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Forsmark site investigation

Geophysical borehole logging in borehole KFM01B, HFM14, HFM15, HFM16, HFM17 and HFM18

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Summary

According to a request from Svensk Kärnbränslehantering, geophysical borehole logging has been performed in the boreholes KFM01B, HFM14, HFM15, HFM16, HFM17 and HFM18, all situated in Forsmark, Sweden. The logging in KFM01B was recorded from 0 m to 500 m, HFM14, HFM15, HFM16, HFM17 and HFM18 was recorded from 0 to the bottom of the borehole, between 100 and 200 m.

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

The processing of the data includes removing of spikes, negative data and data in the casing. All data are stretched. In boreholes without depth markers the data are stretched and shifted using one gamma event in the top of the borehole and one in the bottom. In boreholes with depth markers, all data are stretched to each marker.

The logging were delivered to SKB on CDs, the raw data in Century or Robertson format and the processed data in WellCad and Excel format.

Contents

1 Introduction

This document reports the data gained in January and February 2004 in Forsmark. The geophysical borehole logging operations presented here include boreholes KFM01B, HFM14, HFM15, HFM16, HFM17 and HFM18, see Table 1-1 for technical data and Figure 1-1 for location of the boreholes. KFM01B is a cored drilled borehole, whereas HFM14–18 are percussion drilled. All boreholes were recorded from ground level to the bottom of the borehole.

All measurements were conducted by RAMBØLL during the period January 13–17 and February 25–26, 2004 in accordance with the instructions and guidelines from the method description MD 221.002, version 1.0 ("Metodbeskrivning för geofysisk borrhålsloggning") and activity plan AP PF 400-03-89 (SKB internal controlling document).

Table 1-1. Technical data from the cored borehole KFM01B and the percussion boreholes HFM14, HFM15, HFM16, HFM17 and HFM18.

Borehole parameter	KFM01B	HFM14	HFM15	HFM16	HFM17	HFM18
Co-ordinates (RT90)	6699539.4 N 1632387.7 E	6699313.1 N 1631734.6 E	6699312.4 N 1631733.1 E	6699721.1 N 1632466.2 E	6699461.9 N 1633261.3 E	6698326.8 N 1634037.4 E
Elevation (RHB70B)	3.09 m	3.91 m	3.88 m	3.21 m	3.75 m	5.04 m
Azimuth	267.59°	331.75°	314.31°	327.96°	318.58°	313.30°
Inclination at ground surface	–79.04°	–59.81°	–43.7°	–84.22°	–84.19°	–59.36°
Length	500.52 m	150.4 m	99.5 m	132.5 m	210.65 m	180.65 m
Cleaning level	Level 2	Level 2	Level 2	Level 2	Level 1	Level 1
Borehole diameter	76.3 mm	136 mm	139 mm	139 mm	136 mm	138 mm

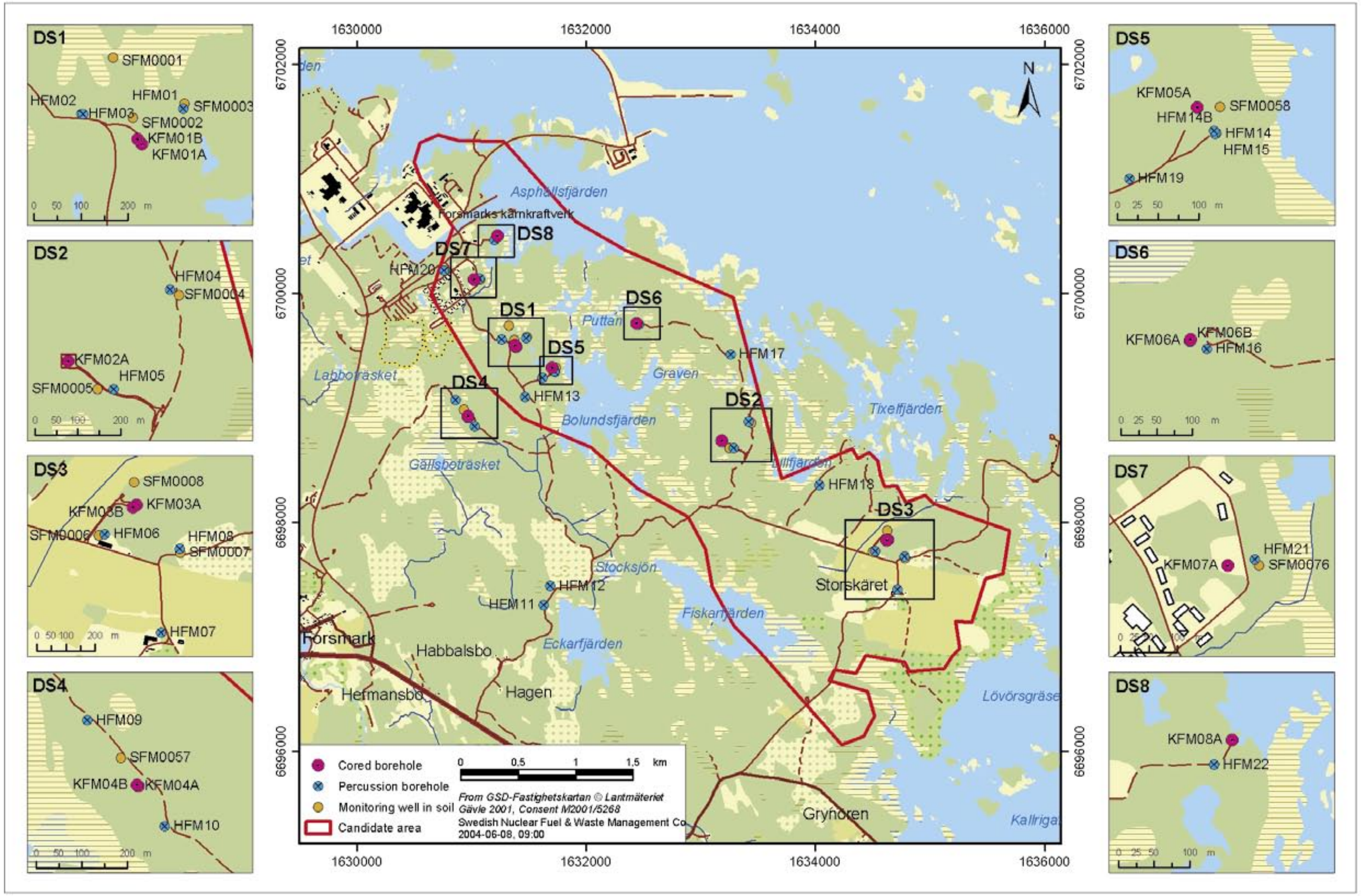

Figure 1-1. *Drill sites at Forsmark. KFM01B is located at drill site 1, HFM14 and HFM15 at drill site 5 and HFM16 at drill site 6. HFM17 (between drill sites 2 and 6) and HFM18 (between drill sites 2 and 3) are drilled on inferred lineaments.*

2 Objective and scope

The objective of the surveys 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. Also the deviation of the borehole is determined.

This field report describes the equipment used as well the measurement procedures. The geophysical logging data are presented in Appendix 1-6.

3 Equipment

The geophysical borehole logging programme in all boreholes was performed with 6 multi tool probes and resulted in a suite of 21 log types, listed in Table 5-1 (see Section 5.1).

The tools and recorded logs are listed in Table 3-1.

Table 3-1. Logging tools and logs recorded in the boreholes.

Tool	Recorded logs	Dimension	Source detector spacing and type	Tool position in borehole
Century 8044 Normal resistivity and Single point resistance	Fluid Conductivity, Fluid Temperature, Normal resistivity (16 and 64 inch), single point resistance and natural gamma.	237·5.3 cm		–
Century 8622 Magnetic susceptibility	Magnetic susceptibility, natural gamma.	203·4.1 cm		–
Century 9030 Gamma density	Gamma density, natural gamma, 140 cm focused guard log resistivity, 10 cm 1-arm calliper.	307·5.6 cm	20.3 cm 125 mCi Cs137	Sidewall Gamma source focused
Century 9072 3 m focused guard	3 m focused guard log resistivity and natural gamma.	310·6.4 cm		–
Century 9310 Sonic	Full wave form travel-time providing P and S-wave velocity picking, compensated P-wave travel-time and natural gamma.	300·6.1 cm	Near 91.4 cm. Far 121.9 cm.	Centralized
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/dip and natural gamma.	246· 4 cm		Centralized

4 Execution

In general the measurement procedures follow the SKB method description MD 221.002, version 1.0 ("Metodbeskrivning för geofysisk borrhålsloggning"). The logging programme was executed in the periods January 13–17 and February 25–26, 2004. All relevant logging events were described in the daily report.

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 according to the SKB method description MD 600.004, version 1.0 ("Metodbeskrivning för rengöring av borrhål-sutrustning och viss markbaserad utrustning") before arriving at the site.

For control, each log run is normally recorded both in downward and in upward direction using the down run as a repeat section. For logging tools 9030 and 9310, a repeat section is made in upward direction. 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.

All data was recorded with maximum10 cm sample interval. The speed of the logging tools was in general 10 m/min, except for the HiRAT Acoustic tool where the speed was 2.4 m/min.

The fluid temperature and resistivity been recorded in all the boreholes both in January, using probe 9042 and in February using probe 8044. Only the results from February have been reported. The natural gamma from probe 9042 has been used to shift the results in borehole HFM14–18.

Due to an instrument error in probe 8044, the normal resistivity 64", lateral resistivity and single point resistance have not been reported. The result shows the right variations but the absolute values are wrong.

5 Results

5.1 Presentation

Table 5-1 lists the logs presented in Appendix 1-6. The logs have not been filtered during logging or presentation.

Table 5-1. Logs presented in Appendix 1 to 6.

Log	Log name short	Unit	Tool
Fluid temperature	TEMP(FL)	deg C	8044, 9042
Fluid resistivity	RES(FL)	ohm-m	8044, 9042
Normal resistivity 16 inch	RES(16N)	ohm-m	8044
Magnetic susceptibility	MAGSUSCEP	SI*10-5	8622
Caliper, 1-arm	CALIPER1	mm	9030
Gamma-gamma density	DENSITY	kg/m3	9030
Focused guard log resistivity, 140 cm	RES(MG)	ohm-m	9030
Natural gamma	GAM(NAT)	µR/h	9030
Focused guard log resistivity, 300 cm	RES(DG)	ohm-m	9072
P-wave velocity	P-VEL	m/s	9310
Full wave form, near receiver	AMP(N)	µs	9310
Full wave form, far receiver	AMP(F)	µs	9310
Caliper, high resolution. 360°	CALIPER 3D	mm	HiRAT
High resolution 1D Caliper	CALIPER MEAN	mm	HiRAT
Borehole azimuth magnetic north	AZIMUTH MN	deg	HiRAT
Borehole Inclination from horizontal	DIP	deg	HiRAT
360° orientated acoustic travel time	TRAVEL TIME	100 ns	HiRAT
360° orientated acoustic travel time	AMPLITUDE	–	HiRAT

5.2 Orientations, alignment and stretch of logs

5.2.1 Orientation of images

The orientation of the results from the HiRAT Acoustic tool, is done after recording. The orientation is done using the raw data from the magnetometers and accelerometers, where spikes and disturbed data are deleted or filtered away.

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. When applicable, overlapping data from the topmost-recorded file is always used (overlapping data are never the mean value from two log runs).

5.2.3 Alignment of data

In order to obtain an exact depth 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 depth scale in WellCAD. All log files are shifted using the new depth scale.

5.2.4 Stretch of logs

There is a minor difference in the used winch between up- and down runs in the depth registration. The size of the defect is about 1.5 m/km. To compensate for this, the logs are stretched using a new depth scale for each tool. The depth scale is established 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 depth scale is added to the log.

5.2.5 Removing of data

The processing of the data includes removing of spikes, negative values and data in the casing. The caliper logs, azimuth and dip have not been removed 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 or 9320. 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.

5.3.1 Calculation of coordinates

To convert the measured azimuth and inclination to grid-coordinates, one needs to take into account the magnetic declination at the site at the time of data acquisition. The actual declination was found by means of the current International Geomagnetic Reference Field (IGRF), see Table 5-3. The actual values can be found below. Disturbances from solar storms etc were not taken into account. By means of the “Radius of Curvature” method implemented in WellCad, the azimuth and inclination were converted to northing, easting and TVD coordinates relative to the top of the borehole (top of casing, TOC). In the same calculation, the magnetic declination was added. Finally, the relative coordinates were added to the given TOC-coordinates (XYZ) in RT90 2.5 gon W and RH70B.

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/cm3] to [kg/m3] units by multiplying with 1000.
Focused guard log resistivity, 140 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	–
Normal resistivity 16 inch	–
Normal resistivity 64 inch	–
Lateral resistivity	–
Single point resistance	–
Focused guard log resistivity, 300 cm	–
P-wave velocity	The P-VEL is calculated using the difference in distance between the far and near receiver divided by the 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 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 acoustical televiewer, the fluid temperature, fluid velocity and the internal travel time in the acoustical televiewer.
Borehole azimuth magnetic north	See 5.3.1
Borehole Inclination from lateral	See 5.3.1
360° orientated acoustic travel time	–
360° orientated acoustic travel time	–

Table 5-3. International Geomagnetic Reference Field (IGRF2000) components.

