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Oskarshamn site investigation

Geophysical borehole logging in borehole KLX09

Uffe Torben Nielsen, Jørgen Ringgaard, Jesper Fris Dahl
RAMBØLL

July 2006

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Abstract

Geophysical borehole logging has been performed in borehole KLX09 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.

The logging in KLX09 was recorded from 12 m to 880 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.

Sammanfattning

Geofysisk borrhålsloggning har genomförts i borrhål KLX09 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 KLX09 från 12 m till 880 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 KLX09, 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 400-05-092 (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 28 and 29, 2005 and June 2, 2006. The borehole was recorded from Top Of Casing (TOC) to the bottom of the borehole. The technical data from the boreholes is 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 KLX09	AP PS 400-05-092	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	**KLX09**
Co-ordinates (RT90)	X: 6367323.448
	Y: 1548863.176
Elevation (RHB70)	Z: 23.53
Inclination (from horizontal)	–85.895°
Azimuth	267.4071°
Length	880.38 m
Borehole diameter	∅ 341 mm (0.0–9.8 m)
	∅ 248 mm (9.8–11.95 m)
	∅ 197 mm (11.95–100.5 m)
	∅ 163 mm (100.5–100.6 m)
	∅ 86 mm (100.6–102.0 m)
	∅ 76 mm (102.0–880.38 m)
Casing	∅ 323/310 mm (0.65– 9.8 m)
	∅ 208/200 mm (0.0–11.95 m)
	Cone from 97.33–102.0 (∅100/∅ 80 mm)
Cleaning level	Level 1

Figure 1-1. *Overview over location of borehole KLX09 in the Laxemar subarea.*

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 360º caliper and to determine the length marks in the core-drilled borehole, KLX09.

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 in drawing no 1.1 in Appendix 1.

3 Equipment

The geophysical borehole logging program in KLX09 was performed with up to 7 multi tool probes and resulted in a suite of 16 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	Comment
Century 8144 Normal resistivity	Normal resistivity (16 and 64 inch), single point resistance, self potential and natural gamma.	237×5.3 cm			
Century 8622 Magnetic susceptibility.	Magnetic susceptibility, natural gamma.	203×4.1 cm			
Century 9042 Fluid temperature and fluid resistivity	Fluid temperature, fluid resistivity and natural gamma.	137×4.1 cm			
Century 9072 3 m focused guard.	3 m focused guard log resistivity and natural gamma.	310×6.4 cm			
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.	
Century 9310 Sonic.	Full wave form travel-time providing P & S-wave velocity picking, compensated P-wave travel-time and natural gamma.	283.2×5.1 cm	Near 2 ft. Far 3 ft.	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 and dip and natural gamma.	246×4 cm		Centralized.	Only partly information

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 28 to 29, 2005 and on June 2, 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 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 in down and in upward direction using the down run as a repeat section. For logging density 9139 the repeat section is logged 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, 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

Due to a tool error in the HiRAT probe, it was only possible to record data in small steps partly around the length marks. No data from the HiRAT probe has been delivered.

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.

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

Log	Log name short	Unit	Tool
Fluid temperature	TEMP(FL)	Deg C	9042
Fluid resistivity	RES(FL)	Ohm-m	9042
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*10^{-5}	8622
Caliper, 1-arm	CALIPER1	mm	9139
Gamma-gamma density	DENSITY	kg/m^3	9139
Focused guard log resistivity, 127 cm	RES(SG)	ohm-m	9139
Natural gamma	GAM(NAT)	µR/h	9072
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

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 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.

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, 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	–
Self-potential	–
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 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 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.
360° orientated acoustic travel time	–
360° orientated acoustic travel time	–

5.4 Borehole KLX09

In order to obtain an exact length calibration in borehole KLX09, 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.

Table 5-3. The reference track marks in the borehole and the recorded track marks form the HiRAT in borehole KLX09.

Reference mark	HIRAT recorded	File
110.00	110	Down_Run1
150.00	149.94	Down_Run1
200.00	200.08	Down_Run1
250.00		
300.00		
350.00		
400.00		
450.00		
500.00		
550.00	550	Down_Run6
600.00		
650.00		
700.00		
750.00		
800.00		
850.00	850.574	Up_run1

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 KLX09, between all logruns, the obtained reference mark correlation is transferred to the other logs.

The complete log suite for borehole KLX09 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.

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
KLX09	8144	Up	KLX09_06-02-06_10-47_8144C_.10_3.00_876.20_ ORIG.log	Start Depth: 876.2 m. End Depth: 3 m
KLX09	8622	Up	KLX09_11-28-05_18-38_8622C_.02_-0.42_875.86_ ORIG.log	Start Depth: 875.86 m. End Depth: –0.42 m
KLX09	9042	Down	KLX9_11-28-05_12-06_9042C_.02_0.22_881.58_ ORIG.log	Start Depth: 0.22 m. End Depth: 881.58 m
KLX09	9072	Up	KLX09_11-29-05_08-23_9072C_.02_481.90_875.74_ ORIG.log	Start Depth: 875.74 m. End Depth: 481.9 m
KLX09	9072	Up	KLX09_11-29-05_09-02_9072C_.02_478.05_484.23_ ORIG.log	Start Depth: 484.23 m. End Depth: 478.05 m
KLX09	9072	Up	KLX09_11-29-05_09-03_9072C_.02_467.73_480.57_ ORIG.log	Start Depth: 480.57 m. End Depth: 467.73 m
KLX09	9072	Up	KLX09_11-29-05_09-04_9072C_.02_422.22_470.22_ ORIG.log	Start Depth: 470.22 m. End Depth: 422.22 m
KLX09	9072	Up	KLX09_11-29-05_09-09_9072C_.02_410.75_424.71_ ORIG.log	Start Depth: 424.71 m. End Depth: 410.75 m
KLX09	9072	Up	KLX09_11-29-05_09-11_9072C_.02_76.85_413.24_ ORIG.log	Start Depth: 413.24 m. End Depth: 76.85 m
KLX09	9072	Up	KLX09_11-29-05_09-45_9072C_.02_-0.28_79.18_ ORIG.log	Start Depth: 79.18 m. End Depth: –0.28 m
KLX09	9139	Up	KLX09_11-28-05_15-16_9139A_.02_0.12_876.20_ ORIG.log	Start Depth: 876.2 m. End Depth: 0.12 m
KLX09	9310	Up	KLX09_11-29-05_10-53_9310C2_.10_798.10_ 874.60_ORIG.log	Start Depth: 874.6 m. End Depth: 798.1 m
KLX09	9310	Up	KLX09_11-29-05_11-01_9310C2_.10_521.40_ 799.80_ORIG.log	Start Depth: 799.8 m. End Depth: 521.4 m
KLX09	9310	Up	KLX09_11-29-05_11-30_9310C2_.10_-0.20_523.10_ ORIG.log	Start Depth: 523.1 m. End Depth: –0.2 m
KLX09	HiRAT	Down	KLX09_90pixels_Down_run1.HED	
KLX09	HiRAT	Up	KLX09_90pixels_ Down_run6.HED	
KLX09	HiRAT	Up	KLX09_90pixels_Up_run4.HED	

