P-09-76

Site investigation SFR

Geophysical borehole logging in boreholes KFR105 and HFM07

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RAMBØLL

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Abstract

Geophysical borehole logging has been performed in boreholes KFR105 situated at SFR in Forsmark, Sweden. A reference logging was performed in the borehole HFM07.

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 logging in KFR105 was recorded almost horizontal from the tunnel in SFR with a length of approximately 307 m.

The logging in HFM07 was performed as a control logging, to compare logging results previously performed in the borehole, during the period of 2003 to 2009.

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 1–2.

Sammanfattning

Geofysisk borrhålsloggning har genomförts i borrhålet KFR105 vid SFR i Forsmark. En referensloggning genomfördes i borrhålet HFM07.

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 i KFR105 genomfördes nästan horisontellt från byggtunneln i SFR till en längd på ca 307 m.

Den geofysiska borrhålsloggningen i HFM07 genomfördes som en kontrollmätning, för att möjliggöra jämförelse med resultaten från tidigare undersökningar under perioden 2003 till 2009.

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

Processerade loggar presenteras i Appendix 1 till 2.

Contents

1 Introduction

This document reports the results gained by the geophysical borehole logging in boreholes KFR105 and HFM07, which is one of the activities performed within the site investigation at SFR. The work was carried out in accordance with activity plan AP SFR-09-010. 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 June 2 to 4, 2009. KFR105 was recorded from the reference point (see Figure 1-2) to the bottom of the borehole and HFM07 from Top Of Casing (T.O.C.). The technical data from the boreholes is shown in Table 1-2. The location of the borehole KFR105 is shown in Figure 1-1, and Figure 1-2 shows the technical description of the borehole.

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.

Activity plan	Number	Version
Geofysisk borrhålsloggning i KFR105	AP SFR-09-010	1.0
Method description	**Number**	**Version**
Metodbeskrivning för geofysisk borrhålsloggning	SKB MD 221.002	3.0

Table 1-2. Technical data for boreholes KFR105 and HFM07.

Borehole parameter	KFR105	HFM07
Co-ordinates (RT90)	6701789.87 1633072.96	6697416.25 1634715.69
Elevation (RHB70)	–106.82	5.78
Azimuth (TOC)	174.48º	342.3º
Inclination from horizontal (TOC)	–10.12º	–84.52º
Length [m]	306.81	122.50
Casing [m]	2.97	18.00
Borehole diameter [mm]	75.8	139.6
Cleaning level	Level 1	Level 1

