Technical Report

Title: ***Borehole Geophysical Logging of US-3 and US-7***

Document ID: **TR-08-03**

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Revision: **1**

Date: **February 5, 2009**

DGR Site Characterization Document
Intera Engineering Project 06-219

Intera Engineering DGR Site Characterization Document		
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Revision Number:	1	Date: February 5, 2009
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Technical Review:	Sean Sterling, Kenneth Raven, Dru Heagle; Jim McLay (OPG); Jacques Delay (GRG)	
QA Review:	John Avis	
Approved by:	 Kenneth Raven	

Document Revision History		
Revision	Effective Date	Description of Changes
0	August 25, 2008	Initial Release
1	February 5, 2009	Updated Section 5 to indicate the probable presence of the Lucas Formation overlying the Amherstburg Formation in both boreholes.

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1 Introduction

Intera Engineering Ltd. has been contracted by Ontario Power Generation (OPG) to implement the Geoscientific Site Characterization Plan (GSCP) for the Bruce site located near Tiverton, Ontario. The purpose of this site characterization work is to assess the suitability of the Bruce site to construct a Deep Geologic Repository (DGR) to store low-level and intermediate-level radioactive waste. The GSCP is described in the Geoscientific Site Characterization Plan, OPG's Deep Geologic Repository for Low and Intermediate Level Waste Report (Intera Engineering Ltd., 2006).

This report summarizes the borehole geophysical logging of boreholes US-3 and US-7 completed as part of the refurbishment of these boreholes for future groundwater monitoring purposes.

Work described in this Technical Report was completed in accordance with Test Plan TP-06-03 (Intera Engineering Ltd., 2007a) that describes the refurbishment of boreholes US-3 and US-7 and relevant parts of TP-07-05 (Intera Engineering Ltd., 2007b), that describes log-specific procedures for borehole geophysical logging of boreholes DGR-1 and DGR-2. This Test Plan was prepared following the general requirements of the Intera DGR Project Quality Plan (Intera Engineering Ltd., 2007c).

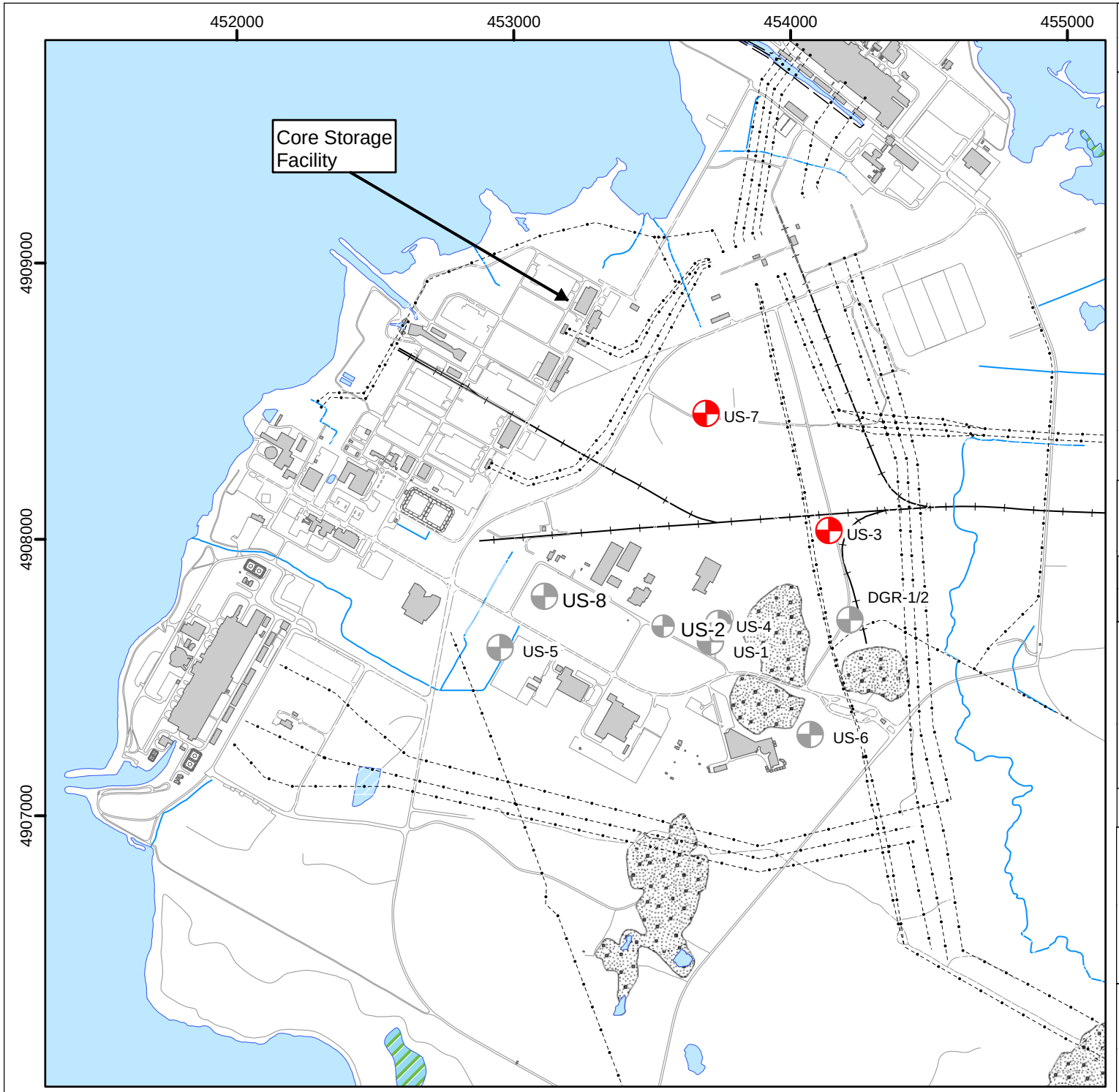
2 Background

The DGR facility is proposed to be constructed within the argillaceous limestone of the Cobourg Formation. As part of the GSCP, a network of deep bedrock boreholes (DGR Series) is being established, which primarily tests and monitors isolated borehole intervals from the Salina Formation F-Unit shale at approximately 200 mBGS down to the Precambrian bedrock at approximately 860 mBGS. In addition to this new network of deep boreholes, a network of shallow bedrock boreholes (US series) with depths of approximately 100 to 200 mBGS are being established to monitor shallow to intermediate hydrogeologic conditions. These shallow US-series boreholes also help to verify the contact elevations in the upper bedrock formations including the Lucas, Amherstburg, Bois Blanc, Bass Island and Salina G Unit Formations.

Six existing shallow bedrock boreholes and monitoring wells are located on the Bruce site in the vicinity of the proposed DGR (i.e., US-1, US-3, US-4, US-5, US-6 and US-7) completed into the upper 100 m of the bedrock. Figure 1 shows the location of these boreholes and monitoring wells on the Bruce site. Four of the six boreholes (US-1, US-5, US-6 and US-7) were instrumented with Westbay MP38 multi-level groundwater monitoring systems when they were drilled in the late 1980's. Detailed sampling and groundwater monitoring was performed in these monitoring wells until about 1994 (Lee et al., 1995) and later in selected intervals of these wells.

Refurbishment and instrumentation of two existing boreholes located on OPG-retained lands (i.e., US-3 and US-7) was recently completed as part of Phase 1 of the GSCP. Refurbishment included removal of existing monitoring casings (US-7), the geophysical logging of natural gamma, acoustic televiewer, and video, and the pumping/development of open boreholes. Refurbishment was required to prepare for installation of new Westbay MP38 multi-level groundwater monitoring systems to establish future shallow bedrock monitoring wells for the Bruce DGR project. TR-07-20 (Intera Engineering Ltd., 2009a) describes the refurbishment and installation of the new Westbay MP38 multi-level groundwater monitoring systems of boreholes US-3 and US-7.

The new monitoring wells (i.e., US-3 and US-7) will provide shallow bedrock monitoring intervals in the vicinity of the proposed DGR. The approximate location of US-3 and US-7 using NAD83 UTM Zone 17N coordinates are 454137.540 Easting and 4908030.430 Northing for US-3 and 453687.040 Easting and 4908459.601 Northing for US-7. The ground surface elevations of US-3 and US-7 are 184.56 m above sea level (mASL) and 182.98 mASL, respectively.



OPG DGR
Site Characterization Plan

Legend

- Location of US-3 and US-7
- Location of DGR-1/2 and US-series Wells
- Buildings
- Roads
- Railway
- Transmission Line
- Pits or Landfills
- Stream or Drainage

Location of US-3 and US-7

Figure 1

N

Scale 1:20,000 (approx.)

0 125 250 500 750 1,000 Meters

Date: 30/04/2008 Drawn: MAM
Project: 06-219 Checked: KGR
P:/Projects/2006/06-219/QMS_DGR/TM_Working Files/
TM-07-19/06-219_Location of US-3 and US-7.mxd

Projection: UTM NAD 83 Zone 17

Data Credits:
NRVIS/OBM, MNR, Ontario Power Generation, Bruce Power

3 Methods

3.1 Borehole Geophysical Logging of US-3 and US-7

A limited suite of borehole geophysical logs was conducted prior to installation of Westbay MP38 multilevel monitoring systems in boreholes US-3 and US-7. The refurbishment procedures as outlined in TP-06-03 for both US-3 and US-7 boreholes were modified by Intera Engineering Ltd. to conduct the borehole geophysical logging prior to borehole purging and sampling. This deviation was approved as it was deemed beneficial to complete the geophysics in boreholes that are in a relatively stable hydraulic state. The geophysical logging for natural gamma, acoustic televiewer (ATV) and borehole video logs was conducted by Lotowater Technical Services (Lotowater), based in Paris, Ontario, Canada, under contract to Intera Engineering Ltd.

Each of the borehole natural gamma and ATV logs were referenced to ground surface, accounting for the 0.25 m and 0.24 m stick-up of the steel well casing in US-3 and US-7, respectively. The natural gamma and ATV logs collected in US-7 and US-3 were conducted on November 20, 2007 and November 21, 2007, respectively. The natural gamma log was collected using a Mount Sopris Instruments Co. Inc. 2 PGA Gamma logger. The ATV logs were collected using Mount Sopris Instruments Co. ABI-40 slimhole acoustic televiewer. The video logs for both US-3 and US-7 were collected on November 21, 2007 using a Laval R2000 DUAL CAM camera.

Borehole geophysical logging and calibration procedures were followed as described for natural gamma, ATV, and video logging in TP-07-05 (Intera Engineering Ltd., 2007c). All recorded depths for natural gamma and ATV logs are accurate within 1% of the measured depth.

On completion of the video logs borehole features such as smooth competent zones, fractures, highly broken rock, breakout zones and voids were noted. Video log review notes are included as Tables A.1 and A.2 in Appendix A for US-3 and US-7, respectively. The results from the video log were used to determine the elevations of fractures in the bedrock, which was important for designing the configuration of the Westbay MP38 multi-level groundwater monitoring systems. The video logs were provided to OPG under cover letter dated January 14, 2008.

The natural gamma and acoustic caliper logs and the formation stratigraphy logs of boreholes US-3 and US-7 are given in Appendix B. The formation contacts of these logs were referenced from previously created borehole logs based on detailed logging of recovered core (Lukajic, 1988). These historical boreholes logs, which are provided in Appendix C, provide detailed information on the stratigraphy, lithology and rock quality encountered by boreholes US-3 and US-7.

3.2 Natural Gamma Log

The natural gamma log measures the natural radioactivity of the bedrock. An increase in radioactivity is indicated by elevated gamma radiation counts. The gamma radiation is measured in counts per second (cps) and allows for the useful identification of lithology and stratigraphic correlation. This is primarily a measurement of potassium, but also uranium and thorium content, which are preferentially concentrated in clays particles. Therefore the log indicates the variation in clay content within the bedrock. This log cannot distinguish between lithologies of similar gamma emission and cannot be used to define geologic boundaries alone. However this log is an excellent tool to locate boundaries between lithologies of substantially different levels of clay content, such as shales versus dolostones.

3.3 ATV Image Log

The acoustic televiewer (ATV) log provides images of the borehole wall that are not available by any other geophysical logging techniques or other borehole investigation methods. The tool generates an image of the

borehole wall by transmitting ultrasonic pulses from a rotating sensor and recording the amplitude and travel time of the signals reflected at the interface between the borehole liquid and borehole wall. The amplitude of these reflections is representative of the rock conditions surrounding the borehole. The reflected amplitude is displayed as a colour spectrum image. The image is a planar representation of a cylindrical object which plots from true north (0 azimuth degrees) back to true north, drawing from left to the right side of the image. This unravelled image plots angled fractures and bedding planes as sinusoidal waves. The amplitude and position of these waves allows for the magnitude and direction of the dipping features to be measured.

3.4 ATV Caliper Log

The acoustic travel time of a pulse generated by the tool and reflected by the borehole wall is used to measure the borehole diameter. The acoustic travel time represents the borehole shape and diameter and is used to provide exceptionally accurate borehole diameter measurements, which makes the tool ideal for casing inspection and structural geology. After calibrating the fluid velocity with a known diameter, (usually inside the casing), the average travel time of the reflected signal around the circumference of the borehole is used to calculate a caliper log. This caliper log indicates the average diameter and locates areas of possible fractures or borehole breakouts.

3.5 Borehole Orientation

The raw data file collected from the ATV logging tool was processed to create the tilt and azimuth direction of both US-3 and US-7. The tilt of the borehole represents the degrees off vertical measured from inclinometers embedded within the ATV logging tool. Similarly the azimuth direction of this tilt was measured from embedded magnetometers.

3.6 Borehole Video Log

The video log collected using the R2000 DUAL CAM borehole camera provides a colour image in a standard axial downhole view and side-view with continuous 360^{o} rotation. The depth difference between the side view camera and the downhole view camera is 76 mm, with the downhole camera being deeper. The depth encrypted on the video log was referenced to ground surface with a starting depth of 0.84 mBGS in both US-3 and US-7 where the depth is measured at the side view camera.

A source of error pertaining to the video log depth encryption is cable stretch. Unlike the other borehole geophysical logs the collective error associated with the depth encryption on the video log cannot be corrected after recording is complete. In order to adjust for this potential error associated with cable stretch, major features identified in the borehole video logs were correlated to these same features identified in the ATV image and ATV caliper logs. Borehole video log features listed in Table A.1 and A.2 for boreholes US-3 and US-7 are depth corrected to ATV logs.

4 Results

4.1 Natural Gamma Logs

The natural gamma logs for boreholes US-3 and US-7, as provided on the borehole logs in Appendix B, are relatively flat, typically less than 50 cps reflecting the relatively uniform bedrock lithology in boreholes US-3 and US-7 as dolostone. The natural gamma logs show several thin (< 1 m) zones of elevated gamma response greater than 100 cps in both boreholes that are likely indicative of clay-rich horizons in the dolostone bedrock of the Amhertsburg and Bois Blanc Formations. These gamma highs in combination with a lack of fracturing are target horizons for setting of MP38 casing packers for effectively isolating groundwater monitoring intervals.

4.2 ATV Logs

The ATV logs are illustrated on the borehole logs of US-3 and US-7 in Appendix B. The borehole logs show the ATV image of the borehole wall, the calculated average borehole diameter in inches, and the orientation of the borehole azimuth and tilt.

The ATV images of the borehole wall are of very good quality, showing the occurrence of both horizontal and inclined fractures, bedding planes and seams, discontinuities, borehole breakouts and other sedimentological features including zones of enhanced porosity and presence of chert nodules. The high quality of the ATV is most likely due to the completion of boreholes US-3 and US-7 using conventional diamond coring methods.

The ATV calculated average borehole diameters for US-3 and US-7 are relatively uniform at 3.0 and 3.8 inches as expected based on the drilling of these boreholes using N and H size coring equipment. The acoustic caliper logs show good correlation with the results of the ATV images of the borehole walls, with increases in borehole diameter corresponding to occurrence of large open discontinuities and seams.

Zones of borehole enlargement or fracture occurrence were noted at depths of 21.5, 23.0, 25.8, 51.9, 54.1, 58.6 and 72.6 mBGS in borehole US-3. Zones of borehole enlargement or fracture occurrence were noted at depths of 21.6, 23.6, 25.0, 28.1, 31.9, 38.4, 49.1, 57.5, 59.6, 63.5, 64.5, 67.5 and 80.2 mBGS in borehole US-7.

