P-03-111

Oskarshamn site investigation

Geophysical borehole logging in borehole KSH02 and KLX02

Uffe Torben Nielsen, Jørgen Ringgaard, Frederik Horn
RAMBØLL

November 2003

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Keywords: geophysical logging.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Summary

According to a request from Svensk Kärnbränslehantering AB geophysical borehole logging has been performed in borehole KSH02 and KLX02, situated in Simpevarp and Laxemar, Oskarshamn, Sweden.

The logging in KSH02 was recorded from 80 m to 1000 m, and KLX02 was recorded from 200 to 1020 m.

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

Composite sheets of all the processed logs are included in Appendix 1 and 2.

Contents

1 Introduction 7

2 Objective and scope 9

3 Equipment 11

4 Execution 13

5 Results 15
5.1 Presentation 15
5.2 Calculated curves 16
5.2.1 Calculation of coordinates 16
5.2.2 Conversion of the magnetic susceptibility 16
5.2.3 Conversion of natural gamma 16
5.3 Borehole KSH02 16
5.4 Borehole KLX02 18

6 Digital delivery 19
6.1 Delivery of logging data 19
6.2 Calculation of the total magnetic field 21
6.3 Calculation of the magnetic inclination 21

Appendix 1 Borehole KSH02
Drawing no 1.1 Borehole logs. 1:500 23

Appendix 2 Borehole KLX02
Drawing no 2.1 Borehole logs. 1:500 35

1 Introduction

This document reports the data gained during June and July 2003 at Simpevarp in Oskarshamn. The geophysical borehole logging operations presented here include boreholes KSH02 and KLX02.

The logging program has been executed by RAMBØLL. RAMBØLL is acting as a subcontractor to DGE and ÅF-IPK.

All measurements were conducted by RAMBØLL during the period June 30 – July 3 2003 in accordance with the instructions and guidelines from SKB (activity plan AP PS 400-03-031 and method description SKB MD 221.002, SKB internal controlling documents) and under supervision of Leif Stenberg, SKB.

In borehole KSH02 logging data was recorded from 80 m to 1000 m. The borehole is cored with a diameter of 76 mm and a slight inclination of approximately –85° from the horizontal plan. The location of the KSH02 is shown in Figure 1-1.

In borehole KLX02 the logs were performed from 200 m to 1027 m. The borehole is cored with a diameter of 76 mm and a slight inclination of approximately –84° from the horizontal plan. Borehole KLX02 is situated in Laxemar and is not shown on Figure 1-1.

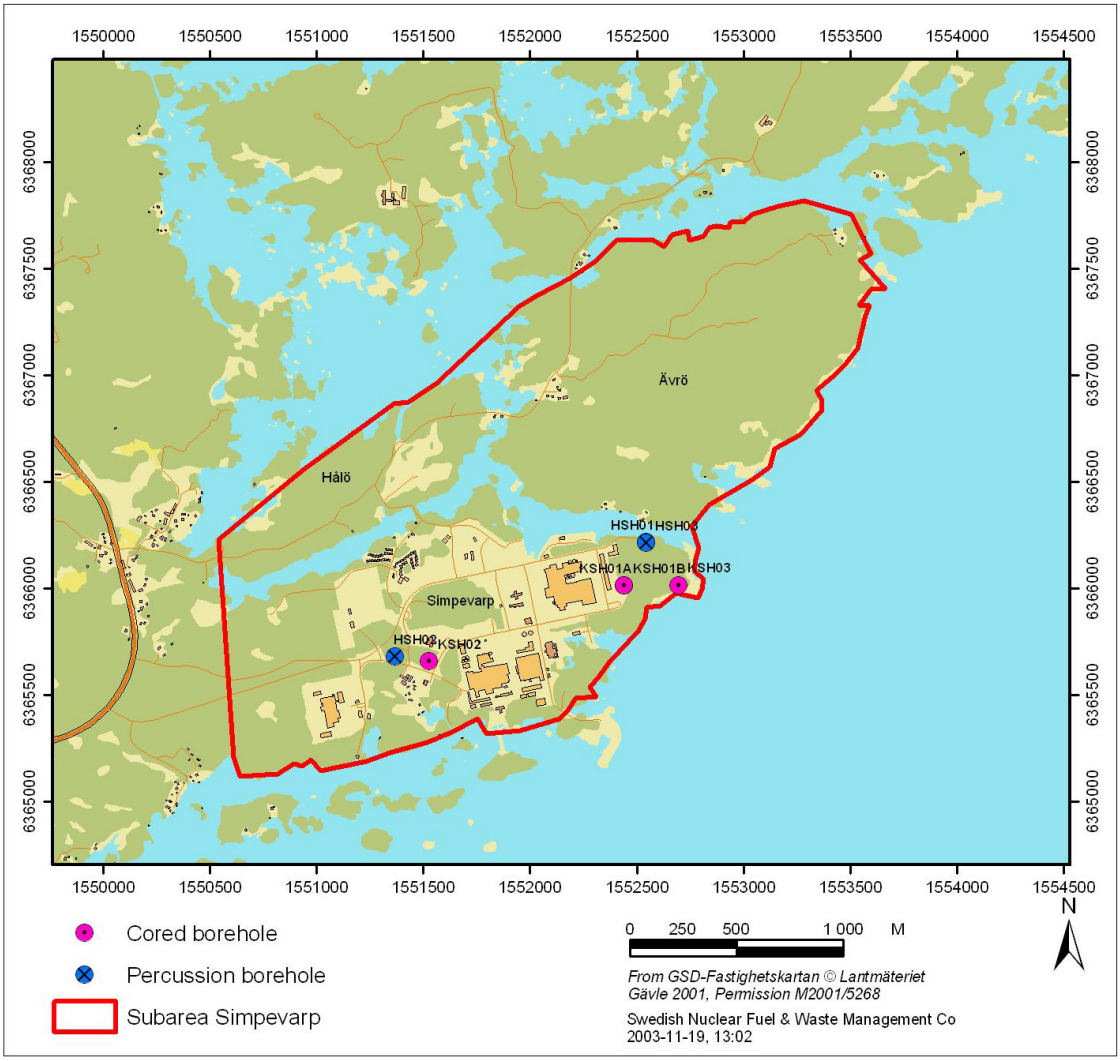

Figure 1-1. *General overview over the Simpevarp subarea in site Oskarshamn.*

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 KSH02 in Appendix 1 and 2.1 for borehole KLX02 in Appendix 2.

3 Equipment

The geophysical borehole logging program in KSH02 was performed with 6 multi tool probes and resulted in a suite of 17 log types, listed in Table 3-1. The logging program in KLX02 was performed with one probe, Century 9042. The tools and recorded logs are listed in Table 3-1.

Table 3-1. Logging tools and logs recorded in KSH02 and KLX02.

Tool	Recorded logs	Dimension	Source detector spacing	Source type
Century 8622 Magnetic susceptibility	Magnetic susceptibility, natural gamma	203 x 4.1 cm		
Century 9030 Gamma density	Gamma density, natural gamma, 140 cm focused guard log resistivity, 10 cm 1-arm calliper	307 x 5.6 cm	20.3 cm	125 mCi Cs137
Century 9042 Fluid resistivity and temperature	Fluid resistivity, fluid temperature, fluid delta temperature, natural gamma	137 x 4.1 cm		
Century 9072 3 m focused guard	3 m focused guard log resistivity and natural gamma	310 x 6.4 cm		
Century 9320 Sonic	Full wave form travel-time providing P & S-wave velocity picking, compensated P-wave travel-time, and natural gamma	283.2 x 5.1 cm	Near 2 ft. Far 3 ft.	
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 x 4 cm		

4 Execution

In general the measurement procedures follow the SKB method description (MD 221.002, SKB internal controlling document). The logging program in borehole KLX02 was executed on June 30, 2003 and in borehole KSH02 in the period from July 1–2, 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.

The applied logging equipment was calibrated before arriving at the site. The procedures and calibration values were delivered separately.

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 9320.

All data was recorded with maximum10 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 3 m/min. Due to an error in the winch system, the sample interval for the HiRAT Acoustic tool has a variation with an average value of 2.5 mm. Data with sample interval (SI) over 10 mm are listed in Table 4.1.

Table 4-1. KSH02. HiRAT. Data with sample interval over 10 mm.

SI	Totals	Depth [m]									
10 mm	40	87.073	89.988	90.961	91.93	103.386	174.83	187.727	193.25	280.782	413.354
		588.436	671.877	672.57	678.424	681.114	727.377	744.267	774.379	778.69	778.7
		779.076	781.164	815.903	819.451	824.37	825.953	839.868	845.741	846.117	848.947
		849.524	850.082	857.993	949.873	950.033	955.727	958.668	958.68	966.509	967.02
11 mm	17	89.015	96.768	97.711	100.546	104.332	130.813	133.677	172.987	245.815	597.051
		750.444	776.608	960.646	966.525	967.985	968.46	974.58			
12 mm	4	771.293	834.77	903.645	967.008						
13 mm	10	177.59	179.432	776.841	777.462	781.775	785.281	845.562	850.644	957.197	958.188
14 mm	6	950.853	953.464	957.222	959.659	960.15	967.503				
15 mm	4	772.524	827.111	957.687	967.177						
17 mm	3	764.506	966.991	968.963							
18 mm	1	968.486									
26 mm	1	959.157									

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 and in no 2.1 in Appendix 2 respectively are presented in Table 5-1.

Table 5-1. Logs presented in drawing no 1.1 in Appendix 1 and for fluid temperature, fluid resistivity and natural gamma in drawing no 2.1 in Appendix 2.

Log	Log name short	Unit	Tool
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
Fluid temperature	TEMP(FL)	Deg C	9042
Fluid resistivity	RES(FL)	Ohm-m	9042
Focused guard log resistivity, 300 cm	RES(DG)	Ohm-m	9072
P-wave velocity	P-VEL	m/s	9320
Full wave form, near receiver	AMP(N)	µs	9320
Full wave form, far receiver	AMP(F)	µs	9320
Magnetic susceptibility	MAGSUSCEP	SI*10-5	8622
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 lateral	DIP	Deg	HiRAT
360° orientated acoustic travel time	TRAVEL TIME	100 ns	HiRAT
360° orientated acoustic travel time	AMPLITUDE	–	HiRAT