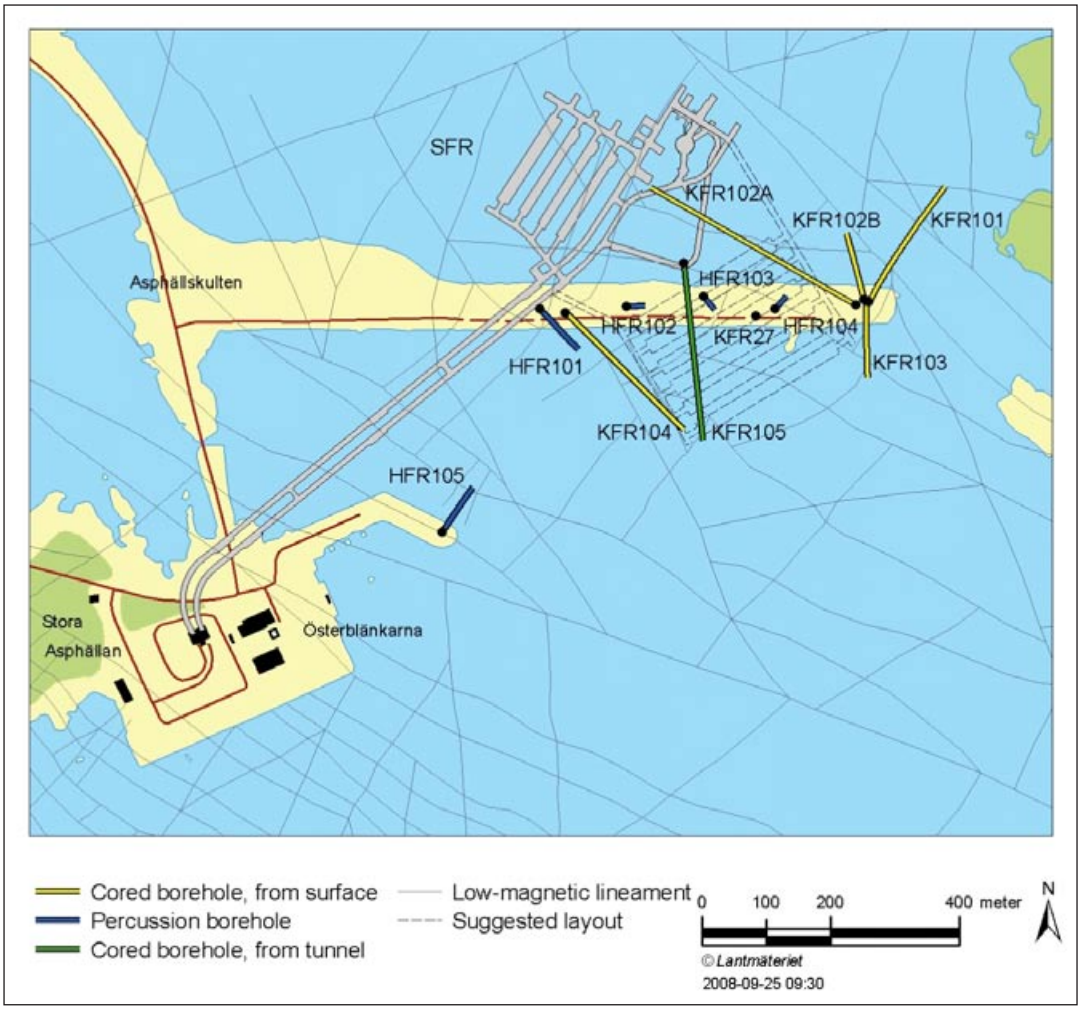
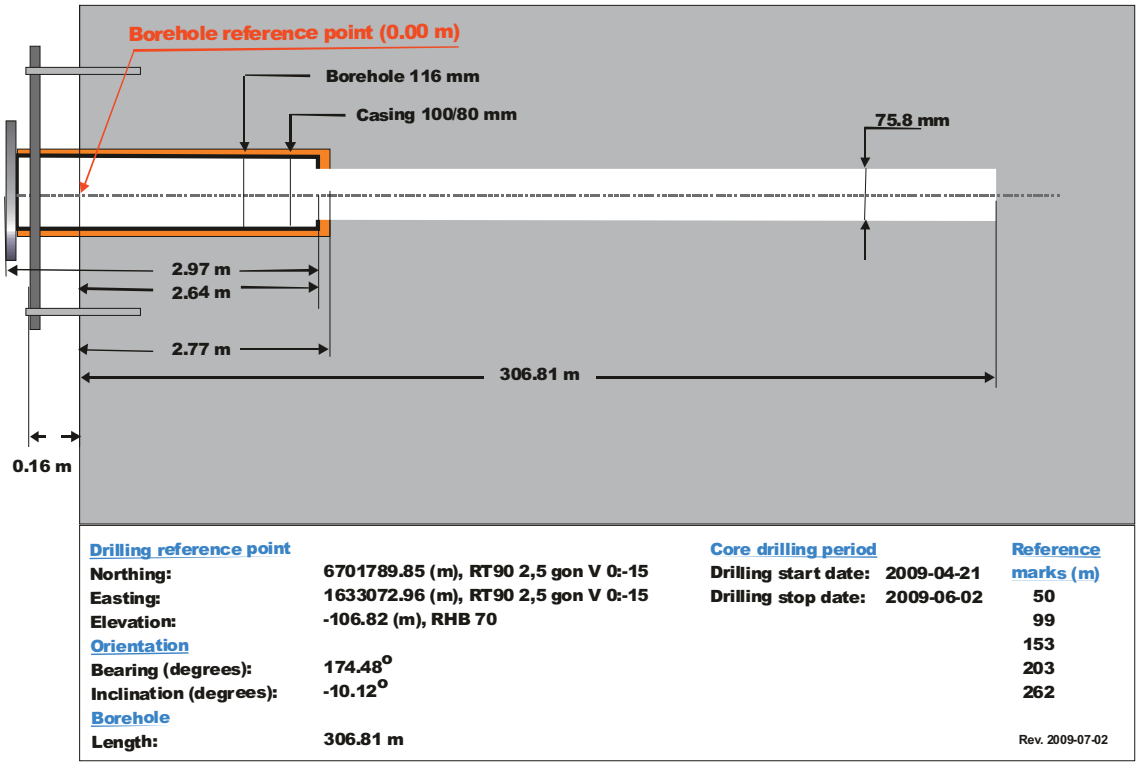


Figure 1-1. *General overview over SFR site investigation area, showing the location of the borehole KFR105.*

Technical data
Borehole KFR105



Drilling reference point		Core drilling period		Reference marks (m)
Northing:	6701789.85 (m), RT90 2,5 gon V 0:-15	Drilling start date:	2009-04-21	
Easting:	1633072.96 (m), RT90 2,5 gon V 0:-15	Drilling stop date:	2009-06-02	50
Elevation:	-106.82 (m), RHB 70			99
Orientation				153
Bearing (degrees):	174.48°			203
Inclination (degrees):	-10.12°			262
Borehole				
Length:	306.81 m			

Rev. 2009-07-02

Figure 1-2. Technical description of borehole KFR105.

2 Objective and scope

The objective of the survey is to receive information of the borehole water and from the rock mass surrounding the borehole. Geophysical borehole logging was used to measure changes in physical properties in the borehole fluid and the bedrock surrounding 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 borehole length on drawings shown in Appendix 1 and 2, Table 2-1.

Table 2-1. Appendix and drawing no.

