REPORT

Drainage Åknes

DATA REPORT CORE LOGGING KH-01-2017

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NORWEGIAN GEOTECHNICAL INSTITUTE
NGI.NO

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for NGI

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Summary

KH-01-17 is a core drilled bore hole at Kulen in the Åknes rock slope. The bore hole is 302.7 meter deep, and was core drilled during August to September 2017. Geodrilling AS performed the core drilling on assignment from Norwegian Water- and Energy directorate (NVE). Henrik Langeland performed engineering geological core logging in mid-September 2017.

The rock type registered in KH-01-2017 is gneiss with variation in grain size and colour according to classification from ISO 14689.

The core logging shows that the core is intersected with crushed zones in the upper 40 meter. In this section also 3 intervals with core loss are registered. From 40 to 100 meter depth the presence of crushed zones decrease, however RQD and fractures/meter (FFm) values are varying. From 100 meter to end of bore hole the rock mass is considered solid with a massive character. Crushed zones are sparsely registered and the rock mass is generally considered good, evaluating RQD- and FFm values. A small section at about 250 meter and between 270-280 meter show lower RQD and higher FFm.

An analysis show high concentration of joints with characteristics corresponding to low friction joints between 40 and 50 meter depth.

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Review and reference page

1 Introduction

KH-01-17 is a core drilled bore hole at Kulen in the Åknes rock slope. The bore hole is 302.7 meter deep, and was drilled during August to September 2017. Geodrilling AS performed the core drilling on assignment from Norwegian Water- and Energy directorate (NVE). Henrik Langeland performed engineering geological core logging in mid-September 2017.

The core drilling is undertaken to investigate the subsurface in the Åknes rock slope, e.g. degree of fracturing, weak zones, lithological composition. In addition to the core logging, several tests will be performed on selected core samples, e.g. to evaluate lithology, mineral composition and strength parameters.

This report gives an overview of the core logging of KH-01-17, method for core logging, and results. All ancillary data are organized in appendices:

Appendix A: Drilling report from Geodrilling
Appendix B: Core logging sheets (Logplot)
Appendix C: Pictures of cores

2 Core drilling KH-01-17

KH-01-17 is a vertical bore hole, located at Kulen in the Åknes rock slope, 506.8 metres above sea level (Figure 1). Drilling depth is 302.7 m. Steel casing is placed from +0.30 m to -4.35 m. Core length, logged length, is 304 meter.

During drilling of the first 30 to 40 meters it was necessary to stabilize the bore hole with concrete in several sections. The casted sections is not specified in the drilling report from Geodrilling (Appendix A). The core drilling has been performed with Diamec U-8 APC rig, with HQ diamond tipped core bit, giving a bore hole diameter of about 96 mm and a core diameter of about 63.5 mm. Geodrilling AS report from core drilling is given in Appendix A.

Core logging sheets, with results from core logging is shown in Appendix B, pictures of the cores is shown in Appendix C.

During drilling two water pressure tests were performed, between 69-88.9 meters and 84-88.9 meters, with single packer setup. Two packers were wrecked in the test. The bore hole has also been logged with optical televiewer, flowmeter and geophysics after core extraction.

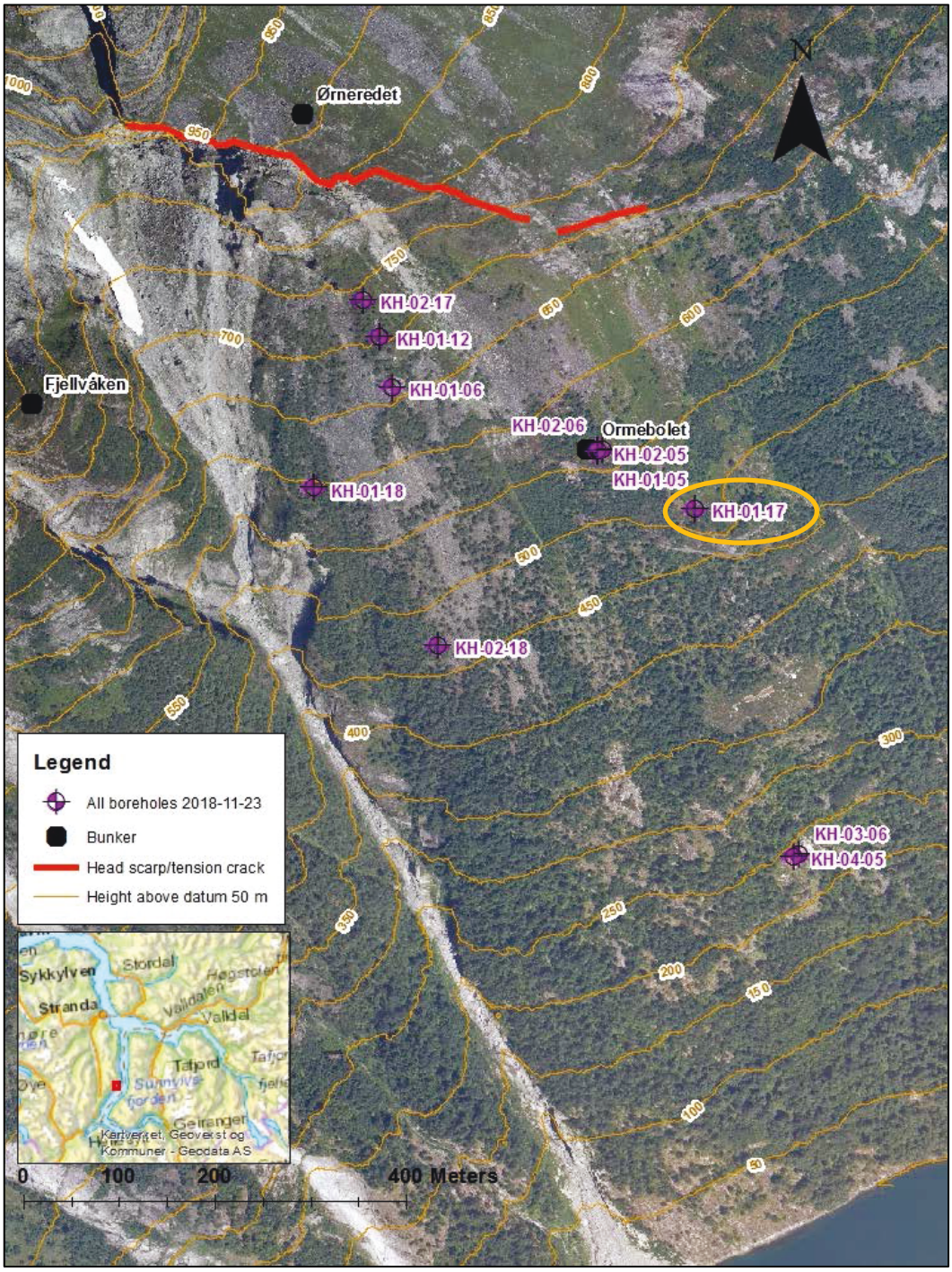

Figure 1. Overview of the Åknes rock slope with bore hole locations, including bore hole KH-01-17 in yellow ellipse.

3 Brief regional geological description

The geology at the Åknes rock slope is thoroughly described, by field mapping and core logging [1] [2] [3] [4].

Åknes is situated in the Western Gneiss Region (WGR), located west of the Caledonian thrust nappe [5]. WGR consists of autochthon Precambrian rocks, mainly granitic- to dioritic gneiss, in some places migmatittic [1]. These rocks are about 1850-1500 million years old, and contain features such as bands with mica rich gneiss and amphibolite [6].

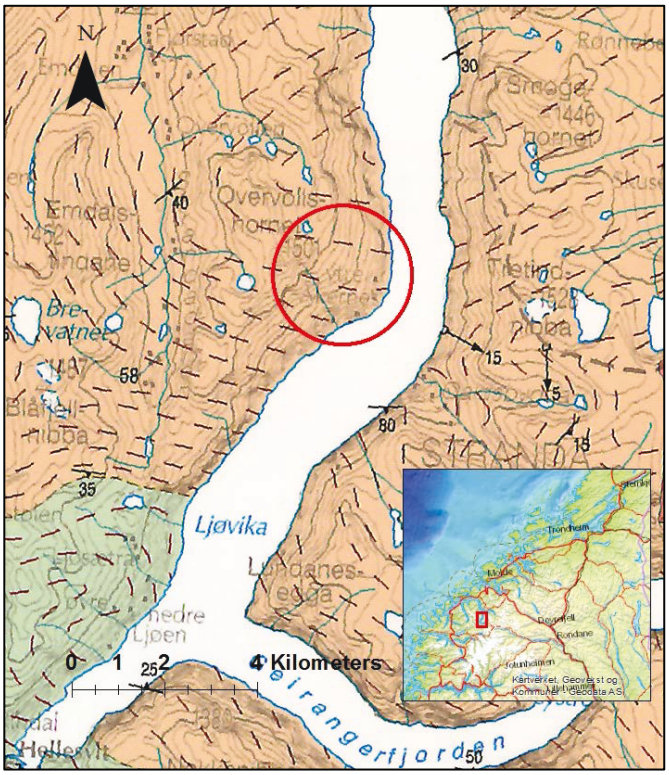

Figure 2. Excerpt of geological map 1:250 000 for the Åknes rock slope (red circle). Light orange color is mapped as: "Gneiss, not grouped, mainly quartzdiorittic to granitic, in some places migmatittic" and light green colour is mapped as: "Mica gneiss, quartz mica gneiss, some garnet amphibolite, garnet mica schist, meta-arkose and anorthosite" [7].

The geological map from the area show that at the Åknes rock slope the bedrock is defined as "Gneiss, not grouped, mainly quartzdiorittic to granitic, in some places migmatittic" [7]. West-southwest of the Åknes rock slope the bedrock is mapped as (2): "Mica gneiss, quartz mica gneiss, some garnet amphibolite, garnet mica schist, meta-arkose and anorthosite".

4 Method

The core logging sheets present a geological description of the core according to ISO 14689:2017 [8], registration of core loss, crushed core, fracture frequency and Q method parameters; RQD (Rock Quality Designation), J_r (joint roughness number) and J_a (joint alteration number). The core is not oriented, but the bore hole has been logged with televiewer, and therefore an overview of joint sets and dip/dip-direction are reported by the Geological Survey of Norway (NGU).

4.1 Q-parameters

The Q-method is a classification system for rock mass in relation to stability of underground excavations such as tunnels and caverns [9]. By determining the 6 Q-parameters one can decide the Q-value for the rock mass:

$$Q = \frac{RQD}{J_n} + \frac{J_r}{J_a} + \frac{J_w}{SRF} \quad (1)$$

where:

RQD = Rock Quality Designation
J_n = Joint set number
J_r = Joint roughness number
J_a = Joint alteration number
J_w = Joint water reduction factor
SRF = Stress reduction factor

Evaluation of the 6 parameters is described by NGI [9]. The Q-value can vary from 0,001 (exceptionally poor) to 1000 (exceptionally good), where values above 10 is equivalent to good rock mass quality. By core logging one can determine the parameters RQD, J_n (if cores are oriented), J_r, og J_a, and by this determine the rock mass properties. The parameters J_w (Joint water reduction factor) and SRF (Stress reduction factor) cannot be determined from cores, and therefore a Q-value from core logging will represent a Q-value where J_w and SRF are not accounted for.

There is also uncertainty connected to J_r- and J_a values in core logging. By logging a 64 mm core, only a small excerpt of the joint is visible. A J_r value determined for a joint in the core is not necessary representative for the bulk scale joint. This is equivalent for the J_a value. Joint filling and -coating can vary along the joint, and drilling can affect the remaining joint infill after core extraction.

J_n-values are not registered during logging, as the core is not oriented. However, the televiewer analysis will describe joint sets and dip/dip-direction of joints.

4.2 Fracture frequency and crushed core

The fracture frequency (fractures/meter, FFm) is evaluated for every meter, based on the number of natural joints, inclusive crushed zones. For crushed zones an FFm value between 2 and 25 is given, counting one joint for every 4 cm of crushed zone in addition to joint in the start and end of crushed zone. Minimum FFm value for crushed zone would then be 2 if the crushed zone is shorter than 4 cm. Maximum FFm value would be 25 for 100 cm core, which implies that the entire core is a crushed zone.

However, deciding FFm from core logging is connected to uncertainty due to the presence of artificial joints caused by drilling and handling of cores in the wireline system. It's sometimes difficult to determine a natural joint from an artificial joint, and the result would be overestimation of joints in the core logging. Having the televiewer analysis in addition to the core logging makes it possible to compare the joint frequency.

4.3 Core loss

Core loss is evaluated for every meter, based on missing core sections. In order for this to be registered correct, the drillers have to mark core loss in the cases.

5 Results

5.1 Overview bore hole

A simplified overview of RQD, average RQD every 10 meters, FFm, average FFm every 10 meters, crushed zone >10 cm and core loss distribution in the bore hole is shown in Figure 3.

5.2 Logging parameters

5.2.1 RQD and FFm

The upper 40 meters of the bore hole is intensely intersected with crushed zones, and 3 sections with core loss is registered. The average RQD value from 0 to 40 meter depth is 46 and the FFm value is 11 (Figure 3).

From 40 meter down to 100 meter the presence of crushed zones decrease, however RQD and FFm values are varying. The average RQD value from 40 to 100 meter depth is 70 and the FFm value is 7.3 (Figure 3).

From 100 meter to end of bore hole the rock mass is considered solid with a rather massive character. Crushed zones are sparsely registered and the rock mass is generally considered good, evaluating RQD- and FFm values. A small section at about 250 meter

and between 270 and 280 meter show lower RQD and higher FFm. The average RQD value from 100 to 304 meter is 90 and the FFm value is 4 (Figure 3).

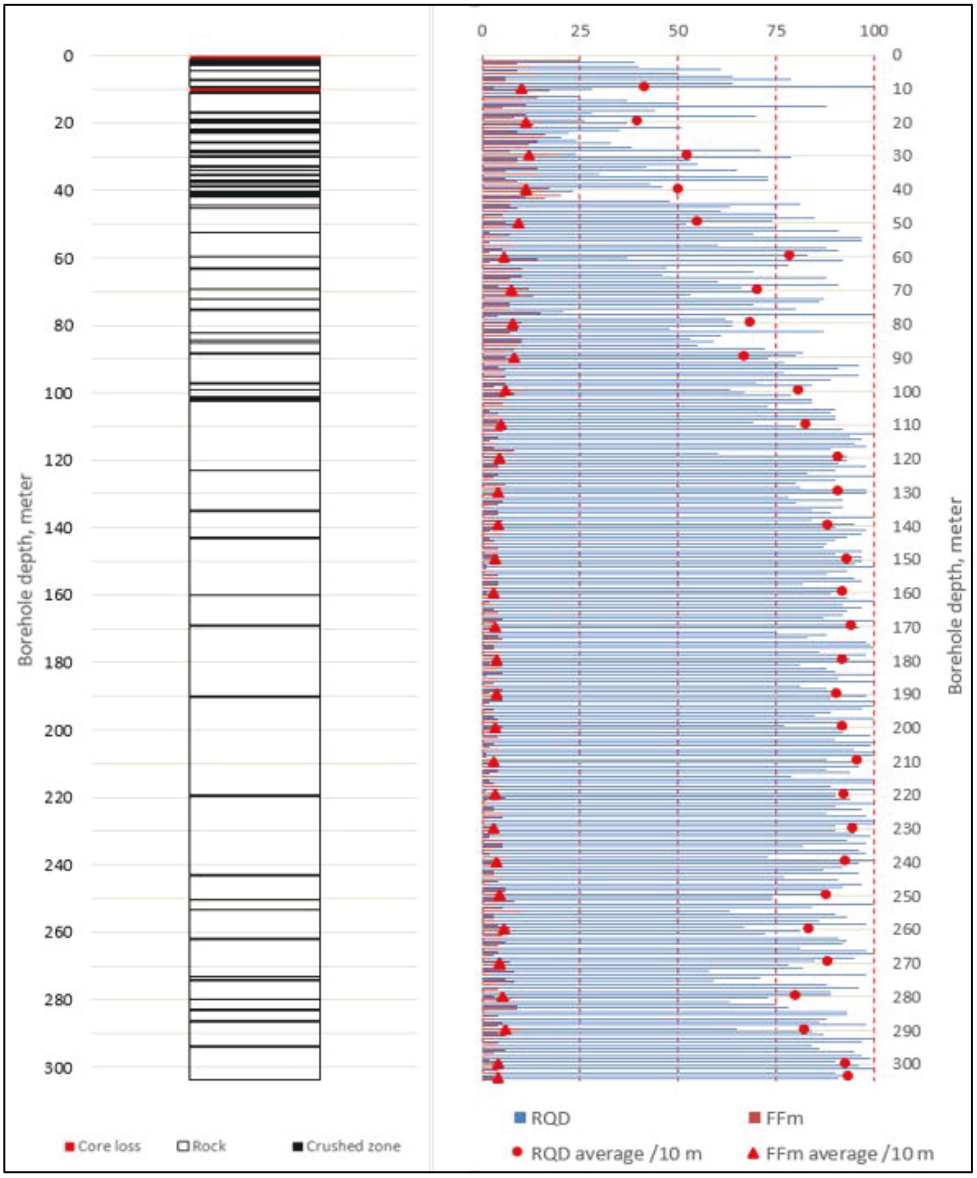

Figure 3. Simplified overview of RQD, average RQD every 10 meters, FFm, average FFm every 10 meters, crushed zone >10 cm and core loss distribution in KH-01-17.

5.2.2 J_r, J_a

J_r and J_a is registered for every joint, besides in the crushed zones where this is practical impossible. Figure 4 show the frequency of J_r and J_a, from a-g. The J_r and J_a categories are given values according to NGI [9]. J_a range from a-p according to NGI [9], but only values from a-g is registered.

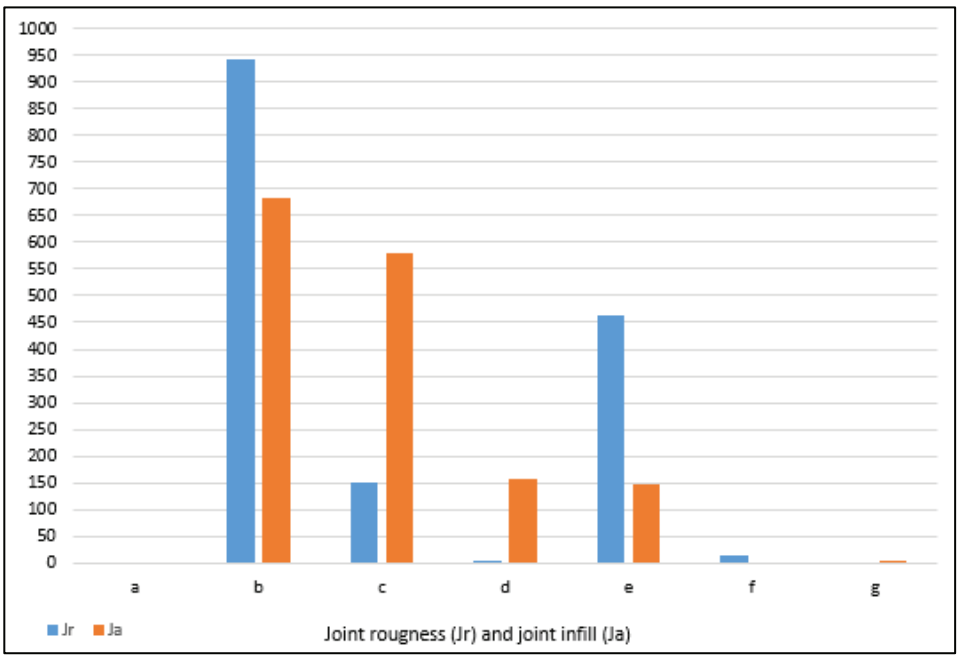

Figure 4. Histogram that represents the frequency of J_r and J_a values for the entire bore hole. J_a values can be determined in the range from a-p (NGI, 2015), but only values from a-g was registered.

The histogram show that J_r categories of b (rough or irregular, undulating) and e (rough, irregular, planar) are dominating, and very few smooth planar (f) or slickensided undulating (d) categories are registered. The dominating J_a categories are b (Unaltered joint walls, surface staining only) and c (Slightly altered joint walls. Non-softening mineral coatings; sandy particles, clay free disintegrated rock, etc.). However, some joints are registered with coating or infilling (d, e and g).

Figure 5 and Figure 6 show distribution of J_r and J_a in relation to bore hole depth. J_r value 1 represent smooth and planar joints, and J_a values 3, 4 and 6 represent coating or infill on joints. I.e. joints registered with J_r value 1 and J_a value 3, 4 and 6 will probably represent low friction joints. An analysis of joints with such characteristics show that we find a high concentration of these joints between 40 and 50 meter depth.

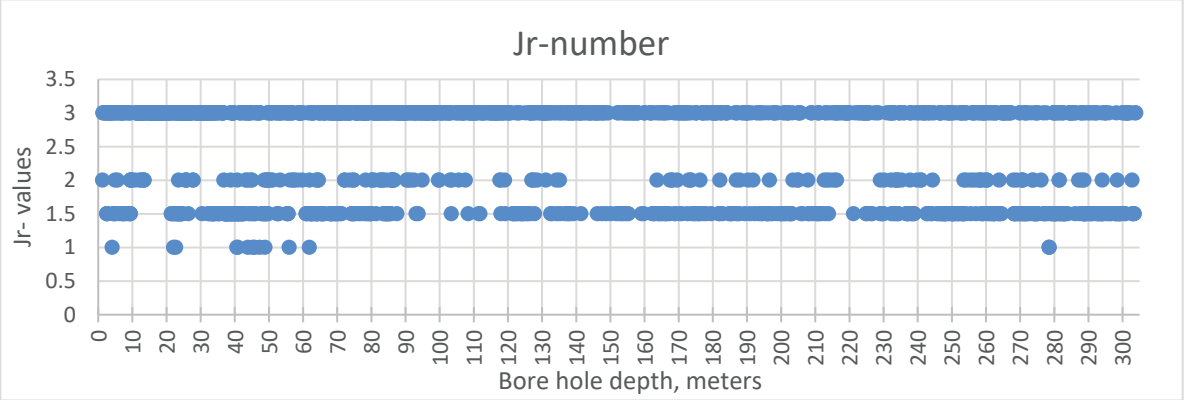

Figure 5. J_r values on joints in relation to bore hole depth.

