LV-2016-102

Landsvirkjun

Krafla – Well K-41

Phases 0 and 1: Drilling for Surface Casing down to 100 m and Anchor Casing down to 293 m

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ÍSOR

ÍSLENSKAR ORKURANNSÓKNIR

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Title: Krafla – Well K-41. Phases 0 and 1: Drilling for Surface Casing down to 100 m and Anchor Casing down to 293 m

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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 gully, and the aim of the drilling was to penetrate fractures associated with the Hveragil fracture zone and in the Vesturhlíðar area further east. This report addresses the drilling history and data acquisition during predrilling and the first phase of the drilling. 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 100.0 m and with 17½" drill bit for 13⅜" anchor casing down to 293.5 m. The stratigraphy of phases 0–1 in well K-41 is composed of hyaloclastite formations down to 220 m, where a glassy basalt formation takes over until 293.5 m MD. Intrusions were observed from 100 m to 150 m. The grade of alteration is generally low. Zeolites are found from the top and quartz enters at ~170 m. The main alteration minerals in the first phases were zeolites, clays and quartz.

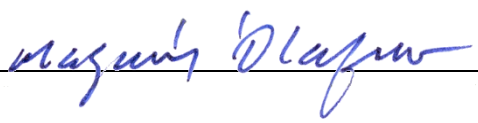
Keywords:

Krafla, well K-41, geothermal field, high temperature, feed zones, wireline logging, Sleipnir, Landsvirkjun, Iceland Drilling, ÍSOR

UWI (Unique Well Id): B58041

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 forborunar og borunar 1. 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 og með 17½" krónu fyrir 13⅜" öryggisfóðringu niður á 293,5 m dýpi. Jarðlögin í forborun og 1. áfanga holu K-41 einkennast af móbergsmyndunum niður að 220 m, þar sem glerjað basalt tekur við í 293,5 m. Innskot fundust á 100–150 m dýpi. Ummyndunin er alla jafnan þónokkur. Zeólítar fundust frá efstu sýnum og kvarts kemur inn á ~170 m dýpi. Meginummyndunarsteindir þessara áfanga voru zeólítar, leirsteindir og kvars.

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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 (Table 1 and Figure 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	Unique 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° : inclination 35 ±3° (310–1000 MD) and 70°± 5°: inclination 35±15° (1600–2000 MD), with reference to true north. The kick-off was planned 20 m below the anchor casing, at 310 m. The angle built up was planned to be 2,5° with the final inclination of 35°.

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 2) 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".
- Phase 1: Drilling for the anchor casing with 17½" drill bit down to ~290 m depth. Cased with 13⅜".
- Phase 2: Drilling for the production casing with 12¼" drill bit down to ~1100 m depth. Cased with 9⅝".
- 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 phases 0 and 1. *The third* describes the geological strata

and the alteration minerals, observed by the on-site geologist, and openings in the well. *The fourth chapter* includes the wireline loggings of phases 0–1, carried out by ÍSOR´s logging engineers.

The aim of this report is to document the geological- and geophysical part from the drilling of phases 0–1 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.

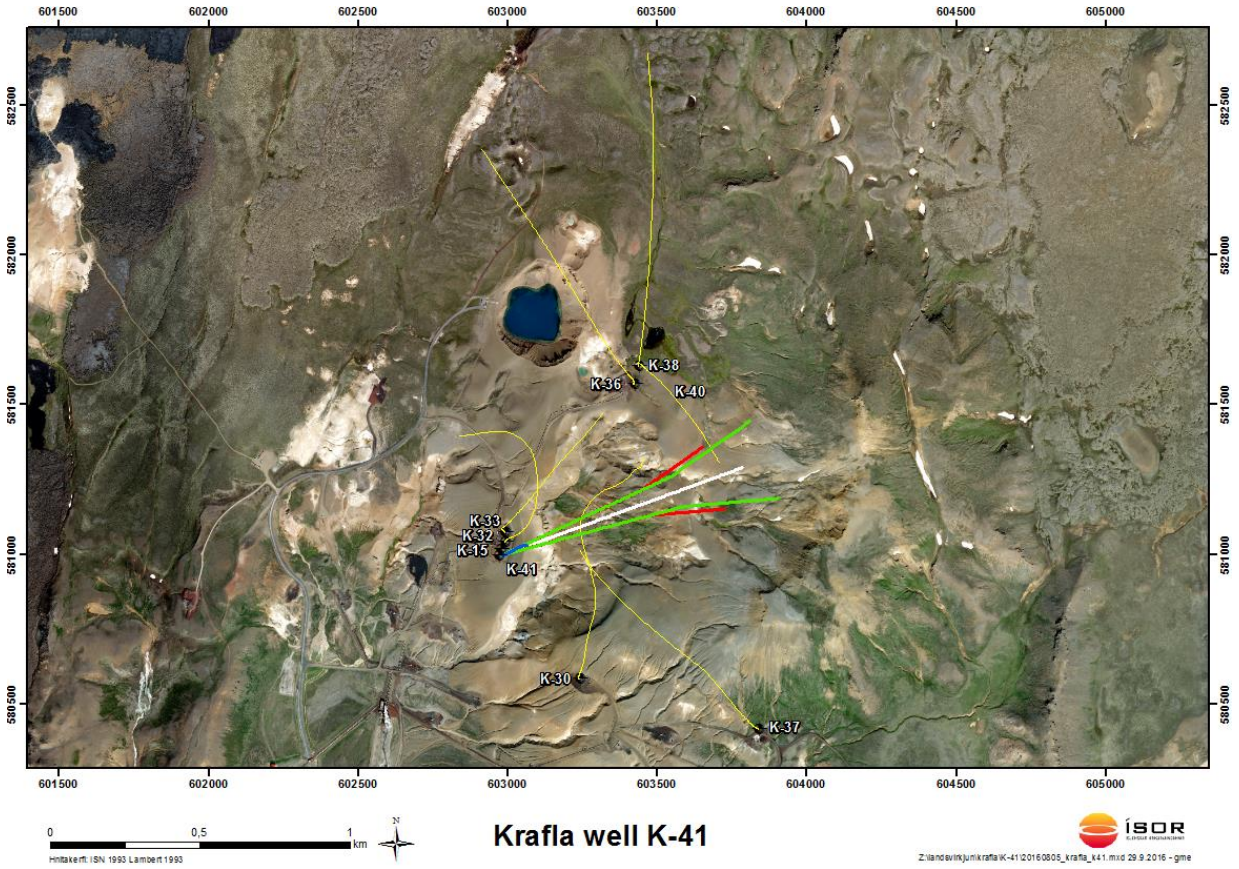

Figure 1. *The planned trajectory of well K-41 in Krafla.*

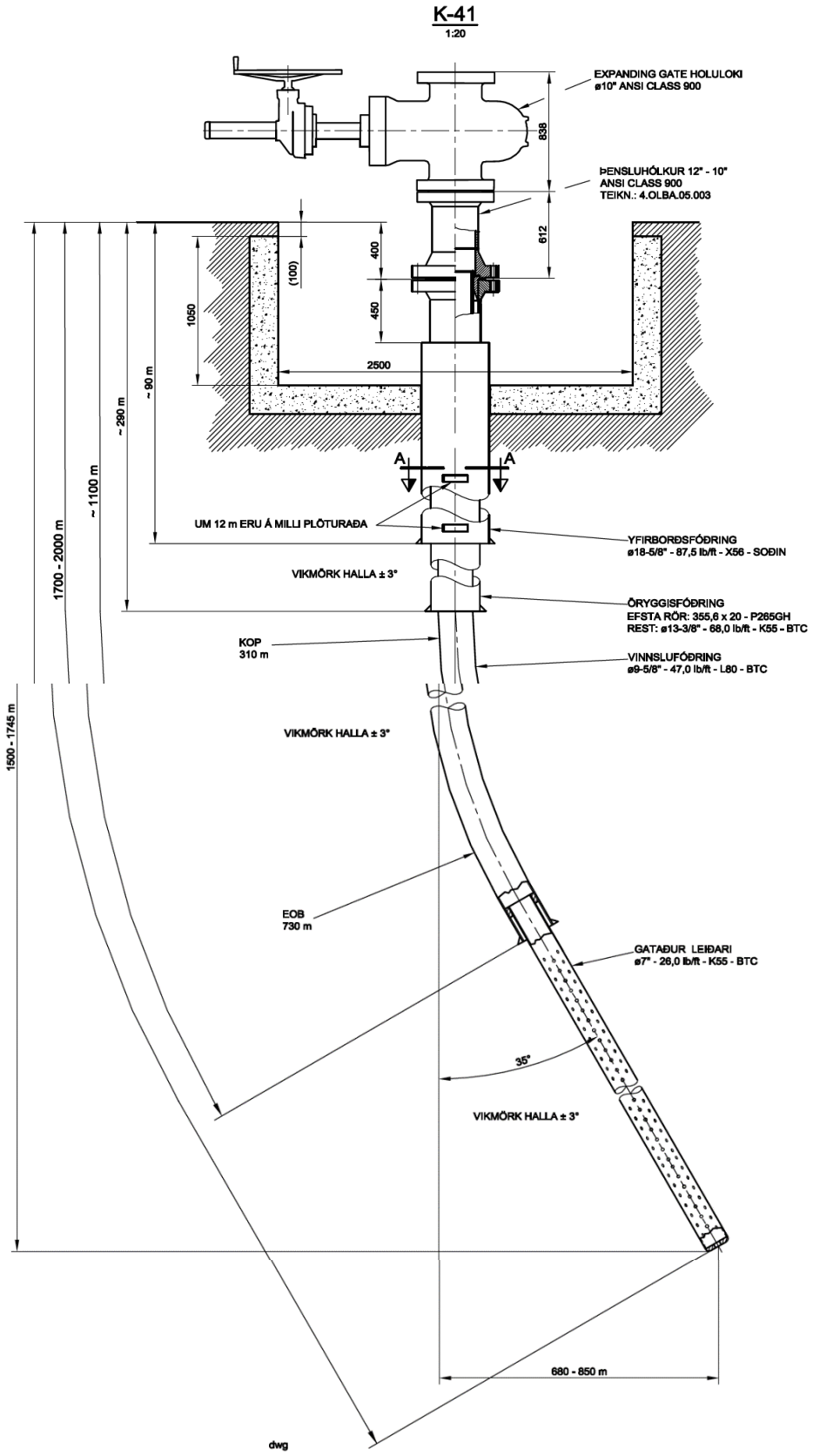

Figure 2. *Well design of well K-41.*

2 Drilling operations

2.1 Overview

Drilling operations of K-41 are divided into phases 0–3. Phases 0–1 are described hereunder.

Drill rig Sleipnir was ready for drilling of phase 0 the 21st of July 2016. Drilling with a 21" drill bit into formation started the same day at 11.5 m depth.

Drilling went on without any major problems or loss of circulation until 100 m depth. Drilling, casing and cementing of phase 0 was complete 25th of July 2016, workday 6. At this point the well was 100 m deep from the drilling platform of Sleipnir (5.64 m above ground). The 18⅝" surface casing was set at 100 m depth.

Preparations for the drilling of phase 1 started on 25th of July 2016. Testing of the blow-out preventers (BOP) was carried out on July 26th. Drilling into formation with a 17½" drill bit started at noon on the 26th of July, at 100 m. Phase 1 was completed at midnight on the 28th of July 2016 (workday 9). A 13⅜" anchor casing was run to 192.62 m depth.

An overview of the drilling phases and details of the casing depths are shown in Table 2. Figure 3 Table 2. *Drilling and casing depths in well K-41.*shows the drilling progress of well K-41 during drilling of phases 0–1.