4.3 Borehole Video Logs

Tabular summaries of borehole video logs for US-3 and US-7 presented in Appendix A, show a good correlation with borehole features mapped from ATV image logging. Although the depth accuracy of the borehole video logs is much poorer than that of the ATV, the colour and resolution of the borehole video images are superior and allow identification of sedimentological features such as mudstone clasts, shaley layers, chert clasts, porous zones and occasionally fracture infilling minerals (e.g., calcite crystals) that are often not discernable with ATV logs. When used in conjunction with depth-accurate ATV logs, the video logs provide excellent images for identifying fractures, breakouts, voids, sedimentological features and smooth competent zones for setting of MP38 packers.

4.4 Borehole Orientation

Based on ATV logs US-3 has a measured tilt of less than 1.3 degrees from vertical in a varied north to northeast direction from approximately 22 mBGS to 50 mBGS and in a northern direction from approximately 50 m BGS and below. US-7 has a measured tilt of less than 1 degree from vertical in a general eastern direction across the entire drilled length. The measured tilt of both holes verifies that the holes are vertical.

5 Data Quality and Use

Data on bedrock formation nomenclature and occurrence in this Technical Report are based on historical borehole logs by Lukajic (1988). Logging and expert geological review of the stratigraphy in borehole DGR-1 at the Bruce site (Intera Engineering Ltd., 2009b) showed the presence of the Lucas Formation overlying the Amherstburg formation. Although the borehole logs by Lukajic (1988) did not identify the Lucas Formation, it most likely overlies the Amherstburg Formation in both US-3 and US-7.

The data presented in this Technical Report were used in the design of Westbay MP38 multi-level monitoring casings for boreholes US-3 and US-7.

The data presented in this Technical Report are also suitable for improving the shallow bedrock geological framework for development of Phase 1 descriptive geosphere site models of the Bruce DGR site.

6 References

Intera Engineering Ltd., 2009a. Technical Report: Westbay MP38 Casing Completions in US-3, US-7 & US-8, TR-07-20, Revision 0, in preparation, Ottawa.

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Lee, D., T. Kotzer and K. King, 1995. Preliminary Assessment of Low- and Intermediate-Level Waste Disposal in the Michigan Basin: Isotopic and Geochemical Measurements, Atomic Energy of Canada Ltd., Chalk River Laboratories, Report COG-95-248-I, June.

Lukajic, B.J., 1988. Preliminary Results of the 1986-87 Geological Investigations, BNPD Proposed Underground Irradiated Fuel Storage Facility, Ontario Hydro Report GHED-DR-8801, July, Toronto.

APPENDIX A

Video Log Review Notes - US-3 & US-7

Table A.1 - US-3 Video Log Review Notes

Table A.2 - US-7 Video Log Review Notes

Table A.1 - US-3 Video Log Review Notes

Zone		Borehole Wall Description
Top (mBGS)	Bottom (mBGS)	
	21.0	Bottom of surface casing
21.0	21.4	Cement
	21.5	Breakouts
	22.0	Vertical fracture
22.0	22.6	Smooth, unfractured
	22.6	Single horizontal fracture breakout
22.6	22.9	Smooth, unfractured
23.1	23.3	Two breakouts
23.2	24.0	Smooth, unfractured
	24.0	Single horizontal fracture breakout
24.0	24.7	Smooth, unfractured
	24.7	Horizontal fracture
24.7	25.0	Smooth, unfractured
	25.0	Two fractures
25.0	25.6	Smooth, unfractured
25.7	25.8	Breakout
25.8	26.9	Smooth, unfractured
	26.9	Fracture breakout
26.9	29.1	Smooth, unfractured
	29.1	Fracture breakout
29.1	31.7	Smooth, unfractured
	31.7	Horizontal fracture
31.7	34.2	Smooth, unfractured
34.2	34.3	Vertical fracture and voids
34.3	35.1	Smooth, unfractured
	35.1	Breakout
35.1	35.6	Smooth, unfractured
	35.6	Breakout
35.6	38.4	Smooth, unfractured
	38.4	Breakout
38.4	39.0	Smooth, unfractured
39.0	39.9	Voids
	39.9	Fracture
39.9	41.2	Smooth, unfractured
	41.2	Horizontal fracture
41.2	41.5	Smooth, unfractured
	41.5	Two fractures
41.5	41.8	Smooth, unfractured
	41.8	Two fractures or breakouts
41.8	45.8	Smooth, unfractured
	45.8	Breakout
45.8	48.0	Smooth, unfractured
	48.0	Breakout or void
48.0	49.2	Smooth, unfractured
49.2	49.4	Vertical fracture
	49.5	Sub-vertical fracture
49.5	50.1	Smooth, unfractured
	50.1	Horizontal fracture and breakout

Table A.1 - US-3 Video Log Review Notes (cont'd)

Zone		Borehole Wall Description
Top (mBGS)	Bottom (mBGS)	
50.1	50.4	Smooth, unfractured
	50.4	Sub-vertical fracture breakout
50.4	50.6	Smooth, unfractured
	50.6	Horizontal fracture, breakout
50.6	50.9	Smooth, unfractured
	50.9	Horizontal fracture
50.9	51.8	Smooth, unfractured
	51.8	Fractures (three) with breakout
51.8	52.2	Breakout with sub-vertical and vertical fractures
52.2	53.1	Smooth, unfractured
	53.1	Breakout
53.1	53.5	Smooth, unfractured
	53.5	Breakout
53.5	54.0	Smooth, unfractured
	54.0	Breakout
54.0	54.3	Smooth, unfractured
	54.3	Breakout
54.3	54.9	Smooth, unfractured
	54.9	Breakout
54.9	57.0	Smooth, unfractured
57.0	57.3	Sub - vertical fracture
57.3	58.5	Smooth, unfractured
58.5	58.8	Sub - vertical fracture and breakout
58.8	59.5	Smooth, unfractured
59.5	59.6	Sub - vertical fracture
59.6	62.0	Smooth, unfractured
	62.0	Horizontal fracture and breakout
62.0	64.6	Smooth, unfractured
64.6	65.3	Sub-vertical fracture and voids
65.3	65.9	Smooth, unfractured
65.9	66.5	Vertical fracture
66.5	67.1	Smooth, unfractured
	67.1	Horizontal fracture
67.1	67.4	Smooth, unfractured
67.4	67.5	Vertical fracture
67.5	70.1	Smooth, unfractured
70.1	70.3	Sub - vertical fracture
70.3	70.4	Sub - vertical fracture breakout
70.4	72.5	Smooth, unfractured
	72.5	Horizontal fracture and breakout
72.5	72.9	Smooth, unfractured
72.9	73.2	Poor visibility, murky
	73.2	End depth of video log

Notes:

mBGS = metres below ground surface

Table A.2 - US-7 Video Log Review Notes

Zone		Borehole Wall Description
Top (mBGS)	Bottom (mBGS)	
	19.8	Bottom of surface casing
19.9	20.1	Sub - vertical fracture with voids
20.1	20.3	Smooth, unfractured
	20.3	Horizontal fracture with breakout
20.3	20.7	Smooth, unfractured
	20.7	Breakout
20.7	21.1	Smooth, unfractured
	21.1	Breakout
21.2	21.7	Dark staining
	21.3	Localized voids
21.5	21.7	Vertical fracture
21.3	21.7	Breakout with horizontal fractures
21.7	22.4	Localized voids
22.4	22.6	Vertical fracture
	22.6	Two horizontal fractures with breakout
22.6	23.3	Smooth, localized voids
	23.3	Horizontal fracture with breakout
	23.6	Horizontal fracture with breakout
23.6	24.1	Smooth, unfractured
	24.1	Horizontal fracture with breakout
	24.4	Breakout
24.5	24.4	Horizontal fractures
	24.7	Breakout
	25.0	Horizontal fracture breakout
25.0	25.3	Increased void density
25.3	25.9	Smooth, unfractured
	25.9	Sub - vertical fracture
25.9	26.2	Localized voids
26.2	26.5	Sub - vertical to vertical fracture
26.5	27.4	Smooth, unfractured, dark staining
	27.4	Horizontal fracture with breakout
27.7	28.0	Four sub - vertical fractures
28.0	28.5	Vertical fracture breakout
28.5	29.0	Sub - vertical fracture breakout
29.0	29.5	Smooth, unfractured, dark staining
	29.5	Horizontal fracture breakout
29.5	29.7	Sub - vertical fracture
29.7	30.2	Smooth, unfractured
30.2	30.4	Sub - vertical fracture
30.7	30.5	Sub - vertical fracture
30.5	31.6	Unfractured, localized voids
31.8	32.1	Sub - vertical fractures
32.1	32.4	Smooth, unfractured
32.4	32.6	Multiple sub - vertical fractures
32.8	33.1	Sub - vertical fractures
33.1	34.7	Smooth, unfractured, dark staining
34.7	37.9	Unfractured, localized breakouts and voids
	37.9	Breakout
37.9	38.5	Unfractured, localized voids
	38.5	Horizontal fracture breakout
38.5	41.2	Unfractured, localized voids
41.2	41.5	Sub - vertical fracture
41.5	42.0	Smooth, unfractured
42.0	42.3	Unfractured, localized voids and breakouts
42.3	43.4	Smooth, unfractured
	43.4	Breakout

Table A.2 - US-7 Video Log Review Notes (cont'd)

Zone		Borehole Wall Description
Top (mBGS)	Bottom (mBGS)	
43.5	43.7	Unfractured, localized voids
43.7	44.5	Smooth, unfractured
	44.5	Sub - vertical fracture
44.5	49.1	Unfractured, localized voids and breakouts
49.1	48.8	Breakout void with crystal development
48.8	51.2	Poor visibility, very murky
51.2	51.7	Smooth, unfractured
	51.7	Breakout
51.7	53.2	Smooth, unfractured
	53.2	Horizontal breakout
	53.4	Two breakouts
53.4	54.3	Smooth, unfractured
	54.3	Horizontal breakout
54.3	55.2	Smooth, unfractured
	55.2	Breakout
55.2	56.2	Smooth, unfractured
	56.2	Horizontal breakout
56.2	56.9	Smooth, unfractured
56.9	57.1	Sub - vertical fracture
	57.1	Horizontal breakout
	57.5	Horizontal breakout
	57.8	Voids and breakouts
57.8	59.5	Smooth, unfractured
	59.5	Horizontal fracture breakout
59.5	59.8	Smooth, unfractured
	59.8	Sub - vertical fracture
	60.0	Localized voids
60.0	62.6	Smooth, unfractured
	62.6	Breakout
62.6	63.4	Smooth, unfractured
	63.4	Horizontal breakout
63.4	64.0	Smooth, unfractured
	64.0	Horizontal breakout
64.0	65.2	Smooth, unfractured
	65.2	Sub - vertical fracture, breakout
65.2	66.4	Smooth, unfractured
	66.4	Breakout
66.6	66.8	Sub - vertical fracture with breakout
	67.4	Horizontal breakout
67.4	68.8	Smooth, unfractured
	69.3	Vertical fracture
69.3	71.6	Smooth, unfractured
	71.6	Horizontal fracture breakout
	72.6	Sub - vertical fracture
	73.0	Sub - vertical fracture
	73.1	Fracture
73.1	74.5	Smooth, unfractured
	74.5	Sub - vertical fracture with breakout
74.5	76.7	Smooth, unfractured
	76.7	Fracture
76.7	80.0	Smooth, unfractured
	80.0	Horizontal breakout
80.0	88.5	Smooth, unfractured, few localized voids
	88.5	End of video log

Notes:

mBGS = metres below ground surface

APPENDIX B

Borehole Geophysical Logs - US-3 & US-7

RECORD OF BOREHOLE US-3

Borehole Number :	US-3	Date Completed:	21-Nov-07
Project Number:	06.219.25.10	Supervisor:	Sean Sterling
Client:	Ontario Power Generation	Reference Surface Elevation:	184.56 mASL
Site Location:	Tiverton, Ontario, Canada	Source Geologist:	S. Rose
Coordinates:	NAD83 UTM Zone 17N	Source:	B. Lukajic, 1988
	Northing = 4908030.430m, Easting = 454137.540m		