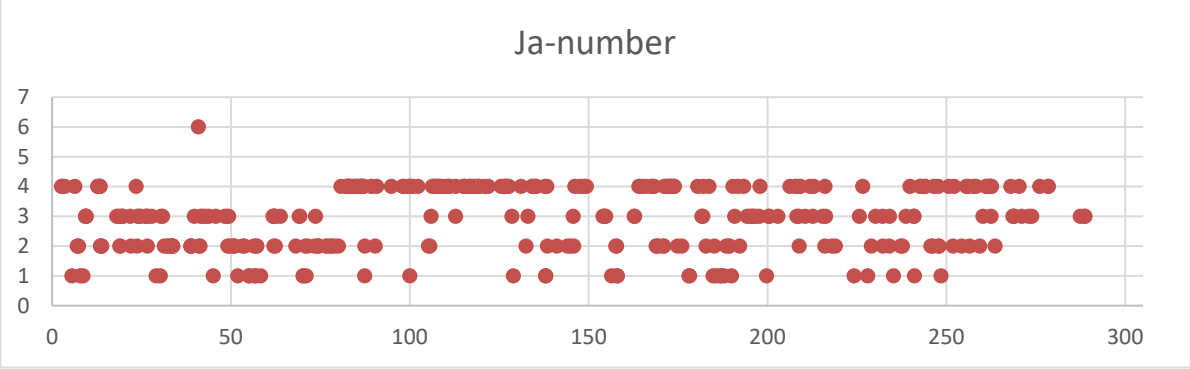

Figure 6. J_a values on joints in relation to bore hole depth.

As an example, the joint registered at 40.92 is the end of a crushed zone registered from 40.81-40.92, with J_a value 6. The core drilling managed to extract this section with intact clay intersecting the crushed zone (Figure 7).

Figure 7. Zone with clay and crushed rock registered at 40.81-40.92.

5.3 Description of the rock mass

Bore hole KH-01-2017 is located in an area, which according to NGU, consists of gneiss [7]. The rock type registered in KH-01-2017 is gneiss with variation in grain size and colour [8]. ISO [8] terms foliated metamorphic rock types as Gneiss, Schist and Slate for coarse-, medium- and fine grain size respectively. It is decided to classify the entire bore hole as Gneiss, but with specification of the different grain size and colour (Table 2 and Appendix B).

Table 1. Description of KH-01-2017 rock type according to ISO 14689:2017 [8].

Identification	Core logging
Genetic group	Metamorphic
Structure	Foliated
Grain size	Coarse-fine
Mineralogical composition by visual inspection	Feldspar, quartz, mica

Table 2. Overview of evaluated grain size and colour in KH-01-17.

From	To	Length	Grain size	Colour	Rock type
0	1,3	1,3	Core loss		
1,3	9,17	7,87	Coarse	Light grey to black	Gneiss
9,17	9,9	0,73	Medium-fine	Dark black	
9,9	10,8	0,9	Core loss		
10,8	17	6,2	Medium-fine	Dark black	Gneiss
17	21,5	4,5	Coarse	Light grey to black	
21,5	26,3	4,8	Medium-fine	Dark black	
26,3	29,93	3,63	Coarse	Light grey to black	
29,93	30	0,07	Core loss		
30	36,75	6,75	Coarse	Light grey to black	Gneiss
36,75	42,5	5,75	Medium-fine	Dark black	
42,5	130	87,5	Coarse	Light grey to black	
130	140	10	Medium-fine	Dark black	
140	200	60	Coarse-fine	Light grey to black	
200	220	20	Coarse	Light grey to black	
220	250	30	Medium-Coarse	Light grey to black	
250	260	10	Coarse-Medium	Light grey to black	
260	270	10	Medium-Coarse	Light grey to black	
270	271	1	Coarse-Medium	Light grey to black	
271	297	26	Medium-fine	Dark black	
297	304	7	Coarse	Light grey to black	

5.3.1 Gneiss, coarse grained

Example of a coarse grained rock, with colour light grey to black is shown in Figure 8.

Figure 8. Case 32, ca. 124.0-124.5 meter.

5.3.2 Gneiss, medium to fine grained

Example of a medium- to fine grained rock, with colour dark black is shown in Figure 9.

Figure 9. Case 70, ca. 276.0-276.5 meter.

6 Reference

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[7] E. Tveten, O. Lutro og T. Thorsnes, Geologisk kart over Noreg, Berggrunnskart ÅLESUND, M 1:250 000, Norges Geologiske Undersøkelse, 1998.

[8] ISO, ISO 14689. Geotechnical investigation and testing - Identification, description and classification of rock, Switzerland: International Standard, 2017.

[9] NGI, Bruk av Q-systemet, Bergmasseklassifisering og bergforsterkning, Oslo: Norges Geotekniske Institutt., 2015.

Appendix A

GEODRILLING, REGISTERED DRILLING DATA KH-01-2017

Contents

A1 Geodrilling, Registered drilling data KH-01-2017

GEO DRILLING AS		REGISTRERING BOREDATA						SIDE 1		GEO DRILLING
PROSJEKT: P - 160117		STED: Åknes			HULL-NR: BH - 01 - 17 Kulen		KRONE: HQ	DATO: August	MASKIN: Diamec U-8 APC	FALL/RETNING: Lodd
FRA BOREDYP	TIL BOREDYP	KJERNE LENGDE	ROTASJON RPM	MATEKRAFT KILO	PENETRERING ca CM/MIN	Mottrykk Spyl.vann Bar	FARVE SPYLEVANN	KOMMENTAR		
0,00	35,30	35,30					Vann gjen. Krone	Boring gjennom dårlig dagfjell, ikke registrert pga mest bare skrotfjell		
35,30	35,40	0,10	800	1600	15	5	40	Ferdig med sementboring		
35,40	38,60	3,20	750	2000	15	4	40	Dårlige soner		
38,60	41,60	3,00	700	1950	16	5	40	Leirsone ved 40,90 meter		
41,60	44,70	3,10	800	2000	16	6	40	Bedre fjell, oppsprukket		
44,70	46,40	1,70	750	2800	14	5	40	Hardt fjell		
46,40	47,30	0,90	700	1500-4500	10	7	20	Rensking, havarert krone, reamer i hullet		
47,30	50,40	3,10	800	1800-4000	15	8	45	Byttet til UMX		
50,40	53,30	2,90	800	2000-4500	15	10	45	Hardt og helt fjell, VANNSTAND FØR START, -41,50 METER		
53,30	56,30	3,00	750	2000-4300	14	15	45	Hardt og helt		
56,30	59,40	3,10	750	2500-4000	14	14	45			
59,40	59,70	0,30	750	2500-4000	14	14	48			
59,70	62,70	3,00	700	2500-4000	14	16	52			
62,70	65,80	3,10	750	2100-4000	14	18	51	Delvis hardt, helt fjell, lettere borbart		
65,80	68,80	3,00	750	1800-4200	14	20	48			
68,80	71,90	3,10	750	2600-4200	14	20	49			
71,90	75,00	3,10	750	3200-4200	13	22	52	VANNSTAND FØR START, -39,80 METER		
75,00	77,70	2,70	750	3100-4200	14	26	49	Fastboring, noe problemer i hullet		
77,70	77,80	0,10	750	2500-4200	13	25	52	Dårlige soner		
77,80	80,80	3,00	750	2500-4200	13	21	51	Hardt og helt		
80,80	83,80	3,00	700	2700-4200	13	23	50			
83,80	86,20	2,40	730	3000-4400	13	16	49	Hardt		
86,20	86,90	0,70	750	3000-4500	13	14	39	VANNSTAND FØR BORING, -46,00 METER, tar opp for logging av hull		
86,90	89,90	3,00	700	3000-4600	13	14	37	Vanntapsmålinger, havari av to packere		
89,90	92,10	2,20	700	3000-4700	13	13	40	Hardt og helt		
92,10	94,90	2,80	700	3500-4700	13	6	30	Dårlig sone 93,10 meter		
94,90	95,30	0,40	750	4000-5500	3-5	3	23	Hardt og helt, VANNSTAND FØR BORING, -57,20 METER		
95,30	98,40	3,10	750	1500-1950	14	15	47	Hard og helt, Ny UMX-10		
98,40	101,50	3,10	750	1400-3700	14	14	49			
101,50	104,50	3,00	750	3000-5000	14	13	46	Hardt		
SUM	104,50	104,50								

GEO DRILLING AS	REGISTRERING BOREDATA						SIDE 2	GEO DRILLING
PROSJEKT: P - 160117	STED: Åknes			HULL-NR: BH - 01 - 17 Kulen		KRONE: HQ	DATO: August	MASKIN: Diamec U-8 APC	FALL/RETNING: Lodd

FRA BOREDYP	TIL BOREDYP	KJERNE LENGDE	ROTASJON RPM	MATEKRAFT KILO	PENETRERING ca CM/MIN	Mottrykk Spyl.vann Bar	FARVE SPYLEVANN	KOMMENTAR
104,50	105,20	0,70	750	5100	7	4	Vann gj. Krone	Hardt og helt, VANNSTAND -42 meter
105,20	108,10	2,90	750	4800	14	9	40	Hardt og helt,
108,10	111,10	3,00	750	4500	13	10	40	Hard, helt. Liten sone sand v/110,70 meter
111,10	114,10	3,00	750	4400	14	10	35	Hardt, noen svake soner
114,10	117,00	2,90	750	3900	14	15	45	Vekslende hardt og mykere
117,00	120,10	3,10	750	3900	14	15	50	Vekslende hardt og mykere
120,10	123,10	3,00	750	4200	14	12	45	Hardt og helt
123,10	126,10	3,00	750	4400	14	14	50	
126,10	129,10	3,00	750	4500	14	20	55	
129,10	132,10	3,00	750	3800	14	17	50	
132,10	135,10	3,00	750	3800	14	14	50	Vekslende hardt og helt, VANNSTAND -42meter
135,10	138,10	3,00	750	4600	14	17	55	
138,10	141,10	3,00	750	3900	14	18	55	
141,10	144,10	3,00	750	4100	14	24	58	Mykere soner, hel kjerne
144,10	147,10	3,00	750	4600	14	16	60	
147,10	150,10	3,00	750	4500	14	16	58	Hel kjerne i 3 meter
150,10	153,10	3,00	750	4500	14	23	55	
153,10	156,10	3,00	750	3700	14	21	55	Hel kjerne i 3 meter
156,10	159,10	3,00	750	3600	14	20	52	
159,10	162,10	3,00	750	3900	14	19	55	Godt fjell
162,10	165,10	3,00	750	3800	14	21	55	Hel kjerne i 3 meter, VANNSTAND -41 meter
165,10	168,10	3,00	750	3800	14	24	55	Hel kjerne
168,10	171,10	3,00	750	4100	14	29	58	
171,10	174,10	3,00	750	4400	14	25	52	Helt og godt fjell
174,10	177,10	3,00	750	4300	14	27	52	
177,10	180,10	3,00	750	4000	14	19	50	Helt og godt fjell, hardere partier
180,10	183,10	3,00	750	4300	14	20	53	
183,10	186,10	3,00	750	3900	14	25	52	Hel kjerne
186,10	189,10	3,00	750	3900	14	23	57	
189,10	192,10	3,00	750	4400	14	25	59	Hel kjerne
192,10	195,10	3,00	750	4100	14	25	50	
SUM	195,10	90,60						

GEO DRILLING AS	REGISTRERING BOREDATA						SIDE 3	GEO DRILLING	
PROSJEKT: P - 160117	STED: Åknes			HULL-NR: BH - 01 - 17 Kulen		KRONE: HQ	DATO: August	MASKIN: Diamec U-8 APC	FALL/RETNING: Lodd
FRA BOREDYP	TIL BOREDYP	KJERNE LENGDE	ROTASJON RPM	MATEKRAFT KILO	PENETRERING ca CM/MIN	Mottrykk Spyl.vann Bar	FARVE SPYLEVANN	KOMMENTAR	
195,10	197,80	2,70	750	4300	12	26	Vann gj krone	Mye slam, spyl og rensk, VANNSTAND -41 METER	
197,80	200,90	3,10	720	3800	14	30	60	Hardt og godt fjell	
200,90	204,00	3,10	700	4300	14	30	65	Hardt og godt fjell	
204,00	207,00	3,00	700	4900	13	24	55		
207,00	210,00	3,00	700	3900	14	25	53	Hardt og godt fjell	
210,00	213,00	3,00	700	4600	13	30	58	Hardt og godt fjell	
213,00	215,60	2,60	700	4800	13	31	63		
215,60	218,70	3,10	700	4200	12	42	66	Mye slam, spyl og rensk,	
218,70	221,80	3,10	700	4900	12	32	59		
221,80	224,90	3,10	700	4200	11	20	50	Harde og løse soner	
224,90	228,00	3,10	700	4700	12	38	60		
228,00	231,00	3,00	700	4900	10	32	58	Hardt og helt fjell	
231,00	233,30	2,30	700	4600	10	45	65		
233,30	236,40	3,10	700	4300	9	42	65	Hardt og helt fjell	
236,40	239,00	2,60	700	3900	9	36	65		
239,00	242,10	3,10	700	4100	10	33	57	Mye slam i hullet, rensk og spyl. VANNSTAND - 43 METER	
242,10	245,20	3,10	700	4400	10	21	52		
245,20	248,00	2,80	700	4100	10	28	55	Hardt	
248,00	251,00	3,00	700	3600	11	28	54		
251,00	254,00	3,00	700	3700	11	34	58	Hardt og helt fjell	
254,00	257,20	3,20	700	4800	9	28	47		
257,20	258,50	1,30	700	3900	9	29	48	Hardt og helt fjell	
258,50	261,10	2,60	700	3600	10	35	55		
261,10	264,10	3,00	700	3800	10	31	48		
264,10	265,80	1,70	700	3900	11	28	45	Havarert borekrone i en sone	
265,80	268,90	3,10	700	2700	10	14	31		
268,90	272,00	3,10	700	2900	11	16	32	To små soner	
272,00	275,10	3,10	700	3400	12	15	32	Bra fjell	
275,10	278,20	3,10	700	3600	13	15	32	Godt fjell, noe lettere	
278,20	281,30	3,10	700	2300	13	15	32	Noen sprikker	
281,30	284,40	3,10	700	2700	13	13	30		
SUM	284,40	89,30							

GEO DRILLING AS	REGISTRERING BOREDATA						SIDE 4	GEO DRILLING
PROSJEKT: P - 160117	STED: Åknes			HULL-NR: BH - 01 - 17 Kulen		KRONE: HQ	DATO: August	MASKIN: Diamec U-8 APC	FALL/RETNING: Lodd

FRA BOREDYP	TIL BOREDYP	KJERNE LENGDE	ROTASJON RPM	MATEKRAFT KILO	PENETRERING ca CM/MIN	Mottrykk Spyl.vann Bar	FARVE SPYLEVANN	KOMMENTAR
284,40	287,50	3,10	700	2400	13	16	Vann gj krone	Soner med svakere fjell
287,50	290,50	3,00	700	2600	13	15	33	
290,50	293,60	3,10	700	3600	13	15	33	Helt og godt fjell
293,60	296,50	2,90	700	3100	13	14	34	
296,50	299,60	3,10	700	4200	12	14	29	Hardt
299,60	302,70	3,10	700	4600	12	13	28	Hardt, noen soner mot slutten.
								Plan om å bore til 400 meter, men dette avlyses
SUM	302,70	18,30						

Appendix B

CORE LOGGING SHEETS (LOGPLOT) KH-01-2017

Contents

B1 Core logging sheets (Logplot) KH-01-2017

Norwegian Geotechnical Institute

CORE DRILLING- CORELOG

BOREHOLE: BH-01-2017

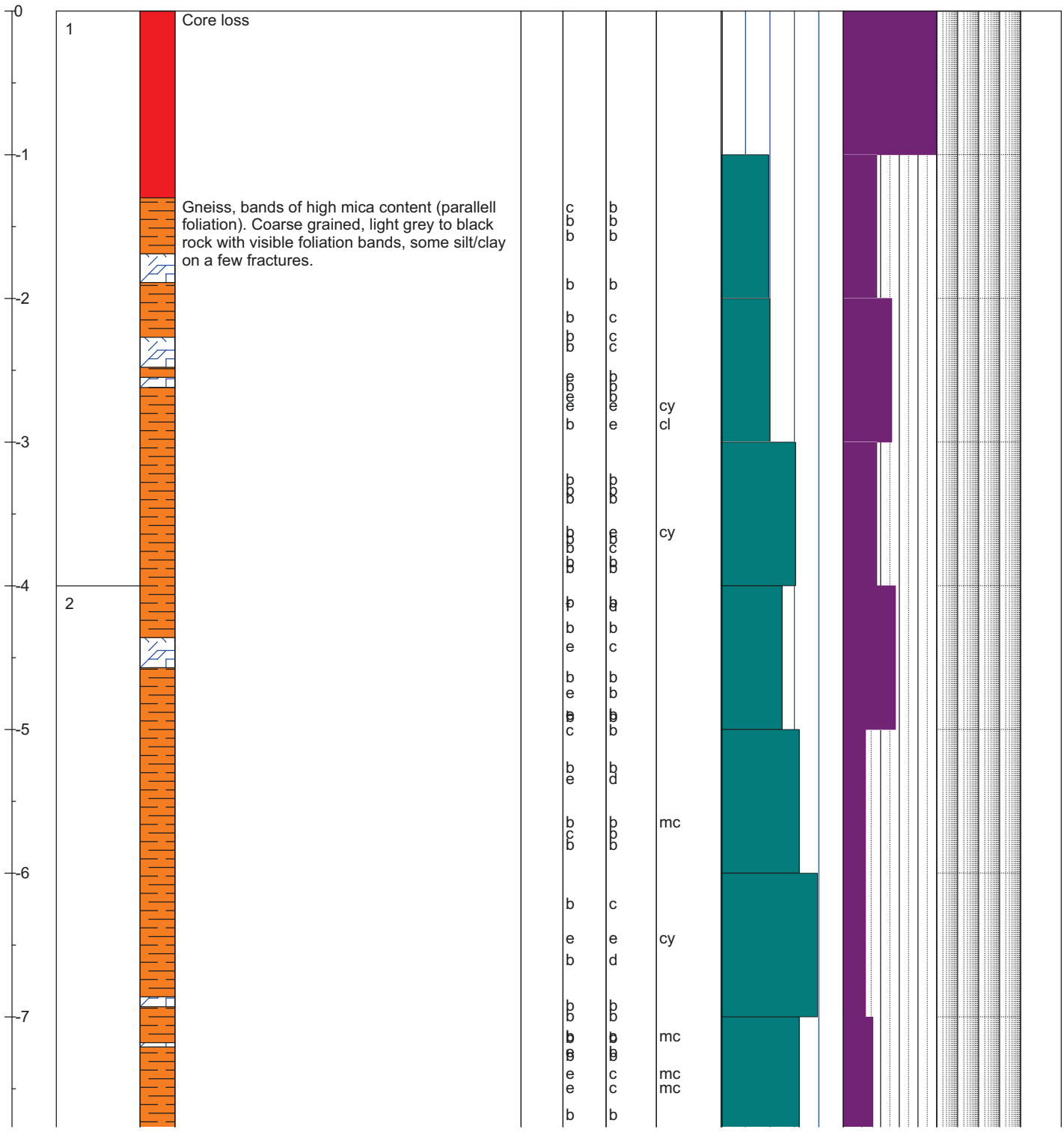
REPORT NO.: **20180662**
PROJECT NAME: **Åknes drainage**

DRILLED LENGTH: **302,7 m**
ELEVATION: **506,8 m**
ORIENTATION: **Vertical**
LOGGING DATE: **2017-09-07 to 19**
NAME: **Henrik Langeland**
File: *P:\2018\06\20180662\Beregninger\BH-01-2017\Logplot\BH012017.dat*

ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**



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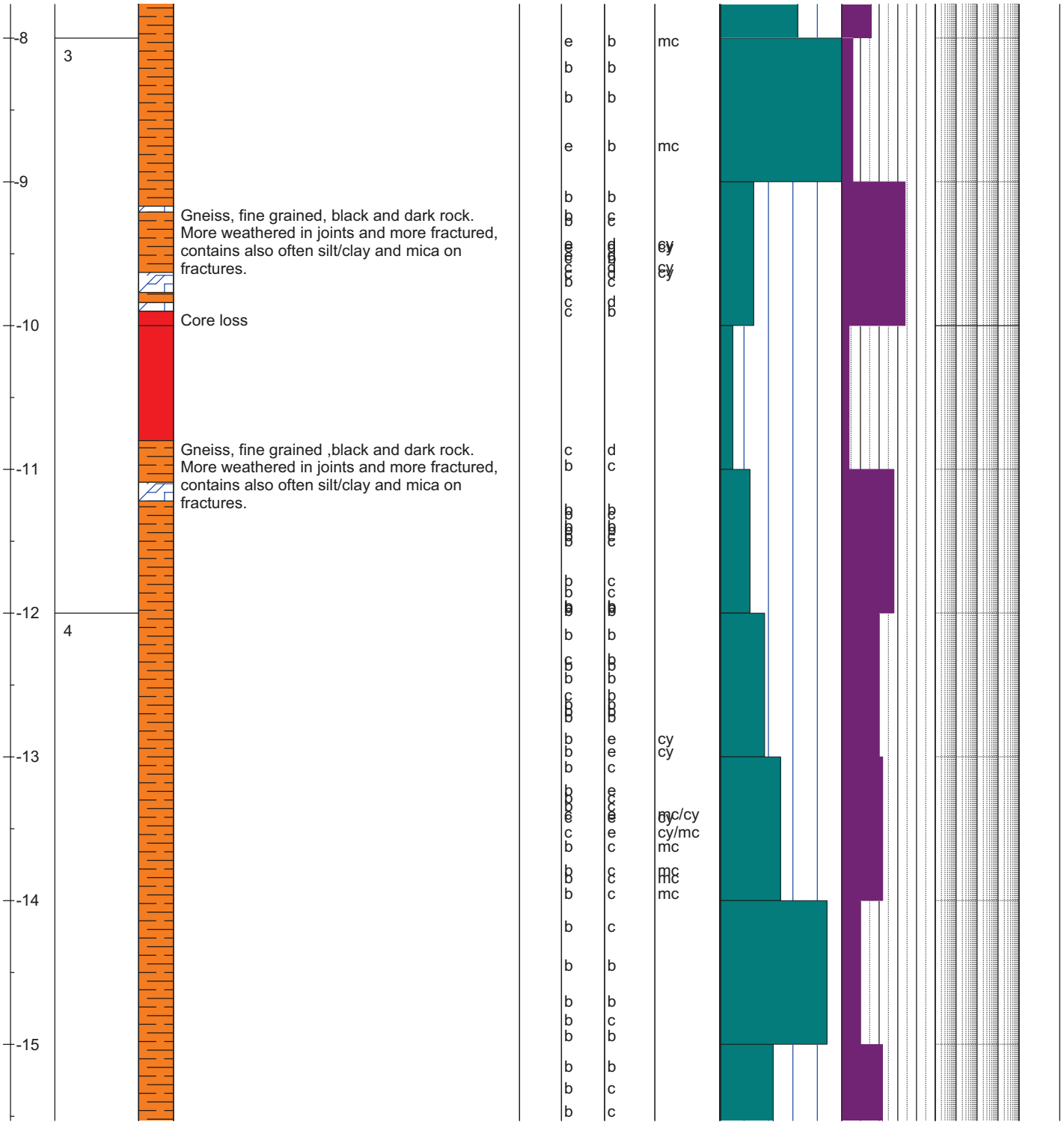