Table 2. *Drilling and casing depths in well K-41***.**

Drill-Rig	Phase	Drill bit	Depth (m)	Depth Reference	Casing Type	Casing Depth
Sleipnir	0	21"	100	Sleipnir RF*	18⅝"	100
Sleipnir	1	17½"	293.5	Sleipnir RF*	13⅜"	292.6

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

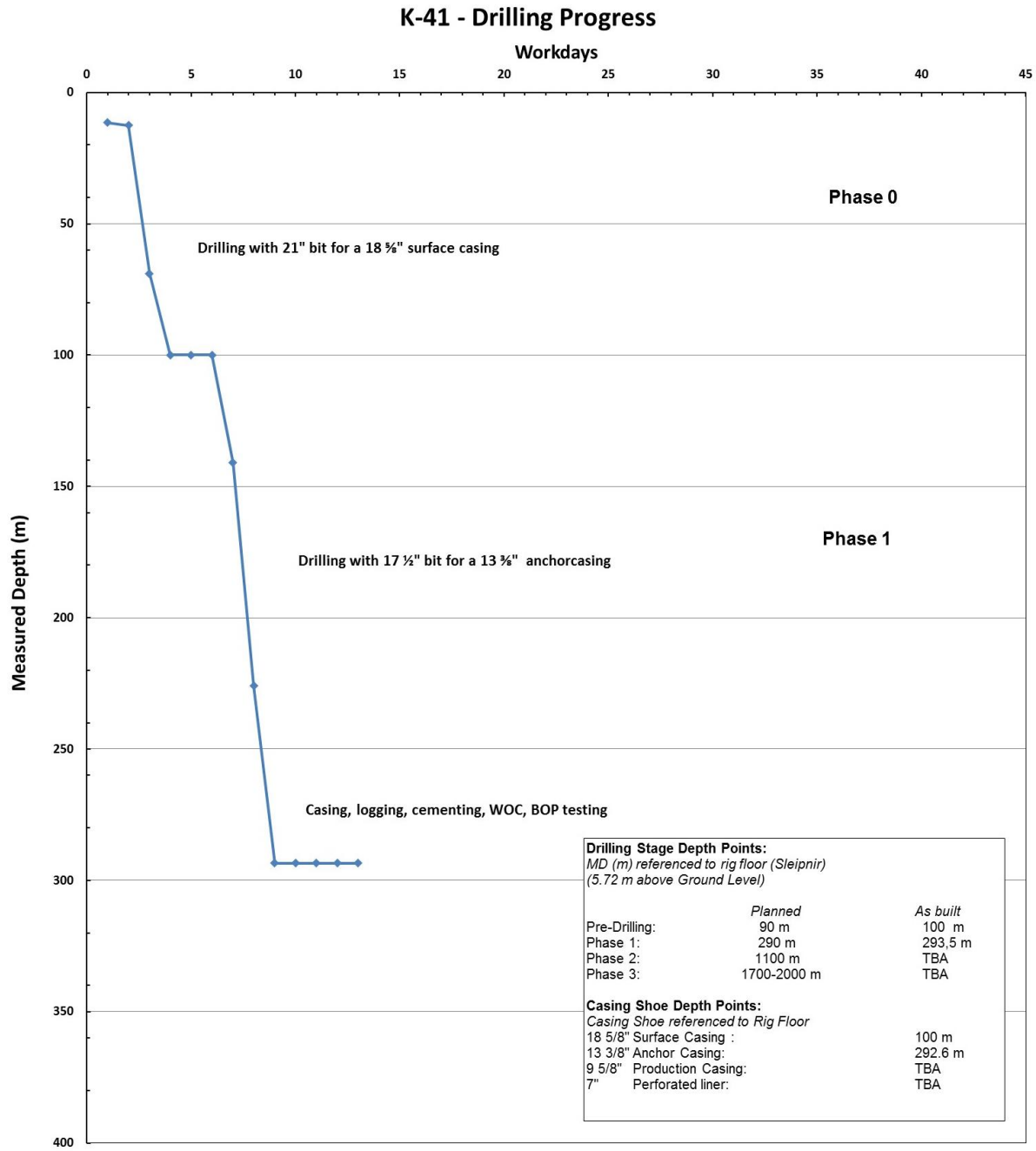

Figure 3. *Drilling progress of well K-41.*

2.2 Pre-drilling for the surface casing (18⅝") - Phase 0

Sleipnir was transported to the drillpad in Krafla in July 2016. The drillpad is located south of Víti and west of Hveragil gully, at 571 m a.s.l. (Figure 1). After rigging up, drilling of well K-41 started on July 21st with a 21" drill bit, and phase 0 (pre-drilling) was completed the 25th of July (workday 6). Drilling was almost continuous down to the final depth of 100 m which was reached at noon on July 23rd.

Late night July 21st, drilling into formation began at 11,5 m after working on the riser and connections, connecting the flowline, compiling the drilling collars and making the drill rig ready for operations. After drilling down to 12,5 m, the drilling mud was mixed, followed by drilling down to 16 m where leakage in the standpipe was observed. The leaking was fixed, a centralizer was added and drilling continued. Drilling was almost continuous, with some short maintenance breaks, with pumping of 30–35 L/s, 2,5–5 tons weight on bit. No circulation losses were observed. When the 100 m were reached, the well was circulated for one hour before pulling out of hole and reaming. After reaming, the well was circulated again and tilt measurement of 0,5° measured at 93 m depth.

Casing job for 18⅝" surface casing started at 1:30 the 24th of July and was completed at 13:30 the same day at 100 m. Next, preparations were made for cementing of the surface casing. After running in the cement string, the well was circulated before the cement job was carried out between 17:00 and 17:30 on the 24th of July. Total of 10.2 m^3 of cement (with density of 2.0 g/cm^3) were pumped down the string. Afterwards, some 0.7 m^3 of water were pumped down to clean the string. The cement returns were observed and the cement level did not subside from the wellhead so fill up was not necessary. Welding of the flange on the 18⅝" surface casing was finished around noon the 25th of July and that marks the end of drilling phase 0.

The progress of drilling during the pre-drilling (phase 0) is shown in Table 3 and Figure 3. Casing and Cement reports from the drilling contractor (Iceland Drilling) are shown in Tables 4 and 5.

Table 3. *Drilling progress of the pre-drilling phase carried out by the drill rig Sleipnir. Depths are referred to the rig floor of Sleipnir (5.64 m above the ground).*

	Date	Workday	Drilled (m)	Time (hrs)	Average ROP (m/hr)	MD (m)	Comment
Phase 0	20.7.2016	1	-	-	-	(11,5)	Rigging up
	21.7.2016	2	1	0,5	2	12,5	Rigging up and drilling
	22.7.2016	3	56,5	20,75	2,7	69	Drilling
	23.7.2016	4	31	12,25	2,5	100	Drilling
	24.7.2016	5	-	-	-	100	Cement job
	25.7.2016	6	-	-	-	100	Flange and BOP's

Table 4. *Casing report for surface casing in K-41.*

Casing Information Report — **Iceland Drilling**
Rig: Sleipnir — Rig No: 28000
Job No: 28000-16-01 — Job Name: K 41

Casing Information

Run Date/Time:	24-júl.-16 13:30		
		Leak Off Test (kg/cu m):	
Well Section:	INT1	**String Type:**	FULL
String Top MD (m):	6,8	**String Top TVD (m):**	
Casing Shoe MD (m):	100,0	**Casing Shoe TVD (m):**	
String Nominal OD (cm):	47,31	**String Nominal ID (cm):**	44,45
Bit Diameter (cm):	53,34	**Avg. Open Hole Diam. (cm):**	54,50
Centralizers: No:		**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 26-júl.-16 09:08		

String Component Details

Joints		Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
	9	JOINT	105,610	47,31	45,10		X-56	WELD	
Totals:	9		105,610						

Table 5. *Cementing report for surface casing in K-41.*

Cementing Report — **Iceland Drilling**
Rig: Sleipnir — Rig No: 28000
Job No: 28000-16-01 — Job Name: K 41

Cement Job Information

Start Date/Time:	24-júl.-16 17:00	**Well Bore:**	Original Well Bore
Job Type:	PRIMARY	**String OD (cm):**	47,31
Well Section:	INT1	**String Type:**	FULL
Cementing Co:	JARDB	**Cementing Engineer:**	Andrés

Primary Job Detail

	Volume (cu m)	Pump Time	Rate (cu.m./min)	Pressure (bar)
Conditioning Data:				
Cement Data:	10,2	27	600,0	12
Displacement Data:				
Calc. Displacement Vol:				

☐ **Batch Mix?** ☐ **Bump Plug?** **Bump Pressure:**
Returns to Surface: ☐ **Reciprocate Pipe?** ☐ **Cement at Surface?**
Calc Top of Cement (m): 87,0 **Excess (%):** **Avg. Hole Size (cm):** 53,34

Slurry Information

Type	Density	Yield	Sacks	Volume	Rate	Additives
LEAD	2			10,2	600,0	
DISPLACE				0,7	300,0	

Post Job Information

Liner Top Test (kg/cu m):		**Job Success?**	No
Actual Top of Cmt (m):		**CBL Bond Quality:**	
Misc. Comments:	Steypt var úr 10.2 m3 eftirdælt 700 L steypa kom upp		

2.3 Drilling for the anchor casing (13⅜") - Phase 1

Drilling operations of phase 1 were conducted from July 25th (workday 6) to July 31st (workday 12). Drilling progress during drilling of phase 1 is shown in Table 6 and Figure 3.

On July 25th the flange was welded on to the surface casing and subsequently, the crew started working on the BOP stack. Early morning 26th of July, the crew started to run in hole with a 17½" bit for drilling for the anchor casing. Top of cement (TOC) was encountered at 78 m depth and at 11:00 the bit tagged the casing shoe at 100 m. At 11:15 the bit entered formation and then the crew started to mix drilling mud. Drilling then continued with a steady pace and 6–9 ton weight on bit until 226 m. The mud tank temperature increased slightly. A deviation survey at 200 m showed an inclination of 0.9°. Drilling went on at a steady pace of 3 m/hr. Casing depth of 293.5 m was reached around midnight 29th of July (workday 10) while drilling into a hard formation consisting of glassy basalt. No circulation losses were observed during phase 1.

The well was circulated before wiper trip and no bottom hole fill was observed. After the wiper trip and reaming however, a bottom fill of 2 m was observed. The well was circulated further and the bottom hole fill was reduced. At 16:00, ÍSOR´s logging engineers arrived on site to carry out a temperature log and a caliper log. At 20:00 in the evening, the 13 3/8" casing was run in hole and set at 292.6 m. After the casing was set, the cement string was RIH and the well was cooled and circulated for few hours. Cementing of the casing got underway shortly after noon July 30th. The cement job took around 40 minutes and a total of 23.2 m^3 of cement slurry was used for the job followed by 2 m^3 of water to clean the cement string. Casing and cement reports can be found in Table 7 and Table 8. Approximately 0.7 m^3 of cement was added on top between the casings after the top of cement had subsided slightly. In the morning of July 31st, ÍSOR's logging engineers carried out temperature and CBL logs. While logging down, the temperature tool stopped at 180 m, but after few attempts it continued to 250 m where it stopped completely. The CBL instrument only went down to ~100 m and attempts to get it further were unsuccessful. Both instruments returned to surface packed with cement slurry (Figure 4). Otherwise the CBL showed good results in the cement bonding for the uppermost 100 m.

In the afternoon, the BOP stack was removed, and flange was welded on the 13⅜" casing. This marks the end of phase 1 on the 31st of July, workday 12 of Sleipnir on the well.

Figure 4. *Logging engineers preparing to run the CBL tool into the well (left) and the centralizer caked in mud on return from the logging of well K41.*

Table 6. *Drilling progress during drilling of phase 1 in K-41.*

	Date	Workday	Drilled (m)	Time (hrs)	Average ROP (m/hr)	MD (m)
Phase 1	26.7.2016	7	41	16	2.6	141
	27.7.2016	8	85	22	3.9	226
	28.7.2016	9	67,5	24	2.8	293.5
	29.7.2016	10	0	0	0.0	293.5
	30.7.2016	11	0	0	0.0	293.5
	31.7.2016	12	0	0	0.0	293.5
	1.8.2016	13	0	0	0.0	293.5

Table 7. *Casing report for the 13⅜" anchor casing.*

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

Casing Information

Run Date/Time:	29-júl.-16 20:00		
		Leak Off Test (kg/cu m):	
Well Section:	INT3	**String Type:**	FULL
String Top MD (m):	0,0	**String Top TVD (m):**	0,0
Casing Shoe MD (m):	292,6	**Casing Shoe TVD (m):**	292,6
String Nominal OD (cm):	33,97	**String Nominal ID (cm):**	31,53
Bit Diameter (cm):	44,45	**Avg. Open Hole Diam. (cm):**	44,45
Centralizers: No:	9	**Manufacturer/Type:**	
Depths:			
Hanger Type:		**Manufacturer:**	
Comments:	Transferred from Casing Tally Detail on 30-júl.-16 05:13		

String Component Details

Joints	Item	Length (m)	OD(cm)	ID (cm)	Weight (kg)	Grade	Connection	Torque
27	JOINT	299,410	33,97	31,53	101,2	K-55	BUTT	2200
1	JOINT	0,580				K-55	BUTT	2200
Totals: 28		299,990						

Table 8. *Cement report for the 13⅜" anchor casing.*

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

Cement Job Information

Start Date/Time:	30-júl.-16 13:00	**Well Bore:**	Original Well Bore
Job Type:	PRIMARY	**String OD (cm):**	33,97
Well Section:	INT3	**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:	23,2	22	700,0	
Displacement Data:				
Calc. Displacement Vol:				

	☐ Batch Mix?	☐ Bump Plug?	**Bump Pressure:**		
Returns to Surface:	PARTIAL	☐ Reciprocate Pipe?	☑ Cement at Surface?		
Calc Top of Cement (m):	268,5	**Excess (%):**	**Avg. Hole Size (cm):**	44,45	

Slurry Information

Type	Density	Yield	Sacks	Volume	Rate	Additives
LEAD	2			22,3	700,0	
FLUSH				2.000,0	400,0	
TAIL	2			0,7	400,0	

Post Job Information

Liner Top Test (kg/cu m):		**Job Success?**	No
Actual Top of Cmt (m):		**CBL Bond Quality:**	
Misc. Comments:	Steypt úr 23,2 m3 af sementi eftirdæling 2 m3 steyp síðan ofan á úr 0,7 m3 steypa sígur aðeins		