Location	
Latitude (North)	60 deg 23 min 28 sec
Longitude (East)	18 deg 13 min 20 sec
Elevation	0.00 km
Date of interest	2004-01-15
Magnetic field components	
Declination (east)	4 deg 4 min
Inclination (down)	73 deg 9min

5.4 Borehole KFM01B

In order to obtain an exact depth calibration, the track marks are used. The connection between the track marks and the logs is obtained from the HiRAT Acoustic tool.

To obtain a common depth reference point, the track mark at 52.96 m in the HiRAT file is used as the marker at depth 53.97 m. The HiRAT tool is therefore shifted 1.01 m down. The same correction value is used for the whole boring.

The reference mark made in the borehole, the recorded track marks from the HiRAT and the corrected depth are observed in the following depths, Table 5-4.

CALIPER_1 have not been reported from 420 m to the bottom of the borehole due to unreliably values.

Table 5-4. The reference mark made in the borehole, the recorded track marks form the HiRAT and the corrected depth.

Reference mark	HiRAT recorded	HiRAT after shift
53.97	52.96	53.970
100.00	98.89	99.900
150.08	148.86	149.870
197.17	195.85	196.860
250.29	248.85	249.860
300.45	298.9	299.910
350.57	348.92	349.930

A new depth scale is made using the corrected depth shown in Table 5-4. The new depth 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 Table 5-5, between all log runs, the obtained reference mark correlation is transferred to the other logs.

Table 5-5. Gamma events in borehole KFM01B.

Events	Depths (m)
Top event	16,54
Mid event	247,85
Bottom event	485,5

The complete log suite for borehole KFM01B is presented as composite log sheets in Appendix 1 (Drawing no 1.1). The logs presented are listed in Table 5-1.

5.5 Borehole HFM14

Using the natural gamma from the probe 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 the events shown in Table 5-6.

Table 5-6. Gamma events in borehole HFM14.

Events	Depths (m)
Top event	22,4
Bottom event	139.4

The complete log suite for borehole KFM14 is presented as composite log sheet in Appendix 2 (Drawing no 2.1). The logs presented are listed in Table 5-1.

5.6 Borehole HFM15

Using the natural gamma from the probe 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 the events shown in Table 5-7.

Table 5-7. Gamma events in borehole HFM15.

Events	Depths (m)
Top event	21,3
Bottom event	83

The complete log suite for borehole HFM15 is presented as composite log sheet in Appendix 3 (Drawing no 3.1). The logs presented are listed in Table 5-1.

5.7 Borehole HFM16

Using the natural gamma from the probe 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 the events shown in Table 5-8.

Table 5-8. Gamma events in borehole HFM16.

Events	Depths (m)
Top event	18,1
Bottom event	87,5

The complete log suite for borehole HFM16 is presented as composite log sheet in Appendix 4 (Drawing no 4.1). The logs presented are listed in Table 5-1.

5.8 Borehole HFM17

Using the natural gamma from the probe 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 the events shown in Table 5-9.

Table 5-9. Gamma events in borehole HFM17.

Events	Depths (m)
Top event	6,0
Bottom event	187,0

The complete log suite for borehole HFM17 is presented as composite log sheet in Appendix 5 (Drawing no 5.1). The logs presented are listed in Table 5-1.

5.9 Borehole HFM18

Using the natural gamma from the probe 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 the events shown in Table 5-10.

Table 5-10. Gamma events in borehole HFM18.

Events	Depths (m)
Top event	19,6
Bottom event	172,27

The complete log suite for borehole HFM18 is presented as composite log sheet in Appendix 6 (Drawing no 6.1). The logs presented are listed in Table 5-1.

6 Data delivery

Apart from the present report, a comprehensive field report was delivered to SKB /1/. The field report comprises logging reports, processing logs, logging reference point descriptions and cleaning and probe sensor descriptions. The calibration values from the probes 8622, 9030 and 9072 are also included (probe 9320 and HiRAT shall not be calibrated).

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

The processed files were delivered in both WellCAD, Table 6-2, and as excel files in SICADA format, Table 6-3. The different excel sheets (one for each log) in SICADA format are listed in Table 6-4.

The Sicada reference to the data from the logging operations is field note Forsmark 304.

Table 6-1. Recorded log files in Century or Robertson format.

Borehole	Probe	Log direction	WellCAD File
KFM01B	8044	Down	KFM01B_02-25-04_09-07_8044C_.01_0.27_494.17_ORIG.WCL
KFM01B	8622	Up	KFM01B_02-26-04_09-03_8622C_.04_0.52_498.83_ORIG.WCL
KFM01B	9030	Up	KFM01B_02-25-04_18-10_9030CA_.04_0.88_499.27_ORIG.WCL
KFM01B	9072	Up	KFM01B_02-25-04_11-24_9072C_.04_0.92_499.43_ORIG.WCL
KFM01B	9310	Up	KFM01B_02-26-04_10-22_9310C2_.02_1.19_497.48_ORIG.WCL
KFM01B	HiRAT	Up	KFM01B_HiRAT_180pixels_up_run3.WCL
HFM14	8044	Down	HFM14_02-26-04_12-04_8044C_.04_1.04_148.31_ORIG.WCL
HFM14	8622	Up	HFM14_01-15-04_09-49_8622C_.02_1.13_148.99_ORIG.WCL
HFM14	9030	Up	HFM14_01-15-04_11-39_9030CA_.02_1.55_149.17_ORIG.WCL
HFM14	9072	Up	HFM14_01-15-04_10-13_9072C_.02_1.43_149.29_ORIG.WCL
HFM14	9310	Up	HFM14_01-15-04_12-07_9310C2_.02_1.31_148.55_ORIG.WCL
HFM14	HiRAT	Up	HFM14_HiRAT_180pixels_up_run2.WCL
HFM15	8044	Down	HFM15_02-26-04_12-41_8044C_.04_0.56_97.40_ORIG.log.WCL
HFM15	8622	Up	HFM15_01-15-04_09-24_8622C_.02_0.66_97.93_ORIG.WCL
HFM15	9030	Down	HFM15_01-15-04_11-07_9030CA_.02_1.09_98.09_ORIG.WCL
HFM15	9072	Up	HFM15_01-15-04_10-39_9072C_.02_0.88_97.79_ORIG.WCL
HFM15	9310	Up	HFM15_01-15-04_12-33_9310C2_.02_0.90_96.77_ORIG.WCL
HFM15	HiRAT	Up	HFM15_HiRAT_180pixels_up_run2.WCL
HFM16	8044	Down	HFM16_02-26-04_13-46_8044C_.04_0.28_130.95_ORIG.log.WCL
HFM16	8622	Up	HFM16_01-17-04_18-44_8622C_.02_0.58_130.17_ORIG.log.WCL
HFM16	9030	Up	HFM16_01-17-04_20-30_9030CA_.02_0.94_130.11_ORIG.log.WCL
HFM16	9072	Up	HFM16_01-17-04_19-12_9072C_.02_0.70_130.23_ORIG.log.WCL
HFM16	9310	Up	HFM16_01-17-04_19-46_9310C2_.02_0.36_128.71_ORIG.log.WCL
HFM16	HiRAT	Up	HFM16_HiRAT_180pixels_up_run1.HED.WCL
HFM17	8044	Down	HFM17_02-26-04_14-31_8044C_.04_0.60_208.48_ORIG.log.WCL
HFM17	8622	Up	HFM17_01-14-04_09-01_8622C_.02_0.72_212.89_ORIG.log.WCL
HFM17	9030	Up	HFM17_01-14-04_10-04_9030CA_.02_1.25_209.33_ORIG.log.WCL
HFM17	9072	Up	HFM17_01-14-04_11-26_9072C_.02_1.15_209.13_ORIG.log.WCL
HFM17	9310	Up	HFM17_01-14-04_10-44_9310C2_.02_0.84_208.17_ORIG.log.WCL
HFM17	HiRAT	Up	HFM17_HiRAT_180pixels_up_run2.HED.WCL
HFM18	8044	Down	HFM18_02-26-04_15-34_8044C_.04_1.28_179.75_ORIG.WCL
HFM18	8622	Up	HFM18_01-16-04_08-53_8622C_.02_0.58_179.66_ORIG.log.WCL
HFM18	9030	Up	HFM18_01-16-04_10-12_9030CA_.02_1.07_179.98_ORIG.log.WCL
HFM18	9072	Up	HFM18_01-16-04_09-21_9072C_.02_1.09_180.53_ORIG.log.WCL
HFM18	9310	Up	HFM18_01-16-04_10-42_9310C2_.02_62.76_182.50_ORIG.log.WCL
HFM18	9310	Up	HFM18_01-17-04_15-18_9310C2_.02_1.13_56.66_ORIG.log.WCL
HFM18	HiRAT	Up	

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KFM01B	1.1	KFM01B_Presentation.WCL
KFM01B	1.2	KFM01B_Deviation.WCL
KFM01B	1.3	KFM01B_Deviation.WCL
HFM14	2.1	HFM14_Presentation.WCL
HFM14	2.2	HFM14_Deviation.WCL
HFM14	2.3	HFM14_Deviation.WCL
HFM15	3.1	HFM15_Presentation.WCL
HFM15	3.2	HFM15_Deviation.WCL
HFM15	3.3	HFM15_Deviation.WCL
HFM16	4.1	HFM16_Presentation.WCL
HFM16	4.2	HFM16_Deviation.WCL
HFM16	4.3	HFM16_Deviation.WCL
HFM17	5.1	HFM17 _Presentation.WCL
HFM17	5.2	HFM17 _Deviation.WCL
HFM17	5.3	HFM17 _Deviation.WCL
HFM18	6.1	HFM18 _Presentation.WCL
HFM18	6.2	HFM18 _Deviation.WCL
HFM18	6.3	HFM18 _Deviation.WCL

Table 6-3. Data files in excel, in SICADA format.

Borehole	Excel file
KFM01B	KFM01B _data.xls
HFM14	HFM14 _data.xls
HFM15	HFM15_data.xls
HFM16	HFM16 _data.xls
HFM17	HFM17_data.xls
HFM18	HFM18_data.xls

Table 6-4. Sheets included in the excel files, in SICADA format.

Sheet	Other
Acoustic televiewer	See description of "total magnetic field" and "magnetic inclination" below
Focused resistivity 140 cm	
Focused resistivity 300 cm	
Fullwave sonic	column: v_velocity (shear wave), not interpreted from the recorded data
Caliper1	
Caliper Mean	Calculated using Fluid resistivity and Acoustic televiewer
Fluid resistivity	
Fluid Temperature	
Density	
Resistivity	
Natural gamma	
Single point resistivity	
Magnetic susceptibility	

Calculation of the total magnetic field

The data delivered in the "tot magn field" column, in the "Acoustic televiewer" sheet, was calculated as the square root of the sum of the 3 components, from the magnetometer in the HiRAT probe, squared.

Calculation of the magnetic inclination

The data delivered in the "magn_inclination" column, in the "Acoustic televiewer" sheet, was found by calculating the angle between the z component and the summarized vector of the x and y components from the magnetometer in the HiRAT probe.

The calculation do not include the inclination of the borehole, all boreholes are in the calculation defined to be vertical.

References

/1/ **Nielsen, U T, Ringgaard J, 2004.** Geophysical borehole logging in borehole KFM01B, HFM14, HFM15, HFM16, HFM17 and HFM18. Rambøll Report 20040330utnaa.

