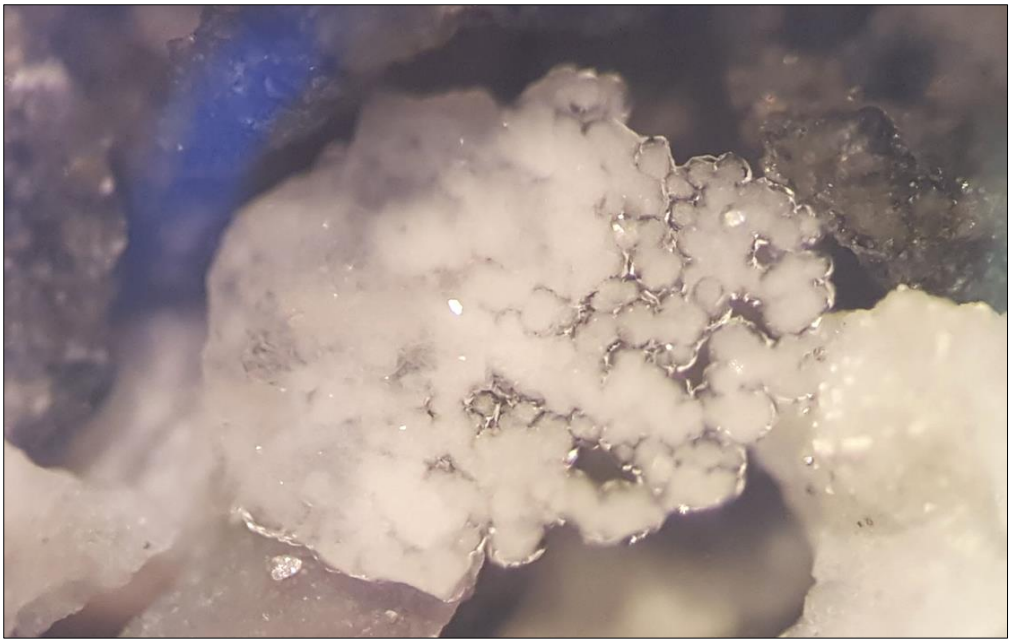


Figure 13. *Photography of crystals of Wairakite observed at 546 m using the binocular microscope*

Figure 14. *Photography of crystals of Calcite overprinting crystals of Epidote at 996 m, as seen using the binocular microscope (bubbles are due to the HCl test on the mineral and the release of CO_2, indicating Calcite)*

3.4 Circulation losses

Circulation losses (LOC) were monitored during the drilling of phase 2 in K-41. Losses started at 547 m and were about 20 L/s, then gradually decreased to 14 L/s at 557 m and 12.5 L/s at 566 m. It was then decided to plug the losses with cement at 566m; two cement jobs were necessary. During the second part of the drilling of phase 2, much smaller losses were encountered, between 0 and 5 L/s, gradually decreasing while drilling. When the final depth of phase 2 was reached at 1039 m, the losses were 5 L/s.

Based on the cuttings analysis, the main losses at 547–566 m have occurred in a basaltic breccia formation. That section shows a particularly high degree of alteration of the rocks and also matches with the presence of crystals of wairakite (Figure 13).

Table 4. *Circulation losses during the drilling of phase 2 of K-41.*

Date	depth (m)	LOC (L/s)	Remarks
4.8.2016	547	20	
4.8.2016	557	14	
4.8.2016	566	12,5	2 cement jobs were necessary to seal off the loss zone (10.4 m^3 and 6.6 m3 of cement slurry were used)
6.8.2016	585	5	Losses gradually decrease
7.8.2016	668	3,5	
7.8.2016	705	0	
10.8.2016	1020	5	Drilling of phase 2 terminated at 1039 m

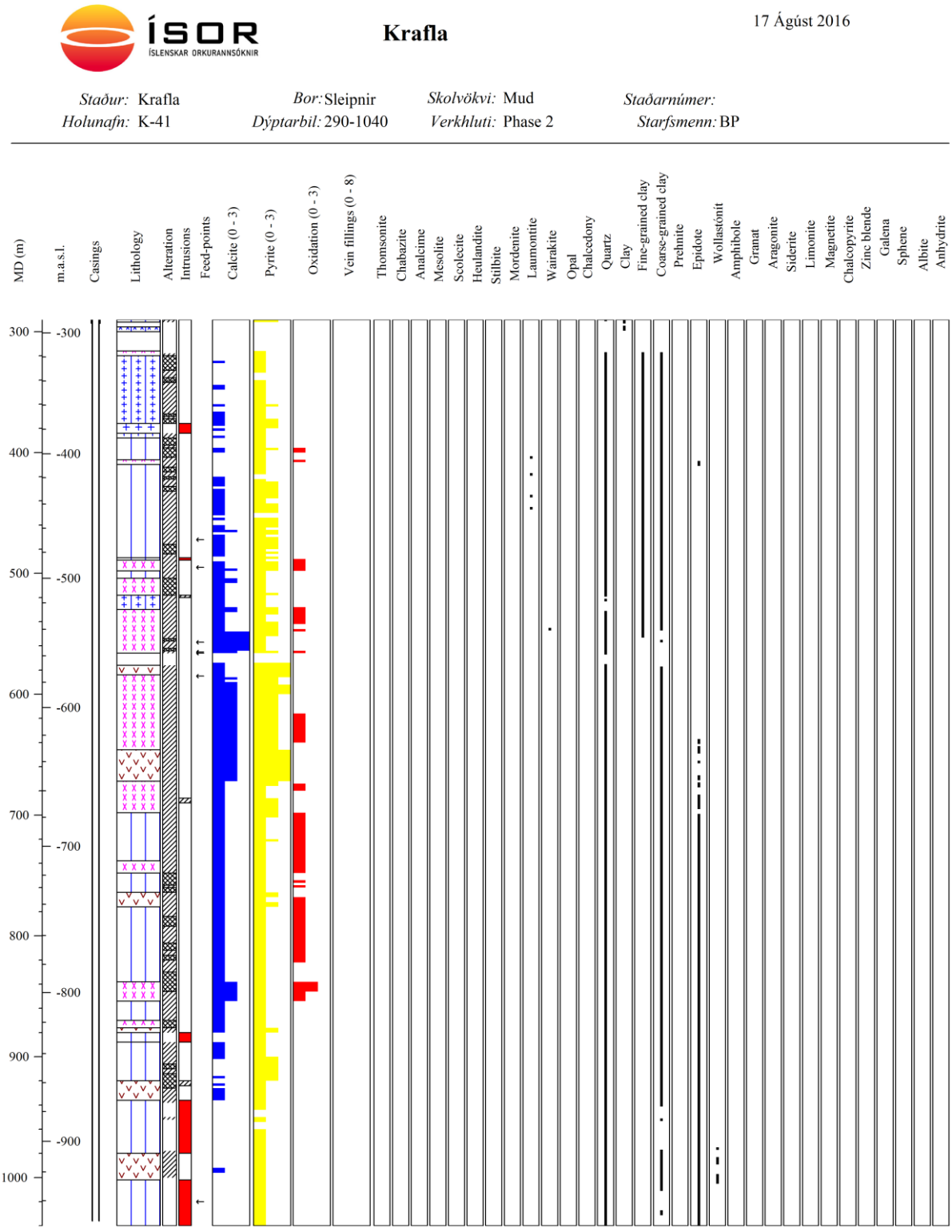


Figure 15. *Lithological log and secondary minerals of well K-41 from 290 to 1040 m.*

3.4 Comparison with KJ-32 and KJ-33

The lithology shows a good correlation with those encountered in nearby well KJ-32 and KJ-33 (Figure 16). The first sequence, mostly composed of basaltic units is situated below hyaloclastite units ended between 300 and 315 m depth in all three wells. This basaltic sequence is then followed by a hyaloclastite sequence with more or less intrusive lithologies. The brecciated units seem to be thicker in well K-41, and intrusions more frequent in the two other wells. This section, in the three wells, extending to about 600 to 700 m depth, corresponds to section where circulation losses were encountered, and further studies of temperature data showed several aquifers. Below that depth, the lithologies of the three wells show more differences, probably related to the difference in trajectory of the wells getting more spaced to each other. Well K-41 for example is mostly constituted in the bottom part of fine to medium grains basaltic flows, separated by few thin basaltic breccias and tuff intervals. Whereas well KJ-32 is mostly showing tuffaceaous lithologies in the same interval. With a few small basaltic units intercalated, and well KJ-33 shows a balanced quantity of tuff and basaltic flows, and more intrusions. One common facts, however, in the three wells, there are several intrusive units starting from 900 m and few loss circulations were recorded associated with them.

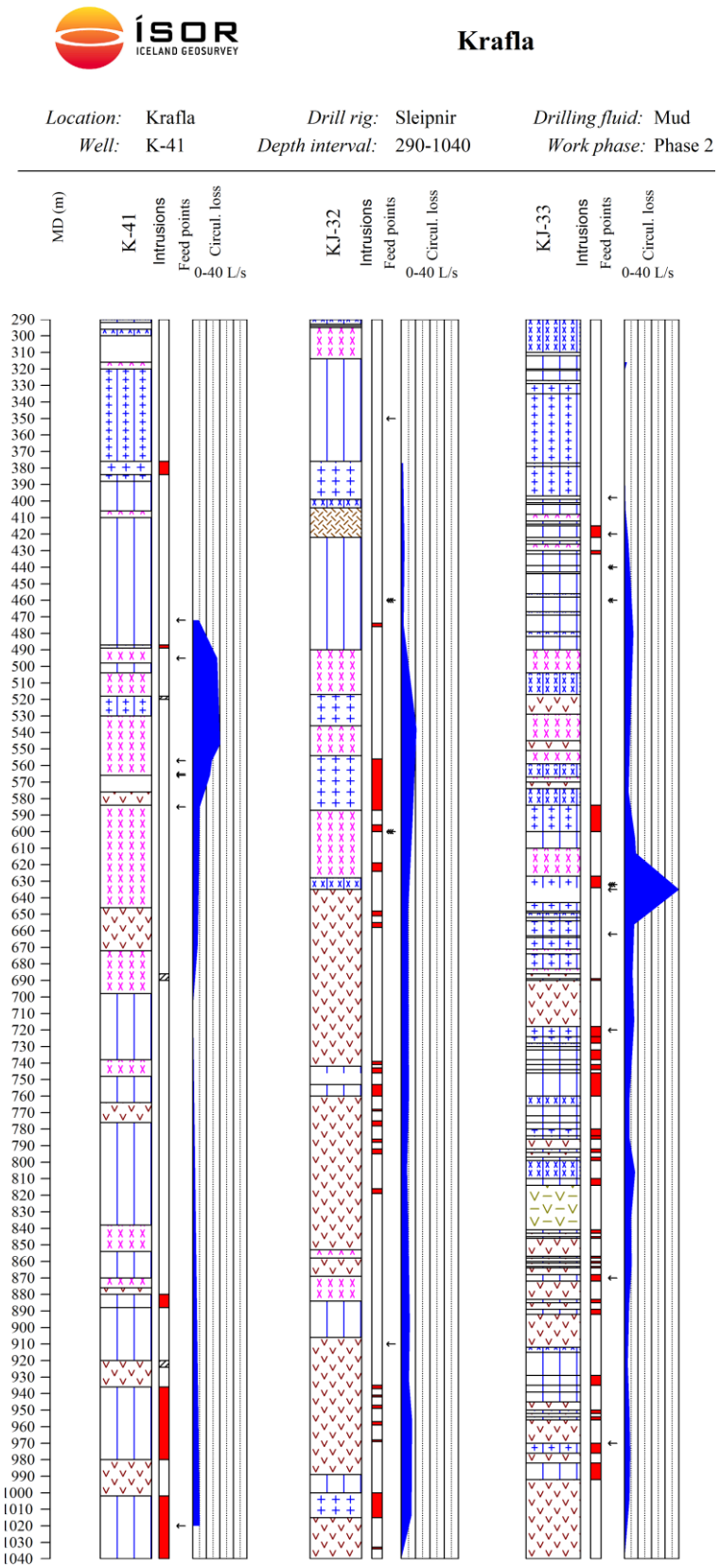


Figure 16. *Lithology, aquifers and loss circulation compilation for wells K-41, KJ-32 and KJ-33 between 290 and 1040 m (corresponding to K-41 Phase 2).*

4 Wireline logging

Wireline logging in phase 2 of well K-41 can be divided into 5 types.

- Gyro surveys to measure inclination and azimuth with depth in order to monitor the directional drilling (angle build-up and direction) and to determine the trajectory of the well when the drilling is completed.
- Temperature log prior to cementing in order to check the warm-up rate inside the well and to locate loss zones if they occur.
- Lithological logs including neutron-neutron, natural gamma radiation, resistivity, self-potential, and acoustic televiewer. Besides this, a caliper-log was run in order to obtain information on the width of the well and to locate cavities (wash out zones).
- Caliper-log prior to cementing in order to map the well's diameter, i.e. cavities and possible obstacles inside the well that require further reaming. In addition, the caliper log gives the minimum volume behind the casing needed to be filled with cement.
- 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 K-41 for the 9⅝" production casing (drilling of phase 2) are introduced and discussed but the analysis and the results of the televiewer logging will be given in a separate report. Overview of the wireline loggings is given in Table 5.

The drilling of phase 2 started August 2nd with drilling in the cement float collar at 268 m depth. The first Gyro log for motor orientation was run when drilling depth was 310 m, which is the kick-off point (KOP). A total of six Gyro runs were performed in phase 2. Two temperature logs were performed to locate feed points for cementing during the drilling phase 2. Production casing (9⅝") depth was reached at 1040 m on Wednesday, August 10th when the drill string got stuck in mud after a failure with one of the mud pumps. Early morning on August 12th, the drill string got unstuck and then pulled out of hole (POOH). Geophysical logging started right after the bottom hole assembly (BHA) had been pulled out at midnight August 12th.

The logging program consisted of the following measurements: Temperature, XY-caliper, electric properties, including normal resistivity and spontaneous potential, neutron-neutron response (back scattering of thermal neutrons), natural gamma radiation from the formation and acoustic televiewer. Temperature log and Cement bond log was performed after cementing of the casing production.

Table 5. *Geophysical logs in phase 2 of K-41.*

Date	Time	Log type	Depth (m)	Purpose	Q [L/s]	Remarks
2.8.2016	13:48-14:20	Gyro	50-275	Motor-tool face	0	Survey depths: 50, 100, 150, 200, 250 and 275 m.
3.8.2016	04:58-05:14	Gyro	273-350	Incl. & azimuth	0	Survey depths: 273, 300, 330 and 350 m.
3.8.2016	18:23-18:37	Gyro	350-413	Incl. & azimuth	0	Survey depths: 350, 380 and 413 m.
4.8.2016	21:16-21:37	Temperature	0-566	Temp / feed point location	-27	33 L/s pumped on kill-line
5.8.2016	02:11-02:30	Gyro	413-557	Incl. & azimuth	0	
5.8.2016	14:35 – 14:52	Temperature	5-483	Temp / feed point location	-18	25 L/s pumped on kill-line
7.8.2016	14:54-15:15	Gyro	557-651	Incl. & azimuth	0	Survey depths: 557, 590, 620 and 651 m.
8.8.2016	13:11-14:20	Gyro	651-803	Incl. & azimuth	0	Survey depths: 651m, 680m, 720m, 750m, 780m, 803m
13.8.2016	01:06-01:42	Temperature	0-1029	Temp / feed point location	-21	21 L/s pumped on kill-line
13.8.2016	03:15-04:01	XY-Caliper	250-1027	Well diameter	-21	
13.8.2016	06:43-11:45	Televiewer	290-1027	Lithology	-21	
13.8.2016	13:10-14:45	Neutron-Neutron	270-1027	Lithology	-21	
13.8.2016	13:10-14:45	Gamma	270-1027	Lithology	-21	
13.8.2016	15:44-16:09	Resistivity	280-1029	Lithology	-21	
15.8.2016	19:58-20:30	Temperature	20-957	Temperature	0	Probe hung up at 957 m depth
15.8.2016	23:16-00:11	CBL	6-950	Cement Bond	0	17 hours after cement job

4.1 Gyro surveys

Table 6 shows the design parameters for the directional drilling of well K-41 including kick-off-point (KOP), angle build-up (AB), inclination and azimuth. To reach the target zones the direction of the well was planned at 70 ± 5° and inclination 35 ± 3° (310–1000 MD). Logging engineers from ÍSOR carried out six gyro surveys in phase 2 of well K-41 and the corresponding depth intervals are listed in Table 7. The same tool, SPT-1408, was used in all the runs.

The first Gyro survey was conducted on August 2nd for the depth interval down to 275 m when the motor "tool face" was logged. The second gyro survey was conducted for depths 273–350 m. For the reminder of the drilling job, four 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 8th when drilled depth was 842 m and the well was logged down to 803 m depth.

Table 6. *Target for inclination and azimuth in well K-41.*

Azimuth	KOP	AB	Inclination	Target
70°	310 m	2,5°/30 m	35°	1700–2000 m (MD)

Table 7 shows all the gyro surveys run in well K-41. The combined results of the Gyro surveys in K-41 are presented in Table 8, including derived parameters. The calculated well path from the measured inclination and azimuth data together with the designed well path and corresponding deviation limits is shown in Figure 17.

The results show that the inclination at 803 m depth is 35.25° and the azimuth 72.7°.

Table 7. *Gyro surveys carried out in phase 2 of well K-41.*

Date	Depth interval (m)	Tool
2.8.2016	50–275	SPT 1408
3.8.2016	273–350	SPT 1408
3.8.2016	350–413	SPT 1408
5.8.2016	413–557	SPT 1408
7.8.2016	557–651	SPT 1408
8.8.2016	651–803	SPT 1408

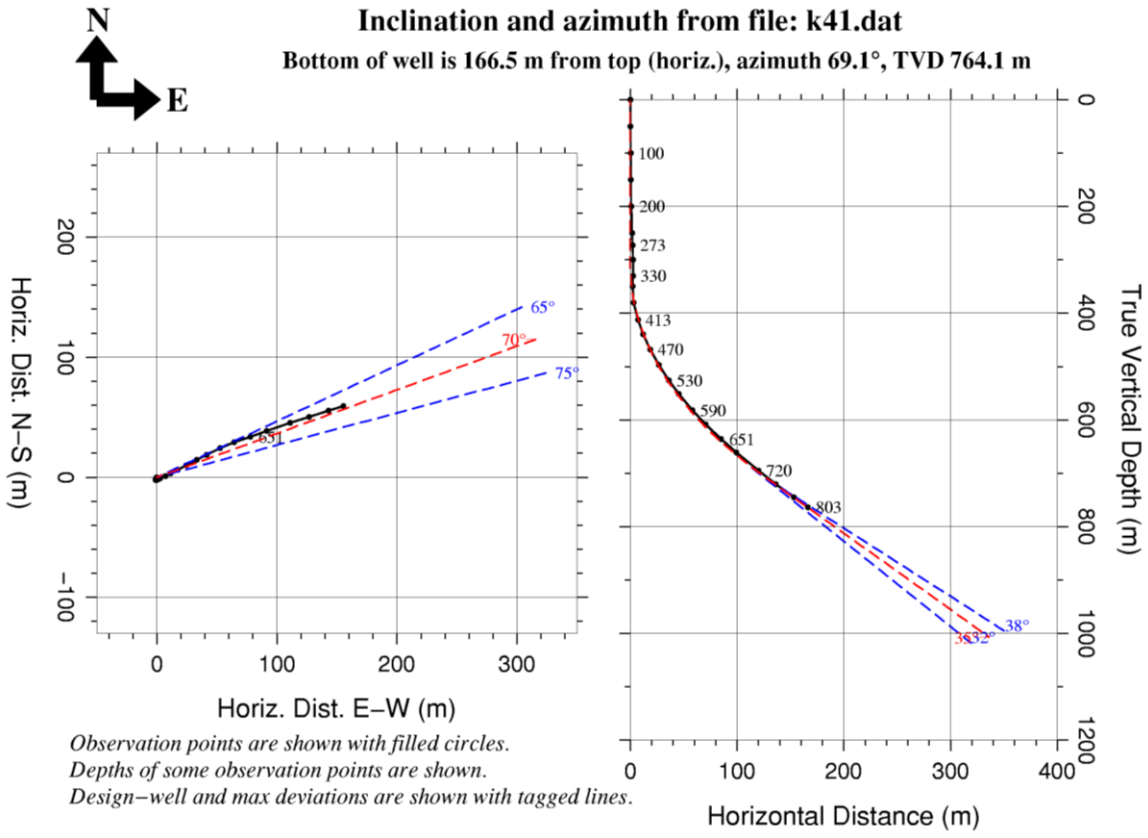


Figure 17. *Calculated well path from the measured inclination and azimuth data together with the designed well path and corresponding deviation limits.*

Table 8. *Inclination, azimuth and derived parameters for well K-41.*

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	602984.2	580998.1	571
50	0.21	221.1	0	50	602984.1	580998.0	521
100	0.20	241.9	0	100	602983.9	580997.9	471
150	0.42	197.2	1	150	602983.8	580997.7	421
200	0.50	208.1	1	200	602983.7	580997.3	371
250	0.95	206.3	2	250	602983.4	580996.8	321
273	1.08	206.3	2	273	602983.2	580996.4	298
300	0.98	195.8	2	300	602983.0	580995.9	271
330	2.03	80.9	2	330	602983.5	580995.8	241
350	3.81	69.8	2	350	602984.4	580996.1	221
380	6.58	66.8	3	380	602987.0	580997.1	191
413	9.49	65.3	7	413	602991.2	580999.0	159
440	11.46	63.3	12	439	602995.6	581001.1	132
470	14.49	62.2	19	468	603001.6	581004.2	103
500	17.16	61.8	27	497	603008.8	581008.0	74
530	19.82	62.0	36	526	603017.2	581012.5	46
557	21.06	63.3	46	551	603025.6	581016.8	20
590	23.82	65.9	58	581	603036.9	581022.2	-10
620	26.37	68.3	71	609	603048.7	581027.2	-38
651	28.78	72.8	85	636	603062.2	581031.9	-65
680	30.47	69.6	99	661	603075.8	581036.6	-90
720	31.95	71.8	120	695	603095.3	581043.4	-124
750	34.23	72.1	136	721	603110.9	581048.5	-150
780	34.76	72.8	153	745	603127.1	581053.6	-174
803	35.25	72.7	167	764	603139.7	581057.5	-193

4.2 Temperature, XY-caliper and geophysical logs

20 L/s circulation loss occurred at 547 m depth and when the depth reached 566 m, it was decided to plug the loss zone. The circulation loss decreased and was measured 12.5 L/s when the drilling finished. After the bottom hole assembly (BHA) had been pulled out of hole (POOH) the circulation loss was estimated about 27 L/s. ÍSOR logging engineers arrived on the site to complete a temperature survey in order to accurately locate the leakage zone, see Figure

18 (red curve). Measurements started at 9:00 pm August 4th. The temperature log showed that most of the 27 L/s injected water exited at BOH.

A fluid loss evaluation was completed once the cement was dry around noon on August 5th, and shown 18 L/s of losses while the cement top was evaluated at 490 m depth. A temperature log was run at 2:00 pm by ÍSOR logging engineers (Figure 18, blue curve). The temperature log showed this time that that most of the 18 L/s injected water exited at ≈ 360 m depth.

When the target depth for the production casing was reached at 1040 m, Wednesday, August 10th the drill string got stuck in mud after a failure with one of the mud pump. Early morning on August 12th, the drill string got unstuck and then pulled out of hole (POOH). Geophysical logging started right after the bottom hole assembly (BHA) had been pulled out at midnight August 12th. The circulation loss in the well was estimated about 21 L/s. The program started with a temperature log on August 13th at 01:06. The temperature profile is shown in Figure 18 (green curve). The temperature log showed that large fraction of the 21 L/s injected water exits the well into a feed zone at 1000 m depth but the feed zone at 550–560 m also accepts a considerable amount of the injected water. The temperature rises below 1000 m but still it is considered that a minor water flow is towards the bottom hole region. All the logging tools in the open hole logging stopped at around 1027–1029 m. This indicates that there was ~11 m bottom fill deposits in the well before the casing was run in hole.

After the temperature log was finished, the 4-arm XY-caliper tool was used to log the well's diameter. The results are shown in Figure 19, where the caliper log shows no obstacles and no major cavities.. The caliper log indicates some eccentricity of the well's cross sectional area (elliptical form) that is common in directionally drilled wells.

The traditional cement washout right below the anchor casing was there, but besides that there was one minor washout at 1000 m where the largest loss zone was located. The caliper log indicated that a minimum of 40 m^3 of cement was needed to fill the annulus outside the 9⅝" production casing. The resistivity log shows rather intermediate or low values, exceeds 100 Ωm at only few places (Figure 20). At 570 m there was some change in character with decreased resistivity down to ~700 m. There below more anomalies appear, indicating layers of less altered formation. No major anomalies are seen in the neutron-neutron response and most of the log shows values 1000–2000 API (Figure 20). However, at 520 m there is a clear change of character of the NN-response where the cutting analysis shows transition from breccia to medium to coarse grained basalt. At 965 m there is a rapid decrease in the NN-response where also the resistivity decreases and the caliper increases.

The natural gamma radiation log shows (Figure 20) basaltic character for most of the well but clear silicic anomalies appear at 463, 550, 673–679, 735–745, 760–773 and 1002 m where there is a clear loss zone.

