PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING, SOUTH BRUCE

WP03 Data Report: Geological and Geotechnical Core Logging, Photography, and Sampling for SB_BH01

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Revision Tracking Table

Revision	Revision Release Date	Description of Modifications/Edits
R0A	July 29, 2022	Initial draft release to NWMO for review
R0B	August 29, 2022	Second draft release to NWMO for review. NWMO comments on the initial draft release dispositioned by Geofirma.
R0	September 15, 2022	Final release

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1 INTRODUCTION

1.1 Background

Geofirma Engineering Ltd. (Geofirma) was retained by the Nuclear Waste Management Organization (NWMO) to complete a drilling and testing program for two deep bedrock boreholes (SB_BH01 and SB_BH02) as part of the NWMO's Phase 2 Geoscientific Preliminary Field Investigations. The full scope of the drilling and testing program for SB_BH01 is described in the Initial Borehole Characterization Plan (Geofirma 2020a). NWMO's process is called the Adaptive Phased Management (APM) plan and comprises multiple phases.

Phase 1 of NWMO's APM plan included preliminary desktop studies using available geoscientific information and a set of key geoscientific characteristics and factors that can be realistically assessed at the desktop phase of the Preliminary Assessment. The Phase 1 Preliminary Assessment of the South Bruce area identified the Cobourg Formation as the preferred host formation for a deep geological repository for used nuclear fuel. The Initial Borehole Drilling and Testing study is a key component of the Phase 2 Geoscientific Preliminary Field Investigations for the NWMO's APM plan.

Borehole SB_BH01 is located approximately 3.5 km northwest of the community of Teeswater, Ontario, and was drilled to 880.84 m below ground surface (m BGS). SB_BH01 was drilled through the entire sedimentary bedrock sequence to approximately 20 m into the Precambrian basement.

1.2 Geologic Setting

The sequence of rocks encountered in the SB_BH01 borehole consist of Paleozoic-aged strata that were deposited within the Michigan Basin northwest of the Algonquin Arch in Southwestern Ontario. The Michigan Basin is a circular-shaped cratonic basin that is composed primarily of shallow marine carbonates, evaporites, and shales that were deposited while eastern North America was in tropical latitudes during the Paleozoic Era (Armstrong and Carter 2006). West of the Algonquin Arch, strata from the Michigan Basin tend to gradually dip westward into the Michigan Basin. Borehole SB_BH01 was drilled through the entire Paleozoic sequence to approximately 20 m into the Precambrian basement, which is composed of high-grade metamorphic rocks of the Grenville Province.

LEGEND

- SB_BH01 Drill Site
- Municipality of South Bruce
- Municipality of Brockton
- Township of Huron-Kinloss
- Provincially Significant Wetland
- Wetland
- Waterbody
- Watercourse
- Major Road
- Local / Street
- OGSRL Well Locations

INSET MAP

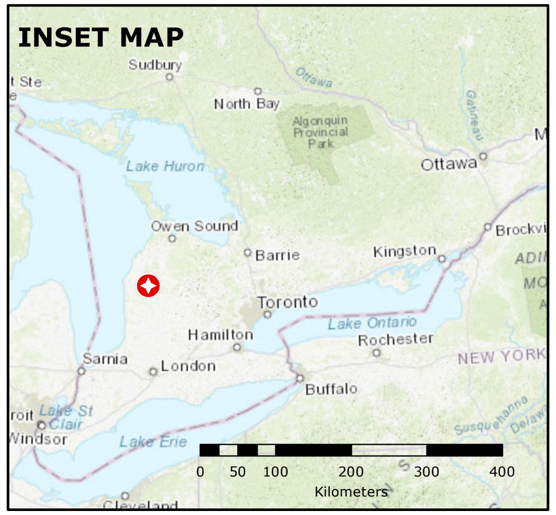

Figure 1
Location of SB_BH01 Drill Site

Scale 1:60,000

0 500 1,000 2,000 3,000 4,000
Meters

N

Projection: NAD 1983 UTM Zone 17N

Source: NWMO, Ontario GeoBase

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

PROJECT No. 20-211-1

NWMO South Bruce
Drilling and Testing

DESIGN: ADG
CAD/GIS: ADG
CHECK: SNS
REV: 0

DATE: 2021-01-27

Geofirma Engineering Ltd

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1.3 Technical Objectives

The primary objective of WP03 was to obtain high quality geological and geotechnical logs, core photographs, and samples from continuous core through the entire Paleozoic sedimentary bedrock sequence and into the Precambrian basement. These core data will be used to:

- Provide a high-quality comprehensive database of photographic and geological log information for reliable documentation and recording of the stratigraphic and structural features. These data will be used to assess:
    - Depths, thicknesses and lithological characteristics of stratigraphic formations, members, and units encountered.
    - Structural, weathering, and alteration features that may impact fluid flow or geotechnical properties
    - Potential for hydrocarbon resources
- Provide high-quality preserved core samples for archive purposes and conducting planned laboratory core testing (WP04)

2 DESCRIPTION OF ACTIVITIES

Core logging activities were completed by Geofirma staff on a core run basis following a workflow that was developed to minimize core processing time, while ensuring high-quality data acquisition (Figure 2). Time-sensitive samples were collected immediately after completion of core run photography, prior to geological and geotechnical core logging. The progress of each core run as it was photographed, logged, and sampled was tracked using the Core Logging, Photography and Sampling Checklist in the WP03 Data Quality Confirmation (DQC) workbook.

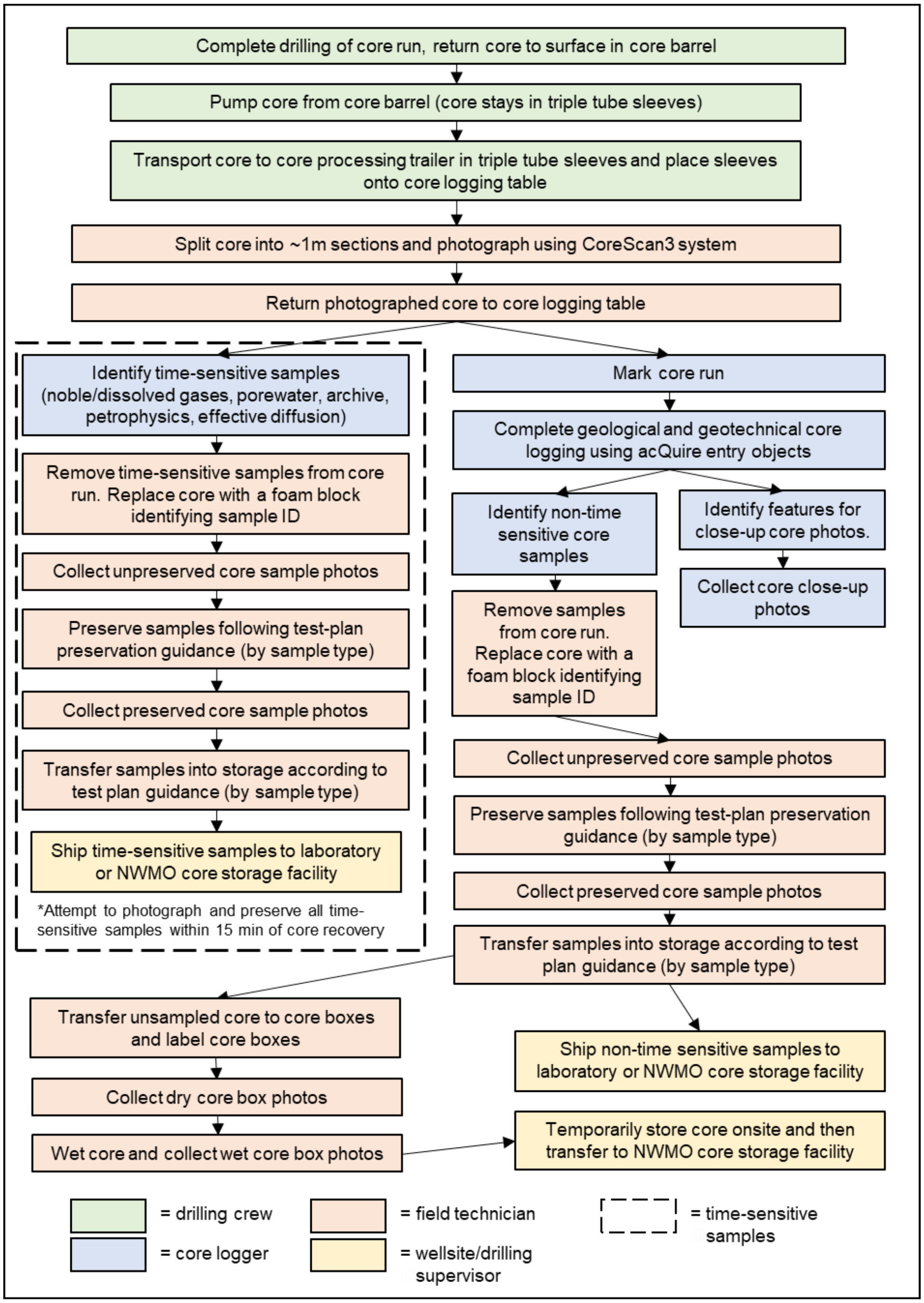


Figure 2: Core Logging, Photography, and Sampling Workflow

2.1 Core Retrieval and Handling

Cores were retrieved using a triple tube core barrel and transferred by drilling staff to the Geofirma core processing trailer. The top (start) and bottom (finish) depths of each core run was recorded by a Geofirma core logger. All depths were recorded in meters along core axis.

Core retrieval and transfer to the core processing trailer was completed as quickly as possible so that the time that the core was exposed to the atmosphere was minimized. If the logging team was not ready to process the next core run, the drilled core was left within the core barrel downhole until the loggers were ready.

2.2 Geological and Geotechnical Core Logging

Geological and geotechnical core logging were completed following core photography and before sampling (except for time-sensitive samples) using the acQuire data entry system provided by the NWMO. Before logging, pieces of core were properly positioned such that all broken features fit together as if they were not broken or rotated out of position. Parallel red and black lines were drawn on the aligned core with permanent markers for a reference line, with the red line on the right when the core is oriented vertically with the bottom down.

Core logging was continuous and included descriptions of bedrock lithology, structural and discontinuity characteristics, sample locations, presence of hydrocarbons, alteration, weathering, rock hardness and additional comments regarding other relevant observations (e.g., locations of lost core) made by the core logger. A detailed description of core logging procedures is provided in the Core Logging Manual (Appendix A) of the WP03 Test Plan (Geofirma 2021a).

Core logging generally followed the steps outlined below:

1. Marking the Core
2. Core Run (including Reference Line) Data Collection
3. Structure and Geotechnical (excluding Rock Strength) Data Collection
4. Lithology Data Collection
5. Alteration and Weathering Data Collection
6. Presence/Absence of Hydrocarbons
7. Rock Strength Data Collection

Core run data were recorded on a core run basis using the Core Run data entry object in acQuire. Items recorded from each core run included: borehole ID, drilled depth interval (m), retrieval time, photograph depth intervals, core logger and photographer initials, total core recovery (TCR), rock quality designation, (RQD) solid core recovery (SCR), count of natural and broken fractures, and count of mechanical breaks.

The top and bottom depth of unique reference lines were captured in the Reference Line tab in acQuire. The start of each unique reference line was marked on core by drawing a “T” with a white wax pencil. If the adjacent core runs could be fit together, the same reference line was continued to the next run.

Structural features identified in core, including their type, width/apparent geological aperture (where applicable), and orientation, were recorded in acQuire using the Structure data entry object. Alpha and beta angles (relative to core orientation reference line) were recorded for planar structures. Depending on the structure type, additional data (e.g., rock wall hardness, roughness) were also recorded in acQuire. An additional geotechnical dataset, rock strength data, was logged in acQuire using the Rock Strength data entry object. Generally, one rock strength measurement was captured per core run.

Lithology was logged on a core run basis using the Lithology data entry object in acQuire. Lithological units were delineated primarily based on mineralogy. Depending on the lithology type, a combination of lithology qualifiers, sedimentary structures, fossil types, bedding thickness, colour, cementation, grain size, sorting and fining, and sediment disturbance were recorded using drop down menus in acQuire. If a lithology spanned multiple core runs, it was logged as several unique lithologies in acQuire.

Lithological logging was completed in acQuire using the hierarchy shown in Figure 3. For a given depth interval, up to three lithologies could logged, to allow for regularly interbedded units to be logged as a single lithological unit. Two layers could be logged for each lithology, so that subtle textural or colour changes in that lithology could be captured (e.g., alternating green and red beds within shale of the Cabot Head Formation).

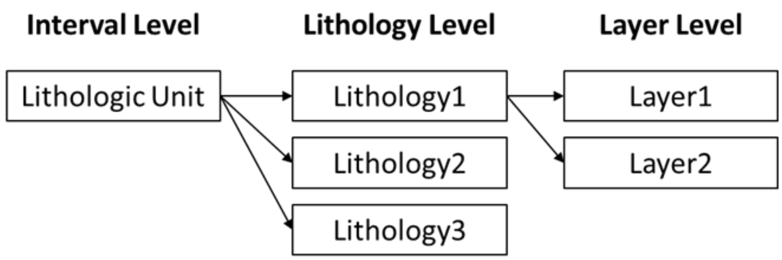


Figure 3: Hierarchy for Lithology Logging in acQuire

Alteration and weathering were also recorded in acQuire using the Alteration and Weathering data entry objects. Alteration was continuously recorded for the entire cored interval, including “unaltered” where no alteration is observed. Weathering was only logged when observed.

Finally, the type (natural gas, oil shows, petroliferous odour, UV visible oil) and intensity of hydrocarbon showings were recorded in acQuire using the Hydrocarbon data entry object in acQuire.

2.3 Core Photography

Core photography was completed by Geofirma staff prior to, during, and after logging. Five types of core photographs were collected during core logging activities:

- Planar core run photographs (prior to logging)
- 360-degree core run photographs (prior to logging)
- Core sample photographs (during logging)
- Photographs of unique geological features (during logging), and
- Wet and dry core box photographs (after logging).

2.3.1 Core Run Photography

Core run photography was completed using the CoreScan3 core scanning system manufactured by DMT Group. Each 3 m core run was broken into approximately three 1 m segments to fit onto the core scanner. For each 1 m segment, a planar photograph (front side) and a rolled (360-degree) photograph were captured. For core intervals that could not be rolled (e.g., highly fractured), a back-side planar photograph was collected instead of the rolled photograph.

Additional information about the core was captured in planar photographs, including white balance and colour correction cards, top and bottom depth of the core interval, core run ID, and borehole ID.

For each core run, the 360-degree rolled CoreScan3 photos were stitched together in PowerPoint to form a single 360 core run photograph.

Core run photographs were named as follows:

SB_BH01_CR###_topdepth_bottomdepth_X.jpg

where ## is the core run number and *X* denotes photo type (front side planar—*F*, back side planar—*B*, rolled 360-degree photos—*R*).

2.3.2 Core Sample Photography

Core sample photography was completed for all core samples using a digital camera and lightbox. Three sample photographs per core sample were captured: unpackaged front, unpackaged back, and packaged. Each core sample photograph included the Sample ID, the date of sample collection, and the sample depth interval (in meters). Sample photograph names were generated using the Core Samples data entry object in acQuire and were named as follows:

SB_BH01_XX###_Y.jpg

where *XX* denotes sample type, ### is the sample number, and *Y* denotes the photo type (front—*F*, back—*B*, packaged—*P*).

2.3.3 Detailed Core Photography

Detailed close-up pictures of rock core were also collected using a handheld digital camera. The core run number and depth of the feature photographed was documented in the photograph alongside the core, unless the photograph was zoomed into a specific feature, such that the other information was not visible. Detailed core photographs were assigned IDs in acQuire and were named as follows:

SB_BH01_centrepointdepth_#.jpg

where # is the photo number (*1*, *2, etc.*).

All other detailed photographs were named as follows:

SB_BH01_XX_topdepth_bottomdepth_#.jpg

where # is the photo number and *XX* denotes feature type

2.3.4 Boxed Core Photography

Photographs of core boxes (both wet and dry) were taken after the core was transferred into wooden core boxes for storage. Core boxes from up to three core runs were photographed in a single core box photo. Each core box photo included a card that showed the borehole ID, core box numbers, core run(s), and depth interval. Core box photos were named based on the depth interval with the following convention:

SB_BH01_BCX_topdepth_bottomdepth.jpg

where *X* denotes the core condition (dry—*D*, wet—*W*).

2.4 Core Sampling

2.4.1 Core Sample Selection, Extraction, and Naming

Unless otherwise indicated, intact sections of core were collected as samples according to NMWO-specified geologic/depth interval targets. Samples were collected such that they were representative of the unit being sampled and did not cross a lithological contact. In addition, samples were not taken from the immediate top or bottom of a core run to preserve the ability to re-align adjacent core runs by re-fitting of the reference line. All samples were extracted using a hammer and chisel (or have pre-existing mechanical/natural breaks on the end).

As much as possible, samples were collected and preserved within 30 minutes of core retrieval (i.e., core arriving at surface). For time-sensitive samples, the objective was to sample and preserve the core within 15 minutes of core retrieval, immediately after core run photography, but prior to core logging.

2.4.2 Core Sample Preservation

Prior to preservation, core samples were wiped clean, photographed, and weighed to an accuracy of 1 gram. Procedures for preservation of core samples were completed according to sample type. All core sample types, other than dissolved gases, noble gases, and microbiology samples, were preserved following the standard procedure outlined below:

1. Wrapped in plastic film
2. Wrapped in Polyethylene (PE) bag
3. Flushed with nitrogen, evacuated and heat sealed using vacuum sealer
4. Wrapped in second PE bag
5. Flushed with nitrogen, evacuated and heat sealed using vacuum sealer
6. Wrapped in aluminum foil pouch
7. Flushed with nitrogen, evacuated and heat sealed using vacuum sealer
8. Refrigerated sample (as required)

Table 1: SB_BH01 Core Sampling Guidance

Core Sample Type		Number of Samples Collected By Geofirma	Number of Samples Collected By NWMO	Time-sensitive	Minimum Required Sample Length	Preservation Procedure (Section3.6.2)	Minimum Shipping Frequency	Analysis Lab/Storage Location
WP04 A	Petrophysics	33		X	30 cm	Standard Procedure	Upon completion of drilling	NWMO
	Effective Diffusion Coefficient	22		X	25 cm			
WP04 B	Uniaxial (UCS)	29			25 cm	Standard Procedure	Upon completion of drilling	CANMET
	Triaxial (TCS)	27			25 cm			
	Tensile Strength (Brazilian)	29			10 cm			
	Direct Shear		9		10 cm			RESPEC
	Thermal Properties and Thermal Expansion (unconfined)	24[1]			25 cm			
	Thermal Expansion (confined)	5[2]			20 cm			
WP04 C	Porewater	60 (30 sets)		X	Sets of 15 cm and 20 cm	Standard Procedure	Next Day	University of Ottawa
	Noble Gases	30		X	10 cm	Stainless-Steel Cylinder		
	Non-reactive Gases	30		X	10 cm as fragments	500 mL IsoJars		
WP04 D	Mineralogical and Geochemistry (rock matrix)	30	10		10 cm	Standard Procedure	Upon completion of drilling	SGS
	Mineralogical and Geochemistry (fracture face)		10		10 cm			
	Mineralogical and Geochemistry (fracture infill) Fluid Inclusion		30[3]		5 cm			BGS
WP04 E	Sorption	6			45 cm	Standard Procedure	Upon completion of drilling	NWMO
WP04 F	Surface Area and Cation Exchange	6			45 cm			
WP04 G	Total Organic Testing, Rock-Eval Pyrolysis, Clay Mineralogy	13			10 cm	Standard Procedure	Upon completion of drilling	Core Labs Canada Ltd.
Microbiology		6			20 cm	As Described in WP03 Test Plan	Upon completion of drilling	University of Waterloo
Archive		45		X	25 cm	Standard Procedure	Upon completion of drilling	NWMO
Total		364	89					

1. Minimum core size for thermal property testing is 15 cm length to yield two core lengths with at least one face ground flat and smooth on each length. If both thermal property and thermal unconfined expansion testing is to be completed, the minimum core size is 25 cm length. Unconfined thermal expansion and thermal property samples will be collected and preserved as a single 25 cm sample for shipment to RESPEC.
2. Confined thermal expansion samples are to be collected and preserved separately from the associated thermal properties sample.
3. 30 samples to be collected as combined fluid inclusion and mineralogical and geochemistry (fracture infill) samples. 30 will be collected to be screened for 15 that will be analysed by BGS. These 30 samples were double counted in the test plan numbers but have been corrected for this report.

In addition to the standard preservation procedure, shale-rich geomechanical samples were placed in rigid cardboard tubes with the space between the tube and the sample filled with foam packing peanuts. This additional protection was implemented to minimize potential for damage of the shale samples prior to analyses at the laboratory.

Noble gas samples were collected using purpose-built stainless-steel containers provided by the University of Ottawa and were preserved following a specialized procedure. Full-diameter cores were placed in stainless-steel chambers with a flange fitted sealed by compression of a copper plate. To remove atmospheric noble gases, the chamber was flushed with high-purity N_2 and evacuated twice before closing a valve to seal the cannister.

Cores for non-reactive (dissolved) gas samples (CH_4, CO_2) were broken into large chunks (~ 5 cm pieces) and placed into two IsoJar (Isotech, USA) containers, capped with a septum-fitted cap. While filling the IsoJar containers, high-purity N_2 was flushed into the containers by needle through the septum.

Core samples for microbiology research and development activities were collected upon completion of core logging and were preserved by sealing them in a Ziploc bag. Once in Ziploc bags, the microbiology samples were stored in a freezer.

2.5 Data Quality Assurance and Quality Control

All core logging, photography, and sampling (WP03) activities were completed following procedures and data quality requirements outlined in the WP03 Test Plan (Geofirma 2021a), the project-specific core logging manual (Appendix A), and the Project Quality Plan (Geofirma 2022). All field data associated with WP03 activities were recorded directly into NWMO's acQuire database or into a purpose-built Data Quality Confirmation (DQC) workbook.

A cross-shift meeting was completed at the start of each shift to transfer knowledge and information from the previous shift. For each shift where logging activities were completed, the crew of the following shift would complete a "Shift Quality Assurance Check" and record the findings of inspection in the DQC workbook. Each shift quality assurance check included an inspection of the core photography equipment, spot check of each type of photo (sample, core run, core box, detailed), and a review of the last two core runs logged by the previous shift. Any deficiencies noted during the quality assurance check would be discussed at the next cross-shift meeting and noted to the WP03 work package lead.

Equipment calibration checks and calibrations were also completed at the start of each shift, for any equipment associated with quality control. All fridges and freezers holding samples were checked to ensure that the internal temperature was within an acceptable range, as outline in the Project Quality Plan. Electronic scales used to weight core samples had calibration checks performed at the start of each and were recalibrated if the readings were outside of the acceptable range. Records of equipment calibration checks and calibrations were recorded in the DQC workbook.

2.6 Health and Safety

All WP03 activities were complete following Geofirma's Health, Safety, and Environment Plan (Geofirma 2022). No incidents, injuries, or environmental issues associated with WP03 activities were reported during the SB_BH01 drilling program.

3 RESULTS

A total of 843.9 m of core was logged for SB_BH01: the recovered core spans from the bottom of surface casing at 36.94 m to the final depth of the borehole at 880.84 m. Drill cuttings were collected, logged, and photographed from ground surface to 36.94 m. The interpreted top of bedrock was at 19.6 m based on recovered cuttings and drilling indicators: no core was collected from cable tool drilling between 19.6 to 36.94 m due to the destructive nature of cable tool drilling.

A summary geological and geotechnical core log for SB_BH01 is provided in Appendix B.

3.1 Geology

3.1.1 Rock Types

Table 2 provides a summary of the different rock types that were logged in SB_BH01. A total of 11 rock types were logged, with the three most common rock types, limestone (42%), shale (36.8%), and dolostone (16.1%) comprising 94.9% of the cored interval. Other logged rock types generally only occurred as secondary rock types (e.g., chert, gypsum, siltstone), or were constrained to thin sections of the borehole, such as sandstone in the Shadow Lake Formation and gneiss in the Precambrian. A marker bed comprised of a thin ash layer was logged in the Coboconk Formation.

Table 2: Summary of Logged Rock Types in SB_BH01

Rock Type	Length Logged (m)[1]	% of Core Logged
Limestone	354.76	42.0%
Shale	310.59	36.8%
Dolostone	135.61	16.1%
Gneiss	20.51	2.4%
Sandstone	7.57	0.9%
Siltstone	5.38	0.6%
Anhydrite	3.48	0.4%
Chert	3.66	0.4%
Carbonate (undifferentiated)	1.99	0.2%
Gypsum	0.30	<0.1%
Ash	0.05	<0.1%

1. for interbedded intervals where multiple lithologies were logged, the length of each lithology for that interval was calculated by multiplying the lithology percentage by the interval length

The distribution of the logged rock types with depth is shown in Figure 4 and is summarized below. Detailed descriptions of the stratigraphic units, including formation top pick criteria, are provided in Section 3.1.4.

- The overburden (ground surface to 19.6 m) consisted of coarse granular material (sand and gravel) underlain by a clay- and gravel-rich till.
- Devonian rocks from the Lucas, Amherstburg, and Bois Blanc formations (19.6-100.59 m) consisted primarily of fossiliferous limestones with minor chert and shaley bituminous laminations.

- The upper Silurian consisted of crystalline dolostones from the Bass Islands Formation (100.59-141.97 m), underlain by shales, carbonates, and evaporitic rocks (anhydrite, gypsum) of the Salina Group (141.97-291.30 m). Carbonate-rich intervals of the Salina Group, including the Salina B, A1, and A2 units were often brecciated with moderate porosity.

- The Silurian Guelph Formation (291.30-339.89 m) was composed of highly porous, fossiliferous limestones and dolostones. Abundant porosity, fossils, and high angle bedding indicate that the Guelph Formation in SB_BH01 is part of a reef-like structure.

- Lower Silurian rocks from the Goat Island, Gasport, Lions Head, and Fossil Hill formations (291.30-395.39 m) consisted of fossiliferous to moderately argillaceous limestones, with some finely crystalline limestone in the lower section of the Fossil Hill Formation. The underlying Cabot Head (395.39-415.81 m) consisted primarily of shale that gradually graded into fossiliferous limestones of the Manitoulin Formation (415.81-424.37 m).

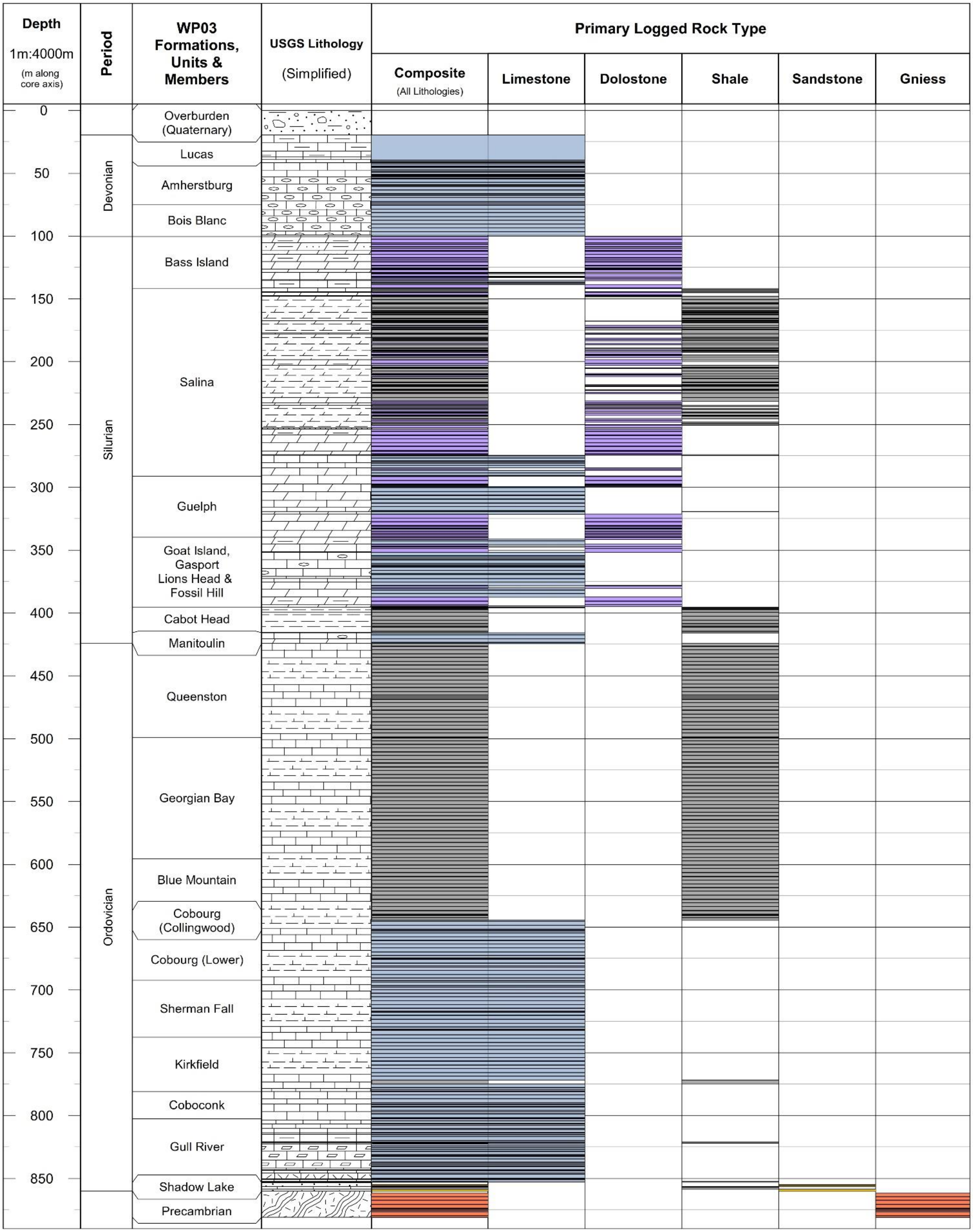
- The upper Ordovician Queenston, Georgian Bay, and Blue Mountain formations (424.37-636.85 m) consisted of thinly bedded to massive primarily non calcareous shales. Some shale intervals are fossiliferous, with abundant carbonate interbeds in parts of the Queenston and Georgian Bay formations.

- The Ordovician Cobourg Formation (636.85-692.59 m) consisted of calcareous shales interbedded with fossiliferous limestone (Collingwood Mbr.) that graded into a very hard, nodular, fossiliferous limestone (Lower Mbr.).

- Below the Cobourg Formation, the Ordovician Sherman Fall, Kirkfield, Coboconk, and Gull River formations (692.59-853.51 m) consisted primarily of hard fossiliferous limestones interbedded with thin shale beds.

- The Ordovician Shadow Lake Formation (853.51-860.33 m) consists of glauconitic sandstone, siltstone, and teal-green shale with abundant rip-up clasts from the underlying Precambrian basement rocks.

- The Precambrian basement rock (860.33-880.874 m) consisted primarily of gneiss with minor schist.



Note: Legend with USGS lithologies and primary rock type symbols is provided with the SB_BH01 Geological and Geotechnical Summary Log in Appendix B.

Figure 4: Summary of WP03 Formations, Units, Members, and Logged Rock Types in SB_BH01

3.1.2 Alteration and Weathering

Logged alteration in SB_BH01 is summarized in Table 3 and is show in Figure 5. Rock logged in SB_BH01 were generally unaltered, with some slight alteration noted in the Bass Islands, Queenston, and Gull River Formations. Moderate alteration of wall rock and along fractures was observed in the Precambrian.

Table 3: Logged Alteration in SB_BH01

Formation/Unit	Alteration Type(s) and Intensity	Comments
Bass Islands	Bleaching (slight)	Slight bleaching along fracture
Queenston	Hematization (slight) Carbonatization (slight)	Slight hematization-carbonatization aureole around carbonate nodules
Gull River	Bleaching (slight)	Slight bleaching associated with porous zones where there is weeping oil
Precambrian	Saussuritization (slight-moderate) Hematization (slight-moderate)	Slight to moderate alteration of wall rock and hematization along fractures

No geological weathering was observed in core fromSB_BH01. For purposes of this project, geological weathering was considered as a destructive process by which rock, on exposure to atmospheric water or processes, is changed in colour, texture, composition, or form. It is worth noting that definition of geological weathering differs from the definition used for geotechnical logging, by which alteration occurs resulting in weakness along a discontinuity: weathering of logged structures was captured with the structural data.

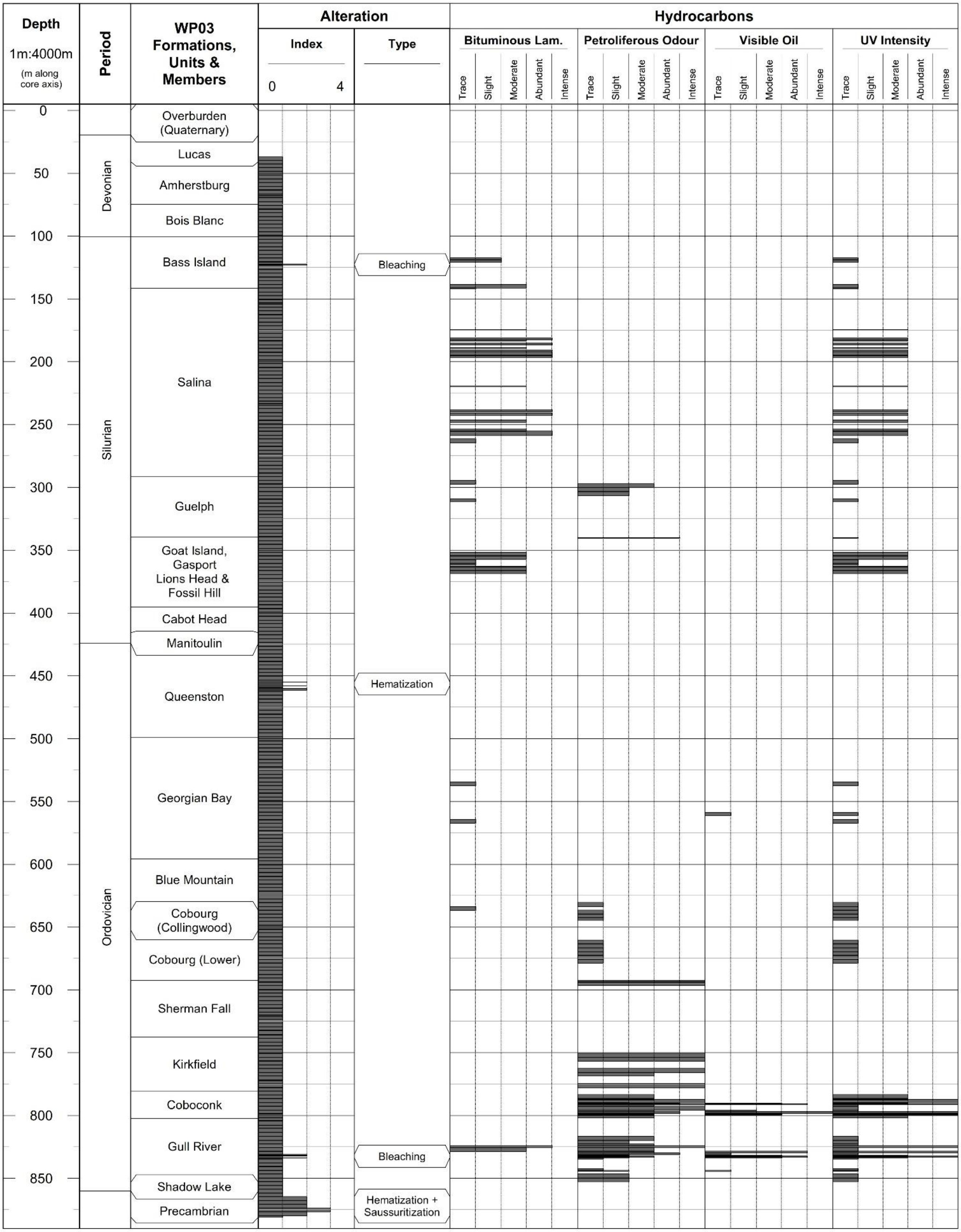


Figure 5: Summary of Logged Alteration and Hydrocarbons in SB_BH01

3.1.3 Hydrocarbons

Logged hydrocarbons in SB_BH01 are summarized in Table 4. Logged hydrocarbons included bituminous laminations, visible oil, degassing/petroliferous odour, and UV visible hydrocarbon products. Bituminous laminations and trace UV visible hydrocarbons were observed throughout most of the sedimentary sequence, with hydrocarbon indicators typically absent to slight/moderate for rocks above the Sherman Fall Formation.

Below the Cobourg Formation, there was a much stronger presence of hydrocarbons. Visible degassing and an intense petroliferous odour were logged in the upper “fragmental” interval of the Sherman Fall Formation. Moderate to intense petroliferous odour was also logged throughout the Sherman Fall and Kirkfield formations, with visible degassing and the strongest odours associated with increased porosity found in some coarser limestone beds. Visible oil and slight-intense petroliferous odours were logged for the Coboconk and Gull River formations.

Table 4: Logged Hydrocarbons in SB_BH01

Formation/Unit	Hydrocarbon Type(s) and Intensity	Comments
Bass Islands	Bituminous laminations (slight to moderate) UV-visible hydrocarbons (trace)	
Salina Group (F Unit, E-Unit, C-Unit, B-Unit, and A2-Carb.)	Bituminous laminations (moderate to abundant) UV-visible hydrocarbons (moderate)	
Guelph	Petroliferous odour (slight to moderate) Bituminous laminations (trace)	
Goat Island and Gasport	Petroliferous odour (abundant) Bituminous laminations (trace to -moderate) UV-visible hydrocarbons (moderate)	
Georgian Bay-Blue Mountain	Petroliferous odour (trace) UV-visible hydrocarbons (trace)	
Cobourg (Collingwood and Lower Mbr.)	Petroliferous odour (trace) Petroliferous odour (intense)	
Sherman Fall	Petroliferous odour (intense)	Strong odour associated with degassing from coarse-grained “fragmental” unit near top of formation
Kirkfield	Petroliferous odour (intense)	
Coboconk	Petroliferous odour (slight to intense) Visible Oil (moderate-intense) UV-visible hydrocarbons (trace to -intense)	Oil weeping from pores and degassing associated with strong petroliferous odour.
Gull River	Petroliferous odour (slight to -intense) Visible Oil (moderate-abundant) UV-visible hydrocarbons (trace to -intense)	

3.1.4 Geological Formations and Units

Formation, member, and unit tops presented in this report represent tops that were estimated based solely on rock core (WP03) observations at the time of drilling. All estimated formation tops were identified in the field by the core loggers and were confirmed by supervisory Geofirma staff familiar with the Paleozoic sedimentary strata in southwestern Ontario. The tops were estimated following guidance from Armstrong and Carter (2006, 2010) and based on pick criteria described in previous reports from drilling that was completed as part of the Bruce Deep Geological Repository study (Geofirma 2011).

The tops presented in this report are to be considered preliminary, as field estimation of formation, member, and unit tops during drilling were made so that core sampling could follow NWMO-specified sampling objectives. The final formation, member, and unit tops will be estimated based on a combination of rock core data (this report) and geophysical logging results (WP05) from SB_BH01 as part of borehole data integration activities (WP10). At the time of writing this report, several of the tops presented in this report (e.g. Cabot Head Fm. and Collingwood Mbr.) are known have been updated as part of the data integration activities (WP10).

The thicknesses of the major stratigraphic packages in SB_BH01 (Table 5) were generally consistent with reported thicknesses for these packages in nearby oil and gas wells logs from the Oil, Gas, and Salt Resources Library (OGSRL) and regional descriptions of these units (Carter et al. 2021, Armstrong and Carter 2010). These major packages include a thick sequence of Ordovician-aged shales (212 m) from the Queenston, Georgian Bay, and Blue Mountain formations that overlie 223 m of Ordovician-aged limestones.

Table 5: Thicknesses of Major Stratigraphic Packages in SB_BH01

Stratigraphic Package	Formations Included	Top Depth (m)	Bottom Depth (m)	Thickness (m)
Devonian	Lucas to Bois Blanc	19.60	100.59	80.99
Silurian	Bass Islands to Manitoulin	100.59	424.37	323.78
Ordovician Shales	Queenston to Blue Mountain	424.37	636.85	212.48
Ordovician Limestones	Cobourg (Collingwood) to Shadow Lake	636.85	860.33	223.48

A total of 34 formations were logged in SB_BH01, spanning from the Devonian Lucas Formation to the Precambrian basement rocks (Table 6). The Salina A0-Unit and the unsubdivided Cambrian were not encountered. The following subsections provide summary descriptions of all formations, members, and units that were observed in SB_BH01, as well as the core-based rational for top estimation during drilling. Representative photos for each unit are provided for Reference in Appendix C.

Table 6: Summary of SB_BH01 Formation Depths and Thicknesses (as logged during drilling)

Formation, Member, or Unit	Top Depth (m)[1]	Bottom Depth (m)[1]	Cored Thickness (m)[1]
Lucas	(19.6)[2] 36.94	41.05	(21.45)[2] 4.11
Amherstburg	41.05	75.00	33.95
Bois Blanc	75.00	100.59	25.59
Bass Islands	100.59	141.97	41.38
Salina G	141.97	147.9	5.93
Salina F	147.91	191.38	43.47
Salina E	191.38	209.38	18.00
Salina D	209.38	210.30	0.92
Salina C	210.30	224.76	14.46
Salina B	224.76	230.81	6.05
Salina B-Equivalent	230.81	250.55	19.74
Salina B-Anhydrite	250.55	253.86	3.31
Salina A2-Carbonate	253.86	274.72	20.86
Salina A2-Anhydrite	274.72	280.72	6.00
Salina A1-Carbonate	280.72	291.15	10.43
Salina A1-Evaporite	291.15	291.30	0.15
Salina A0	Not Present	Not Present	--
Guelph	291.30	339.89	48.59
Goat Island	339.89	361.43	21.54
Gasport	361.43	368.69	7.26
Lions Head	368.69	371.44	2.75
Fossil Hill	371.44	395.39	23.95
Cabot Head	395.39	415.81	20.42
Manitoulin	415.81	424.37	8.56
Queenston	424.37	499.40	75.03
Georgian Bay	499.40	595.86	96.46
Blue Mountain	595.86	636.85	40.99
Cobourg (Collingwood)	636.85	652.65	15.80
Cobourg (Lower)	652.65	692.59	39.94
Sherman Fall	692.59	737.66	45.07
Kirkfield	737.66	781.05	43.39
Coboconk	781.05	802.74	21.69
Gull River	802.74	853.51	50.77
Shadow Lake	853.51	860.33	6.82
Cambrian (unsubdivided)	Not Present	Not Present	--
Precambrian	860.33	880.84	20.51

Notes:

1. Top/bottom depths and thicknesses of units reported in this table were estimated during drilling based solely on rock core observations. Final estimates that integrate rock core (WP03) and geophysical well log data (WP05) are to be reported by Geofirma as part of final borehole integration activities (WP10).
2. Bracketed top depth and thickness of Lucas Formation are based on the top of bedrock identified from cuttings obtained during drilling and installation of conductor and surface casing with a cable-tool drilling rig.

3.1.4.1 *Lucas Formation (Detroit River Group)*

The Devonian Lucas Formation is the uppermost formation intersected in SB_BH01. The first 17 meters of the Lucas Formation were drilled with a cable tool rig for setting of the surface casing. In drill cuttings, the Lucas consists of light to dark brown, slightly laminated limestones with minor shale and bituminous laminations. Rare evaporitic clasts (interpreted to be mostly anhydrite and gypsum) and a few occurrences of carbonate sand were also logged.

In drill core, the Lucas consists of tan-brown and light-medium grey, medium bedded, planar laminated, finely crystalline limestone with minor vugs and moderate pinhole porosity. Trace to moderate amounts of tabulate and rugose corals are also present.

Pick Criteria: The top of Lucas was coincident with the top of bedrock in SB_BH01.

3.1.4.2 *Amherstburg Formation (Detroit River Group)*

The Amherstburg Formation consists of grey-brown fossiliferous, cherty, nodular, argillaceous dolomitic limestone to banded finely-crystalline limestone, with some laminations. The upper Amherstburg contains stromatoporoids with sparse corals and brachiopods. The lower Lucas consists of medium grey limestone and minor dolostone with irregular light grey cherty blebs/nodules ranging from 0.5-10 cm in diameter.

Pick Criteria: The top of Amherstburg was placed where light tan-brown limestones of the Lucas Formation transition to dark brown bituminous limestone/dolostones of the Amherstburg Formation.

3.1.4.3 *Bois Blanc Formation*

The Bois Blanc Formation consists of fine to medium grained, brown- grey, blotchy dolomitic fossiliferous limestone with abundant light grey to white chert nodules. Crinoid, bivalve, brachiopod, and coral fossils in the Bois Blanc were often partially silicified. Although chert nodules/cherty dolostones constitute much of the Bois Blanc, argillaceous limestone beds with laminations and stylolites are also observed.

Pick Criteria: The contact between the Amherstburg and Bois Blanc was very gradual in SB_BH01 and was extremely difficult to pick in the core. The top of the Bois Blanc was selected based on a gradual increase in chert content at a depth where the inferred Amherstburg Formation thickness would be generally consistent with regional thicknesses for the formation.

3.1.4.4 *Bass Islands Formation*

The Bass Islands Formation consists of fine crystalline, slightly brecciated, argillaceous, tan to grey, laminated dolostone with occasional blue-grey evaporite mineral molds. Occasional decimeter scale beds of grey vuggy dolostones are also observed throughout the Bass Islands. Bituminous layering is common, with occasional vugs infilled by calcite, trace pyrite, and a blue-grey mineral that is interpreted to be celestite.

Pick Criteria: The top of the Bass Islands Formation was placed at the unconformity with the overlying Bois Blanc which was observed in core as an easily distinguished abrupt change from cherty limestone to tan-grey crystalline dolostone of the Bass Islands.

3.1.4.5 *Salina – G Unit*

The Salina Formation G-Unit consists of very fine grained, grey argillaceous dolostone, and dolomitic shale with minor vugs. Moderate to abundant cm-scale white-grey anhydrite and gypsum beds/veins occur throughout. Secondary tan-brown argillaceous dolostone beds are also observed throughout the G-Unit.

Pick Criteria: The top of the Salina G-unit was placed at sharp transition from tan-grey vuggy dolostone to a grey-green calcareous shale with abundant anhydrite/gypsum beds/veins.

3.1.4.6 *Salina – F Unit*

The Salina F-Unit consists of dark green dolomitic shale with subordinate tan-brown dolostones. Red staining, 1-10 cm diameter pink-orange anhydrite nodules, and cm-scale gypsum beds/veins are common throughout the F-Unit.

Pick Criteria: The top of F Shale was placed at a sharp transition from tan-brown laminated dolostone to red-green dolomitic shale with anhydrite nodules.

3.1.4.7 *Salina– E Unit*

The Salina E-Unit consisted of interbedded, laminated to massive tan dolostone, grey-green argillaceous dolostone, and dark green laminated to massive dolomitic shale with abundant white anhydrite/gypsum bed/veins. The intensity of brecciation within dolostone beds increases with depth.

Pick Criteria: The top of the E-Unit was placed at sharp transition from tan laminated argillaceous dolostone to grey-green dolomitic shale with gypsum layers**.**

3.1.4.8 *Salina– D Unit*

The interpreted Salina D-Unit was ~1 m thick and consisted of tan-grey brecciated shaly dolostone with gypsum beds/veins and a bluish anhydrite matrix.

Pick Criteria: Top of the Salina D was placed at a gradational change from dolostone to blue-grey anhydritic dolostone.

3.1.4.9 *Salina – C Unit*

The Salina C-Unit consists of two main lithologies: the upper section of the C-Unit is composed primarily of red and green dolomitic shale, with anhydrite nodules and cm-scale gypsum beds/veins throughout. The lower C-Unit consists a of grey-blue anhydritic, dolomitic shale with minor brecciated anhydrite clasts. A 0.40m tan dolostone bed with mm-scale anhydrite nodules and thin wavy gypsum layers is observed halfway through the C-Unit.

Pick Criteria: Top of C Unit was placed at a semi-gradational transition from grey-brown anhydritic dolostone to red and green dolomitic shale.

3.1.4.10 *Salina – B Unit*

The Salina B-Unit consists of a thin tan-brown dolostone bed, underlain by grey-green argillaceous dolostone and dolomitic shale. Centimeter-scale gypsum and anhydrite beds/veins are found throughout with common brecciation.

Pick Criteria: The top of the Salina B-Unit was placed at the top of a thin (<1m) tan-brown dolostone bed that separates more anhydritic dolostones of the overlying C-Unit from dolomitic shales of B-Unit.

3.1.4.11 *Salina – B Unit Equivalent*

Like the overlying B-Unit, the Salina B-Equivalent consists of a brecciated brown to grey-green argillaceous dolostone to dolomitic shale with abundant white-grey anhydrite/gypsum beds/veins.

Pick Criteria: In the absence of salt beds within the B-Unit, separating the B-Unit from B-Equivalent is nearly impossible in core. The top of the B-Equivalent was placed ~6m from the top of the B-Unit based on expected thicknesses from other boreholes in the study area.

3.1.4.12 *Salina – B Unit Anhydrite*

The Salina B-Unit Anhydrite consists of interbedded grey-blue and brown anhydritic-dolomitic shale with abundant mm to cm-scale gypsum beds/veins. In SB_BH01, the unit has a fibrous-brecciated texture with anhydrite and gypsum infill.

Pick Criteria: The top of the Salina B-Anhydrite was placed at a sharp contact between brecciated brown dolostone and interbedded grey-blue anhydritic shale and brown dolostone.

3.1.4.13 *Salina – A2 Unit Carbonate*

The Salina A2-Carbonate consists of laminated to massive tan-brown porous dolostone interbedded with subordinate grey-brown argillaceous dolostone and dark-grey dolomitic shale. Dark brown to black bituminous laminae that emit a petroliferous odour are common within the tan dolostone beds. Stromatoporoid and small coral fossils are found throughout.

Pick Criteria: The top of the A2-Carbonate was easily distinguished and was placed at a sharp contact between dolomitic shale and tan-brown dolostone.

3.1.4.14 *Salina – A2 Unit Anhydrite*

The Salina A2-Anhydrite consists of a light grey-blue, very fine grained thinly bedded to laminated anhydritic dolostone. Millimetre scale anhydrite grains are distributed throughout that, where dissolved, results in minor porosity. Much of the bedding occurs as bulbous stromatoporid-like structures.

Pick Criteria: The top of the A2-Anhydrite was placed at a sharp contact marked by the appearance of fine-grained evaporitic minerals (anhydrite and gypsum) within the grey-blue laminated dolostone.

3.1.4.15 *Salina – A1 Unit Carbonate*

The Salina A1-Carbonate consists of grey to tan-brown porous and fossiliferous (crinoids and corals) dolostone and limestone with common dark grey petroliferous shale laminae. Millimeter to cm-scale vugs increase in frequency with depth and are associated with moldic porosity.

Pick Criteria: The top of the A1-Carbonate was easily distinguished and was placed at a sharp contact marked by the appearance of vuggy, porous brown dolostone and the disappearance of fine grained evaporate (gypsum, anhydrite) minerals

3.1.4.16 *Salina – A1 Unit Evaporite*

The interpreted Salina A1-Evaporite (15 cm) consists of a single bed of light-medium grey dolostone that is found between porous grey-brown dolostones of the overlying A1-Cabonate and the underlying Guelph Formation.

Pick Criteria: The top of the Salina A1 Evaporite was placed at the top of light-grey dolostone below porous brown dolostones of the overlying A1-Carbonate.

3.1.4.17 *Guelph Formation*

The Guelph Formation consists of mottled grey to tan-brown fine-medium grained fossiliferous limestone and dolostone. High-angle bedding, abundant fracturing, and coarse mm-cm scale porosity are present in the upper 28 m of the Guelph in SB_BH01. Bedding in the lower 20 m of the Guelph is closer to horizontal with less fracturing and finer (mm-scale) porosity. Observed fossils include crinoids, corals, bivalves, brachiopods, and gastropods.

Pick Criteria: The top of the Guelph Formation was easily distinguished and was placed at a sharp transition from light-grey dolostone to tan-brown fossiliferous limestone with abundant porosity and high-angle bedding.

3.1.4.18 *Goat Island Formation*

The Goat Island Formation consists of light- medium grey-brown, very fine grained, nodular, argillaceous, fossiliferous dolostone and limestone. Minor chert with rare dark grey irregular bituminous laminae.

Pick Criteria: The top of the Goat Island Formation was semi-gradational and was placed where porous brown limestone and dolostone of the Guelph Formation transition into less-porous nodular argillaceous dolostone.

3.1.4.19 *Gasport Formation*

The Gasport Formation consists of medium to light grey thinly bedded fossiliferous dolomitic limestone with abundant bituminous wavy laminations. Grain size and the abundance of white-grey fossils/clasts (mm scale) increase gradually with depth. Locally abundant cm-scale chert beds/nodules with mm-scale crinoid and cm-scale coral/bryozoan fossils throughout.

Pick Criteria: The top of the Gasport Formation was difficult to identify and was placed at a very gradual transition to lighter grey, coarser grained, slightly-more porous limestone than the overlying Goat Island.

3.1.4.20 *Lions Head Formation*

The Lions Head Formation consists of a thin to medium bedded, mottled light grey to grey-brown fine grained, argillaceous limestone. Limestone of the Lions Head was sparsely fossiliferous with trace shale and siltstone clasts.

Pick Criteria: The top of the Lions Head Formation was placed at a sharp increase in brown-grey shale content, associated with a finer grain size and decrease in fossil abundance.

3.1.4.21 *Fossil Hill Formation*

The upper Fossil Hill consists of a grey to tan fossiliferous dolomitic limestone with common shaley laminations and weak wispy stylolites. The lower 9 m of the Fossil Hill in SB_BH01 may be interpreted as the St. Edmunds Formation, which consists of a mottled tan, sparsely fossiliferous nodular dolostone with minor laminations and pinhole porosity.

Pick Criteria: The top of the Fossil Hill Formation was placed at a sharp contact marked by an abrupt increase in the frequency of shaley laminations and the abundance of mm-scale white fossil fragments.

3.1.4.22 *Cabot Head Formation*

The Cabot Head Formation consists of mottled to uniform, red and dark green calcareous shale with thin carbonate interbeds. Brachiopod and trace partial trilobite fossils are found throughout. The Cabot Head grades with depth to interbedded shale and fossiliferous limestone.

Pick Criteria: The top of the Cabot Head Formation was easily distinguished and was placed at a sharp contact between tan-brown dolostone and the uppermost green shale bed.

3.1.4.23 *Manitoulin Formation*

The Manitoulin Formation consists of mottled grey to brown argillaceous, fossiliferous limestone with minor and calcareous green shale interbeds. Fossils in the Manitoulin are mostly shell fragments (brachiopods) with trace to moderate amounts of coral.

Pick Criteria: The top of the Manitoulin Formation is gradational and was placed at the base of lowermost significant (> 10 cm) green shale bed in the Cabot Head Formation.

3.1.4.24 *Queenston Formation*

The Queenston Formation consists of red-maroon and teal-grey calcareous and non-calcareous shale with minor siltstone and carbonate interbeds. Locally contains mm-scale gypsum and anhydrite nodules.

Pick Criteria: The top of the Queenston was easily distinguished and was placed at a sharp change contact between grey fossiliferous limestone and grey-green shale.

3.1.4.25 *Georgian Bay Formation*

The Georgian Bay Formation consists of fissile grey non-calcareous shale with subordinate fossiliferous limestone and hard carbonate interbeds. Fossiliferous limestone beds decrease in abundance with depth.

Fossils that are observed in the Georgian Bay include: brachiopods, bivalves, crinoids, and cephalopods. A petroliferous odour is observed near the bottom of the formation.

Picking Criteria: The top of the Georgian Bay was gradational and was placed where the of the lowermost red shale of the Queenston Formation transitions to a grey-green shale with grey carbonate interbeds.

3.1.4.26 *Blue Mountain Formation*

The Blue Mountain consists of fissile blue-grey non-calcareous shale interbedded with minor cm-thick grey siltstone and limestone beds. The shale transitions to a grey to dark grey shale with depth. Crinoids, brachiopods, shell fragments and trace fossils are abundant in the formation. The shale has petroliferous odour. Calcite infilled fractures with pyrite mineralization are observed throughout.

Pick Criteria: The top of the Blue Mountain Formation was gradational and was very difficult to make from core. The contact was placed bottom of the last significant (>10 cm) calcareous limestone bed near where there is subtle increase in core disking.

3.1.4.27 *Cobourg Formation – Collingwood Member – (Trenton Group)*

The Collingwood Member of the Cobourg Formation consists of dark brown-grey to black, calcareous shale interbedded with grey fossiliferous limestone. The Collingwood Member is much harder than the overlying Blue Mountain and is less prone to core disking. Fossils include cephalopods, gastropods, and corals. The abundance of fossiliferous limestone beds increases with depth.

Pick Criteria: The top of the Collingwood Member was placed at a semi-gradational change in colour from the dark grey shale of the Blue Mountain to brown-grey shale of the Collingwood Member.

3.1.4.28 *Cobourg Formation – Lower Member – (Trenton Group)*

The Lower Member of the Cobourg Formation consists of mottled, wavy grey-brown, argillaceous, fossiliferous limestone. Fossils in the lower Cobourg include brachiopods, crinoids, and shell fragments. This lower member has petroliferous odour with trace-minor degassing.

Pick Criteria: The top of the Lower Member of the Cobourg was sharp and was placed at the base the lowermost significant (>10cm) dark grey-black shale bed of the Collingwood Member. Below this pick, there are no significant shale beds in the lower Cobourg.

3.1.4.29 *Sherman Fall Formation – (Trenton Group)*

The upper Sherman Fall Formation consists of grey, medium to coarse grained, laminated and cross-bedded limestone. This upper interval includes bioclastic grainstones with abundant porosity and has a strong petroliferous odour caused by the degassing of methane. The upper unit is interpreted to be the "fragmental unit" described in Armstrong and Carter (2006). The rest of the Sherman Fall consists of light-medium grey fossiliferous and nodular micritic limestones interbedded with dark grey calcareous and non-calcareous shale. The abundance of the dark grey shale beds increases with depth.

Pick Criteria: The top of the Sherman Fall was easily distinguished and was placed at a sharp contact between nodular argillaceous limestone overlying medium to coarse grained laminated/cross bedded limestone of the "fragmental" unit.

3.1.4.30 *Kirkfield Formation (Trenton Group)*

The Kirkfield Formation consists of grey to blue-grey, fine to medium grained fossiliferous limestone interbedded with dark grey shale beds containing minor limestone fragments.

Pick Criteria: The contact between the Sherman Fall and the Kirkfield is very gradational and is typically picked from gamma logs. In core, the contact was very difficult to identify and was placed at the top of a 0.75 m thick bioclastic limestone bed (consisting of 3 distinct 15-20 cm thick layers) below which, a gradual decrease in shale content was observed.

3.1.4.31 *Coboconk Formation (Black River Group)*

The Coboconk Formation consists of a grey to brown, fine grained, fossiliferous, and bioturbated limestone with irregular bituminous shale laminations. The Coboconk has visible oil weeping from porous intervals and a trace to strong petroliferous odour. A thin clay (volcanic ash) marker bed is observed approximately 10 m from the top of the Coboconk.

Pick Criteria: The top of the Coboconk Formation was easily distinguished and was placed at a sharp transition from interbedded bluish-grey limestone and shale of Kirkfield, to cleaner, light grey, bioturbated limestone of the Coboconk.

3.1.4.32 *Gull River Formation (Black River Group)*

The Gull River consists of grey-blue, fine to medium grained, locally bioturbated and fossiliferous limestone with brown to black bituminous shale laminae and beds. The Gull River is petroliferous, with visible oil weeping from porous intervals and a trace-strong petroliferous odour.

Pick Criteria: The top of the Gull River Formation was easily distinguished and was placed where there is a sharp change in the character of the shale beds from distorted/bioturbated beds to less-disturbed planar beds. A subtle change in colour from brown to grey-blue is observed near the contact in the limestone beds.

3.1.4.33 *Shadow Lake Formation (Black River Group)*

The Shadow Lake Formation consists of interbedded grey, green, and brown glauconitic sandstone, siltstone, and shales. The shalier interval near the bottom of the Shadow Lake contains abundant granitic clasts forming thin conglomerate-like beds.

Pick Criteria: The top of the Shadow Lake was a sharp contact, placed at the top of the first a grey-green, glauconitic, silty sandstone bed.

3.1.4.34 *Precambrian basement (Grenville Province)*

The Precambrian basement rocks consist of a medium to coarse grained, syenitic to granitic gneiss. The pink to white felsic banding is commonly potassium feldspar-dominated with plagioclase, biotite, and quartz. Darker mafic bands are dominated by biotite and amphibole. There is a strong foliation (gneissosity) throughout.

Picking Criteria: The top of the Precambrian was easily distinguished and was placed at the sharp unconformity separating the Paleozoic sedimentary rocks (green shale with granitic clasts) from the underlying Precambrian crystalline basement rocks (grey and pink gneiss).

3.2 Logged Structures and Geotechnical Parameters

3.2.1 Summary of Structures

A total of 3637 structures were logged from core in SB_BH01, including 2992 mechanical breaks and 645 natural structures (Table 7). Natural structures logged in SB_BH01 consisted almost entirely of brittle deformation structures, except for gneissosity in the Precambrian basement rocks. The distribution of logged structures in SB_BH01 is shown in Figure 6.

