

PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING, IGNACE AREA

WP10 – Rock Mass Classification for IG_BH02

APM-REP-01332-0304

December 2022

Golder Associates Ltd.

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REPORT

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WP10 - Rock Mass Classification for IG_BH02

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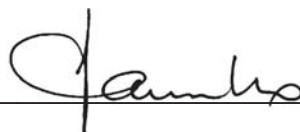
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Table of Contents

1.0 INTRODUCTION	1
2.0 BACKGROUND INFORMATION.....	1
2.1 Geological Setting	1
3.0 OBJECTIVE	4
4.0 FINAL STRUCTURE LOG	4
5.0 ROCK MASS CLASSIFICATION	7
5.1 Geomechanics Classification, Rock Mass Rating (RMR) Index	7
6.0 SUMMARY OF ROCK MASS CLASSIFICATION PARAMETERS	9
6.1 Strength.....	9
6.2 RQD	9
6.3 Fracture Spacing	9
6.4 Condition of Discontinuities.....	10
6.5 Groundwater.....	10
7.0 SUMMARY OF ROCK MASS CLASSIFICATION BY RUN.....	11
8.0 SUMMARY OF ROCK MASS RATING INDEX DISTRIBUTION BY SECTIONS OF BOREHOLE IG_BH02.....	13
8.1 Adjustments to RMR Data for Engineering Use.....	13
8.1.1 Groundwater Ratings	13
8.1.2 Rating Adjustments for Discontinuity Orientations.....	14
9.0 REFERENCES	16
TABLES	
Table 1: Example of Final Structure Log Compilation	5
Table 2: Rock Mass Rating System (Engineering rock mass classifications, Bieniawski (1989))	8
Table 3: Summary of Hydraulically Conductive Feature intervals for IG_BH02 (from Sykes et al., 2022)	11
Table 4: Summary of mean and median values for RMR Index for borehole IG_BH02	13
Table 5: Rating Adjustment for Discontinuity Orientations (see also Table 6)	14
Table 6: Effect of Discontinuity Strike and Dip on Orientation in Tunnelling	14

FIGURES

Figure 1: Location of IG_BH02 in Relation to the Wabigoon / Ignace Area.....	2
Figure 2: Geological setting and location of boreholes IG_BH01, IG_BH02 and IG_BH03 in the northern portion of the Revell Batholith	3
Figure 3: Stereographic projection of all integrated final structures: Top: structures by type; Bottom: contour plot (with Terzaghi weighting)	6
Figure 4: Summary profile of rock mass characteristics, including components of RMR'89, used to develop the RMR Index (rightmost column) for IG_BH02.....	12
Figure 5: RMR Index distribution for 100 m sections of borehole IG_BH02 (RMR Index by run)	15

1.0 INTRODUCTION

The Initial Borehole Drilling and Testing project in the Wabigoon and Ignace Area, Ontario is part of Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase.

This project involves the drilling and testing of the first of three deep boreholes within the northern portion of the Revell batholith. The third drilled borehole, IG_BH02, is located a direct distance of approximately 21 km southeast of the Wabigoon Lake Ojibway Nation and a direct distance of 44 km northwest of the Town of Ignace. Access to the IG_BH02 drill site is via Highway 17 and primary logging roads, as shown on Figure 1.

The project was carried out by a team led by Golder Associates Ltd. (Golder) on behalf of the NWMO. The overall program is described in the Initial Borehole Characterization Plan (Golder, 2017). This report describes the rock mass characterization based on the data collected during the field activities for borehole IG_BH02 as described in the Work Package 3 (WP03) Data Report – Geological and Geotechnical Core Logging, Photography, and Sampling for IG_BH02 (Golder, 2020), and the subsequent analyses and compilation of the data as described in the WP04b Data Report – Geomechanical Testing of Core for IG_BH02 (Golder, 2021a), the WP05 Data Report – Geophysical Well Logging for IG_BH02 (Golder, 2021b), the WP10 – Geological Integration Report for Borehole IG_BH02 (Parmenter et al., 2022), and the Discrete Fracture Network Report for the Revell Site (Sykes et al., 2022).

