P-13-21

Äspö Hard Rock Laboratory

Geophysical borehole logging in borehole KA3065A01

Uffe Torben Nielsen, Jørgen Ringgaard
RAMBØLL

May 2013

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

ISSN 1651-4416
SKB P-13-21
ID 1332848

Äspö Hard Rock Laboratory

Geophysical borehole logging in borehole KA3065A01

Uffe Torben Nielsen, Jørgen Ringgaard
RAMBØLL

May 2013

Keywords: Geophysical logging.

Abstract

Geophysical borehole logging has been performed in borehole KA3065A01 situated in Äspö Hard Rock Laboratory, 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.

The borehole was recorded from Top Of Casing (TOC) to the bottom of the borehole. KA3065A01 was approximately 125 m long.

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.

Sammanfattning

Geofysisk borrhålsloggning har genomförts i borrhålet KA3065A01 i Äspölaboratoriet.

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 KA3065A01 från TOC till ca 125 m.

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

Processerade loggar presenteras i Appendix 1.

Contents

1 Introduction

This document reports the results gained by the geophysical borehole logging in borehole KA3065A01. The work was carried out in accordance with activity plan AP TD TUDP002-11-095. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

All measurements were conducted by RAMBØLL during the period January 3 to 4, 2012. The borehole was recorded from Top Of Casing (TOC) to the bottom of the borehole. The technical data from the borehole is shown in Table 1-2. The location of the borehole 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
Äspö utbyggnad, DP1-Karakterisering-Geofysisk loggning av KA3065A01	AP TD TUDP002-11-095	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för geofysisk borrhålsloggning	SKB MD 221.002	3.0
Metodinstruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0