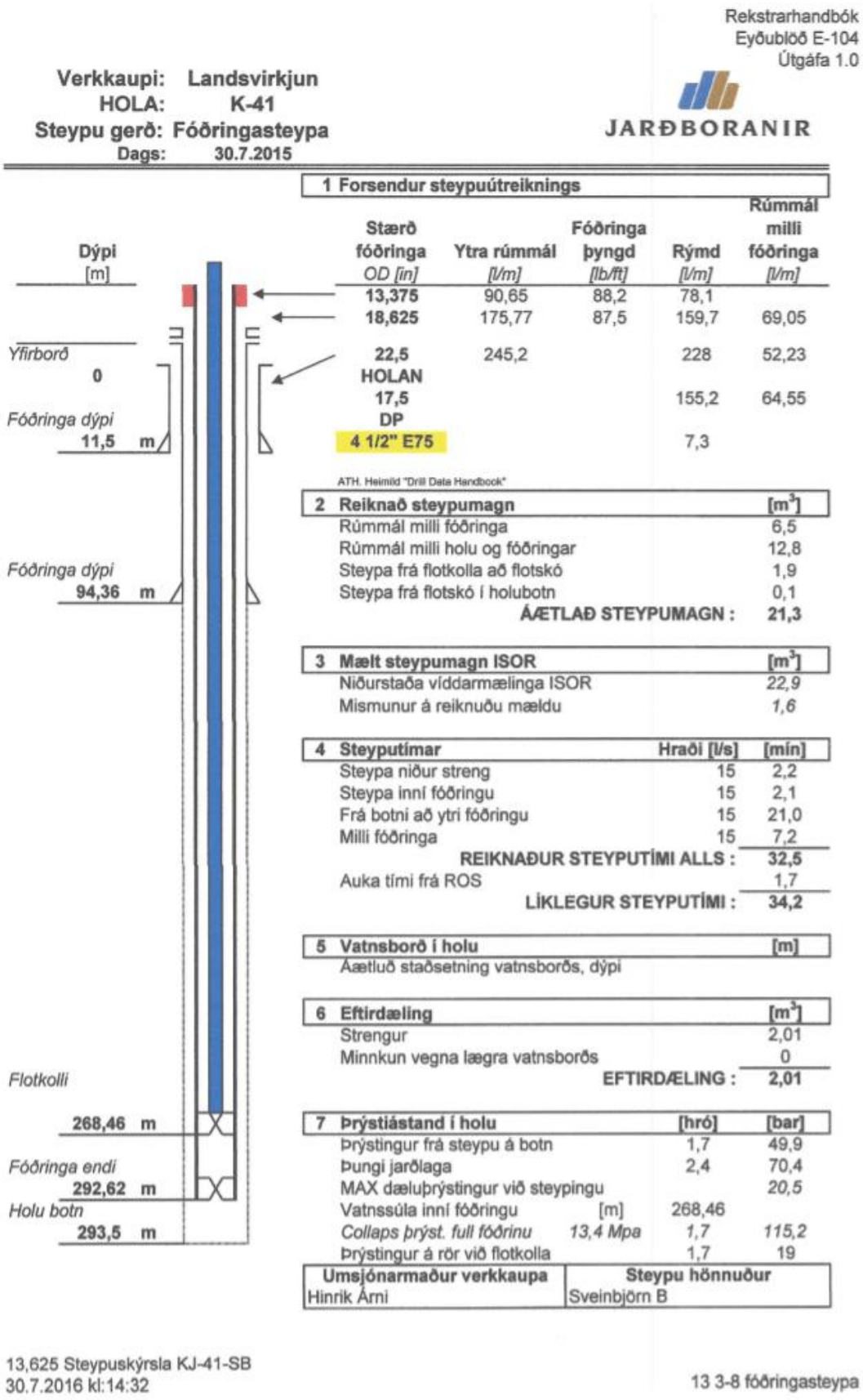

Figure 5. *Cement report for the 13⅜" anchor casing in well K-41.*

3 Lithology, alteration, intrusions and circulation losses

The drilling crew collected cutting samples at two meters interval during the drilling of phases 0–1 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 1 and determined the lithology and the alteration mineral assemblage through the aid of a binocular microscope. No geologist was required on site for phase 0 and therefore no cuttings were analyzed on site during that time. This was done after the drilling was finished and the results can be seen below. 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.

3.1 Lithology of phases 0–1

The lithology of phases 0–1 in well K-41 corresponds well to what was seen in in wells KJ-32 (Guðmundsson et al., 1998) and very well with KJ-33 (Guðmundsson et al., 1999). All wells are drilled from the same wellpad so similarities were expected.

A detailed lithological log for well K-41 from 12 to 293.5 m depth is compiled in Figures 6–10, where different lithological units are described. The legend for these figures is showed in Figure 6. For comparison the lithology of well K-41, KJ-32 and KJ-33 is shown in Figure 9.

A recap of the drilling history during the drilling for the surface casing and anchor casing is shown in Figure 9. A cursory inspection of the figures reveals that the breccia was easier to drill through (higher ROP's for a given WOB) than the tuff and glassy basalt.

The description of the drill cuttings sampled from well K-41 is as follows:

Phase 0 (0–100 m)

In phase 0 the dominant lithologies were hyaloclastite formations (tuff and breccia). No intrusions were observed

10–22: REWORKED TUFF

Oxidized and altered reworked tuff. Different tuff fragments, size, color, alteration. Few basaltic fragments.

22–26: BASALTIC BRECCIA

Tuff and fine-med grained basalt fragments mixed together. Less alteration than above. Few very oxidized (bright red or orange) and very porous fragments. Some basalt fragments are porous, other not.

26–30: BASALTIC TUFF

Tuff layer with somewhat altered fragments

30–58: BASALTIC BRECCIA

Similar as the breccia above. Porous basaltic breccia with zeolites in pores. Further down there is an abrupt change in lithology. More alteration and the cuttings were green-blue. No oxidation, more pyrite. further down this formation the green color disappears and the fragments become dark grey-black and the tuff ratio increases.

58–66: FINE-MEDIUM GRAINED BASALT

Dark grey basalt with little alteration. Dense and almost no pores. Some big lumps of pyrite. The last part of this layer consisted of light grey fine-med. grained basalt.

66–70: MEDIUM-COARSE GRAINED BASALT

Medium-coarse grained basalt with some pores and vesicles.

70–80: BASALTIC BRECCIA

Dark and light fragments with different alteration. Some fragments are porous with heulandite

80–100: BASALTIC TUFF

A thick tuff formation composed of tuff fragments. Same as below.

Phase 1 (100–293.5 m)

Below 100 m, tuff (100–170 m), breccia (170–220 m) and glassy basalt (220–293.5 m) are dominant. Few intrusions and possible intrusions were observed.

100–122 m: BASALTIC TUFF

The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt.

122–124 m: FINE-MEDIUM GRAINED BASALT

The cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between 122 m and 123 m depth.

124–130 m: BASALTIC TUFF

More or less identical to the tuff above the intrusion.

130–170 m: BASALTIC TUFF

An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170–220 m: BASALTIC BRECCIA

Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia. At 212 m wairakite appears, which correlates well with wells 32 and 33.

220–292 m: GLASSY BASALT

Change from the softer breccia to a harder formation of glassy basalt. The basalt is dense and apparently without pores and showing some alteration. Primary minerals are pyroxene and plagioclase along with alteration minerals such as clay (appear at ~222 m) and quartz.

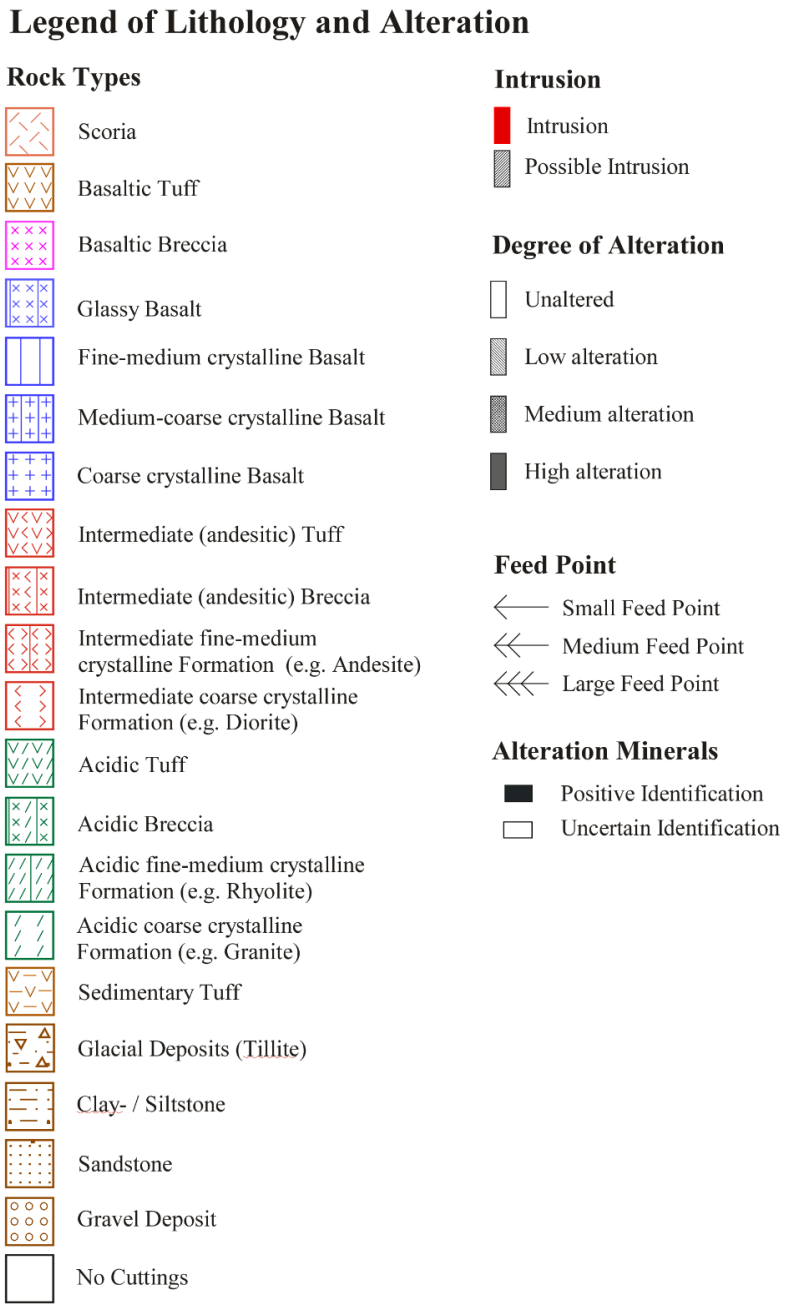

Figure 6. *Lithology legend for Figures 7–10.*

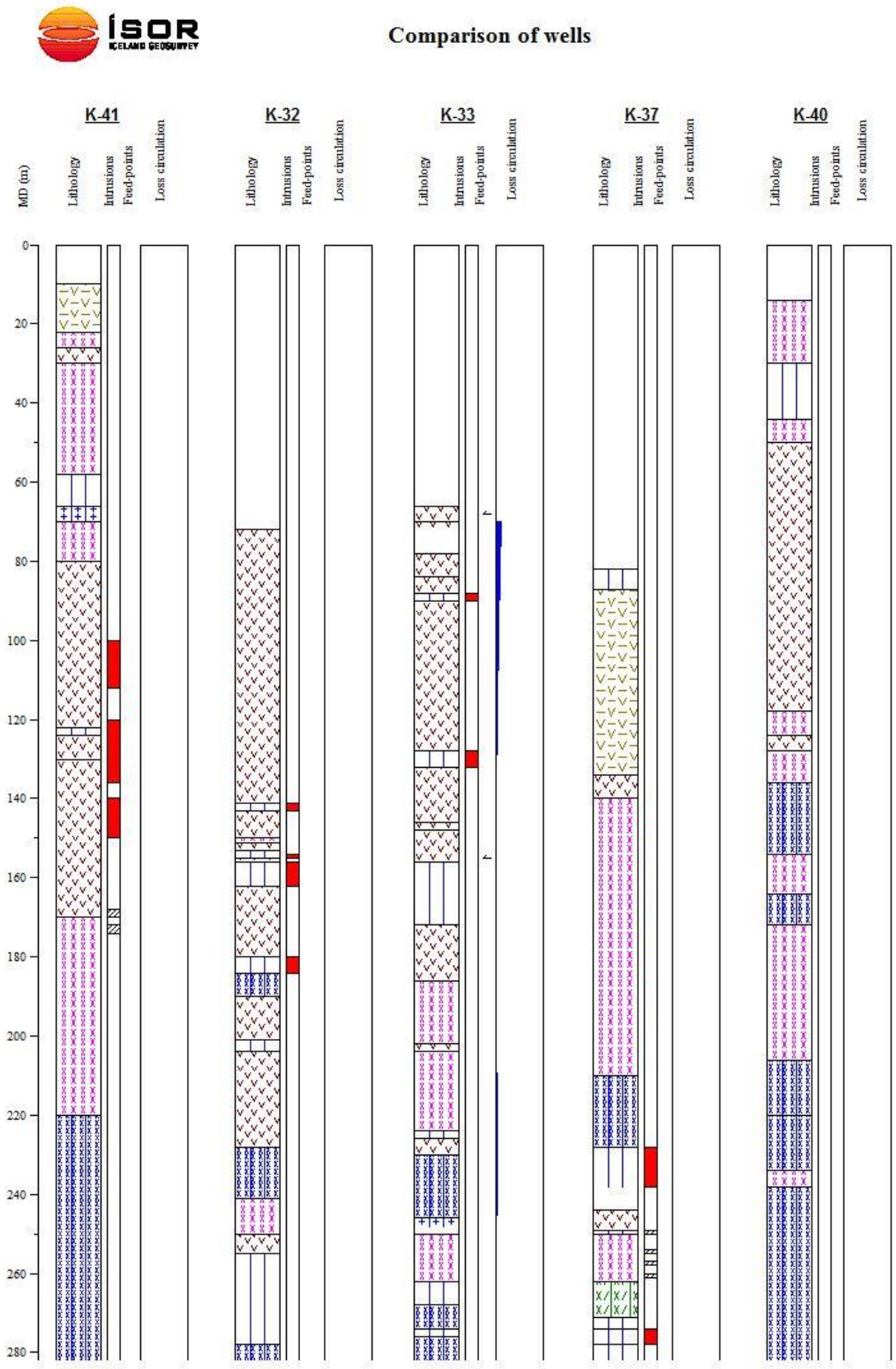

Figure 7. *Comparison of the lithology and intrusions in wells K- 41, KJ-32, KJ-33, K-37 and K-40.*

3.2 Intrusions

Well K-41 intersects a few intrusions and possible intrusions in phase 1. Intrusions were observed at 100–112, 120–136 and 140–150 m. Possible intrusions were observed at 168–170 and 172–174 m.