5.2 Calculated curves

5.2.1 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)    I (+ Down)
   (deg)         (deg)
  3d   8m    71d    17m
```

5.2.2 Conversion of the magnetic susceptibility

The magnetic susceptibility was converted for CGS units to SI units by multiplying the CGS value by 4π.

5.2.3 Conversion of 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.

5.3 Borehole KSH02

In order to obtain an exact depth calibration in borehole KSH02, the track marks made while drilling are used. The connection between the track marks and the logs is obtained from the HiRAT Acoustic tool.

The HiRAT image logs are shifted 1.99 m down and the natural gamma 0.57 m down. To obtain a common depth reference point, the track mark at 103.07 m in the HiRAT file is used as the marker at depth 105 m. The HiRAT tool is therefore shifted 1.93 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 5.2.

Table 5-2. 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
105	103.07	105.000
153	151.084	153.014
203	201.139	203.069
256	254.162	256.092
317	315.214	317.144
362	360.235	362.165
415	413.261	415.191
468	466.309	468.239
519	517.354	519.284
571	569.354	571.284
624	622.457	624.387
674	672.472	674.402
727	725.502	727.432
780	778.532	780.462
830	828.572	830.502
852	850.62	852.550
900	898.63	900.560
950	948.683	950.613

Using the natural gamma from the HiRAT as reference, the natural gamma logs from the other probes are aligned to the same depth, and the shift correction value for the other tools is found. These values are shown in Table 5-3.

Table 5-3. Shift correction values in borehole KSH02 for the other tools using natural gamma logs from the other probes.

Tool	Shift correction value
8622	1.152 m down
9030	1.05 m down
9030. Medium guard	1.30 m down
9042	1.099 m down
9072	1.252 down
9320	1.65 down
HiRAT	1.73 m down

There is a minor difference in the used winch in the depth registration between up- and down runs. The size of the fault is about 1.5 m/km. To compensate for this the logs recorded downward are stretched. The stretch value is found by means of comparison of the gamma logs, in this borehole only the logs from the 9042 have been stretched.

The complete log suite for borehole KSH02 is presented as composite log sheets in drawing no 1.1 in Appendix 1. The logs presented on drawing no 1.1 are listed in Table 5-1.

The inclination (dip) and azimuth from the HiRAT probe are presented in drawing no 1.1 in Appendix 1.

5.4 Borehole KLX02

Only the century probe 9042 has been executed in borehole KLX02. The log has been shifted 0.75 m down. The log suite for borehole KLX02 is presented as composite log sheet in drawing no 2.1 in Appendix 2.