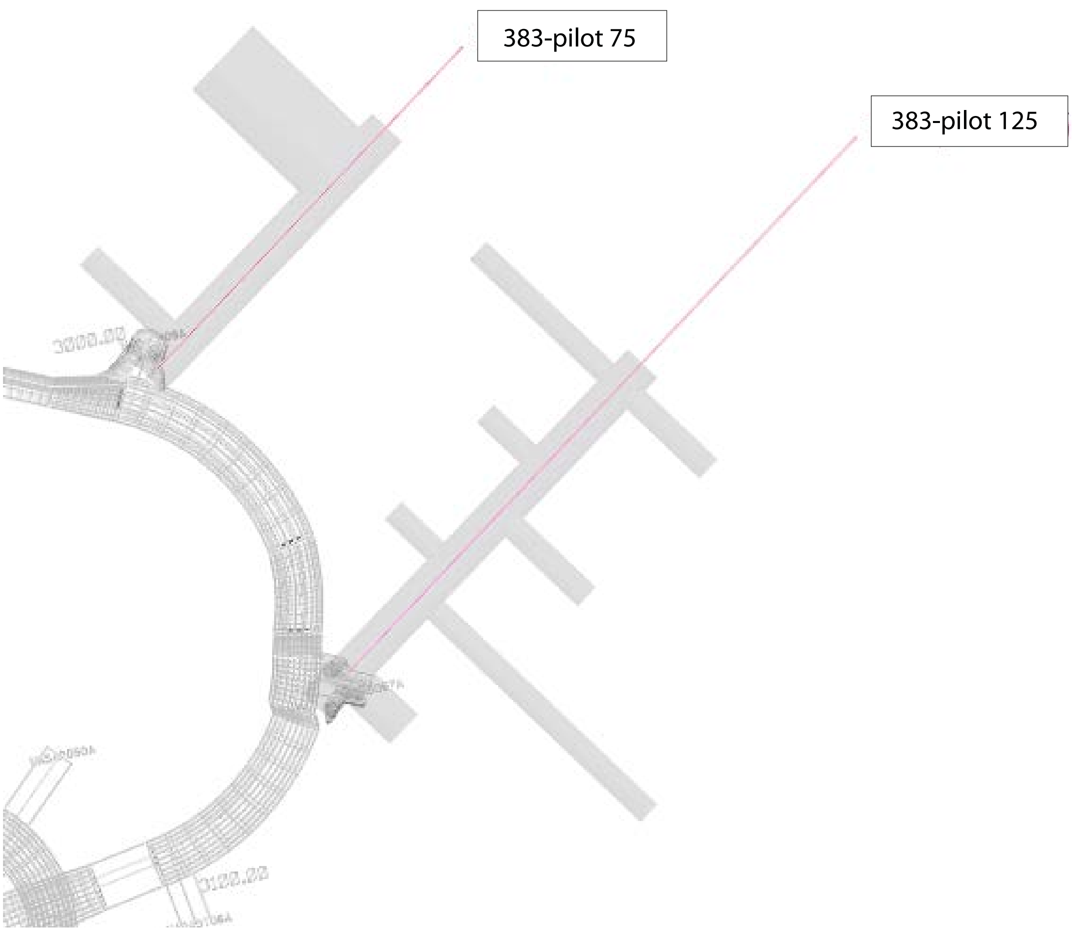


Figure 1-1. Map of the location of the borehole KA3065A01 (383-pilot 125) at Äspö HRL.

Table 1-2. Technical data for boreholes KA3065A01.

Borehole Parameter	KA3065A01
Co-ordinates (Äspö96)	7,348.01 2,389.47
Elevation (RHB70)	–406.65
Azimuth (RT90 2,5 gon V)	43.5°
Azimuth (Äspö96)	55.35°
Inclination from horizontal (TOC)	–0.56°
Length (m)	125.25
Casing (m)	2.51
Borehole diameter (mm)	75.8 mm
Cleaning level	Level 1

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 borehole.

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.

Borehole	Drawing no.	Appendix
KA3065A01	1.1	1

3 Equipment

The geophysical borehole logging program were performed with 9 tools and resulted in the suite of logs, 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	Radioactive source
GeoVista NGAM Natural Gamma	Natural gamma	70 x 3.8 cm		
GeoVista TCIL Fluid temperature and resistivity	Fluid temperature and resistivity	70 x 3.8 cm		
GeoVista DLL3 Dual Guard Focused Resistivity Sonde	Medium and a Deep LL3 focused resistivity	237 x 3.8 cm		
GeoVista MSUS Magnetic susceptibility	Magnetic susceptibility	200 x 3.6 cm		
GeoVista BHTV Acoustic televiewer	Full waveform acoustic amplitude and traveltime, 360° orientated acoustic image, 360° very high resolution caliper, borehole azimuth and dip and natural gamma	210 x 4.2 cm		
Century 8144 Normal resistivity, Lateral, Self Potential and Single point resistance	Normal resistivity (16 & 64 inch), single point resistance, Self Potential and natural gamma.	237 x 5.3 cm		
Century 9139 Compensated gamma Density	Compensated Gamma density, natural gamma, 127 cm focused guard log resistivity, 15 cm 1-arm caliper	280.3 x 5.6 cm	20.3 cm	7,400 MBq Cs137
Century 9310 Sonic	Full wave form traveltime providing P & S-wave velocity picking, compensated P-wave traveltime, cement bond location, natural gamma	300 x 6.1 cm	Near 91.4 cm, far 121.9 cm	

4 Execution

4.1 General

In general the measurement procedures follow the SKB method description (SKB MD 221.002, SKB internal controlling document). The logging program was executed during January 3 and 4, 2012. 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. 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 1 (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 the density tool 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.

All data was recorded with max. 10 cm sample interval. The speed of the logging for the density tool was 5 m/min and for all other tools 10 m/min, except for the Acoustic televiewer tool where the speed was approximately 2.5 m/min.

4.2 Nonconformities

The logging has been performed in accordance with the activity plan.

5 Results

5.1 Presentation

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

Logs presented in drawing no. 1.1 are presented in Table 5-1.