Stratigraphic Legend

Till

Dolostone

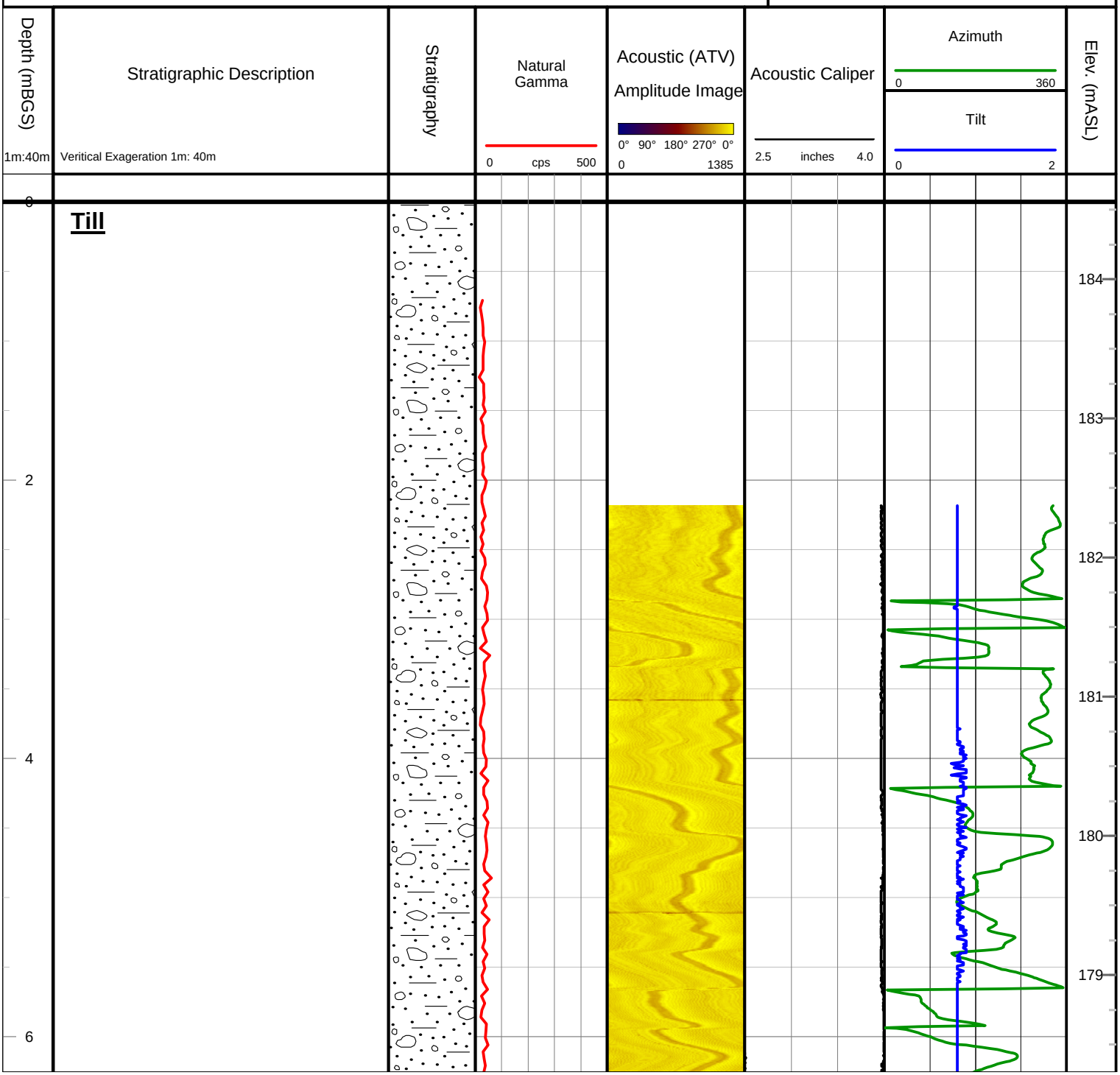
Cherty Dolostone

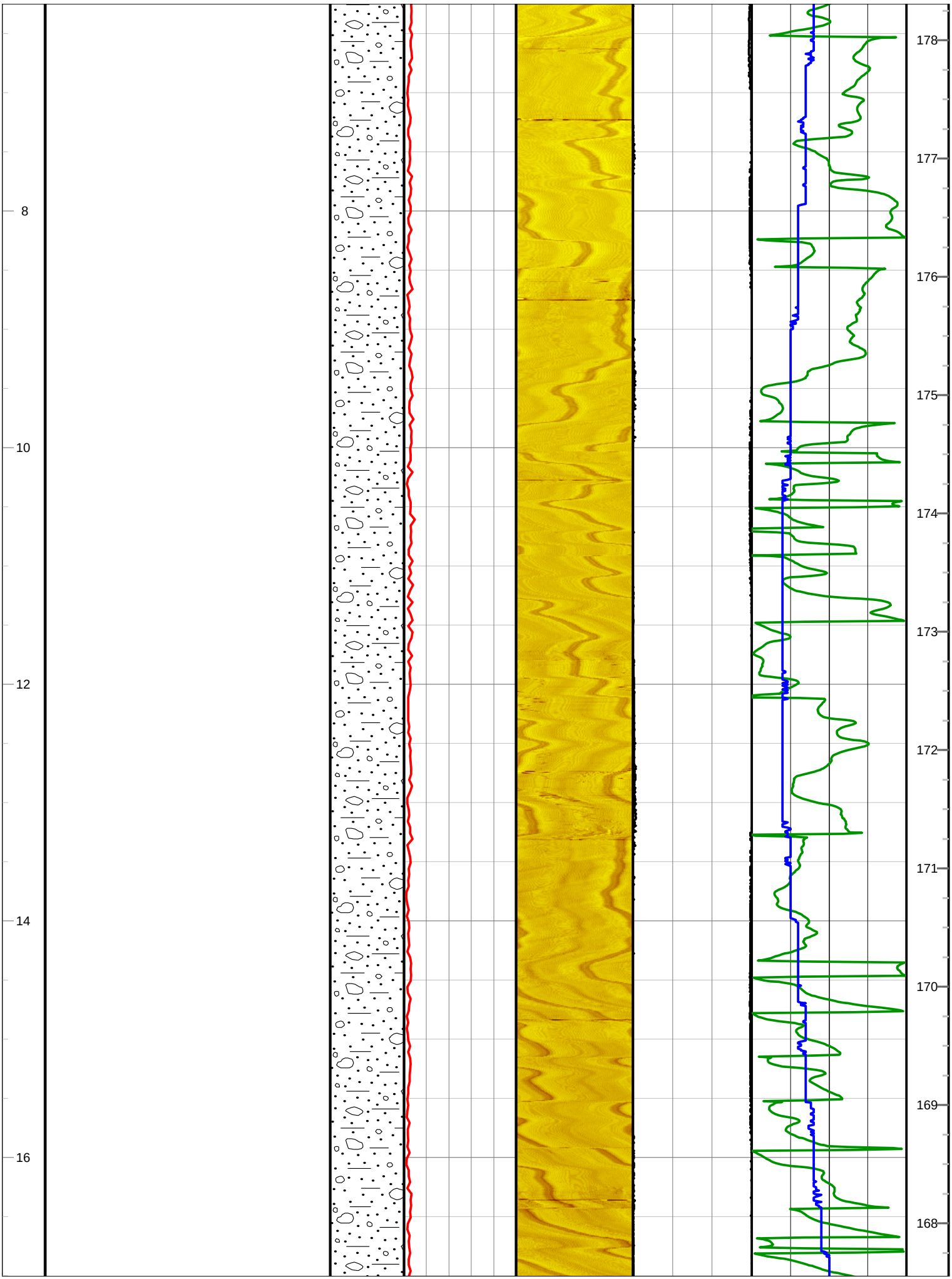
Contact Legend

Borehole Boundary

Casing

Formation Contact

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14
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176
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174
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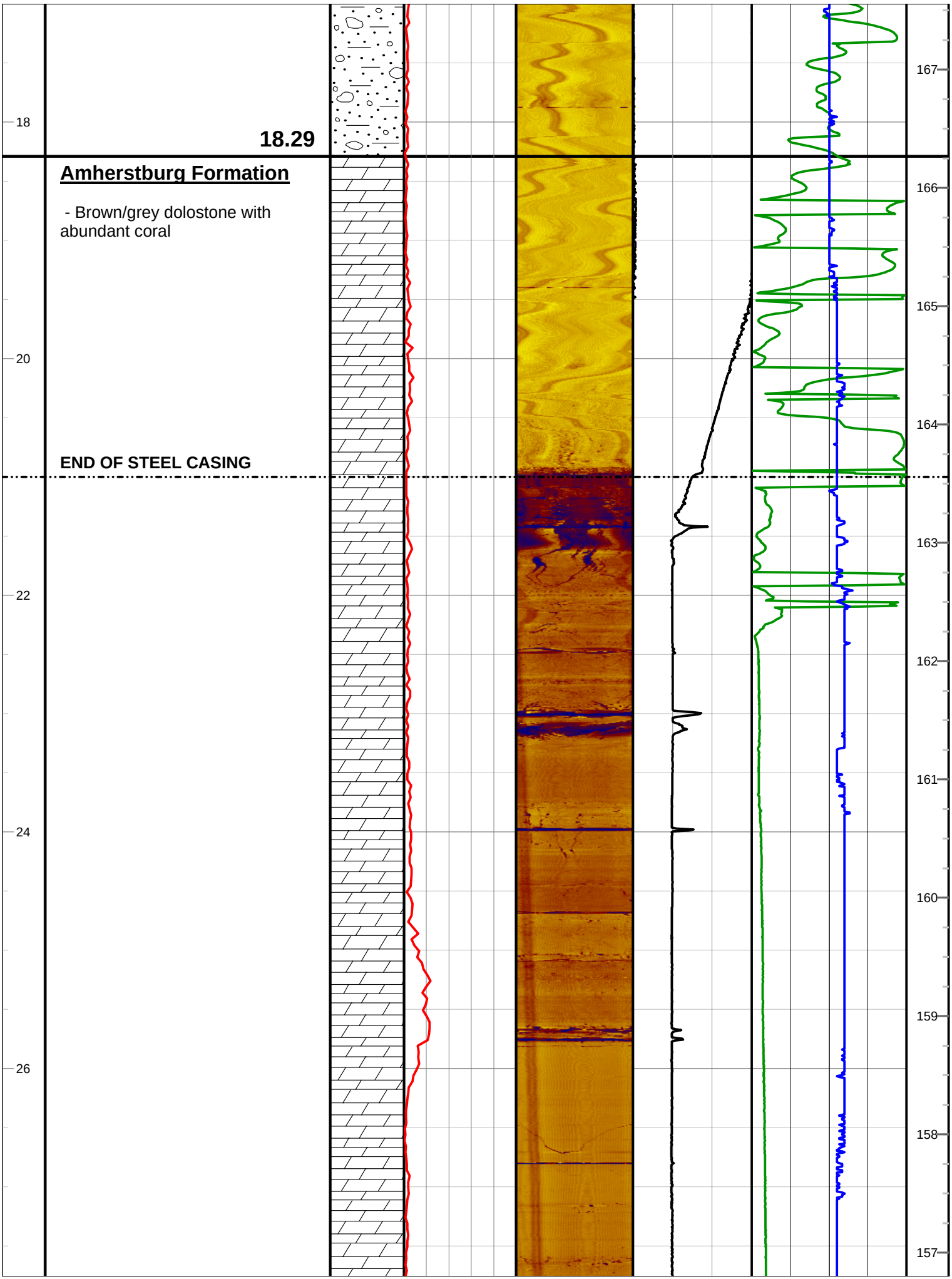
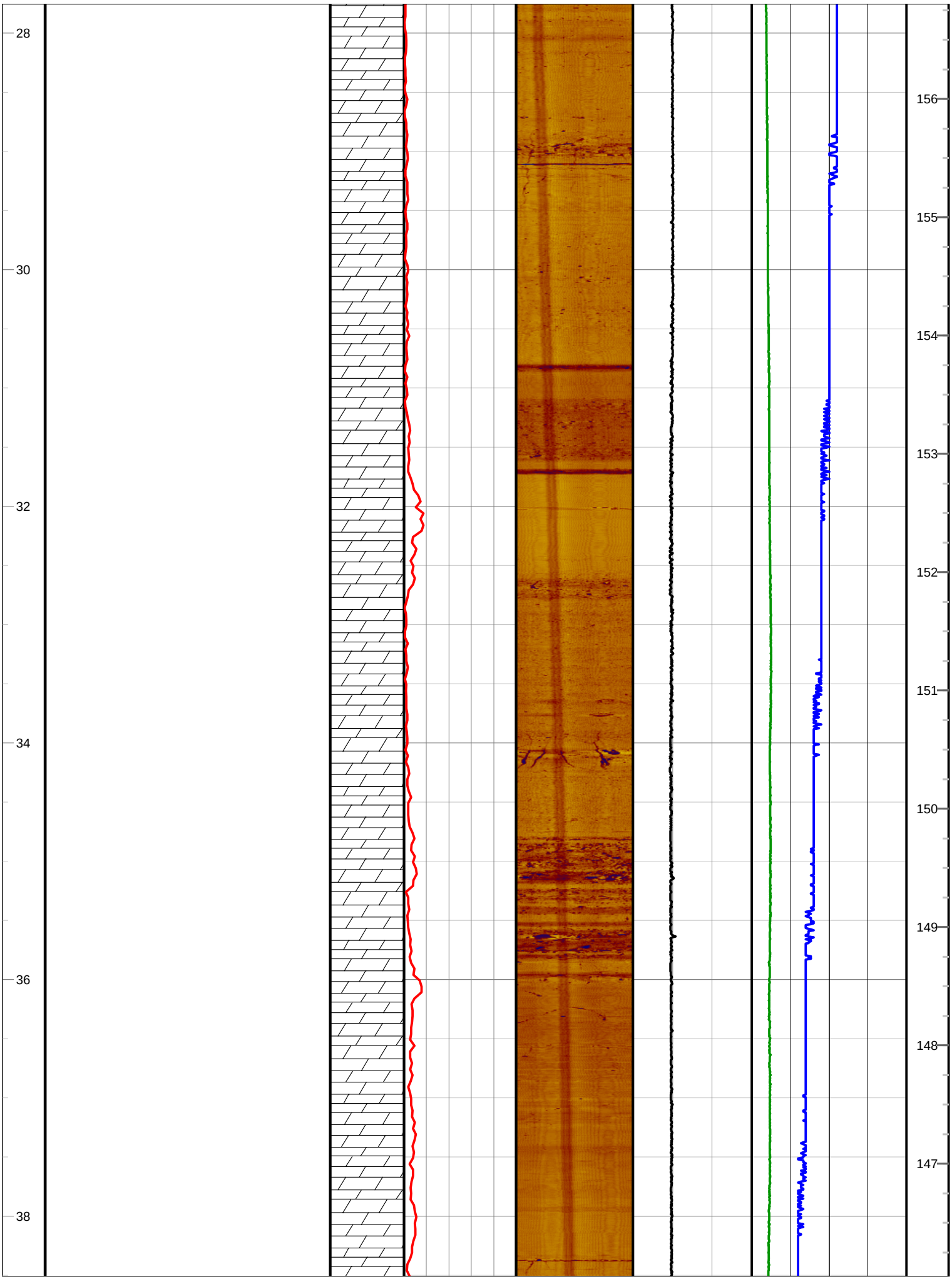
172
171
170
169
168