6 Digital 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 Note No 109.

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
KSH02	8622	Up	F:\360210A\ksh02\KSH02_07-01-03_14-22_8622C_.1_-1.30_1000.10_ORIG.log
KSH02	9030	Up	F:\360210A\ksh02\KSH02_RAWDATA\KSH02_07-02-03_16-15_9030CA_.10_66.90_999.70_ORIG.log
KSH02	9042	Down	F:\360210A\ksh02\KSH02_07-01-03_09-56_9042C_.10_78.10_600.00_ORIG.log
KSH02	9042	Down	F:\360210A\ksh02\KSH02_07-01-03_12-51_9042C_.1_540.10_672.10_ORIG.log
KSH02	9042	Down	F:\360210A\ksh02\KSH02_07-01-03_11-51_9042C_.1_651.50_994.50_ORIG.log
KSH02	9072	Up	F:\360210A\ksh02\KSH02_07-01-03_19-41_9072C_.10_75.70_1000.40_ORIG.log
KSH02	9320	Up	F:\360210A\ksh02\KSH02_07-01-03_18-35_9320C2_.10_27.60_282.10_ORIG.log
KSH02	9320	Up	F:\360210A\ksh02\KSH02_07-01-03_17-04_9320C2_.10_270.20_1000.00_ORIG.log
KSH02	HiRAT	Up	F:\360210A\ksh02\KSH02_RAWDATA\KSH02_HiRAT_up_120_run5.LGX
KSH02	HiRAT	Up	F:\360210A\ksh02\KSH02_RAWDATA\KSH02_HiRAT_up_120_run7.LGX
KSH02	HiRAT	Up	F:\360210A\ksh02\KSH02_RAWDATA\KSH02_HiRAT_up_120_run8.LGX
KLX02	9042	Down	F:\360210A\KLX02\KLX02_06-30-03_14-57_9042C_.1_0.20_1028.40_ORIG.log

Table 6-2. Drawing files in WellCad format.

Borehole	Drawing	WellCad file
KSH02	1.1	KSH02_Presentation.WCL