5.2 Orientation, alignment and stretch of logs

5.2.1 Orientation of images

The images from the Acoustic televiewer tool are processed to high side of the borehole, 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).

5.2.3 Alignment of data

In order to obtain an exact length calibration, gamma events in the top and the bottom of the borehole are used.

Table 5-1. Logs presented in drawings no. 1.1, are presented in Appendix 1.

Log	Log name short	Unit	Tool
Fluid temperature	TEMP(FL)	deg C	TCIL
Fluid resistivity	RES(FL)	ohm-m	TCIL
Natural gamma	GAM(NAT)	µR/h	NGAM
Normal resistivity 16 inch	RES(16N)	ohm-m	8144
Normal resistivity 64 inch	RES(64N)	ohm-m	8144
Lateral resistivity	LATERAL	ohm-m	8144
Single point resistance	SPR	Ohm	8144
Self potential	SP	V	8144
Magnetic susceptibility	MAGSUSCEP	$SI \cdot 10^{-5}$	MSUS
Caliper, 1-arm	CALIPER1	mm	9139
Gamma-gamma density	DENSITY	kg/m^3	9139
Focused guard log resistivity, 128 cm	RES(SG)	ohm-m	DLL3
Focused guard log resistivity, 300 cm	RES(DG)	ohm-m	DLL3
P-wave velocity	P-VEL	m/s	9310
S-wave velocity	S-VEL	m/s	9310
Full wave form, near receiver	AMP(N)	µs	9310
Caliper, high resolution, 360°	CALIPER 3D	mm	BHTV
High resolution 1D Caliper	CALIPER MEAN	mm	BHTV

5.2.4 Stretch of logs

There can be a minor difference in the length registration between up- and down runs for the used winch. 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 Acoustic televiewer 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.

5.3 Calculated log curves

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

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^3) to (kg/m^3) units by multiplying with 1,000.
Focused guard log resistivity, 128 cm	–
Natural gamma	The natural gamma log was converted from CPS to μR/h by multiplying with 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 from CGS units to SI units by multiplying the CGS value by 4π.
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.
Radius	–
Amplitude	–

5.4 Borehole KA3065A01

Using the natural gamma from the acoustic televiewer as a reference, the natural gamma logs from the other tools are aligned to the same length. A new length scale is added to each log and afterwards the logs are stretched using different gamma events.

The complete log suite for borehole KA3065A01 is presented as a composite log sheet in drawing 1.1 in Appendix 1. The logs presented in drawing no. 1.1 are listed in Table 5-1.

6 Data delivery

Geophysical logging data from the measurements, recorded in GeoVista or Century format, are included in the data delivery. 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 GeoVista format used for processing.

Borehole	Probe	Log direction	WellCAD File
KA3065A01	8144	Up	KA3065A01_01-04-12_09-31_8144C_.01_-0.81_123.49_ORIG.log
KA3065A01	9139	Up	KA3065A01_01-03-12_18-26_9139C_.01_-1.21_123.06_ORIG.log
KA3065A01	9310	Up	KA3065A01_01-04-12_10-34_9310C2_.10_-1.10_122.20
KA3065A01	BHTV	Up	KA3065A01_BHTV_180pixels_20120104_1237_up_H.hed
KA3065A01	DLL3	Up	KA3065A01_DLL3-4279_NGRS_20120104_0912_up.Hdr
KA3065A01	MSUS	Up	KA3065A01_NGRS_MSUS-4391_20120103_1530_up.Hdr
KA3065A01	TCIL	Down	KA3065A01_NGRS_TCME3444_20120103_1311_dn.Hdr

Table 6-2. Drawing files in WellCAD format.

