SAMPLE: END09-02_291.40-291.50

Length: N/A

Diameter: N/A

Density: N/A

Peak Strength: N/A

Young's Modulus: N/A

Poisson's Ratio: N/A

Failure Cause N/A

SAMPLE: END09-02_319.50-319.60

Length: N/A

Diameter: N/A

Density: N/A

Peak Strength: N/A

Young's Modulus: N/A

Poisson's Ratio: N/A

Failure Cause N/A

APPENDIX B

Rock Mass Classification

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TABLES

FIGURES

1.0 INTRODUCTION

This appendix presents the results of the rock mass classification carried out on the 2009 geotechnical borehole data for Kiggavik Main Zone (MZ) and Centre Zone (CZ). The data analysed in the rock mass classification work has been discussed in the previous appendices and the 2009 data report (Golder 2009). In total, there was approximately 1360 m of core drilled at MZ and CZ.

The following appendix discusses the rock mass classification procedures, and outlines the rock mass classification results for the MZ/CZ sites, including interpretations for slope design.

2.0 ROCK MASS CLASSIFICATION PROCEDURE

For classification of the rock mass, the 1976 Rock Mass Rating (RMR) system was used (Bieniawski 1976). For validation of the RMR classification scheme, the Norwegian Geotechnical Institute Q-System (Barton et al. 1974) for rock mass classification was also used; however these results have not been presented herein.

Due to the variability in the rock mass quality for any particular rock lithology, the RMR was carried out at the logging interval level, meaning a separate classification was carried out on intervals ranging from 0.10 m to a maximum of once per drill run (i.e., typically 3 m of core or less). Using this approach, the RMR distribution in the borehole delineates intercepted geotechnical features, or zones in the rock mass which share similar geotechnical characteristics such as strength, fracture spacing, or alteration.

The RMR value per drilling interval is calculated as follows (on a scale of 100):

$$RMR = P_1 + P_2 + P_3 + P_4 + P_5$$

Where P_1 through P_5 represent values assigned based on the following rock mass parameters:

- *Strength of Intact Rock (P_1)*; assessed on a per run basis according to either the laboratory Unconfined Compressive Strength (UCS) data if available, the Point Load Test (PLT) – $I_{s(50)}$ data if available, or the field assessment of intact rock strength (R) based on the ISRM field classification. These strength parameters are discussed in Appendix A.
- *Rock Quality Designation, RQD (P_2)*; this parameter was assessed in the field for every drill run of core as discussed in the data report (Golder 2009).
- *Fracture Spacing (P_3)*; this parameter was calculated based on the fracture frequency which was assessed in the field for every drill run of core as discussed in the data report (Golder 2009).
- *Condition of Joints (P_4)*; this parameter was taken as the average joint condition value (J_{con}) per drill run of core for the individual discontinuities assigned in the field (Golder 2009).
- *Groundwater (P_5)*; for the calculation of the rock mass RMR, the ground was assumed dry (P_5 = 10). ***For stability assessment considerations, the appropriate value will have to be subtracted from the calculated RMR values to reflect in situ seepage conditions, or in the case of numerical modelling, considered separately, such as a water table.***

The RMR classification parameters are shown on Table B1.

Table B1: 1976 Rock Mass Rating (RMR) classification parameters (after Bieniawski 1974).

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	PARAMETER		RANGES OF VALUES						
1	Strength of intact rock material	Point load strength index	>8 MPa	4-8 MPa	2-4 MPa	1-2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial compressive strength	>200 MPa	100 - 200 MPa	50 - 100 MPa	25 - 50 MPa	10-25 MPa	3-10 MPa	1-3 MPa
	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 joints		>3 m	1-3 m	0.3-1 m	50 - 300 mm	<50 mm		
	Rating		30	25	20	10	5		
4	Condition of joints		Very rough surfaces Not continuous No separation Hard joint wall rock	Slightly rough surfaces Separation <1 mm Hard joint wall rock	Slightly rough surfaces Separation <1 mm Soft joint wall rock	Slickensided surfaces or Gouge <5 mm thick or Joints open 1-5 mm Continuous joints	Soft gouge >5 mm thick or Joints open >5 mm Continuous joints		
	Rating		25	20	12	6	0		
5	Ground water	Inflow per 10 m tunnel length	None		<25 litres/min.	25-125 litres/min.	>125 litres/min.		
		OR Ratio joint water pressure / major principal stress	0		0.0 - 0.2	0.2 - 0.5	>0.5		
		OR General conditions	Completely dry		Moist only (interstitial water)	Water under moderate pressure	Severe water problems		
	Rating		10		7	4	0		

The calculated RMR values by drill interval for the MZ and CZ 2009 boreholes are plotted on the striplogs in Figures B1 and B2. Also shown on these striplogs are the lithology obtained from AREVA's geologists, and the ISRM strength index value (R) assessed in the field. As discussed in Appendix A, the R values agree reasonably well with the available laboratory testing. The RMR and R values have been color coded as per the legend shown on these figures. Records of Drillholes are presented in the data report (Golder 2009).

Several geotechnical boreholes from 2007/2008 (SRK 2009) were also cross-checked following a similar rock mass classification approach using the geotechnical data provided by AREVA. The cross-checks showed that the calculated RMR (1976) values for the drill run intervals followed closely to previous rock mass classification carried out by SRK using the 1989 RMR system. The 2007/2008 data are not presented in this document, however some of these boreholes were used to aid the interpretation as discussed herein.

The interpretation and classification results are discussed further in the following sections.