KSH02	1.2	KSH02_Deviation.WCL
KSH02	1.3	KSH02_Deviation.WCL
KLX02	2.1	KLX02_Presentation.WCL

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

Borehole	Excel file
KSH02	KSH02_data.xls
KLX02	KLX02_data.xls

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

Sheet	Borehole	Other
Acoustic televiewer	KSH02	See description of “total magnetic field” and “magnetic inclination” below
Focused resistivity 140 cm	KSH02	
Focused resistivity 300 cm	KSH02	
Fullwave sonic	KSH02	column: v_velocity (shear wave), not interpreted from the recorded data
Caliper1	KSH02	
Caliper Mean	KSH02	Calculated using Fluid resistivity and Acoustic televiewer
Fluid resistivity	KSH02, KLX02	
Fluid Temperature	KSH02, KLX02	
Density	KSH02	
Resistivity	KSH02	
Natural gamma	KSH02, KLX02	
Self potential	KSH02	
Single point resistivity	KSH02	
Magnetic susceptibility	KSH02	

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.

Borehole No. KSH02

Co-ordinates in RT90 2,5 gonV

X: 6365658.355m Y: 1551528.952m Z: 5.745m

Diametre:	76mm
Reaming Diametre:	-
Outer Casing:	-
Inner Casing:	-
Borehole Length:	1001m
Cone:	
Inclination at ground surface:	-85°
Azimuth:	330°
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 lateral	HiRAT	deg
TRAVEL TIME	360 degrees orientated acoustic travel time	HiRAT	100 ns