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KLX09	1.1	KLX09_Presentation.WCL

Table 6-3. Data files in SICADA format.

Sheet	Comment
KLX09_CALIPER1_GP040 – Caliper logging.xls	
KLX09_TEMP(FL)_RES(FL)_GP060 – Fluid temperature and resistivity logging.xls	
KLX09_DENSITY_GP090 – Density logging.xls	
KLX09_MAGSUSCEP_GP110 – Magnetic susceptibility logging.xls	
KLX09_GAM(NAT)_GP120 – Natural gamma logging.xls	
KLX09_RES(MG)_GP161 – Resistivity, focused 140 cm.xls	
KLX09_RES(DG)_GP162 – Resistivity, focused 300 cm.xls	
KLX09_P-VEL_GP175 – Fullwave sonic.xls	
KLX09_SPR_GP150 – Single point resistance logging.xls	
KLX09_RES(64N)_GP160 – Resistivity, normal 1.6 m (64 in).xls	
KLX09_LATERAL_GP163 – Resistivity, lateral 1.6–0.1 m.xls	
KLX09_RES(16N)_GP164 – Resistivity, normal 0.4 m (16 in).xls	
KLX09_SP_GP180 – Self potential logging.xls	

Borehole KLX09. Drawing no. 1.1. Borehole logs

Borehole No. KLX09

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

Northing: 6367323.448m Easting: 1548863.176m Elevation: 23.453m, RHB70

Diameter:	76mm
Reaming Diameter:	
Outer Casing:	
Inner Casing:	
Borehole Length:	880.38m
Cone:	97.33 - 102.00m
Inclination at ground surface:	-85.29°
Azimuth:	267.41°
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
CALIPER1	Caliper, 1-arm	9030/9139	mm
DENSITY	Gamma-gamma density	9030/9139	kg/m³
RES(MG)	Focused guard log resistivity, 140cm	9030	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
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	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	mV
RES(SG)	Focused guard log resistivity, 128 cm	9139	ohm-m

Rev.	Date	Drawn by	Control	Approved
2	2006-07-25	JRI	UTN	UTN

Job: 547310A

Scale: 1:500

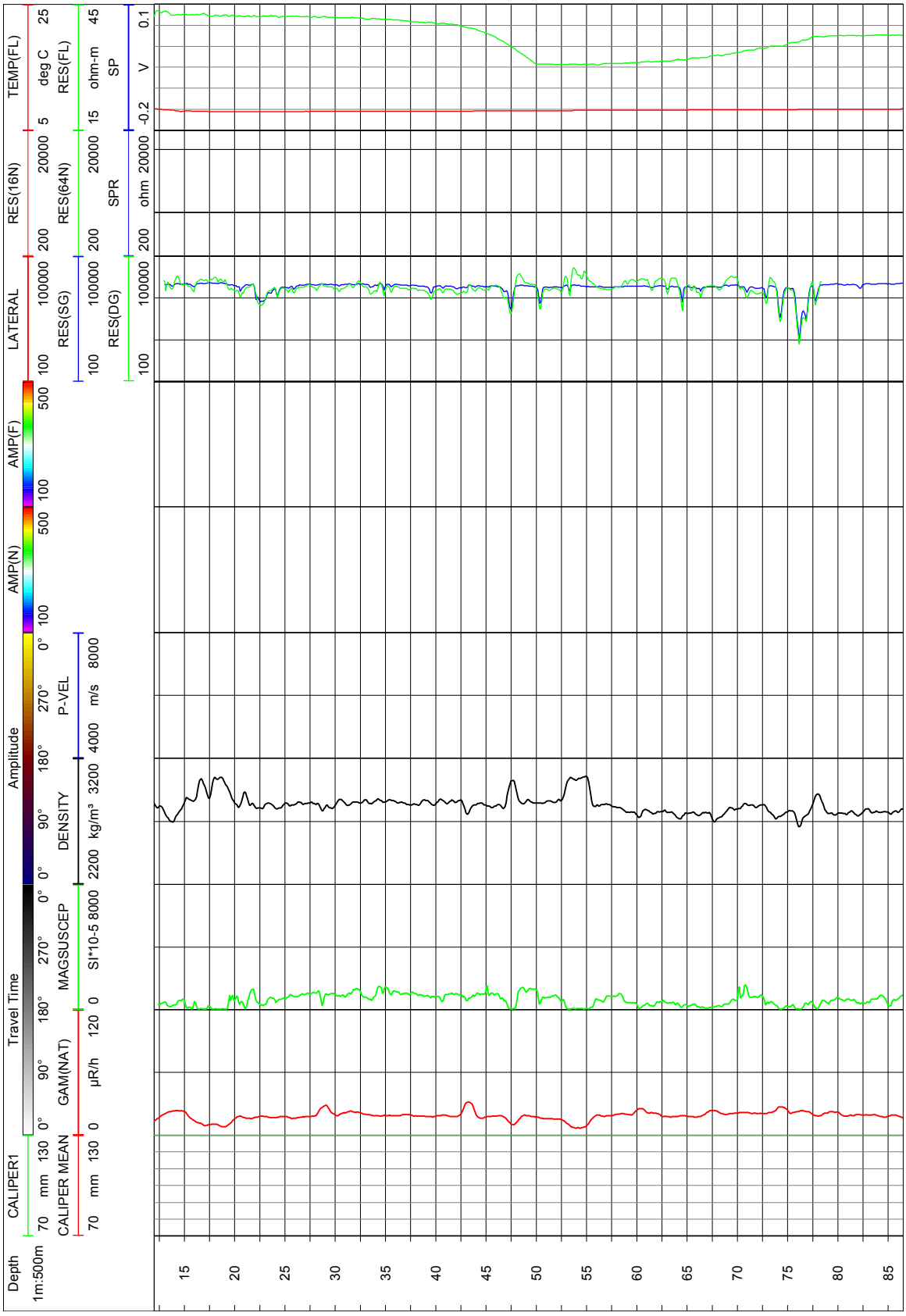
RAMBØLL
Rambøll. Bredevej 2, DK-2830 Virum
Phone + 45 45 98 60 00, Fax + 45 45 98 67 00