MZ-09-01

From	To	Geology	R	RMR
15.00	18.00	GnPsaPel	4	68.7
18.00	21.00	GnPsaPel	5	64.8
21.00	24.00	GnPsaPel	5	66.8
24.00	27.00	GnPsaPel	4	57.4
27.00	29.00	GnPsaPel	4	58.5
29.00	30.00	GnPsaPel	4	50.9
30.00	33.00	GnPsaPel	4	61.5
33.00	36.00	GnPsaPel	4	65.3
36.00	39.00	GnPsaPel	4	56.9
39.00	42.00	GnPsaPel	4	69.1
42.00	45.00	GnPsaPel	4.5	62.3
45.00	48.00	GnPsaPel	4	52.9
48.00	51.00	GnPsaPel	4	51.3
51.00	54.00	GnPsaPel	4	61.8
54.00	57.00	GnPsaPel	4	58.0
57.00	60.00	GnPsaPel	4	61.3
60.00	63.00	GnPsaPel	4	71.1
63.00	66.00	GnPsaPel	4	62.8
66.00	69.00	GnPsaPel	4	67.4
69.00	72.00	GnPsaPel	4	59.2
72.00	75.00	GnPsaPel	4	58.9
75.00	78.00	GnPsaPel	4	56.9
78.00	81.00	BxQtz	4	61.7
81.00	84.00	GnPsaPel	4	65.3
84.00	87.00	GnPsaPel	4	74.6
87.00	90.00	GnPsaPel	4	79.0
90.00	93.00	GnPsaPel	4	78.6
93.00	96.00	GnPsaPel	4	70.0
96.00	99.00	GnPsaPel	4	66.5
99.00	102.00	GnPsaPel	4	66.4
102.00	105.00	GnPsaPel	4	61.1
105.00	108.00	GnPsaPel	4	69.5
108.00	111.00	GnPsaPel	4	70.0
111.00	114.00	GnPsaPel	4	58.3
114.00	117.00	GnPsaPel	4	55.3
117.00	120.00	GnPsaPel	4	59.3
120.00	123.00	GnPsaPel	4	67.1
123.00	126.00	GnPsaPel	4	64.8
126.00	129.00	GnPsaPel	4	59.8
129.00	132.00	GnPsaPel	4	61.2
132.00	135.00	GnPsaPel	4	62.5
135.00	138.00	GnPsaPel	4	66.2
138.00	141.00	GnPsaPel	4	66.5
141.00	144.00	GnPsaPel	4	69.2
144.00	147.00	GnPsaPel	4	65.2
147.00	150.00	GnPsaPel	4	68.4
150.00	153.00	GnPsaPel	4	65.0
153.00	156.00	GnPsaPel	4	75.4
156.00	159.00	GnPsaPel	4	73.0
159.00	162.00	GnPsaPel	4	74.2
162.00	165.00	GnPsaPel	4.5	68.1
165.00	168.00	GnPsaPel	4	71.3
168.00	171.00	GnPel	3.5	59.3
171.00	174.00	GnPel	3.5	70.0
174.00	177.00	GnPel	3.5	65.5
177.00	180.00	GnPel	4	67.8
180.00	183.00	GnPel	4	61.0
183.00	186.00	GnPel	4	65.7
186.00	189.00	GnPel	4	63.2
189.00	191.50	GnPel	4	66.5
191.50	193.05	GnPel	4	66.1
193.05	194.05	GnPel	3	55.8
194.05	194.66	GnPel	4	73.7
194.66	197.83	GnPel	4	59.3
197.83	201.00	GnPel	4	62.9
201.00	203.85	GnPel	3.5	55.7
203.85	207.00	GnPel	3.5	64.8
207.00	210.00	GnPel	3.5	61.7
210.00	213.00	GnPel	3.5	48.4
213.00	216.00	GnPel	3.5	57.2
216.00	219.00	GranT	4	66.6
219.00	222.00	GranT	4	67.5
222.00	222.55	GranT	4	62.2
222.55	224.15	GranT	3.5	58.8
224.15	225.00	GranT	4	71.4
225.00	228.00	GranT	3.5	65.6
228.00	231.00	GranT	4	66.1
231.00	234.00	GranT	4	64.1
234.00	237.00	GranT	3.5	53.5
237.00	240.00	GranT	4	59.7
240.00	243.00	GranT	2.5	58.4
243.00	244.88	GranT	1	50.2
244.88	246.00	GranT	2.5	56.5
246.00	246.63	GranT	2	53.1
246.63	247.30	GranT	2	47.6
247.30	249.00	GranT	2.5	57.0
249.00	252.00	GranT	2.5	69.1
252.00	255.00	GranT	2.5	50.8
255.00	258.00	GranT	2.5	70.8
258.00	261.00	GranT	2.5	67.3
261.00	263.30	GranT	2.5	53.4
263.30	264.56	GranT	3.5	47.8
264.56	267.00	GranT	3.5	59.0
267.00	270.00	GranT	3.5	57.9
270.00	273.00	GranT	4	67.3
273.00	276.00	GranT	4	64.2
276.00	279.00	GranT	4	61.0
279.00	282.00	GranT	4	62.5
282.00	285.00	GranT	4	75.1
285.00	288.00	GranT	4	68.8
288.00	291.00	GranT	4	70.4
291.00	294.00	GranT	4.5	88.6
294.00	297.00	GranT	4	86.8
297.00	300.00	GranT	4.5	89.7
300.00	303.00	GranT	4	68.4
303.00	306.00	GranT	4	69.8
306.00	309.00	GranT	4	80.5

MZ-09-02

From	To	Geology	R	RMR
19.5	20	GnPsaPel	0.5	28.9
20	23	GnPsaPel	1	48.1
23	26	GnPsaPel	1	36.9
26	29	GnPsaPel	3	46.5
29	32	GnPsaPel	1.5	46.0
32	35	GnPsaPel	2	46.9
35	36.6	GnPsaPel	4	52.5
36.6	37.98	GnPsaPel	2	57.8
37.98	39.72	GnPsaPel	0	22.5
39.72	41	GnPsaPel	3	39.4
41	41.5	GnPsaPel	0	29.0
41.5	44	GnPsaPel	3	52.5
44	47	GnPsaPel	3	45.1
47	50	GnPsaPel	4	50.7
50	53	GnPsaPel	4	61.2
53	56	GnPsaPel	4	61.7
56	59	GnPsaPel	4.5	60.2
59	62	GnPsaPel	4.5	67.7
62	65	GnPsaPel	4.5	67.4
65	68	GnArk	4.5	59.0
68	71	GnArk	4	56.0
71	74	GnPsaPel	4.5	63.5
74	77	GnPsaPel	5	66.8
77	80	GnPsaPel	5	67.8
80	83	GnPsaPel	4.5	68.6
83	86	GnArk	4.5	60.4
86	89	GnPsaPel	4.5	57.5
89	91	Diab	4.5	65.7
91	92	GnArk	5	64.1
92	93.25	GnArk	5	67.6
93.25	95	GnArk	5	60.1
95	97	GnArk	5	66.8
97	98	GnArk	4.5	58.9
98	101	GnArk	3.5	60.5
101	104	GnPsaPel	2.5	58.8
104	104.75	GnPsaPel	2.5	58.6
104.75	107	GnPsaPel	3.5	64.8
107	110	GnPsaPel	3.5	73.0
110	113	GnPsaPel	3.5	72.1
113	116	GnPsaPel	3.5	72.5
116	119	GnPsaPel	3.5	78.5
119	122	GnPsaPel	3.5	75.1
122	125	GnPsaPel	3.5	78.2
125	128	GnPsaPel	3.5	60.9
128	131	GnPsaPel	3.5	64.8
131	134	GnPsaPel	3.5	70.1
134	137	GnArk	3.5	67.8
137	140	GnArk	3.5	66.4
140	143	GnPsaPel	3.5	66.8
143	146	GnPsaPel	3.5	67.9
146	149	GnPsaPel	3.5	62.5
149	152	GnPsaPel	4	71.6
152	155	GnPsaPel	4	65.5
155	158	GnPsaPel	3	60.3
158	161	GnPsaPel	3.5	63.9
161	164	GnPsaPel	4	68.9
164	167	GnPsaPel	3.5	67.4
167	170	GnPsaPel	4	70.4
170	173	GnPsaPel	4	67.1
173	176	GnPsaPel	4	68.5
176	179	GnPsaPel	4.5	73.5
179	182	GnPsaPel	4.5	69.2
182	184.2	GnPsaPel	4.5	56.8
184.2	185	GranT	3.5	69.3
185	185.4	GranT	3.5	74.2
185.4	188	GranT	3.5	61.5
188	191	GranT	3.5	69.7
191	194	GranT	3.5	74.0
194	197	GranT	3.5	58.0
197	200	GranT	3.5	60.6
200	203	GranT	4.5	55.6
203	206	GranT	4.5	63.3
206	209	GranT	4.5	67.1
209	212	GranT	4.5	72.3
212	215	GranT	4.5	75.3
215	218	GranT	4.5	70.4
218	221	GranT	4.5	70.1
221	224	GranT	4.5	66.5
224	227	GranT	4.5	68.3
227	230	GranT	4.5	71.7
230	233	GranT	4.5	84.7
233	236	GranT	4.5	72.6
236	238.08	GranT	4.5	68.0
238.08	239	GranT	5	84.7
239	242	GranT	5	77.0
242	245	GranT	5	91.8
245	248	GranT	5	85.4
248	251	GranT	5	82.1
251	254	GranT	5	77.7
254	257	GranT	5	83.8
257	260	GranT	5	84.2