Borehole	Drawing	WellCAD file
KA3065A01	1.1	KA3065A01 _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(SG)_GP159 – Resistivity, focused 128 cm.xls	Medium
"Borehole"_RES(DG)_GP162 – Resistivity, focused 300 cm.xls	Deep
"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	

Appendix 1

Borehole KA3065A01. Drawing no. 1.1. Borehole logs

Co-ordinates in Äspö 96

Northing: 7348.01 m Easting: 2389.47 m Elevation: -406.66 m, lokalt

Diameter:	75.8 mm
Reaming Diameter:	116 mm
Outer Casing:	100 mm
Inner Casing:	80 mm
Casing Length:	2.04 m
Borehole Length:	125.25 m
Cone:	
Inclination at ground surface:	-0.56° Äspö 96
Azimuth:	55.35° Äspö 96
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9139/FDSB	mm
DENSITY	Gamma-gamma density	9139/FDSB	kg/m³
RES(SG)	Focused guard log resistivity, 128 cm	9139/DLL3	ohm-m
GAM(NAT)	Natural gamma	9042/NGAM	µR/h
TEMP(FL)	Fluid temperature	9042/TCME	deg C
RES(FL)	Fluid resistivity	9042/TCME	ohm-m
RES(DG)	Focused guard log resistivity, 300cm	9072/DLL3	ohm-m
P-VEL	Compressional wave velocity	9310	m/s
S-VEL	Shear wave velocity	9310	m/s
AMP(N)	Full wave form, near receiver	9310	µs
MAGSUSCEP	Magnetic susceptibility	8622/MSUS	SI*10-5
CALIPER 3D	Caliper, high resolution 360 degrees	HiRAT/BHTV	mm
CALIPER MEAN	High resolution 1D caliper	HiRAT/BHTV	mm
AZIMUTH MN	Borehole azimuth magnetic north	HiRAT/BHTV	deg
DIP	Borehole inclination from horizontal	HiRAT/BHTV	deg
RADIUS	360 degrees orientated acoustic radius	HiRAT/BHTV	mm
AMPLITUDE	360 degrees orientated acoustic amplitude	HiRAT/BHTV	-
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 resistance	8144	ohm
SP	Self Potential	8144	v
OPTICAL	360 degrees oriented optical image	OPTV	-