Appendix 1

Geophysical borehole logging, borehole KFM01B

Borehole No. KFM01B

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

Northing: 6699539.40m Easting: 1632387.67m Elevation: 3.09m, RHB70

Diameter:	76.3mm
Reaming Diameter:	101mm and 150mm
Outer Casing:	90mm
Inner Casing:	78mm
Borehole Length:	500.52m
Cone:	
Inclination at ground surface:	-79.04°
Azimuth:	267.59°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	µR/h
TEMP(FL)	Fluid temperature	8044	deg C
RES(FL)	Fluid resistivity	8044	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	8044	ohm-m
RES(64N)	Normal resistivity 64 inch	8044	ohm-m
LATERAL	Lateral resistivity	8044	ohm-m
SPR	Single point resistivity	8044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2004-03-25	JRI	FDH	UTN

Job	Scale
360210A	1:500

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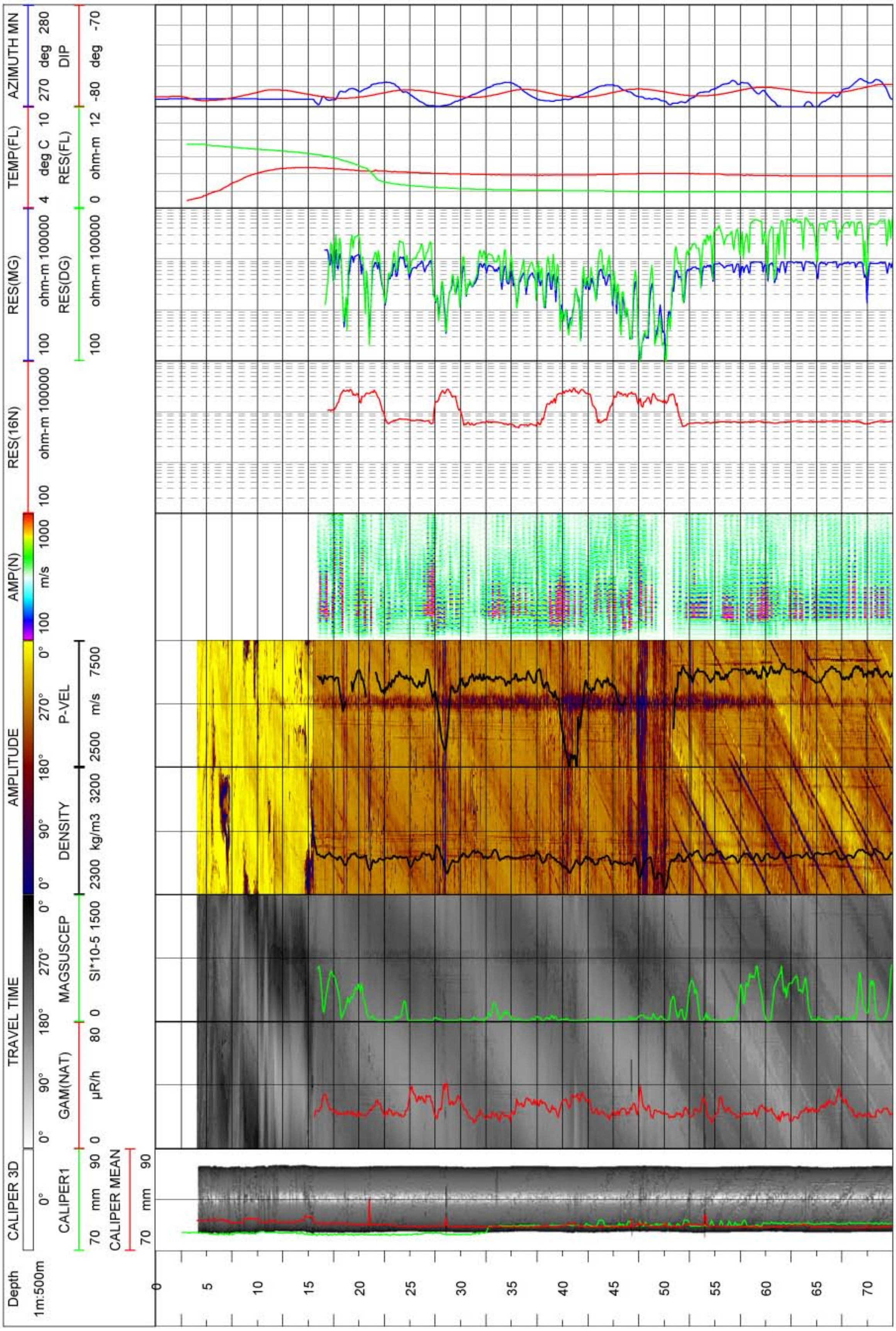
SKB geophysical borehole logging
Borehole KFM01B. Forsmark