Table 7: SB_BH01 Logged Structures Summary, by Structure Type

Structure Type	Structure Sub-type	# Logged in SB_BH01	% of Logged Structures (All)	% of Logged Structures (Natural)
Mechanical Break (*MB*)	Single Break (*MB-SB*)	2906	79.9%	--
	Broken Core Zone (*MB-BCZ*)	75	2.1%	--
	Lost Core Zone (*MB-LCZ*)	11	0.3%	--
Lost Core Zone (*LCZ*)		6	0.2%	0.9%
Broken Core Zone (*BCZ*)		40	1.1%	6.2%
Joint (*JN*)	Broken (*BR*) Joint	331	9.1%	51.3%
	Partially Intact (*PIN*) Joint	11	0.3%	1.7%
	Intact (*IN*) Joint	53	1.5%	8.2%
Intact Fracture Zone (*IFZ*)	Minor (*MI*)	3	0.1%	0.5%
	Moderate (*MO*)	14	0.4%	2.2%
	Heavy (*HE*)	3	0.1%	0.5%
Veins (*VN*)	Broken (*BR*) Vein	6	0.2%	0.9%
	Partially Intact (*PIN*) Vein	11	0.3%	1.7%
	Intact (*IN*) Vein	73	2.0%	11.3%
Vein Zones (*VNZ*)	Broken (*BR*) Vein Zone	1	0.0%	0.2%
	Partially Intact (*PIN*) Vein Zone	2	0.1%	0.3%
	Intact (*IN*) Vein Zone	86	2.4%	13.3%
Fault (*FLT*)		2	0.1%	0.3%
Breccia (*BX*)		1	0.0%	0.2%
Gneissosity (*GNS*)		2	0.1%	0.3%
	Total	3637	100%	100%

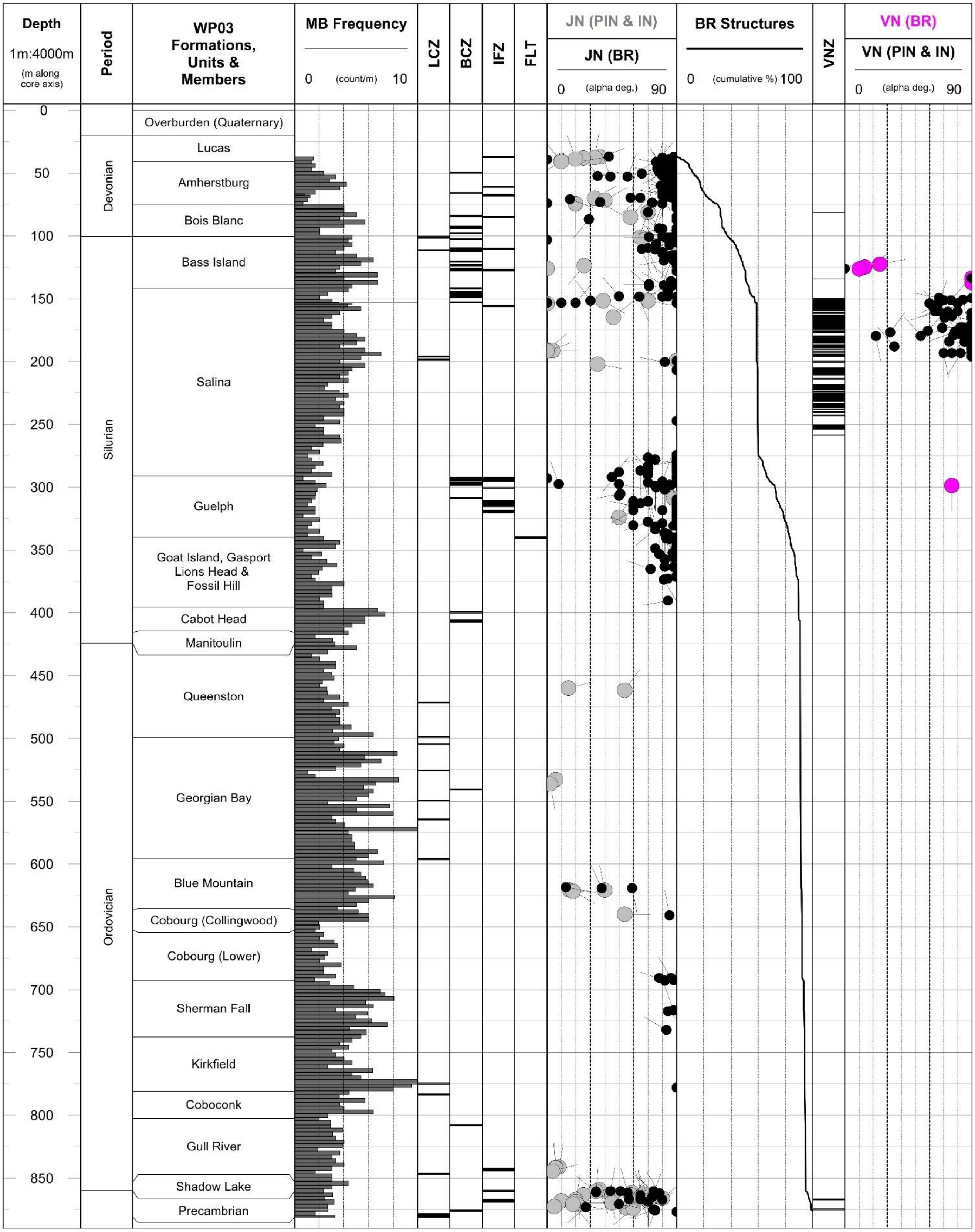


Figure 6: Summary of Logged Structures in SB_BH01. Lost Core Zone (LCZ), Broken Core Zone (BCZ), Intact Fracture Zone (IFZ), Fault (FLT), Joint (JN), Vein/Vein Zone (VN/VNZ)

3.2.2 Core Recovery Considerations and Mechanical Breaks

Most of the logged planar structures (joints, veins, faults) were near-horizontal and roughly parallel to bedding. Some higher angle, near vertical structures were observed, but the frequency of these structures is likely underestimated from the SB_BH01 core data due borehole orientation bias (Terzaghi 1965).

Core loggers marked all natural structures and mechanical breaks that were observed upon completion of core photography at the start of logging. Some fissile shale units, in particular the Georgian Bay and Blue Mountain formations, would develop mechanical breaks during the logging process, due to decompression of the core. In these units, the core would typically be retrieved with just 1 or 2 mechanical breaks, but greater than 20 mechanical breaks would be observed at the end of core logging. Mechanical breaks that formed after core marking and photography were not marked or logged by the core loggers.

3.2.3 Joints

Joints were the most common natural structure logged, composing 61% of all logged natural structures in SB_BH01. A total of 395 joints were logged, including 331 broken (BR) joints, 53 intact (IN) joints, and 11 partially intact (PIN) joints.

Joint orientations were mostly near-horizontal with 52% of joints having an alpha angle greater than 85 degrees (dip <5 degrees). 70% of joints had alpha angles greater than 70 degrees (dips < 20 degrees). Only 9% of joints had alpha angles less than 25 degrees (dips > 65 degrees). Beta angles measured relative to core axis angle were not corrected to geophysics as part of WP03 activities, so no trends in dip direction for logged structures could be determined.

Partially intact and intact joints were assigned a Joint Condition Rating (JCR) of 30, while broken joints were assigned JCR values between 11-27 (Figure 7). The mean JCR for logged joints was 19.6.

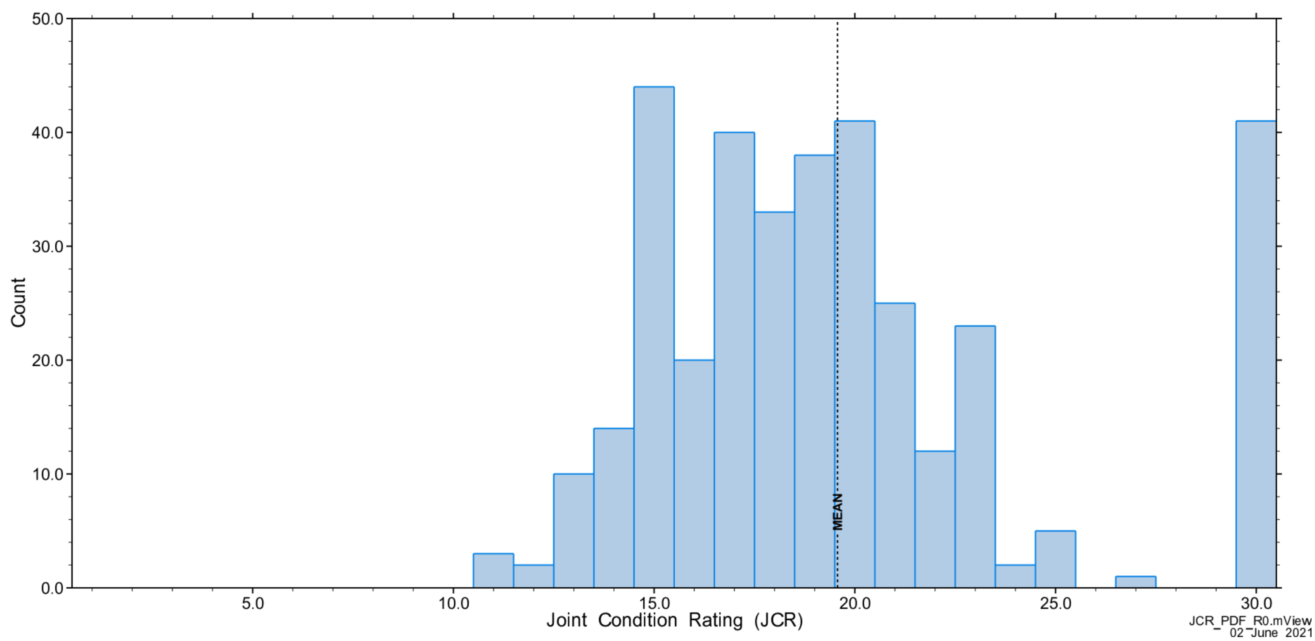


Figure 7: SB_BH01 Joint Condition Rating Distribution, All Joints (BR, IN, PIN). Partially intact (PIN) and intact (IN) joints were assigned a JCR of 30.

The vertical distribution of joints was concentrated in the shallow bedrock (<155 m), the lower Silurian limestones and dolostones (275-375 m), and in the Precambrian basement rocks (>860 m). Approximately 60% of broken structures, including joints and broken core zones, occurred within the shallow bedrock at a depth of less than 155 m. 30 % of broken structures occur in between 275-375 m, with another 5 % of broken structures distributed sparsely across the Ordovician limestones, and the remaining 5 % in the Precambrian basement rocks.

3.2.4 Broken Core Zones, Lost Core Zones, and Faults

Broken Core Zones (BCZ) and Lost Core Zones (LCZ) were generally associated with highly fractured core intervals and were concentrated in the shallow bedrock (<155 m) and in the upper part of Guelph Formation from 290-325 m.

Two interpreted fault structures, likely associated with a single fault were logged near the base of the Guelph Formation between 339.80-340.46 m. In core, the interpreted fault occurs as a zone of heavily brecciated angular rock fragments in a fine-grained grey-green gouge matrix.

3.2.5 Veins and Vein Zones

Any discontinuities or interpreted natural fractures with infill thickness > 1 mm thick were logged as veins in accordance with geotechnical logging criterion defined in the core logging manual (Geofirma 2021). Under this classification criterion, several natural fractures were logged as broken veins, including fractures that were open, water-producing, zones associated with some of the opportunistic groundwater sampling events (OGW).

Veins and vein zones logged in SB_BH01 could be roughly subdivided into two subtypes: Broken veins structures that were logged in accordance with the criteria described above, and intact/partially intact vein-like structures associated with gypsum and anhydrite bedding in evaporitic units. The first type, broken veins were observed in the Bass Islands and Guelph formations.

The intact or partially intact gypsum and anhydrite vein-like structures were observed in the Salina Group. These vein-like gypsum/anhydrite structures were generally parallel to bedding, but also occasionally cross-cut bedding or occurred as brecciated intervals with anhydrite/gypsum containing mm to cm-scale angular dolomitic shale fragments.

3.2.6 Calculated Geotechnical Parameters

Logged geotechnical parameters, including recovery, solid core recovery (SCR), and rock quality designation (RQD) were recorded on a run-by-run basis and are show in Figure 8.

Field strength was logged opportunistically and was typically recorded where core was broken for core run photos. Field strength was generally high (R4-R6), except for shaley intervals in the Salina Group and in the shale-rich Ordovician Queenston, Georgian Bay, and Blue Mountain formations. These shales were logged with lower rock strength ratings (R1-R3) as they were readily broken along bedding planes during core retrieval and logging. However, these shales are well-cemented and had higher strength ratings of R4-R5 when hammered perpendicular to bedding (as done for collection of dissolved gas samples).

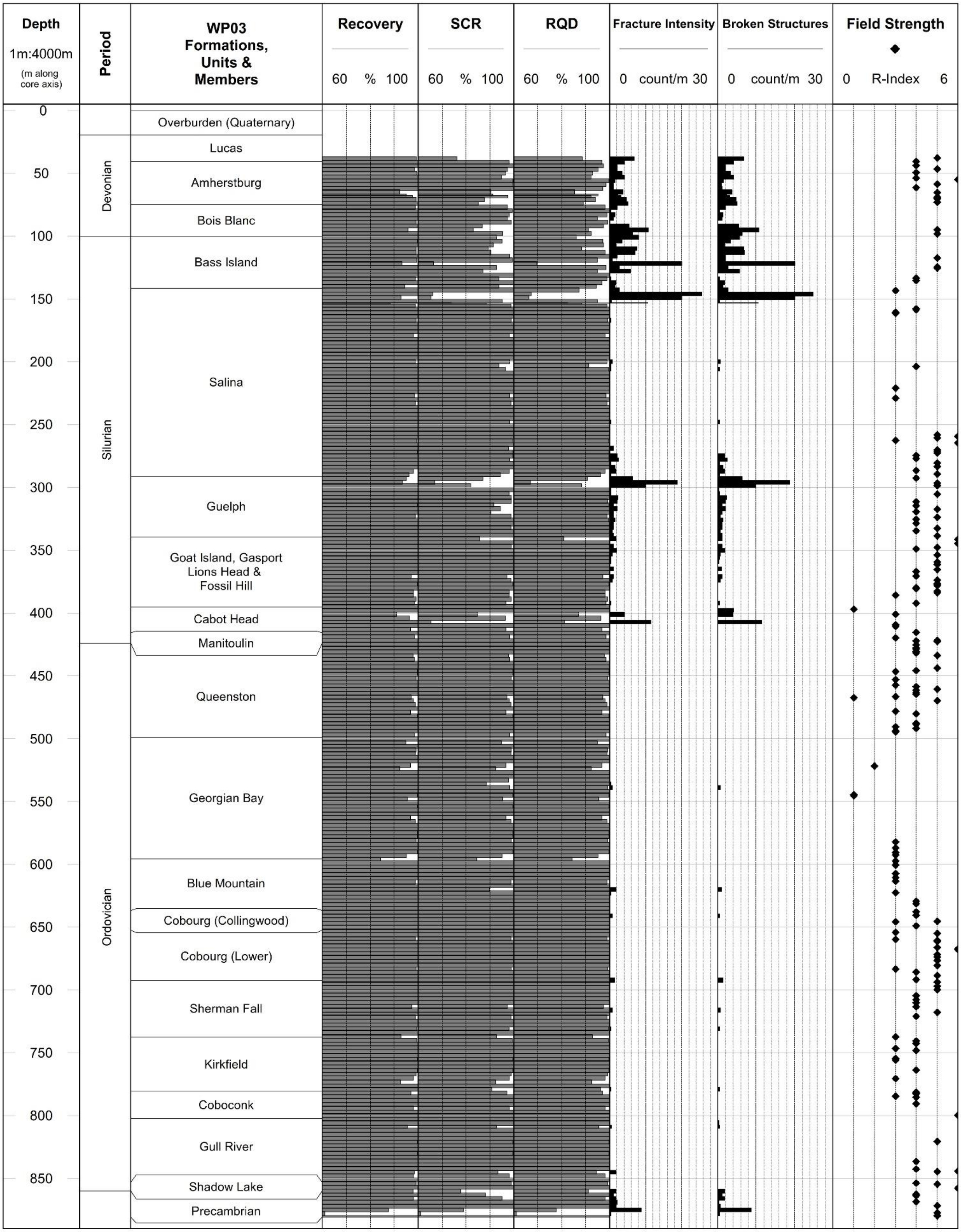


Figure 8: Summary of Geotechnical Parameters Logged in SB_BH01

The core quality of SB_BH01 was generally high, with 94% of the core run intervals rated excellent based on the RQD classification scheme presented in Deere (1968) and Bieniawski (1989). 6% of the cored interval had fair to good ratings, with no core rated poor or very poor (Table 8). Core intervals rated fair or good were located primarily in highly fractured intervals of the shallow bedrock (<155 m), the lower Silurian carbonates, and in the Precambrian basement rocks, however, the lower RQD-rated intervals in the Precambrian may be associated with drilling equipment issues that occurred while coring that section of the borehole.

Table 8: Rock Quality Designation (RQD) Summary

RQD (% of Core Run)	RQD Rating (Bieniawski 1989)	# of Core Runs Logged	% of Core Logged
90-100	Excellent	267	94%
75-90	Good	14	4%
50-75	Fair	5	2%
25-50	Poor	0	0%
<25	Very Poor	0	0%

3.3 Core Sampling

3.3.1 Summary of Sample Collection

A total of 481 core samples were collected from SB_BH01, including 436 collected by Geofirma during drilling and 45 collected by NWMO after drilling (Table 9). Most of the samples were collected for geomechanical, geochemical, and mineralogic testing that will be coordinated by Geofirma as part of the core testing activities (WP04). Some of the samples will undergo laboratory testing that will be coordinated by NWMO (cation exchange capacity, sorption, microbiology, petrophysics) or be archived by the NWMO. The distribution of core samples, by sample type (as collected) is shown in Figure 9.

Samples were collected, preserved, and transported according to procedures that are summarized in Table 1 (this report) and are described in detail in the WP03 test plan (Geofirma 2021).

Most of the prescribed samples were collected according to the NWMO sampling guidance for SB_BH01, however some samples may be assigned to different formations than originally logged if the tops that were picked during coring (WP03) are changed based on integration with geophysical data as part of borehole data integration activities (WP10). Notable exceptions where samples were not collected according to the NWMO-provided sampling guidance include:

- 6 samples from the Lucas, Amherstburg, and Bois Blanc formations due to difficult pick criteria for these units and sampling issues that occurred at the start of the borehole
- 8 samples from the Salina A1-A0 units due to a much thinner Salina A1 interval than was anticipated based on the regional geological prognosis and the Salina A0 unit not being present. The thinner Salina interval is associated with the presence of an overthickened reef-like structure in the underlying Guelph Formation
- 9 samples from the Cambrian interval, which was not encountered in SB_BH01

Table 9: SB_BH01 Core Sample Summary, by Sample Type (as collected)

Sample Type	Specified in Test Plan[1]	Collected by Geofirma and NWMO	Difference	Comments
Petrophysics Suite	33	34	+1	Additional sample returned to core box
Effective Diffusion Coefficient	22	24	+2	Additional samples from Gasport (returned to core box) and Collingwood (submitted for UCS)
UCS	29	30	+1	Additional sample archived
Brazilian	29	30	+1	Additional sample archived
Triaxial	27	27	0	
Direct Shear	9	9	0	Collected after drilling with NWMO
Thermal Prop Only	15	16	9	One sample returned to core box and one sample archived
Thermal Prop and Unconfined Thermal Expansion	8	8	0	
Confined Thermal Expansion	5	5	0	
Porewater	60	67	+7	Additional samples from Bass Islands (2) and Gasport (1) returned to core box. Other additional samples archived, or shipped to RESPEC for thermal properties (SB_BH01_PW020)
Dissolved Gas	30	33	+3	Two additional samples returned to core box and one sample archived
Noble Gas	30	34	+4	Additional samples returned to core box
Mineralogical and Geochemistry (rock matrix)	30	34	+4	Additional samples returned to core box
Mineralogy & Geochemistry (fracture infill) and Fluid Inclusion (BGS)	30	25	-5	Collected by NWMO
Mineralogical and Geochemistry (fracture face, rock matrix)	20	20	0	Collected by NWMO
Sorption	6	6	0	
BET/CEC (Surface Area)	6	6	0	
Organics	13	18	+5	Additional samples returned to core box
Microbiology	6	6	+0	
Archive[2]	45	49	+4	
Total	**453[1,3]**	**481**	+28	

1. Test plan included 9 samples targeted for the Cambrian unit which was not encountered in SB_BH01. The planned Cambrian samples included: 1 UCS, 1 Brazilian, 1 Thermal Property, 2 Porewater, 1 Noble Gas, 1 Dissolved Gas, 1 Mineralogical, and 1 Archive.
2. Only includes samples originally collected with archive (AR) code. Count does not include other sample types that were subsequently archived.
3. Fluid inclusion and NWMO-collected mineralogical and geochemistry (fracture infill) samples were collected as combined samples.

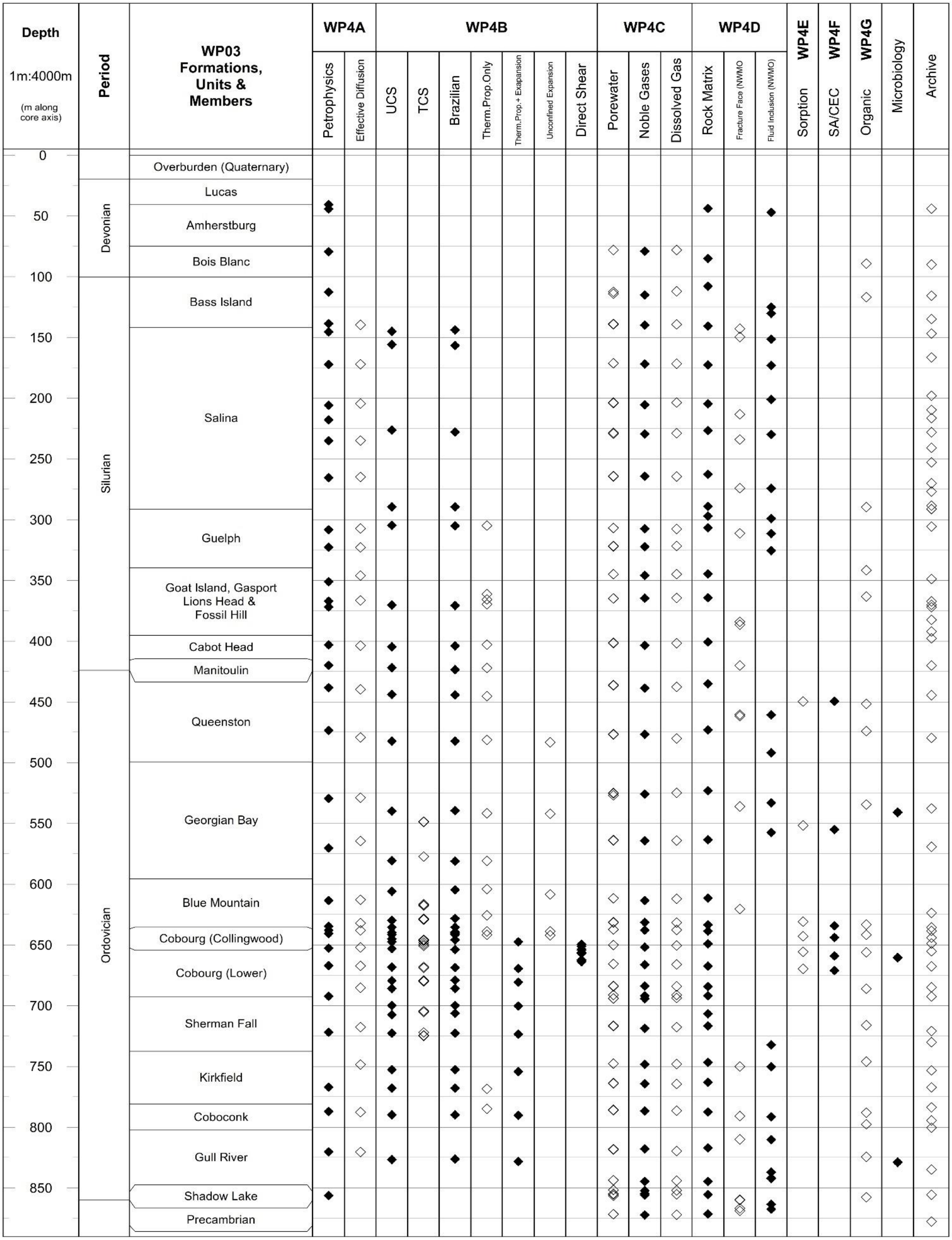


Figure 9: Distribution of Core Samples in SB_BH01, by sample type (as collected)

4 CONCLUSIONS

Geofirma Engineering Ltd. completed core logging, photography, and sampling activities for rock core produced during drilling of SB_BH01, the first of two boreholes in the South Bruce study area that were drilled as part of the NWMO's Phase 2 Geoscientific Preliminary Field Investigations. All core processing activities were completed by Geofirma staff on a run-by-run basis immediately after the core was retrieved at ground surface.

Geological formation picks presented in this report are based solely on core data and represent the picks that were made in the field during drilling and logging activities. Some tops may change when compared to geophysical logs as part of borehole data integration.

The top of rock in SB_BH01 was at 19.6 m BGS. Coring started at 36.94 m BGS in the Devonian Lucas Formation and ended approximately 20.5 m into the Precambrian basement rocks at 880.84 m BGS. Continuous core was recovered through the entire Paleozoic sequence. The thickness of the Silurian-aged strata from the Bass Islands Formation to the Manitoulin Formation was 323.78 m. The upper Ordovician-aged shales, comprised of the Queenston, Georgian Bay, and Blue Mountain formations had a combined thickness of 212.48 m. These shales were underlain by a sequence of Ordovician-aged limestones with minor shale interbeds that had a combined thickness of 223.48 m.

Formation, unit, and member thicknesses and rock types were generally consistent with regional well data and from boreholes drilled as part of the Bruce Deep Geological Repository study (Geofirma 2011) with the following exceptions:

- The interpreted Salina A2 and A1 Carbonate units were composed primarily of brown fossiliferous and porous dolostones. The combined thickness of the A2 and A1 units was just 37.44 m, which is much thinner than is typically observed for these units in nearby oil and gas wells and in regional studies (Carter et al. 2021, Armstrong and Carter 2010).). The Salina A1 unit was only 10.58 m thick in SB_BH01 and the Salina A0 unit was not encountered.

- The thinner and more dolomitic lower Salina units are associated with an overthickened reef-like structure in the underlying Guelph Formation. The thickness of the interpreted Guelph Formation in SB_BH01 was 48.59 m.

- The thickness of the interpreted Fossil Hill Formation was 23.95 m, which is much thicker than was anticipated based on regional data sets (Carter et al. 2021, Armstrong and Carter 2010). The lower 9 m of the Fossil Hill in SB_BH01 may be the St. Edmunds Formation, which consists of a mottled tan, sparsely fossiliferous nodular dolostone with minor laminations and pinhole porosity.

- An upper unit of the Sherman Fall Formation was observed that is interpreted to be the "fragmental unit" described by Armstrong and Carter (2006). This "fragmental unit" consisted of medium to coarse grained, laminated to cross-bedded limestones and bioclastic grainstones. This unit had abundant porosity and a strong petroliferous odour caused by degassing of methane.

- No Cambrian strata were encountered; the Shadow Lake Formation occurs immediately above the Precambrian crystalline basement rocks.

Logged alteration in the Paleozoic sedimentary rocks was limited to minor bleaching and hematization that were observed at a few discrete locations. Dolomitization of limestone was not logged. Hematization and saussuritization were observed in the Precambrian crystalline basement rocks. No geological weathering was observed in core, except for minor weathering along fracture surfaces in the shallow bedrock.

No significant hydrocarbon accumulations were observed. Bituminous laminations were logged throughout the Silurian-aged strata, including rocks from the Salina Group and the Guelph, Goat Island, and Gasport formations. Strong to intense petroliferous odours were observed in the Sherman Fall Formation and the underlying Kirkfield, Coboconk, and Gull River formations. Visible oil was also observed in the Coboconk and Gull River formations.

A total of 645 natural structures were logged, consisting almost entirely of brittle deformation structures. Joints were the most common structure, comprising 61% of all logged natural structures. Rock quality was generally high, with 94% of the cored interval having a RQD rating of excellent; no core intervals had a RQD rating of poor or very poor. The frequency of high-angle (near vertical) structures is likely underestimated from the SB_BH01 core data due borehole orientation bias (Terzaghi 1965).

Joints were concentrated in the shallow bedrock (<155 m), the lower Silurian limestones and dolostones (275-375 m), and in the Precambrian basement rocks (>860 m). The Ordovician aged shales and underlying limestones were relatively fracture-poor with logged fracture intensities that were typically 0-2 fractures per meter. Many of the core runs from these Ordovician intervals had no natural fractures recorded.

481 core samples were collected from SB_BH01 following NWMO-sampling guidance, including 436 collected by Geofirma and 45 collected by the NWMO. Samples were collected, preserved, and shipped to commercial laboratories and research institutions for a large suite of analyses.

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Appendix A

Core Logging Manual

Phase 2 Initial Borehole Drilling and Testing, South Bruce

WP03 – Geological and Geotechnical Core Logging Procedures Manual

Revision: 3 (Final)

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Project Number: 20-211-1
Document ID: 20-211-1_Core_Logging_Manual_R3.docx

December 30, 2021

Title:	Phase 2 Initial Borehole Drilling and Testing, South Bruce WP03 – Geological and Geotechnical Core Logging Procedures Manual
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Project Number:	20-211-1
Document ID:	20-211-1_Core_Logging_Manual_R3.docx
Revision Number:	3A (Draft) — Date: December 30, 2021
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Revision Tracking Table

Revision	Revision Release Date	Description of Modifications/Edits
R0	April 19, 2021	Initial Release
R1	July 9, 2021	Addition of sphalerite, galena, and pyrite to infill type list for logged structures
R2	August 22, 2021	Addition of anhydrite, gypsum and unidentified infill types (Table 5) and migmatite, schist, pegmatite, and conglomerate lithologies (Table 11).
R3	December 30, 2021	Addition of ash and “no core recovered” lithology (Table 11). Modifications to core marking and reference line instructions (Section 2.3),

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Appendix 1 Examples of fossil types commonly observed in Paleozoic sedimentary rocks of Southwestern Ontario.

1 INTRODUCTION

The activities described in this geological and geotechnical core logging procedures manual ("core logging manual") constitute one component of the geoscientific investigation that is to be completed by Geofirma Engineering Ltd. (Geofirma) as part of the Nuclear Waste Management Organization's (NWMO) Phase 2 Initial Borehole Drilling and Testing Program within the South Bruce study area, near Teeswater, Ontario. Specifically, this core logging manual outlines the procedures that Geofirma core loggers will follow to complete geological and geotechnical core logging of continuous rock core from boreholes SB_BH01 and SB_BH02.

All work is to be completed following guidance of Geofirma's Project Quality Plan (Geofirma, 2020a) and under the project-specific Environment, Health, and Safety Plan (Geofirma, 2020b).

1.1 Purpose and Objectives

The purpose of this core logging manual is to provide a detailed description of equipment and procedures that will be used by Geofirma staff to complete geological and geotechnical core logging as part of Work Package 3 (WP03) during the drilling activities at boreholes SB_BH01 and SB_BH02. This document, along with the associated WP03 Test Plan (APM-PLAN- 01332-0336), are intended to be used for reference by Geofirma project team members performing WP03 tasks.

The primary objective of the core logging and processing program is to obtain high quality geological and geotechnical logs, core photographs and samples from continuous core through the entire Paleozoic bedrock sequence at the study site. These data will be used to:

- Provide a high-quality comprehensive database of photographic and geological log information for the entire length of core recovered from each borehole. This database will provide reliable documentation and recording of the stratigraphic and structural features of the Paleozoic bedrock sequence; and,
- Provide high quality, preserved core samples for conducting planned core testing (WP04), additional studies that will be completed outside of the main scope of work, and for archive purposes.

The core logging, photography and sampling dataset will allow for the assessment of:

- Depths and thicknesses of all stratigraphic formations, members, and units encountered;
- Fracture intensity;
- Presence and thickness of salt layers; and
- Potential for hydrocarbon resources.

Geological and geotechnical core logging, photography and sampling information will be captured in an acQuire Geoscientific Information Management (GIM) database customized for this project.

1.2 Geologic Background for South Bruce Study Area

Boreholes SB_BH01 and SB_BH02 are to be located approximately 3 to 5 km northwest of the community of Teeswater, Ontario and will be drilled to a total target depth of approximately 900 m below ground surface (m BGS). The cored interval will include the entire sedimentary bedrock sequence through to the Cambrian sandstone, or Precambrian bedrock if the Cambrian is absent. The boreholes will be drilled using PQ3 wireline coring equipment that produces a 123 mm diameter borehole and 83 mm diameter core.

The nomenclature and stratigraphy that will be used for core logging will generally follow the regional conceptual model developed by Armstrong and Carter (2006) and will be consistent with the nomenclature and stratigraphy developed during the drilling of the Bruce DGR boreholes.

The Ontario Geological Survey open file report of Armstrong and Carter (2006) was released as an updated and reformatted hard cover Special Volume publication (Armstrong & Carter, 2010). The subsurface bedrock stratigraphic nomenclature is the same in both publications, although Armstrong and Carter (2010) include a modernized stratigraphic chart that removes the Middle Silurian and re-assigns the Middle Ordovician units to an expanded Upper Ordovician. The stratigraphic chart of Armstrong and Carter (2006) is used in this manual to remain consistent with previously reported stratigraphic nomenclature associated with the Bruce DGR boreholes (DGR1-DGR8).

Figure 1 shows the predicted subsurface bedrock formation contact depths and thicknesses for SB_BH01 based on a nearby OGSRL (Ontario Gas, Salt Resources Library) borehole log (T004881) and data from the Bruce DGR boreholes.

Standard Reference		Area of South Bruce		SB_BH01 Predicted Fm. Top (mBGS)	SB_BH01 Predicted Thickness (m)	Lithology
				GS elevation = 289 mASL		
Devonian	Middle		Drift	0	15	n/a
Devonian	Middle	Detroit River Gp	Lucas Fm	15	52	dolostone
Devonian	Middle	Detroit River Gp	Amherstburg Fm	67	33	dolostone
Devonian	Lower		Bois Blanc Fm	100	26	cherty dolostone
Silurian [b]	Upper		Bass Island Fm	126	42	dolostone
Silurian [b]	Upper	Salina Fm	G Unit	168	9	argillaceous dolostone
Silurian [b]	Upper	Salina Fm	F Unit	177	45	dolomitic shale
Silurian [b]	Upper	Salina Fm	E Unit	222	28	brecciated dolostone and dolomitic shale
Silurian [b]	Upper	Salina Fm	D Unit	--	--[d]	anhydritic dolostone
Silurian [b]	Upper	Salina Fm	C Unit	250	13	dolomitic shale and shale
Silurian [b]	Upper	Salina Fm	B Unit	263	6	argillaceous dolostone
Silurian [b]	Upper	Salina Fm	B Unit-Equivalent	269	16	salt
Silurian [b]	Upper	Salina Fm	B Unit-Evaporite	285	5	anhydrite
Silurian [b]	Upper	Salina Fm	A2 Unit-Carbonate	290	22	dolostone
Silurian [b]	Upper	Salina Fm	A2 Unit-Evaporite	312	4	anhydritic dolostone
Silurian [b]	Upper	Salina Fm	A1 Unit-Carbonate	316	37	argillaceous dolostone
Silurian [b]	Upper	Salina Fm	A1 Unit-Evaporite	353	8	anhydritic dolostone
Silurian [b]	Upper	Salina Fm	A0 Unit [c]	--	--[d]	bituminous dolostone
Silurian [b]	Lower		Guelph Fm	361	5	dolostone
Silurian [b]	Lower		Goat Island Fm	366	21	dolostone
Silurian [b]	Lower		Gasport Fm	387	8	dolostone and dolomitic limestone
Silurian [b]	Lower		Lions Head Fm	395	4	dolostone and dolomitic limestone
Silurian [b]	Lower		Fossil Hill Fm	399	3	dolostone and dolomitic limestone
Silurian [b]	Lower		Cabot Head Fm	402	18	shale
Silurian [b]	Lower		Manitoulin Fm	420	9	cherty dolostone and minor shale
Ordovician [a]	Upper		Queenston Fm	429	75	red shale
Ordovician [a]	Upper		Georgian Bay Fm	504	98	grey shale
Ordovician [a]	Upper		Blue Mountain Fm	602	51	dark grey shale
Ordovician [a]	Upper	Trenton Gp	Cobourg Fm (Collingwood Mb)	653	15	black calcareous shale
Ordovician [a]	Upper	Trenton Gp	Cobourg Fm [1]	668	33	argillaceous limestone
Ordovician [a]	Upper	Trenton Gp	Sherman Fall Fm [2]	701	54	argillaceous limestone
Ordovician [a]	Upper	Trenton Gp	Kirkfield Fm [3]	755	36	argillaceous limestone
Ordovician [a]	Upper	Black River Gp	Coboconk Fm [3]	791	12	bioturbated limestone
Ordovician [a]	Upper	Black River Gp	Gull River Fm	803	63	lithographic limestone
Ordovician [a]	Upper	Black River Gp	Shadow Lake Fm	866	4	siltstone and sandstone
Cambrian			Cambrian (Unsubdivided)	--	--[d]	sandstone
Precambrian			Precambrian Basement	870		gneiss

Notes:

a - Strata traditionally referred to as Middle Ordovician (i.e., Black River and Trenton groups; Armstrong and Carter, 2006) are now considered Part of the Upper Ordovician.
b - The formal term Middle Silurian (e.g., Armstrong and Carter, 2006) has been abandoned so all strata have been re-assigned to either the Lower or Upper Silurian.
c - A0 Unit (Salina Formation) is recognized based on site characterization activities at the Bruce nuclear site (Intera, 2011).
d - Unit/Formation is not expected but may be present.

