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Oskarshamn site investigation

Geophysical borehole logging in borehole KAV01

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RAMBØLL

July 2004

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Abstract

Geophysical borehole logging has been performed in borehole KAV01 situated in Simpevarp, Sweden.

The objective of the surveys is to determine 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 KAV01 was recorded from 0 m to 740 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.

Sammanfattning

Geofysisk borrhålsloggning har genomförts i borrhål KAV01 i delområde Simpevarp, 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 KAV01 från 0 m till 740 m.

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

Contents

1 Introduction

This document reports the results gained by the geophysical borehole logging in borehole KAV01, 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 400-03-031 (SKB internal controlling document). In Table 1-1 controlling documents for performing this activity are listed.

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

Activity plan	Number	Version
Geofysisk borrhålsloggning i KSH02 samt KAV01.	AP PS 400-03-031	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

All measurements were conducted by RAMBØLL during September 30 until October 5, 2003. KAV01 was recorded from ground level to 740 metres. The technical data from the boreholes are shown in Table 1-2. The borehole is cored with a diameter of 56 mm and a slight inclination of app. –89° from the horizontal plan.

The location of the borehole is shown in Figure 1-1.

Table 1-2. Technical data for core borehole KAV01.

Boreholes parameter	KAV01
Co-ordinates (RT90)	6367257,524 N 1553084,922 E
Elevation (RHB70)	14,100 m
Inclination (from horizontal)	–89°
Azimuth	225°
Length	743 m
Borehole diameter	Ø 76 mm (0–743 m)
Casing	11.74 m
Cleaning level	Level 1

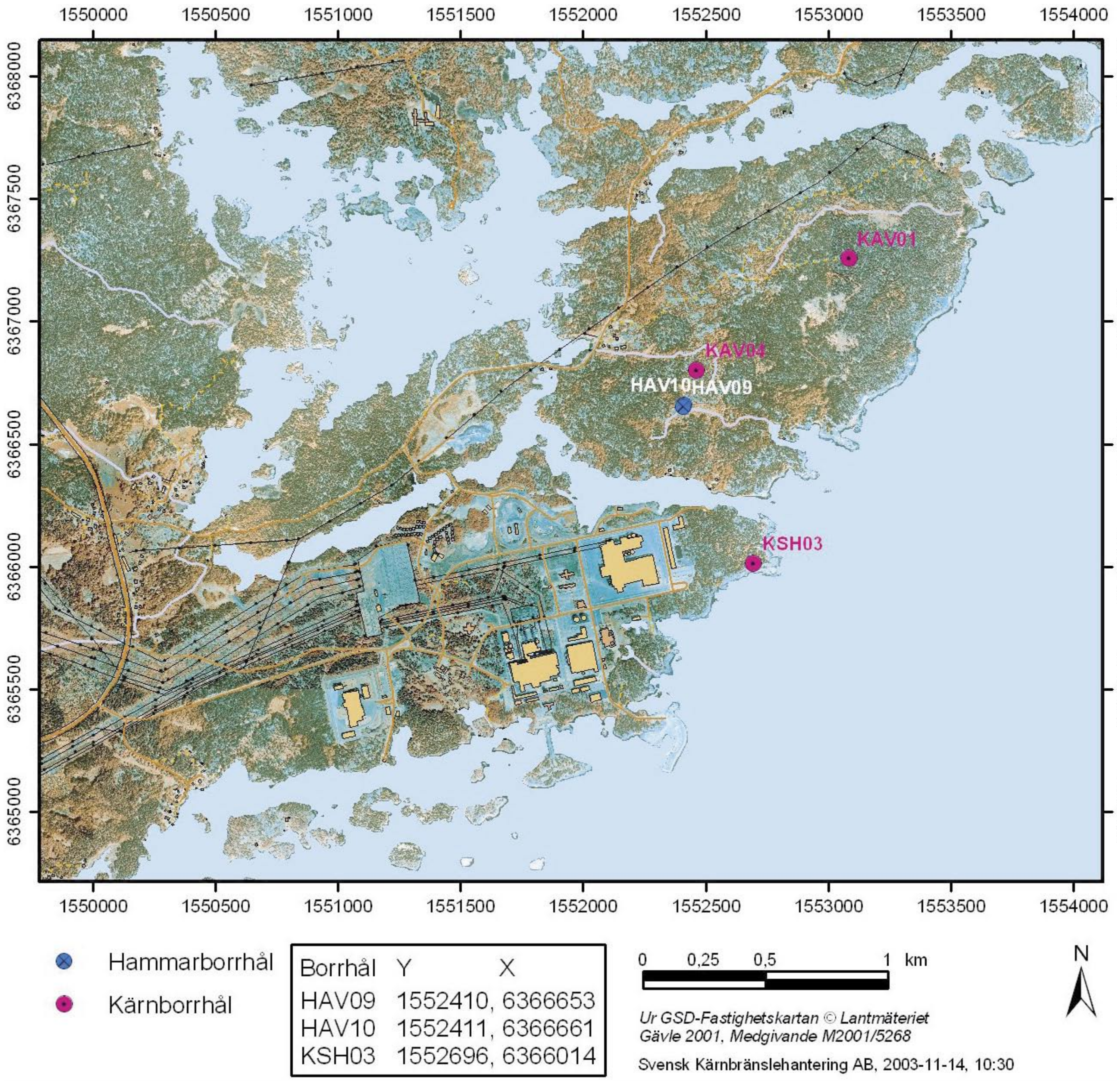


Figure 1-1. *General overview over the Simpevarp subarea and location of borehole KAV01 situated on the Ävrö island.*

The delivered data have been inserted in the database (SICADA) of SKB and field notes no are presented in Table 1-3.

Table 1-3. Data references.

Subactivity	Database	Identity number
Geofysiska loggningar i borrhålen KSH02, KLX02 och KAV01	SICADA	Field note 109
Geofysisk borrhålsloggning KAV01	SICADA	Field note 149

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. Acoustic televiewer was used for determination of the deviation of the borehole (azimuth and inclination).

