P-05-31

Oskarshamn site investigation

Geophysical borehole logging in borehole KLX06

Uffe Torben Nielsen, Jørgen Ringgaard, Frederik Horn
RAMBØLL

January 2005

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ISSN 1651-4416
SKB P-05-31

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Keywords: Geophysical logging.

Abstract

Geophysical borehole logging has been performed in borehole KLX06 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 KLX06 was recorded from 100 m to 995 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 KLX06 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 KLX06 från 100 m till 995 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 KLX06, 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 400-04-119 (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 January 4 to 5, 2005. 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.

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

Activity plan	Number	Version
Geofysisk borrhålsloggning i KLX06	AP PS 400-04-119	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för geofysisk borrhålsloggning	SKB MD 221.002	1.0
Metodbeskrivning för krökningsmätning av hammar- och kärnborrhål	SKB MD 224.001	1.0

Table 1-2. Technical data from core borehole KLX06.

Borehole parameter	KLX06
Co-ordinates (RT90)	X: 6367806.637
	Y: 1548566.882
Elevation (RHB70)	Z: 17.681
Inclination (from horizontal)	–65.015°
Azimuth	330.208°
Length	994.94 m
Borehole diameter	∅ 341 mm (0.00– 9.1 m)
	∅ 253 mm (9.1–11.88 m)
	∅ 195 mm (11.88–100.2 m)
	∅ 76 mm (100.2–994.94 m)
Casing	∅ 323/310 mm (0–9.1 m)
	∅ 208/200 mm (9.1–11.88 m)
	Cone ∅ 100/ ∅ 77 mm (97–101.40 m)
Cleaning level	Level 2

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

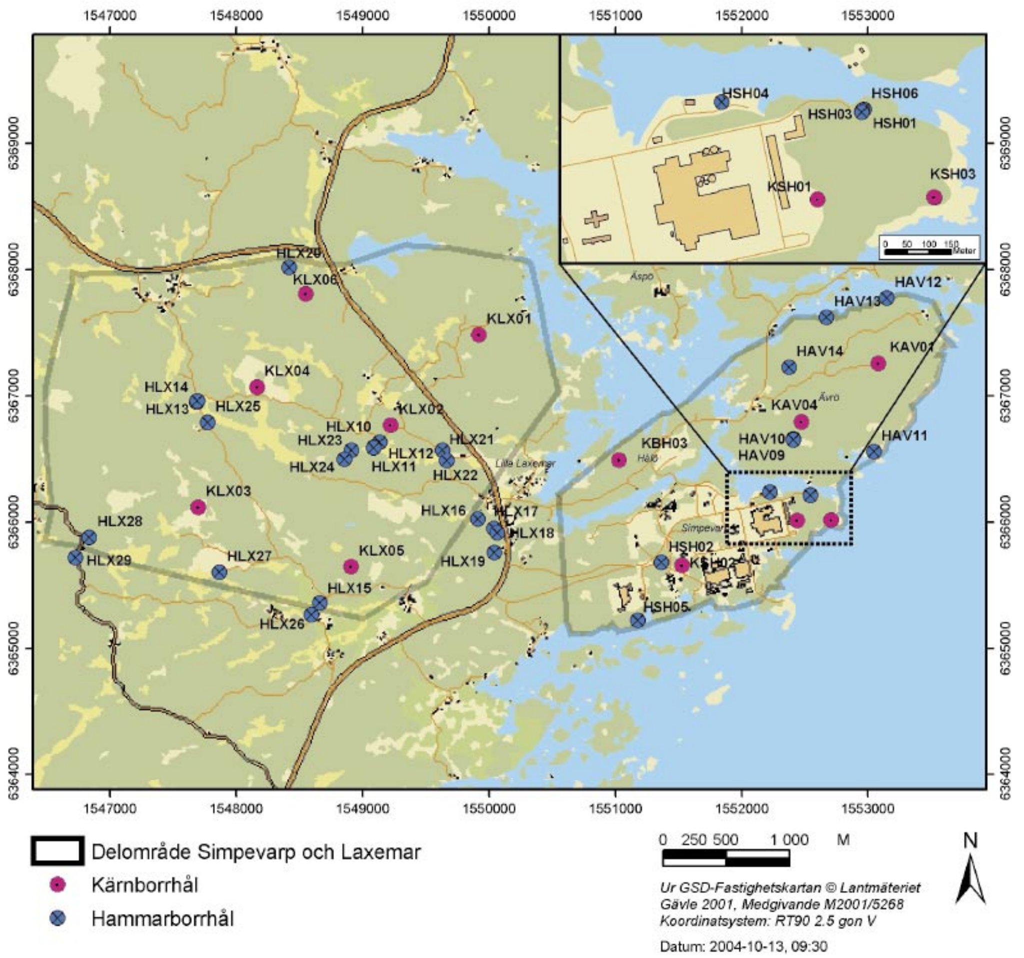


Figure 1-1. *General overview over the Simpevarp and Laxemar subareas with the location of borehole KLX06.*

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 deviation of the borehole (azimuth and inclination) as well as to determine the length marks in the core drilled borehole, KLX06.

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 for borehole KLX06 in Appendix 1.

3 Equipment

The geophysical borehole logging program in all boreholes was performed with 6 multi tool probes and resulted in a suite of 19 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 in KLX06.

Tool	Recorded logs	Dimension	Source detector spacing and type	Tool position in borehole
Century 8044 Normal resistivity, fluid temperature and fluid resistivity.	Normal resistivity (16 and 64 inch), single point resistance, fluid resistivity, fluid temperature 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.	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.

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 January 4 to 5, 2005. All relevant logging events are described in the daily report sheets delivered to SICADA and are traceable by the activity plan number.

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

The applied logging equipment was calibrated and cleaned before arriving at the site according to SKB cleaning level 2 (SKB internal controlling document SKB MD 600.004). Furthermore, all equipment was wiped with alcohol before it was lowered into the borehole.

A function test of the deviation measurements in the HiRAT tool was performed before arriving at the site, following SKB internal controlling document SKB MD 224.001.

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 tool 9030 recording a repeat section in upward direction controls the data. The depth of the probe in the borehole is shown on both the recording computer and the winch. On the winch the tension of the cable is also shown. The winch will automatically stop, if the tension changes rapidly. The tension was recorded on all log runs using Century equipment, except tool 9310.

All data was recorded with max10 cm sample interval. The speed of the logging tools was in general 10 m/min for the used log runs.

4.2 Nonconformities

The HiRAT – Acoustic televiewer tool have only been recorded to a depth of 962 m, because the tool got stocked in the borehole and due to the dip of the borehole (less than 40 degrees).

The down run from the 9072 tool has been used in the processing.

Due to disturbance of the cone between 97 and 101.40 m and bad data in the wider part of the borehole (195 mm) between 11.88 and 100.2 m data has been skipped in that part.