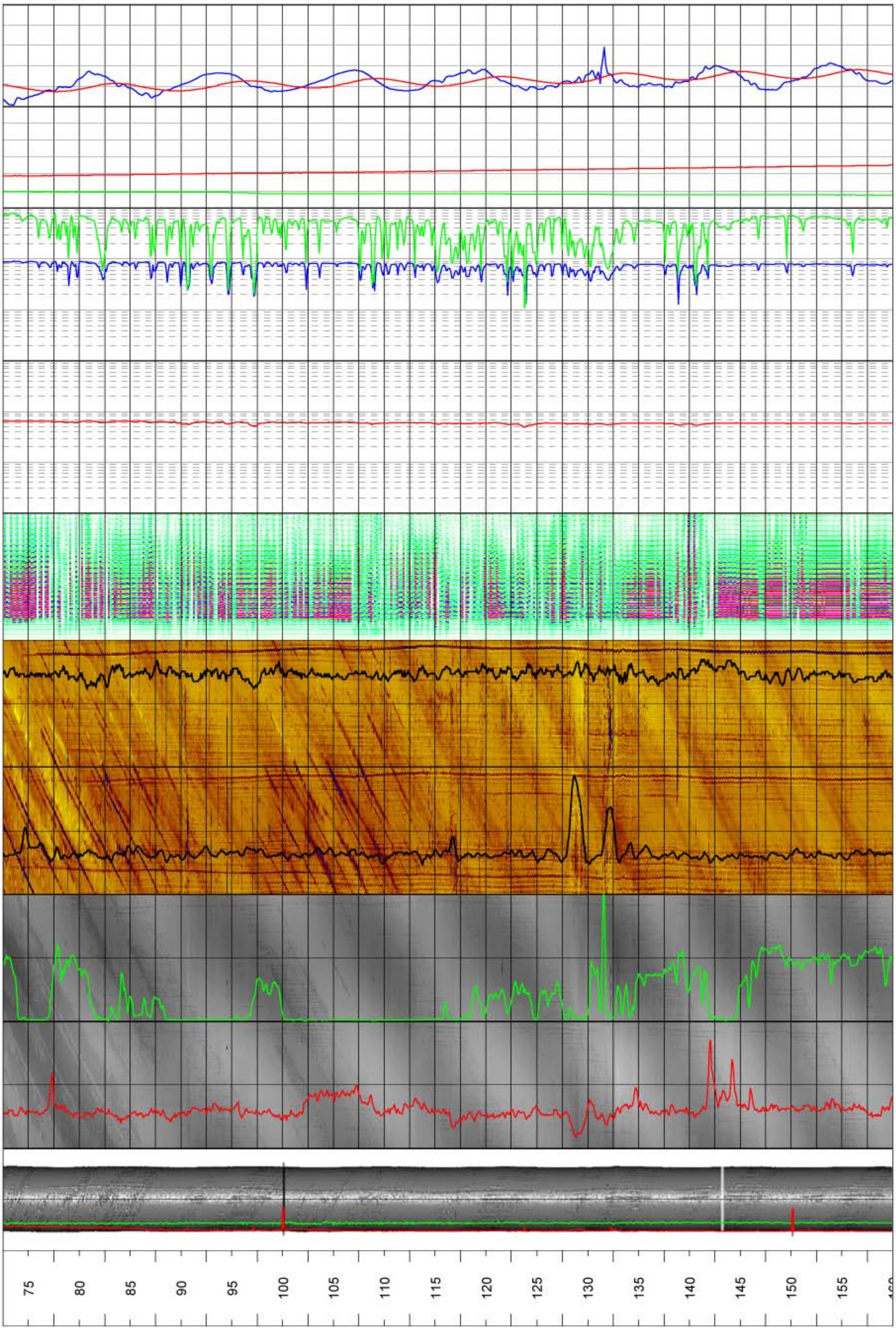
Presentation

Filename:
KFM01B_Presentation.wcl

Drawing no.:
1.1



Depth
1m:500m
CALIPER 3D
CALIPER1
70 mm 90
CALIPER MEAN
70 mm 90
TRAVEL TIME
GAM(NAT)
0 μR/h 80
MAGSUSCEP
0 SI*10-5 1500
AMPLITUDE
DENSITY
2300 kg/m3 3200
P-VEL
2500 m/s 7500
AMP(N)
100 m/s 1000
RES(16N)
100 ohm-m 100000
RES(MG)
100 ohm-m 100000
RES(DG)
100 ohm-m 100000
TEMP(FL)
4 deg C 10
RES(FL)
0 ohm-m 12
AZIMUTH MN
270 deg 280
DIP
-80 deg -70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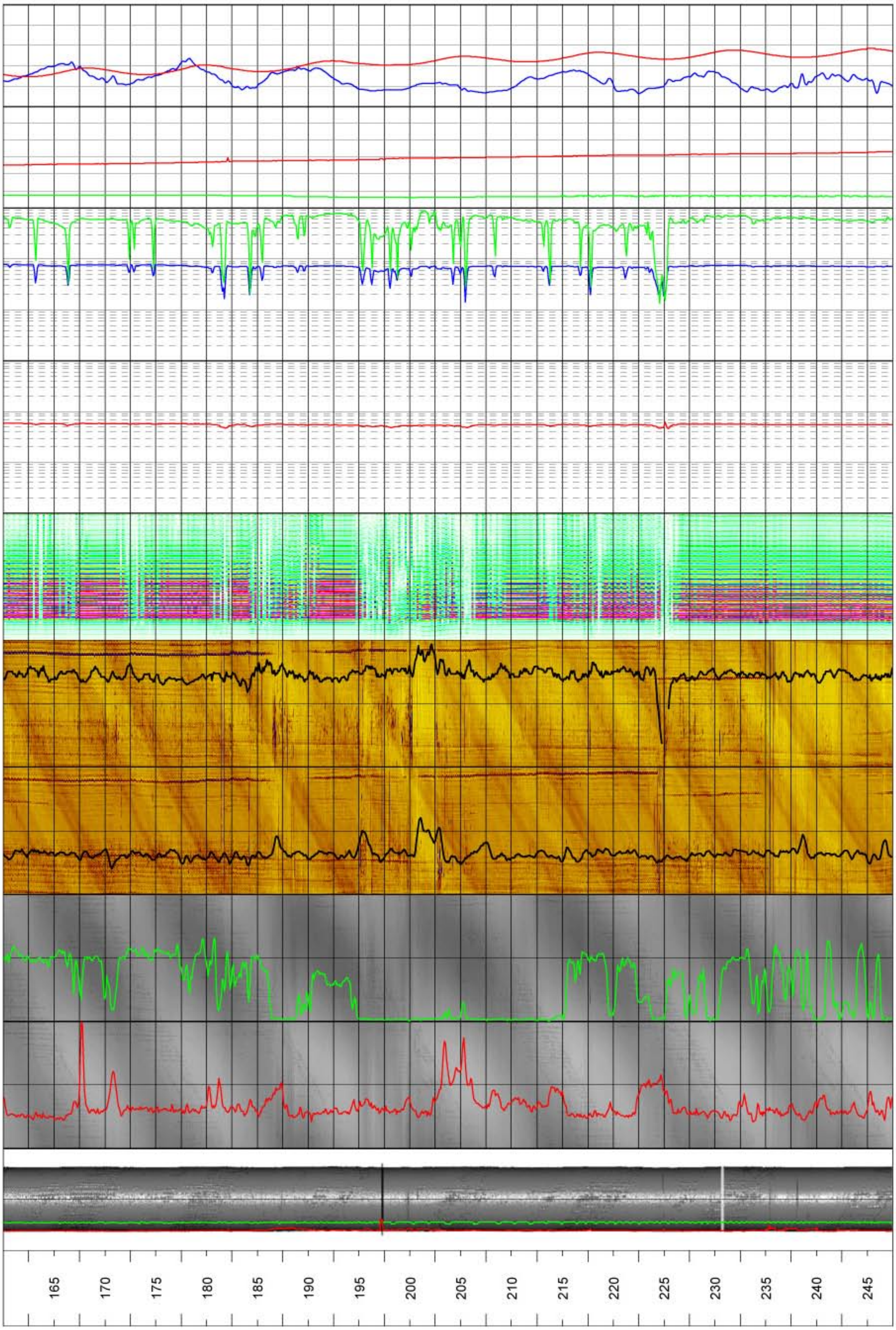
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175
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190
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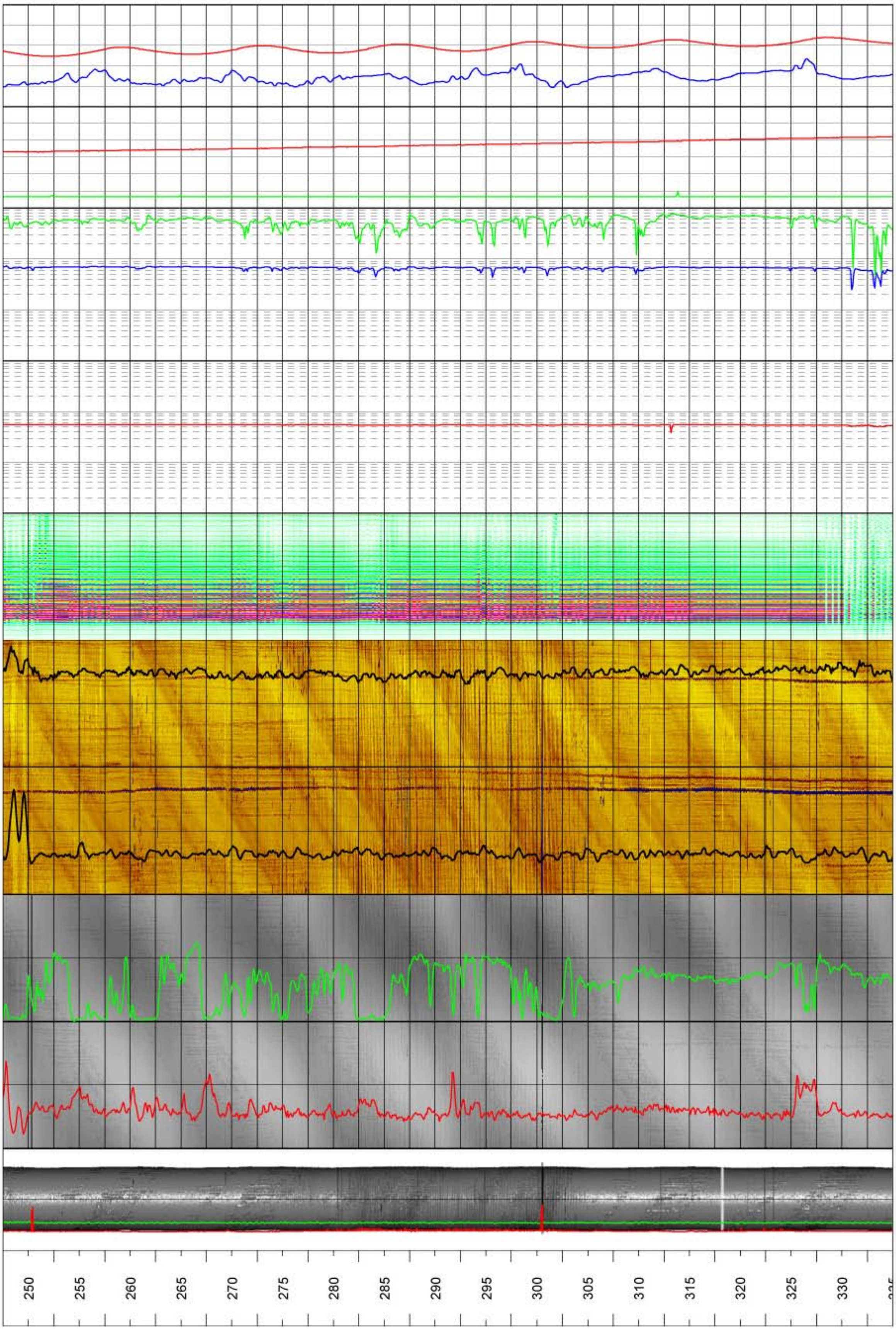
200
205
210
215
220
225
230
235
240
245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300
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310
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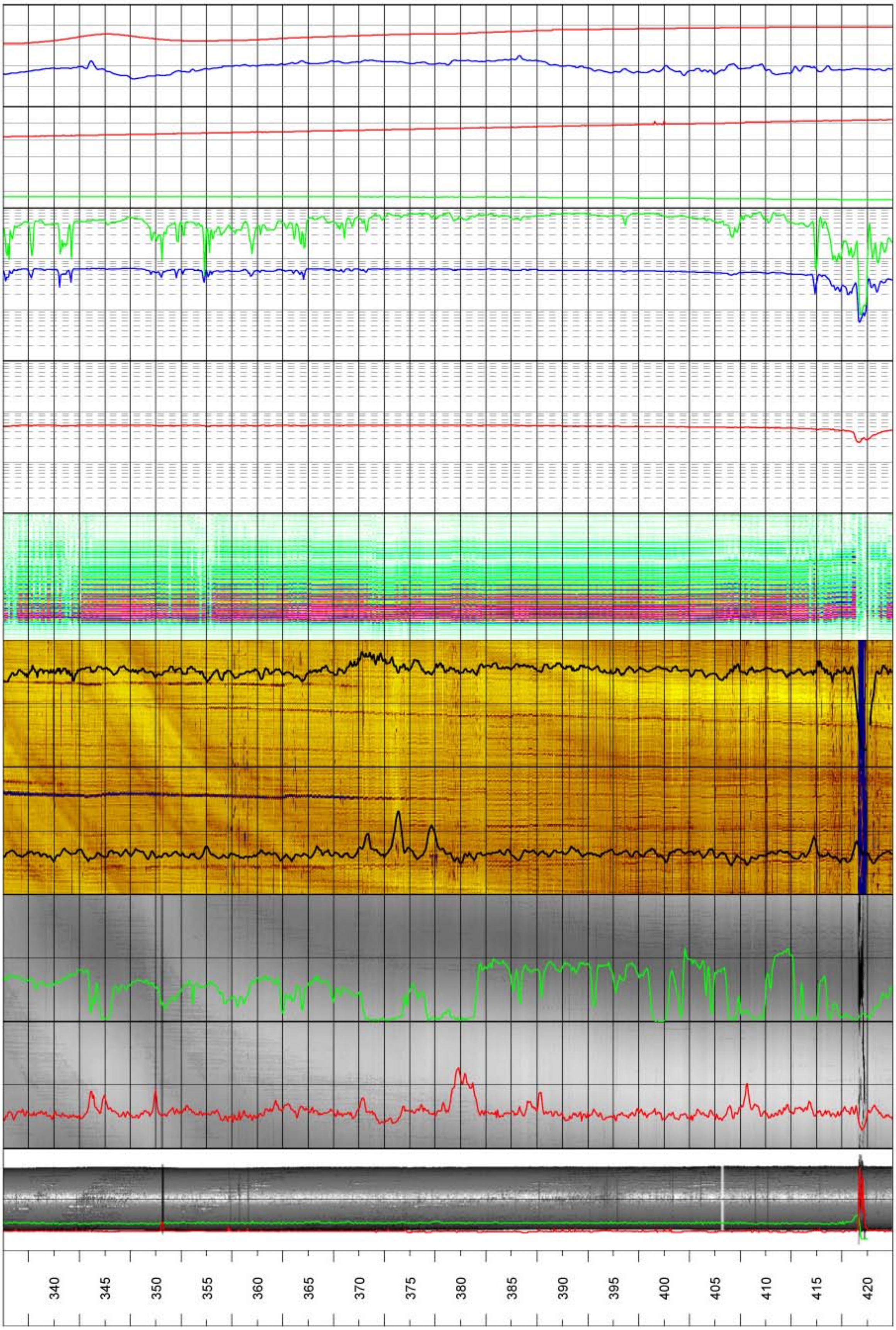
325
330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360
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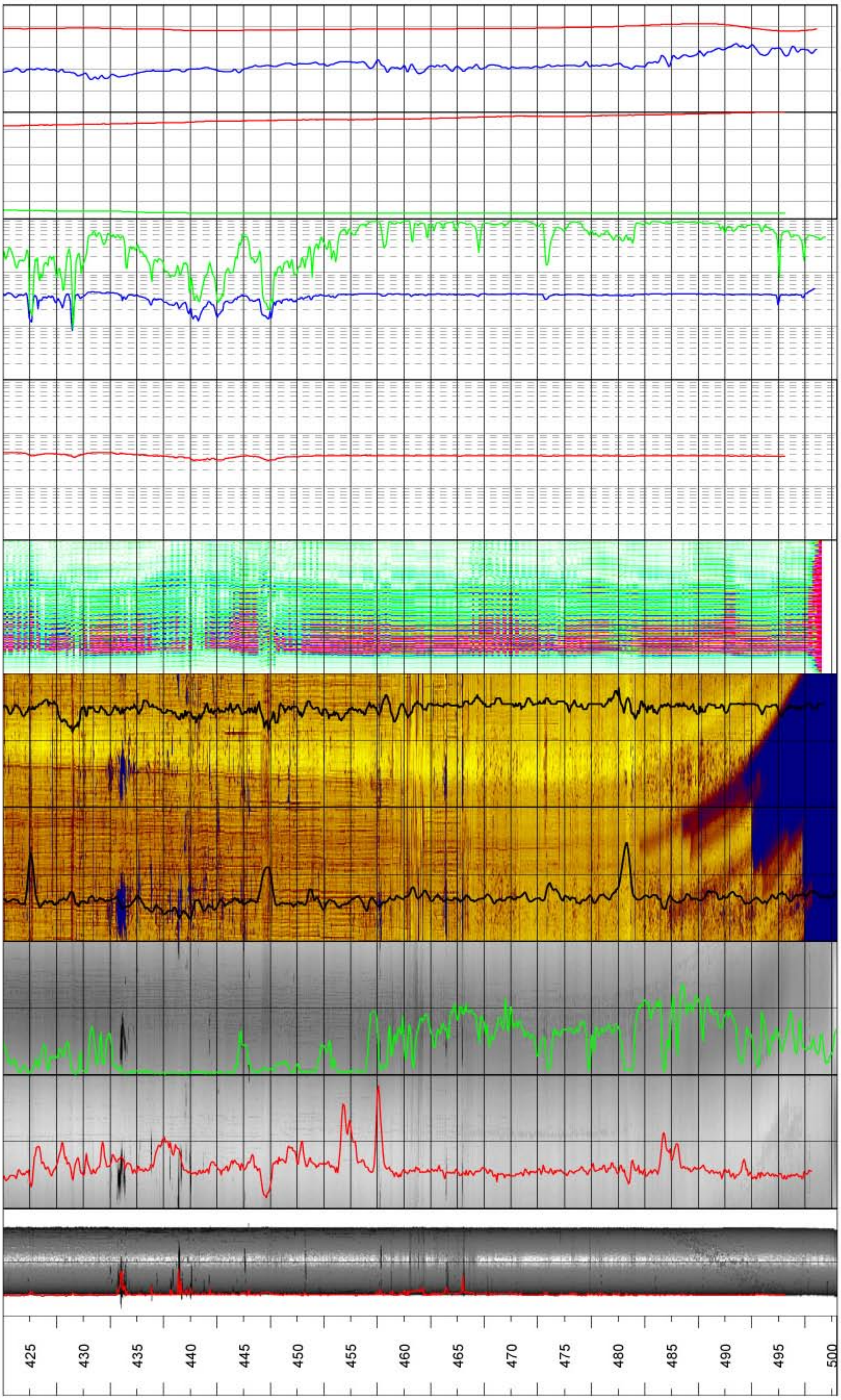
375
380
385
390
395
400
405
410
415
420


425
430
435
440
445
450
455
460
465
470
475
480
485
490
495
500

Appendix 2

Geophysical borehole logging, borehole HFM14

Borehole No. HFM14

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

Northing: 6699313.14m Easting: 1631734.59m Elevation: 3.91m, RHB70

Diameter:	136mm
Reaming Diameter:	
Outer Casing:	168mm
Inner Casing:	160mm
Borehole Length:	150.4m
Cone:	
Inclination at ground surface:	-59.81m
Azimuth:	331.75°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	μR/h
TEMP(FL)	Fluid temperature	9042/9044	deg C
RES(FL)	Fluid resistivity	9042/9044	ohm-m
RES(DG)	Focused guard log resistivity, 300cm	9072	ohm-m
P-VEL	P-wave velocity	9320	m/s
AMP(N)	Full wave form, near receiver	9320	μs
AMP(F)	Full wave form, far receiver	9320	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	9044	ohm-m
RES(64N)	Normal resistivity 64 inch	9044	ohm-m
LATERAL	Lateral resistivity	9044	ohm-m
SPR	Single point resistivity	9044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2004-03-25	JRI	FDH	UTN