This field report describes the equipment used as well the measurement procedures. Geophysical borehole logging data is presented in graphs as a function of depth in drawing no 1.1 for borehole KAV01 in Appendix 1.

3 Equipment

The geophysical borehole logging program in all boreholes was performed with 3 multi tool probes and resulted in a suite of 10 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 KAV01.

Tool	Recorded logs	Dimension	Source detector spacing and type	Tool position in borehole
Robertson FDGS Gamma density	Gamma density and 10 cm 1-arm calliper.	307×5.6 cm	20.3 cm 125 mCi Cs137	Sidewall. Gamma source focused.
Century 9042 Fluid temperature and resistivity	Fluid Conductivity, Fluid Temperature and natural gamma.	237×5.3 cm		–
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.	246×4 cm		Centralized.

4 Execution

In general the measurement procedures follow the SKB method description (MD 221.002, SKB internal controlling documents). The logging program in borehole KAV01 was executed during the period September 30 to October 5, 2003.

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 cleaned according to SKB cleaning level 1 (SKB internal controlling document SKB MD 600.004) before arriving at the site.

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 FDGS 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.

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

4.1 Nonconformities

There were no nonconformities according to the Activity plan.

5 Results

5.1 Presentation

All relevant logging events were described in the daily report sheet which was delivered separately. A function test of the deviations measurements in the HiRAT tool was performed before arriving at the site, following SKB internal controlling document SKB MD 224.001.

The logs have not been filtered during logging or presentation. Logs presented in drawing no 1.1 in Appendix 1 are presented in Table 5-1.

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

Log	Log name short	Unit	Tool
Caliper, 1-arm	CALIPER1	mm	FDGS
Gamma-gamma density	DENSITY	kg/m^3	FDGS
Natural gamma	GAM(NAT)	μR/h	FDGS
Fluid temperature	TEMP(FL)	deg C	9042
Fluid resistivity	RES(FL)	ohm-m	9042
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, 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 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 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 values and data in the casing. The caliper logs, azimuth and dip have not been removed in the casing.

5.3 Calculated log curves

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

Table 5-2. Calculated log curves.

Log	Description of log calculation
Caliper, 1-arm	The Caliper was converted from [cm] to [mm] units by multiplying [cm] with 10.
Gamma-gamma density	The Gamma-gamma was converted from [g/cm^3] to [kg/m^3] units by multiplying with 1,000.
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	–
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 amplitude	–
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.

```
Model: IGRF2000
Latitude: 57 deg, 24 min, 49 sec
Longitude: 16 deg, 39 min, 46 sec
Elevation: 0.03 km
Date of Interest: 7/2/2003
D(+East)(deg)  I (+Down)(deg)
  3 d    8 m      71 d   17 m
```

5.4 Borehole KAV01

In order to obtain an exact depth calibration, as described in 5.2.3, the track marks are used. The connection between the track marks and the logs is obtained from the HiRAT Acoustic tool.

The HiRAT image logs are shifted 2.00 m down and the natural gamma 0.57 m down. To obtain a common depth reference point, the track mark at 99.1 m in the HiRAT file is used as the marker at depth 100 m. The HiRAT tool is therefore shifted 0.9 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 5-3.

Table 5-3. 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
100.00	99.10	100
150.00	149.10	150
200.00	199.12	200.02
250.00	249.10	250
300.00	299.11	300.01
350.00	349.14	350.04
400.00	399.05	399.95
451.00	450.02	450.92
500.00	498.99	499.89
550.00	548.91	549.81
600.00	598.87	599.77
650.00	648.78	649.68
700.00	698.89	699.79

A new depth scale is made using the corrected depth shown in Table 5-3. 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 is obtained. By means of alignment of the observed gamma events in Table 5-4, between all logruns, the obtained reference mark correlation is transferred to the other logs.

Table 5-4. Gamma events in borehole KAV01.

Events	Depths
Top event	118.16
Bottom event	737.94

The complete log suite for borehole KAV01 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

6.1 Delivery of logging data

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. The SICADA reference to the present activity is field notes no 109 and 149 respectively.

The processed files shown on the drawing have been 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.

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

Borehole	Probe	Log direction	WellCAD File	Start and End Depth
KAV01	9042	Down	KAV01_10-01-03_14-05_9042C_.04_0.24_744.13_ORIG.log	Start Depth: 0 m. End Depth: 742 m.
KAV01	FDGS	Up	KAV01_FDGS_Up_run1.LOG	Start Depth: 740 m. End Depth: 0 m.
KAV01	FDGS	Up	KAV01_FDGS_Up_run2.LOG	Start Depth: 740 m. End Depth: 0 m.
KAV01	HiRAT	Up	KAV01_HiRAT_up_120pixels_125uS_run2.LGX	Start Depth: 739 m. End Depth: 331 m.
KAV01	HiRAT	Up	KAV01_HiRAT_down_120pixels_run3.LGX	Start Depth: 335 m. End Depth: 0 m.

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KAV01	1.1	KAV01_Presentation.WCL
KAV01	1.2	KAV01_Deviation.WCL
KAV01	1.3	KAV01_Deviation.WCL

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

Borehole	Excel file
KAV01	KAV01 _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
Caliper1	
Caliper Mean	Calculated using Fluid resistivity and Acoustic televiewer
Fluid resistivity	
Fluid Temperature	
Density	
Natural gamma	

6.2 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.

6.3 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.