4.3 Cement bond logs

The cementing of the 9⅝" production casing was finished August 15th at 06:30. In total, 55 m^3 of cement were used. ÍSOR´s logging engineers started temperature and CBL logging shortly after dinner August 15th. The temperature log was performed first and the results can be seen in Figure 21 (red curve). The temperature tool hung up at 957 m depth and got stuck in cement slurry inside the casing and only got loose after pulling on it with considerable force. The highest temperature measured was 111°C, at 800 m depth.

The CBL log was carried out approximately 17 hours after cementing (Figures 22 and 23). The CBL-tool hung up at 950 m depth and revealed that cement was behind the casing at all depths. The cement was still very soft between the casings and the cement bond was especially poor in the interval 145–170 m. Below the anchor casing the cement looked good in most places, even though the signal is dampened in some places i.e. 375, 510 and 725 m.

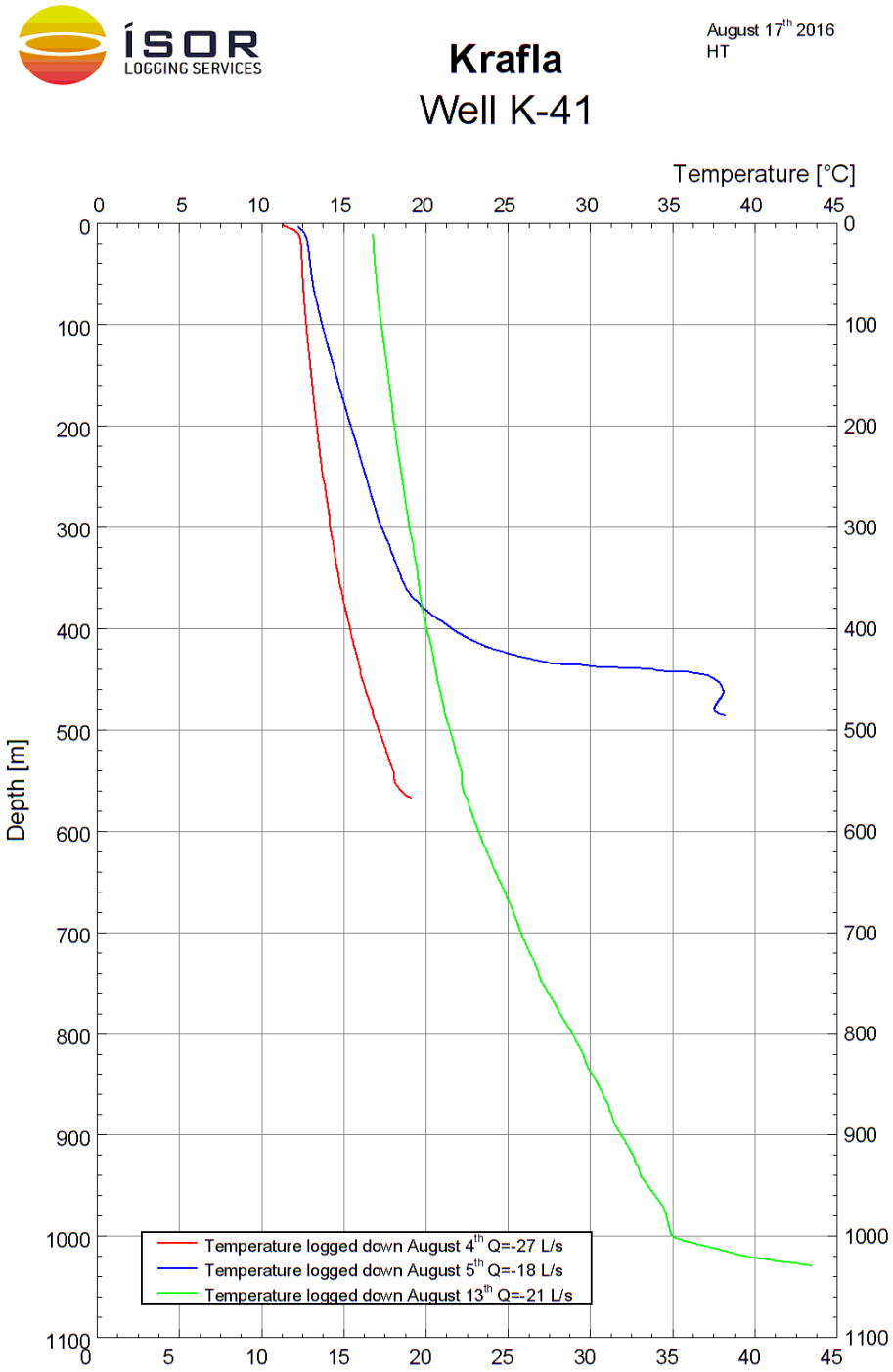


Figure 18. *Temperature logs in well K-41 at drilling phase 2.*

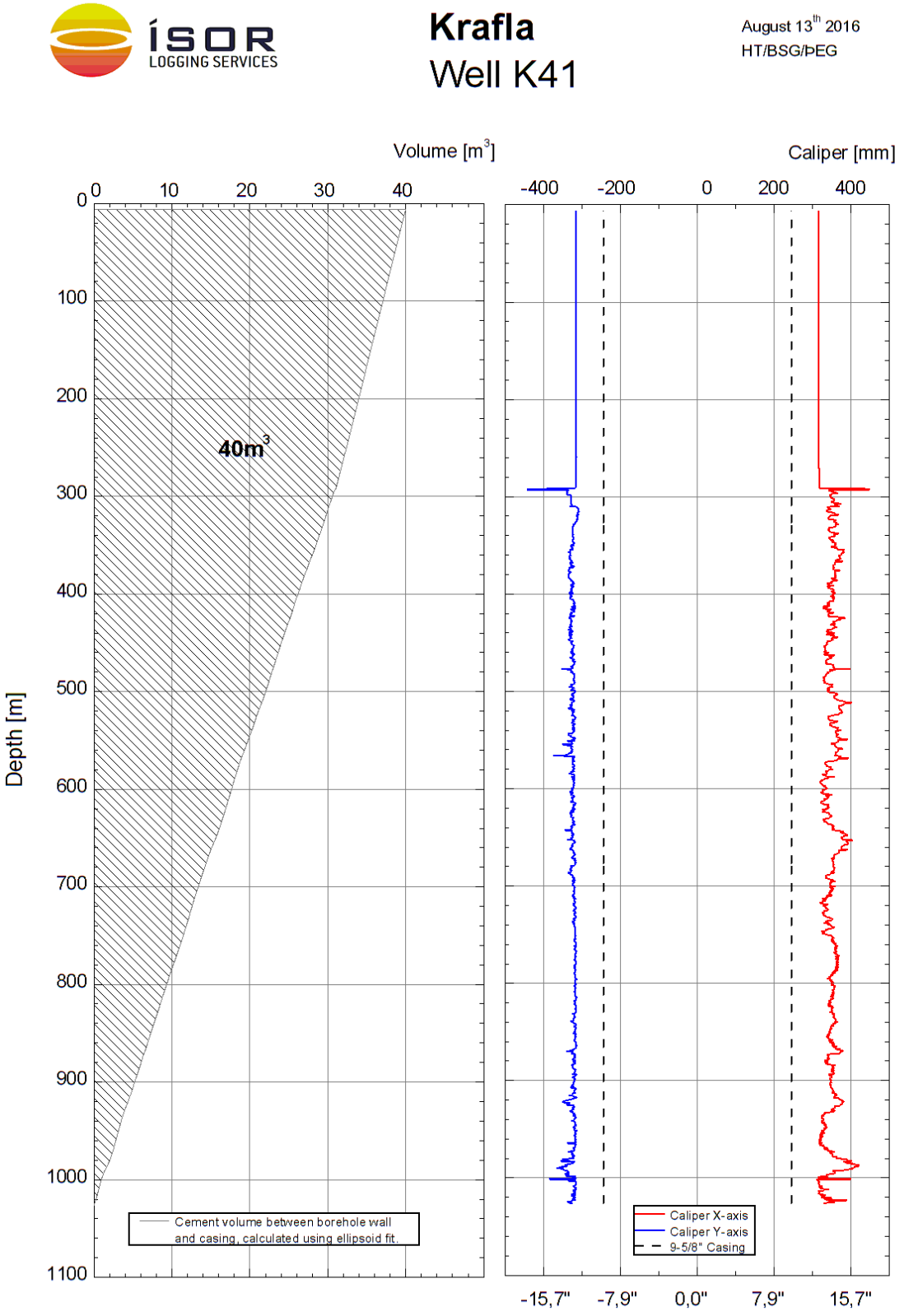


Figure 19. *Caliper log and an estimated amount of cement for the production casing in K-41.*

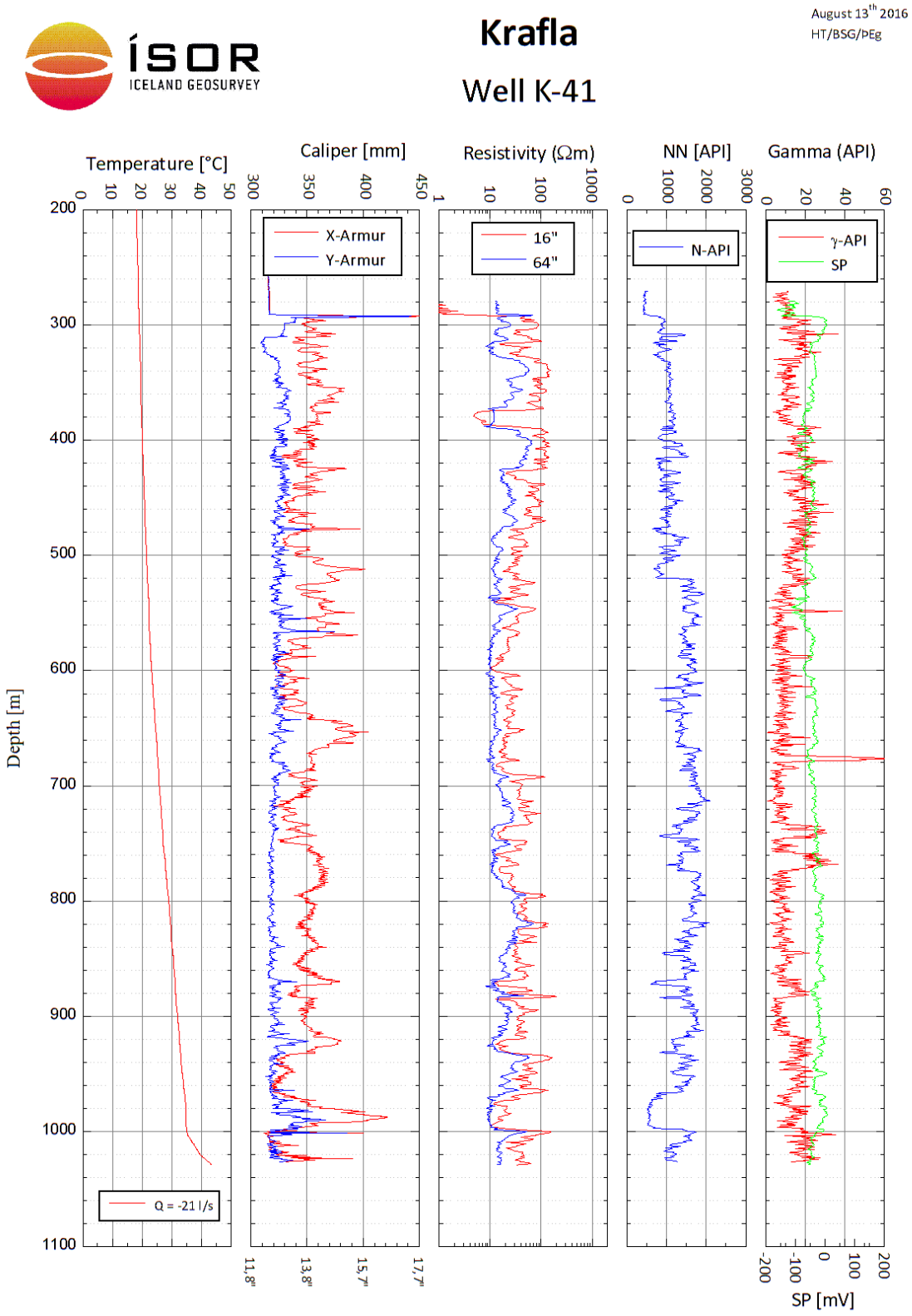


Figure 20. *Geophysical logs after phase 2 of the drilling of well K-41.*

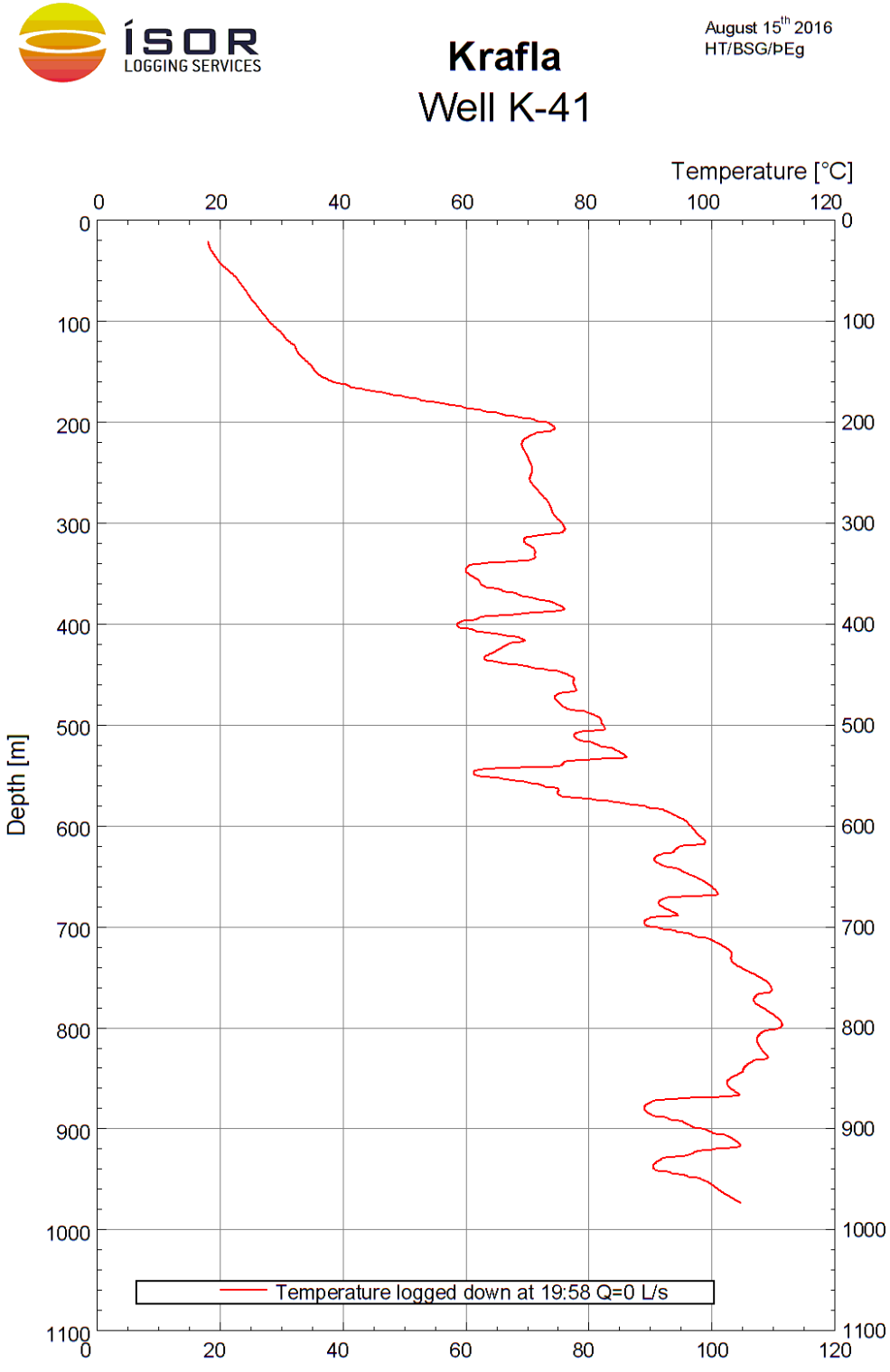


Figure 21. *Temperature log before CBL log in well K-41 at drilling phase 2.*

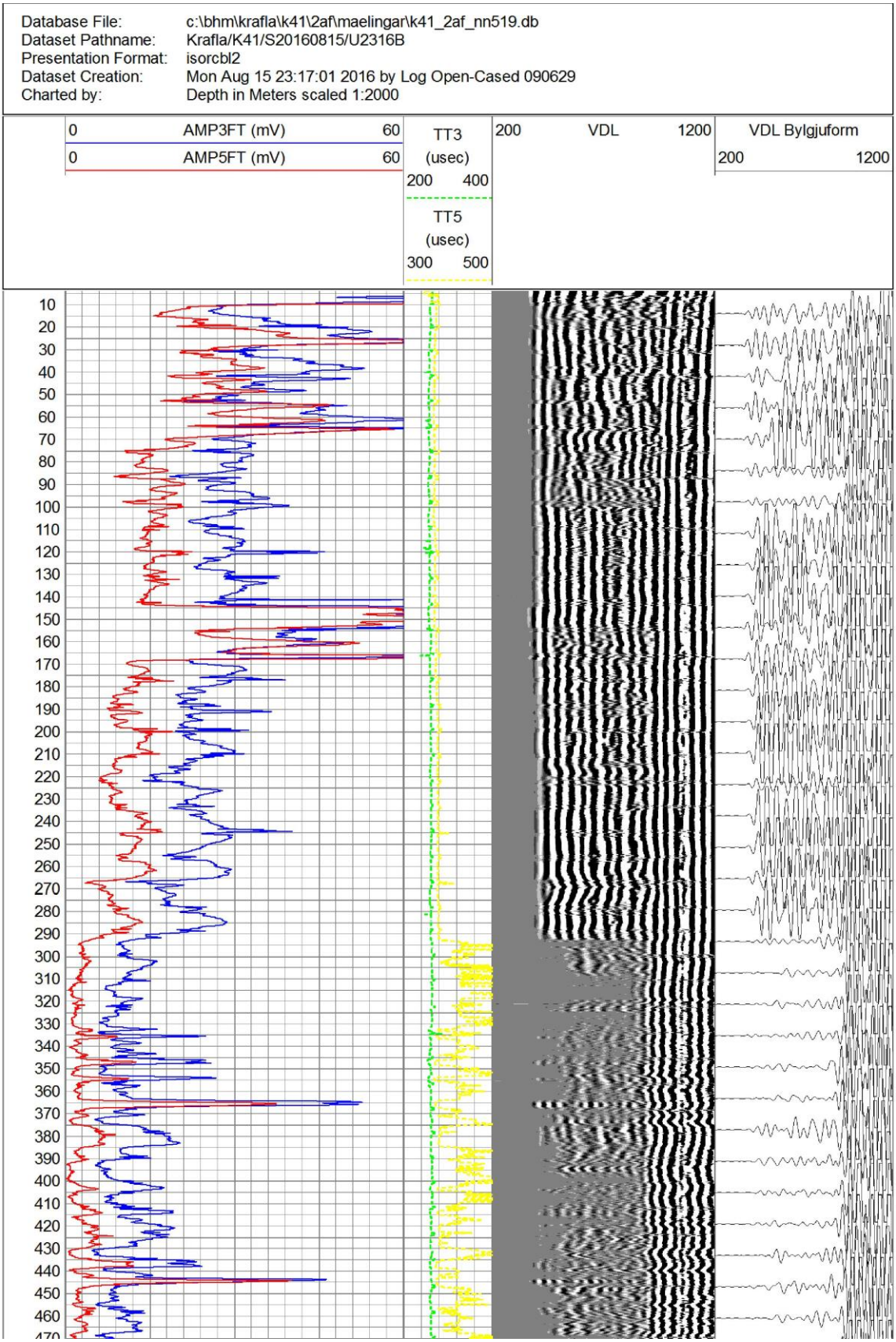


Figure 22. *Cement Bond Log – Production casing, ~17 hours after cementing.*

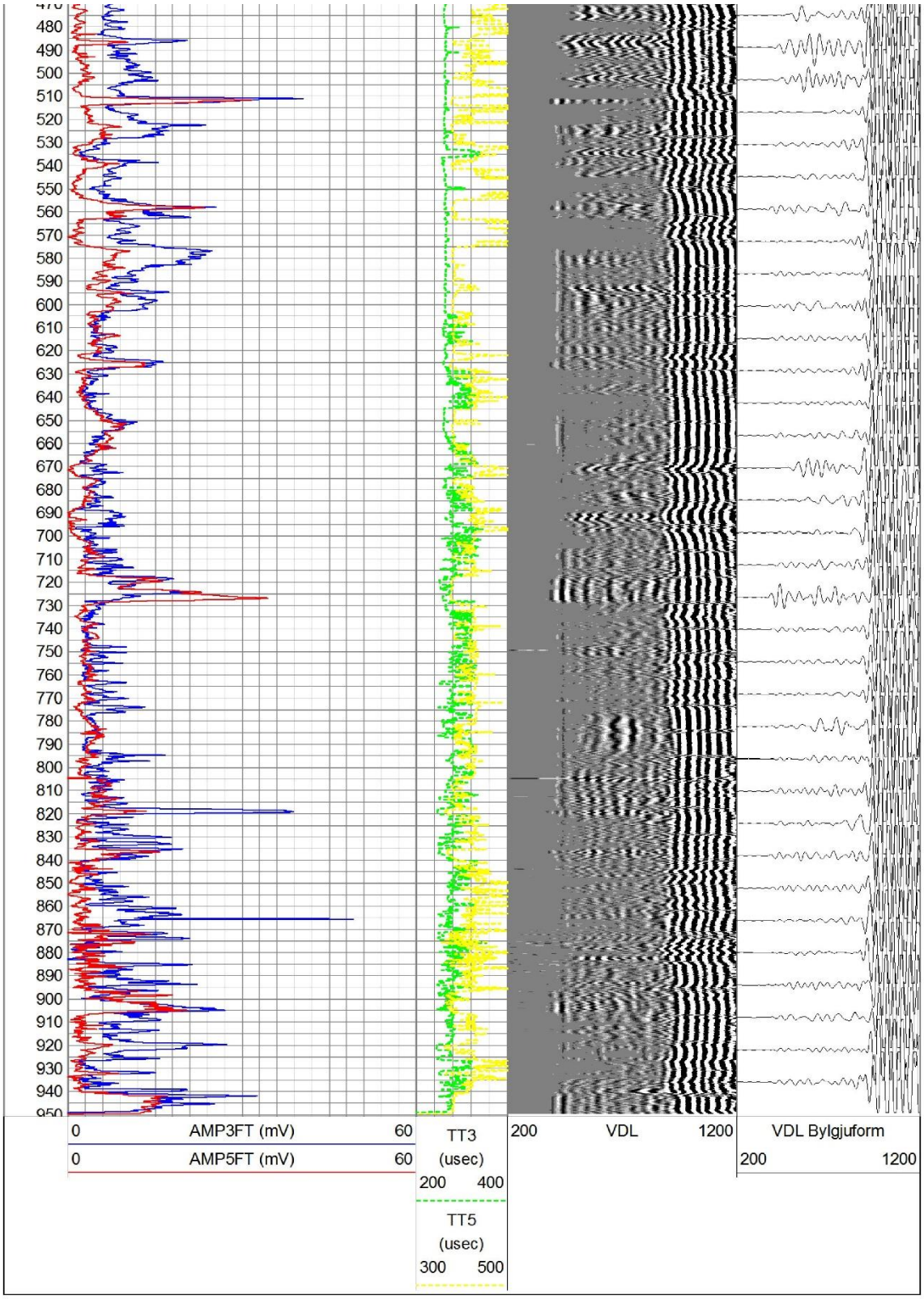


Figure 23. *Cement Bond Log – Production casing, ~17 hours after cementing.*

5 References

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Appendix A: 9⅝" production casing report