AMPLITUDE	360 degrees orientated acoustic amplitude	HiRAT	-

Rev.	Date	Drawn by	Control	Approved
0	2003-09-03	JRI	UTN	UTN

Job	Scale
360210A	1:500

DGE Dansk Geo-servEx a/s
DGE, Håndværkersvinget 11, 2970 Hørsholm, Phone +45 70 10 34 00, Fax + 45
RAMBØLL. Bredevej 2, DK-2830 Virum, Phone + 45 45 98 60 00, Fax + 45 45 9

SKB geophysical borehole logging
Borehole KSH02

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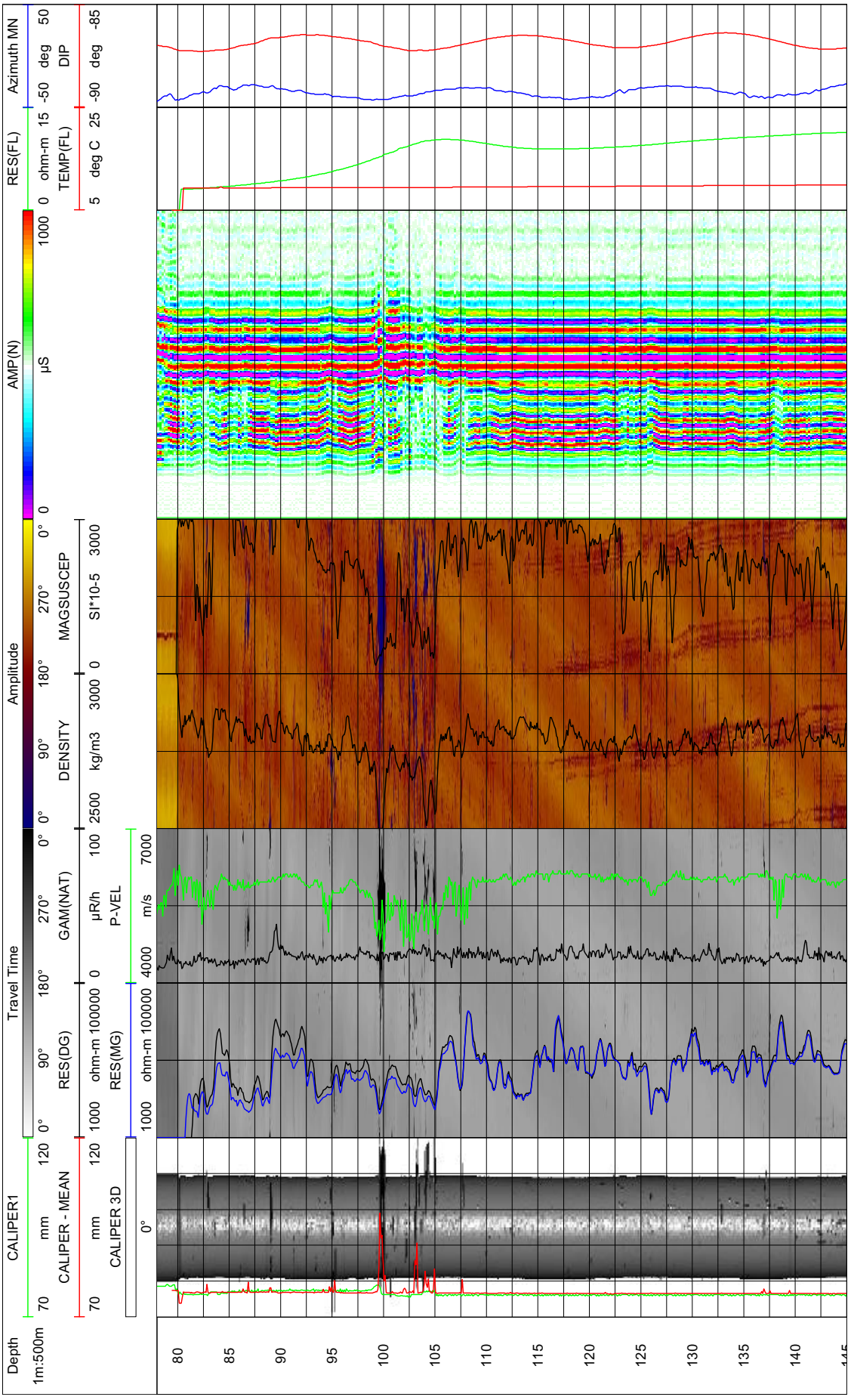
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CALIPER - MEAN
70 mm 120
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RES(MG)
1000 ohm-m 100000
GAM(NAT)
0 µR/h 100
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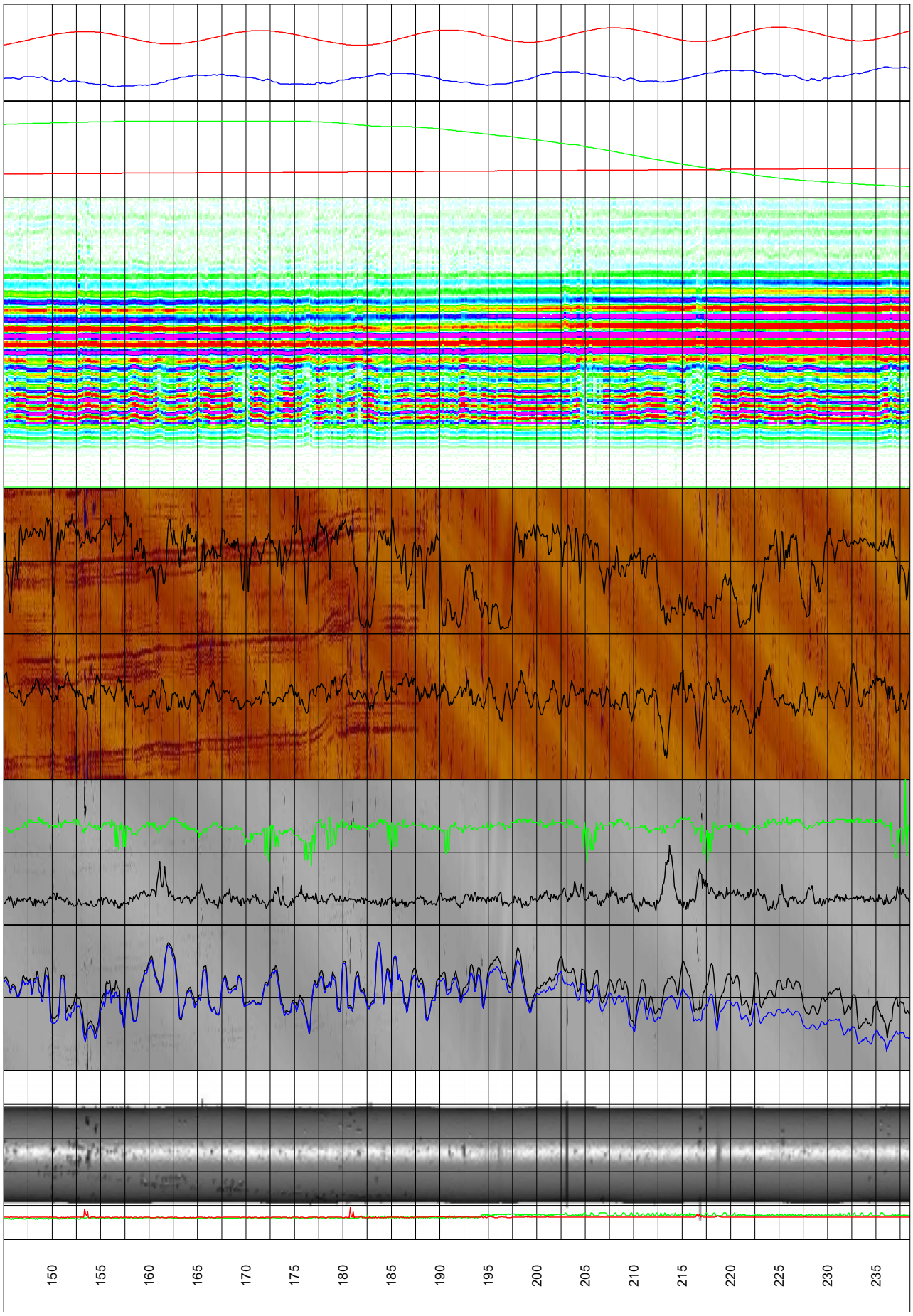
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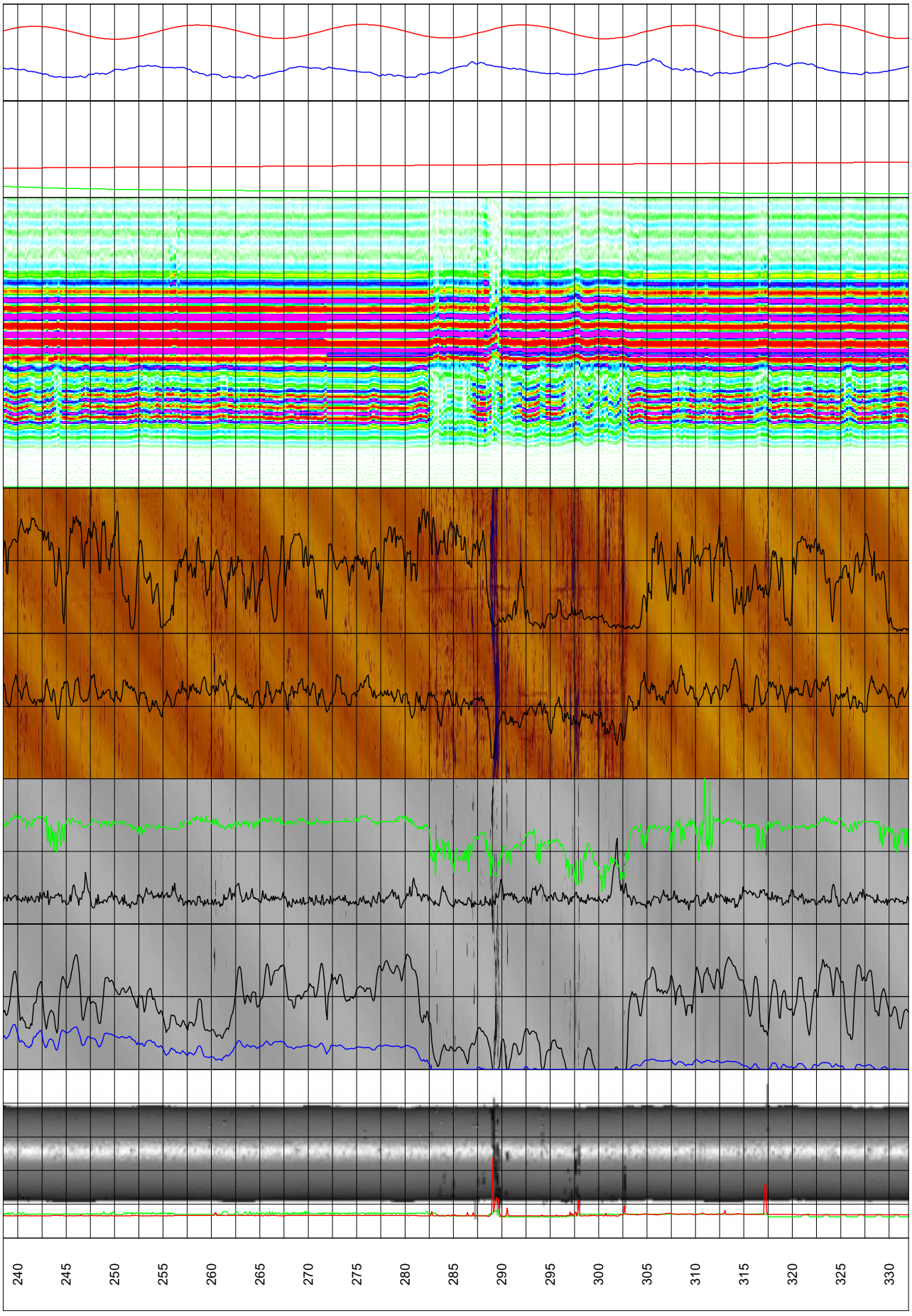
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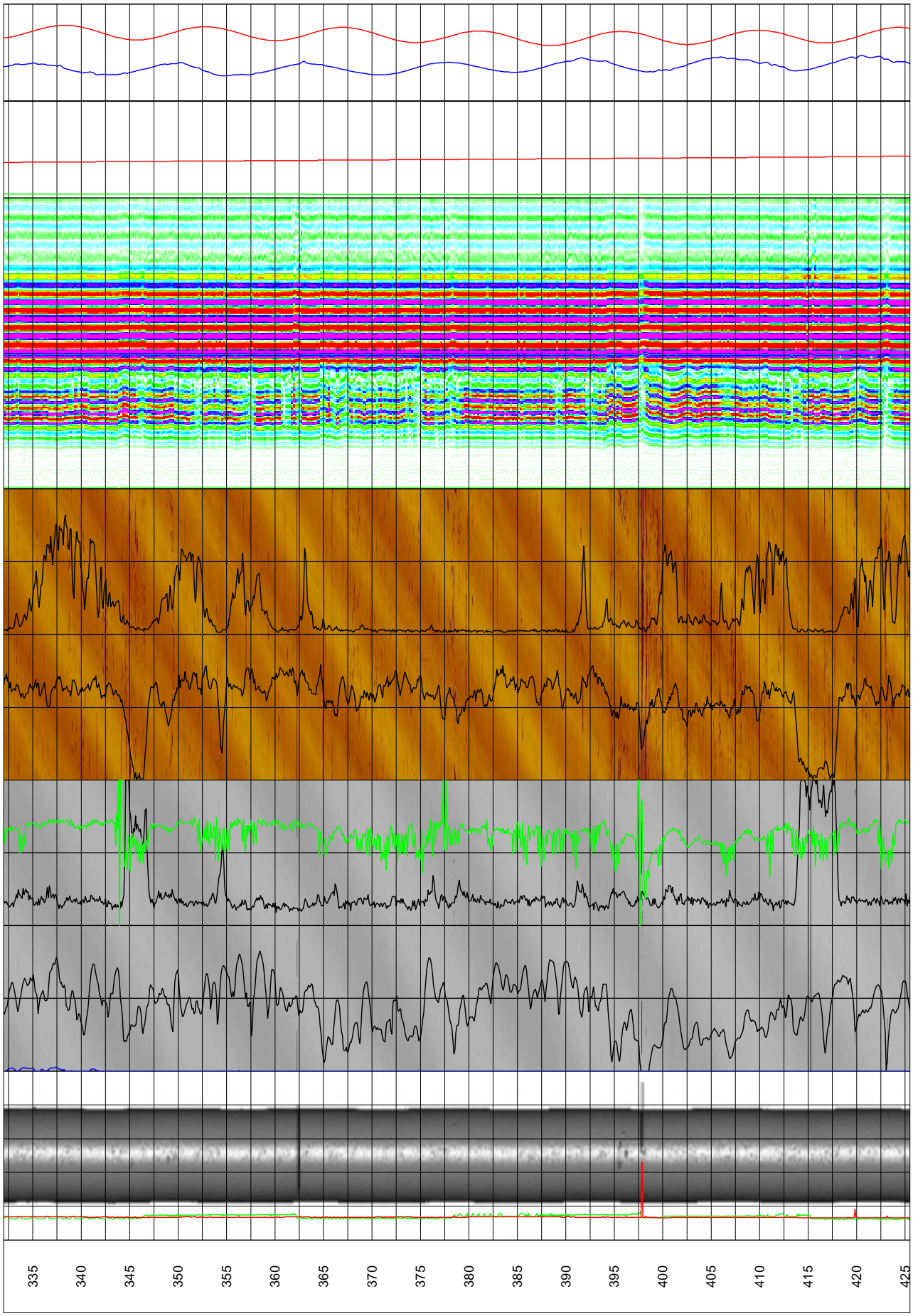
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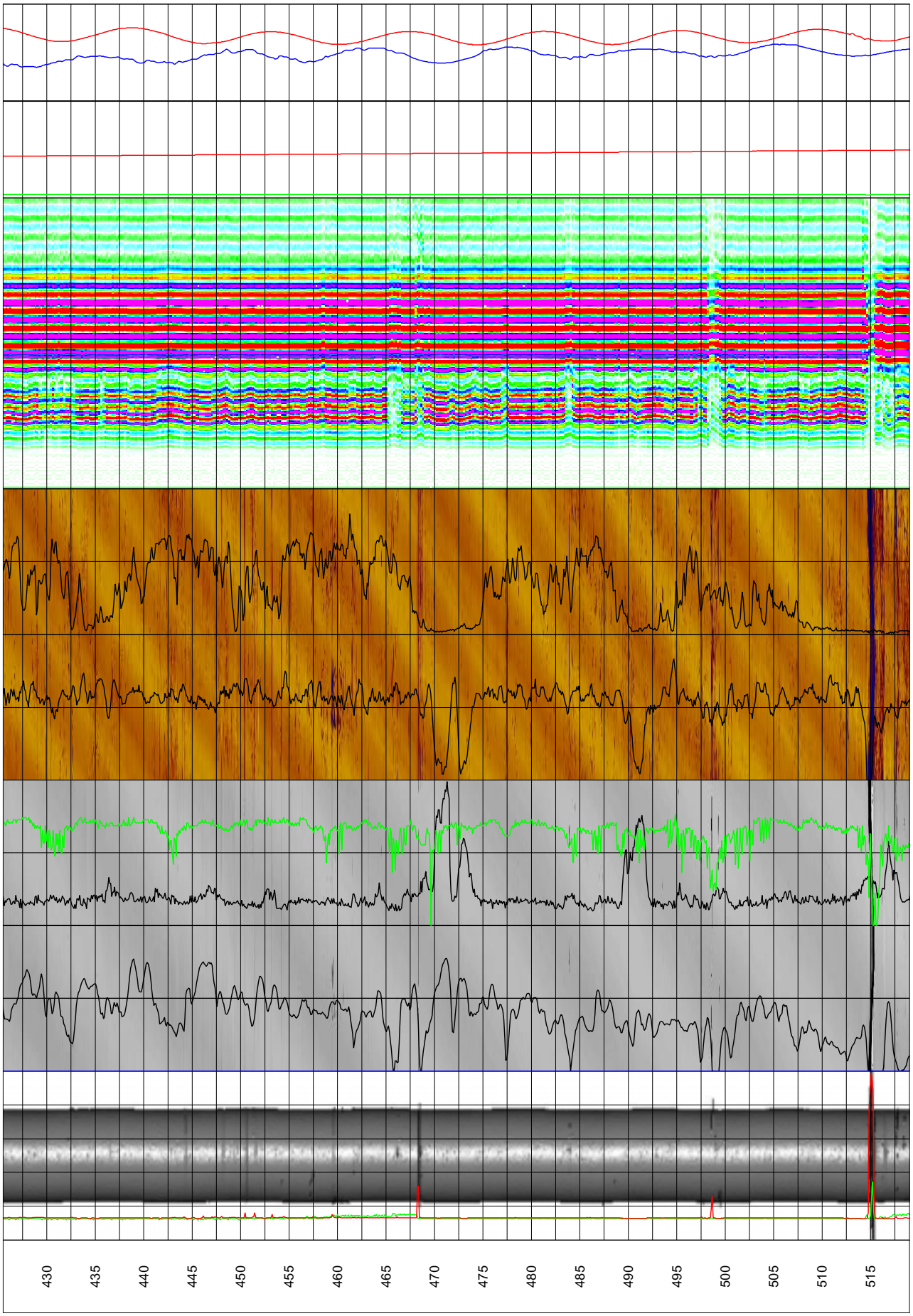
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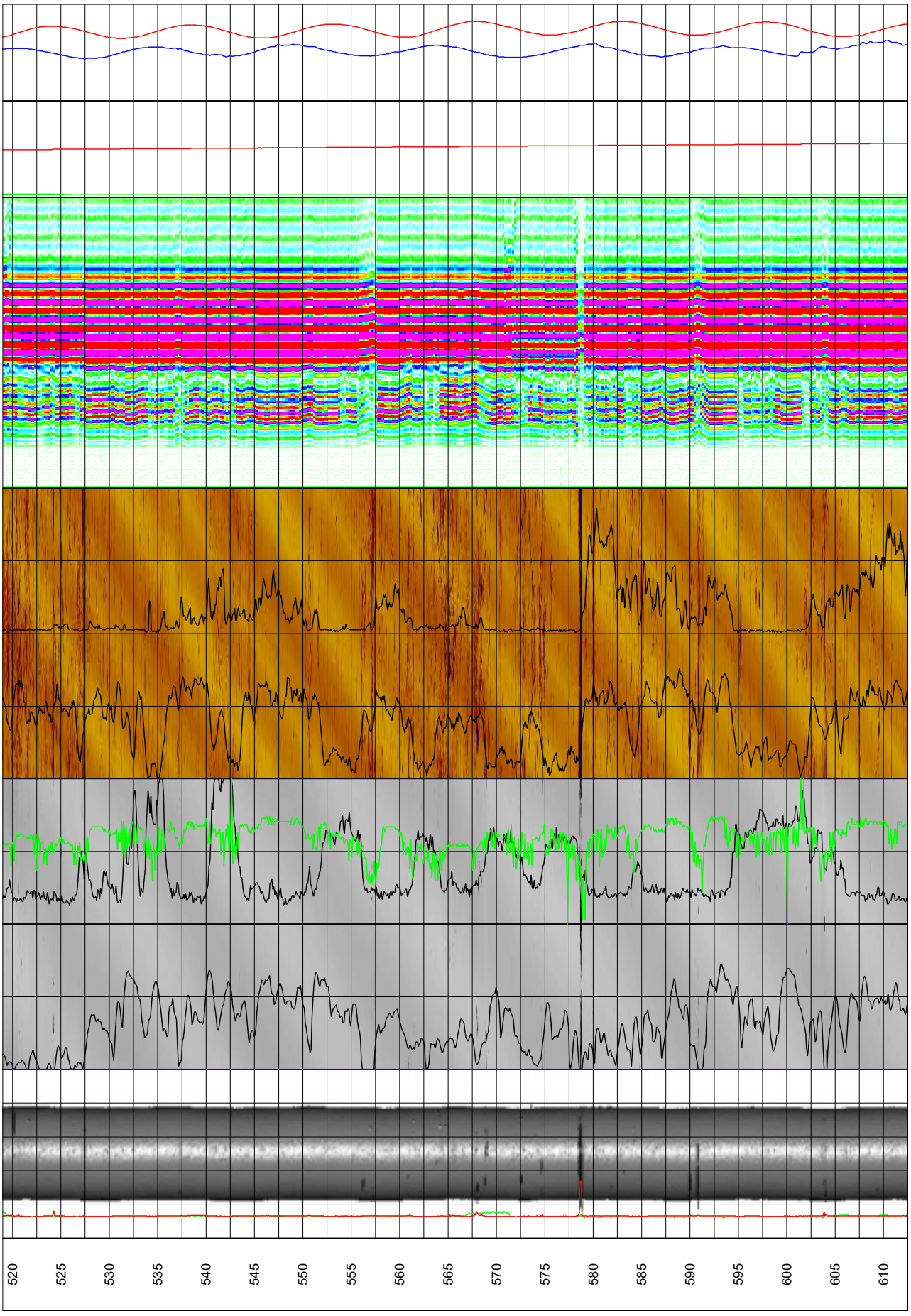
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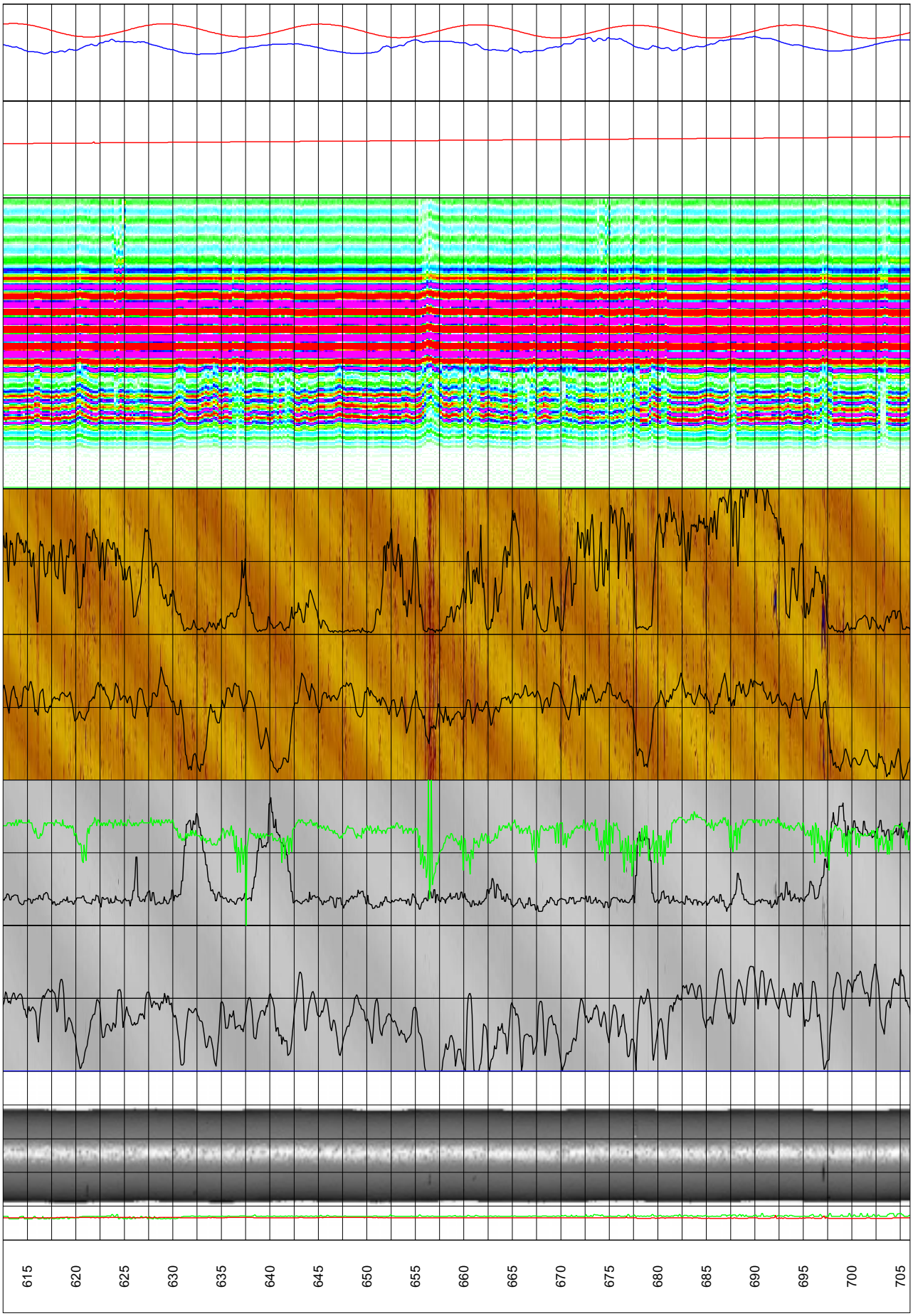
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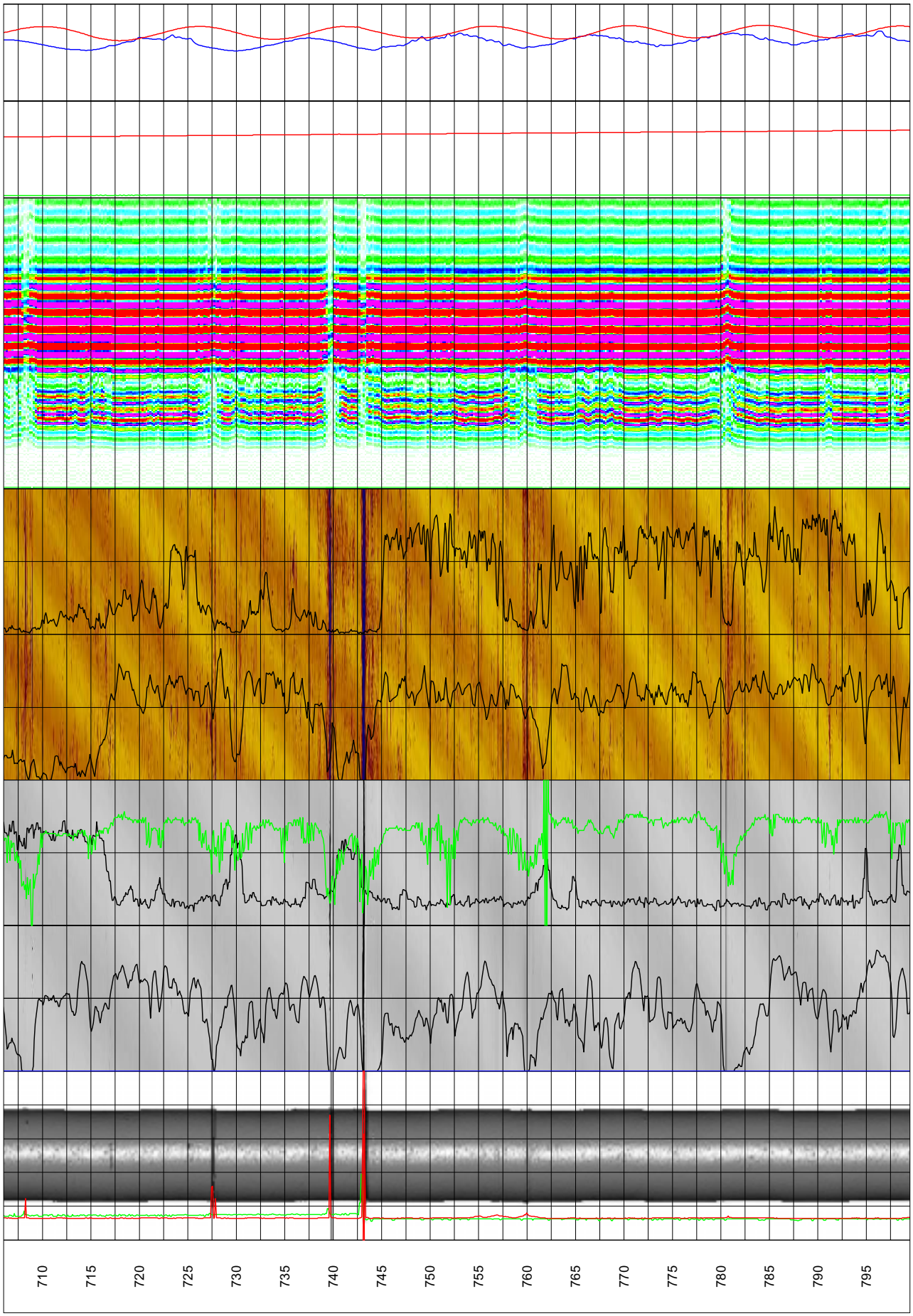