MZ-09-03

From	To	Geology	R	RMR
21.96	24	GnPsaPel	4	67.3
24	26.2	GnPsaPel	4	73.8
26.2	27.14	Lamp	4	59.4
27.14	30	GnPsaPel	4	60.9
30	33	Lamp	5	53.4
33	36	Episyen	5	50.8
36	39	Episyen	5	61.5
39	42	Episyen	5	70.5
42	45	Episyen	5	71.8
45	48	Episyen	5	70.7
48	51	Episyen	5	72.4
51	54	Episyen	5	69.0
54	57	Episyen	5	71.1
57	60	Episyen	5	68.0
60	63	Episyen	5	71.9
63	66	Episyen	5	68.0
66	69	GnPsaPel	5	74.9
69	72	GnPsaPel	5	70.3
72	75	GnPsaPel	5	71.8
75	78	GnPsaPel	5	71.0
78	81	GnPsaPel	4	71.5
81	84	GnPsaPel	4	70.0
84	87	GnPsaPel	4.5	69.0
87	90	GnPsaPel	5	67.5
90	93	GnPsaPel	4.5	64.7
93	96	GnPsaPel	4.5	66.5
96	97.15	GnPsaPel	4.5	70.5
97.15	98.48	Episyen	5	69.0
98.48	99	Episyen	4.5	59.1
99	101.36	GnPsaPel	4.5	68.3
101.36	102	GnPsaPel	3	62.8
102	104.25	Peg	3	71.7
104.25	105	Peg	4.5	69.5
105	107	GnArk	4.5	68.6
107	109.64	GnArk	4.5	74.9
109.64	111.52	Episyen	4.5	66.1
111.52	114	GnPsaPel	4.5	68.8
114	117	GnPsaPel	4.5	65.8
117	120	GnPsaPel	4.5	65.7
120	123	GnPsaPel	4.5	67.0
123	126	GnPsaPel	4.5	70.1
126	129	GnPsaPel	4.5	67.2
129	132	GnPsaPel	4.5	72.6
132	135	GnPsaPel	4.5	75.3
135	138.2	GnPsaPel	4.5	79.9
138.2	141	GranT	4.5	65.1
141	144	GranT	4.5	68.1
144	147	GranT	4.5	65.7
147	150	GranT	4.5	69.1
150	153	GranT	4.5	74.5
153	156	GranT	4.5	72.0
156	159	GranT	4.5	67.3
159	162	GranT	4.5	70.2
162	165	GranT	4.5	61.5
165	166.9	GranT	4.5	67.0
166.9	168	GnPsaPel	4.5	66.0
168	169.7	GnPsaPel	4.5	73.3
169.7	171	GnPsaPel	4.5	66.6
171	174	GnPsaPel	4.5	71.7
174	177	GnPsaPel	4.5	70.8
177	180	GnPsaPel	4.5	73.7
180	182	GnPsaPel	4.5	64.7
182	183	GnPsaPel	4.5	65.2
183	186	GnPsaPel	4.5	67.5
186	189	GnPsaPel	4.5	62.6
189	192	GnPsaPel	4.5	72.3
192	195	GnPsaPel	4.5	70.7
195	198	GnPsaPel	4.5	65.7
198	201	GnPsaPel	4.5	72.2
201	204	GnPsaPel	4.5	69.1
204	207	GnPsaPel	4.5	67.2
207	210	GnPsaPel	4.5	66.5
210	213	GnPsaPel	4.5	67.7
213	216	GranT	5	68.5
216	219	GranT	5	73.0
219	222	GranT	2.5	67.0
222	225	GranT	4.5	61.8
225	228	GranT	4.5	72.1
228	231	GranT	4.5	73.3
231	234	GranT	5	73.8
234	237	GranT	5	72.7
237	240	GranT	5	67.0
240	243	GranT	5	69.0
243	246	GranT	5	76.6
246	247.82	GranT	4.5	70.8

MZ-09-04

From	To	Geology	R	RMR
4.49	6	GnPsaPel	4.5	64.6
6	9	GnPsaPel	4.5	62.1
9	12	GnPsaPel	4.5	63.5
12	15	GnPsaPel	4.5	65.6
15	18	GnPsaPel	4.5	70.2
18	21	GnPsaPel	4.5	69.4
21	24	GnPsaPel	4.5	67.6
24	27	GnPsaPel	4.5	67.3
27	30	GnPsaPel	5	71.5
30	33	GnPsaPel	5	67.5
33	36	GnPsaPel	5	68.1
36	39	GnPsaPel	5	71.1
39	42	GnPsaPel	5	73.5
42	43.15	GnPsaPel	5	74.2
43.15	45	GranT	4.5	75.5
45	48	GranT	4.5	71.6
48	51	GranT	4.5	72.2
51	54	GnPsaPel	4.5	71.0
54	57	GnPsaPel	4.5	70.2
57	60	GnPsaPel	4.5	70.2
60	63	GnPsaPel	4.5	70.6
63	66	GnPsaPel	4.5	70.5
66	69	GnPsaPel	4.5	69.0
69	72	GnPsaPel	4.5	70.2
72	75	GnPsaPel	4.5	69.3
75	78	GnPsaPel	4.5	68.0
78	81	Myl	4.5	66.5
81	84	Myl	4.5	63.4
84	87	Myl	4.5	69.6
87	90	Myl	4.5	69.5
90	93	Myl	4.5	70.7
93	96	Myl	4.5	71.1
96	99	GnPsaPel	4.5	68.8
99	101.95	GnPsaPel	4.5	70.6
101.95	102.65	GnPsaPel	4.5	70.3
102.65	105	GnPsaPel	4.5	69.4
105	108	GnPsaPel	4.5	73.3
108	111	GnPsaPel	4.5	70.6
111	114	GnPsaPel	4.5	70.3
114	117	GnPsaPel	4.5	72.0
117	120	GnPsaPel	4.5	69.4
120	123	GnPsaPel	4.5	74.2
123	126	GnPsaPel	4.5	72.0
126	129	GnPsaPel	4.5	72.0
129	132	GnPsaPel	4.5	72.6
132	135	GnPsaPel	4.5	69.7
135	138	GnPsaPel	4.5	73.3
138	141	GnPsaPel	4.5	70.6
141	144	GnPsaPel	4.5	67.2
144	147	GnPsaPel	4.5	73.7
147	150	GnPsaPel	3	65.4
150	153	GnPsaPel	5	80.0
153	156	GnPsaPel	4	65.2
156	159	GnPsaPel	4.5	71.3
159	162	GnPsaPel	4.5	72.9
162	165	GnPsaPel	4.5	68.9
165	168	GnPsaPel	4.5	69.0
168	171	GnPsaPel	4.5	71.9
171	173.11	GnPsaPel	4.5	68.1
173.11	174	GnPsaPel	5	68.9
174	177	GnPsaPel	5	67.1
177	180	GnPsaPel	5	78.2
180	183	GnPsaPel	5	76.3
183	186	GnPsaPel	5	69.1
186	189	GnPsaPel	5	68.4
189	192	GnPsaPel	5	80.1
192	195	GnPsaPel	5	75.7
195	198	GnPsaPel	5	73.4
198	201	GnPsaPel	5	76.8
201	204	GnPsaPel	5	83.8
204	207	GnPsaPel	5	72.4
207	210	GnPsaPel	5	77.7
210	213	GnPsaPel	5	72.6
213	216	GnPsaPel	5	71.2
216	219	GnPsaPel	5	73.5
219	222	GnPsaPel	5	69.8
222	225	GnPsaPel	5	68.3
225	228	GnPsaPel	5	80.4
228	231	GranT	5	76.5
231	234	GranT	5	78.3
234	237	GranT	5	80.4
237	240	GranT	3	64.5
240	243	GranT	5	77.7
243	246	GranT	5	69.1
246	249	GranT	5	80.4
249	252	GranT	5	76.3
252	255	GranT	5	78.3
255	258	GranT	5	64.6
258	261	GranT	5	83.8
261	264	GranT	5	73.1
264	267	GranT	5	76.3
267	270	GranT	5	75.2

(left) STRENGTH

- R0: Extremely Weak Rock
- R1: Very Weak Rock
- R2: Weak Rock
- R3: Medium Strong Rock
- R4: Strong Rock
- R5: Very Strong Rock

RMR (right)

- 0 to 20
- 20 to 40
- 40 to 60
- 60 to 80
- 80 to 100

Geology provided by Areva. See Appendix A for lithology code descriptions.

