

**P-06-315**

## **Oskarshamn site investigation**

### **Geophysical borehole logging in boreholes KLX17A and HLX43**

Uffe Torben Nielsen, Jørgen Ringgaard  
RAMBØLL

December 2006

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*Keywords:* Geophysical logging.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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## **Abstract**

Geophysical borehole logging has been performed in boreholes KLX17A and HLX43 both situated in Laxemar in Oskarshamn, Sweden.

The objective of the survey is to determine the physical properties of the rock mass around the borehole, e.g. to determine rock types and quantify the fracture frequency and localise deformation zones in the rock. Geophysical borehole logging was used to measure changes in physical properties in the borehole fluid and the bedrock surrounding the boreholes.

All boreholes were recorded from Top Of Casing (TOC). The logging in KLX17A was recorded to app. 700 m and HLX43 was recorded to app. 170 m.

The present report comprises a description of the applied equipment and the performed logging program, the fieldwork, data delivery and a presentation and discussion of the results.

Composite sheets of all the processed logs are included in Appendix 1 to 2.

# Sammanfattning

Geofysisk borrhålsloggning har genomförts i borrhålen KLX17A och HLX43 i delområde Laxemar, Oskarshamn.

Syftet med geofysisk borrhålsloggning är att bestämma bergets fysikaliska egenskaper för att bestämma bergartsfördelningen i det genomborrade bergpartiet samt att kvantifiera sprickfrekvensen och att lokalisera deformationszoner. Med geofysisk borrhålsloggning mäts bergets och borrhålsvattnets fysikaliska egenskaper i borrhålet och omgivande berg.

Den geofysiska borrhålsloggningen genomfördes i KLX17A från TOC till 700 m och i HLX43 från TOC till 170 m.

Rapporten beskriver använd utrustning, genomfört loggningsprogram, fältarbete, leverans av data och en diskussion av resultatet.

Processerade loggar presenteras i Appendix 1 till 2.

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# 1 Introduction

This document reports the results gained by the geophysical borehole logging in boreholes KLX17A and HLX43, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-135 (SKB internal controlling document). In Table 1-1 controlling documents for performing this activity are listed.

All measurements were conducted by RAMBØLL during the period November 13 and 14, 2006. The boreholes were recorded from Top Of Casing (TOC) to the bottom of the borehole. The technical data from the boreholes are shown in Table 1-2. The location of the boreholes is shown in Figure 1-1.

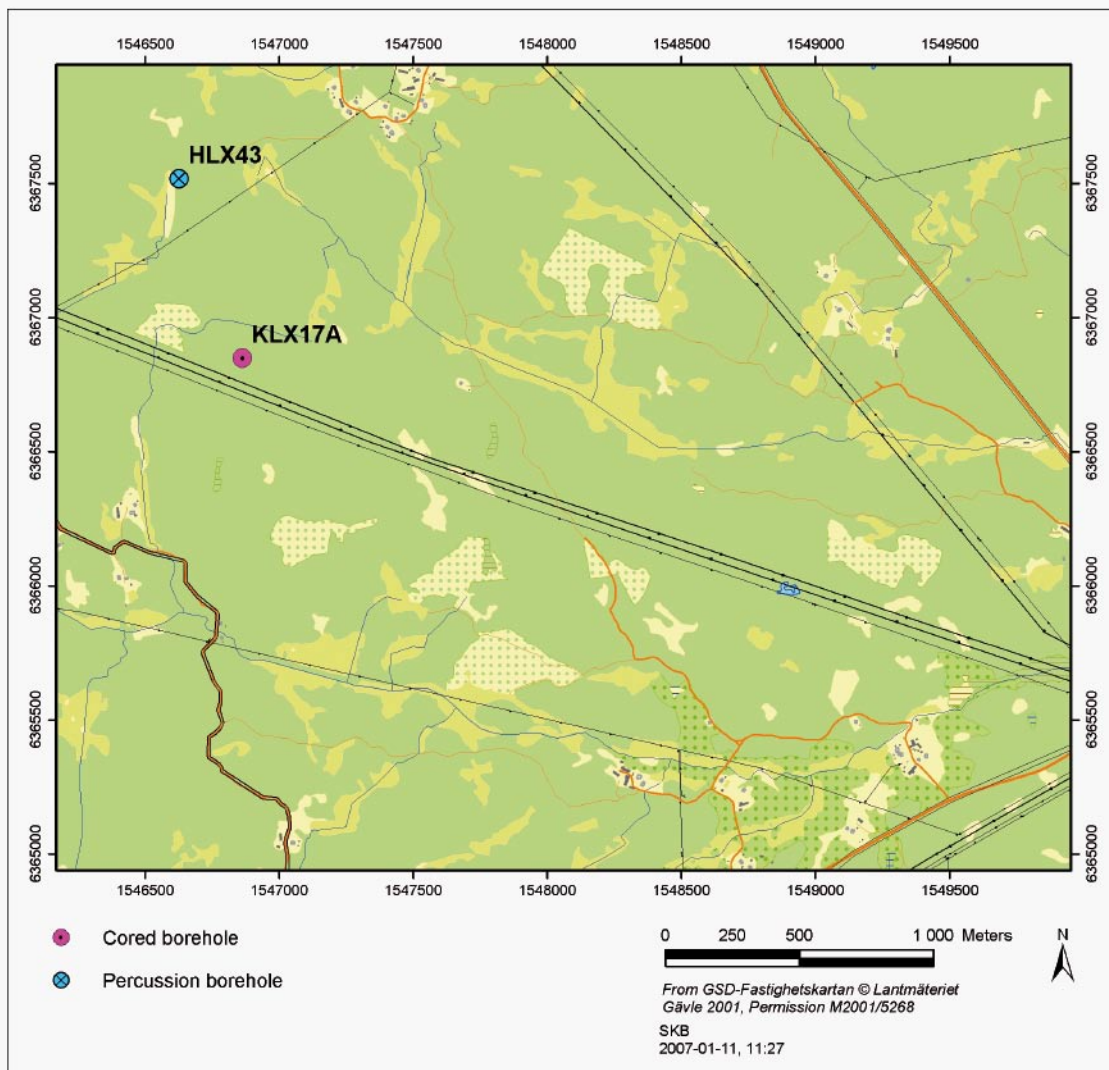
The delivered raw and processed data have been inserted in the database of SKB (SICADA) and data are traceable by the activity plan number.

**Table 1-1. Controlling documents for the performance of the activity (SKB internal controlling documents).**

Activity plan	Number	Version
Geofysisk borrhålsloggning i KLX17A och HLX43	AP PS 400-06-135	1.0
Method descriptions	Number	Version
Metodbeskrivning för geofysisk borrhålsloggning	SKB MD 221.002	2.0

**Table 1-2. Technical data for the boreholes.**

Borehole Parameter	KLX17A	HLX43
Coordinates (RT90)	X: 6366848.75 Y: 1546862.09	X: 6367517.45 Y: 1546626.60
Elevation (RHB70)	Z: 27.63	Z: 24.20
Inclination (from horizontal)	-61.34°	-50.74°
Azimuth	11.21°	268.55°
Length	701.08 m	170.60 m
Borehole diameter	Ø 339 mm (0.15–2.60 m) Ø 248 mm (2.60–11.95 m) Ø 197 mm (11.95–65.35 m) Ø 169 mm (65.35–65.42 m) Ø 86 mm ( 65.42–66.76 m) Ø 76 mm (66.76–701.08 m)	Ø 180 mm (0.0–6.0 m) Ø 140 mm (6.0–170.60 m)
Casing	Ø 208/200 mm (0.0–11.50 m) Ø 323/310 mm (0.15–2.50 m) Ø 323/280 mm (2.50–2.60 m) Cone from 62.02–66.76 (Ø 100/ Ø 80 mm)	Ø 168/160 mm (0.0–5.91 m) Ø 168/143 mm (5.91–6.0 m)
Cleaning level	Level 2	Level 1



*Figure 1-1. Map of the location of the boreholes KLX17A and HLX43 in the Laxemar subarea, Oskarshamn.*

## 2 Objective and scope

The objective of the survey is to both receive information of the borehole itself, and from the rock mass around the borehole. Geophysical borehole logging was used to measure changes in physical properties in the borehole fluid and the bedrock surrounding the boreholes. Acoustic televiewer was used for determination of the 360° caliper and to determine the length marks in the boreholes.