Appendix 1

Borehole KAV01, drawing no 1.1, borehole logs

Borehole No. KAV01

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

X: 6367257.524 m Y: 1553084.922 m Z: 14.1 m, RHB70

Diameter:	56 mm
Reaming Diameter:	
Outer Casing:	
Inner Casing:	160 mm
Borehole Length:	740
Cone:	70-72 m
Inclination at ground surface:	-89 deg.
Azimuth:	225 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	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	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

Rev.	Date	Drawn by	Control	Approved
2	2003-12-10	JRI	TVP	UTN

Job	Scale
360210A	1:500

DGE Dansk Geo-servEx a/s — RAMBØLL

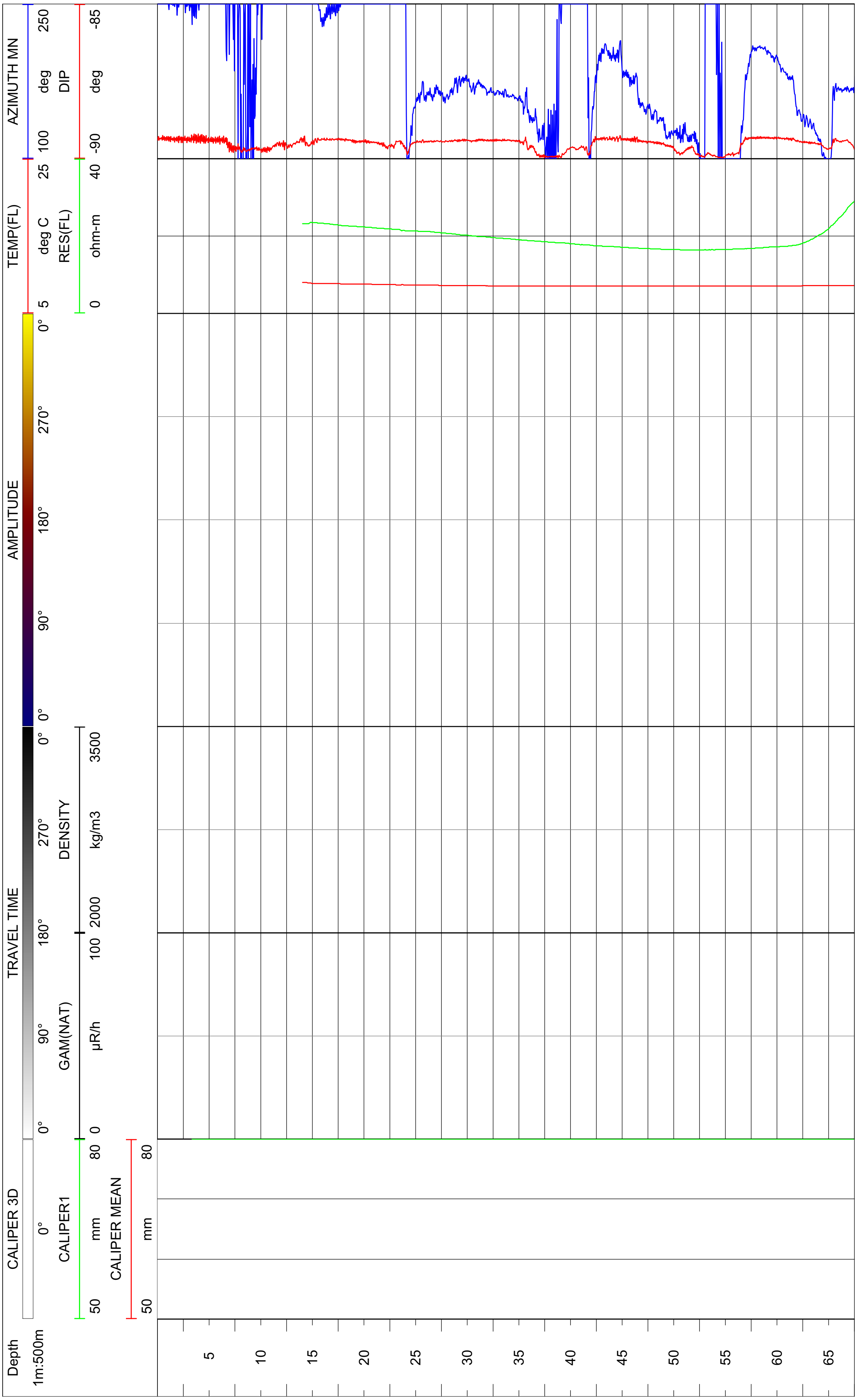
DGE, Håndværkersvinget 11, 2970 Hørsholm, Phone +45 70 10 34 00, Fax + 45 39 16 39 90
RAMBØLL. Bredevej 2, DK-2830 Virum, Phone + 45 45 98 60 00, Fax + 45 45 98 67 00