Borehole	Drawing no.	Appendix
KFR105	1.1	1
HFM07	2.1	2

3 Equipment

The geophysical borehole logging program were performed with 5 multi tool probes and resulted in a suite of 15 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
Century 8622 Magnetic susceptibility.	Magnetic susceptibility, natural gamma.	203x4.1 cm		
Century 9042 Fluid temperature and fluid resistivity.	Fluid temperature, fluid resistivity and natural gamma.	137x4.1 cm		
Century 9072 3 m focused guard.	3 m focused guard log resistivity and natural gamma.	310x6.4 cm		
Century 9139 Compensated gamma density.	Compensated gamma density, natural gamma, 128 cm focused guard log resistivity, 1-arm caliper.	380.3x5.6 cm	20.3 cm 200 mCi Cs137	Sidewall. Gamma source focused.
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.	246x4 cm		Centralized.

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 June 2 to 4, 2009. All relevant logging events are described in the daily report sheets delivered to Sicada and are traceable by the activity plan number.

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). Furthermore, all equipment was wiped with alcohol before it was lowered into the borehole.

For control, each log run is normally recorded both direction using the down run as a repeat section. 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.

4.2 Nonconformities

The logging has been performed in accordance with the activity plan AP SFR-09-010 without nonconformities.

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 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).

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 length readings from the track marks and from the HiRAT tool is used to create 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 magnitude 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 created 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 applied to the log. The bottom of the borehole is considered in stretching the logs in order to ensure 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.

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

Log	Log name short	Unit	Tool
Fluid temperature	TEMP(FL)	deg C	9042
Fluid resistivity	RES(FL)	Ohm-m	9042
Magnetic susceptibility	MAGSUSCEP	SI*10^{-5}	8622
Gamma-gamma density	DENSITY	kg/m^3	9139
Focused guard log resistivity, 128 cm	RES(SG)	ohm-m	9139
Natural gamma	GAM(NAT)	µR/h	9042
Focused guard log resistivity, 300 cm	RES(DG)	ohm-m	9072
High resolution 1D Caliper	CALIPER MEAN	mm	HiRAT
360° orientated acoustic travel time	RADIUS		HiRAT
360° orientated acoustic travel time	AMPLITUDE		HiRAT

5.3 Calculated log curves

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

5.4 Caliper mean

The caliper mean is normally calculated using the mean travel time from the acoustic televiewer, the fluid temperature, fluid velocity and the internal travel time in the acoustic televiewer.

Due to the special conditions in the borehole KFR105, the mix-up of the water caused by the different log runs is worse than usual. The values from fluid temperature and resistivity logs are normally used in the conversion of data from the acoustical televiewer from Travel Time to caliper. Due to the fluid mix-up the standard formulas give unrealistic values. Therefore the compensation has been done the other way around, assuming that the borehole has a constant average value, a formula to compensate for fluid- and sonde internal traveltime has been derived and applied for in the borehole.

5.5 Borehole KFR105

Using the natural gamma from the HiRAT as reference, the natural gamma logs from the other probes are aligned to the same borehole 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 KFR105 is presented as composite log sheet in drawing no. 1.1 in Appendix 1. The logs presented in drawing no. 1.1 are listed in Table 5-1.

5.6 Borehole HFM07

Using the natural gamma from the 9042 as reference, the natural gamma logs from the other probes are aligned to the same borehole 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 HFM07 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.

Table 5-2. Calculated log curves.

Log	Description of log calculation
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 the constant 0.077. This constant was computed from the logs previously performed in borehole KLX02 located in Oskarshamn.
Fluid temperature	–
Fluid resistivity	–
Focused guard log resistivity, 300 cm	–
Magnetic susceptibility	The magnetic susceptibility was converted for CGS units to SI units by multiplying the CGS value by 4π.
Caliper, high resolution. 360°	The caliper 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.
360° orientated acoustic amplitude	–

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
KFR105	HiRAT	Down	KFR105_hirat_120pixels_2mm_up_unaligned_run2.HED	Start Length: 305 m End Length: 0 m
KFR105	9139	Up	KFR105_06-03-09_17-54_9139A_.01_-0.27_306.35_ORIG.log	Start Length: 306.35 m End Length: –0.27 m
KFR105	9072	Up	KFR105_06-03-09_15-43_9072C_.01_0.29_306.13_ORIG.log	Start Length: 306.13 m End Length: 0.29 m
KFR105	8622	Up	KFR105_06-03-09_13-39_8622C_.01_1.01_305.24_ORIG.log	Start Length: 305.24 m End Length: 1.01 m
KFR105	9042	Down	KFR105_06-03-09_08-17_9042C_.01_0.22_305.27_ORIG.log	Start Length: 0.22 m End Length: 305.27 m
HFM07	9072	Up	HFM07_06-02-09_18-29_9072C_.01_0.43_122.29_ORIG.log	Start Length: 122.29 m End Length: 0.43 m
HFM07	9139	Up	HFM07_06-02-09_17-56_9139A_.01_0.85_122.11_ORIG.log	Start Length: 122.11 m End Length: 0.85 m
HFM07	8622	Up	HFM07_06-02-09_17-26_8622C_.01_0.23_122.03_ORIG.log	Start Length: 122.03 m End Length: 0.23 m
HFM07	9042	Down	HFM07_06-02-09_12-57_9042C_.01_0.22_122.64_ORIG.log	Start Length: 0.22 m End Length: 122.64 m
KFR105	HiRAT	Down	KFR105_hirat_120pixels_2mm_up_unaligned_run2.HED	Start Length: 305 m End Length: 0 m

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KFR105	1.1	KFR105_Presentation.WCL
HFM07	2.1	HFM07_Presentation.WCL

Table 6-3. Data files in Sicada format.