ICELAND DRILLING

Casing Tally Run Report
Rig: Sleipnir
Job No: 28178

Jarðboranir
Rig No: 28000
Job Name: K 41

String Nominal OD (cm): 24,45 **String Type: FULL**

Items Run:	**94**	**Length Run:**	**1.040,760**	**Top Depth:**	**5,600**
Items Excluded:	**0**	**Length Excluded:**	**0,000**	**Bottom Depth:**	**1.036,080**
Items Tallied:	**94**	**Length All Items:**	**1.040,760**	**Cut Off Length:**	**10,280**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
1		SHOE	0,570	1.035,510	1.036,080	24,45 x 22,66 K-55 BUTT			
2	92	JOINT	11,380	1.024,130	1.035,510	24,45 x 22,66 K-55 BUTT		2	
3	91	JOINT	11,600	1.012,530	1.024,130	24,45 x 22,66 K-55 BUTT		1	
4		FLOAT	0,540	1.011,990	1.012,530	24,45 x 22,66 K-55 BUTT		1	
5	90	JOINT	11,000	1.000,990	1.011,990	24,45 x 22,66 K-55 BUTT		1	
6	89	JOINT	11,120	989,870	1.000,990	24,45 x 22,66 K-55 BUTT		1	
7	88	JOINT	11,160	978,710	989,870	24,45 x 22,66 K-55 BUTT		1	
8	87	JOINT	11,190	967,520	978,710	24,45 x 22,66 K-55 BUTT		1	
9	86	JOINT	11,110	956,410	967,520	24,45 x 22,66 K-55 BUTT		1	
10	85	JOINT	11,480	944,930	956,410	24,45 x 22,66 K-55 BUTT		1	
11	84	JOINT	11,230	933,700	944,930	24,45 x 22,66 K-55 BUTT		1	
12	83	JOINT	11,370	922,330	933,700	24,45 x 22,66 K-55 BUTT		1	
13	82	JOINT	11,110	911,220	922,330	24,45 x 22,66 K-55 BUTT		1	
14	81	JOINT	11,080	900,140	911,220	24,45 x 22,66 K-55 BUTT		1	
15	80	JOINT	11,730	888,410	900,140	24,45 x 22,66 K-55 BUTT		1	
16	79	JOINT	11,410	877,000	888,410	24,45 x 22,66 K-55 BUTT		1	
17	78	JOINT	11,270	865,730	877,000	24,45 x 22,66 K-55 BUTT		1	
18	77	JOINT	11,070	854,660	865,730	24,45 x 22,66 K-55 BUTT		1	
19	76	JOINT	11,710	842,950	854,660	24,45 x 22,66 K-55 BUTT		1	
20	75	JOINT	10,830	832,120	842,950	24,45 x 22,66 K-55 BUTT		1	
21	74	JOINT	11,270	820,850	832,120	24,45 x 22,66 K-55 BUTT		1	
22	73	JOINT	11,670	809,180	820,850	24,45 x 22,66 K-55 BUTT		1	
23	72	JOINT	10,990	798,190	809,180	24,45 x 22,66 K-55 BUTT		1	
24	71	JOINT	11,060	787,130	798,190	24,45 x 22,66 K-55 BUTT		1	
25	70	JOINT	11,280	775,850	787,130	24,45 x 22,66 K-55 BUTT		1	
26	69	JOINT	11,400	764,450	775,850	24,45 x 22,66 K-55 BUTT		1	
27	68	JOINT	11,130	753,320	764,450	24,45 x 22,66 K-55 BUTT		1	
28	67	JOINT	11,620	741,700	753,320	24,45 x 22,66 K-55 BUTT		1	
29	66	JOINT	11,070	730,630	741,700	24,45 x 22,66 K-55 BUTT		1	
30	65	JOINT	11,110	719,520	730,630	24,45 x 22,66 K-55 BUTT		1	
31	64	JOINT	11,690	707,830	719,520	24,45 x 22,66 K-55 BUTT		1	
32	63	JOINT	11,670	696,160	707,830	24,45 x 22,66 K-55 BUTT		1	
33	62	JOINT	11,390	684,770	696,160	24,45 x 22,66 K-55 BUTT		1	
34	61	JOINT	11,350	673,420	684,770	24,45 x 22,66 K-55 BUTT		1	
35	60	JOINT	11,290	662,130	673,420	24,45 x 22,66 K-55 BUTT		1	
36	59	JOINT	11,690	650,440	662,130	24,45 x 22,66 K-55 BUTT		1	
37	58	JOINT	11,100	639,340	650,440	24,45 x 22,66 K-55 BUTT		1	
38	57	JOINT	11,100	628,240	639,340	24,45 x 22,66 K-55 BUTT		1	
39	56	JOINT	11,330	616,910	628,240	24,45 x 22,66 K-55 BUTT		1	
40	55	JOINT	11,700	605,210	616,910	24,45 x 22,66 K-55 BUTT		1	
41	54	JOINT	11,570	593,640	605,210	24,45 x 22,66 K-55 BUTT		1	

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ICELAND DRILLING

Casing Tally Run Report

Rig: Sleipnir
Job No: 28178

Jarðboranir
Rig No: 28000
Job Name: K 41

String Nominal OD (cm): 24,45 **String Type: FULL**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
42	53	JOINT	11,690	581,950	593,640	24,45 x 22,66 K-55 BUTT		1	
43	52	JOINT	11,680	570,270	581,950	24,45 x 22,66 K-55 BUTT		1	
44	51	JOINT	11,250	559,020	570,270	24,45 x 22,66 K-55 BUTT		1	
45	50	JOINT	11,120	547,900	559,020	24,45 x 22,66 K-55 BUTT		1	
46	49	JOINT	11,490	536,410	547,900	24,45 x 22,66 K-55 BUTT		1	
47	48	JOINT	11,650	524,760	536,410	24,45 x 22,66 K-55 BUTT		1	
48	47	JOINT	11,700	513,060	524,760	24,45 x 22,66 K-55 BUTT		1	
49	46	JOINT	11,700	501,360	513,060	24,45 x 22,66 K-55 BUTT		1	
50	45	JOINT	11,130	490,230	501,360	24,45 x 22,66 K-55 BUTT		1	
51	44	JOINT	11,970	478,260	490,230	24,45 x 22,66 K-55 BUTT		1	
52	43	JOINT	11,660	466,600	478,260	24,45 x 22,66 K-55 BUTT		1	
53	42	JOINT	11,190	455,410	466,600	24,45 x 22,66 K-55 BUTT		1	
54	41	JOINT	11,100	444,310	455,410	24,45 x 22,66 K-55 BUTT		1	
55	40	JOINT	11,050	433,260	444,310	24,45 x 22,66 K-55 BUTT		1	
56	39	JOINT	10,980	422,280	433,260	24,45 x 22,66 K-55 BUTT		1	
57	38	JOINT	10,980	411,300	422,280	24,45 x 22,66 K-55 BUTT		1	
58	37	JOINT	11,420	399,880	411,300	24,45 x 22,66 K-55 BUTT		1	
59	36	JOINT	11,220	388,660	399,880	24,45 x 22,66 K-55 BUTT		1	
60	35	JOINT	11,680	376,980	388,660	24,45 x 22,66 K-55 BUTT		1	
61	34	JOINT	11,140	365,840	376,980	24,45 x 22,66 K-55 BUTT		1	
62	33	JOINT	11,120	354,720	365,840	24,45 x 22,66 K-55 BUTT		1	
63	32	JOINT	11,200	343,520	354,720	24,45 x 22,66 K-55 BUTT			
64	31	JOINT	11,090	332,430	343,520	24,45 x 22,66 K-55 BUTT			
65	30	JOINT	11,070	321,360	332,430	24,45 x 22,66 K-55 BUTT		1	
66	29	JOINT	11,240	310,120	321,360	24,45 x 22,66 K-55 BUTT			
67	28	JOINT	11,090	299,030	310,120	24,45 x 22,66 K-55 BUTT			
68	27	JOINT	11,150	287,880	299,030	24,45 x 22,66 K-55 BUTT		1	
69	26	JOINT	11,000	276,880	287,880	24,45 x 22,66 K-55 BUTT			
70	25	JOINT	10,930	265,950	276,880	24,45 x 22,66 K-55 BUTT			
71	24	JOINT	11,190	254,760	265,950	24,45 x 22,66 K-55 BUTT		1	
72	23	JOINT	11,270	243,490	254,760	24,45 x 22,66 K-55 BUTT			
73	22	JOINT	10,940	232,550	243,490	24,45 x 22,66 K-55 BUTT			
74	21	JOINT	11,080	221,470	232,550	24,45 x 22,66 K-55 BUTT		1	
75	20	JOINT	11,190	210,280	221,470	24,45 x 22,66 K-55 BUTT			
76	19	JOINT	11,330	198,950	210,280	24,45 x 22,66 K-55 BUTT			
77	18	JOINT	11,160	187,790	198,950	24,45 x 22,66 K-55 BUTT		1	
78	17	JOINT	11,060	176,730	187,790	24,45 x 22,66 K-55 BUTT			
79	16	JOINT	11,100	165,630	176,730	24,45 x 22,66 K-55 BUTT			
80	15	JOINT	11,170	154,460	165,630	24,45 x 22,66 K-55 BUTT		1	
81	14	JOINT	11,060	143,400	154,460	24,45 x 22,66 K-55 BUTT			
82	13	JOINT	11,370	132,030	143,400	24,45 x 22,66 K-55 BUTT			
83	12	JOINT	11,680	120,350	132,030	24,45 x 22,66 K-55 BUTT		1	
84	11	JOINT	11,490	108,860	120,350	24,45 x 22,66 K-55 BUTT			
85	10	JOINT	11,650	97,210	108,860	24,45 x 22,66 K-55 BUTT			

ICELAND DRILLING

Casing Tally Run Report

Rig: Sleipnir

Job No: 28178

Jarðboranir

Rig No: 28000

Job Name: K 41

String Nominal OD (cm): 24,45 **String Type: FULL**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
86	9	JOINT	11,130	86,080	97,210	24,45 x 22,66 K-55 BUTT		1	
87	8	JOINT	11,090	74,990	86,080	24,45 x 22,66 K-55 BUTT			
88	7	JOINT	11,630	63,360	74,990	24,45 x 22,66 K-55 BUTT			
89	6	JOINT	11,410	51,950	63,360	24,45 x 22,66 K-55 BUTT		1	
90	5	JOINT	11,640	40,310	51,950	24,45 x 22,66 K-55 BUTT			
91	4	JOINT	11,710	28,600	40,310	24,45 x 22,66 K-55 BUTT			
92	3	JOINT	10,670	17,930	28,600	24,45 x 22,66 K-55 BUTT		1	
93	2	JOINT	11,650	6,280	17,930	24,45 x 22,66 K-55 BUTT			
94	1	JOINT	10,960	-4,680	6,280	24,45 x 22,66 K-55 BUTT			

Appendix B

Daily reports

ÍSOR ICELAND GEOSURVEY	K-41	Tuesday 2nd of August 2016 Workday #14 of Sleipnir

Krafla	**Report for Workday #14** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSÁ (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	293.5 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	293.5 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	- m/hr

Drilling operation

The new flange was welded on the 13⅜" casing at midnight and a BOP stack installed. After a short maintenance break, the BOP's and flowline were connected. The BOP stack was pressure tested in the afternoon by applying pressure of 30 bar for 15 min. No major issues occurred and at 18:30 RIH of a 12¼" BHA started.

After drilling through cement, drilling into formation commenced this morning at around 8:00. Drilling will continue until 310 m (KOP) and then ÍSOR's logging engineers will carry out surveys. Figure 1 shows the progress of the drilling so far.

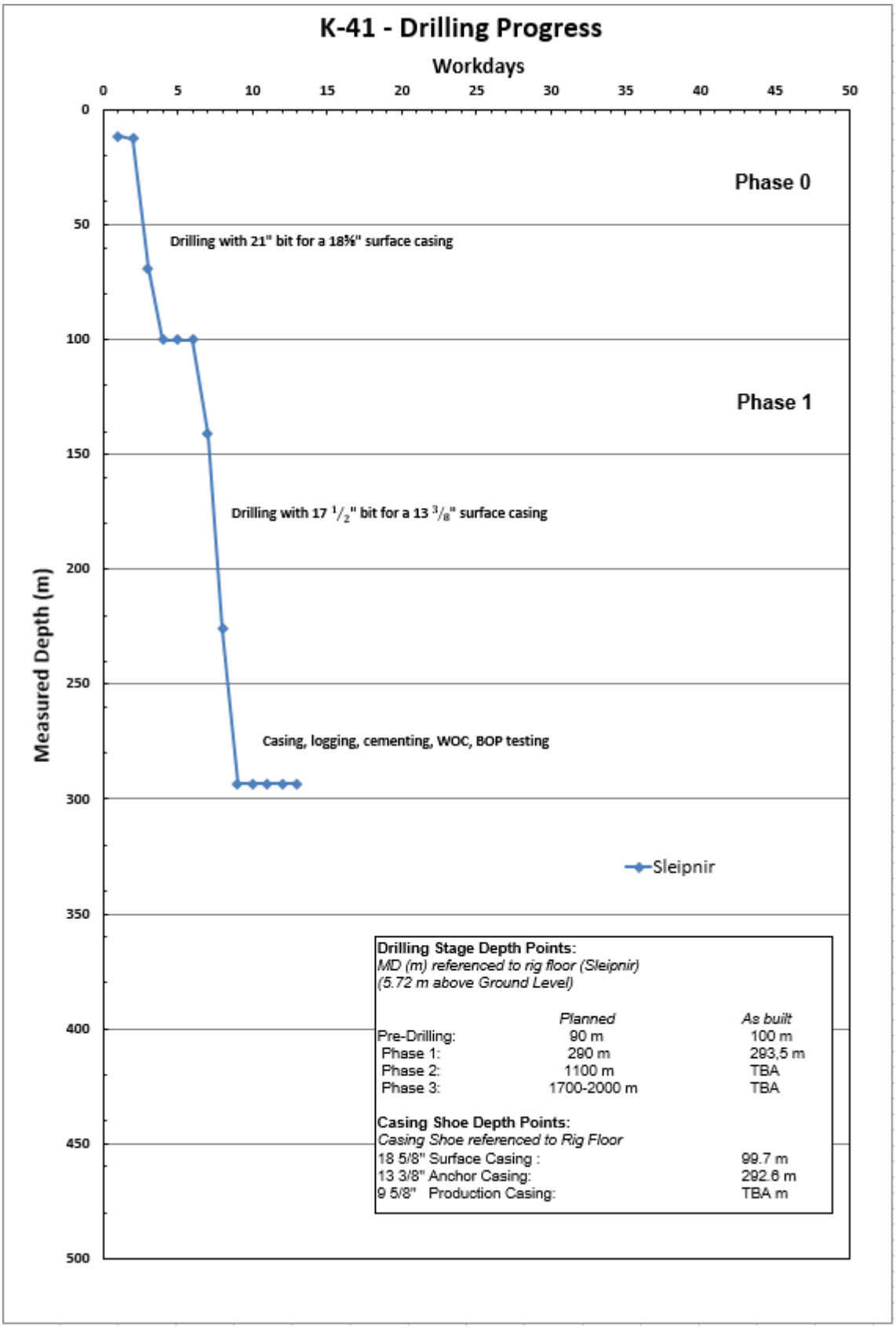

Figure 1. Drilling process for well K-41.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Wednesday 3rd of August 2016 Workday #15 of Sleipnir

Krafla	**Report for Workday #15** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSÁ, HT, VG, HÖS (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	364 m	Hole made last 24 hrs. :	70.5 m
Last casing depth:	292.6 m	Depth at 8:00.	402 m	Drilling time:	16.5 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	4.3 m/hr

Drilling operation

Early yesterday morning a BHA with a 12 ¼" bit was RIH. The float collar was tagged at 262 m and the shoe at 293,5 m around noon. Drilling into formation was ongoing until at 310 m. ÍSOR's logging engineers arrived on site before noon and started a gyro survey at 13:45 (Table 1).

Table 1. Gyro survey since yesterday at noon

MD [m]	Incl. [°]	True Az. [°]
273	0.27	204.4
250	0.95	206.3
200	0.50	208.1
150	0.42	197.2
100	0.20	241.9
50	0.21	221.1

Drilling resumed in the afternoon and has been almost continuous since. ÍSOR´s logging engineers arrived on site again early this morning at 2:30 and carried out another gyro survey (Table 2).

Table 2. The gyro survey since early this morning

MD [m]	Incl. [°]	True Az. [°]
347	3.66	69.8
347	3.66	70.4
330	2.03	80.9
300	0.98	195.8
273	1.08	206.3

Due to mistakes at the rig, very few samples were collected from 292-318 m. Basaltic breccia occurs at 318-320 m with little alteration. More altered, medium-coarse grained basalt takes over at 322 m and continuous on at least to 350 m. Cuttings from deeper parts of the well are being analyzed at present.

Borvakt

Krafla	**Report for Workday #16** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSÁ, BP, HT, VG, HÖS (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	488 m	Hole made last 24 hrs. :	124 m
Last casing depth:	292.6 m	Depth at 8:00.	548 m	Drilling time:	18.75 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	20 L/s	Average ROP:	6.6 m/hr

Drilling operation

After ÍSOR´s gyro survey early yesterday morning drilling continued with 55 l/s pumping and WOB of 8-10 ton until 451 m MD. ÍSOR´s logging engineers arrived back on site for another gyro survey (Table 1) at 18:00. Drilling continued without any problems from 451 m. Early this morning, circulation losses were measured 20 l/s at 545 m. Figure 1 shows the lithology of the well down to 450 m MD. Further cutting analysis is taking place at present. Figure 2 shows few parameters from last night, where some heat pulses were observed.

Table 1. Gyro survey since yesterday evening.

MD [m]	Incl. [°]	True Az. [°]
413	9.49	65.3
380	6.58	66.8
350	3.81	69.8

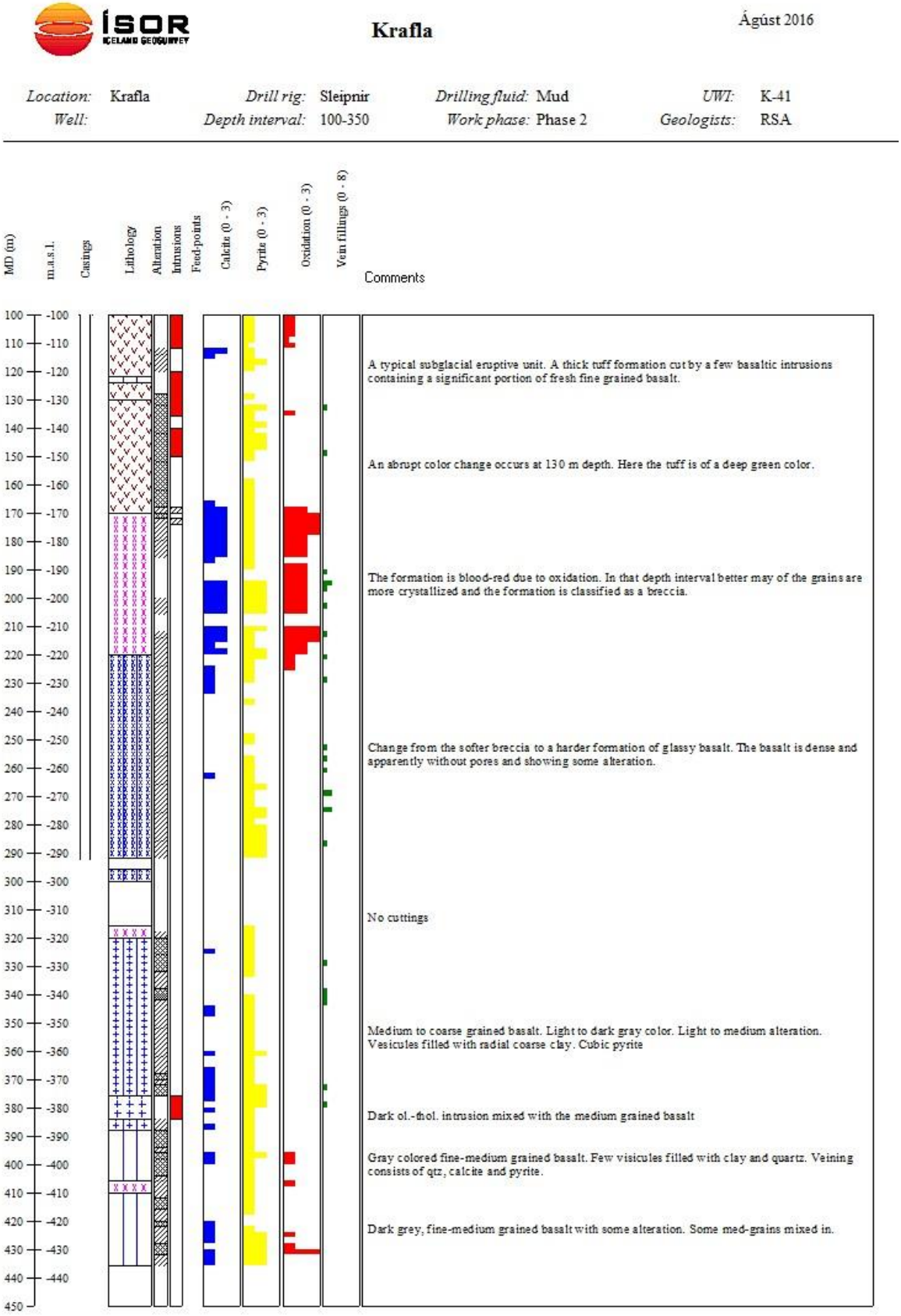

Figure 1. Lithology for well K-41 from -100 to -450 m.

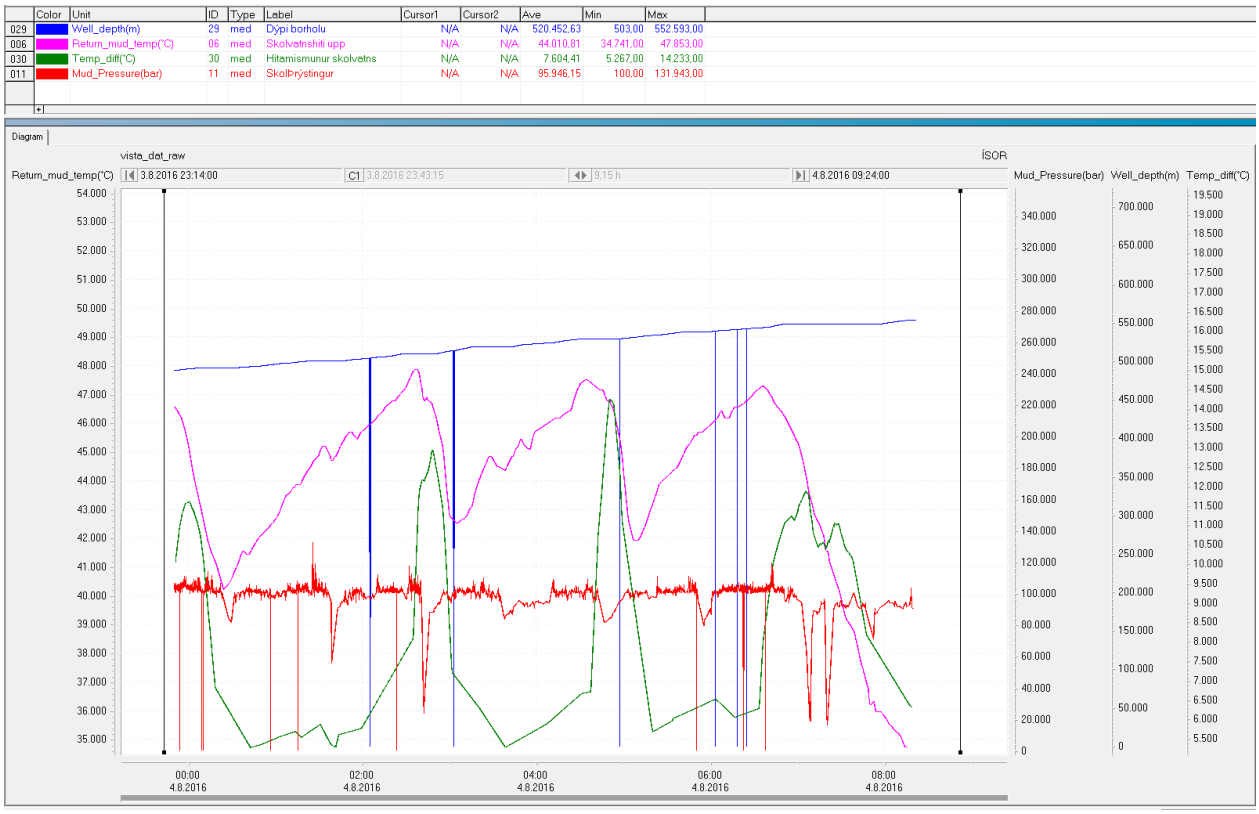

Figure 2. Heat pulses from last midnight until 8 AM this morning.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Friday 5th of August 2016 Workday #17 of Sleipnir

Krafla	**Report for Workday #17** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSÁ, BP, HT, VG, HÖS (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	566 m	Hole made last 24 hrs. :	78 m
Last casing depth:	292.6 m	Depth at 8:00.	566 m	Drilling time:	10.5 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	7.42 m/hr

Drilling operation

Drilling continued throughout the night until 10.30 am, to reach a depth of 566 m. WOB was between 7 and 10 tons and pumping between 53.9 and 55 l/s. Fluid losses measurements are visible in table 1. Drilling was stopped at 10.30 am and after circulating for 1.5 hour, it was decided to cement the bottom of the well to stop the circulation losses. The drilling crew starting POOH at 1.45pm and the drill string was completely out at 5.30pm.

MD [m]	Fluid loss l/s
547	20
557	14
566	12.5

Table 1: Fluid losses measurements

ÍSOR logging engineers arrived on the site to complete a temperature survey. Measurements started at 9.00 pm and took 1.5 hour to complete. The temperature profile can be seen in Figure 1.

At midnight, the drilling crew was putting the cement string in hole.

A gyro survey was completed in the morning of August 5th by ISOR (Table 2) and then the bottom of the well was cemented with 10.4 m^3 at 500 m. Cement will be drying until 1.00pm before checking if there are still circulation losses.

MD	Incl.	TrueAz.
557	21.75	61.8
530	19.82	62.0
500	17.16	61.8
470	14.49	62.2
440	11.46	63.3
413	9.28	63.4

Table 2: Results of gyro survey on August 5th

Geology

316 – 320: BASALTIC BRECCIA

Beige-green color tuffaceous fragments, light alteration, aggregates of fine and coarse grains clay, mixed with fine grains basaltic fragments

320 – 375: BASALT

Medium to coarse grains basalt, grey color, vesicles filled with radial crystals of coarse grain clay, green color, rare pyrite and calcite, presence of quartz

375 – 383: INTRUSION

Olivine tholeiite intrusion, medium-coarse grains, black color, lightly altered. Rare pyrite, veining and light oxidation. Mix with altered basalt similar to above

383 – 388: BASALT

Medium to coarse grains basalt, grey color, vesicles filled with radial crystals of coarse grain clay, green color, rare pyrite and calcite, presence of quartz. Few fragments of intrusive olivine tholeiite.