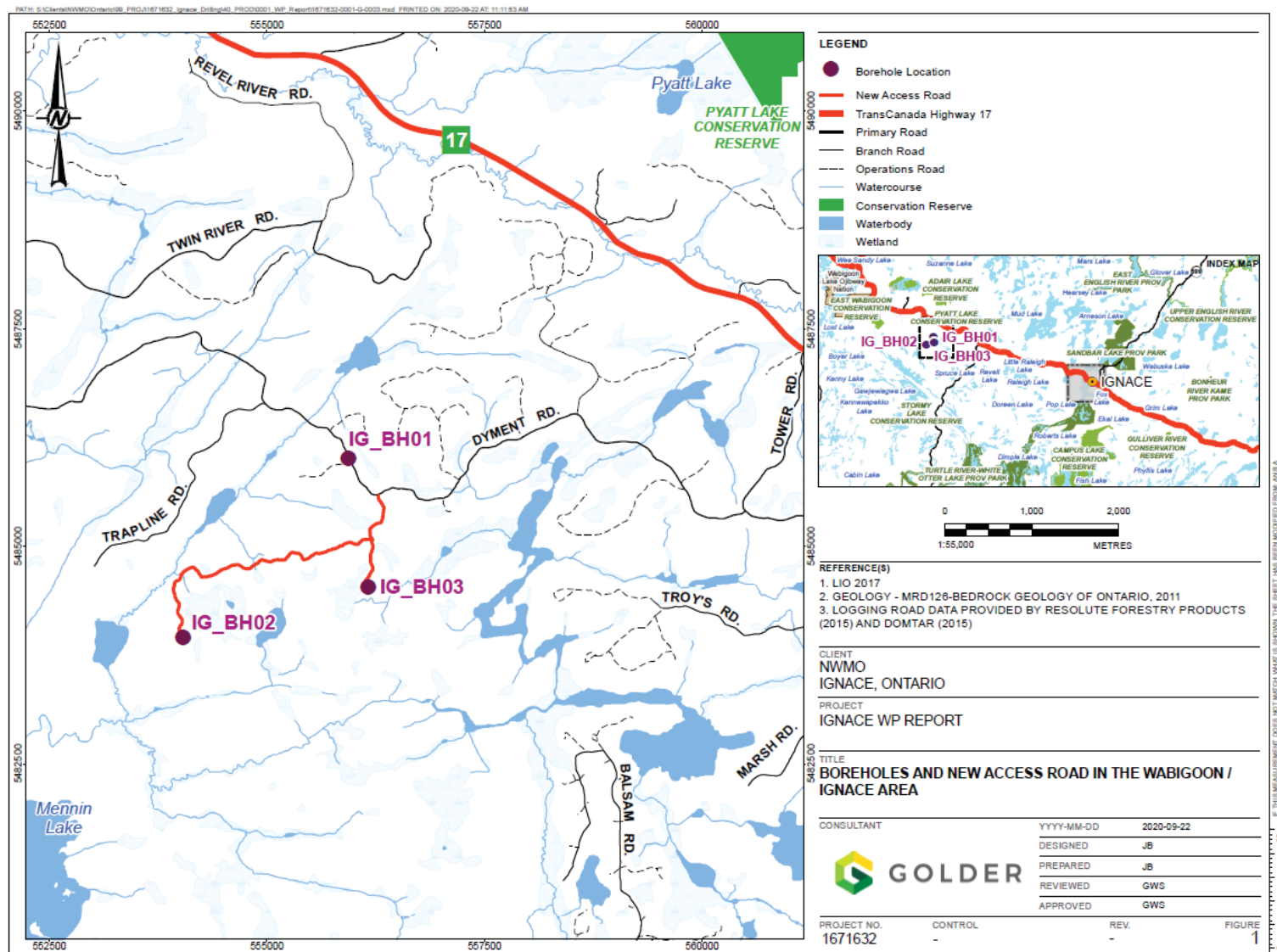


Figure 1: Location of IG_BH02 in Relation to the Wabigoon / Ignace Area

2.0 BACKGROUND INFORMATION

2.1 Geological Setting

The approximately 2.7 billion year old Revell batholith is located in the western part of the Wabigoon Subprovince of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km². Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL, 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (Figure 2).

Borehole IG_BH02 is located within an investigation area of approximately 19 km² in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 1).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 2). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone, 2009; Stone, 2010a; Stone, 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz, 1996; Stone et al., 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al., 2010).

Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite (Figure 2). Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of 2734.2 +/-0.8 Ma (Stone et al., 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of 2732.3 +/-0.8 Ma (Stone et al., 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 2). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of 2694.0 +/-0.9 Ma (Stone et al., 2010).

The bedrock surrounding IG_BH02 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder, 2015; Golder and PGW, 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW, 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG_BH01, is approximately 15-20 m wide (Figure 2). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of 1887 \pm 13 Ma (Stone et al., 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW, 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 1). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW, 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 2; DesRoches et al., 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 2). Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).