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Proj. No.: 08-1362-0613	KIGGAVIK MAIN ZONE 2009 HOLES ROCK MASS RATING (RMR) AND STRENGTH (R)	
Date: November 2009		
Drawn: BC	Kiggavik	Figure B1
Check: MR		

CZ-09-01

From	To	Geology	R	RMR
18	21	GnPsaPel	1	34.9
21	22.86	GnPsaPel	1	30.6
22.86	24	GnPsaPel	0	23.9
24	25.76	GnPsaPel	0	47.1
25.76	27	GnPsaPel	4	56.5
27	28.81	GnPsaPel	2	31.1
28.81	30	GnPsaPel	2	50.0
30	31.72	GnPsaPel	2	45.4
31.72	32.58	GnPsaPel	0	23.8
32.58	33	GnPsaPel	2	51.5
33	34.67	GnPsaPel	0	26.0
34.67	36	GnPsaPel	1.5	54.5
36	37.15	GnPsaPel	0	27.6
37.15	39	GnPsaPel	2	46.3
39	40.65	GnPsaPel	0.5	35.0
40.65	42	GnPsaPel	0	26.6
42	45	GnPsaPel	2.5	52.7
45	48	GnPsaPel	2.5	51.3
48	50.7	GnPsaPel	2.5	64.9
50.7	51	GnPsaPel	0	32.3
51	54	GnPsaPel	2.5	56.6
54	57	GnPsaPel	2.5	55.7
57	60	GnPsaPel	3	52.3
60	63	GnPsaPel	3	53.2
63	64.17	GnPsaPel	3	46.5
64.17	64.95	GnPsaPel	3	27.9
64.95	66	GnPsaPel	3	54.8
66	69	GnPsaPel	3	55.7
69	72	GnPsaPel	3	59.5
72	75	GnPsaPel	4	62.6
75	78	GnPsaPel	4	68.8
78	81	GnPsaPel	4	64.8
81	84	GnPsaPel	4	64.2
84	87	GnPsaPel	4	63.2
87	90	GnPsaPel	2.5	61.5
90	93	GnPsaPel	3.5	76.0
93	96	GnPsaPel	3.5	74.2
96	99	GnPsaPel	3.5	73.9
99	102	GnPsaPel	3	66.9
102	105	GnPsaPel	3	54.3
105	108	GnPsaPel	3	64.6
108	111	GnPsaPel	3	65.1
111	114	GnPsaPel	3	67.1
114	117	GnPsaPel	3	68.9
117	120	GnPsaPel	3	67.8
120	123	GnPsaPel	3	65.1
123	126	GnPsaPel	3	70.6
126	129	GnPsaPel	3	67.7
129	132	GnPsaPel	3	64.8
132	135	GnPsaPel	3	61.7
135	138	GnPsaPel	3	62.1
138	141	GnPsaPel	4	76.5
141	144	GnPsaPel	4	68.8
144	147	GnPsaPel	4	67.2
147	150	GnPsaPel	4	63.5
150	153	GnPsaPel	4	67.5
153	156	GnPsaPel	4	63.6
156	159	GnPsaPel	4	63.9
159	162	GnPsaPel	4	70.4
162	165	GnPsaPel	4	69.8
165	168.48	GnPsaPel	4	64.4
168.48	170.25	GnPsaPel	4	67.9
170.25	171	GnPsaPel	4	63.0
171	173	GnPsaPel	4	70.0
173	174.06	GnPsaPel	4	77.2
174.06	177	GnPsaPel	4	65.9
177	180	GnPsaPel	4	80.9
180	183	GnPsaPel	4	66.1
183	184.16	GnPsaPel	3.5	69.3
184.16	186	GranT	4	81.5
186	189	GranT	4	77.8
189	189.76	GranT	4	80.1
189.76	192	GnPsaPel	3.5	65.0
192	195	GnPsaPel	3.5	65.4
195	198	GnPsaPel	3.5	60.6
198	201	GnPsaPel	4	71.7
201	204	GnPsaPel	4	73.1
204	207	GnPsaPel	4	78.6
207	210	GnPsaPel	4	63.6
210	213	GnPsaPel	4	69.1
213	216	GnPsaPel	4	75.5
216	219	GnPsaPel	4	66.6
219	222	GnPsaPel	4	72.0
222	222.97	GnPsaPel	4	70.1
222.97	225	GranT	5	67.7
225	228	GranT	5	72.0
228	231	GranT	5	71.1
231	232.51	GranT	5	70.4
232.51	234	GranT	4	80.4
234	234.23	GranT	4	67.3
234.23	236.19	GranT	5	68.3
236.19	237	GranT	4	67.6
237	238.04	GranT	4	77.4
238.04	240	GranT	5	69.4
240	243	GranT	5	76.3
243	246	GranT	5	75.2
246	249	GranT	5	72.3
249	252	GranT	5	72.3
252	255	GranT	5	60.6
255	258	GranT	5	84.9
258	259.85	GranT	5	74.3
259.85	261	GnPsaPel	5	81.5
261	264	GnPsaPel	5	68.2
264	267	GnPsaPel	4	68.4
267	270.11	GnPsaPel	4	73.4

(left) STRENGTH

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RMR (right)

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Geology provided by Areva. See Appendix A for lithology code descriptions.

Golder Associates

Proj. No.: 08-1362-0613	KIGGAVIK CENTRE ZONE 2009 HOLES ROCK MASS RATING (RMR) AND STRENGTH (R)
Date: November 2009	
Drawn: BC	Kiggavik
Check: MR	Figure B2

3.0 ROCK MASS CLASSIFICATION RESULTS

The 2007/2008 and 2009 geotechnical borehole RMR and rock strength index (R) values were plotted in the 3D Surpac geology model for the Kiggavik Main and Centre Zone pits. These models include the lithology, mineralization and faulting structure data provided by AREVA. On these sections, the boreholes show the R values (left bar), the lithology (middle bar), and the RMR values (right bar). Several sections were plotted across the pit boundary and some general interpretation was carried out to delineate geotechnical domains.

3.1 Main Zone

Figure B3 presents a geological section for the Kiggavik Main Zone pit outlining the inferred zones of fault and mineral alteration, as well as the main lithological domains.

The lower quality and strength domains at Main Zone appear to be associated with inferred faulting and mineralization zones. However, the Main Zone boreholes show appreciably higher rock mass quality and strength. The geology appears to be considerably less complicated, with reduced mineral alteration and fewer faults transecting the ore zones and pit walls.

There is a general lack of borehole data within the planned pit walls, as the majority of the boreholes are located towards the centre of the pit. It is inferred that rock mass quality and strength would tend to increase away from the main zones of mineralization, however additional drilling would be required to confirm these assumptions and refine the geotechnical models.