388 – 406: BASALT

Fine to medium grains basalt, medium to dark grey color, light to moderate alteration, trace of pyrite, presence of fine and coarse grains clay, mostly in vesicles and fractures, associated with quartz and pyrite. Presence of Laumontite at 404m

406 – 410: BASALTIC BRECCIA

Mix of lithologies, fragments of fine grains altered basalt and brecciated appearance fragments. Presence of few crystals of epidote, associated with quartz.

410 - 487: BASALT

Fine to medium grains basalt, medium to dark grey color, light to moderate alteration, trace of pyrite, presence of fine and coarse grains clay, mostly in vesicles and fractures, associated with quartz and pyrite. Few sections are slightly more altered and contain more pyrite. Rare presence of Laumontite crystals and amorphous silica.

487 - 489: INTRUSION

Olivine tholeiite intrusion, medium-coarse grains, black color, lightly altered. Rare pyrite, veining and light oxidation.

489 - 498: BASALTIC BRECCIA

Basaltic breccia, white greenish color, fine tuff grains mixed with basaltic fragments, light alteration, noticeable pyrite associated with quartz and calcite in fracture veining. Presence of oxidized fragments.

498 - 504: BASALT

Fine to medium grain basalt, grey color, light alteration, presence of vesicles filled with clay, quartz and calcite.

504 – 566: BASALTIC BRECCIA

Basaltic breccia, similar to the previous one, green white color, locally pinkish, fine grains tuffaceous material, mixed with altered basaltic fragments. Presence of pyrite and rare fracture filling (clay, quartz, calcite). Wairakite crystals at 546m

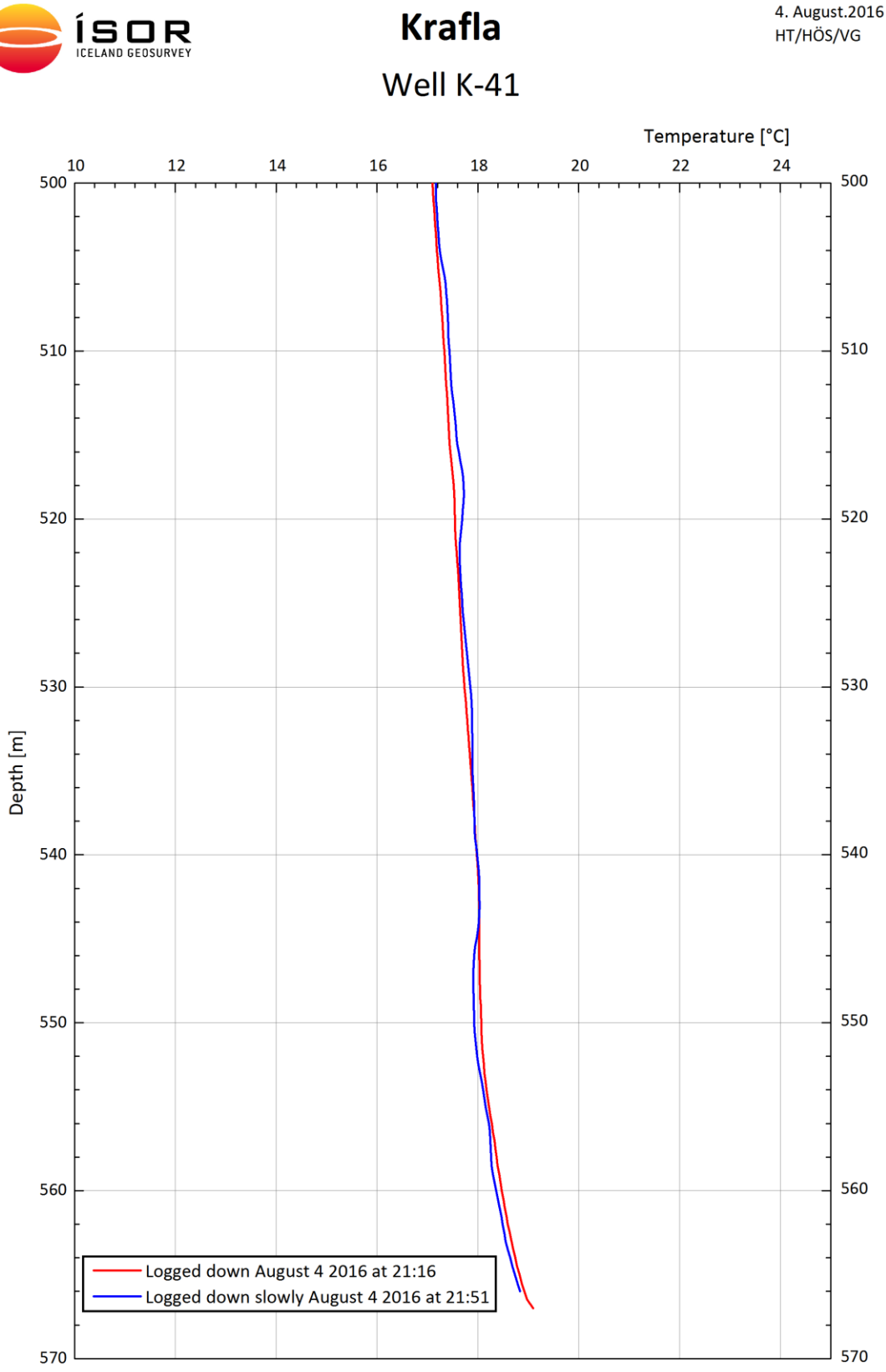

Figure 1: Temperature profile from survey completed on August 4th

Borvakt

Krafla	**Report for Workday #18** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	566 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	566 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	0 m/hr

Drilling operation

After getting the cement string in hole, the gyro survey was completed, as stated in yesterday report (#17). Results are shown in table 1 below.

MD	Incl.	TrueAz.
557	**21.75**	**61.8**
530	19.82	62.0
500	17.16	61.8
470	14.49	62.2
440	11.46	63.3
413	9.28	63.4

Table 1: Results of gyro survey on August 5t

Cement job started at 3.00 am, pumping 10.4 m^3 of cement and 4 m^3 of water. A fluid loss evaluation was completed once the cement was dry around noon, and shown 18 l/s of losses while the cement top was evaluated at 490 m depth. A temperature log was run at 2.00 pm by ISOR logging engineers (see figure 1) and a second fluid loss measurement was completed at 370 m, indicating 21.5 l/s of loss.

Consequently, a second cement job was completed in the afternoon, injecting 6.6 m^3 of cement and 3.1 m^3 of water. The cement was still drying at midnight.

On the morning of August 6th, the drilling string was RIH starting at 3.00 am and drilling through the cement started at 4.20 am with similar BHA as before (Figure 2).

Updated geological column can be seen in Figure 3 and Drilling progress diagram in Figure 4.

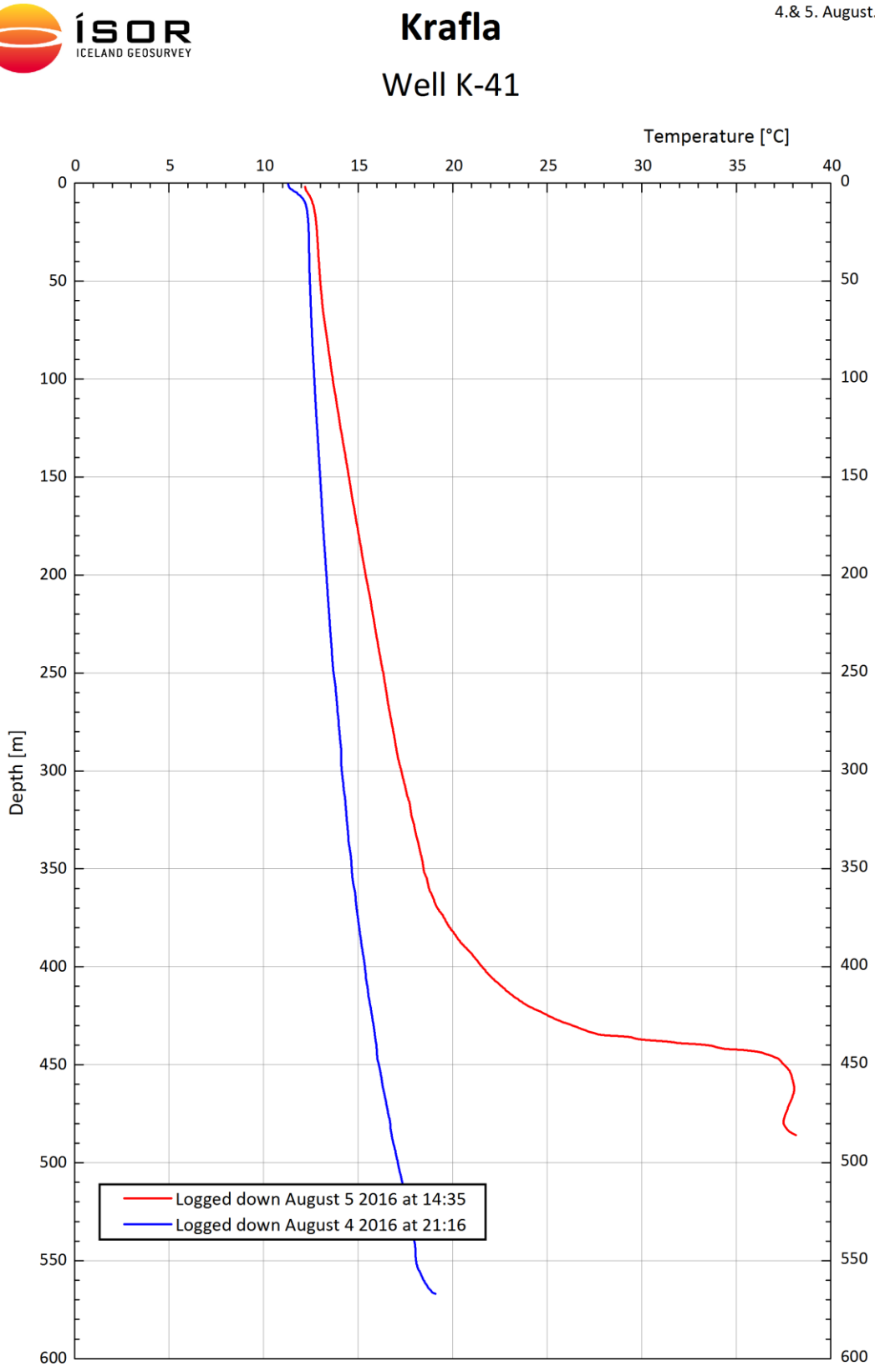

Figure 1: Temperature profiles of August 4th and August 5th (KRA-K41-LB-WL-IS1015)

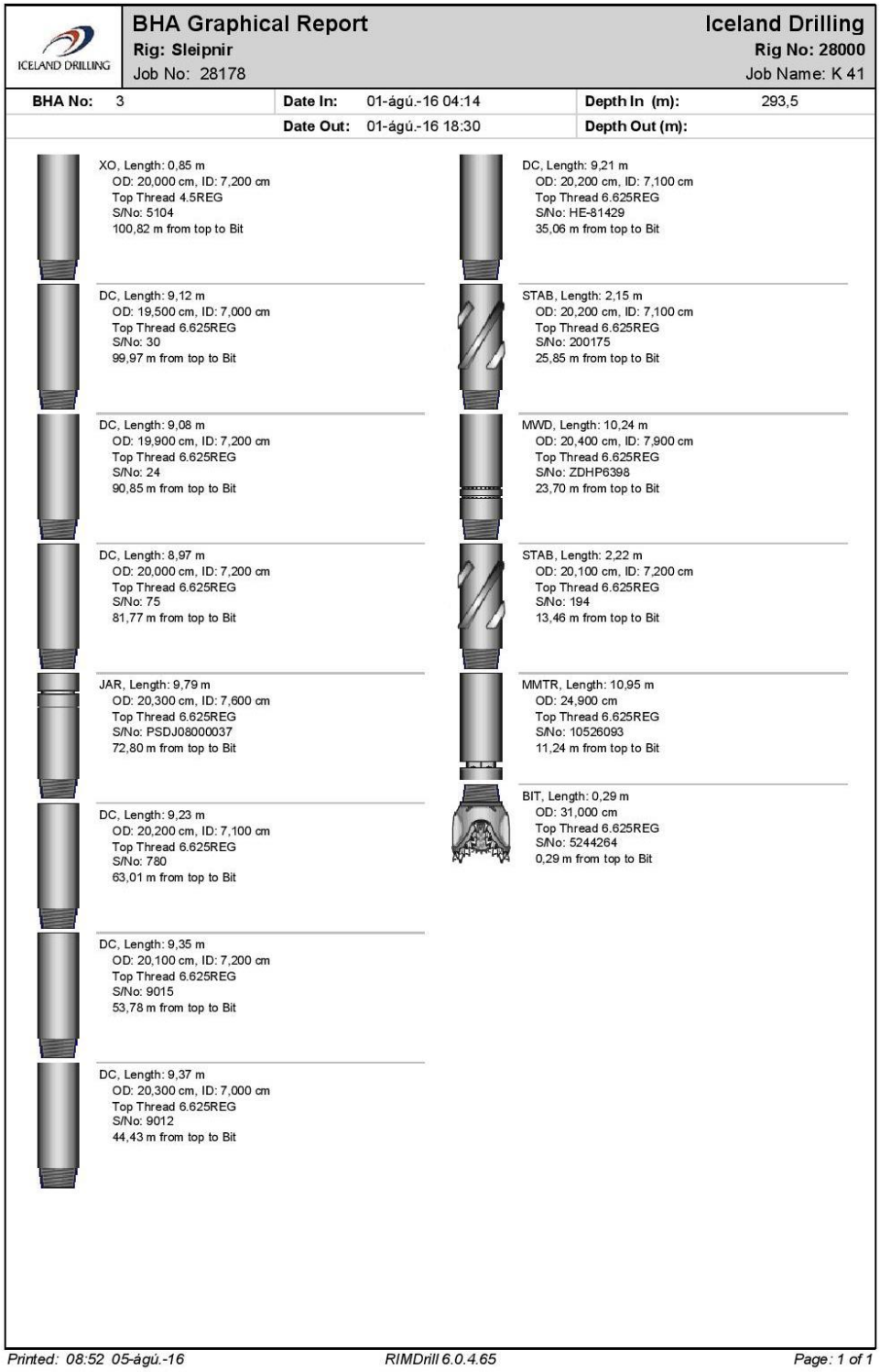

Figure 2: BHA graphical report

Location:	Krafla	*Drill rig:*	Sleipnir	*Drilling fluid:*	Mud	*UWI:*	
Well:	K-41	*Depth interval:*	100-566	*Work phase:*	Phase 2	*Geologists:*	BP

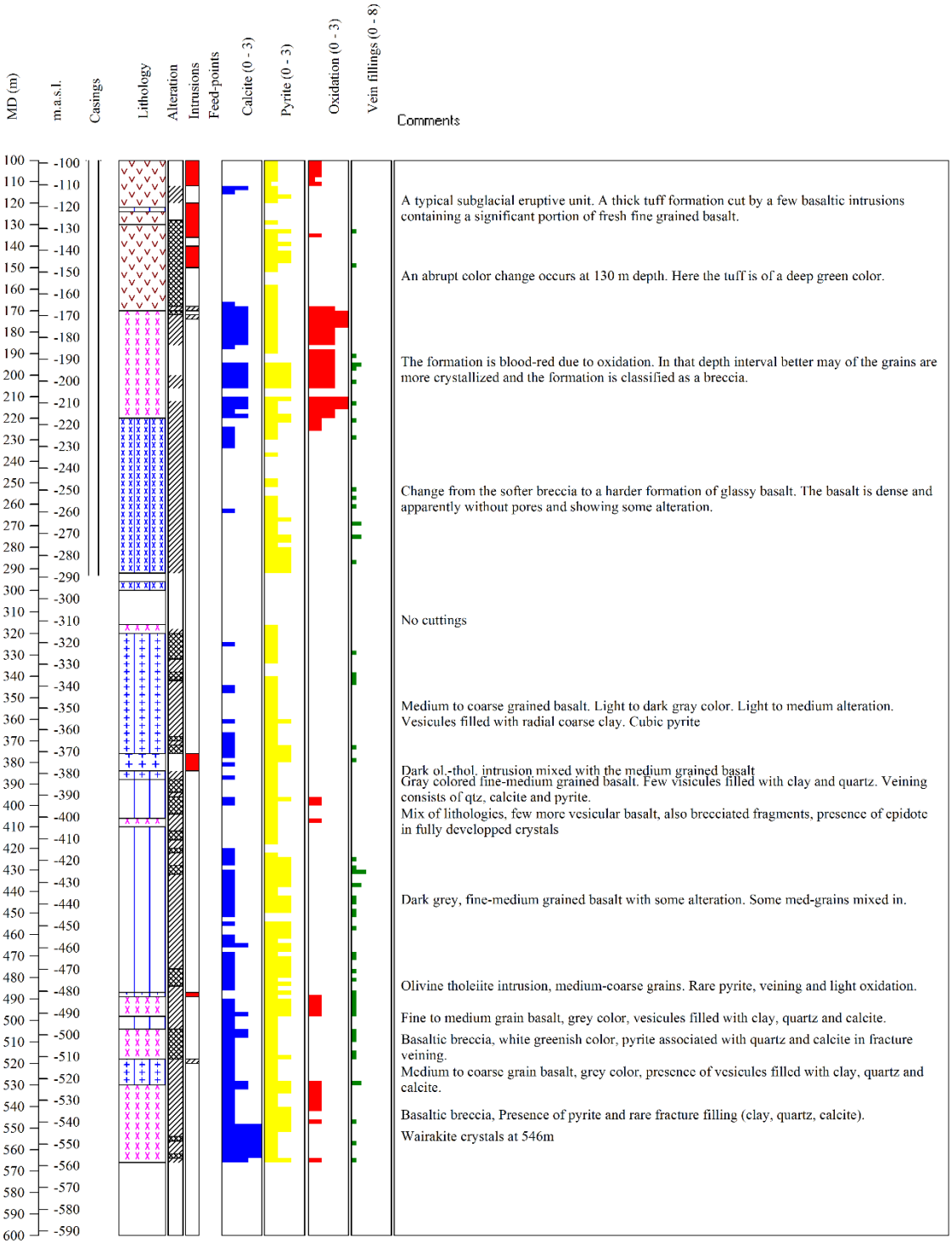

Figure 3: Geological column from 100 to 566m

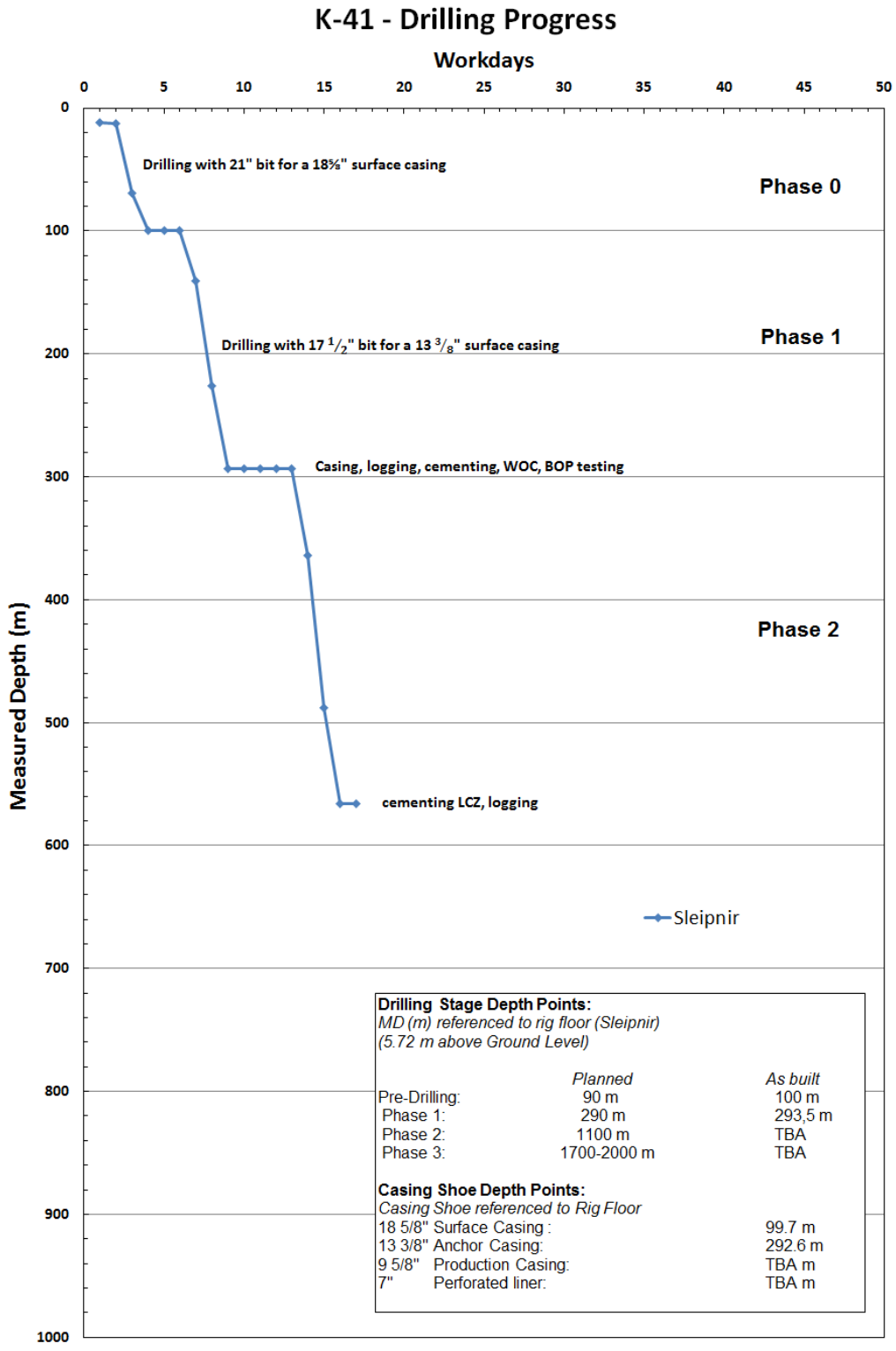

Figure 4: Drilling progress of well K-41 on August 5th, 2016

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Sunday 7th of August 2016 Workday #19 of Sleipnir

Krafla	**Report for Workday #19** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	585 m	Hole made last 24 hrs. :	19 m
Last casing depth:	292.6 m	Depth at 8:00.	651 m	Drilling time:	2 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	9,5 m/hr

Drilling operation

Once the cement was dry, the drilling string was RIH starting at 3.00 am and drilling through the cement started at 4.20 am with similar BHA as before. Cuttings of cement were checked regularly for fragments of formation.

At 472 m, loss circulation was evaluated at 4.5 l/s, and at 565 m it was about 3-4 l/s.

Formation was reached at 22.00 and drilling continued from 566 m to reach 585 m at midnight, with an average WOB of 4 tons and about 4-5 l/s of fluid losses.

On August 8th, at 4:00, there was no more fluid loss, drilling continues.

Geology

566 – 574: NO CUTTINGS

574 – 584: BASALTIC TUFF

White – greenish color, fine grains tuff formation, light alteration, common to abundant disseminated cubic pyrite, rare quartz and calcite. Few fragments greenish color probably chlorite. Few fragments show quartz veining.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Monday 8th of August 2016 Workday #20 of Sleipnir

Krafla	**Report for Workday #20** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	748 m	Hole made last 24 hrs. :	163 m
Last casing depth:	292.6 m	Depth at 8:00.	820 m	Drilling time:	21,25 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	7,67 m/hr

Drilling operation

Drilling continued from midnight to 13:00 from 585 to 691 m, with an average ROP of 8,15 m/hr. WOB about 3,5 tons to 615 m, then increase to 9,2 tons from 615 to 632 m. Between 632 and 668 m it was lowered to 5 tons, and then increase again to 8 tons down to 691 m. In that section circulation losses were 3,5 L/s, measured at 668 m.

After circulating for about an hour, a gyro survey was completed by the ISOR logging team to 651 m. Results are shown in the Table 1 below

MD (m)	Incl.	TrueAz.
651	29.13	71.6
620	26.37	68.3
590	23.82	65.9
557	21.jún	63.3

Table 1: results of the gyro survey at 651 m

Following the gyro survey, a measurement of the circulation losses indicated 9,5 l/s.

Drilling resumed at around 15:45 from 691 m to reach the depth of 748 m at midnight, the average ROP for this section is 6,91 m/hr. WOB varied between 3,8 and 10 tons in that section. There were no more circulation losses measured at 705 m.

Throughout the day the temperature of the drilling mud significantly increased, from 21,2°C in and 25,3°C out at 600m to a maximum of 37,3°C in and 43,8°C out.

At 8:00 in the morning, drilling was continuing at a depth of 820 m at rate of about 10 to 12 m/hr. WOB is about 7 tons. Next gyro survey is planned around noon.

Figure 1 show the lithology and the drilling parameters for the interval 0 to 748 m and Figure 2 shows the drilling progress of well K-41 up to the end of August 7th. Figure 3 show the planned well path for well K-41, as well as the other wells around, on a map of the surface CO_2 flux diffusion.