This field report describes the equipment used as well as the measurement procedures. Geophysical borehole logging data is presented in graphs as a function of depth on drawings shown in Table 2-1.

**Table 2-1. Appendix and drawing no.**

<b>Borehole</b>	<b>Drawing no.</b>	<b>Appendix</b>
KLX17A	1.1	1
HLX43	2.1	2



### 3 Equipment

The geophysical borehole logging program was performed with up to 7 multi tool probes and resulted in a suite of 18 log types, listed in Table 5-1. The tools and recorded logs are listed in Table 3-1.

**Table 3-1. Logging tools and logs recorded.**

Tool	Recorded logs	Dimension	Source detector spacing and type	Tool position in borehole	Tool used in borehole
Century 8144 Normal resistivity	Normal resistivity (16 and 64 inch), single point resistance, self potential and natural gamma.	237×5.3 cm			All boreholes
Century 8622 Magnetic susceptibility	Magnetic susceptibility, natural gamma.	203×4.1 cm			All boreholes
Century 9042 Fluid temperature and fluid resistivity	Fluid temperature, fluid resistivity and natural gamma.	137×4.1 cm			All boreholes
Century 9072 3 m focused guard	3 m focused guard log resistivity and natural gamma.	310×6.4 cm			All boreholes
Century 9139 Compensated gamma density	Compensated gamma density, natural gamma, 140 cm focused guard log resistivity, 1-arm caliper.	280.3×5.6 cm	20.3 cm 200 mCi Cs137	Sidewall Gamma source focused	All boreholes
Century 9310 Sonic	Full wave form travel-time providing P and S-wave velocity picking, compensated P- wave travel-time and natural gamma.	300×6.0 cm	Near 91.4 cm Far 121.9 cm	Centralized	All boreholes
RG 25 112 000 HiRAT. Acoustic televiewer	Full waveform acoustic amplitude and travel-time, 360° orientated acoustic image, 360° very high resolution caliper, borehole azimuth and dip and natural gamma.	246×4 cm		Centralized	All boreholes

## **4 Execution**

### **4.1 General**

In general the measurement procedures follow the SKB method description (MD 221.002, SKB internal controlling document). The logging program was executed in the period November 13 and 14, 2006. All relevant logging events are described in the daily report sheets delivered to SICADA and are traceable by the activity plan number.

The fluid resistivity and temperature logs are recorded in downward direction, as the first log run. All other log types are recorded running the tool in upward direction in the borehole.

The applied logging equipment was calibrated and cleaned before arriving at the site according to SKB cleaning level 2 (KLX17A) and level 1 (HLX43) (SKB internal controlling document SKB MD 600.004).

For control, each log run is normally recorded both in down and in upward direction using the down run as a repeat section. For logging density tool 9139 recording a repeat section in upward direction controls the data. The depth of the probe in the borehole is shown on both the recording computer and the winch. On the winch the tension of the cable is also shown. The winch will automatically stop, if the tension changes rapidly. The tension was recorded on all log runs using Century equipment, except tool 9310.

All data was recorded with max.10 cm sample interval. The speed of the logging for the 9139 tool was 5 m/min, for the 8622 tool 20 m/min and for all other tools 10 m/min.

### **4.2 Nonconformities**

The logging has been performed in accordance with the activity plan AP PS 400-06-135.

## 5 Results

### 5.1 Presentation

All relevant logging events were described in the daily report sheets, which were delivered separately.

Logs presented in drawings no. 1.1–2.1 are presented in Table 5-1.

### 5.2 Orientation, alignment and stretch of logs

#### 5.2.1 Orientation of images

The orientation of the results from the HiRAT Acoustic tool, are processed in the tool while recording, using the magnetometers and accelerometers in the tool.

#### 5.2.2 Overlapping data

If the log data from one probe have been recorded in more than one file, the files are merged using events in both files. Overlapping in data is always used from the topmost-recorded file (overlapping data are never the mean value from two log runs).

**Table 5-1. Logs presented in drawings no. 1.1 through 2.1 in Appendices 1 to 2.**

Log	Log name short	Unit	Tool	Recorded/ calculated in borehole
Fluid temperature	TEMP(FL)	deg C	9042	All
Fluid resistivity	RES(FL)	ohm-m	9042	All
Natural gamma	GAM(NAT)	μR/h	9042	All
Normal resistivity 16 inch	RES(16N)	ohm-m	8144	All
Normal resistivity 64 inch	RES(64N)	ohm-m	8144	All
Lateral resistivity	LATERAL	ohm-m	8144	All
Single point resistance	SPR	Ohm	8144	All
Self potential	SP	V	8144	All
Magnetic susceptibility	MAGSUSCEP	SI×10 <sup>-5</sup>	8622	All
Caliper, 1-arm	CALIPER1	mm	9139	All
Gamma-gamma density	DENSITY	kg/m <sup>3</sup>	9139	All
Focused guard log resistivity, 127 cm	RES(SG)	ohm-m	9139	All
Focused guard log resistivity, 300 cm	RES(DG)	ohm-m	9072	All
P-wave velocity	P-VEL	m/s	9310	All
Full wave form, near receiver	AMP(N)	μs	9310	All
Full wave form, far receiver	AMP(F)	μs	9310	All
Caliper, high resolution. 360°	CALIPER 3D	mm	HiRAT	All
High resolution 1D Caliper	CALIPER MEAN	mm	HiRAT	All

### **5.2.3 Alignment of data**

In order to obtain an exact length calibration, the track marks made while drilling are used. In boreholes without track marks, gamma events in the top and the bottom of the borehole are used. The connection between the track marks and the logs is obtained from the HiRAT Acoustic tool. The depths from the track marks and from the HiRAT tool are used to make a new length scale in WellCAD. All log files are shifted using the new length scale.

### **5.2.4 Stretch of logs**

There is a minor difference in the length registration between up- and down runs for the used winch. The size of the defect is about 1.5 m/km. To compensate for this the logs are stretched using another new length scale for each tool. The length scale is made by using gamma events from the tool compared with the same gamma events from the HiRAT tool. The events in both files are matched, and the new length scale is made and added to the log. The bottom of the borehole is considered in stretching the logs in case that no data will occur below the bottom of the borehole.

### **5.2.5 Removing of data**

The processing of the data includes removing of spikes, negative and unrealistic values and data in the casing.