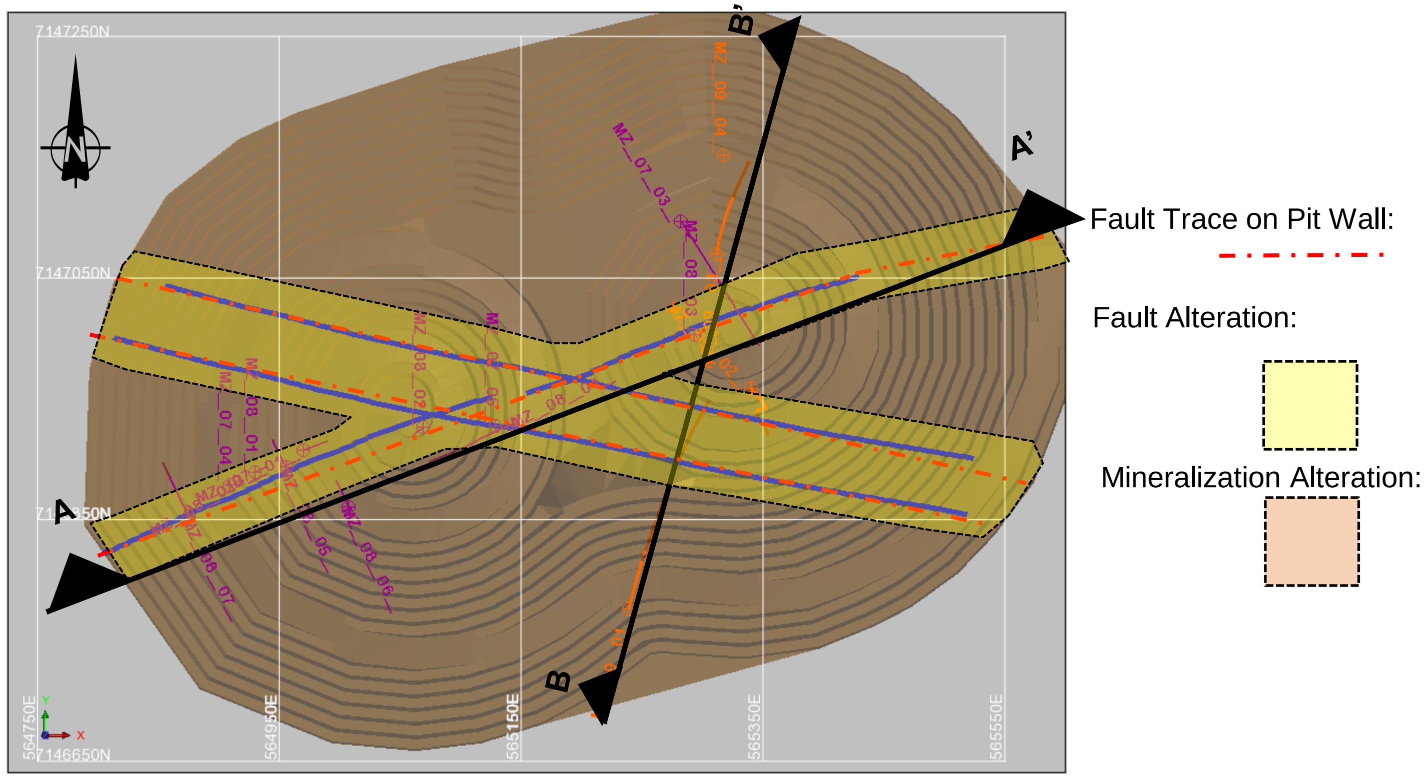
Figure B4 shows a south-southwest-north-northeast section along the Kiggavik Main Zone pit. The section shows metasediments underlain by granites. The mineralization in the metasediments shows higher alteration compared to the mineralization zones in the granites. The main zones of mineralization appear to follow in general proximity to the metasediment/granite contact. Previous interpretation of the granite contact shows the majority of the southwest pit wall to be comprised of granites, and the majority of the northeast pit wall is to be comprised of metasediments. The 2009 boreholes indicate that more granites might be expected in the north-east pit walls as previously anticipated, as will be discussed below.

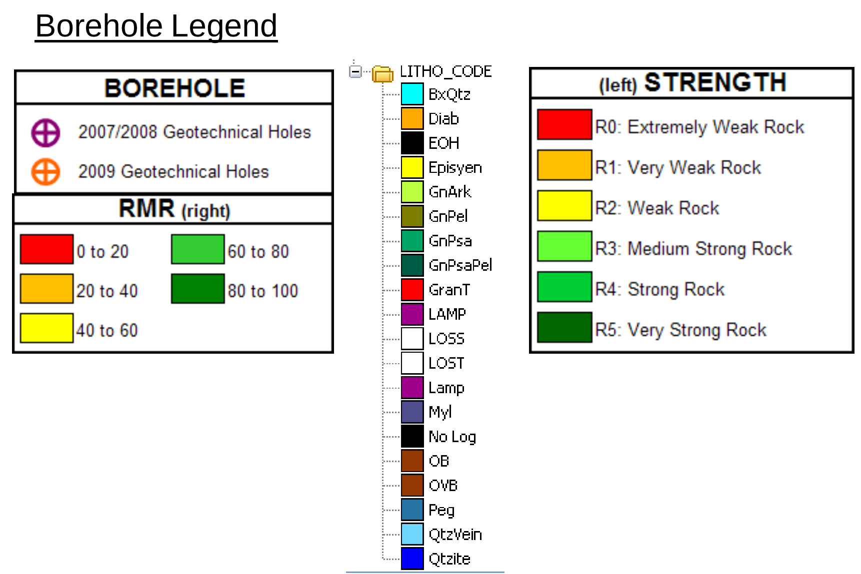
Borehole MZ09-02 is plotted on Figure B4 (slightly cut-off). This borehole appears to be trending sup-parallel and in close proximity to a west-northwest-east-southeast trending fault, although the overall rock mass quality in the borehole does not appear to be effected appreciably by this fault. The upper 50 m of the borehole in metasediments appears to be poor to fair quality, very weak to moderately strong. This zone is possibly associated with weathering or alteration/faulting near surface. From 50 m to 185 m in the metasediments, the rock is generally good quality and strong. Below 185 m, into the granites, the quality and strength improve slightly.