Rev.	Date	Drawn by	Control	Approved
0	2012-01-22	JRI	UTN	UTN

Job: 0547310A Scale: 1:500

RAMBØLL

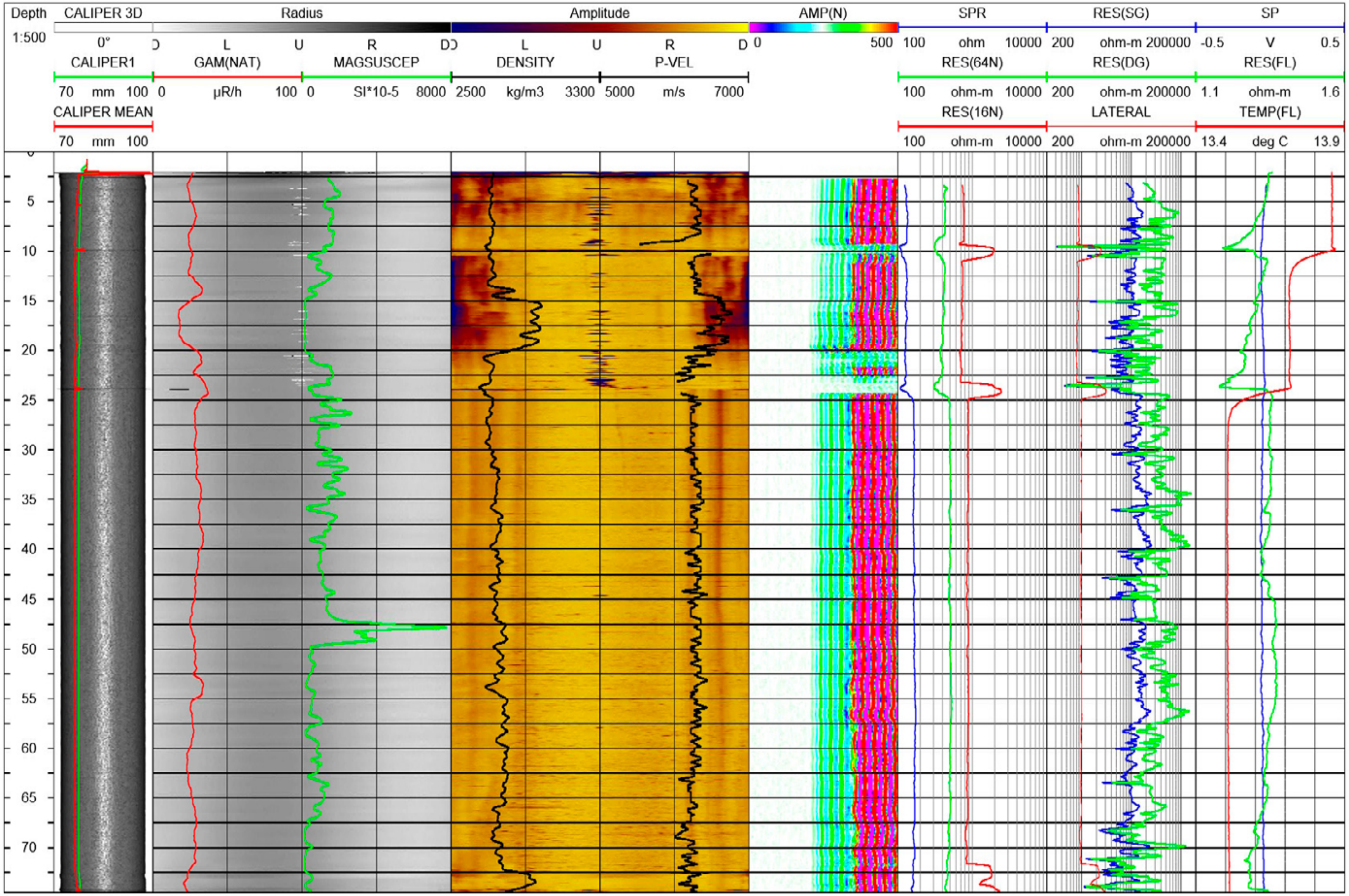
Rambøll DK, Hannemanns Allé 53, DK-2300 København S
Phone + 45 5161 1000, Fax + 45 5161 1001.