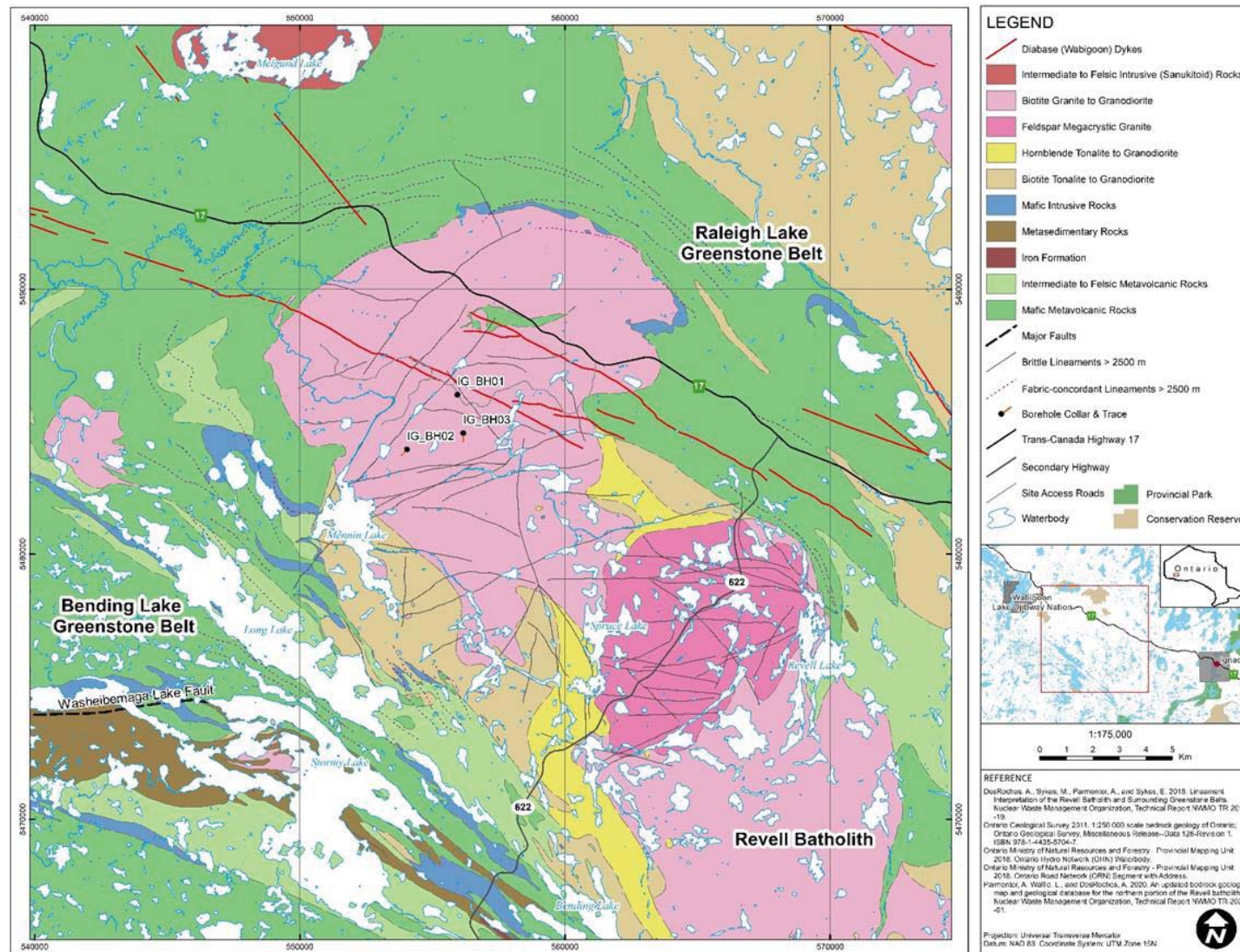


Figure 2: Geological setting and location of boreholes IG_BH01, IG_BH02 and IG_BH03 in the northern portion of the Revell Batholith

3.0 OBJECTIVE

The objective of this report is to present the methodology and the results for the development of the Rock Mass Rating (RMR) Index profile (along borehole) for IG_BH02. The report also presents a summary of the final structure log developed through the integration of structures identified during core logging (WP03, Golder 2020) and downhole televiwer logging (WP05, Golder 2021b), which is an important input into the RMR Index presented herein.

4.0 FINAL STRUCTURE LOG

The orientation of all structures measured during core logging, as described in the WP03 data report (Golder 2020), are initially defined based on alpha and beta angles relative to (1) the core axis, and (2) an arbitrary reference line drawn along the length of each core run. Since the core retrieved from the borehole (IG_BH02) is not oriented, these relative orientation angles (beta for planes; delta for lineations) for each logged structure need to be corrected to a true orientation in order to produce the final structure log for IG_BH02. As part of this process, structures were also interpreted by the geophysical team (WP05) using optical and acoustic televiwer logs independently of the structures picked from the core logging. Interpreted structure orientations were corrected from apparent dip and dip direction to true dip and dip direction (i.e., relative to true north), using the final Tilt and Azimuth logs, as described in the WP05 data report (Golder 2021b).

Once both WP03 and WP05 interpretations were completed, they were integrated as a specific task as part of completion of the WP10 geological integration report for IG_BH02 (Parmenter et al., 2022). This comparison identified structures that are common to both televiwer logs and core logging, based on similar position along borehole and relationship to adjacent structures, and possibly structure type and its characteristics (e.g., geological aperture). The complete methodology used in integrating the structures into a final structure log is included in Appendix D of the WP10 report (Parmenter et al., 2022).

Note that geological aperture is an estimated measurement of the open space between two adjacent fracture surfaces determined visually during geological core logging, during interpretation of downhole televiwer logs, or during the integration of data from these two sources. For our purposes, geological apertures are estimated values only because there are multiple possible sources of uncertainty in how a reported aperture value relates to the true aperture of a fracture identified as broken. There are uncertainties related to measurement inaccuracy, including where the opening is very small, where the opposing fracture planes are not parallel or fit poorly together, or due to limits in televiwer resolution. In addition, effects due to drilling or decompression may create or enhance the visible open space identified as aperture. Finally, aperture measured in core or on a borehole wall is only a local aperture that is not necessarily representative over the entire fracture.

The result of the integrated structure log includes a table that captures a complete set of attributes of each structure recorded either from core logging, televiwer logging, or a combination of both. Where certain attributes are duplicated between the two logging approaches (i.e., structure type, or position along borehole) decisions are made to carry forward the most accurate value to the final structure log. For example, orientation data will be obtained from the televiwer logged structures, whereas structure type should be obtained from core logging structures. Table 1 shows an example of the integrated structure log compilation. Figure 3 shows a stereographic plot of the integrated final structures by type (top) and a contoured plot of all integrated final structures (bottom).