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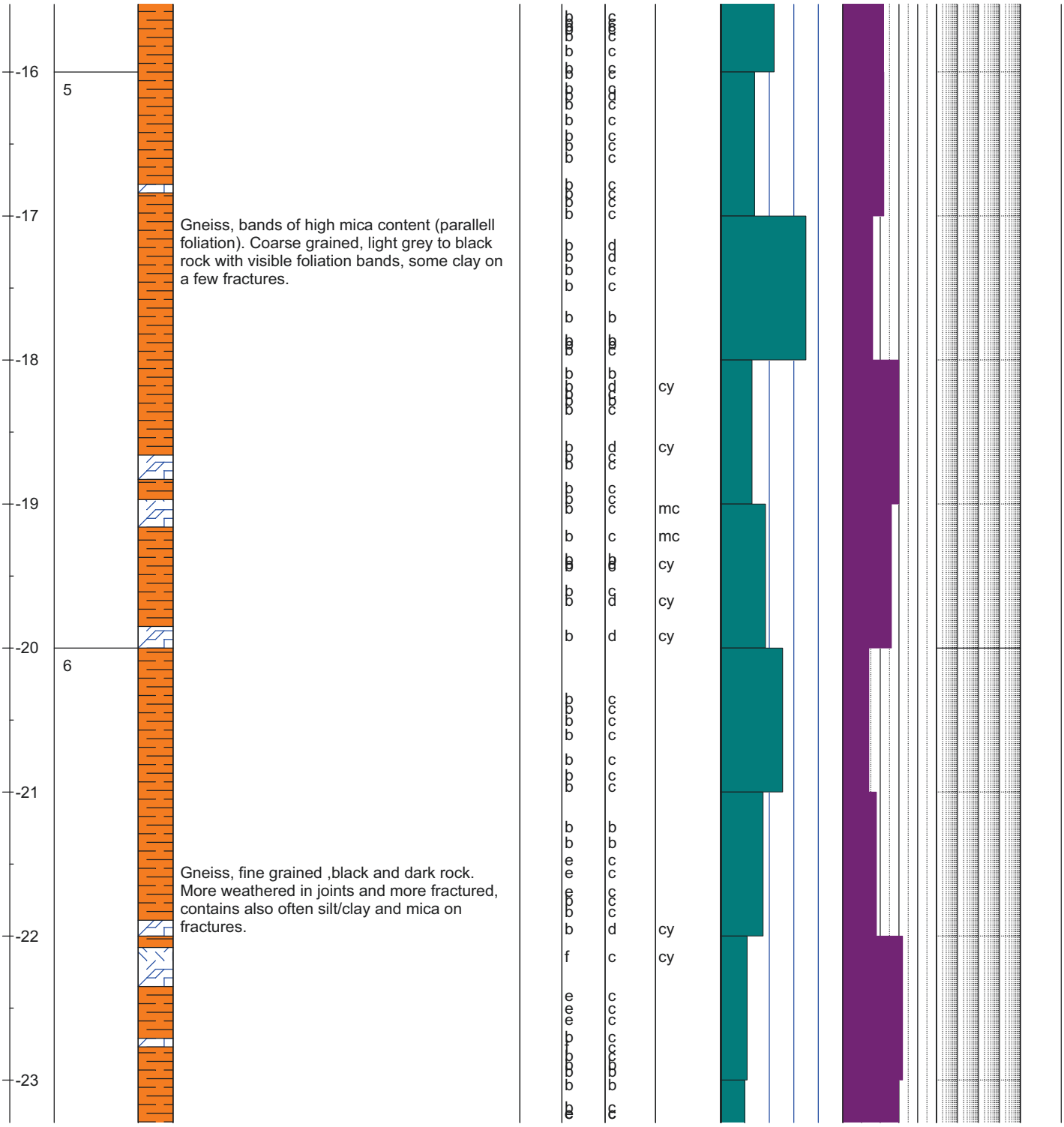
ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**

HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa

-16
5
-17
Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.
-18
-19
-20
6
-21
Gneiss, fine grained ,black and dark rock. More weathered in joints and more fractured, contains also often silt/clay and mica on fractures.
-22
-23



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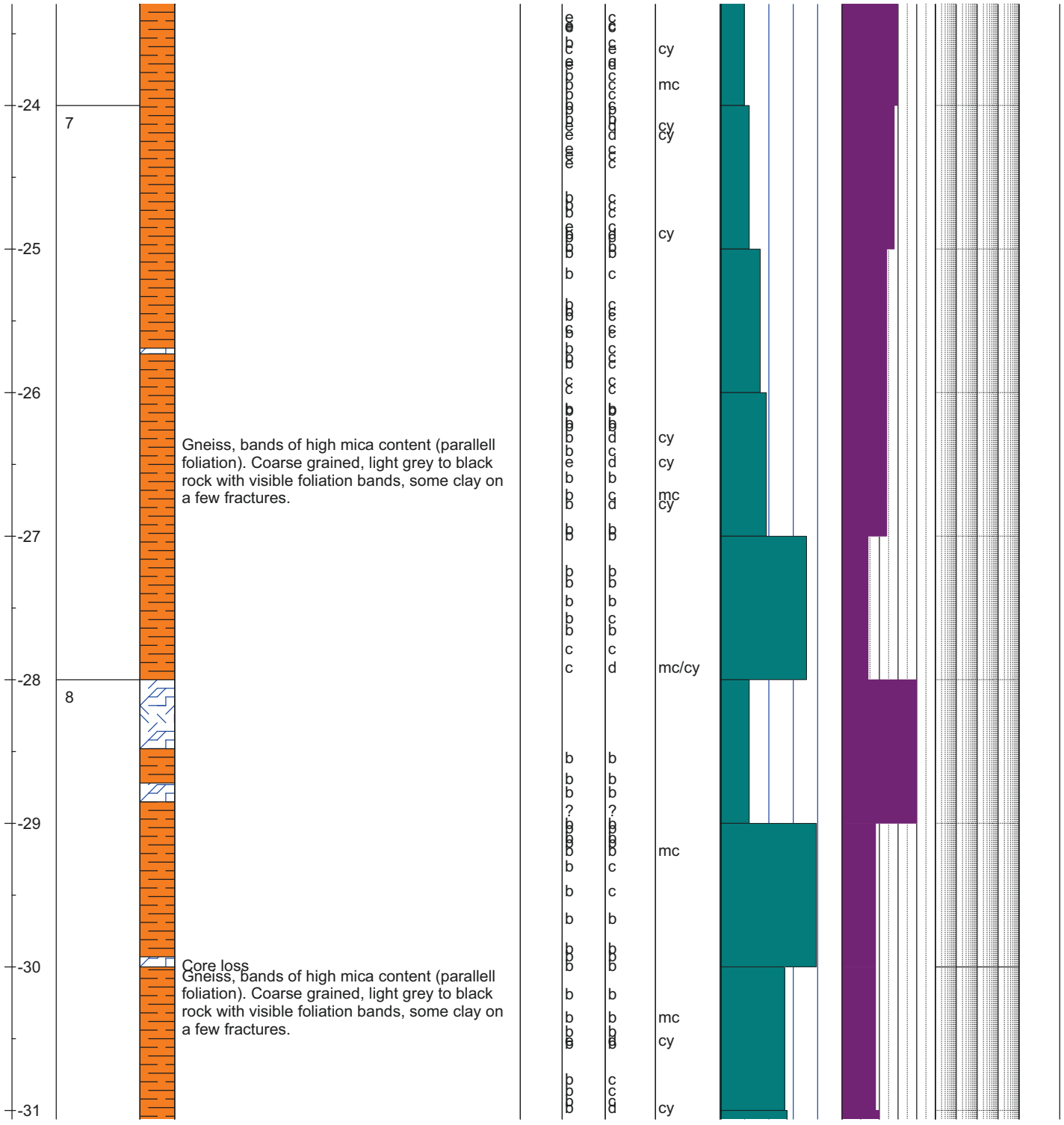
HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa

-24
7
-25
-26
-27
-28
8
-29
-30
-31

Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.

Core loss

Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.



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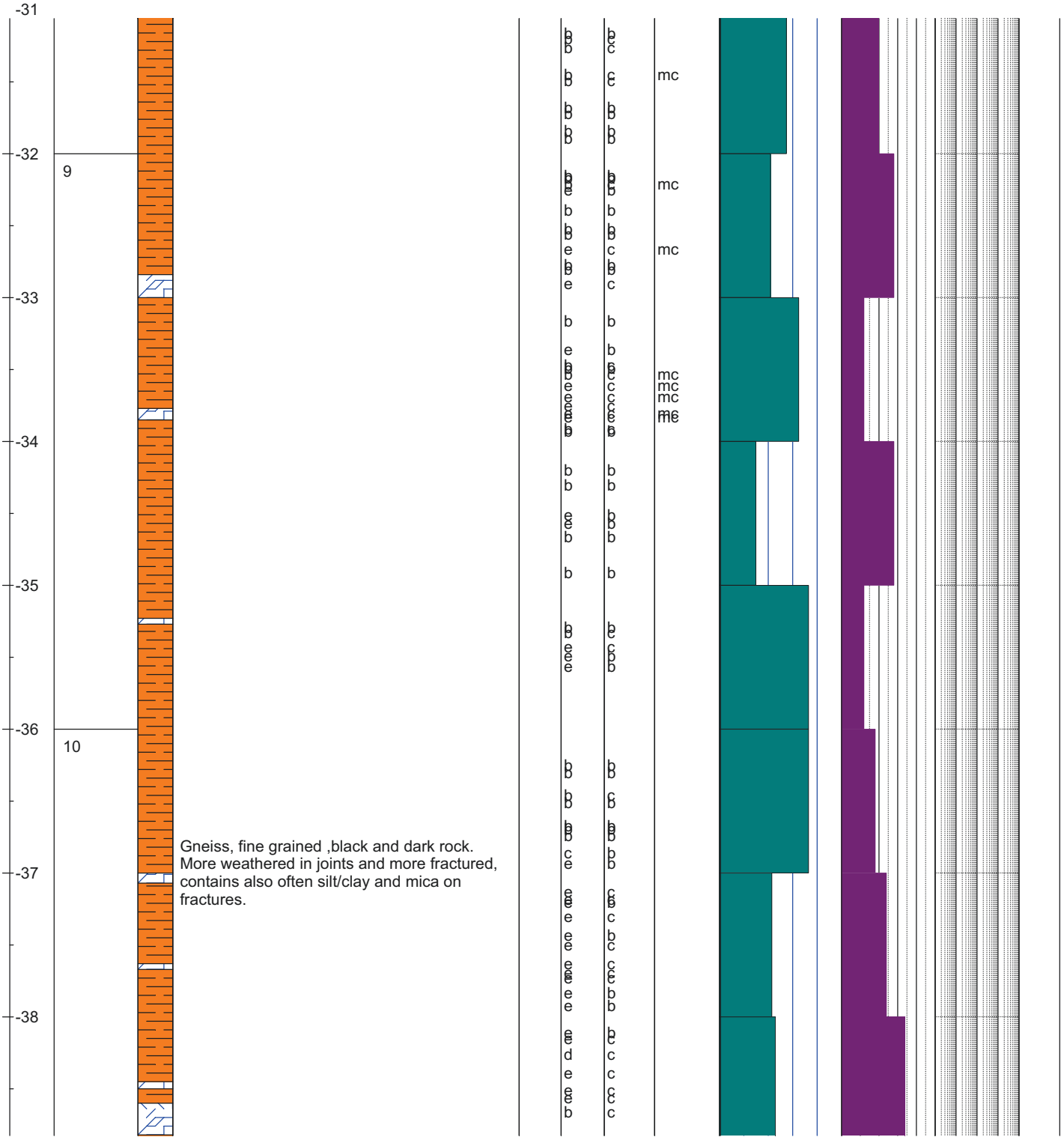
HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa

-31
-32
9
-33
-34
-35
-36
10
-37
-38

Gneiss, fine grained ,black and dark rock. More weathered in joints and more fractured, contains also often silt/clay and mica on fractures.



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HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa

-39
-40
-41
-42
-43
-44
-45
-46

11
12

Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.

Joint infill material: mc, cy, cy/mc, cy/mc, cy, cy, mc, cy, cy, mc, mc

Norwegian Geotechnical Institute

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ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

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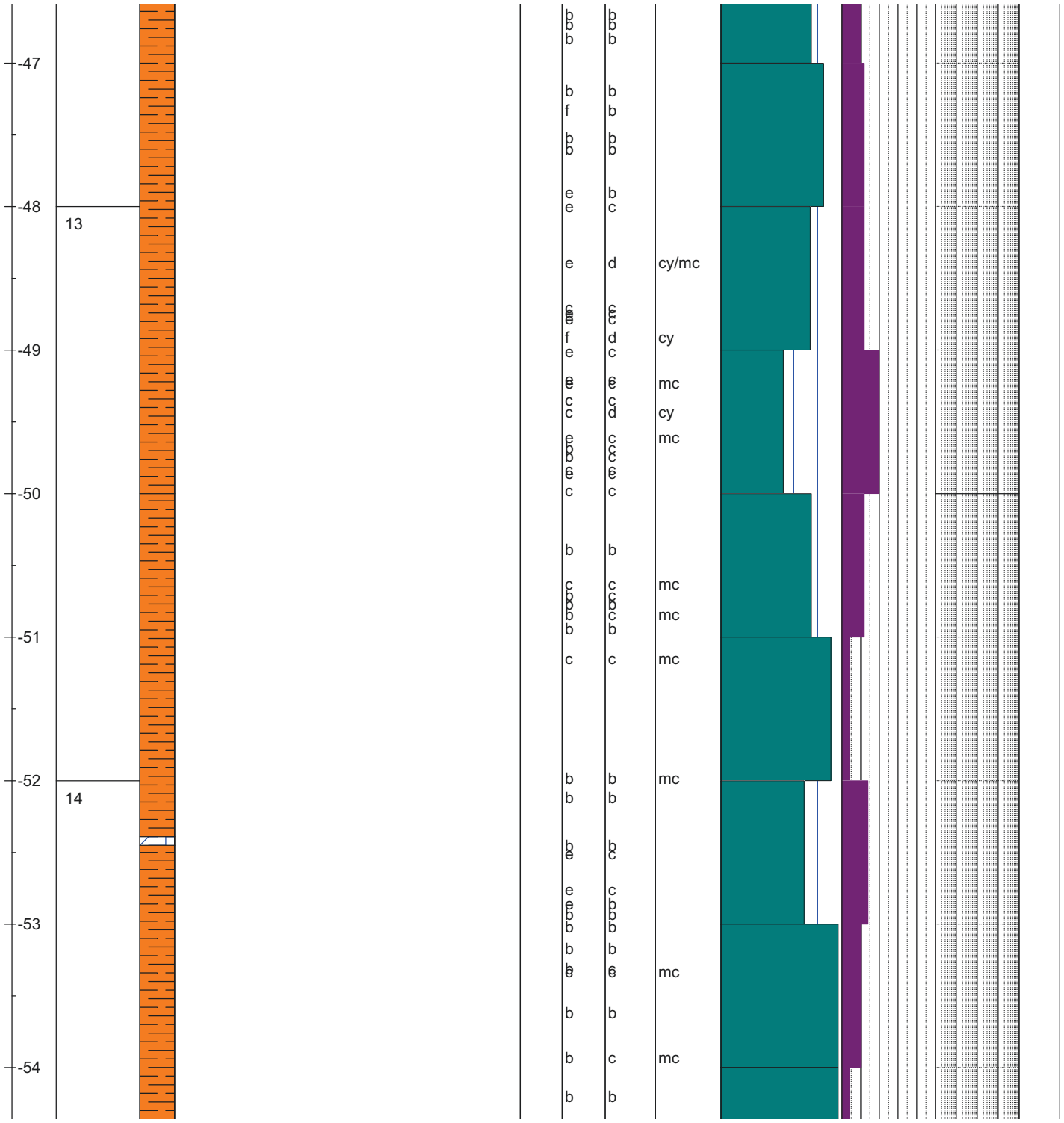

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ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

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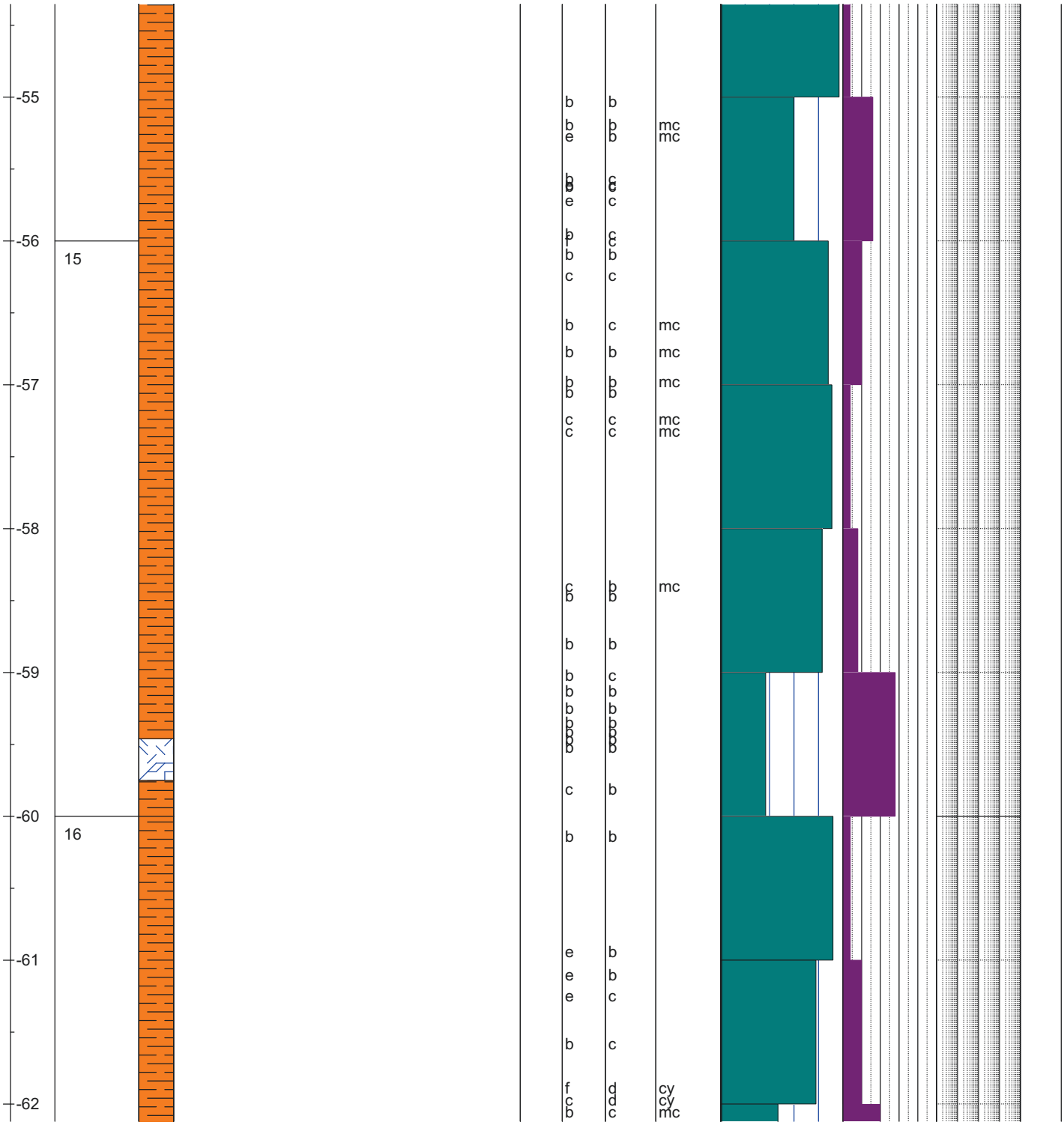

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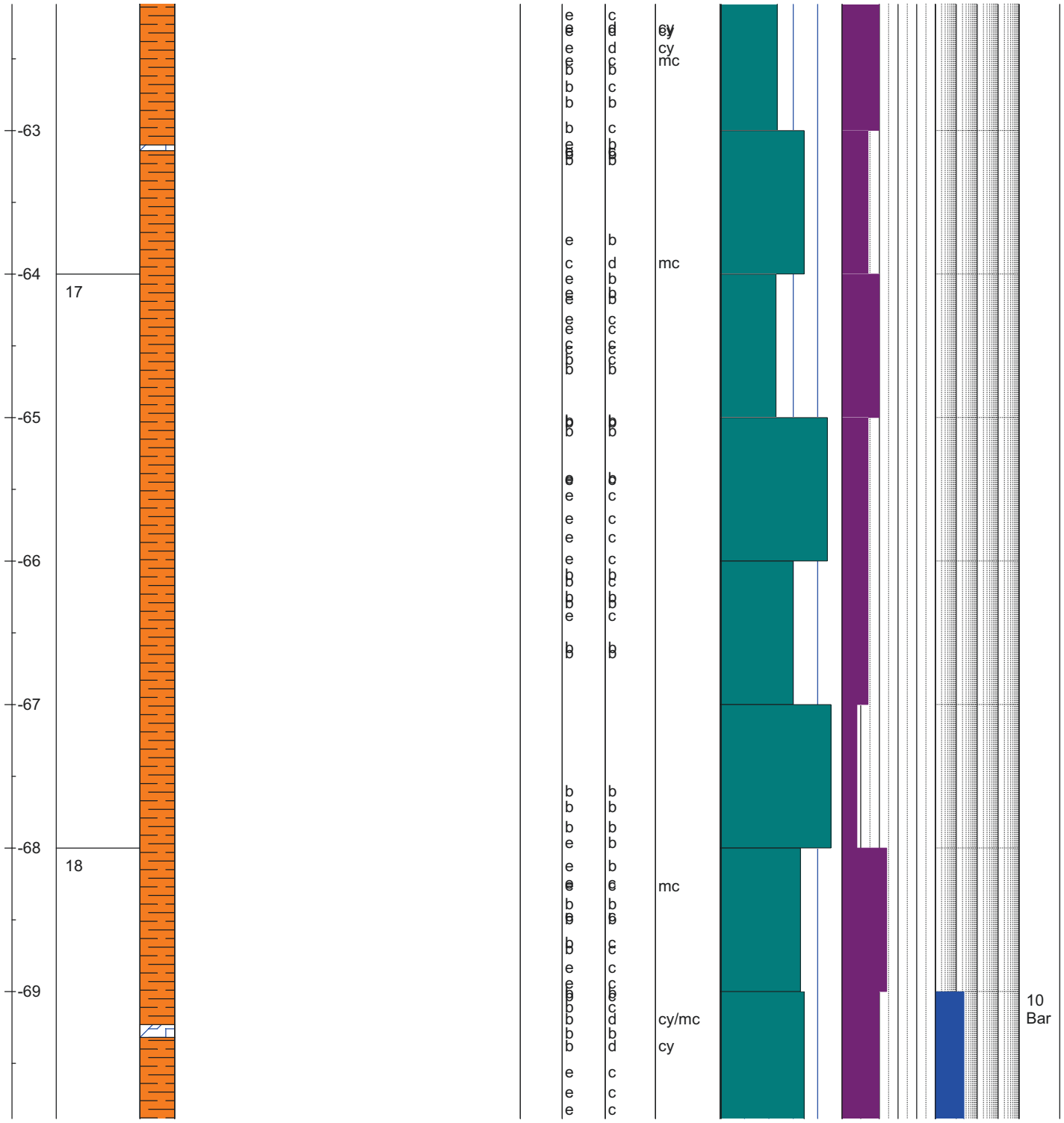
ROCK TYPE:
Gneiss