SKB geophysical borehole logging
Borehole KAV01 Ävrö

Presentation

Filename:
KAV01_Presentation_1.wcl

Drawing no.:
1.1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DENSITY
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AMPLITUDE
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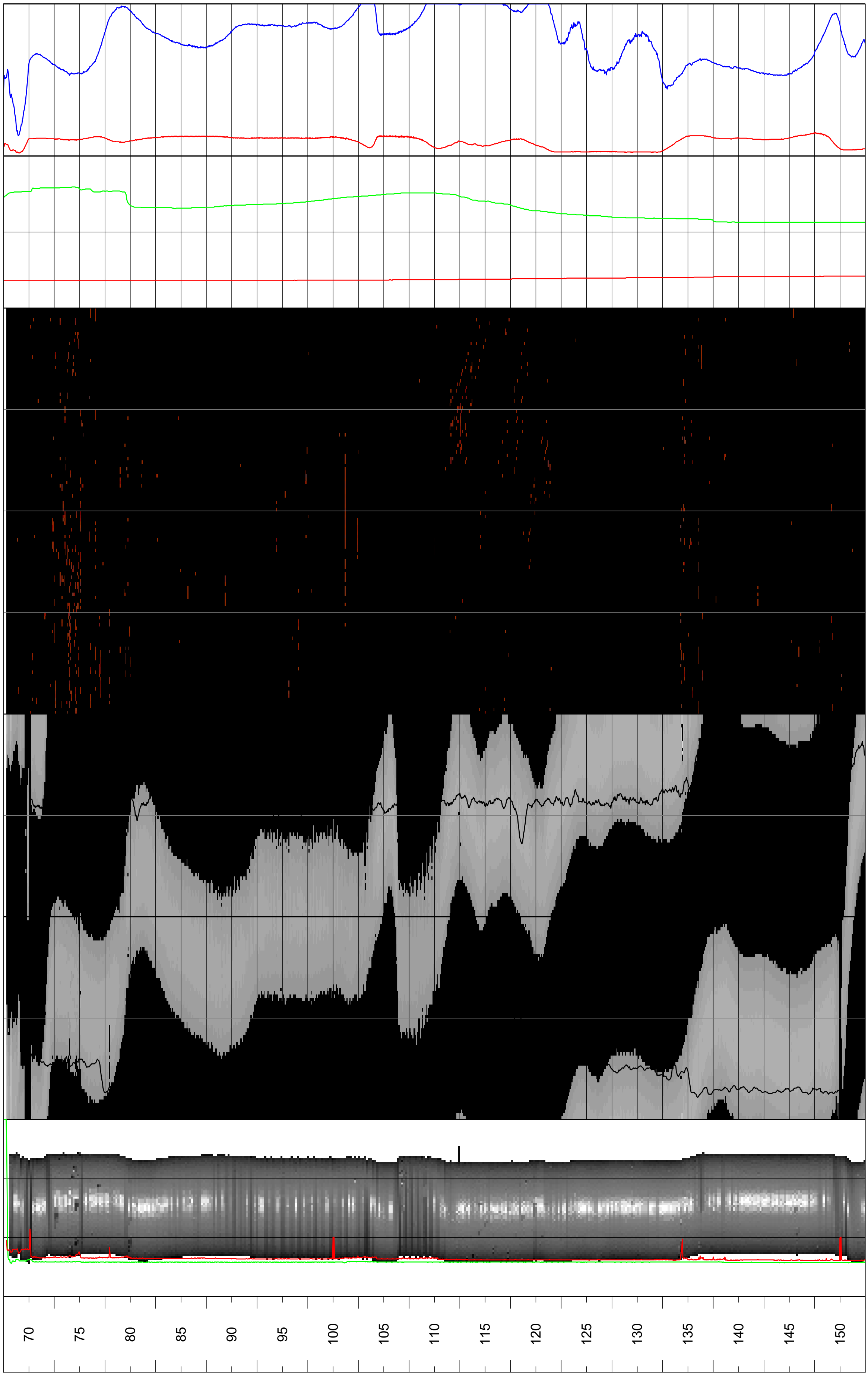
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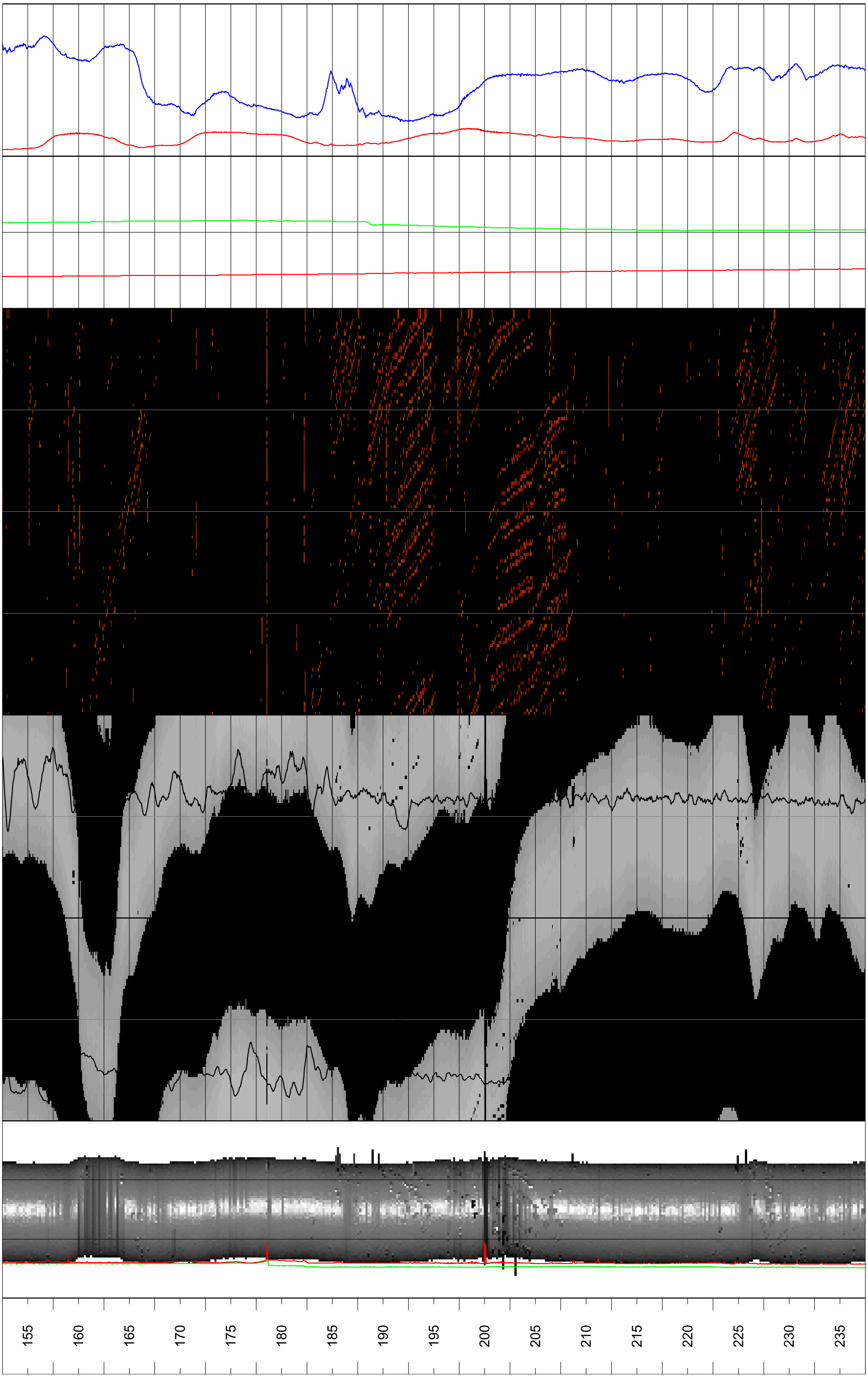