Table 1: Example of Final Structure Log Compilation

Structure #	Reference Line	Beta CF	Beta CF St. Dev.	Final position along borehole	Corr_ Alpha	Corr_ Beta	True_ Dip	True_ DDIR	Type	Condition	Width (cm)	Geological Aperture (mm)	Infill Thickness (mm)
45	RL011	200.40	0.00	6.99	69	175	2	93	JN	BR	-	5	0
49	RL012	263.35	6.03	7.45	62	188	8	214	JN	BR	-	0	0
50	RL012	263.35	6.03	7.51	60	238	25	283	JN	PIN	-	0	0
51	RL012	263.35	6.03	7.52	18	106	68	103	JN	BR	-	1	1
52	RL012	263.35	6.03	7.65	67	233	19	294	JN	PIN	-	0	0
53	RL012	263.35	6.03	8.20	22	317	84	326	JN	BR	-	0	0
54	RL012	263.35	6.03	8.29	17	102	70	100	JN	IN	-	0	1

NOTE:

Beta CF – Beta Correction Factor for the reference line

Beta CF St. Dev. – Standard deviation for Beta Correction Factor for the reference line

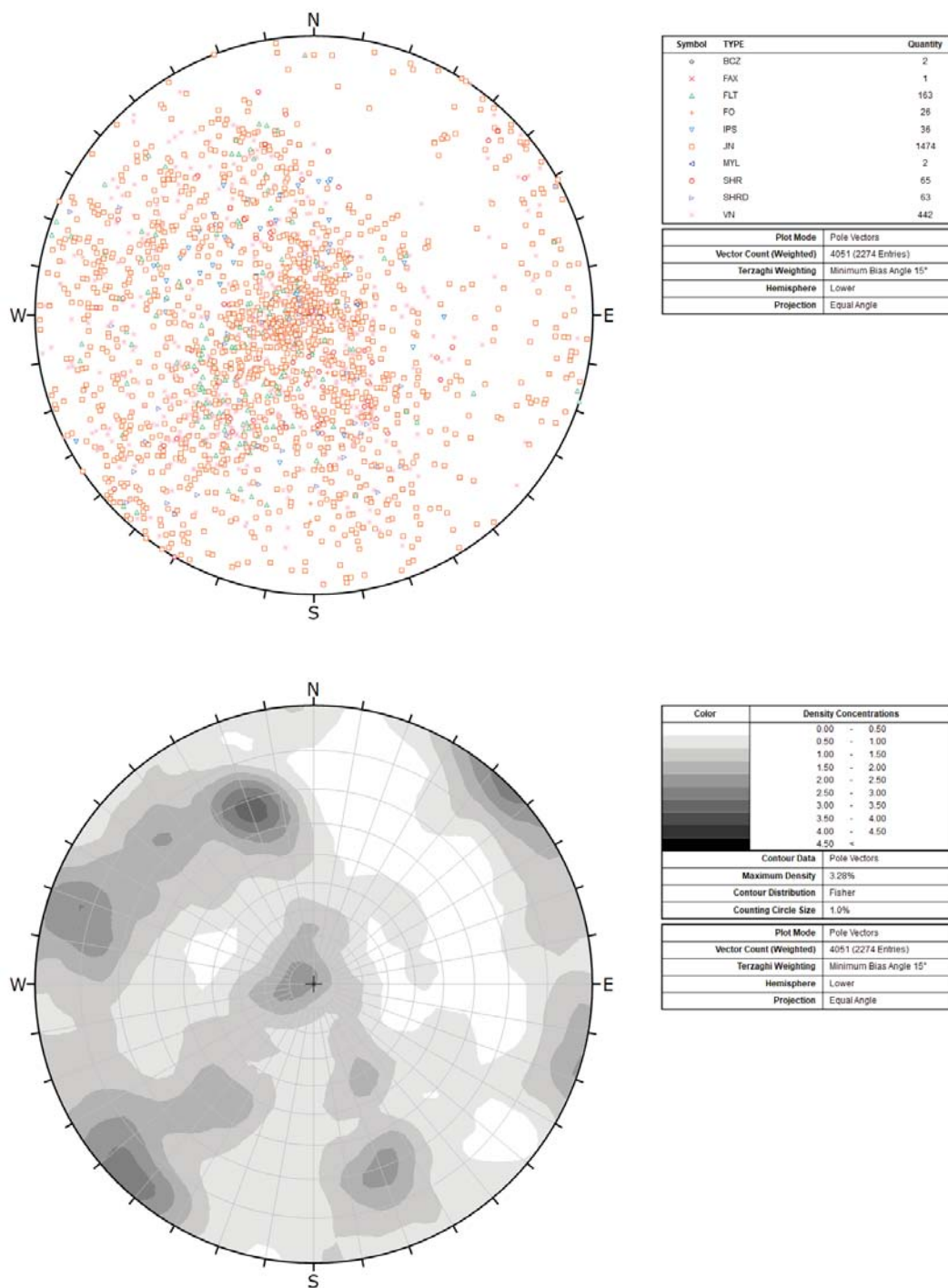


Figure 3: Stereographic projection of all integrated final structures: Top: structures by type; Bottom: contour plot (with Terzaghi weighting)

5.0 ROCK MASS CLASSIFICATION

One of the widely used rock mass classifications is the Rock Mass Rating (RMR) system of Bieniawski (1973, 1976, and 1989). The classification includes information on the strength of the intact rock material, Rock Quality Designation (RQD), the spacing and surface properties of the structural discontinuities as well as ratings for the influence of subsurface groundwater, and an adjustment for discontinuity orientation relative to the orientation of an engineered structure (e.g., tunnel). This classification was developed primarily for the estimation of the support requirements in tunnels, but its use has been expanded to cover many other fields (Hoek, 2018).