KIGGAVIK MAIN ZONE
GEOLOGICAL SECTIONS WITH INFERRED ALTERATION ZONES AND LITHOLOGICAL DOMAINS

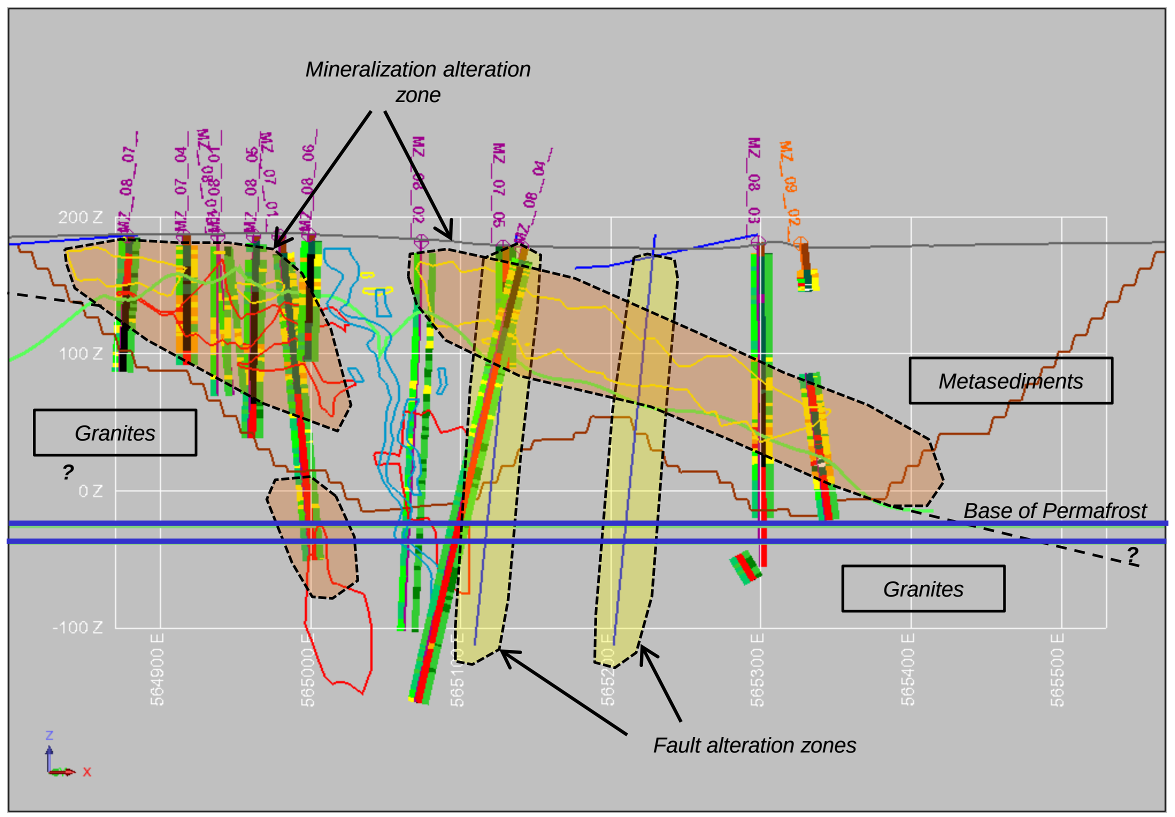
FIGURE B3

a) Kiggavik Main - pit plan view showing faulting and inferred fault alteration zone on pit walls.

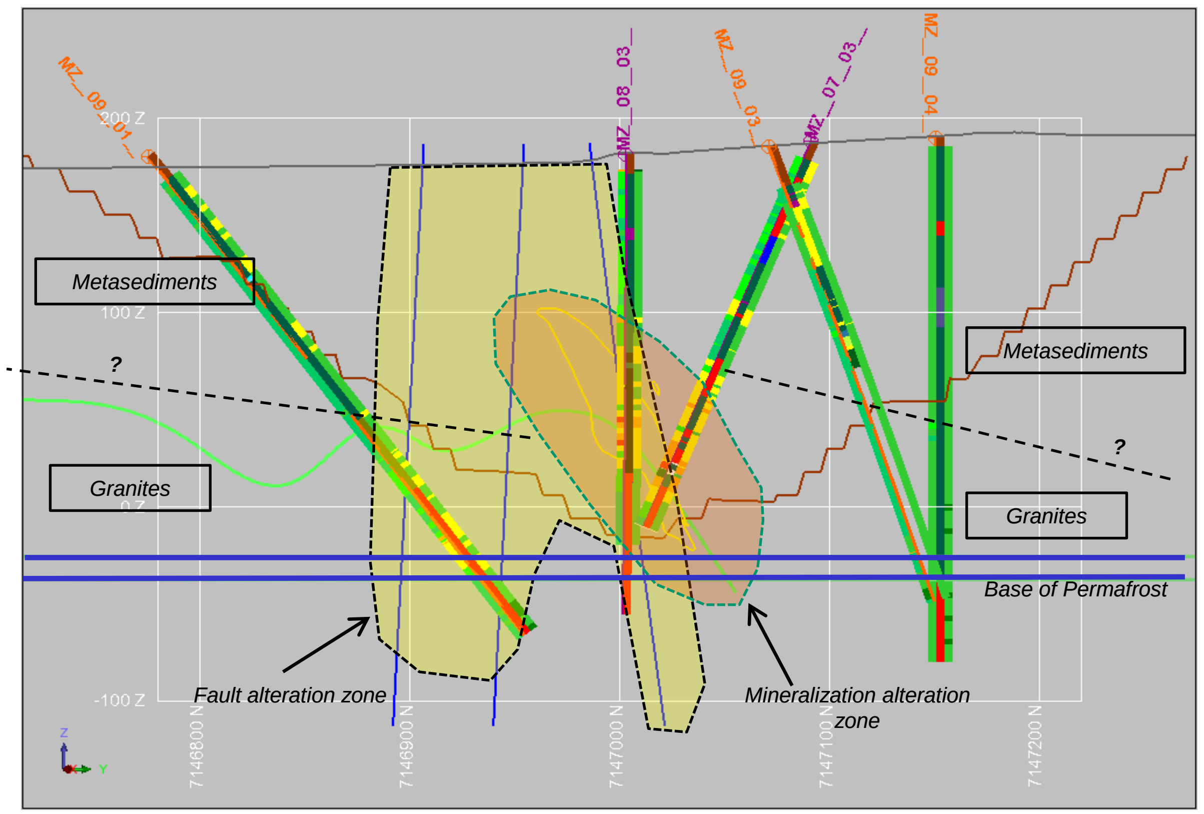




b) Section A – borehole projections of strength (R) and RMR with inferred alteration zones and lithological domains. The majority of alteration seen on this section is inferred to be related with the mineralization alteration.



c) Section B – borehole projections of strength (R) and RMR with inferred alteration zones and lithological domains. Fault influenced alteration iis inferred in the lower portion of the south wall. Mineralization alteration is inferred at the toe of the north wall.