18
18.29
Amherstburg Formation
- Brown/grey dolostone with abundant coral
20
END OF STEEL CASING
22
24
26
167
166
165
164
163
162
161
160
159
158
157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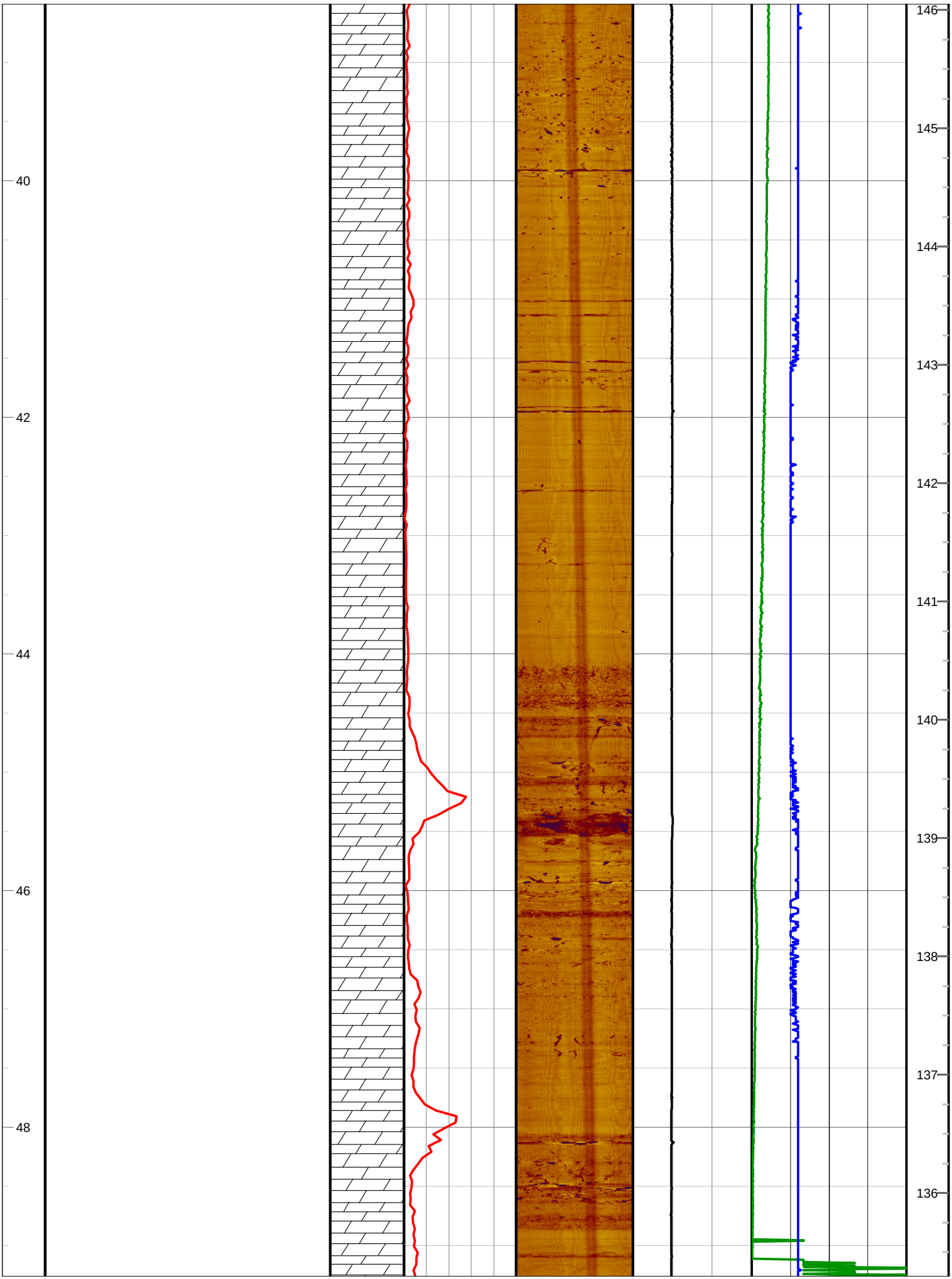
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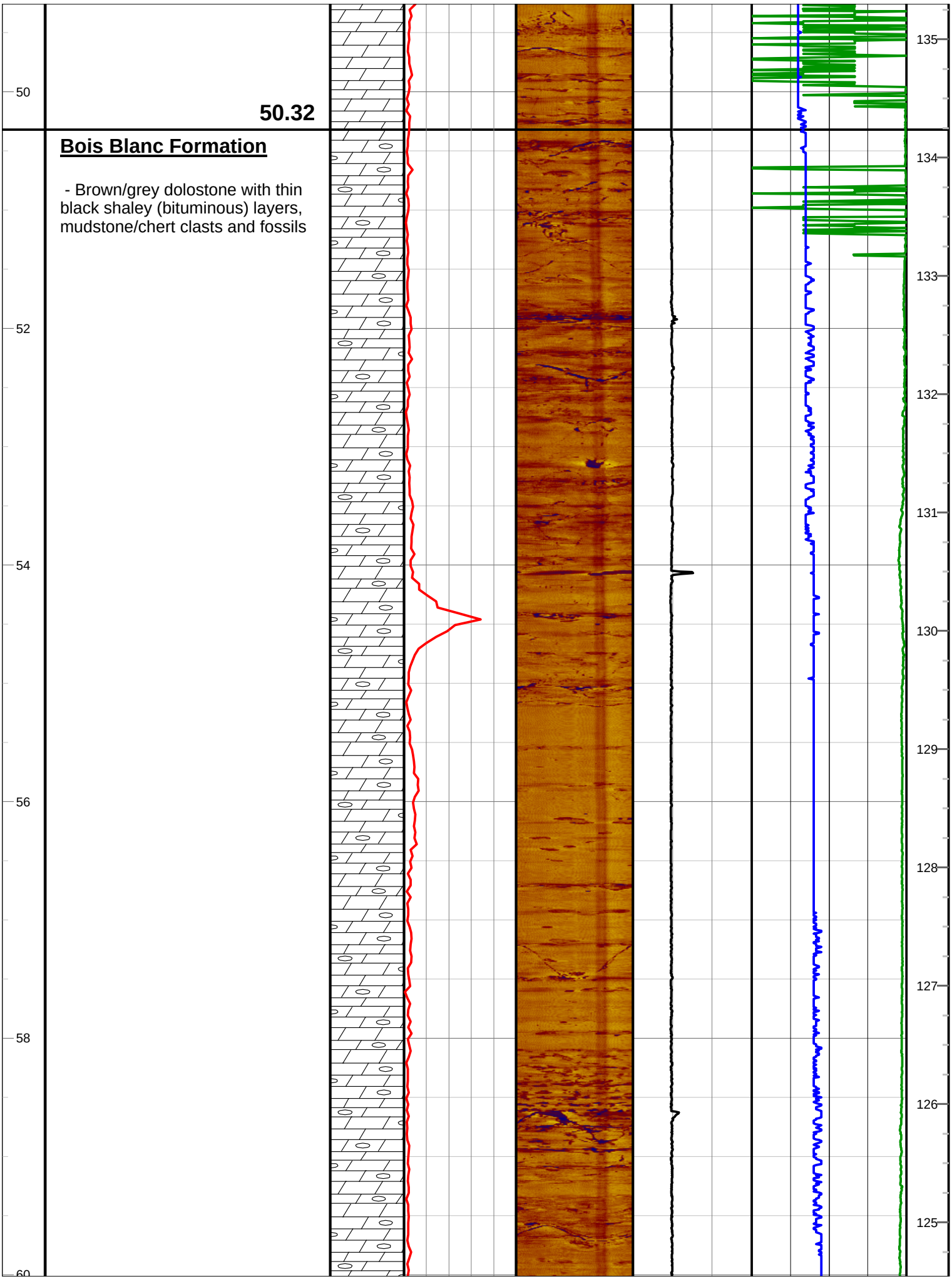
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50.32
Bois Blanc Formation
- Brown/grey dolostone with thin black shaley (bituminous) layers, mudstone/chert clasts and fossils
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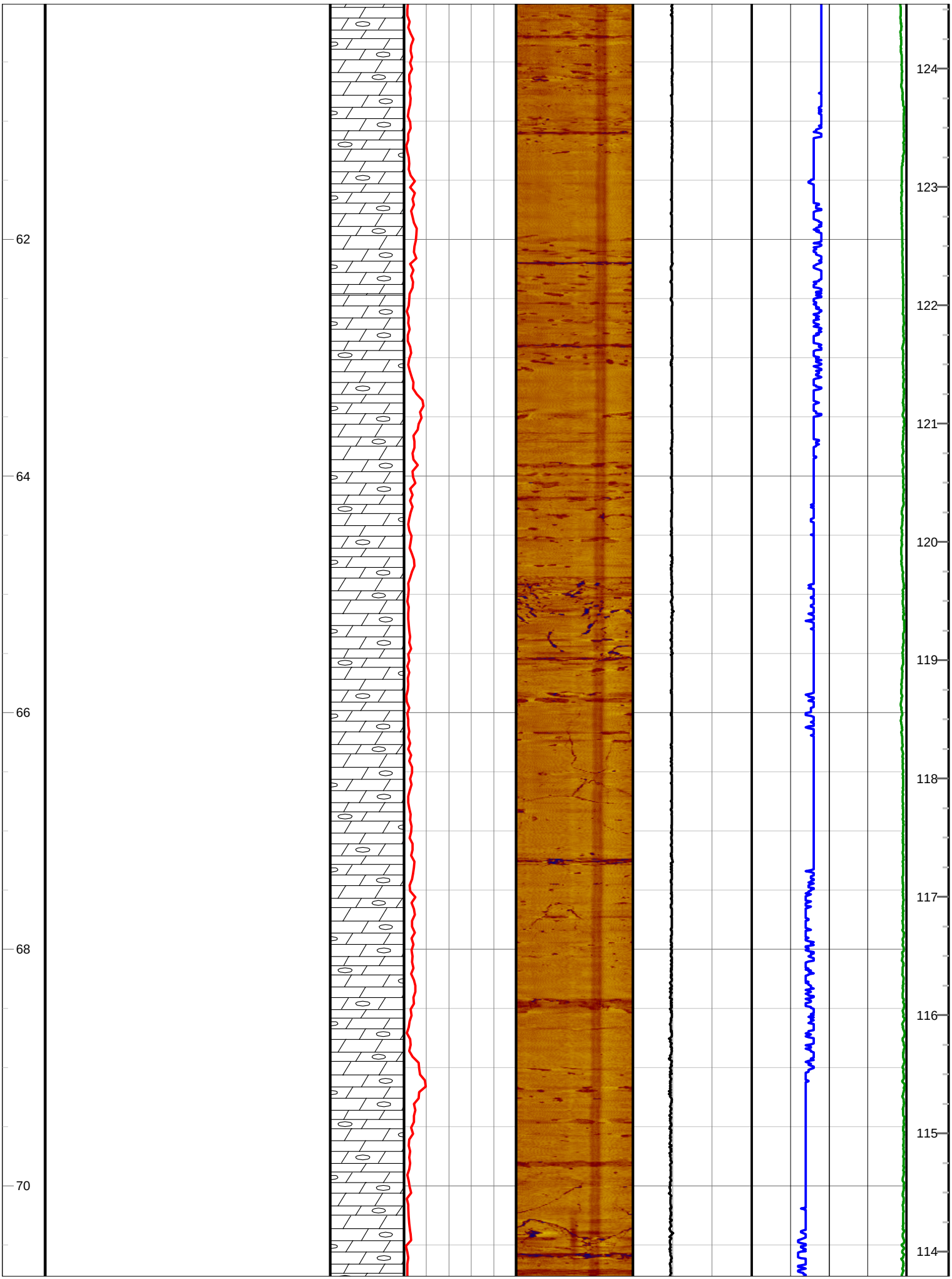
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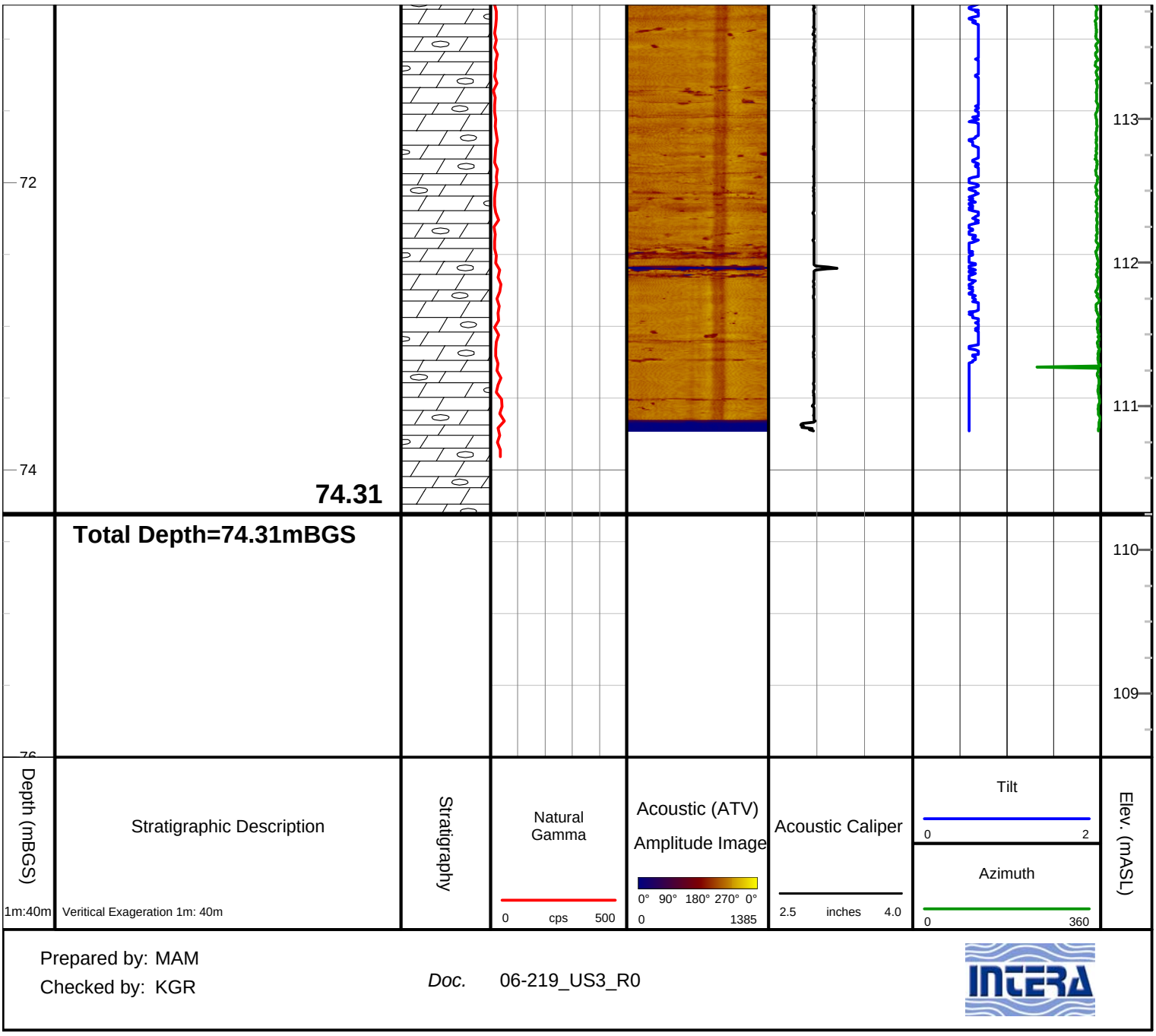


Prepared by: MAM
Checked by: KGR

Doc. 06-219_US3_R0

RECORD OF BOREHOLE US-7

Borehole Number :	US-7	Date Completed:	21-Nov-07
Project Number:	06.219.25.10	Supervisor:	Sean Sterling
Client:	Ontario Power Generation	Reference Surface Elevation:	182.98 mASL
Site Location:	Tiverton, Ontario, Canada	Source Geologist:	R. Herntier
Coordinates:	NAD83 UTM Zone 17N, Northing = 4908459.601m, Easting = 453687.040m	Source:	Lukajic, 1988