5.1 Geomechanics Classification, Rock Mass Rating (RMR) Index

The RMR Index described herein is based on the RMR⁸⁹ classification. However, it incorporates information from only five of six characteristics: strength of the intact rock material, the spacing and/or number of fractures, the surface properties of the fractures, as well as a rating for the influence of subsurface groundwater, where interpreted to be present. Because of the unknown orientation of potential excavations, no adjustment can be made for the discontinuity orientations at this time. The RMR index therefore describes the rock mass independent of orientation and adjustments will have to be made when utilizing it for tunnel or shaft support estimations. For tunnels and shafts, the RMR = RMR Index - (0 to 12) points when accounting for orientation.

The RMR Index is therefore based on the sum of the following five ratings:

- R_1 – Strength of intact rock material (Max rating = 15) – Based on laboratory testing (UCS); Strength Index values obtained during drilling/logging also correlate well with the UCS values and show consistency over the full length of the borehole;
- R_2 – Drill core quality RQD (%) (Max rating = 20) – Compiled from core logging by run;
- R_3 – Spacing of discontinuities (Max rating = 20) – Compiled from core logging by run;
- R_4 – Condition of discontinuities (Max rating = 30) – Compiled from core logging for each individual fracture and compiled by run; the minimum value for the run was used in the estimation of RMR; and
- R_5 – Groundwater condition (Max rating = 15) – Compiled from hydraulically conductive features (HCF) identified during hydrogeological testing (20 m long straddle packer tool) of the borehole and supported by Flowing Fluid Electrical Conductivity (FFEC) logs.

As noted above, the RMR Index describes the rock mass characteristics independently of orientation.

A description of the ratings based on the above five parameters can be found in Table 2. Table 7 of Appendix A of the WP03 Data Report (Golder 2020) provides more detailed descriptions of the condition of discontinuities (therein referred to as Joint Condition Rating or JCR), compared to the original RMR⁸⁹ table, and were tailored for this project. When assigning the RMR Index rating for UCS, RQD and Spacing parameters, interpolations were carried out between defined rating categories. When assigning the RMR Index rating for the Groundwater condition parameter to areas coincident with HCFs, the general condition of 'Damp' was applied ($R_5 = 10$).

Table 2: Rock Mass Rating System (Engineering rock mass classifications, Bieniawski (1989))

Parameter			Ranges of Values						
1	Strength of intact rock material	Point-load strength index (MPa)	>10	4 – 10	2 – 4	1 – 2	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength (MPa)	>250	100 – 250	50 – 100	25 – 50	5 – 25	1 – 5	<1
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD (%)		90 – 100	75 – 90	50 – 75	25 – 50	<25		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0.6 – 2 m	200 – 600 mm	60 – 200 mm	<60 mm		
	Ratings		20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1 – 5 mm Continuous	Soft gouge > 5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater condition	Inflow per 10 m tunnel length (L/min)	or None	or <10	or 10 – 25	or 25 – 125	or >125		
		Joint water pressure	0	<0.1	0.1 – 0.2	0.2 – 0.5	>0.5		
		Ratio $\frac{\text{Major principal stress}}{\text{Joint water pressure}}$							
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating ¹		15	10	7	4	0		

¹ – based on analysis of hydraulic conductivity testing of an HQ borehole (96 mm)

6.0 SUMMARY OF ROCK MASS CLASSIFICATION PARAMETERS

The identified parameters used to determine rock mass classification were measured directly in the field, and based on integration of some field information, including development of final structure log and determination of hydraulically conductive features. Both field measurements and laboratory testing data were utilized for the strength factor in this system. The parameters used to develop the rock mass classification, are based on the data presented in the following documents:

- WP03 Data Report – Geological and Geotechnical Core Logging, Photography and Sampling for IG_BH02 (Golder, 2020)
- acQuire core logging database
- Final structure log from WP10 - Geological Integration Report for IG_BH02 (Parmenter et al., 2022)
- WP04b Data Report – Geomechanical Testing of Core for IG_BH02 (Golder, 2021a)
- Discrete Fracture Network (DFN) Model Report for the Revell Site (Sykes et al., 2022)

The following subsections provide a summary of the input to the RMR Index presented below for the five ratings listed above in Section 5.1.

6.1 Strength

Discrete field strength index measurements (69) were only taken opportunistically while breaking the core with a geological hammer strike when sampling or fitting core into the core boxes. All but one of these field tests were carried out on the tonalite. In general, the tonalite was mostly classified as strong (R4) (26 occurrences, 38%) to very strong (R5) (33 occurrences, 49%) rock, with an increased relative amount of R4 values in the lower half of the borehole and R5 dominating in the upper half of the borehole. Medium strong (R3) was measured in three occurrences (4%), and extremely strong (R6) in 6 occurrences (9%). One strength index measurement was collected within a felsic dyke as R5 (very strong rock). This agrees with the results of the laboratory tests, which reported an average UCS value of 220 MPa for tonalite based on 3 tests (Golder, 2021a).