ZONES:
Fractured zone
Core loss

JOINT INNFILL MATERIAL:
cy, Clay
cl, Chlorite
mc, Mica
ca, Calcite

HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa



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ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

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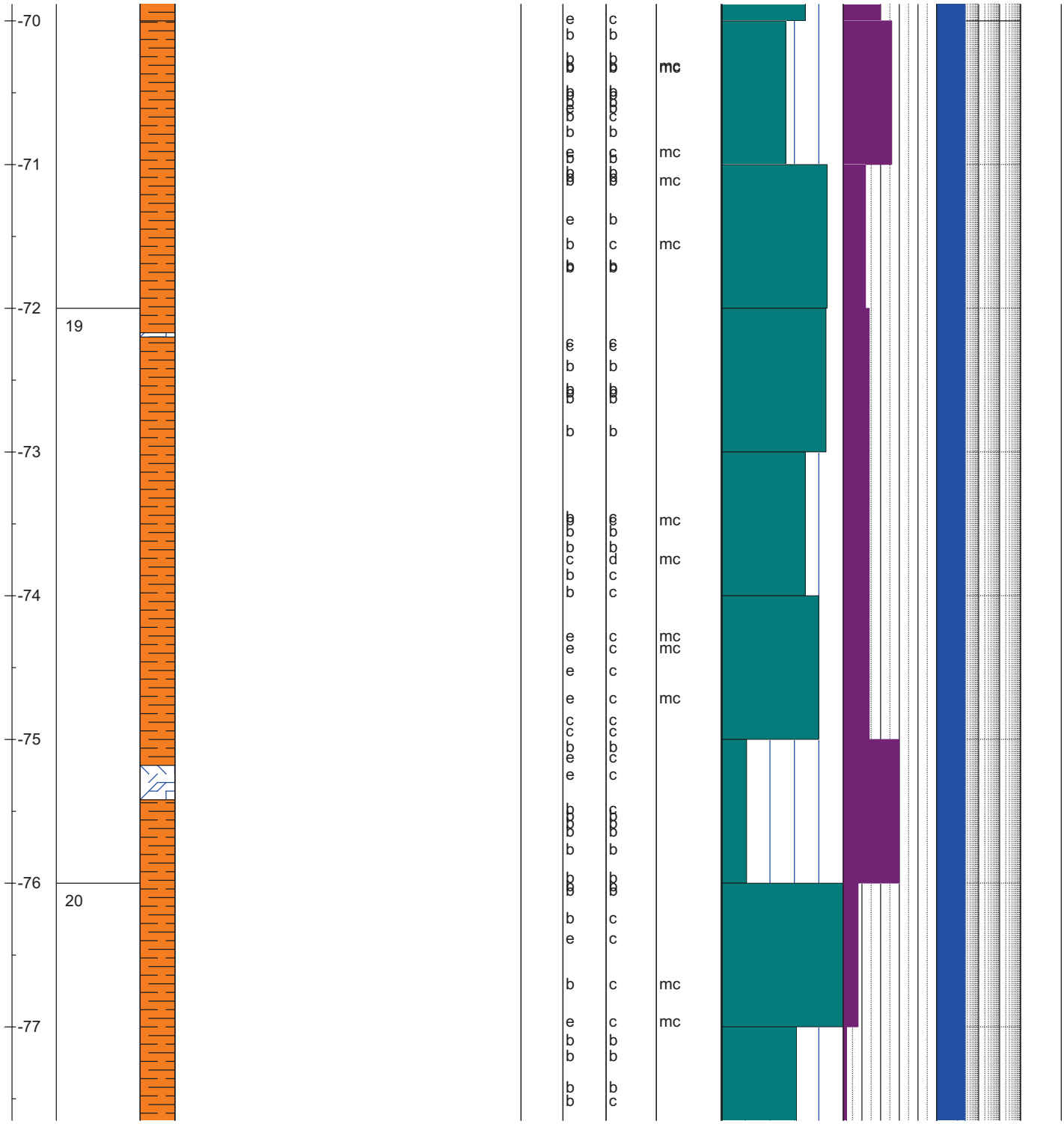

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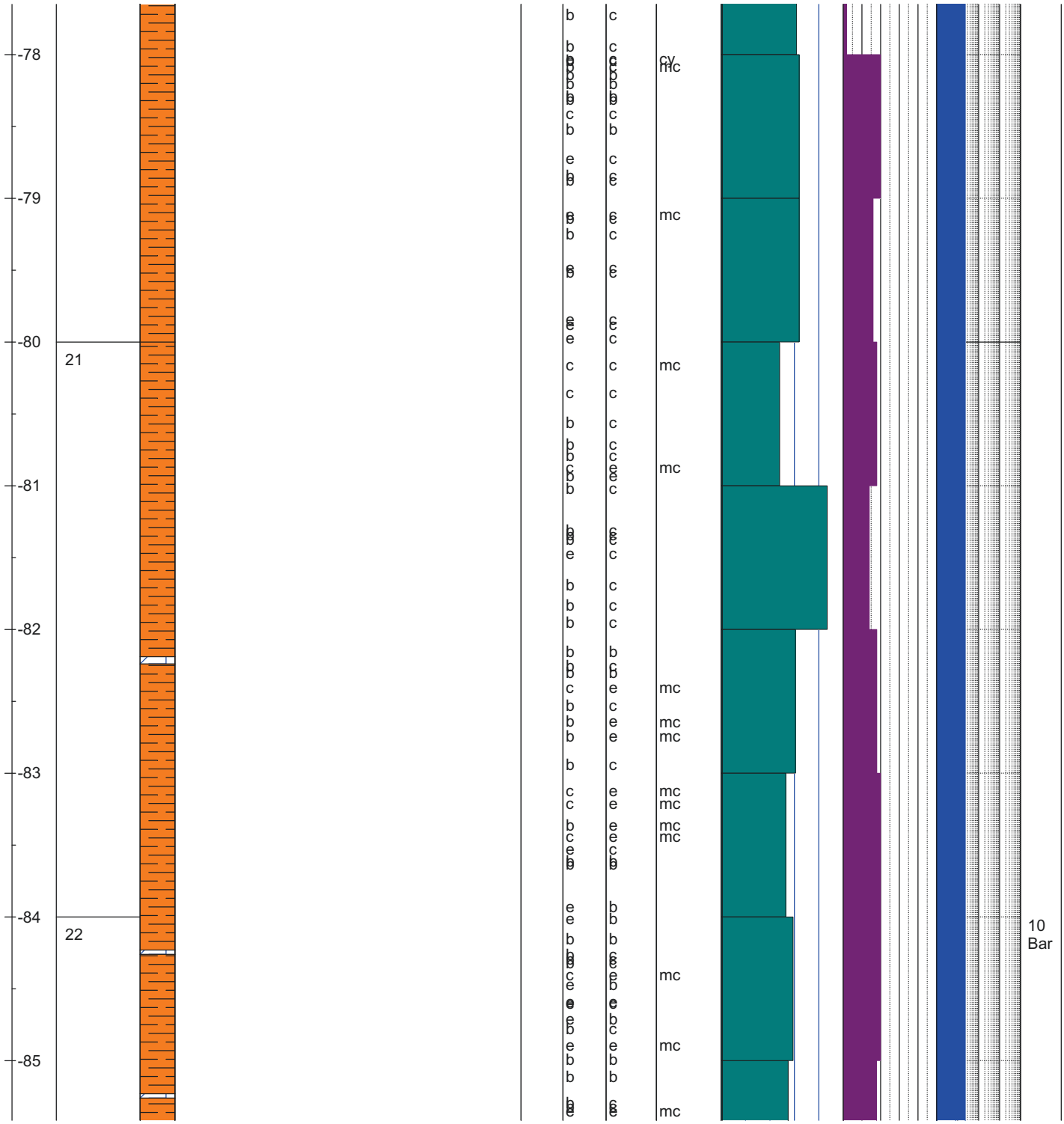

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Gneiss

ZONES:
Fractured zone
Core loss

JOINT INNFILL MATERIAL:
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mc, Mica
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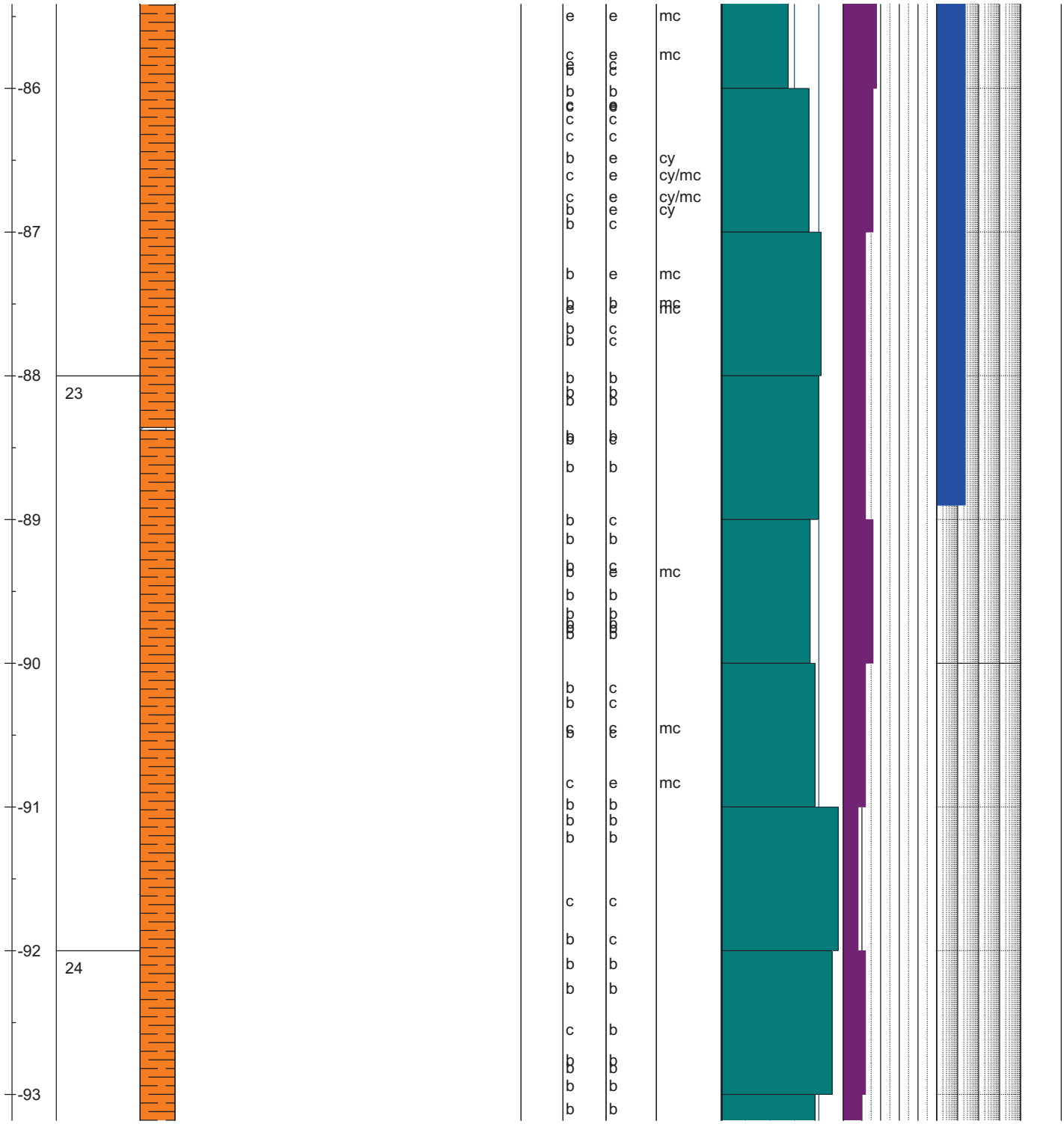

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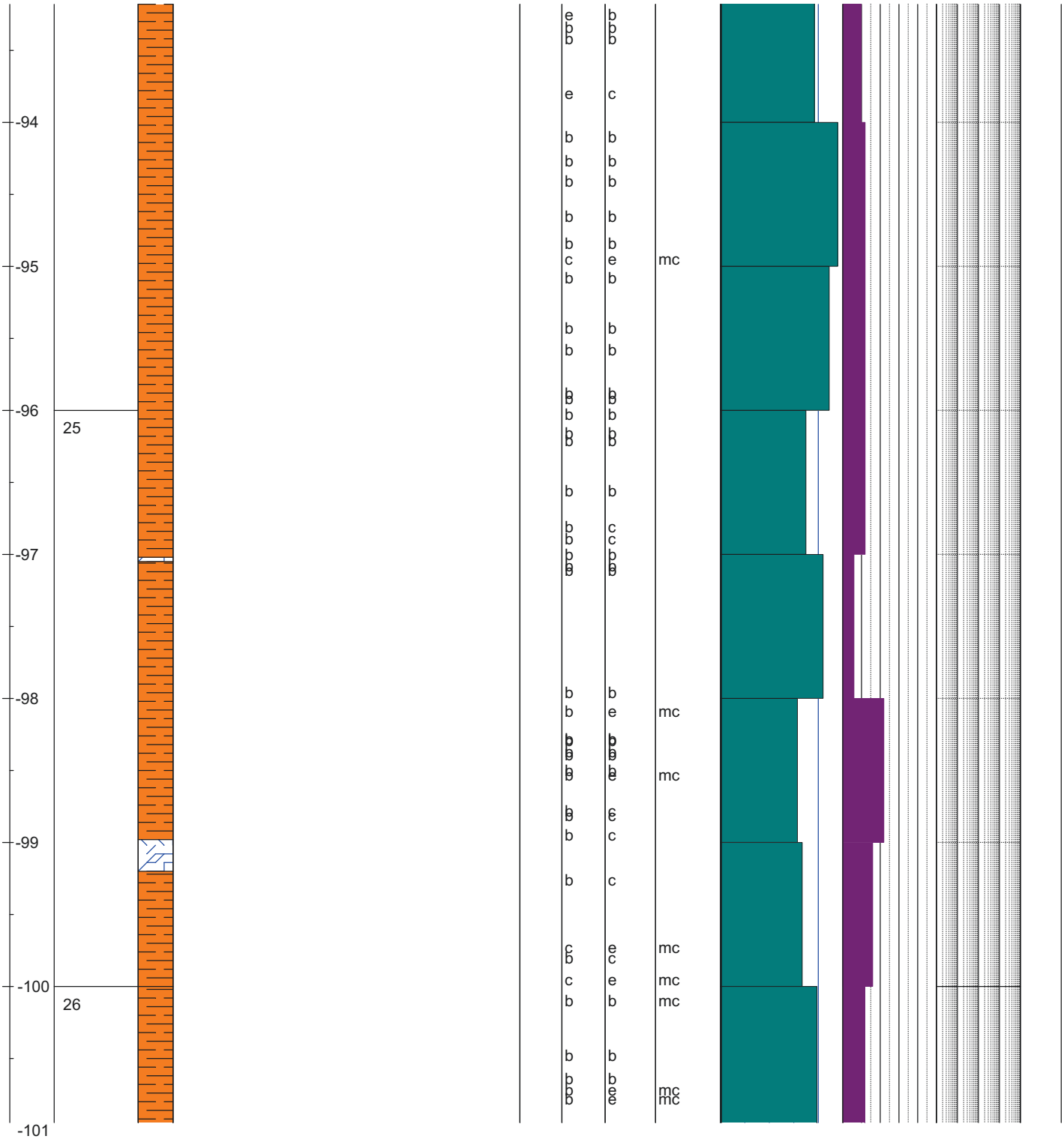

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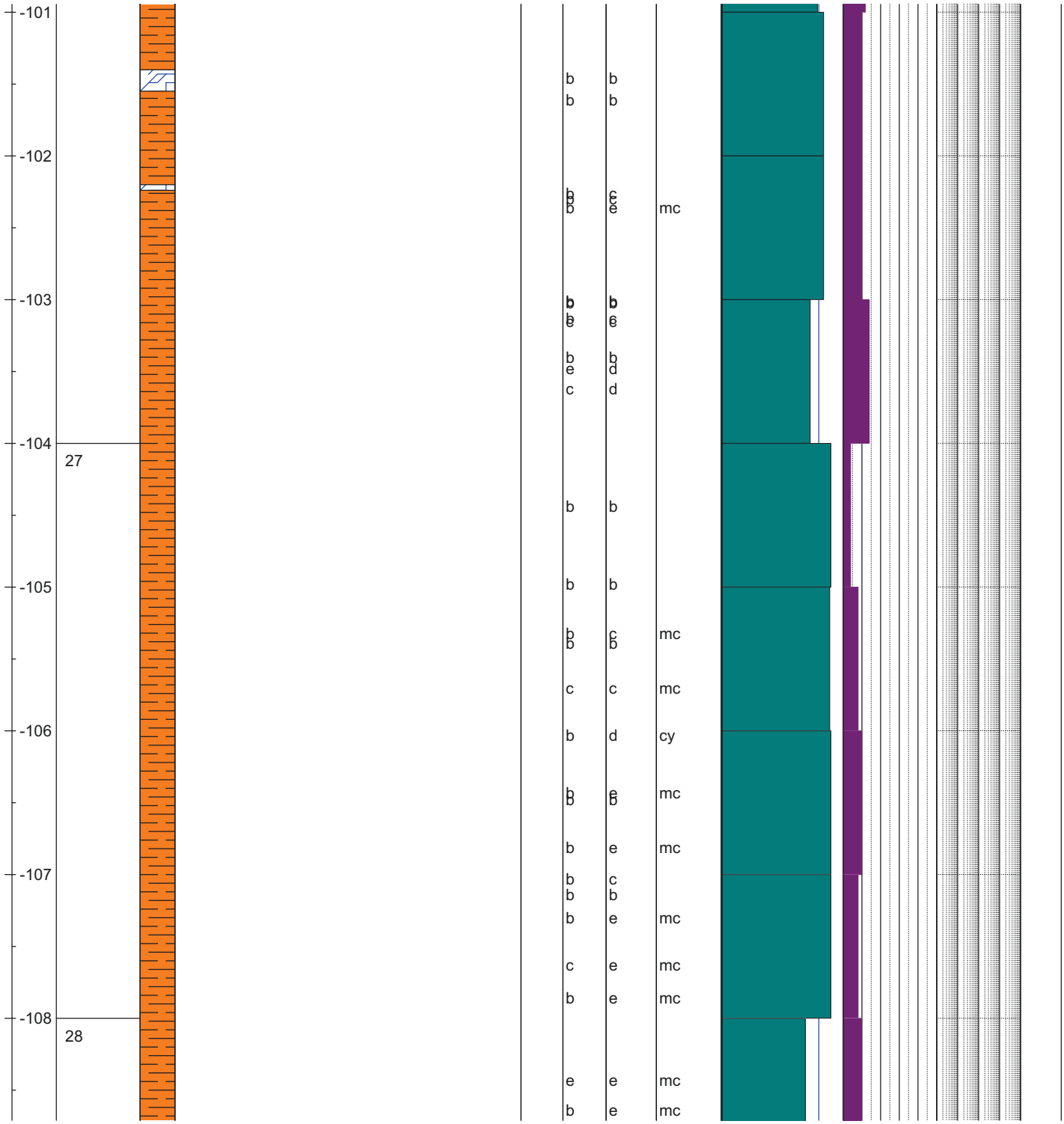

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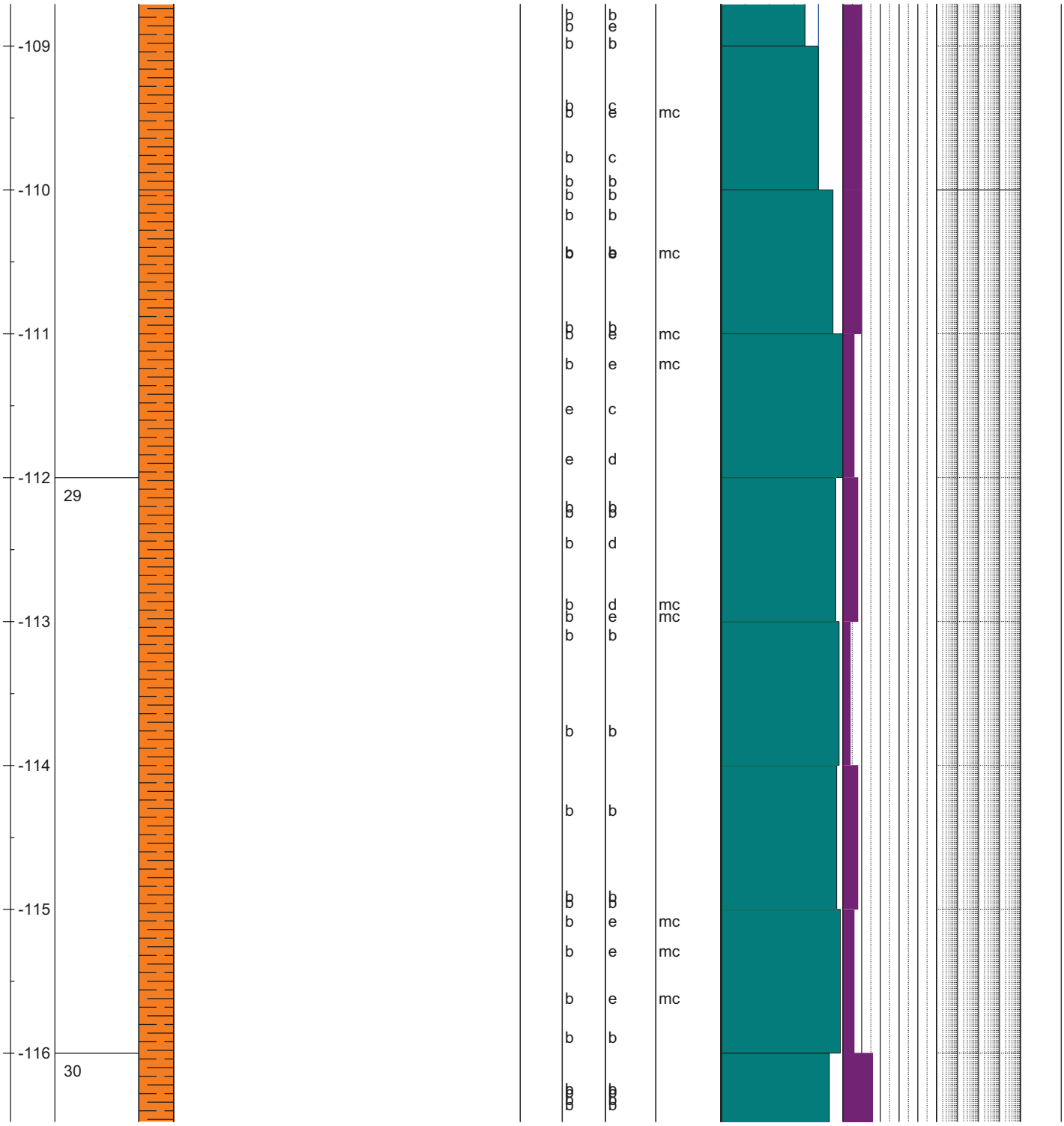