Stratigraphic Legend

Till

Cherty Dolostone

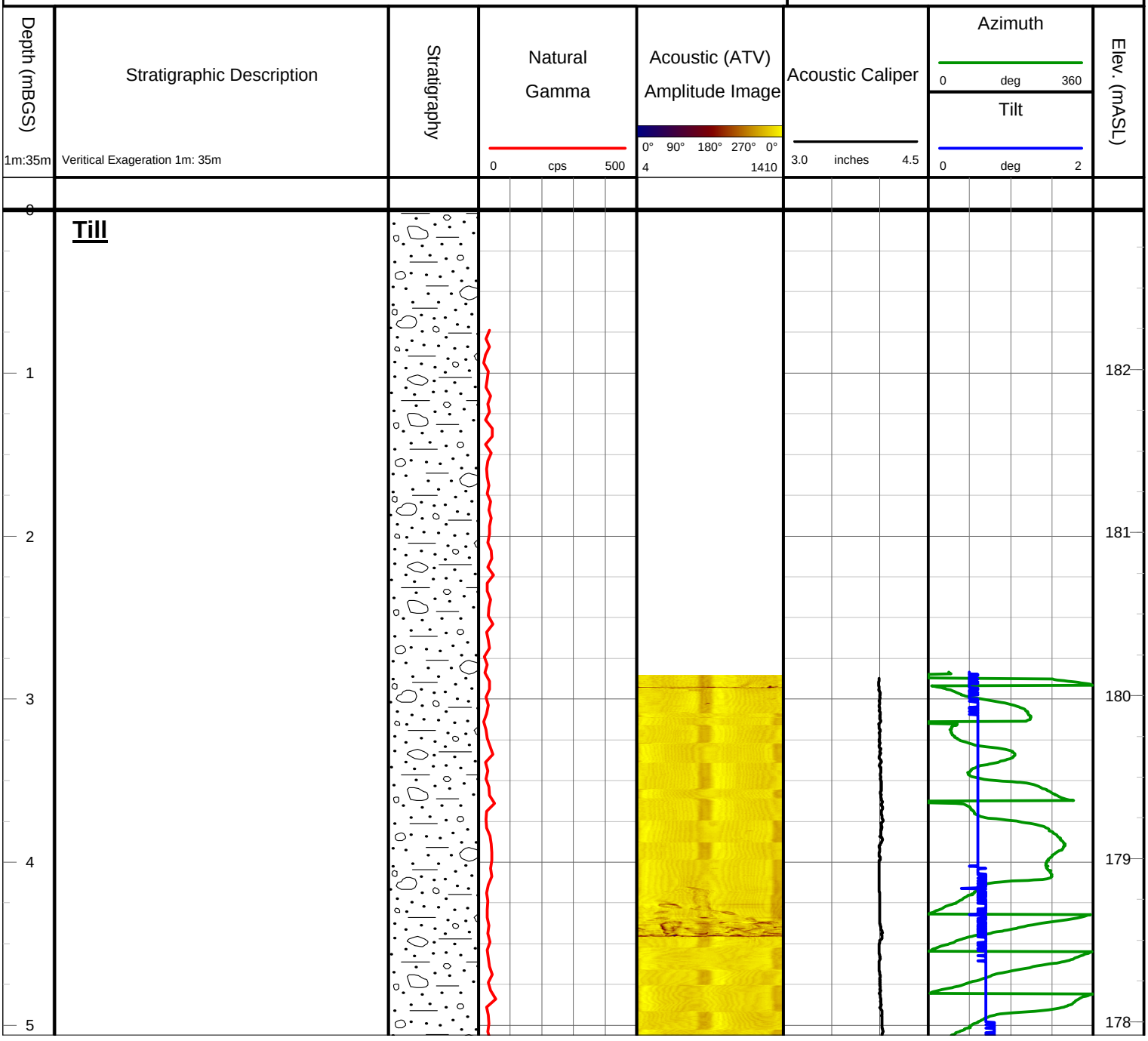
Dolostone

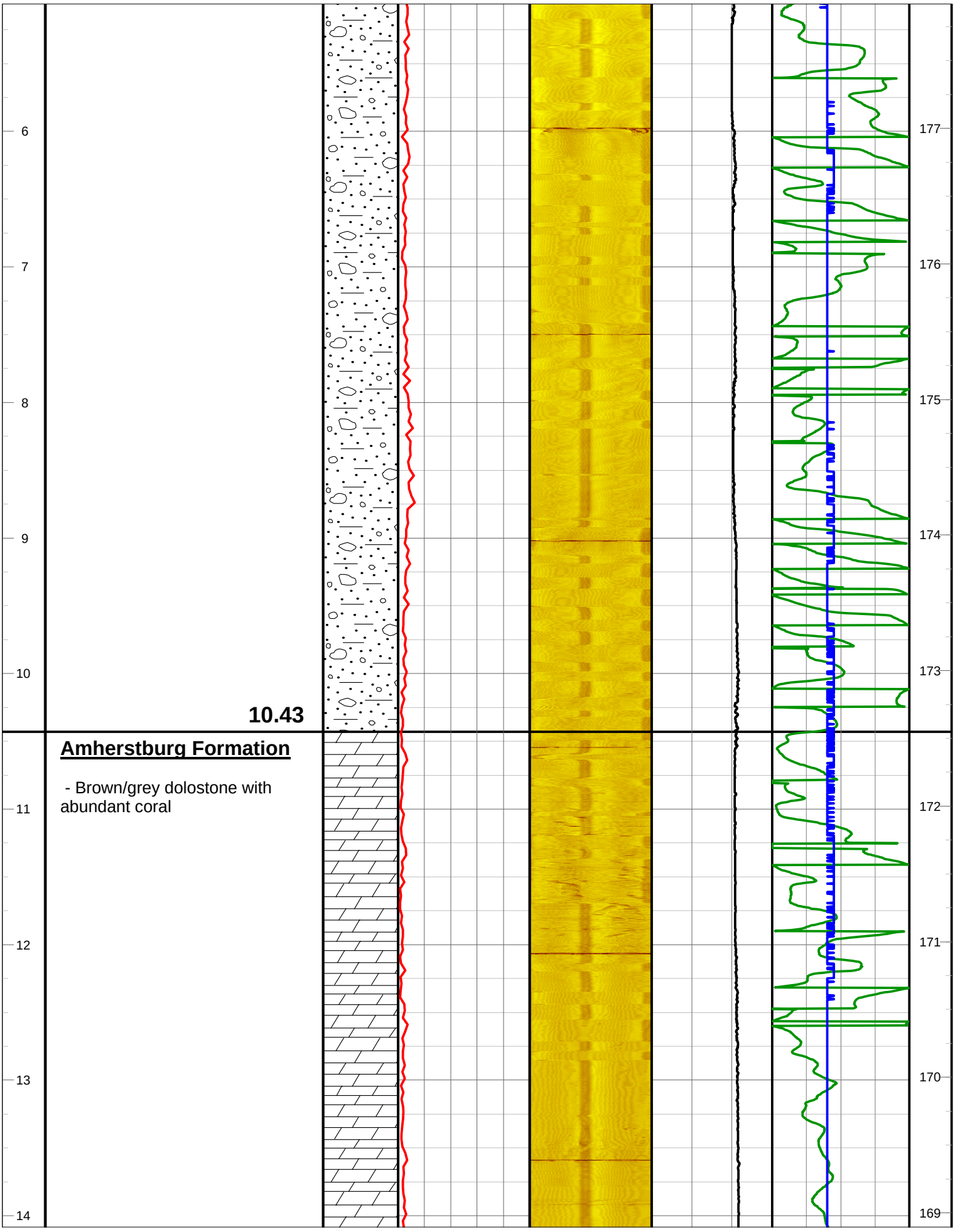
Contact Legend

Borehole Boundary

Casing

Formation Contact

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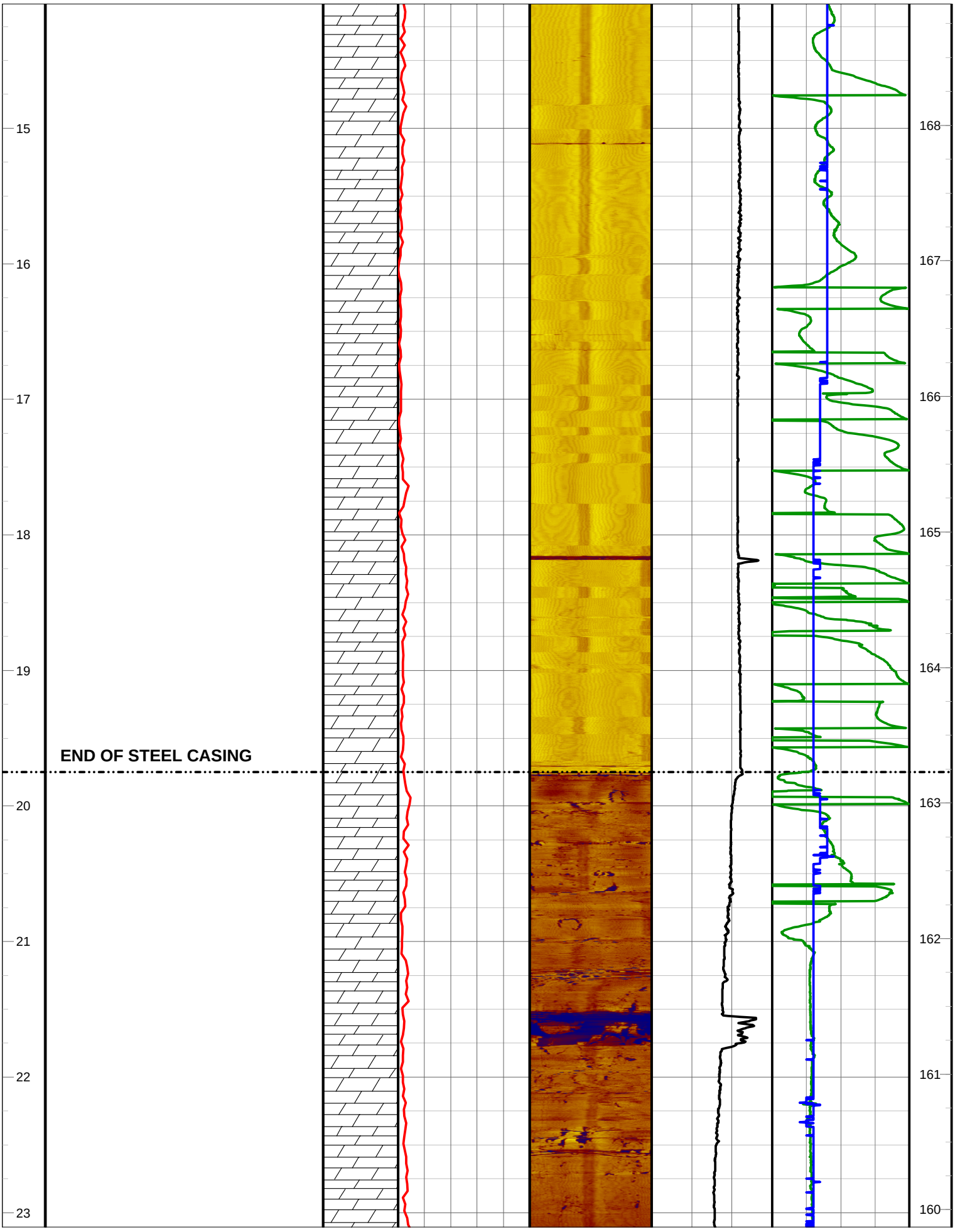
Amherstburg Formation
- Brown/grey dolostone with abundant coral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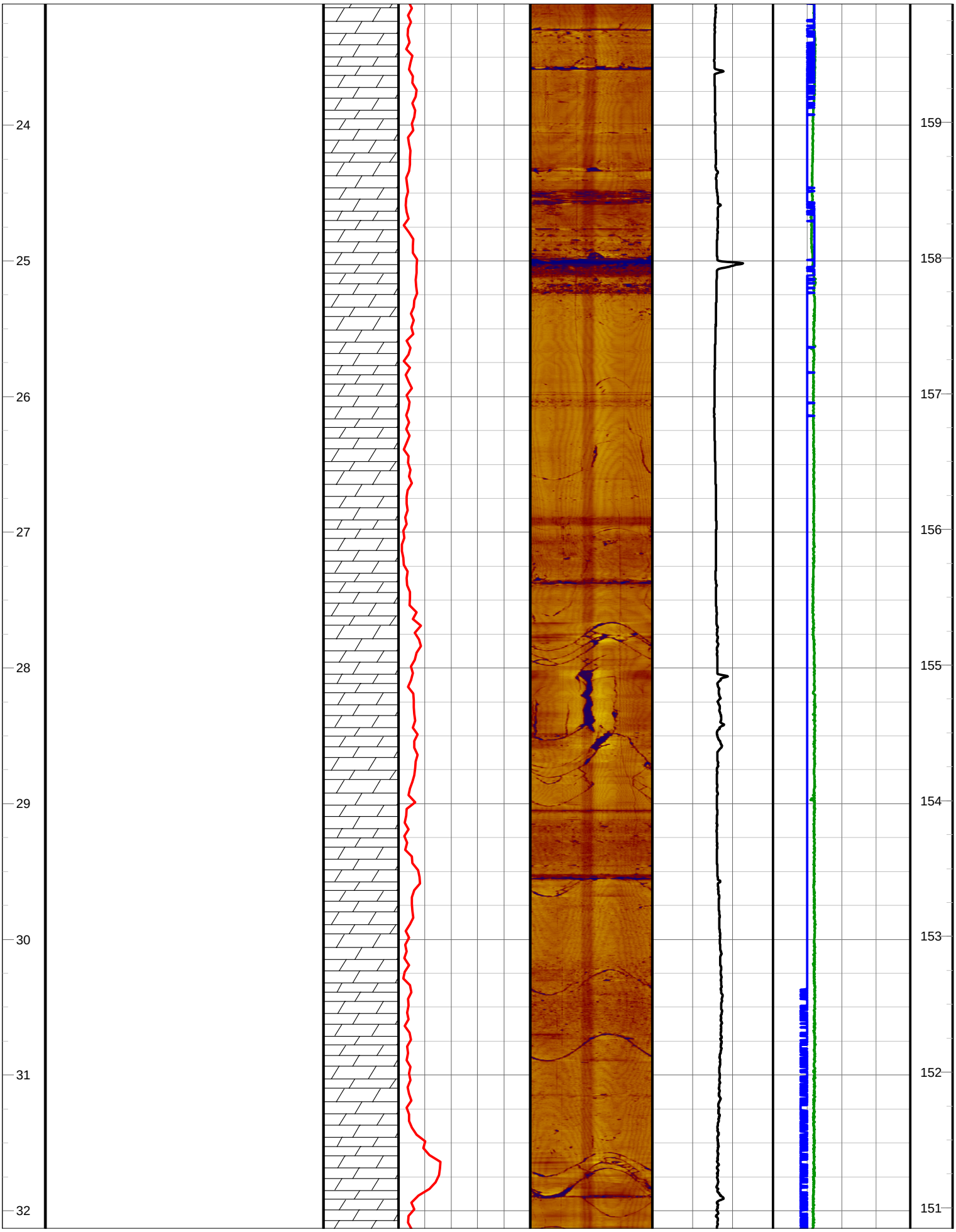
END OF STEEL CASING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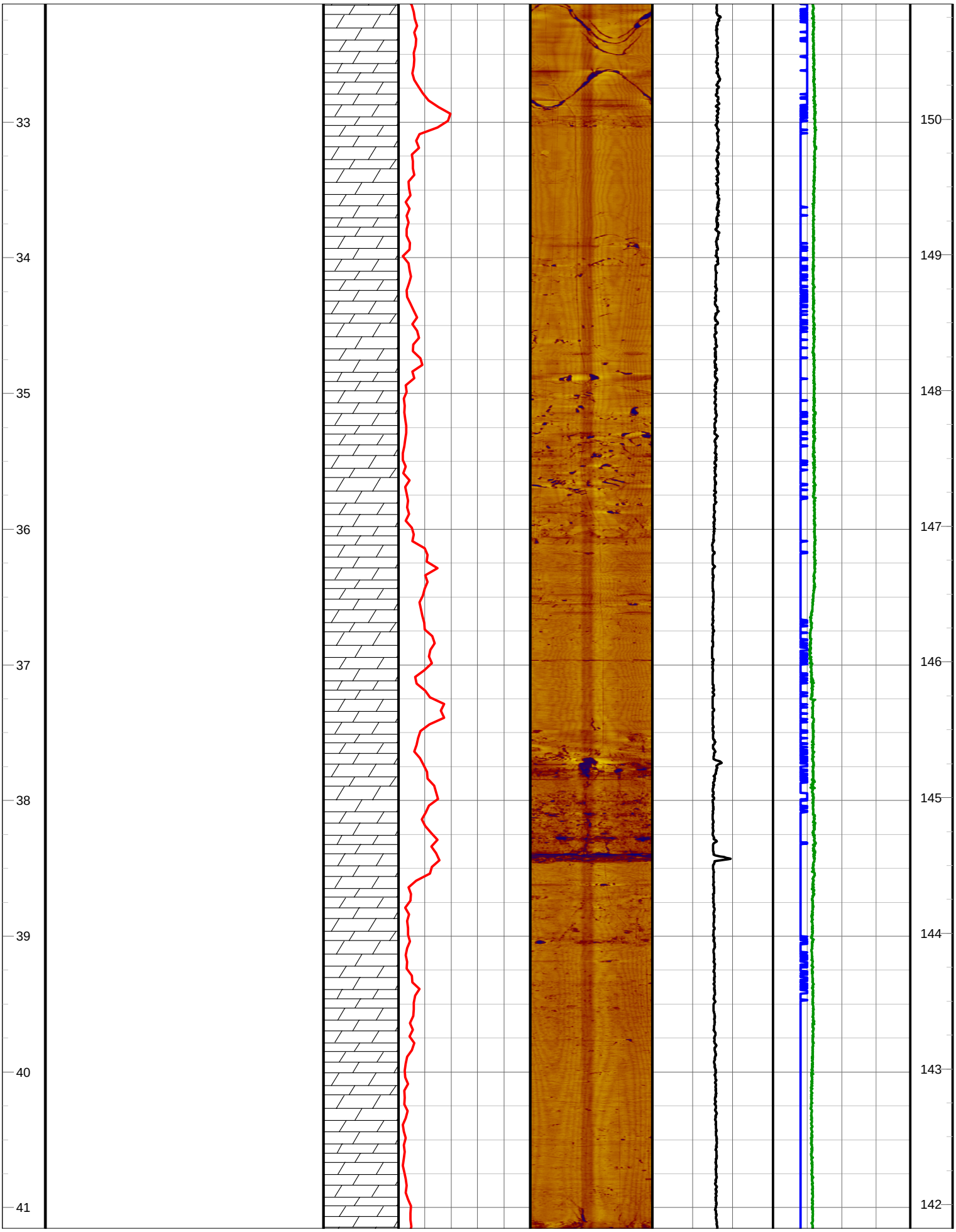
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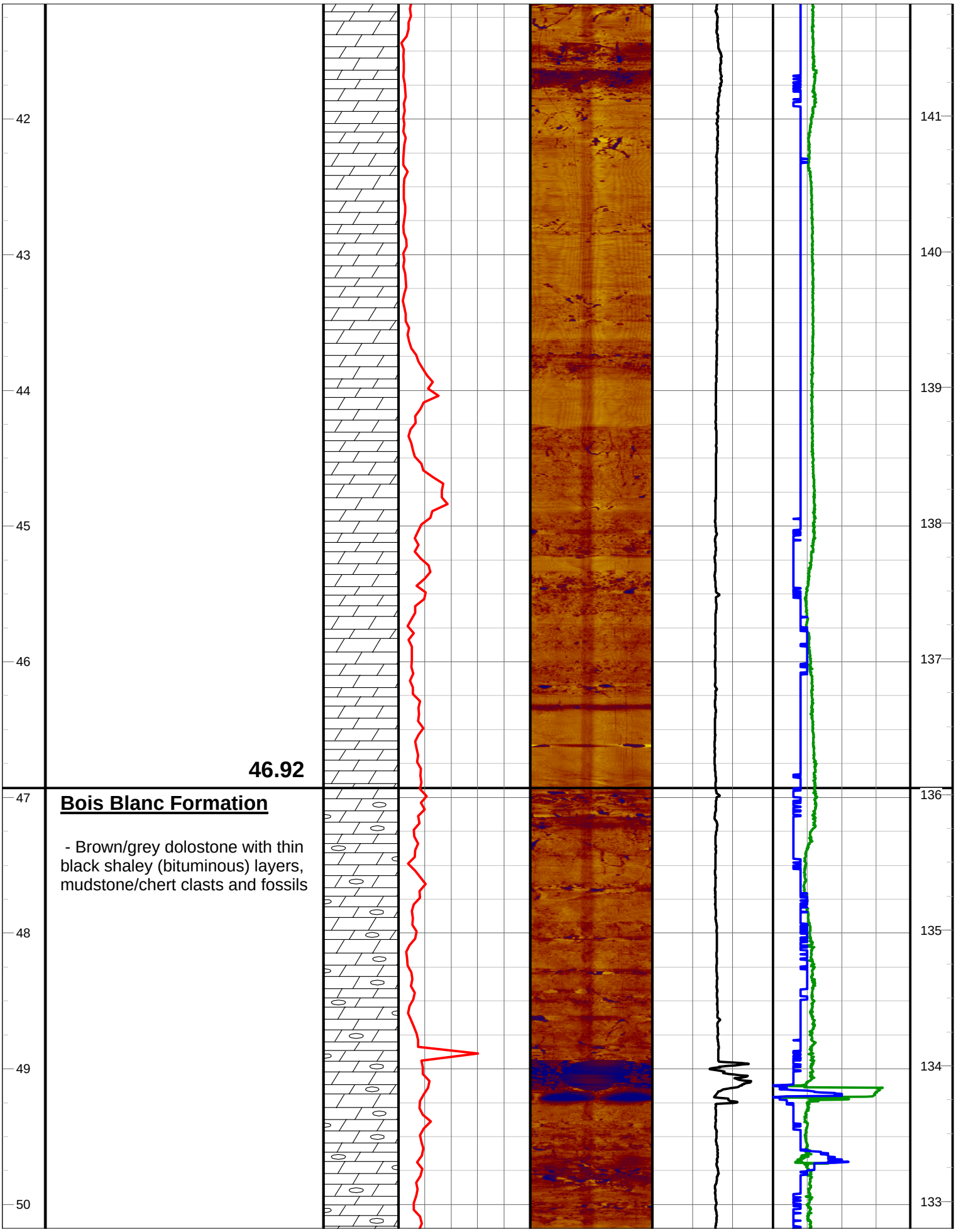