Geology

584 – 646: BASALTIC BRECCIA

White-greenish tuff fragments, fine grains, with disseminated and aggregates of cubic pyrite mixed with fragments of lightly altered fine to medium grains basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include Chlorite, Quartz (rarely fully developed crystals). Few crystals of Epidote were identified at the bottom of the formation, starting from 638 meters

646 – 672: BASALTIC TUFF

White greenish, grey color tuff fragments, fine grains, abundant crystals of cubic pyrite disseminated and in aggregates, locally oxidized fragments. Presence of epidote become more frequent after 674m and is associated with a higher quantity of quartz, probably linked to veining.

672 – 698: BASALTIC BRECCIA

Similar to the basaltic breccia from 584 to 646, but shows a higher quantity of crystals of Epidote. A thin basaltic intrusion is possible at about 688m, presence of few dark grey, not altered, medium grains fragments of basalt.

698 – 738: BASALT

Fine to medium grains basaltic formation, light to medium alteration, greenish grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include Chlorite, Quartz, common pyrite and Epidote (now solid presence)

738 - 748: BASALTIC BRECCIA

Similar to the basaltic breccia from 672 to 698 m

Location: Krafla *Drill rig:* Sleipnir *Drilling fluid:* Mud *UWI:*
Well: K-41 *Depth interval:* 100-748 *Work phase:* Phase 2 *Geologists:* BP

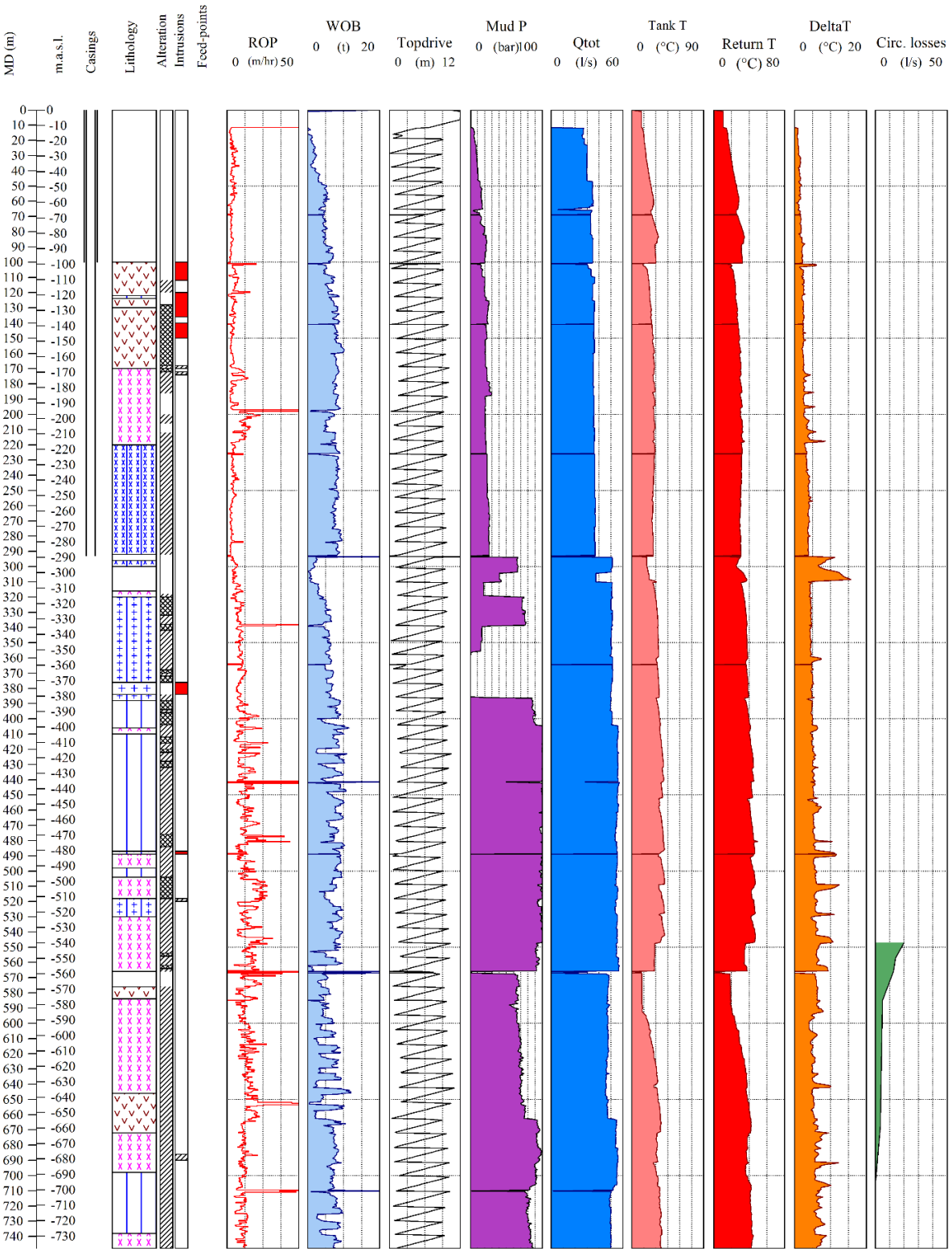

Figure 1: Lithology and drilling parameters log from 0 to 748m

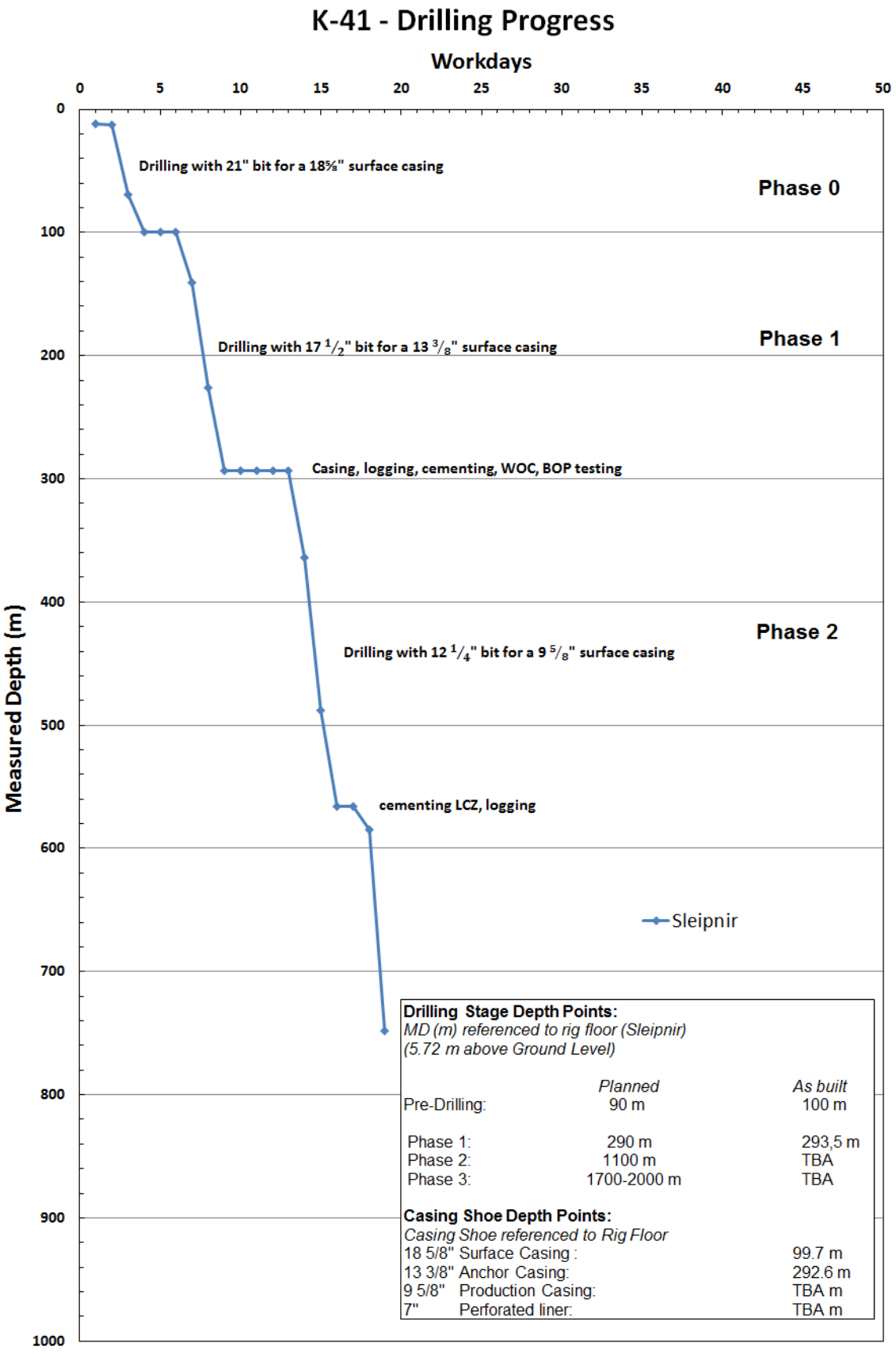

Figure 2: Drilling progress of well K-41 on August 8th

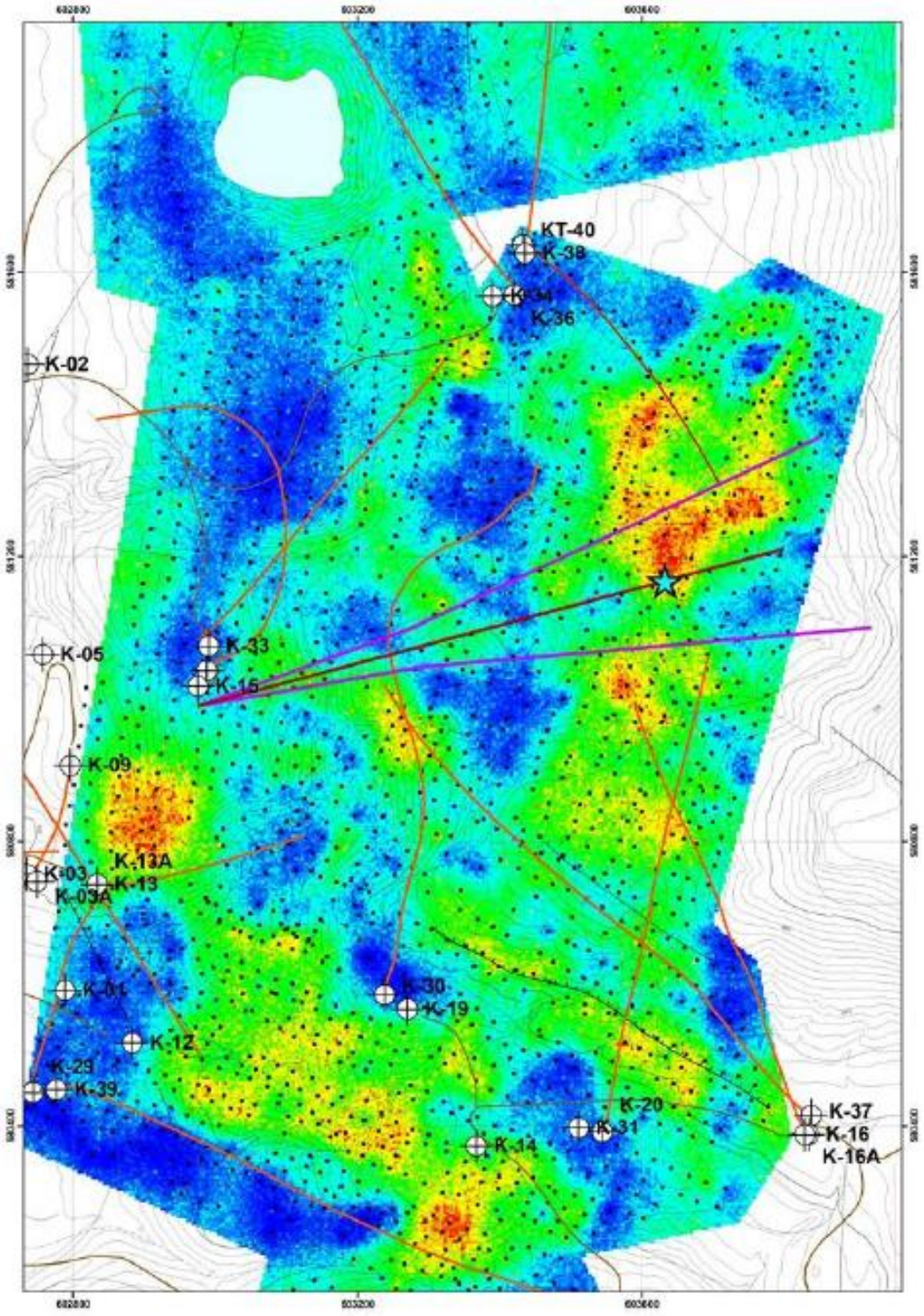

Figure 3: planned well path for well K-41, as well as the other wells around, on a map of the surface CO2 flux diffusion (red for high gas concentration, blue for low gas concentration).

Borvakt

Krafla	**Report for Workday #21** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	910 m	Hole made last 24 hrs. :	162 m
Last casing depth:	292.6 m	Depth at 8:00.	926 m	Drilling time:	20,75 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	7,80 m/hr

Drilling operation

Drilling continued from midnight to 11:30 from 748 to 842 m, with an average ROP of 8,17 m/hr. WOB varied between 7 and 10 tons, and pumping about 50-53 l/s of mud into the drill string. Measurements showed no fluid losses in that portion.

After circulating for about an hour and a half, a gyro survey was completed by the ISOR logging team to 803 m. Results are shown in the Table 1 below

MD	Incl.	TrueAz.
651	28.78	72.8
680	30.47	69.6
720	31.95	71.8
750	34.23	72.1
780	34.76	72.8
803	35.25	72.7

Table 1: results of the gyro survey at 803 m

Drilling resumed at around 14:45 from 842 m to reach the depth of 910 m at midnight, the average ROP for this section is 7.35 m/hr. WOB varied between 5.5 and 6 tons in that section. No fluid losses were encountered in that portion neither.

Mud temperature are still quite high, about 35 to 37°C for the mud in and up to 47°C for the mud return.

On August 9th, At 2:00 in the morning, the drilling was stopped at 926 m due to a leak in the standpipe. The drill string was pulled back into the last casing to 262 m, the leaking part has been remove from the rig at 7:30 am and is being repaired at 11:30 am.

Figure 1 show the lithology column of well K-41 from 500 to 900 m, Figure 2 shows the drilling parameters for the interval 0 to 900 m and Figure 3 and 4 show the well trace as of August 8th (748 m) and the planned well trace on map and on profile section.

Geology

748 – 764: BASALT

Fine to medium grains basaltic formation, light to medium alteration, greenish grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include Chlorite, Quartz, common pyrite and Epidote

764 – 776: BASALTIC TUFF

White greenish, grey color tuff fragments, fine grains, abundant crystals of cubic pyrite disseminated and in aggregates, locally oxidized fragments.

776 – 838: BASALT

Light to moderately altered fine to medium grains basalt, dark grey color with a crystalline appearance, locally with a greenish color due to chlorite. Secondary minerals include Chlorite, Quartz and Epidote. From 790 to 798 m, more oxidation presence of veining with quartz, calcite and pyrite.

838 – 854: BASALTIC BRECCIA

White-greenish tuff fragments, fine grains, with disseminated cubic pyrite mixed with fragments of lightly altered fine to medium grains basalt, dark grey color with a crystalline appearance, locally with a greenish color. Secondary minerals include Chlorite, Quartz. Oxidation is high at in the top part of the formation

854 - 870: BASALT

Similar to the basalt from 776 to 838 m

870 – 876: BASALTIC BRECCIA

Similar to the basaltic breccia from 838 to 854 m, lower quantity of Calcite

876 – 880: BASALTIC TUFF

White greenish, grey color tuff fragments, fine grains, locally oxidized fragments. Rich in Epidote. Few fragments of basalt

880 – 888: INTRUSION

Dark grey – black fine grains intrusive basalt, not altered, presence of pyrite and epidote related to few fragments of tuff like above.

888 – 900: BASALT

Similar to the basalt from 776 to 838 m, mixed with few fragments of intrusive fine grains basalt.

Location:	Krafla	*Drill rig:*	Sleipnir	*Drilling fluid:*	Mud	*UWI:*	
Well:	K-41	*Depth interval:*	500-900	*Work phase:*	Phase 2	*Geologists:*	BP

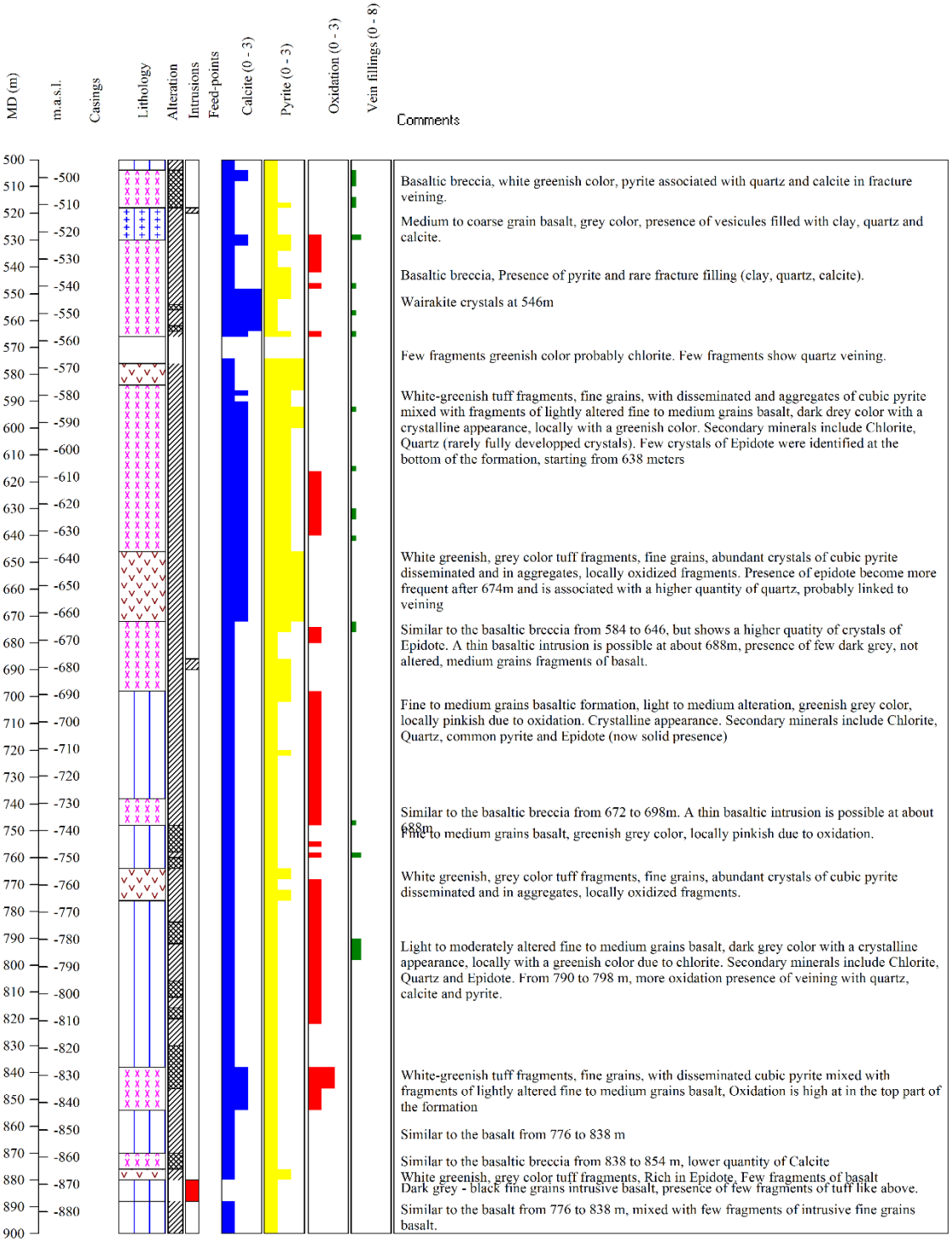

Figure 1: Lithological log of well K-41 from 500 to 900m

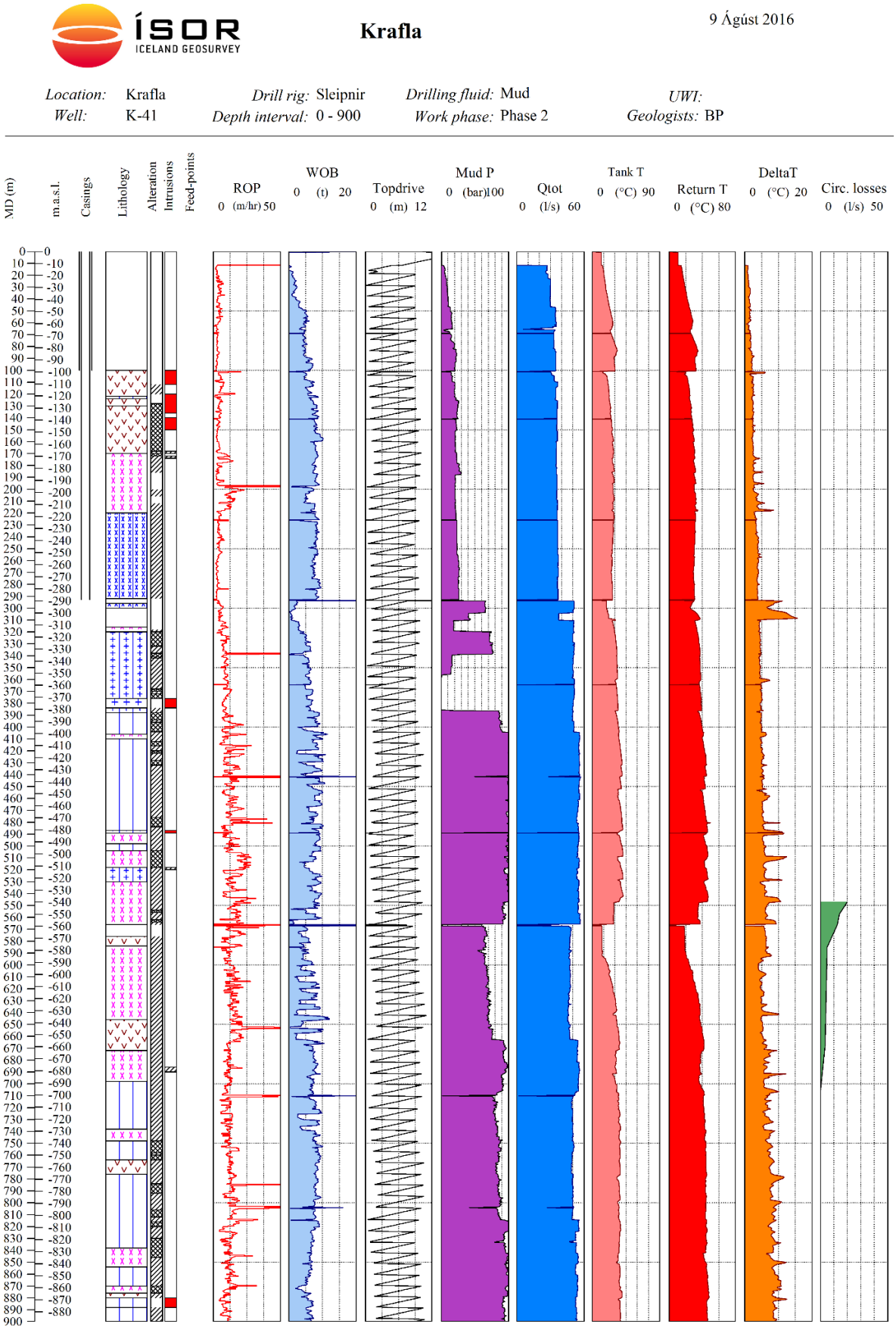

Figure 2: Lithology and drilling parameters for well K-41 from 0 to 900m

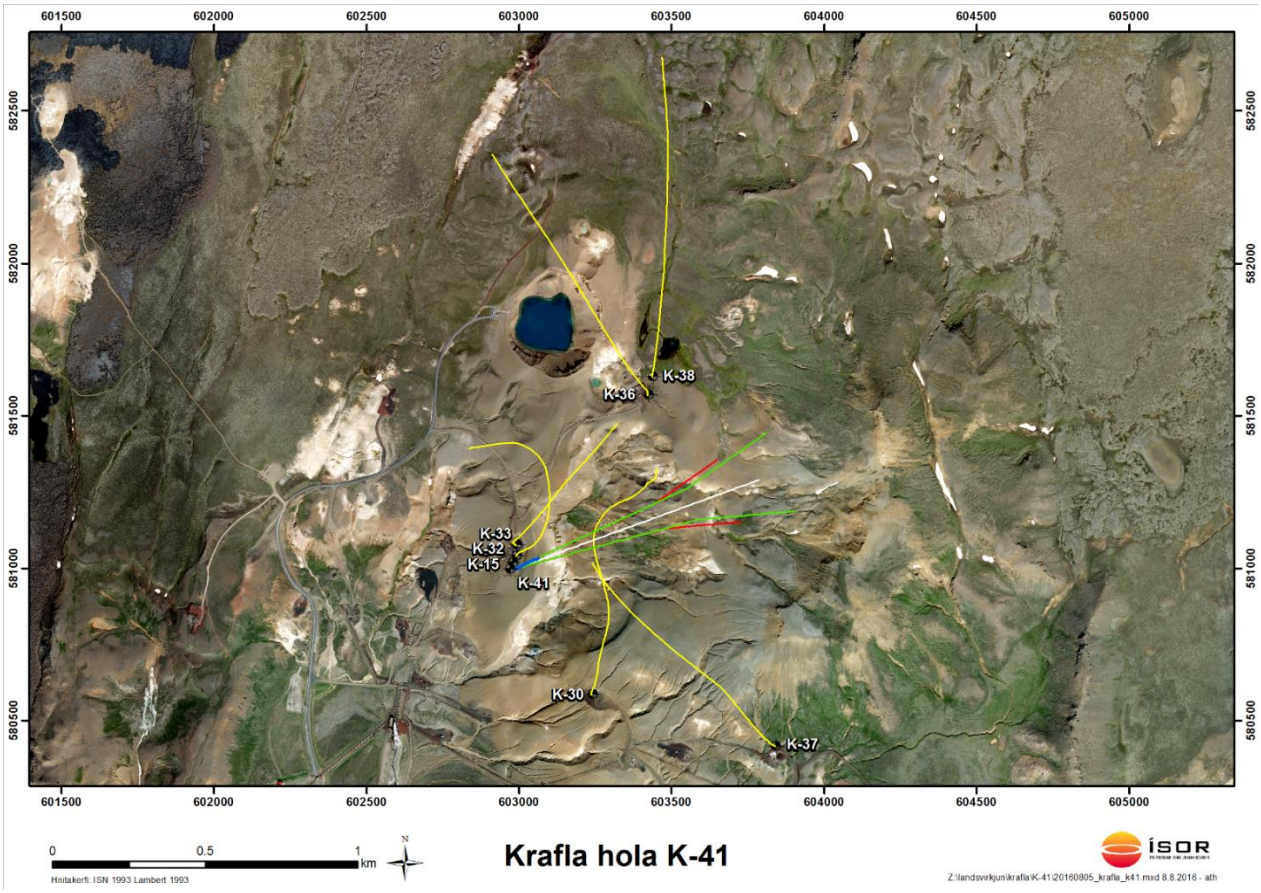

Figure 3: Current (blue line, at 748m) and planned (white line, to 2000 m) trace of well K-41 as of August 8th, view with other well traces on satellite image.