### **5.2.6 Repicking of sonic log**

The sonic velocity is normally calculated using an automatic picking routine in the sonic tool, 9310. In inclined boreholes the routine is often picking the wrong arrivals, due to so-called “road noise”. Therefore all sonic logs have been manually repicked in WellCAD using the full wave signal.

## **5.3 Calculated log curves**

The different logs are calculated as described in Table 5-2.

## **5.4 Borehole KLX17A**

In order to obtain an exact length calibration in borehole KLX17A, the reference track marks made while drilling are used. The correlation between the track marks and the logs is obtained from the HiRAT Acoustic tool.

The reference track marks in the borehole and the recorded track marks from the HiRAT are observed in the following depths, Table 5-3.

To compensate for the difference between the reference track marks and the recorded track marks the logs are stretched. The result from the stretching is a new length scale. The new length scale is applied to the HiRAT file. In this way a perfect match between given depths of the reference marks and the recorded data is obtained. By means of alignment of the observed gamma events in KLX17A, between all logruns, the obtained reference mark correlation is transferred to the other logs.

The complete log suite for borehole KLX17A is presented as composite log sheets in drawing 1.1 in Appendix 1. The logs presented in drawing no. 1.1 are listed in Table 5-1.

**Table 5-2. Calculated log curves.**

Log	Description of log calculation
Caliper, 1-arm	The caliper was converted from [cm] to [mm] units by multiplying [cm] with 10.
Gamma-gamma density	The gamma-gamma was converted from [g/cm <sup>3</sup> ] to [kg/m <sup>3</sup> ] units by multiplying with 1,000.
Focused guard log resistivity, 140 cm	–
Natural gamma	The natural gamma log was converted from CPS to $\mu$ R/h by multiplying the constant 0.077. This constant was computed from the logs previously performed in borehole KLX02 located in Oskarshamn.
Fluid temperature	–
Fluid resistivity	–
Normal resistivity 16 inch	–
Normal resistivity 64 inch	–
Lateral resistivity	–
Single point resistance	–
Self-potential	The SP value was converted from [mV] to [V] by dividing with 1,000
Focused guard log resistivity, 300 cm	–
P-wave velocity	The P-VEL velocity is calculated using the difference in distance between the far and near receiver divided by the time difference between the first arrival from the far and near signal. (121.9 cm – 91.4 cm)/(Time(far) – Time(near)).
Full wave form, near receiver	–
Full wave form, far receiver	–
Magnetic susceptibility	The magnetic susceptibility was converted for CGS units to SI units by multiplying the CGS value by $4\pi$ .
Caliper, high resolution. 360°. CALIPER 3D	The caliper 3D is calculated using the acoustic travel time and the velocity in the borehole fluid. The velocity in the fluid is calculated using the fluid temperature and fluid conductivity.
High resolution 1D Caliper CALIPER MEAN	The caliper mean is calculated using the mean travel time from the acoustic televiewer, the fluid temperature, fluid velocity and the internal travel time in the acoustic televiewer.

**Table 5-3. The reference track marks in the borehole and the recorded track marks from the HiRAT in borehole KLX17A.**

Reference mark	HIRAT recorded
75.00	75
100.00	100.105
150.00	150.296
200.00	200.489
250.00	250.705
300.00	300.92
350.00	351.137
400.00	401.352
450.00	451.561
500.00	501.777
550.00	552.009
600.00	602.224
650.00	652.448
680.00	682.577

## **5.5 Borehole HLX43**

Using the natural gamma from the 9042 as reference, the natural gamma logs from the other probes are aligned to the same depth. A new depth scale is added to each log and afterwards the logs are stretched using different gamma events.

The complete log suite for borehole HLX43 is presented as composite log sheet in drawing no. 2.1 in Appendix 2. The logs presented in drawing no. 2.1 are listed in Table 5-1.

## 6 Data delivery

Geophysical logging data from the measurements, recorded in Century and Robertson format, were delivered directly after the termination of the field activities. The recorded data files used in the processing have also been delivered in WellCAD format, Table 6-1.

The delivered data have been inserted in the database (SICADA) of SKB and are traceable by the activity plan number.

The processed files shown on the drawings have been delivered in WellCAD, Table 6-2, and as excel files (one for each borehole) in SICADA format, Table 6-3.

**Table 6-1. Recorded log files in Century or Robertson format used for processing.**

Borehole	Probe	Log direction	WellCAD File	Description
KLX17A	8144	Up	KLX17A_11-14-06_10-36_8144C_10_-1.30_699.90_ORIG.log	Start Depth: 699.9 m. End Depth: -1.3 m
KLX17A	8622	Up	KLX17A_11-13-06_19-43_8622C_1_-1.00_701.80_ORIG.log	Start Depth: 701.8 m. End Depth: -1 m
KLX17A	9042	Down	KLX17A_11-13-06_10-20_9042C_1_0.20_702.50_ORIG.log	Start Depth: 0.2 m. End Depth: 702.5 m
KLX17A	9072	Up	KLX17A_11-13-06_18-08_9072C_1_-1.10_699.40_ORIG.log	Start Depth: 699.4 m. End Depth: -1.1 m
KLX17A	9139	Up	KLX17A_11-13-06_15-12_9139A_1_-0.80_699.80_ORIG.log	Start Depth: 699.8 m. End Depth: -0.8 m
KLX17A	9310	Up	KLX17A_11-14-06_08-57_9310C2_10_-2.10_699.00_ORIG.log	Start Depth: 699 m. End Depth: -2.1 m
KLX17A	9310	Down	KLX17A_11-14-06_08-19_9310C2_10_0.20_698.20_ORIG.log	Start Depth: 0.2 m. End Depth: 698.2 m
KLX17A	HiRAT	Up	KLX17A_HIRAT_180pixels_UP_run1.HED	Start Depth: 696 m. End Depth: 0 m
HLX43	8144	Up	HLX43_11-14-06_18-05_8144C_10_-0.20_170.90_ORIG.log	Start Depth: 170.9 m. End Depth: -0.2 m
HLX43	8622	Up	HLX43_11-14-06_18-34_8622C_10_-0.30_170.10_ORIG.log	Start Depth: 170.1 m. End Depth: -0.3 m
HLX43	9042	Down	HLX43_11-14-06_14-17_9042C_10_0.20_170.70_ORIG.log	Start Depth: 0.2 m. End Depth: 170.7 m
HLX43	9072	Up	HLX43_11-14-06_17-05_9072C_10_0.00_171.00_ORIG.log	Start Depth: 171 m. End Depth: 0 m
HLX43	9139	Up	HLX43_11-14-06_16-08_9139A_10_-0.30_170.40_ORIG.log	Start Depth: 170.4 m. End Depth: -0.3 m
HLX43	9310	Up	HLX43_11-14-06_17-36_9310C2_10_-0.10_169.50_ORIG.log	Start Depth: 169.5 m. End Depth: -0.1 m
HLX43	9310	Down	HLX43_11-14-06_17-27_9310C2_10_0.20_169.80_ORIG.log	Start Depth: 0.2 m. End Depth: 169.8 m
HLX43	HiRAT	Up	HLX43_HIRAT_180pixels_up_run1.HED	Start Depth: 168 m. End Depth: 0 m

**Table 6-2. Drawing files in WellCad format.**

Borehole	Drawing	WellCad file
KLX17A	1.1	KLX17A_Presentation.WCL
HLX43	2.1	HLX43_Presentation.WCL