Date: November 2009

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Drawn: BC

Chkd:: MR

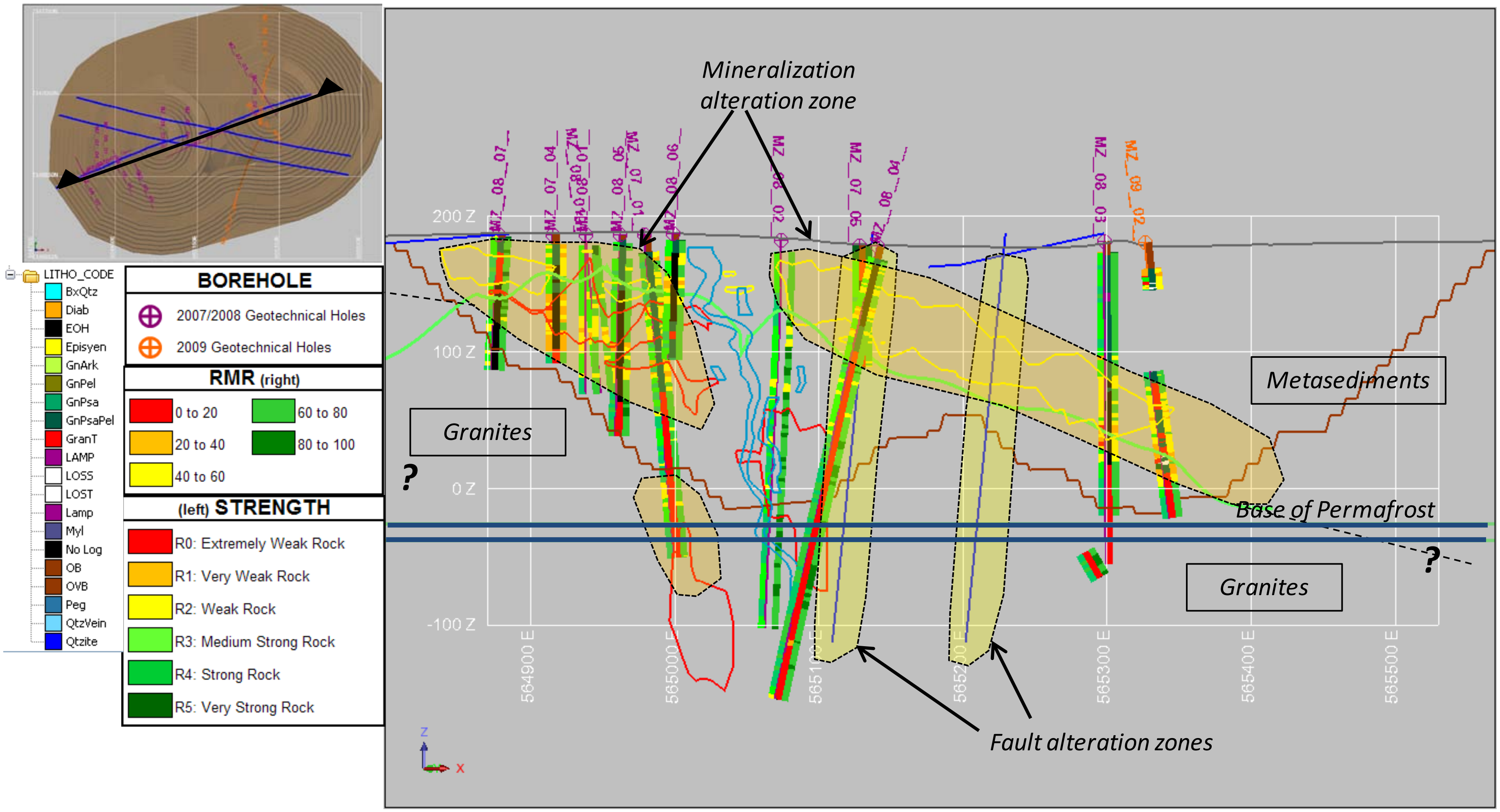


Figure B4: Kiggavik Main Zone Pit – Generalized Geotechnical Section (SSW-NNE). Inferred Fault and Mineralization Alteration Zones are Highlighted on the Figure.

Figure B5 (after Figure B3) shows a N-S section of the Kiggavik Main Zone pit. Boreholes MZ09-01, -03, and -04 are plotted on this section. Borehole MZ09-01 shows strong, fair to good quality metasediments in the upper 216 m of the borehole. Below 216 m into the granites, a weak to moderately strong, fair quality zone is encountered from 234 m to 270 m. This reduced quality and strength is inferred to be associated with two west-northwest-east-northeast trending faults as plotted on Figure B3. Outside of the inferred fault zone, the granites are shown to be strong and good quality.

Borehole MZ09-03 shows mainly strong to very strong, good quality rock throughout, with a slight increase in strength into the granites (at 213 m). Borehole MZ09-04 shows the best quality of all Kiggavik 2009 boreholes, with good to very good quality, and strong to very strong rock throughout. Both MZ09-03 and MZ09-04 trend away from the fault and mineralization zones.

It was noted that the previous geological interpretation of the granite contact (Figure B5) shows there to be minimal granites expressed in the north and east walls. However, granites were encountered at shallower depths in both MZ09-03 and MZ09-04 suggesting that the lower portions of these walls could also be comprised of granites.

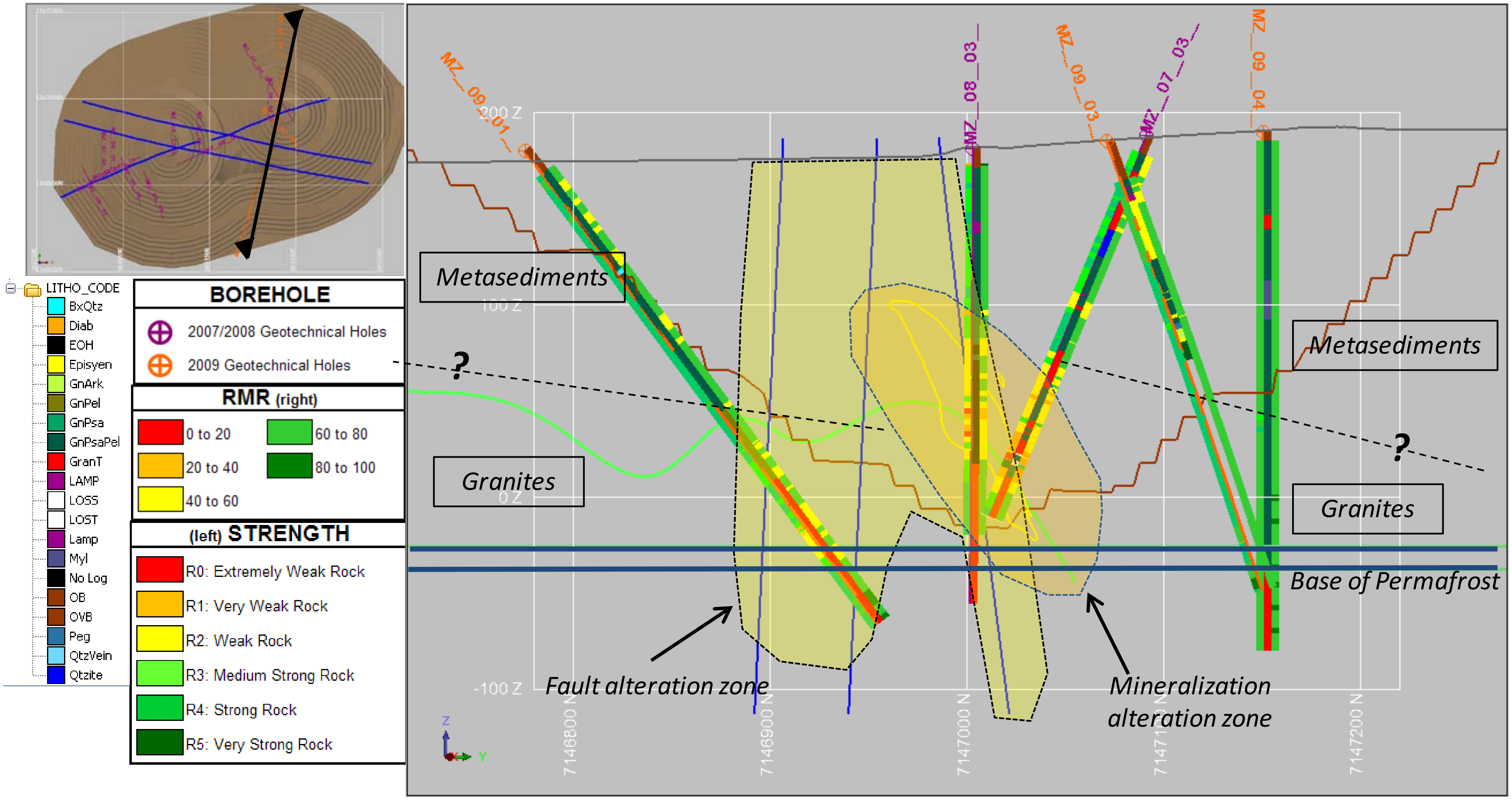


Figure B5: Kiggavik Main Zone Pit - Generalized Geotechnical Section (S-N). Inferred Fault and Mineralization Alteration Zones are Highlighted on the Figure

3.2 Centre Zone

Figure B6 presents geological sections with inferred zones of ortho-mineralization alteration plotted on sections and the planned pit shell.