Surface Nomenclature Equivalent (approx.): 1 - Lindsay Fm; 2 - Verulam Fm; 3 - Bobcaygeon Fm

~~~~~ Unconformity

Figure 1: Generalized Approximate Stratigraphic Sequence in South Bruce Area (after Armstrong and Carter, 2010 and Geofirma Engineering Ltd., 2014)
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2 CORE LOGGING PROCEDURES

Geological and geotechnical logging of recovered core will be performed on site in the core processing trailer by Geofirma staff. Core logging will be performed after the core run photography has been completed and will generally follow the steps outlined below:

1. Marking the Core
2. Core Run Data Collection (acQuire Data Entry Object)
3. Reference Line Data Collection (acQuire Date Entry Object)
4. Structure Data Collection (acQuire Data Entry Object)
5. Lithology Data Collection (acQuire Data Entry Object)
6. Alteration Data Collection (acQuire Data Entry Object)
7. Hydrocarbon Data Collection (acQuire Data Entry Object)
8. Weathering Data Collection (acQuire Data Entry Object)
9. Rock Strength Data Collection (acQuire Data Entry Object)
10. Sedimentary Formation Contacts Data Collection (acQuire Data Entry Object)

Time-sensitive sampling and photography will occur prior to undertaking the procedures listed above, when required. Otherwise, all sampling and boxing of core will be conducted after the core logging is completed.

2.1 Depth Control and Measurements along Core Axis

All core logging and depth measurements will be recorded in metric units (metres, centimetres, millimetres). Depths will be measured to the nearest centimetre and will be recorded in meters along core axis. The depth reference will always be recorded alongside any measurements.

Drilled depth markers will be marked on the core at meter increments following procedure outlined in Section 2.3 and will be used to measure the depth of lithological contacts and structural features.

2.1.1 Drilling Rod Tally and Depth Calculations

Geofirma will complete a detailed drilling rod count prior to drilling, where each drill rod will be measured and recorded in an inventory. This will ensure that the exact number and length of drill rods in the borehole is known during drilling. The drill rod tally will be recorded in the WP02 scientific notebook and then digitized into an Excel spreadsheet.

When required, the drilled depth or depth to the bottom of the drill rod will be calculated by adding up the lengths of all drill rods and the length of the core barrel assembly (coring bit, core barrel, stabilizers, etc), and then subtracting the length of drill rod above the reference datum (e.g. drill floor or ground surface). The formula used for this calculation is provided below:

Drilled Depth = ∑ drill rod lengths (on drill string) + length of core barrel assembly - length of drill rod above depth datum.

2.2 AcQuire Data Entry Objects

All core logging data will be captured in an acQuire database customized for this project. All required fields (highlighted red in acQuire) must be entered for a given entry for acQuire to 'accept' the entry. Most of the entry fields have been pre-populated with drop-down lists of options to choose from and have been set up to include the features/parameters that are most likely to be encountered during the drilling of SB_BH01 and SB_BH02. The drop-down lists are customizable and changes may be made upon consultation between Geofirma and the NWMO. Standardization of the data entry results in consistency in the type and detail of data recorded in the field by the various core loggers.

Logging, sample, and chain of custody creation will occur online using a VPN connection to the NWMO server - acQuire database and its associated customized data entry forms. A pool of acQuire licences will allow simultaneous access for logging and QA/QC activities on multiple computers.

Consistent internet connectivity is required for the online logging into the acQuire database and will be made available onsite using a wireless router, wireless hotspot, or internet stick (USB). If connectivity is lost, core logging will be completed offline on a single laptop using a standalone acQuire data entry license. Once stable online logging is again available, synchronization (merging) will be performed between offline and online databases.

During the synchronization (merging) process, no logging can be conducted between the time of exporting the offline database and the merger of the online and offline databases. Other than unplanned connectivity issues (loss of internet, downed servers), there is one planned outage per month for NWMO (IT) server maintenance. During that 24hr period data logging will be conducted using the offline method. NWMO will notify Geofirma of these maintenance windows at least 24 hours before they occur and plan the time of least interruption to Geofirma for merging.

All applicable acQuire data collection fields for core logging, photography and sampling, and their associated pick lists, are described in detail below in the following sub-sections. Detailed instructions for each entry object, including a description of all options included in the pick lists are provided. These logging instructions will be followed by the core loggers to ensure consistency and quality among field staff.

2.3 Marking the Core

Core marking will take place after the 360-degree core photography and time-sensitive sampling (if applicable) have been completed. These markings will highlight many of the geological and geotechnical features in the core that will be subsequently logged. The Core Logger will mark the run of core following a standard set of procedures that are listed below and described in detail.

- Draw Reference Line
- Mark and Label Meterage
- Identify and Mark Mechanical Breaks
- Identify and Mark Broken Structures
- Identify and Mark Intact or Partially Intact Structures

2.3.1 Draw Reference Line

All pieces of core will be properly positioned such that all broken features fit together as if they were not broken or the core pieces were not rotated out of position. Following this procedure, parallel **Red** and **Black** lines will be drawn on the aligned core with permanent markers for a reference line. The red marker will be on the right side of the core when the core is oriented vertically with the bottom down. Permanent marker may not work on very hard, shaley, or silicified core, in which case red and black china marker (crayon) may be used instead. The reference line is included for ease of re-alignment when handling the core.

Marking of the core will occur such that the reference line is visible in the photographs of boxed core, which are taken after the core logging has been completed. The line will be carried to all subsequent runs whenever possible; if a broken core section makes continuing this line impossible, then a new line will be started at the bottom of the broken core section. The start of each unique reference line will be marked on core by drawing a “T” with a white wax pencil, where the cross of the “T” is perpendicular to the core axis and the bottom of the “T” points downwards.

2.3.2 Mark and Label Meterage

Depths will be marked on the core at even 1-meter increments (e.g. 101, 102, 103) using a yellow crayon. Meterage markers will be marked by a straight line perpendicular to the core axis and have the meterage number written immediately beside the line. The first meterage marker on each core run will be identified by measuring to an even meter from the top depth of the core run (e.g. measuring out 0.7 m from 101.3 m to mark 102 m). Each subsequent meterage marker will be measured from the previous marker using a metric measuring tape and marked. The top of each core run will be marked with a foam block that indicates the core run number (e.g. CR001) and the top depth of the core run.

2.3.3 Identify and Mark Mechanical Breaks

Non-natural, mechanical breaks may occur during the coring, retrieval, and handling process. The core logger will identify and mark mechanical breaks so that they are not included in calculations of rock quality designation (RQD) or fracture intensity.

Clean, fresh, irregular surfaces that are oriented at close to 90° to the core axis and/or that can be rejoined with only a hair-line separation are typically considered to be a mechanical break (e.g. Figure 2). Surfaces that are stained, weathered, contain infilling or coatings, occur at some angle other than near-perpendicular to the core axis, or cannot be rejoined cleanly are characteristics common to natural broken fractures. It is sometimes difficult to distinguish natural broken fractures from mechanical breaks; if in doubt, the core logger will identify the discontinuity as natural.

Mechanical breaks in the core, based on the judgement of the Core Logger, will be marked using two parallel white lines, perpendicular to and crossing the break. The core will be aligned such that lines will be visible in the boxed core photographs.

Figure 2: Example of a Mechanical Break

2.3.4 Identify and Mark Broken Structures'

Broken structures, in the context of geotechnical characterization, refer to natural non-mechanical fractures that break the core into separate pieces. Broken structures will be marked on the core using a Blue crayon or china marker (Figure 3). The Core Logger will identify and label the structure using its unique structure type code from the acQuire Structure data entry object (e.g. JN, joint). The core logger will trace both sides of the structure, using solid lines, if it has an identifiable width or aperture. Depth values will be measured, and marked, at the midpoint of the natural fracture along core axis or midpoint of the identified zone (Figure 3). The final assessment of the dip and dip direction of natural broken fractures will be completed in association with analysis of the televiewer data (collected as part of WP05), for those fractures that are apparent in both the core and the televiewer data. It is possible that some natural broken fractures may not be apparent in the televiewer data.

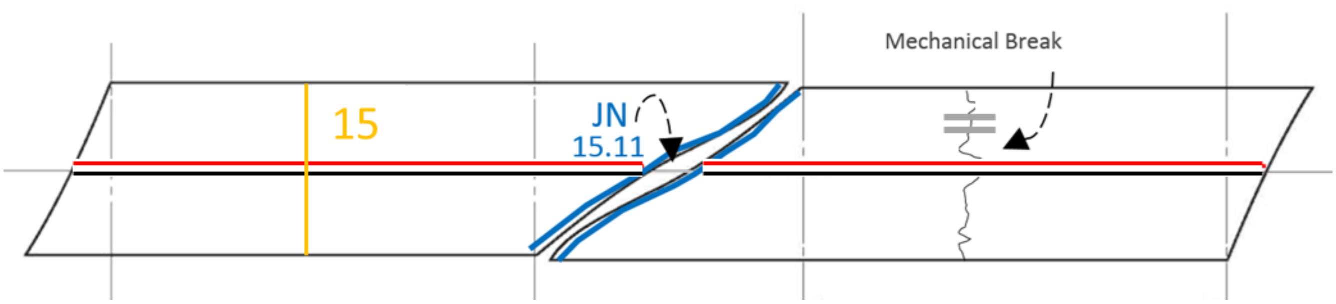


Figure 3: Example of Reference Line (red and black parallel lines) and Marking of Natural (parallel blue lines), Depth (yellow) and Mechanical Breaks (parallel white lines). Note that JN is the structure code for Joint in the acQuire database.

2.3.5 Identify and Mark Intact or Partially Intact Structures

The Core Logger will also identify intact structures in the core run. In the context of geotechnical characterization, intact refers to natural fractures that are cohesive, and these fractures may be completely intact or partially intact, and this distinction will be captured in the acQuire database. The intact and partially intact structures are marked similarly to natural fractures, except the traced lines marking both sides of the feature are dashed.

The initial interpretation that partially intact structures are grouped with intact structures implies that the broken portion of an otherwise intact fracture is the result of a mechanical process. The validity of this assumption will be ultimately determined by re-assessment of all logged partially intact structures in association with analysis of the televiewer data (collected as part of WP05) for the borehole integration report (WP10).

2.4 Core Run Data Collection

After the core is marked, the core run data will be recorded using the Core Run Entry Object within the acQuire database, including:

- Drilled From/To (Depth)
- (Core) Run Number
- Retrieval Time (of Core)
- Logged By, Photographs By
- Total Core Recovery (TCR)
- Rock Quality Designation (RQD)
- Solid Core Recovery (SCR)
- Count of Natural Fractures
- Count of Mechanical Breaks

Core run data will be recorded in its entirety as one entry regardless of lithological, alteration, weathering, or other geotechnical changes occurring throughout the run. The Core Logger will not break up the run into multiple geotechnical intervals. Figure 4 shows the screen in the acQuire database for inputting the Core Run data.

The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

Figure 4: Core Run Entry Object (acQuire)

AcQuire automatically generates values for TCR (%), RQD (%), SCR (%) and fractures/m based on core logger inputs. AcQuire also automatically generates a file name for planar and the stitched 360-degree core run photographs. The core logger, separately, will rename the stitched photograph from the CoreScan3 to be consistent with this automatically generated photograph name.

The Count of Natural Fractures should equal the number of logged natural broken fractures, unless broken core or lost core zones, deemed to be natural (i.e. not mechanical), are encountered, for which 1 fracture for every 1 cm of logged broken core or lost zone will be added. In acQuire, the number of fractures logged on the structure tab shown on the core run tab considers the additional breaks associated with the broken core or lost core zones, so that there is a direct comparison with the count of natural fractures.

2.4.1 Record Core Retrieval Timestamp

The first data to be entered into the core run data sheet in acQuire is the Date and Time that the core run was retrieved to the ground (and subsequently delivered to the core shack). This data is important as it provides a way to ensure that time-sensitive laboratory samples are collected within any exposure time limits.

2.4.2 Record Drilled From/To Depths

Depth data is entered in meters to the nearest centimeter for both the top (from) and bottom (to) of the drilled run length. It is important to always enter the drilled depth (according to the total length of the rod string in the ground and stick-up) and not necessarily the recovered depths in these input fields.

2.4.3 Record Core Run Number

The acQuire logging template will automatically generate a core run number once the top and bottom depth of the run are entered. Core runs are numbered sequentially starting from the first core run into bedrock. It is important to enter all runs in sequential order (as drilled) since the acQuire system will assign run numbers based on the entry sequence not the depth sequence.

2.4.4 Record Logged By/Photographed By

A three-letter initial code, based on a staff member's first, middle, and last name will be recorded (two letters is only acceptable if the logger has no middle name). Different initial codes may be used if a different person completes the core logging, sampling and photography, however one person should solely complete each task (i.e. two people cannot log one core run).

2.4.5 Measure and Record TCR, RQD, and SCR

Total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) will be measured and recorded as length in metres, which is compared to the length of the run drilled. TCR, SCR, and RQD will be generated automatically as a percentage of the total run length in acQuire once the core run data entry is accepted.

2.4.5.1 *Total Core Recovery (TCR)*

TCR records the total amount of core recovered over the measured length drilled for each core run.

The length of any broken core zone or gouge must be estimated as its true length in the rock mass (not as it appears spread out in the split tube) and is included in the total recovery length. When the core is highly fragmented, the length of such portions will be estimated by assembling the fragments and estimating the length of core that the fragments appear to represent.

Core losses are an important indication of potentially poor geotechnical conditions, since they most commonly occur in weak or highly fractured zones, which may be important for determining rock mass properties. Rubble or slough which has fallen into the borehole and is recovered at the top of a core lift is not counted as recovered core and will be discarded or clearly labeled to avoid subsequent misclassification.

AcQuire will calculate a TCR percentage by dividing the TCR (m) by the length of the core run.

2.4.5.2 *Rock Quality Designation (RQD)*

RQD is a quantitative index of rock quality based on the total cumulative length of sound core recovered in lengths greater than 10 cm (4 inches), as measured from midpoint to midpoint of natural Broken discontinuities (including the midpoint of the sub-parallel discontinuities), along the centre line axis of the core, as shown in Figure 5.

RQD is estimated by measuring the length of only those pieces of hard, sound core that are longer than 100 mm. Therefore, RQD value is obtained by summing the pieces of core which are 100 mm or greater in length. AcQuire will then calculate an RQD percentage as follows:

$$RQD(\%) = 100 \times \frac{\text{length of core in pieces 100 mm or longer}}{\text{length of core run}}$$

If there is a joint running along the core axis or natural break running through the entire run, the RQD of that run is 100% (where the SCR is 0%).

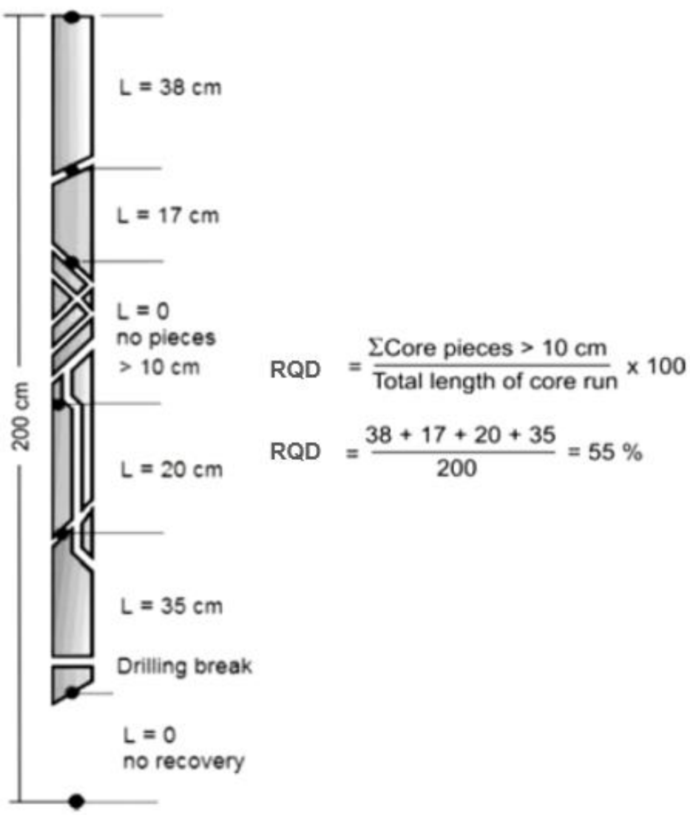


Figure 5: Example Determination of RQD (Deere, 1989)

2.4.5.3 *Solid Core Recovery (SCR)*

SCR is another measure of core quality. It involves recording the cumulative length of all core pieces, regardless of individual length, that are recovered at full axial diameter (full circumference), as shown in Figure 6. AcQuire will calculate a SCR percentage by dividing the SCR (m) by the length of the core run. If there is a vertical fracture running through the entire run, the solid core recovery is 0%.

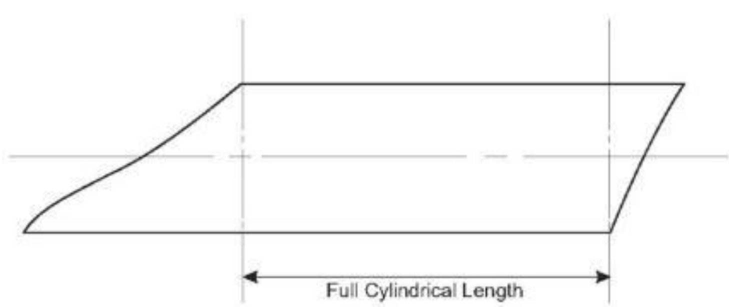


Figure 6: Determination of SCR

2.4.6 Record Fracture Count

Fracture count is simply a count of the number of naturally occurring non-cohesive (BROKEN) fractures over the length of the run, including broken core and lost core zones. This count does not include mechanical breaks, intact fractures or partially intact fractures.

For broken and lost core zones, if individual fractures cannot be seen, the maximum number of fractures that will be recorded is 1 fracture per 1 cm of broken or lost core. In some case, such as a vug or void, there may only be a single fracture present. If the core logger can piece together a broken core zone or there is some indication as to the true number of fractures that existed in the core, the true or estimated value will be recorded.

Acquire will automatically create a Fracture Spacing (fracs/m) based on the recorded Fracture Count. A QA step included in acQuire is the ability to check and confirm that the total number of broken structures logged in the Structure Tab (see below) is consistent with the count of fractures made in the Core Run tab. Once the core run tab and structure tab have been completed, the logger should check the core run tab and see if there is a discrepancy.

2.4.7 Record Mechanical Break Count

The number of mechanical breaks logged over the length of the core run will be recorded in acQuire. Note: the bottom of each core run is often a mechanical break that is caused by core extraction from the borehole. However, it is possible that the core splits near the bottom of the core run at a natural fracture. The core logger will use professional judgement and indicators (e.g. alteration, poor fit) to determine whether the bottom of each core run will be logged as natural or mechanical.

2.5 Reference Line Data Collection