5 Results

5.1 Presentation

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

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

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	8044
Fluid resistivity	RES(FL)	ohm-m	8044
Normal resistivity 16 inch	RES(16N)	ohm-m	8044
Normal resistivity 64 inch	RES(64N)	ohm-m	8044
Lateral resistivity	LATERAL	ohm-m	8044
Single point resistance	SPR	Ohm	8044
Magnetic susceptibility	MAGSUSCEP	$SI*10^{-5}$	8622
Caliper, 1-arm	CALIPER1	mm	9030
Gamma-gamma density	DENSITY	kg/m^3	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 from 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 Orientation, alignment and stretch of logs

5.2.1 Orientation of images

The orientation of the results from the HiRAT Acoustic tool, are 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. 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 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 depth 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 depth scale for each tool. The depth 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 depth scale is made and added to the log.

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.

Log	Description of log calculation
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 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 acoustic televiewer, the fluid temperature, fluid velocity and the internal travel time in the acoustic 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	–

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). 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. In the same calculation, the magnetic declination was added. Finally, the relative coordinates were added to the given coordinate in RT90 for the top of the borehole.

Latitude: 57 deg, 25 min, 59 sec

Longitude: 16 deg, 36 min, 49 sec

Elevation: 0.00 km

Date of Interest: 5/1/2005

Declination = 3.403°

5.4 Borehole KLX06

In order to obtain an exact depth calibration in borehole KLX06, 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 shown in Table 5-3.

Table 5-3. The reference track marks in the borehole and the recorded track marks form the HiRAT in borehole KLX06.

Reference mark	HIRAT recorded
103.00	100.346
151.00	148.409
200.00	197.44
250.00	247.529
300.00	297.603
350.00	347.682
400.00	397.753
450.00	447.835
500.00	497.916
550.00	548.002
600.00	598.107
650.00	648.155
700.00	698.227
750.00	748.365
800.00	798.418
850.00	848.548
900.00	898.658
950.00	948.793

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 depth scale. 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 KLX06, between all logruns, the obtained reference mark correlation is transferred to the other logs.

The complete log suite for borehole KLX06 is presented as composite log sheets in drawing no 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 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
KLX06	8044	Down	KLX06_01-04-05_11-55_8044C_.02_ 0.28_992.40_ORIG.log	Start Depth: 0.28 m. End Depth: 992.4 m
KLX06	8622	Up	KLX06_01-05-05_08-44_8622C_.10_ 3.10_995.10_ORIG.log	Start Depth: 995.1 m. End Depth: 3.1 m
KLX06	9030	Up	KLX06_01-04-05_17-28_9030CA_.10_ 0.80_993.20_ORIG.log	Start Depth: 993.2 m. End Depth: 0.8 m
KLX06	9072	Down	KLX06_01-05-05_12-23_9072C_.10_ 34.20_997.50_ORIG.log	Start Depth: 34.2 m. End Depth: 997.5 m
KLX06	9310	Up	KLX06_01-04-05_19-37_9310C2_.10_-1.30_992.90_ORIG.log	Start Depth: 992.9 m. End Depth: -1.3 m
KLX06	9310	Up	KLX06_01-04-05_15-35_9310C2_.10_-0.50_698.10_ORIG.log	Start Depth: 698.1 m. End Depth: -0.5 m
KLX06	HiRAT	Up	KLX06_HiRAT_90_pixels_UP_run2.HED	Start Depth: 980 m. End Depth: 0 m

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KLX06	1.1	KLX06_Presentation.WCL

Table 6-3. Data files in SICADA format.

Sheet	Comment
KLX06_GP040 – Caliper logging.xls	
KLX06_GP041 – 3-D caliper.xls	
KLX06_GP060 – Fluid temperature and resistivity logging.xls	
KLX06_GP090 – Density logging.xls	
KLX06_GP110 – Magnetic susceptibility logging.xls	
KLX06_GP120 – Natural gamma logging.xls	
KLX06_GP150 – Single point resistance logging.xls	
KLX06_GP160 – Resistivity, normal 1.6 m (64 in).xls	
KLX06_GP161 – Resistivity, focused 140 cm.xls	
KLX06_GP162 – Resistivity, focused 300 cm.xls	
KLX06_GP163 – Resistivity, lateral 1.6–0.1 m.xls	
KLX06_GP164 – Resistivity, normal 0.4 m (16 in).xls	
KLX06_GP175 – Fullwave sonic.xls	
KLX06_GP830 – Acoustic televiewer_ny_20050120.xls	

Appendix

Borehole KLX06. Drawing no 1.1. Borehole logs

Borehole No. KLX06

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

Northing: 6367806,637 Easting: 1548566,882 Elevation: 17,681

Diameter:	76 mm
Reaming Diameter:	195 mm
Outer Casing:	208 mm
Inner Casing:	200 mm
Borehole Length:	994,94 m
Cone:	97 - 101,40 m
Inclination at ground surface:	-65.015 deg
Azimuth:	330,208 deg
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
SP	Self Potential	8044	mV