SKB geophysical borehole logging
Borehole KLX09

Presentation

Filename: KLX09_Presentation.wcl

Drawing no.: **1.1**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CALIPER MEAN
70 mm 130
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Amplitude
0° 90° 180° 270° 0°
MAGSUSCEP
0 SI*10-5 8000
AMP(N)
100 500
DENSITY
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AMP(F)
100 500
P-VEL
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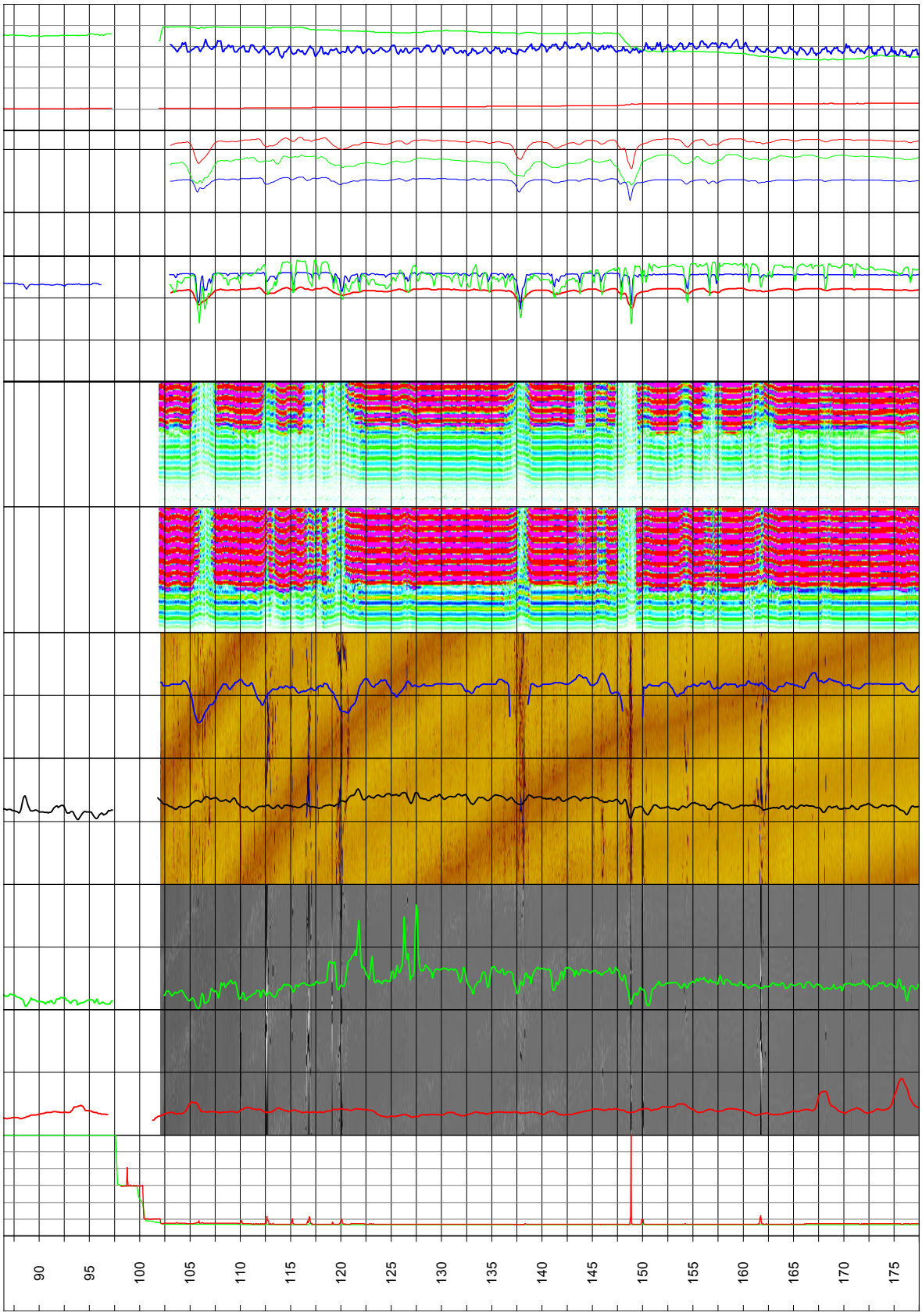
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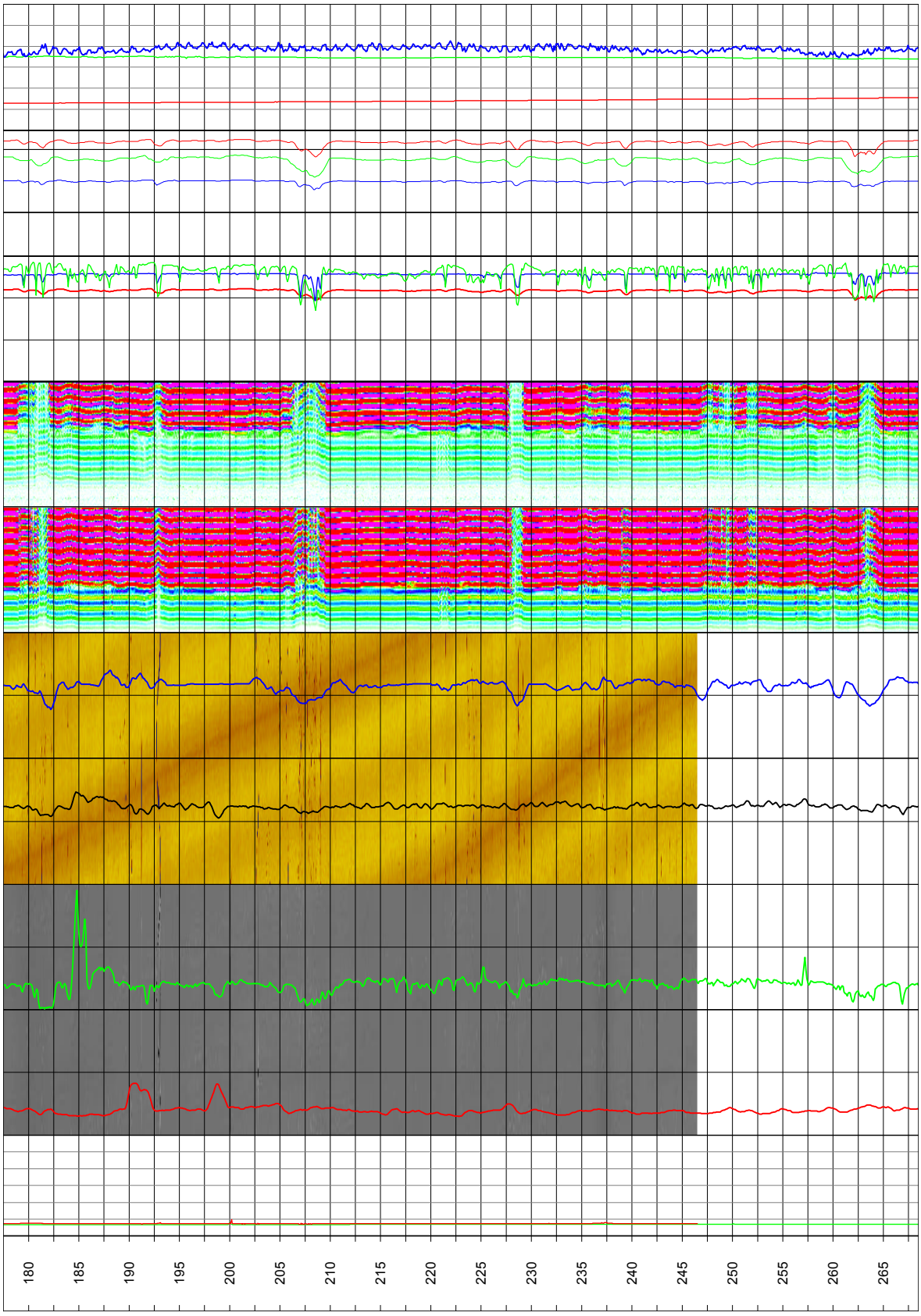