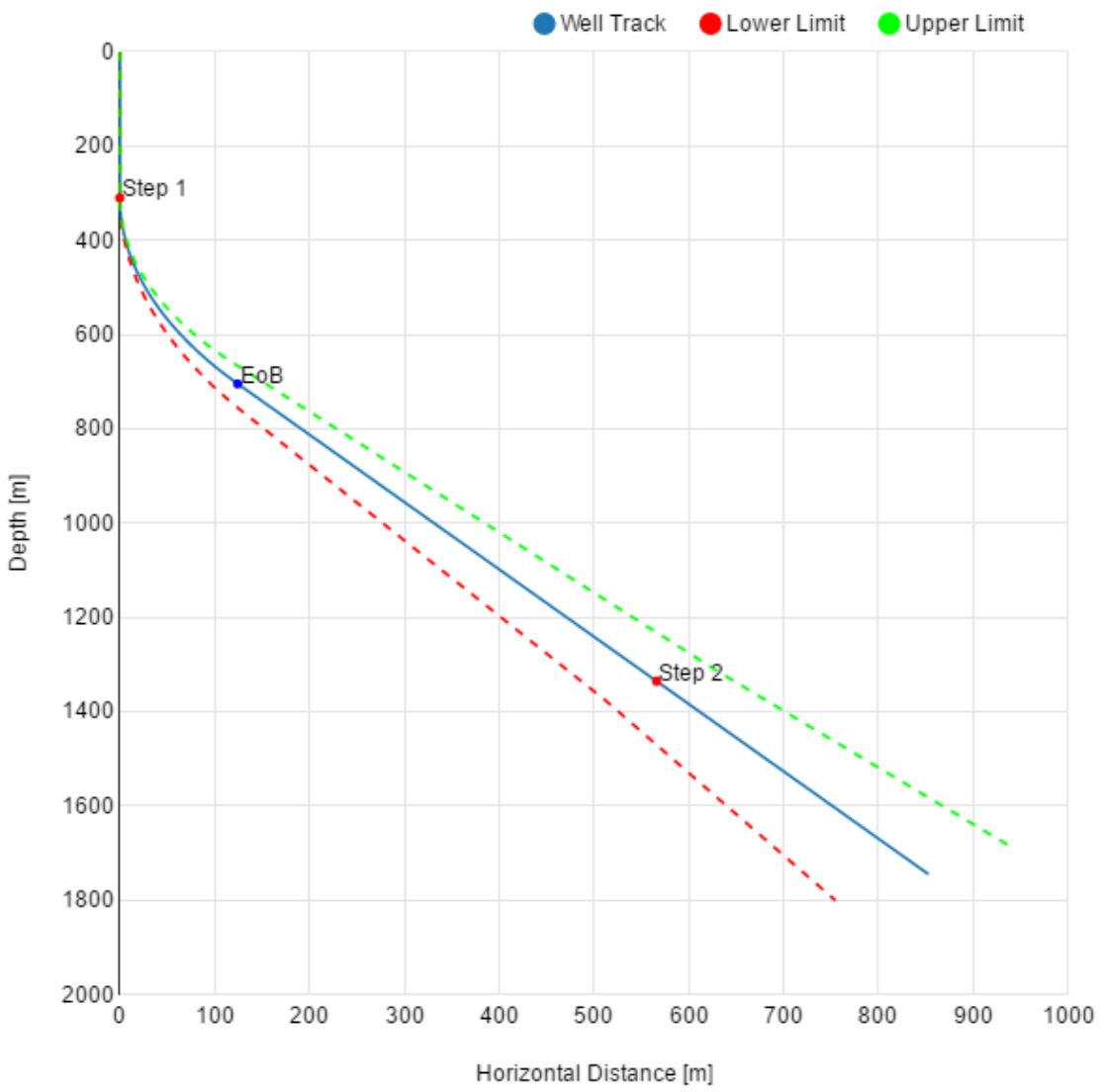

Figure 4: Well path profile section of well K-41, EoB point represents the current depth of the well as of August 8th (748 m)

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Wednesday 10th of August 2016 Workday #22 of Sleipnir

Krafla	**Report for Workday #22** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	936 m	Hole made last 24 hrs. :	26 m
Last casing depth:	292.6 m	Depth at 8:00.	974 m	Drilling time:	3 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	8.67 m/hr

Drilling operation

Drilling continued from midnight to 2:00am from 910 to 926 m, with an average ROP of 8,00 m/hr. WOB was about 7, and pumping 53 l/s of mud into the drill string. Measurements showed no fluid losses in that portion. The drilling was stopped because of a leak in the standpipe.

After the drill string was pulled back into the last casing to 262 m, the leaking part was removed from the rig at 7:30 am to be repaired.

Once the repair was finished, the drill string was put back in hole to 926m, it was also necessary to fix the elevation sensor of the top drive.

Drilling resumed at 23:00 and the depth was 936 m at midnight

On August 10th, drilling continues, 1000 m measured depth was reached at 10:30am

According to the well design, when the drilled depth reached 1000 m, the true depth value is 925 m at a distance of approximatively 280 m away (ENE) from the well head.

Figure 1 shows the drilling progress of well K-41 on August 9th, Figure 2 represent the position of the well bottom at 1000 m on a profile section of the well path.

Geology

900 – 920: BASALT

Fine to medium grains basaltic formation, light to medium alteration, greenish grey color, locally pinkish due to oxidation. Crystalline appearance. Secondary minerals include Chlorite, Quartz, common pyrite and Epidote. Calcite disappears at about 902-904m.

920 – 936: BASALTIC TUFF

White greenish, grey color tuff fragments, fine grains, abundant crystals of cubic pyrite disseminated and in aggregates, locally oxidized fragments. Between 928 and 932, there is a lot of crystals of pyrite.

936 –974: INTRUSION

Fine grains basaltic intrusion, no alteration, dark grey to black color. Few cubic crystals of pyrite and some sections are mixed with tuff fragments similar to the one described above which are associated with secondary minerals such as Chlorite, Pyrite, Epidote and Wollastonite

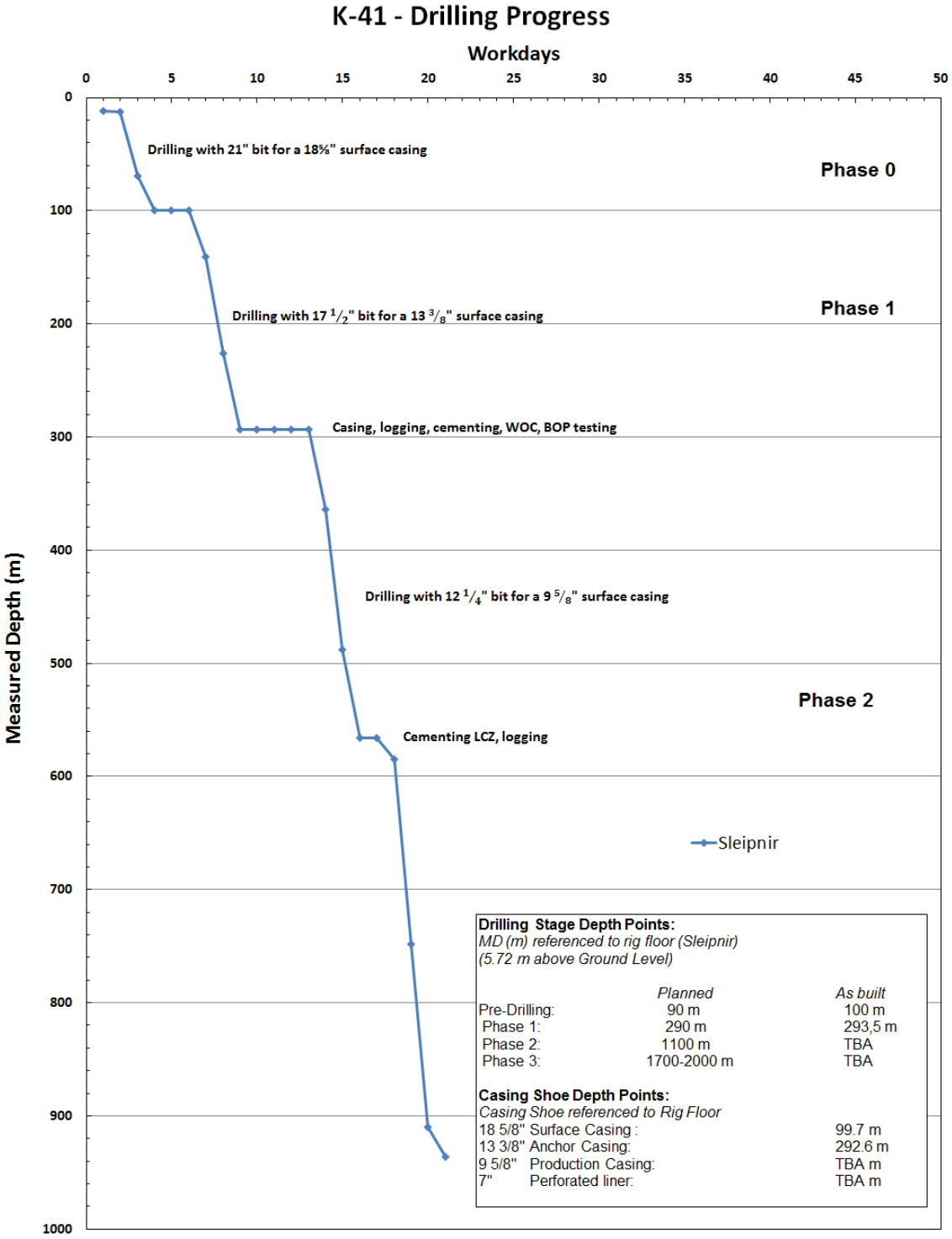

Figure 1: Drilling progress of well K-41 on August 9th

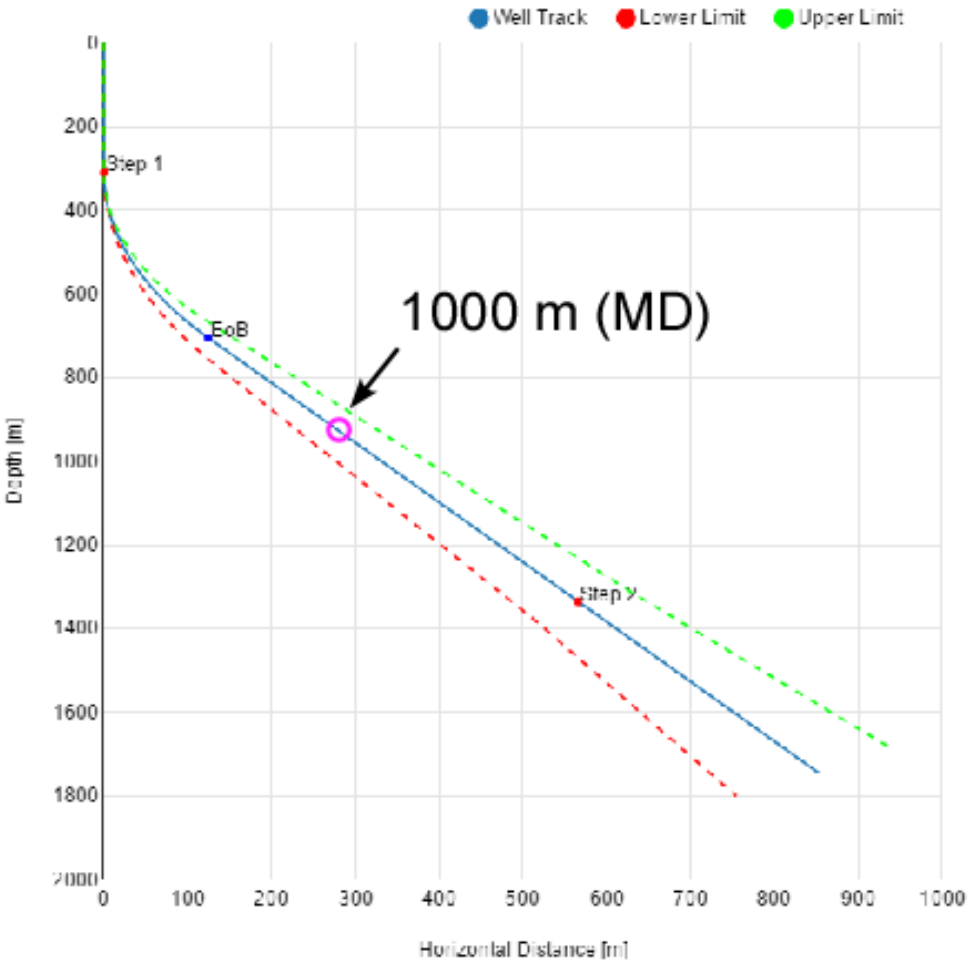

Figure 2: Well path profile section showing the well bottom location at 1000 m measured depth

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Thursday 11th of August 2016 Workday #23 of Sleipnir

Krafla	**Report for Workday #23** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1039 m	Hole made last 24 hrs. :	103 m
Last casing depth:	292.6 m	Depth at 8:00.	1039 m	Drilling time:	18 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	5 L/s	Average ROP:	5.72 m/hr

Note: at the time of writing this report, the rig computer system is down and the driller´s report is not available.

Drilling operation

Drilling continued from midnight to approximatively 18:00 from 936 to 1039 m, with an average ROP of 5,72 m/hr. Measurements showed fluid losses of about 5 l/s at 1010 m.

Drilling stopped at 17:30 due to a failure with one of the mud pump, after fixing it, it appeared that there was also a failure in the hydraulic system, it was necessary to pull back to the casing shoe to repair but the drill string got stuck.

On August 11th, the drill string is still stuck at the time of this report (11am). The intention is to keep drilling after repairs, to get below the current intrusion and observe the mineralogy before deciding to set the casing.

Figure 1 shows a picture of Calcite on Epidote at 996 m, Figure 2 shows the lithological log from 500 to 1038 m

Geology

938 – 980: INTRUSION

Fine grains basaltic intrusion, no alteration, dark grey to black color. Few cubic crystals of pyrite and some sections are mixed with tuff fragments similar to the one described above which are associated with secondary minerals such as Chlorite, Pyrite, Epidote and Wollastonite

980 – 1002: BASALTIC TUFF

White greenish, grey color tuff fragments, fine grains, abundant crystals of cubic pyrite disseminated and in aggregates, locally oxidized fragments, secondary minerals include Chlorite, Epidote and Wollastonite. Between 982 and 988, there is still fragments of intrusive basalt similar to the formation above. A fragments at 996 m show over printing of Calcite on Epidote (Figure 1), indicating a system that had cooled down.

1002 – 1038: INTRUSION

Fine to medium grains basaltic intrusion, no alteration, dark grey to black color. Few cubic crystals of pyrite and some sections are mixed with tuff fragments similar to the one described above which are associated with secondary minerals such as Chlorite, Pyrite, Epidote.

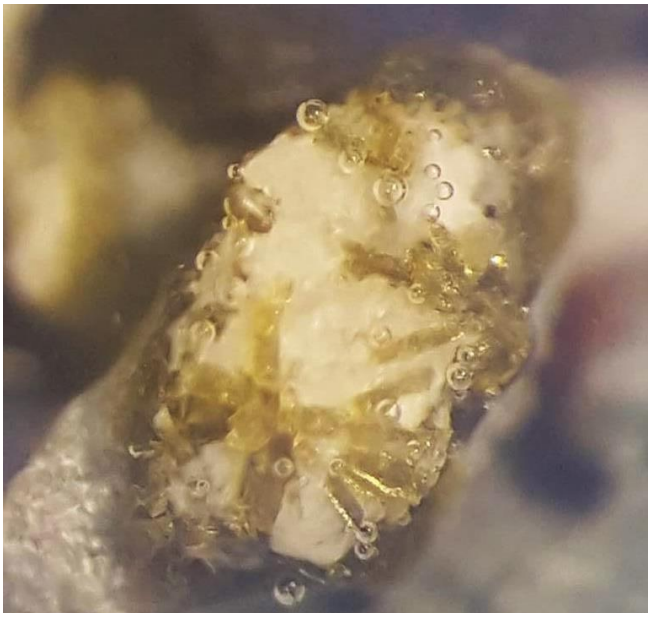

Figure 1: Fragments showing the calcite overprinting the Epidote crystals at 996 m (bubbles are due to the HCl test on the mineral, indicating Calcite)

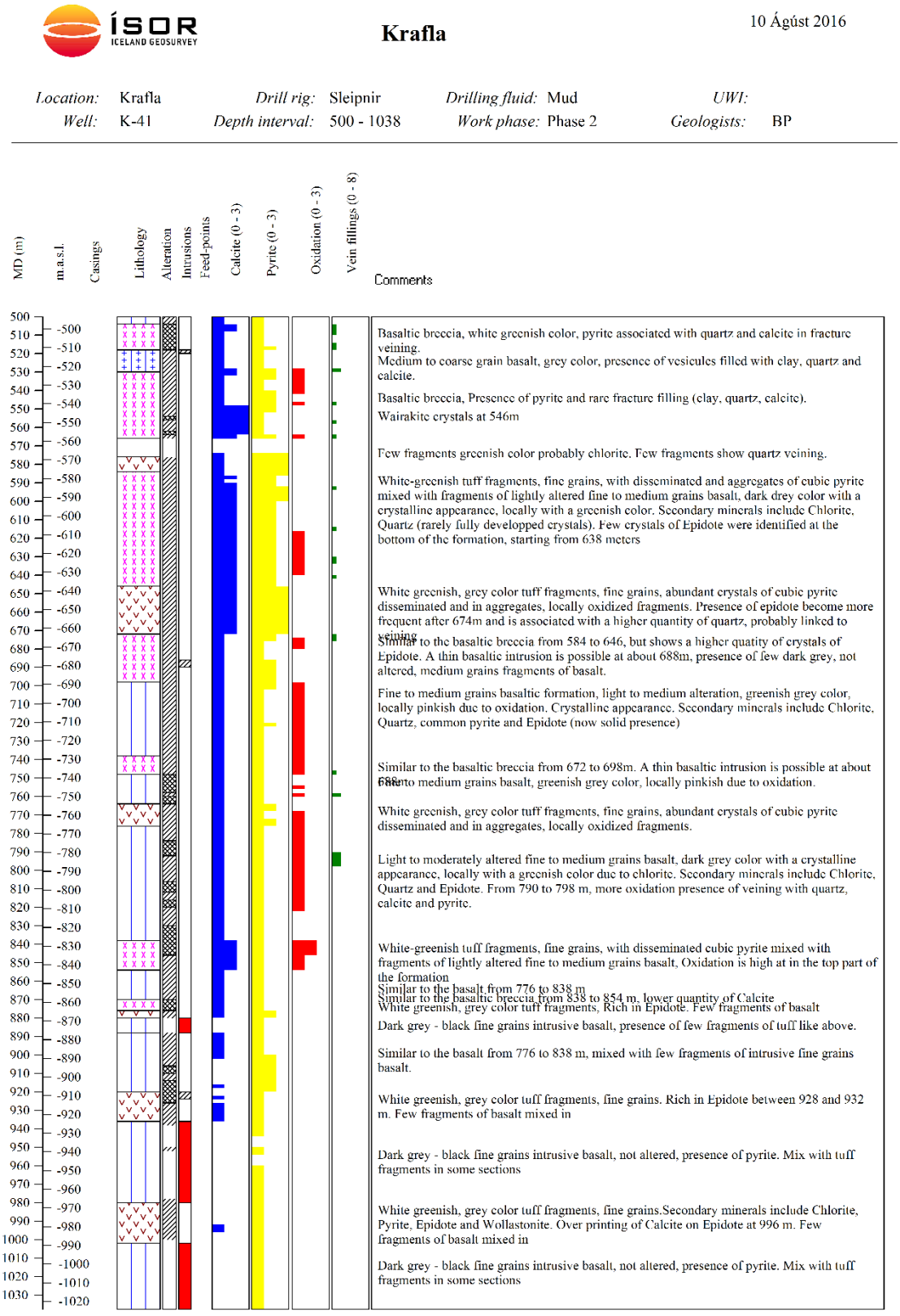

Figure 2: Lithological log, secondary mineralogy and description from 500 to 1038m

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Friday 12th of August 2016 Workday #24 of Sleipnir

Krafla	**Report for Workday #24** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	BP / HT, HI, FP (E-mail: bastien.poux@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1039 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	1039 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	20L/s	Average ROP:	0 m/hr

Drilling operation

Drill string is stuck for the whole day and soda mixed with water was circulated starting from 7:00 am

On August 12th, the drill string got released around 7:20 am

Figure 1 shows the drilling progress as of August 11th

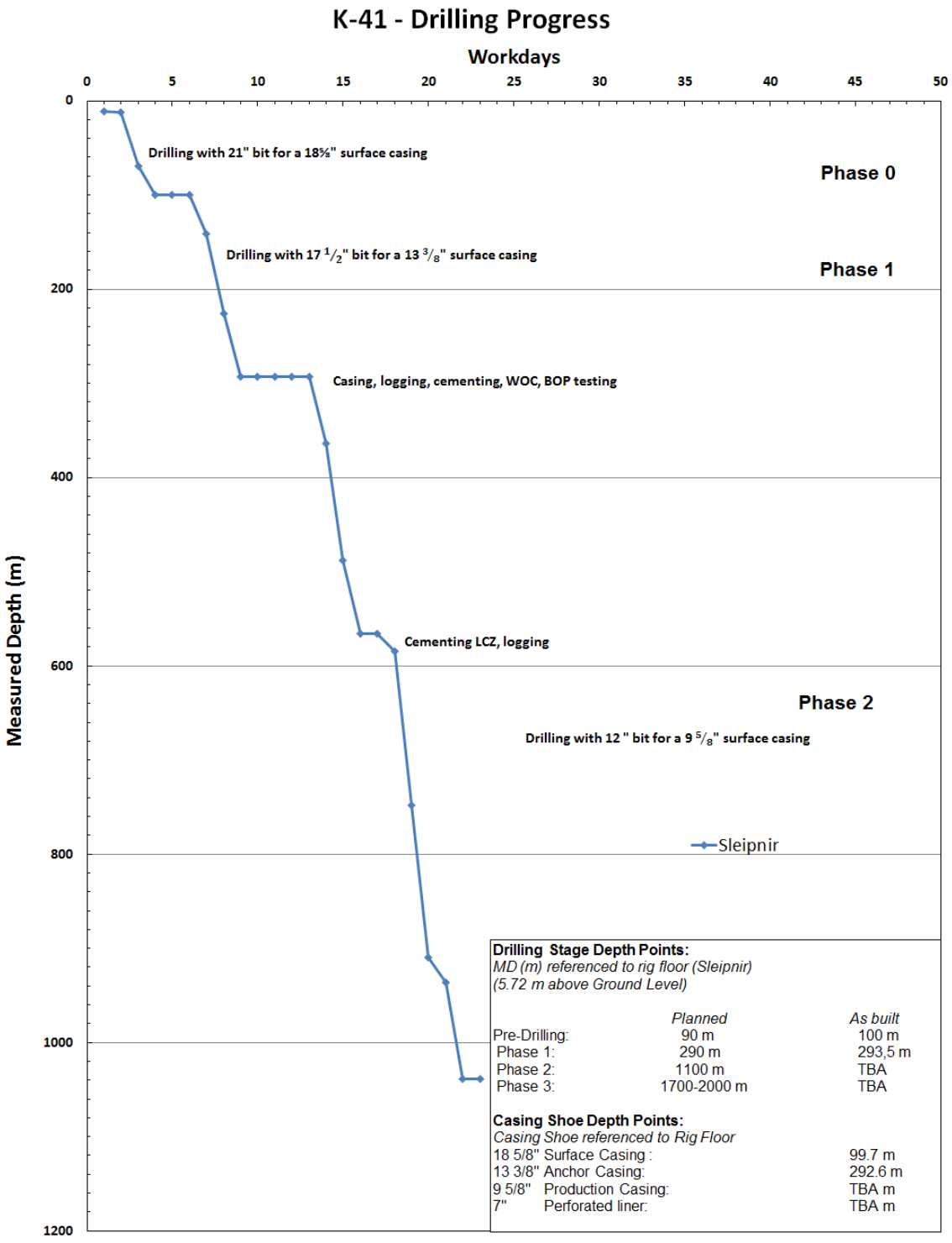

Figure 1: Drilling progress of well K-41 on August 11th

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ÍSOR ICELAND GEOSURVEY	K-41	Saturday 13th of August 2016 Workday #25 of Sleipnir

Krafla	**Report for Workday #25** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSA / HT, ÞEg, BSG (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1040 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	1040 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	20L/s	Average ROP:	0 m/hr

Drilling operation

After midnight, a jar, polymer pills and soda were used to try to get the drill string unstuck. At around 2 AM the jar had gone down 30 cm. At 7:20, after stopping jarring for few hours and only circulating, the string got unstuck after 3 hits with the jar. A total of 1125 kg of soda have been used for the last two days. The well was circulated with polymer pills to ensure that the string was not stuck anymore. Circulation losses of 18 l/s were observed during reaming from 900-1040 m. Wiper trip from 900-1040 m indicated no bottom hole deposits. The drill string was POOH between 14:00 and 00:00. At midnight ÍSOR´s logging engineers arrived on site to carry out logs (temperature, caliper NN, gamma, resistivity and acoustic televiewer). Temperature log from surface to bottom can be seen in Figure 1 and caliper from 250 to bottom can be seen in Figure 2. Currently 21 L/s are being pumped, with a total loss of circulation.