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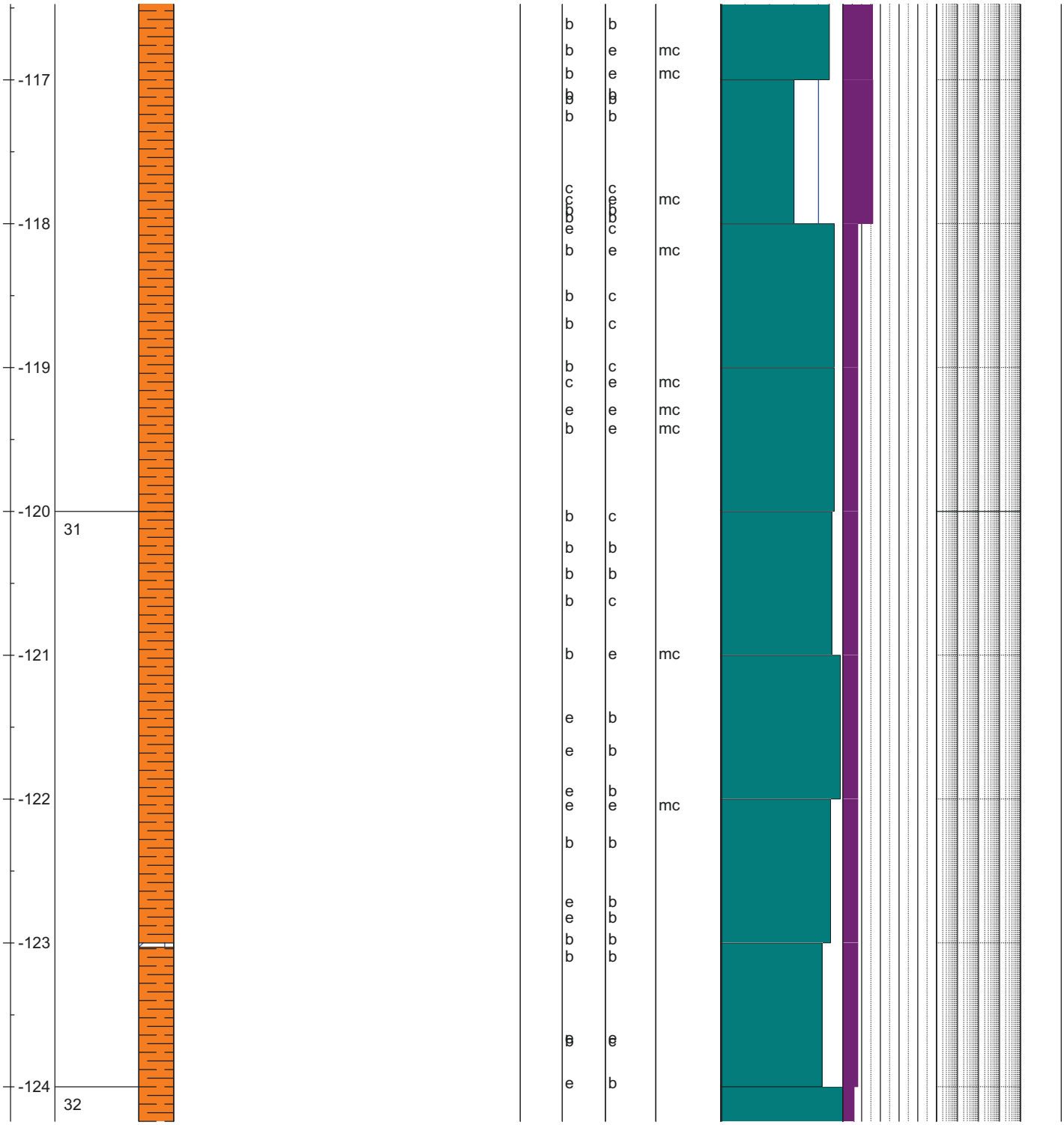

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HOLE DEPTH	BOX NO.	ROCK TYPE	DESCRIPTION/COMMENTS	CORELOSS, CM	Jr	Ja	Joint infill material	RQD, % (20 40 60 80)	JOINT FREQUENCY natural joints pr. m. (5 10 15 20)	WATERLOSS MEASUREMENT Lugeon (1 10 100)	OVERPRESSURE, MPa
-125				e e e b e e b b e b b b c b b c b b b	c b b c e c b e b b e e c b c b b		mc mc mc mc				
-126											
-127											
-128	33										
-129											
-130			Gneiss, fine grained ,black and dark rock. More weathered in joints and more fractured, contains also often silt/clay and mica on fractures.								
-131											
-132											

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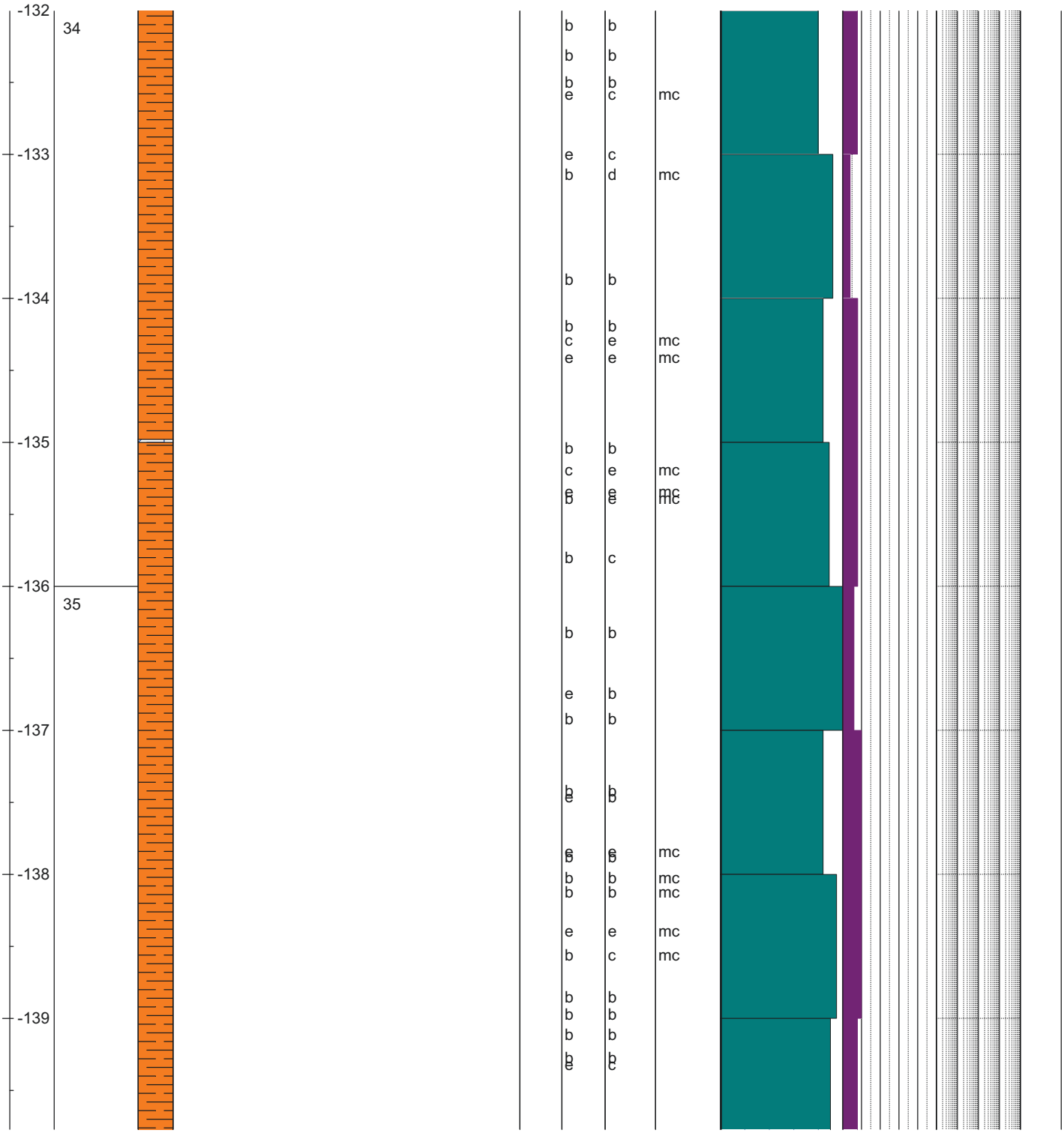

Norwegian Geotechnical Institute

CORE DRILLING- CORELOG

BOREHOLE: BH-01-2017

REPORT NO.: **20180662**
PROJECT NAME: **Åknes drainage**

DRILLED LENGTH: **302,7 m**
ELEVATION: **506,8 m**
ORIENTATION: **Vertical**
LOGGING DATE: **2017-09-07 to 19**
NAME: **Henrik Langeland**
File: *P:\2018\06\20180662\Beregninger\BH-01-2017\Logplot\BH012017.dat*

ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**

HOLE DEPTH	BOX NO.	ROCK TYPE	DESCRIPTION/COMMENTS	CORELOSS, CM	Jr	Ja	Joint infill material
-140	36		Coarse- to fine grained Gneiss		b	c	
					b	b	
-141					b	b	
					b	c	mc
					e	c	
					b	c	
					b	b	
-142					b	b	
-143					b	b	
					b	b	
-144	37				b	c	
					b	c	mc
					b	c	
-145					b	c	mc
					b	b	
					b	d	mc
					b	c	mc
-146					b	b	
					b	b	
					e	e	mc
					b	b	
					b	b	
-147					b	b	

RQD, % (20 40 60 80)

JOINT FREQUENCY natural joints pr. m. (5 10 15 20)

WATERLOSS MEASUREMENT Lugeon (1 10 100)

OVERPRESSURE, MPa

Norwegian Geotechnical Institute

CORE DRILLING- CORELOG

BOREHOLE: BH-01-2017

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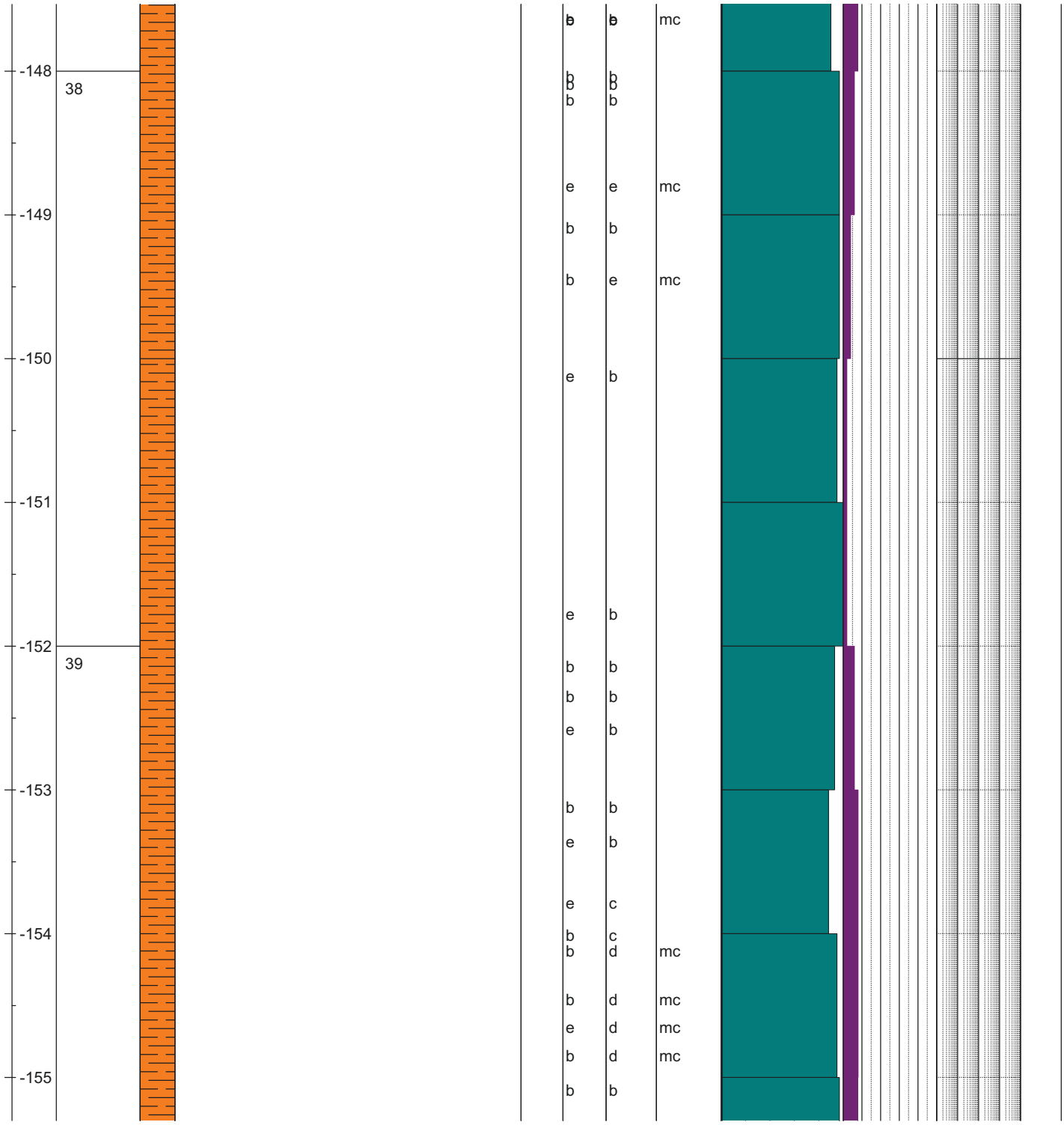
ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**



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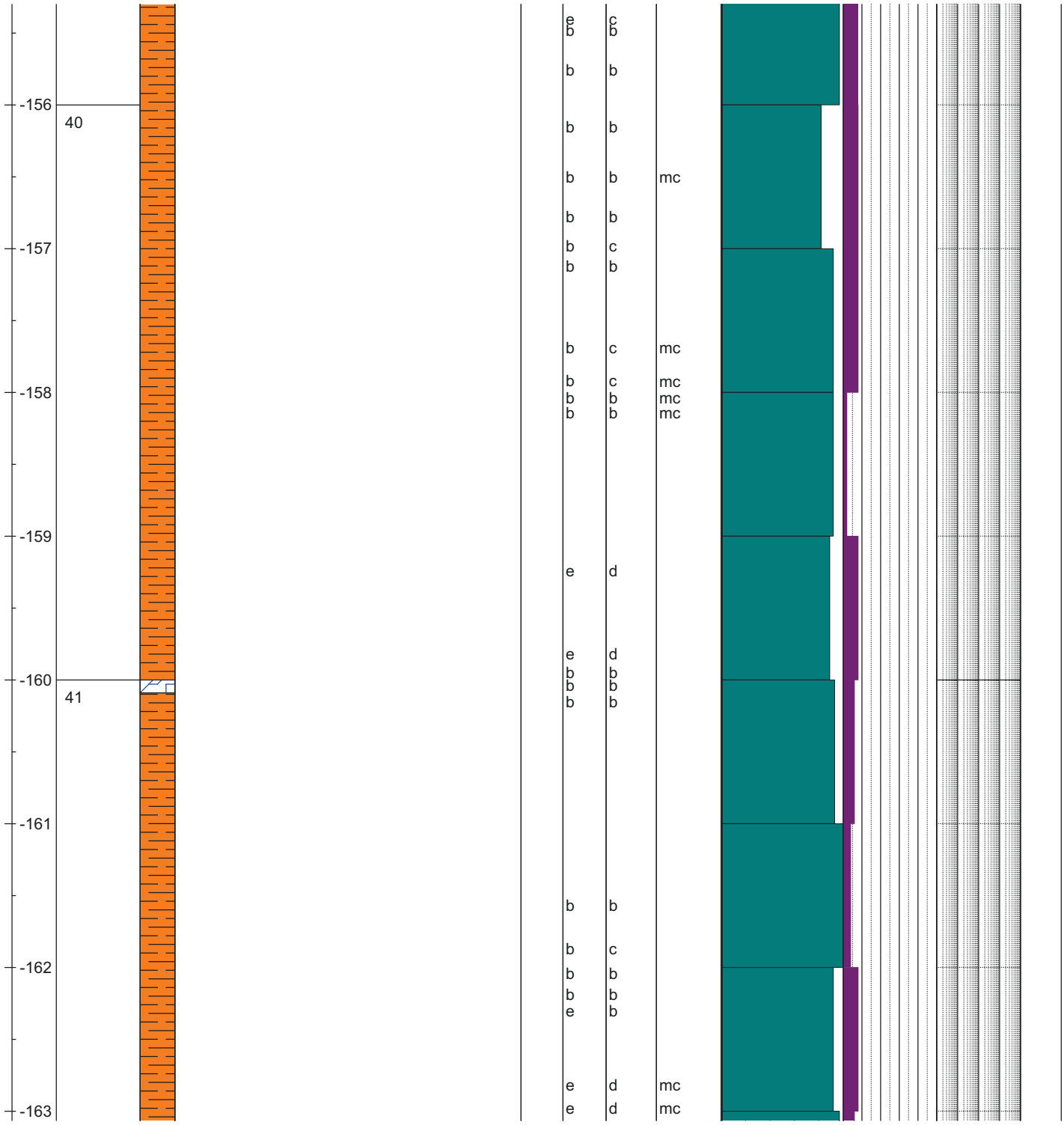

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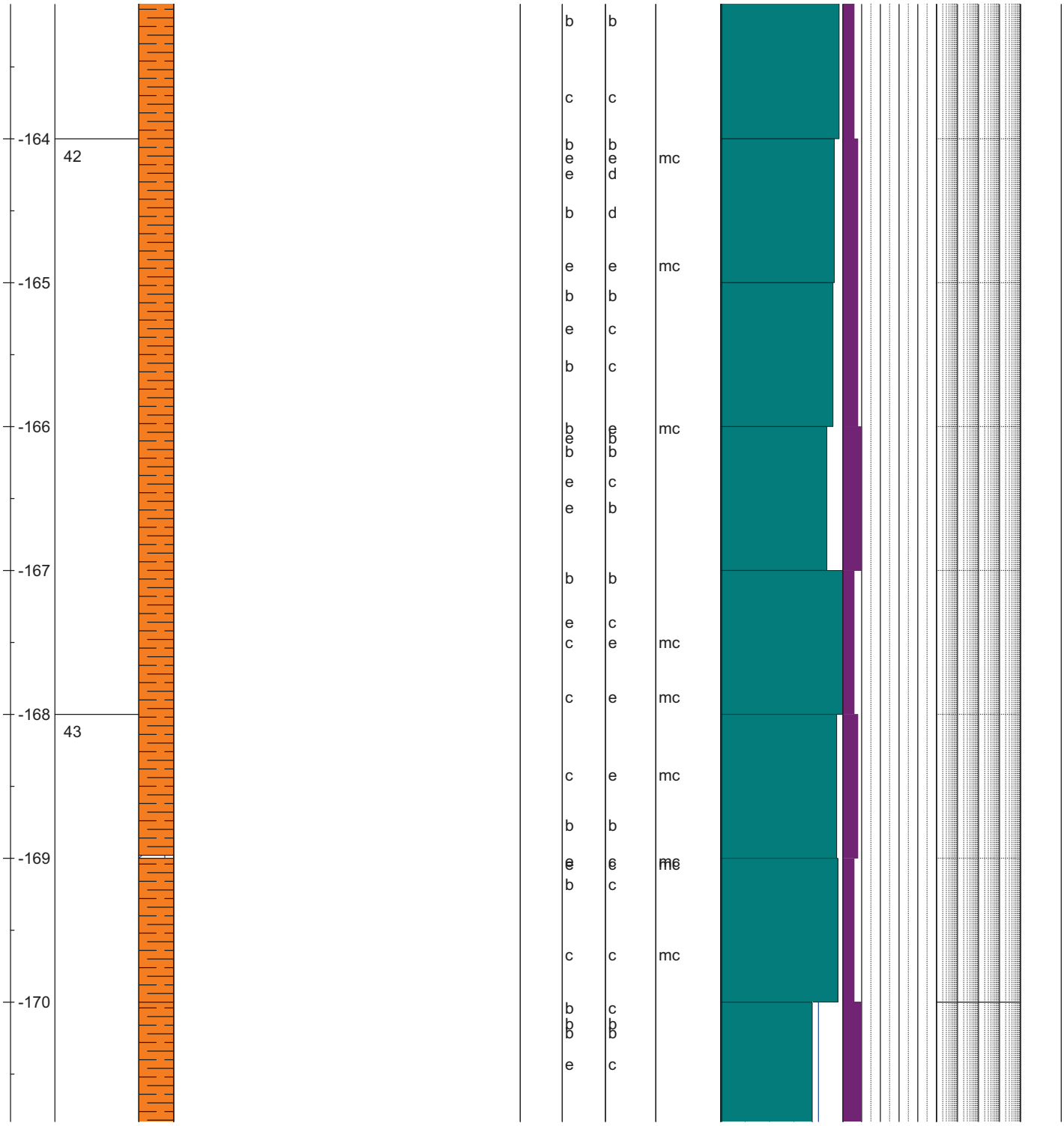