The Reference Line data entry object (Figure 7) is included in acQuire to document each individual reference line. A new, unique reference line is entered into acQuire when the extracted core cannot be confidently fit together with the broken end of the core from the previous run. Each unique reference line is then automatically sequentially numbered in acQuire (e.g., RL001, RL002, etc.). If the adjacent core runs can be fit together, the same reference line is continued, with only the 'Drilled To (m)' depth updated to reflect the continuation of the same reference line. The reference line orientation field is filled in once acoustic and optical televiewer logs are available to orient the reference line relative to true north.

The reference line marked onto each core run provides a relative marker from which to measure the orientation of planar and linear structures in the core. The televiewer data collected as part of the geophysical well logging activity (WP05) will be used to orient the reference line and correct the orientation of all structures, including structures not identified in the geophysical survey, to their true orientations. This will provide a final corrected structural dataset. As part of the correction, the angle (0 – 360°) between the reference line and true north, which is a known orientation in the televiewer dataset, will be determined and captured in acQuire.

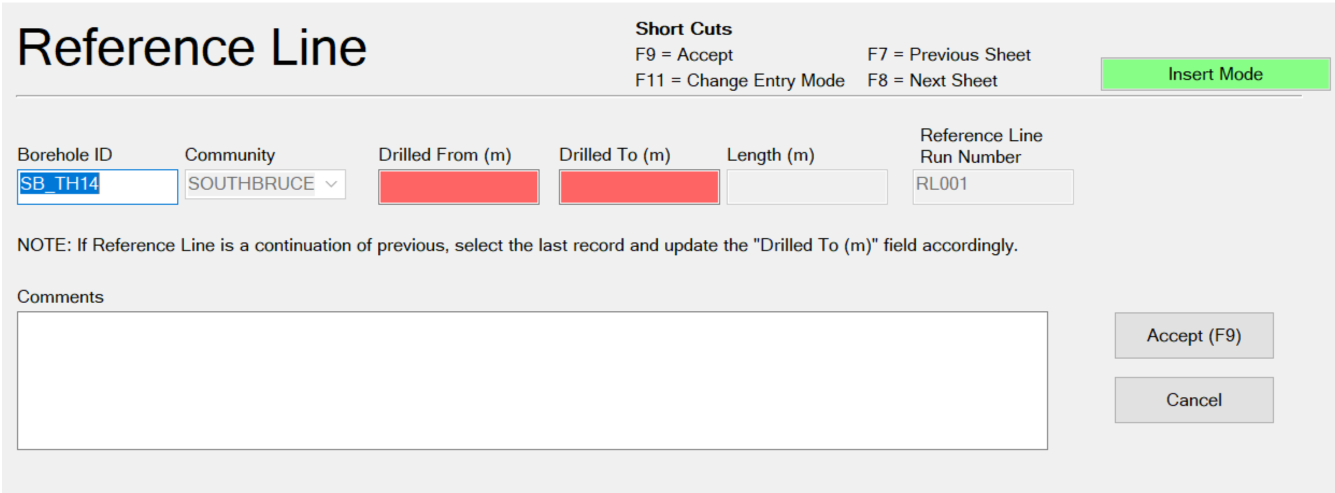


Figure 7: Reference Line Entry Object (acQuire)

2.6 Structure Data Collection

The following Structure data is recorded in the Core Run data entry object (Figure 8) within the acQuire database (where applicable):

- Structure Depth
- Type (of structure)
- Sub-Type[1,2]
- Broken/Intact/Partially Intact[1,2,3]
- Intensity
- Width
- Alpha Angle, Beta Angle
- Defining Mineral
- Geological Aperture[3]
- Shape[1,3]
- Roughness[1,3]
- Infill Character[1,2]
- Infill Type[2,]
- Infilling Thickness[2]
- Inferred Discontinuity Length[3]
- Infill Gouge[3]
- Discontinuity Weathering[3]
- Lineation (with sub-type, defining mineral, Gamma and Delta angles)[4]

[1]Inputs for Joint Roughness (Jr) Number determination
[2]Inputs for Joint Alteration (Ja) Number determination
[3]Inputs for Joint Condition Rating (JCR) Number determination
[4]Logger will enter lineation information (when applicable) as part of the characterization of each planar structure

AcQuire will automatically calculate several geotechnical parameters using information entered into a subset of the fields listed above, including inputs for determination of Joint Roughness (Jr) number, Joint Alteration (Ja) number and Joint Condition Rating (JCR) number. The relationships employed to determine these numbers are based on the Norwegian Geotechnical Institute (NGI) Q-system (NGI, 2015) and rock Mass Rating (RMR) number (Bienawski, 1989), which are current best practice classification systems for rock masses with respect to stability of underground openings. Derivation of these geotechnical parameters is discussed further towards the end of this section.

Detailed photographs of specific structures not captured in any of the other photograph products are captured directly in the Structure tab. Primarily this feature will be used to document structures that are not visible on the outer surface of the core and already captured by one of the other types of photograph. For example, lineations, karst structures or mineral infill preserved on planar surfaces. AcQuire will automatically generate photograph names for detailed structural photographs. The core logger, separately, will rename the photograph in the camera to be consistent with this automatically generated photograph name.

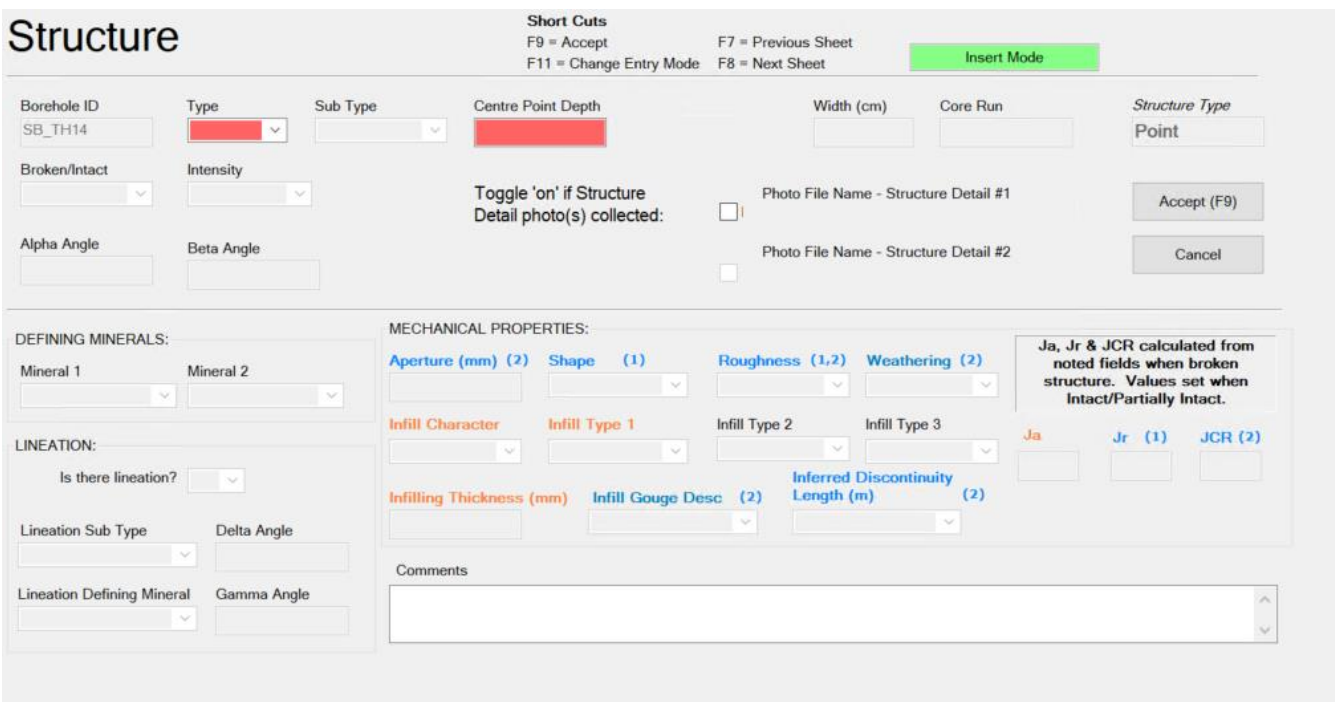


Figure 8: Structure Entry Object (acQuire)

2.6.1 Identify and Record Structure Type & Sub-Type

Structures marked on the core will be identified and classified as one of the structures listed below. It is likely that joints and foliation will be the most common structure types encountered.

- **VEIN** (VN, Broken, Intact or Partially Intact)
- **VEIN ZONE** (VNZ)
- **JOINT** (JN, Broken, Intact or Partially Intact)
- **FAULT** (FLT, Broken, Intact or Partially Intact)
- **BROKEN CORE ZONE** (BCZ, Broken)
- **INTACT FRACTURE ZONE** (IFZ, Intact or Partially Intact)
- **LOST CORE ZONE** (LCZ, Broken)
- **MECHANICAL BREAK** (MB, Broken)
- **GNEISSOSITY** (GNS)
- **BRECCIA** (BRX)
- **KARST** (KST)

These structures are defined below in Table 1 along with *Sub-Type* descriptors also noted below, where applicable. Brittle structures (e.g., joint, fault, broken core zone) and contacts are also characterized as either Broken, Intact or Partially Intact, as applicable. Structures will be entered as point data (with a midpoint) or interval data (with a from/to depth).

In addition, the table below indicates the Structural Data acQuire inputs for each Structure Type. The circumstances and procedures for measuring or assigning these different inputs are described in further detail later in this section.

Table 1: Structure Type Descriptions

Structure Type (acQuire Symbol)	Description
VEIN **(VN, Broken, Intact or Partially Intact)**	A fracture 5 cm or less in width and containing a mineral infilling that is more significant than a surface coating or stain. **No Sub-Type.** **Entered as point data.** **Note:** *1.* *Depth* is recorded at the mid-point of where the VN is identified. *2.* *Alpha and Beta* angles will be entered. *3.* If Broken, *Aperture,, Shape* and *Roughness, Discontinuity Weathering, Infill Gouge Description and Inferred Discontinuity Length,* will be entered. *4.* Mineral Infill Character and Infill Type will be entered. *5.* Mineral Infilling Thickness (in mm) will be entered.
VEIN ZONE	A zone of veining/fracturing where individual veins/fractures are not discernable. **No sub-Type.** **Entered as interval data.** **Note:** 1. *Depth* is recorded as a from/ to for the zone

	2. If possible, an *alpha and beta angle* will be entered that represents the average for the zone. 3. Mineral Infill Character and Infill Type will be entered 4. Record infill thickness (e.g. thickness of veins) in the comment section. Provide a range if several vein thicknesses are observed within the vein zone. 5. Record Intact, Partially Intact, Broken. Where multiple types are observed within the vein zone, record the most conservative type (e.g. broken), and indicate that there was a range in the comment section.
JOINT (JN, Broken, Intact or Partially Intact)	A fracture on which there is no measurable fracture displacement along the fracture plane. A group of joints having the same general orientation is termed a set. Joints sets intersect to form a joint system. AcQuire will automatically enter 0 mm for infill thickness for joints, so mineral infilling will be restricted to a surface coating or stain only. Otherwise, characterize as 'vein'. **No Sub-Type.** **Entered as point data.** **Note:** *1.* *Depth* is recorded, where structure intercepts the core-axis. *2.* *Alpha and Beta* angles will be entered. *3.* *If Broken, Aperture, Shape*, *Roughness, Discontinuity Weathering, Infill Character, Infill Type (when applicable), Infill Thickness (when applicable) and Infill Gouge Description (when applicable)* will be entered.
FAULT (FLT, Broken, Intact or Partially Intact)	A fracture or a zone of fractures that occurs as a result of brittle deformation and within which there is relative displacement parallel to the fracture surfaces. **Sub-Type:** Unknown slip; dextral (right-lateral); sinistral (left-lateral); normal; reverse. **Note:** **1.** *Depth* is recorded as from/for the zone. 2. If FLT is greater than 0.3 m wide, a Lithology Change is triggered and CO Structures are taken, in addition to a FLT Structure. 3. *Alpha and Beta* angles will be entered. 4. *If Broken, Aperture, Shape*, *Roughness, Discontinuity Weathering, Infill Character, Infill Type (when applicable), Infill Thickness (when applicable) and Infill Gouge Description (when applicable)* will be entered. 5. Record any associated lineation (when observed). Lineation types include: mineral, stretching, intersection, slickenline, fold axis
BROKEN CORE ZONE (BCZ, Broken)	Naturally-occurring feature characterized by core pieces that do not form full circumferential segments (e.g., not disks or cylinders). Broken core generally consists of angular fragments. The broken core generally has the same intact rock strength as the surrounding core. **No Sub-Type.** **Entered as interval data.** **Note:** *1.* *Depth* is recorded as a from and to for the zone. If BCZ is greater than 0.3 m, a *Lithology Change* is triggered and CO Structures are taken, in addition to a BCZ Structure. *2.* *Alpha and Beta angles* will be entered, if possible. *3.* Mineral Infill Character and Infill Type will be entered. *4.* Mineral Infilling Thickness (in mm) will be entered.

INTACT FRACTURE ZONE (IFZ, Intact or Partially Intact)	A brittle high-strain zone composed of a network of intact fractures. **Sub-Type:** None; Minor: spacing more than 100 mm; Moderate: spacing 10 to 100 mm; Heavy: spacing <10 mm **Entered as interval data** **Note:** *1.* *Depth* is recorded as a from and to for the zone. *Alpha and Beta* angles will be entered. *2.* Mineral Infill Character and Infill Type will be entered, if present. *3.* Mineral Infilling Thickness (in mm) will be entered, if present.
LOST CORE ZONE (LCZ)	Naturally-occurring feature characterized by missing blocks or zones of core, where the pieces recovered do not fit together cleanly. Lost core can occur in zones of unconsolidated material (i.e., sand seams, clay beds), highly broken zones, fault zones. Zones of 'lost core' may also occur due to natural voids in the subsurface encountered during drilling. **No Sub-Type.** **Entered as interval data** **Note:** *1.* *Depth* is recorded as from/to for the zone *2.* Identify a *Depth Confidence (Low, Moderate, High)* in the Comments based on Core Loggers ability to accurately place the location of the LCZ.
MECHANICAL BREAK (MB, Broken)	Mechanical breaks are unnatural breaks observed in the core, determined based on the judgement of the Core Logger **Sub-Type:** MB - Broken Core Zone; MB – Lost Core Zone, MB – Single Break **Entered as point data.** **Note:** 1. *Depth* is recorded, where break intercepts the center-axis. 2. *Width* is recorded for subtypes MB – Broken Core Zone and MB – Lost Core Zone.
GNEISSOSITY (GNS) Type of foliation	Foliation in coarse-grained, medium- or high-grade, metamorphic rock defined by a planar grain-shape fabric or by compositional layering/banding. Alternating dark (mafic) and light (felsic or silicic) layers (bands) are common. **No Sub-Type.** **Entered as interval data** Note: 1. *Depth* is recorded as a from and to for the zone 2. *Intensity* will be assigned. 3. Mineral(s) defining this foliation type will be entered in Defining Mineral (1/2), as applicable. 4. *Alpha and Beta angles* will be entered 5. Any associated lineation (incl. sub-type, gamma and delta angles, defining mineral) will be captured.

	6. Record any associated lineation (when observed). Lineation types include: mineral, stretching, intersection, slickenline, fold axis
Breccia (BX)	Coarse rock fragments or minerals bound together by a fine-grained matrix within a defined zone. **No Sub-type**. **Entered as interval data** Note: 1. *Depth* is recorded as a from and to for the zone 2. Record the infill mineral (i.e. Cement) 3. Record the average infill thickness (mm) in the comments 4. *Alpha and Beta angles* will be recorded if possible 5. *Width* also recorded. BRZ thickness measured perpendicular to zone.
Karst (KST)	Karst structure formed by the dissolution of soluble rocks/minerals (e.g. limestone, gypsum). Karst features may include large vugs, voids, and dissolution enhanced fractures. **No Sub-Type.** **Entered as interval data.** Note: 1. *Depth* is recorded as the midpoint of the karst zone 2. *Width,* also recorded. KST thickness measured perpendicular to the zone. 3. Record the infill material (if present)

2.6.2 Record Geological Aperture

Geological aperture is an estimated measurement of the open space between two adjacent fracture surfaces determined visually during geological core logging, as seen in Figure 9. Geological apertures are estimated values only, and are not necessarily representative of the true, in-situ aperture of the logged structure. Aperture is measured perpendicular to the structure surface. If an infilling behaves like a soil (Strength Rating, R0; See Section 2.11), the infill thickness will be included as the geological aperture.

For broken structures, core loggers will re-fit broken pieces together as best possible to visually assess average aperture for each structure. All apertures less than 1 mm but greater than 0 mm, will be logged as 1 mm.

For intact and partially intact structures, the core loggers will estimate aperture. If no aperture is evident, aperture will be logged as 0 mm.

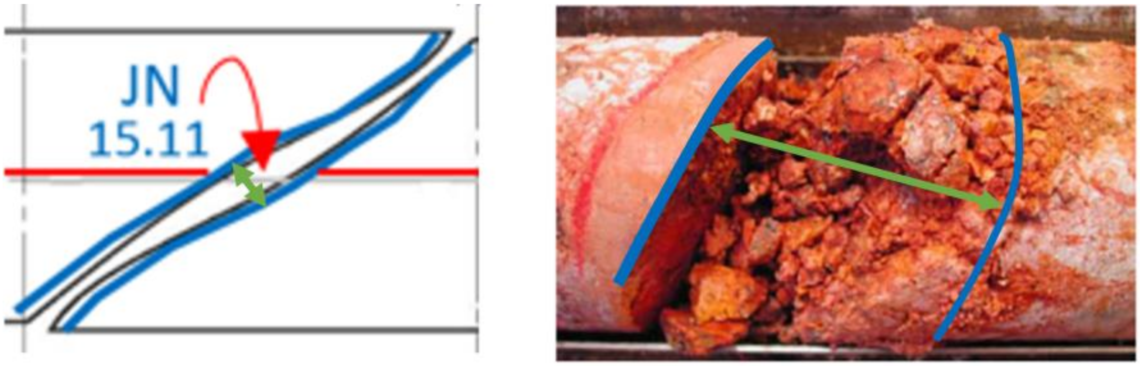


Figure 9: Examples of Geological Aperture Measurements (shown by green arrow)

2.6.3 Record Defining Mineral

Defining Mineral(s) will capture characteristic or distinctive minerals that are identified in the fabric of gneissosity. For example, the biotite may define the gneissosity. Options for defining mineral in acQuire are included below:

- Chlorite
- Calcite
- Dolomite
- Quartz
- Alkali-Feldspar
- Biotite
- Hornblende
- Muscovite
- Plagioclase
- Apatite
- Magnetite

2.6.4 Record Width

A width is recorded for applicable structures (interval type) that are not a singular discontinuity but extend over a definable zone. Widths are automatically calculated in acQuire based on the from and to depth entered for the structure. Where applicable, all structure descriptors (Shape, Roughness, Infill, Alpha, Beta, etc.) will be measured at the **TOP** margin of the zone that has a measurable width.

2.6.5 Record Discontinuity Shape and Roughness

The shape and roughness of each natural discontinuity (e.g., joint or broken contact, etc.) will be described using the abbreviations shown below in Table 2 and Table 3. Examples of combined discontinuity Shape and Roughness are provided in Figure 10.

Table 2: Discontinuity Shape

Shape Symbol	Description
PL	Planar
UN	Undulated
CU	Curved
ST	Stepped
IR	Irregular

Table 3: Discontinuity Roughness

Roughness Symbol	Description
K	Slickensided
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very rough
GO	Gouge Filled >5 mm

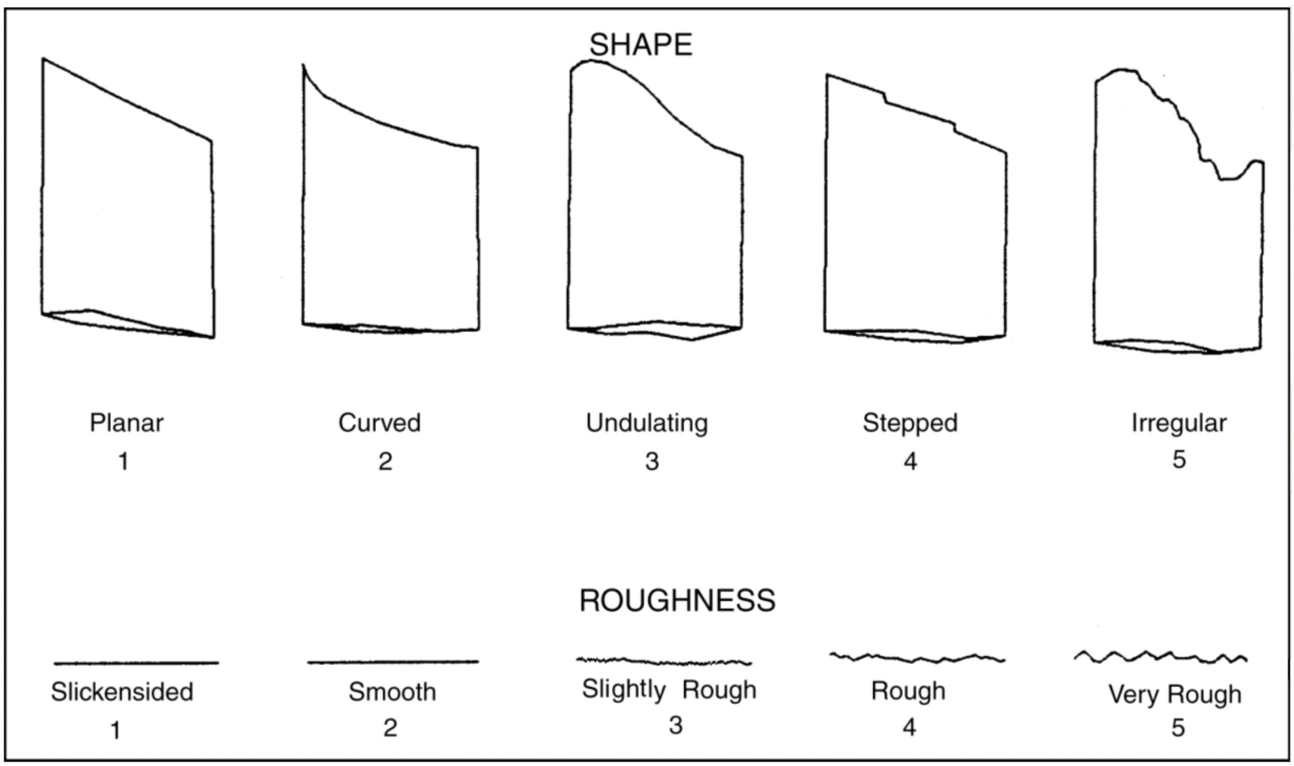


Figure 10: Examples of Discontinuity Shape and Roughness

2.6.6 Record Infill Character, Type and Thickness

Where present, the infill character, infill type, and infill thickness will be captured for Broken, Intact and Partially Intact structures. The infill character and infill type will be described using the appropriate abbreviations listed in Table 4 and Table 5. Any infilling minerals identified during logging that are not listed in Table 5 will be noted in the Comment field of the structure tab.

The infill thickness will be entered as a measurement perpendicular to the structure plane, in mm, for any infill where the Infill Character is Continuous Coating (CT) or Continuous Infill (IN).

Table 4: Infill Character

Infill Character	Symbol	Description
Clean	CL	No infill material or staining
Staining	ST	Staining only – no apparent change to frictional properties
Slightly Altered	SA	Slightly altered through chemical processes. The joint wall rock has been altered to an apparently weaker mineral assemblage.
Continuous Coating	CT	Continuous coating < 1 mm - mineral coating is thin enough that joint asperities (edges) are in contact
Continuous Infill	IN	Continuous infill > 1 mm and mineral infills joint completely. **Record value for Infill Thickness (mm)**

Table 5: Infill Type

Infill Type Symbol	Description		Typical Occurrence
Cl	Clay	SOFT	Common Alteration Mineral
Go_Sw	Clay Gouge (Swelling)	SOFT	Associated with shear or fault zones (Infill material, IN only)
Go_So	Clay Gouge (Soft)	SOFT	Associated with shear or fault zones (Infill material, IN only)
Go_St	Clay Gouge (Stiff)	SOFT	Associated with shear or fault zones (Infill material, IN only)
Br	Broken Rock	HARD	Crushed rock, often associated with shear or fault zones (Infill material, IN only)
Chl Talc	Chlorite Talc	SOFT	Commonly found in veins or broken joints
Cal	Calcite	HARD	Found in veins, joints, and vugs
Gal	Galena	SOFT	Found in veins, joints, and vugs
Sph	Sphalerite	HARD	Found in veins, joints, and vugs
Py	Pyrite	HARD	Found in veins, joints, and vugs
Qtz Afs Bt Hbl Ms Pl Ap Mag	Quartz Alkali-Feldspar Biotite Hornblende Muscovite Plagioclase Apatite Magnetite	HARD	Commonly found in veins
Bc	Breccia	HARD	Associated with shear or fault zones (Infill material, IN only)
Fe	Iron Oxide	HARD	Sometimes found on discontinuities, appears as rust as FeOx (iron oxide). Specific mineralogy (e.g., hematite) will be included in the comment field
Ep	Epidote	HARD	Commonly found in veins or broken joints

Anh	Anhydrite	HARD	Common mineral in evaporite rocks
Gpy	Gypsum	SOFT	Common mineral in evaporite rocks
UnHd	Unidentified	HARD	Infill cannot be identified, description provided in comments
UnSo	Unidentified	SOFT	Infill cannot be identified, description provided in comments

2.6.7 Record Infill Gouge

The infill (Gouge) parameter is a combination of the joint wall hardness and infill thickness (Bieniawski, 1989) that is a required input for the Joint Condition Rating (JCR) calculations. The distinction between SOFT and HARD infill is based on Moh's scale of mineral hardness, where any mineral with a Moh's hardness of 1 or 2 is considered SOFT and any mineral higher on the scale is considered HARD. Options listed in GIVE REF are available for Infill Gouge in acQuire.

Gouge Type
None
Hard Infill, <= 5mm
Hard Infill, >5 mm
Soft Infill, <= 5mm
Soft Infill, >5 mm

2.6.8 Record Discontinuity Weathering

Discontinuity weathering is the degree of alteration observed in the vicinity of a discontinuity (fault, joint, vein) and is a required input for calculation of Joint Condition Rating (Section 2.6.10). Discontent weathering includes all alteration and is not to be confused with weather recorded as part of lithological logging (Section 2.10). The degree of discontinuity weathering will be visually estimated using the ISRM (1981) standards according to Table 6.

Table 6: Discontinuity Weathering

Assigned Rating (for JCR Calculations)	Degree of Weathering	Description
6	Unweathered/fresh	No visible sign of weathering are noted; rock fresh, crystals bright.
5	Slightly weathered	Discontinuities are stained or discoloured and may contain a thin filling of altered material. Discoloration may extend into the rock from the discontinuity surface to a distance of up to 20% of the discontinuity spacing.
3	Moderately weathered	Slight discoloration extends from the continuity planes for greater than 20% of the discontinuity spacing. Discontinuities may contain infilling of altered material. Partial opening of grain boundaries may be observed
1	Highly weathered	Discoloration extends throughout the rock, and the rock material is partially friable. The original texture of the rock has mainly been preserved, but separation of the grains has occurred.
0	Completely weathered	The rock is totally discoloured and decomposed and in a friable condition. The external appearance is that of soil.

2.6.9 Record Inferred Discontinuity Length