The next steps with time estimates are as follows:

1) ~~POOH Wiper trip (12 hrs)~~
2) Logging (17 hrs, ongoing)
3) RIH with 9 5/8" casing (24 hrs)
4) Prepare to cement and cementing (6 hrs)
5) WOC and CBL (24 hrs)

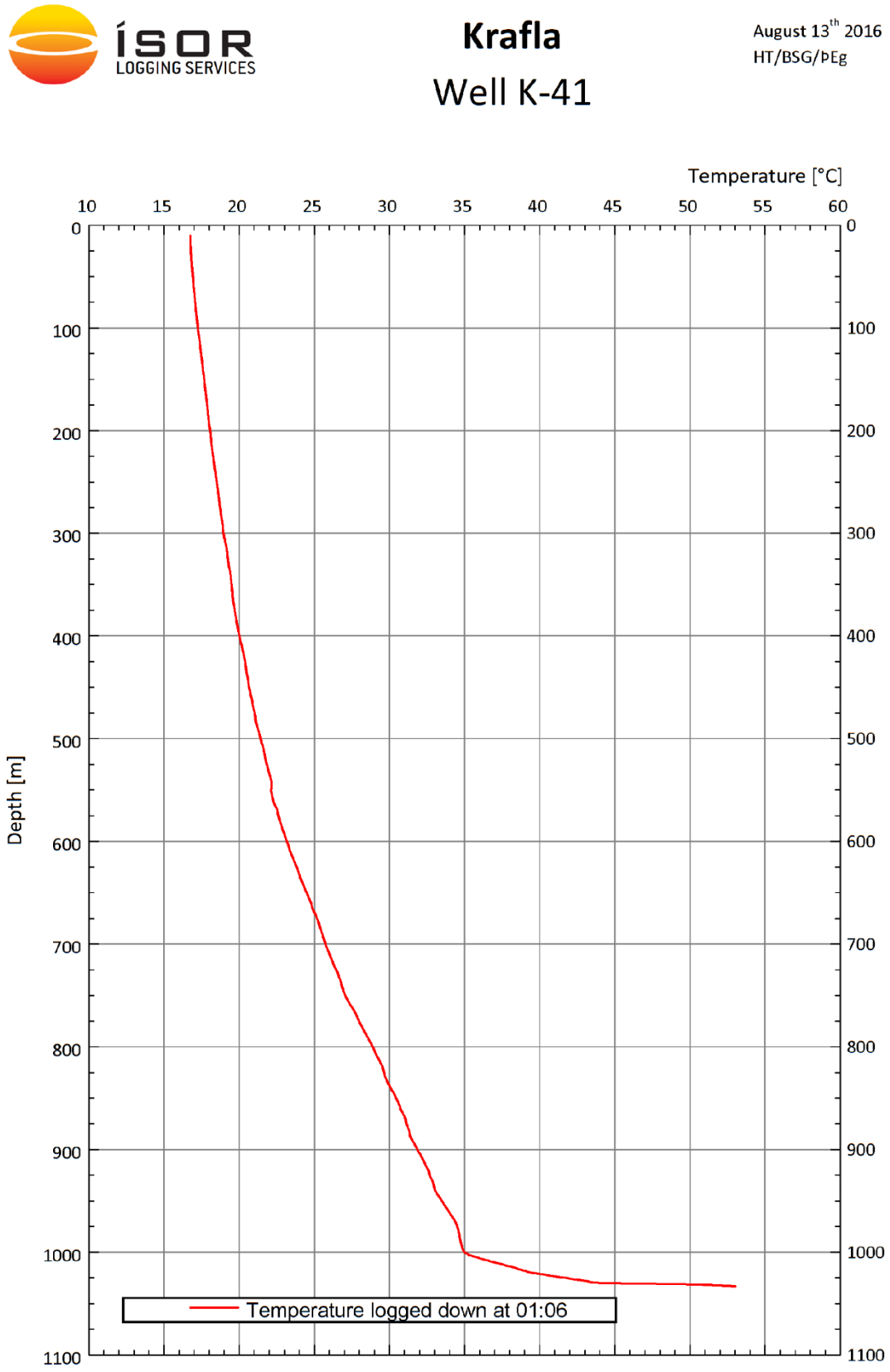

Figure 1. Temperature logged down well K-41 indicating that circulation loss occurs at 1000 m MD

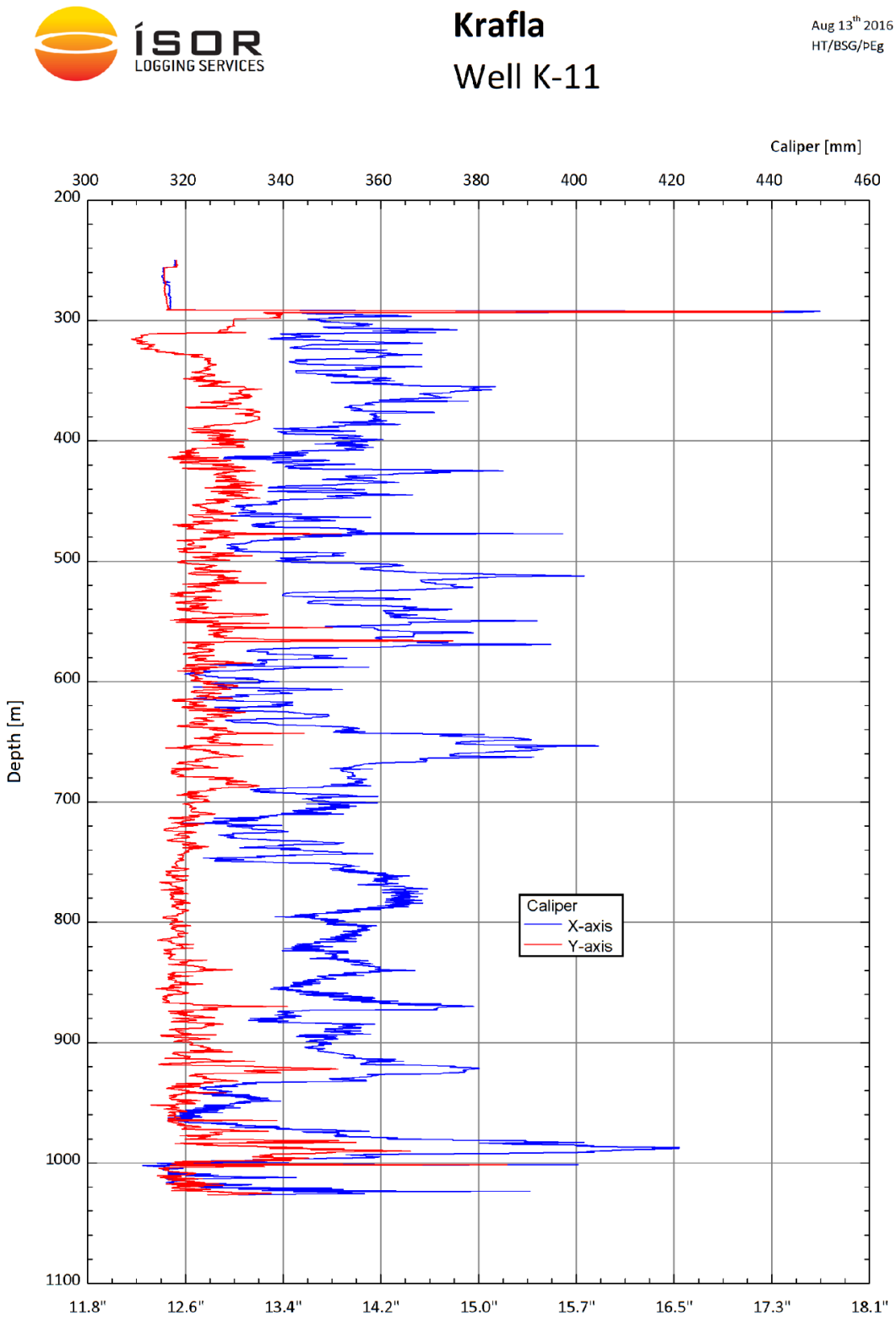

Figure 1. Caliper log of well K-41 indicating an elliptical shape immediately after the anchor casing.

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ÍSOR ICELAND GEOSURVEY	K-41	Sunday 14th of August 2016 Workday #26 of Sleipnir

Krafla	**Report for Workday #26** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSA / HT, ÞEg, BSG (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1040 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	1040 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	- L/s	Average ROP:	0 m/hr

Drilling operation

ÍSOR´s logging engineers carried out logs yesterday from midnight until 17:00 in the afternoon (Figures 1-2). Before running in with the casing, the top drive needed to be maintained. At 19:00 the blind ram was shut and 20 L/s pumped on kill line when problems occurred with the hydraulic system. Repairs took place all night and casing began around 10:00 this morning.

In the last report the temperature log showed that most of the 21 l/s injected water exited the well at 1000 m depth, only small amount passed down to BOH. All the logging tools stopped at around 1029 m depth which is the same location where the drill string got stuck. This indicates that there is ~11 m bottom fill deposits in the well.

The caliper log indicates some eccentricity of the well's cross sectional area (elliptical form) that is common in directionally drilled wells. However, no serious key-hole is detected (Figure 1).

An acoustic televiewer log was conducted. For good lateral resolution this log is POOH with a low tool speed. From BOH up to 900 m the resolution was adjusted to 4 mm which requires maximum tool speed of 2 m/min to minimize recording errors which were kept within 1% of the recorded data. At 900 m depth the resolution was decreased to 6 mm and the tool speed was increased to about 3 m/min and recording errors were kept within 0.2 % of the recorded data. During the televiewer log a lot of scattering within the irregular well shape occurred.

The resistivity log shows rather intermediate or low values, exceeds 100 Ωm at only few places. At 570 m there is some change in character with decreased resistivity down to ~700 m. There below more anomalies appear, indicating layers of less altered formation.

No major anomalies are seen in the neutron-neutron response and most of the log shows values 1000-2000 API. However, at 520 m there is a clear change of character of the NN-response where the cutting analysis shows transition from breccia to medium to coarse grained basalt. At 965 m there is a rapid decrease in the NN-response where also the resistivity decreases and the caliper increases.

The natural gamma radiation log shows basaltic character for most of the well but clear silicic anomalies appear at 463 m, 550 m, 673-679 m, 735-745 m, 760-773 m and 1002 m where there is a clear loss zone.

The next steps with time estimates are as follows:

1) ~~POOH Wiper trip (12 hrs)~~
2) ~~Logging (17 hrs)~~
3) RIH with 9 5/8" casing (24 hrs) -ongoing
4) Prepare to cement and cementing (6 hrs)
5) WOC and CBL (24 hrs)

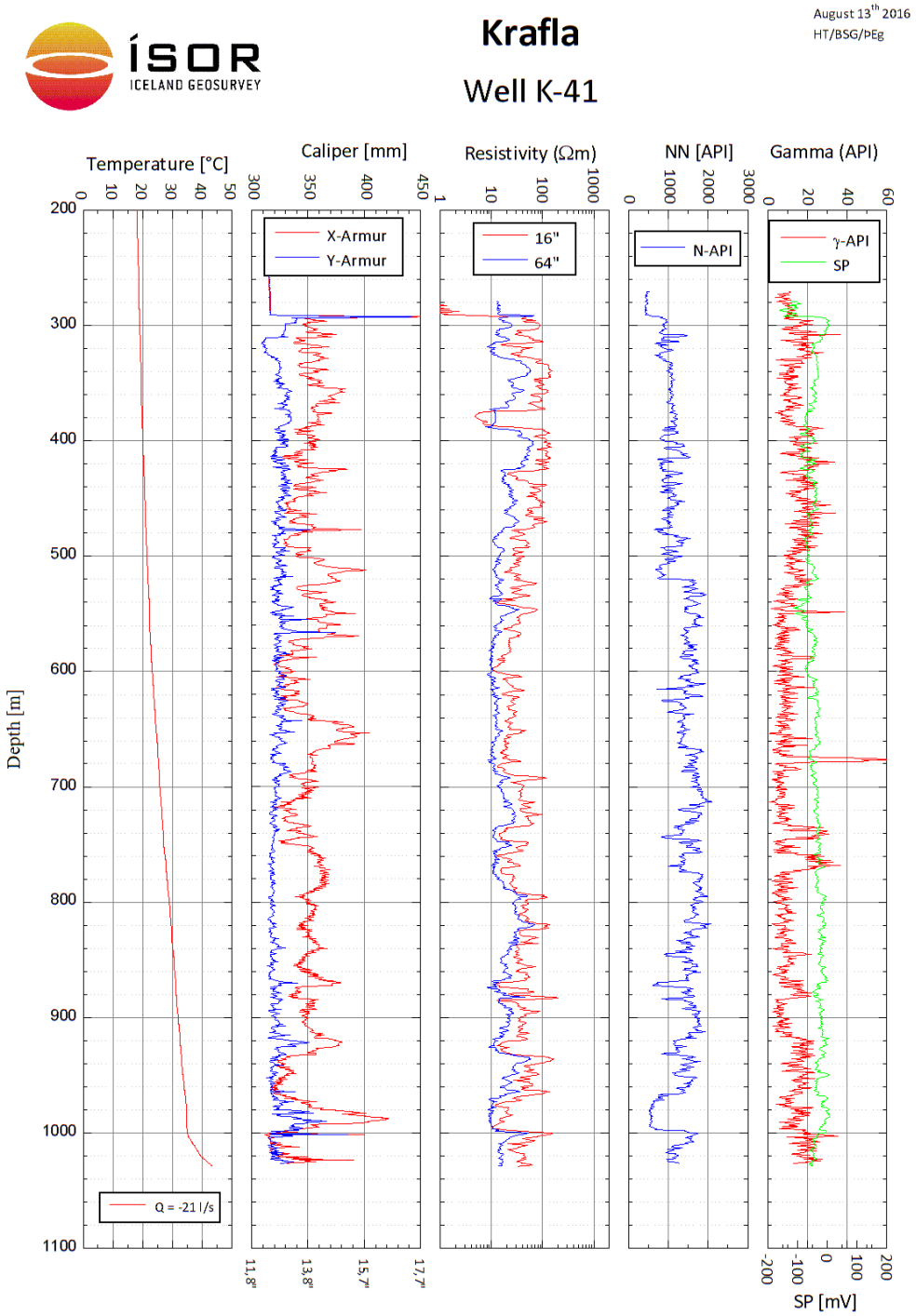

Figure 1. Temperature, caliper, resistivity, NN and gamma logged in well K-41.

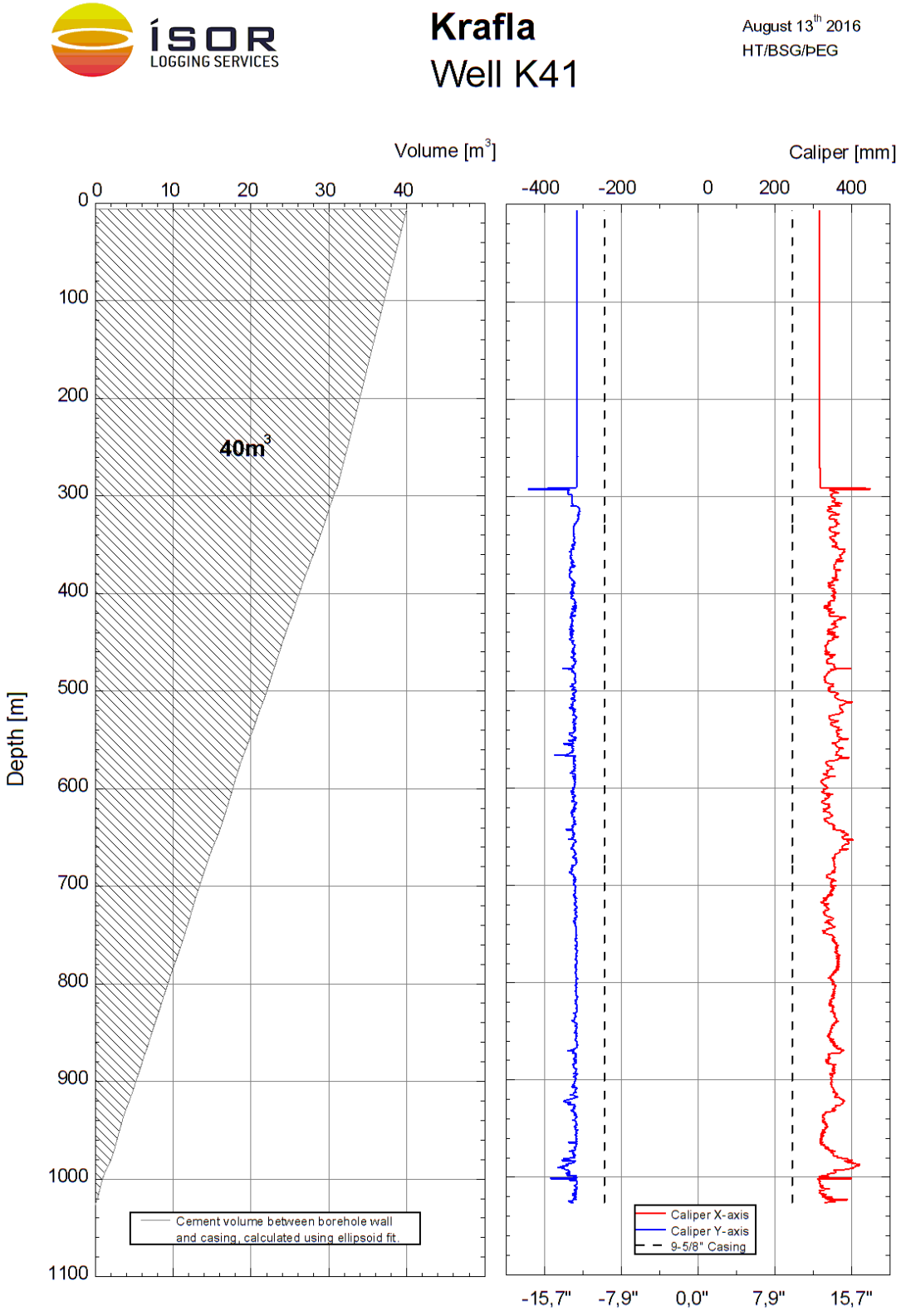

Figure 2. Cement volume between borehole wall and casing, calculated using ellipsoid fit.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Monday 15th of August 2016 Workday #27 of Sleipnir

Krafla	**Report for Workday #27** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSA (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1040 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	1040 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	- L/s	Average ROP:	0 m/hr

Drilling operation

After repairing the hydraulic system, RIH with the 9⅝" casing started at 9:30 and at 19:00 slips and dog collar were mounted and four clamps were welded on the casing to secure it in place. The casing went down to 1036 m without resistance, i.e. the logging tools must have stopped in a cavity washout at ~1030 m and not because of bottom fill deposits as earlier regarded. In the evening, collars and jar were put away as well as the casing equipment. At 21:00, RIH with the cement string begun and the shoe was tagged at 1013 m. Cementing started at 5:30 and finished around 7:00 this morning and currently the cement string is POOH. The plan is to wait for four hours until the next cement fill will be put on top. Figure 1 shows the drilling progress of phases 0-2. Figure 2 shows the internal temperature of the MWD during drilling with BHA-4 in Phase 2 as a function of time.

The next steps with time estimates are as follows:

1) ~~POOH Wiper trip (12 hrs)~~
2) ~~Logging (17 hrs)~~
3) ~~RIH with 9 5/8" casing (24 hrs)~~
4) ~~Prepare to cement and cementing (6 hrs)~~
5) WOC and CBL (24 hrs)

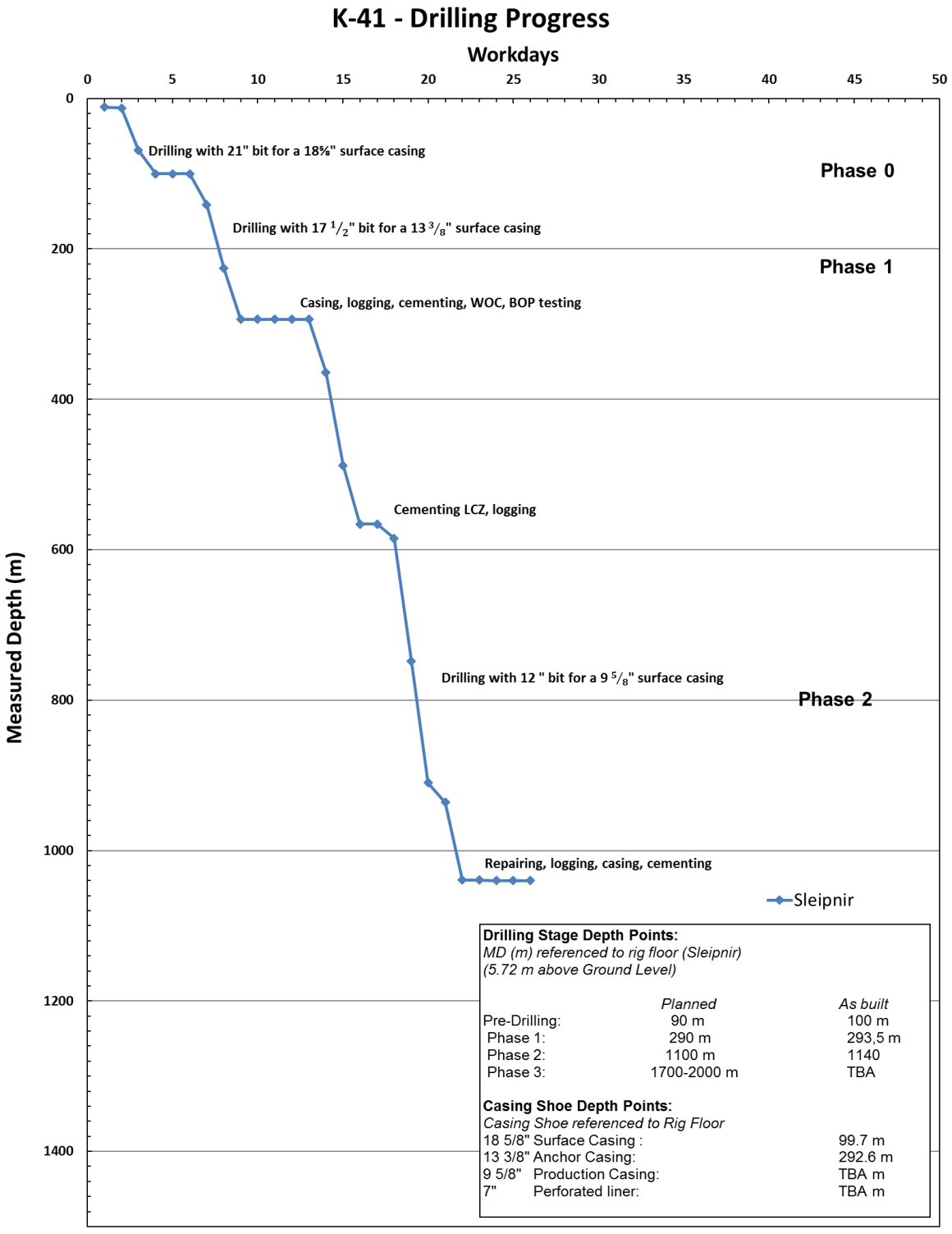

Figure 1. Drilling progress of phases 0-2.