Sheet	Comment
“Borehole”_CALIPER1_GP040 – Caliper logging.xls	Only delivered for HFM07
“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”_RES(SG)_GP159 – Resistivity, focused 128 cm.xls	
“Borehole”_RES(DG)_GP162 – Resistivity, focused 300 cm.xls	
“Borehole”_GP830 – Acoustic televiewer.xls	

Appendices

Borehole No. KFR105

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

Northing: 6701789.85 m Easting: 1633072.96 m Elevation: -106.82 m, RHB70

Diameter:	75.8 mm
Reaming Diameter:	116 mm
Outer Casing:	100 mm
Inner Casing:	80 mm
Casing Length:	2.97 m
Borehole Length:	306.81 m
Cone:	
Inclination at ground surface:	-10.12°
Azimuth:	174.48°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9139	mm
DENSITY	Gamma-gamma density	9139	kg/m³
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

Rev.	Date	Drawn by	Control	Approved
0	2009-06-08	JRI	UTN	UTN

Job 547310A

Scale 1:500

RAMBØLL

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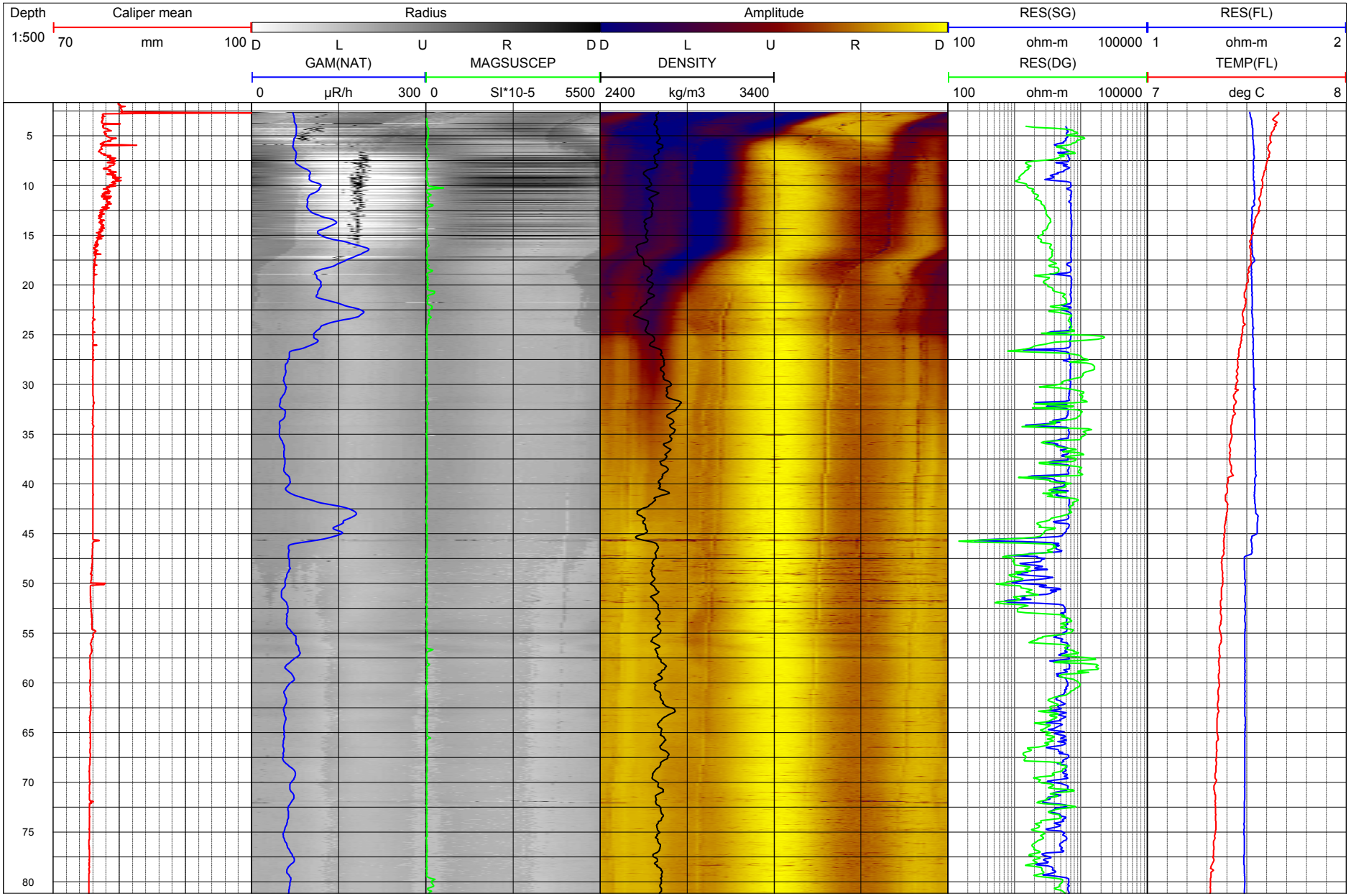
SKB geophysical borehole logging
Borehole KFR105