Discontinuity length for the purposes of this core logging program is considered at is the length of a linear structure (e.g. broken joint). Discontinuity length (persistence) is typically assessed during mapping of a rock face and, except for very small fractures, cannot be observed in borehole. Since discontinuity length is a required input for calculation of Joint Condition Rating (Section 2.6.10), it must be inferred based on logged core parameters. Table 7 will be used to assign a value for the Inferred Discontinuity Length, measured in metres.

Table 7: Guideline for Recording Inferred Discontinuity Length

Assigned Rating (for JCR Calculations)	Logged/Observed Parameter(s)	Inferred Discontinuity Length
6	Intact and Partially Intact Joints	<1 m
4	Broken, fresh, thin/hairline fractures that fit together perfectly with no signs of alteration, weathering, or displacement along plane (e.g. slickenside, gouge)	1-3 m
2	Broken joints, systematic (e.g. repeated orientation), pieces are easily fitted together, no or minimal signs displacement along plane, minor alteration or weathering	3-10 m
1	Broken (open) fracture, pieces cannot easily be fitted back together easily, obvious evidence of displacement along plane (e.g. gouge), intense alteration or weathering	>10 m

2.6.10 Derived Discontinuity Properties

AcQuire will automatically calculate several geotechnical parameters using information entered in a subset of the fields described above, including inputs for determination of Joint Roughness (Jr) and Joint Alteration (Ja), and Joint Condition Rating (JCR) . Jr, Ja, and JCR will be calculated for the following structures:

- Joints
- Veins
- Faults

The relationships employed to determine these numbers are based on the Norwegian Geotechnical Institute (NGI) Q-system (Barton et al. 1974; NGI, 2015) and Rock Mass Rating (RMR) number (Bienawski, 1989), which are current best practice classification systems for rock masses with respect to stability of underground openings.

The values for Jr range between 0.5-4 and are derived as indicated in Table 8. The following logged parameters are used for the derivation of Jr:

1. Intact/Broken sub-type (broken, partially intact)
2. Shape
3. Roughness
4. Infill Character

The Ja values are derived as indicated in Table 9. The following logged parameters are used for the derivation of Ja:

1. Intact Broken sub-type (broken, partially intact)
2. Infill Character
3. Infill Type
4. Infill Thickness

In addition, according to the Bieniawski criteria, the general condition of the natural fractures or series of natural discontinuities within a recorded interval are assigned a particular Joint Condition Rating (JCR) number as indicated in Table 10. Intact (IN) and partially intact (PIN) joints and veins will automatically be assigned a JCR value of 30. The assigned JCR value, out of 30, is calculated automatically in acQuire according to the five logged parameters listed below:

1. Intact Broken sub-type (broken, partially intact)
2. Geological Aperture
3. Roughness
4. Infill Gouge (infill character, type, and thickness)
5. Inferred Discontinuity Length

Table 8: Joint Roughness, JR (after Barton et al. 1974, Hutchinson and Diederichs 1996)

Intact/Broken	Shape	Roughness	Infill Character	Jr
IN *(Intact)*	Any, incl. null	Any, incl. null	Any, incl. null	4
PIN *(Partially Intact)*	Any, incl. null	Any, incl. null	Any, incl. null	4
Broken	PL	K	CL, ST, SA, CT	0.5
	PL	SM	CL, ST, SA, CT	1
	PL	SR	CL, ST, SA, CT	1.25
	PL	RO	CL, ST, SA, CT	1.5
	PL	VR	CL, ST, SA, CT	1.75
	UN, CU,	K	CL, ST, SA, CT	1.5
	UN, CU	SM	CL, ST, SA, CT	1.75
	UN, CU	SR	CL, ST, SA, CT	2
	UN, CU	RO	CL, ST, SA, CT	2.5
	UN, CU	VR	CL, ST, SA, CT	3

Intact/Broken	Shape	Roughness	Infill Character	Jr
	ST, IR	K	CL, ST, SA, CT	2
	ST, IR	SM	CL, ST, SA, CT	2.5
	ST, IR	SR	CL, ST, SA, CT	3
	ST, IR	RO	CL, ST, SA, CT	3.5
	ST, IR	VR	CL, ST, SA, CT	4
	ANY	GO	CL, ST, SA, CT	1
	ANY	ANY	IN	1

Table 9: Joint Alteration, Ja (after Barton et al. 1974)

Intact/Broken	Infill Character	Infill Type	Infill Thickness	Ja
IN *(Intact)*	Any, incl. null	Soft & Hard Mineral	any	0.75
PIN *(Partially Intact)*	Any, incl. null	Soft & Hard Mineral	any	0.75
BR *(Broken)*	IN *(Continuous Infill)*	Clay Gouge (Swelling)	>5mm	20
		Clay Gouge (Soft)	> 5mm	13
		Clay Gouge (Stiff)	> 5mm	10
		Soft Mineral (Not Clay Gouge)	> 5mm	6
		Hard Mineral	> 1mm	3
		Clay Gouge (Swelling)	≤5mm, >1mm	12
		Clay Gouge (Soft)	≤5mm, >1mm	8
		Clay Gouge (Stiff)	≤5mm, >1mm	6
		Soft Mineral (Not Clay Gouge)	≤5mm, >1mm	4
	CT *(Continuous Coating)*	Soft Mineral	≤1mm	4
		Hard Mineral	≤1mm	3
	SA *(Slightly Altered)*	Soft Mineral	<1mm	3
		Hard Mineral	<1mm	2
	ST	ANY	<1mm	1

Intact/Broken	Infill Character	Infill Type	Infill Thickness	Ja
	CL	null	<1mm	1

Table 10: Joint Condition Rating, JCR (after Bieniawski, 1989)[1]

Geological Aperture	Roughness	Weathering	Infill Gouge	Inferred Discontinuity Length
>5mm **(0)**	Slickensided or Gouge **(0)**	Completely Weathered **(0)**	Soft Infill >5mm **(0)**	>10 m **(1)**
>1-5mm **(1)**	Smooth/Polished **(1)**	Highly Weathered **(1)**	Soft Infill <5mm **(2)**	>3-10 m **(2)**
>0.1-1mm **(4)**	Slightly Rough **(3)**	Moderately Weathered **(3)**	Hard Infill >5mm **(2)**	
<0.1mm **(5)**	Rough **(5)**	Slightly Weathered **(5)**	Hard Infill <5mm **(4)**	>1-3 m **(4)**
Null **(6)**	Very Rough **(6)**	Unweathered **(6)**	Null **(6)**	<=1 **(6)**

1. JCR is calculated by summation of assigned values for each of the five parameters. Values for each parameter are shown in brackets.

2.6.11 Record Structure Orientation (Alpha, Beta, Gamma, and Delta Angles)

Planar and linear structural orientations will be measured during the core logging. The core will not be oriented, so the measurements will be made relative to the core axis and the reference line that will be drawn on the core (Section 2.3.1). Two angles (Alpha – α and Beta – β,) are measured to describe the dip magnitude and dip direction of planar structures, with respect to the core axis and the reference line. Two angles (Gamma – γ and Delta – δ) are measured to describe the plunge and trend of linear structures, with respect to the core axis and the reference line. Alpha and Beta will be recorded for all structures in Table 1 except for Lost Core Zone and Lineation. It is understood that for intact structures the orientation of planar structures will be approximate.

The Alpha angle is measured as the acute angle of the structure, relative to the core axis. An Alpha angle of 90° indicates an orientation perpendicular to the core axis (or horizontal for a vertical borehole); a measured angle of 0° indicates an orientation parallel to the core axis. Alpha angle will be measured in single degree increments using a Protractor. The example shown in Figure 11 would be recorded as Alpha = 59°.

Figure 11: Alpha Angle Measurement

The Beta angle is the circumferential angle measured from the reference line drawn on the core to the line of "maximum dip" of the structure. The Beta angle is measured in 5-degree increments with a linear protractor around the circumference of the core. The convention for defining the Beta angle is to measure in a clockwise direction from the reference line to the point where the maximum dip vector of the discontinuity intersects the side of the core, when looking in a down hole direction. The example shown in Figure 12 would be recorded as Beta = 300°.

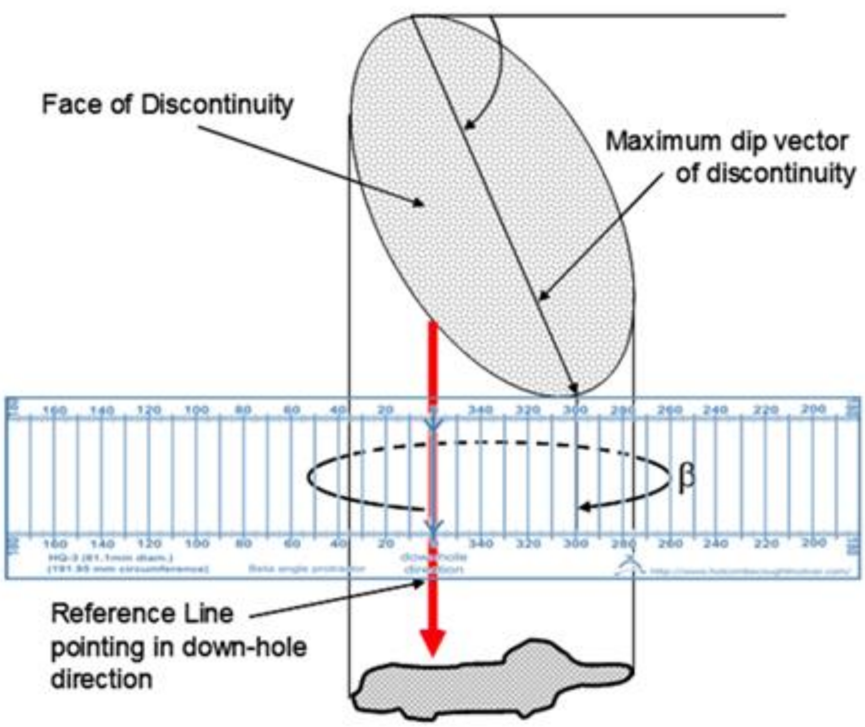


Figure 12: Beta Angle Measurement

The Gamma angle is measured as the acute angle of the lineation in the direction of its plunge, relative to the core axis. A Gamma angle of 0° indicates a lineation parallel to the core axis; a Gamma angle of 90° indicates a lineation that is perpendicular to core axis. This angle will be measured in single degree increments using a Carpenter's Protractor.

The Delta angle is another circumferential angle measured from the reference line drawn on the core to the line of trend of the lineation. The Delta angle is measured in 1-degree increments with a linear protractor. The convention for measuring Delta is to measure from the reference line in the clockwise direction to the point of the lower intersection between the lineation and the edge of the core, as indicated in Figure 13 below. The example shown in Figure 13 below would be recorded as Delta = 330°.

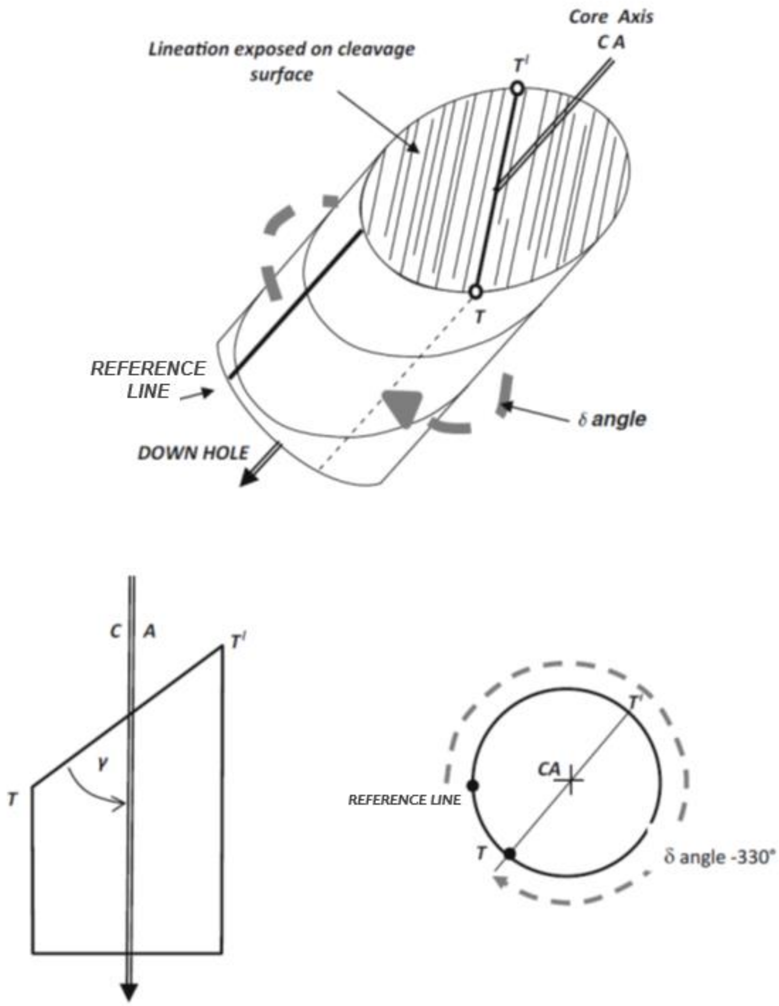


Figure 13: Gamma and Delta Angle Measurements

2.7 Lithology Data Collection

Lithology will be logged continuously, on a core-run basis, for the entire cored interval of the SB_BH01 and SB_BH02 in acQuire using the Lithology data entry object, DE-04 (Figure 14). Lithologies will be delineated primarily based on mineralogy, using additional qualifiers to capture other sedimentary features (e.g. structures, bedding thickness, grain size,). Lithology will generally be logged at a 5 cm resolution, except for marker beds which have a unique geological significance (e.g. volcanic ash bed).

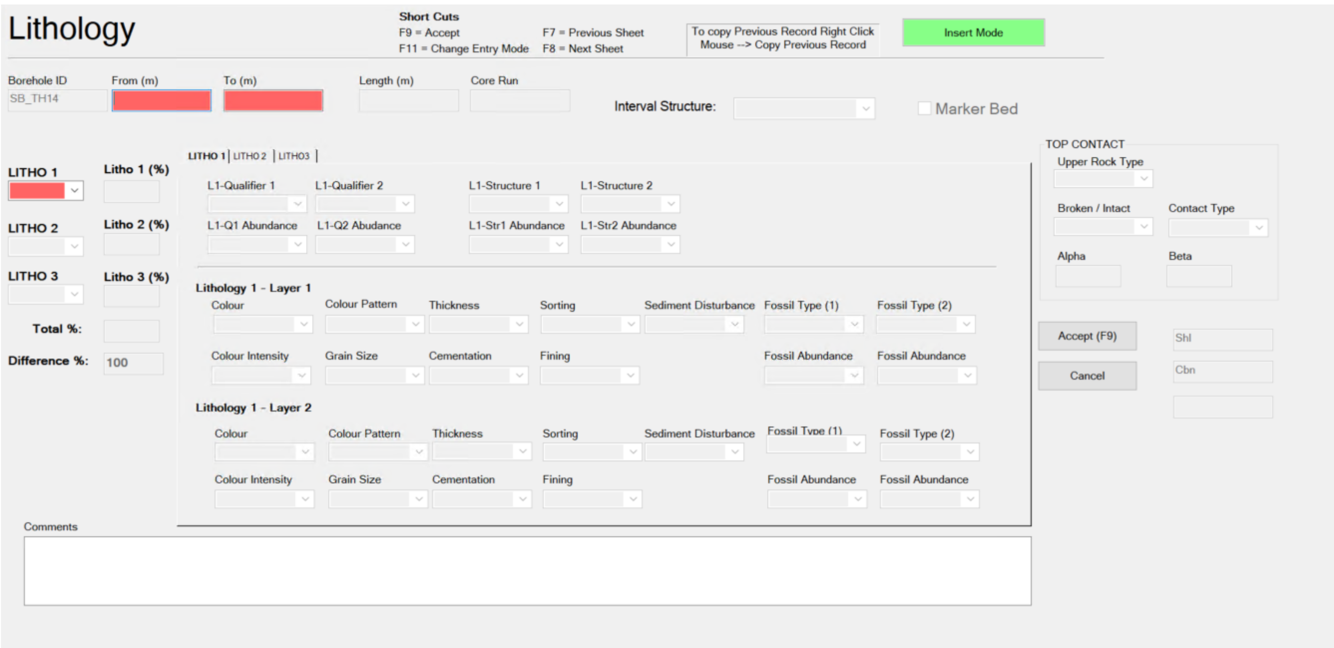


Figure 14: Lithology Data Entry Object (acQuire)

All lithological data will be recorded in the Lithology data entry object (Figure 14) within the acQuire database (where applicable):

- Record the from (m) and to (m) depths of the lithology interval
- Identify and Record Lithology Type(s) and Relative Percentages
- Record Interval Structure
- Record Presence of a Marker Bed
- Record Top Contact Information (Upper Rock Type, Broken/Intact/Partly Intact, Contact Type, Alpha, Beta)
- Record Lithology Qualifier(s) and Abundance(s)
- Record Sedimentary Structure(s) and Abundance(s)
- Record Colour, Colour Pattern, and Colour Intensity
- Record Layer Thickness(es)

- Record Grain Size(s)
- Record Cementation
- Record Sorting
- Record Fining
- Record Ichnofabric/Sediment Disturbance Index
- Record Fossil Type(s) and abundance(s)

For a given depth interval, up to three lithologies can be logged, allowing for interbedded units to be logged as a single lithological unit (Figure 15). Up to two layers can also be logged for each lithology, so that subtle textural or colour changes within the unit are recorded (e.g. alternating green and red shale beds within the Cabot Head Formation).

Lithology types, relative abundance, interval structure and top contact information are recorded at the interval level. Lithological qualifier(s) and abundances, sedimentary structure(s) and abundances, and bedding thickness(es) are recorded at the lithology level. All other lithological data are recorded at the layer level.

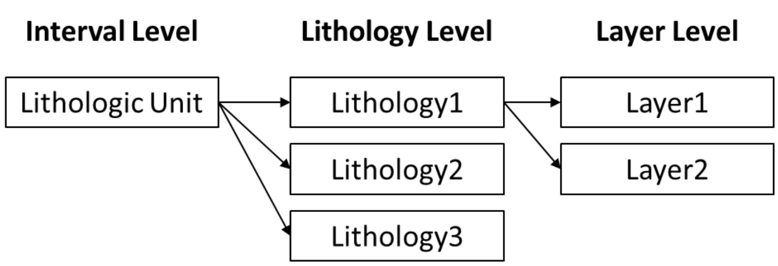


Figure 15: Hierarchy for Lithology Logging in acQuire

2.7.1 Identify and Record Lithology Type(s) and Relative Percentages

Lithology type(s) will be determined following the logging guidance outlined in Table 11 and are logged at the lithology level (Figure 15). Lithologies that will be logged include a variety of chemical sedimentary rocks, clastic sedimentary rocks, and crystalline granite or gneiss. Note: up to three lithology types can be logged for a given lithologic unit .

Chemical sedimentary rocks will be classified by their mineralogical composition, determined by visual inspection of distinguishing mineral features (e.g. hardness and crystal habit for halite). Hydrochloric acid (HCl) tests will be used to determine the composition of carbonate rocks (e.g. dolostone vs. limestone).

Clastic sedimentary rocks will be classified by grain size. Grain size will be determined by a visual comparison of core to a grain size reference card for grain sizes ranging from silt to very coarse-grained sand. Shale will be distinguished from siltstone by the presence of strong lamination and fissile behaviour.

The percentage abundance of each lithology within the interval will be manually entered in acQuire. Litho 1 will represent the most abundant lithology, Litho 2 the second most abundant lithology and Litho 3 the least abundant lithology in the interval. If only one lithology is present for a given interval, the abundance will be logged as 100%. The percentages entered for Litho 1, Litho 2 and Litho3 should always add up to 100%.

Table 11: Lithology Type Descriptions

Lithology	acQuire Symbol	Description and Logging Guidance
Dolostone	Dol	Carbonate sedimentary rock composed primarily of dolomite. Distinguished from limestone using 10% HCl acid test. Dolomite will not effervesce unless scratched into a powder. Pure dolomite may also be harder than calcite (3.5-4 Mohs Scale) Record Dunham (1962) classification in the Lithology Qualifier Tab to describe fossil/clast and micrite (carbonate) mud content.
Limestone	Lim	Carbonate sedimentary rock composed primarily of calcite. Distinguished from dolostone using 10% HCl acid test. Calcite readily effervesces when exposed to acid. Pure calcite has a hardness of 3 (Mohs scale). Record Dunham (1962) classification in the Lithology Qualifier Tab to describe fossil/clast and micrite (carbonate) mud content.
Shale	Shl	Fine-grained sedimentary rock composed primarily of clay sized grains/particles. May contain silt. Distinguished from siltstone by fissile nature and strong lamination.
Carbonates	Cbn	Generic term for carbonate sedimentary rock containing dolostone, limestone and/or other carbonate minerals. Used for logging when the mineralogical composition cannot be distinguished by HCL acid test. Record Dunham (1962) classification in the Lithology Qualifier Tab to describe fossil/clast and micrite (carbonate) mud content.
Siltstone	Slt	Fine-grained sedimentary rock composed of silt and some clay. Distinguished from shale by lower clay content and non-fissile behaviour.
Chert	Cht	Chemical sedimentary rock formed of microcrystalline quartz. Distinguished by its hardness (Mohs scale 7), conchoidal fracture pattern, and typical nodular deposition in carbonate rock.
Sandstone	Sds	Clastic sedimentary rock composed primarily of sand-sized particles. Distinguished using grain size card. When possible, the sand mineralogy/composition will be described in the lithology comments.
Conglomerate		Coarse grained clastic sedimentary rock containing coarse clasts (e.g. gravel) in a finer matrix.
Halite	Hal	Chemical sedimentary rock/mineral composed of halite (rock salt). Distinguished by its cubic crystal shape, typically transparent nature, and hardness. Commonly occurs as medium to thick beds within the Salina Formation.
Anhydrite	Anh	Chemical sedimentary rock/mineral that commonly occurs within evaporite deposits. Sulfate mineral that is the dehydrated version of gypsum. Distinguished from gypsum by hardness (3-3.5 Mohs scale) and cubic cleavage (when possible to be observed)

Lithology	acQuire Symbol	Description and Logging Guidance
Gypsum	Gyp	Chemical sedimentary rock/mineral that commonly occurs within evaporite deposits. Sulphate mineral that is the hydrated version of anhydrite. Distinguished from anhydrite by hardness (2 Mohs scale)
Granite	Grn	Medium- to coarse-grained intrusive igneous rock. Composed of quartz, feldspar and mafic minerals (biotite, amphibole, pyroxene). Granite or gneiss are expected in the Pre-Cambrian basement rock that may be drilled at the bottom of SB_BH01 and SB_BH02.
Gneiss	Gns	Crystalline metamorphic rock with gneissic banding. Variable composition based on protolith, but generally composed of quartz, feldspar, and mafic minerals (biotite, amphibole, pyroxene). Granite or gneiss are expected in the Pre-Cambrian basement rock that may be drilled at the bottom of SB_BH01 and SB_BH02.
Schist	Sch	Crystalline metamorphic rock showing schistosity. Variable composition based on protolith, but generally composed platy minerals (e.g. biotite, muscovite, talc, chlorite) and other minerals (feldspar, quartz, amphibole, pyroxene). May be observed in the Pre-Cambrian basement rock that may be drilled at the bottom of SB_BH01 and SB_BH02.
Migmatite	Mgt	Crystalline metamorphic rock showing evidence of partial melting and recrystallization. Migmatities typically consist of melanosome (darker mafic-rich) and leucosome (lighter quartz/feldspar rich) layering. May be observed in the Pre-Cambrian basement rock that may be drilled at the bottom of SB_BH01 and SB_BH02.
Pegmatite	Pgt	Very coarse grained, intrusive, igneous rock. Typical composition includes very coarse grained, feldspar, quartz, and biotite. May be observed in the Pre-Cambrian basement rock that may be drilled at the bottom of SB_BH01 and SB_BH02.
Volcanic Ash	Ash	Clay layer interpreted to be formed from accumulation of ash sourced from a volcanic eruption. An ash marker bed is commonly found in the Coboconck Formation.
No Core Recovered	NCR	Recorded for core intervals with significant core loss (>1m), or when intervals of lost core (<1m) cannot be confidently inferred by the core logger based on the overlying/underlying recovered core.

2.7.2 Record Interval Structure

Sedimentary structures will be used to describe textural features that reflect depositional conditions or post-depositional alteration of the sedimentary rock. Sedimentary structures logged at the interval scale will be common for all lithologies present within the interval (Figure 15). Sedimentary structures can also be logged at the lithology level (Section 2.7.6)

A list of sedimentary structures is provided in Table 12. If a sedimentary structure is observed in core that is not included in the pick-list, the core logger will record it in the comments box. Sedimentary structure abundance will be recorded for logged sedimentary structures, when applicable (e.g. moderately vuggy).

Table 12: Sedimentary Structures with Descriptions

Sedimentary Structure	Symbol	Description
Interbedded	Itb	Alternating beds of a different lithology type.
Pitted	Pit	mm to cm-scale holes caused by the erosion or loss of a material during or after deposition.
Vuggy	Vug	Cavities, voids, or large pores formed by dissolution of rock matrix. May contain secondary mineral infill/precipitates.
Fissile	Fis	Rock that tends to split along flat planes of weakness. Commonly occurs in laminated shales.
Cross-Laminated/ Bedded	Clm	Inclined stratification that occurs at an angle to the primary bedding orientation. Commonly observed in sediments deposited in high-energy depositional environments.
Hummocky	Hum	Cross-cutting “smile-shaped” stratification deposited during storm events in a subaqueous depositional environment. Commonly observed in shallow marine sandstones.
Planar Laminated	Pld	Planar laminations formed by subtle contrasts in grain size. Planar laminations can occur in shales, siltstones, or sandstones deposited in high-energy depositional environments.
Wavy Laminated	Wlm	Wavy laminations formed by subtle contrasts in grain size.
Porous	Por	Rock contains notable macroporosity. Porosity type (e.g. moldic, intragrain) may be described in the comments box.
Mud Drapes	Mdr	A layer of mud (silt or clay) deposited on top of pre-existing sedimentary structure. Common in depositional environments with fluctuating energy (e.g. tidal flats).
Mud Cracks	Mck	Vertical fractures formed by shrinking of mud when it is dried out. Typically occurs in fine-grained sedimentary rock that has been subject to sub-aerial exposure.
Clasticx	Cla	Contains fragments of rock resting within a finer matrix material. When “Clast” is selected, describe the composition of the clasts and matrix in the comments box.
Slump Structures	Slp	Soft-sediment deformation features formed by displacement of sedimentary bedding prior to consolidation and lithification.
Karst	Kst	Karst structure formed by the dissolution of soluble rocks/minerals (e.g. limestone, gypsum). Karst features may include large vugs, voids, and dissolution enhanced fractures