Although the intrusions in well K-41 are probably dikes rather than sills it is of interest to compare locations of intrusives among wells on the same pad. In well KJ-33 intrusions were observed at 90 m and 128–132 m and possible intrusions at 156–172, 124 and 146 m. In well KJ-32, intrusions were observed at 140 m, and around 160 m.

3.3 Alteration

A summary of the distribution of alteration minerals in well K-41 is presented in Figure 10. A regular progressive hydrothermal alteration with increasing depth was noticed from the alteration mineral assembly. the first zeolites were noticed at 14 m depth (Heulandite). At deeper levels in the well the clay becomes coarser grained and quartz appears at ~150 m. Pyrite was found all samples with only very few exceptions. Calcite was first observed at 56 m and in great amount a little bit deeper, at 72 m. Oxidation was limited in phase 0 and 1, except for the top formation and at 168–226 m where oxidation got increasingly higher while penetrating the breccia. Some veining was observed.

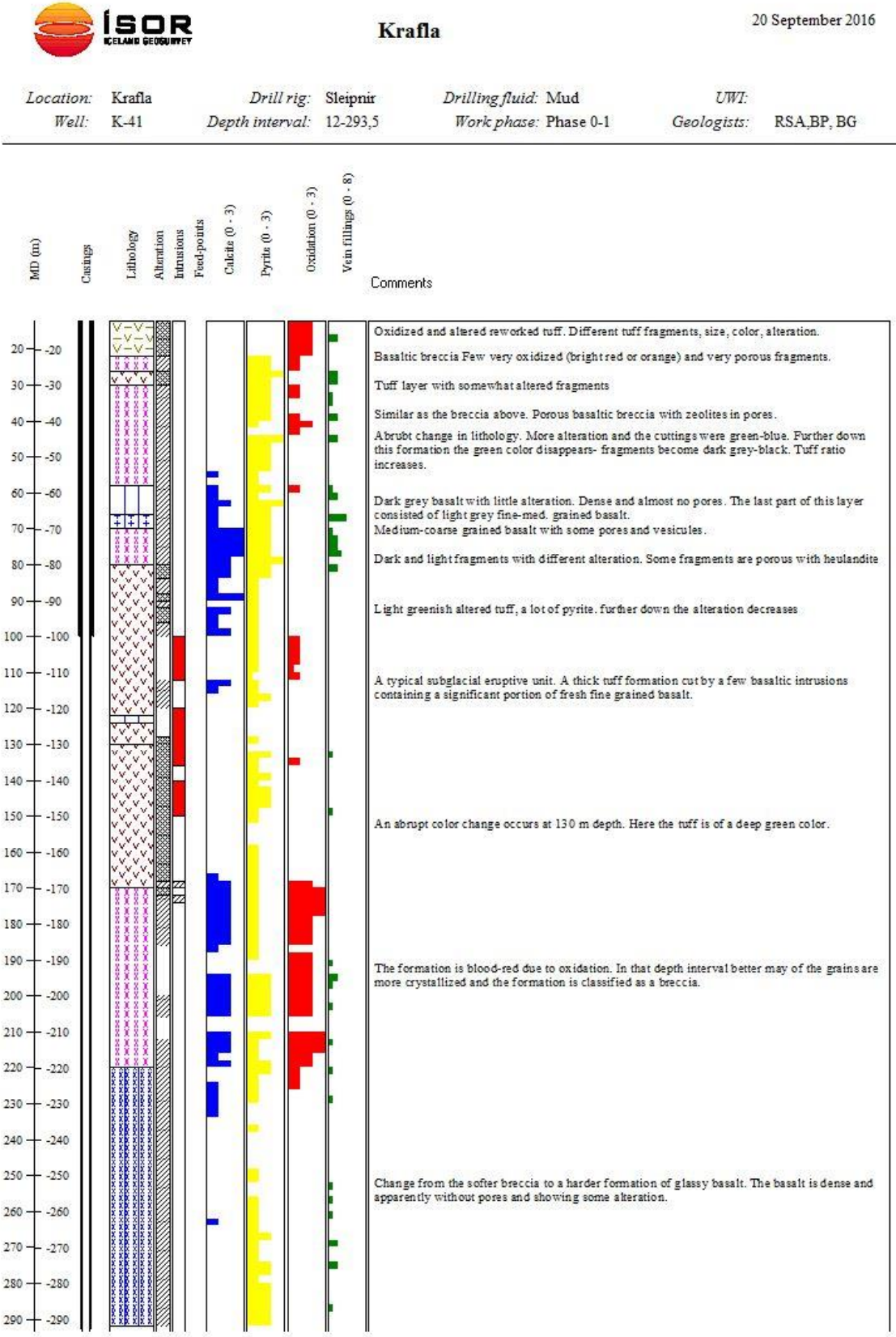

Figure 8. *Lithology, alteration and description of lithology at 12–294 m depth in K-41.*

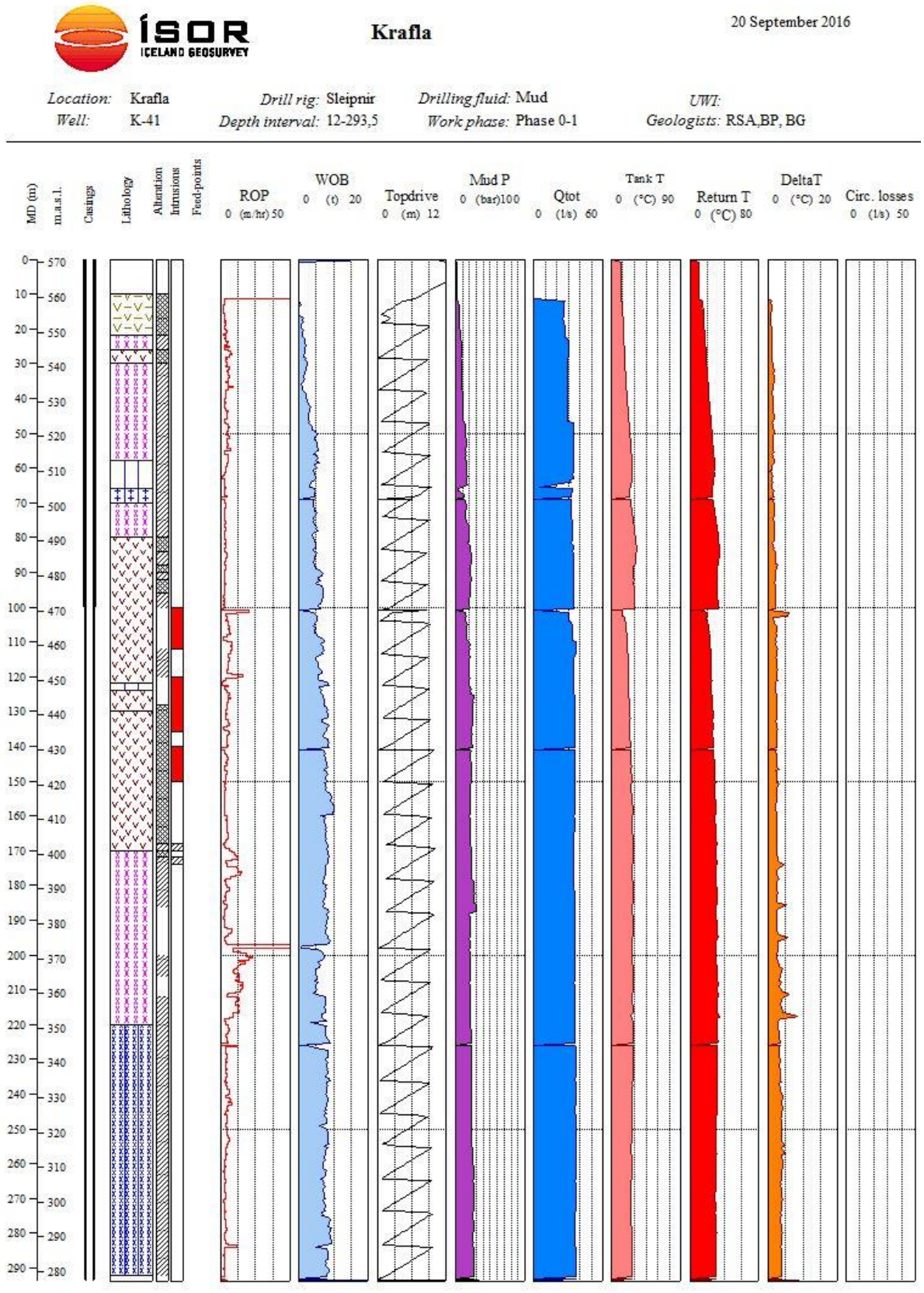

Figure 9. *Comparison of lithology and drilling data from 0–300 m depth in K-41.*

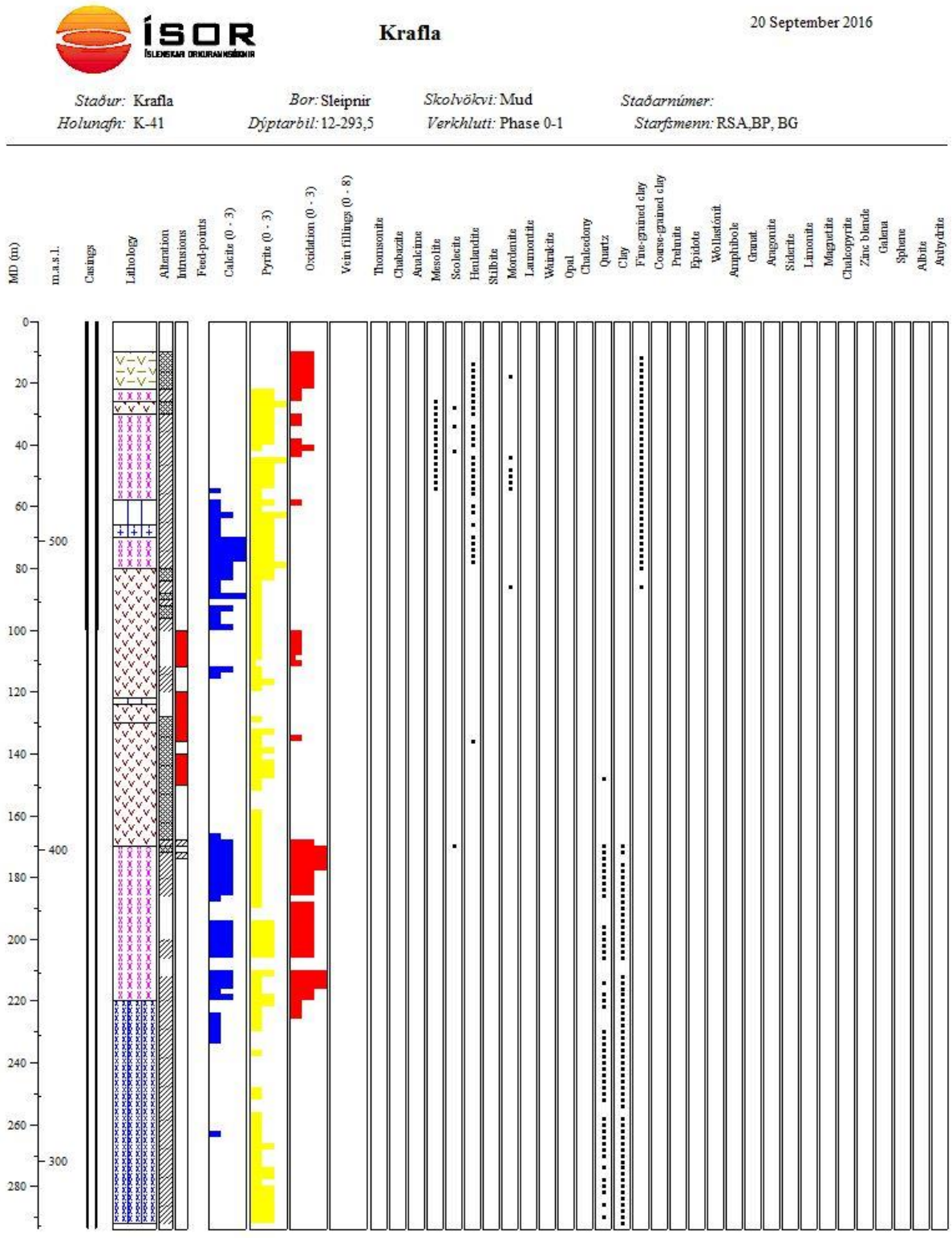

Figure 10. *A summary of the alteration minerals found in well K-41 during drilling of phases 0 and 1.*

3.4 Circulation losses during drilling of phases 0–1

Circulation losses were monitored during drilling of phases 0–1 in K-41. No circulation losses were measured during drilling of phases 0–1. In well KJ-32, there were possible losses of 0.5 l/s at 210–220 m and 1 l/s at 274–283 m, but these numbers are possibly due to uncertainties in measurements. In well KJ-33 a 4 l/s loss was observed at the surface casing depth (~100 m) and 2 l/s at 224–240 m and again at 310 m.