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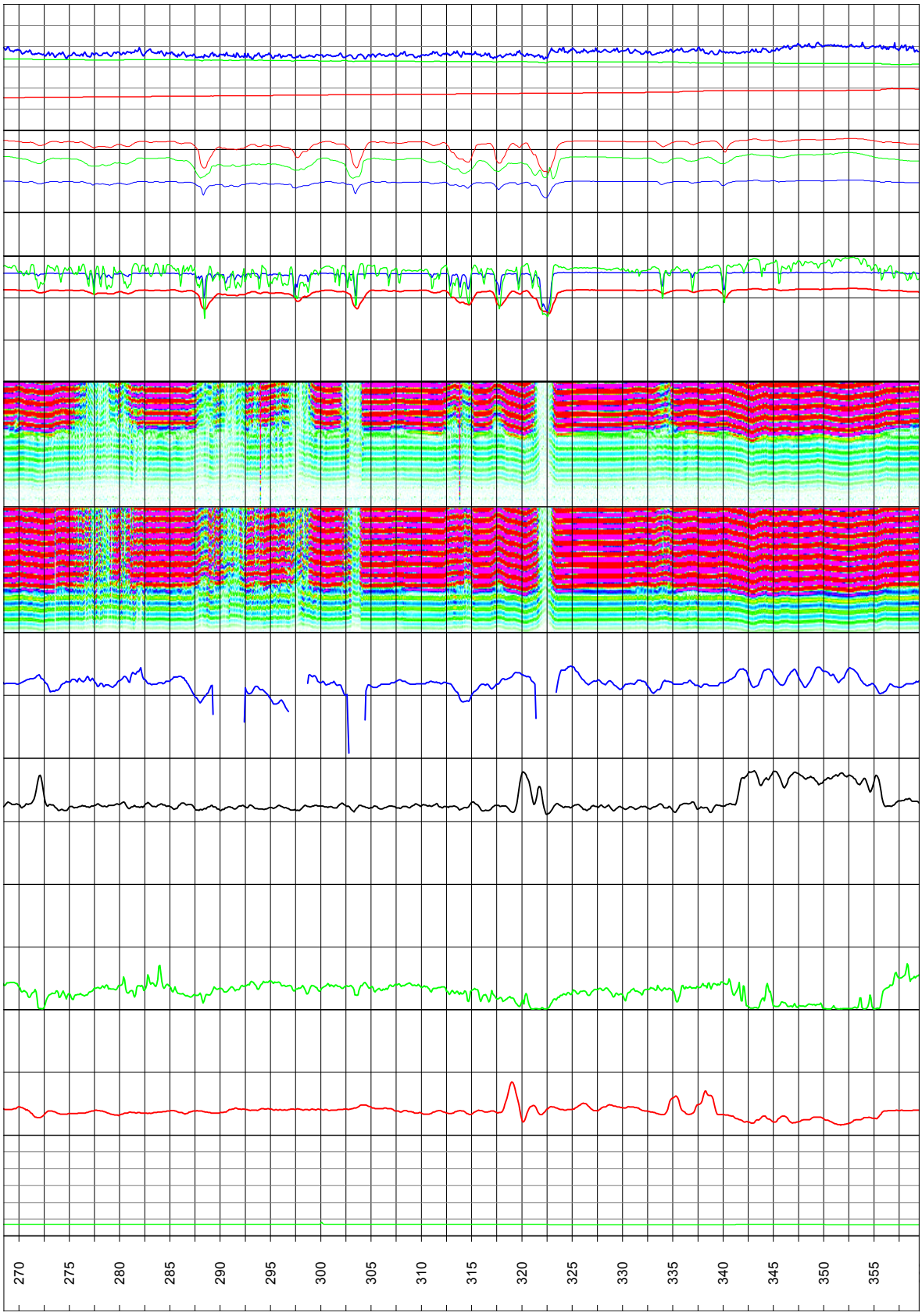
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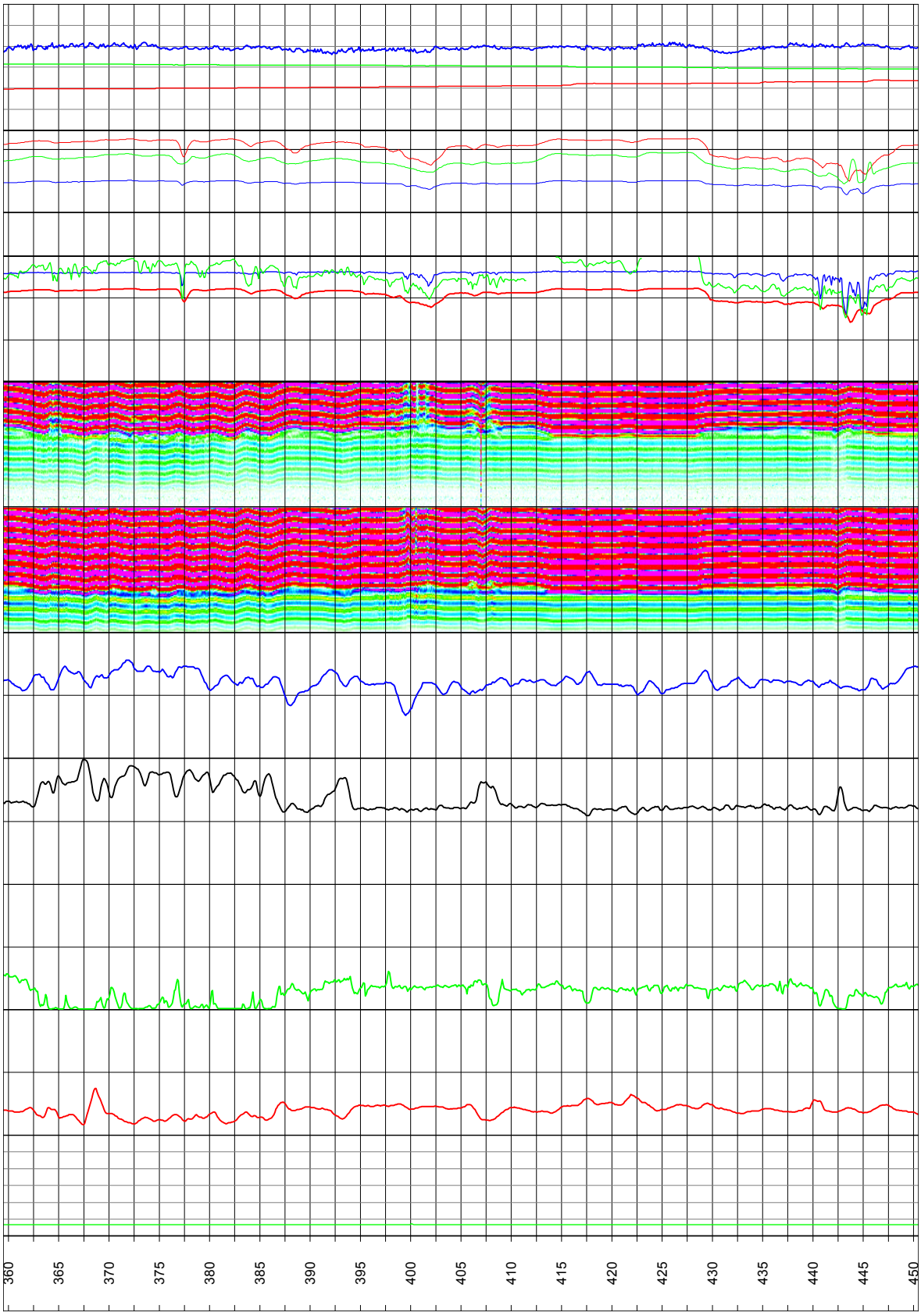
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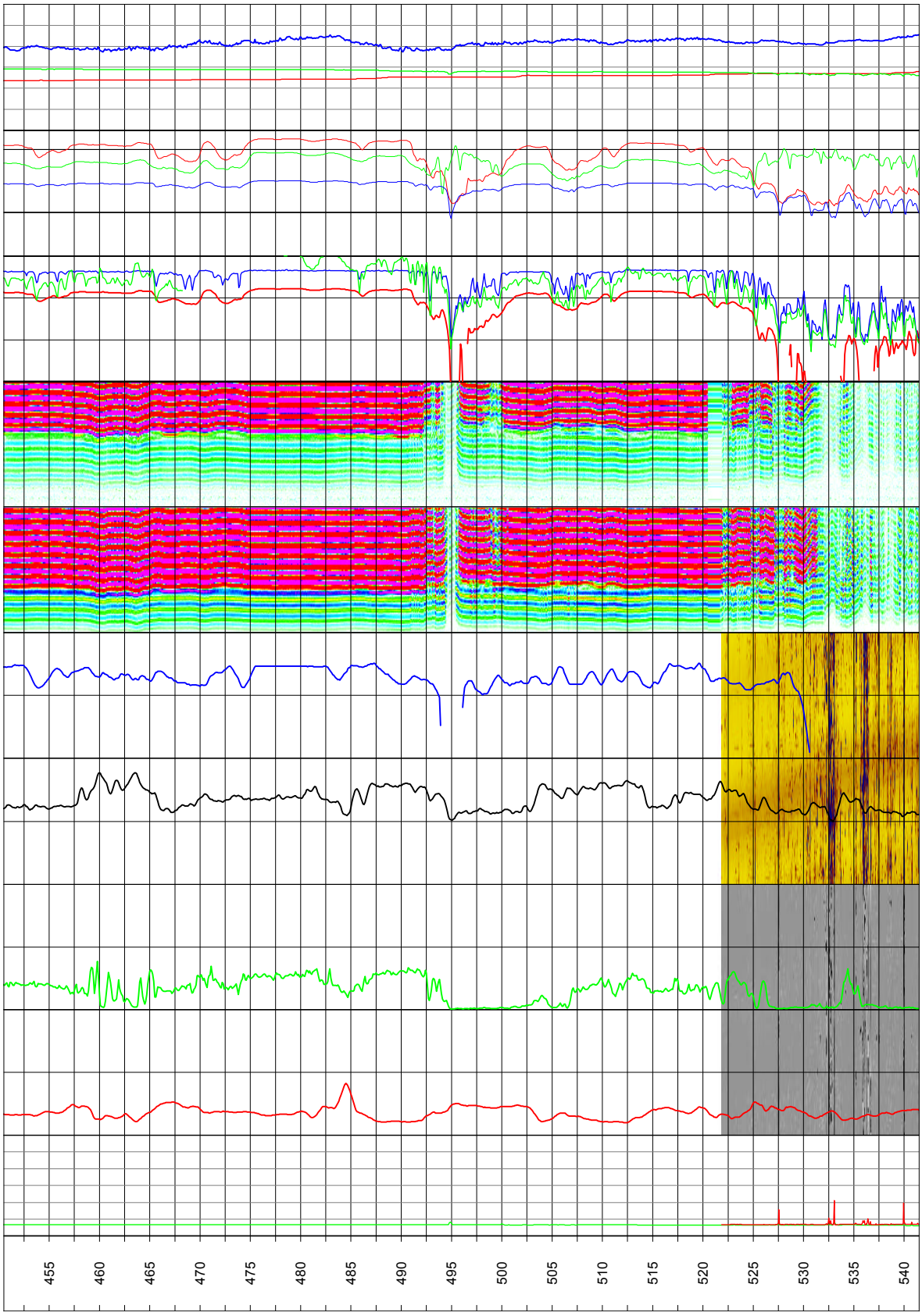