Brecciated	Brc	Coarse angular rock fragments within a finer matrix material.

2.7.3 Record Presence of Marker Beds

Certain lithology occurrences are classified as marker beds as they are indicative of the formation in which they appear. Due to the significance of these marker beds, it is important to identify them in the lithological sequence. By default, the marker bed check box is left unchecked in the data entry object. Upon intersection of a marker bed, the logger is required to check the box, indicating the presence of a marker bed. Marker beds should be captured as a stand-alone lithology. Based on nearby drilling at the Bruce DGR, marker beds that may be encountered in SB_BH01 are listed below. Photographs of these marker beds in core can be found in the Technical Report – Bedrock Formations in DGR-1 to DGR-6 (Geofirma, 2011)

- Brown dolostone bed within grey shale of the Salina F Unit
- Limestone bed within shale in the Queenston Formation
- Fossiliferous limestone within shale of the Georgian Bay Formation
- Volcanic ash bed in limestone of the Coboconk Formation
- Tan dolostone bed in grey limestone of the Coboconk Formation

2.7.4 Record Top Contact Information

Contact information will be captured for the upper contact of each lithological unit. In the case where a new interval is entered due to a change in core run and there has been no change in lithology, the contact type will be entered as NA/End of Core Run. Where there is a change in lithology and a new interval is entered, the following information will be captured:

- Upper Rock Type (for cases where there is an interbedded unit above, select the bottom-most lithology present that is directly adjacent to the contact)
- Broken/Intact/Partly Intact – Indicate whether the contact between the lithological intervals is broken, intact or partially intact
- Alpha and Beta – Record the Alpha and Beta angles (only for Sharp and Intrusive contacts)
- Contact Type – Use the table below to select the contact type

Table 13: Contact Types

Type	Description
Not Observed (NO)	The contact cannot be observed due to broken core.
Gradational	The transition from one lithological interval to another is gradational and an exact depth at which the transition occurs is not discernable. The logger should use their discretion to pick a midpoint of the change in lithological interval.
Sharp	The transition from one lithological interval to another is almost immediate. A discernable depth can be given as representing a definitive change.
Intrusive	Used in the case where there is an intrusive body cutting into the stratigraphic sequence.

2.7.5 Record Lithology Qualifier(s) and Abundance

Lithology qualifiers will be used to provide additional information about the composition of logged lithologies and are logged at the lithology level (Figure 15). A total of two lithology qualifiers can be selected for each lithology. If more than two qualifiers are identified, the logger will record the less abundant qualifier(s) in the comments field.

Six lithological qualifiers are from the Dunham's (1962) carbonate classification scheme and are used to describe the relative abundance of carbonate mud (micrite) and carbonate clasts (e.g. fossils). The

Dunham (1962) qualifiers will be recorded for limestone, dolostone, and carbonate lithologies using Figure 16 as a visual reference.

A list of lithology qualifiers is provided in Table 14. If a composition is observed in core that is not included in the lithology or qualifier tab, the core logger will record it in the comments box for the lithology.

Table 14: Lithology Qualifiers with Descriptions

Lithology Qualifier	Symbol	Description
Argillaceous	Arg	Contains clay and silt. Commonly used for carbonate rocks with notable amounts of fine-grained material (e.g. argillaceous dolostone)
Bituminous	Btm	Contains bitumen, highly viscous oil substance
Calcareous	Cal	Contains calcite as a secondary mineral. Commonly used for siltstones and shales with notable amounts of calcite (e.g. calcareous shale)
Fossiliferous	Fos	Contains fossils. Note: when fossiliferous is selected as qualifier, specific fossil types should be selected using the fossil type(s) tab.
Dolomitic	Dol	Contains dolomite as a secondary mineral. Commonly used for siltstones and shales with notable amounts of dolomite (e.g. calcareous shale)
Nodular	Nod	Contains rounded objects that have a distinct lithology from the rest of the rock matrix (e.g. chert nodules in dolostone)
Anhydritic	Anh	Contains anhydrite as a secondary mineral.
Cherty	Chy	Contains chert as a secondary mineral. Chert is commonly found in carbonate rocks as cm-scale to dm-scale nodules.
Surcrosic	Suc	Rock with coarse “sugary” texture. Commonly used to describe limestone and dolostone.
Quartzose	Qtz	Contains notable amounts of quartz. Commonly used as an additional descriptor for quartz-rich sandstones (e.g. quartzose sandstone).
Feldspathic	Fel	Contains notable amounts of feldspars. Commonly used as an additional descriptor for feldspar-rich sandstones (e.g. feldspathic sandstone).
Organic-rich	Org	Contains notable amount of organic material. Organic rich rocks typically have a uniform dark colour and weak proliferous odour.
Glauconitic	Glc	Contains glauconite as a secondary mineral. Glauconite is a dark teal-green mineral that is commonly found in marine sandstones (e.g. glauconitic sandstone).
Oolitic	Ool	Contains oolites. Oolites are mm-scale spherical grains composed of concentric carbonate layers. Oolites are typically found in shallow marine carbonate (e.g. oolitic limestone).
Lithoclastic	Lit	Contains irregular carbonate fragments formed by the erosion and transport of previously lithified carbonate rock.
Stylolitic	Sty	Contains stylolites. Stylolites are dark grey or brown serrated surfaces that are composed of insoluble minerals and organic matter.
Dunham (1962) Carbonate Classifications (Figure 16 provided for reference) for Dol, Lim, Cbn Lithologies		
Mudstone	Mst	Carbonate mud supported, <10% carbonate clasts/grains
Wackestone	Wks	Carbonate mud supported, >10% carbonate clasts/grains

Lithology Qualifier	Symbol	Description
Packstone	Pks	Grain supported, contains carbonate mud
Grainstone	Gst	Grain supported, <10% carbonate mud
Boundstone	Bst	Original components bound during deposition
Crystalline	Cry	Depositional texture not recognizable

Table 15: Lithology Qualifier Abundance

Abundance	Description
Trace	<10% of core volume
Moderate	10-35%of core volume
Abundant	>35% of core volume

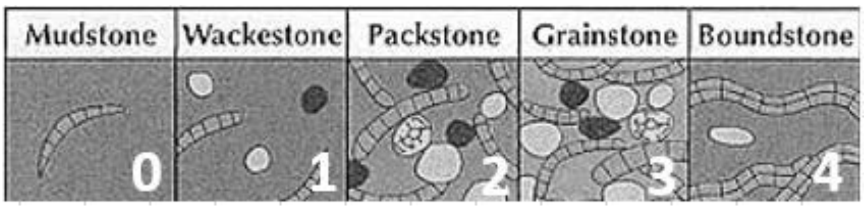


Figure 16: Examples of Dunham (1962) Classification Scheme

2.7.6 Record Lithology Sedimentary Structure(s) and Structure Abundance

Like interval structure, sedimentary structures may be logged for all lithology types lithology level in acQuire (Figure 15). Sedimentary structures logged at the interval level will not be logged at the lithology level.

A list of sedimentary structures is provided in Table 12. If a sedimentary structure is observed in core that is not included in the pick-list, the core logger will record it in the comments box. Sedimentary structure abundance will be recorded for logged sedimentary structures, when applicable (e.g. moderately vuggy).

2.7.7 Record Colour, Colour Pattern, and Colour Intensity

A representative colour will be recorded for each lithology type logged in acQuire and will be recorded at a layer level. Secondary colours for a given lithology type can be logged under Layer2 (e.g. red and green layers for shale in the Cabot Head Formation). For each colour identified, a colouring pattern and colour intensity will also be recorded in acQuire. The symbols and associated descriptions for recording colour are provided in Table 16, Table 17, and Table 18.

Table 16: acQuire Colours

acQuire Code	Description
Br	Brown
Gr	Grey
Bk	Black
Bl	Blue
Rd	Red
Ma	Maroon

Tn	Tan
Gn	Green
Wt	White
Cl	Clear
Pk	Pink
Bg	Blue-grey

Table 17: acQuire Colour Pattern

acQuire Code	Description
Banded	Approximately parallel bands of varying colour
Streaked	Randomly orientated streaks of colour
Blotched	Large irregular patches of colour (>75mm diameter)
Mottled	Irregular patches of colour (10-75mm diameter)
Speckled	Very small patches of colour (<10mm diameter)
Stained	Large colour variations associated with other features (i.e. bedding, joints etc.)
Uniform	Uniform colour throughout
With-bedding	Approximately parallel bands of various colour associated with bedding

Table 18: acQuire Colour Intensity

acQuire Code	Description
VLt	Very light
Lgt	Light
Med	Medium
Drk	Dark
VDk	Very dark

2.7.8 Record Layer Thickness

Like bedding thickness, the average thickness for each layer identified for each lithology will be captured. The thickness of layers should be measured using a measuring tape and an approximate average should be determined. Where only one layer is present for a lithology, the specified layer thickness will equal the lithology's thickness. A list of thicknesses is present in Table 19.

Table 19: Lithological/Layer Thicknesses

Bedding Thickness	Thickness
Laminated	<10 mm
Thin	10-100 mm
Medium	100-300 mm
Thick	300 mm -3 m
Massive	>3 m or uniform

2.7.9 Record Grain Size

Grain size will be determined using reference card and recorded for all clastic lithology types (sandstone, siltstone, shale) at a layer level in acQuire. Grain size will be classified according to a modified version of the Wentworth (1922) classification scheme shown in Table 20. An example of a grain size reference card is provided in Figure 17.

Table 20: Simplified Grain Size Chart (modified after Wentworth, 1922)

Grain Size		Diameter (mm)
Clay		<0.004
Silt		0.004-0.063
Sand	Very Fine-Grained	0.063-0.125
	Fine-Grained	0.125-0.25
	Medium-Grained	0.25-0.5
	Coarse-Grained	0.5-1.0
	Very Coarse-Grained	1.0-2.0
Gravel/Pebbles		> 2.0

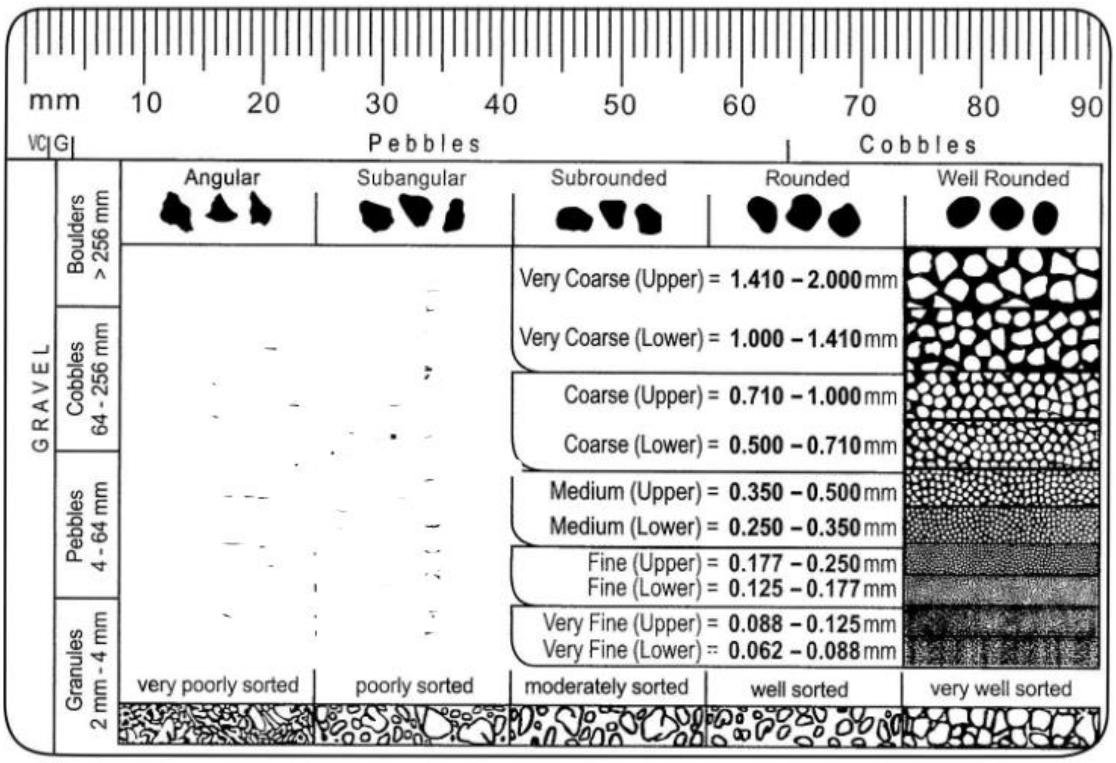


Figure 17: Example of Grain Size Reference Card (not to scale)

2.7.10 Record Cementation

Cementation will be recorded for all lithology types at the layer level in acQuire. Cementation will be described qualitatively based on the criteria outlined in Table 21.

Table 21: Cementation Types and Descriptions

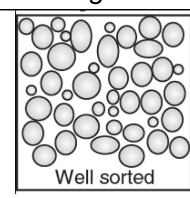
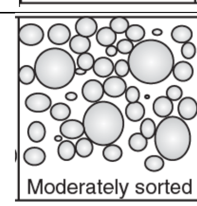
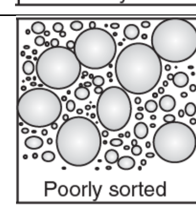
acQuire code	Cementation Level	Description
Unc	Unconsolidated/Not Cemented	No cement present or unconsolidated sediments

PrC	Poorly Cemented	Easily disaggregated, abundant visible porosity
MdC	Moderately Cemented	Not easily disaggregated, visible porosity
WlC	Well Cemented	No loose grains, some visible porosity
VWC	Very Well Cemented	No visible porosity, very hard

2.7.11 Record Sorting

Sorting describes the distribution of grain size in sediments and sedimentary rock and will be identified using a reference card or table (e.g. sorting images in Figure 17). Sorting will be picked from a list of four options (Table 22) and logged at a layer level in acQuire. Sorting will always be recorded for clastic lithology types, and will be recorded for carbonate lithology types, when applicable.

Table 22: Sorting Types and Descriptions

acQuire code	Sorting Type	Description/Example
NS	Not Sorted	No sorting observed.
PS	Well Sorted	
MS	Moderately Sorted	
WS	Poorly Sorted	

2.7.12 Record Fining

Fining will be recorded to describe vertical changes in grain size with depth. Fining will only be logged when it is observed. Three options will be available:

- None: Not sorted
- Fining Upward: grain size increases with depth along core axis
- Fining Downward: grain size decreases with depth along core axis

2.7.13 Record Ichnofabric/Sediment Disturbance Index

Sediment disturbance will be logged in acQuire according to a modified sediment disturbance index (SDI), that was originally presented as an Ichnofabric index by Droser and Bottjer (1986). SDI is used to record the level of disturbance to primary bedding structures and can be used to interpret depositional environments. SDI will be logged in acQuire at the layer level using reference images shown in Figure 18. The numbers in the image correspond to:

Table 23: Sediment Disturbance Index descriptions, SDI (after Droser & Bottjer, 1986)

SDI	acQuire code	Description
1	ND	Not Disturbed
2	DD	Discretely Disturbed (0-10%)
3	MD	Moderately Disturbed (10-40%)
4	WD	Well Disturbed (40-60%)
5	VWD	Very Well Disturbed (>60%)

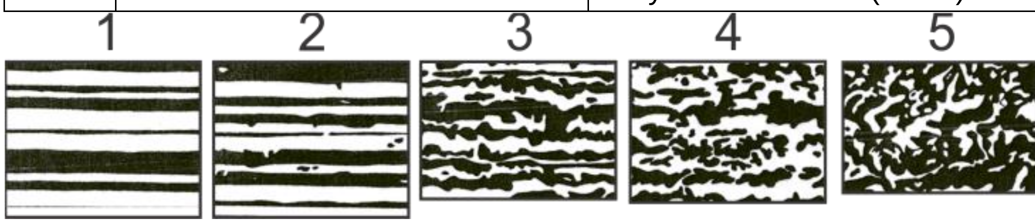


Figure 18: Sediment Disturbance Index chart, SDI (after Droser & Bottjer, 1986)

2.7.14 Record Fossil Type(s) and Abundance

A variety of fossil types are commonly found within the Paleozoic strata of Southwestern Ontario. When present, fossil types will be logged at the layer level in acQuire. Up to two primary fossil types can be logged per layer in acQuire. If more fossil types are observed, or if a fossil type not included in the picklist is observed, these additional fossils will recorded in the comments box.

Table 24 provides a summary of the fossil types that are available in acQuire. Figure 19 provides a visual comparison of bivalve and brachiopod symmetries that can be used to distinguish between these two fossil types when they are observed in core. Photographs of all fossil types, including examples from rock core, are provided for reference in Appendix 1. Abundance of the fossils within the lithology layer should also be identified. It should follow the classification classes in Table 15.

Table 24: Fossil Types and Descriptions

acQuire Code	Fossil Type	Description
Cri	Crinoid	Rock contains crinoids “ancient sea-lilies”. Crinoids appear as mm to cm-scale cheerio-shaped fossils (in cross-section), or as series of stacked cheerios (along stem).
Bra	Brachiopod	Rock contains brachiopod shells or brachiopod shell fragments. Shells rarely appear as intact pieces. More commonly, shells will be broken and appear as mm-thick concave fragments that retain some of the shell’s original surface texture. Brachiopods shells are symmetrical perpendicular to their hinge (Figure 19).

acQuire Code	Fossil Type	Description
Cor	Coral	Rock contains coral. Coral may occur as intact coral structures or as coral fragments. Both coral and bryozoans appear in core as mm-scale geometrical patterns with a sponge-like texture. Coral may be distinguished from bryozoans based on the size of the openings within the structure (coral = mm-scale, bryozoan < mm or pinhole scale)
Bry	Bryozoan	Rock contains bryozoans. Bryozoans may occur as intact structures or as fragments. Both coral and bryozoans appear in core as mm-scale geometrical patterns with a sponge-like texture. Bryozoans may be distinguished from coral based on the size of the openings within the structure (coral = mm-scale, bryozoan < mm or pinhole scale)
Biv	Bivalve	Rock contains bivalve shells or shell fragments. Fossils rarely appear as intact pieces. More commonly, shells will be broken and appear as mm-thick concave fragments that retain some of the shell's original surface texture. Bivalve shells are symmetrical about their hinge (Figure 19).
Tri	Trilobite	Contains trilobite fossils. Trilobites occur as mm to cm-scale shell-ike fossils with three sections: a Cephalon (Head), Thorax (Middle), and Pygydium (Tail). Trilobites can occur as grey, brown or black in core.
Gas	Gastropod	Rock contains gastropod fossils. Gastropods have a variety of shell shapes and textures in core. Gastropods commonly occur as spiral shaped shells (e.g. snail shell). Shell-type fossils not classified as a bivalve or brachiopod will be logged as gastropod.
Str	Stromatolite	Rock has a stromatolite texture. Stromatolites appear as thin alternating light/dark beds of carbonate fragments bound by carbonate mud. Stromatolites may contain fragments of shells or other carbonate fossils.
Oth	Other/Unidentified	This is used as a generic term to record fossil types that cannot be identified or are not included in the acQuire pick list. When other/unidentified fossils are selected, a brief description of the fossil should be included in the comments box.

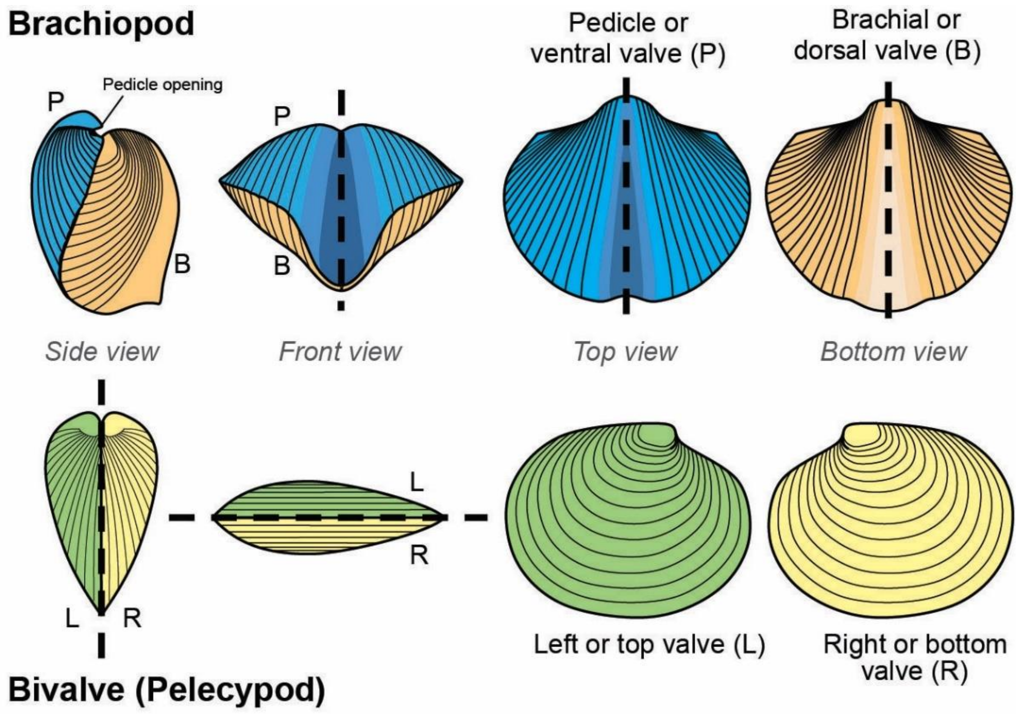


Figure 19: Comparison of Bivalve and Brachiopod Symmetries

2.8 Alteration Data Collection

Characteristics associated with the alteration of the rock mass will be logged in acQuire using the Alteration data entry sheet shown in Figure 20. Alteration refers to any change in the mineralogical composition of a rock brought about by the action of geochemical processes (e.g. silicification). Alteration is distinct from weathering (Section 2.10), which is a destructive process by which rock, on exposure to atmospheric processes at or near the Earth's surface, is changed in colour, texture, composition or form.

Alteration will be continuously recorded for the entire cored interval. Alteration characteristics will also be assigned by the core logger to all structural features entered into the Structure data entry object (see Section 2.6) that exhibit evidence of alteration.

Karstification and dolomitization are considered alteration types but will be captured in other data entry objects in acQuire (Karstification in Structure and Dolomitization in Lithology). To avoid redundancy, these two alteration types will not be captured under the alteration data entry object. However, they will be included as an alteration type in the WP03 report.

Alteration characterization includes two steps, including:

- Record Alteration Index
- Record Alteration Type

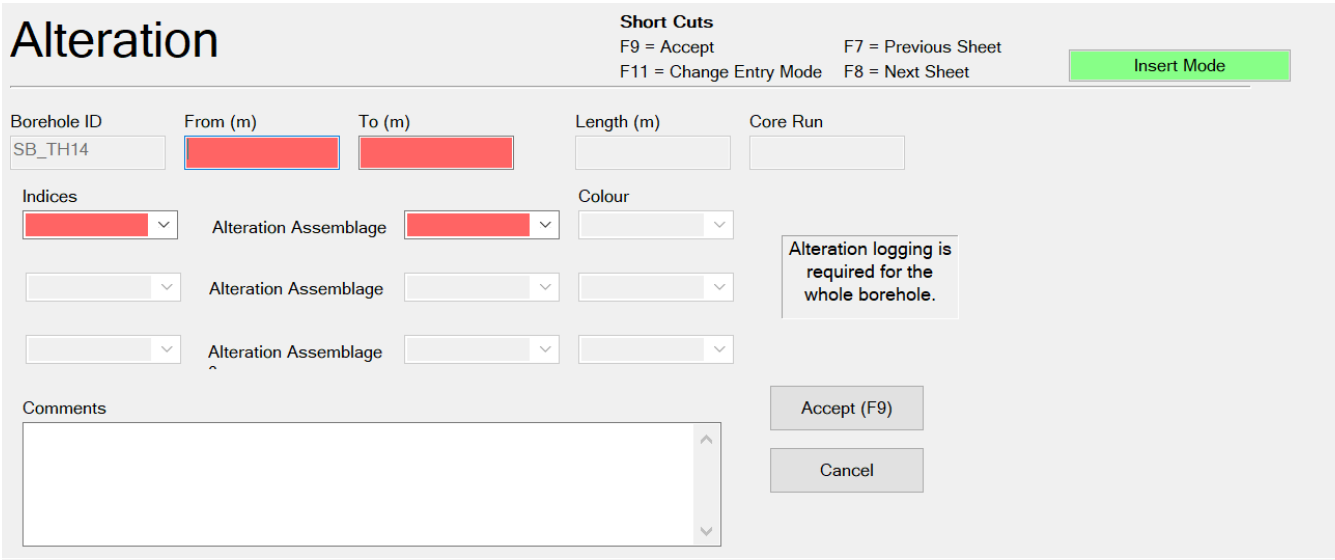


Figure 20: Alteration Entry Object (acQuire)

2.8.1 Record Alteration Index

The alteration state, or degree of alteration, is recorded using one of the alteration index descriptions shown in Table 25. These descriptions are indicative of how the mechanical properties of the rock mass are affected by the physical and chemical changes to the rock-forming minerals, and are also based on the presence (or lack thereof) of secondary mineralization in structures such as fractures or shear zones. The comments field will be used to describe the colour of the alteration, if not adequately captured in another field.

Table 25: Alteration Index (after ISRM, 1981)

Term	Symbol	Description
Unaltered	A1	Fresh rock; or rock without any alteration assemblage that significantly alters the parent rock.
Slightly altered	A2	Generally alteration is confined to veins and/or veinlets; little or no penetration of alteration beyond vein/veinlet boundaries; no discernible effect on the strength properties of the parent rock type
Moderately altered	A3	Alteration is controlled by veins and may penetrate wallrock as narrow vein selvages or envelopes; alteration may be pervasive; alteration results in slightly lower rock strength, but rock may still be hard and brittle.
Highly altered	A4	Pervasive alteration of rock forming minerals and rock mass to assemblages that significantly decrease the strength properties of the parent rock type such as sericite, chlorite, ankerite, graphite, kaolinite, talc, gypsum, or anhydrite; obvious degradation of rock strength; some individual veinlet control is still visible; fracture surfaces and vein selvages, where noted, may be friable.
Completely altered	A5	Intense, pervasive, complete alteration of rock forming minerals to weaker mineral assemblages such as sericite, chlorite, ankerite, graphite, kaolinite, talc, gypsum, or anhydrite; rock mass may be friable, or ‘rotten’; rock mass may resemble soil as in the case of fault gouge; inter-crystalline bonds are destroyed; no perceptible