Job	Scale
360210A	1:500

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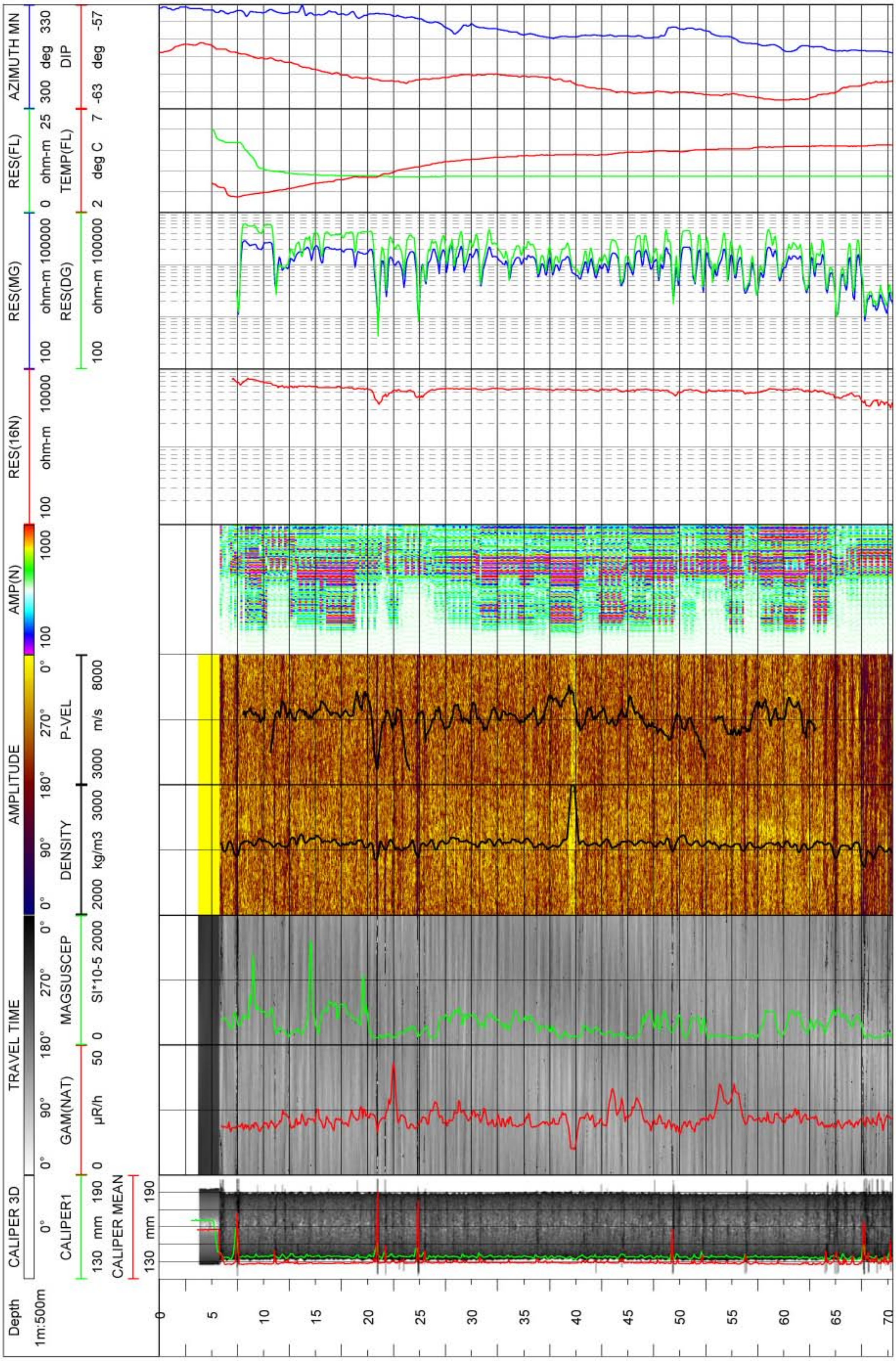
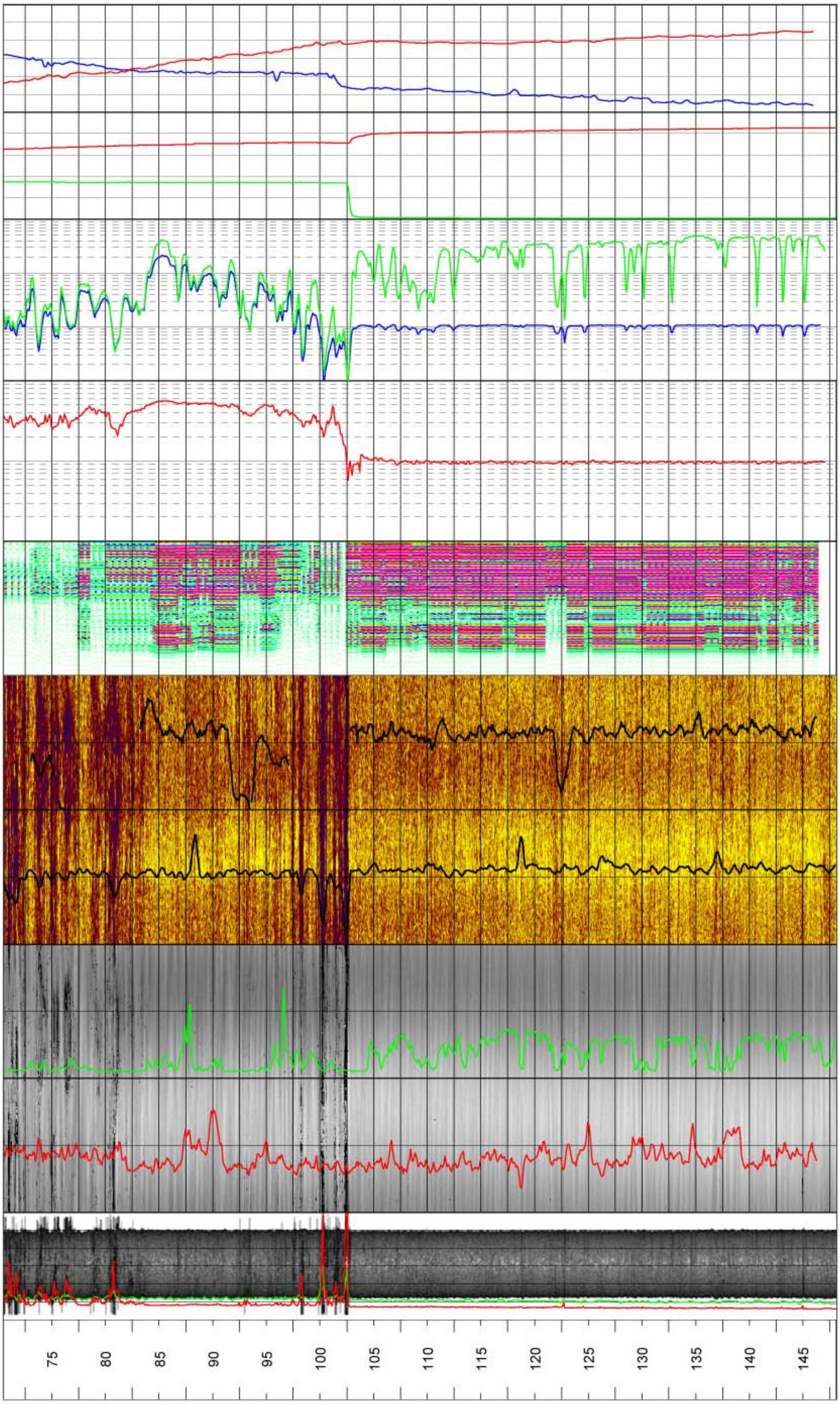
SKB geophysical borehole logging
Borehole HFM14. Forsmark

Presentation

Filename: HFM14_Presentation.wcl

Drawing no.: **2.1**


Depth
1m:500m
CALIPER 3D
CALIPER1 130 mm 190
CALIPER MEAN 130 mm 190
TRAVEL TIME
GAM(NAT) 0 µR/h 50
MAGSUSCEP 0 SI*10-5 2000
AMPLITUDE
DENSITY 2000 kg/m3 3000
P-VEL 3000 m/s 8000
AMP(N) 100 1000
RES(16N) 100 ohm-m 10000
RES(MG) 100 ohm-m 100000
RES(DG) 100 ohm-m 100000
RES(FL) 0 ohm-m 25
TEMP(FL) 2 deg C 7
AZIMUTH MN 300 deg 330
DIP -63 deg -57


75
80
85
90
95
100
105
110
115
120
125
130
135
140
145

Geophysical borehole logging, borehole HFM15

Borehole No. HFM15

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

Northing: 6699312.44m Easting: 1631733.08m Elevation: 3.88m, RHB70

Diameter:	139mm
Reaming Diameter:	
Outer Casing:	168mm
Inner Casing:	160mm
Borehole Length:	99.5m
Cone:	
Inclination at ground surface:	-43.7°
Azimuth:	314.31°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	μR/h
TEMP(FL)	Fluid temperature	8044	deg C
RES(FL)	Fluid resistivity	8044	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	8044	ohm-m
RES(64N)	Normal resistivity 64 inch	8044	ohm-m
LATERAL	Lateral resistivity	8044	ohm-m
SPR	Single point resistivity	8044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2003-03-25	JRI	FDH	UTN

Job	Scale
360210A	1:500

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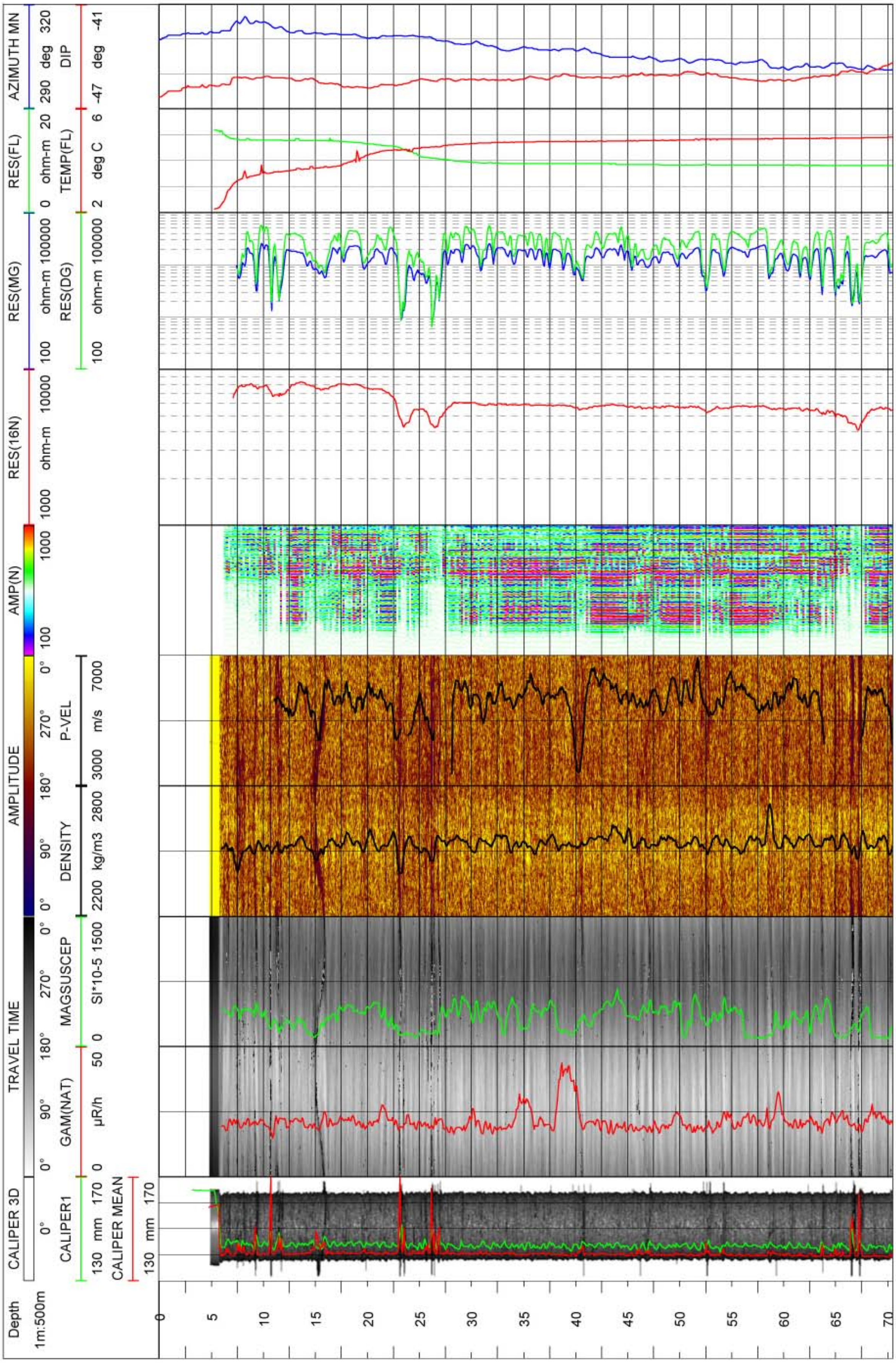
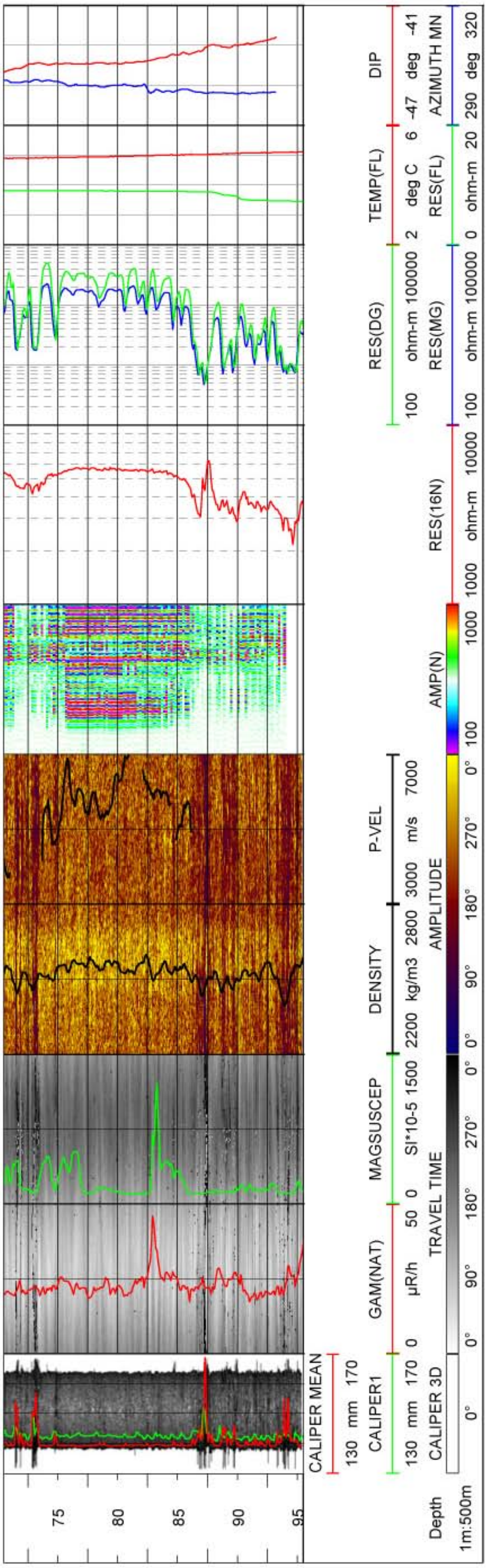
SKB geophysical borehole logging
Borehole HFM15. Forsmark