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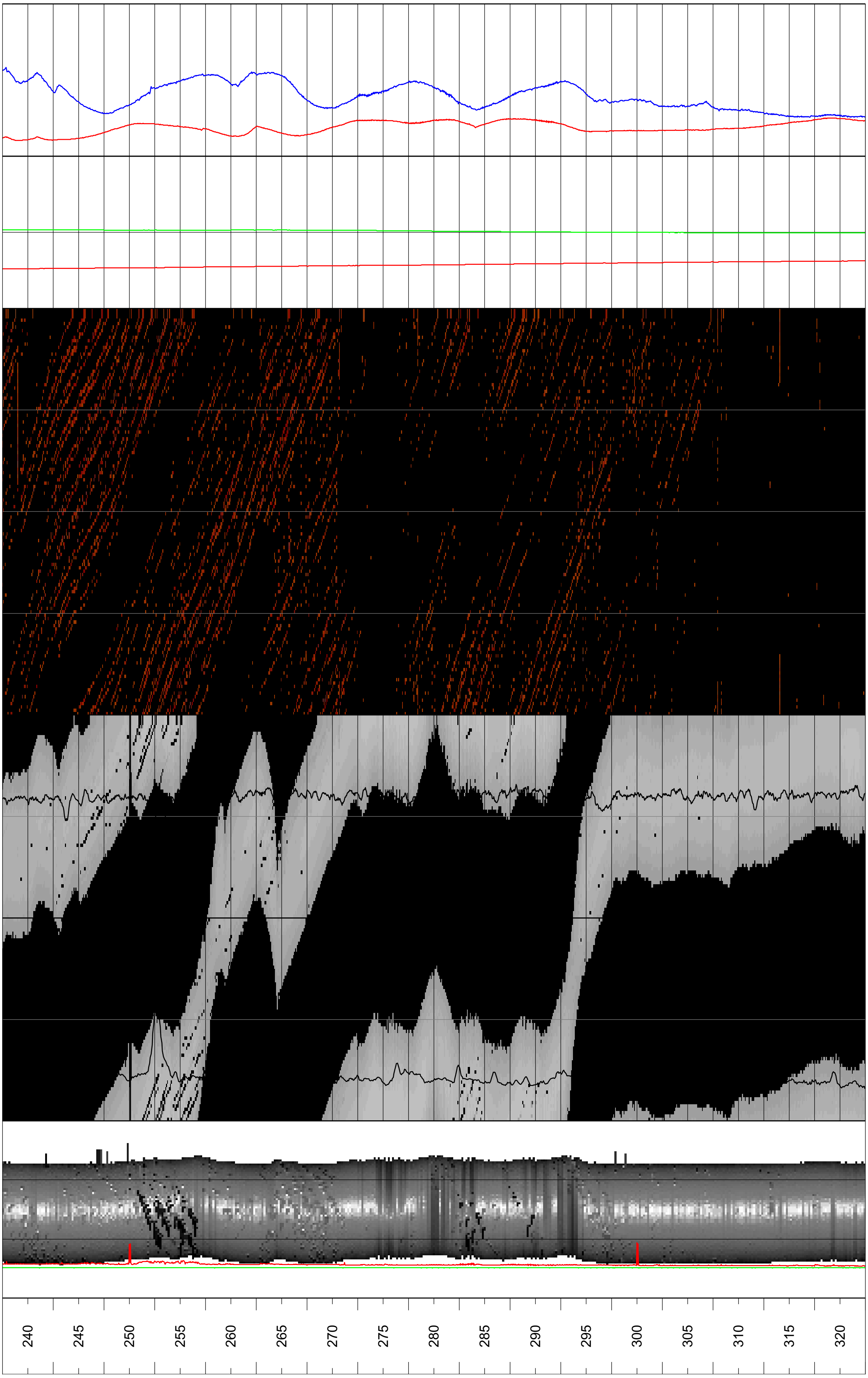
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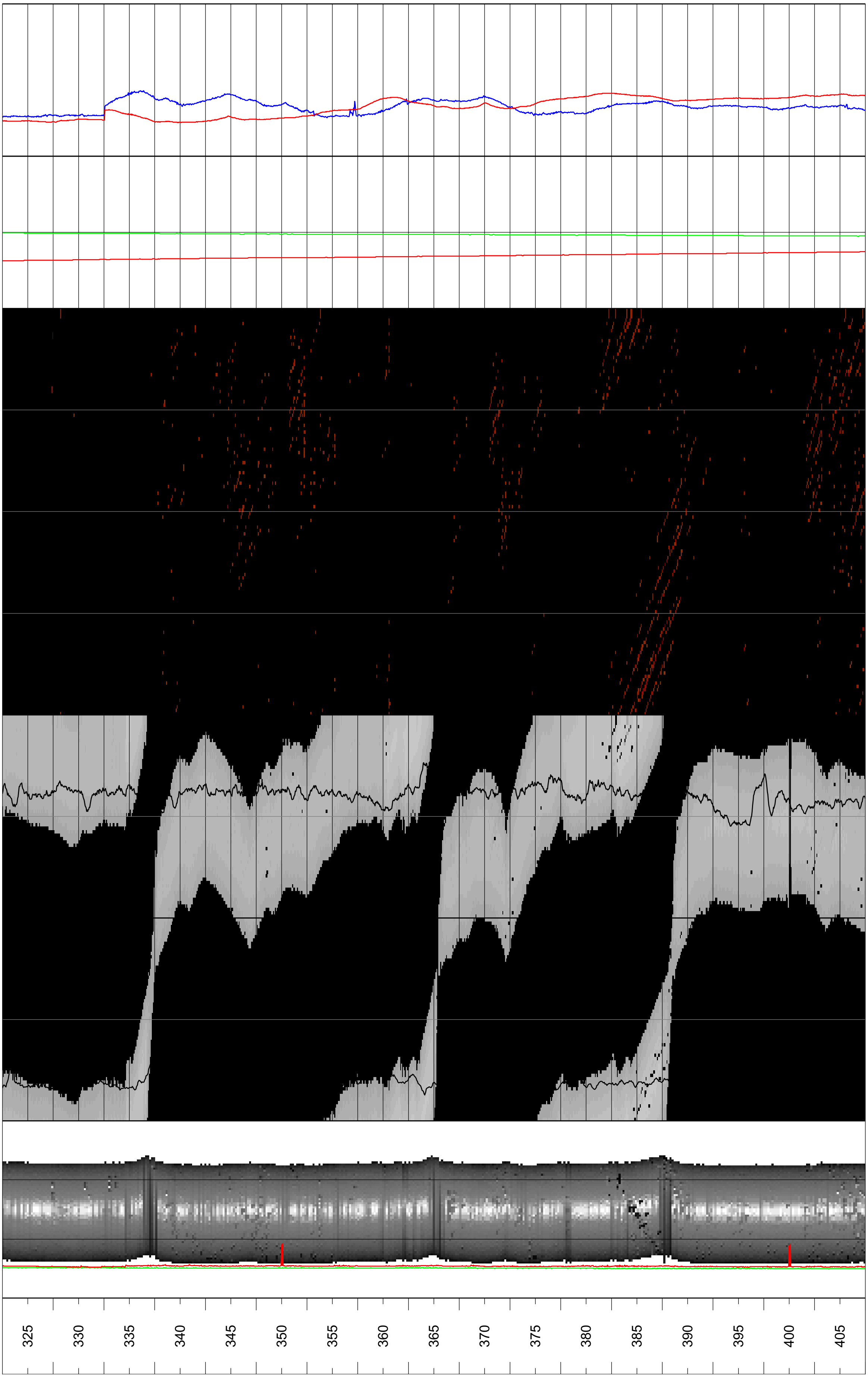