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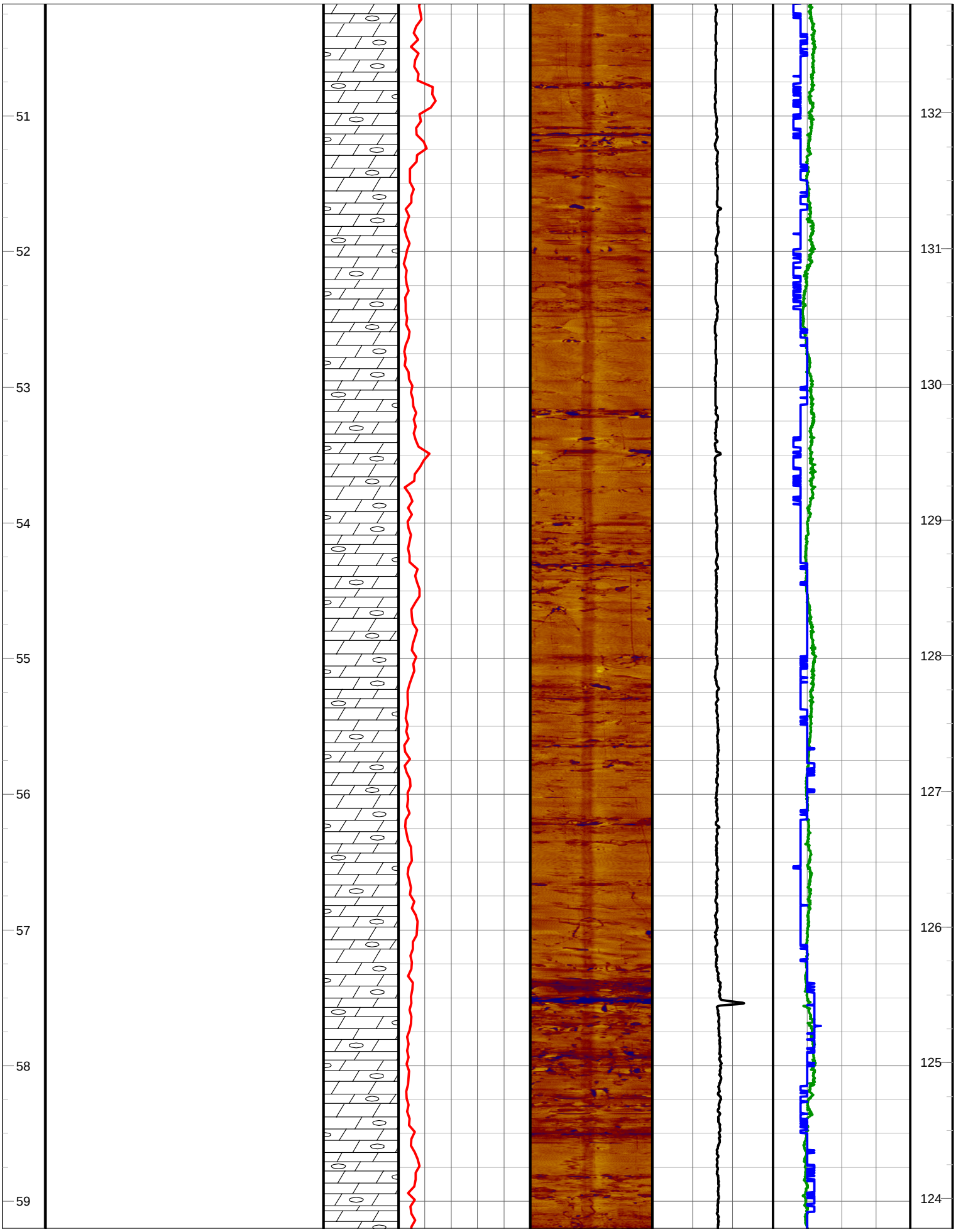
Bois Blanc Formation
- Brown/grey dolostone with thin black shaley (bituminous) layers, mudstone/chert clasts and fossils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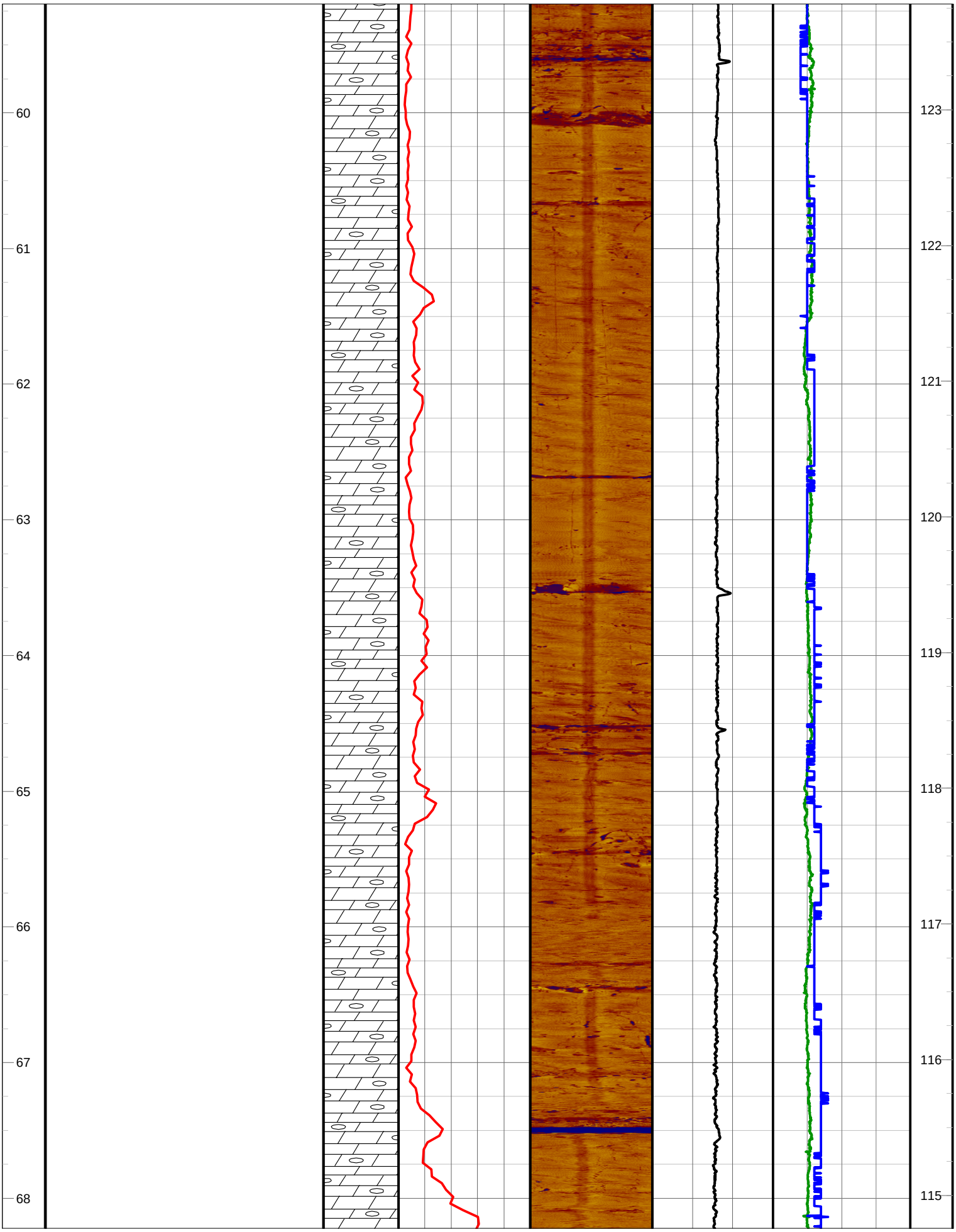
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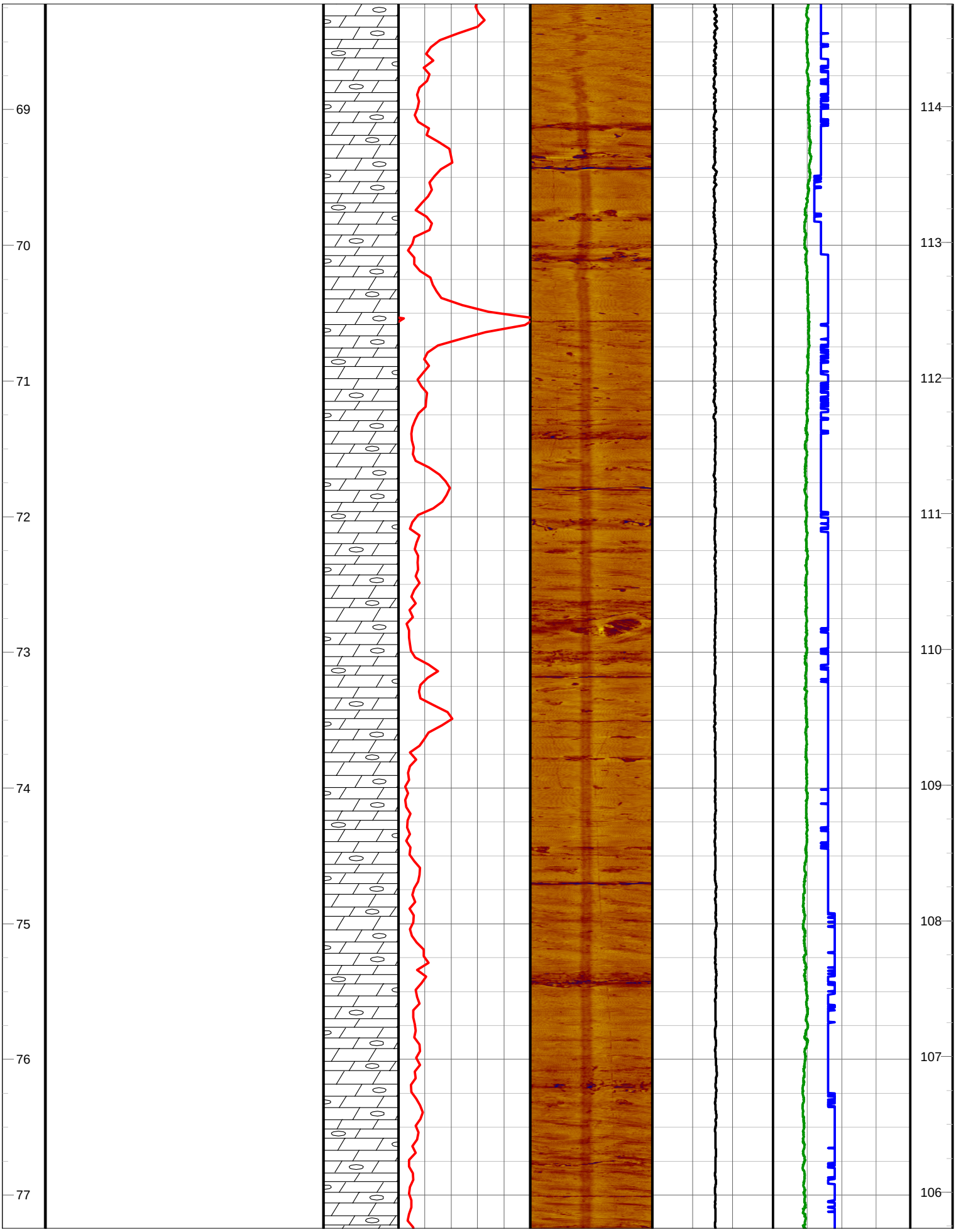
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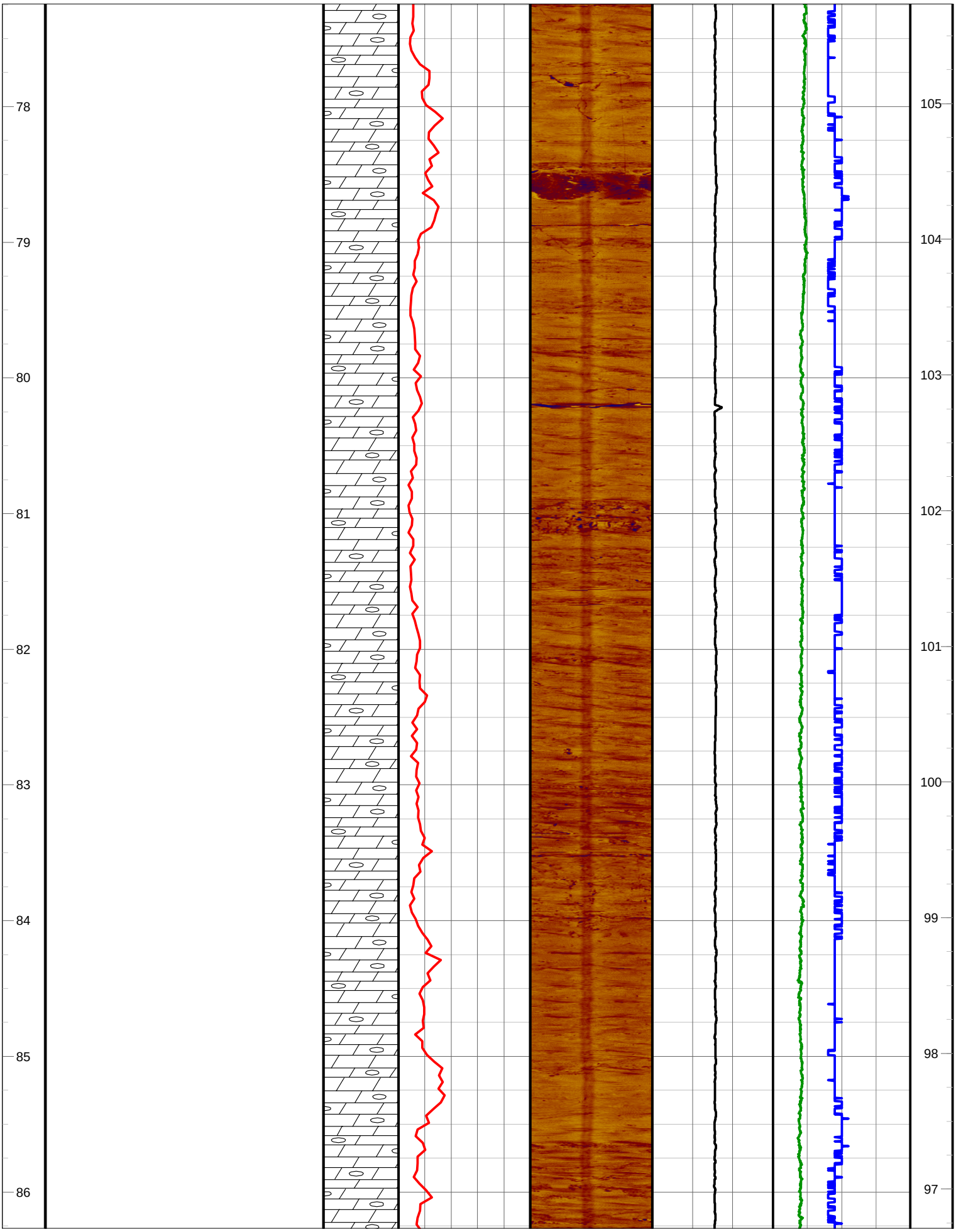
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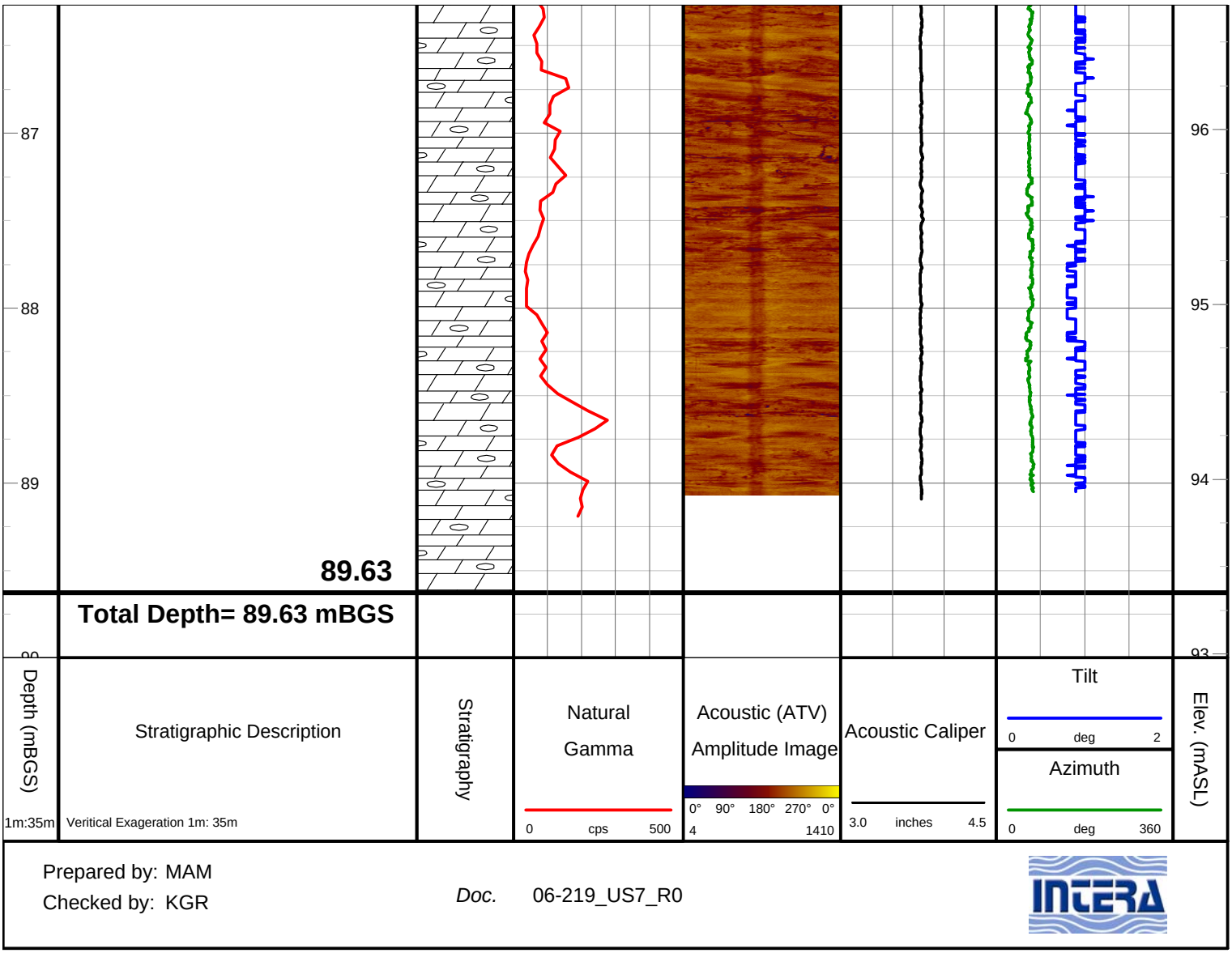