Presentation

Filename:
HFM15_Presentation.wcl

Drawing no.:
3.1


Depth
1m:500m
CALIPER 3D
CALIPER1
130 mm 170
CALIPER MEAN
130 mm 170
TRAVEL TIME
GAM(NAT)
0 µR/h 50
MAGSUSCEP
0 SI*10-5 1500
AMPLITUDE
DENSITY
2200 kg/m3 2800
P-VEL
3000 m/s 7000
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(MG)
100 ohm-m 100000
RES(DG)
100 ohm-m 100000
RES(FL)
0 ohm-m 20
TEMP(FL)
2 deg C 6
AZIMUTH MN
290 deg 320
DIP
-47 deg -41



Depth
1m:500m
75
80
85
90
95
CALIPER MEAN
130 mm 170
CALIPER1
130 mm 170
CALIPER 3D
0°
GAM(NAT)
0 µR/h 50
TRAVEL TIME
0° 90° 180° 270° 0°
MAGSUSCEP
0 SI*10-5 1500
DENSITY
2200 kg/m3 2800
AMPLITUDE
0° 90° 180° 270° 0°
P-VEL
3000 m/s 7000
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(DG)
100 ohm-m 100000
RES(MG)
100 ohm-m 100000
TEMP(FL)
2 deg C 6
RES(FL)
0 ohm-m 20
DIP
-47 deg -41
AZIMUTH MN
290 deg 320

Geophysical borehole logging, borehole HFM16

Borehole No. HFM16

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

Northing: 6699721.10m Easting: 1632466.18m Elevation: 3.21m, RHB70

Diameter:	139mm
Reaming Diameter:	
Outer Casing:	168mm
Inner Casing:	160mm
Borehole Length:	132.50m
Cone:	
Inclination at ground surface:	-84.22°
Azimuth:	327.96°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	μR/h
TEMP(FL)	Fluid temperature	8044	deg C
RES(FL)	Fluid resistivity	8044	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	8044	ohm-m
RES(64N)	Normal resistivity 64 inch	8044	ohm-m
LATERAL	Lateral resistivity	8044	ohm-m
SPR	Single point resistivity	8044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2004-03-25	FDH	JRI	UTN

Job	Scale
360210A	1:500

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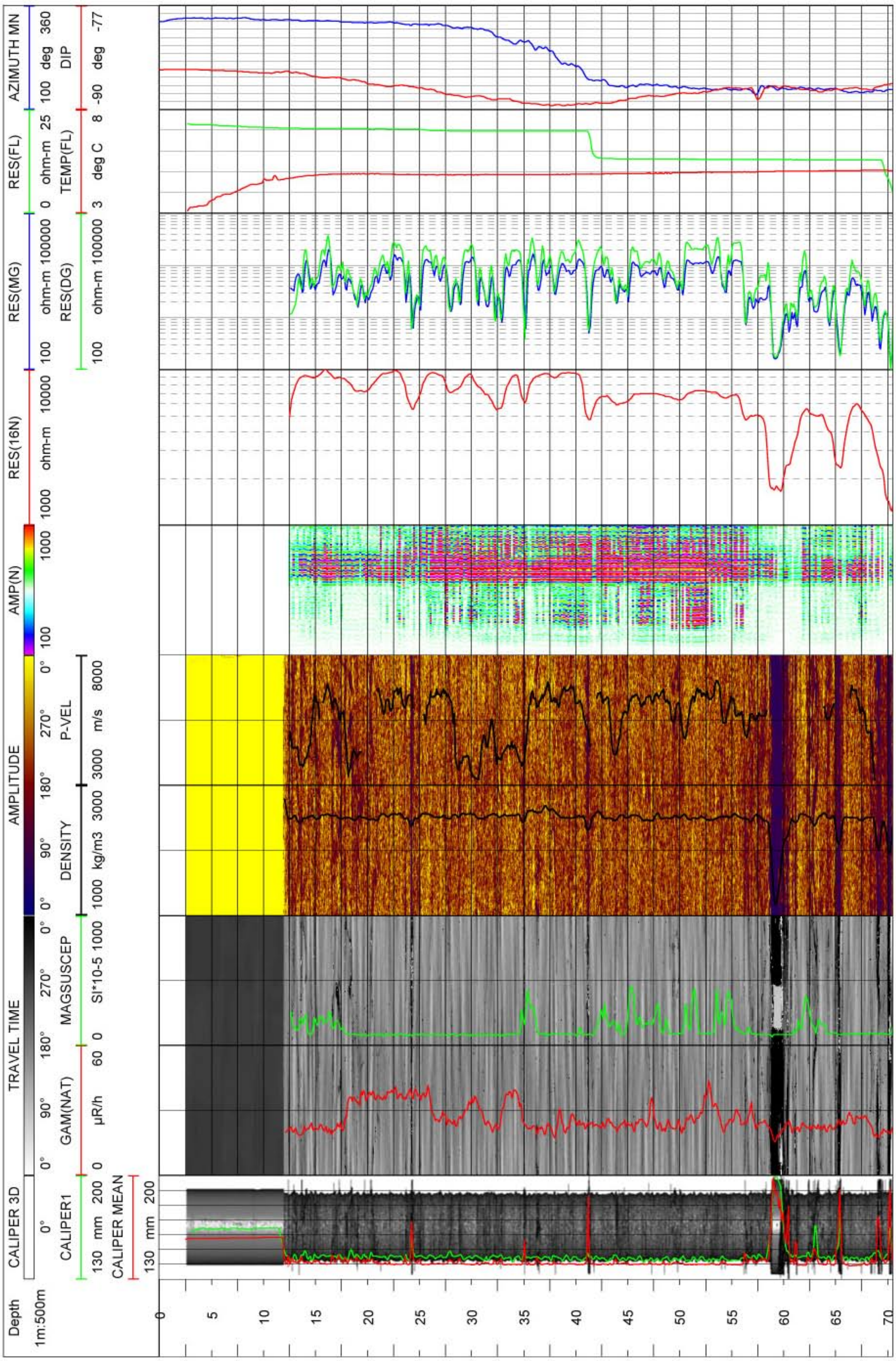
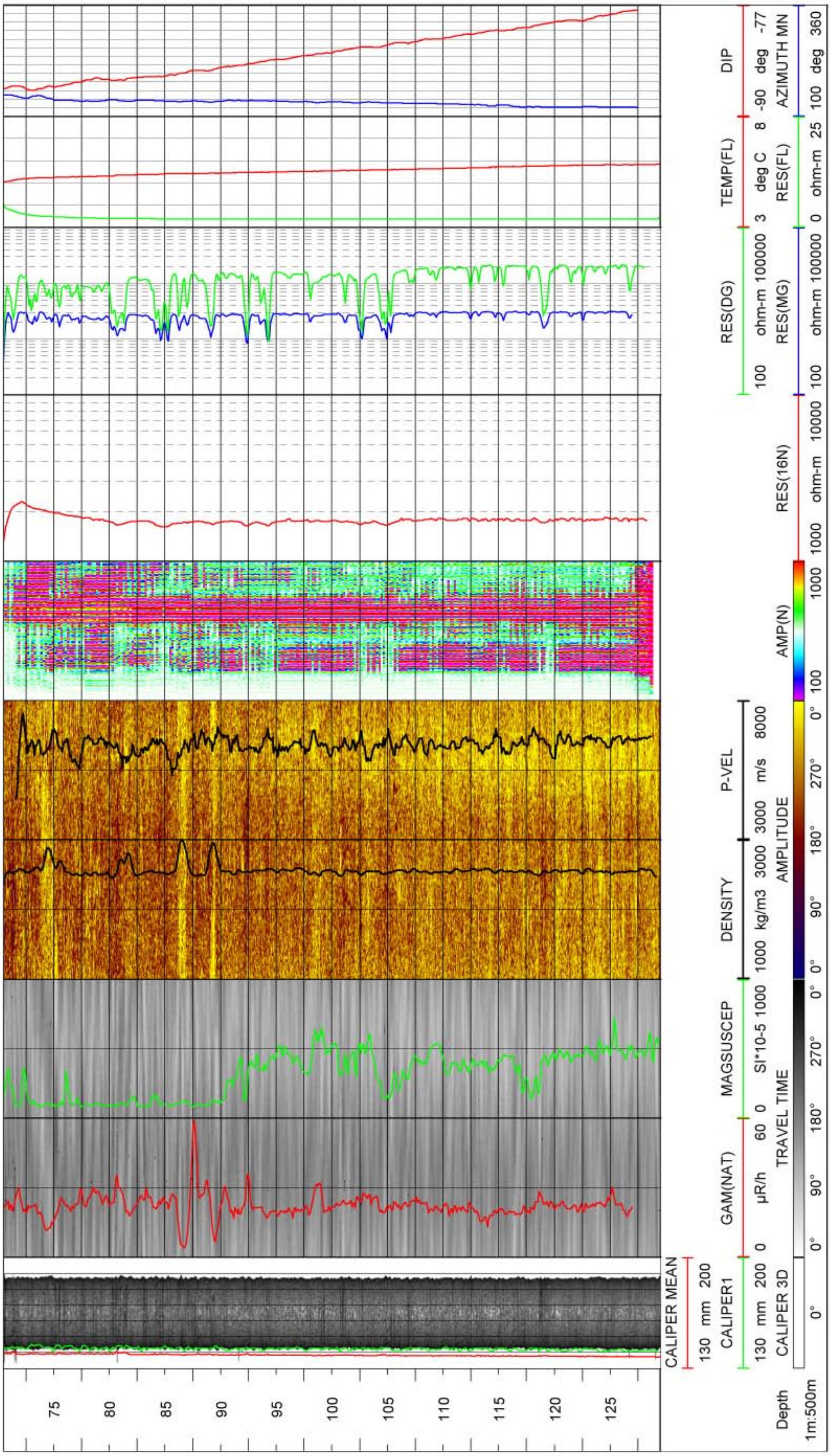
SKB geophysical borehole logging
Borehole HFM16. Forsmark

Presentation

Filename: HFM16_Presentation.wcl

Drawing no.: **4.1**


Depth
1m:500m
CALIPER 3D
CALIPER1
130 mm 200
CALIPER MEAN
130 mm 200
TRAVEL TIME
GAM(NAT)
0 µR/h 60
MAGSUSCEP
0 SI*10-5 1000
AMPLITUDE
DENSITY
1000 kg/m3 3000
P-VEL
3000 m/s 8000
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(MG)
100 ohm-m 100000
RES(DG)
100 ohm-m 100000
RES(FL)
0 ohm-m 25
TEMP(FL)
3 deg C 8
AZIMUTH MN
100 deg 360
DIP
-90 deg -77


Depth
1m:500m
75
80
85
90
95
100
105
110
115
120
125
CALIPER MEAN
130 mm 200
CALIPER1
130 mm 200
CALIPER 3D
0°
GAM(NAT)
0 µR/h 60
TRAVEL TIME
0° 90° 180° 270° 0°
MAGSUSCEP
0 SI*10-5 1000
DENSITY
1000 kg/m3 3000
AMPLITUDE
0° 90° 180° 270° 0°
P-VEL
3000 m/s 8000
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(DG)
100 ohm-m 100000
RES(MG)
100 ohm-m 100000
TEMP(FL)
3 deg C 8
RES(FL)
0 ohm-m 25
DIP
-90 deg -77
AZIMUTH MN
100 deg 360

Appendix 5

Geophysical borehole logging, borehole HFM17

Borehole No. HFM17

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

Northing: 6699461.95m Easting: 1633261.31m Elevation: 3.75m, RHB70

Diameter:	136mm
Reaming Diameter:	
Outer Casing:	168mm
Inner Casing:	160mm
Borehole Length:	210.65m
Cone:	
Inclination at ground surface:	-84.19°
Azimuth:	318.58°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	µR/h
TEMP(FL)	Fluid temperature	8044	deg C
RES(FL)	Fluid resistivity	8044	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	8044	ohm-m
RES(64N)	Normal resistivity 64 inch	8044	ohm-m
LATERAL	Lateral resistivity	8044	ohm-m
SPR	Single point resistivity	8044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2004-03-25	JRI	FDH	UTN