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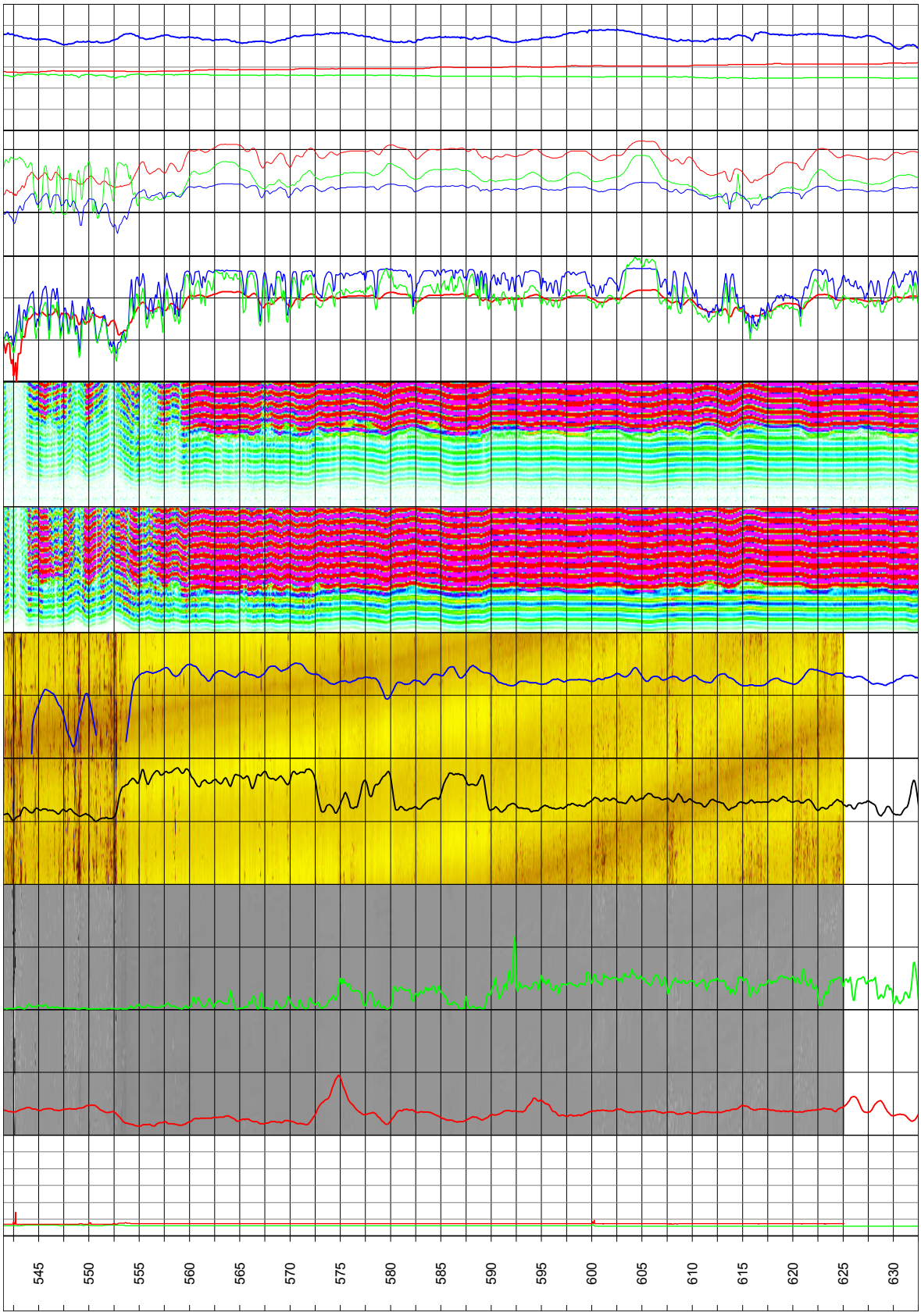
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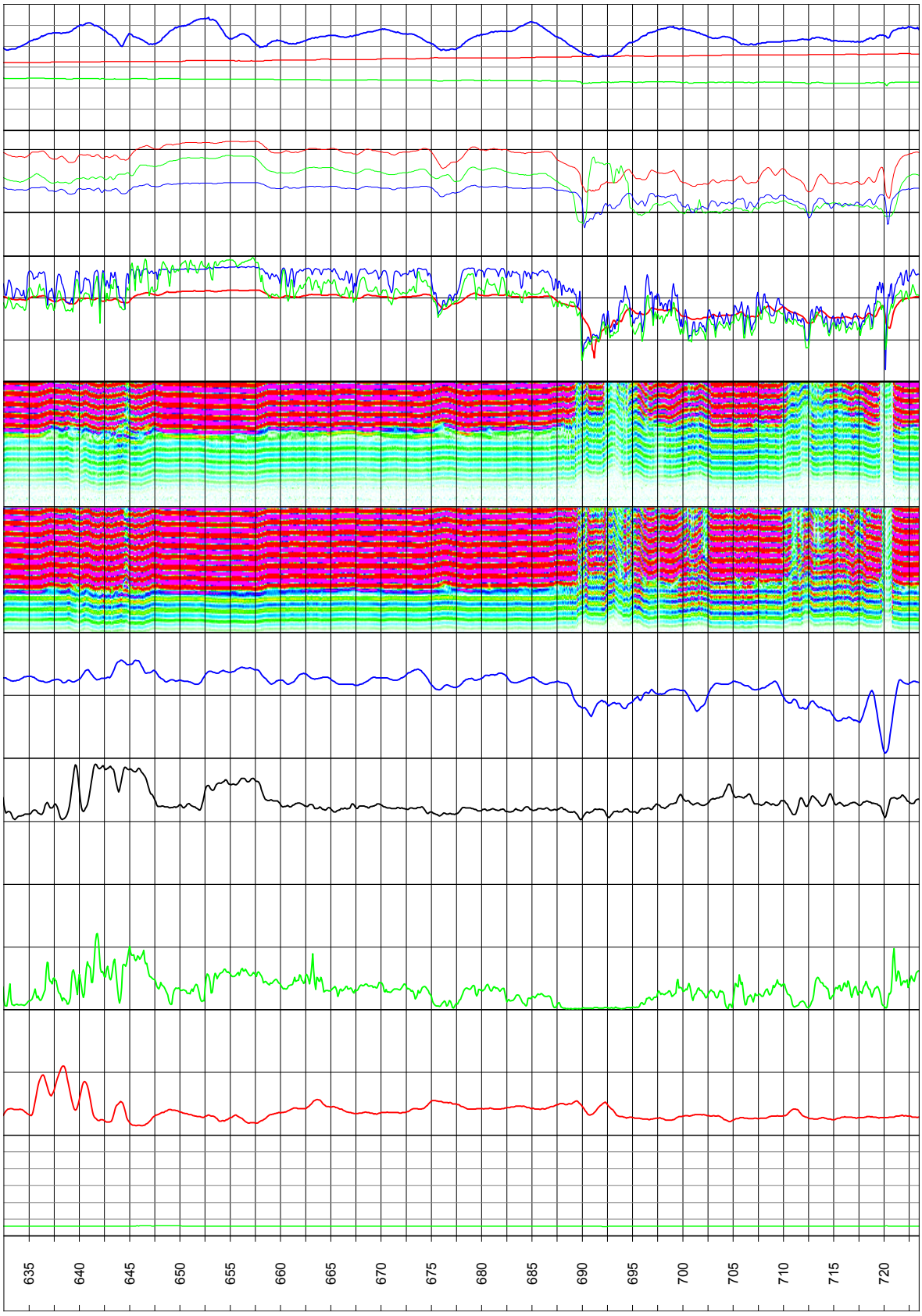
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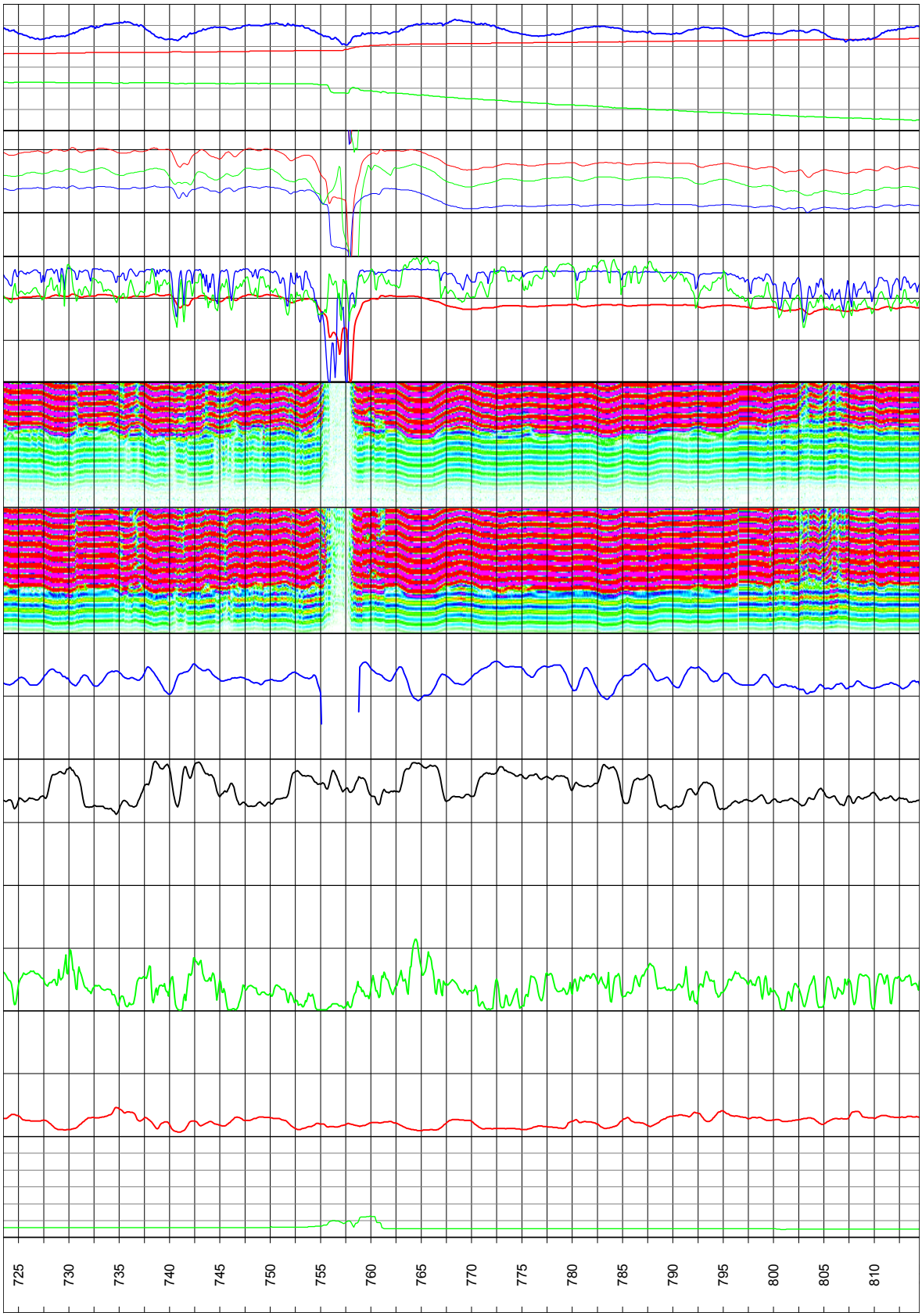