4 Wireline logging

Wireline logging in drilling phase 1 may be categorized as follow:

- Temperature log to locate possible feed zones in the section drill during phase 1.
- 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.
- Temperature log and CBL-log after cementing in order to check the hardening- and the binding process of the cement that is exoergic and heats up the stagnant water inside the casing.

Table 9 shows an overview of all logs performed during phase 1 of well K-41.

Table 9. *Overview of wireline logging in drilling phase 1 for the anchor casing.*

Date	Time	Log type	Depth (m)	Purpose	Q [l/s]	Remarks
29.7.2016	16:25-16:36	Temperature	15-292	Temperature, flow zones	0	Logged in open hole
29.7.2016	17:25-17:43	XY-Caliper	50-292	Well diameter, obstacles, washouts.	0	
31.5.2016	08:01-08:42	Temperature	15-250	Temperature	0	Instrument stopped in cement at 250 m depth.
31.7.2016	11:00-11:15	CBL	0-100	Cement Bond	0	About 21 hours after last cementing Instrument stopped in cement at 100 m depth.

In this chapter the logging activity and the logging results in phase 1 in K-41 are introduced and discussed. After drilling for the anchor casing, temperature and caliper logs were planned prior to running in hole and cementing of the 13⅝" casing. Following the cementing of the anchor casing, temperature and cement bond logs (CBL) were scheduled in order to map the actual bonding of the casing.

Drilling of phase 1 (drilling for the anchor casing) commenced on July 26th. Casing depth was reached around midnight July 28th at 293.5. No logging was performed during the drilling of phase 1.

Logging engineers from ÍSOR came to the drill site for temperature and caliper logging shortly after lunch on July 29th. The measured temperature profile are shown in Figure 11. No loss of

circulation had been reported and no water was pumped on the well while logging. The bottom was tagged at 292 m depth and the highest temperature measured was 47°C at the bottom.

The XY-caliper tool was next run in hole (Figure 12). The log shows a small cave from below the surface casing and at 175 m depth where boundaries between tuff and breccia were observed as well as possible intrusions. At this depth interval the rate of penetration increased when leaving the harder tuffaceous formation and going into the softer breccia. Otherwise the well was fairly smooth. According to the XY-caliper log, the approximate volume needed to cement behind the 13⅜" anchor casing (annular volume) was ~21 m^3 as shown in Figure 12. The actual amount of cement used was, however, 23.9 m^3.

The cementing of the 13⅜" anchor casing was finished shortly after lunch on July 30th. About 18 hours after the completion of the cement job, ÍSOR's logging engineers arrived at the drill site for temperature and CBL logging. The temperature log was performed first and the results are shown in Figure 11. The temperature probe hung up at 180 m depth but went down after a few attempts. The probe hung up again at 245 m depth and after many attempts probe finally stopped 250 m depth. Highest temperature measured was 92°C at the bottom.

When the temperature tool came out of the well the temperature sensor was full of cement. The cement isolates the temperature sensor and it makes the temperature profile relatively smooth and prevents us from seeing minor natural changes in the temperature profile.

Figure 13 shows the CBL-log measured inside the anchor casing 21 hours after the cement job finished. CBL-tool hung up at 100 m depth and it was impossible to get it deeper. When the CBL tool came out of the well the CBL centralizer was packed with cement slurry (Figure 4 and Figure 14). The surface casing depth in well K-41 is 100 m so the CBL-log shows only the cement bond to the anchor casing down to the surface casing depth. The cement between the casings below 15 m depth already showed clear signs of bonding 21 hours after the cementing. Above 15 m the 0.7 m^3 fill up cement has not set yet.

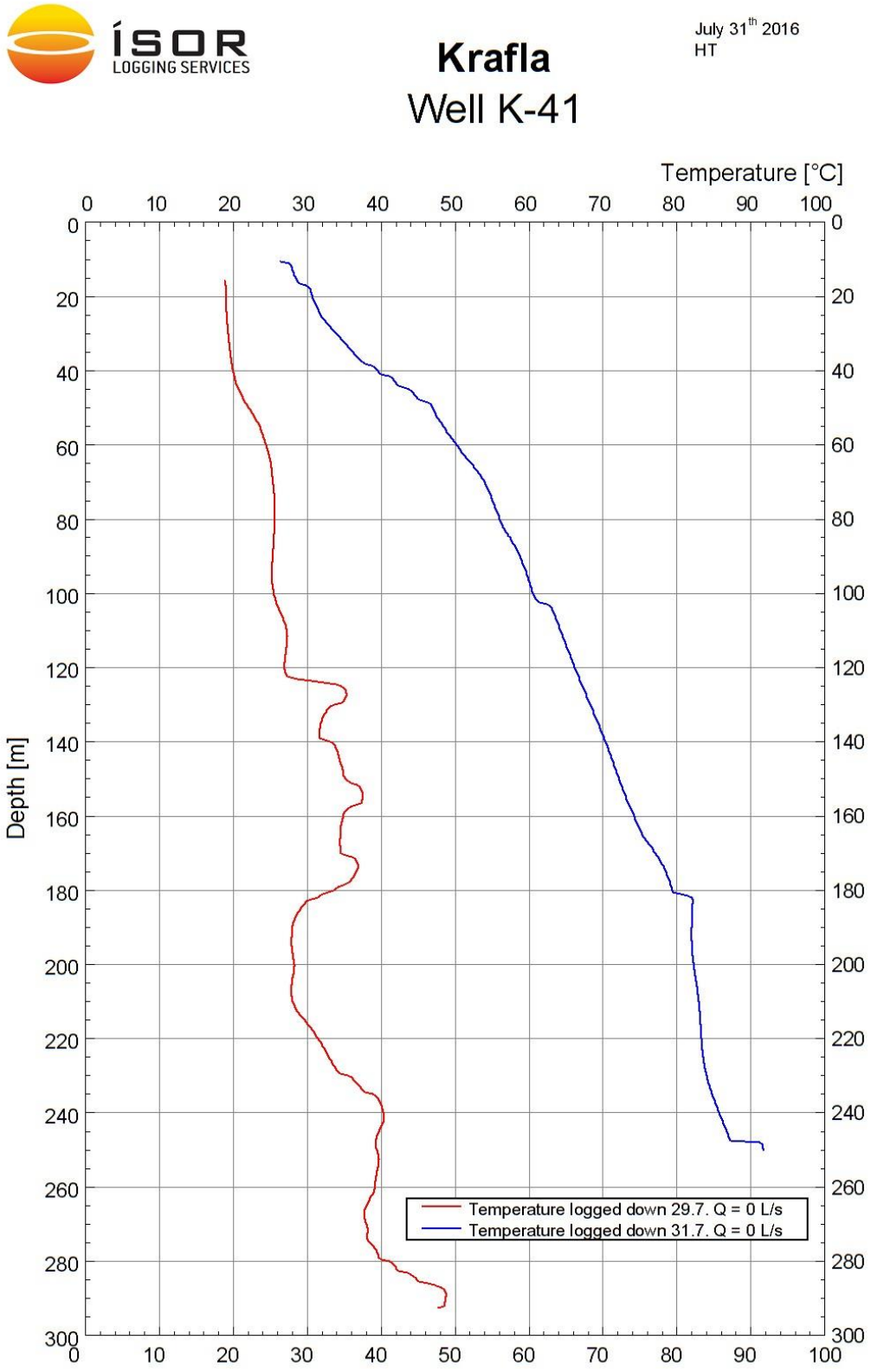

Figure 11. *Temperature logs in K-41 during phase 1.*

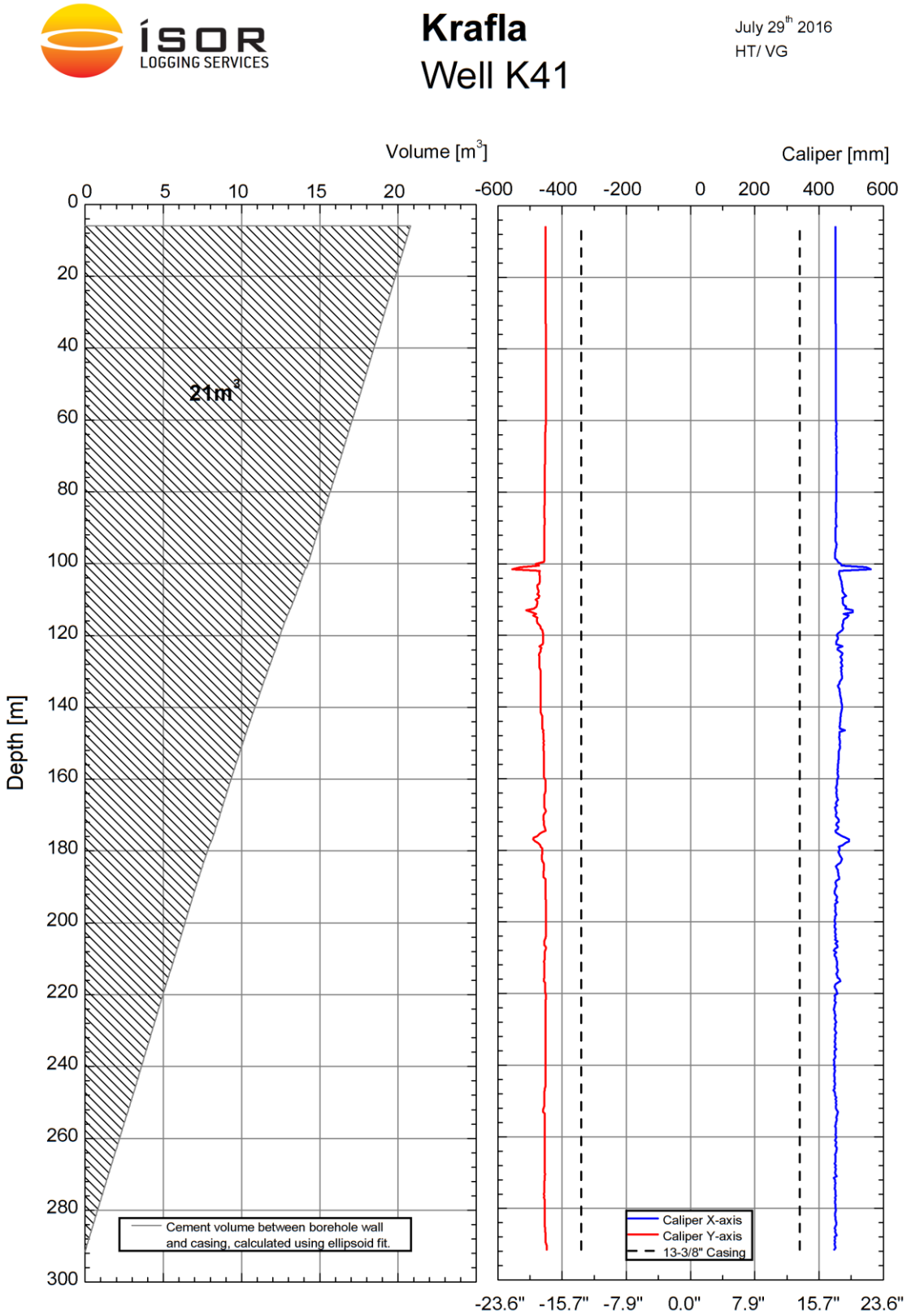

Figure 12. *2D caliper log of K-41 and calculated volume of the annulus outside the anchor casing. This is the estimated amount of cement needed for cementing the casing.*