Job	Scale
360210A	1:500

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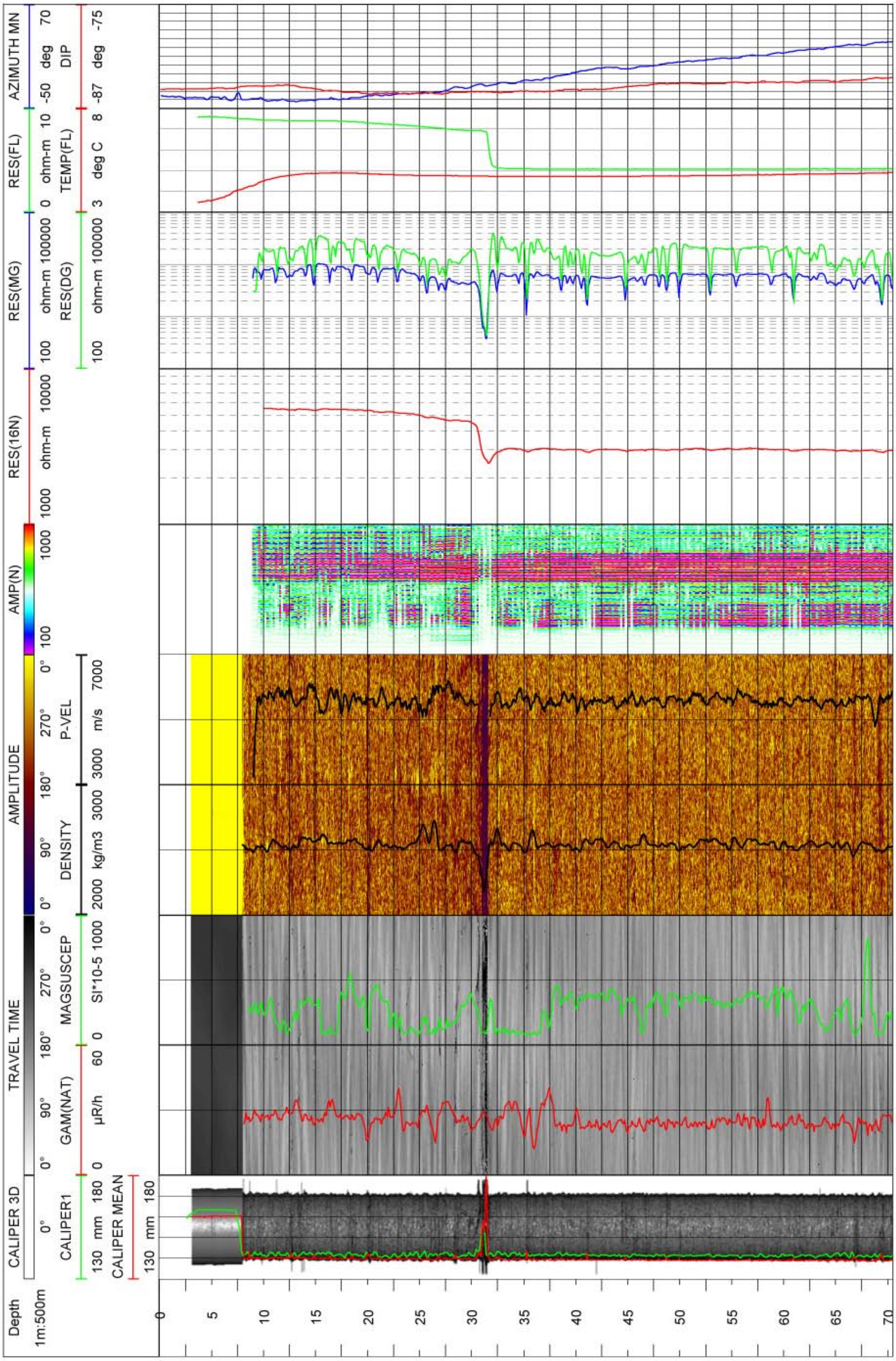
SKB geophysical borehole logging
Borehole HFM17. Forsmark

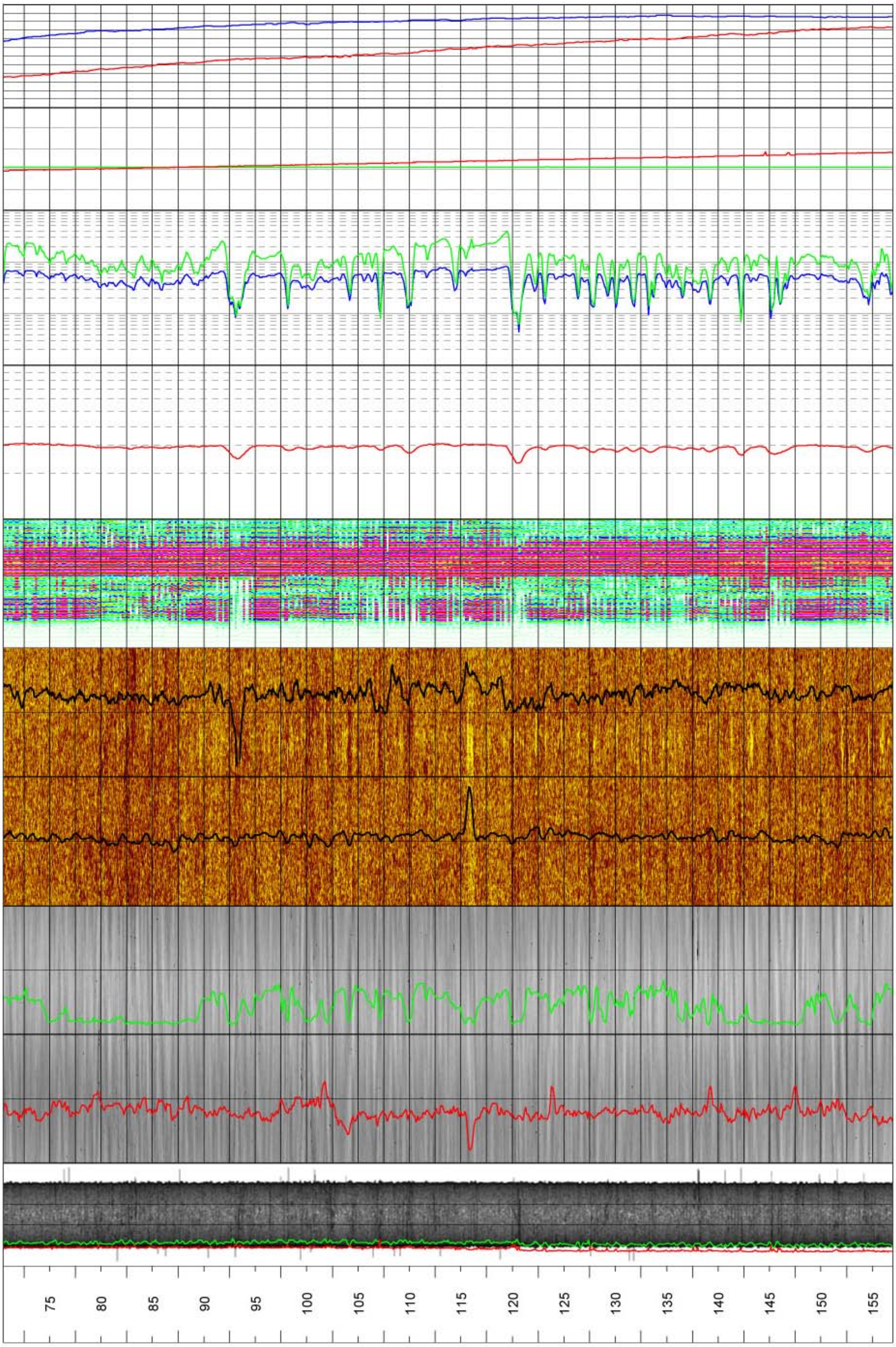
Presentation

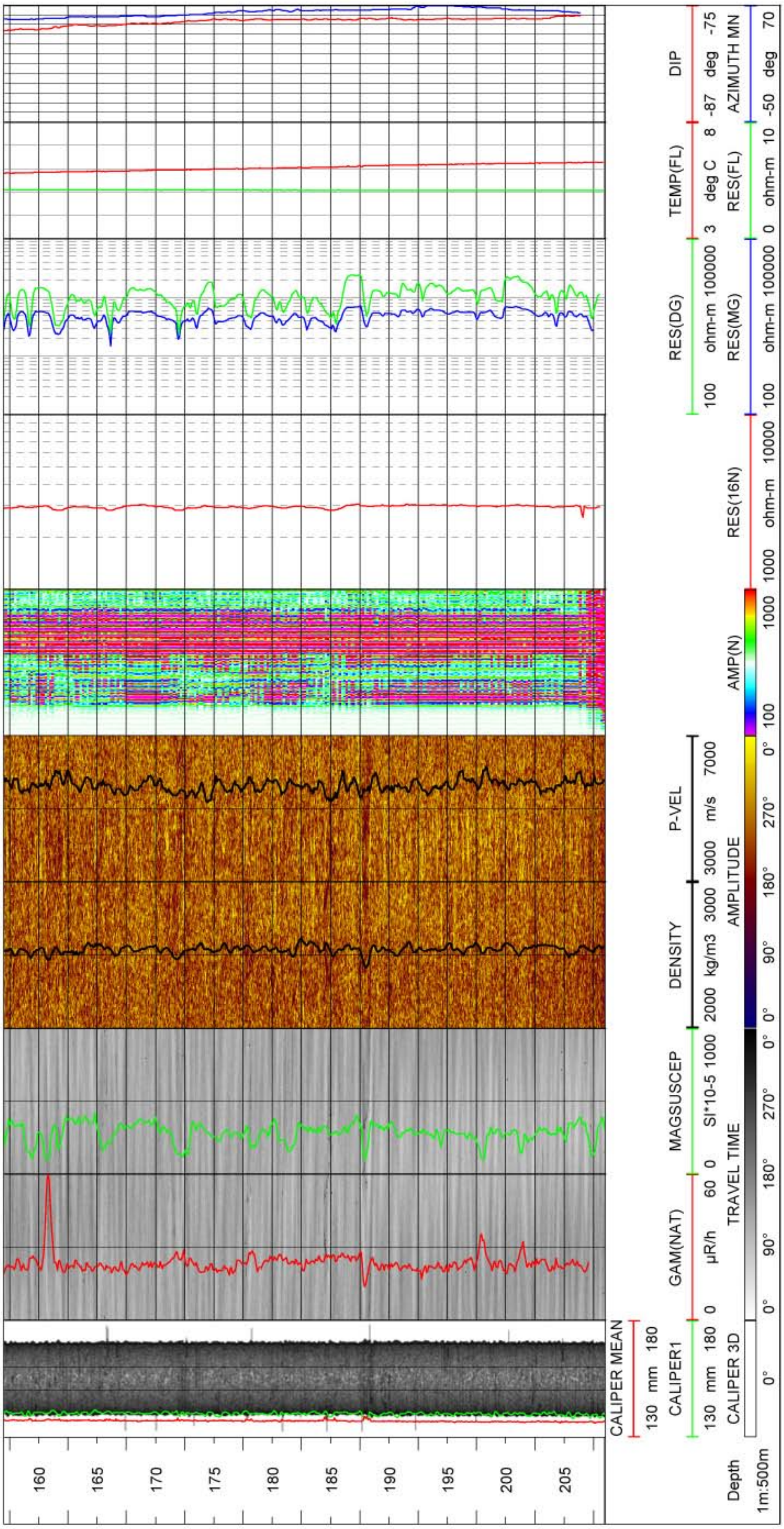
Filename:
HFM17_Presentation.wcl

Drawing no.:
5.1



Depth
1m:500m
CALIPER 3D
0°
CALIPER1
130 mm 180
CALIPER MEAN
130 mm 180
TRAVEL TIME
0° 90° 180° 270° 0°
GAM(NAT)
0 µR/h 60
MAGSUSCEP
0 SI*10-5 1000
AMPLITUDE
0° 90° 180° 270° 0°
DENSITY
2000 kg/m3 3000
P-VEL
3000 m/s 7000
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(MG)
100 ohm-m 100000
RES(DG)
100 ohm-m 100000
RES(FL)
0 ohm-m 10
TEMP(FL)
3 deg C 8
AZIMUTH MN
-50 deg 70
DIP
-87 deg -75
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155


Depth
1m:500m
160
165
170
175
180
185
190
195
200
205
CALIPER MEAN
130 mm 180
CALIPER1
130 mm 180
CALIPER 3D
0°
GAM(NAT)
0 µR/h 60
MAGSUSCEP
0 SI*10-5 1000
TRAVEL TIME
0° 90° 180° 270° 0°
DENSITY
2000 kg/m3 3000
P-VEL
3000 m/s 7000
AMPLITUDE
0° 90° 180° 270° 0°
AMP(N)
100 1000
RES(16N)
1000 ohm-m 10000
RES(DG)
100 ohm-m 100000
RES(MG)
100 ohm-m 100000
TEMP(FL)
3 deg C 8
RES(FL)
0 ohm-m 10
DIP
-87 deg -75
AZIMUTH MN
-50 deg 70