6.2 RQD

The results for IG_BH02 indicate that, overall, the rock quality is excellent, averaging 99% RQD, and ranging between 63% and 100%. The lowest RQDs are recorded at approximately 377 m along borehole, in runs that intersect a zone of increased fracture intensity, water loss, and feldspar-phyric felsic dykes (Golder, 2020).

6.3 Fracture Spacing

Overall, a broken structure frequency greater than 2 per m was observed in 4% of the core by length, while 4.86 m of core (approximately 0.5% by length) has broken structure frequency greater than 10 per m. The highest logged broken structure count was 25 per m, encountered near surface at 7 m along borehole. The broken structure frequency is highest in the upper 60 m of the borehole; however, zones of greater broken structure frequency are interspersed within zones of lesser broken fracture frequency along the length of the borehole. In general, the core runs containing lithological contacts have an increased broken structure count. However, it should be noted that aplite and pegmatite dykes are characterized by intact contacts and are not commonly associated with increased fracture frequency.

The broken core and lost core (BCZ/LCZ) zones are assumed to have 1 fracture / cm. Therefore, the BCZ/LCZ thickness (in mm) is divided by 10 mm to give the number of intervals and added of 1 to get the number of fractures. That number is then added to the other fractures in the run. That total is then divided by the run length to obtain the fracture frequency.

The true fracture spacing can only be estimated after all measured discontinuities are plotted on a stereonet and sets are identified. This usually results in spacings greater than the inverse of the fracture frequency from the logs. For the purpose of RMR Index estimation, the inverse of the fracture frequency was used; even so, 78% of the core runs were assigned the maximum R₃ rating and 18% were assigned the next best rating.

6.4 Condition of Discontinuities

The condition of discontinuities was recorded in all core logging data for all fracture types (i.e., faults, joints, veins) as a Joint Condition Rating (JCR). It is a frictional index based on intactness, geological aperture, rock wall strength, shape, roughness, infill character, and infill type of all fracture types (joints, faults and veins). Most of the logged joints (98%) exhibited zero geological aperture. In the remaining occurrences mm- to cm-scale geological apertures were logged. Of the total logged joints, 1% were logged as clean; elsewhere the surface condition was logged as stained, slightly altered, coated, or infilled. The most common mineral phase associated with logged joints was quartz, identified in 504 occurrences (35%), followed by calcite in 269 occurrences (19%), epidote in 203 occurrences (14%), muscovite in 148 occurrences (10%), iron oxide (hematite) in 139 occurrences (10%), chlorite in 109 occurrences (8%), and plagioclase in 15 occurrences (1%).

A total of 166 faults were logged in IG_BH02. Most of the logged faults (79%) were broken, allowing the full plane to be observed. One hundred and forty-nine of the logged faults (90%) were identified as hairline structures with no geological aperture. The remaining 17 faults had a mm- to cm-scale geological aperture. The most common mineral phase associated with logged faults was chlorite, followed by epidote, quartz, calcite, muscovite, iron oxide or hematite, and soft gouge derived from the adjacent wall rock.

JCR values were generally higher than 20 with 62% of the structures having the maximum rating of 30 (Golder, 2020). In general, features logged within dyke and amphibolite units have slightly reduced JCR values when compared to the overall data distribution.

The minimum JCR for the run was adopted when calculating the RMR for the run. A separate assessment with the average JCR for the run showed very little difference from the minimum JCR assessment.

6.5 Groundwater

As part of the workflow in developing a site-scale discrete fracture network (DFN) model (Sykes et al., 2022), intervals with groundwater were identified as hydraulically conductive features (HCFs) by either correspondence to the location of an opportunistic water sample (OGW), or to an interpreted inflow during flowing fluid electrical conductivity (FFEC) logging. A total of eight (8) HCF intervals were identified in IG_BH02 (Table 3). All core runs that overlap with locations of HCF intervals are assigned a rating of 10 (out of 15) indicating 'damp' conditions. The remainder of the core runs along the borehole are assigned a rating of 15 indicating 'dry' conditions.

Table 3: Summary of Hydraulically Conductive Feature intervals for IG_BH02 (from Sykes et al., 2022)

Borehole ID	HCF ID	From [m down hole]	To [m down hole]
IG_BH02	IG_BH02_HCF_1	14.36	19.16
IG_BH02	IG_BH02_HCF_2	59.3	64.11
IG_BH02	IG_BH02_HCF_3	374.46	377.05
IG_BH02	IG_BH02_HCF_4	587.35	587.94
IG_BH02	IG_BH02_HCF_5	617.01	622.99
IG_BH02	IG_BH02_HCF_6	668.18	670.76
IG_BH02	IG_BH02_HCF_7	679.12	680.88
IG_BH02	IG_BH02_HCF_8	727.01	732.99

7.0 SUMMARY OF ROCK MASS CLASSIFICATION BY RUN

The RMR Index described herein per core run is based on the RMR'89 classification. The data collected from borehole IG_BH02 were used to assemble the geotechnical information.

The information for the five parameters comprising RMR'⁸⁹ was compiled as follows:

R_1 – Based on laboratory testing (UCS) and Strength Index values;

R_2 – Compiled from core logging by run;

R_3 – Spacing of discontinuities – Compiled from distances between fractures recorded from core logging by run;

R_4 – Condition of discontinuities– Available from core logging for each discontinuity individually; compiled by run using the minimum value for the run; and

R_5 – Groundwater condition – Compiled from hydraulically conductive features identified during hydrogeological testing of the borehole and supported by FFEC logs (Sykes et al., 2022).