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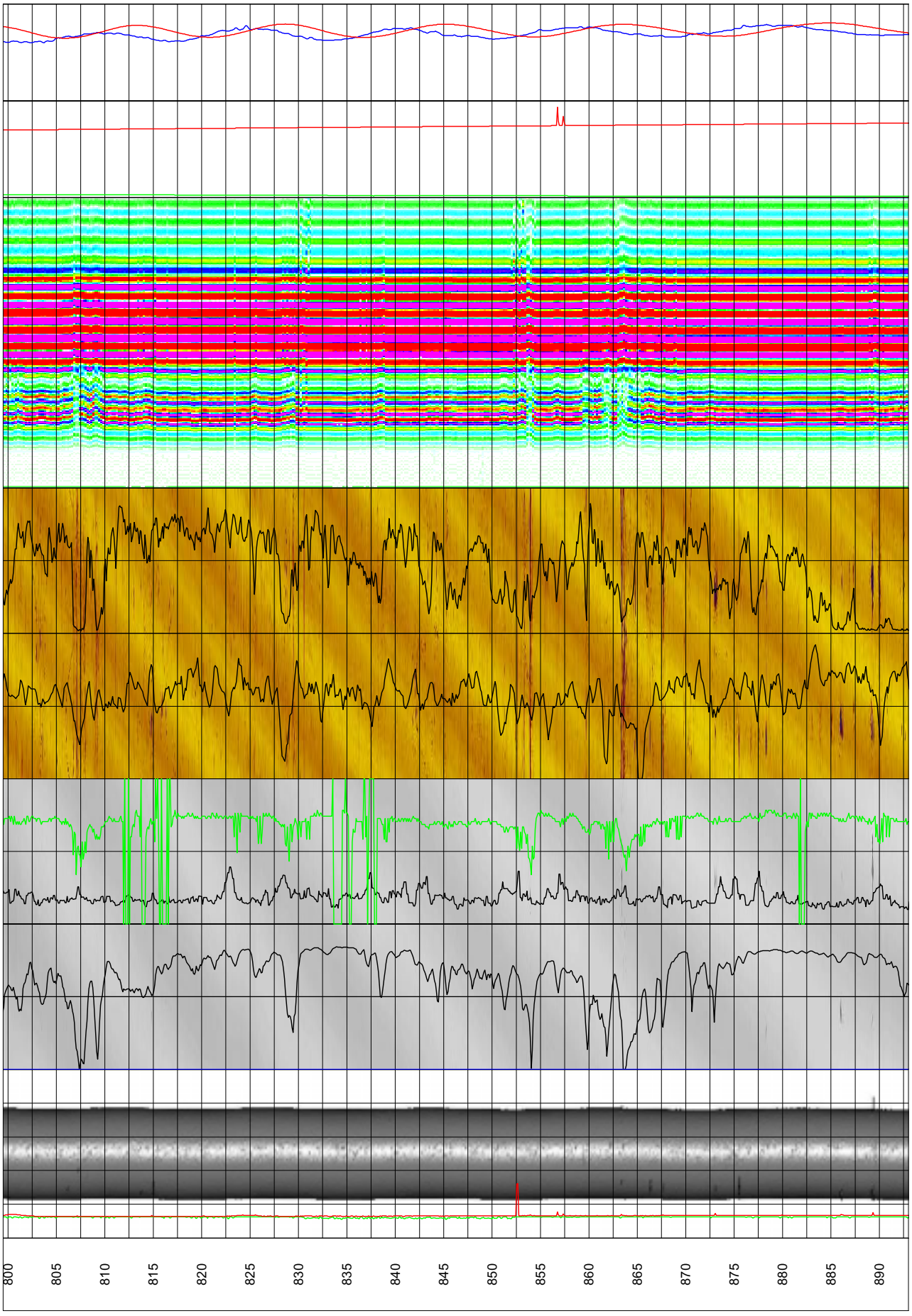
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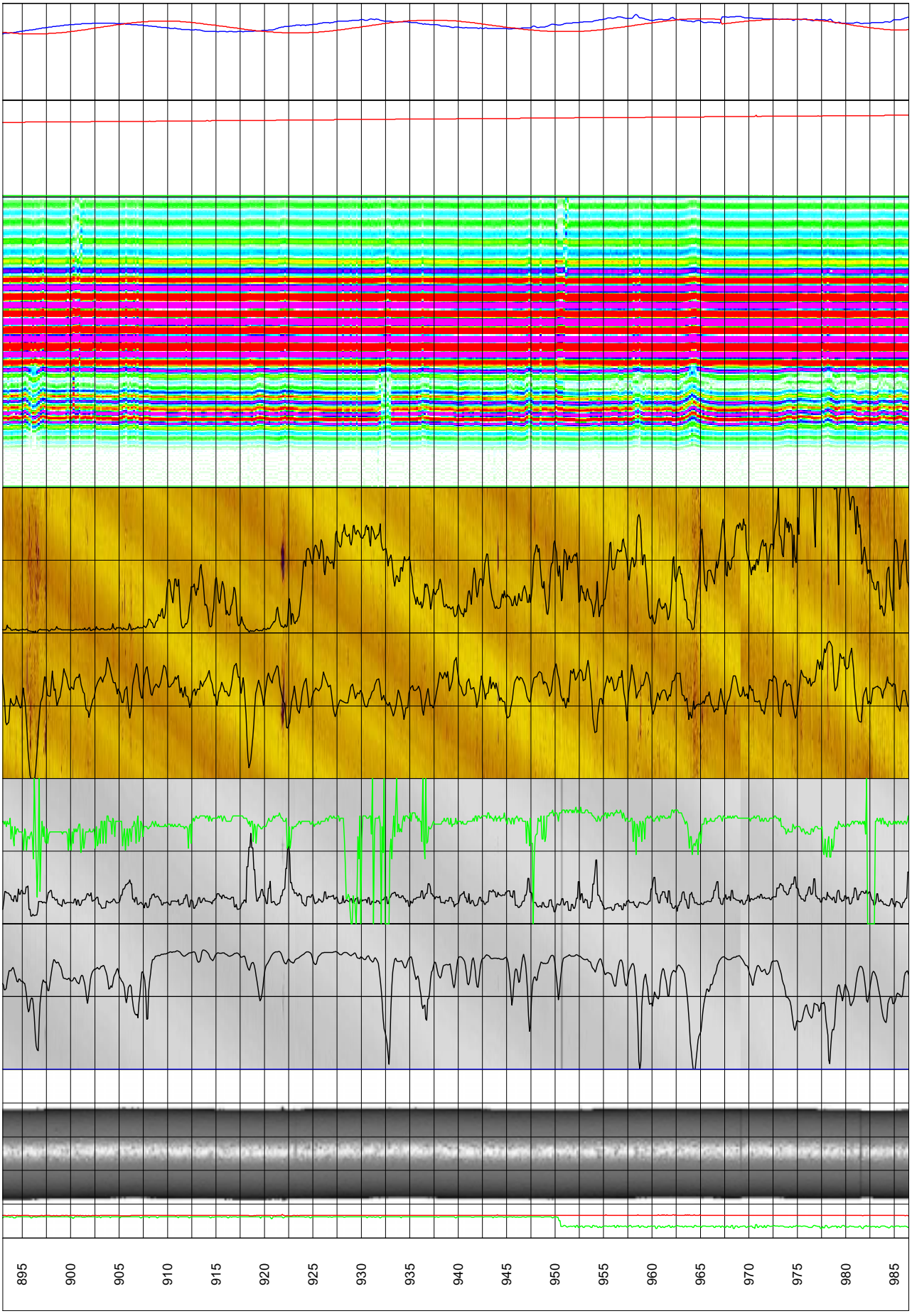
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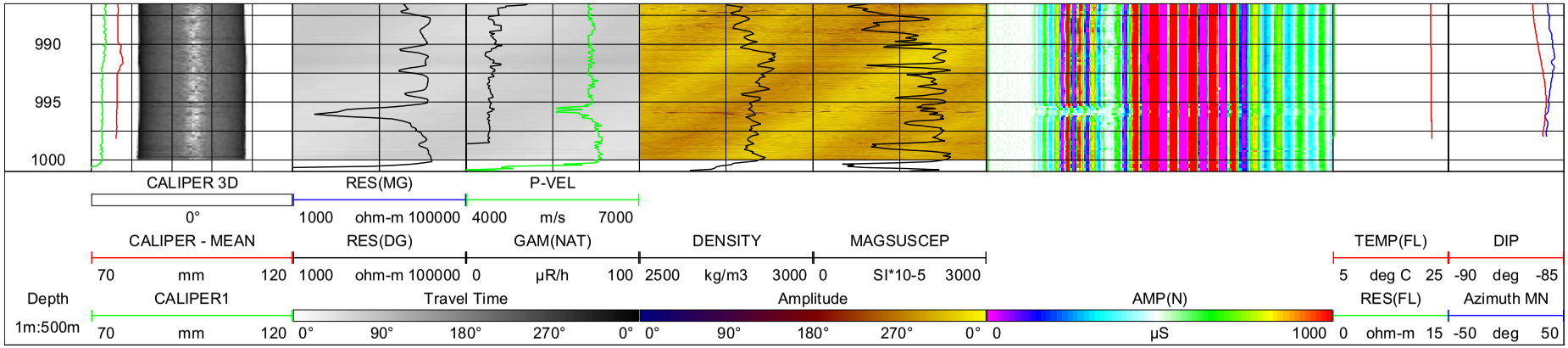

990
995
1000
CALIPER 3D
RES(MG)
P-VEL
0°
1000 ohm-m 100000
4000 m/s 7000
CALIPER - MEAN
RES(DG)
GAM(NAT)
DENSITY
MAGSUSCEP
TEMP(FL)
DIP
70 mm 120
1000 ohm-m 100000
0 µR/h 100
2500 kg/m3 3000
0 SI*10-5 3000
5 deg C 25
-90 deg -85
Depth
1m:500m
CALIPER1
Travel Time
Amplitude
AMP(N)
RES(FL)
Azimuth MN
70 mm 120
0° 90° 180° 270° 0°
0° 90° 180° 270° 0°
0 µS 1000
0 ohm-m 15
-50 deg 50

Borehole No. KLX02

Co-ordinates in RT90 2,5 gon V

X: 6366768.597 Y: 15499224.233 Z: 18.31

Diametre:	75.7mm from 202.95 to 1700.5 m
Reaming Diametre:	165 mm from0 to 201 m
Outer Casing:	304 m from 0 to 3 m
Inner Casing:	193.7 mm from 0 to 200.80 m
Borehole Length:	1700.5 m
Cone:	From 200.8 to 202.95, diameter 179/84 mm
Inclination at ground surface:	85 deg.
Azimuth:	357 deg MN
Comments:	

Borehole logging programme

Name	Description	Tool	Unit
GAM(NAT)	Natural gamma	9030	µR/h
TEMP(FL)	Fluid temperature	9042	deg C
RES(FL)	Fluid resistivity	9042	ohm-m

Rev.	Date	Drawn by	Control	Approved
0	2003-09-08	JRI	UTN	UTN

Job 360210A

Scale 1:500