Appendix 6

Geophysical borehole logging, borehole HFM18

Borehole No. HFM18

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

Northing: 6698326.86m Easting: 1634037.37m Elevation: 5.04m, RHB70

Diameter:	138mm
Reaming Diameter:	
Outer Casing:	168mm
Inner Casing:	160mm
Borehole Length:	180.65m
Cone:	
Inclination at ground surface:	-59.36°
Azimuth:	313.30°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030	mm
DENSITY	Gamma-gamma density	9030	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	ohm-m
GAM(NAT)	Natural gamma	9030	μR/h
TEMP(FL)	Fluid temperature	8044	deg C
RES(FL)	Fluid resistivity	8044	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
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
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	8044	ohm-m
RES(64N)	Normal resistivity 64 inch	8044	ohm-m
LATERAL	Lateral resistivity	8044	ohm-m
SPR	Single point resistivity	8044	ohm

Rev.	Date	Drawn by	Control	Approved
0	2004-03-25	JRI	FDH	UTN

Job	Scale
360210A	1:500

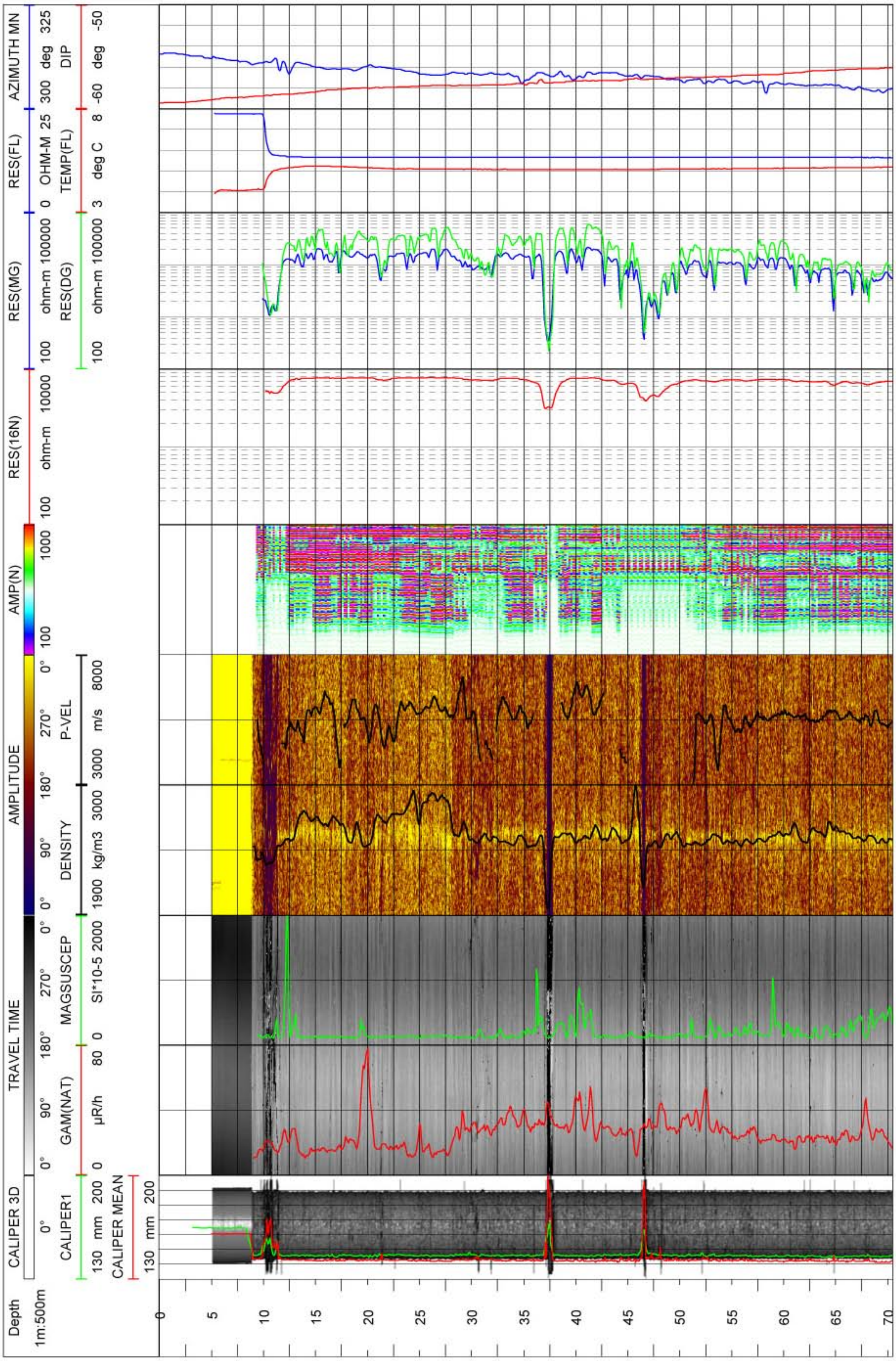
DGE Dansk Geo-servEx a/s
RAMBØLL
DGE, Håndværkersvinget 11, 2970 Hørsholm, Phone +45 70 10 34 00, Fax + 45 39 16 39 90
RAMBØLL. Bredevej 2, DK-2830 Virum, Phone + 45 45 98 60 00, Fax + 45 45 98 67 00

SKB geophysical borehole logging
Borehole HFM18. Forsmark

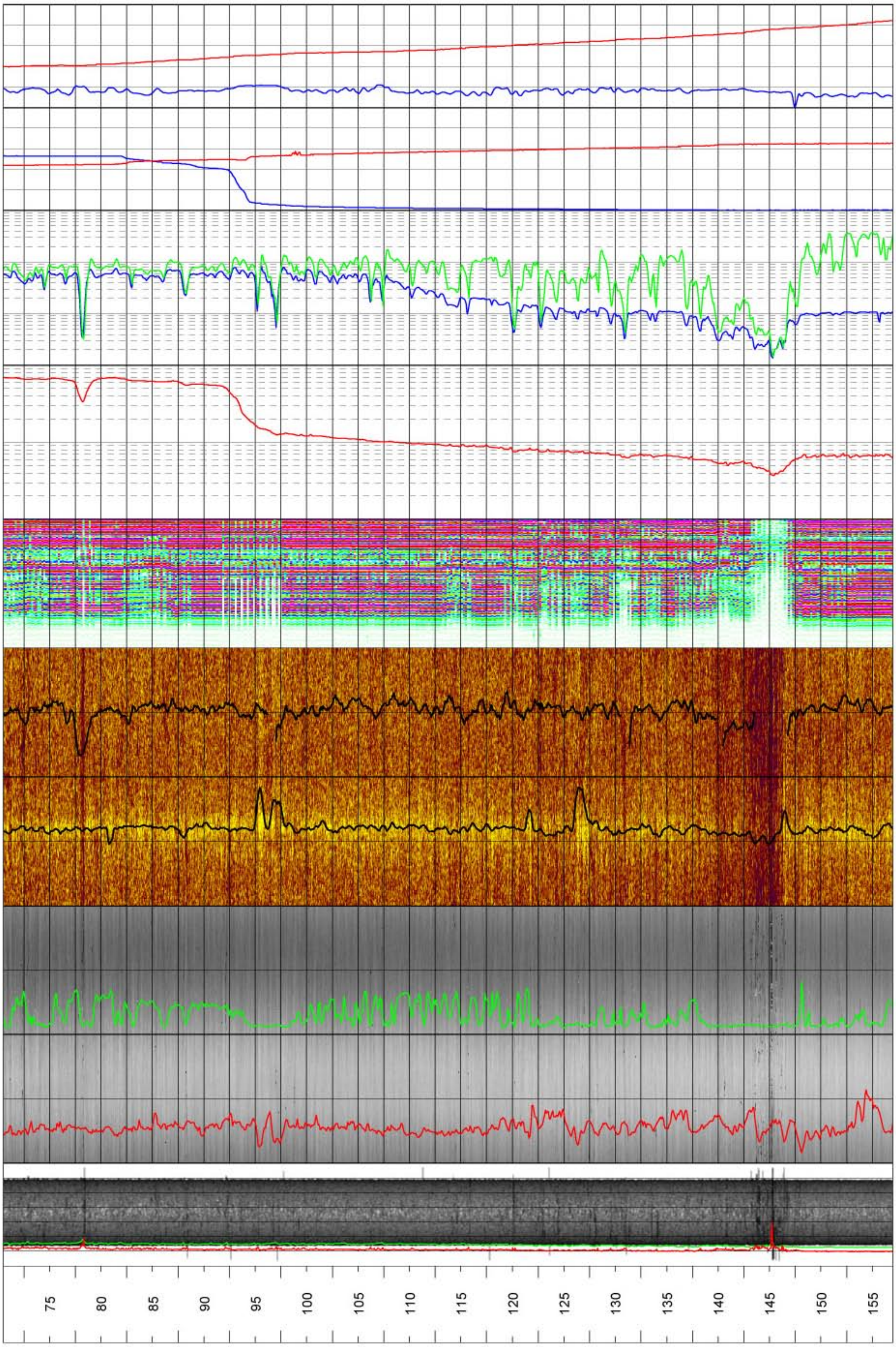
Presentation

Filename:
HFM18_Presentation.wcl

Drawing no.:
6.1



Depth
1m:500m
CALIPER 3D
0°
CALIPER1
130 mm 200
CALIPER MEAN
130 mm 200
TRAVEL TIME
0° 90° 180° 270° 0°
GAM(NAT)
0 µR/h 80
MAGSUSCEP
0 SI*10-5 2000
AMPLITUDE
0° 90° 180° 270° 0°
DENSITY
1900 kg/m3 3000
P-VEL
3000 m/s 8000
AMP(N)
100 1000
RES(16N)
100 ohm-m 10000
RES(MG)
100 ohm-m 100000
RES(DG)
100 ohm-m 100000
RES(FL)
0 OHM-M 25
TEMP(FL)
3 deg C 8
AZIMUTH MN
300 deg 325
DIP
-60 deg -50
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70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100
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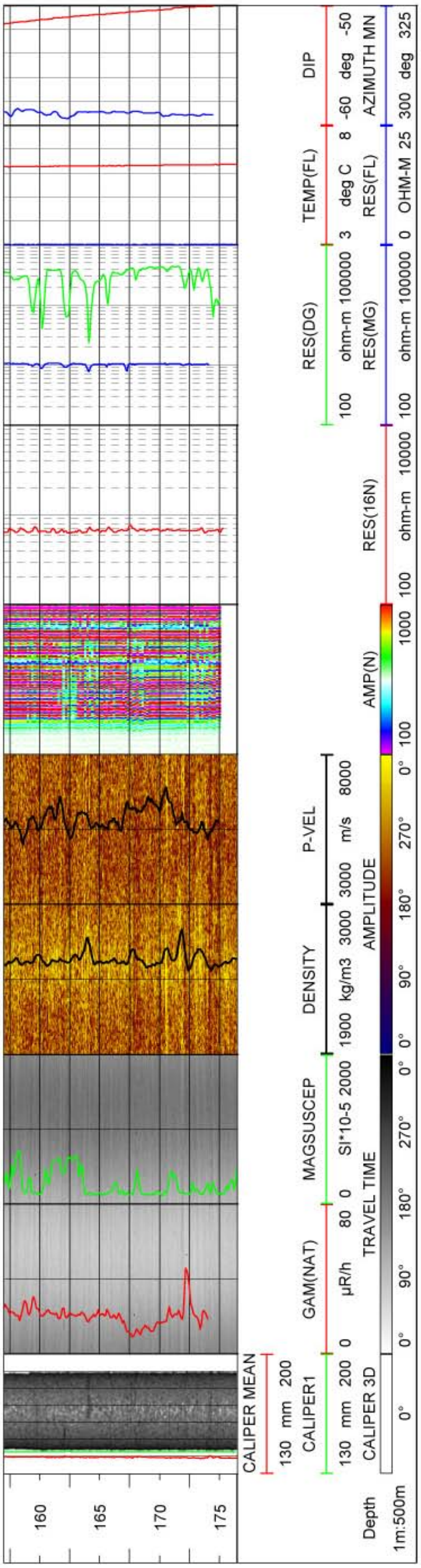
150
155


Depth
1m:500m
160
165
170
175
CALIPER MEAN
130 mm 200
CALIPER1
130 mm 200
CALIPER 3D
0°
GAM(NAT)
0 µR/h 80
MAGSUSCEP
0 SI*10-5 2000
TRAVEL TIME
0° 90° 180° 270° 0°
DENSITY
1900 kg/m3 3000
P-VEL
3000 m/s 8000
AMPLITUDE
0° 90° 180° 270° 0°
AMP(N)
100 1000
RES(16N)
100 ohm-m 10000
RES(DG)
100 ohm-m 100000
RES(MG)
100 ohm-m 100000
TEMP(FL)
3 deg C 8
RES(FL)
0 OHM-M 25
DIP
-60 deg -50
AZIMUTH MN
300 deg 325