The RMR Index describes the rock mass characteristics independently of discontinuity orientations. An additional /adjustment should be applied once the engineering application is known.

Figure 4 shows a summary of rock mass characteristics, including the components of RMR'⁸⁹, and the RMR Index profile by run along the borehole.

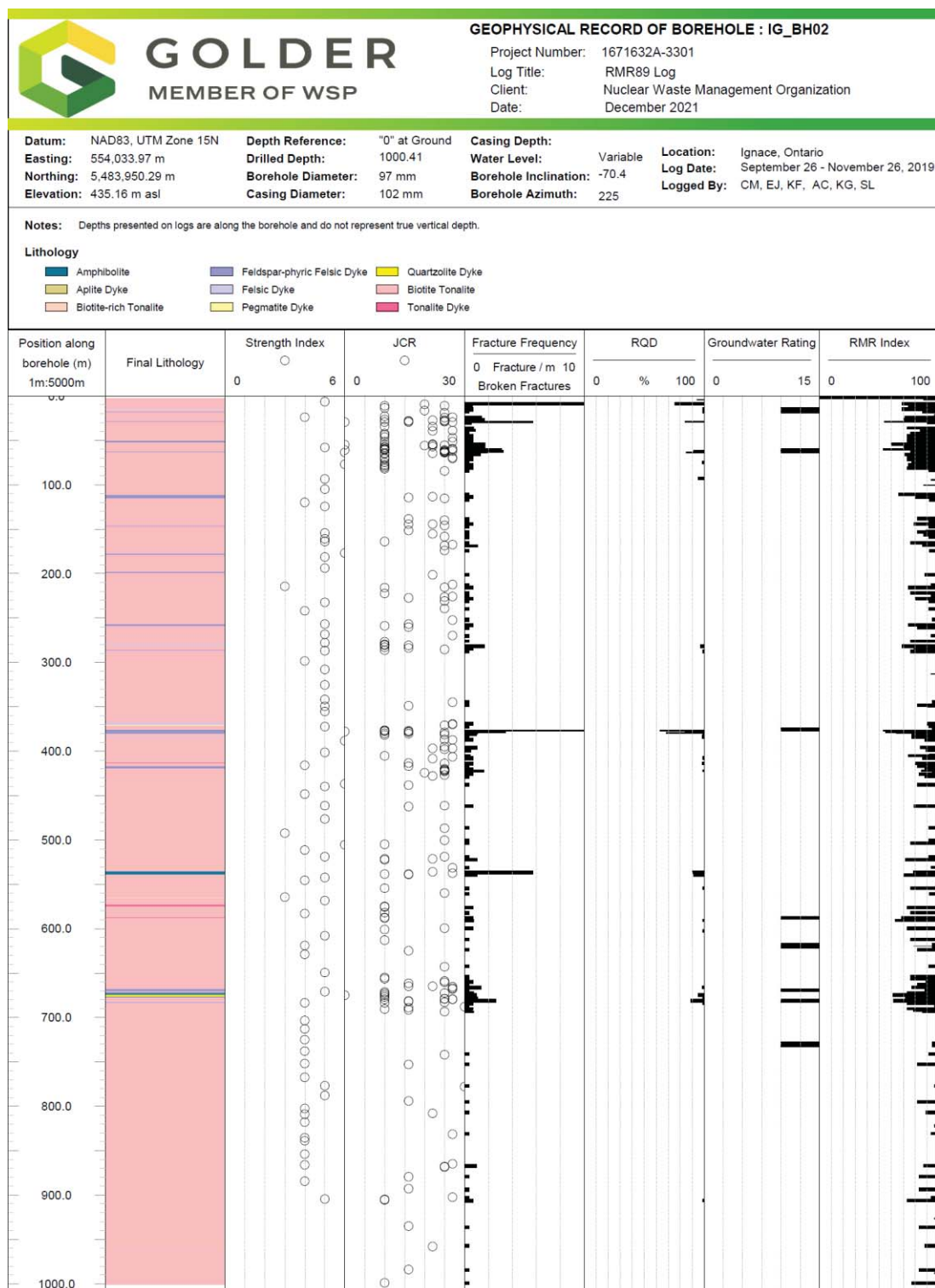


Figure 4: Summary profile of rock mass characteristics, including components of RMR'89, used to develop the RMR Index (rightmost column) for IG_BH02

8.0 SUMMARY OF ROCK MASS RATING INDEX DISTRIBUTION BY SECTIONS OF BOREHOLE IG_BH02

Distributions of the RMR Index for 100 m sections along the borehole are presented in Figure 5. This presentation of the data by borehole section in the form of histograms was made to allow an assessment of the variability of the rock quality with position along borehole. Mean and median values for the RMR Index are presented in Table 4 and RMR Index, by core run, is shown on Figure 4 alongside the borehole profile.

Table 4: Summary of mean and median values for RMR Index for borehole IG_BH02

Depth (position along borehole) Interval (m)	RMR Index		
	minimum	mean	median
0 – 100	53	80	76
100 – 200	66	93	99
200 – 300	69	92	99
300 – 400	53	91	99
400 – 500	74	94	99
500 – 600	63	91	99
600 – 700	61	88	91
700 – 800	82	97	99
800 – 900	73	96	99
900 – 1000.41	77	97	99

8.1 Adjustments to RMR Data for Engineering Use

8.1.1 Groundwater Ratings

The groundwater ratings used to generate the RMR Index profile were based on analysis of field hydrogeological testing of 20 m intervals in the more conductive features as identified from core logging and FFEC testing that was done as part of development of a site-scale DFN for the Revell Site (Sykes et al., 2022). The hydraulic conductivity values that led to the identification of the more conductive zones are representative only for the size of the HQ borehole (96 mm).