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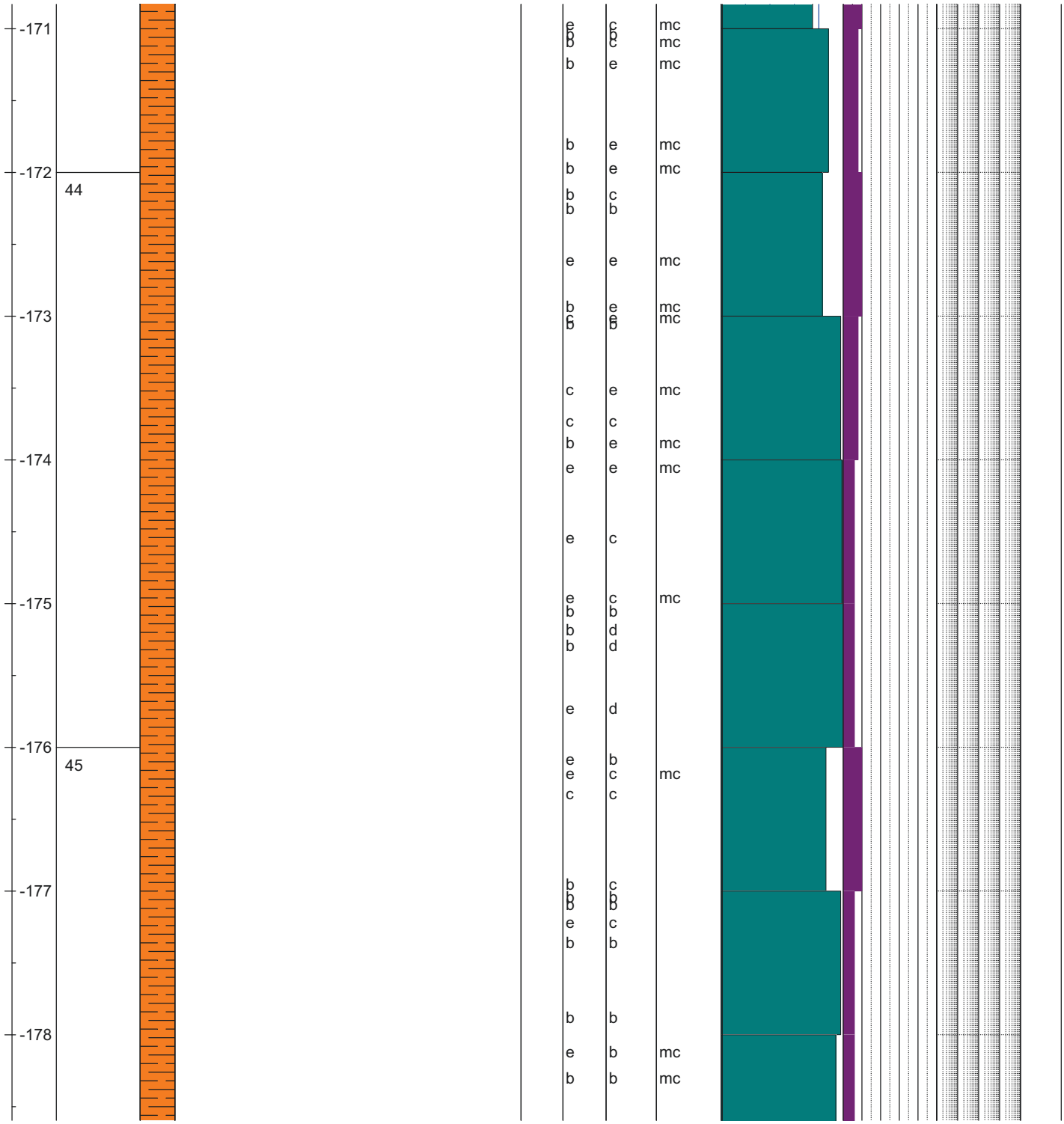

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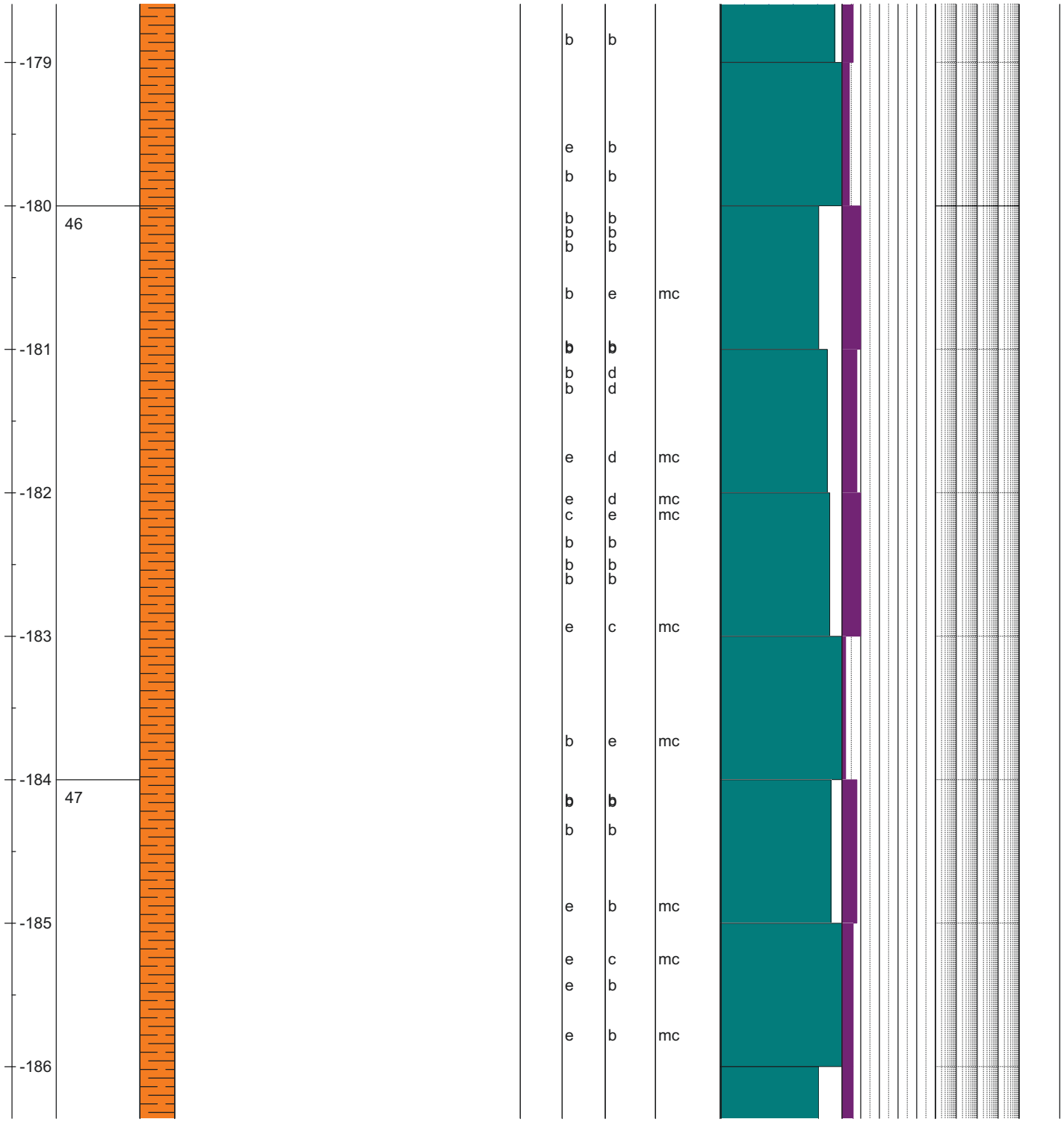

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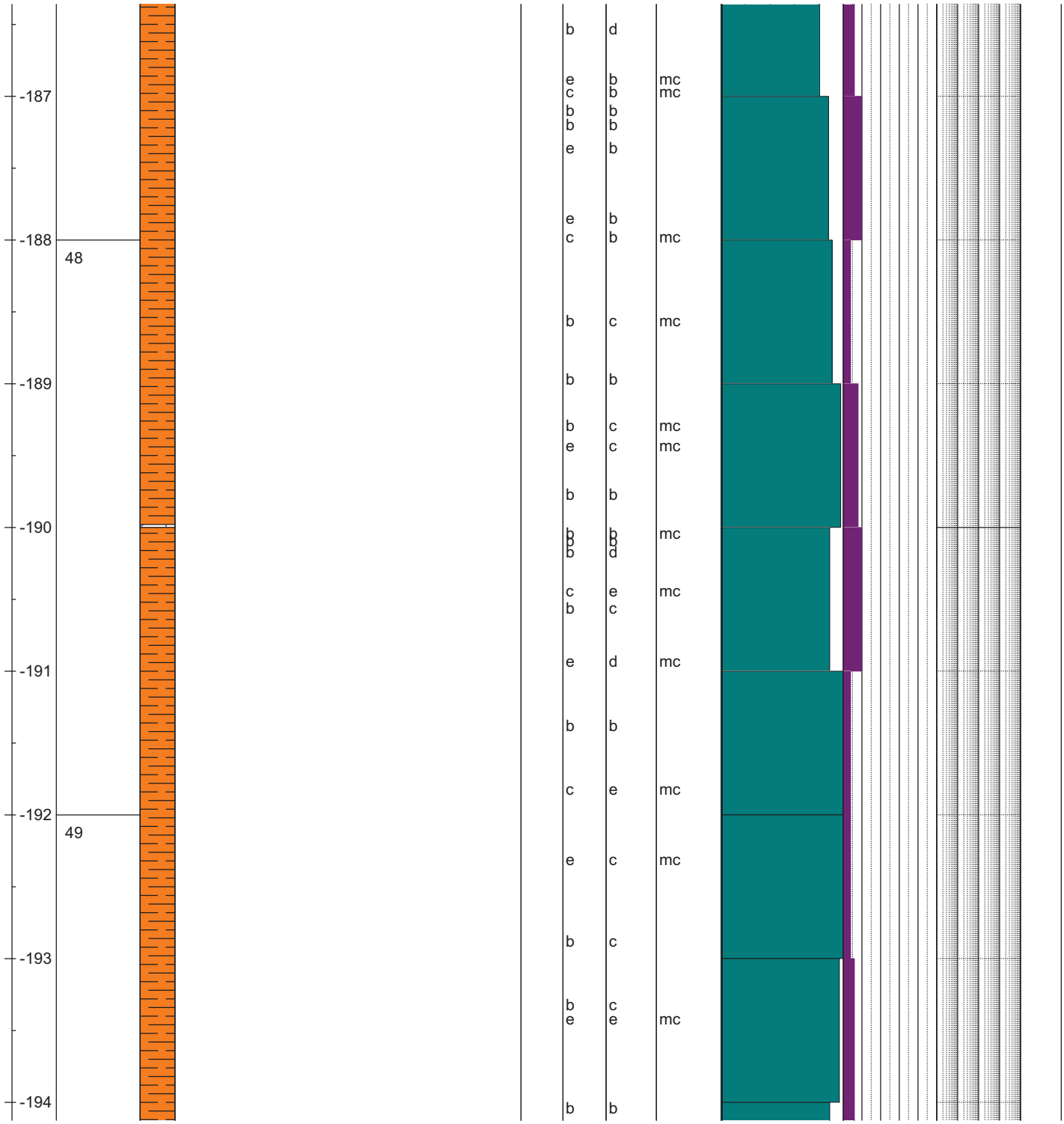

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ROCK TYPE: **Gneiss**

ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**

HOLE DEPTH	BOX NO.	ROCK TYPE	DESCRIPTION/COMMENTS	CORELOSS, CM	Jr	Ja	Joint infill material
-195					b	b	
					e	d	mc
					e	b	
					b	d	mc
					e	d	mc
-196					e	b	
	50				e	d	mc
					e	c	
					b	c	
					c	d	mc
-197					e	b	
					e	b	
					b	d	mc
-198					b	e	mc
					b	b	
					b	c	
-199					e	c	
					b	b	
					e	b	mc
-200					e	b	
	51		Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.		e	d	mc
					e	d	mc
					b	c	
-201					b	c	
					e	c	
					e	c	
					b	b	

RQD, % (20 40 60 80)

JOINT FREQUENCY natural joints pr. m. (5 10 15 20)

WATERLOSS MEASUREMENT Lugeon (1 10 100)

OVERPRESSURE, MPa

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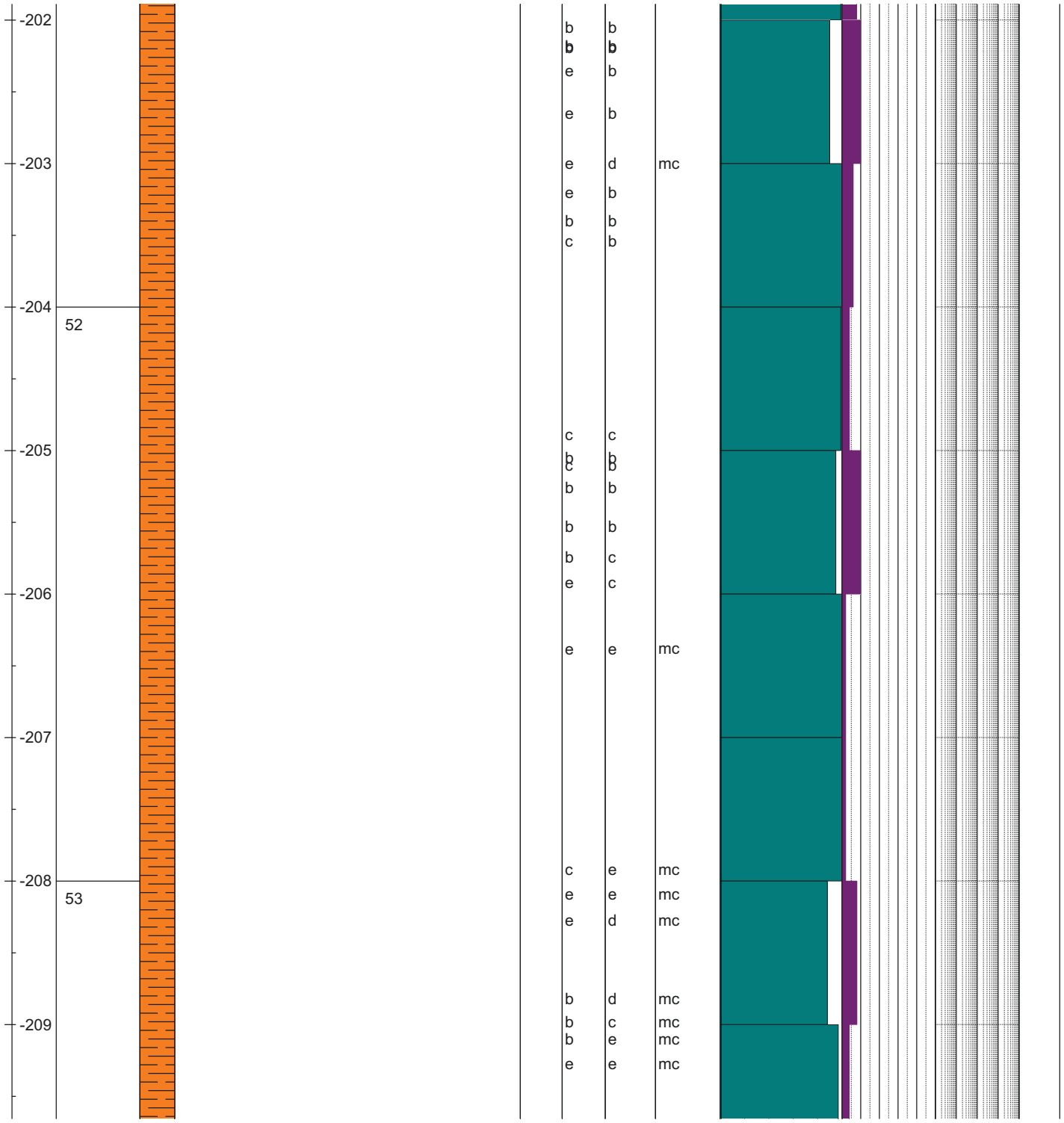
JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**



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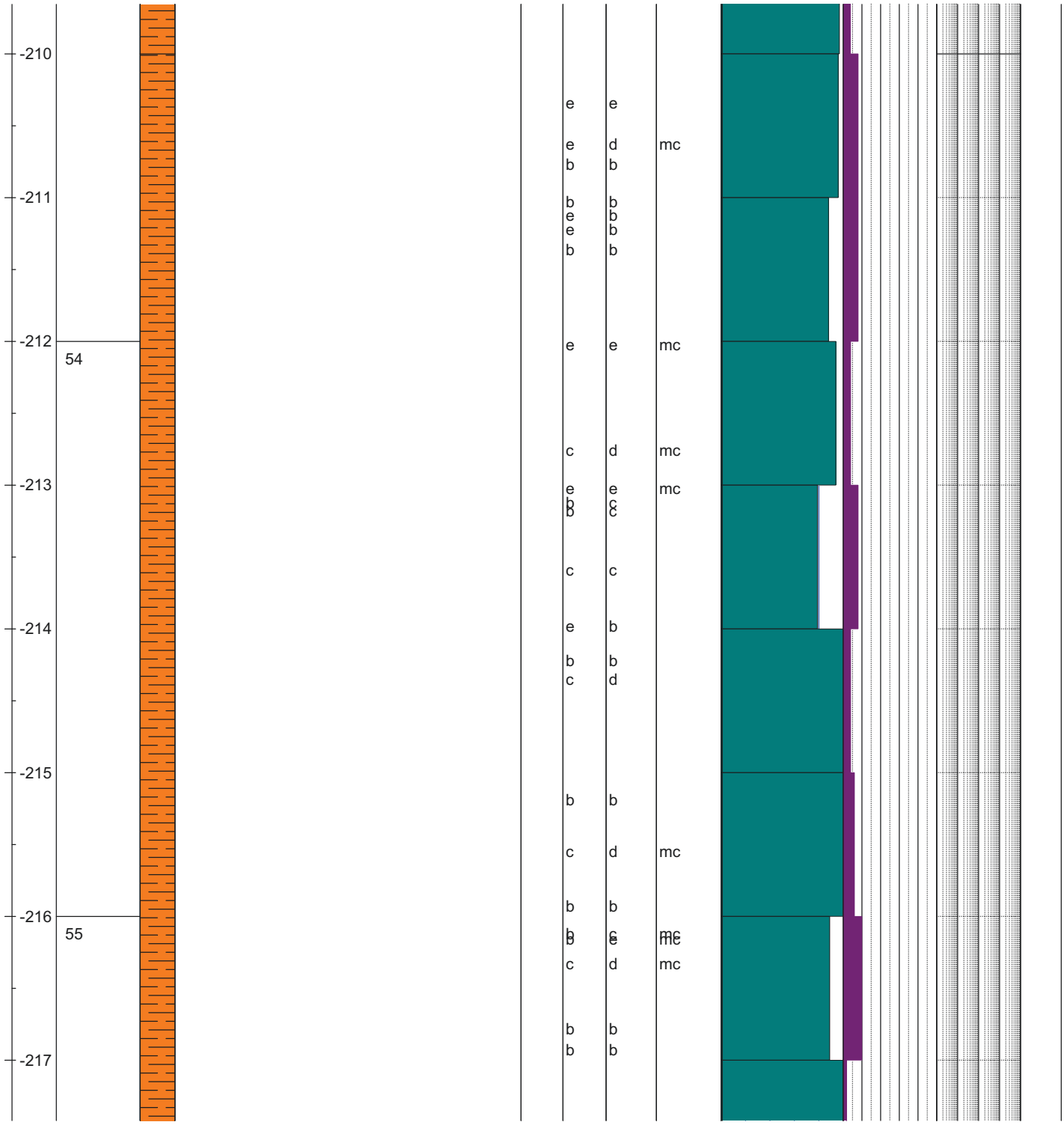
ZONES: **Fractured zone**, **Core loss**

JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**



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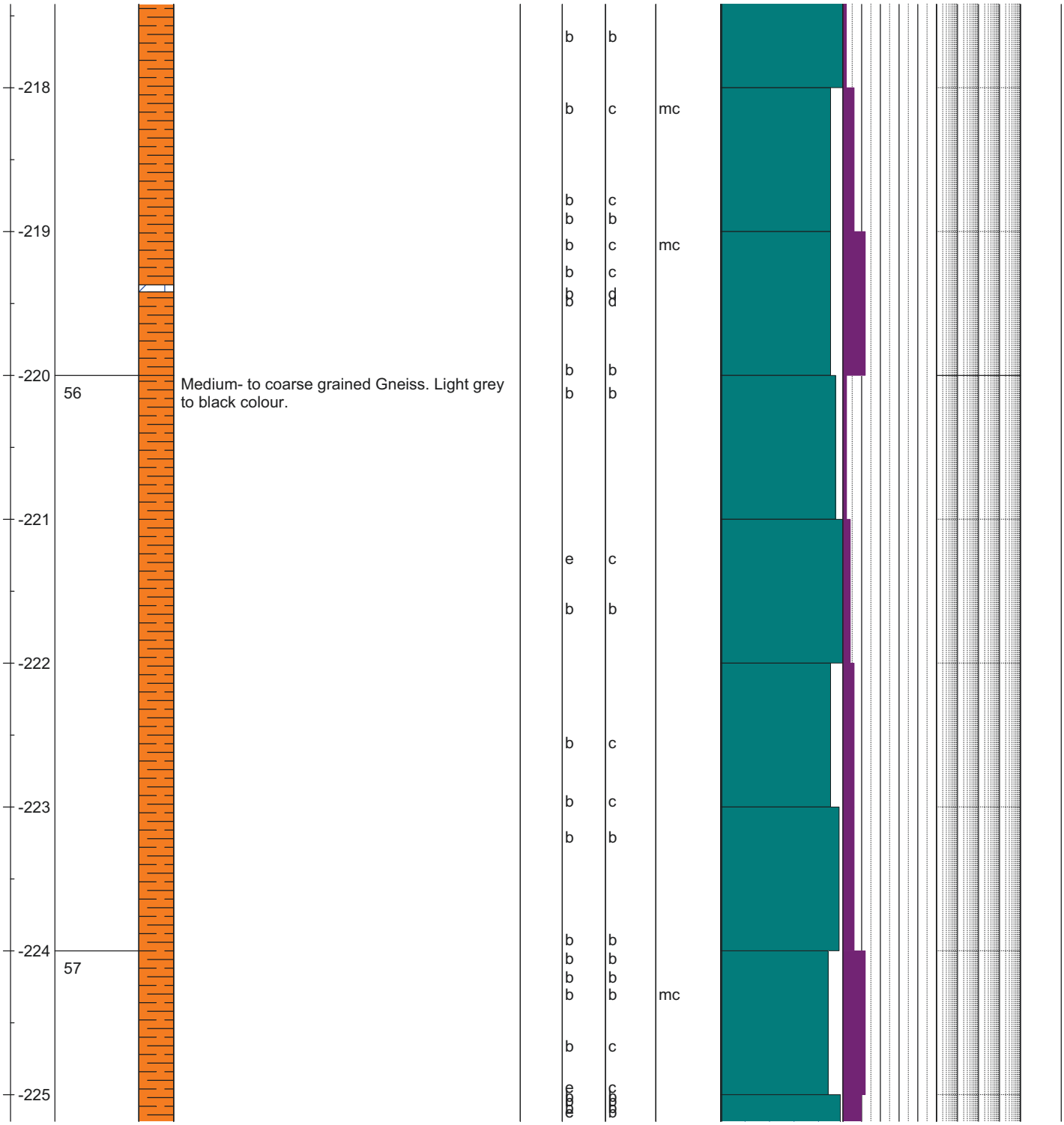
ROCK TYPE:
Gneiss