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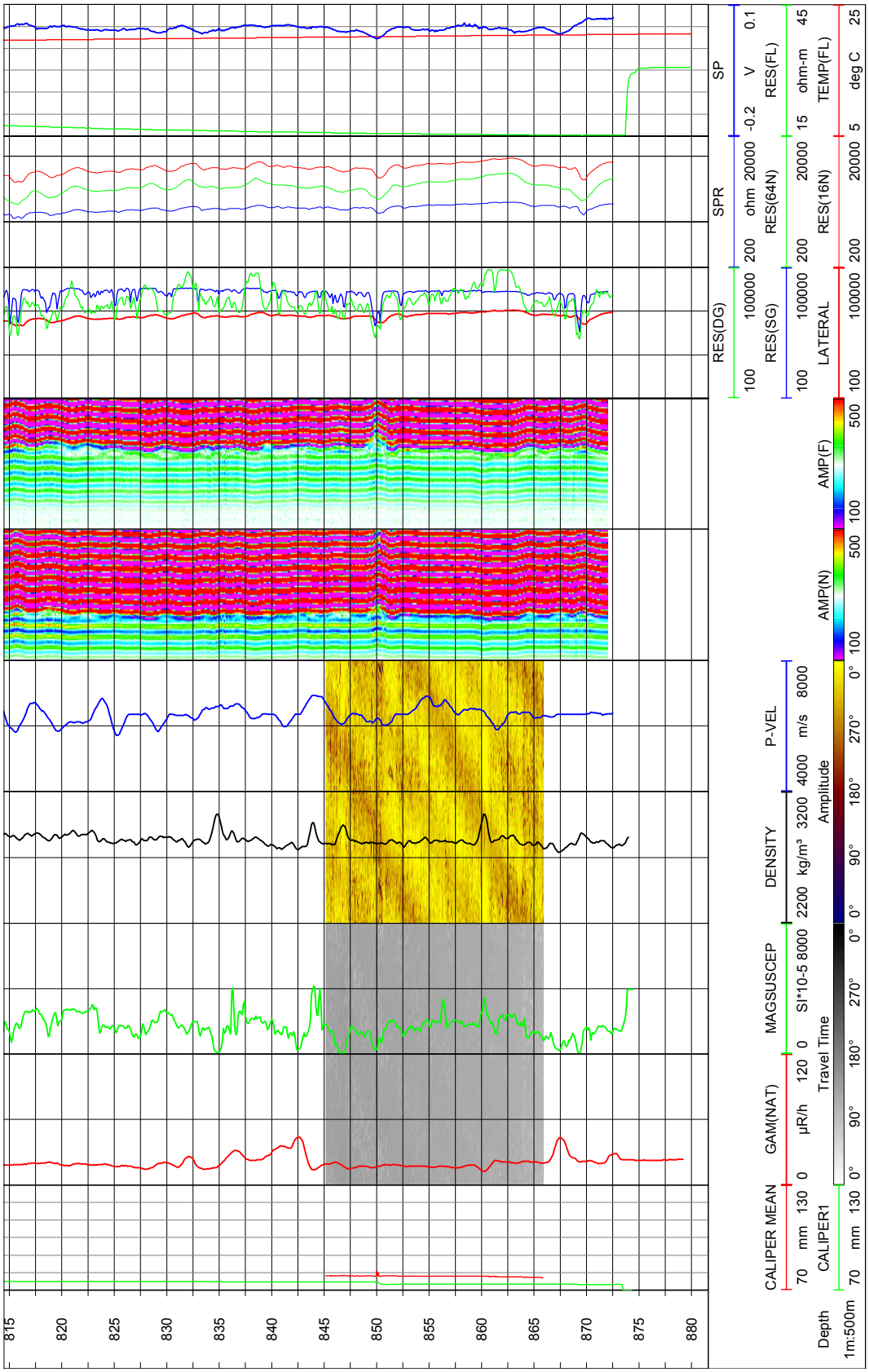
805
810


Depth
1m:500m
CALIPER1
70 mm 130
CALIPER MEAN
70 mm 130
GAM(NAT)
0 µR/h 120
Travel Time
0° 90° 180° 270° 0°
MAGSUSCEP
0 SI*10-5 8000
DENSITY
2200 kg/m³ 3200
P-VEL
4000 m/s 8000
Amplitude
0° 90° 180° 270° 0°
AMP(N)
100 500 100
AMP(F)
100 500 100
LATERAL
100 100000 200
RES(16N)
100 100000 200
RES(64N)
100 100000 200
RES(SG)
100 100000 200
SPR
200 ohm 20000
RES(DG)
100 100000 200
SP
-0.2 V 0.1
RES(FL)
15 ohm-m 45
TEMP(FL)
5 20000 25
deg C
815
820
825
830
835
840
845
850
855
860
865
870
875
880