When using these data for engineering analysis or design of larger excavations, e.g., tunnels or shafts, a re-assessment of the groundwater conditions will be required to replace the ratings provided in this report.

8.1.2 Rating Adjustments for Discontinuity Orientations

The RMR Index ratings presented in this report will need to be adjusted by an additional parameter, namely, the influence of the orientation of the discontinuities. This step is usually left to the user of the data because the influence of the discontinuity orientations depends on the engineering application (see Table 5 and Table 6).

Table 5: Rating Adjustment for Discontinuity Orientations (see also Table 6)

Strike and Dip Orientations of Discontinuities		Very Favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels and mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-25	-25
	Slopes	0	-5	-25	-50	-60

Table 6: Effect of Discontinuity Strike and Dip on Orientation in Tunnelling

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 – 90°	Drive with dip - Dip 20 – 45°	Dip 45 – 90°	Dip 20 – 45°
Very favourable	Very favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20° - Irrespective of strike	
Fair	Unfavourable	Fair	

Modified after Wickham et al (1972)

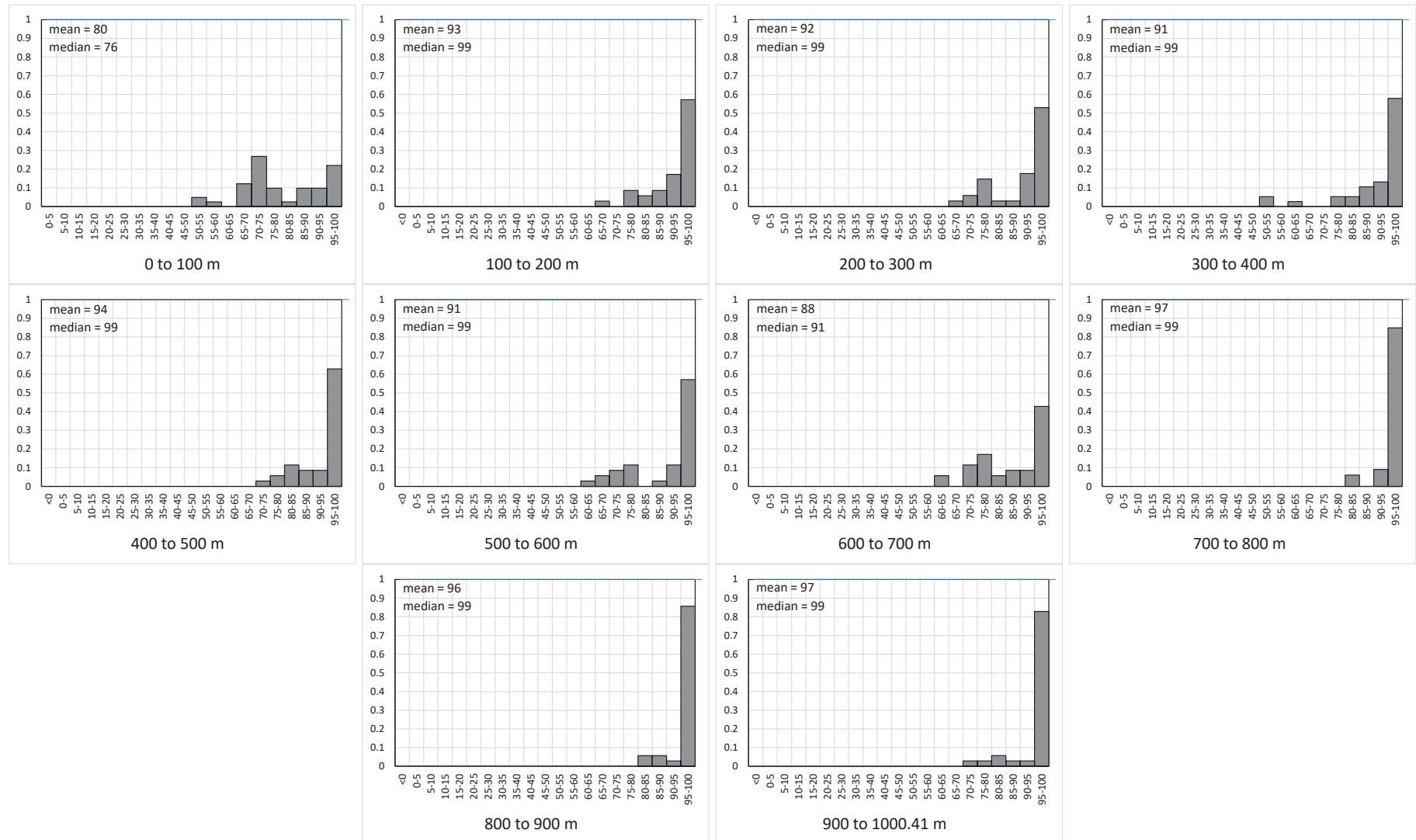


Figure 5: RMR Index distribution for 100 m sections of borehole IG_BH02 (RMR Index by run)

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