**Table 6-3. Data files in SICADA format.**

Sheet	Comment
"Borehole"_CALIPER1_GP040	– Caliper logging.xls
"Borehole"_CALIPER MEAN_GP041	– 3-D caliper.xls
"Borehole"_TEMP(FL)_RES(FL)_GP060	– Fluid temperature and resistivity logging.xls
"Borehole"_DENSITY_GP090	– Density logging.xls
"Borehole"_MAGSUSCEP_GP110	– Magnetic susceptibility logging.xls
"Borehole"_GAM(NAT)_GP120	– Natural gamma logging.xls
"Borehole"_SPR_GP150	– Single point resistance logging.xls
"Borehole"_RES(64N)_GP160	– Resistivity, normal 1.6 m (64 in).xls
"Borehole"_RES(MG)_GP161	– Resistivity, focused 140 cm.xls
"Borehole"_RES(DG)_GP162	– Resistivity, focused 300 cm.xls
"Borehole"_LATERAL_GP163	– Resistivity, lateral 1.6–0.1 m.xls
"Borehole"_RES(16N)_GP164	– Resistivity, normal 0.4 m (16 in).xls
"Borehole"_P-VEL_GP175	– Fullwave sonic.xls
"Borehole"_SP_GP180	– Self potential logging.xls



## Borehole KLX17A. Drawing no. 1.1. Borehole logs


Co-ordinates in RT90 2,5 gon V 0:-15

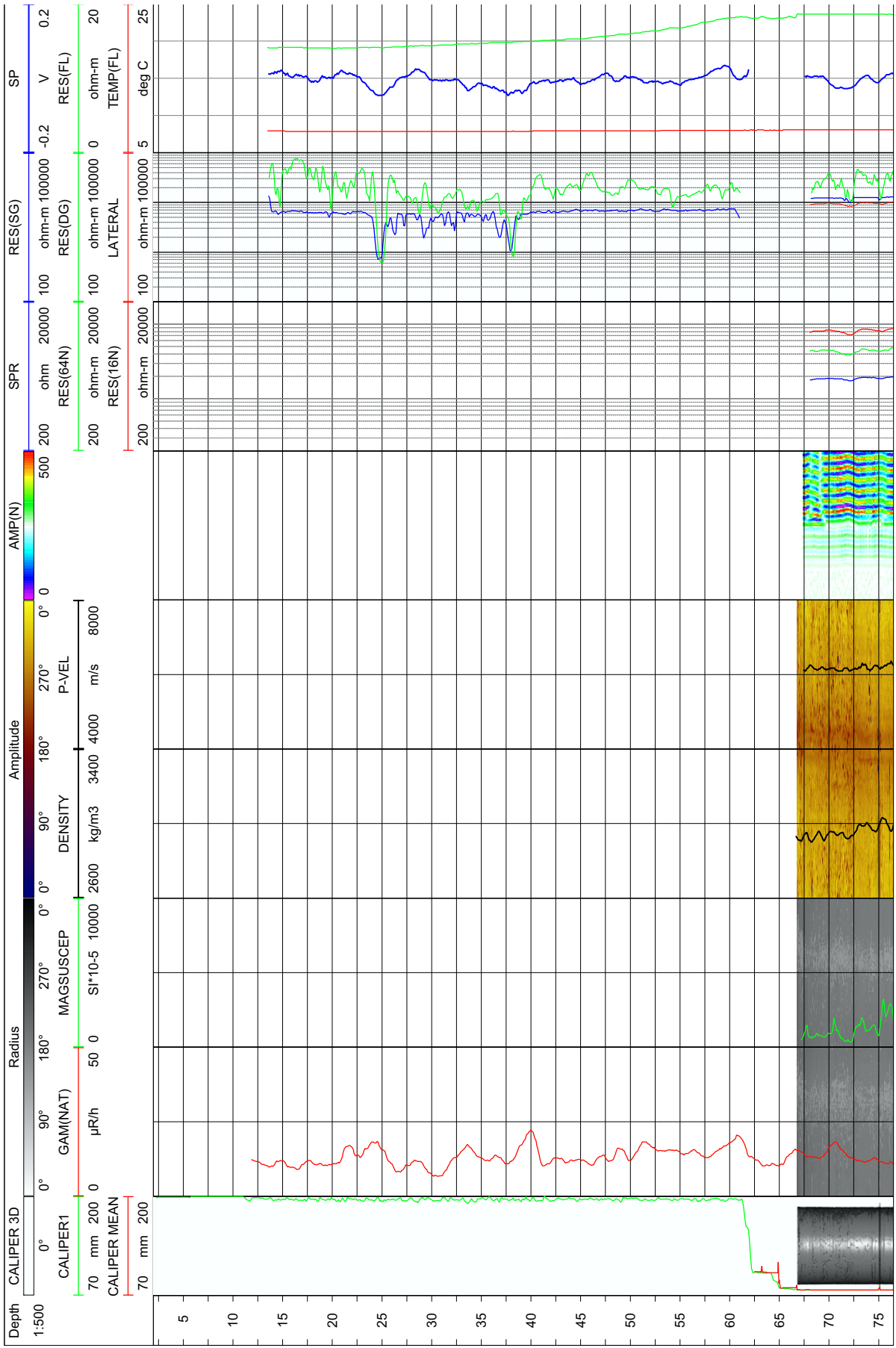
Northing: 6366848.75m Easting: 1546862.09m Elevation: 27.63m, RHB70

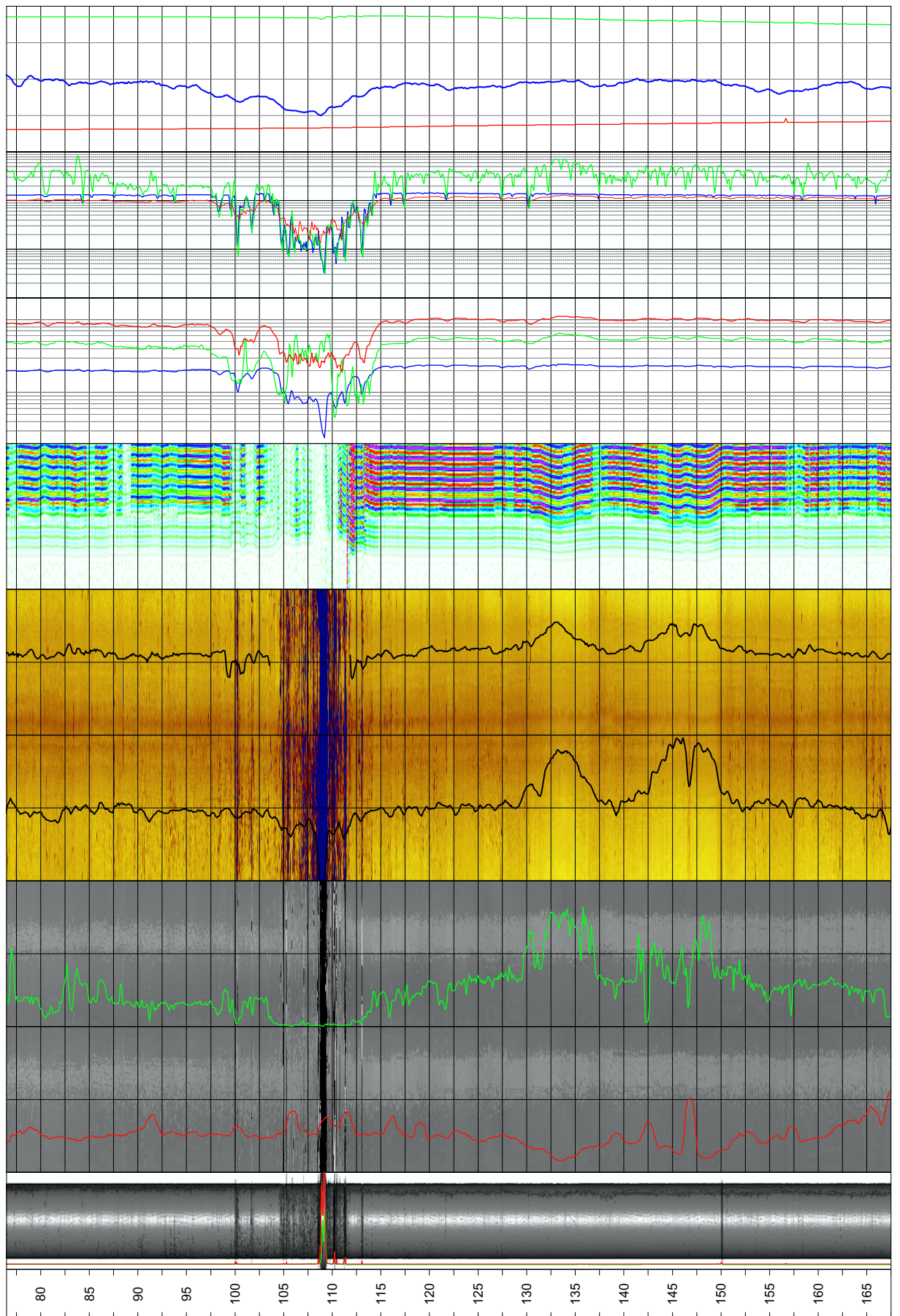
Diameter: 75.8mm  
 Reaming Diameter: 196.8mm  
 Outer Casing:  
 Inner Casing: 80-100mm  
 Casing Length: 11.95m  
 Borehole Length: 701.08m  
 Cone:  
 Inclination at ground surface: -61.34°  
 Azimuth: 11.21°  
 Comments:

### Borehole logging programme

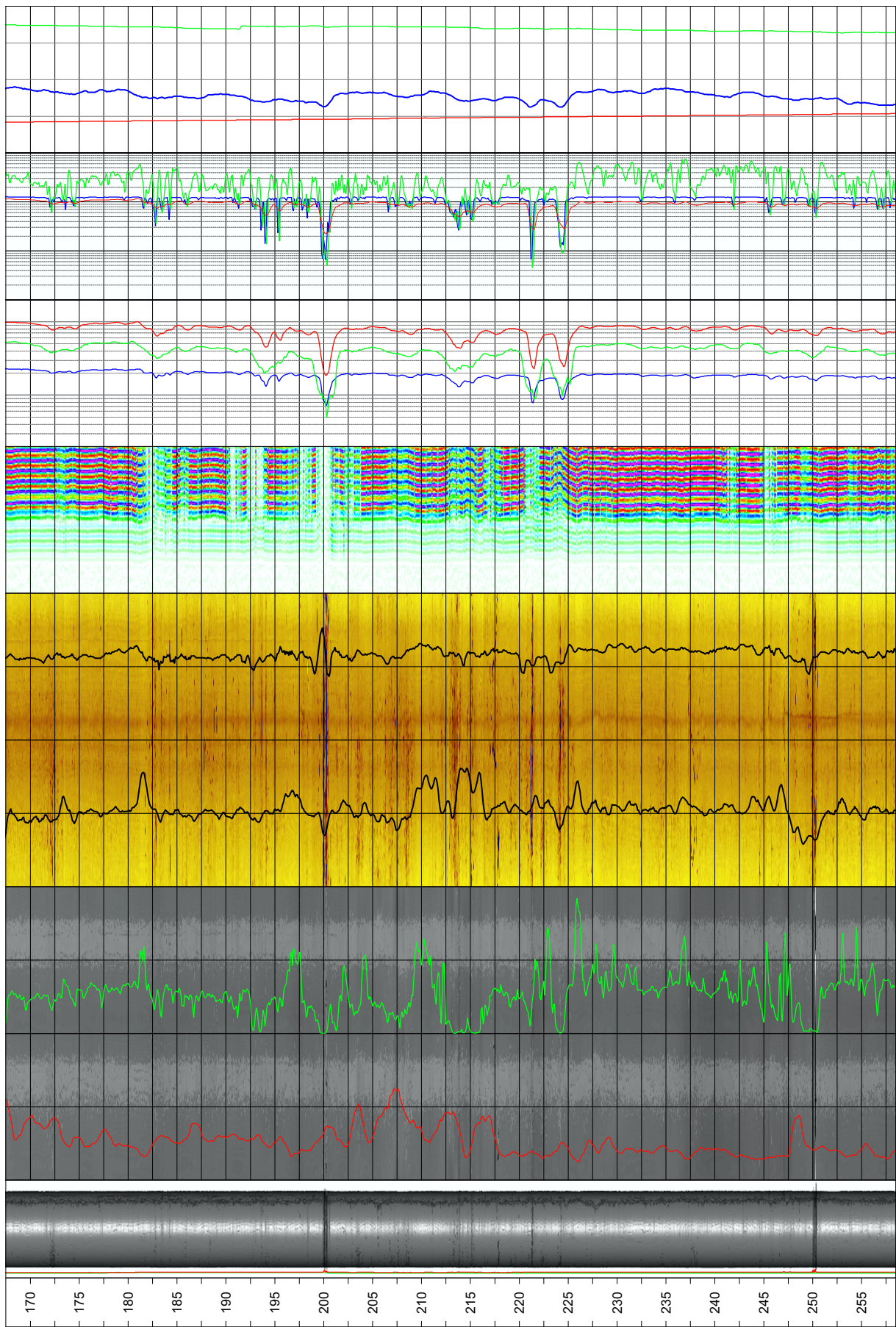
Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9139	mm
DENSITY	Gamma-gamma density	9139	kg/m <sup>3</sup>
RES(SG)	Focused guard log resistivity, 128 cm	9139	ohm-m
GAM(NAT)	Natural gamma	9072	µR/h
TEMP(FL)	Fluid temperature	9042	deg C
RES(FL)	Fluid resistivity	9042	ohm-m
RES(DG)	Focused guard log resistivity, 300cm	9072	ohm-m
P-VEL	P-wave velocity	9310	m/s
AMP(N)	Full wave form, near receiver	9310	µs
AMP(F)	Full wave form, far receiver	9310	µs
MAGSUSCEP	Magnetic susceptibility	8622	SI*10-5
CALIPER 3D	Caliper, high resolution 360 degrees	HiRAT	mm
CALIPER MEAN	High resolution 1D caliper	HiRAT	mm
AZIMUTH MN	Borehole azimuth magnetic north	HiRAT	deg
DIP	Borehole inclination from horizontal	HiRAT	deg
RADIUS	360 degrees orientated acoustic radius	HiRAT	mm
AMPLITUDE	360 degrees orientated acoustic amplitude	HiRAT	-
THORIUM	Spectral gamma, Thorium component	9080	PPM
URANIUM	Spectral gamma, Uranium component	9080	PPM
POTASSIUM	Spectral gamma, Potassium component	9080	percent
RES(16N)	Normal resistivity 16 inch	8144	ohm-m
RES(64N)	Normal resistivity 64 inch	8144	ohm-m
LATERAL	Lateral resistivity	8144	ohm-m
SPR	Single point resistivity	8144	ohm
SP	Self Potential	8144	V