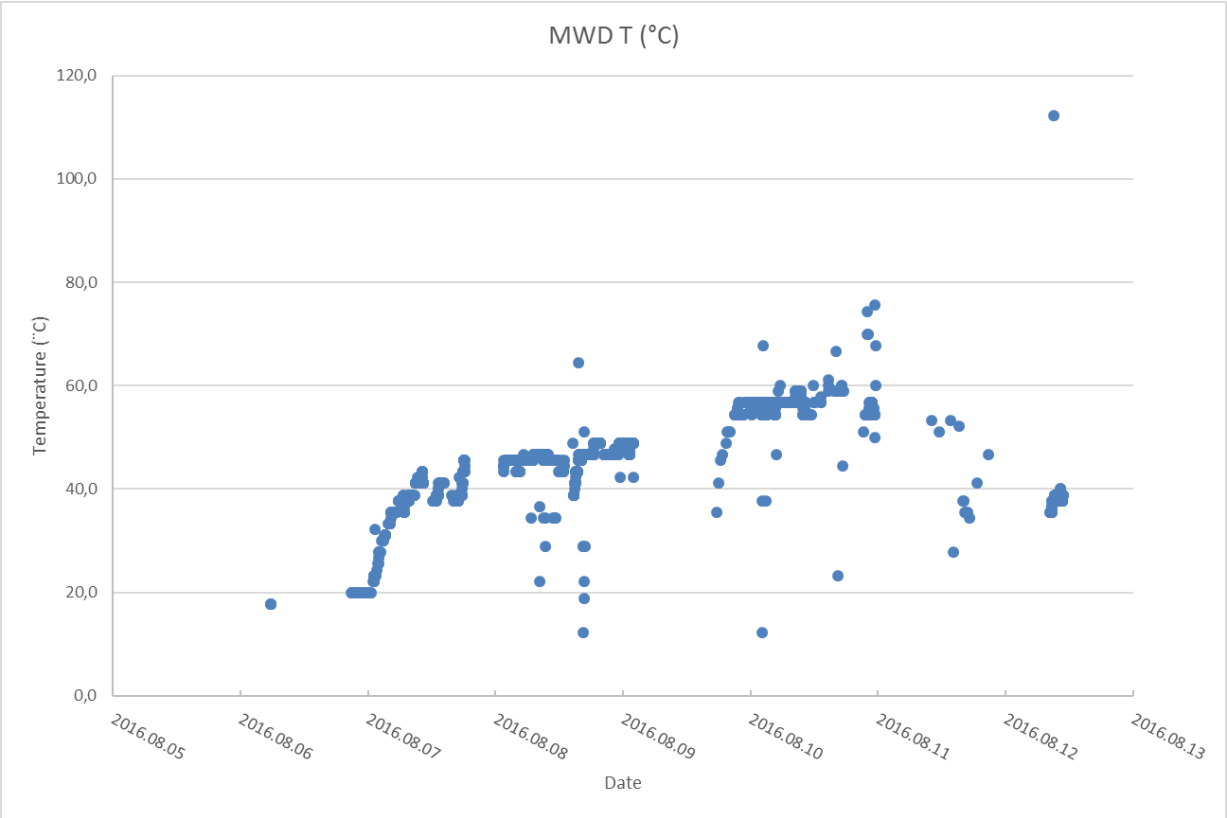

Figure 2. *Internal temperature in the MWD tool as a function of time. A slow but steady increase in T as a function of time (depth). Cooling at the end due to string getting stuck.*

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ÍSOR ICELAND GEOSURVEY	K-41	Tuesday 16th of August 2016 Workday #28 of Sleipnir

Krafla	**Report for Workday #28** Preliminary results	Phase 2 (9 5/8" production casing)

Operator:	Landsvirkjun	*Drilling Company:*	Iceland Drilling Company
Well Name:	K-41	*Drill-Rig:*	Sleipnir
Well-Id:	58041	*Geologist/Geophysicist:*	RSA, HT, BSG, ÞEg (E-mail: rsa@isor.is)

Last casing size:	13 3/8" (anchor casing)	Depth at 24;00.	1040 m	Hole made last 24 hrs. :	0 m
Last casing depth:	292.6 m	Depth at 8:00.	1040 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	- L/s	Average ROP:	0 m/hr

Drilling operation

Cementing of the casing got underway early yesterday morning after casing (Table 1). The cement job took around 2,50 hours and a total of 5 m^3 of cement slurry was cemented through the string and 51 m^3 on kill-line mixed in with 19 bags of mica (Table 2). Around 9:00 the cement string was POOH followed by WOC. Last night, ÍSOR´s logging engineers carried out a temperature and a CBL log (Figures 1 and 2). The logging tools only went down to 950 m and the temperature instrument got stuck in cement-slurry inside the casing. It only got loose after pulling on it with considerable force. As can be seen in figure 1, the temperature below 600 m was already over 100°C. The CBL log indicates cement all the way, but it had not hardened yet between casings. Below that, the cement looked good in most places, even though the signal is dampened in some places. Logging the area around and below the opening at 1000 m was unsuccessful. Figure 3 shows temperature logged with MWD in BHA 3 and BHA 4. Temperature increases with depth, except when the drill string got stuck, the temperature decreased while pumping cold water down.

The next steps with time estimates are as follows:

1) ~~POOH Wiper trip (12 hrs)~~
2) ~~Logging (17 hrs)~~
3) ~~RIH with 9 5/8" casing (24 hrs)~~
4) ~~Prepare to cement and cementing (6 hrs)~~
5) ~~WOC and CBL (24 hrs)~~

Table 1. *Casing information report for last casing, at 1036 m. In total 72 centralizers were used.*

Casing Information Report — **Iceland Drilling**
Rig: Sleipnir — Rig No: 28000
Job No: 28178 — Job Name: K 41

Casing Information

Run Date/Time:	14-ágú.-16 00:00		
		Leak Off Test (kg/cu m):	
Well Section:	INT2	**String Type:**	FULL
String Top MD (m):	5,6	**String Top TVD (m):**	
Casing Shoe MD (m):	1.036,1	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	24,45	**String Nominal ID (cm):**	22,66
Bit Diameter (cm):	31,11	**Avg. Open Hole Diam. (cm):**	31,11
Centralizers: No:	72	**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 15-ágú.-16 01:39		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
1	SHOE	0,570	24,45	22,66		K-55	BUTT	
2	JOINT	22,980	24,45	22,66	17,3	K-55	BUTT	
1	FLOAT	0,540	24,45	22,66		K-55	BUTT	
90	JOINT	1.016,670	24,45	22,66	17,3	K-55	BUTT	
Totals: 94		1.040,760						

Table 2. *Cementing report. In total 56 m³ of cement slurry were used, thereof 51 m³ pumped in kill-line. 19 bags of mica were added to the mix.*

Cementing Report — **Iceland Drilling**
Rig: Sleipnir — Rig No: 28000
Job No: 28178 — Job Name: K 41

Cement Job Information

Start Date/Time:	15-ágú.-16 04:30	**Well Bore:**	Original Well Bore
Job Type:	PRIMARY	**String OD (cm):**	24,45
Well Section:	INT2	**String Type:**	FULL
Cementing Co:	JARDB	**Cementing Engineer:**	Einar

Primary Job Detail

	Volume (cu m)	Pump Time	Rate (cu.m./min)	Pressure (bar)
Conditioning Data:				
Cement Data:	56,0	80	0,7	14
Displacement Data:	5,2	13	0,7	14
Calc. Displacement Vol:	5,2			

	☐ **Batch Mix?**	☐ **Bump Plug?**	**Bump Pressure:**	14	
Returns to Surface:	PARTIAL	☐ **Reciprocate Pipe?**	☑ **Cement at Surface?**		
Calc Top of Cement (m):	1.012,9	**Excess (%):**	100,00%	**Avg. Hole Size (cm):**	24,45

Slurry Information

Type	Density	Yield	Sacks	Volume	Rate	Additives
LEAD	2		19	56,0	0,7	19 pokar af mica
DISPLACE	2			5,0	0,4	

Post Job Information

Liner Top Test (kg/cu m):		**Job Success?**	No
Actual Top of Cmt (m):		**CBL Bond Quality:**	
Misc. Comments:	Steypt 5m3 í gegnum streng og 51m3 í gegnum kill-line og 19 pokar af mica		

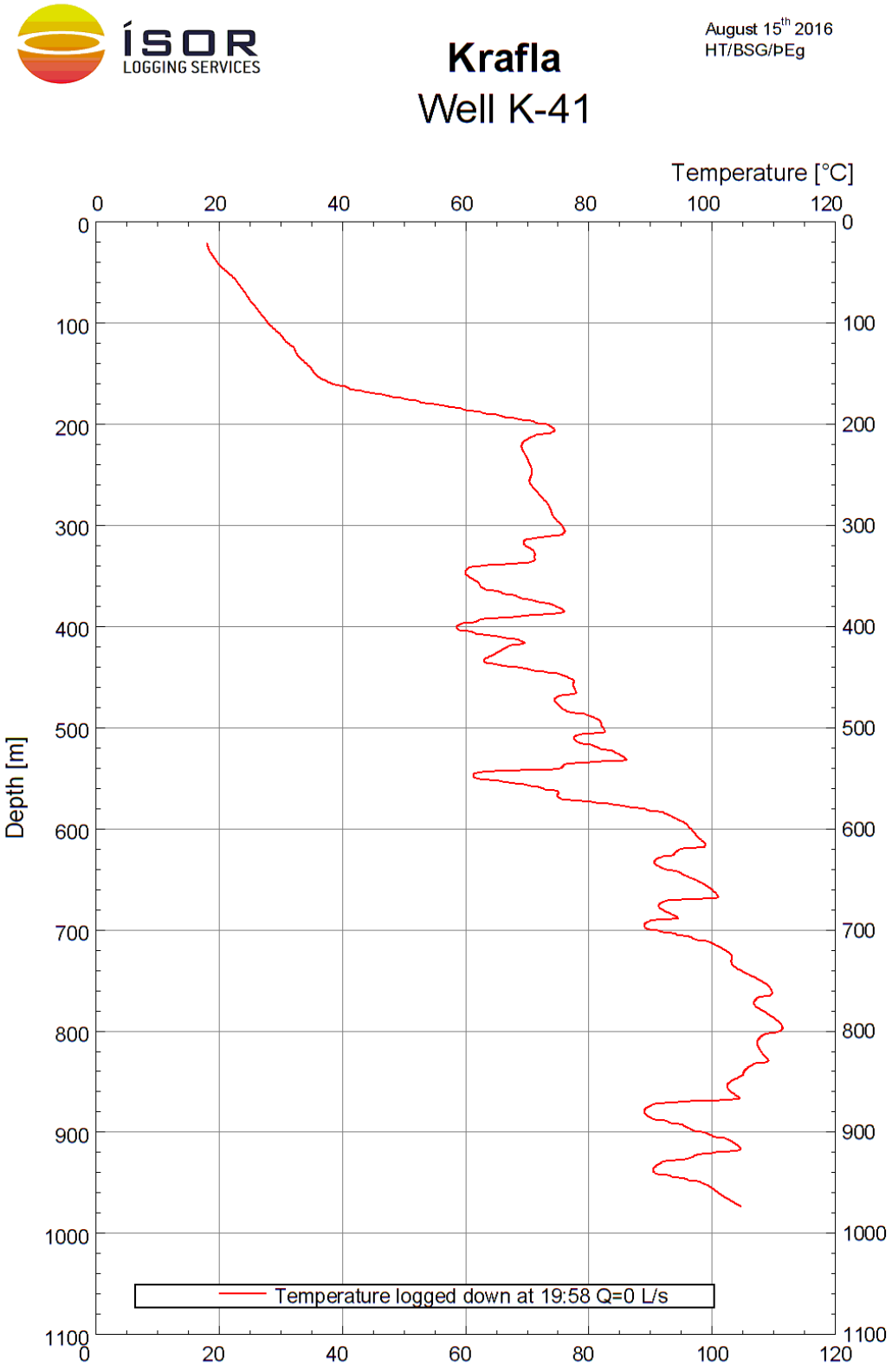

Figure 1. *Temperature logged down well K-41.*

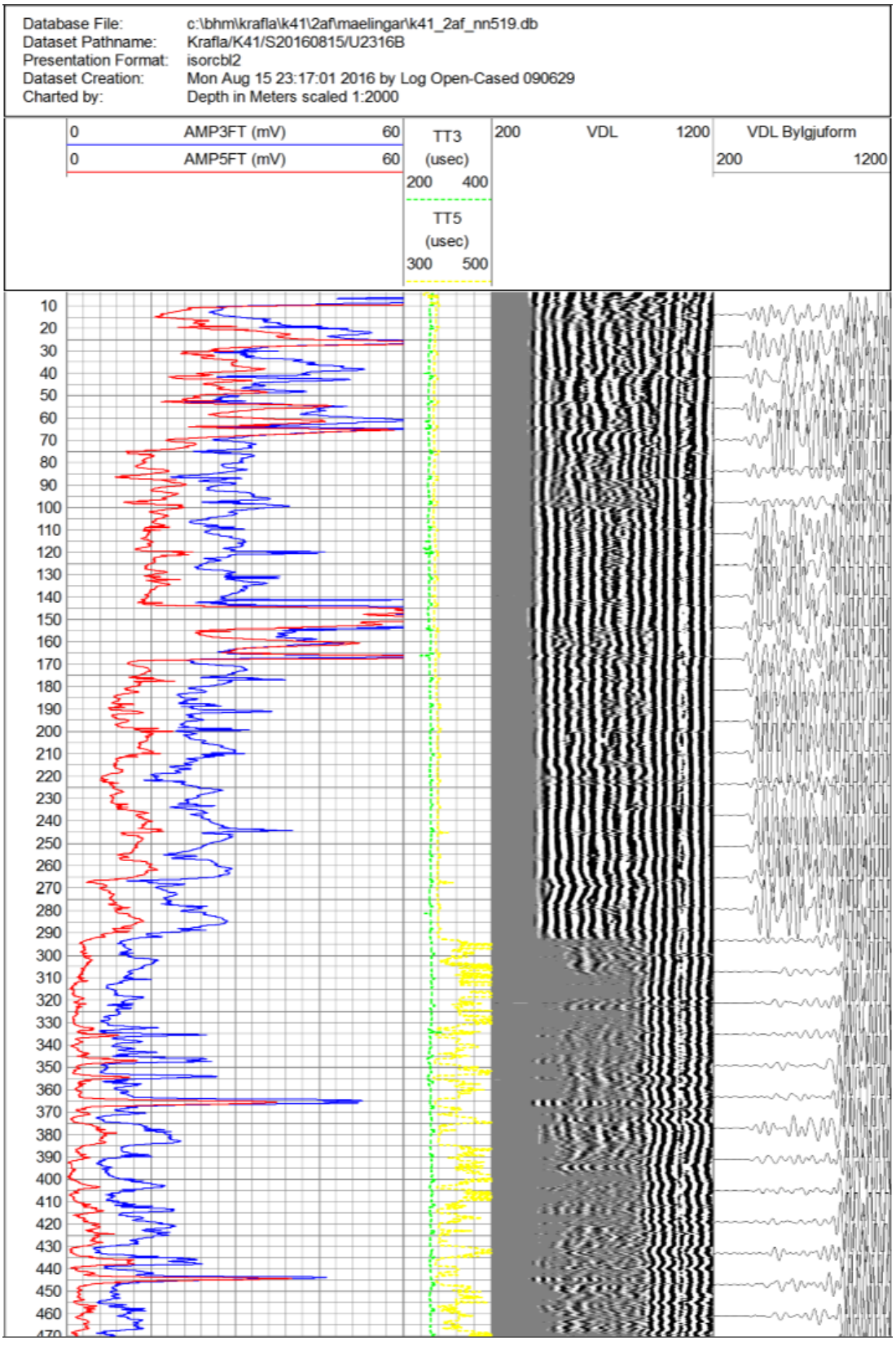

Figure 2. *CBL log from surface to 470 m. The anchor casing goes down to 293 m.*

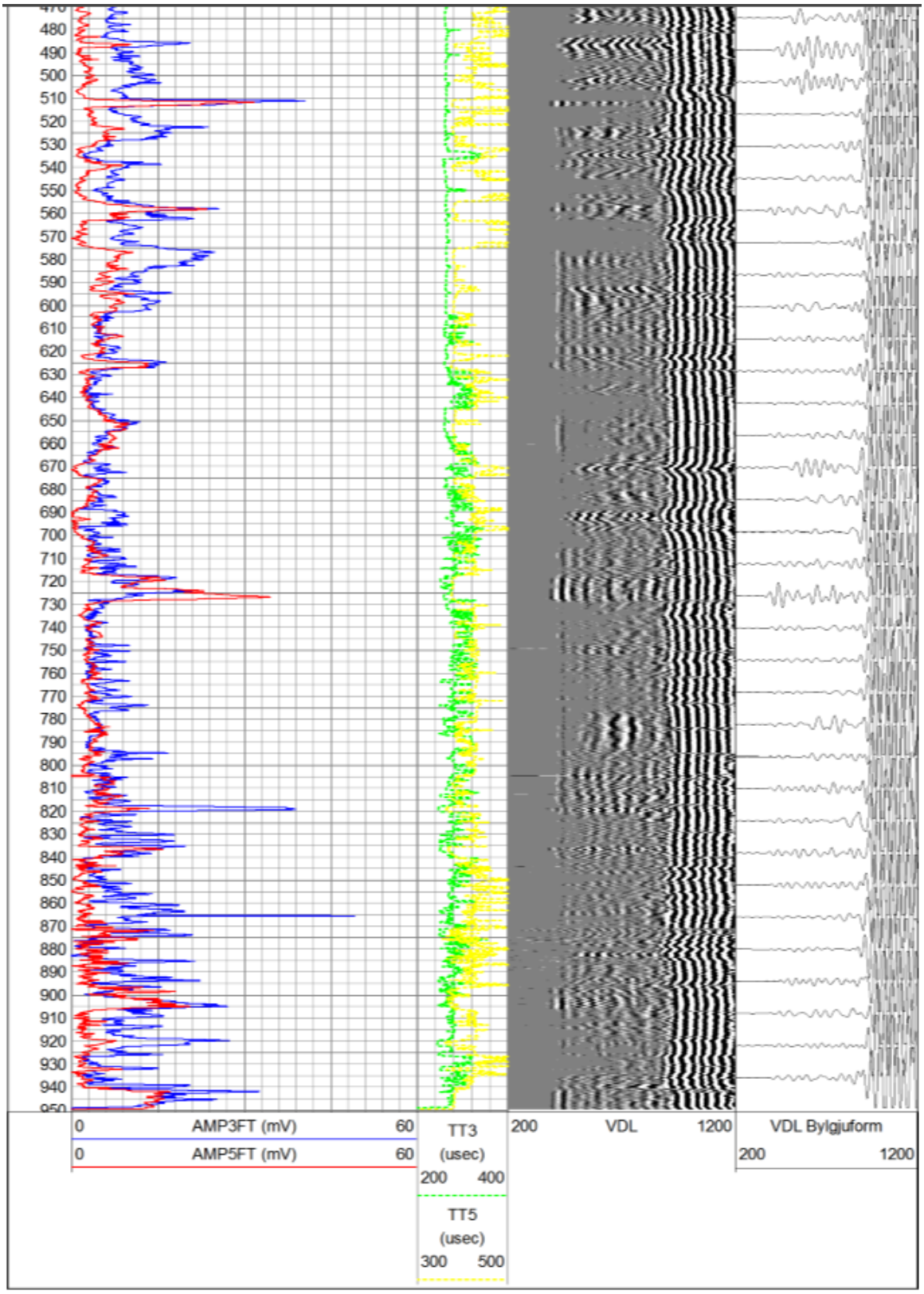

Figure 2 (continued). *CBL logged from 470-950 m.*

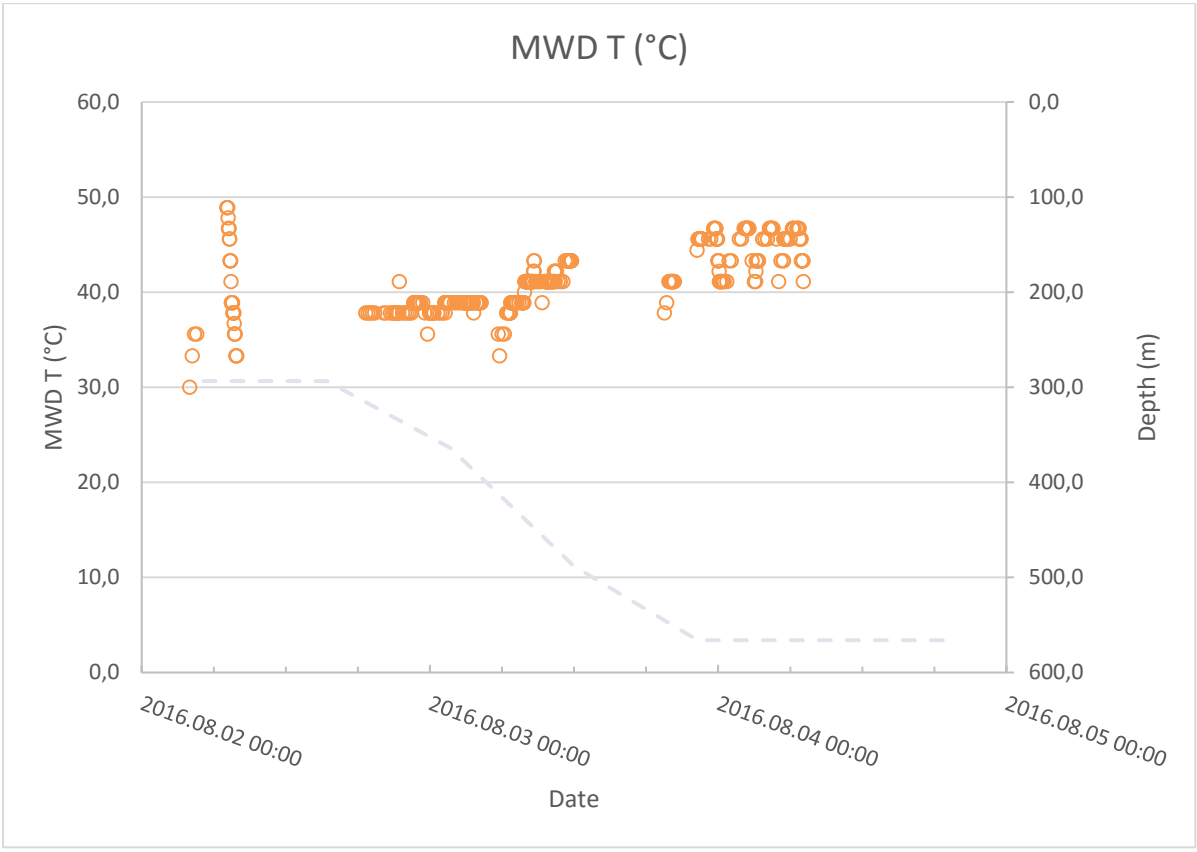

Figure 3. *Temperature logged using MWD from BHA 3.*

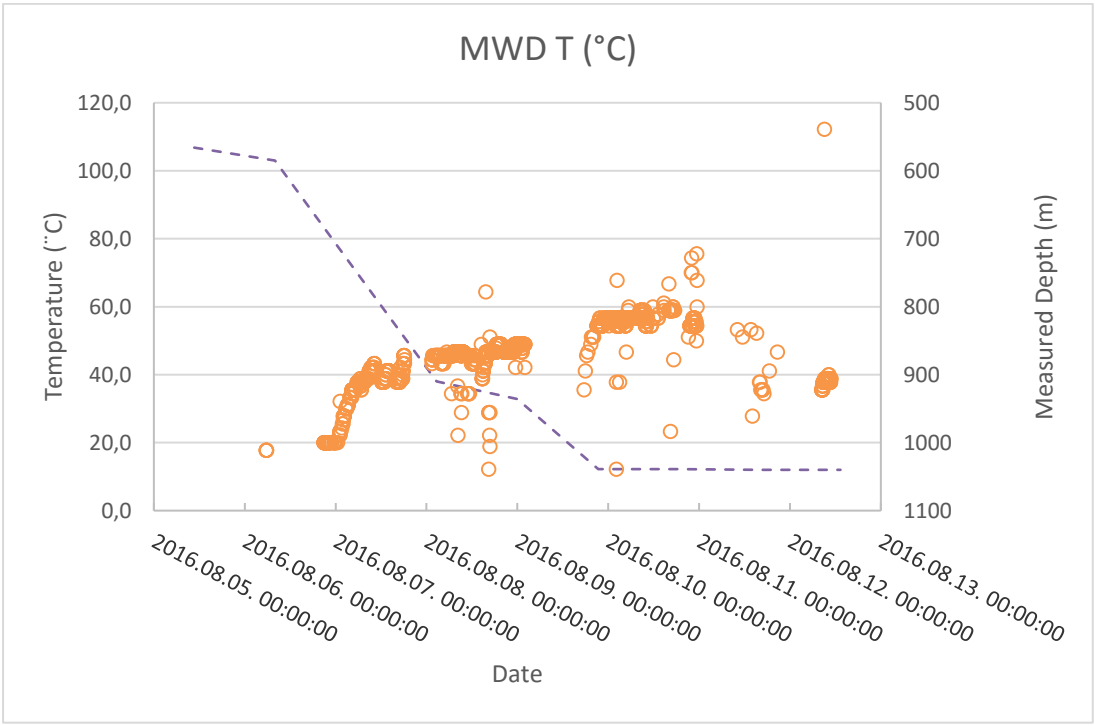

Figure 4. *Temperature logged using MWD from BHA 4.*

Borvakt

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Prentað efni