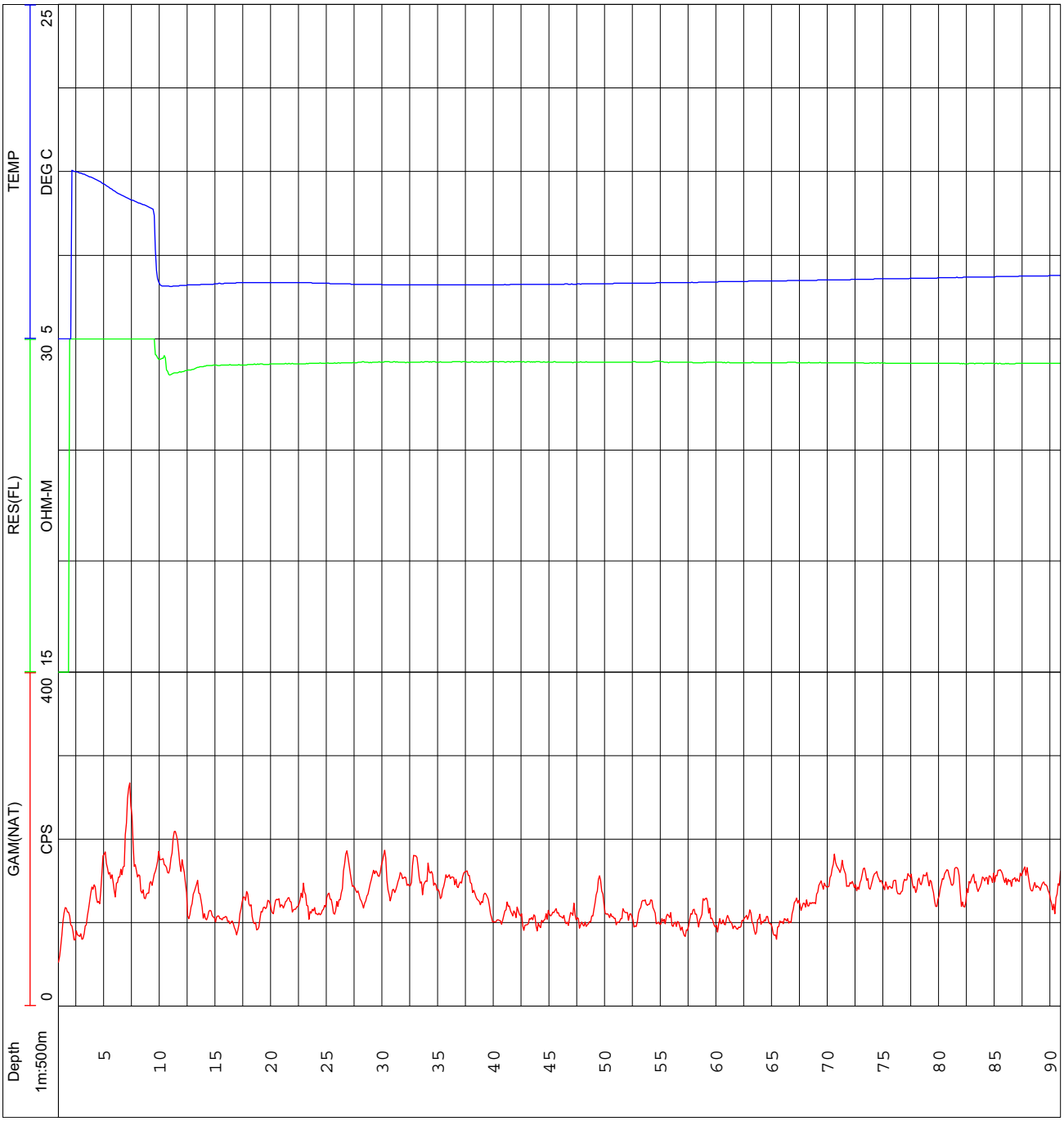
DGE Dansk Geo-servi'a a/s

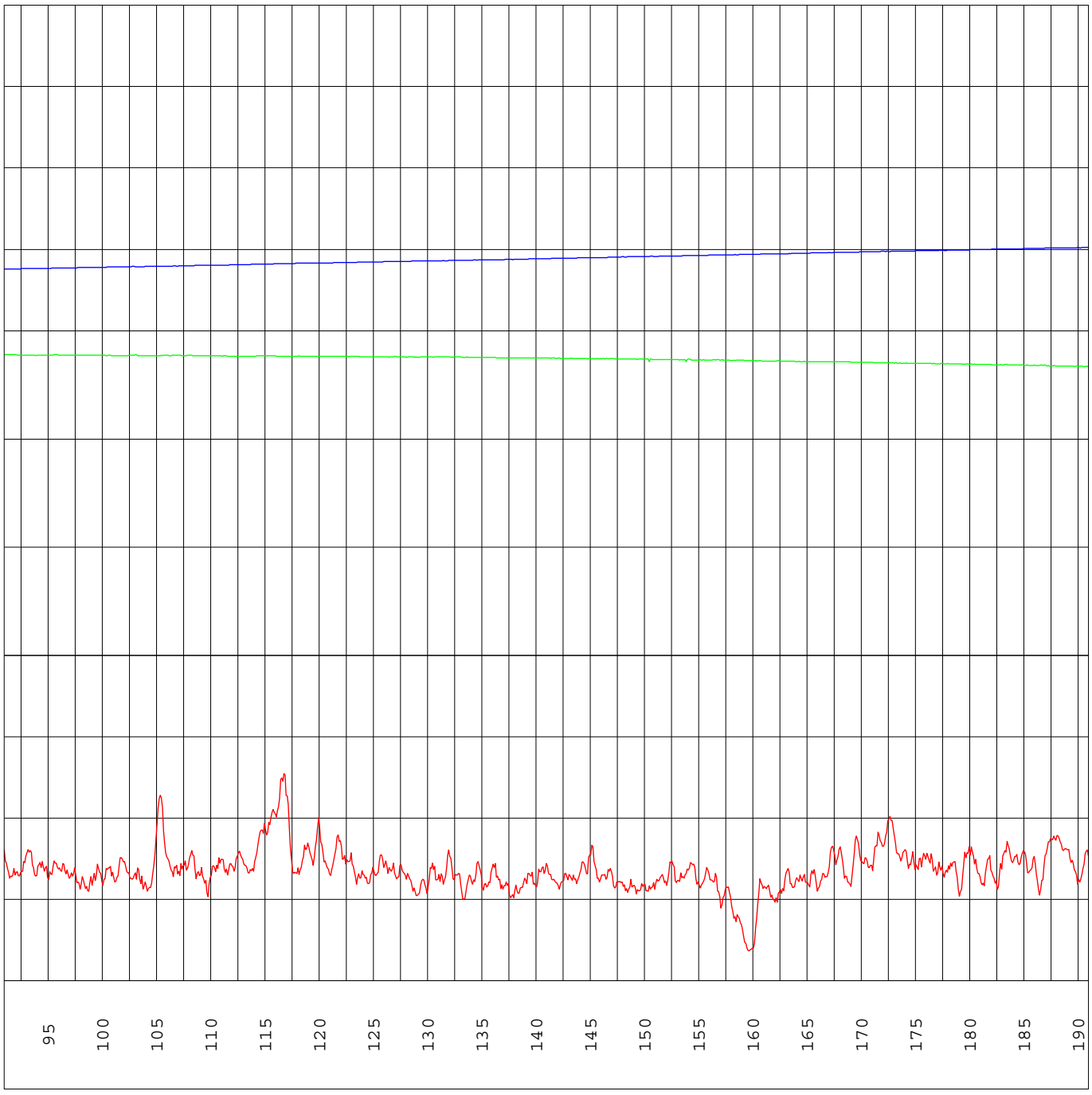
RAMBØLL

SKB geophysical borehole logging
Borehole KLX02 Oskarshamn

Filename: KLX02_Presentation.ai

Drawing no.:
2.1


Depth
1m:500m
GAM(NAT)
0
CPS
400
RES(FL)
15
OHM-M
30
5
TEMP
DEG C
25
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90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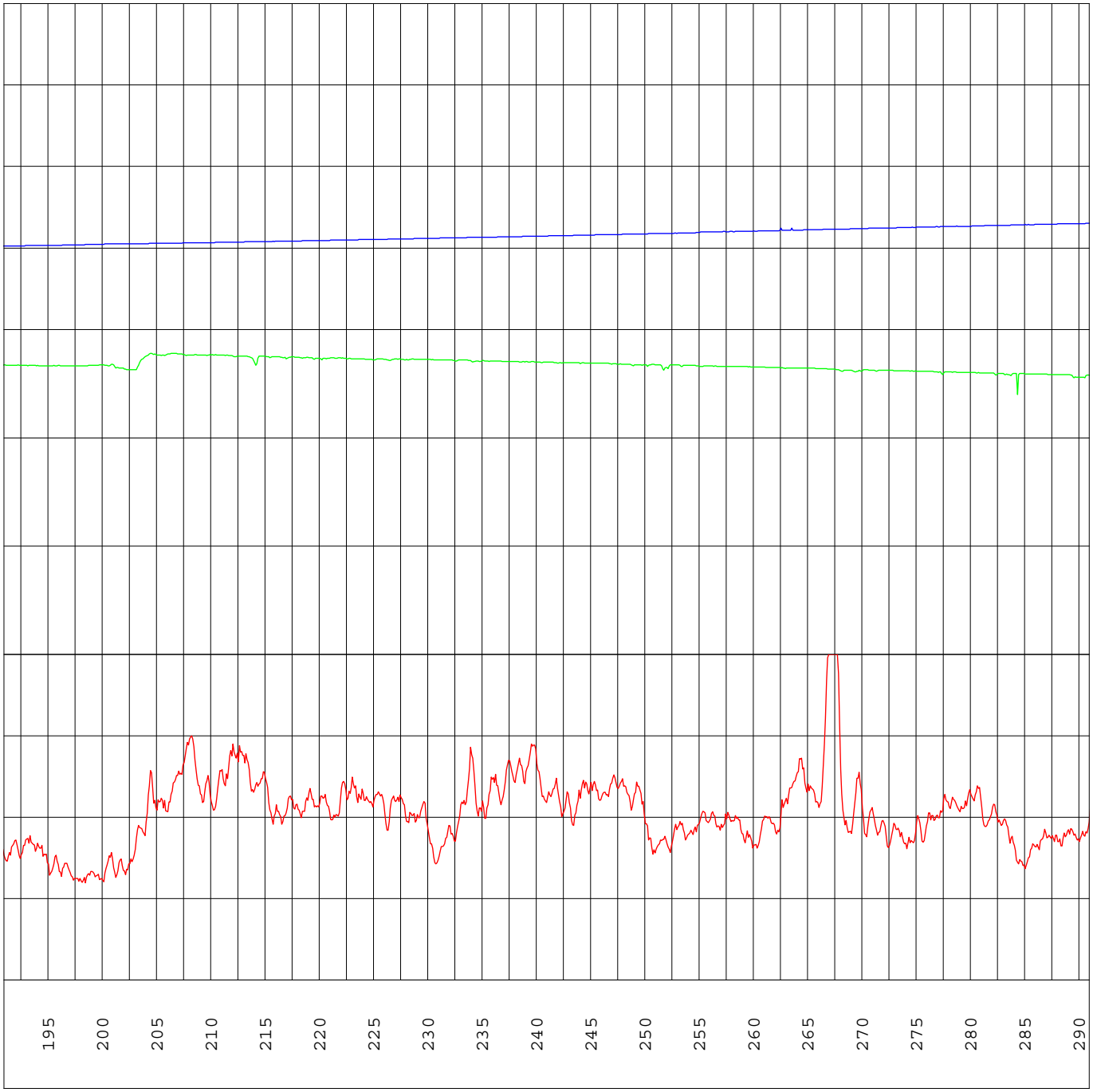
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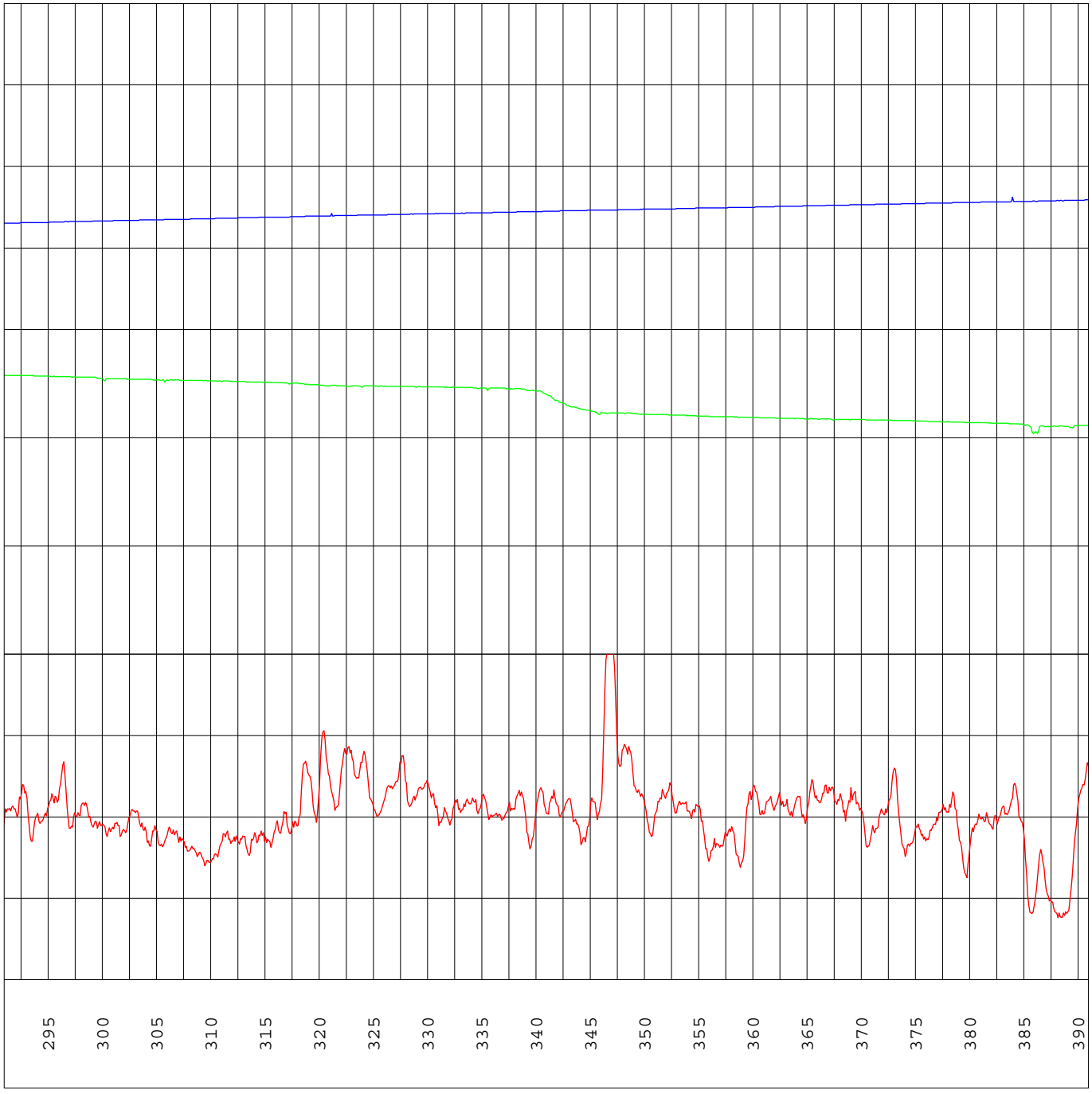
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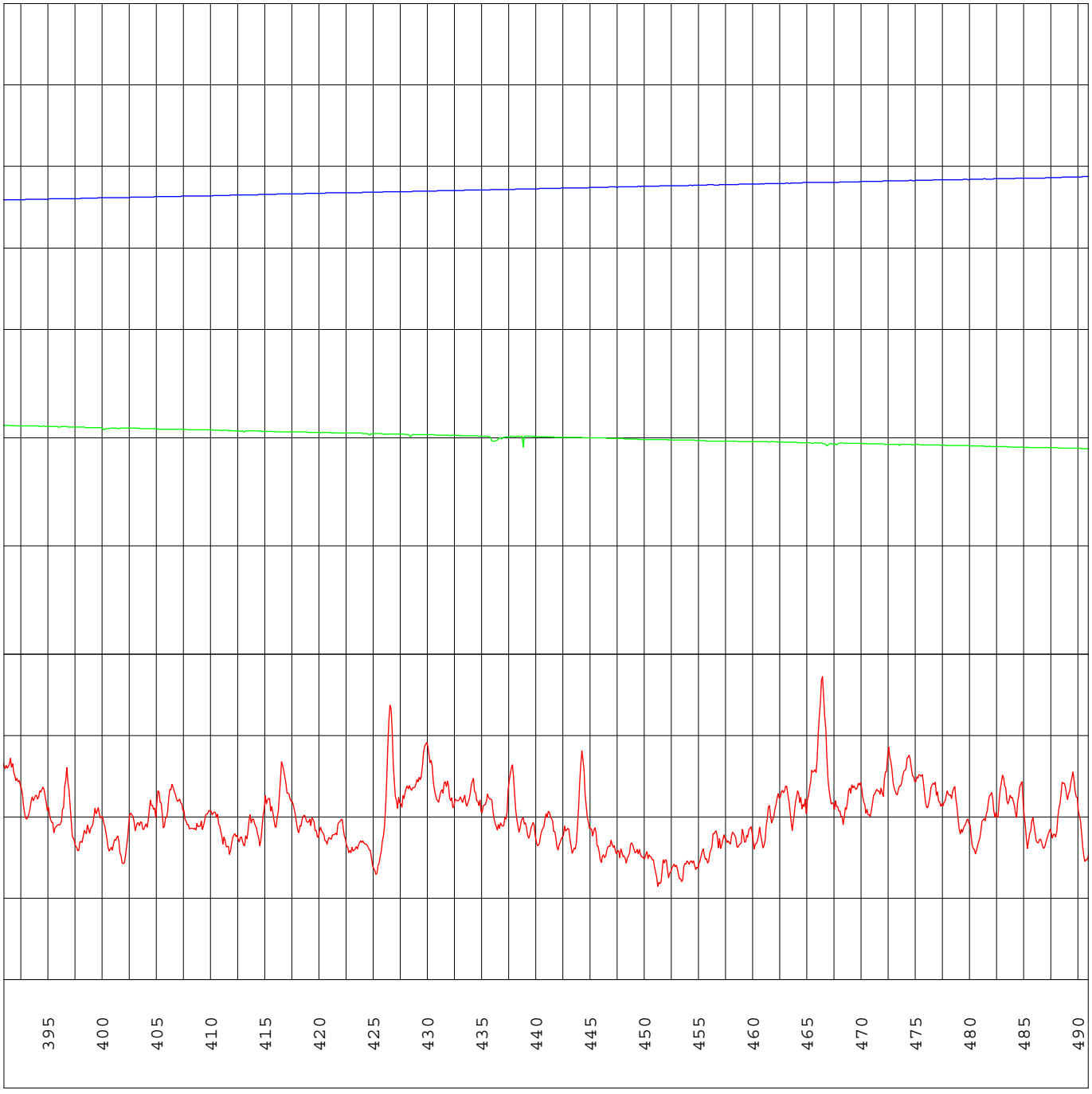
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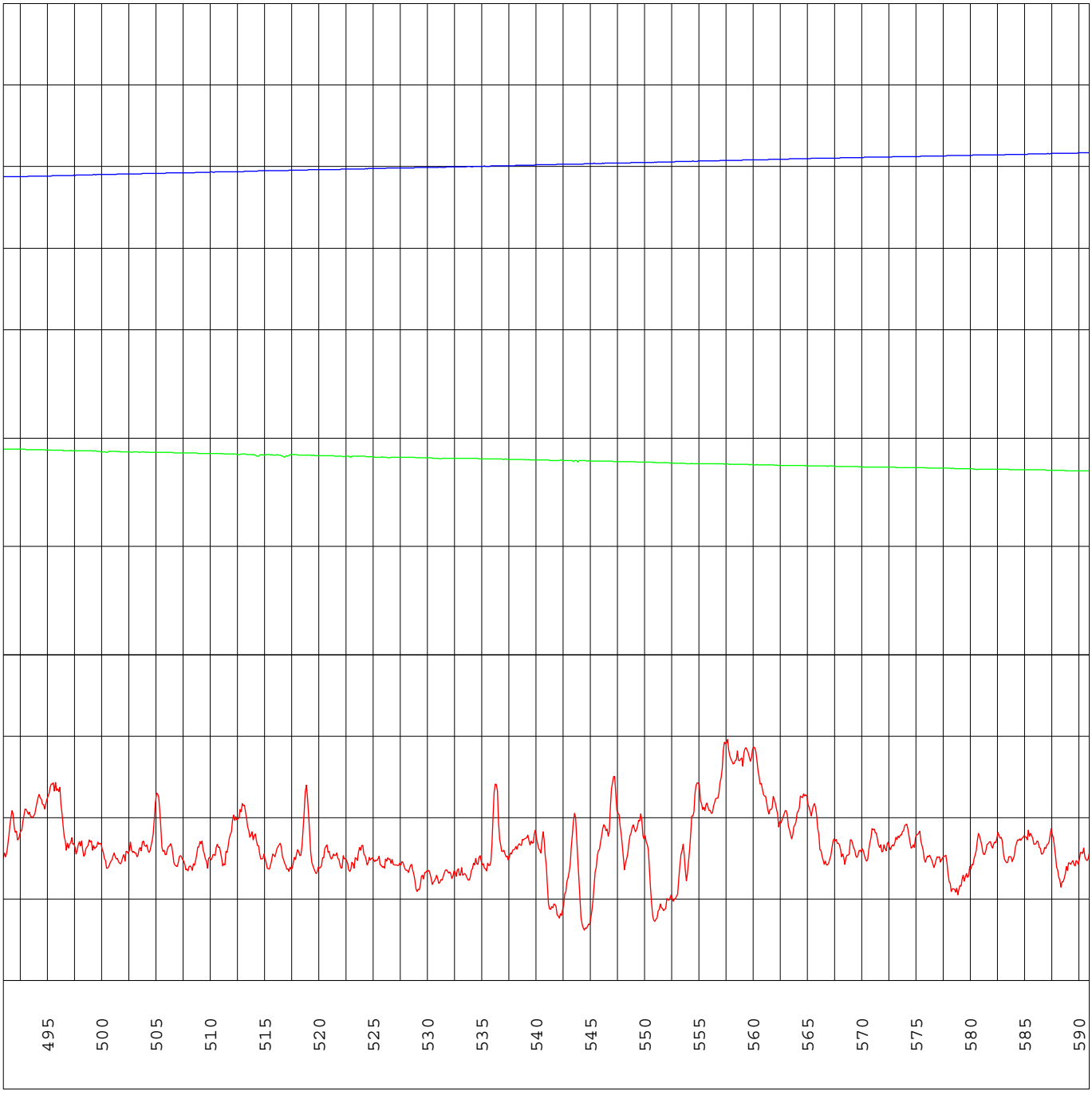
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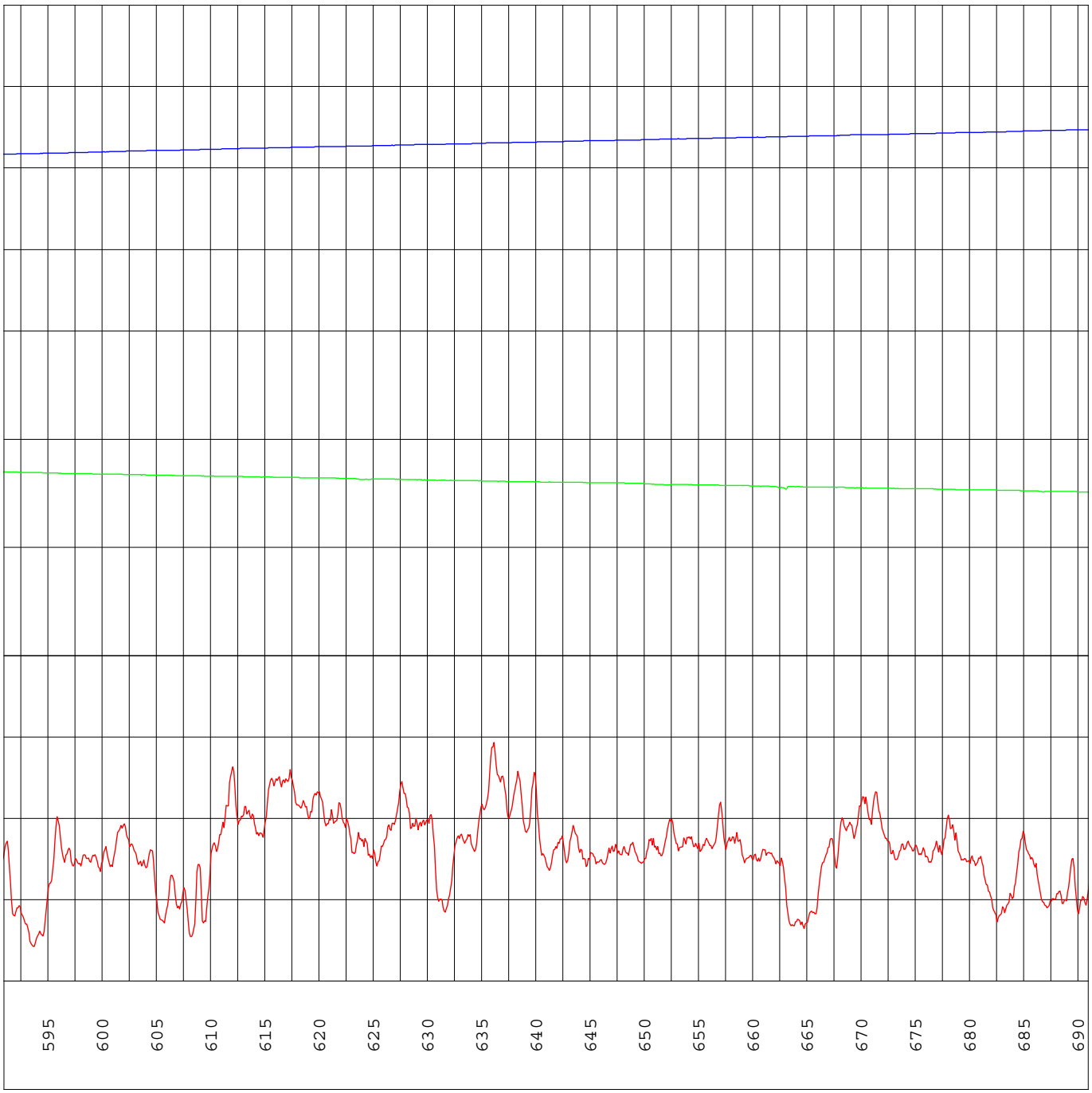
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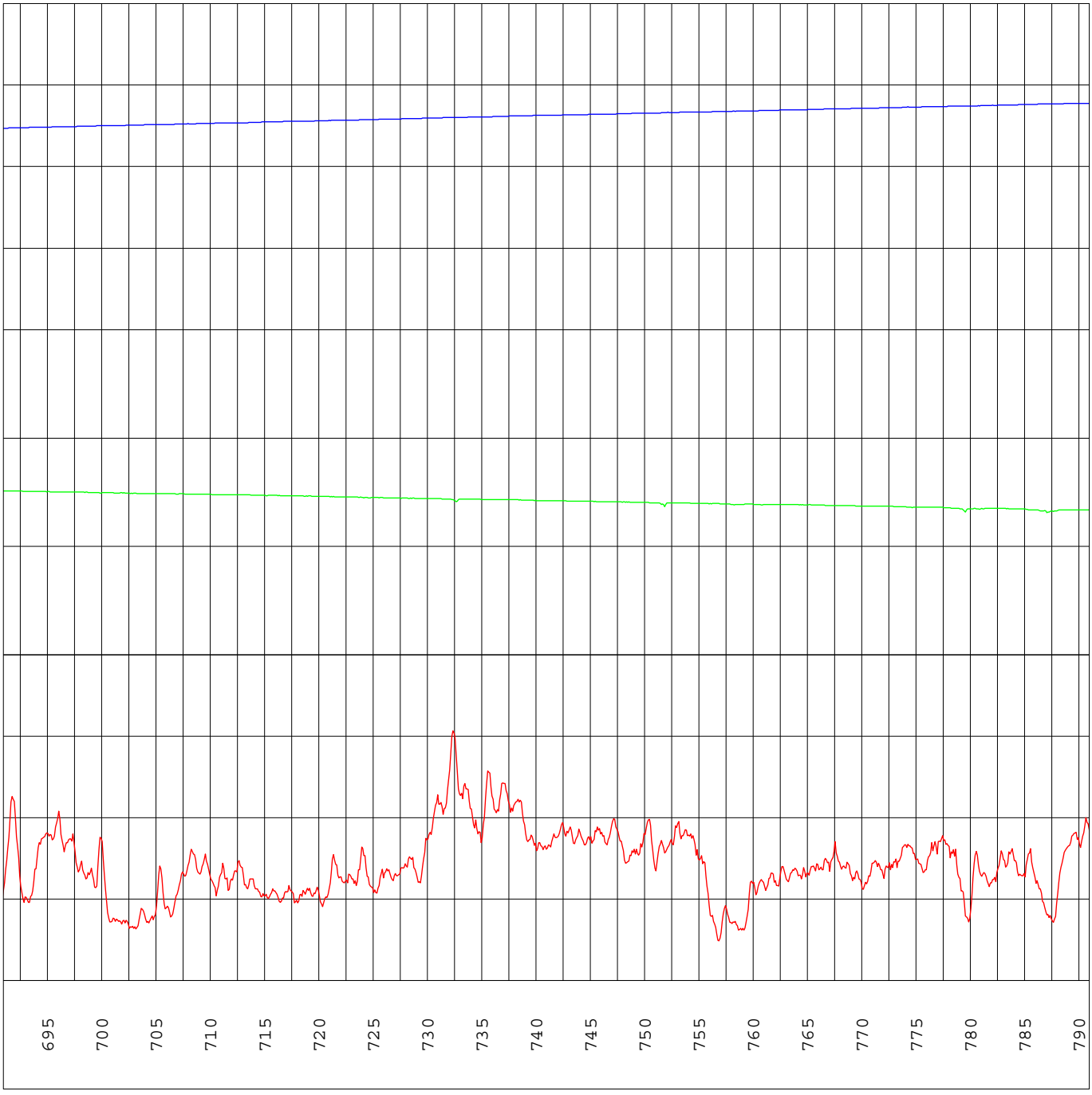
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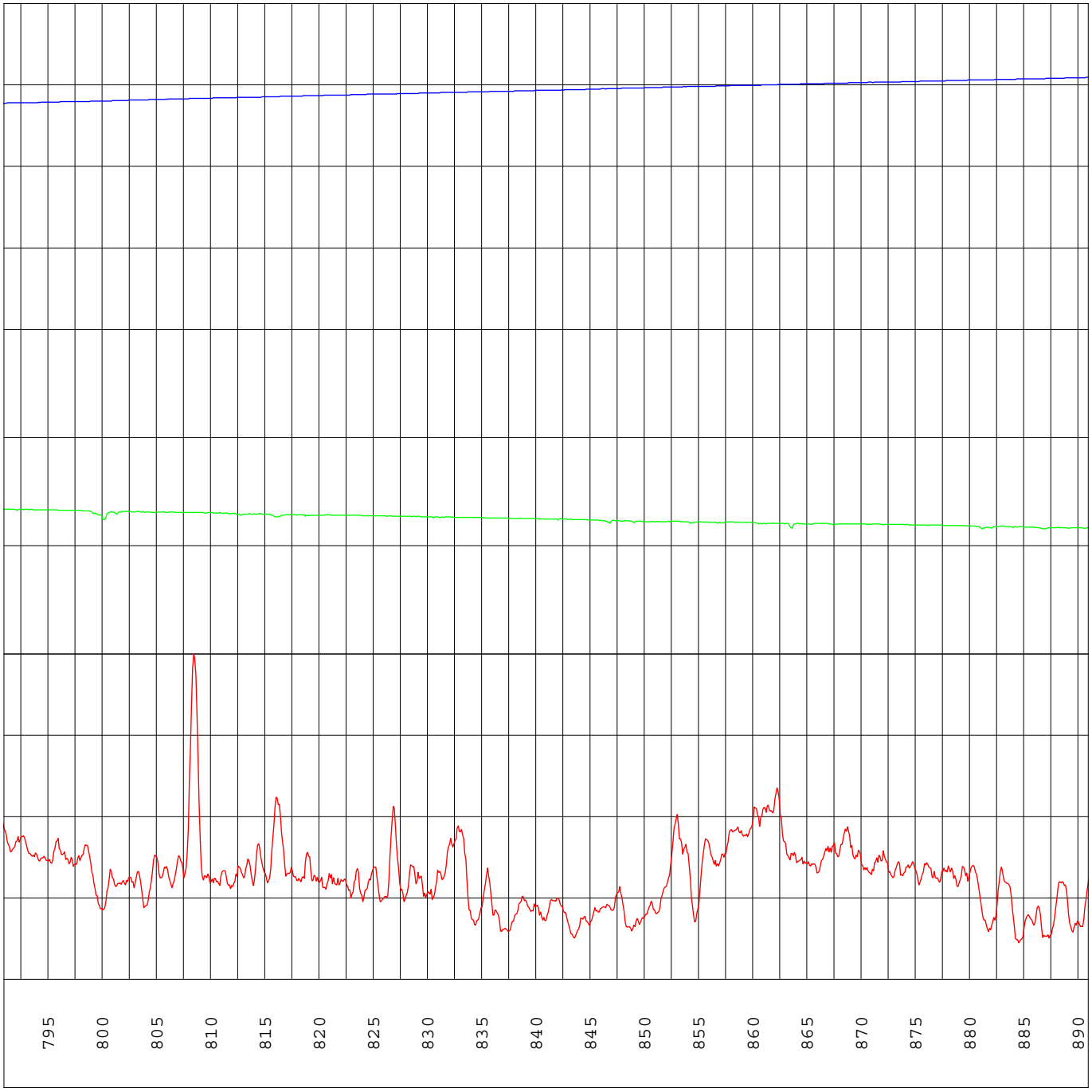
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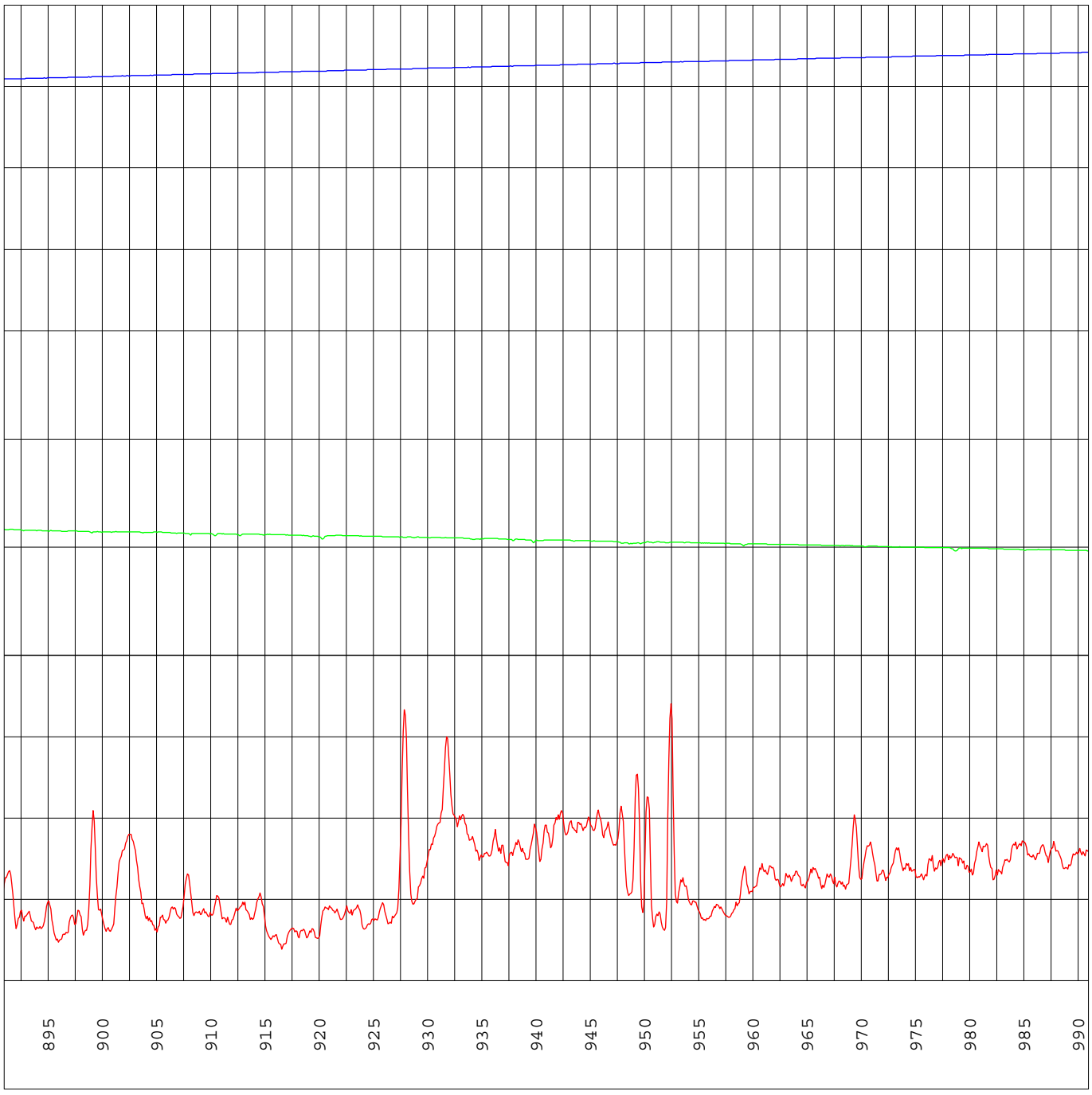
880
885
890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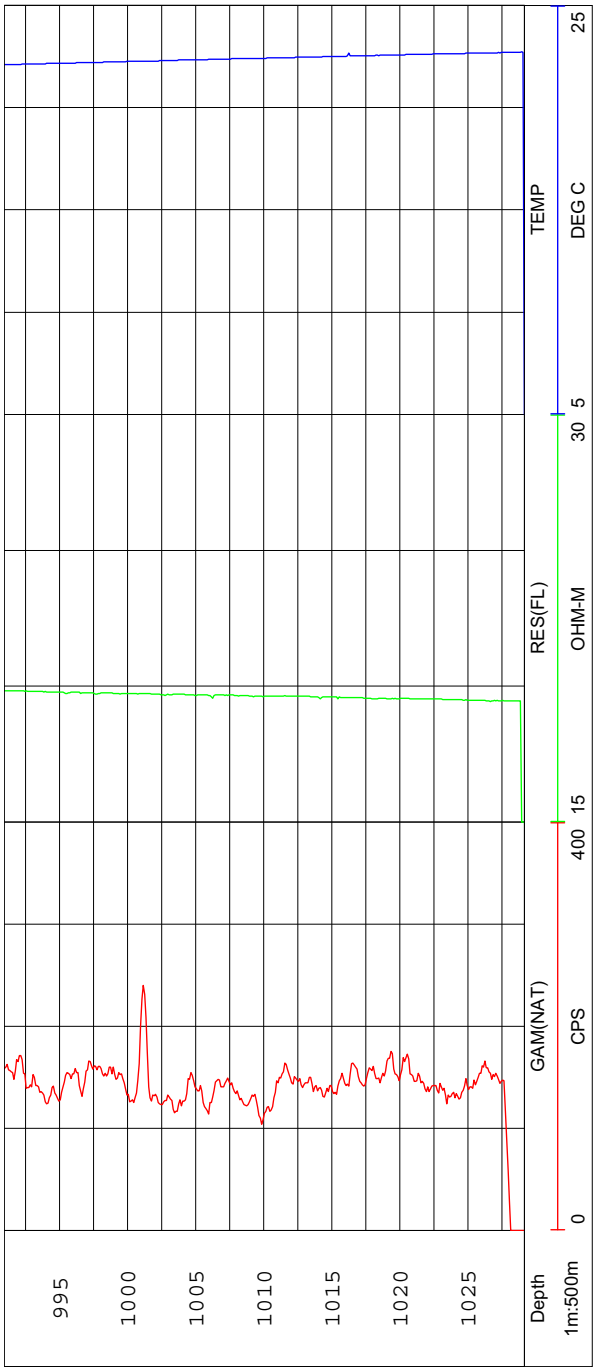
985
990


995
1000
1005
1010
1015
1020
1025
Depth
1m:500m
GAM(NAT)
CPS
0
400
15
RES(FL)
OHM-M
30
5
TEMP
DEG C
25