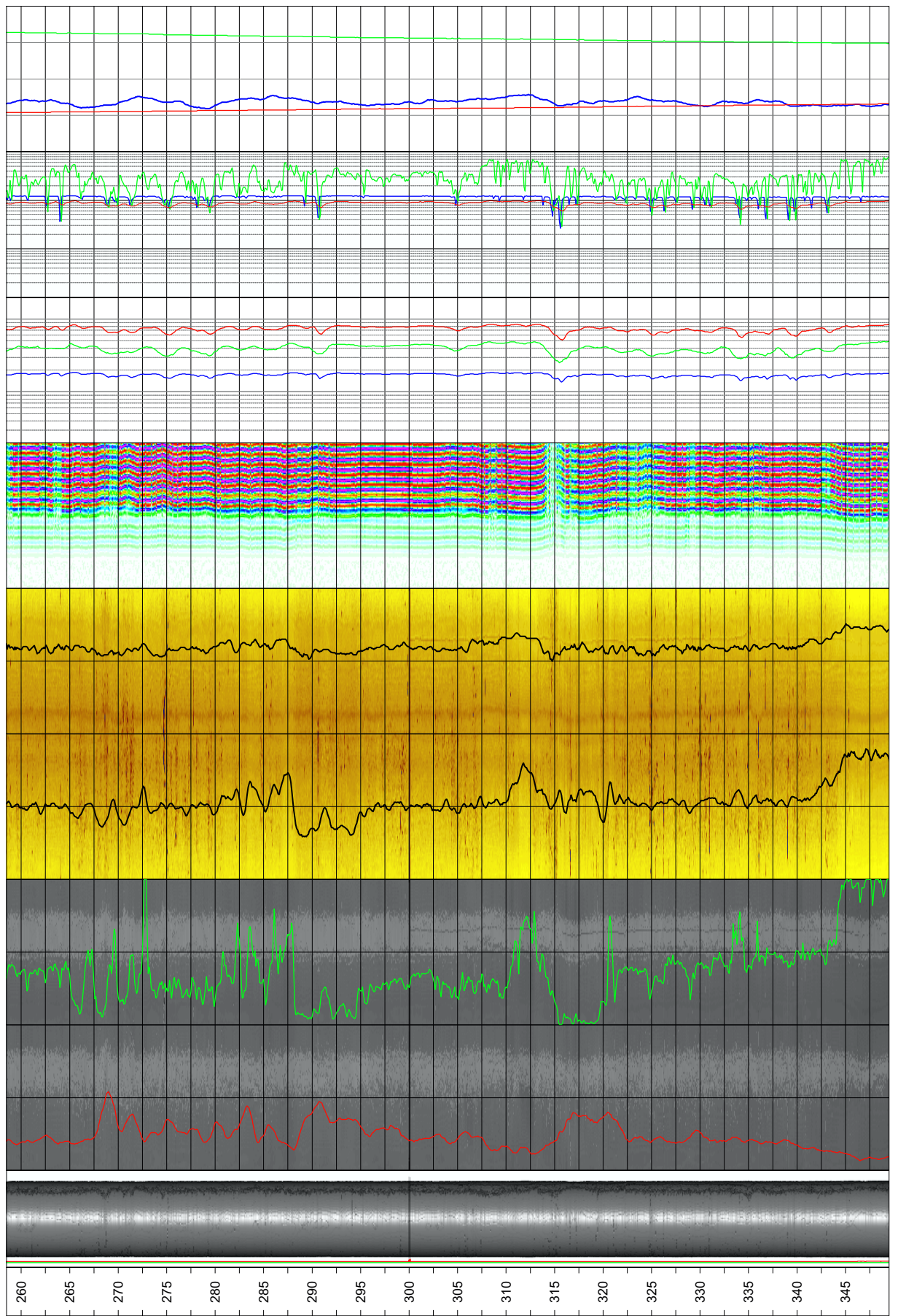
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<b>Job</b> 547310A	<b>Scale</b> 1:500				
<h2>SKB geophysical borehole logging</h2> <h3>Borehole KLX17A</h3>					
Presentation					Filename: KLX17A_Presentation.wcl  Drawing no.: <b>1.1</b>