Presentation

Filename: KFR105_Presentation.wcl

Drawing no.: **1.1**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SI*10-5
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Amplitude
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U
R
D
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kg/m3
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RES(DG)
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ohm-m
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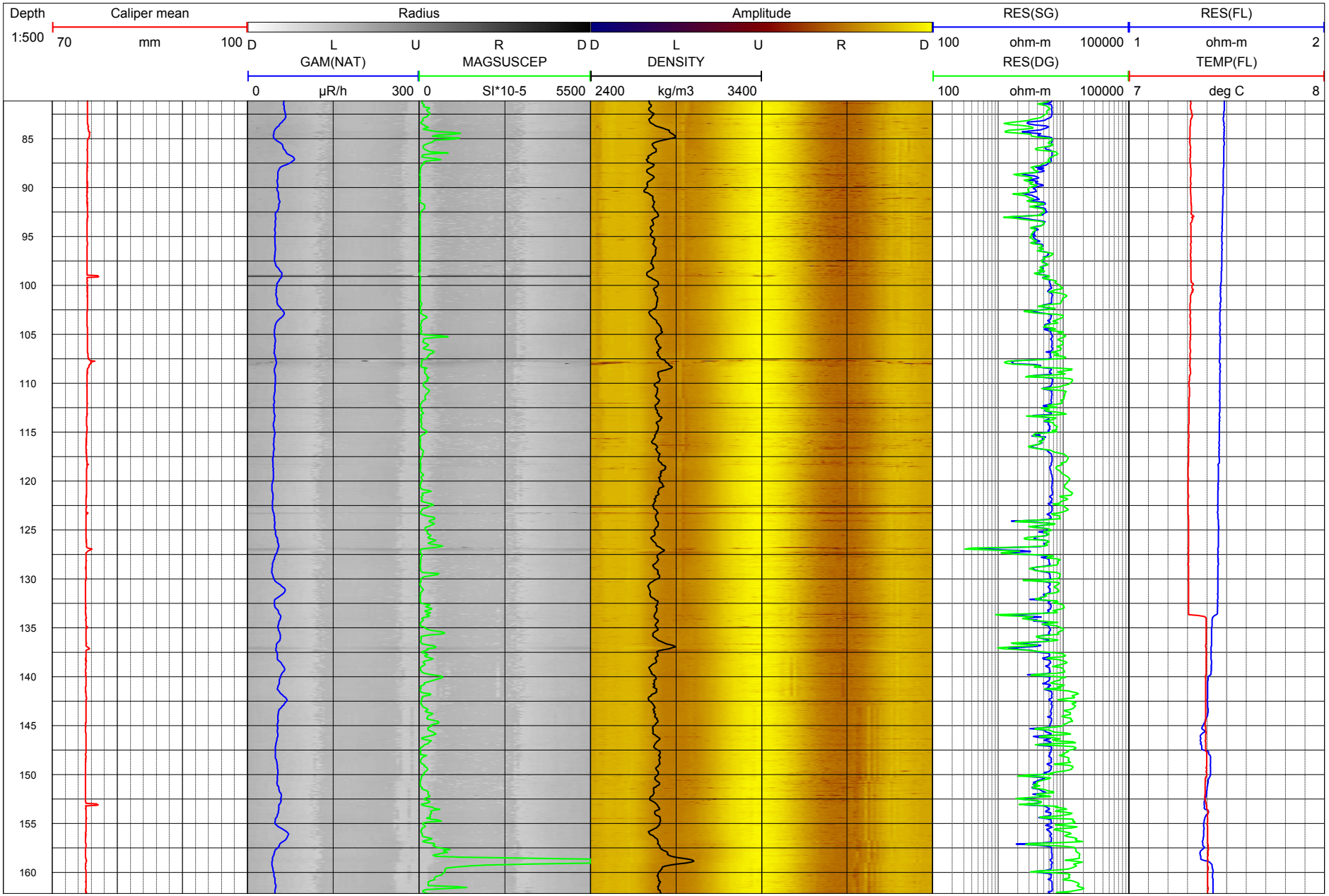
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ohm-m
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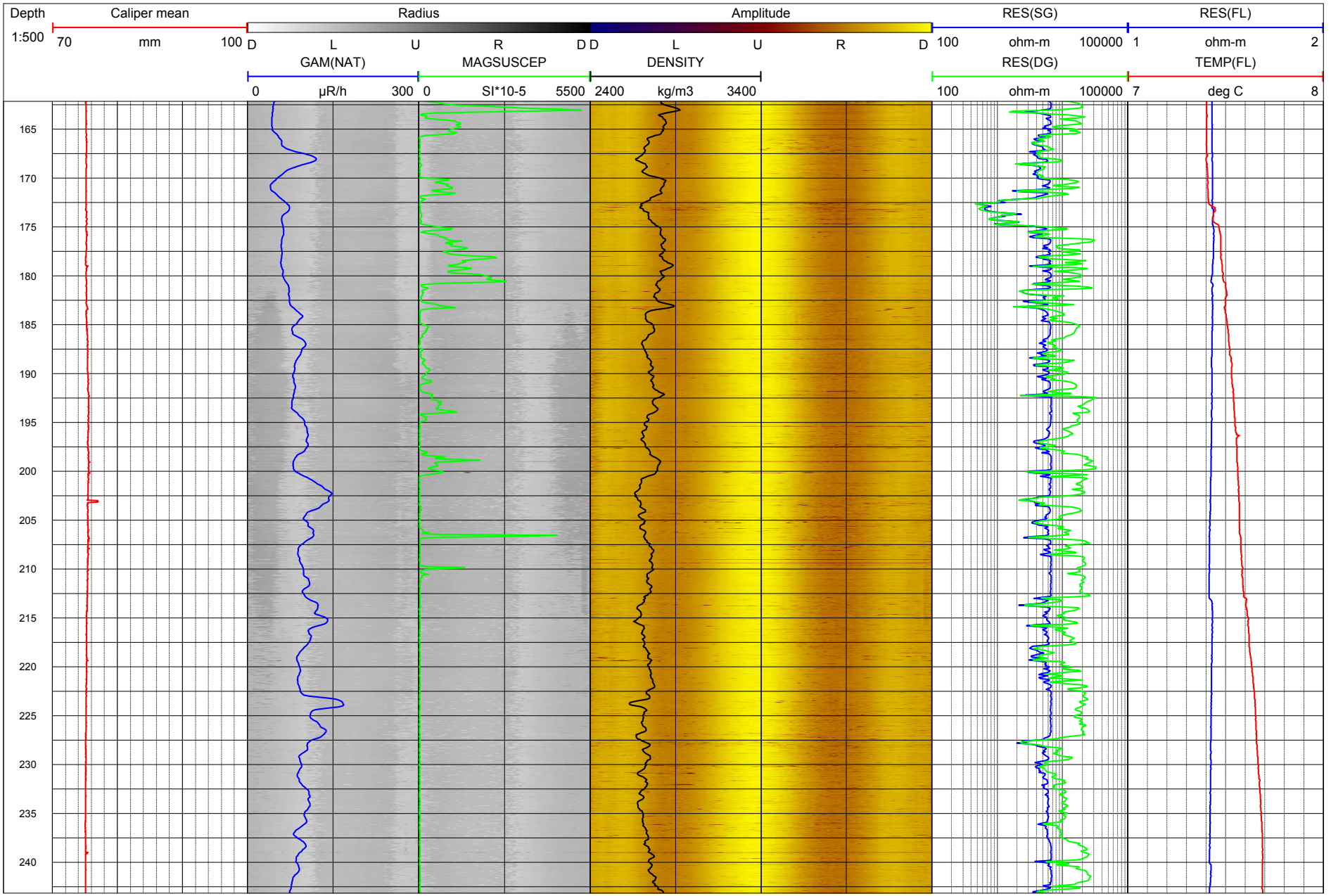
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SI*10-5
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RES(DG)
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ohm-m
100000
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ohm-m