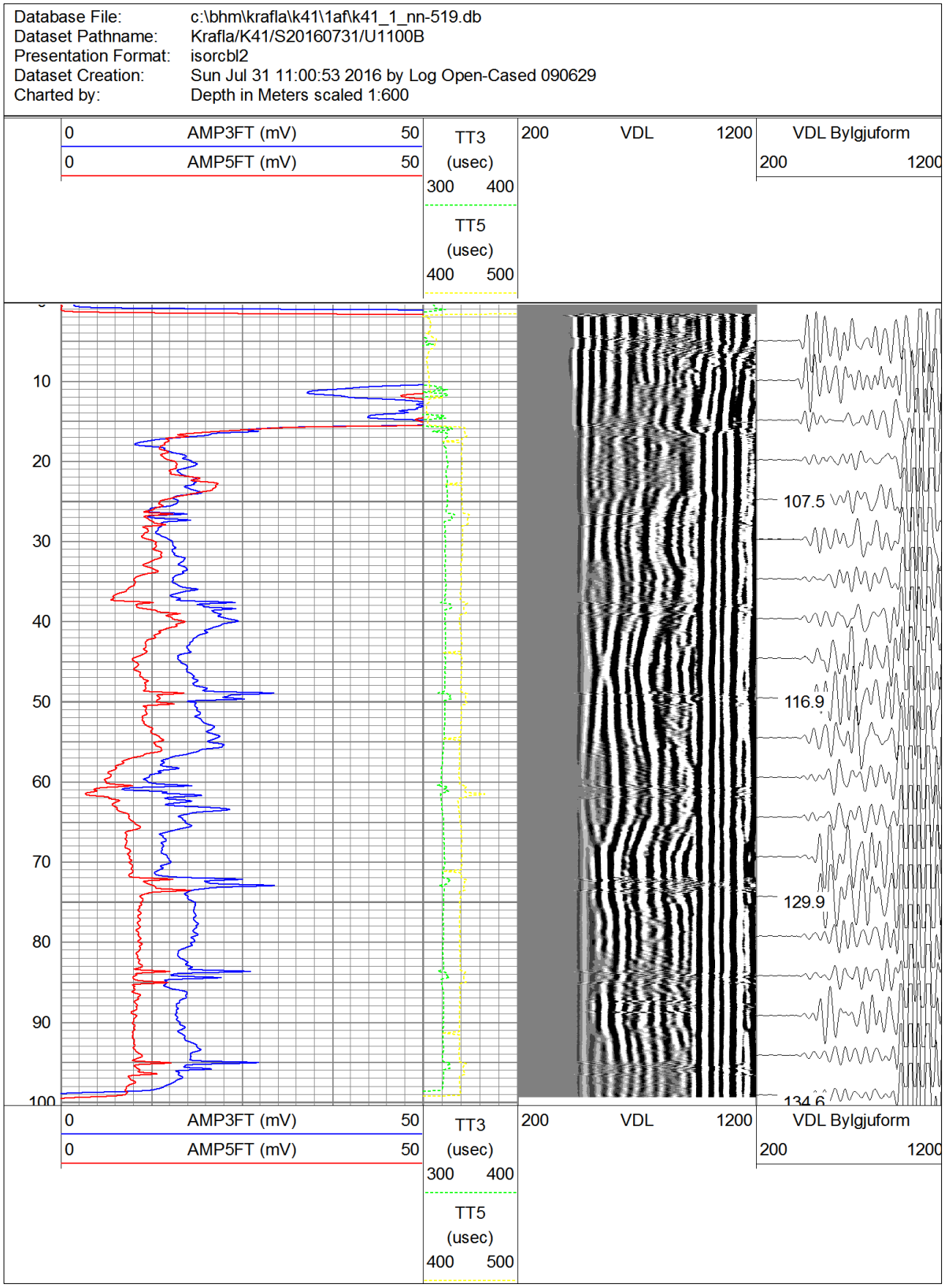

Figure 13. *CBL log from July 31st in well K-41, 21 hours after cementing.*

Figure 14. *The lower centralizer of the CBL-probe after the CBL-log on July 31st in well K-41.*

5 References

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Appendix A: Casing report

Surface casing

ICELAND DRILLING

Casing Tally Run Report
Rig: Sleipnir
Job No: 28178

Jarðboranir
Rig No: 28000
Job Name: K 41

String Nominal OD (cm): 47,31 **String Type: FULL**

Items Run:	**9**	**Length Run:**	**105,610**	**Top Depth:**	**6,820**
Items Excluded:	**0**	**Length Excluded:**	**0,000**	**Bottom Depth:**	**100,000**
Items Tallied:	**9**	**Length All Items:**	**105,610**	**Cut Off Length:**	**12,430**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
1	9	JOINT	11,790	88,210	100,000	47,31 x 45,10 X-56 WELD	3635		
2	8	JOINT	11,670	76,540	88,210	47,31 x 45,10 X-56 WELD	3635		
3	7	JOINT	11,740	64,800	76,540	47,31 x 45,10 X-56 WELD	3635		
4	6	JOINT	11,710	53,090	64,800	47,31 x 45,10 X-56 WELD	1632		
5	5	JOINT	11,700	41,390	53,090	47,31 x 45,10 X-56 WELD	1363		
6	4	JOINT	11,780	29,610	41,390	47,31 x 45,10 X-56 WELD	1632		
7	3	JOINT	11,660	17,950	29,610	47,31 x 45,10 X-56 WELD	3635		
8	2	JOINT	11,790	6,160	17,950	47,31 x 45,10 X-56 WELD	3634		
9	1	JOINT	11,770	-5,610	6,160	47,31 x 45,10 X-56 WELD	3635		

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Anchor casing

ICELAND DRILLING

Casing Tally Run Report
Rig: Sleipnir
Job No: 28178

Jarðboranir
Rig No: 28000
Job Name: K 41

String Nominal OD (cm): 33,97 **String Type: FULL**

Items Run:	**28**	**Length Run:**	**299,990**	**Top Depth:**	**0,000**
Items Excluded:	**0**	**Length Excluded:**	**0,000**	**Bottom Depth:**	**292,620**
Items Tallied:	**28**	**Length All Items:**	**299,990**	**Cut Off Length:**	**7,370**

Run No.	Joint No	Item	Length	Top	Bottom	Description	Comments	Cnt	Scr
1	28	JOINT	11,670	280,950	292,620	33,97 x 31,53 K-55 BUTT			
2	27	JOINT	11,280	269,670	280,950	33,97 x 31,53 K-55 BUTT	Hefirör		
3	26	JOINT	11,070	258,600	269,670	33,97 x 31,53 K-55 BUTT			
4	25	JOINT	11,060	247,540	258,600	33,97 x 31,53 K-55 BUTT			
5	24	JOINT	11,330	236,210	247,540	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
6	23	JOINT	11,590	224,620	236,210	33,97 x 31,53 K-55 BUTT			
7	22	JOINT	11,660	212,960	224,620	33,97 x 31,53 K-55 BUTT			
8	21	JOINT	11,510	201,450	212,960	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
9	20	JOINT	11,390	190,060	201,450	33,97 x 31,53 K-55 BUTT			
10	19	JOINT	11,660	178,400	190,060	33,97 x 31,53 K-55 BUTT			
11	18	JOINT	11,480	166,920	178,400	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
12	17	JOINT	11,280	155,640	166,920	33,97 x 31,53 K-55 BUTT			
13	16	JOINT	11,650	143,990	155,640	33,97 x 31,53 K-55 BUTT			
14	15	JOINT	11,370	132,620	143,990	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
15	14	JOINT	11,580	121,040	132,620	33,97 x 31,53 K-55 BUTT			
16	13	JOINT	11,660	109,380	121,040	33,97 x 31,53 K-55 BUTT			
17	12	JOINT	11,660	97,720	109,380	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
18	11	JOINT	11,380	86,340	97,720	33,97 x 31,53 K-55 BUTT			
19	10	JOINT	11,660	74,680	86,340	33,97 x 31,53 K-55 BUTT			
20	9	JOINT	11,660	63,020	74,680	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
21	8	JOINT	11,660	51,360	63,020	33,97 x 31,53 K-55 BUTT			
22	7	JOINT	11,670	39,690	51,360	33,97 x 31,53 K-55 BUTT			
23	6	JOINT	11,230	28,460	39,690	33,97 x 31,53 K-55 BUTT	1 miðjustillir		
24	5	JOINT	11,670	16,790	28,460	33,97 x 31,53 K-55 BUTT			
25	4	JOINT	0,570	16,220	16,790	33,97 x 31,53 K-55 BUTT	Flotkolli		
26	3	JOINT	11,340	4,880	16,220	33,97 x 31,53 K-55 BUTT			
27	2	JOINT	11,670	-6,790	4,880	33,97 x 31,53 K-55 BUTT	2 miðjustillar		
28	1	JOINT	0,580	-7,370	-6,790	0,00 x 0,00 K-55 BUTT	Flotskór		

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Appendix B

Daily reports

ÍSOR ICELAND GEOSURVEY	K-41	Tuesday 26th of July 2016 Workday #7 of Sleipnir

Krafla	**Report for Workday #7** Preliminary results	Phase 1 (13⅜" anchor casing)

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

Last casing size:	18 ⅝" (surf. casing)	Depth at 24;00.	100 m	Hole made last 24 hrs. :	0 m
Last casing depth:	100 m	Depth at 8:00.	100 m	Drilling time:	0 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	- m/hr

Drilling operation

Drilling for the 18⅝" surface casing with a 21" bit commenced on July 21st 2016, at around 23:00. (Table 1). Drilling for the surface casing was completed two days later, at 100 m depth relative to Sleipnir's rig floor which is 5.72 m above surface.

Table 1. *Drilling and work progress during Phase 1 in well K-41*

	Date	Workday	Drilled (m)	Time (hrs.)	Average ROP (m/hr.)	MD (m)	Comment
Phase 1	20.07.16	1	-	-	-	(11.5)	Rigging up
	21.07.16	2	1	0.50	2.0	12.5	Rigging up & drilling
	22.07.16	3	56.5	20.75	2.7	69	
	23.07.16	4	31	12.25	2.5	100	
	24.07.16	5	-	-	-	100	Cement job
	25.07.16	6	-	-	-	100	Flange & BOP's

The surface casing in K-41 was cemented in last Sunday. Yesterday the flange was welded onto the casing. Subsequently the crew started working on the BOP stack. Early this morning the crew started RIH with a 17 ½" bit for drilling for the anchor casing. Top of cement (TOC) was encountered at 78 m depth and at 11:00 this morning the bit tagged the casing shoe at 99,7 m. At 11:15 the bit entered formation and then the crew started to mix drilling mud.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Wednesday 27th of July 2016 Workday #8 of Sleipnir

Krafla	**Report for Workday #8** Preliminary results	Phase 1 (13⅜" anchor casing)

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

Last casing size:	18 ⅝" (surf. casing)	Depth at 24;00.	141 m	Hole made last 24 hrs. :	41 m
Last casing depth:	100 m	Depth at 8:00.	164 m	Drilling time:	16 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	2.6 m/hr

Drilling operation

Drilling continued yesterday at a steady pace with 6 to 9 ton WOB. No LOC has been recorded so far in this section. The container for the on-site geologist arrived yesterday and has been rigged up with water, electricity and running water.

Geology

The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m where the color changes abruptly and the tuff is of a deep green color. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt. Similarly, at 122 m and 124 m the cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between from 122 m to 123 m depth. Another abrupt color change occurs at 170 m depth. From 170 m to 180 m the formation is blod-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia.

The tuff is quite altered and alteration minerals include heulandite, calcite, pyrite and some oxidation is seen mainly on the grains from the intrusive basalts. Quartz appears in considerable quantities at 174 m depth indicating temperatures have at some point exceeded 180 °C.

This is very similar to what was observed on wells KJ-32 and KJ-33 which were drilled from the same pad.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Thursday 28th of July 2016 Workday #9 of Sleipnir

Krafla	**Report for Workday #9** Preliminary results	Phase 1 (13⅜" anchor casing)

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

Last casing size:	18 ⅝" (surf. casing)	Depth at 24;00.	226 m	Hole made last 24 hrs. :	85 m
Last casing depth:	100 m	Depth at 8:00.	254 m	Drilling time:	22 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	3.9 m/hr

Drilling operation

Drilling continued yesterday at a steady pace from 141-226 m with 8-9 ton WOB. No LOC has been recorded so far in this section and mud tank temperatures are slightly increasing. Deviation survey at 200 m showed inclination of 0.9°.

Geology

As mentioned in yesterday's report the formations immediately below the casing is a typical subglacial hyaloclastite unit where basaltic tuffs dominate. The tuffs are intersected by relatively thin intrusions of basalt and breccia lenses. The tuff can be subdivided based primarily on color.

100 m – 122 m: TUFF

The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt.

122 m – 124 m: INTRUSION

The cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between from 122 m to 123 m depth.

124 m – 130 m: TUFF

More or less identical to the tuff above the intrusion.

130 m – 170 m: TUFF

An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170 m – 220 m: BRECCIA

Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia.

220 m – m: FINE-MEDIUM GRAINED BASALT

Abrupt change from breccia to crystalline basalt, medium grained. No oxidation.