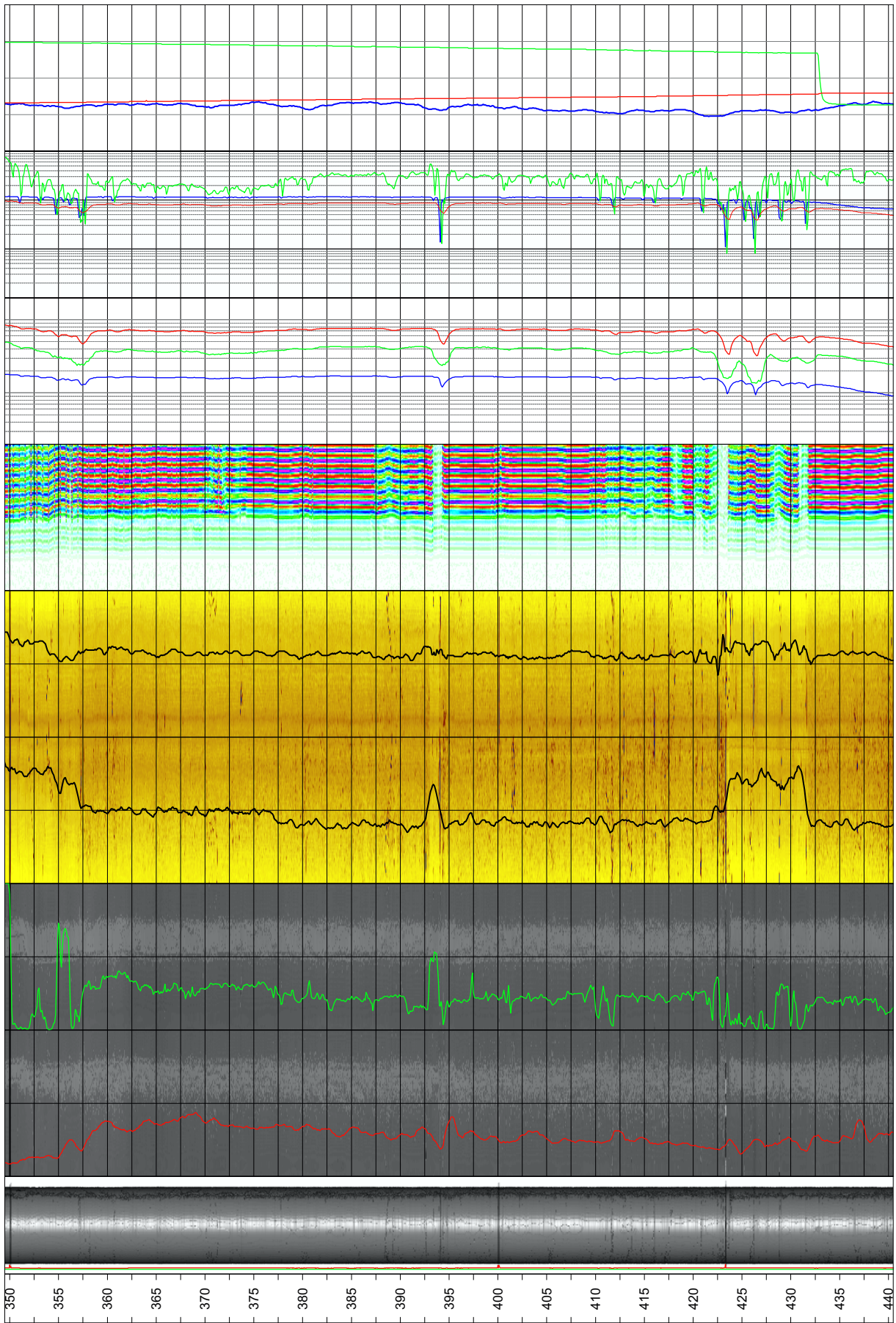


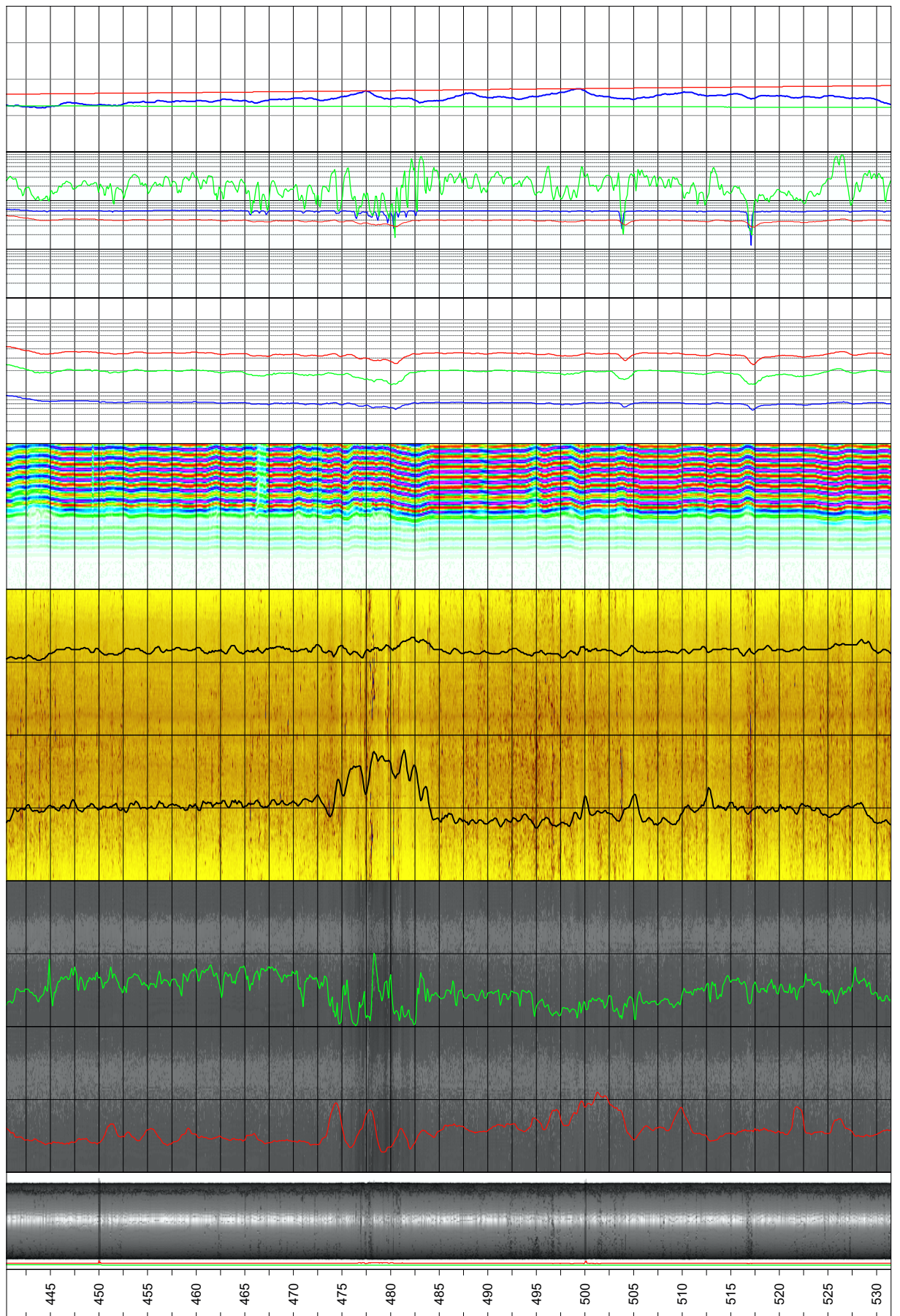




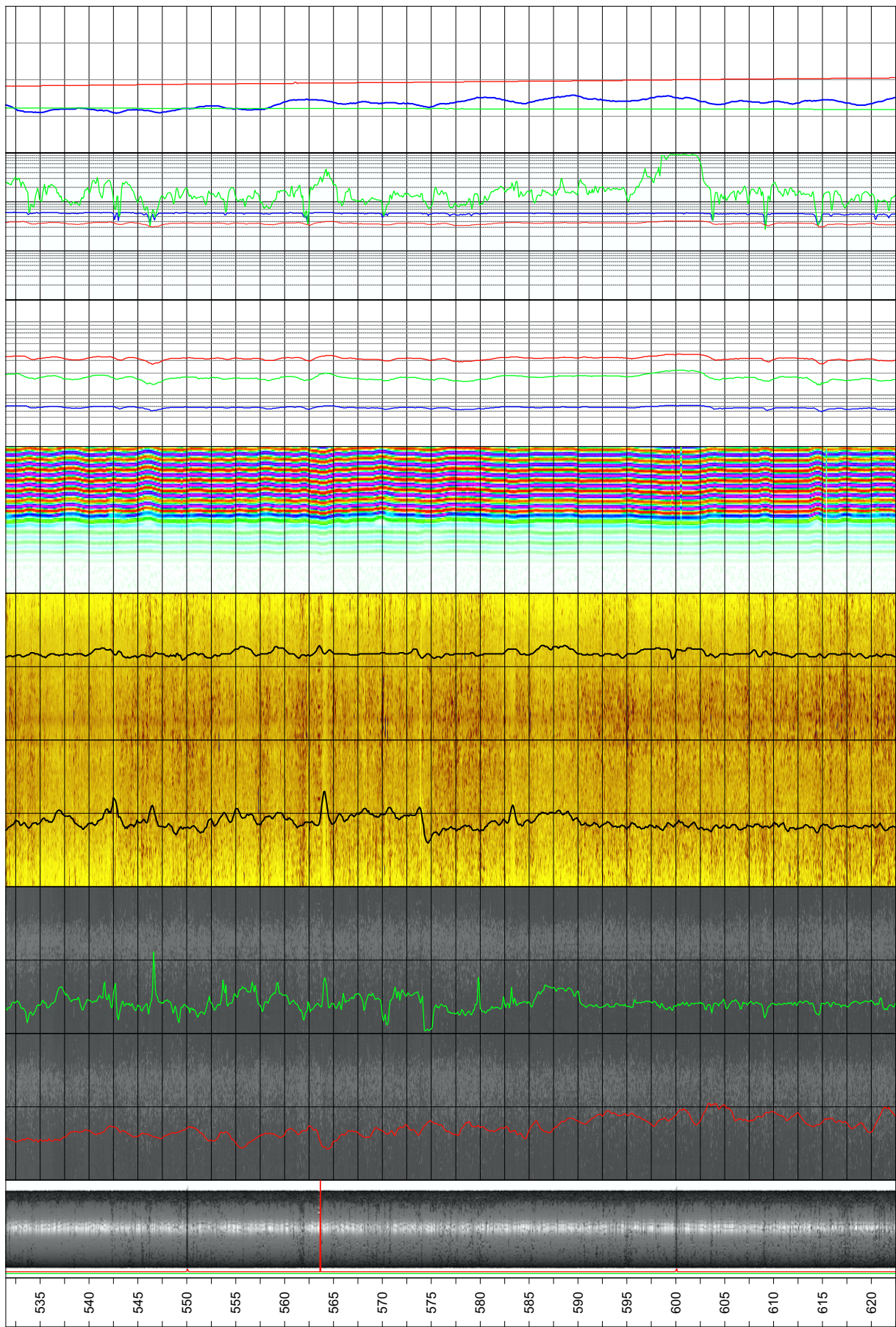




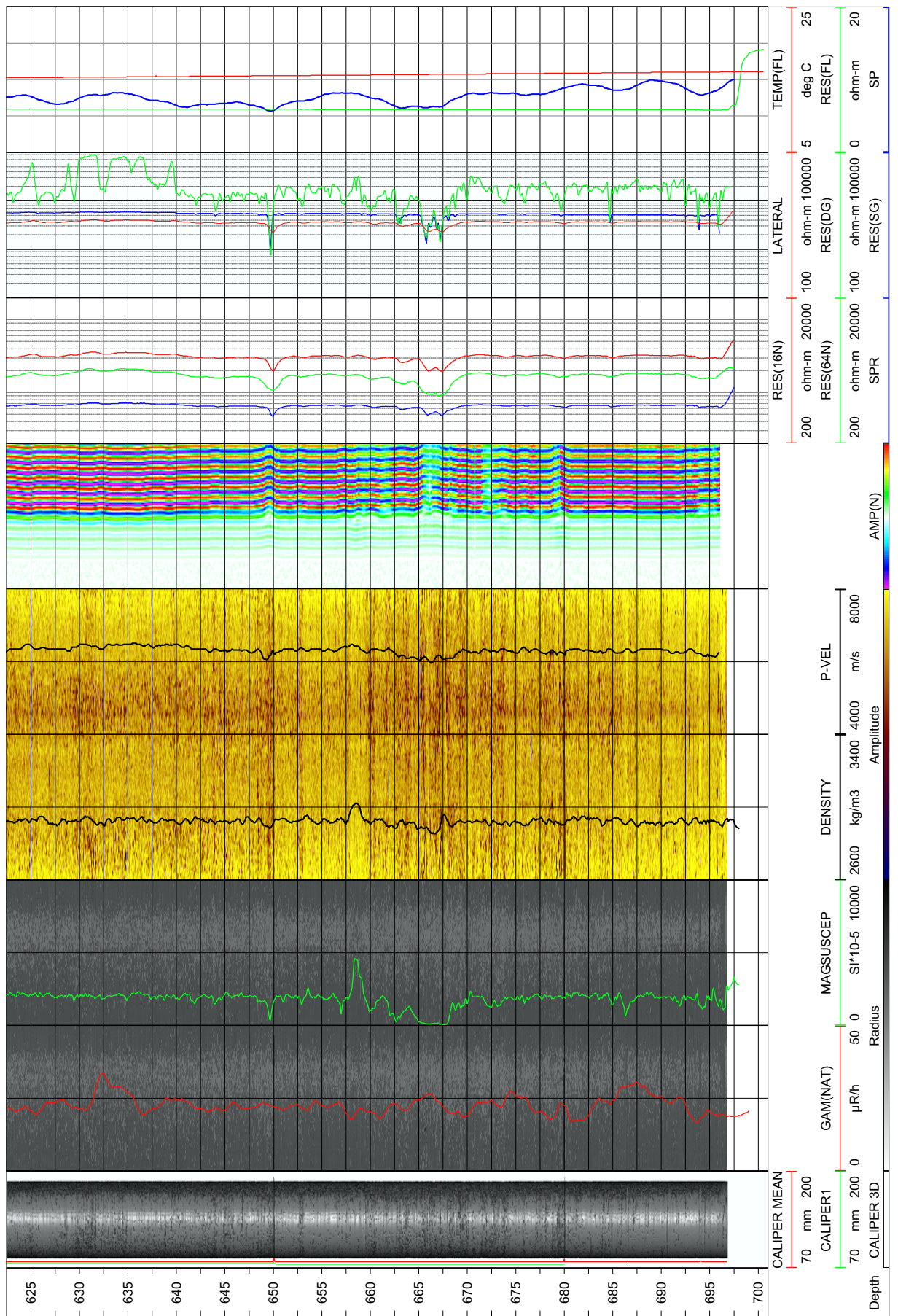














### Borehole HLX43. Drawing no. 2.1. Borehole logs

Co-ordinates in RT90 2,5 gon V 0:-15

Northing: 6367517.45m Easting: 1546626.60m Elevation: 24.2m, RHB70

Diameter: 140mm  
 Reaming Diameter: 180mm  
 Outer Casing: 168mm  
 Inner Casing: 160mm  
 Casing Length: 6.00m  
 Borehole Length: 170.60m  
 Cone:  
 Inclination at ground surface: -50.74°  
 Azimuth: 268.55° GN  
 Comments:

### Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9139	mm
DENSITY	Gamma-gamma density	9139	kg/m <sup>3</sup>
RES(SG)	Focused guard log resistivity, 128 cm	9139	ohm-m
GAM(NAT)	Natural gamma	9072	µR/h
TEMP(FL)	Fluid temperature	9042	deg C
RES(FL)	Fluid resistivity	9042	ohm-m
RES(DG)	Focused guard log resistivity, 300cm	9072	ohm-m
P-VEL	P-wave velocity	9310	m/s
AMP(N)	Full wave form, near receiver	9310	µs
AMP(F)	Full wave form, far receiver	9310	µs
MAGSUSCEP	Magnetic susceptibility	8622	SI*10-5