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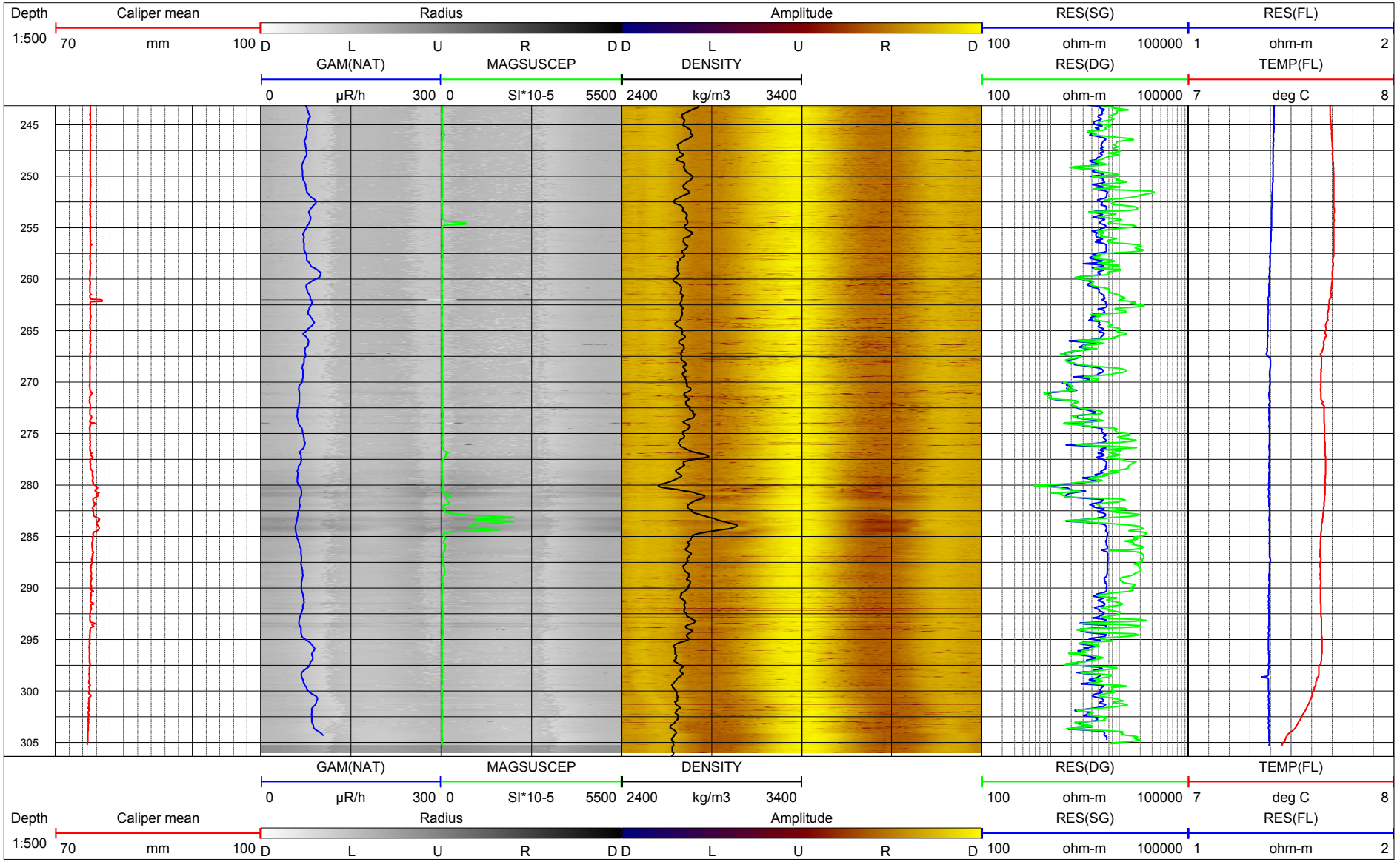
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ohm-m
100000
RES(FL)
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ohm-m
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GAM(NAT)
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µR/h
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MAGSUSCEP
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SI*10-5
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DENSITY
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kg/m3
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RES(DG)
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ohm-m
100000
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deg C
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255
260
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270
275
280
285
290
295
300
305