Term	Symbol	Description
		individual veinlet control; any alteration assemblage that results in the nearly complete, or complete, degradation of rock strength relative to the parent rock type.

2.8.2 Record Alteration Type

The alteration that has been identified will be characterized based on the mineral assemblage that defines it. Table 26 below provides the list of mineral assemblages and their descriptions that will be used for this characterization.

Table 26: Alteration Types and Descriptions

Alteration Type	Description
Argillization	Formation of clay minerals, including kaolinite and the smectite group (mainly montmorillonite). Mainly affects plagioclase feldspar.
Carbonatization	Formation of carbonate minerals (calcite, dolomite, magnesite, siderite, etc.) during alteration of a rock.
Hematization	Associated with oxidizing fluids and the formation of minerals with a high Fe^{3+}/Fe^{2+} ratio (e.g., Hematite), with associated K-feldspar, sericite, chlorite, and epidote.
Potassic	Formation of new K-feldspar and/or biotite, usually together with minor muscovite (sericite), chlorite, and quartz.
Silicification	Formation of new quartz or amorphous silica minerals in a rock during alteration of a rock.
Bleaching	Not characterized by any specific mineral assemblage, but rather recognized by a color change between altered and unaltered rock.
Saussuritization	Alteration of calcium-bearing plagioclase to saussurite minerals (zoisite, chlorite, amphibole and carbonates)
Other	If an alteration assemblage is encountered that is not listed. Capture the alteration assemblage in the comments field

2.9 Hydrocarbon Data Collection

Hydrocarbon data will only be logged when present. For the South Bruce boreholes, hydrocarbon showings are not expected above the top of the Salina Formation.

When present, the type(s) of hydrocarbon showing will be recorded using the Hydrocarbon entry object in acQuire (Figure 21). Up to two different Hydrocarbon types may be identified. If more are identified, they should be recorded in the comments field. Four steps will be completed to record hydrocarbons as part of the core logging:

- Hydrocarbon Type and Intensity
- Record UV Visible Oil

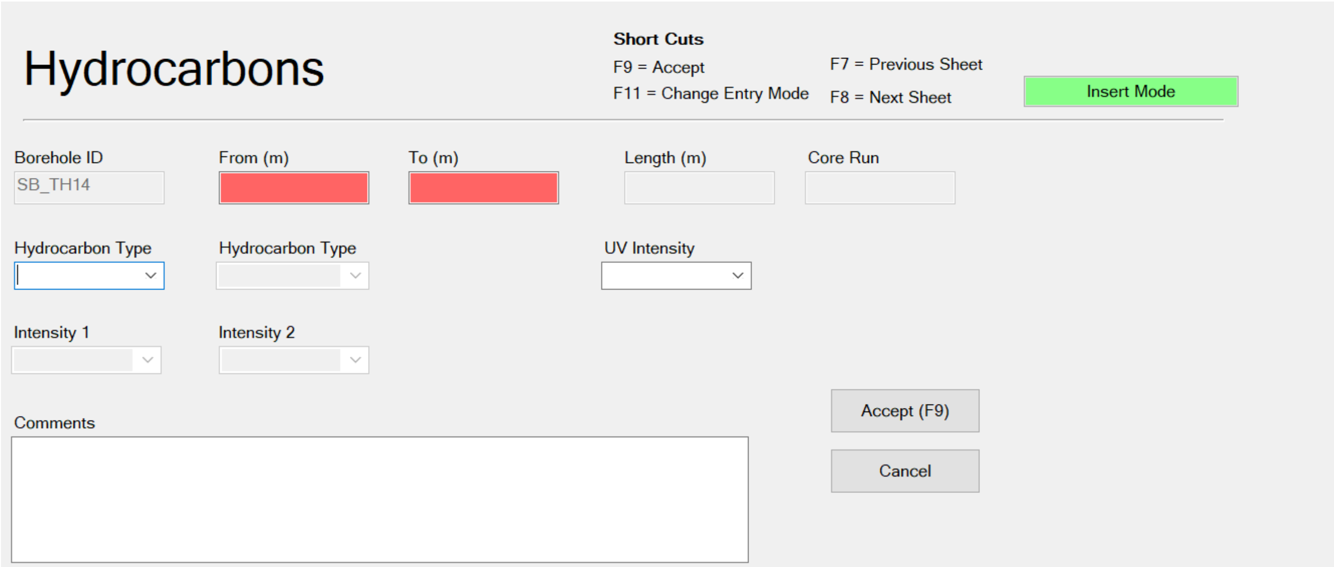


Figure 21: Hydrocarbon Data Entry Object (acQuire)

2.9.1 Record Hydrocarbon Type and Intensity

Three types of Hydrocarbon can be recorded in acQuire: bituminous layering, petroliferous odour/degassing, and visible oil. When a type is recorded, the intensity will also be recorded on a scale ranging from none to intense (trace, moderate, intense). Up to two Hydrocarbon types and respective intensities can be recorded per interval.

2.9.2 Record UV Visible Oil

A Tektite UV flashlight will be used to scan the core for UV visible oil products. If present, UV intensity of visible oil will be recorded as trace, moderate, or intense. It is recommended that lights in the logging trailer be temporarily shut off when using the UV flashlight to scan for oil products, as trace levels of UV visible products may not be observed when other lights are on.

2.10 Weathering Data Collection

Weathering data will only be logged when present. The degree of weathering will be recorded in acQuire using the Weathering entry object (Figure 22) according to the classification scheme described in Table 27. The comments field will be used to describe weathering colouring and any interpretations (e.g. saprolite), if not adequately captured in another field.

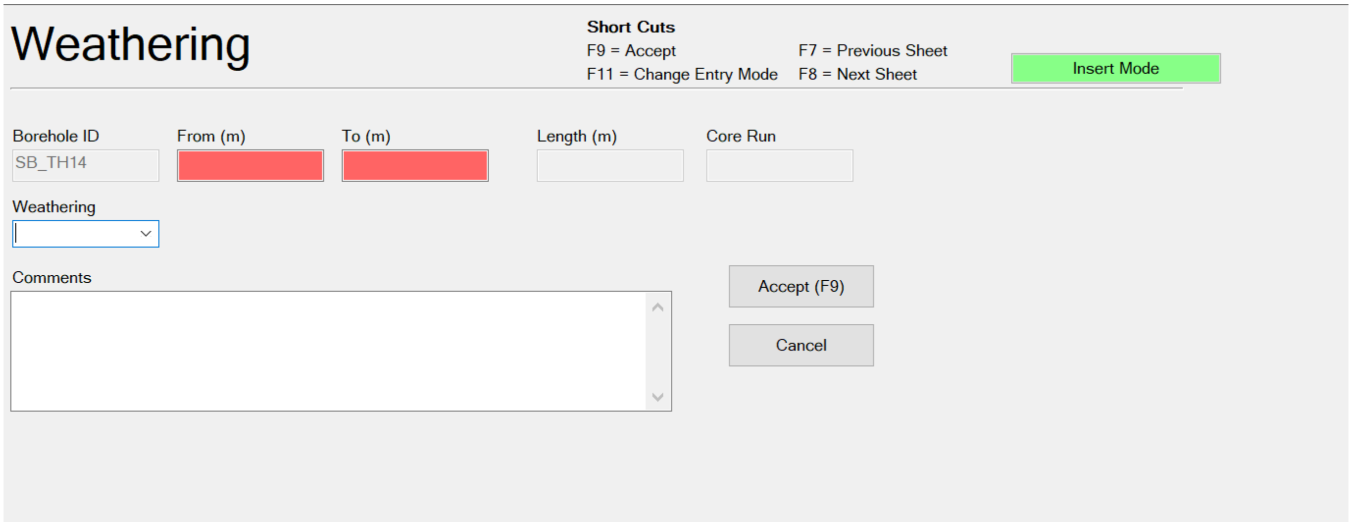


Figure 22: Weathering Entry Object (acQuire)

Table 27: Weathering Classification Table (after ISRM, 1981)

Term	Symbol	Description	Discolouration Extent	Surface Characteristics
Residual Soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed	Throughout	n/a
Completely Weathered	W5	100% of rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	Throughout	Filled with alteration minerals
Highly Weathered	W4	More than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	Throughout	Filled with alteration minerals
Moderately Weathered	W3	Less than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. Visible texture of the host rock still preserved. Surface planes are weathered (oxidized or carbonate filling) even when breaking the “intact rock”.	>20% of fracture spacing on both sides of fracture	Discoloured, may contain thick filling
Slightly Weathered	W2	Discoloration indicates weathering of rock material on discontinuity surfaces (usually oxidized). Less than 5% of rock mass altered.	<20% of fracture spacing on both sides of fracture	Discoloured, may contain thin filling
Fresh	W1	No visible sign of rock material weathering.	None	Closed or not discoloured

2.11 Rock Strength Data Collection

Field estimation of intact rock strength for core from the South Bruce boreholes will be based on the International Society of Rock Mechanics (ISRM, 1981) guidelines shown in Table 28.

Confirming the strength rating by hammer blows will be carried out opportunistically, when breaking the core for sampling and for fitting the core pieces into the core boxes. This approach is taken to preserve the integrity of the core as much as possible. However, whenever a change in strength is suspected, the full range of tests will be performed to determine hardness, including hitting the core with a rock hammer, scraping or peeling with a knife and scratching with your thumbnail, as per the procedures described in Table 28. Strength measurements are recorded in acQuire as point measurements using the entry object show in Figure 23.

The rock type on which the strength test was carried out on will be entered. AcQuire will limit the test rock type options available to those lithologies logged at the given depth.

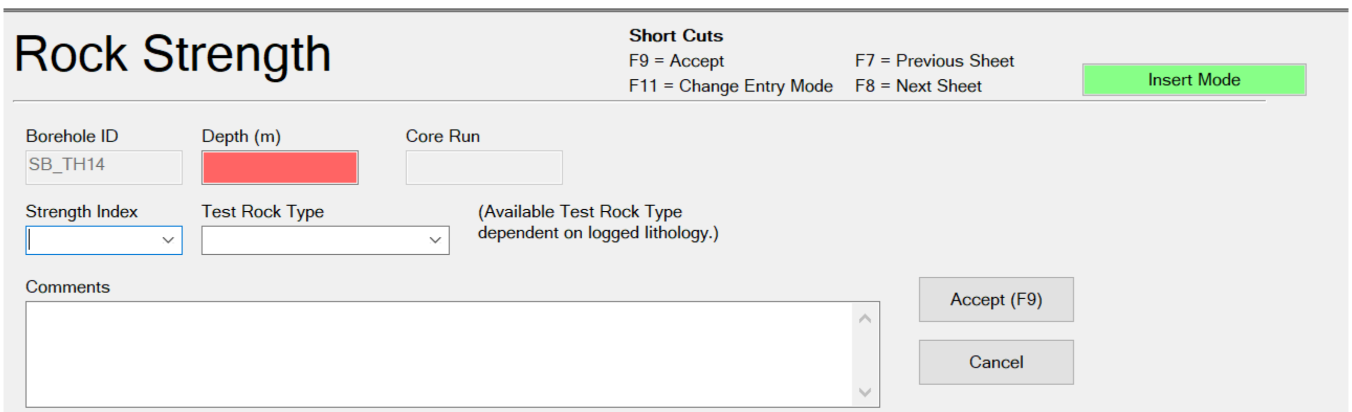


Figure 23: Rock Strength Entry Object (acQuire)

Table 28: Field Estimation of Rock Hardness (ISRM, 1981)

Term	Symbol	Field Identification	Approximate UCS Range (MPa)
Extremely weak rock	R0	Indented by thumbnail.	0.25 -1
Very weak rock	R1	Material can be shaped with a pocket knife or can be peeled by a pocket knife. Crumbles under firm blows of pick (or point) of geological hammer.	1.0 – 5.0
Weak rock	R2	Knife cuts material but too hard to shape into triaxial specimens or material can be peeled by a pocket knife with difficulty. Shallow indentations (< 5 mm) made by firm blow with pick (or point) of geological hammer.	5.0 – 25
Medium strong rock	R3	Cannot be scraped or peeled with a pocket knife. Hand held specimens can be fractured with *single* firm blow of geological hammer.	25 – 50

Term	Symbol	Field Identification	Approximate UCS Range (MPa)
Strong rock	R4	Hand held specimen requires more than one blow of geological hammer to fracture it.	50 – 100
Very strong rock	R5	Specimen requires many blows of geological hammer to break intact rock specimens (or to fracture it).	100 – 250
Extremely strong rock	R6	Specimen can only be chipped under repeated hammer blows, rings when hit.	>250

2.12 Core Sample Data Collection

Core sample data is recorded in the core sample entry object in acQuire (Figure 24). The core sampler must specify the sample depths, sample type, sample date/time, sampler initials, and preservation type (chemical, steel cannister). The sample ID and sample photo names are automatically generated in acQuire based on the Borehole ID and specified sample type.

All sample weights will be measured before preservation and recorded in the sample weight object.

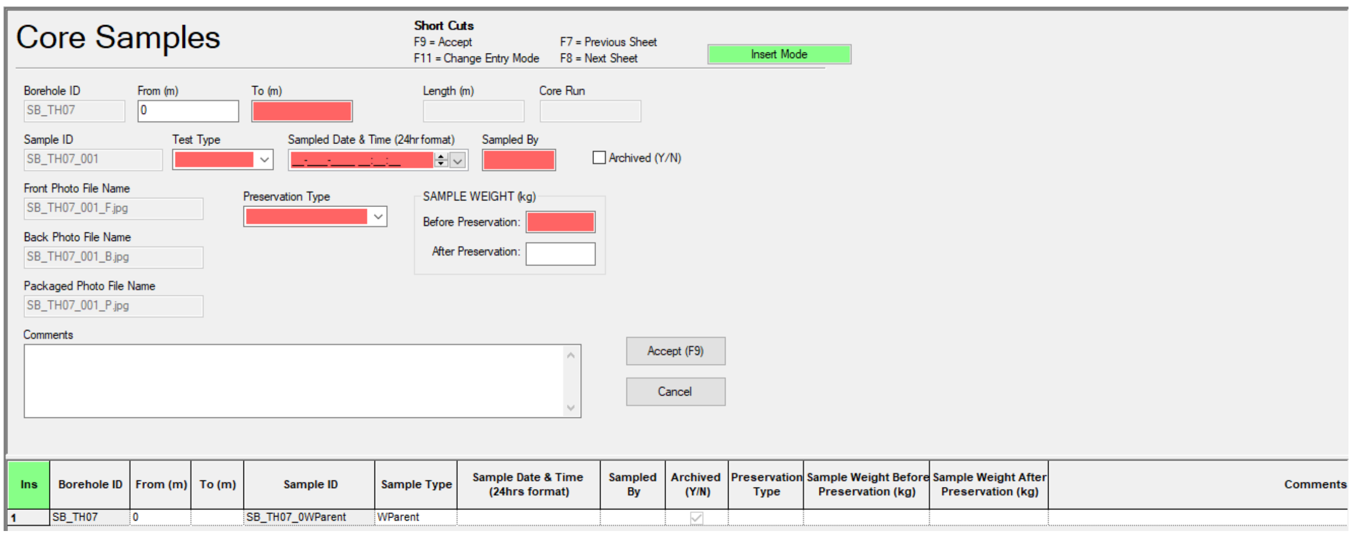


Figure 24: Core Samples Entry Object (acQuire)

2.13 Core Box Intervals Data Collection

Core box data is recorded in the core box intervals object in acQuire (Figure 25). The core sampler must specify the box number and the From/To depths of the core stored in the box. acQuire will automatically determine the core runs included within the core box based on the specified depth interval.

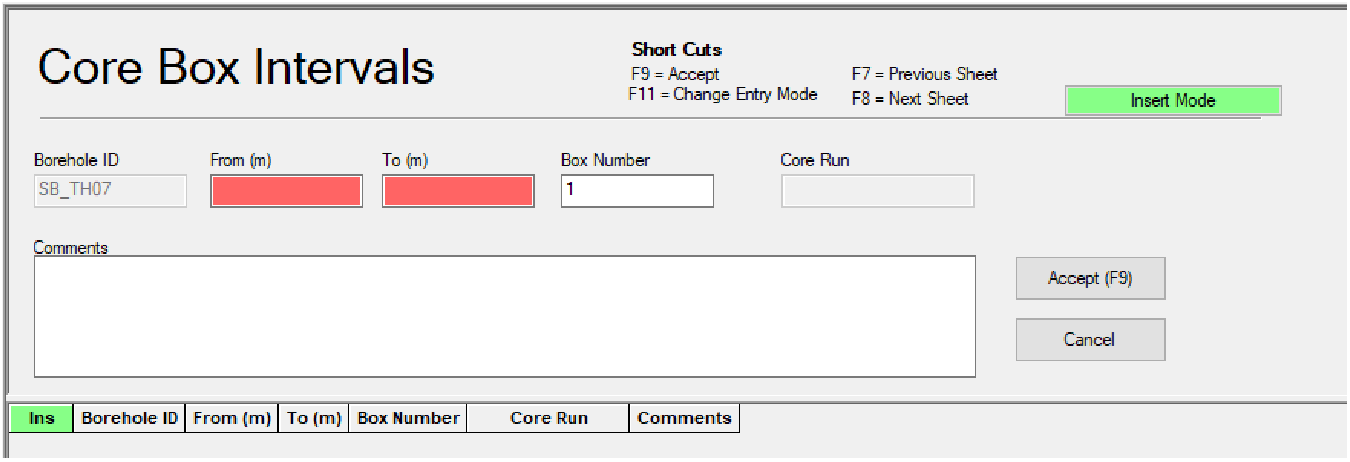


Figure 25: Core Box Intervals Entry Object (acQuire)

2.14 Core Box Photos Data Collection

Core box photo data is recorded in the core box photos entry object in acQuire (Figure 26). Since multiple core boxes can be included in a single core box photo, the first and last box numbers must be specified by the core logger/sampler. acQuire will automatically determine the From/To depths and core run number(s) based on the box numbers entered by the logger. Core box photo names (wet and dry) are also automatically generated in acQuire.

The person entering the core box photo data will ensure that the core box photo IDs match the IDs generated in acQuire.

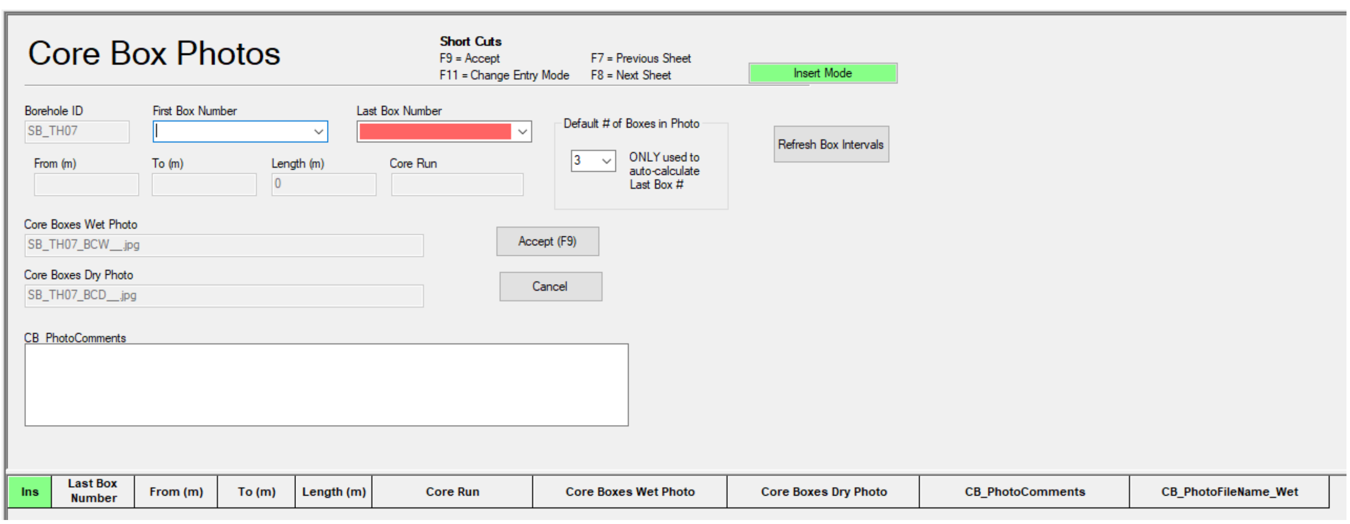


Figure 26: Core Box Photos Entry Object (acQuire)

2.15 Detail Core Photos Data Collection

Detailed core photo data is recorded in the detailed core photos entry object in acQuire (Figure 27). The From/To depths, photo type, and a comment must be entered by the core logger. Available detailed photo types include:

- Lithology
    - Lithology (LL)
    - Qualifier (LQ)
    - Structure (LS)
    - Marked Bed (LM)
    - Disturbance Index (LD)
    - Colour/Colour Pattern (LC)
    - Bedding (LB)
    - Sorting/Fining (LG)
    - Fossils (LF)
- Alteration (AA)
- Weathering (WW)
- Hydrocarbons
    - Hydrocarbons (HH)
    - UV Fluorescence (HU)

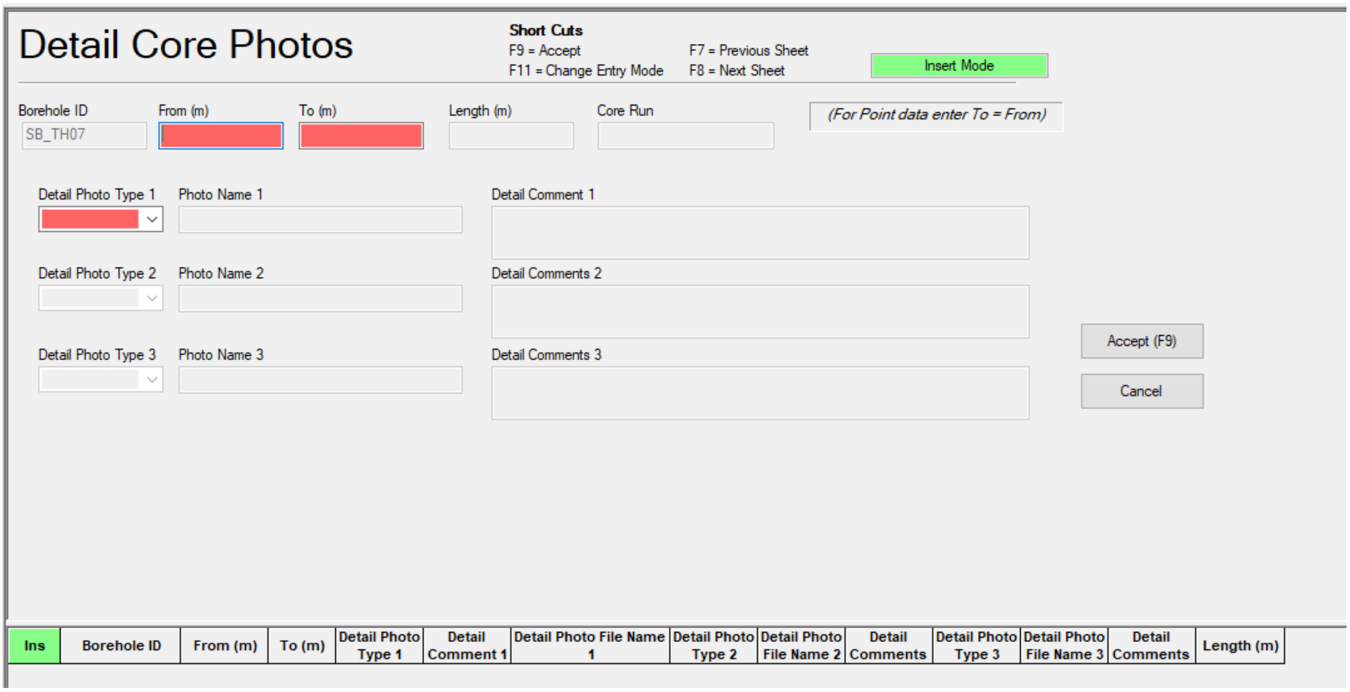


Figure 27: Detail Core Photos Entry Object (acQuire)

2.16 Sedimentary Formation Contacts Data Collection

Rock core data (WP03) and the geophysical well logs (WP05) will be used to identify/confirm formation tops as part of the borehole integration report (WP10). When possible, preliminary formation contacts will be logged in the field using the Sedimentary Formation Contacts entry object (DE-05) in acQuire (Figure 28). Field identification of formation tops will be used to adjust sampling locations (when necessary) or aid in identification of opportunistic groundwater samples (e.g. in Guelph Formation).

Stratigraphic descriptions of bedrock formations from Geofirma's Bruce DGR work will be used as a reference to identify the formation tops in SB_BH01 and SB_BH02. A table of bedrock formation picks in DGR-1 to DGR-6, including detailed descriptions and pick criteria for each formation, is provided for reference in Appendix F of the WP03 Test Plan.

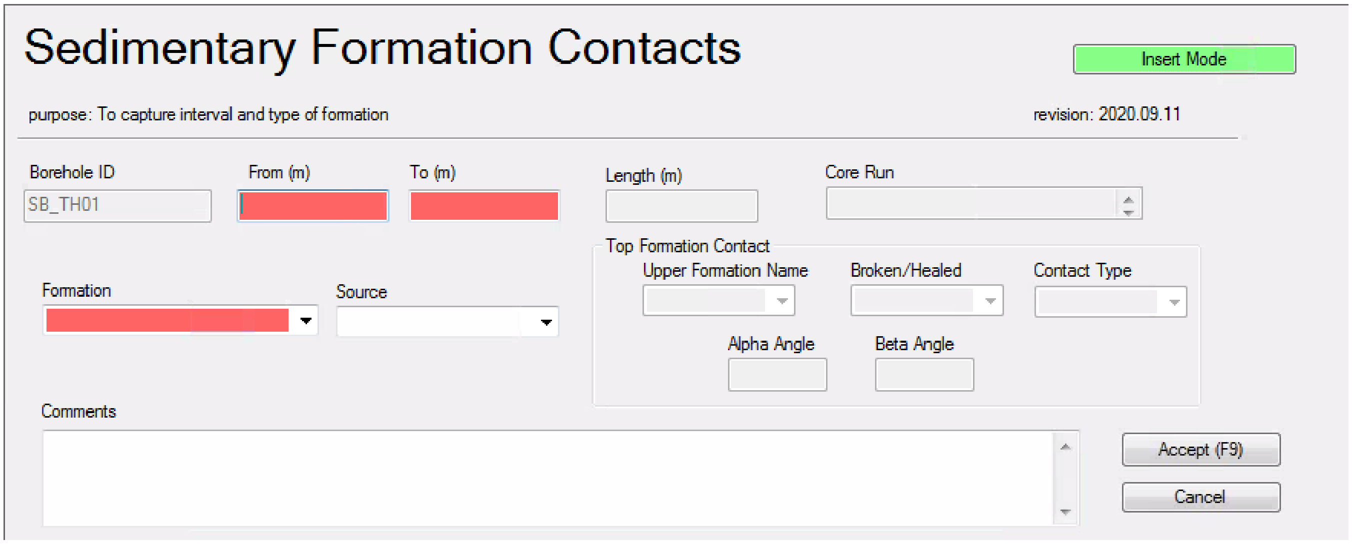


Figure 28: Sedimentary Formation Contacts Entry Object (acQuire)

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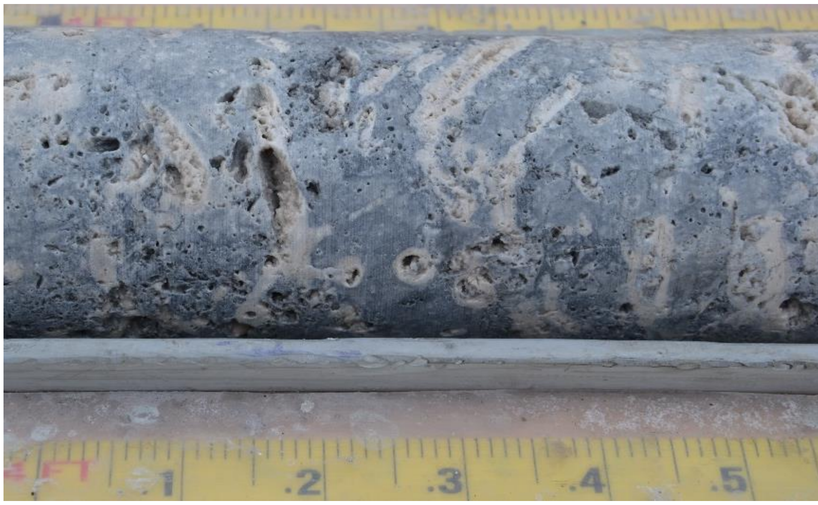
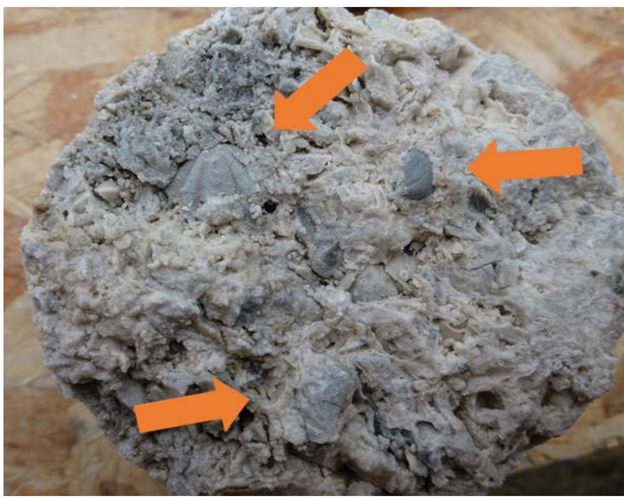
Appendix 1

Examples of Fossil Types Commonly Observed in Paleozoic Sedimentary Rock from Southwestern Ontario

Crinoid



Brachiopod

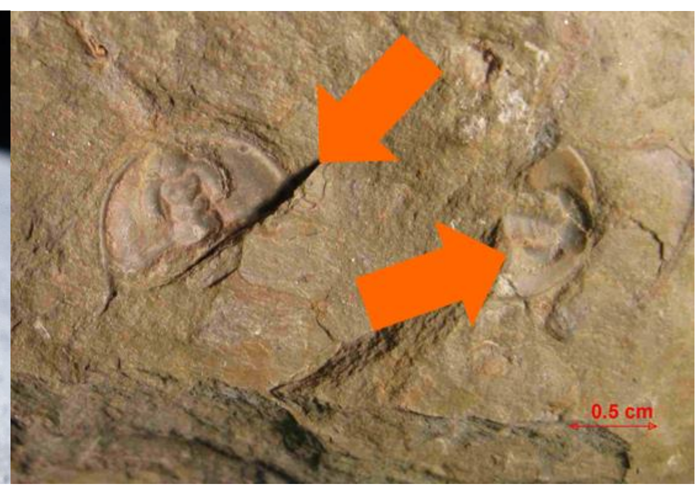


Coral

Bryozoan


Bivalve

Trilobite

Gastropod

Stromatolite

Appendix B

SB_BH01 Geological and Geotechnical Summary Log

SB_BH01, WP03 Summary Log

GEOFIRMA ENGINEERING

Project: 20-211-1 NWMO South Bruce Drilling and Testing

Drilled Dates: June 6 - September 18, 2022 (for coring activites)

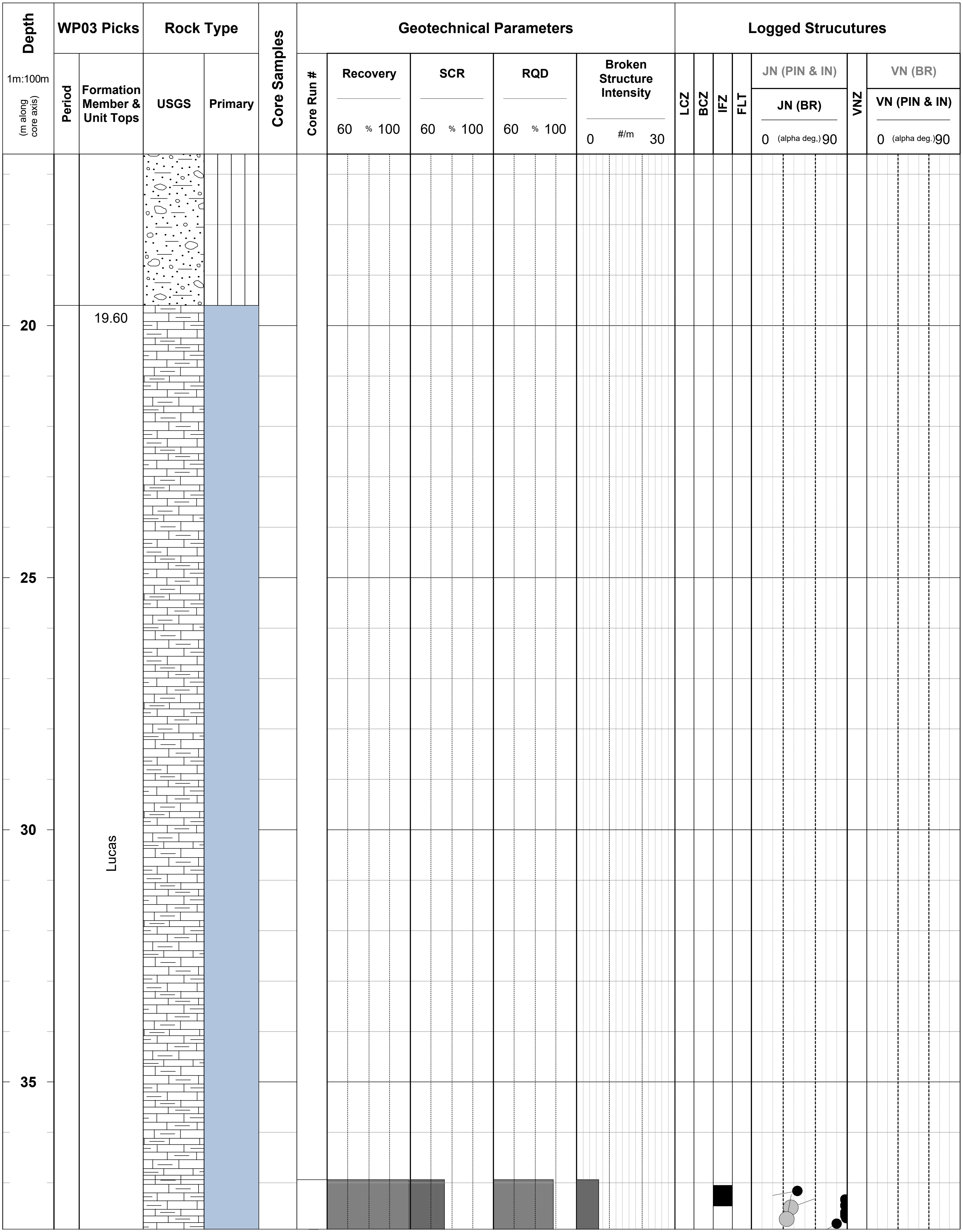
Drilling Company: Vital Drilling, PQ3 Coring

Total Depth (m): 880.84

Comments:
Summary log for geological logging, geotechnical logging, and core sampling that was completed by Geofirma Engineering for borehole SB_BH01
A legend for colouring, symbology, and acronyms used in the summary log is provided at the end of the log.
Top of rock was 19.6 m BGS, Coring started at 36.94 m BGS. All formations, unit, and member tops are preliminary based soley on core data.

Document Tracking
Created by: CAM (28-Jul-22)
Checked by: SNS (28-Jul-22)
File Name: SB_BH01_Summary_Log_R0

Depth 1m:100m (m along core axis)	WP03 Picks: Period	WP03 Picks: Formation Member & Unit Tops	Rock Type: USGS	Rock Type: Primary	Core Samples	Core Run #	Geotechnical Parameters: Recovery (60 % 100)	SCR (60 % 100)	RQD (60 % 100)	Broken Structure Intensity (0 #/m 30)	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) (0 (alpha deg.) 90)	VNZ	VN (BR) / VN (PIN & IN) (0 (alpha deg.) 90)
0	Quaternary																
5																	
10																	
15																	



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1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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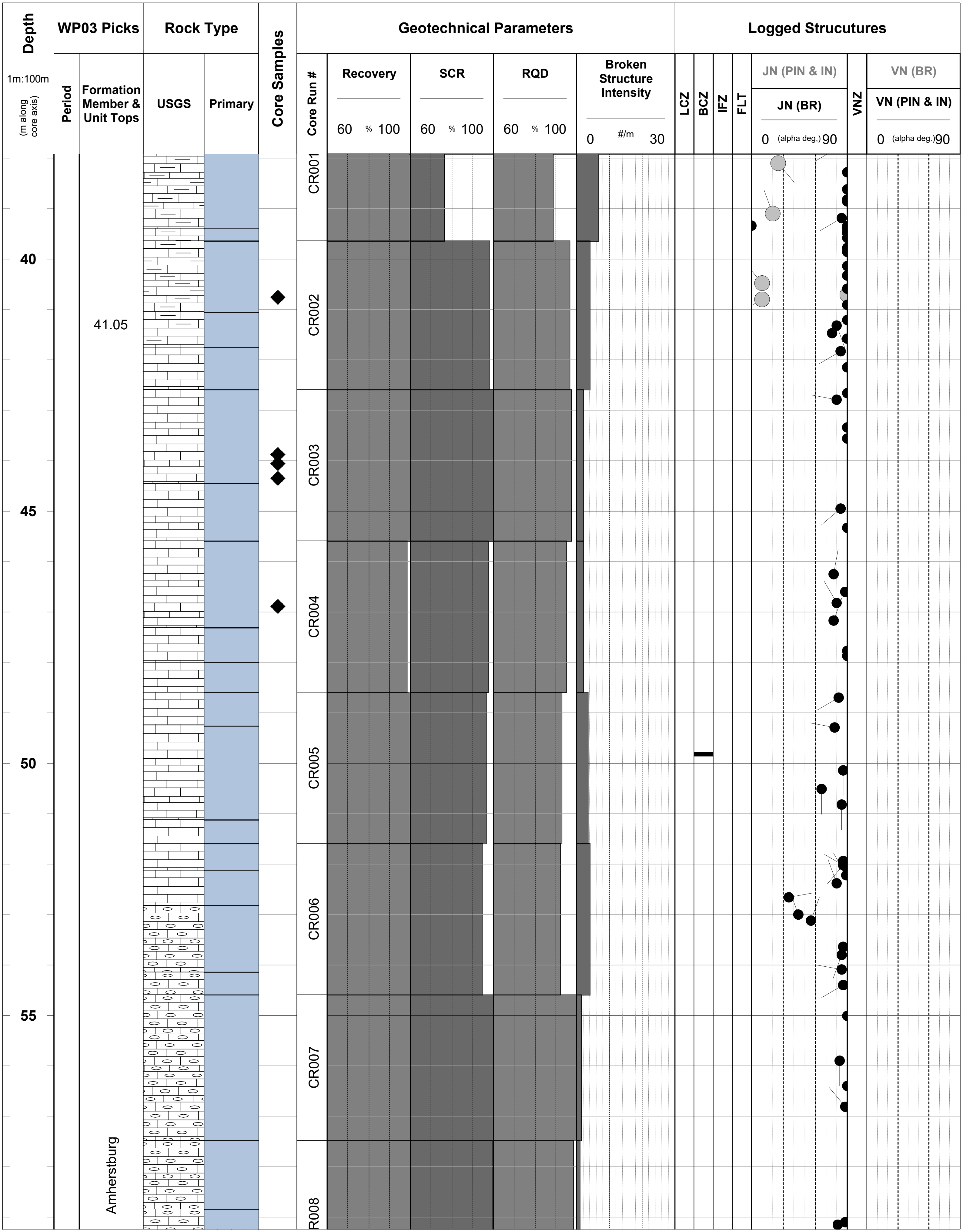
20
25
30
35
Lucas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(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
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Amherstburg
Rock Type
USGS
Primary
Core Samples
Core Run #
CR001
CR002
CR003
CR004
CR005
CR006
CR007
R008
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
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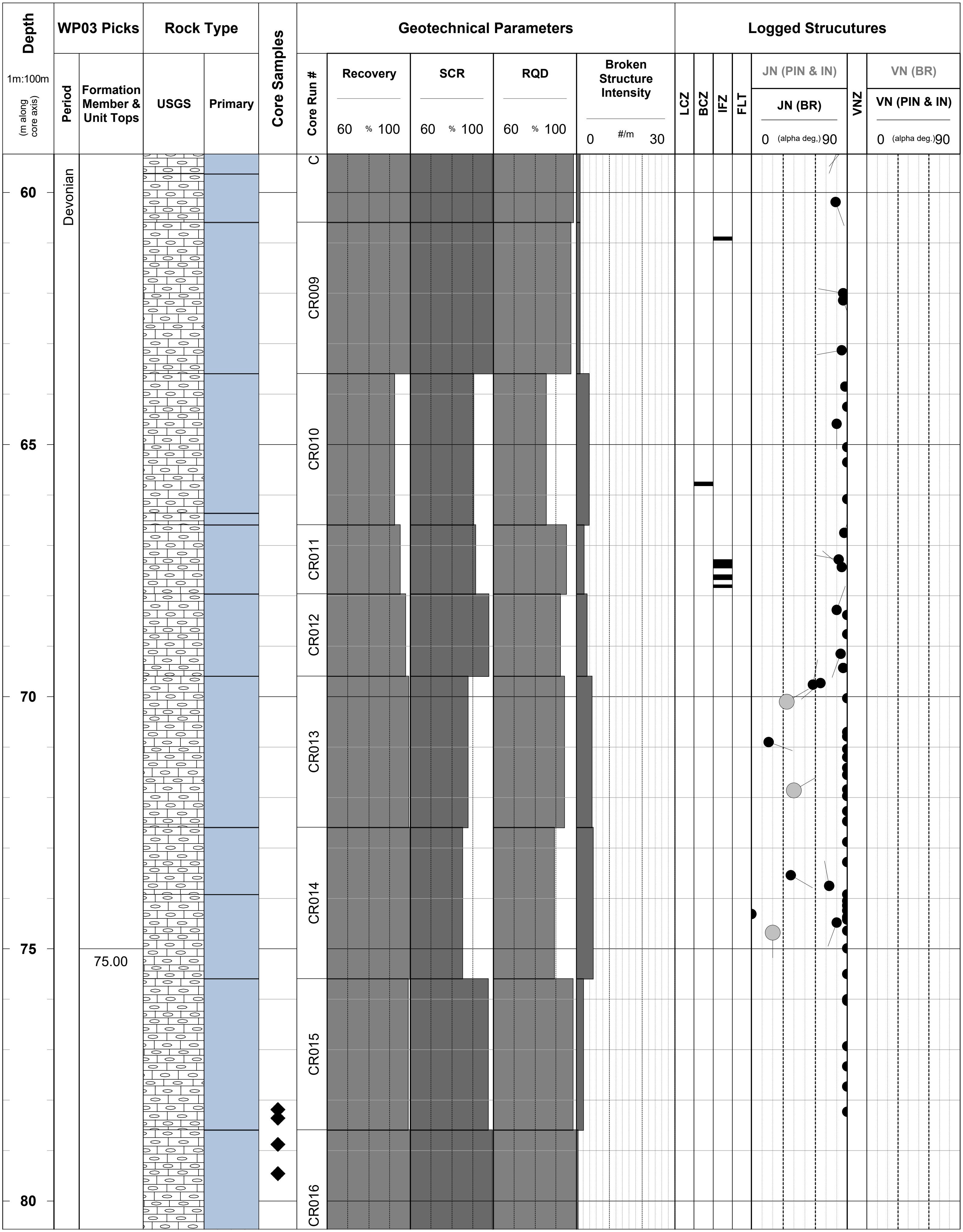
45
50
55



Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Stucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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65
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75
80
Devonian
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CR011
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CR015
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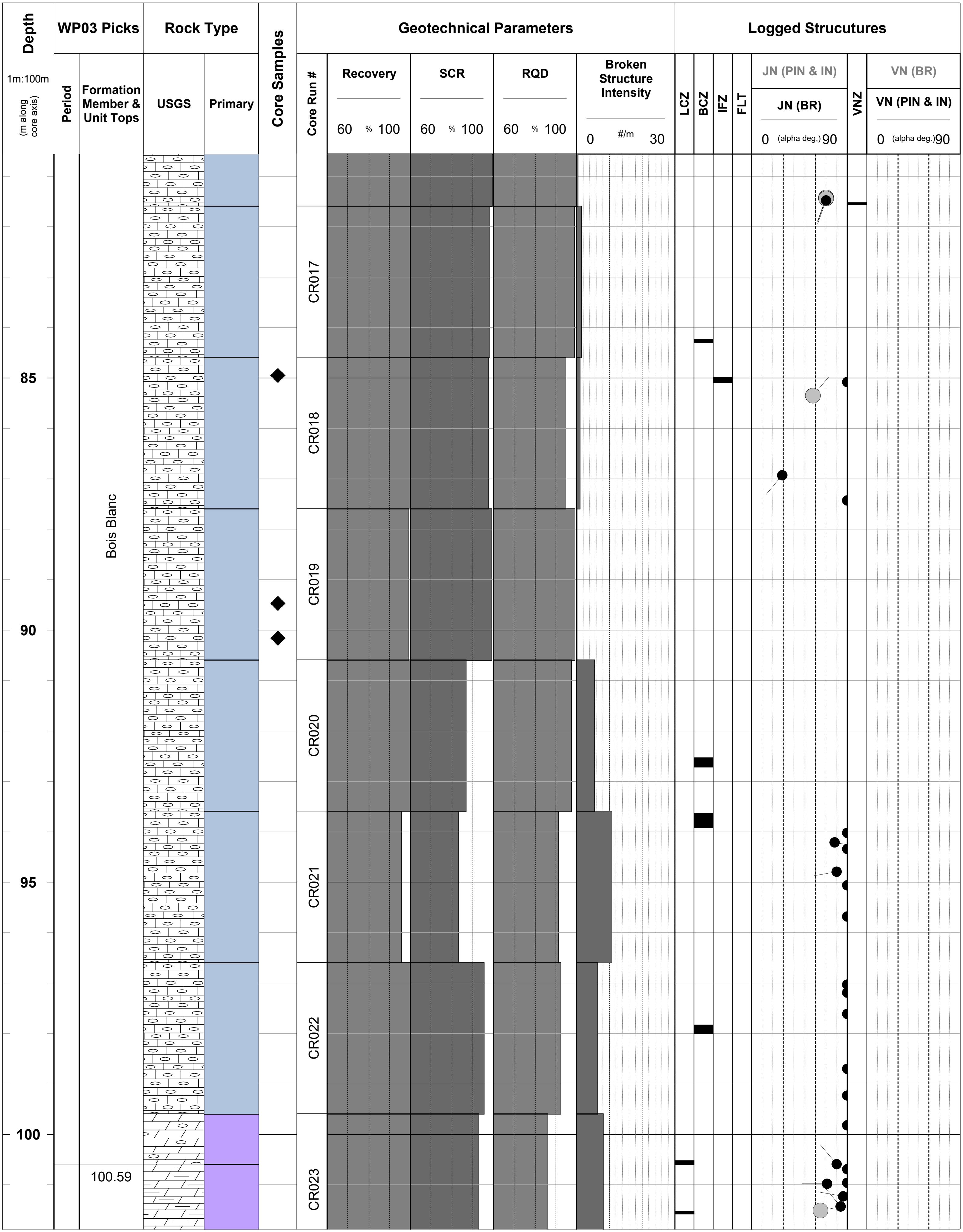
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Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
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VNZ
VN (BR)
VN (PIN & IN)
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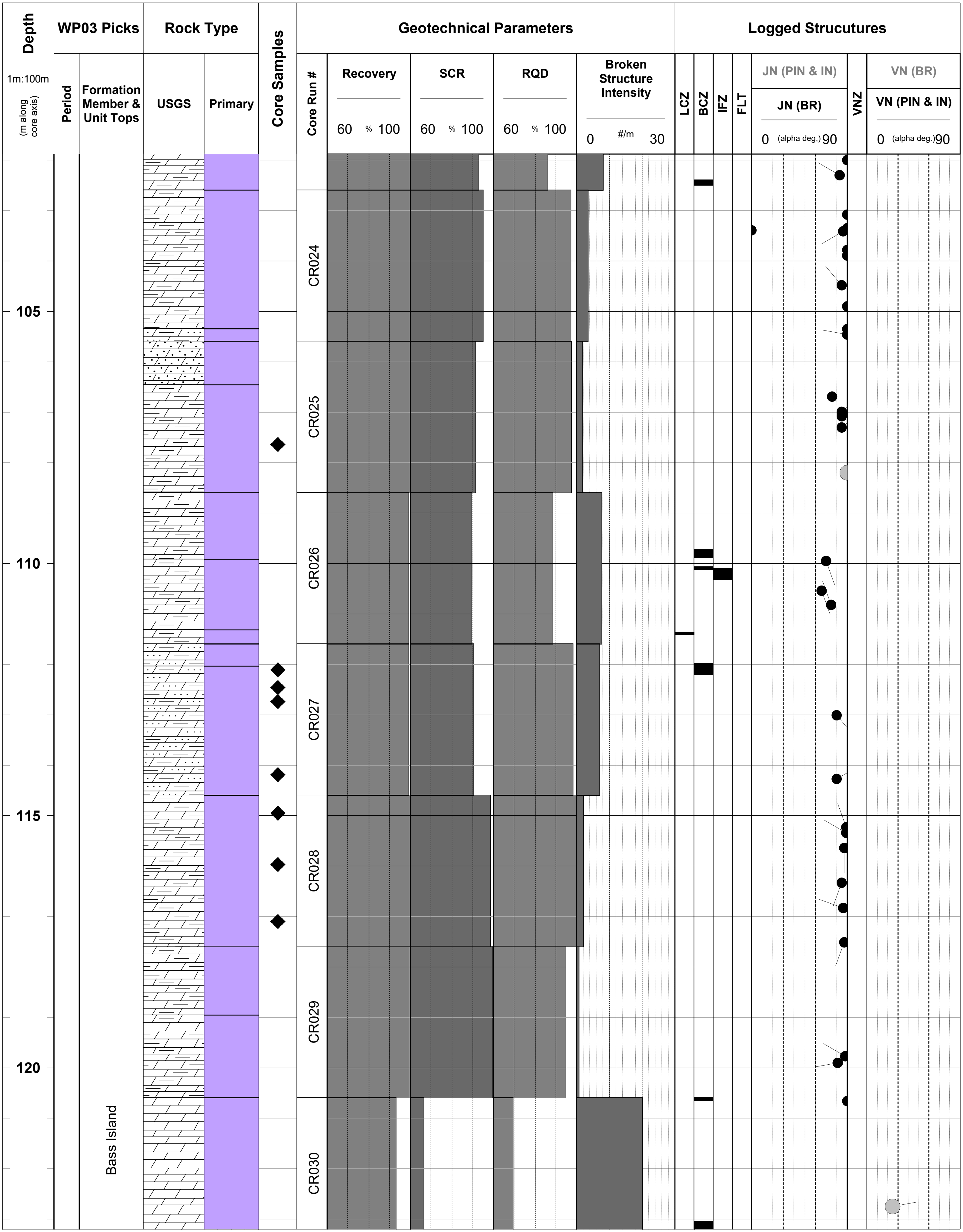
CR020
CR021
CR022
CR023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Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Structures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
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110
115
120
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CR025
CR026
CR027
CR028
CR029
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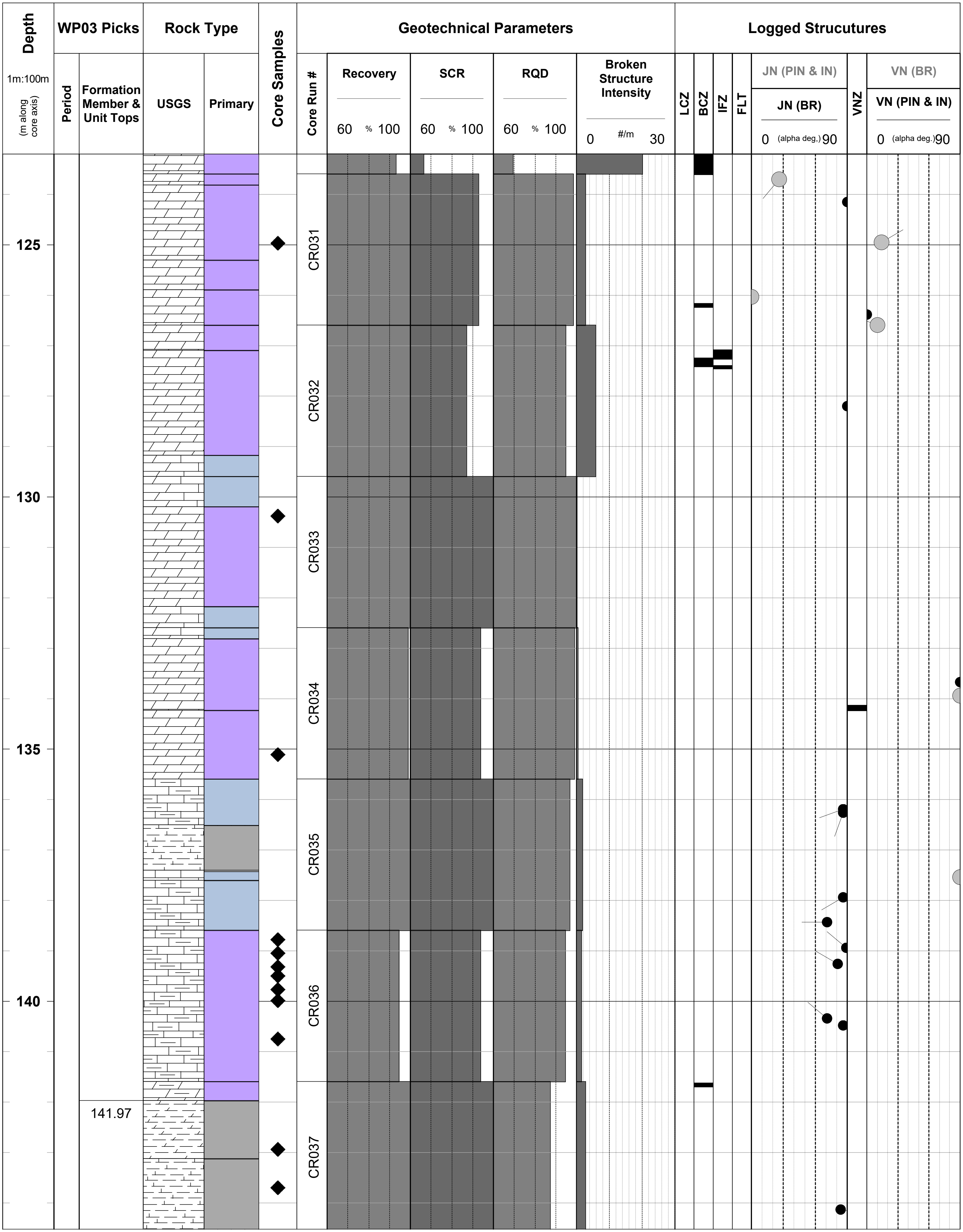
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Period
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Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
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Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Structures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
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140
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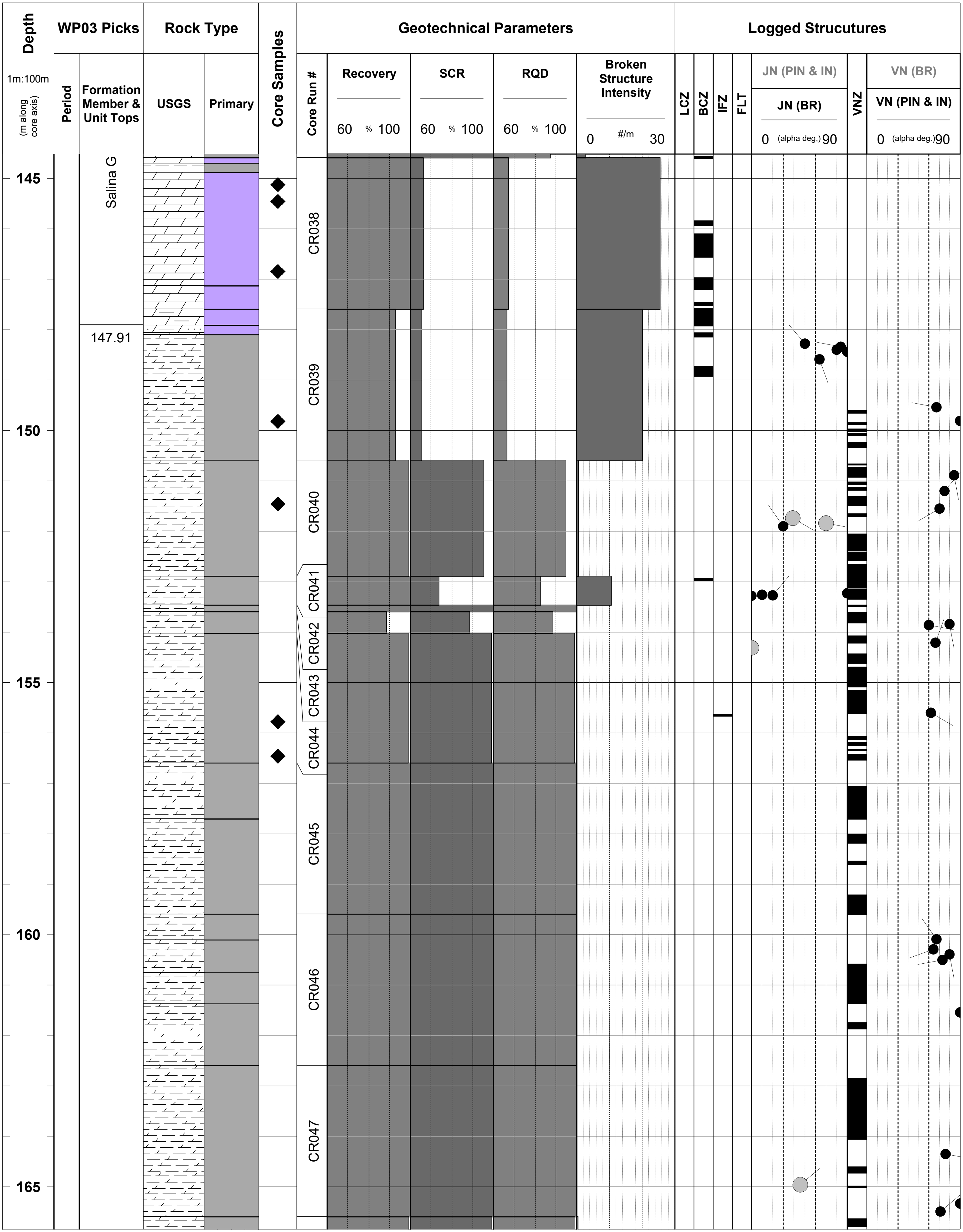
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Rock Type
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Primary
Core Samples
Geotechnical Parameters
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Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
145
150
155
160
165
Salina G
147.91
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CR039
CR040
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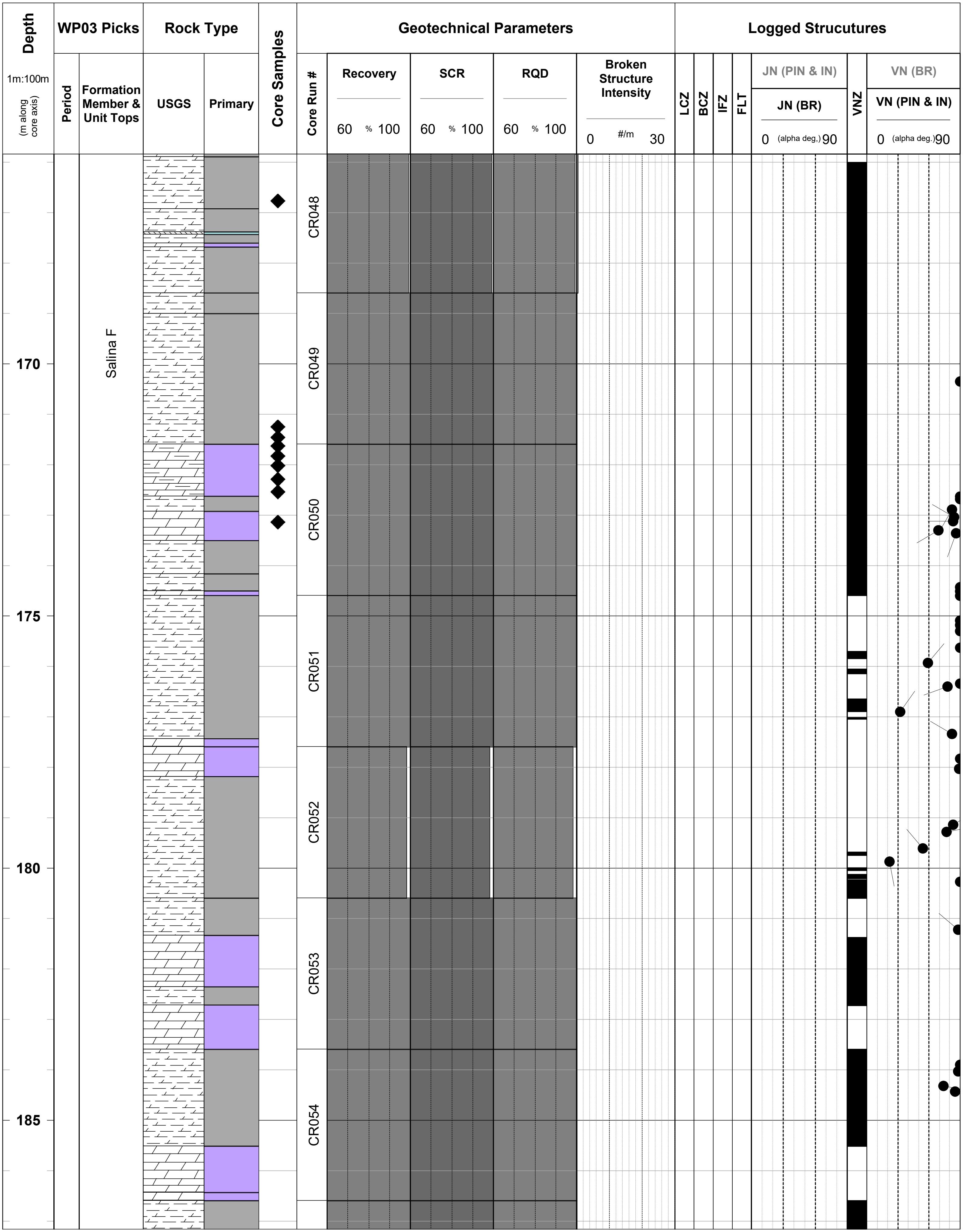
CR042
CR043
CR044
CR045
CR046
CR047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Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
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Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
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175
180
185
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CR049
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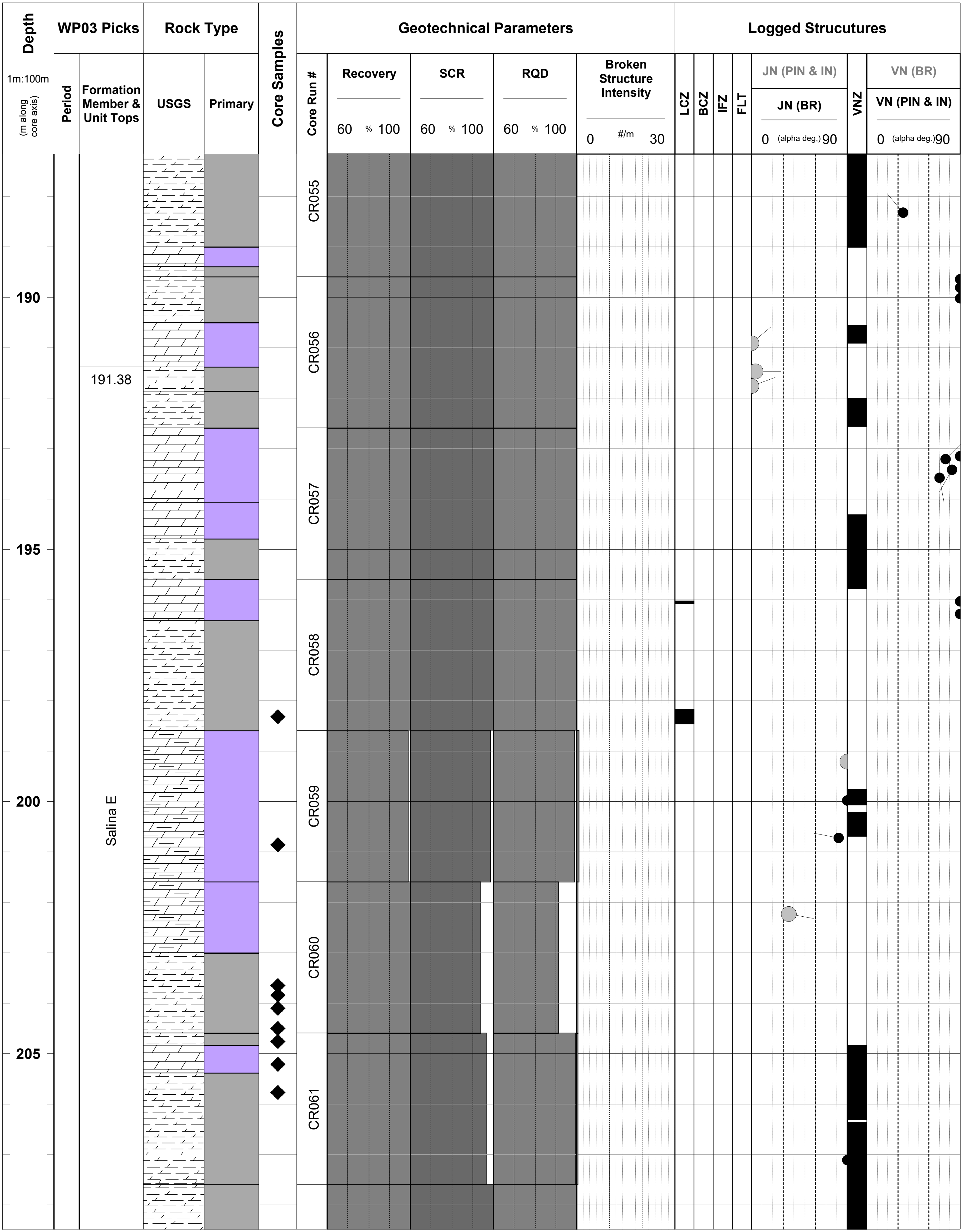
CR052
CR053
CR054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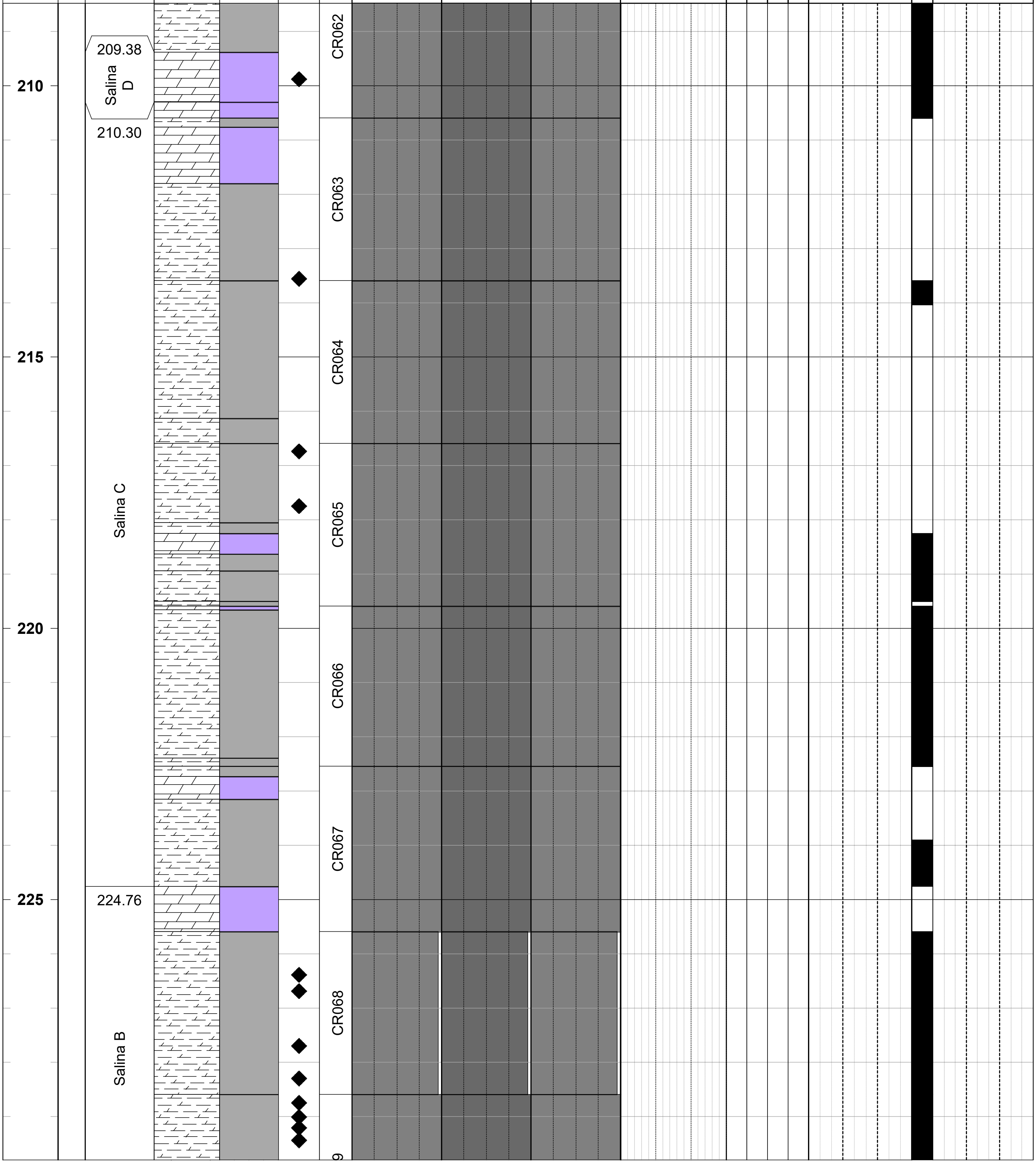
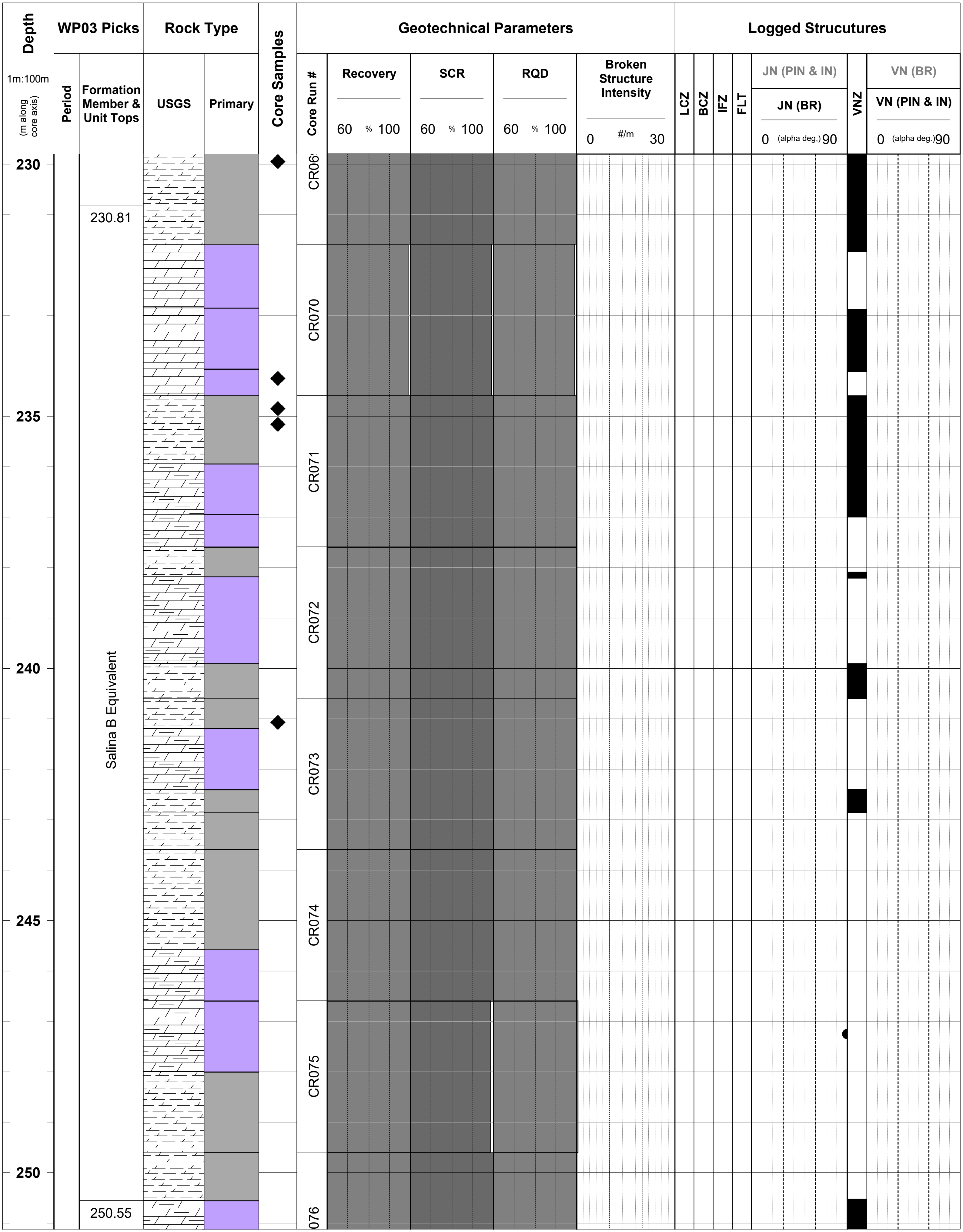
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
190
195
200
205
191.38
Salina E
CR055
CR056
CR057
CR058
CR059
CR060
CR061

Depth	WP03 Picks		Rock Type		Core Samples	Geotechnical Parameters					Logged Strucutures						
1m:100m (m along core axis)	Period	Formation Member & Unit Tops	USGS	Primary		Core Run #	Recovery 60 % 100	SCR 60 % 100	RQD 60 % 100	Broken Structure Intensity 0 #/m 30	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) 0 (alpha deg.) 90	VNZ	VN (BR) / VN (PIN & IN) 0 (alpha deg.) 90

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Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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Salina B Equivalent
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CR071
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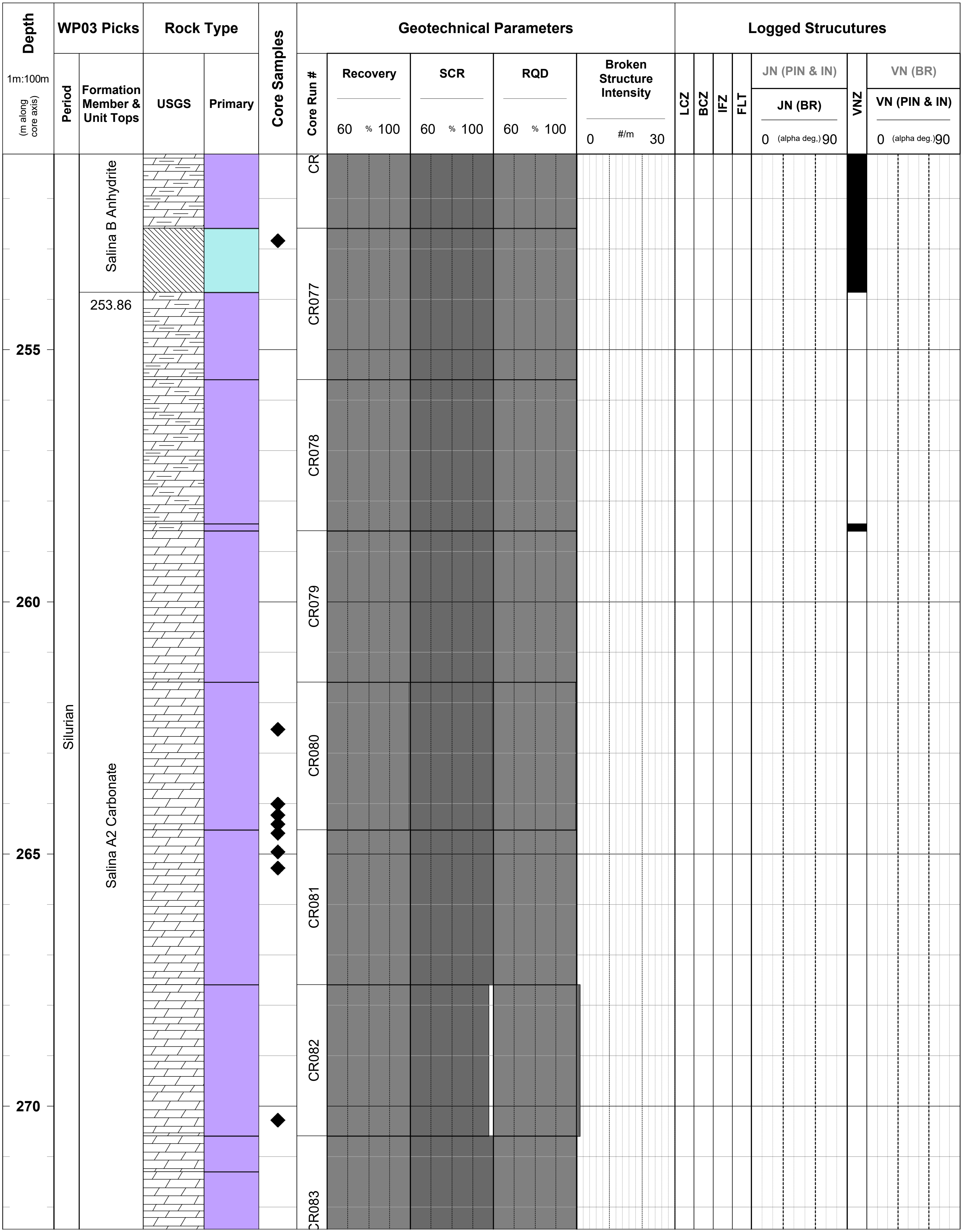
CR073
CR074
CR075
076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60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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260
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270
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Salina A2 Carbonate
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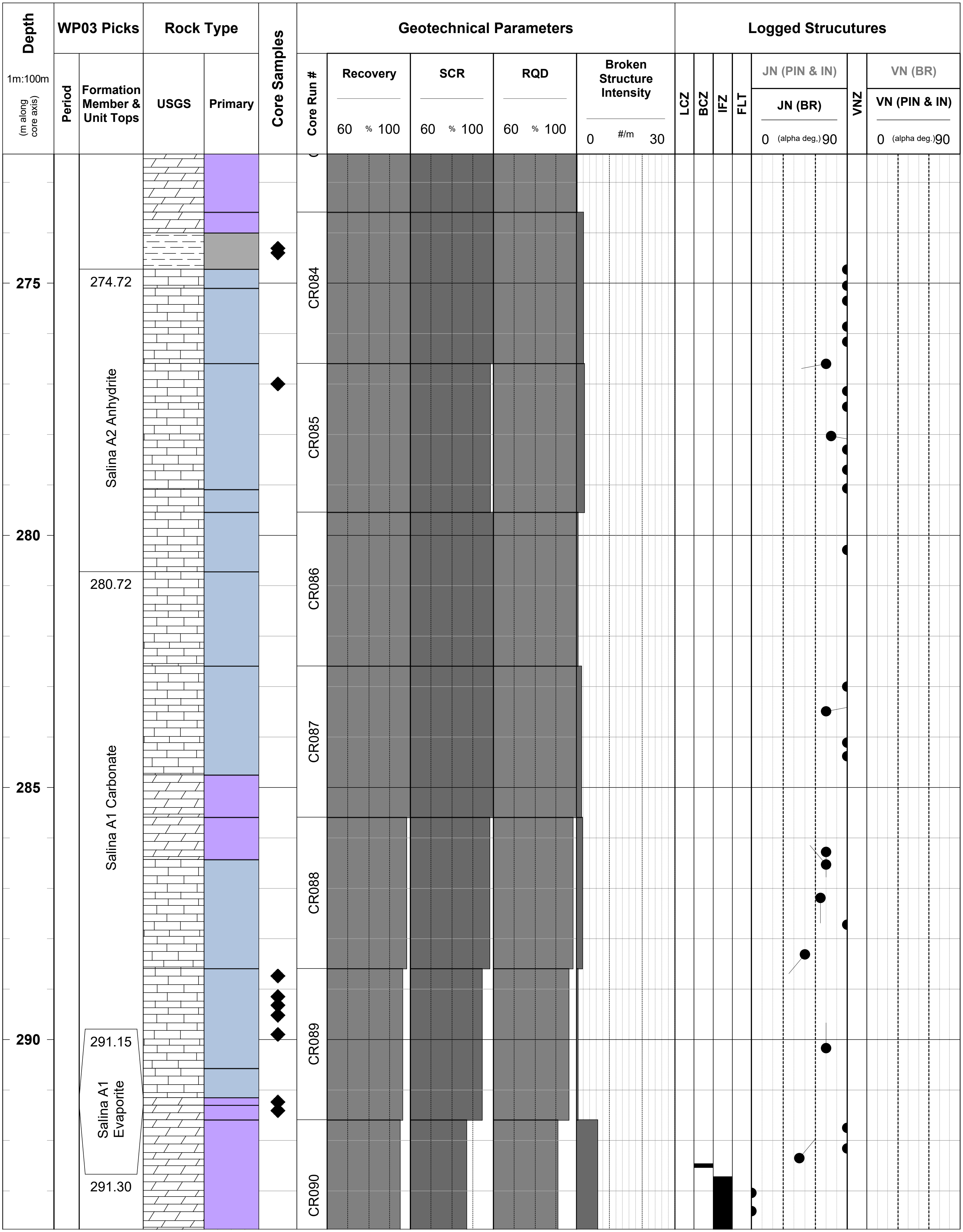
CR077
CR078
CR079
CR080
CR081
CR082
CR083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Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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280
285
290
274.72
Salina A2 Anhydrite
280.72
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CR085
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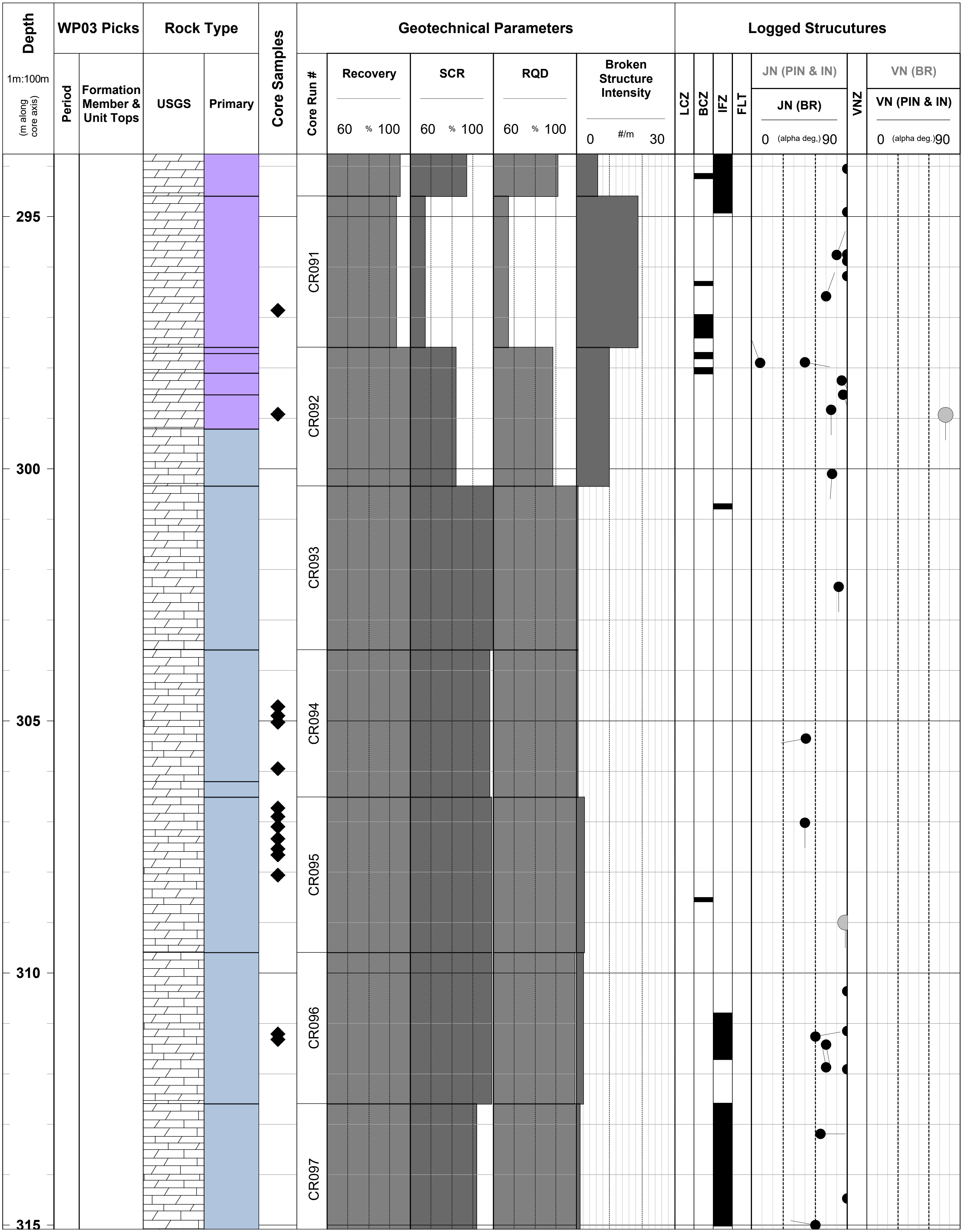
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Recovery
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SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
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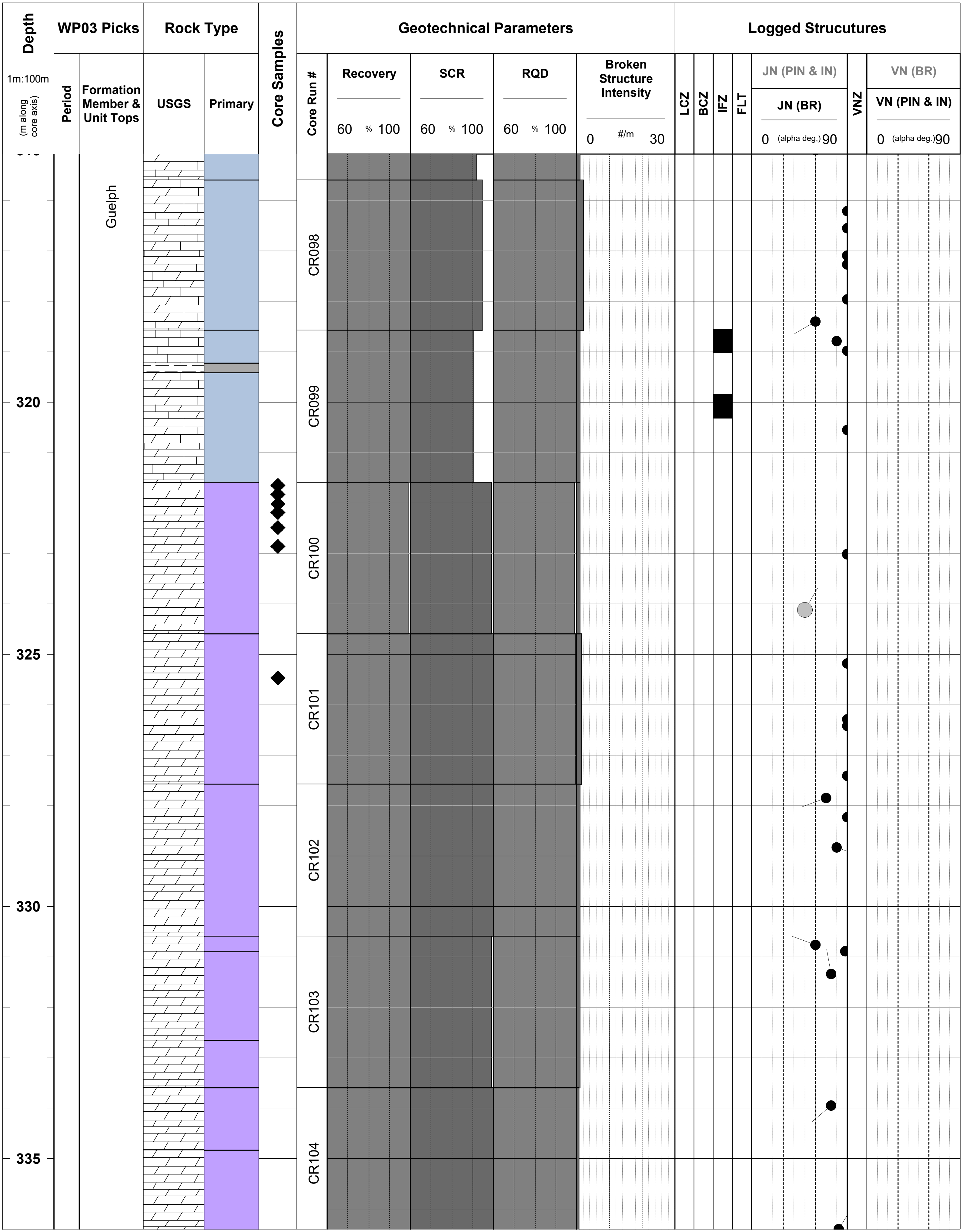
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60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
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CR099
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CR102
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CR104
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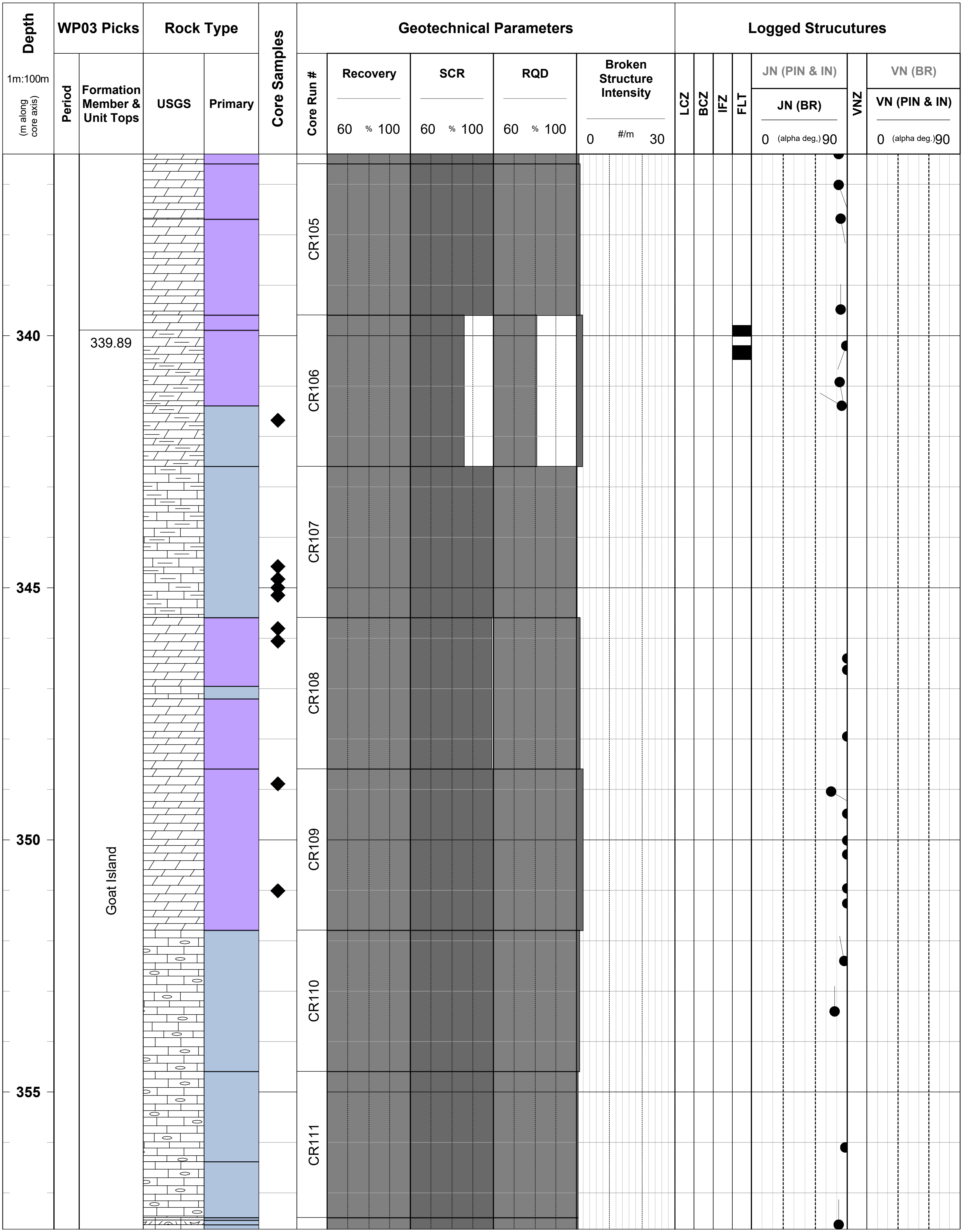
325
330
335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RQD
60 % 100
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0 #/m 30
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BCZ
IFZ
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VNZ
VN (BR)
VN (PIN & IN)
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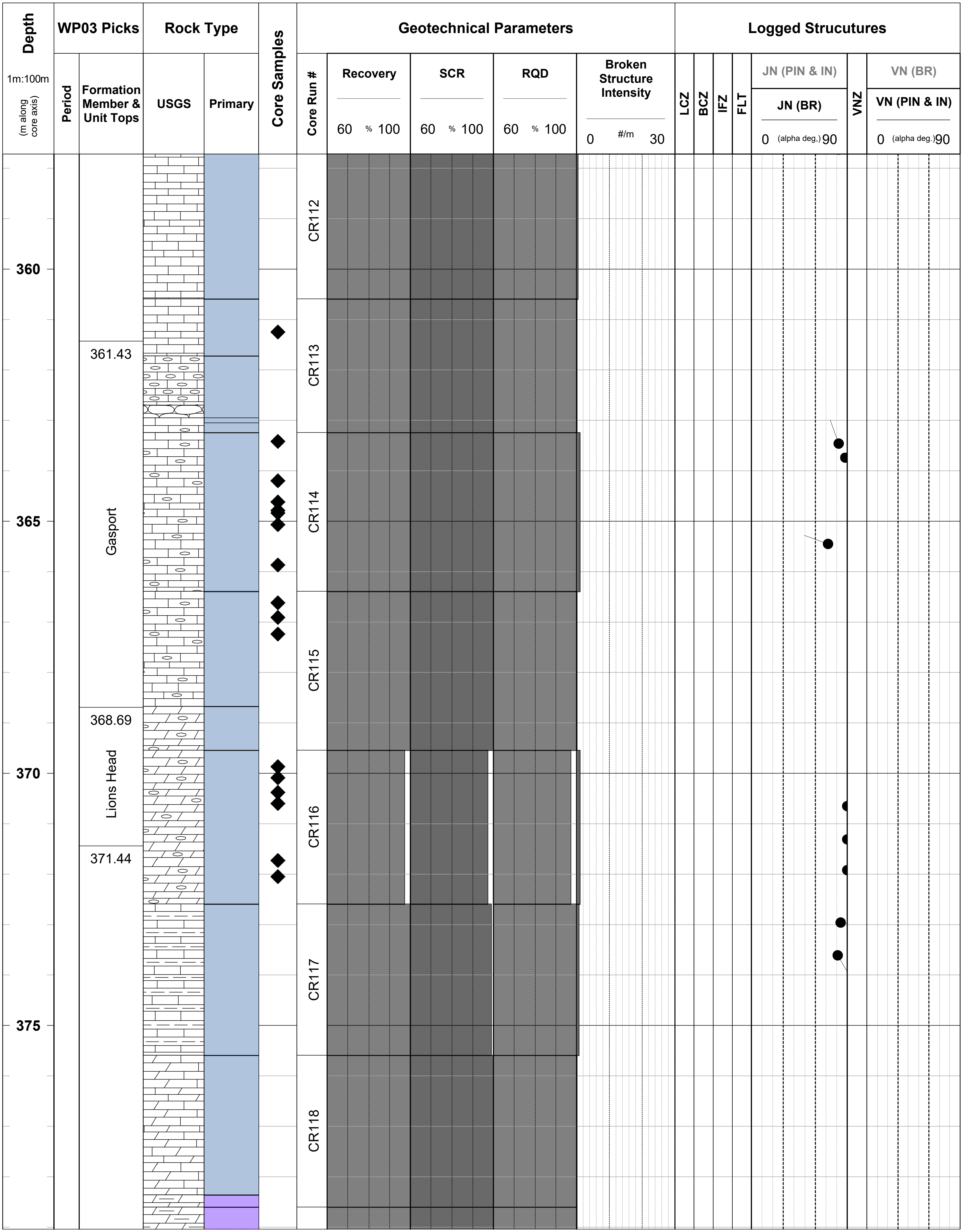
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Primary
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Geotechnical Parameters
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60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
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BCZ
IFZ
FLT
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JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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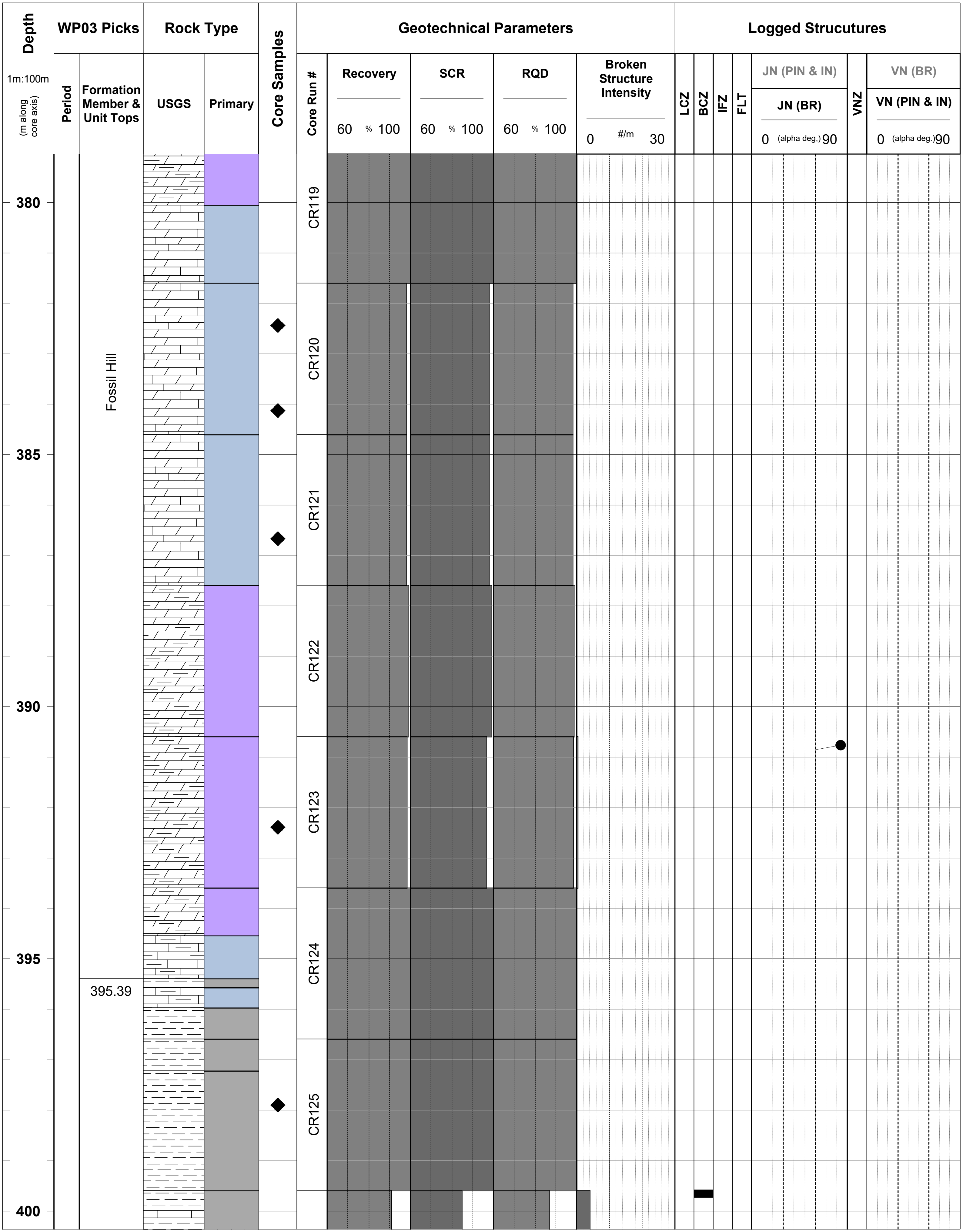
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Primary
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60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
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BCZ
IFZ
FLT
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JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
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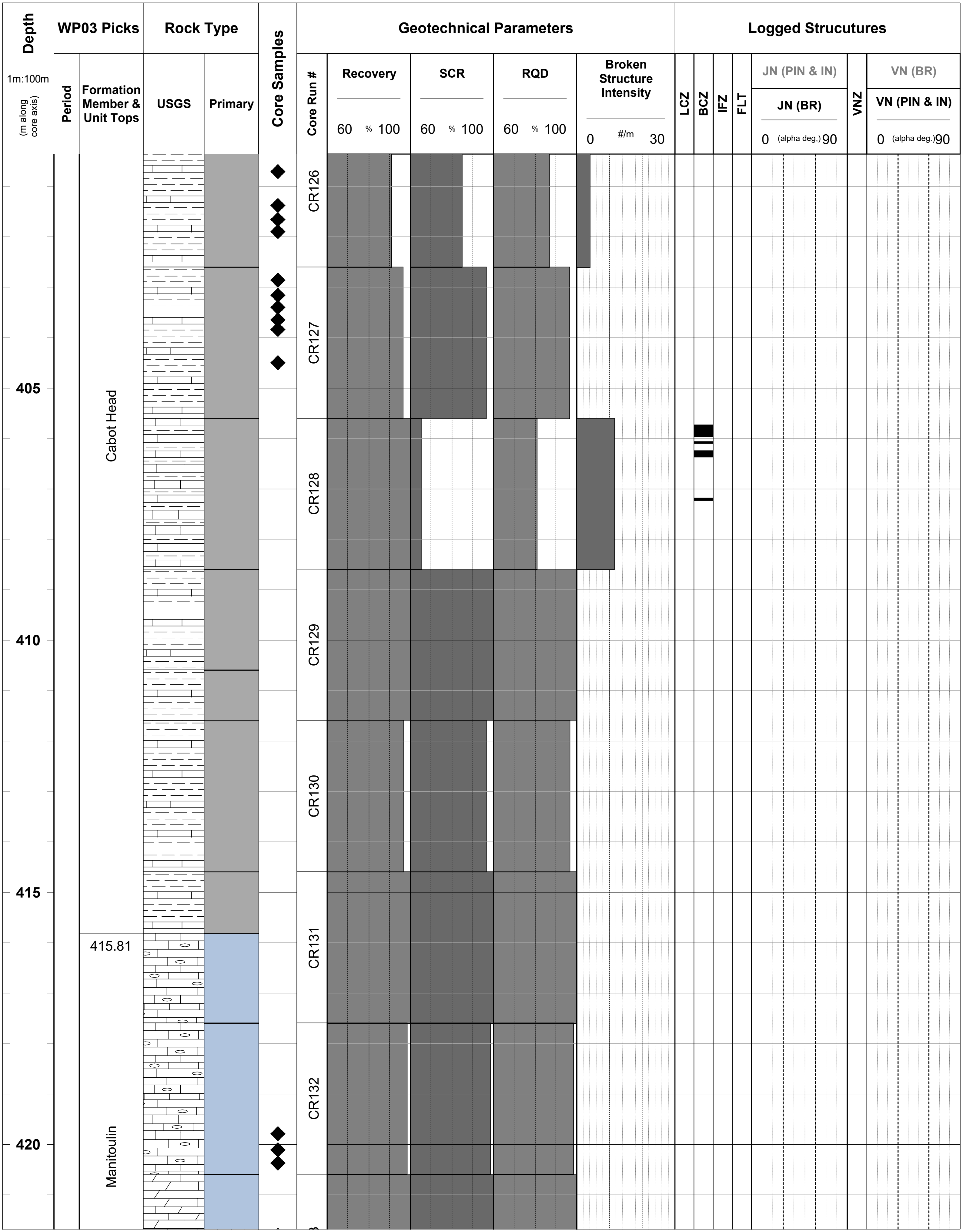
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RQD
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Broken Structure Intensity
0 #/m 30
Logged Strucutures
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BCZ
IFZ
FLT
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JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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420
Cabot Head