CALIPER 3D	Caliper, high resolution 360 degrees	HiRAT	mm
CALIPER MEAN	High resolution 1D caliper	HiRAT	mm
AZIMUTH MN	Borehole azimuth magnetic north	HiRAT	deg
DIP	Borehole inclination from horizontal	HiRAT	deg
RADIUS	360 degrees orientated acoustic radius	HiRAT	mm
AMPLITUDE	360 degrees orientated acoustic amplitude	HiRAT	-
THORIUM	Spectral gamma, Thorium component	9080	PPM
URANIUM	Spectral gamma, Uranium component	9080	PPM
POTASSIUM	Spectral gamma, Potassium component	9080	percent
RES(16N)	Normal resistivity 16 inch	8144	ohm-m
RES(64N)	Normal resistivity 64 inch	8144	ohm-m
LATERAL	Lateral resistivity	8144	ohm-m
SPR	Single point resistivity	8144	ohm
SP	Self Potential	8144	V

<b>Rev.</b> 0	<b>Date</b> 2006-12-04	<b>Drawn by</b> JRI	<b>Control</b> UTN	<b>Approved</b> UTN
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<b>Job</b> 547310A	<b>Scale</b> 1:500
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## SKB geophysical borehole logging Borehole HLX43

Presentation

Filename:  
 HLX43\_Presentation.wcl

Drawing no.:  
**2.1**