Rev.	Date	Drawn by	Control	Approved
0	2005-01-14	UTN	JRI	UTN

Job: 360210A
Scale: 1:500

RAMBØLL

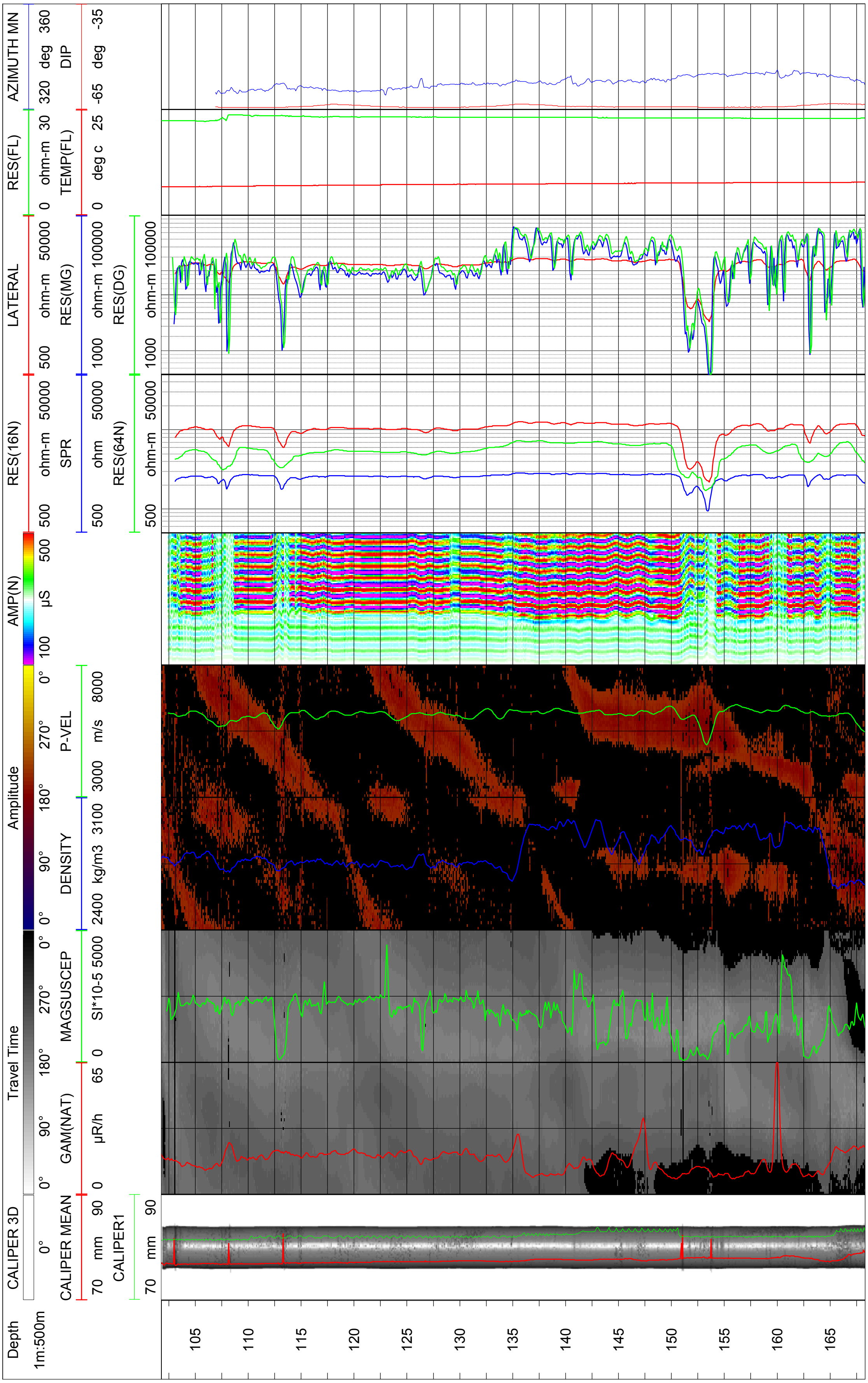
Rambøll, Bredevej 2, DK-2830 Virum
Phone + 45 45 98 60 00, Fax + 45 45 98 67 00