Prepared by: MAM
Checked by: KGR

Doc. 06-219_US7_R0

APPENDIX C

Stratigraphic and Casing Installation Logs - Boreholes US-3 & US-7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY	hole type ROTARY DIAMOND	observer S. Rose
location 29+81.31N, 48+34.38E (DPG)	hole size HW & NQ	compiled J. Grass
dip 90°	drilled 17-28 SEP 87	checked JG, MH
datum C.G.D. bearing -----	drawn 29 JAN 88 RM	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	606.29				W.R.	DATUM = GROUND SURFACE										
2	603.67 / 2.62				▽	(W.L. on compl)										
4																
6						OVERBURDEN (TILL)										
8																
10																
12																
14																
16																
18																
20																
22																
24																
26																
28																
30																
32																
34																
36																
38																
40	566.29 / 40.00					CONTINUED ON SHEET 2 OF 7										

file name: 003.ugs

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.

sheet 1 OF 7

project	BNPD UNDERGROUND NUC WASTE STORAGE STUDY	hole type	ROTARY DIAMOND	observer	S. Rose
location	29+81.31N, 48+34.38E (DPG)	hole size	HW & NQ	compiled	J. Grass
	dip 90°	drilled	17-28 SEP 87	checked	JG, MH
datum	C.G.D.	bearing	-----	drawn	29 JAN 88 RM
				approved	B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale ft -	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft^3	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	566.29 / 40.00				W.R.	CONTINUED FROM SHEET 1 OF 7										
42						OVERBURDEN (Till)										
44																
46																
48																
50																
52																
54																
56																
58																
60	546.29 / 60.00					AMHERSTBURG FORMATION DOLOSTONE — Triconed grey, fine grained, hard, lightly fractured, massive bedded, some bituminous partings along bedding planes at 90° to core axis										
62						62.8–64.0 ft: irregular vertical joints											
64				33		possible soft seam washed out										
66				44												
68						68.5 ft: joint (20°)										
70																
72				65	100%											
74																
76				98		76.6–76.8 ft: vuggy										
78																
80	526.29 / 80.00			84		CONTINUED ON SHEET 3 OF 7										

file name: 003s2.ugs

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.

sheet 2 OF 7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY | hole type ROTARY DIAMOND | observer S. Rose
location 29+81.31N, 48+34.38E (DPG) | hole size HW & NQ | compiled J. Grass
dip 90° | drilled 17-28 SEP 87 | checked JG, MH
datum C.G.D. | bearing ----- | drawn 29 JAN 88 RM | approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	526.29				W.R.	CONTINUED FROM SHEET 2 OF 7										
	80.00					AMHERSTBURG FORMATION DOLOSTONE: (For Description See Sheet 2 of 7)										
82				84												
84								0.4 / 120								
						84.8–84.9 ft: vuggy										
86				83												
88						87.7 ft: joint (35°)										
90																
92				100				0.22 / 90								
94																
96				87												
98																
100																
102				100	100%											
104																
	501.66															
	104.63					AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: brownish grey, fine grained, hard, lightly fractured, finely laminated, mottled, fossilliferous, massive bedded, a few bituminous partings occur along bedding planes at 90° to core axis											
106				100												
108								0.23 / 100								
110																
112				100												
114																
	491.65															
	114.64					AMHERSTBURG FORMATION LIMESTONE: grey to brown, fine grained, hard, lightly fractured, massive bedded, bedding at 90° to core axis											
116				100												
118																
	487.82															
	118.47							0.4 / 120								
120	486.29			100		AMHERSTBURG FORMATION LIMESTONE: (For Description See Sheet 4 of 7)										
	120.00					CONTINUED ON SHEET 4 OF 7										

file name: 003s3.ugs

Ontario Hydro
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Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.
sheet 3 OF 7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY | hole type ROTARY DIAMOND | observer S. Rose
location 29+81.31N, 48+34.38E (DPG) | hole size HW & NQ | compiled J. Grass
dip 90° | drilled 17-28 SEP 87 | checked JG, MH
datum C.G.D. | bearing ----- | drawn 29 JAN 88 RM | approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	486.29				W.R.	CONTINUED FROM SHEET 3 OF 7										
	120.00					AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: grey, fine grained, hard, finely laminated, lightly fractured, massive bedded with some sections of very thin bituminous partings along bedding planes at 90° to core axis										
122				100												
124				100												
126																
128																
130				100		stylolitic below 131.2 ft										
132																
134								0.4 120								
136				100												
138																
140				100	100%											
142																
144																
	460.99															
146	145.30			100		AMHERSTBURG FORMATION CORAL LIMESTONE: grey, coarse grained, hard, lightly fractured, highly fossiliferous, massive bedded, some bituminous partings along bedding at 90° to core axis										
148																
150				100												
152																
154								0.05 150								
156				100												
158																
	448.03															
	158.26			100		158.7 ft: vuggy, calcite crystals										
160	446.29					AMHERSTBURG FORMATION DOLOMITIC LIMESTONE (For Description of See Sheet 5 of 7)										
	160.00					CONTINUED ON SHEET 5 OF 7										

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Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.
sheet 4 OF 7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY | hole type ROTARY DIAMOND | observer S. Rose
location 29+81.31N, 48+34.38E (DPG) | hole size HW & NQ | compiled J. Grass
dip 90° | drilled 17-28 SEP 87 | checked JG, MH
datum C.G.D. | bearing ----- | drawn 29 JAN 88 RM | approved B. Lukajic

borehole data						borehole log	water inf.	field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	446.29 / 160.00				W.R.	CONTINUED FROM SHEET 4 OF 7										
162				100		AMHERSTBURG FORMATION DOLOMITIC LIMESTONE: brownish grey, fine grained, lightly fractured, massive bedded, bedding at 90° to core axis										
164								0.05 / 150								
166	441.21 / 165.08			97		BOIS BLANC FORMATION LIMESTONE: grey, fine grained, hard, large chert nodules throughout, lightly fractured, massive bedded, bedding at 90° to core axis										
168																
170				97												
172								0 / 170								
174																
176				100												
178																
180				94	100%											
182								0.08 / 180								
184																
186				100												
188																
190				100		189.0 ft: joint (10°) 189.8 ft: joint (20°)										
192								0.08 / 190								
194						193.7 ft: joint (30°) calcite crystals 195.0 ft: thin bituminous partings										
196				97		196.1 ft: joint (40°) calcite crystals 196.8 ft: joint (40°) bituminous coated										
198																
200	406.29 / 200.00			100				0.75 / 200								
						CONTINUED ON SHEET 6 OF 7										

file name: 003s5.ugs

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Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.
sheet 5 OF 7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY	hole type ROTARY DIAMOND	observer S. Rose
location 29+813.1N, 48+34.38E (DPG)	hole size HW & NQ	compiled J. Grass
	dip 90°	drilled 17-28 SEP 87	checked JG, MH
datum C.G.D.	bearing -----	drawn 29 JAN 88 RM	approved B. Lukajic

borehole data						borehole log	water inf.	field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and casing	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture % content	shear strength psi type	shear strength psi results	special tests type	special tests results
	406.29				W.R.	CONTINUED FROM SHEET 5 OF 7										
	200.00															
202				100		BOIS BLANC FORMATION LIMESTONE: grey, fine grained, hard, large chert nodules throughout, lightly fractured, massive bedded. Bedding at 90° to core axis										
204								0.75 200								
206				100												
208																
210				100												
212																
214						214.0–215.3 ft: vuggy, pyrite and calcite crystals										
216				100												
218						218.8 ft: joint (10°) very rough, bituminous coated										
220					100%											
222				100												
224								0.72 205								
226						225.0 ft: joint (30°) very rough, bituminous coated										
228				100												
230																
232				97												
234																
236				100												
238																
240	366.29			100												
	240.00					CONTINUED ON SHEET 7 OF 7										

file name: 003s6.ugs

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

geotechnical data sheet

hole no. US-3 | fig.

sheet 6 OF 7

project BNPD UNDERGROUND NUC WASTE STORAGE STUDY | hole type ROTARY DIAMOND | observer S. Rose

location 29+81.31N, 48+34.38E (DPG) | hole size HW & NQ | compiled J. Grass

dip 90° | drilled 17-28 SEP 87 | checked JG, MH

datum C.G.D. | bearing ----- | drawn 29 JAN 88 RM | approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft^3	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	366.29				W.R.	CONTINUED FROM SHEET 6 OF 7										
	240.00															
242				100	100%	BOIS BLANC FORMATION LIMESTONE: (For Description See Sheet 6 of 7)		0.72 205								
244	362.49															
	243.80					END OF BOREHOLE C.R. 96%										
246																
248																
250						NOTES 1. Geological contacts are approximate 2. Borehole left open on completion 3. For Log of Joints and Discontinuities see following pages											

file name: 003s7.ugs

Ontario Hydro
Design & Construction Branch
Geotechnical & Hydraulic Engineering

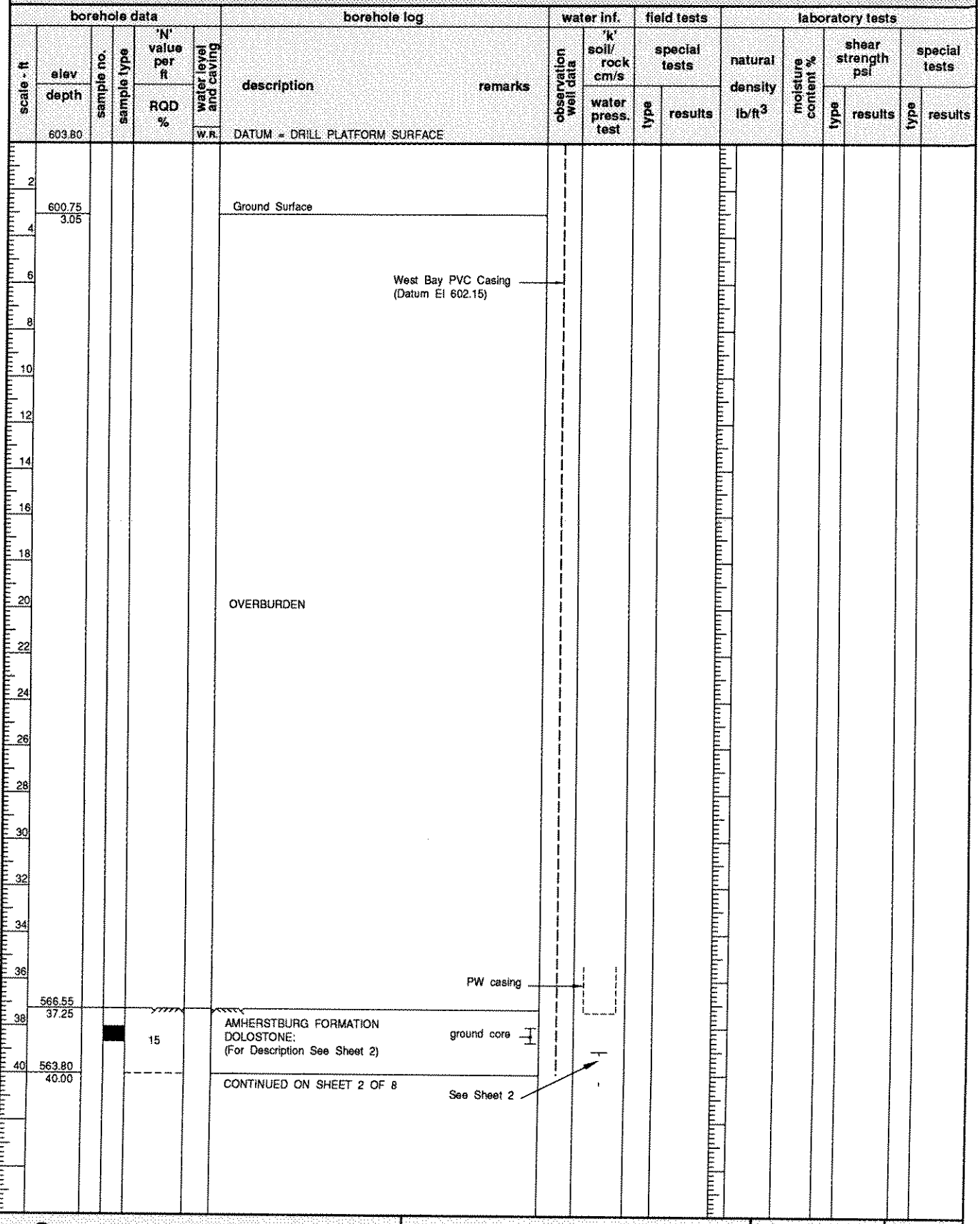
geotechnical data sheet

hole no. US-3 | fig.