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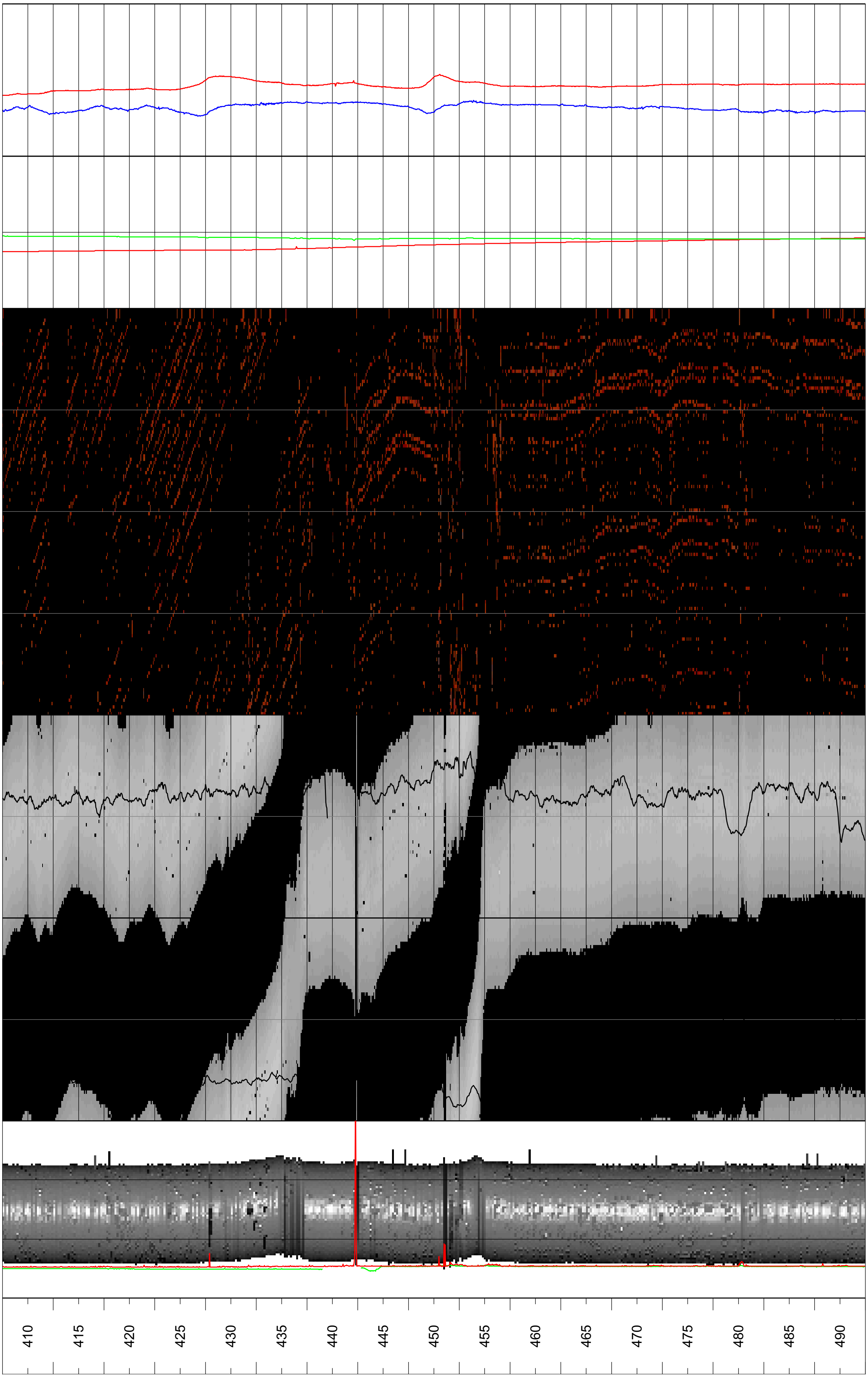
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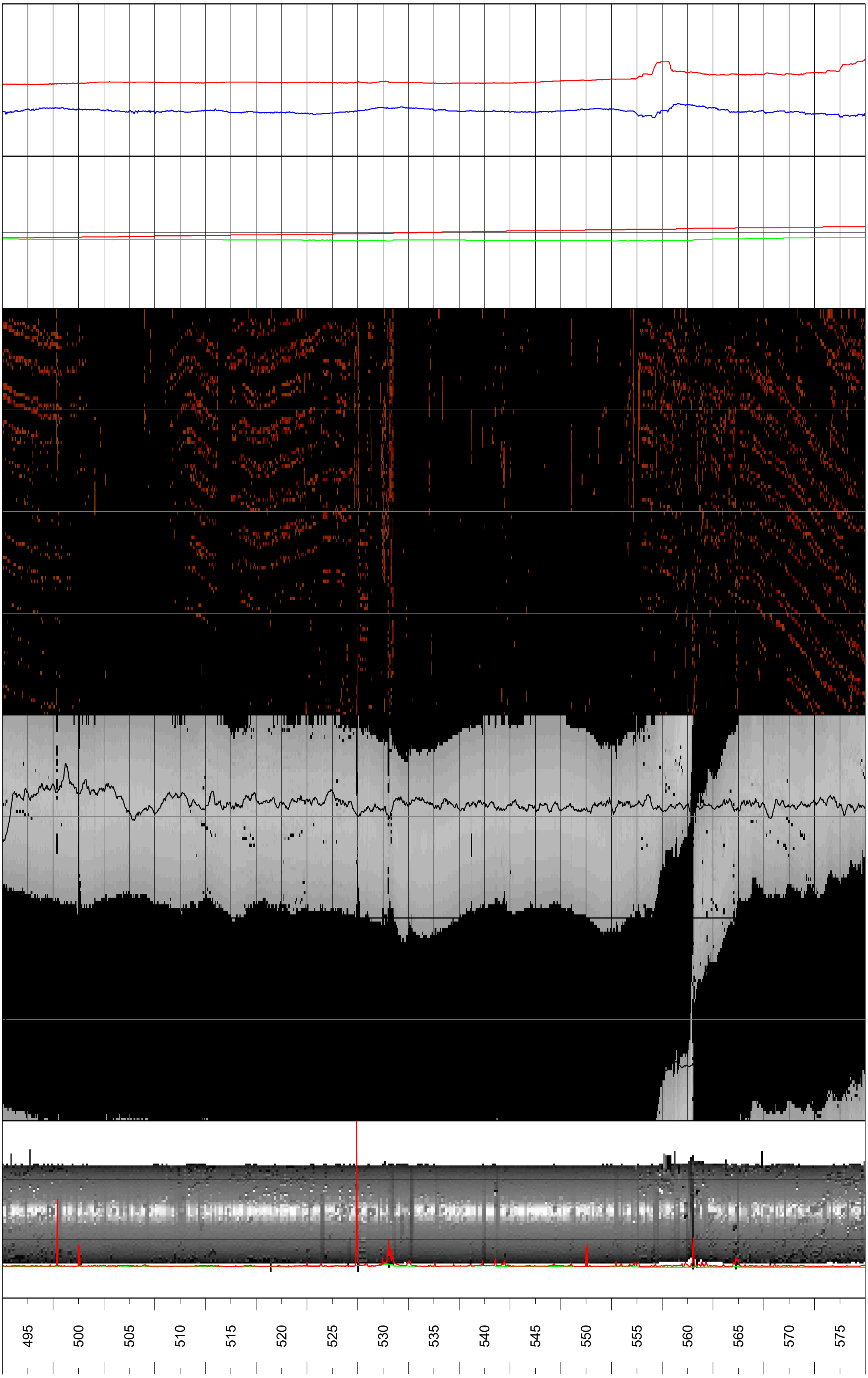