SKB geophysical borehole logging
Borehole KLX06 Oskarshamn

Presentation

Filename:
KLX06_Presentation.wcl

Drawing no.:
1.1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0 µR/h 65
MAGSUSCEP
0 SI*10-5 5000
Amplitude
0° 90° 180° 270° 0°
DENSITY
2400 kg/m3 3100
P-VEL
3000 m/s 8000
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100 µS 500
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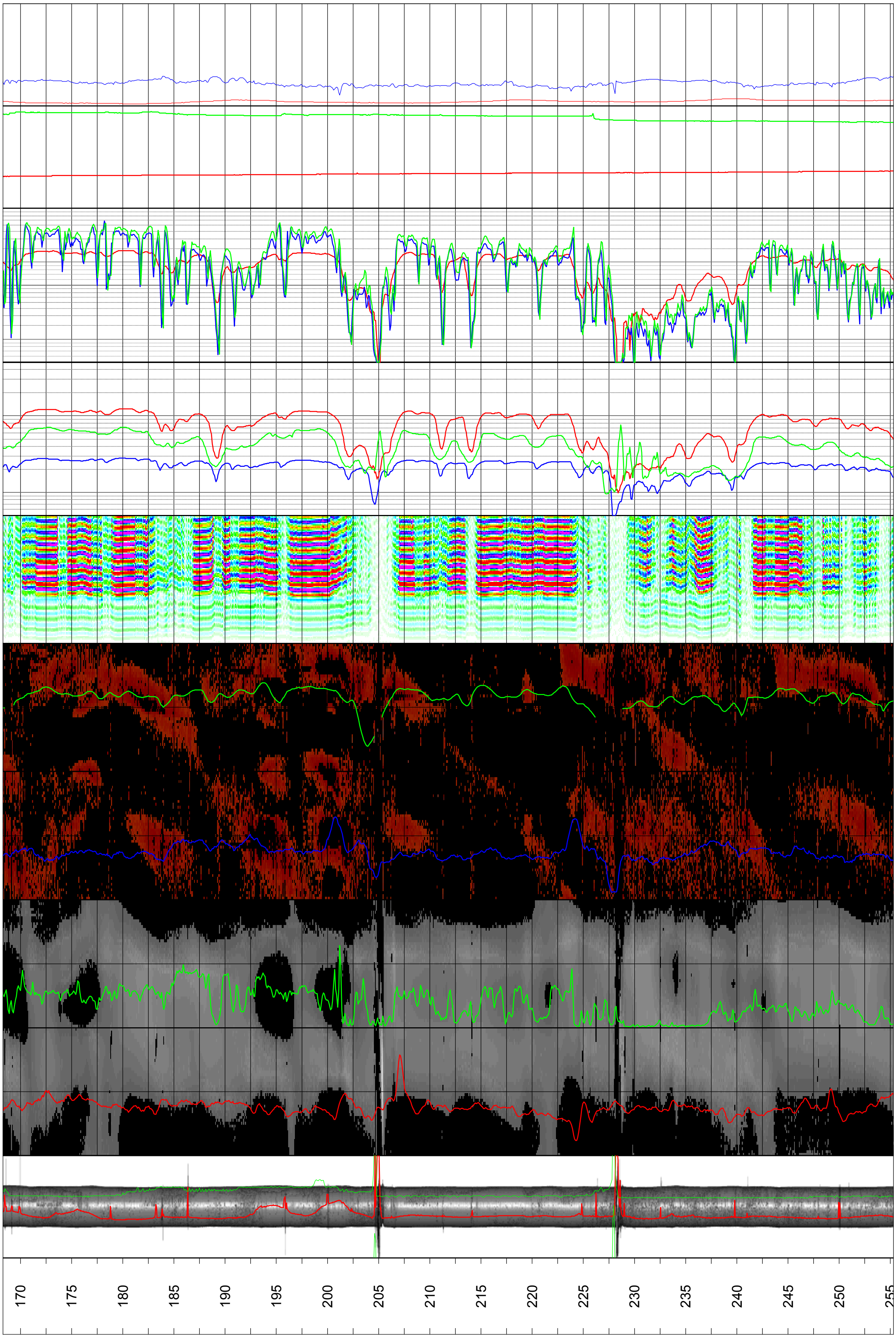
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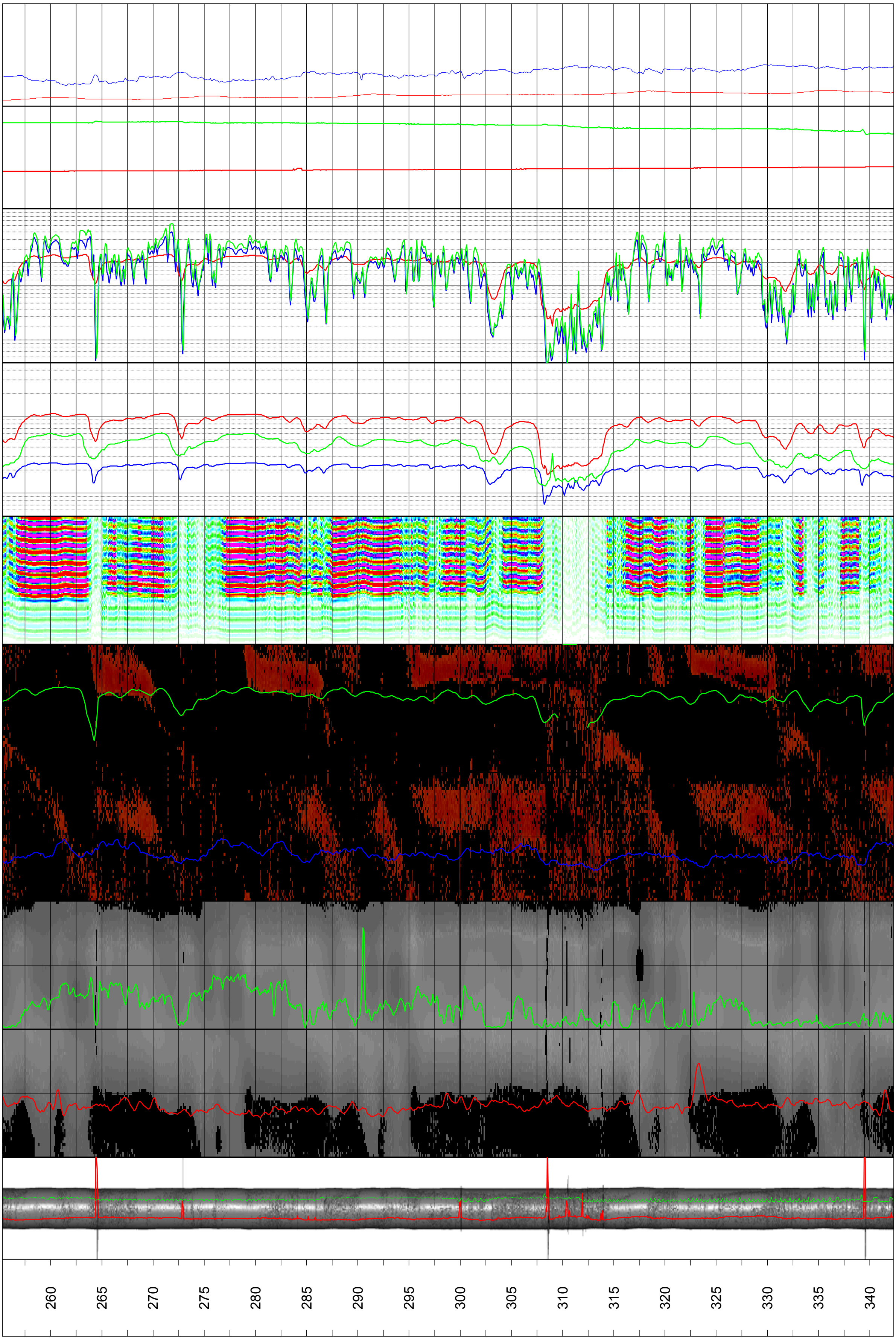