ZONES:
Fractured zone
Core loss

JOINT INNFILL MATERIAL:
cy, Clay
cl, Chlorite
mc, Mica
ca, Calcite



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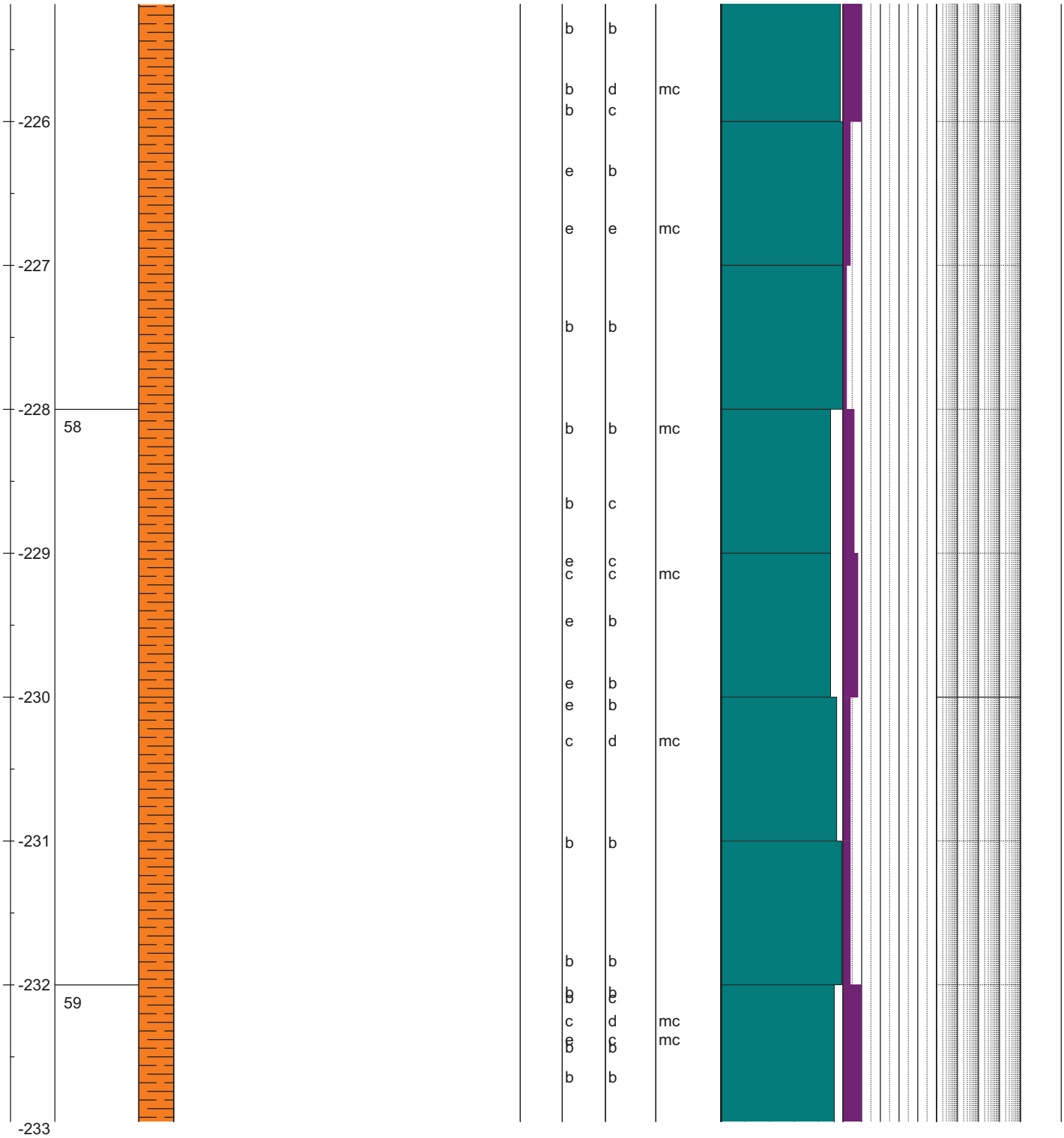

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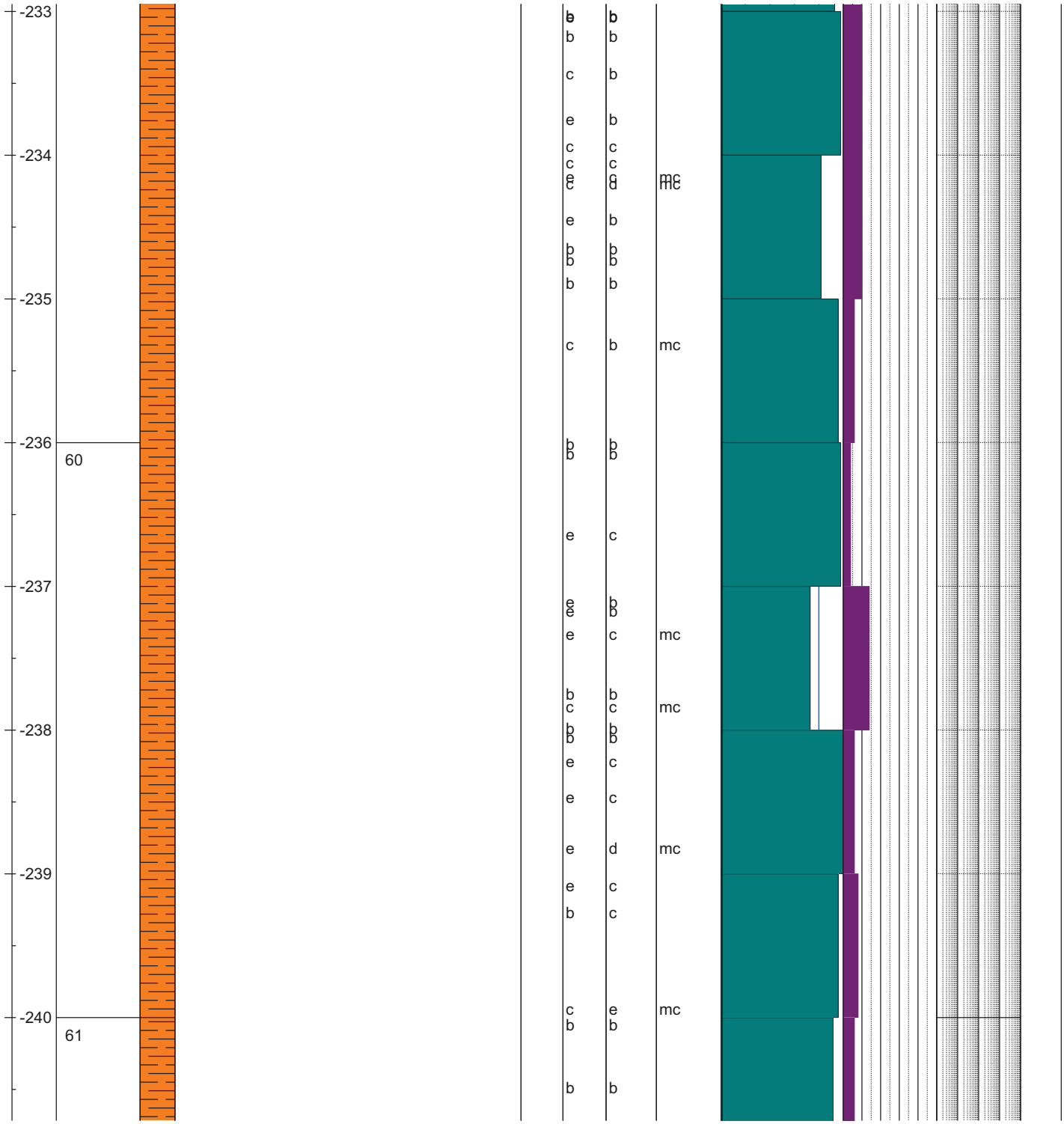

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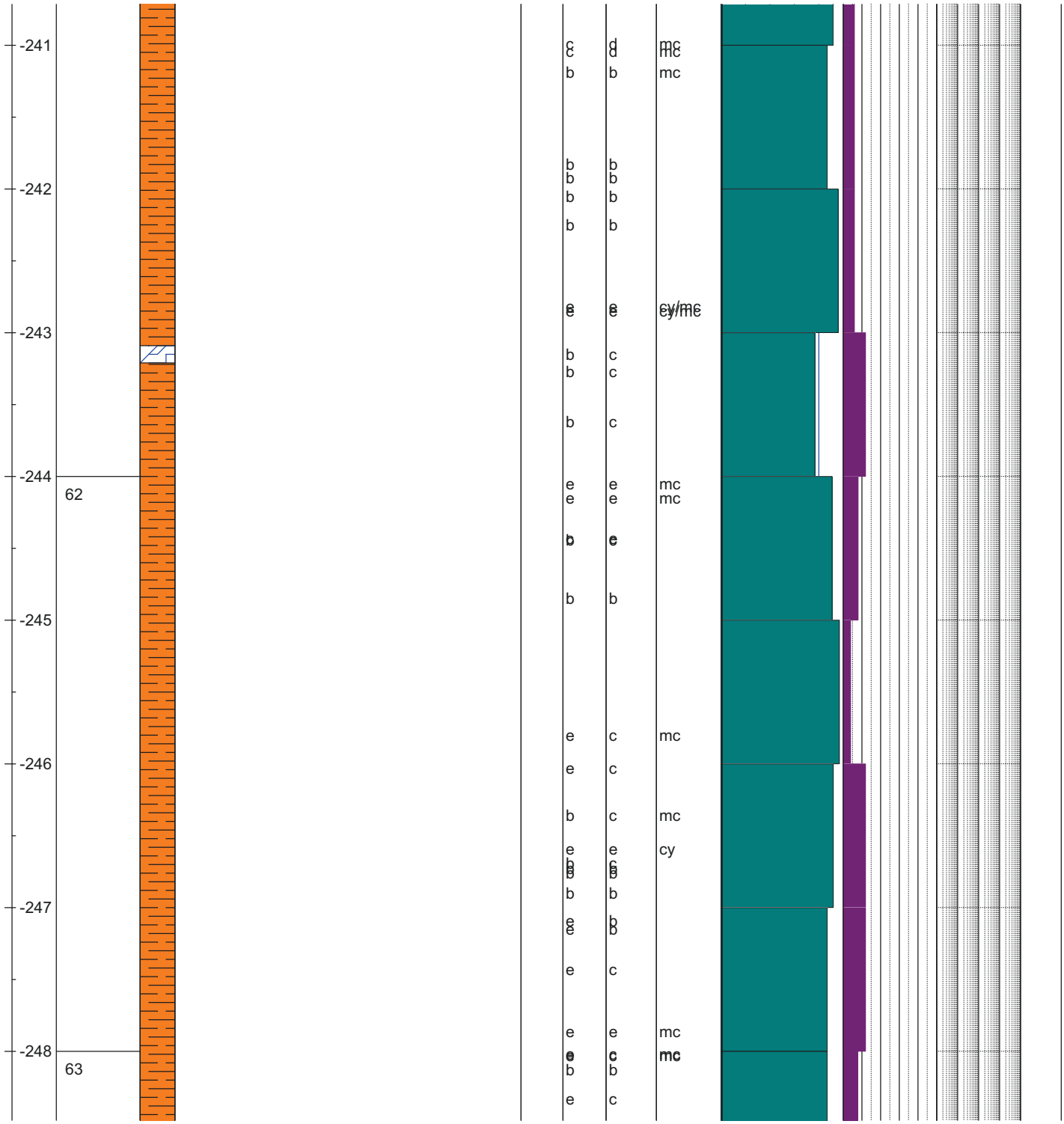

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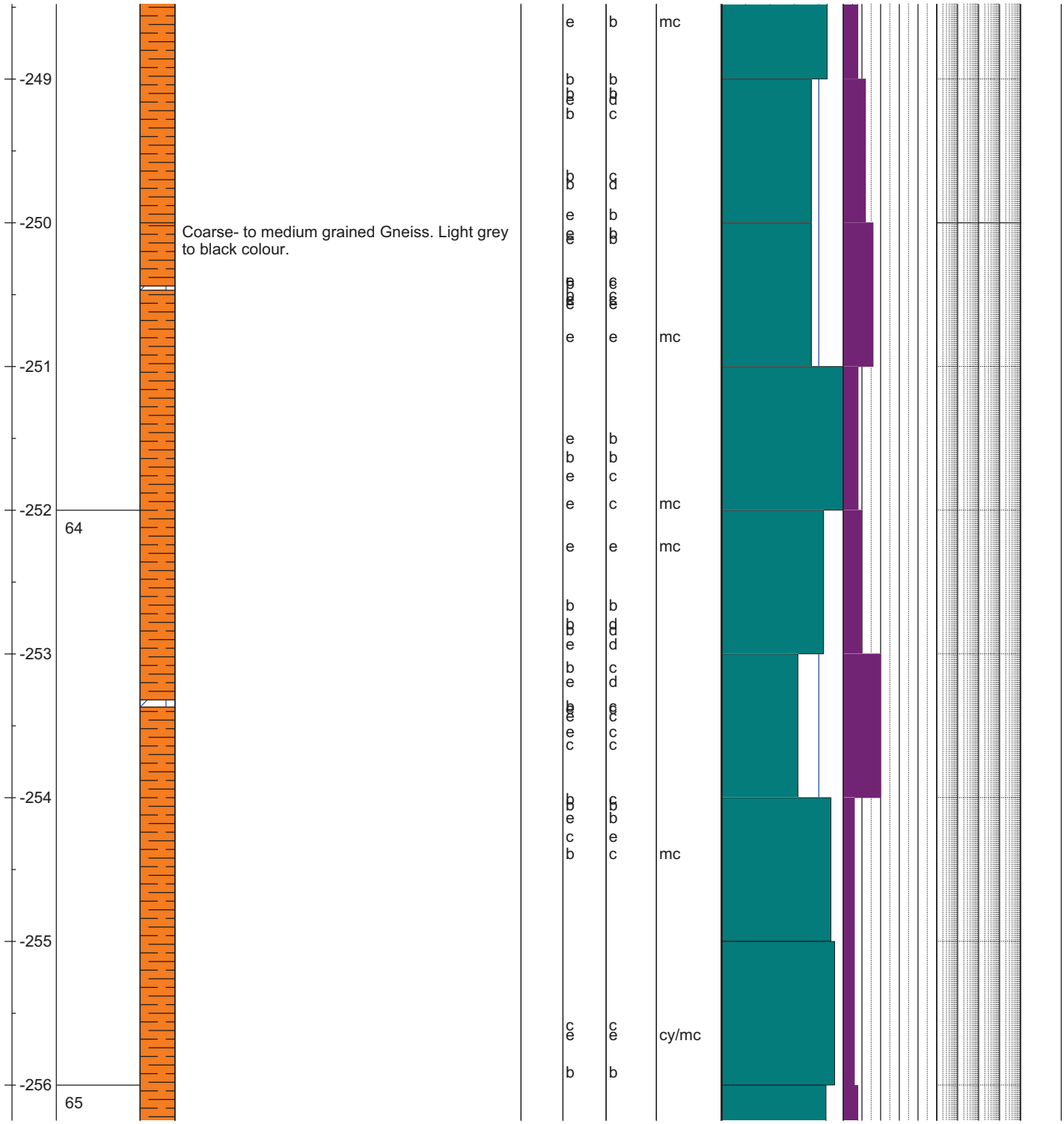

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JOINT INNFILL MATERIAL: **cy, Clay**, **cl, Chlorite**, **mc, Mica**, **ca, Calcite**

HOLE DEPTH	BOX NO.	ROCK TYPE	DESCRIPTION/COMMENTS	CORELOSS, CM	Jr	Ja	Joint infill material	RQD, % (20 40 60 80)	JOINT FREQUENCY natural joints pr. m. (5 10 15 20)	WATERLOSS MEASUREMENT Lugeon (1 10 100)	OVERPRESSURE, MPa
-257					b c c	e c c	mc				
-258					b e	b d					
-259					c b b	e b b	cy				
-260	66		Medium- to coarse grained Gneiss. Light grey to black colour.		c c	e c	mc				
-261					e b b	c c c					
-262					b b e	b b e	mc				
-263					e e	e e	mc mc				
-264					b e e b b b	c e d e b b	mc/cy mc mc				

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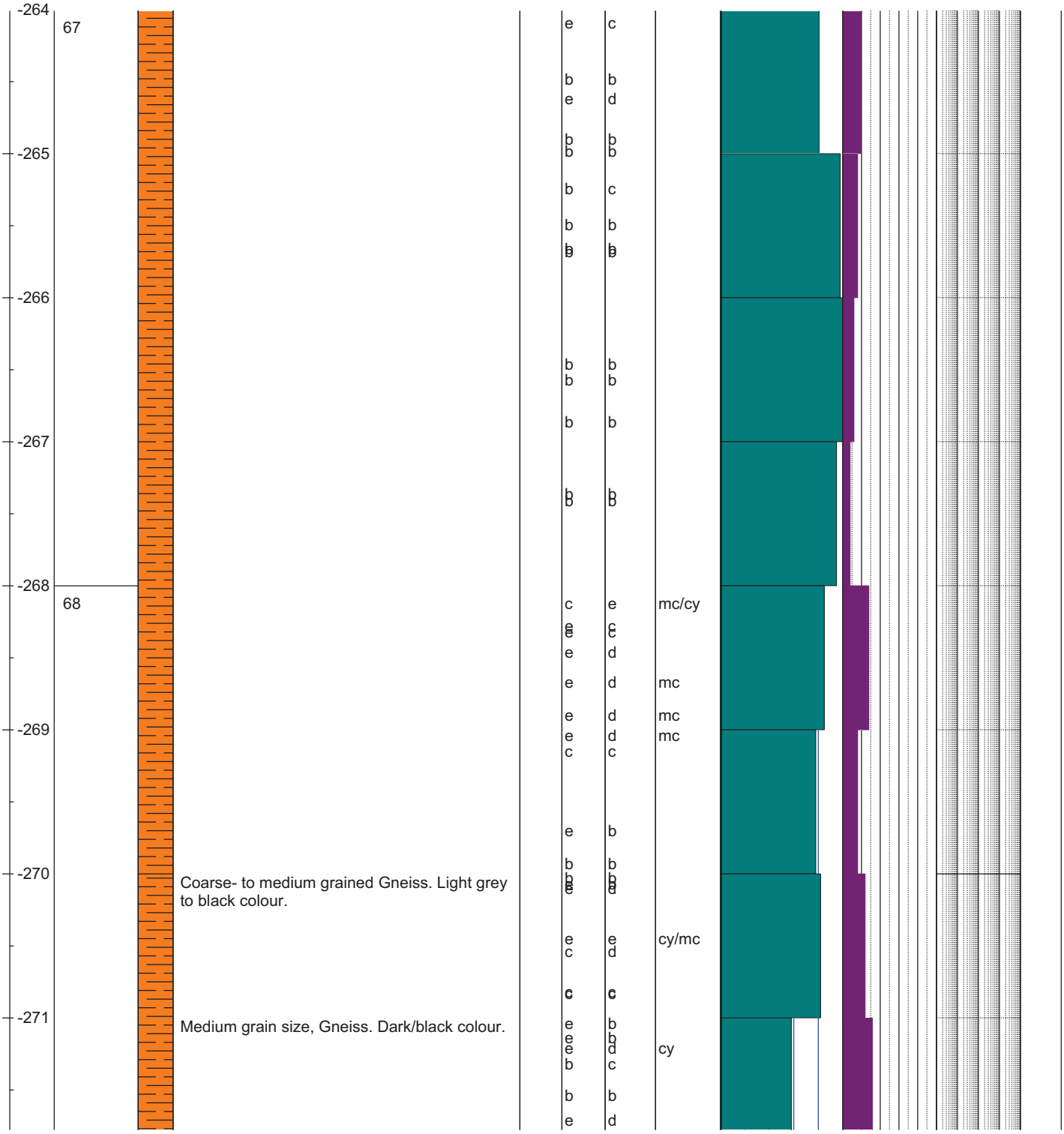