sheet 7 OF 7

project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND
location	34+83N, 28+58E (DPG)	hole size	HQ
	dip 90°	drilled	11-18 JULY 88
datum	CGD	bearing ——	drawn 28 JULY 88 GP

observer R. Herntier
compiled J. Grass
checked JG,EC
approved B. Lukajic



file name: bruce_us/007.ugs

Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

geotechnical data sheet

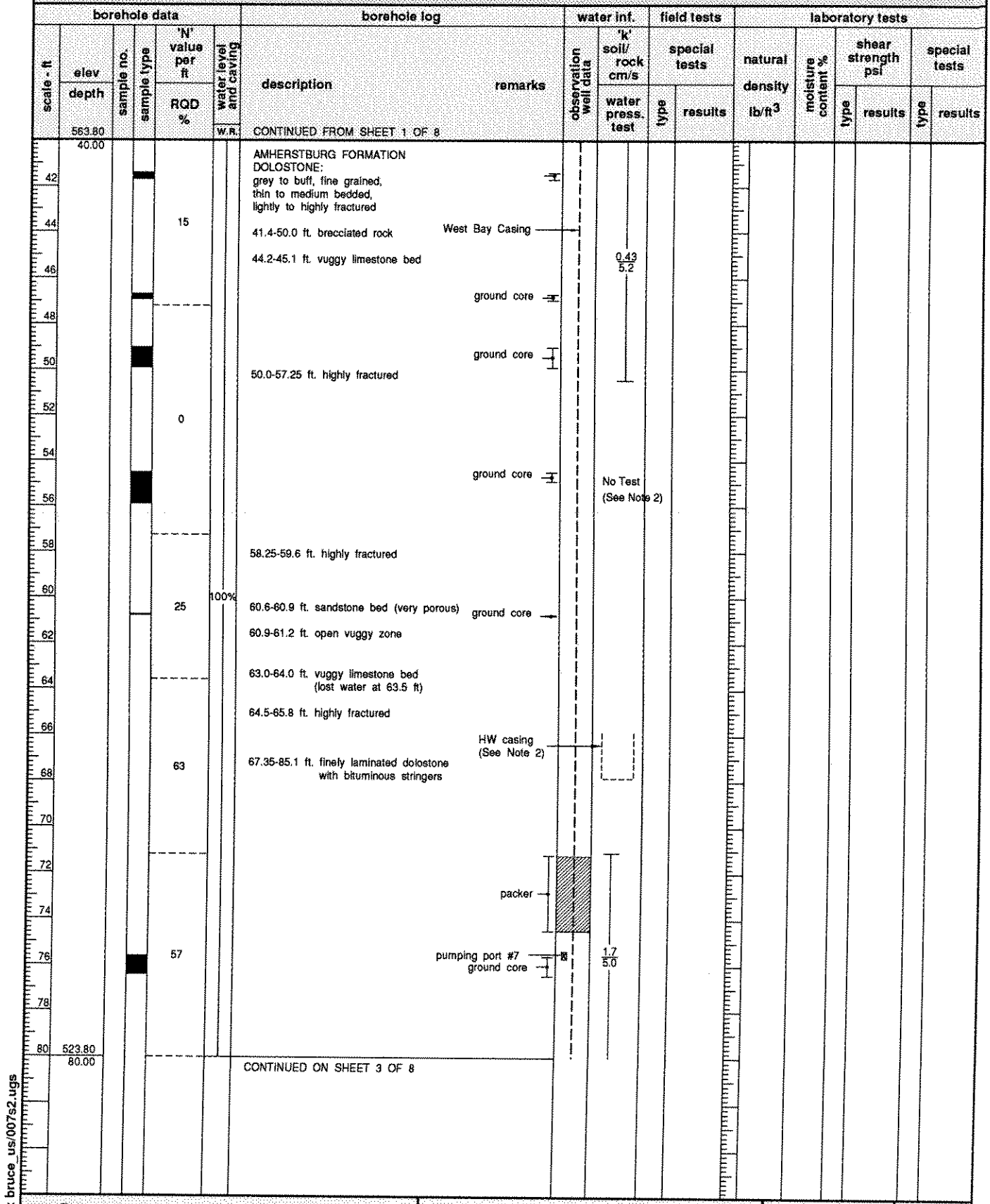
hole no. US-7
fig.
sheet 1 OF 8

project BNPD UNDERGROUND NUCLEAR WASTE STORAGE | hole type ROTARY DIAMOND | observer R. Herntier

location 34+83N, 28+58E (DPG) | hole size HQ | compiled J. Grass

dip 90° | drilled 11-18 JULY 88 | checked JG,EC

datum CGD | bearing —— | drawn 28 JULY 88 GP | approved B. Lukajic



Ontario Hydro
Design & Construction Branch
Civil Engineering & Architecture Dept

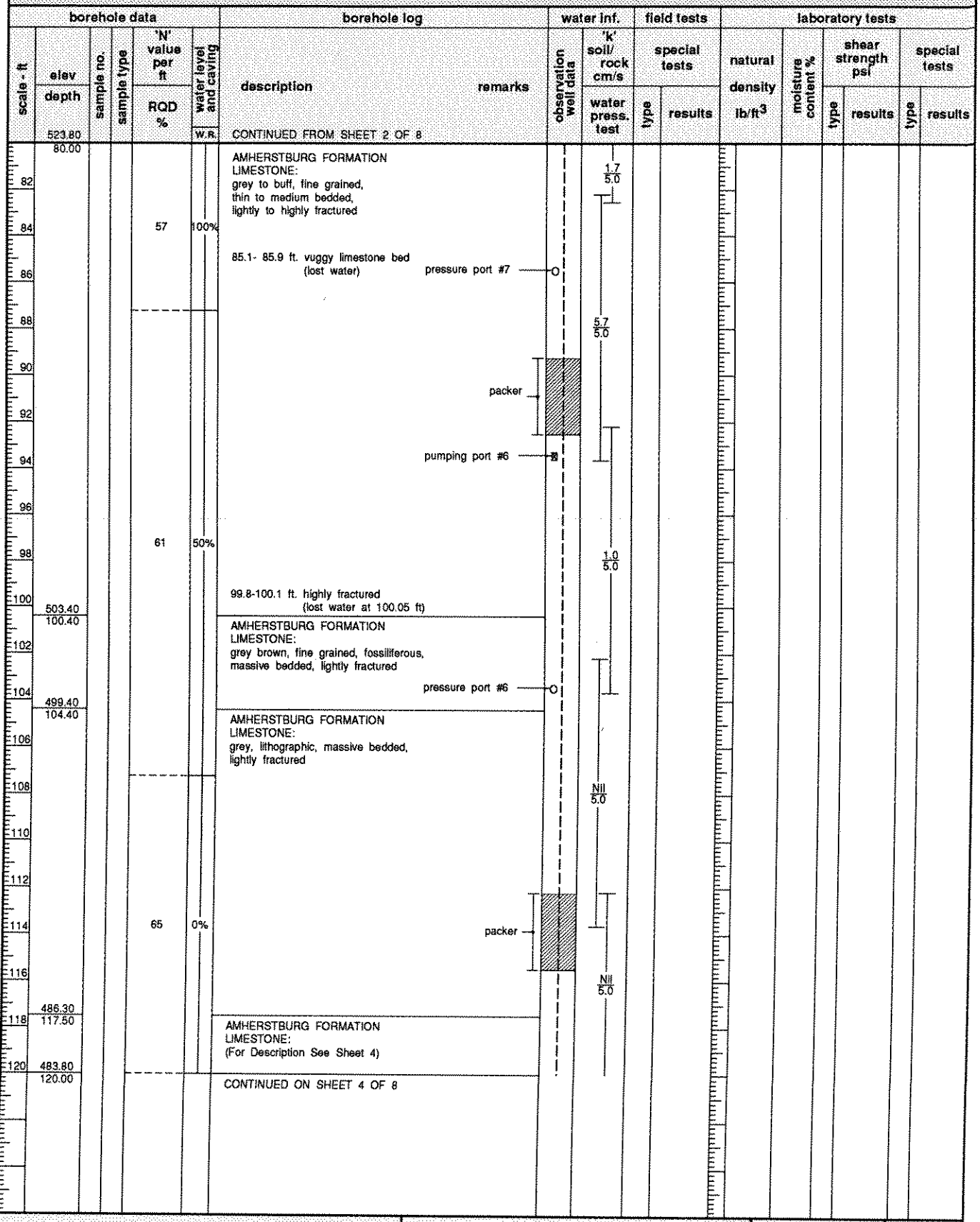
geotechnical data sheet

hole no. US-7 | fig.

sheet 2 OF 8

file name: bruce_us/007s2.ugs

project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herntier
location	34+83N, 28+58E (DPG)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	11-18 JULY 88	checked	JG,EC
datum	CGD	bearing -----	drawn	28 JULY 88 GP	approved	B. Lukajic



file name: bruce_us/007s3.ugs+007s3l

Ontario Hydro Design & Construction Branch Civil Engineering & Architecture Dept	geotechnical data sheet	hole no. US-7	fig.
		sheet 3 OF 8	

project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE		hole type	ROTARY DIAMOND	observer R. Herntier
location	34+83N, 28+58E (DPG)		hole size	HQ	compiled J. Grass
		dip 90°	drilled	11-18 JULY 88	checked JG,MH
datum	CGD	bearing -----	drawn	28 JULY 88 GP	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	483.80				W.R.	CONTINUED FROM SHEET 3 OF 8										
	120.00															
122	481.60					AMHERSTBURG FORMATION LIMESTONE: grey, fine grained, fossiliferous, with some bituminous, coated bedding planes, lightly fractured		Nil / 5.0								
	122.20															
124				65												
126																
						pumping port #5										
128								0.9 / 5.0								
						West Bay Casing										
130																
132						AMHERSTBURG FORMATION CORAL LIMESTONE: grey to brown, fine to coarse grained, highly fossiliferous, massive bedded, lightly fractured										
134																
136																
						pressure port #5										
138				89				Nil / 5.0								
140					0%											
142																
144																
146																
	457.50															
	146.30					AMHERSTBURG FORMATION DOLOSTONE: brown, fine grained, massive bedded, lightly fractured										
148								Nil / 5.0								
150																
152																
154				76												
156																
						packer		Nil / 5.0								
	446.80															
	157.00					BOIS BLANC FORMATION (For Description See Sheet 5)										
158																
160	443.80															
	160.00					CONTINUED ON SHEET 5 OF 8										

file name: bruce_us/007s4.ugs

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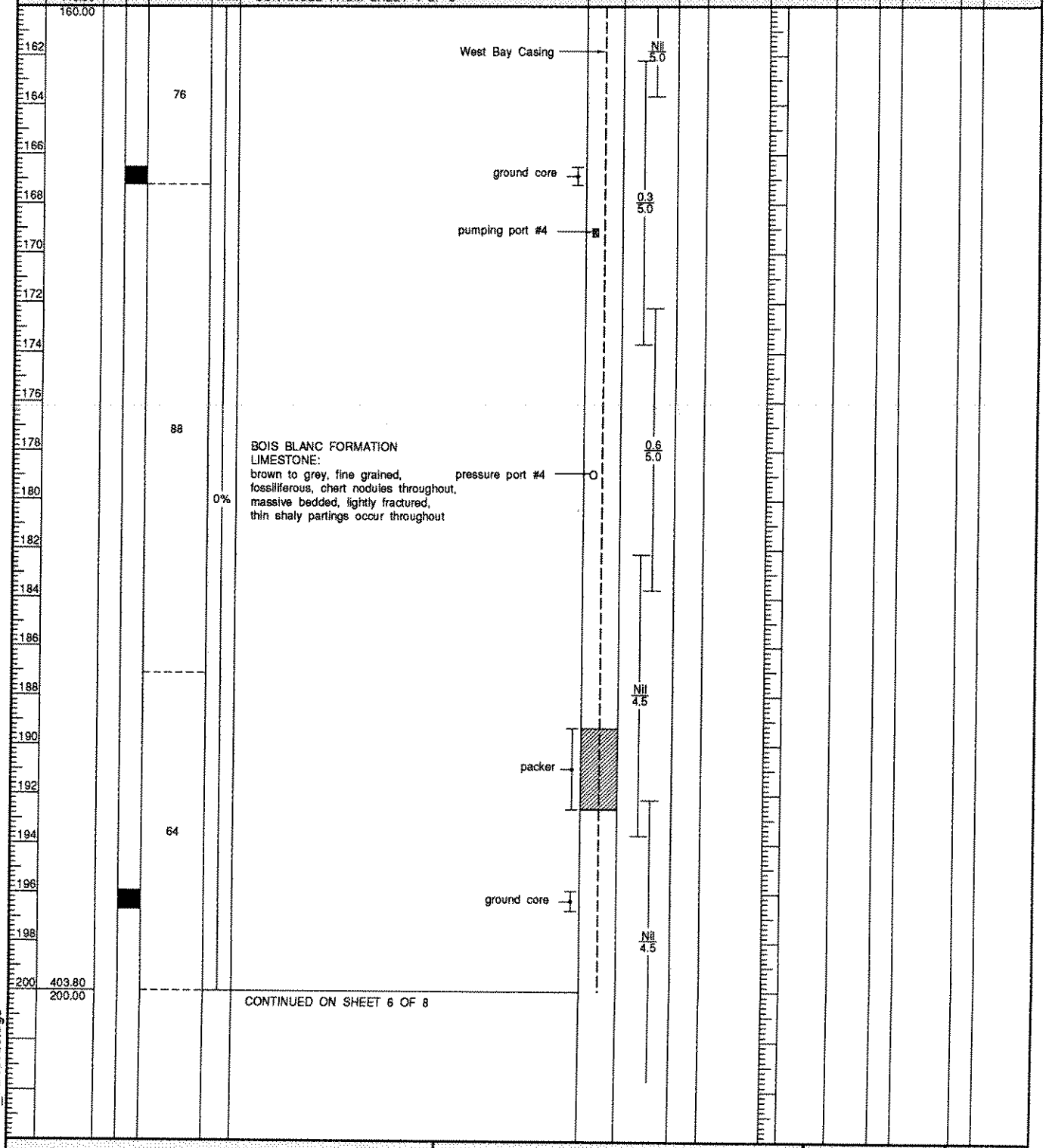
project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herntier
location	34+83N, 28+58E (DPG)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	11-18 JULY 88	checked	JG,EC
datum	CGD	bearing ———	drawn	28 JULY 88 GP	approved B. Lukajic



Ontario Hydro Design & Construction Branch Civil Engineering & Architecture Dept	geotechnical data sheet	hole no. US-7	fig.
		sheet 5 OF 8	

file name: bruce_us/007s5.ugs

project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herntier
location	34+83N, 28+58E (DPG)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	11-18 JULY 88	checked	JG,MH
datum	CGD	bearing ——	drawn	28 JULY 88 GP	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	403.80				W.R.	CONTINUED FROM SHEET 5 OF 8										
	200.00															
202								Nil / 4.5								
204				64	0%	pumping port #3	⊠									
206																
208								0.45 / 4.5								
210																
212																
214						pressure port #3	O									
216						BOIS BLANC FORMATION LIMESTONE: brown to grey, fine grained, fossiliferous, chert nodules throughout, massive bedded, lightly fractured, thin shaly partings occur throughout										
218				93				Nil / 4.5								
220						packer										
222																
224					25%											
226																
228								2.0 / 4.5								
230																
232																
234				91		pumping port #2	⊠									
236								Nil / 4.5								
238																
240	363.80 / 240.00					CONTINUED ON SHEET 7 OF 8										

file name: bruce_us/007s6.ugs

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project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herntier
location	34+83N, 28+58E (DPG)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	11-18 JULY 88	checked	JG,EC
datum	CGD	bearing -----	drawn	28 JULY 88 GP	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	363.80				W.R.	CONTINUED FROM SHEET 6 OF 8										
	240.00															
242						West Bay Casing		Nil 4.5								
244				91		pressure port #2										
246																
248								Nil 4.5								
250						packer										
252																
254						pressure port #1										
256																
258				89		pumping port #1		Nil 4.5								
260					25%	BOIS BLANC FORMATION CHERTY LIMESTONE: brown to grey, fine grained, fossiliferous, chert nodules throughout, massive bedded, lightly fractured, thin shaly partings occur throughout										
262																
264																
266																
268						End Cap (El 267.52)		1.8 4.5								
270																
272																
274				95												
276								Nil 4.5								
278																
280	323.80															
	280.00					CONTINUED ON SHEET 8 OF 8										

file name: bruce_us/007s7.ugs

Ontario Hydro
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geotechnical data sheet

hole no. US-7 | fig.

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project	BNPD UNDERGROUND NUCLEAR WASTE STORAGE	hole type	ROTARY DIAMOND	observer	R. Herntier
location	34+83N, 28+58E (DPG)	hole size	HQ	compiled	J. Grass
	dip 90°	drilled	11-18 JULY 88	checked	JG,MH
datum	CGD	bearing -----	drawn	28 JULY 88 GP	approved B. Lukajic

borehole data						borehole log	water inf.		field tests		laboratory tests					
scale - ft	elev / depth	sample no.	sample type	'N' value per ft / RQD %	water level and caving	description / remarks	observation well data	'k' soil/rock cm/s / water press. test	special tests type	special tests results	natural density lb/ft³	moisture content %	shear strength psi type	shear strength psi results	special tests type	special tests results
	323.80				W.R.	CONTINUED FROM SHEET 7 OF 8										
282	280.00					BOIS BLANC FORMATION CHERTY LIMESTONE: brown to grey, fine grained, fossiliferous, chert nodules throughout, massive bedded, lightly fractured, thin shaly partings occur throughout		Nil / 4.5								
284				95												
286																
288					25%			Nil / 4.5								
290																
292				97												
294																
296																
	306.70															
298	297.10					END OF BOREHOLE C.R. 98 %										

NOTES:
1. All geological contacts are approximate
2. Due to sections of fractured rock HW casing drilled to 67.85 ft and grouted
3. For details of structural features see Log of Discontinuities
4. West Bay Multi-Level Casing installed Nov, 1988
5. Water pressure test performed using constant head method

file name: bruce_us/007s8.ugs

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