Borehole No. HFM07

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

Northing: 6697416.25m Easting: 1634715.69m Elevation: 5.78m, RHB70

Diameter:	139.6 mm
Reaming Diameter:	214 mm
Outer Casing:	168 mm
Inner Casing:	160 mm
Casing Length:	18 m
Borehole Length:	122.5 m
Cone:	
Inclination at ground surface:	-84.52°
Azimuth:	342.32°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9139/FDSB	mm
DENSITY		9139/FDSB	kg/m³
RES(SG)	Focused guard log resistivity, 128 cm	9139/FDSB	ohm-m
GAM(NAT)	Natural gamma	9072/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/TCME	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/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	-
THORIUM	Spectral gamma, Thorium component	9080	PPM
URANIUM	Spectral gamma, Uranium component	9080	PPM
POTASSIUM	Spectral gamma, Potassium component	9080	percent

Rev.	Date	Drawn by	Control	Approved
0	2009-11-03	JRI	UTN	UTN

Job: 547310A

Scale: 1:500

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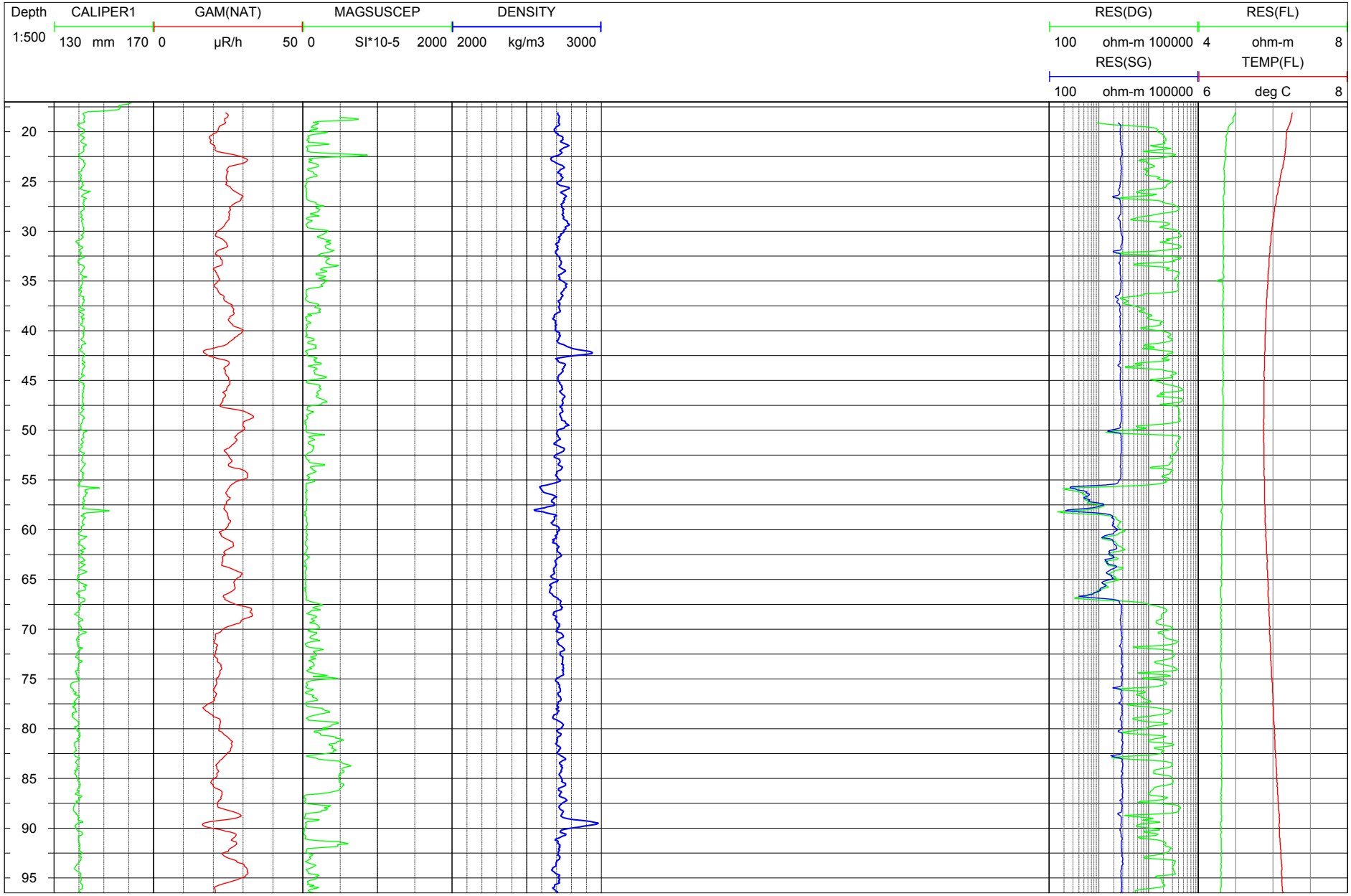
SKB geophysical borehole logging
Borehole HFM07

Presentation

Filename: HFM07_Presentation_Jun_2009.wcl

Drawing no.: **2.1**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GAM(NAT)
0 µR/h 50
MAGSUSCEP
0 SI*10-5 2000
DENSITY
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RES(DG)
100 ohm-m 100000
RES(FL)
4 ohm-m 8
RES(SG)
100 ohm-m 100000
TEMP(FL)
6 deg C 8
20
25
30
35
40
45
50
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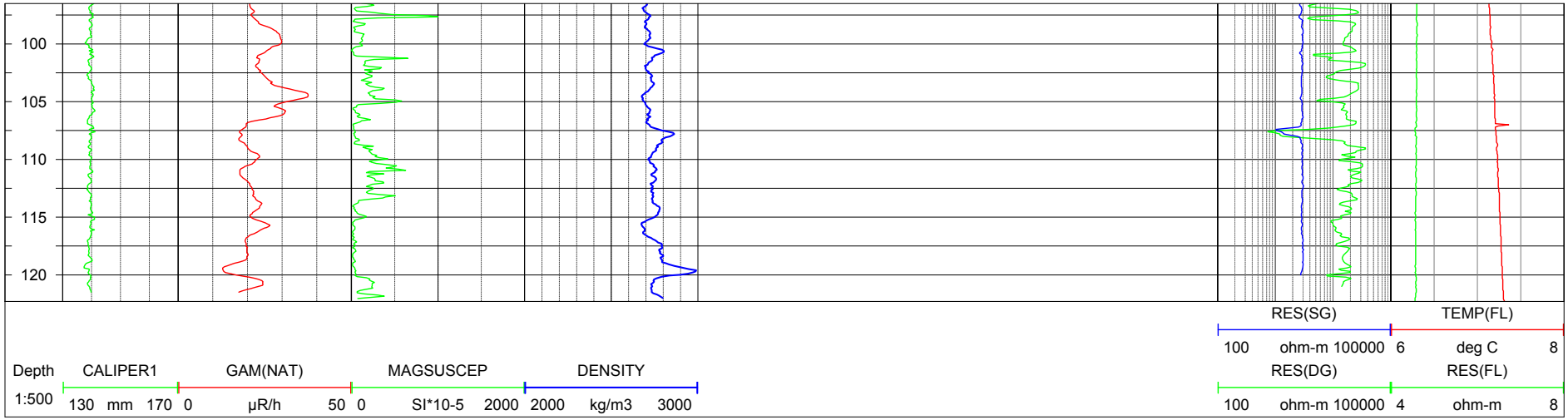
85
90
95


100
105
110
115
120
RES(SG)
TEMP(FL)
100
ohm-m 100000
6
deg C
8
Depth
CALIPER1
GAM(NAT)
MAGSUSCEP
DENSITY
RES(DG)
RES(FL)
1:500
130
mm
170
0
µR/h
50
0
SI*10-5
2000
2000
kg/m3
3000
100
ohm-m 100000
4
ohm-m
8