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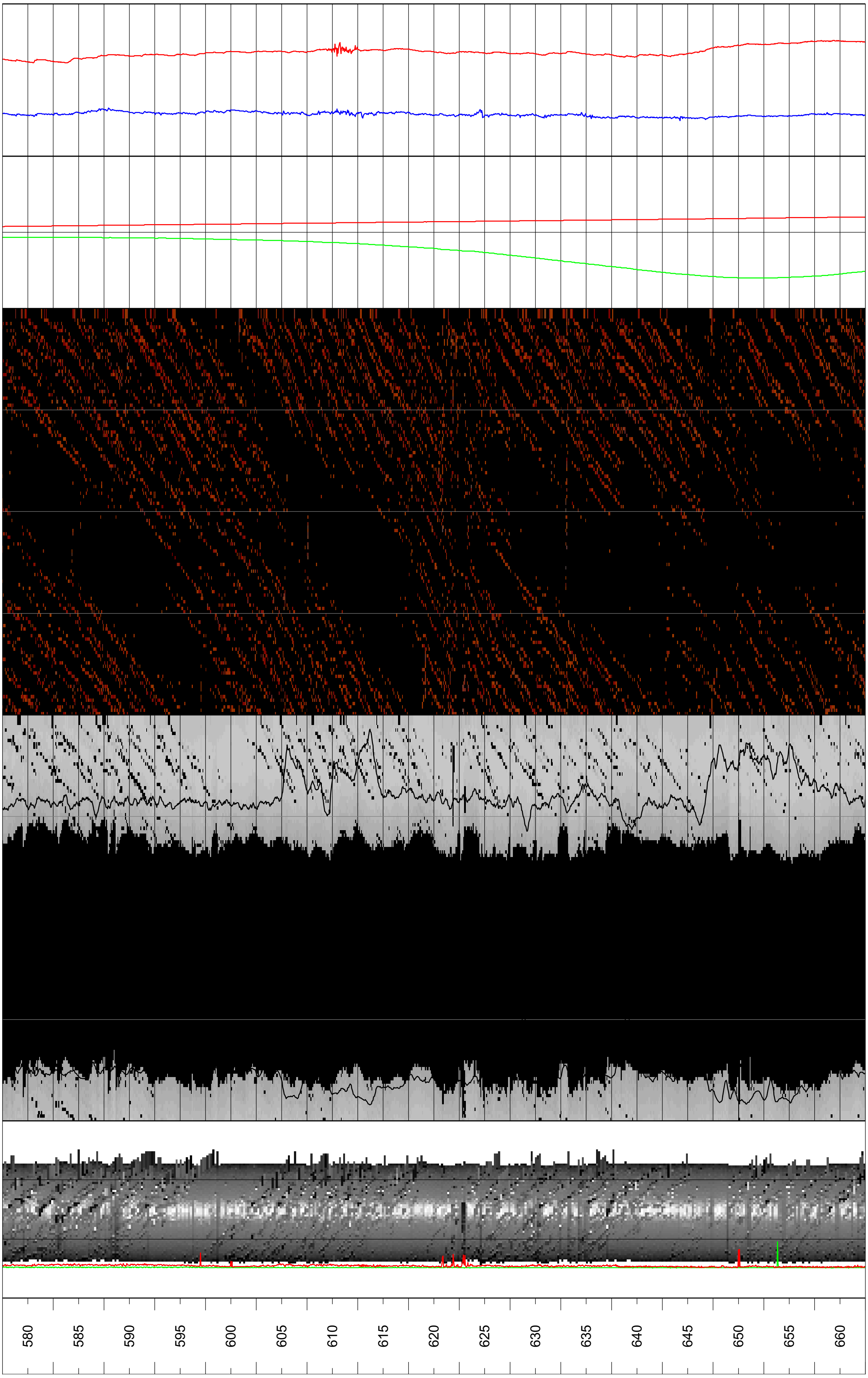
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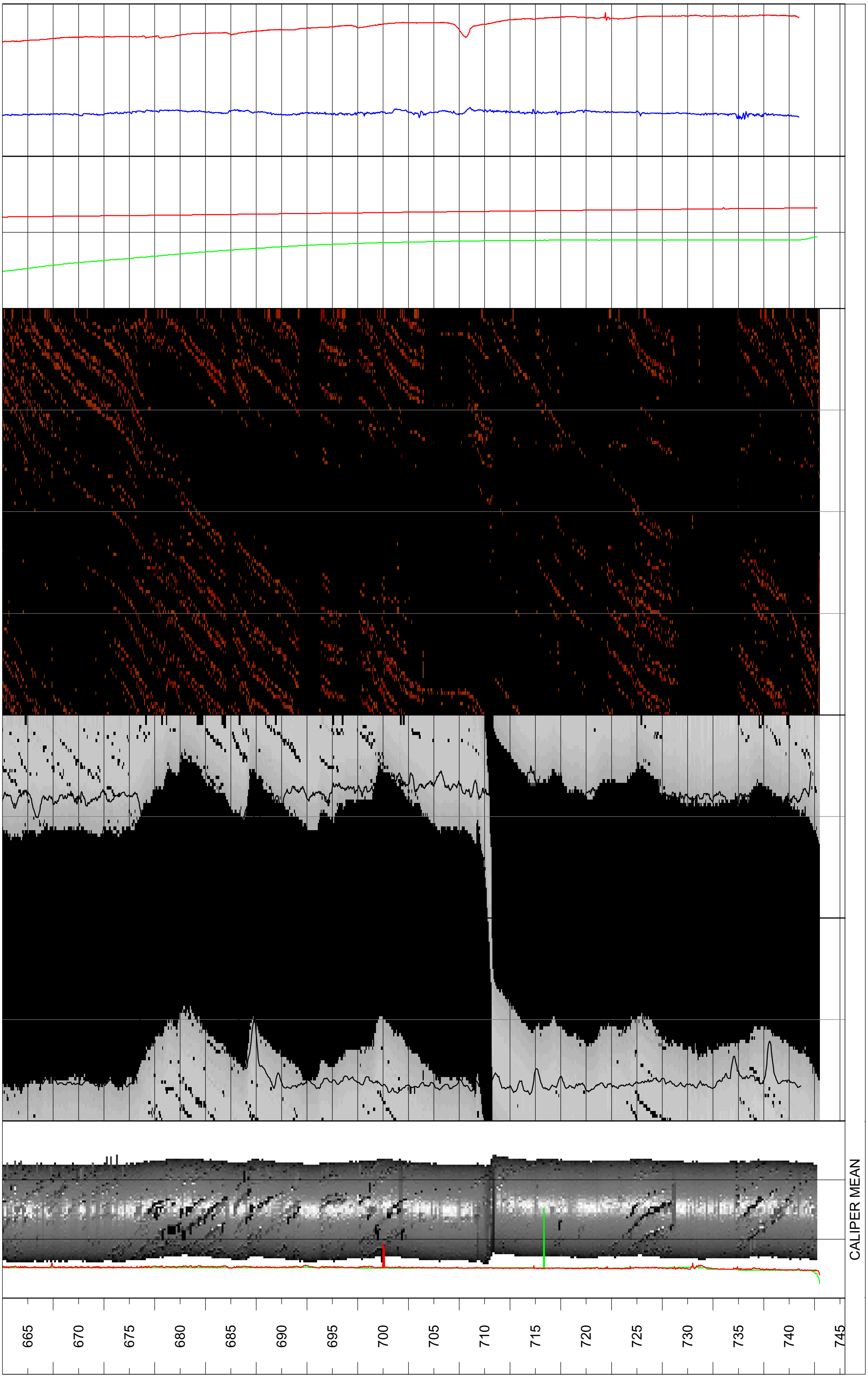
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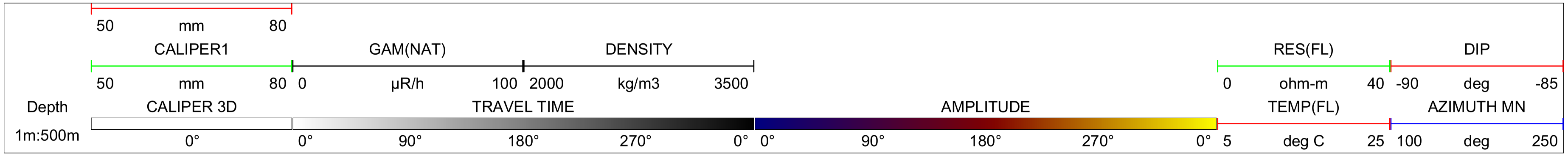
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CALIPER 3D
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AMPLITUDE
TEMP(FL)
AZIMUTH MN
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0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
5 deg C 25
100 deg 250