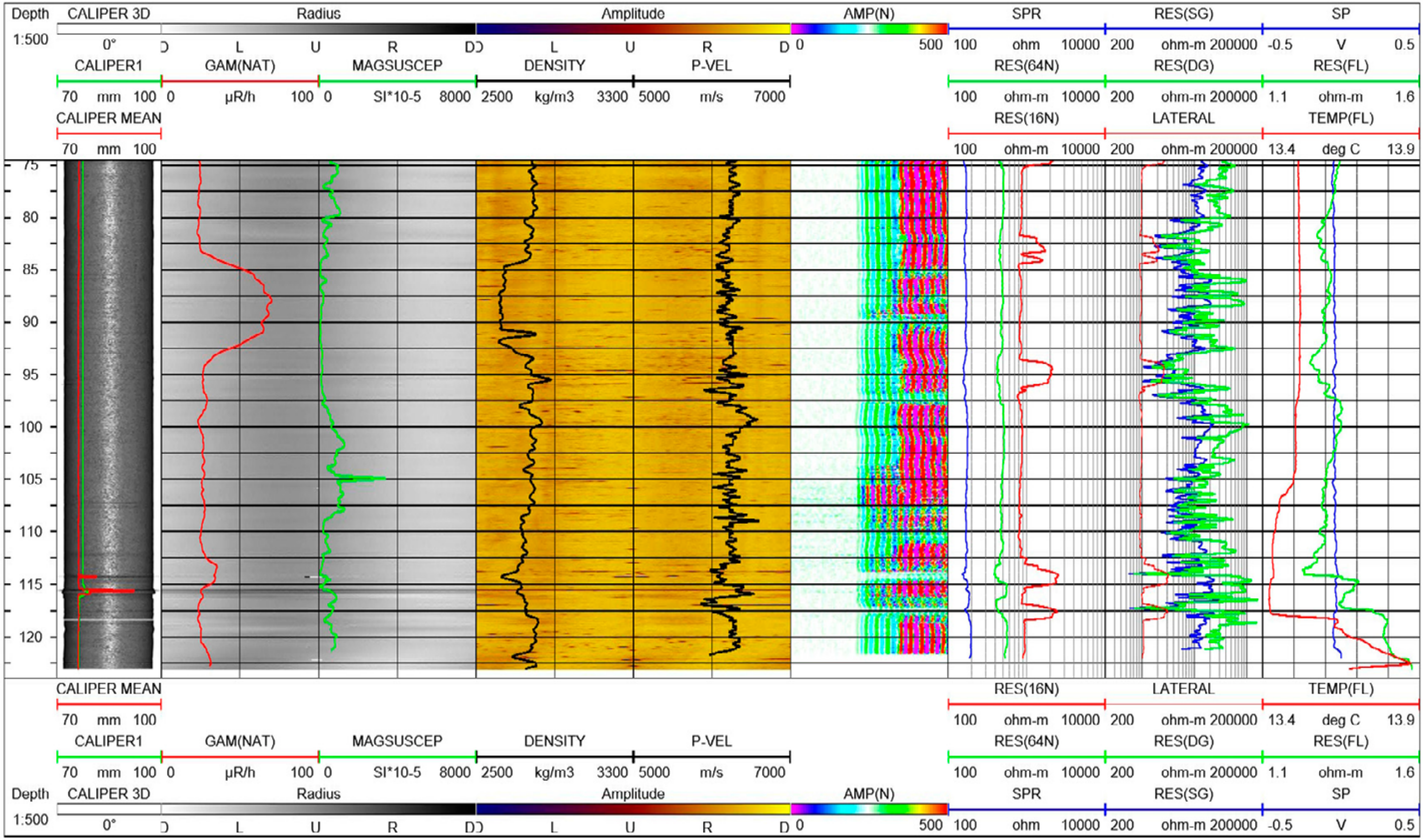
SKB geophysical borehole logging
Borehole KA3065A01

Presentation

Filename: KA3065A01_Presentation.wcl

Drawing no.: 1.1


Depth
1:500
CALIPER 3D
0°
CALIPER1
70 mm 100
CALIPER MEAN
70 mm 100
Radius
D L U R D
GAM(NAT)
0 µR/h 100
MAGSUSCEP
0 SI*10-5 8000
Amplitude
D L U R D
DENSITY
2500 kg/m3 3300
P-VEL
5000 m/s 7000
AMP(N)
0 500
SPR
100 ohm 10000
RES(64N)
100 ohm-m 10000
RES(16N)
100 ohm-m 10000
RES(SG)
200 ohm-m 200000
RES(DG)
200 ohm-m 200000
LATERAL
200 ohm-m 200000
SP
-0.5 V 0.5
RES(FL)
1.1 ohm-m 1.6
TEMP(FL)
13.4 deg C 13.9
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Depth
1:500
CALIPER 3D
0°
Radius
Amplitude
AMP(N)
0 500
SPR
100 ohm 10000
RES(SG)
200 ohm-m 200000
SP
-0.5 V 0.5
CALIPER1
70 mm 100
GAM(NAT)
0 μR/h 100
MAGSUSCEP
0 SI*10-5 8000
DENSITY
2500 kg/m3 3300
P-VEL
5000 m/s 7000
RES(64N)
100 ohm-m 10000
RES(DG)
200 ohm-m 200000
RES(FL)
1.1 ohm-m 1.6
CALIPER MEAN
70 mm 100
RES(16N)
100 ohm-m 10000
LATERAL
200 ohm-m 200000
TEMP(FL)
13.4 deg C 13.9
75
80
85
90
95
100
105
110
115
120