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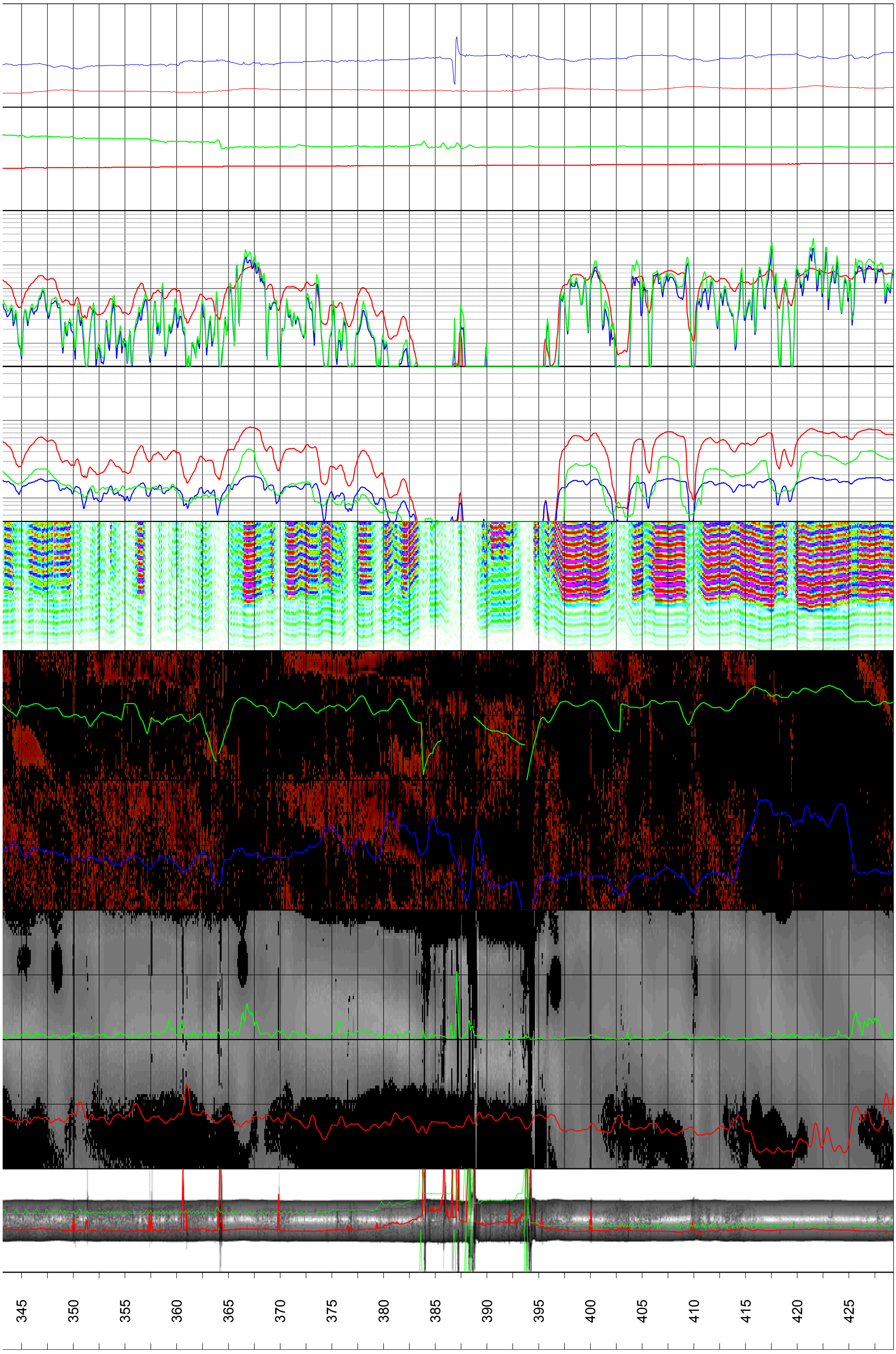
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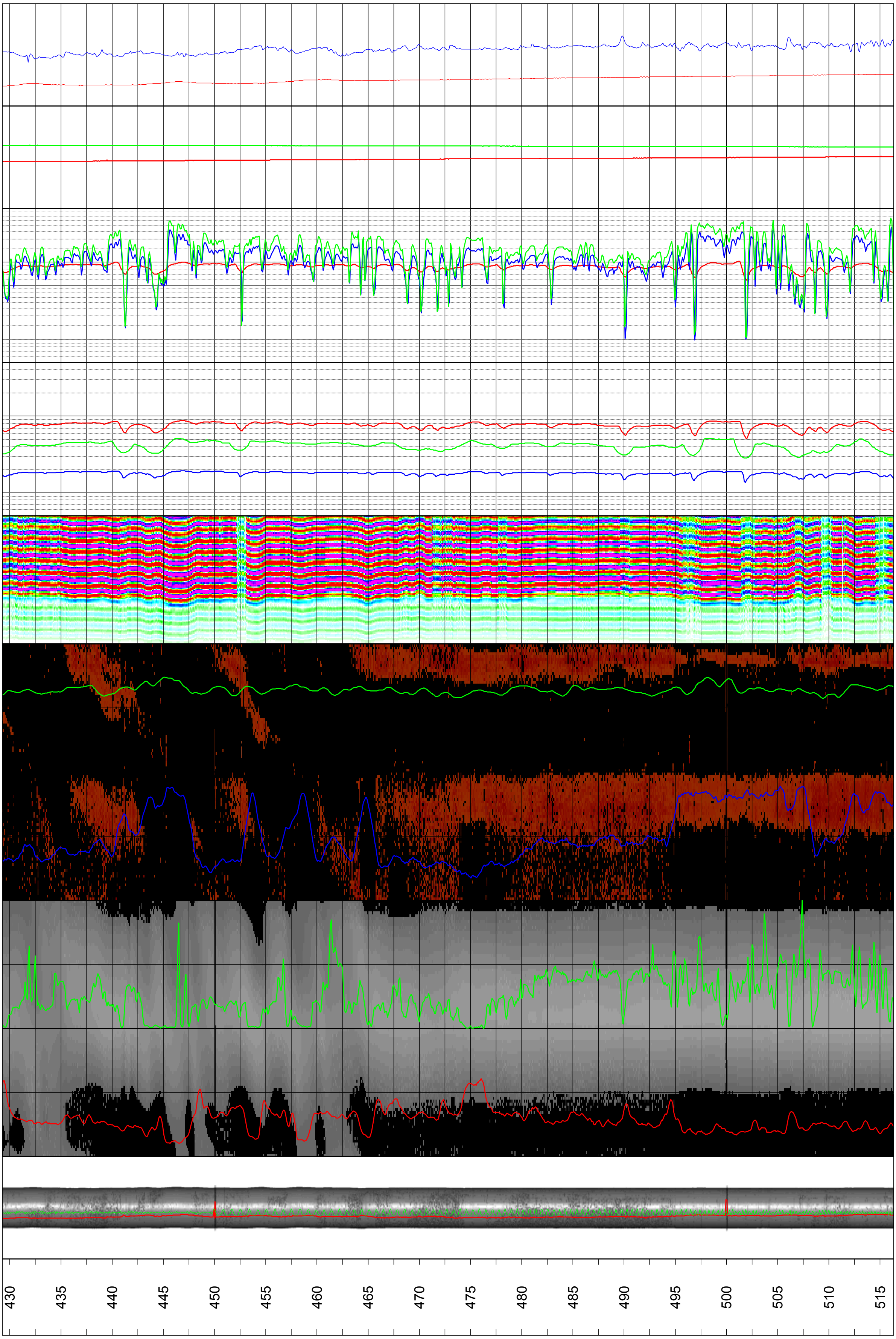
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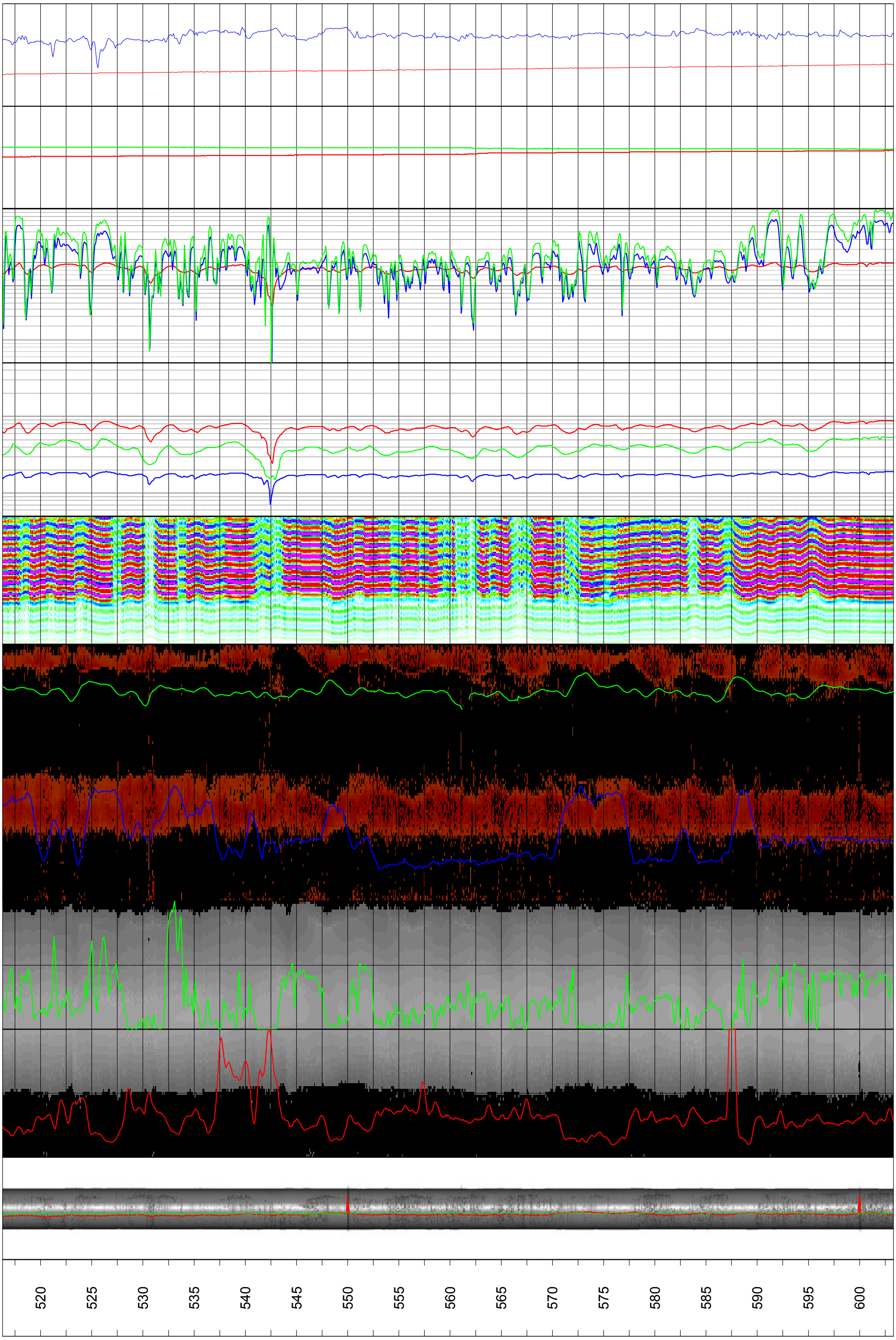