Borvakt

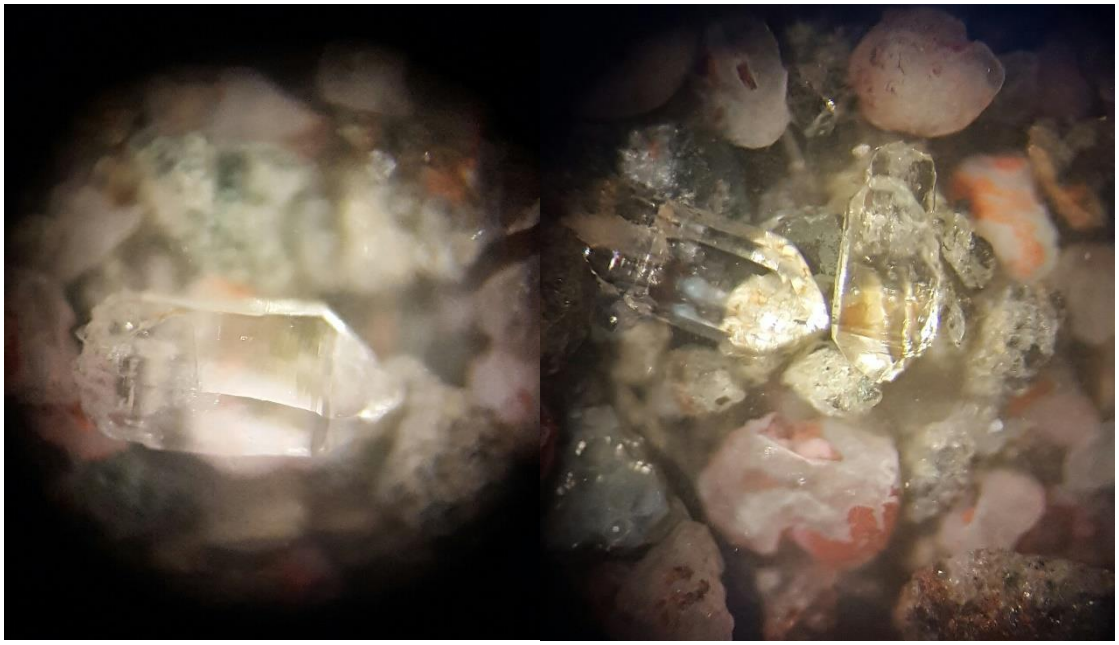

Figure 1. *Quartz crystals from 174 m.*

ÍSOR ICELAND GEOSURVEY	K-41	Friday 29th of July 2016 Workday #10 of Sleipnir

Krafla	**Report for Workday #10** Preliminary results	Phase 1 (13⅜" anchor casing)

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

Last casing size:	18 ⅝" (surf. casing)	Depth at 24;00.	293.5 m	Hole made last 24 hrs. :	67.5 m
Last casing depth:	100 m	Depth at 8:00.	293.5 m	Drilling time:	24 hrs.
Drilling fluid:	Mud	Circulation losses at 8:00	0 L/s	Average ROP:	2.8 m/hr

Drilling operation

Drilling was ongoing all day with a steady ROP of around 3 m/hr and no circulation losses. Casing depth was reached around midnight last night at 293.5 m while drilling into a hard formation consisting of glassy basalt. This morning, ÍSOR´s logging engineers will carry out temperature and caliper logs before casing will be RIH.

Geology

100 m – 122 m: TUFF: The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt.

122 m – 124 m: INTRUSION: The cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between from 122 m to 123 m depth.

124 m – 130 m: TUFF: More or less identical to the tuff above the intrusion.

130 m – 170 m: TUFF: An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170 m – 220 m: BRECCIA: Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia. At 212 m wairakite appears, which correlates well with wells 32 and 33.

220 m – 293.5 m: GLASSY BASALT: Change from the softer breccia to a harder formation of glassy basalt. The basalt is dense and apparently without pores and showing some alteration. Primary minerals are pyroxene and plagioclase along with alteration minerals such as clay (appear at ~222 m) and quartz.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Saturday 30th of July 2016 Workday #11 of Sleipnir

Krafla	**Report for Workday #11** Preliminary results	Phase 1 (13 ⅜" anchor casing)

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

Last casing size:	18 ⅝" (surf. casing)	Depth at 24;00.	293.5 m	Hole made last 24 hrs. :	0 m
Last casing depth:	100 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

After the anchor casing depth was reached around midnight the well was circulated before wiper trip. No bottom hole deposits were observed at first but after wiper trip and reaming the bottom hole deposits were 2 m. The well was circulated further and the bottom hole deposit decreased. At 16:00, ÍSOR´s logging engineers arrived on site and carried out a temperature log (Figure 1) and a caliper log (Figure 2). At 20:00 last night, the 13 3/8" casing was RIH.

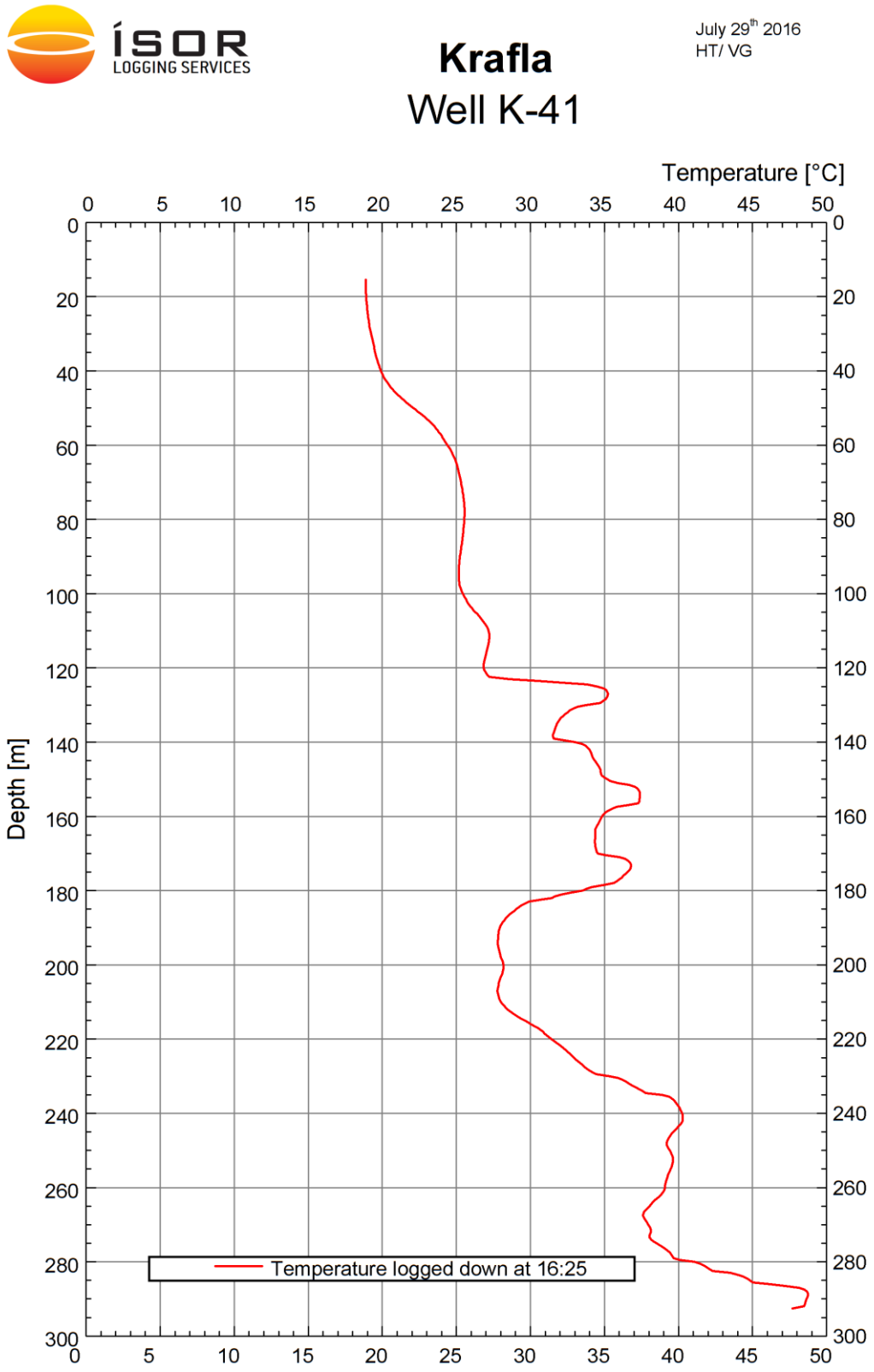

Figure 1. Temperature logged down in well K-41.

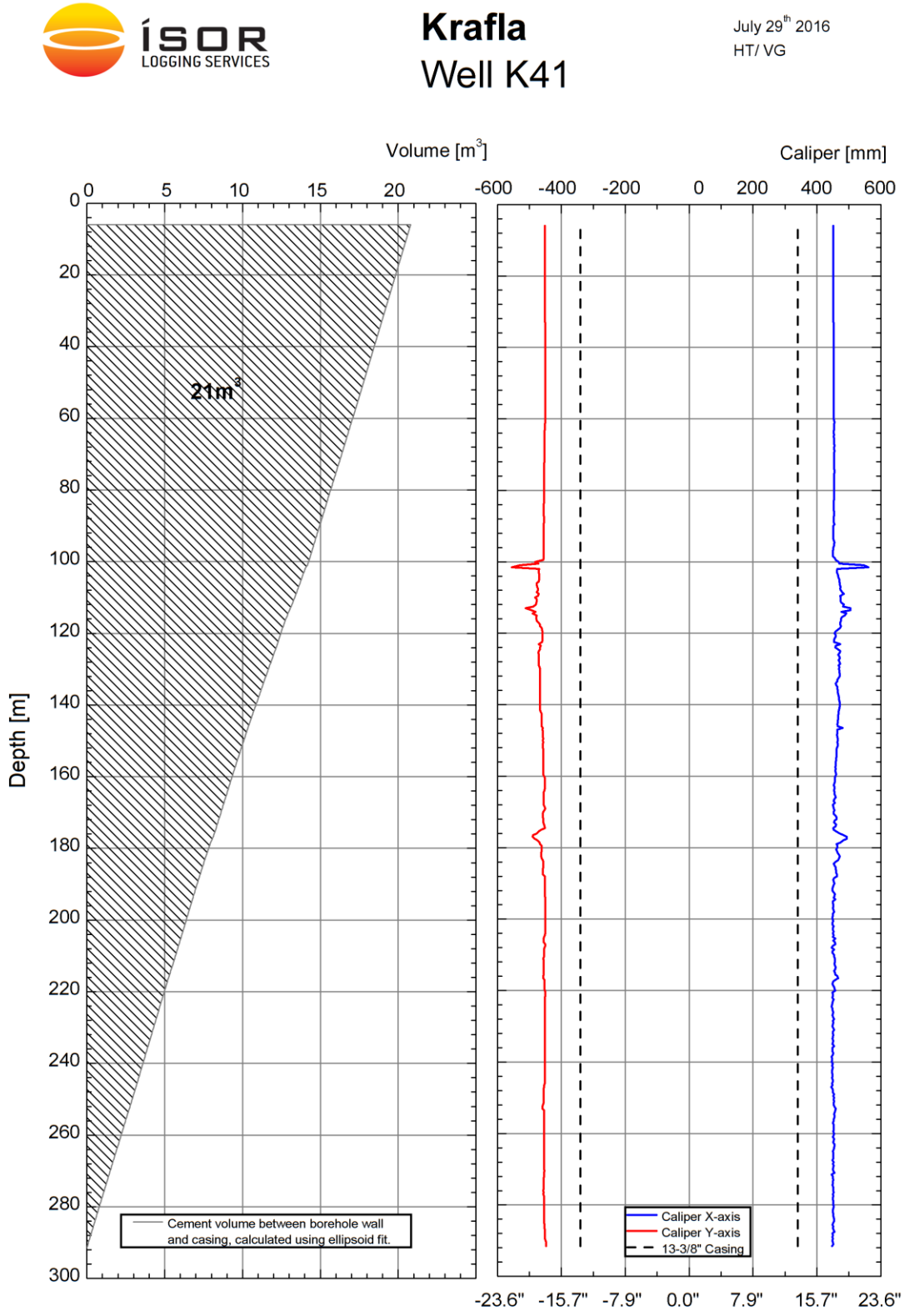

Figure 2. Caliper log and the calculated cement volume for the well.

Geology

100 m – 122 m: TUFF

The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt.

122 m – 124 m: INTRUSION

The cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between from 122 m to 123 m depth.

124 m – 130 m: TUFF

More or less identical to the tuff above the intrusion.

130 m – 170 m: TUFF

An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170 m – 220 m: BRECCIA

Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia. At 212 m wairakite appears, which correlates well with wells 32 and 33.