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Manitoulin
CR126
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CR131
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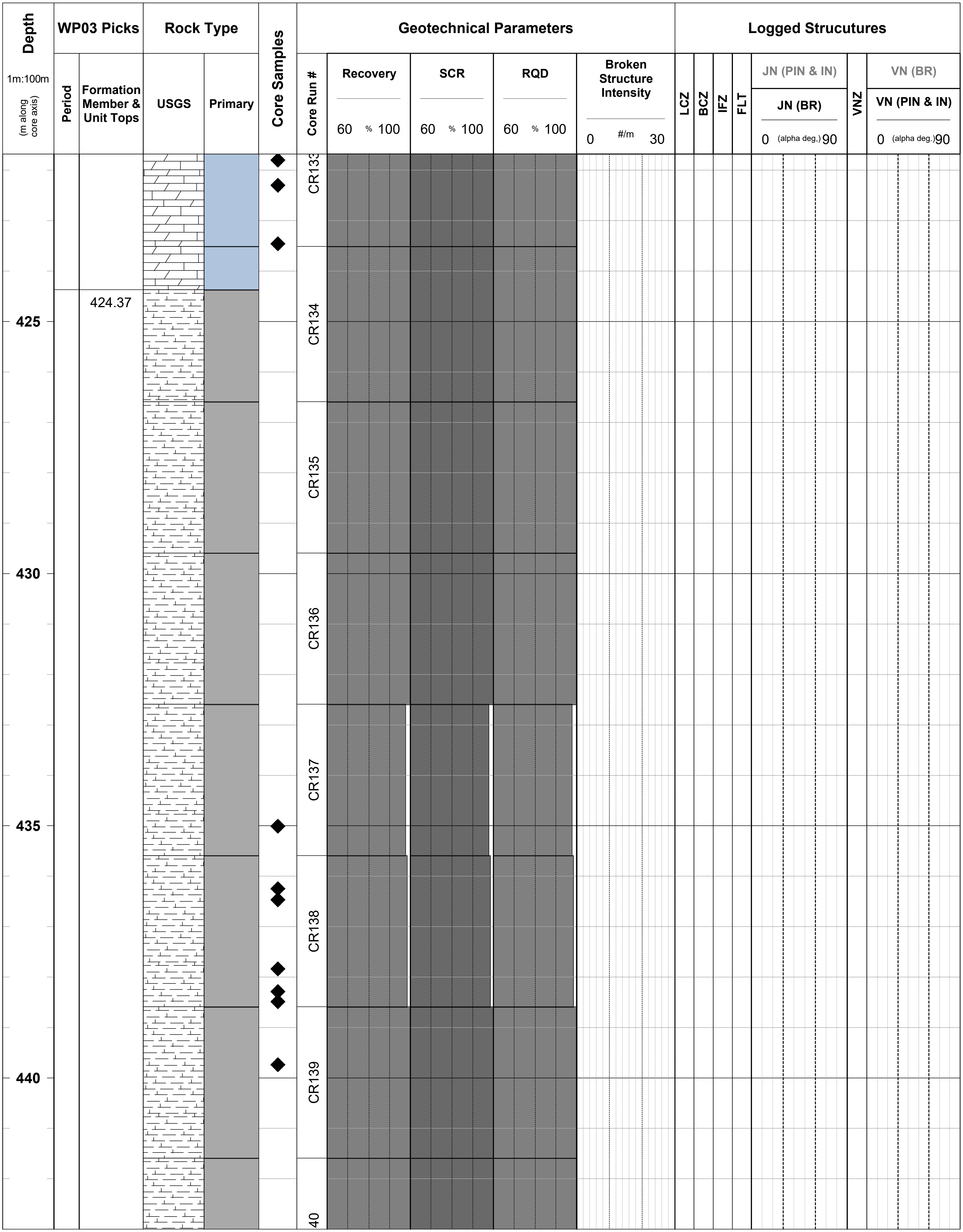
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Primary
Core Samples
Core Run #
Geotechnical Parameters
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SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
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JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
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435
440
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CR135
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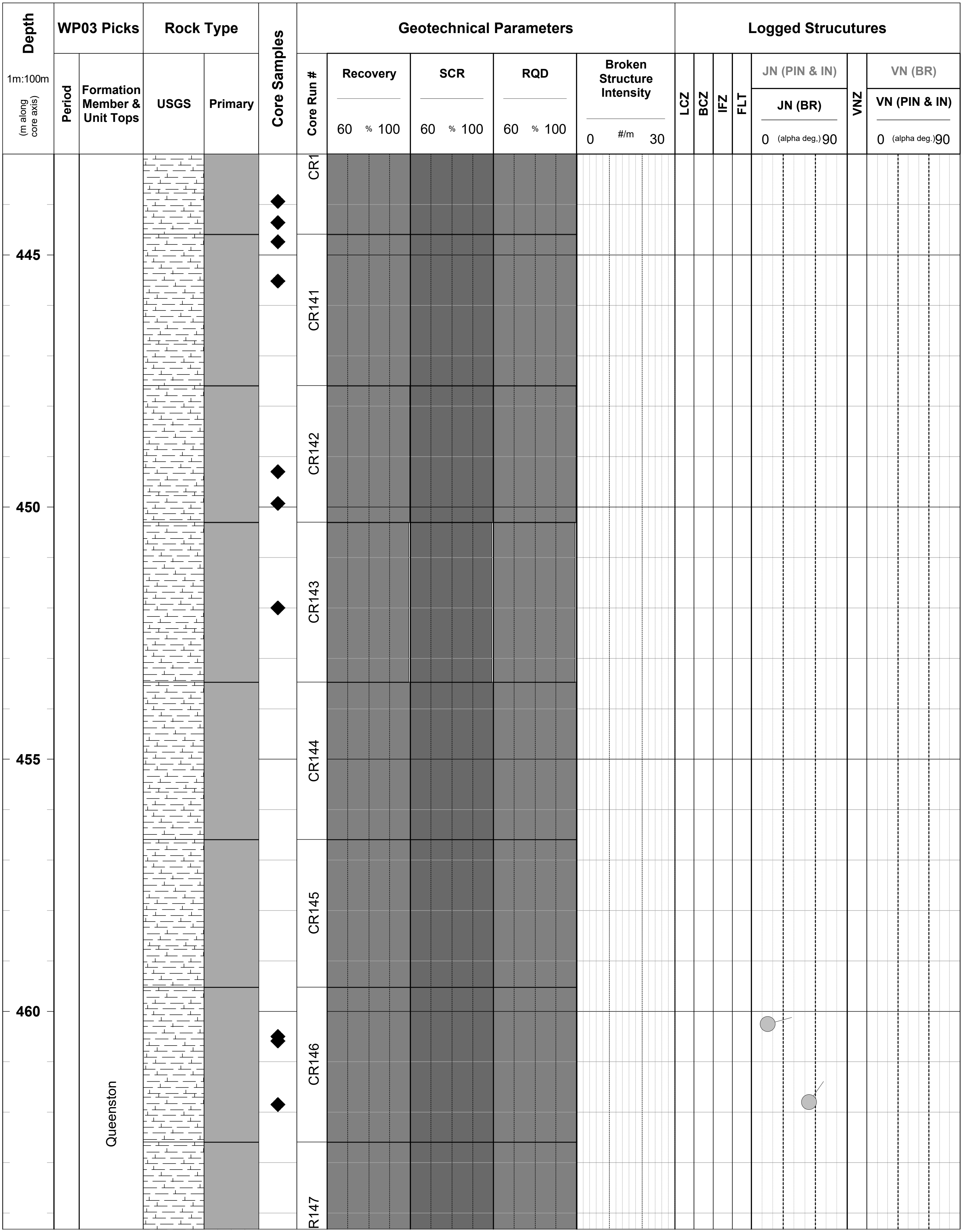
CR137
CR138
CR139
40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Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
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SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
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450
455
460
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CR141
CR142
CR143
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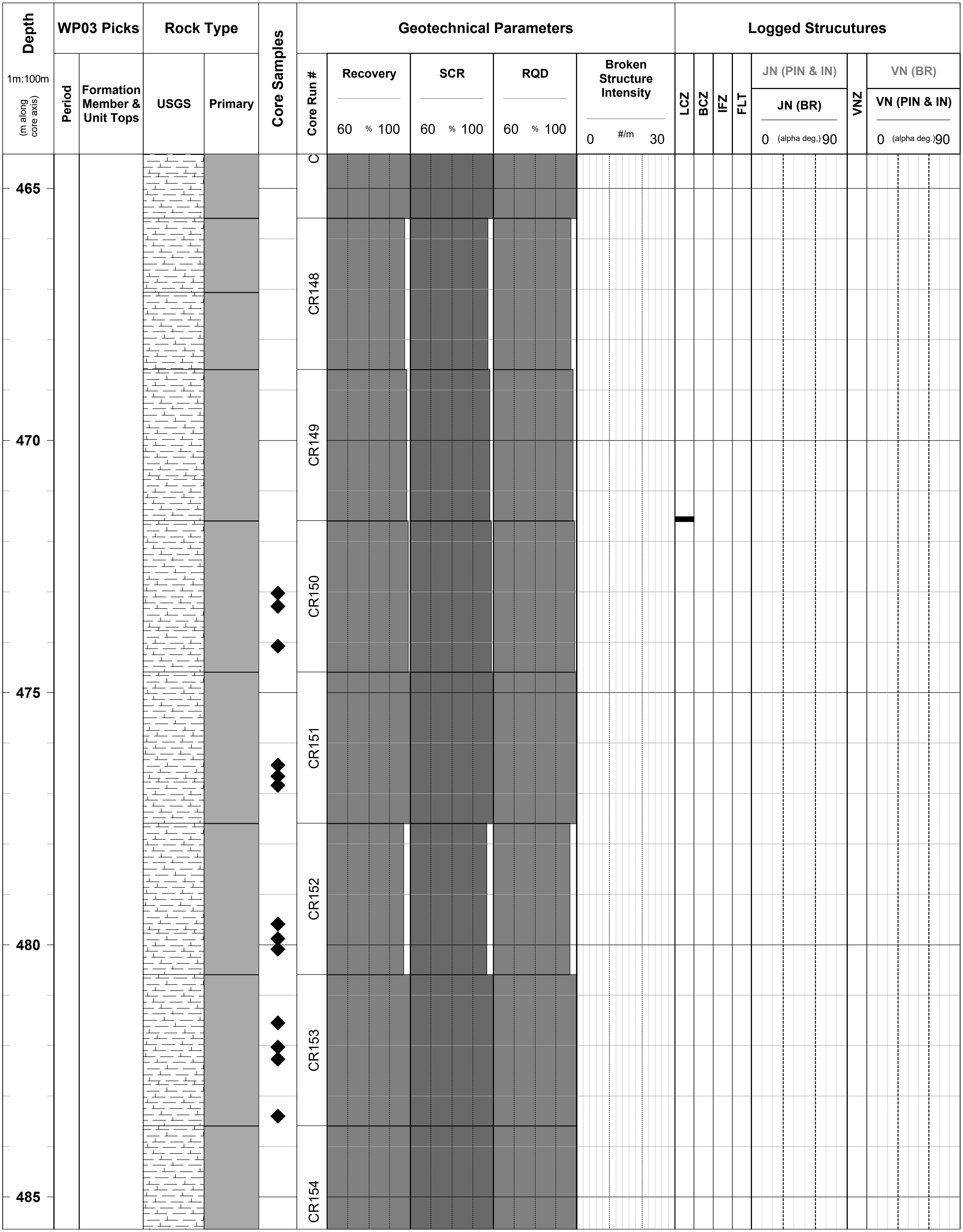
CR145
CR146
R147
Queenston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(m along core axis)
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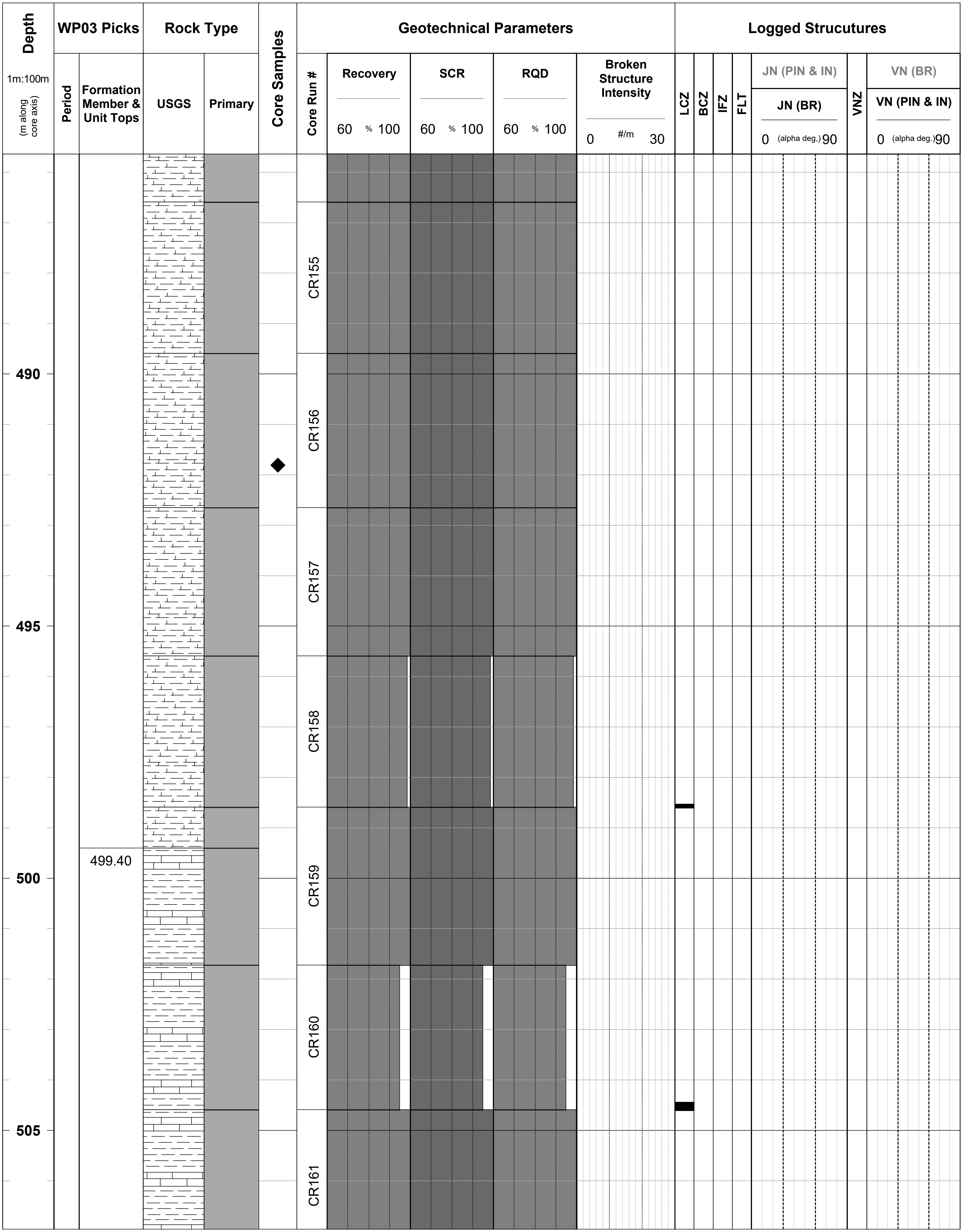
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
465
470
475
480
485
C
CR148
CR149
CR150
CR151
CR152
CR153
CR154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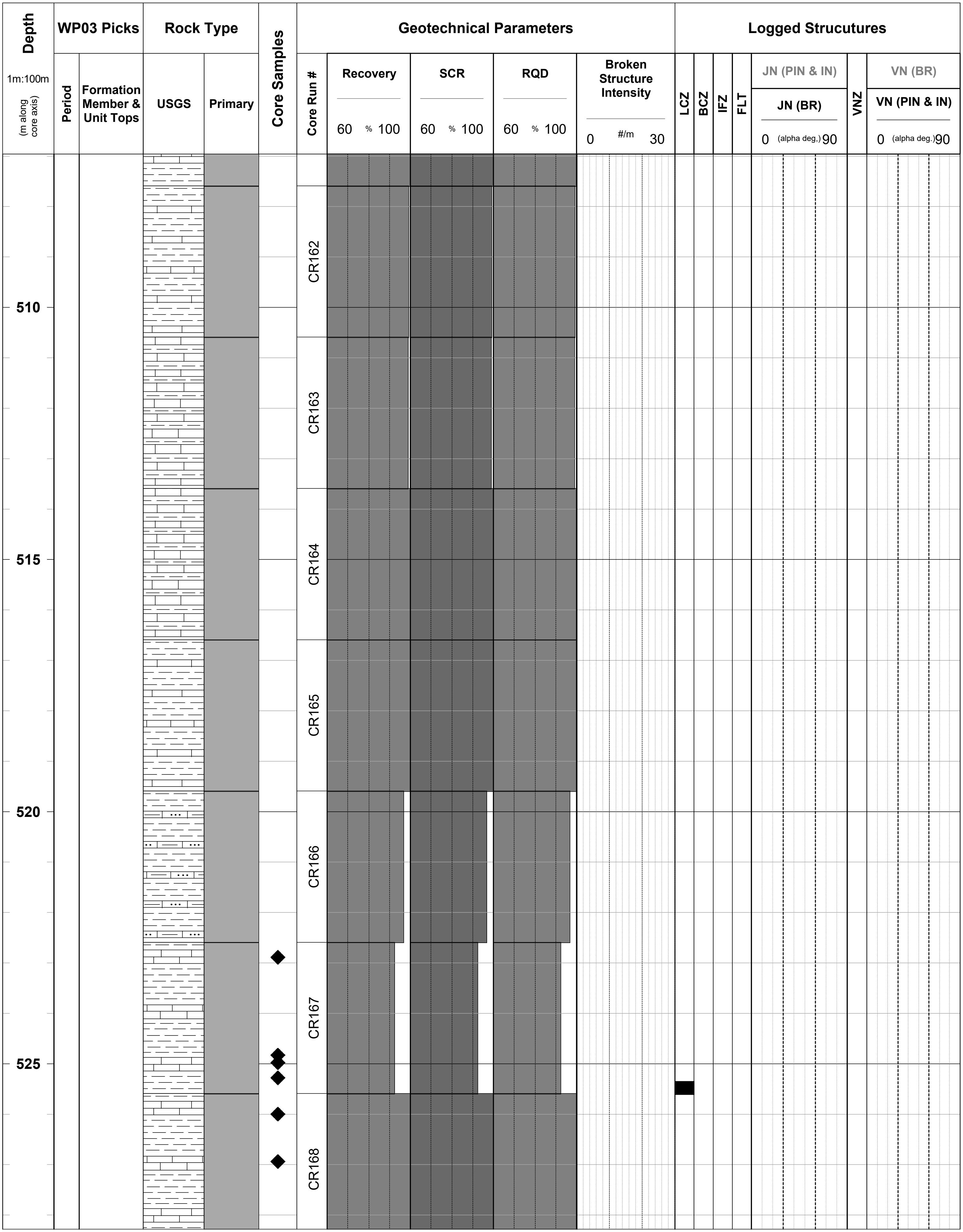
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
490
495
500
505
499.40
CR155
CR156
CR157
CR158
CR159
CR160
CR161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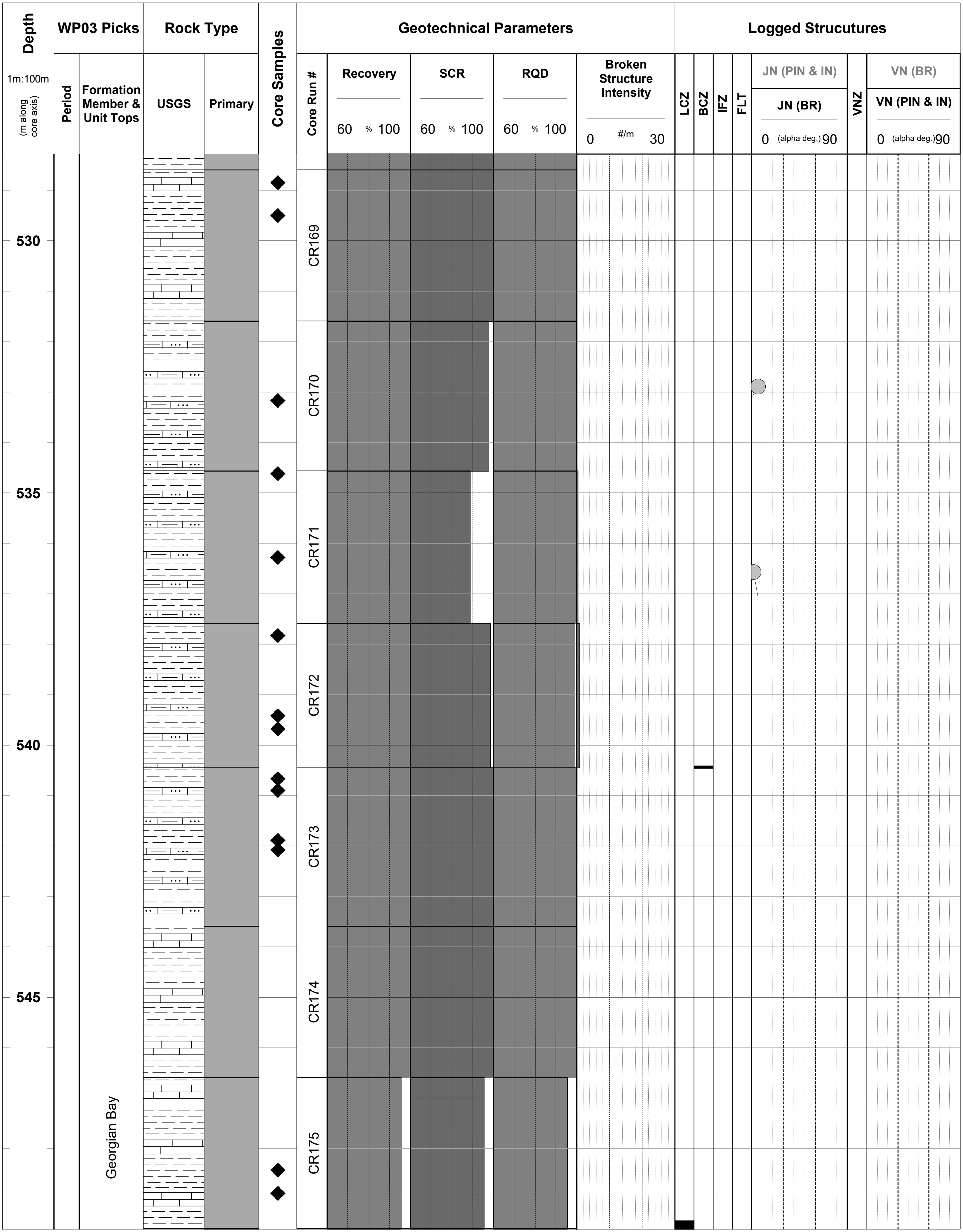
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
510
515
520
525
CR162
CR163
CR164
CR165
CR166
CR167
CR168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WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
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JN (BR)
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VNZ
VN (BR)
VN (PIN & IN)
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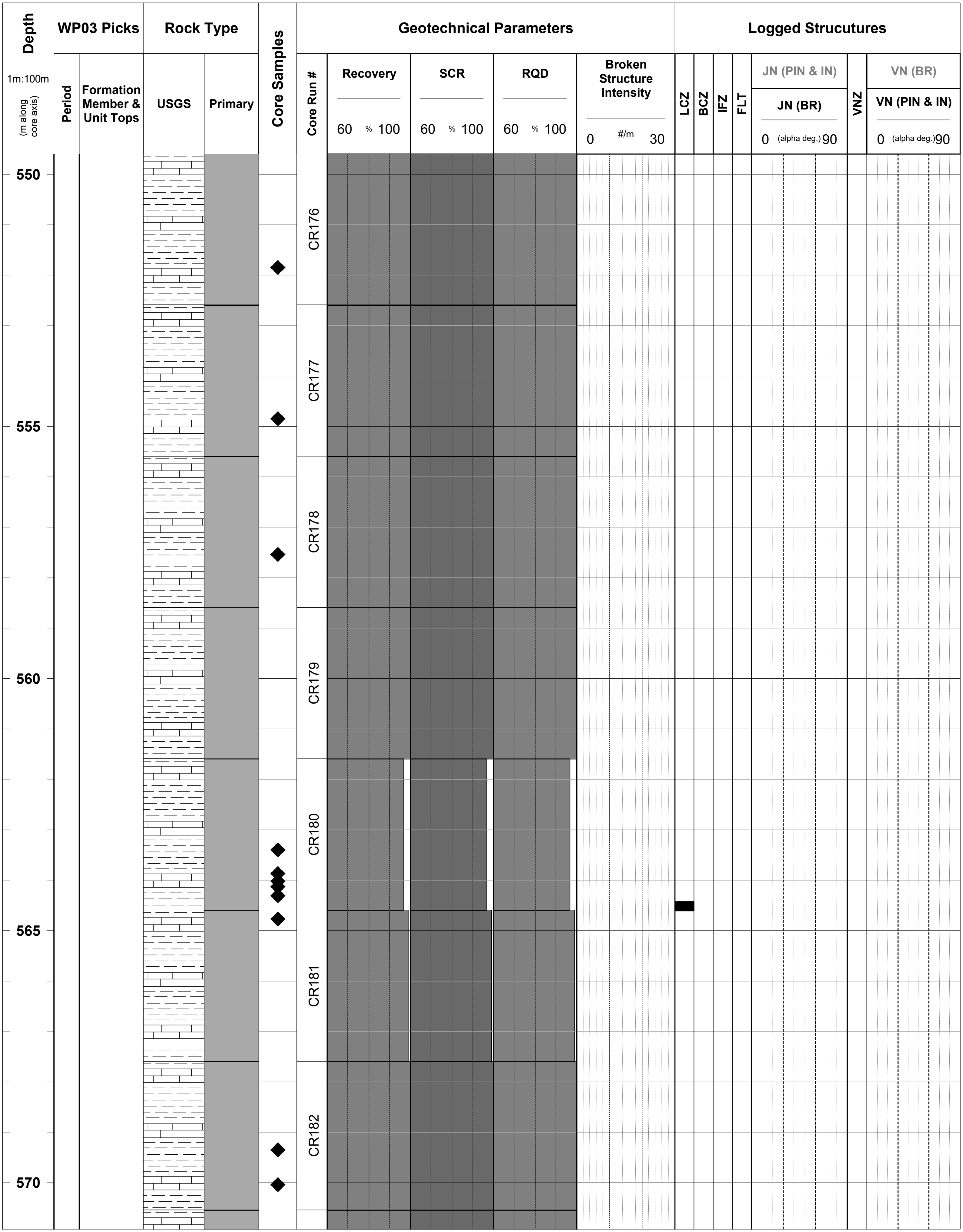
535
540
545
CR169
CR170
CR171
CR172
CR173
CR174
CR175
Georgian Bay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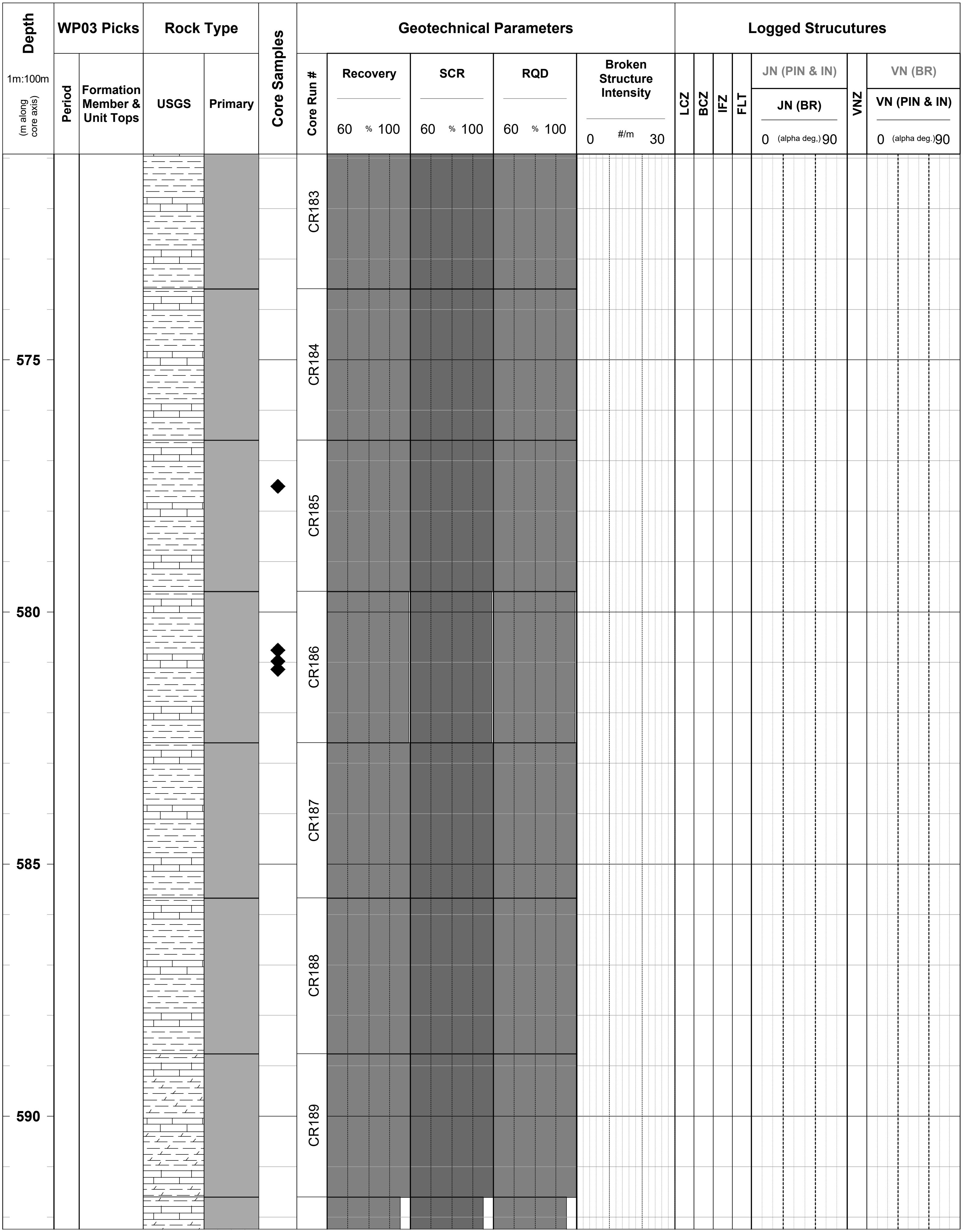
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
550
555
560
565
570
CR176
CR177
CR178
CR179
CR180
CR181
CR182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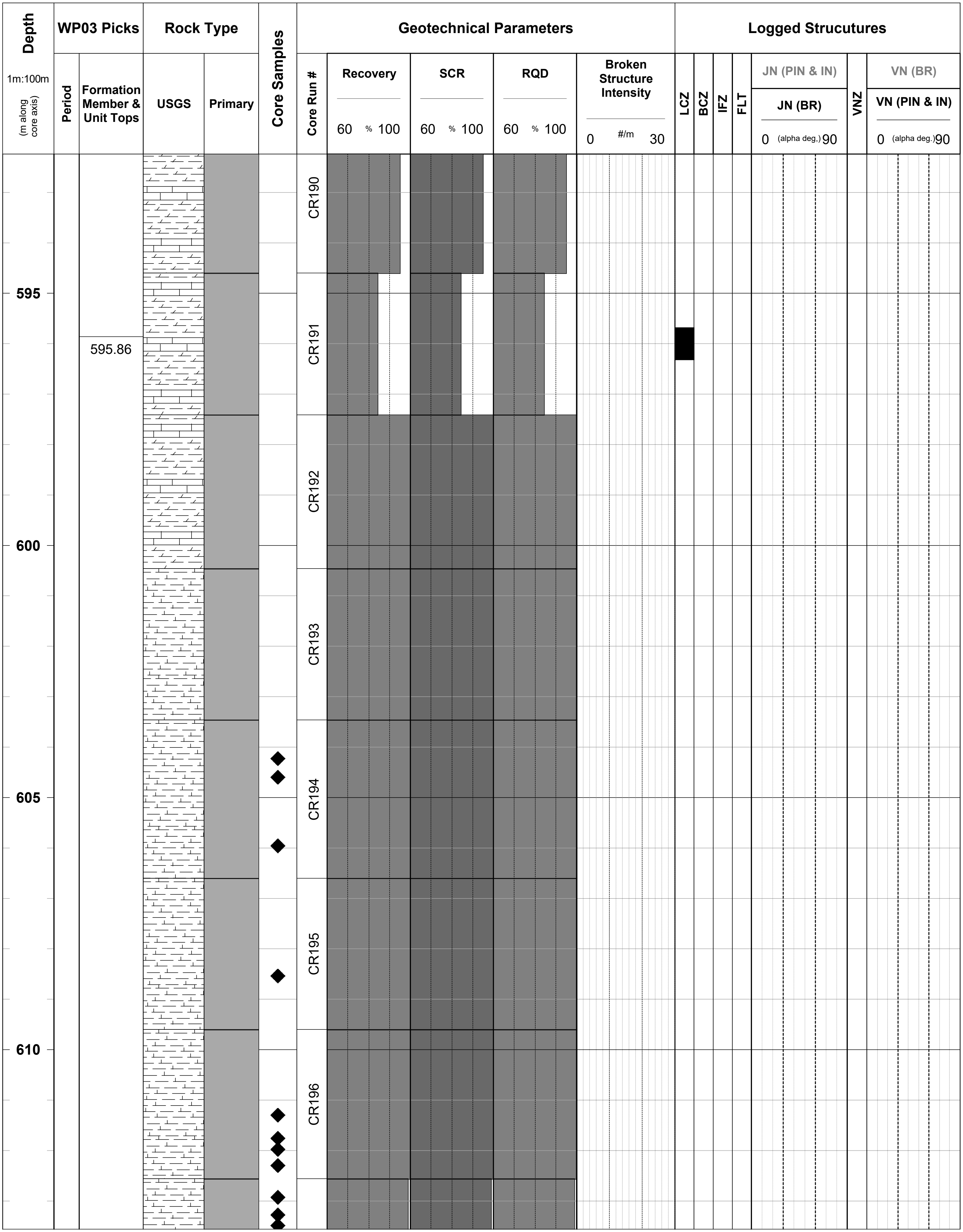
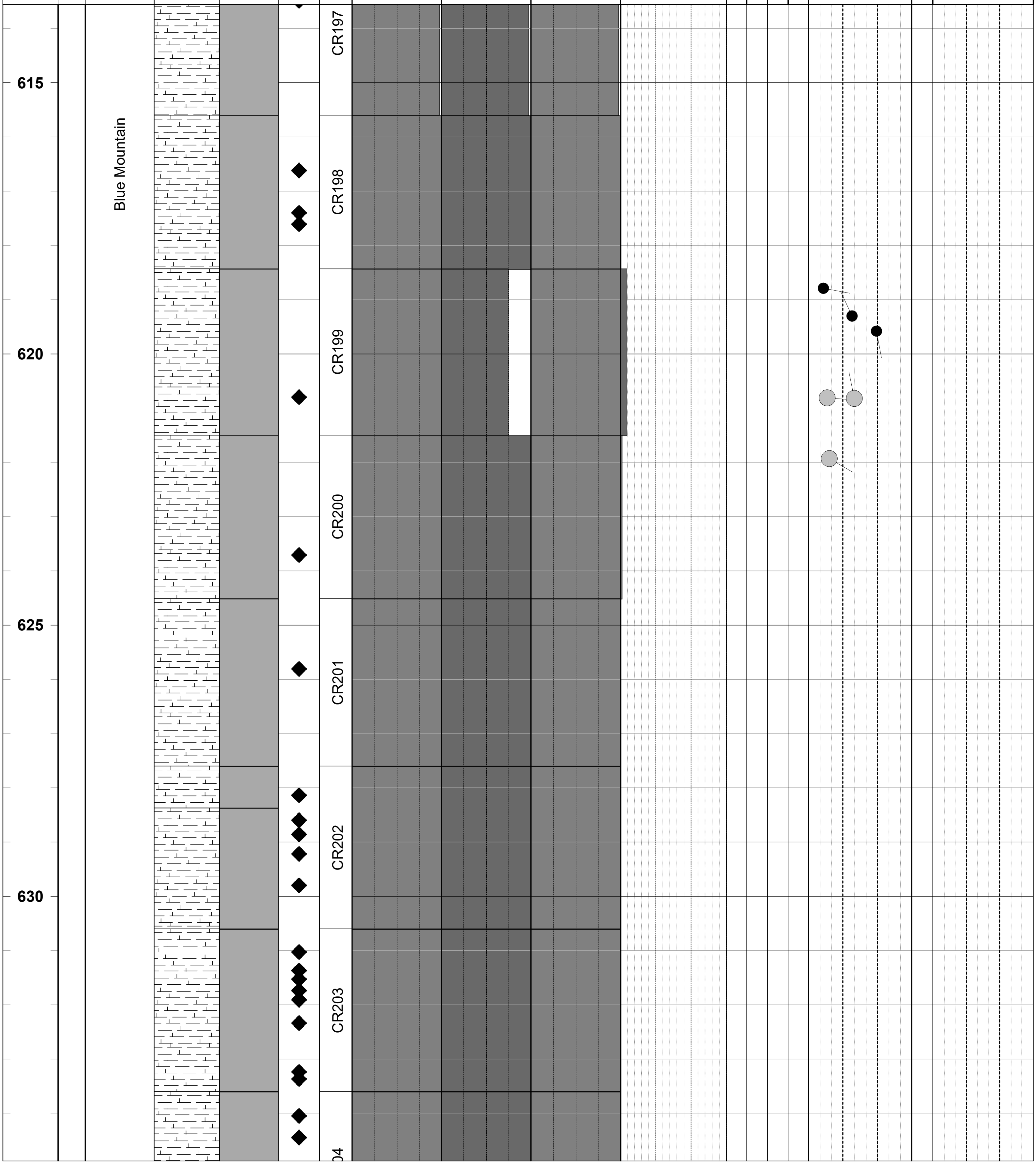
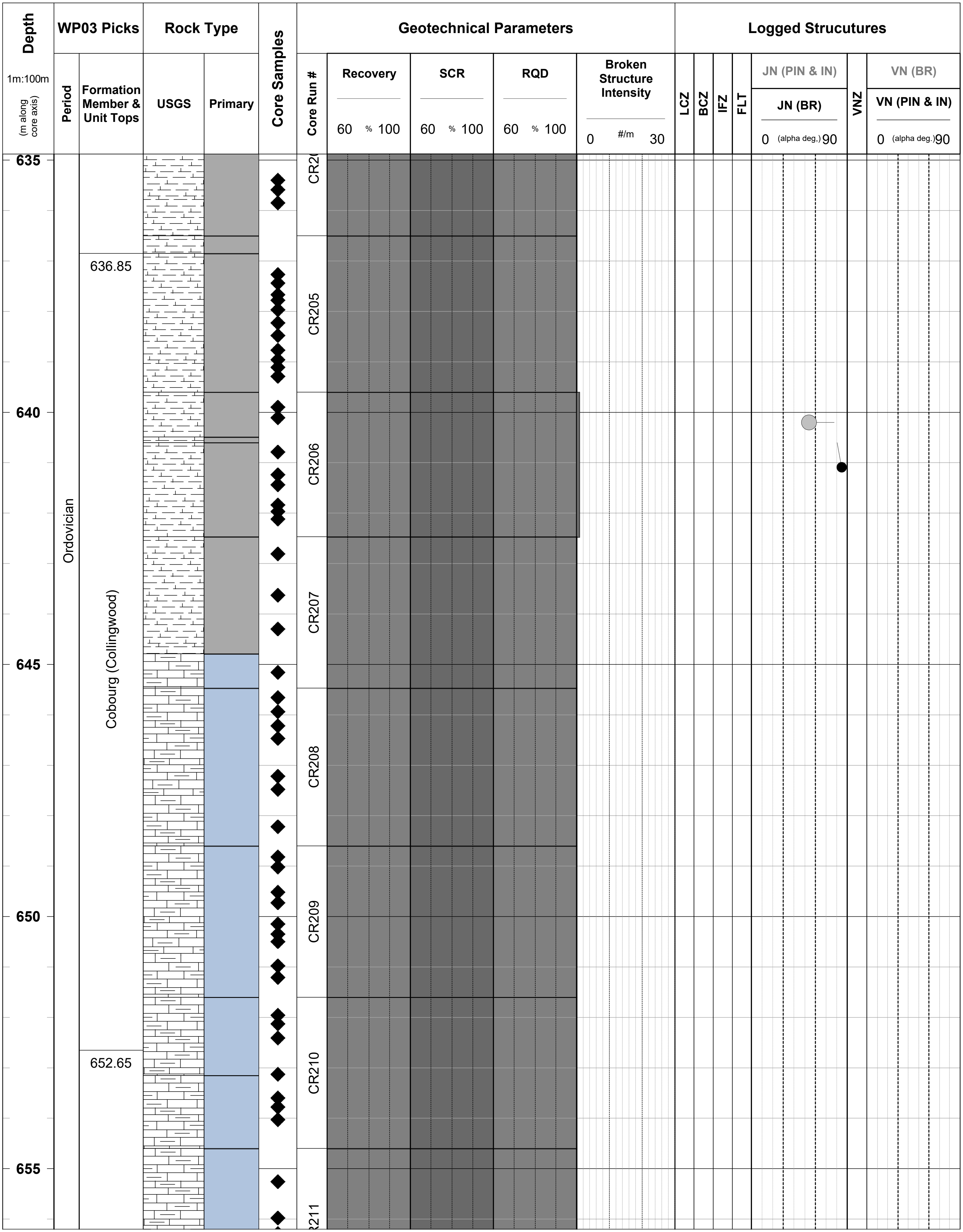
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
575
580
585
590
CR183
CR184
CR185
CR186
CR187
CR188
CR189

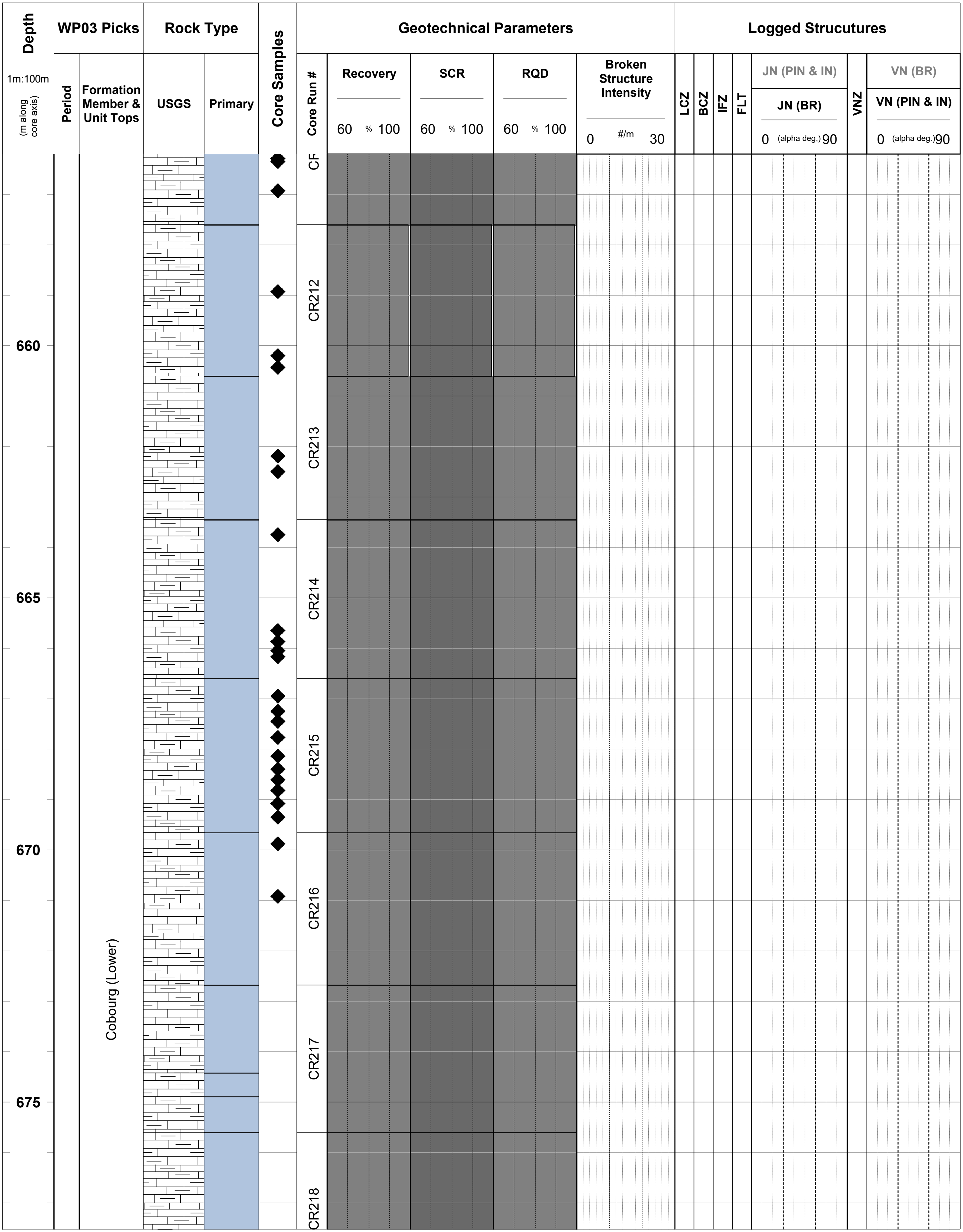

Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
595
600
605
610
595.86
CR190
CR191
CR192
CR193
CR194
CR195
CR196

Depth	WP03 Picks		Rock Type		Core Samples	Geotechnical Parameters					Logged Strucutures						
1m:100m (m along core axis)	Period	Formation Member & Unit Tops	USGS	Primary		Core Run #	Recovery 60 % 100	SCR 60 % 100	RQD 60 % 100	Broken Structure Intensity 0 #/m 30	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) 0 (alpha deg.) 90	VNZ	VN (BR) / VN (PIN & IN) 0 (alpha deg.) 90

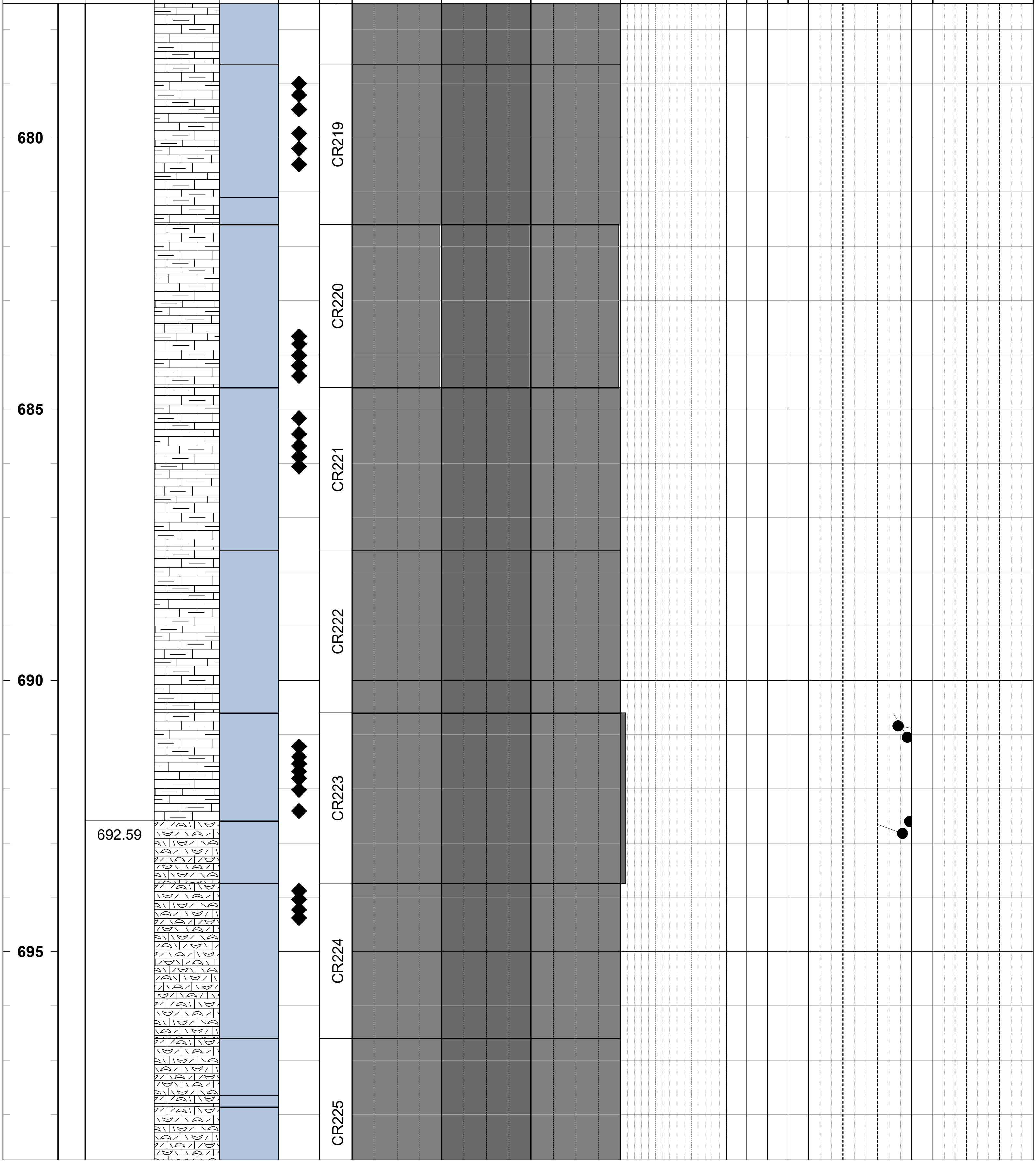


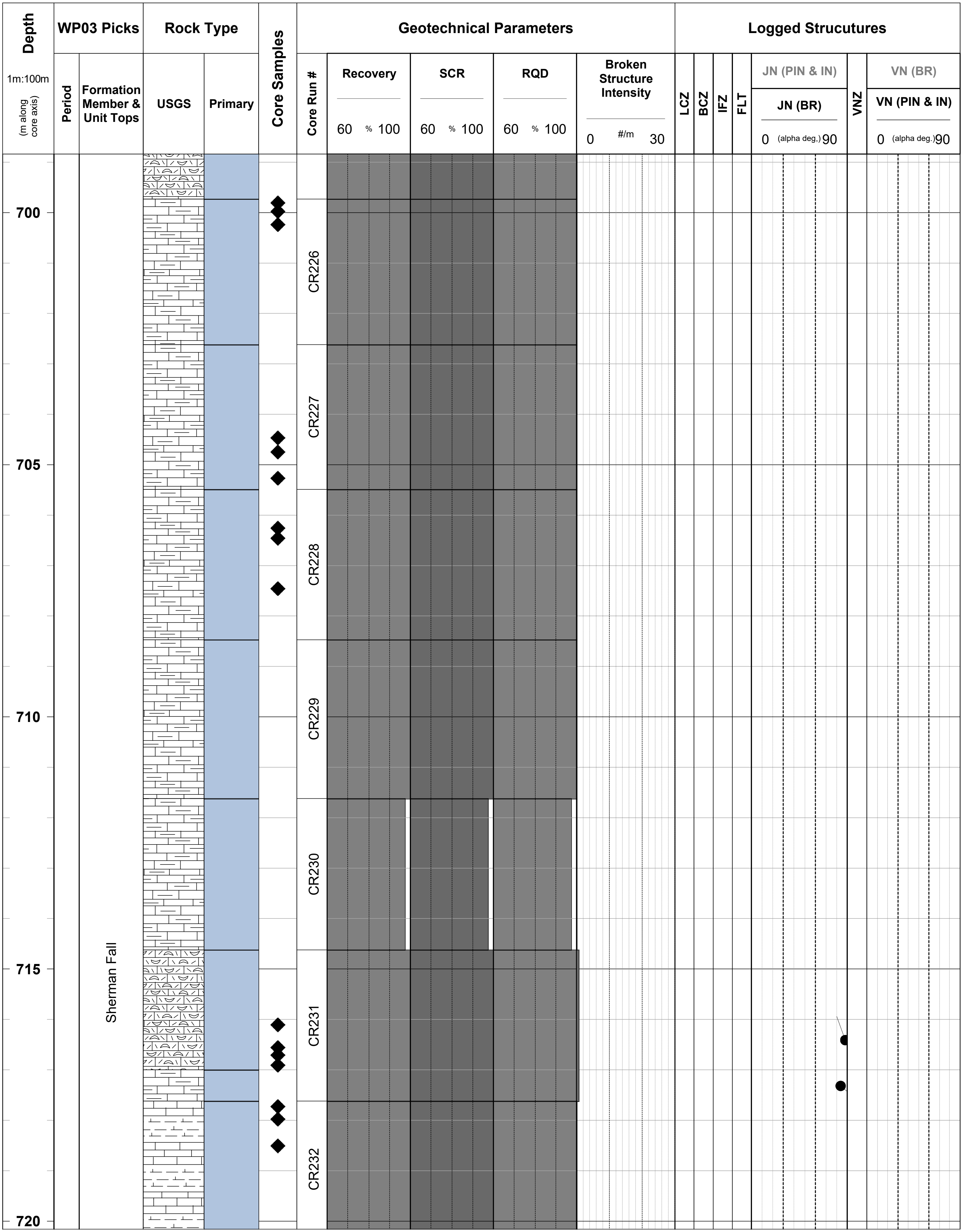


Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
635
640
645
650
655
Ordovician
636.85
Cobourg (Collingwood)
652.65
CR205
CR206
CR207
CR208
CR209
CR210

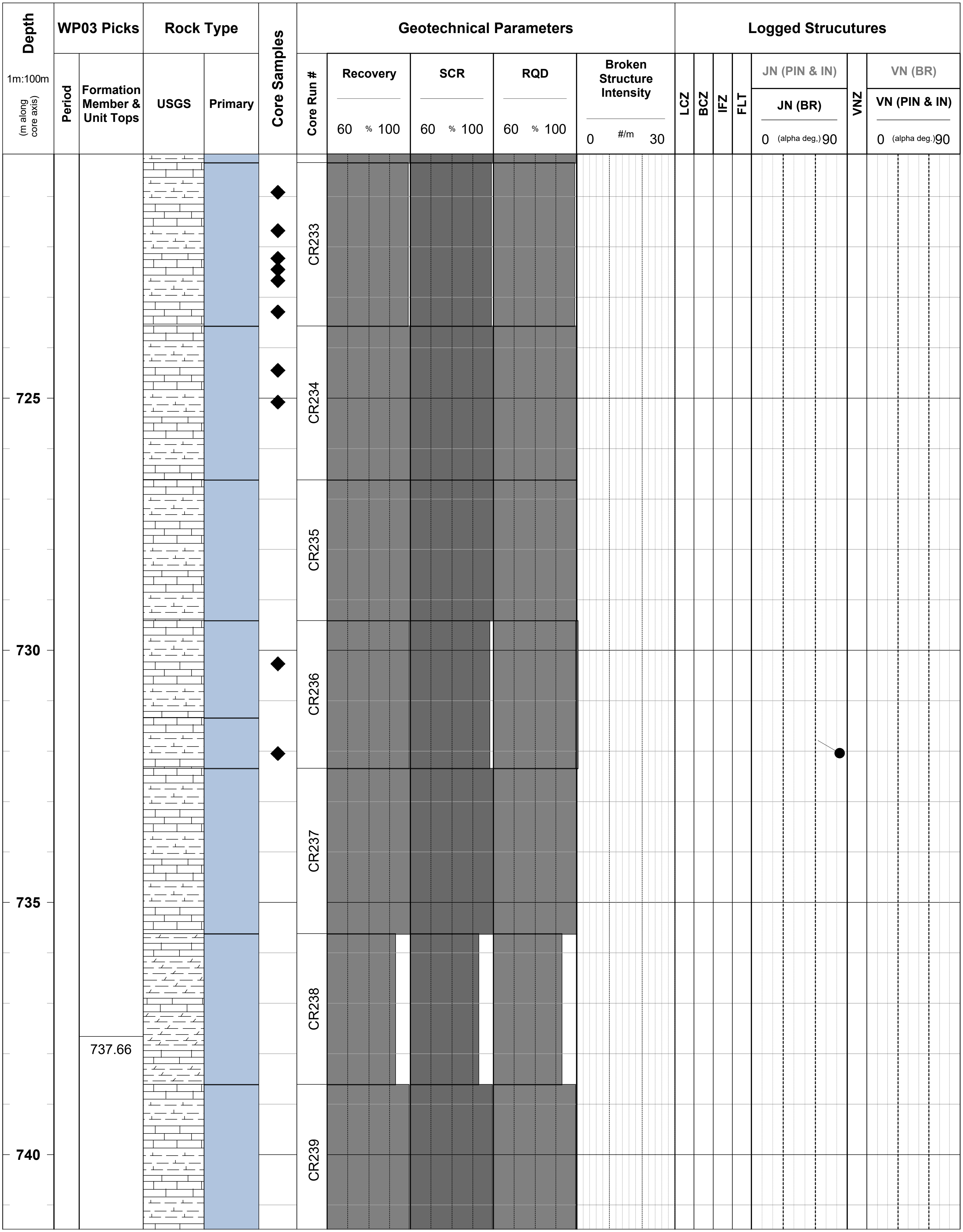

Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
660
665
670
675
CR
CR212
CR213
CR214
CR215
CR216
CR217
CR218
Cobourg (Lower)

Depth (m along core axis) 1m:100m	WP03 Picks: Period	WP03 Picks: Formation Member & Unit Tops	Rock Type: USGS	Rock Type: Primary	Core Samples	Core Run #	Recovery 60 % 100	SCR 60 % 100	RQD 60 % 100	Broken Structure Intensity 0 #/m 30	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) 0 (alpha deg.) 90	VNZ	VN (BR) / VN (PIN & IN) 0 (alpha deg.) 90

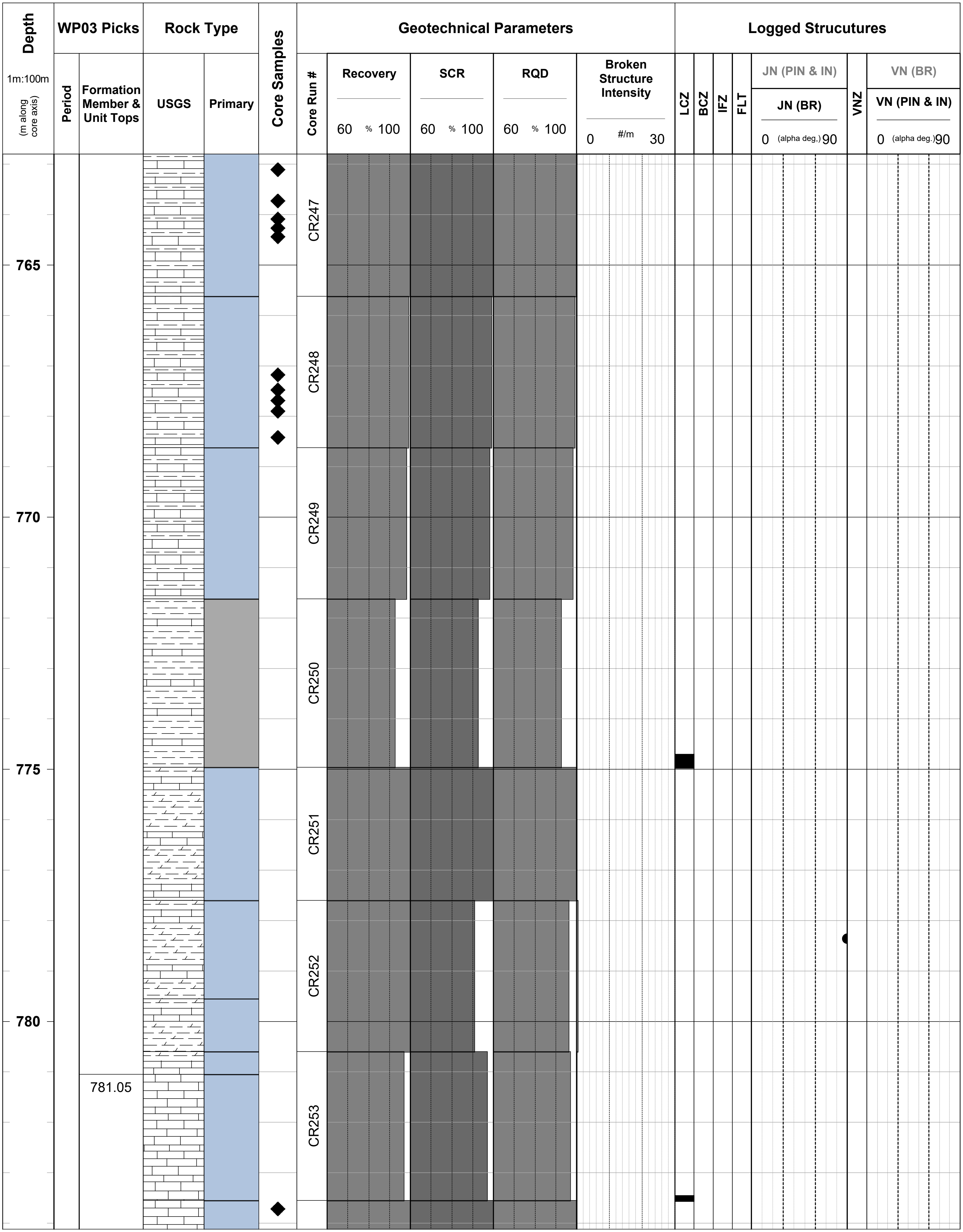


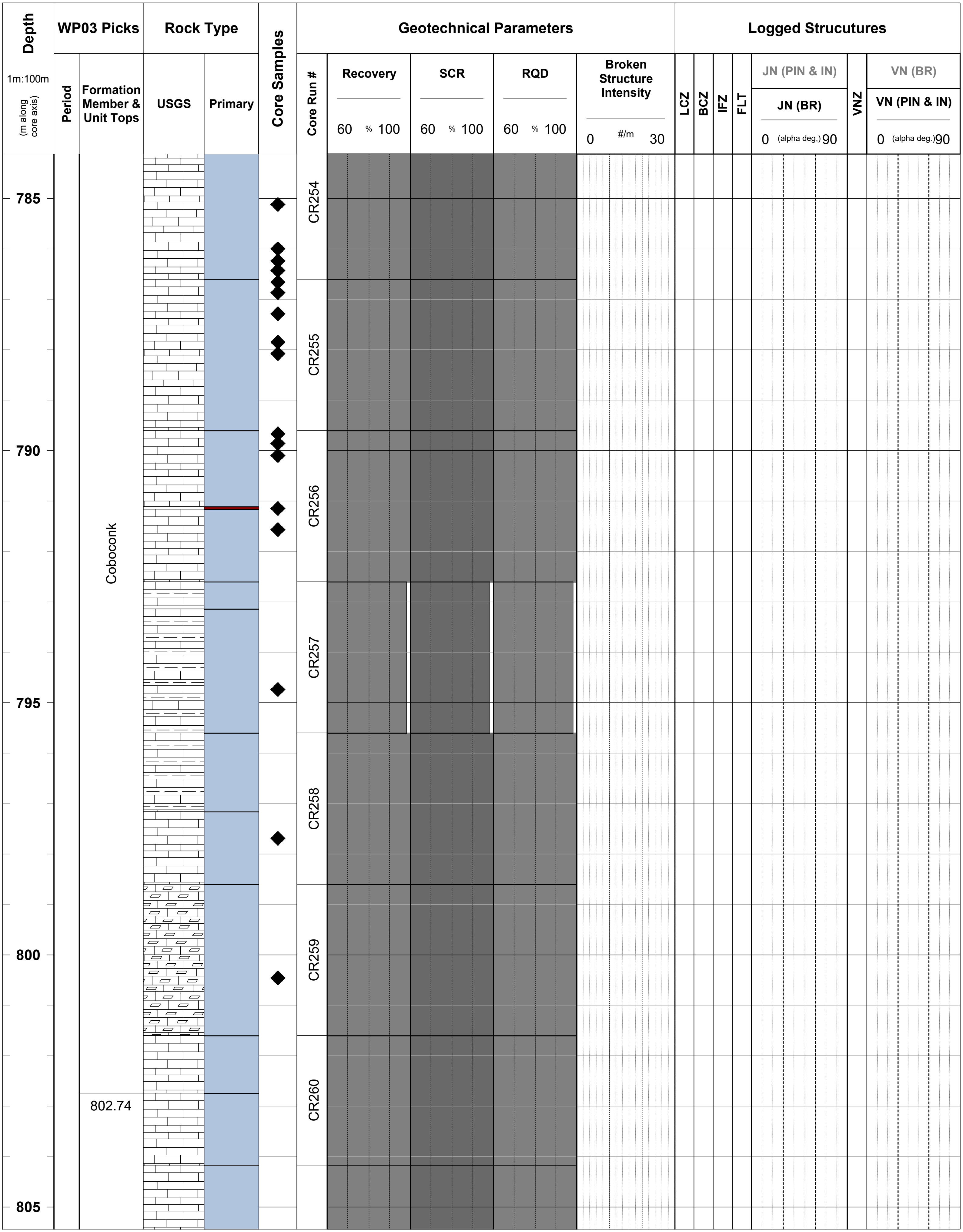


Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
700
705
710
715
720
Sherman Fall
CR226
CR227
CR228
CR229
CR230
CR231
CR232

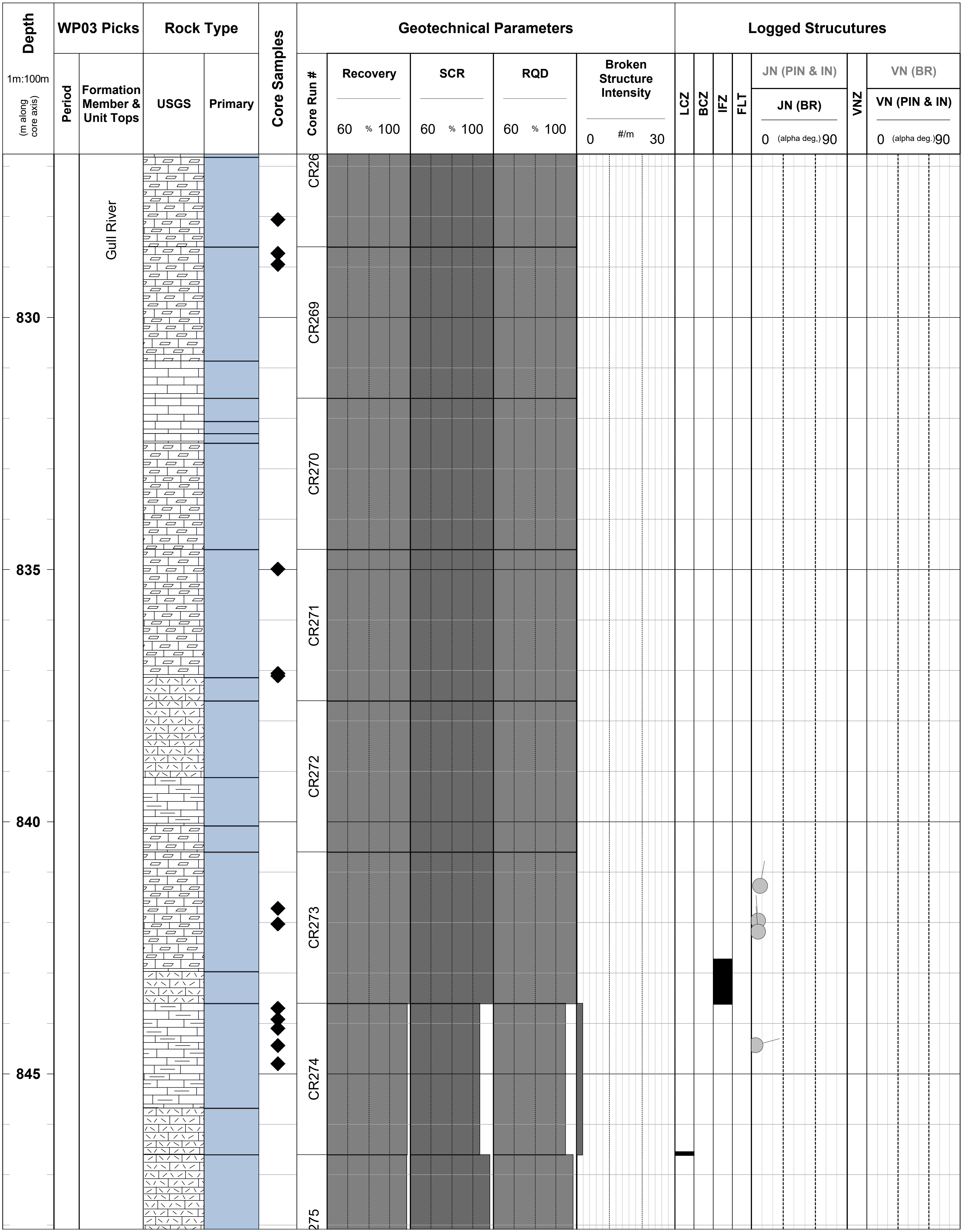

Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
725
730
735
740
737.66
CR233
CR234
CR235
CR236
CR237
CR238
CR239

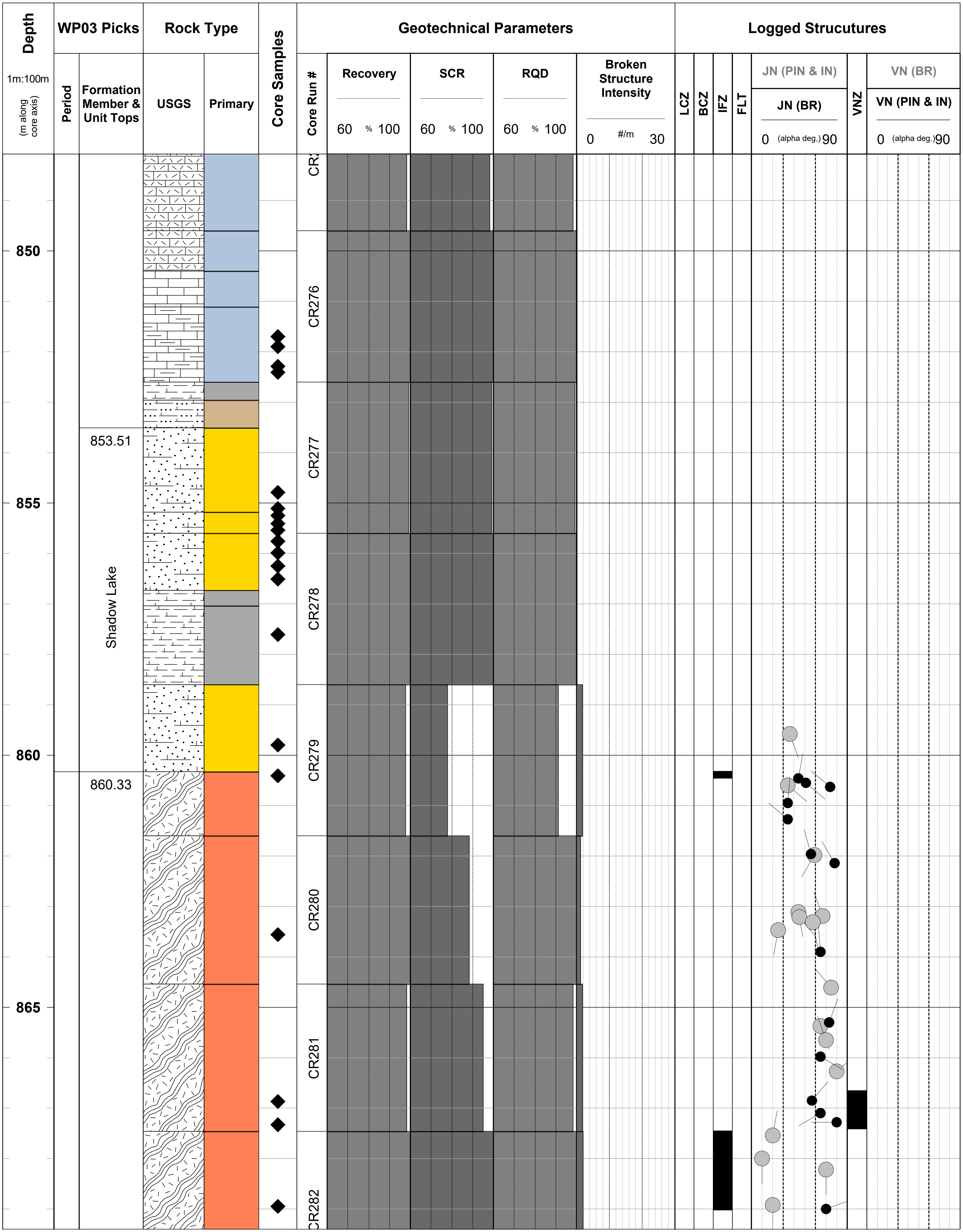
Depth	WP03 Picks		Rock Type		Core Samples	Geotechnical Parameters					Logged Strucutures						
1m:100m (m along core axis)	Period	Formation Member & Unit Tops	USGS	Primary		Core Run #	Recovery 60 % 100	SCR 60 % 100	RQD 60 % 100	Broken Structure Intensity 0 #/m 30	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) 0 (alpha deg.) 90	VNZ	VN (BR) / VN (PIN & IN) 0 (alpha deg.) 90
						CR240											
745						CR241											
						CR242											
750						CR243											
755						CR244											
		Kirkfield				CR245											
760						CR246											

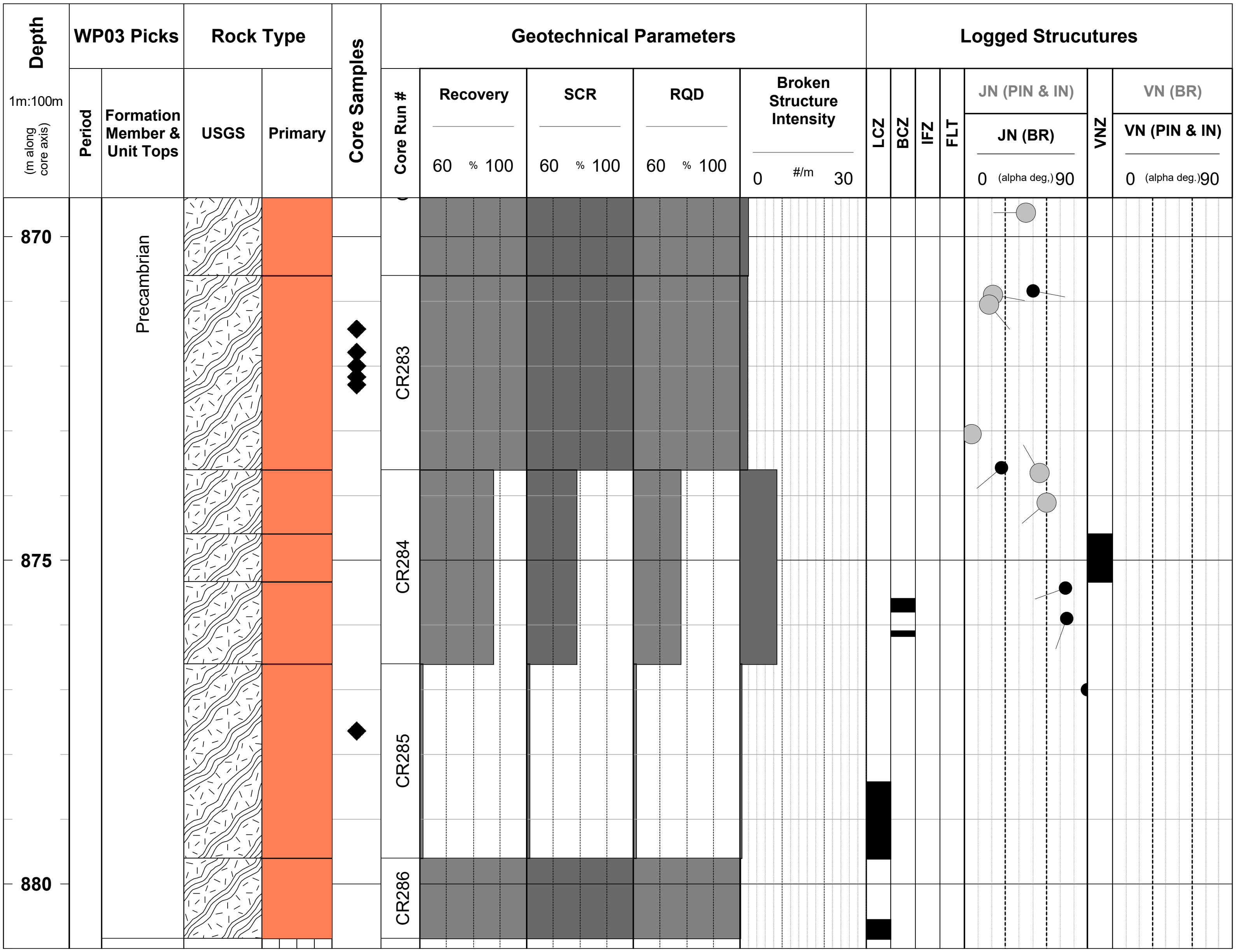

Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
765
770
775
780
781.05
CR247
CR248
CR249
CR250
CR251
CR252
CR253


Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
785
790
795
800
805
Coboconk
802.74
CR254
CR255
CR256
CR257
CR258
CR259
CR260

Depth	WP03 Picks		Rock Type		Core Samples	Geotechnical Parameters					Logged Strucutures							
1m:100m (m along core axis)	Period	Formation Member & Unit Tops	USGS	Primary		Core Run #	Recovery 60 % 100	SCR 60 % 100	RQD 60 % 100	Broken Structure Intensity 0 #/m 30	LCZ	BCZ	IFZ	FLT	JN (PIN & IN) / JN (BR) 0 (alpha deg.) 90	VNZ	VN (BR) / VN (PIN & IN) 0 (alpha deg.) 90
						CR261											
						CR262											
810						CR263											
815						CR264											
						CR265											
820						CR266											
						CR267											
825						8											


Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Structuctures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
830
835
840
845
Gull River
CR26
CR269
CR270
CR271
CR272
CR273
CR274
275

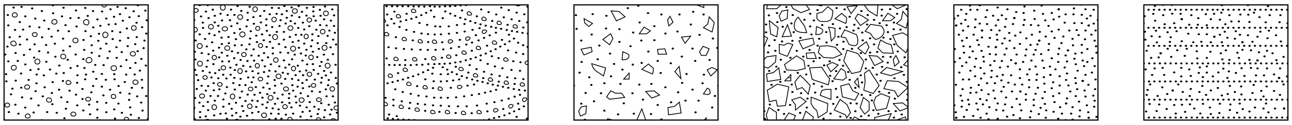

Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Geotechnical Parameters
Core Run #
Recovery
60 % 100
SCR
60 % 100
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
0 (alpha deg.) 90
850
855
860
865
853.51
Shadow Lake
860.33
CR276
CR277
CR278
CR279
CR280
CR281
CR282


Depth
1m:100m
(m along core axis)
WP03 Picks
Period
Formation Member & Unit Tops
Rock Type
USGS
Primary
Core Samples
Core Run #
Geotechnical Parameters
Recovery
SCR
RQD
60 % 100
Broken Structure Intensity
0 #/m 30
Logged Strucutures
LCZ
BCZ
IFZ
FLT
JN (PIN & IN)
JN (BR)
0 (alpha deg.) 90
VNZ
VN (BR)
VN (PIN & IN)
870
875
880
Precambrian
CR283
CR284
CR285
CR286

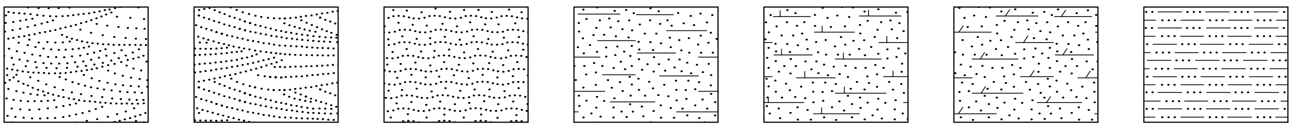
37—LITHOLOGIC PATTERNS

[Lithologic patterns are usually reserved for use on stratigraphic columns, sections, or charts]

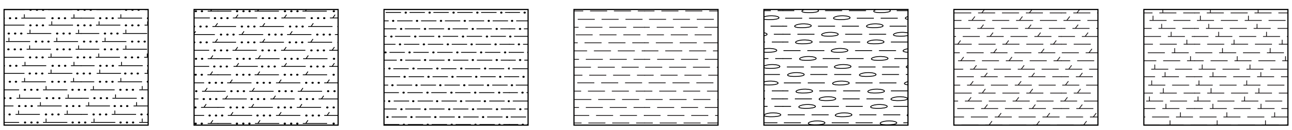
37.1—Sedimentary-rock lithologic patterns



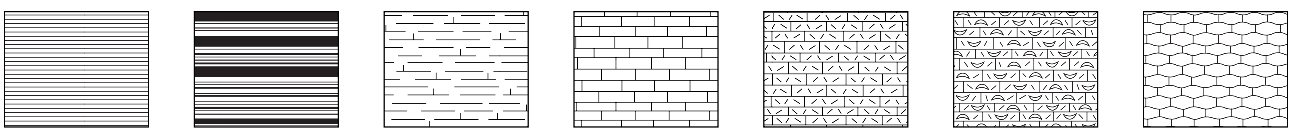
- 601 Gravel or conglomerate (1st option)
- 602 Gravel or conglomerate (2nd option)
- 603 Crossbedded gravel or conglomerate
- 605 Breccia (1st option)
- 606 Breccia (2nd option)
- 607 Massive sand or sandstone
- 608 Bedded sand or sandstone



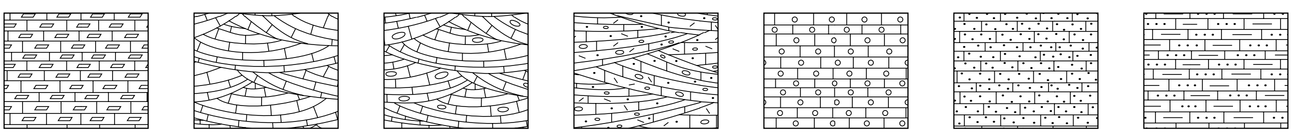
- 609 Crossbedded sand or sandstone (1st option)
- 610 Crossbedded sand or sandstone (2nd option)
- 611 Ripple-bedded sand or sandstone
- 612 Argillaceous or shaly sandstone
- 613 Calcareous sandstone
- 614 Dolomitic sandstone
- 616 Silt, siltstone, or shaly silt



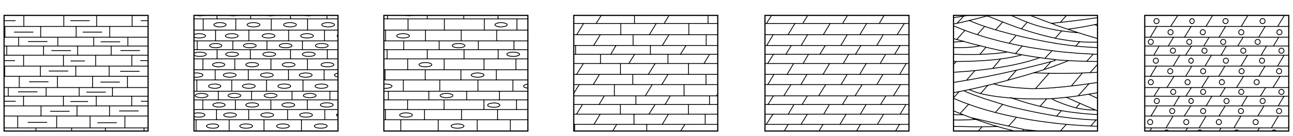
- 617 Calcareous siltstone
- 618 Dolomitic siltstone
- 619 Sandy or silty shale
- 620 Clay or clay shale
- 621 Cherty shale
- 622 Dolomitic shale
- 623 Calcareous shale or marl



- 624 Carbonaceous shale
- 625 Oil shale
- 626 Chalk
- 627 Limestone
- 628 Clastic limestone
- 629 Fossiliferous clastic limestone
- 630 Nodular or irregularly bedded limestone



- 631 Limestone, irregular (burrow?) fillings of saccharoidal dolomite
- 632 Crossbedded limestone
- 633 Cherty crossbedded limestone
- 634 Cherty and sandy crossbedded clastic limestone
- 635 Oolitic limestone
- 636 Sandy limestone
- 637 Silty limestone



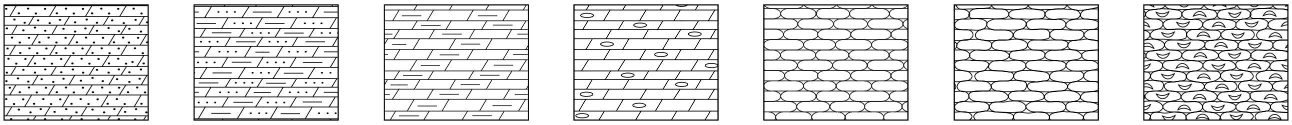
- 638 Argillaceous or shaly limestone
- 639 Cherty limestone (1st option)
- 640 Cherty limestone (2nd option)
- 641 Dolomitic limestone, limy dolostone, or limy dolomite
- 642 Dolostone or dolomite
- 643 Crossbedded dolostone or dolomite
- 644 Oolitic dolostone or dolomite

*For more information, see general guidelines on pages A-i to A-v.

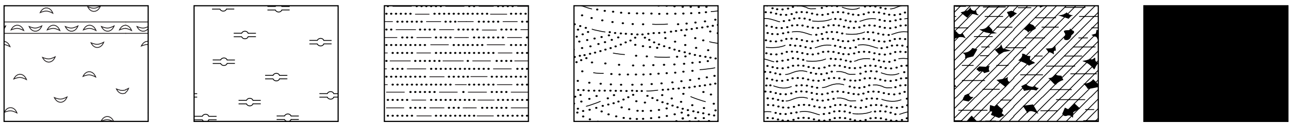
37—LITHOLOGIC PATTERNS (continued)

[Lithologic patterns are usually reserved for use on stratigraphic columns, sections, or charts]

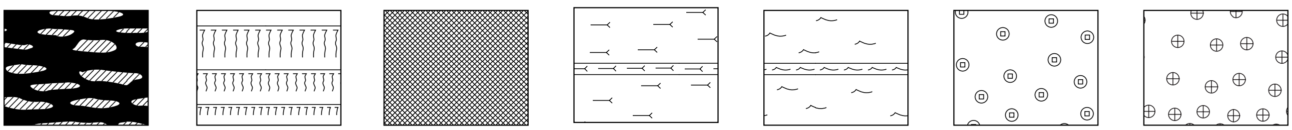
37.1—Sedimentary-rock lithologic patterns (continued)



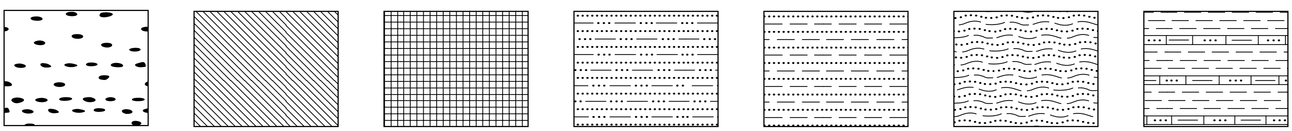
645 Sandy dolostone or dolomite	646 Silty dolostone or dolomite	647 Argillaceous or shaly dolostone or dolomite	648 Cherty dolostone or dolomite	649 Bedded chert (1st option)	650 Bedded chert (2nd option)	651 Fossiliferous bedded chert



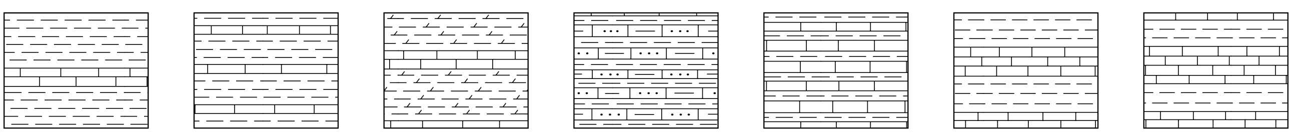
652 Fossiliferous rock	653 Diatomaceous rock	654 Subgraywacke	655 Crossbedded subgraywacke	656 Ripple-bedded subgraywacke	657 Peat	658 Coal



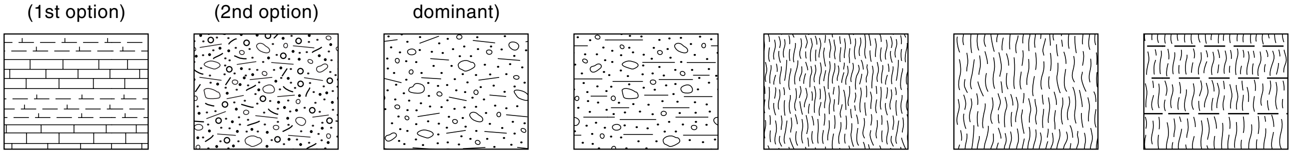
659 Bony coal or impure coal	660 Underclay	661 Flint clay	662 Bentonite	663 Glauconite	664 Limonite	665 Siderite



666 Phosphatic-nodular rock	667 Gypsum	668 Salt	669 Interbedded sandstone and siltstone	670 Interbedded sandstone and shale	671 Interbedded ripple-bedded sandstone and shale	672 Interbedded shale and silty limestone (shale dominant)



673 Interbedded shale and limestone (shale dominant) (1st option)	674 Interbedded shale and limestone (shale dominant) (2nd option)	675 Interbedded calcareous shale and limestone (shale dominant)	676 Interbedded silty limestone and shale	677 Interbedded limestone and shale (1st option)	678 Interbedded limestone and shale (2nd option)	679 Interbedded limestone and shale (limestone dominant)



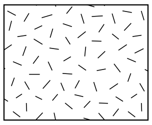
680 Interbedded limestone and calcareous shale	681 Till or diamicton (1st option)	682 Till or diamicton (2nd option)	683 Till or diamicton (3rd option)	684 Loess (1st option)	685 Loess (2nd option)	686 Loess (3rd option)

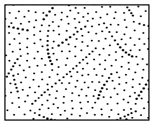
*For more information, see general guidelines on pages A-i to A-v.

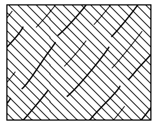
37—LITHOLOGIC PATTERNS (continued)

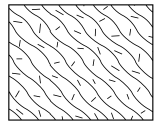
[Lithologic patterns are usually reserved for use on stratigraphic columns, sections, or charts]

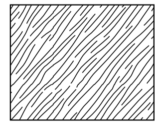
37.2—Metamorphic-rock, igneous-rock, and vein-matter lithologic patterns

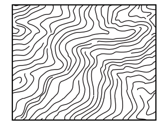

701
Metamorphism

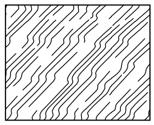

702
Quartzite

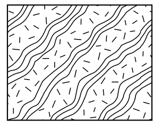

703
Slate

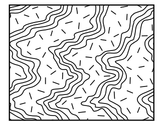

704
Schistose or gneissoid granite

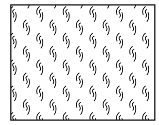

705
Schist

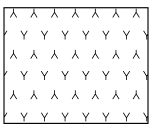

706
Contorted schist

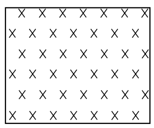

707
Schist and gneiss

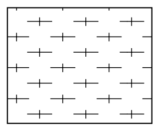

708
Gneiss

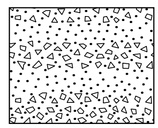

709
Contorted gneiss

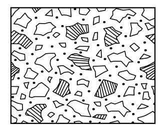

710
Soapstone, talc, or serpentinite

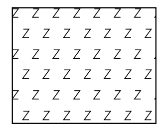

711
Tuffaceous rock

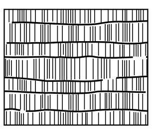

712
Crystal tuff

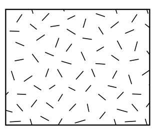

713
Devitrified tuff

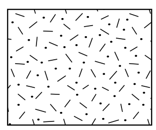

714
Volcanic breccia and tuff

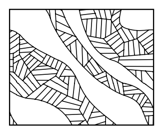

715
Volcanic breccia or agglomerate

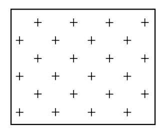

716
Zeolitic rock

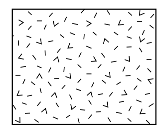

717
Basaltic flows

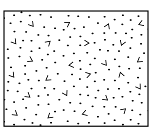

718
Granite (1st option)

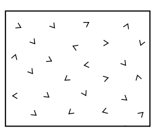

719
Granite (2nd option)

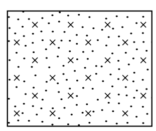

720
Banded igneous rock

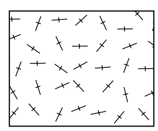

721
Igneous rock (1st option)

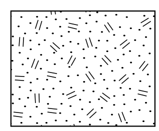

722
Igneous rock (2nd option)

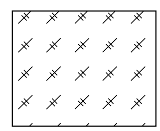

723
Igneous rock (3rd option)

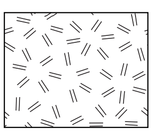

724
Igneous rock (4th option)

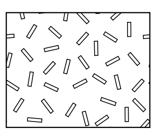

725
Igneous rock (5th option)

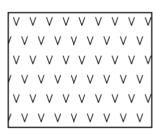

726
Igneous rock (6th option)

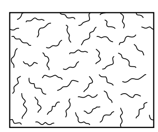

727
Igneous rock (7th option)

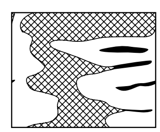

728
Igneous rock (8th option)


729
Porphyritic rock (1st option)


730
Porphyritic rock (2nd option)


731
Vitrophyre


732
Quartz


733
Ore

**For more information, see general guidelines on pages A-i to A-v.*

Legend: Logged Primary Rock Type

= Limestone

= Dolostone

= Shale

= Anhydrite

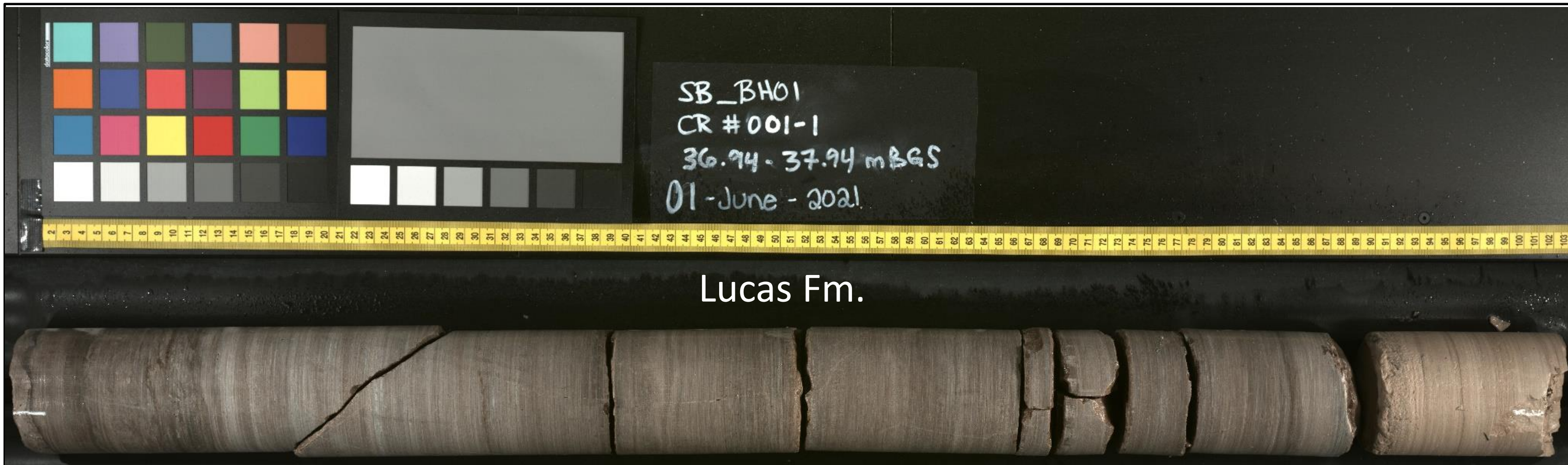
= Siltstone

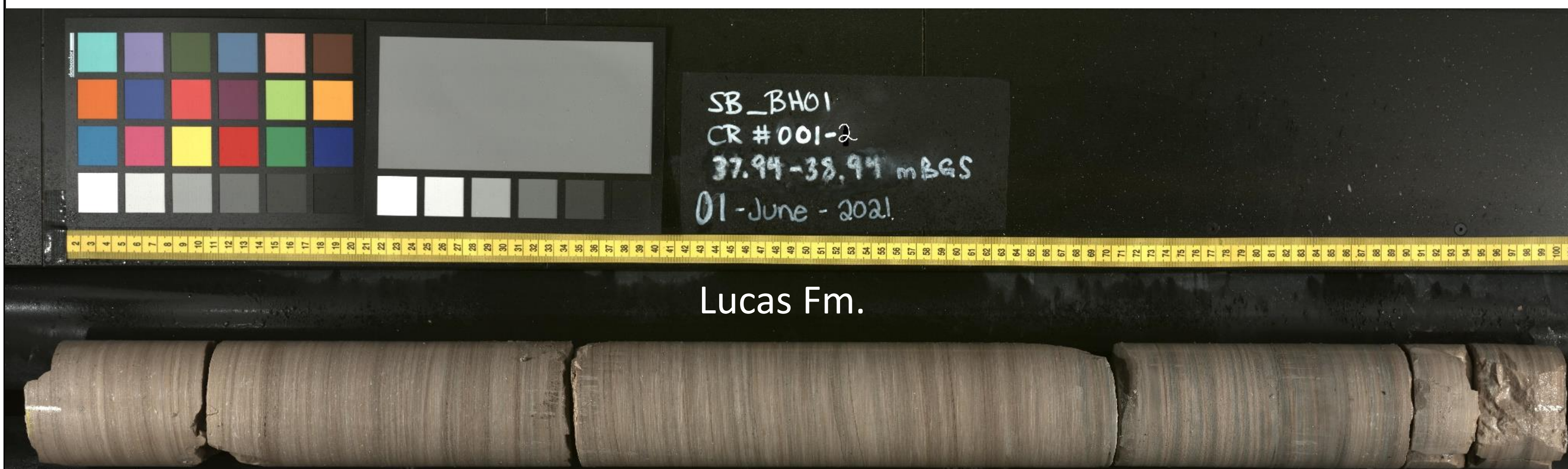
= Sandstone

= Gniess

Appendix C

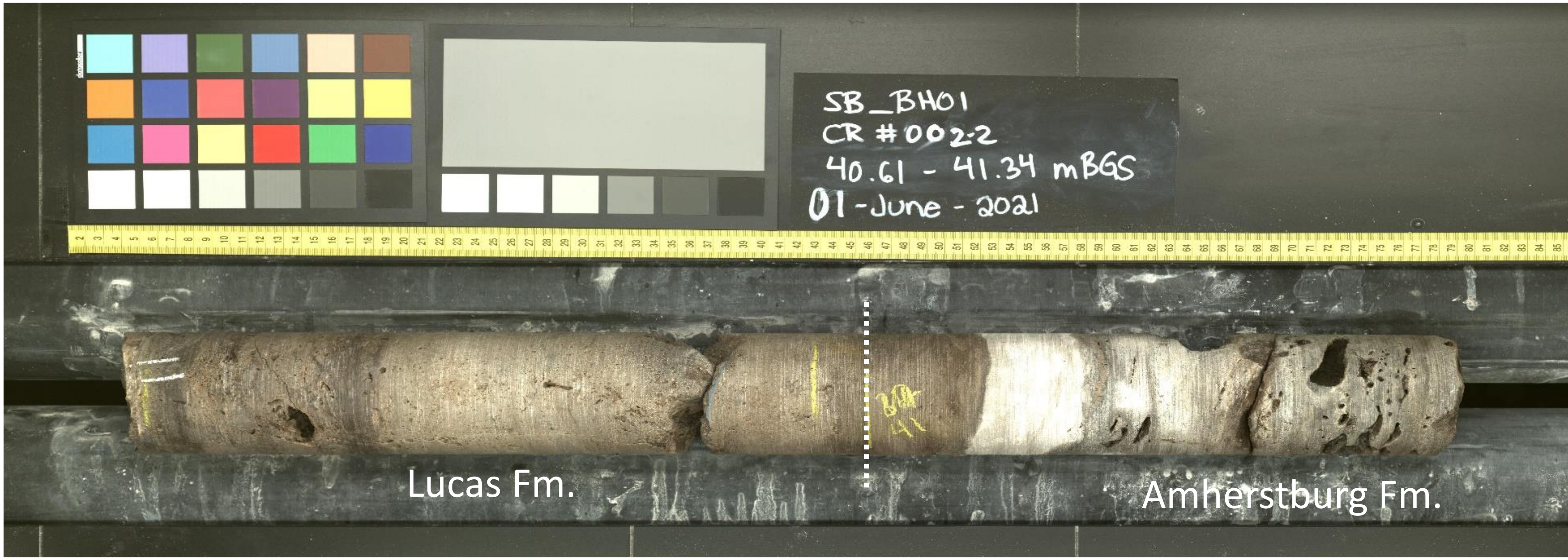
Representative Core Photos by Formation, Unit, and Member

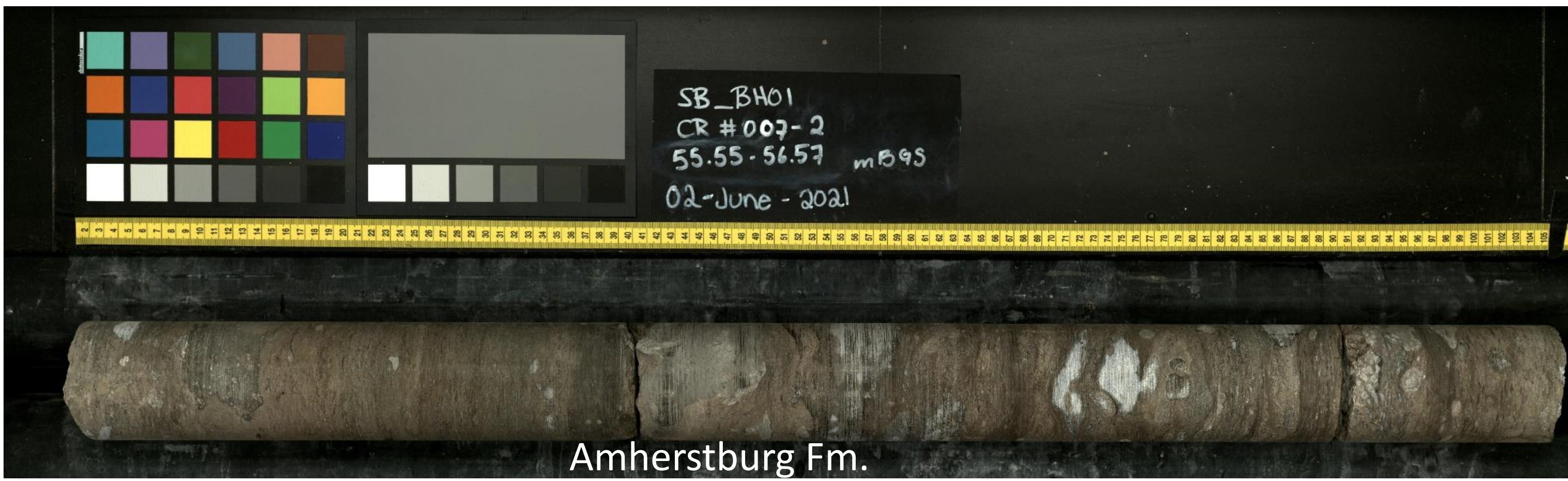




Lucas Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING





Amherstburg Formation Core From SB_BH01

NWMO South Bruce Drilling and Testing

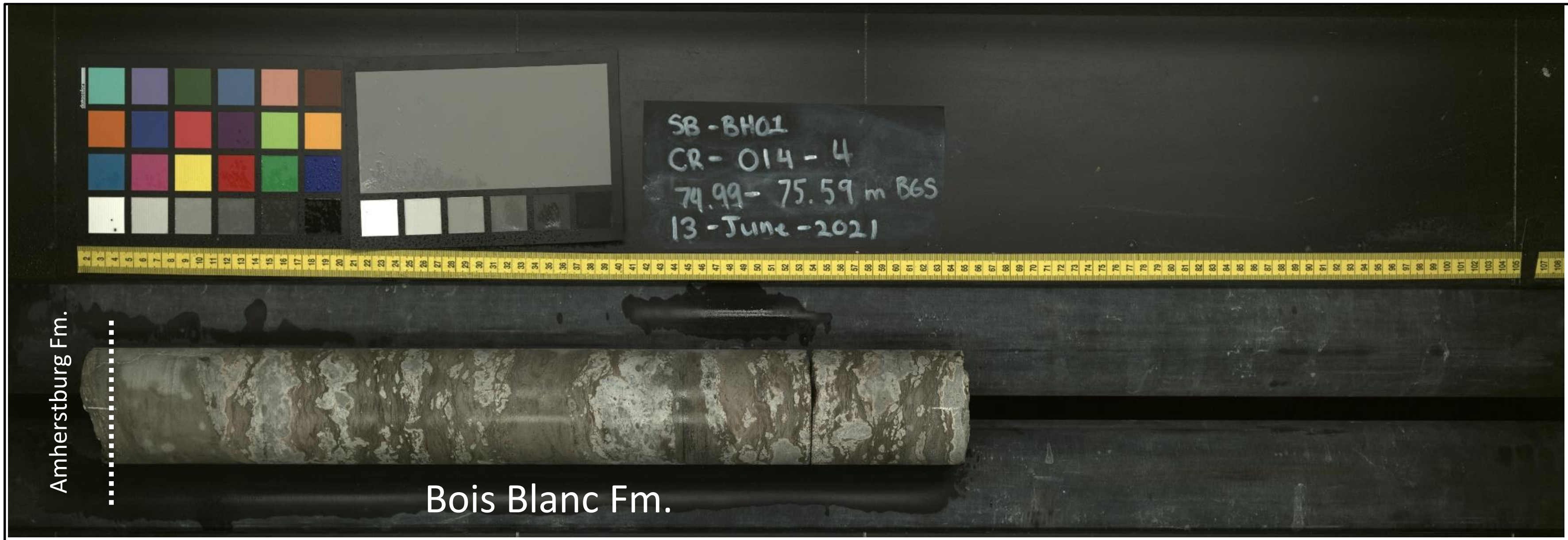
Prepared by: ACMC

Reviewed by: CAM

Date: 28-Jul-22

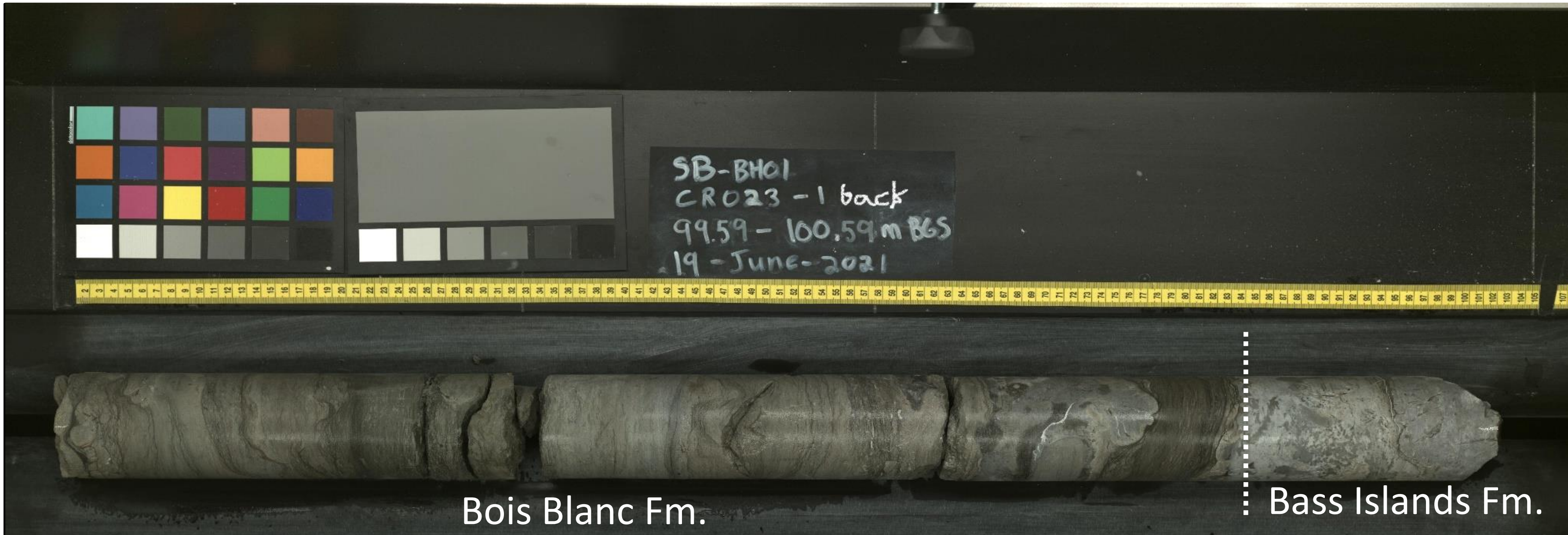
20-211-1

SB_BH01 Representative Photos for Formations, Members, and Units



Bois Blanc Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING



Bass Islands Formation Core From SB_BH01

NWMO South Bruce Drilling and Testing

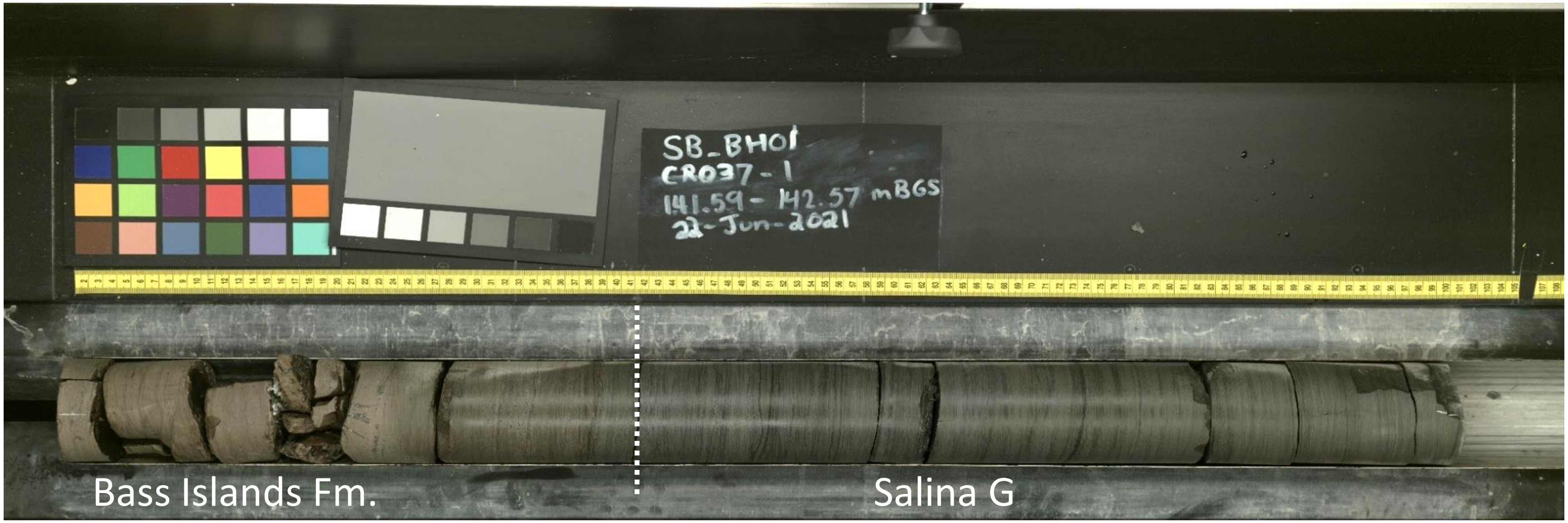
20-211-1 SB_BH01 Representative Photos for Formations, Members, and Units

Prepared by: ACMC

Reviewed by: CAM

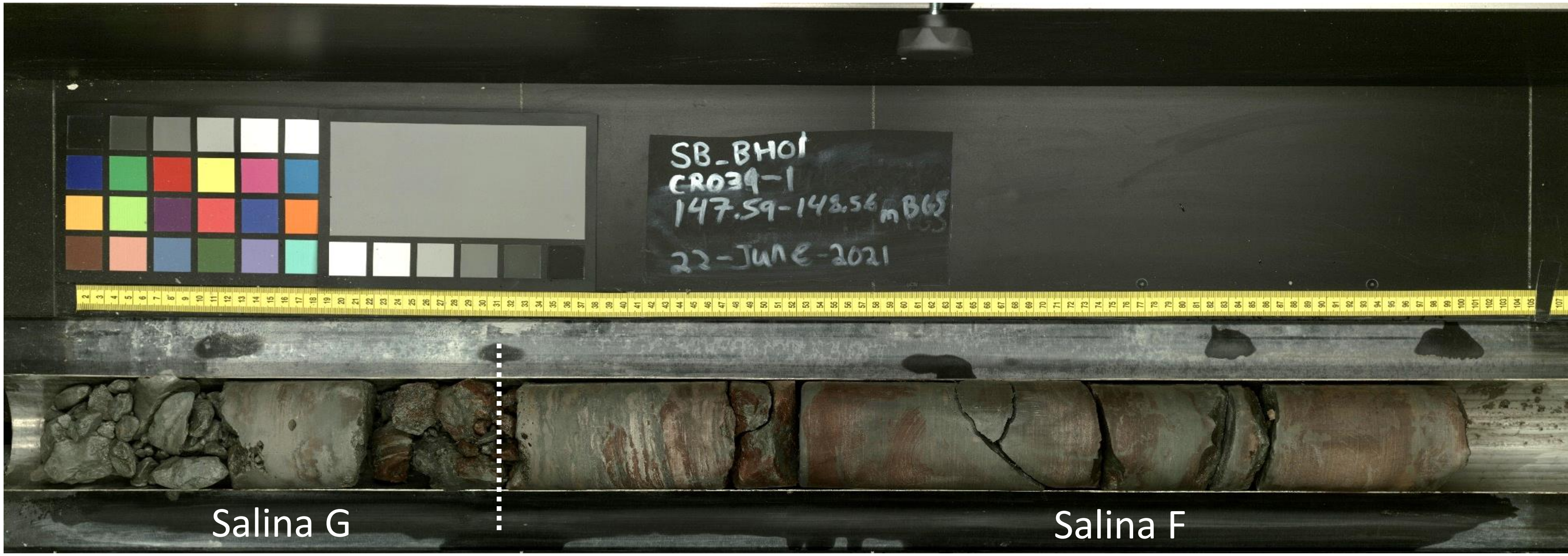
Date: 28-Jul-22

GEOFIRMA ENGINEERING



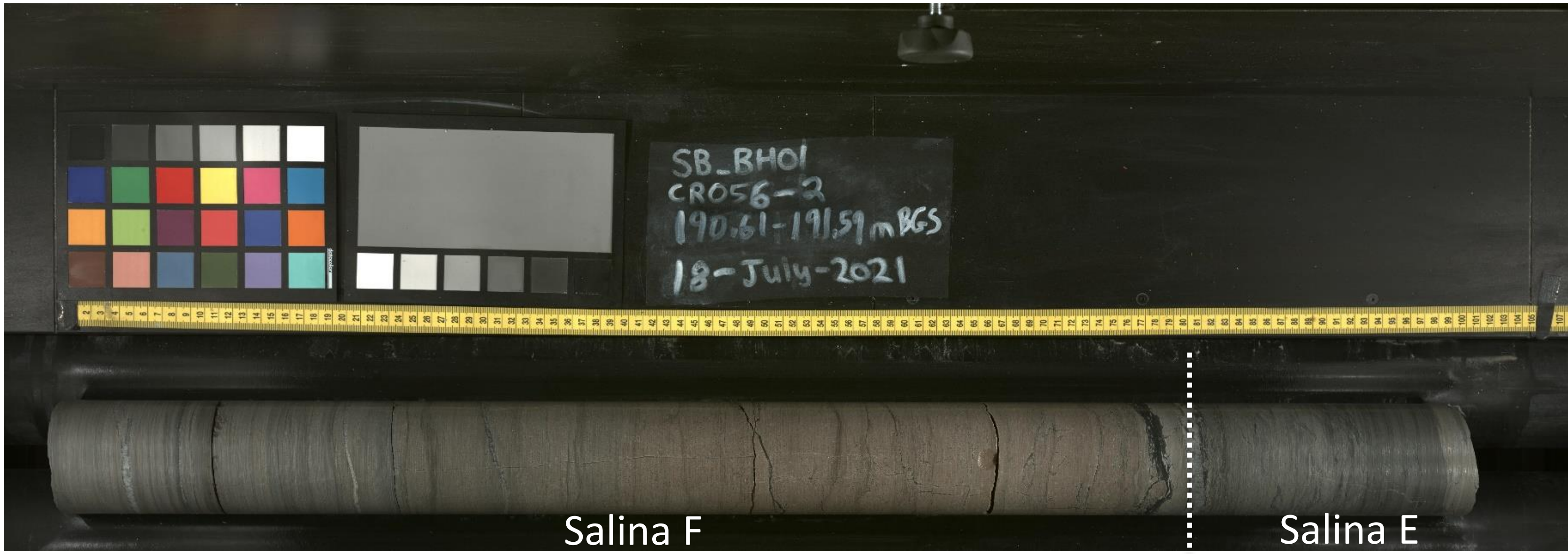
Salina G Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

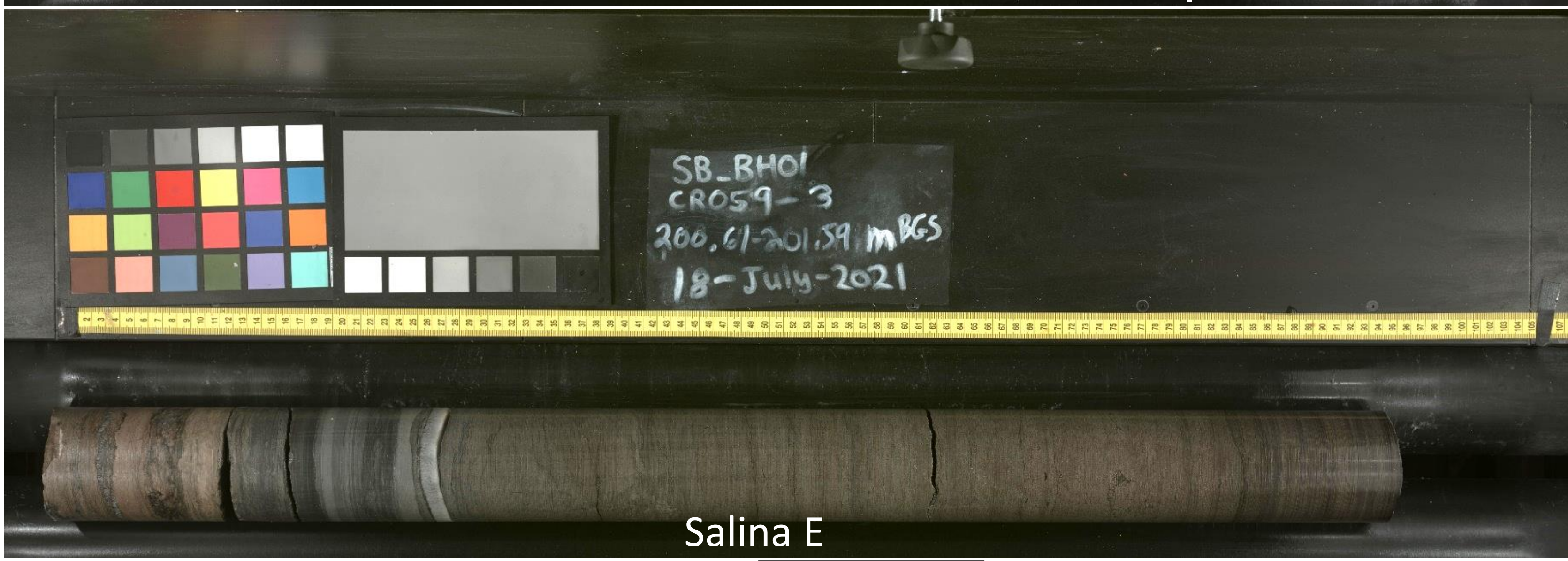
GEOFIRMA ENGINEERING



Salina F Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

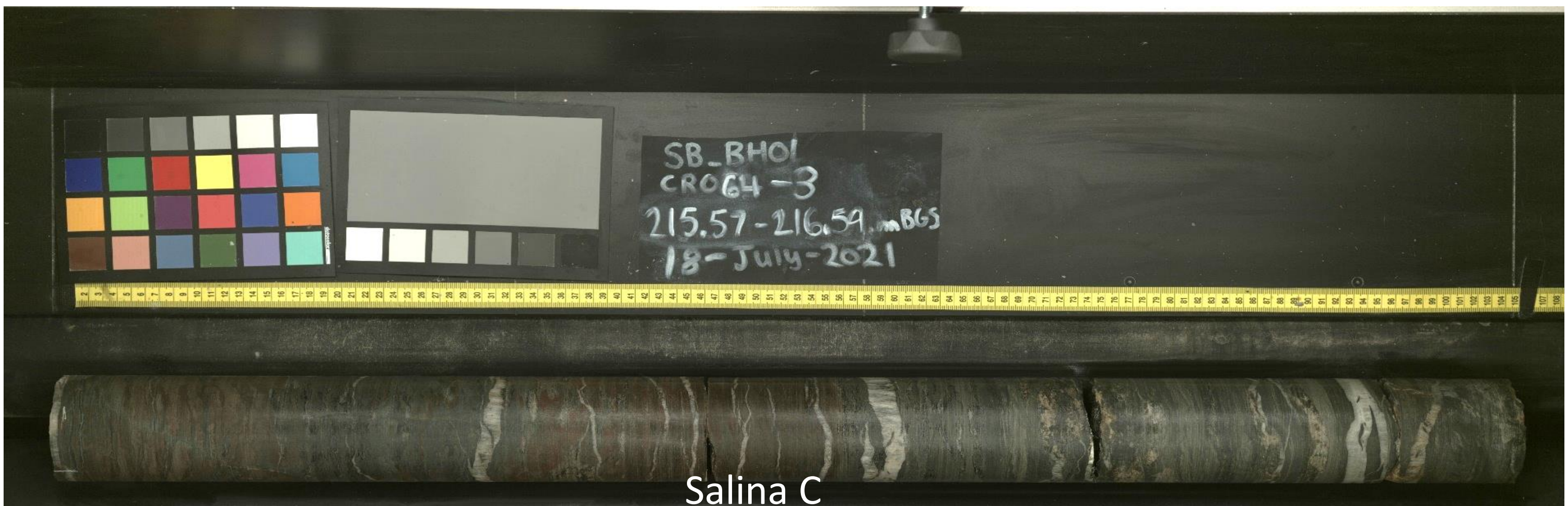
GEOFIRMA ENGINEERING





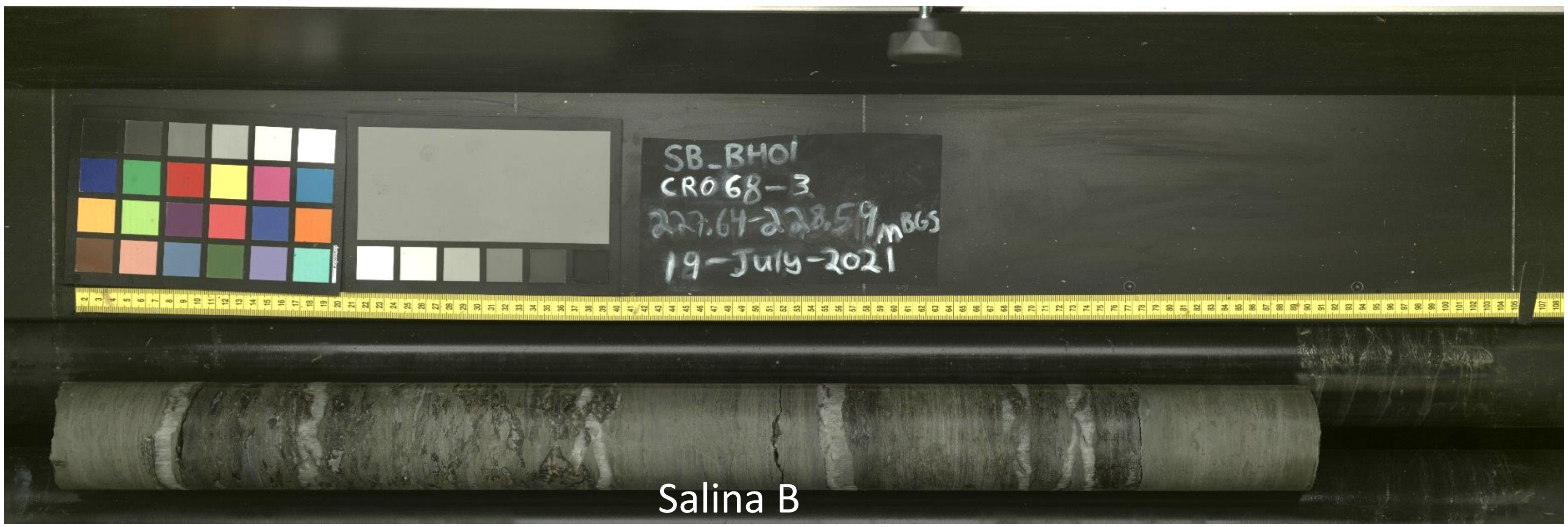
Salina E Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING



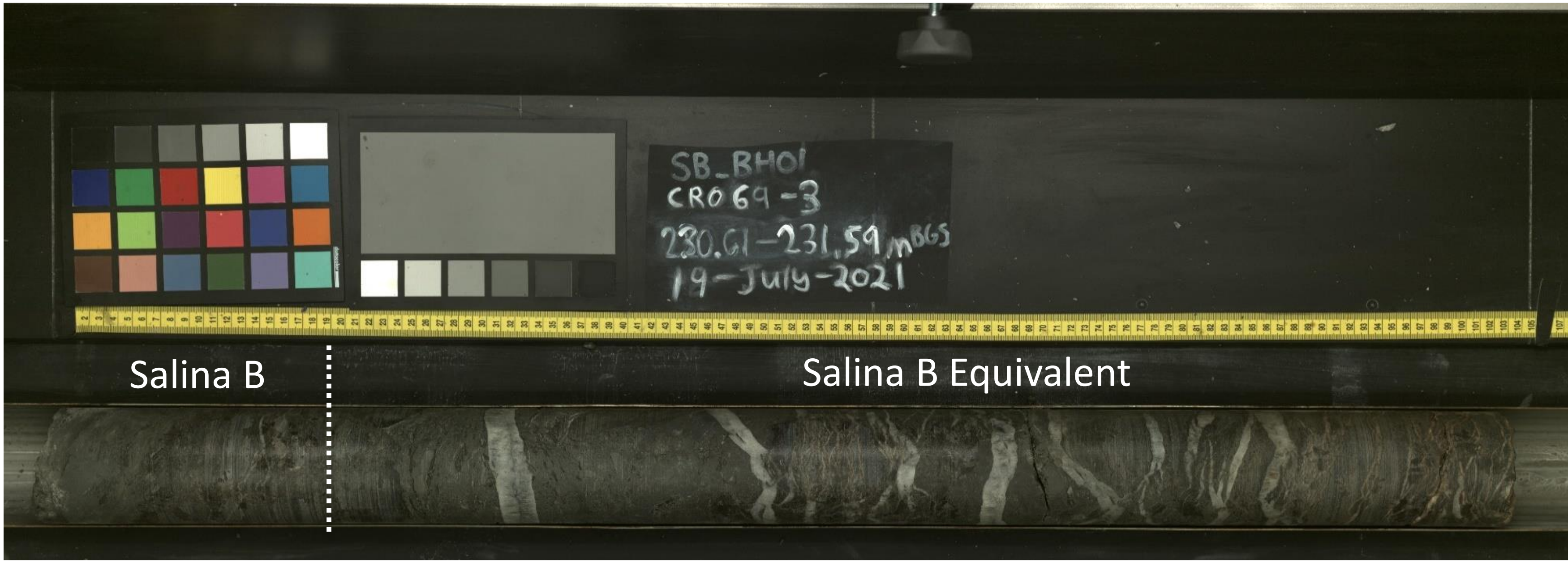
Salina D unit and C Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

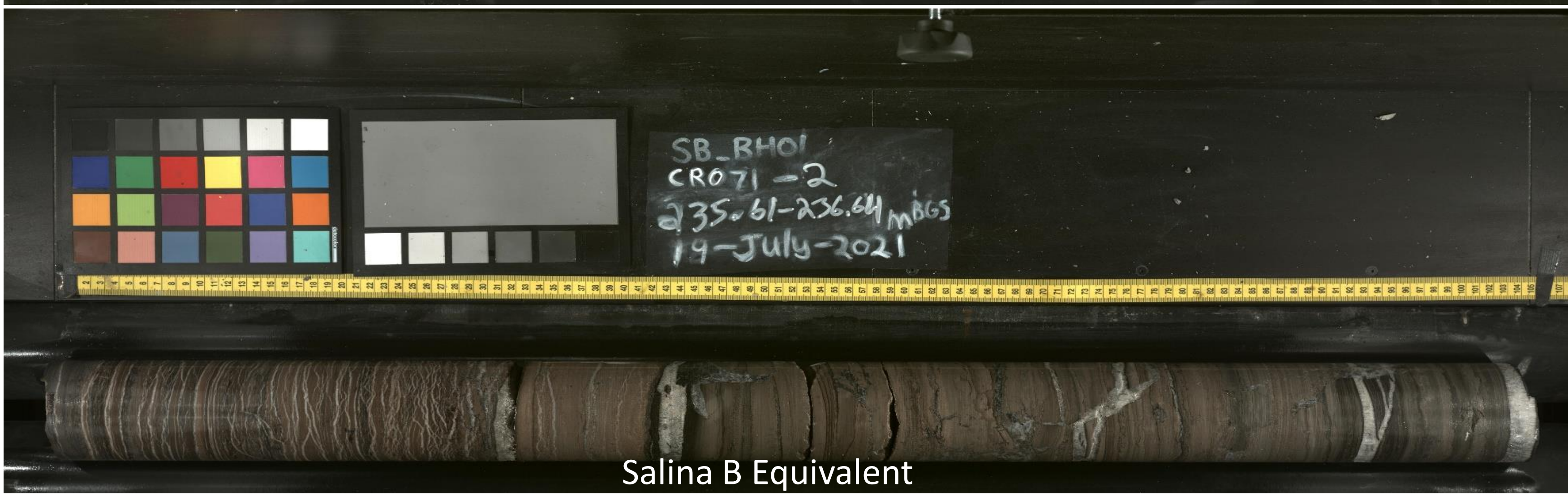
GEOFIRMA ENGINEERING



Salina B Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1 SB_BH01 Representative Photos for Formations, Members, and Units	

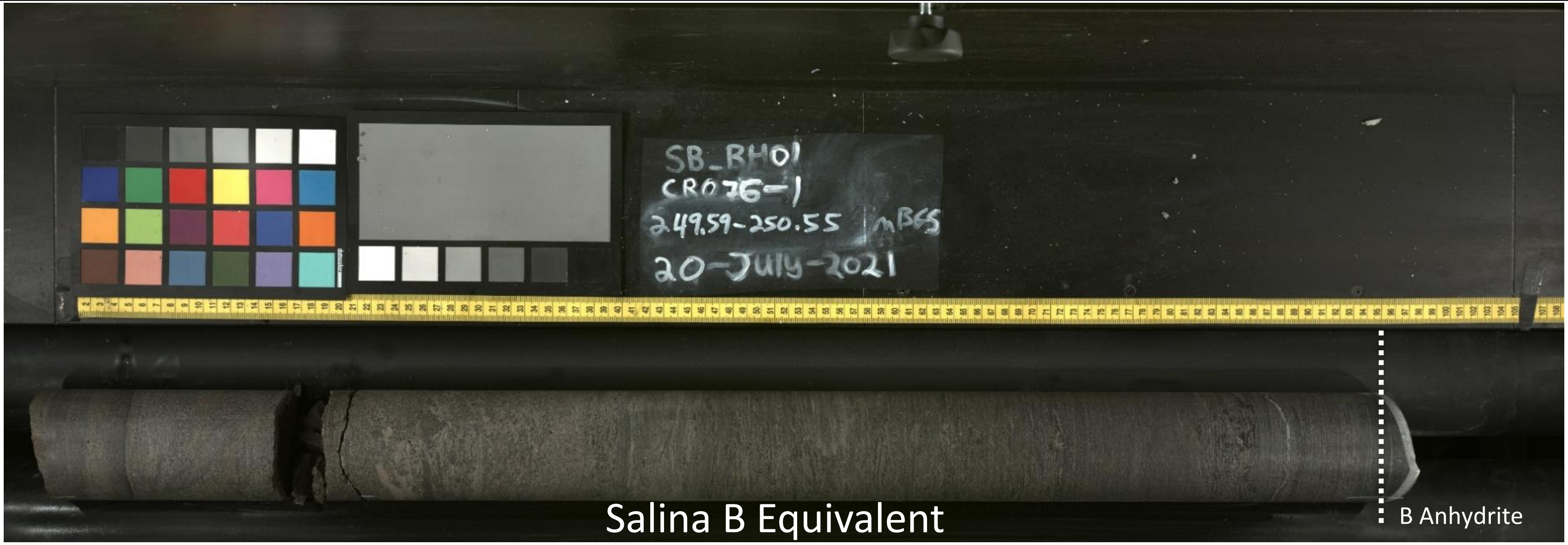
GEOFIRMA ENGINEERING

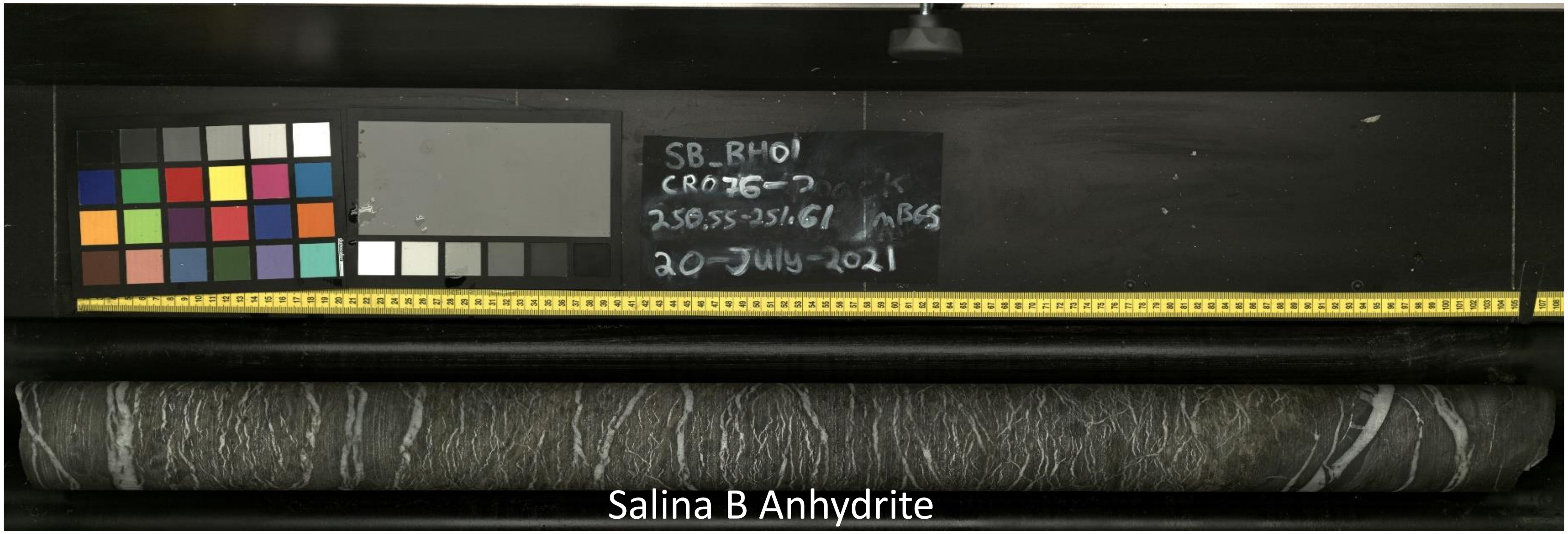




Salina B Equivalent Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC
	Reviewed by: CAM
20-211-1 — SB_BH01 Representative Photos for Formations, Members, and Units	Date: 28-Jul-22

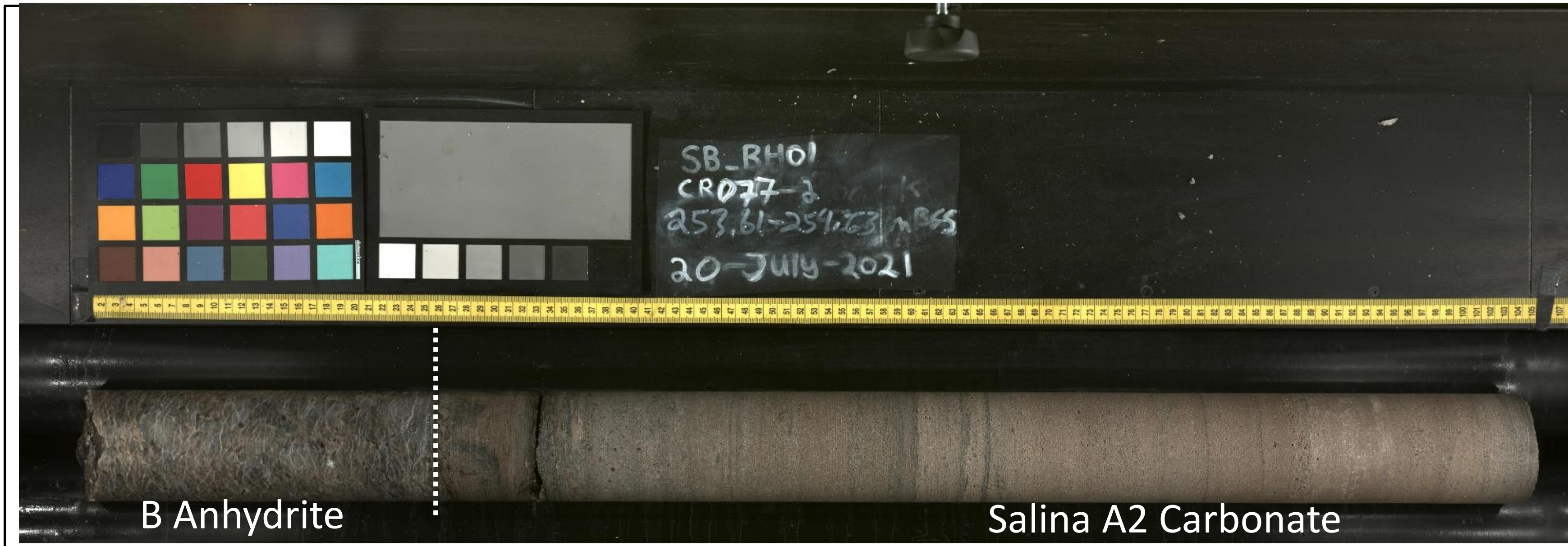
GEOFIRMA ENGINEERING

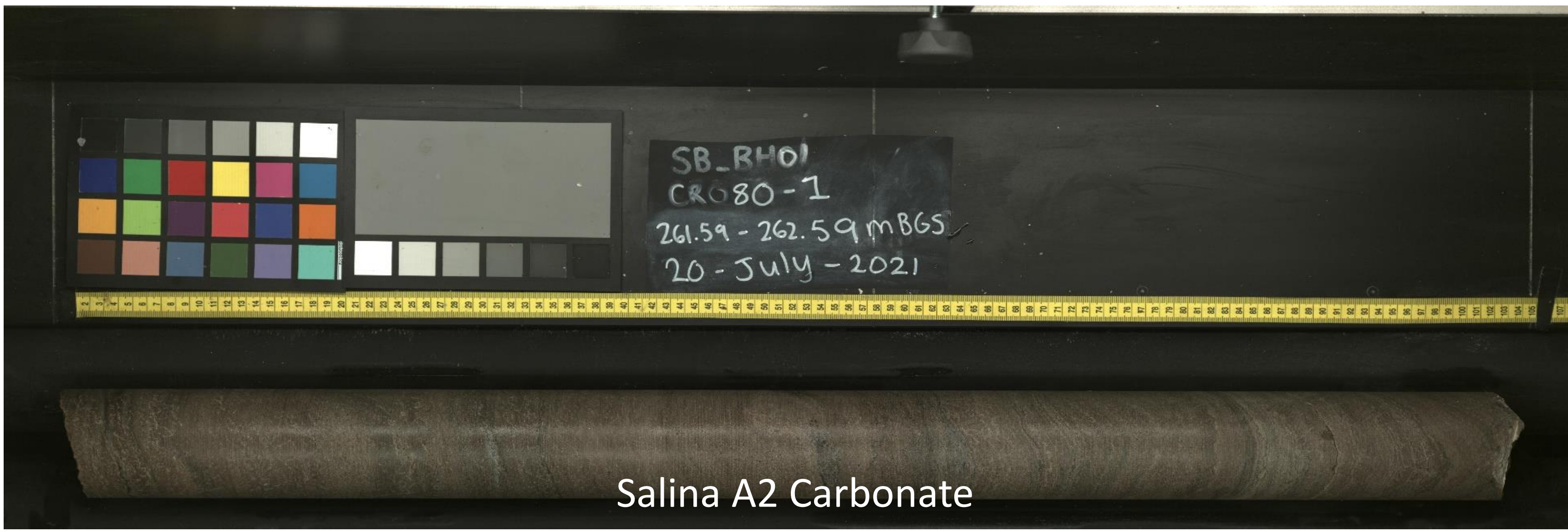




Salina B Anhydrite Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

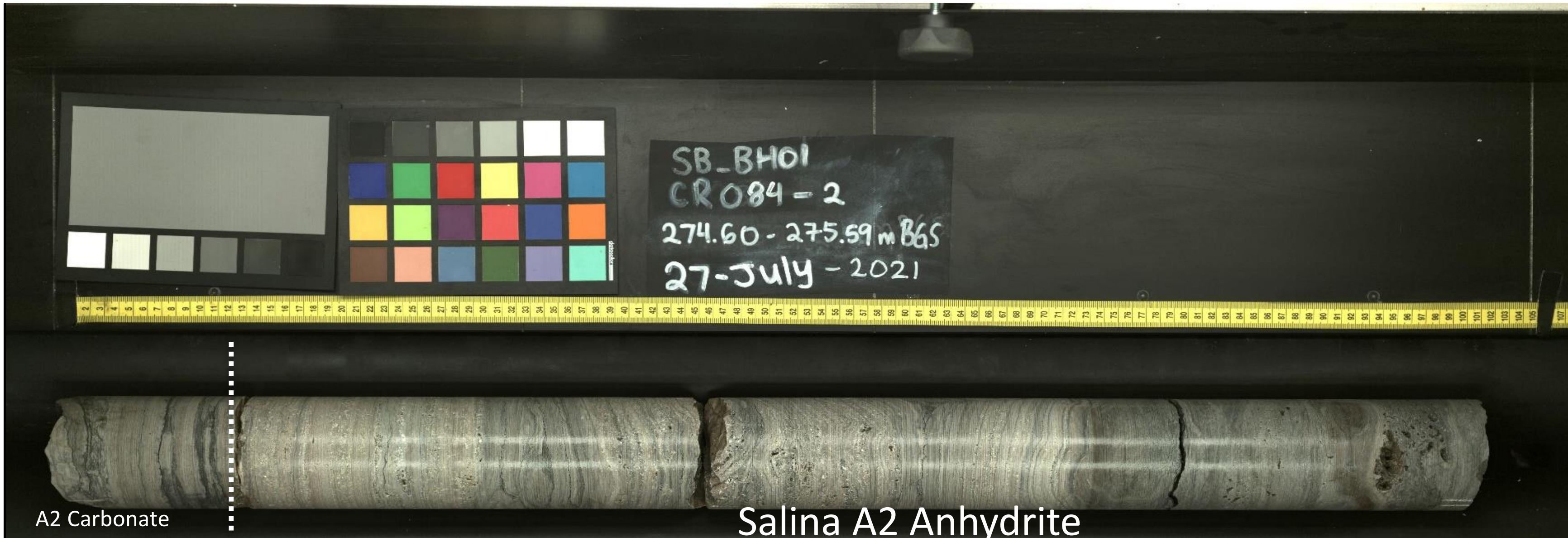
GEOFIRMA ENGINEERING

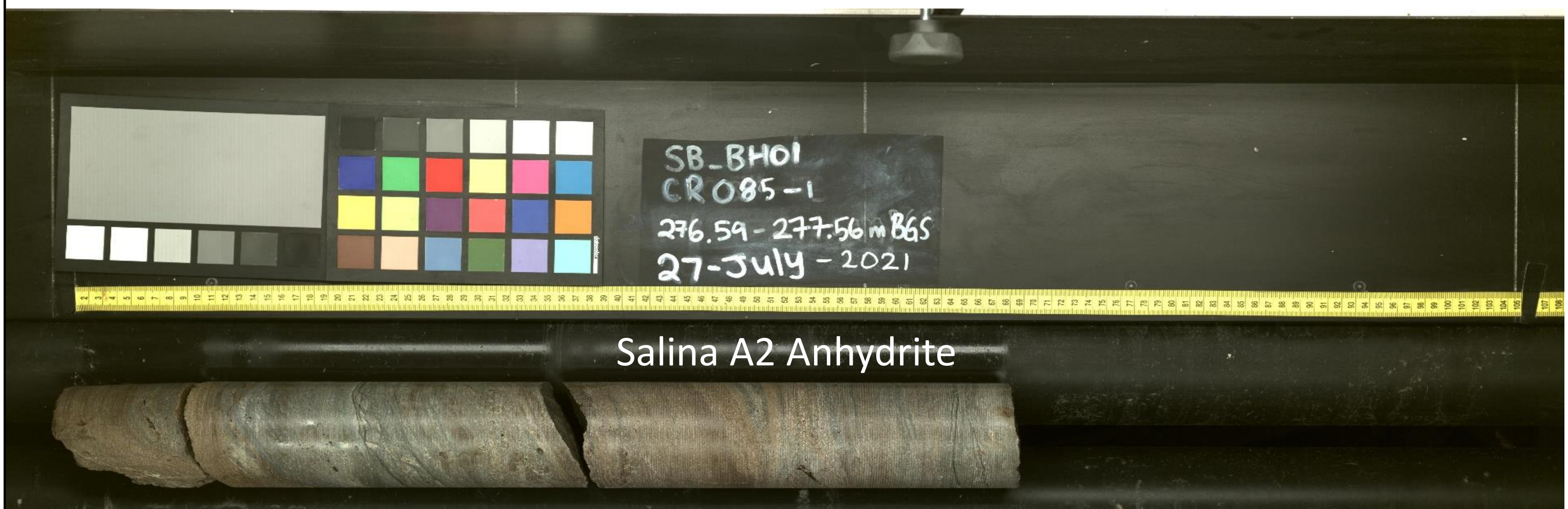




Salina A2 Carbonate Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING



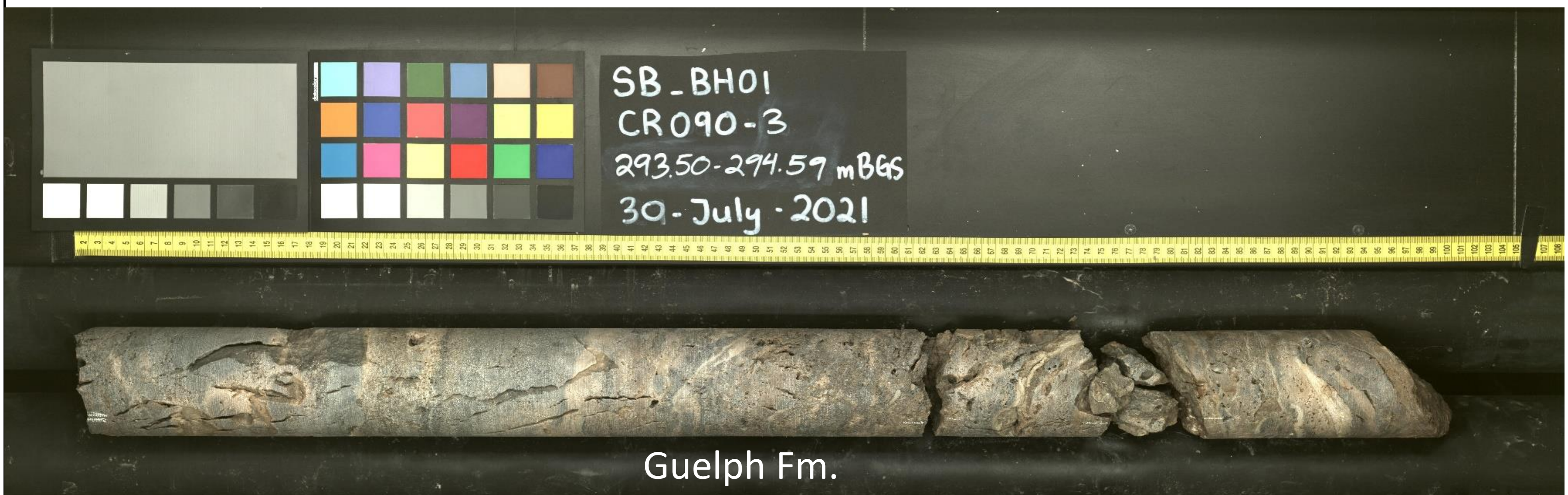


Salina A2 Anhydrite Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING

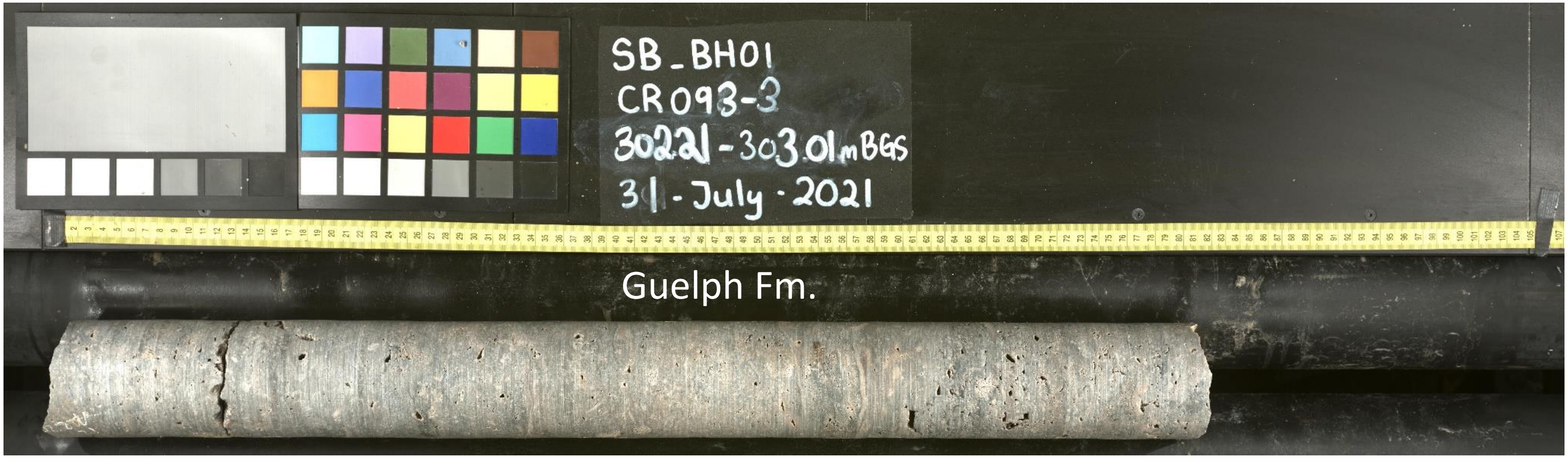
Salina A1 Carbonate Unit Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units

GEOFIRMA ENGINEERING



Salina A1 Evaporite and Guelph Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1 SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING

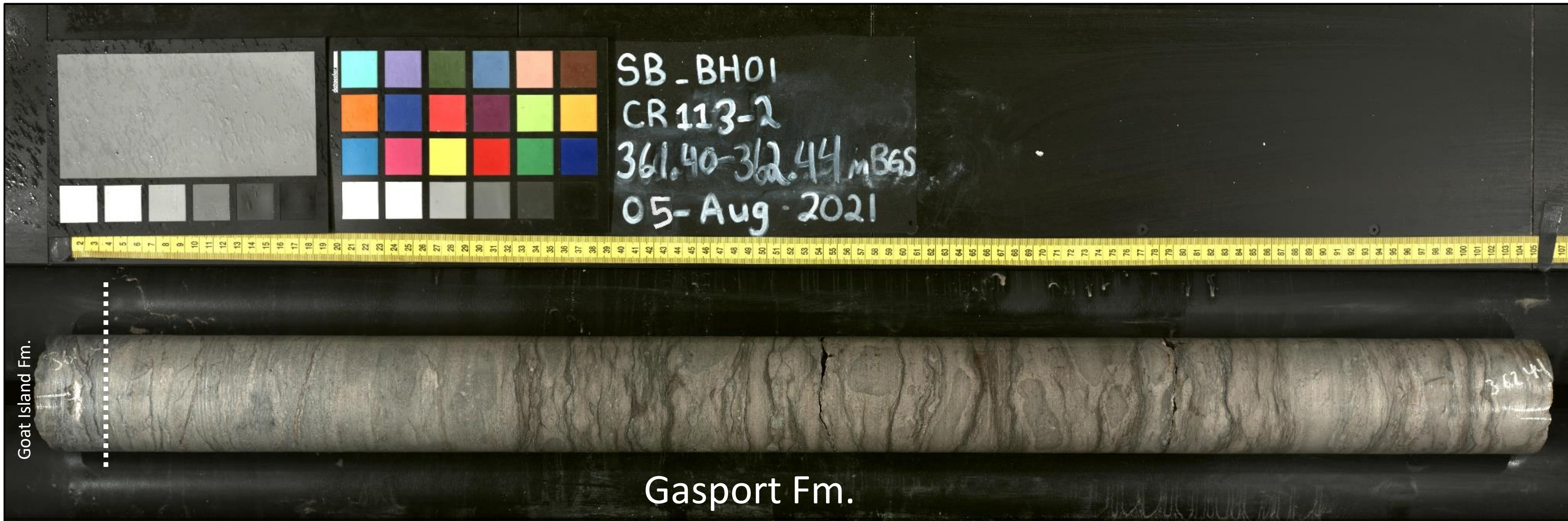


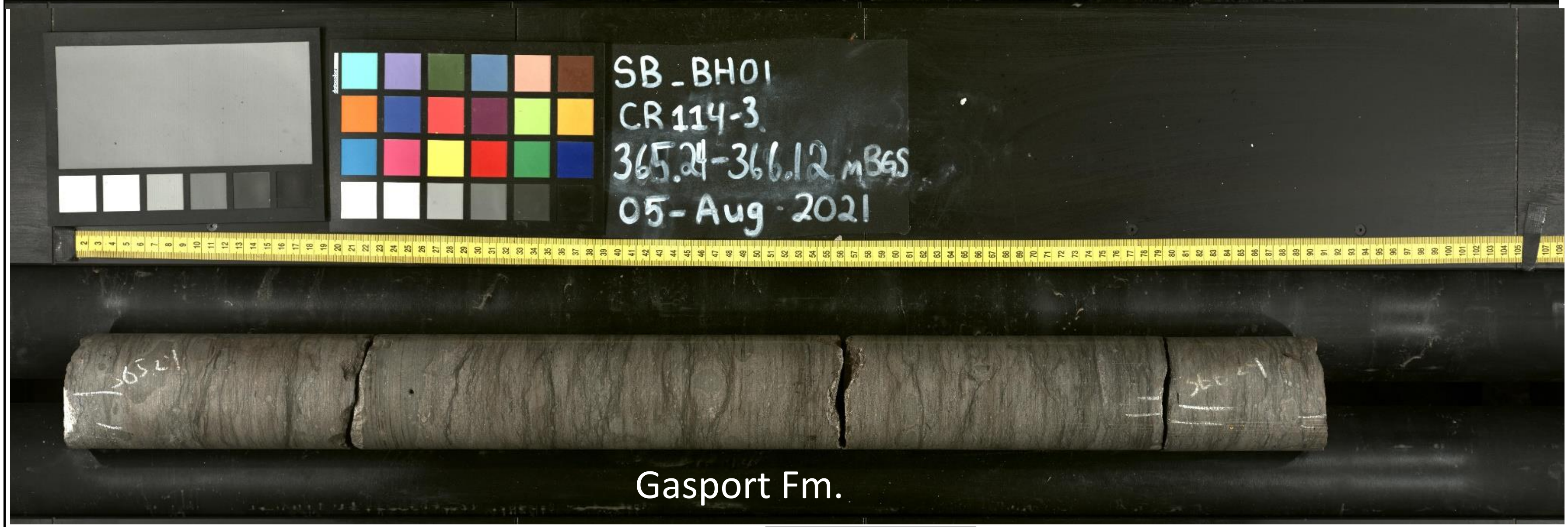
Guelph Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1 — SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING

Goat Island Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

GEOFIRMA ENGINEERING





Gasport Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1 — SB_BH01 Representative Photos for Formations, Members, and Units	

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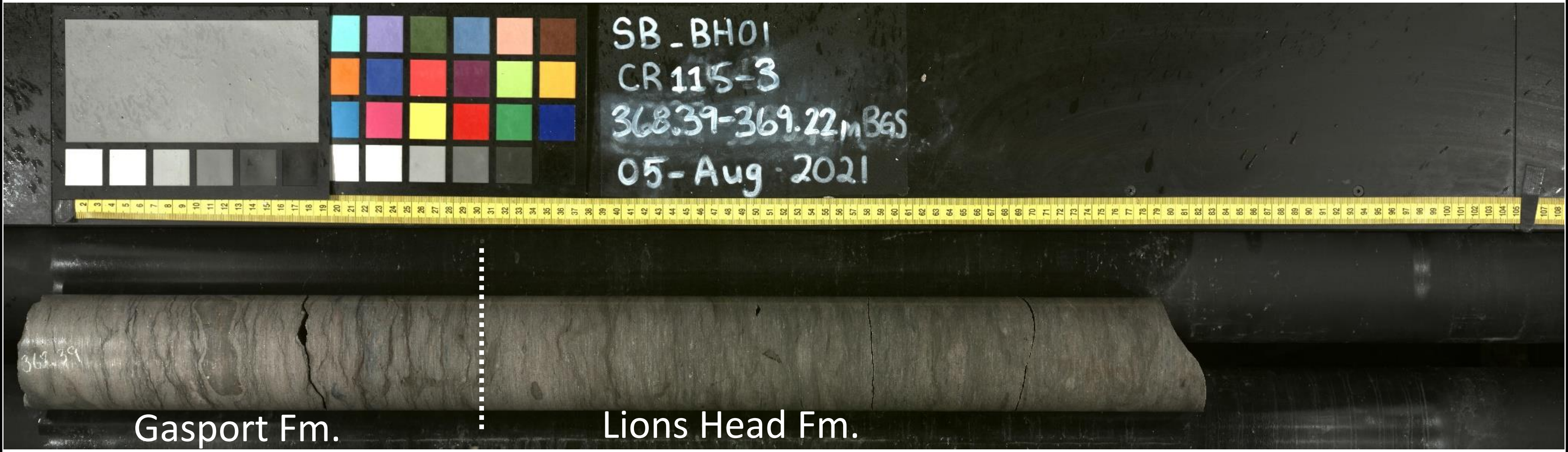

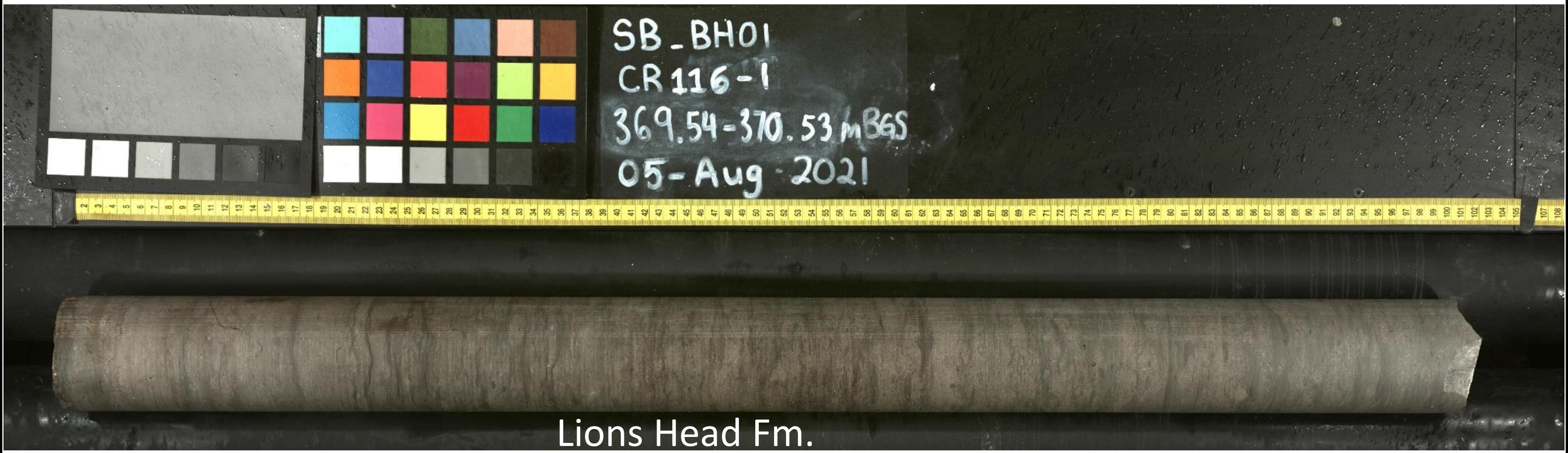

Lions Head Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

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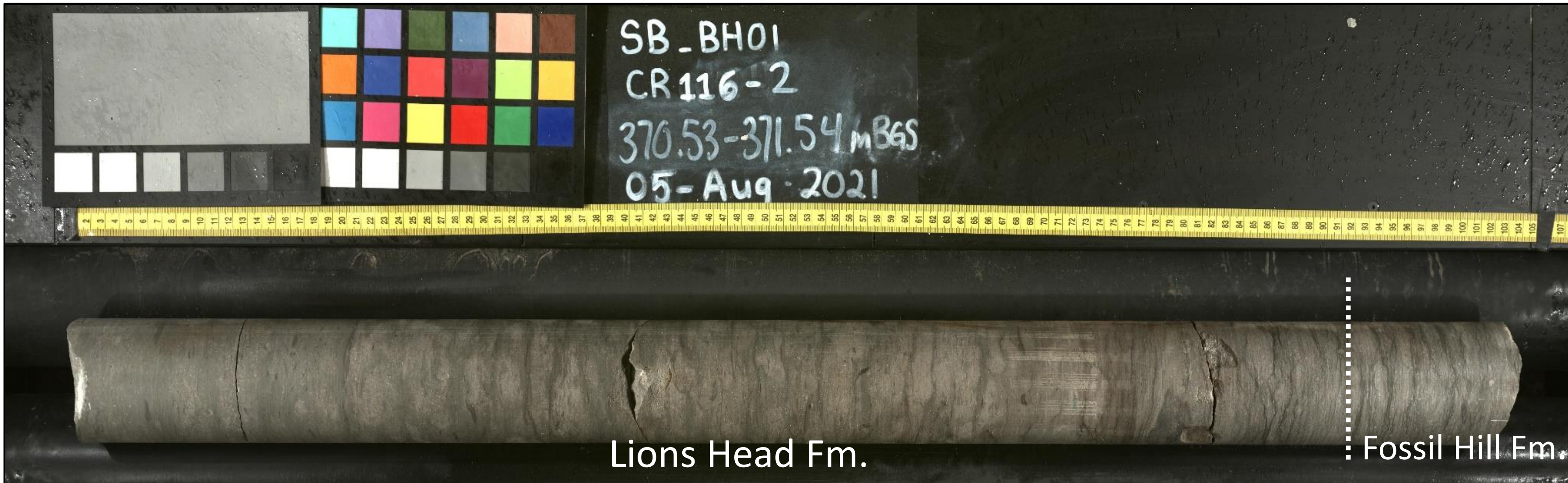

Fossil Hill Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM
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Lower Fossil Hill Formation (Possible St. Edmund Fm.) Core **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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Cabot Head Formation Core From SB_BH01

NWMO South Bruce Drilling and Testing

20-211-1

SB_BH01 Representative Photos for Formations, Members, and Units

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Manitoulin Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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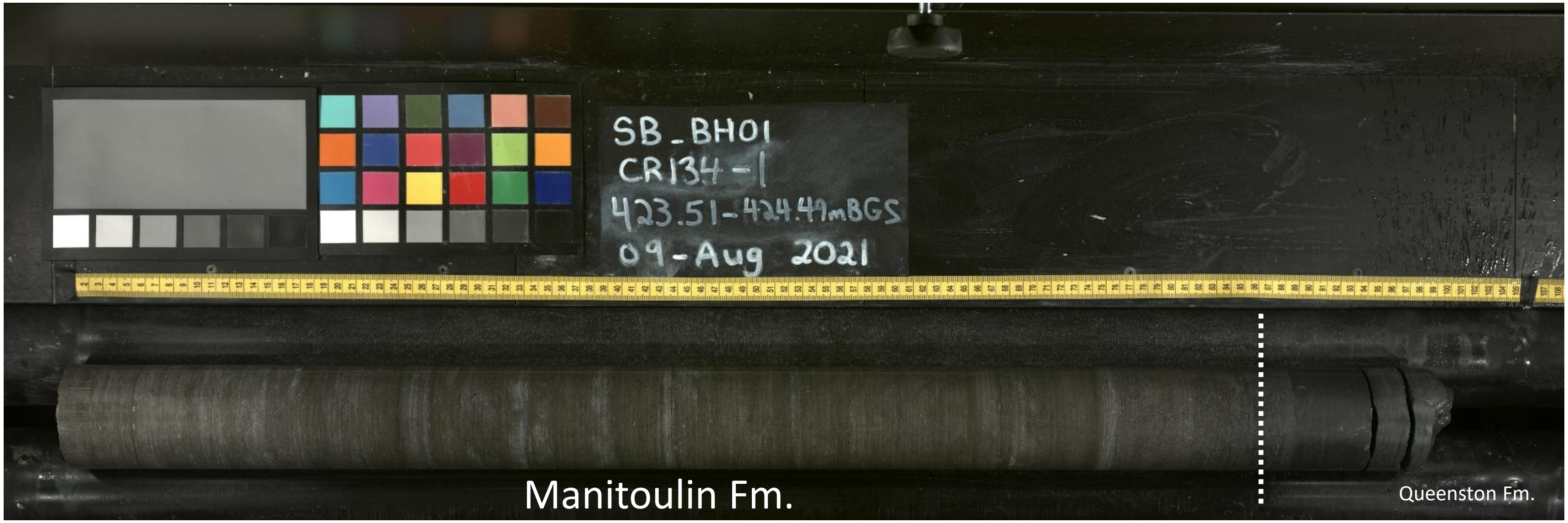

Queenston Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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Georgian Bay Formation Core From SB_BH01 NWMO South Bruce Drilling and Testing		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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Blue Mountain Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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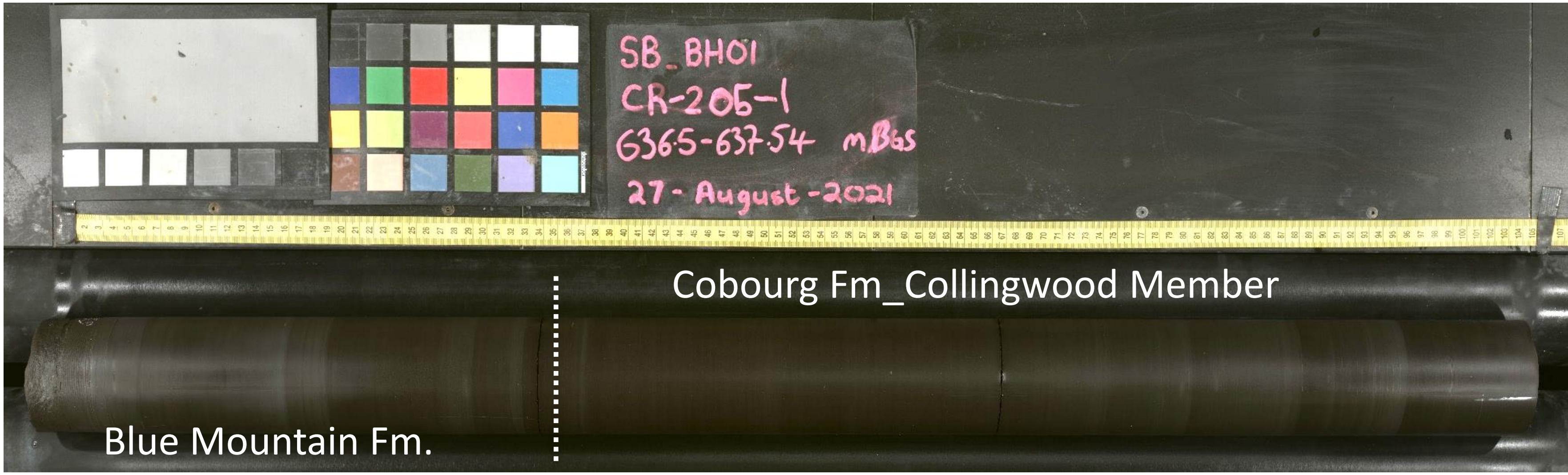

Cobourg Formation- Collingwood Member Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
20-211-1 | SB_BH01 Representative Photos for Formations, Members, and Units	

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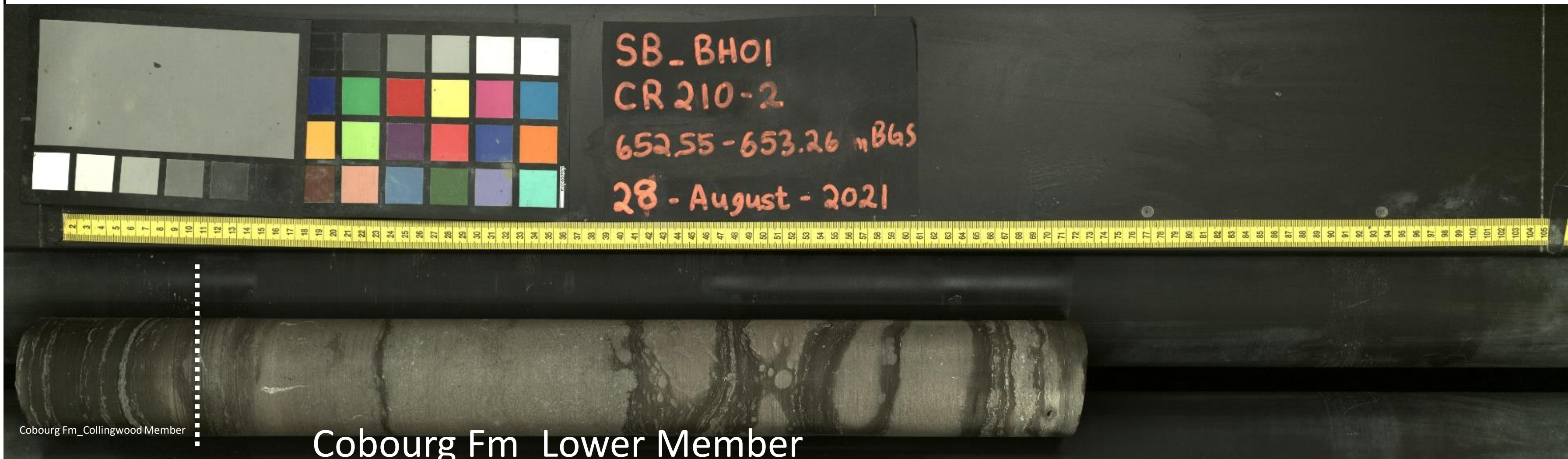

Cobourg Formation- Lower member Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM
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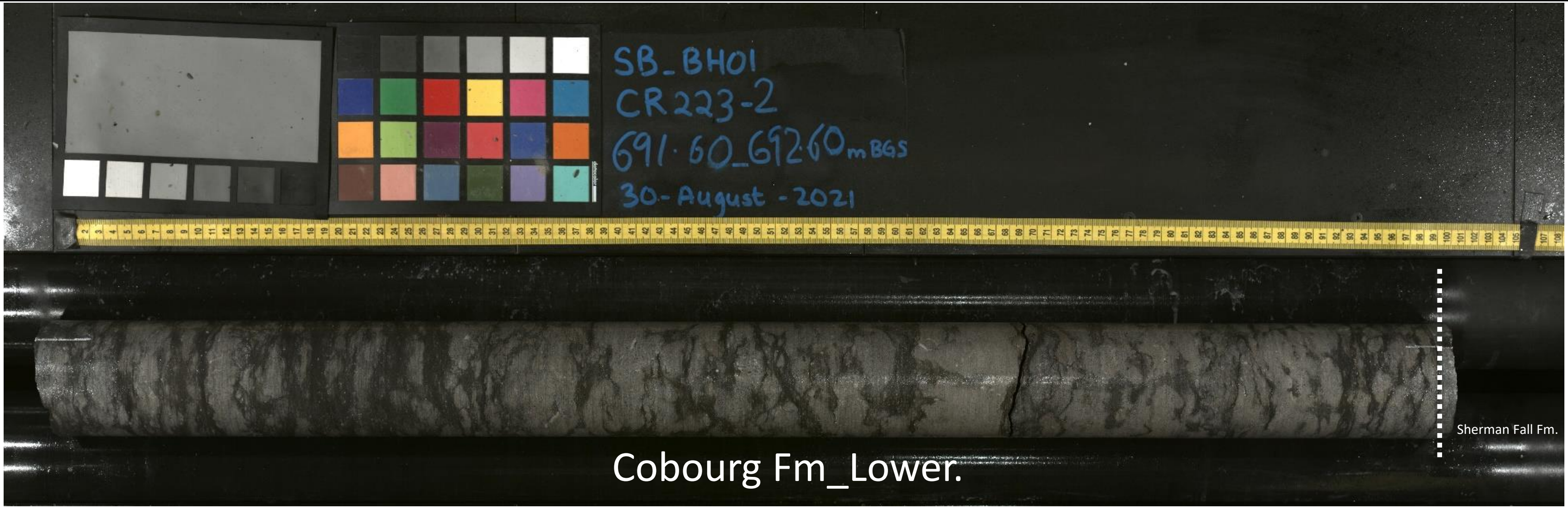

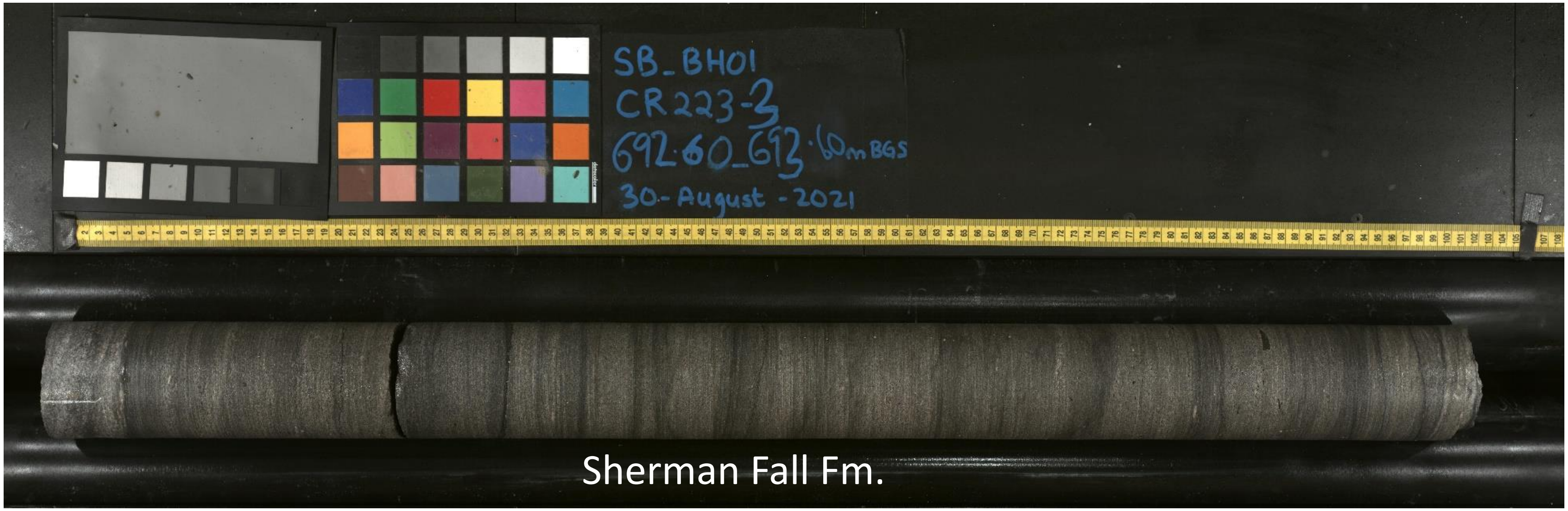

Sherman Fall Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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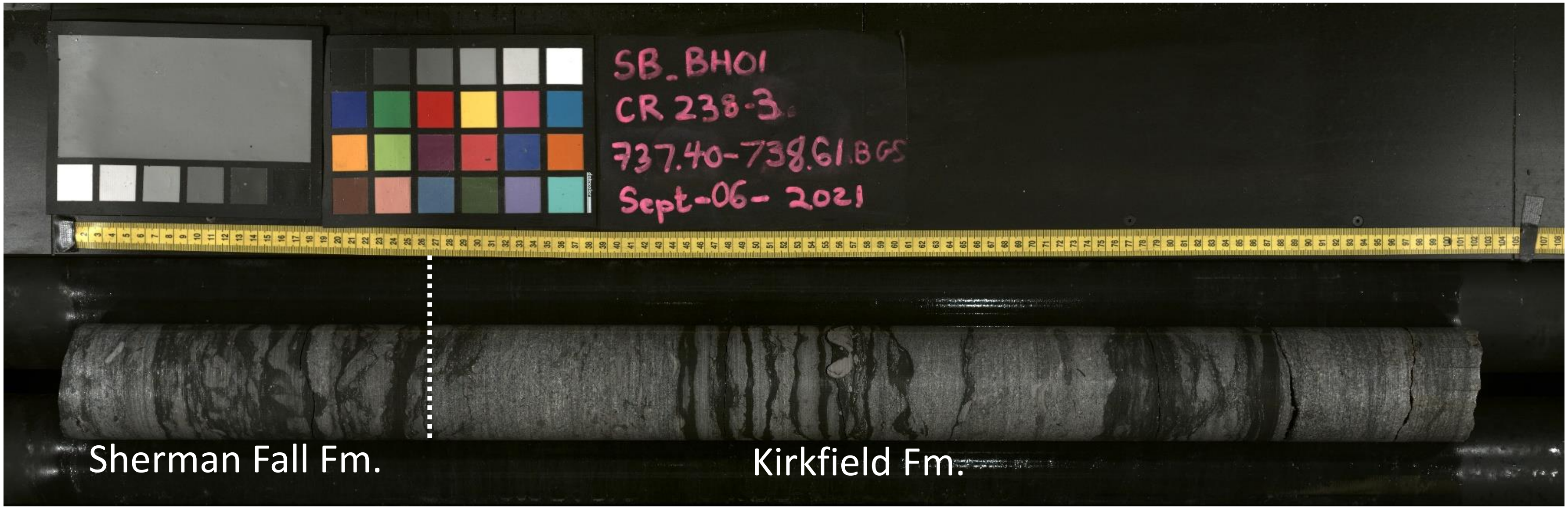

Kirkfield Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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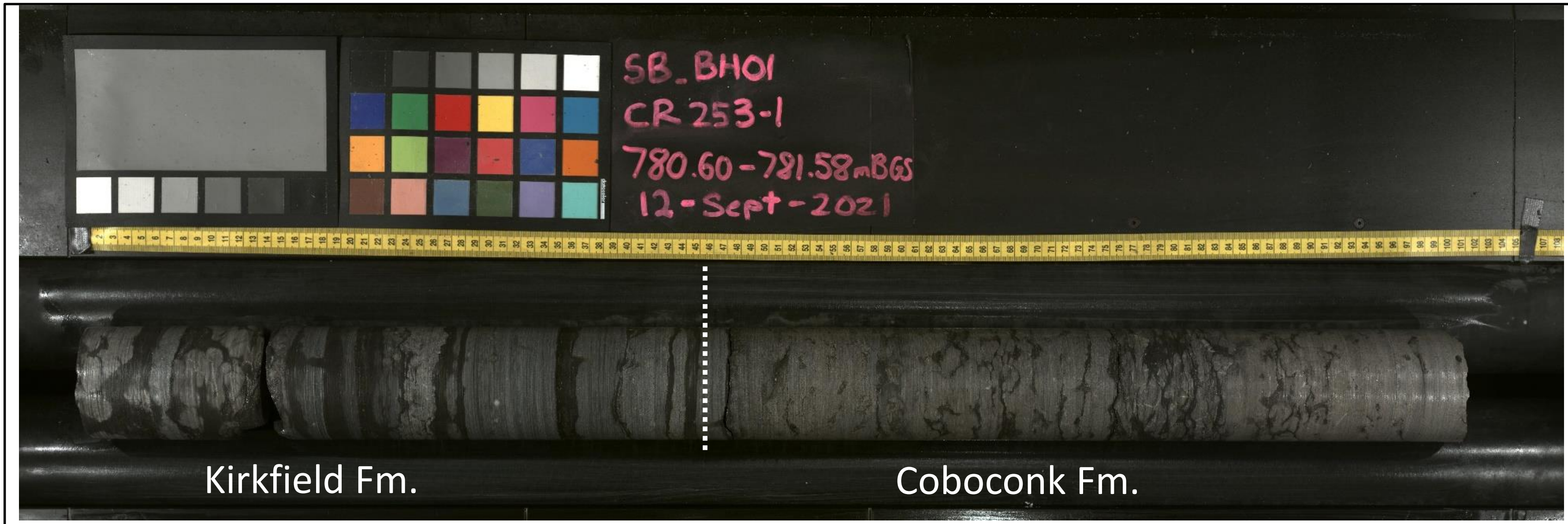

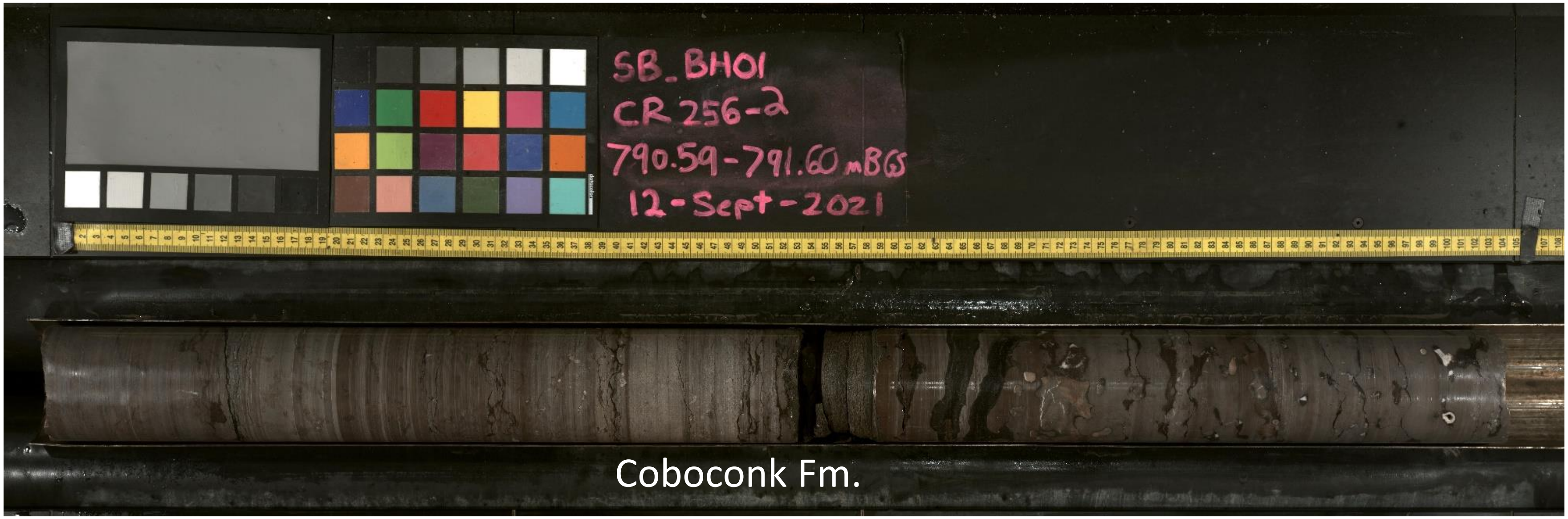

Coboconk Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**	Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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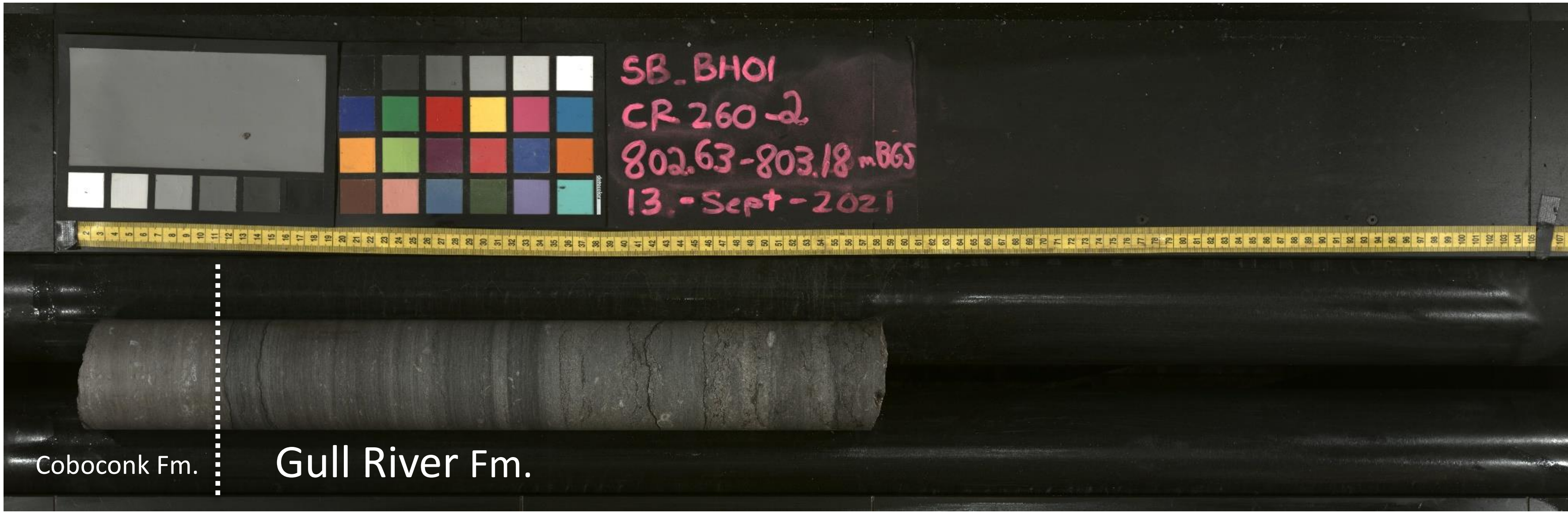

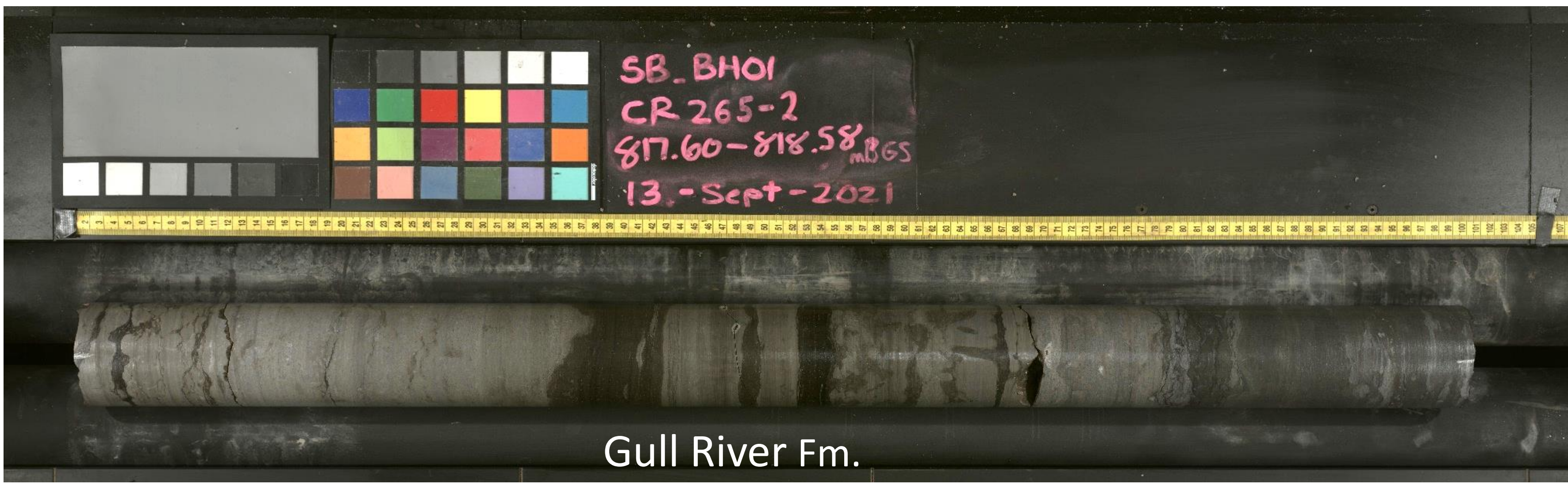

Gull River Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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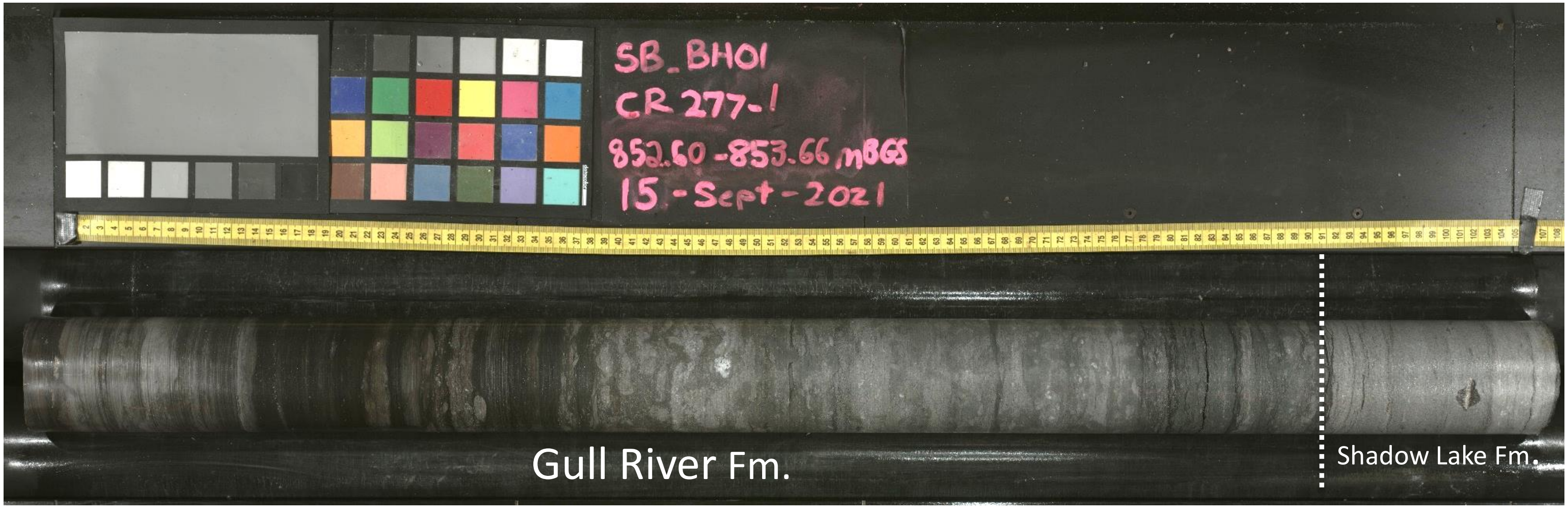

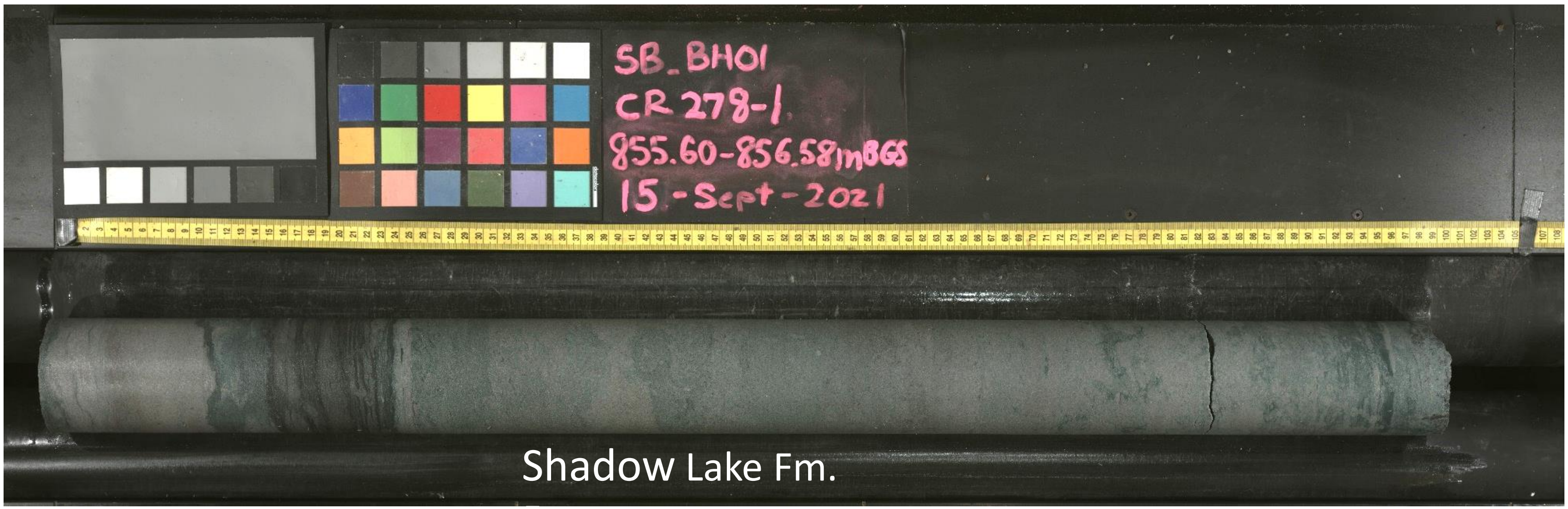

Shadow Lake Formation Core From SB_BH01 **NWMO South Bruce Drilling and Testing**		Prepared by: ACMC Reviewed by: CAM Date: 28-Jul-22
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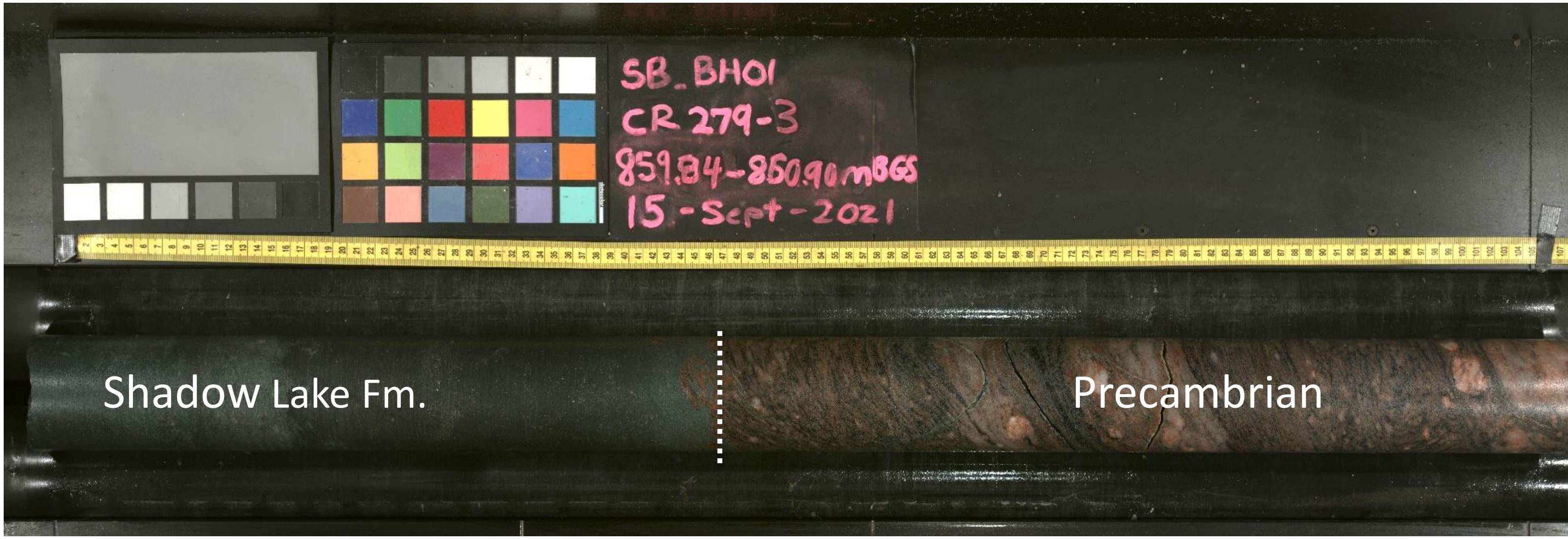

Precambrian basement **NWMO South Bruce Drilling and Testing**		Prepared by: LIM Reviewed by: CAM Date: 28-Jul-22
20-211-1	SB_BH01 Representative Photos for Formations, Members, and Units	

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