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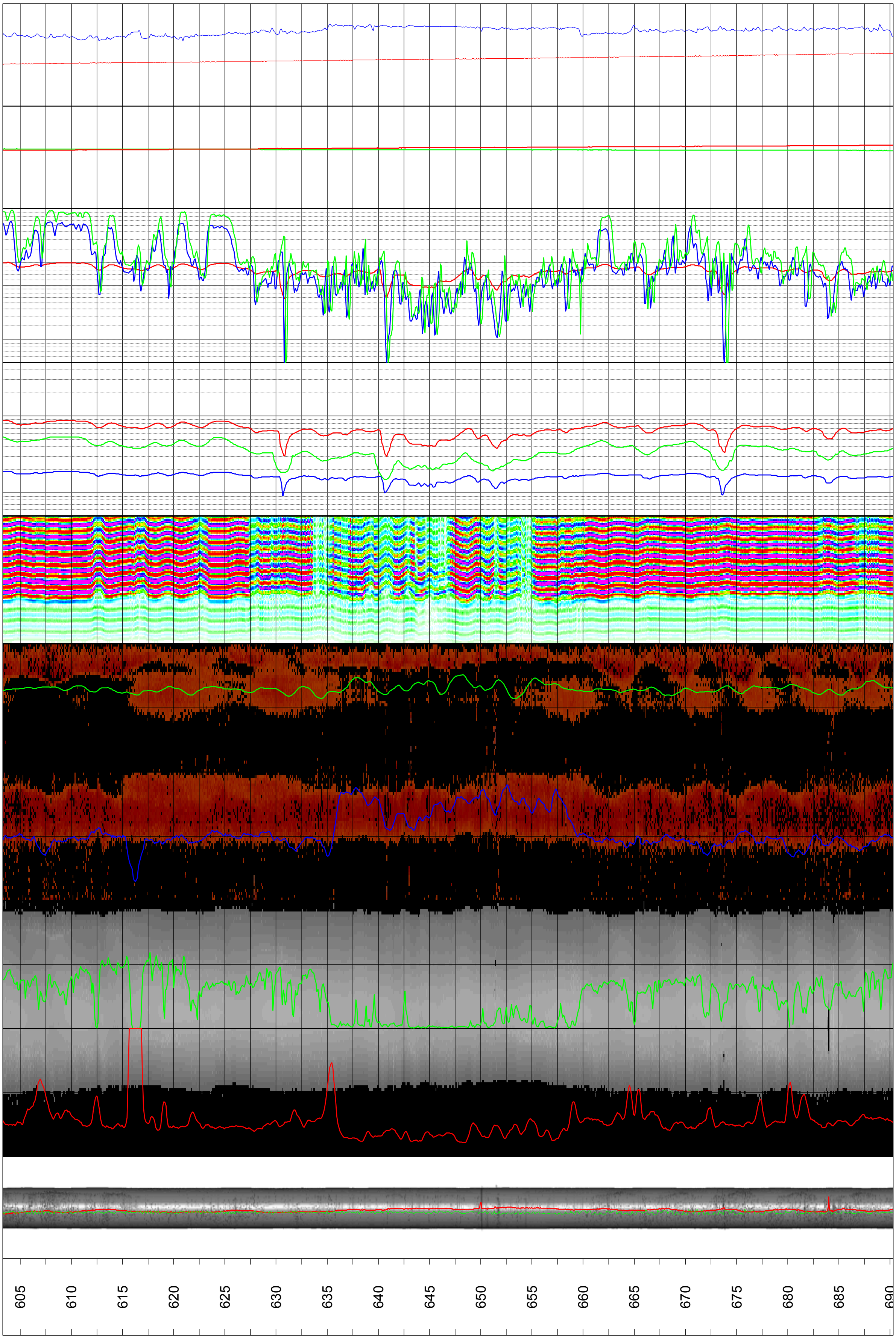
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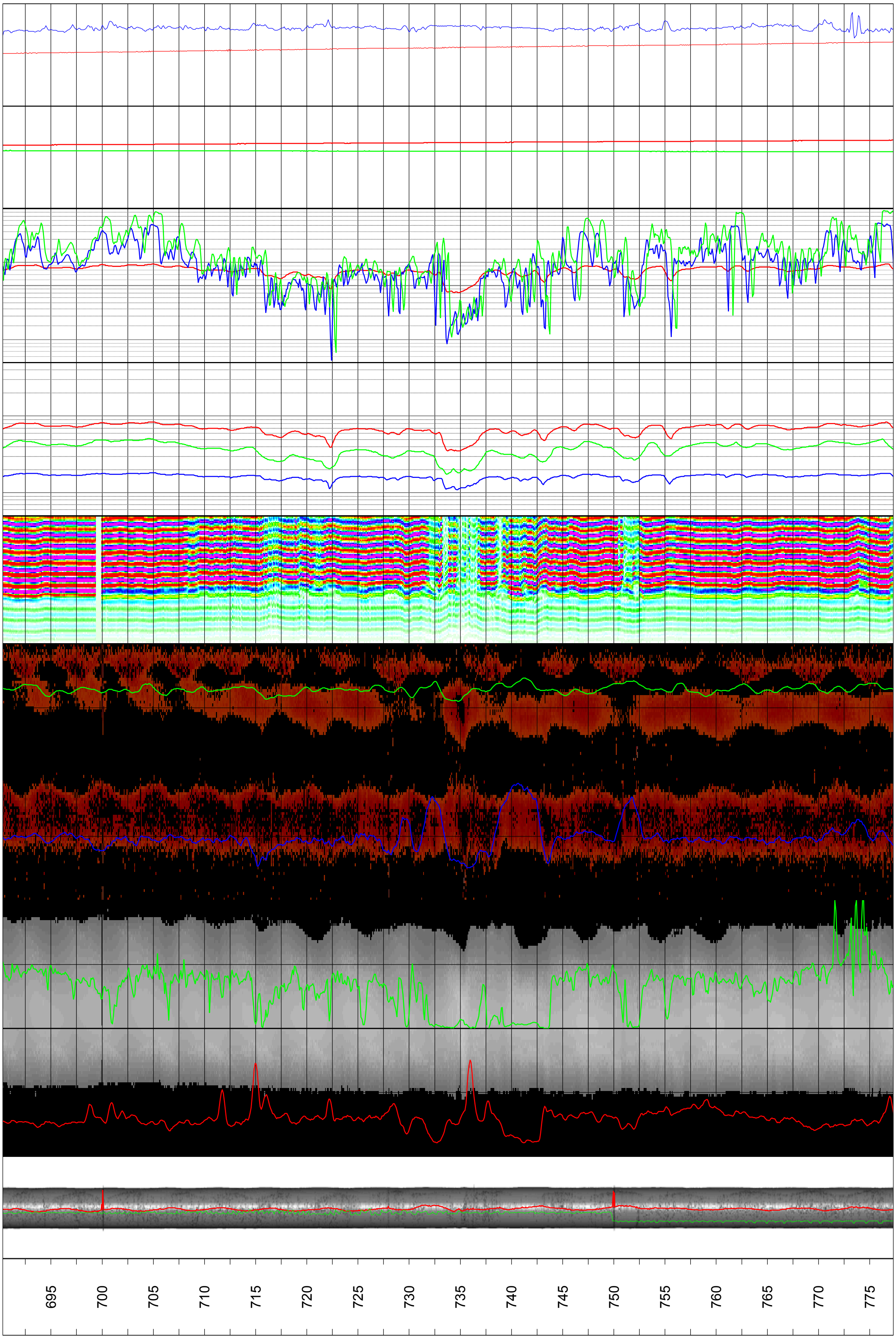
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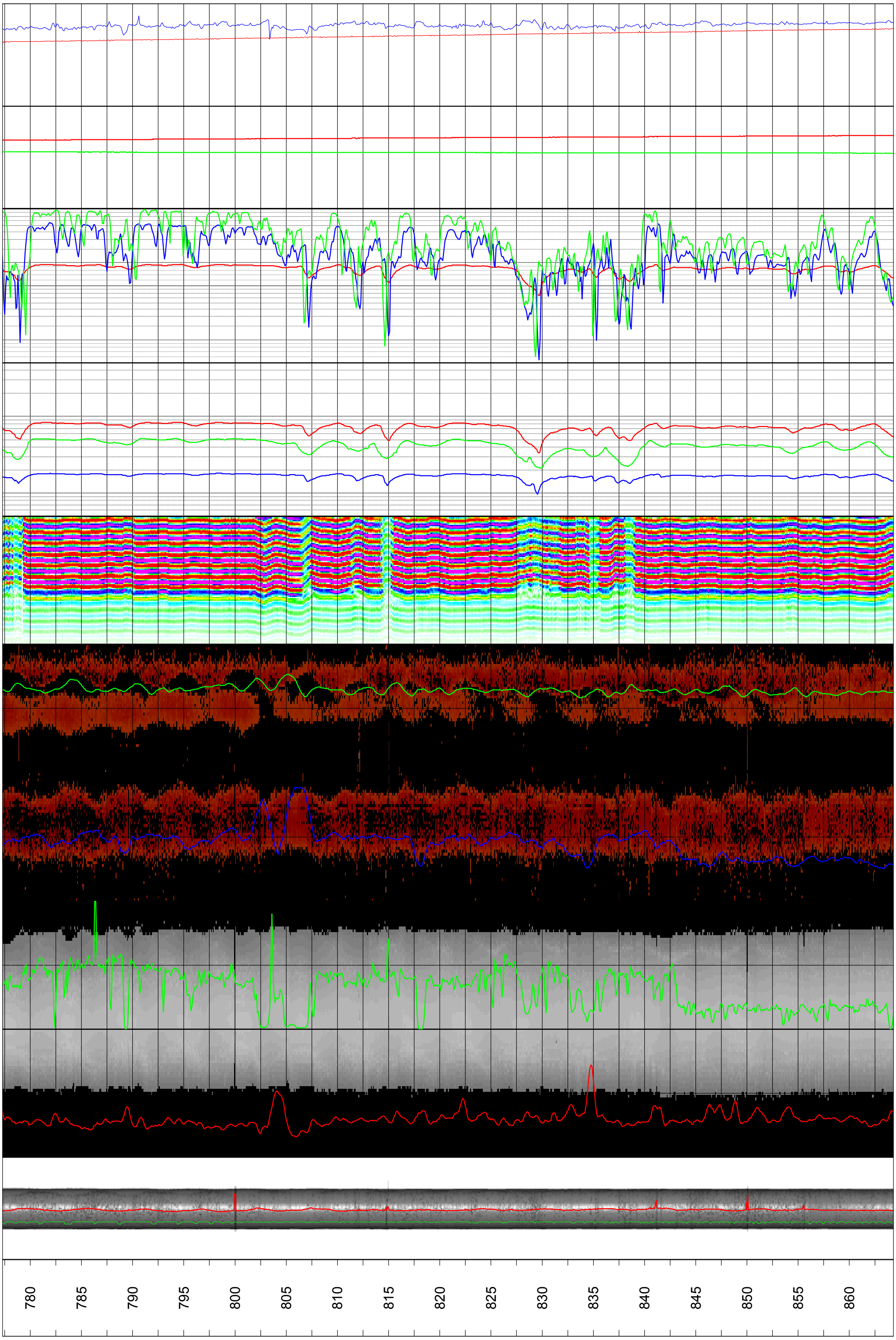
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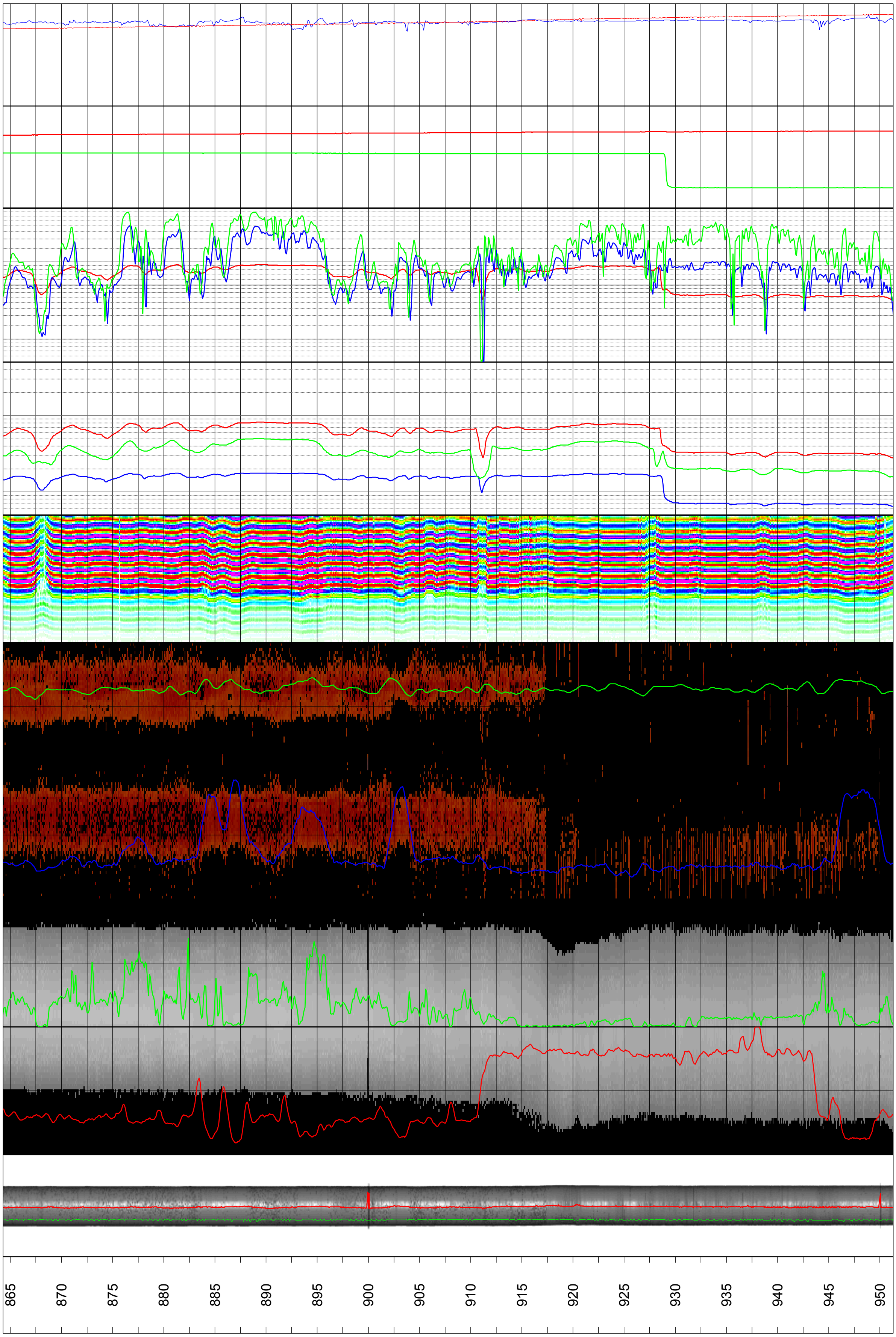
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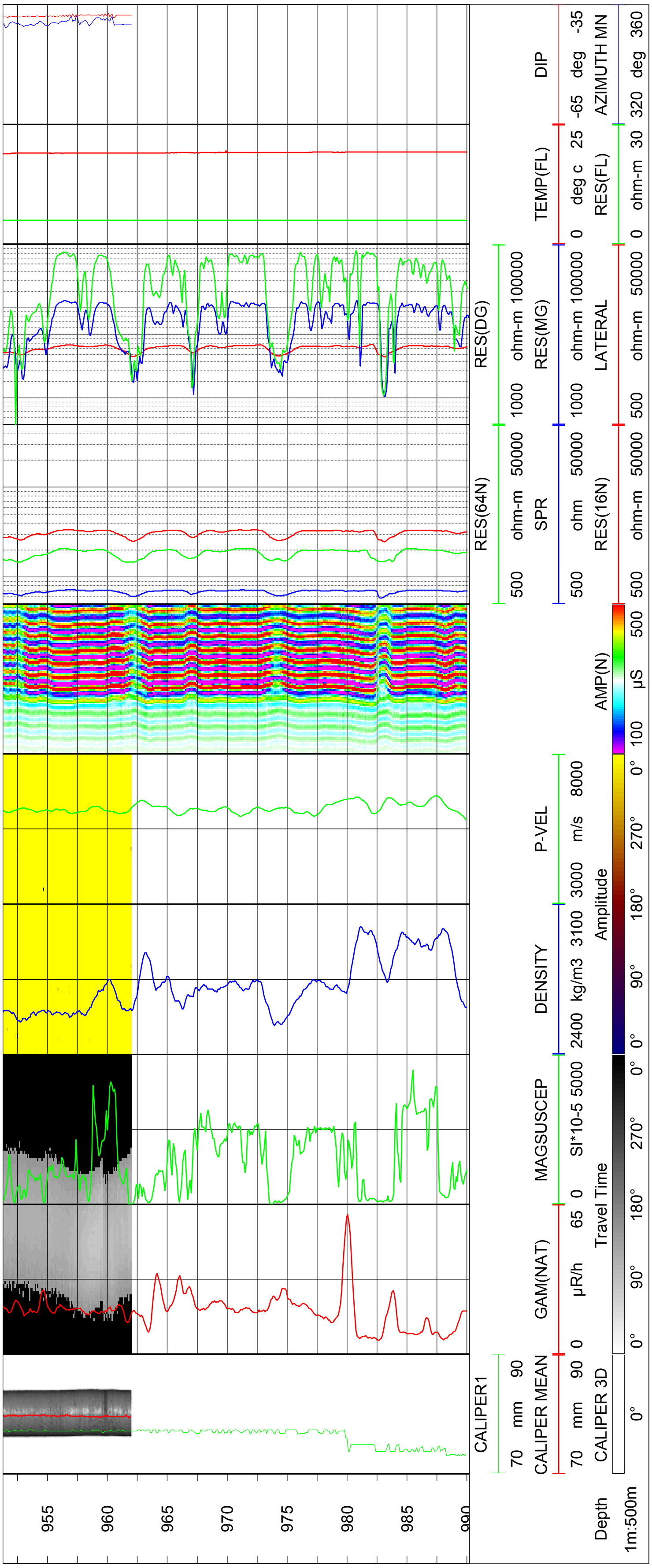
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CALIPER MEAN
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CALIPER 3D
0°
GAM(NAT)
0 µR/h 65
Travel Time
0° 90° 180° 270°
MAGSUSCEP
0 SI*10-5 5000
0° 90° 180° 270° 0°
DENSITY
2400 kg/m3 3100
Amplitude
P-VEL
3000 m/s 8000
AMP(N)
100 µS 500
RES(64N)
500 ohm-m 50000
SPR
500 ohm 50000
RES(16N)
500 ohm-m 50000
RES(DG)
1000 ohm-m 100000
RES(MG)
1000 ohm-m 100000
LATERAL
500 ohm-m 50000
TEMP(FL)
0 deg c 25
RES(FL)
0 ohm-m 30
DIP
-65 deg -35
AZIMUTH MN
320 deg 360