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ROCK TYPE:
Gneiss

ZONES:
Fractured zone
Core loss

JOINT INNFILL MATERIAL:
cy, Clay
cl, Chlorite
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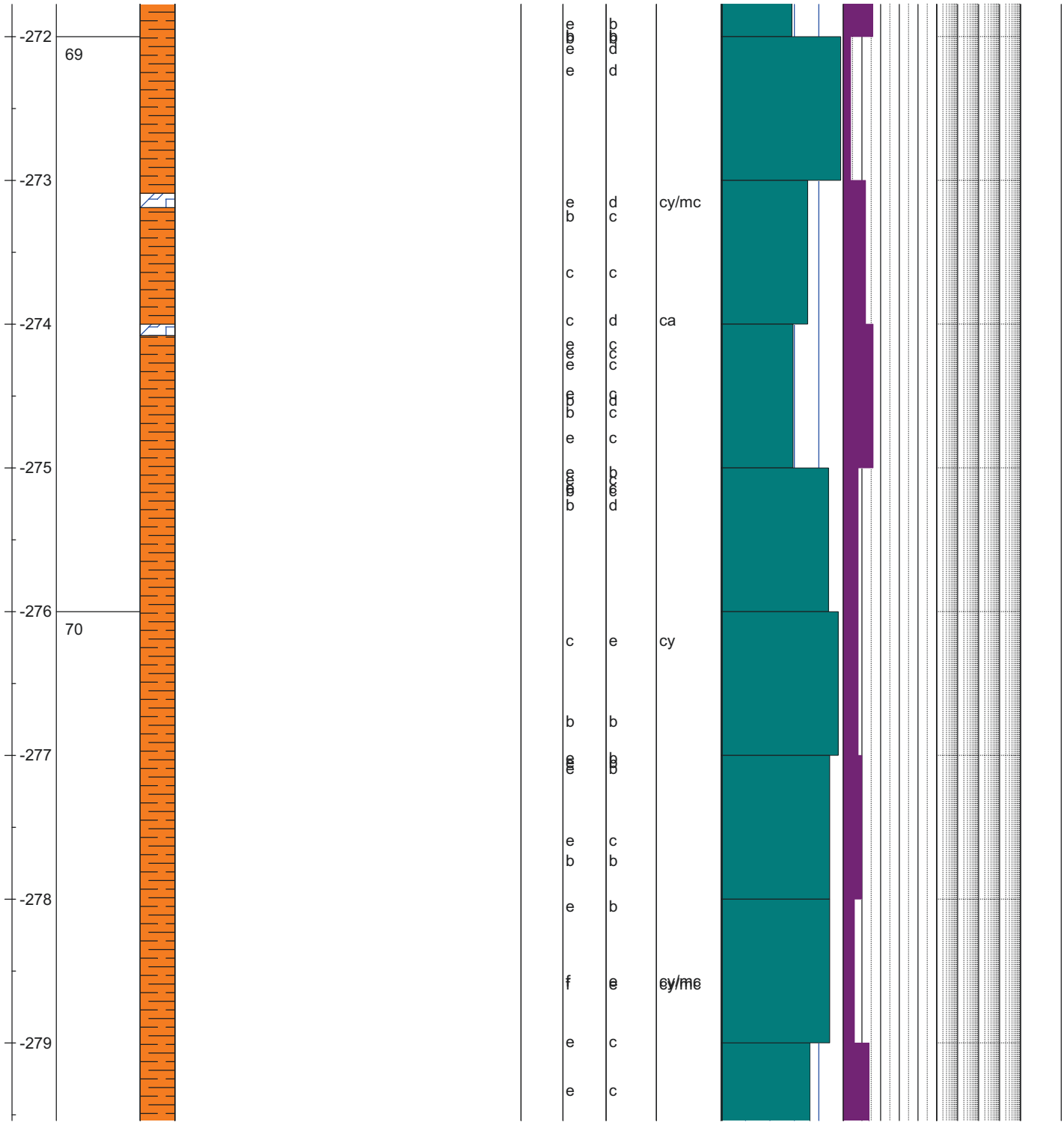
HOLE DEPTH | BOX NO. | ROCK TYPE | DESCRIPTION/COMMENTS | CORELOSS, CM | Jr | Ja | Joint infill material | RQD, % (20 40 60 80) | JOINT FREQUENCY natural joints pr. m. (5 10 15 20) | WATERLOSS MEASUREMENT Lugeon (1 10 100) | OVERPRESSURE, MPa



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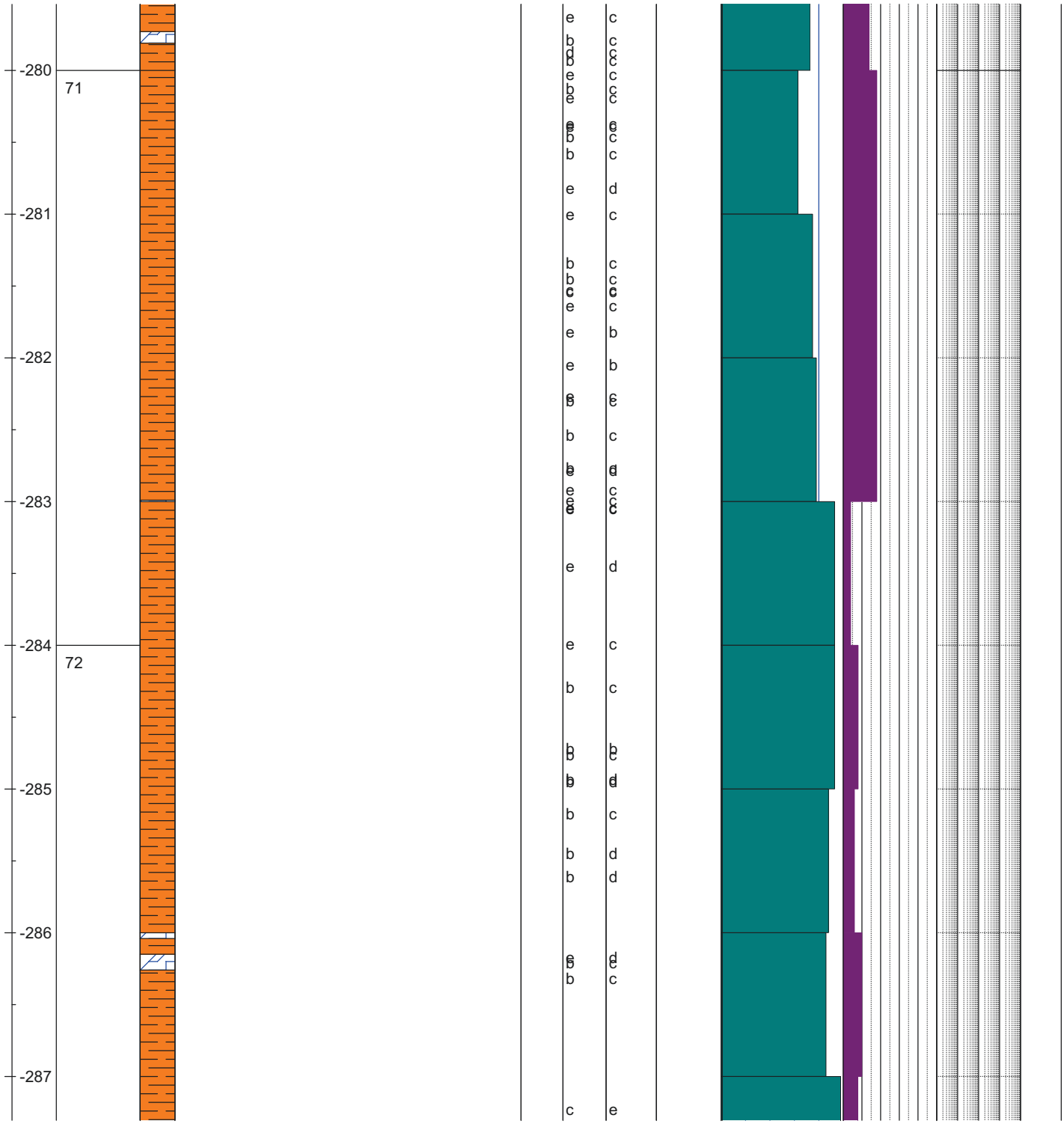

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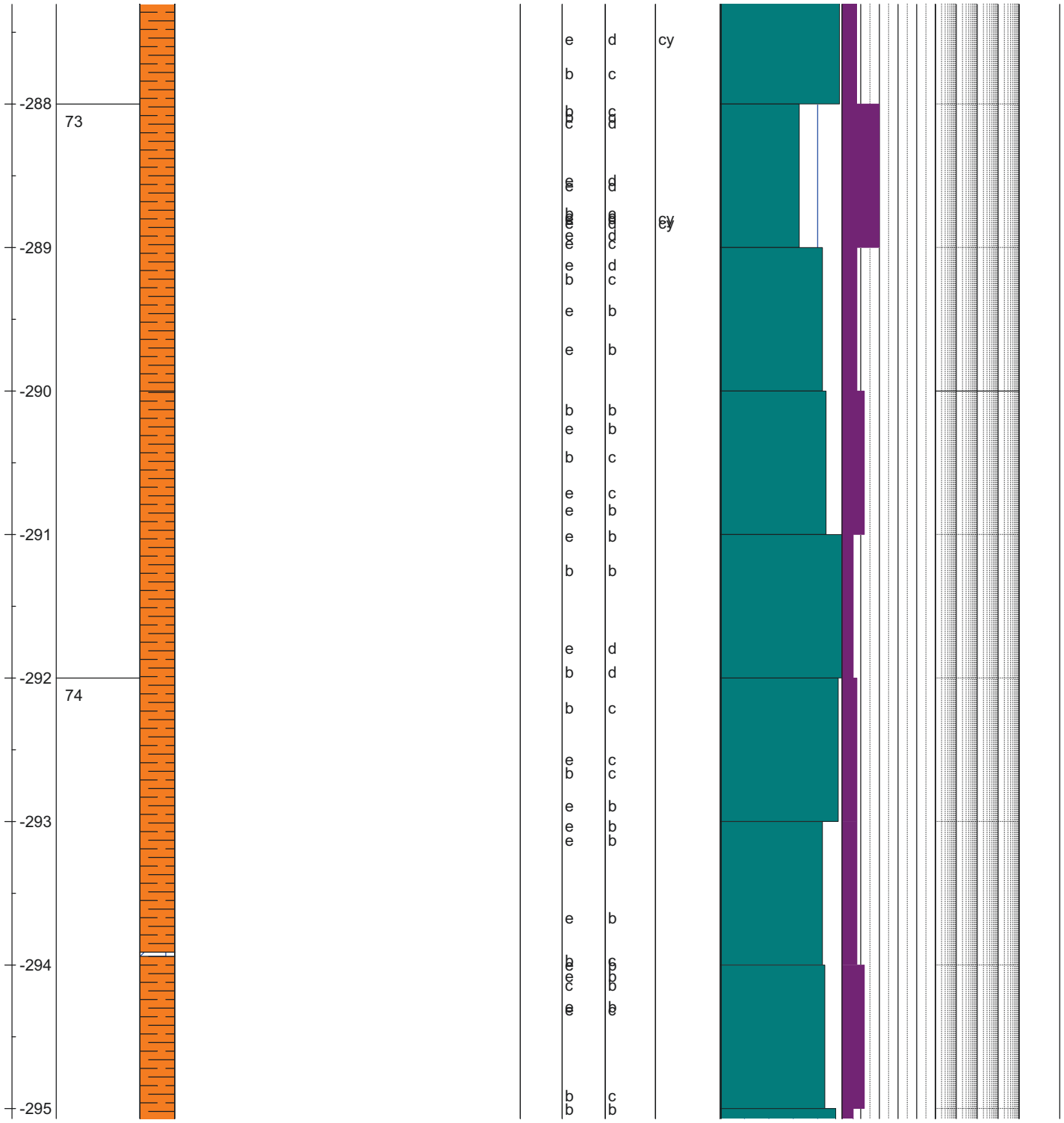

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-296	75		Gneiss, bands of high mica content (parallell foliation). Coarse grained, light grey to black rock with visible foliation bands, some clay on a few fractures.		b e e b e e	b c b b b b					
-297											
-298					e e e b c e	c c c c c c					
-299					e e e e	c d d c					
-300	76				b b	b b					
-301					e b e b b b	b b b b b b					
-302					b b	b b					

Norwegian Geotechnical Institute

CORE DRILLING- CORELOG

BOREHOLE: BH-01-2017

REPORT NO.: **20180662**
PROJECT NAME: **Åknes drainage**

DRILLED LENGTH: **302,7 m**
ELEVATION: **506,8 m**
ORIENTATION: **Vertical**
LOGGING DATE: **2017-09-07 to 19**
NAME: **Henrik Langeland**
File: *P:\2018\06\20180662\Beregninger\BH-01-2017\Logplot\BH012017.dat*

ROCK TYPE:
Gneiss

ZONES:
Fractured zone
Core loss

JOINT INNFILL MATERIAL:
cy, Clay
cl, Chlorite
mc, Mica
ca, Calcite

HOLE DEPTH	BOX NO.	ROCK TYPE	DESCRIPTION/COMMENTS	CORELOSS, CM	Jr	Ja	Joint infill material	RQD, %	JOINT FREQUENCY natural joints pr. m.	WATERLOSS MEASUREMENT Lugeon	OVERPRESSURE, MPa
								20 40 60 80	5 10 15 20	1 10 100	

Appendix C

PICTURES OF CORES KH-01-2017

Contents

C1 Pictures of cores KH-01-2017

Table 1. Overview of case no. and core length in KH-01-17.

Case no.	From	To	Length		Case no.	From	To	Length
1	0	4	4		39	152	156	4
2	4	8	4		40	156	160	4
3	8	12	4		41	160	164	4
4	12	16	4		42	164	168	4
5	16	20	4		43	168	172	4
6	20	24	4		44	172	176	4
7	24	28	4		45	176	180	4
8	28	32	4		46	180	184	4
9	32	36	4		47	184	188	4
10	36	40	4		48	188	192	4
11	40	44	4		49	192	196	4
12	44	48	4		50	196	200	4
13	48	52	4		51	200	204	4
14	52	56	4		52	204	208	4
15	56	60	4		53	208	212	4
16	60	64	4		54	212	216	4
17	64	68	4		55	216	220	4
18	68	72	4		56	220	224	4
19	72	76	4		57	224	228	4
20	76	80	4		58	228	232	4
21	80	84	4		59	232	236	4
22	84	88	4		60	236	240	4
23	88	92	4		61	240	244	4
24	92	96	4		62	244	248	4
25	96	100	4		63	248	252	4
26	100	104	4		64	252	256	4
27	104	108	4		65	256	260	4
28	108	112	4		66	260	264	4
29	112	116	4		67	264	268	4
30	116	120	4		68	268	272	4
31	120	124	4		69	272	276	4
32	124	128	4		70	276	280	4
33	128	132	4		71	280	284	4
34	132	136	4		72	284	288	4
35	136	140	4		73	288	292	4
36	140	144	4		74	292	296	4
37	144	148	4		75	296	300	4
38	148	152	4		76	300	304	4

K1

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K3

K4

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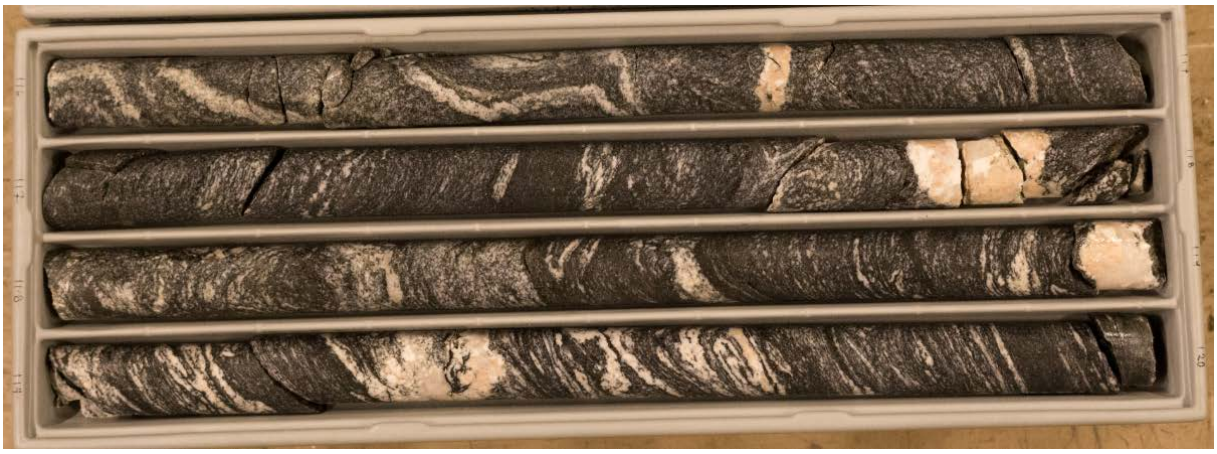
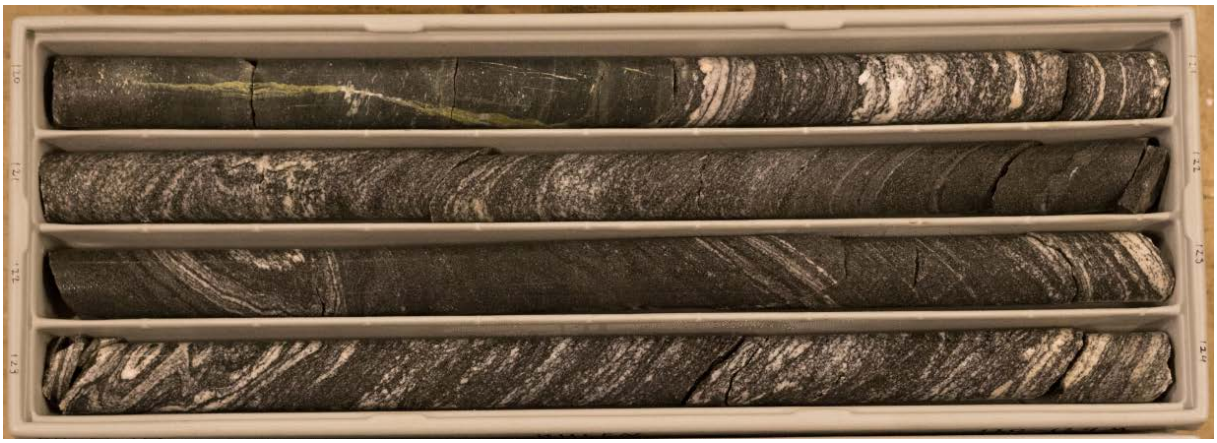


K31



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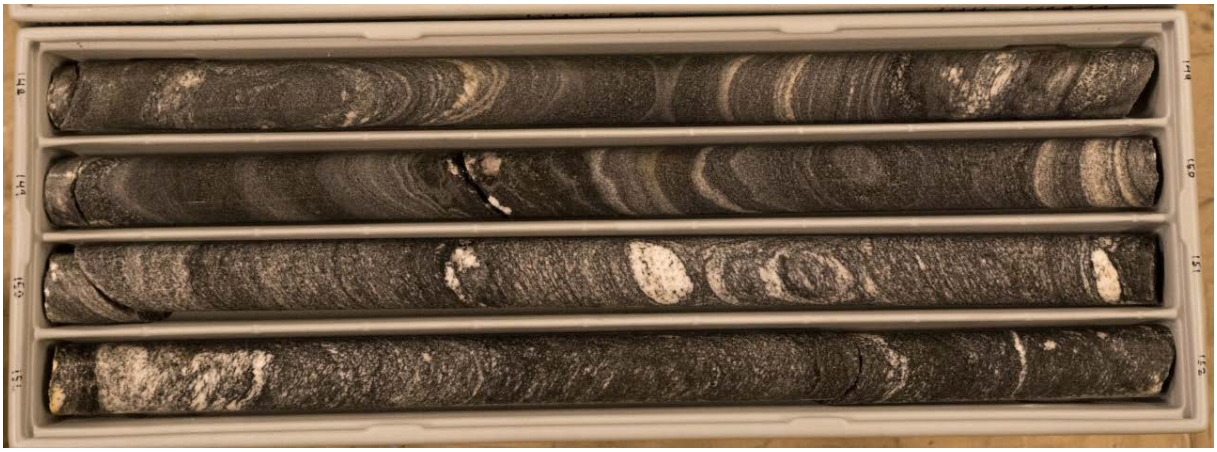

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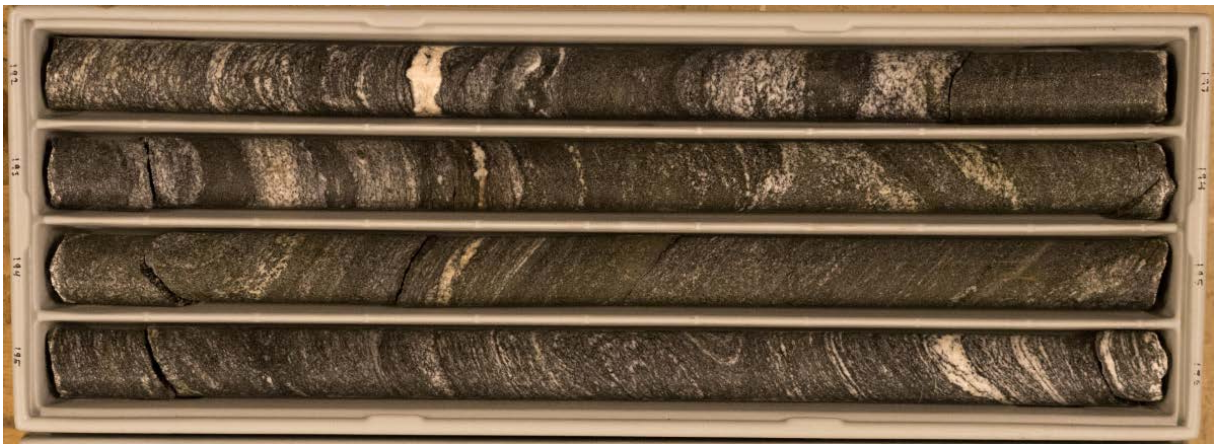

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Kontroll- og referanseside/ Review and reference page

Dokumentinformasjon/*Document information*		
Dokumenttittel/*Document title* Datareport corelogging KH-01-2017		**Dokumentnr./*Document no.*** 20180662-01-R
Dokumenttype/*Type of document* Rapport / Report	**Oppdragsgiver/*Client*** NVE	**Dato/*Date*** 2018-11-29
Rettigheter til dokumentet iht kontrakt/ *Proprietary rights to the document according to contract* NGI		**Rev.nr.&dato/*Rev.no.&date*** 0 /
Distribusjon/*Distribution* BEGRENSET: Distribueres til oppdragsgiver og er tilgjengelig for NGIs ansatte / LIMITED: Distributed to client and available for NGI employees		
Emneord/*Keywords* Corelogging, RQD, fracture frequency		

Stedfesting/*Geographical information*	
Land, fylke/*Country* Norway	**Havområde/*Offshore area***
Kommune/*Municipality* Stranda	**Feltnavn/*Field name***
Sted/*Location* Åknes	**Sted/*Location***
Kartblad/*Map* 1219-2 Geiranger	**Felt, blokknr./*Field, Block No.***
UTM-koordinater/*UTM-coordinates* **Zone:** 33N**East:** 84568,29**North:** 6919727,39	**Koordinater/*Coordinates*** **Projection, datum: East: North:**

Dokumentkontroll/*Document control*
Kvalitetssikring i henhold til/*Quality assurance according to NS-EN ISO9001*

Rev/ *Rev.*	**Revisjonsgrunnlag/*Reason for revision***	**Egenkontroll av/ *Self review by:***	**Sidemanns-kontroll av/ *Colleague review by:***	**Uavhengig kontroll av/ *Independent review by*:**	**Tverrfaglig kontroll av/ *Interdisciplinary review by:***
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	29 November 2018	Kristin H. Holmøy

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