220 m – 293.5 m: GLASSY BASALT

Change from the softer breccia to a harder formation of glassy basalt. The basalt is dense and apparently without pores and showing some alteration. Primary minerals are pyroxene and plagioclase along with alteration minerals such as clay (appear at ~222 m) and quartz.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Sunday 31st of July 2016 Workday #12 of Sleipnir

Krafla	**Report for Workday #12** Preliminary results	Phase 1 (13 ⅜" anchor 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:	18 ⅝" (surf. casing)	Depth at 24;00.	293.5 m	Hole made last 24 hrs. :	0 m
Last casing depth:	100 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

After the casing was finished, the cement string was RIH and the well was cooled and circulated for a few hours. Cementing of the casing got underway shortly after noon yesterday. The cement job took around 40 minutes and a total of 23,2 m^3 of cement slurry was used for the job. Approximately 0,7 m^3 was added on top between the casings after the top slurry-level subsided slightly. This morning ÍSOR´s logging engineers are carrying out a CBL log.

Figure 1. ÍSOR´s logging engineers, Hörður and Valdís, preparing for CBL this morning.

Geology

100 m – 122 m: TUFF

The formations immediately below the casing is a typical subglacial eruptive unit. A thick tuff formation composed of whitish tuff-grains from 100 to 130 m. The formation is cut by a few basaltic intrusions. So the cuttings from 100 m to 110 m contain a significant portion of fresh fine grained basalt.

122 m – 124 m: INTRUSION

The cuttings are dominated by fresh fine-grained basalt. Interestingly the tool-pusher noted that the formation was very hard between from 122 m to 123 m depth.

124 m – 130 m: TUFF

More or less identical to the tuff above the intrusion.

130 m – 170 m: TUFF

An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170 m – 220 m: BRECCIA

Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia. At 212 m wairakite appears, which correlates well with wells 32 and 33.

220 m – 293.5 m: GLASSY BASALT

Change from the softer breccia to a harder formation of glassy basalt. The basalt is dense and apparently without pores and showing some alteration. Primary minerals are pyroxene and plagioclase along with alteration minerals such as clay (appear at ~222 m) and quartz.

Borvakt

ÍSOR ICELAND GEOSURVEY	K-41	Monday 1st of August 2016 Workday #13 of Sleipnir

Krafla	**Report for Workday #13** Preliminary results	Phase 1 (13 ⅜" anchor casing)

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

Last casing size:	13 3/8" (prod. 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

After WOC, ÍSOR´s logging engineers carried out a temperature and a CBL log. While logging down, the temperature instrument stopped at 180 m, but after few attempts it continued to 250 m where it stopped completely (Figure 1). The CBL instrument only went down to ~100 m (Figure 2) and attempts to get it further were unsuccessful. Both instruments returned to surface packed with cement slurry (Figure 3 and 4). Otherwise the CBL showed good results in the cement bonding for the uppermost 100 m.

In the afternoon, the BOP stack was removed, and a new flange was welded on the 13 3/8" casing.

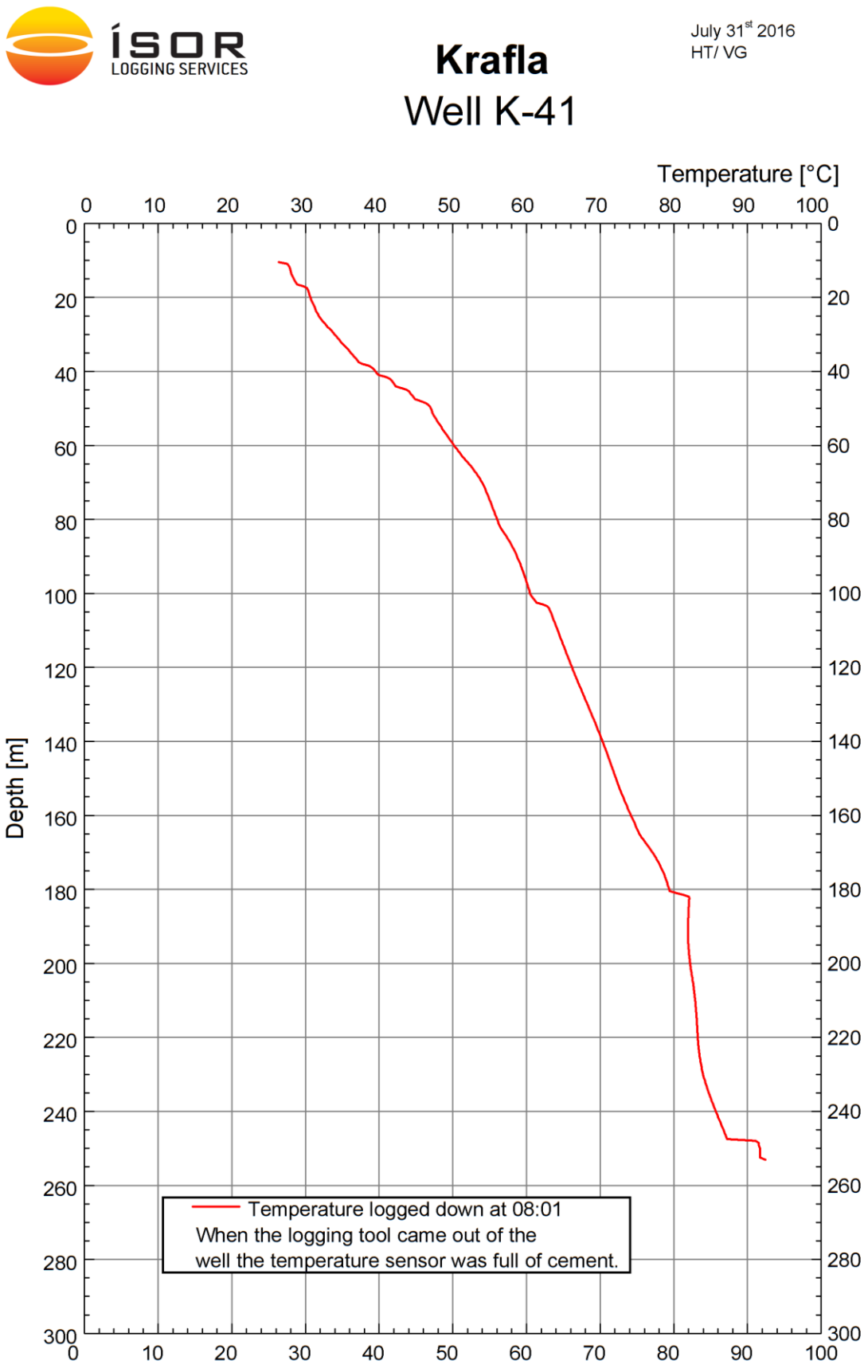

Figure 1. Temperature logged down well K-41 July 31st.

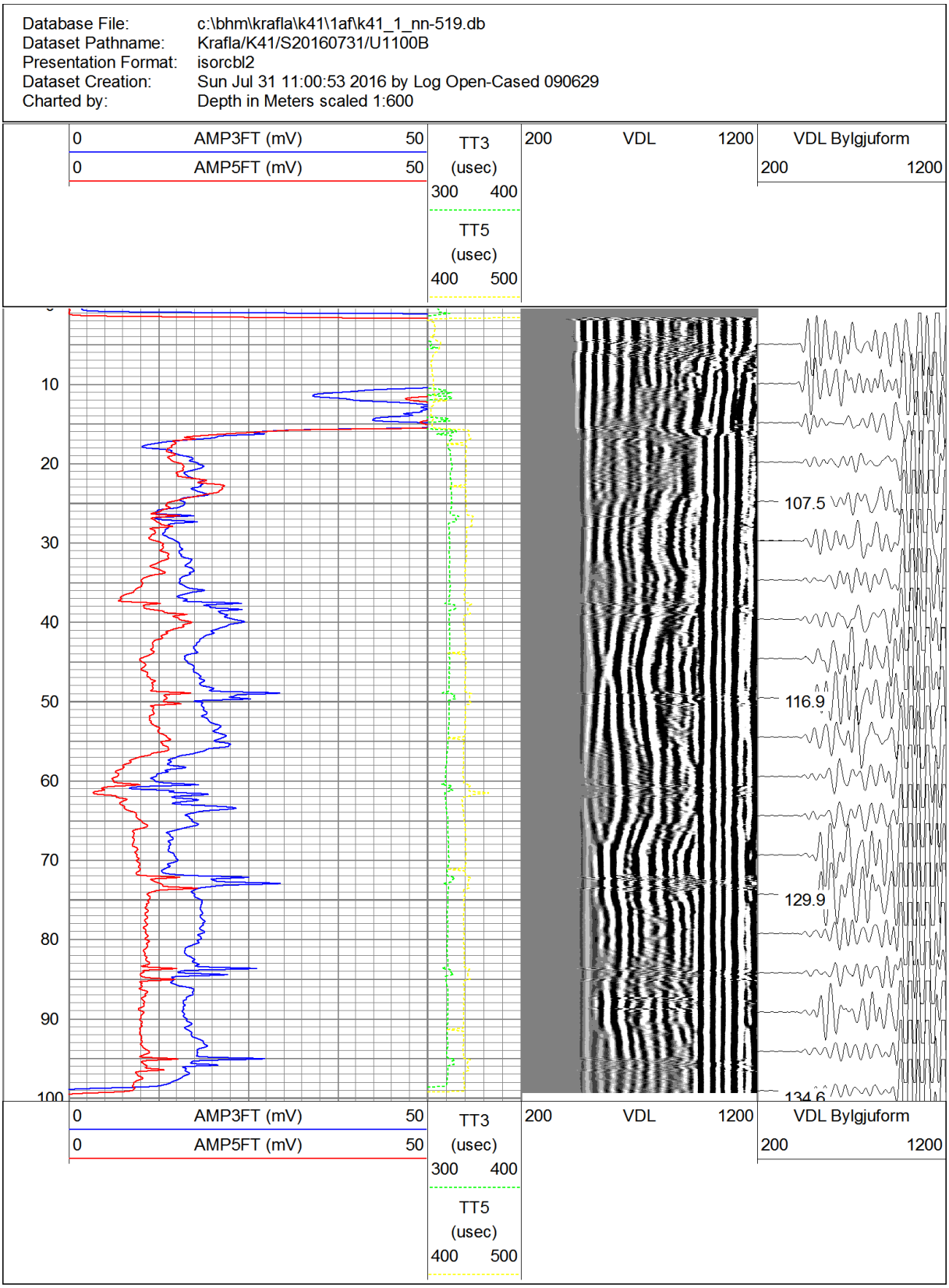

Figure 2. The CBL instrument only reached ~100 m depth in the well.

Figure 1. CBL instrument after logging yesterday.

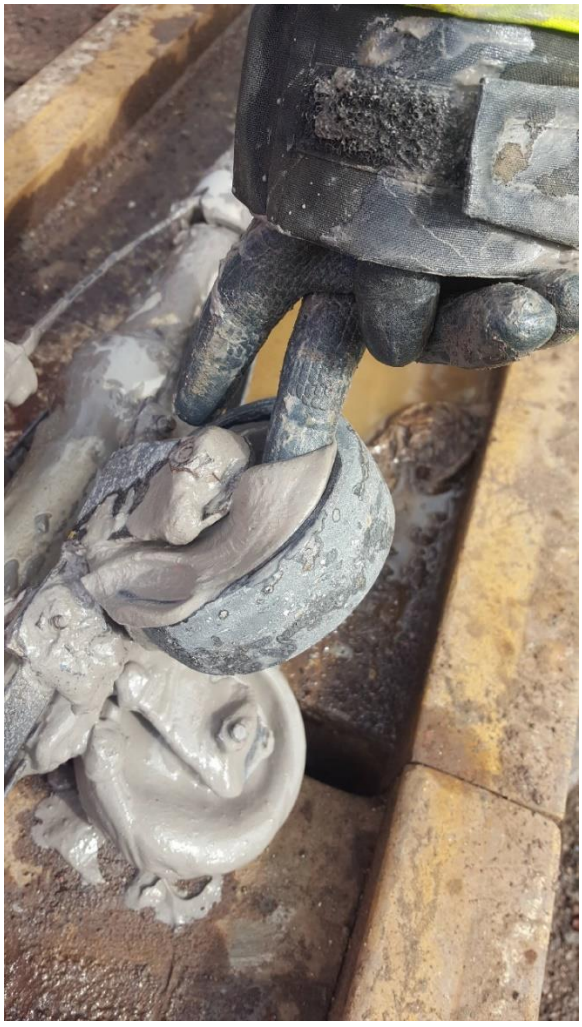

Figure 2. CBL instrument packed with cement.

Geology

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More or less identical to the tuff above the intrusion.

130 m – 170 m: TUFF

An abrupt color change occurs at 130 m depth. Here the tuff is of a deep green color.

170 m – 220 m: BRECCIA

Another abrupt color change occurs at 170 m depth. From 170 m to 220 m the formation is blood-red due to oxidation. In that depth interval better may of the grains are more crystallized and the formation is classified as a breccia. At 176 m clays appear and at 212 m wairakite appears, which correlates well with wells 32 and 33.

220 m – 293.5 m: GLASSY BASALT

Change from the softer breccia to a harder formation of glassy basalt. The basalt is dense and apparently without pores and showing some alteration. Primary minerals are pyroxene and plagioclase along with alteration minerals such as clay (appear at ~222 m) and quartz.

Borvakt

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Prentað efni