A southwest-northeast section taken through the Kiggavik Centre pit is shown on Figure B7 (after Figure B6). This section trends parallel to the zone of mineralization. Based on the available information, no major faults have been interpreted in the Centre Zone pit. The majority of lower quality rock conditions are interpreted to be related to mineralization alteration.

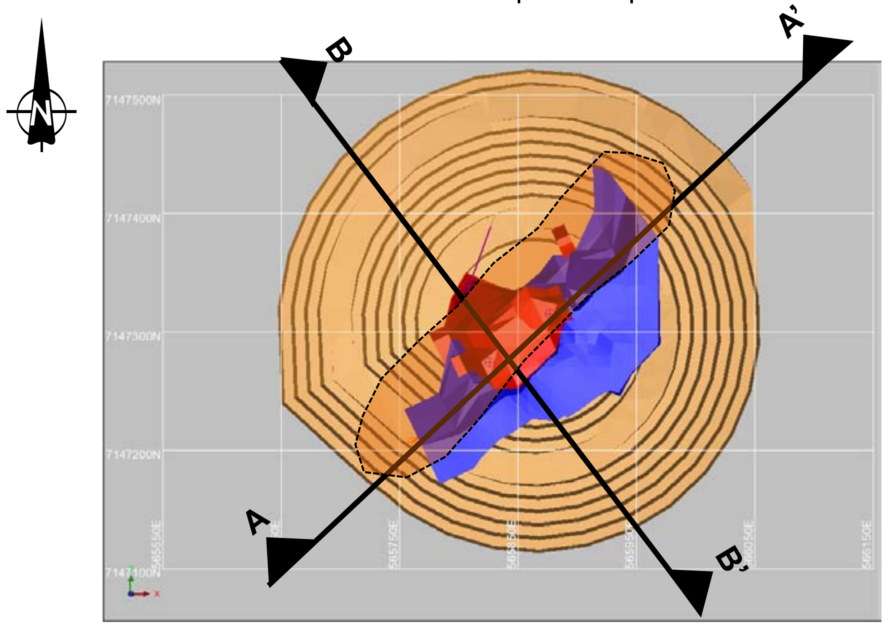
Borehole CZ09-01 is plotted on Figure B7. The first 72 m of CZ09-01, in metasediments, shows poor to fair quality, extremely weak to weak rock. This zone is inferred to be related to the mineralization alteration, also possibly related to weathering and water infiltration near surface. Below 72 m the rock mass quality becomes good to very good, and strong to very strong. The rock is predominantly metasediments; however a zone of granite was encountered between 223 m and 260 m.

A northwest-southeast section is plotted on Figure B8 which depicts a section through the pit hanging wall to footwall. No 2009 boreholes are plotted on this section. Similar to Figure B7, the inferred mineralization alteration zone appears to extend across the pit. Some lower quality rock conditions might be expected along the toe of the hanging wall, and possibly into the upper limits of the footwall. Additional drilling is required to confirm this.

KIGGAVIK CENTRE ZONE
GEOLOGICAL SECTIONS WITH INFERRED ALTERATION ZONES AND LITHOLOGICAL DOMAINS

FIGURE B6

a) Kiggavik Centre - pit plan view showing faulting and inferred mineralization alteration on the planned pit walls.

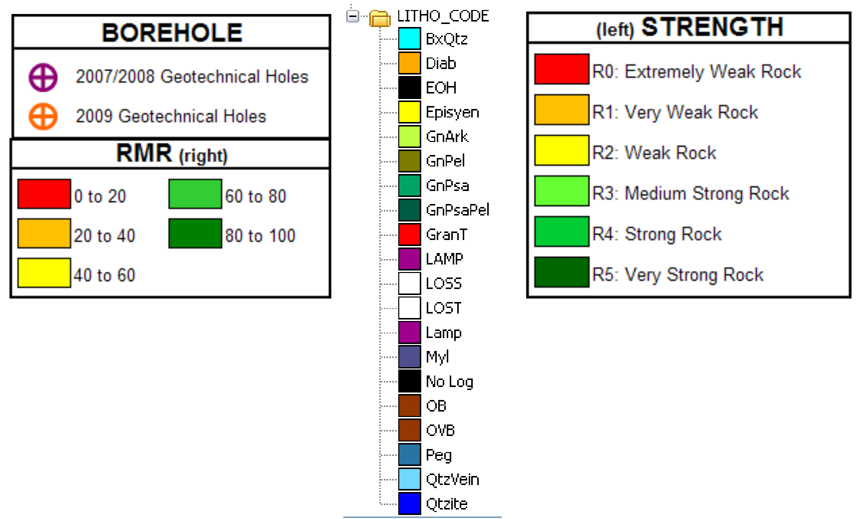


Fault Trace on Pit Wall:

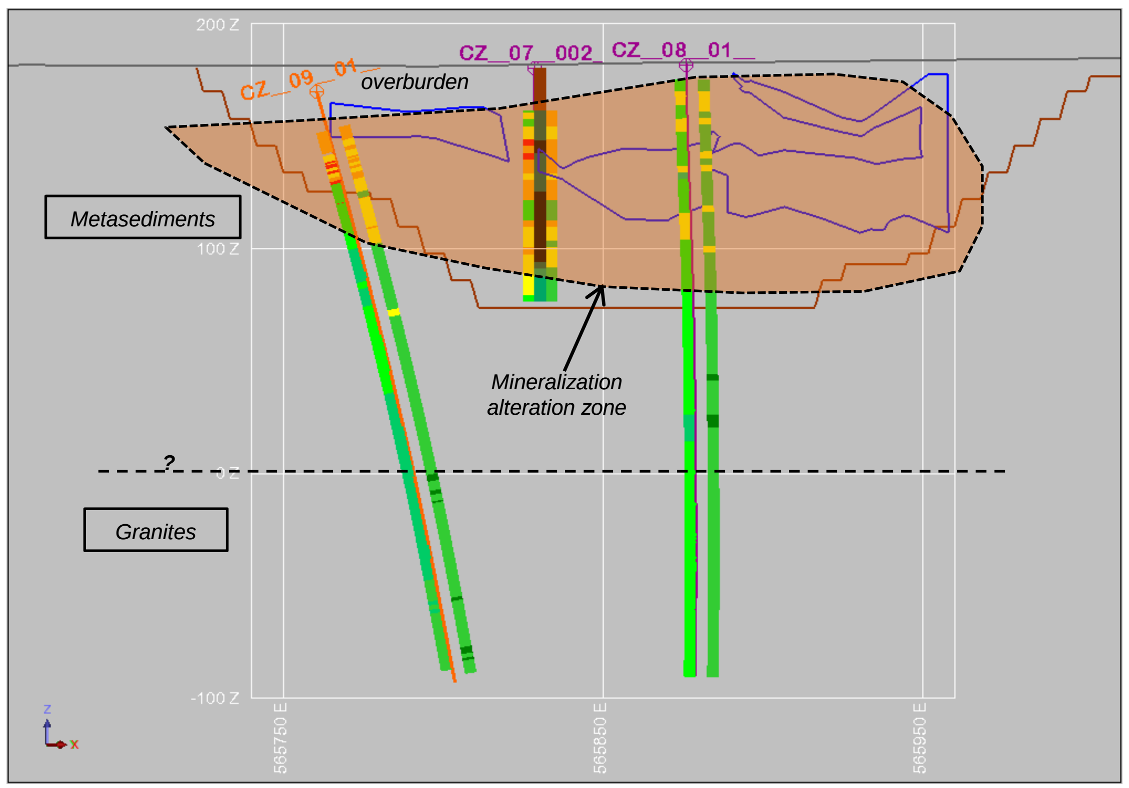
Fault Alteration:

Mineralization Alteration:

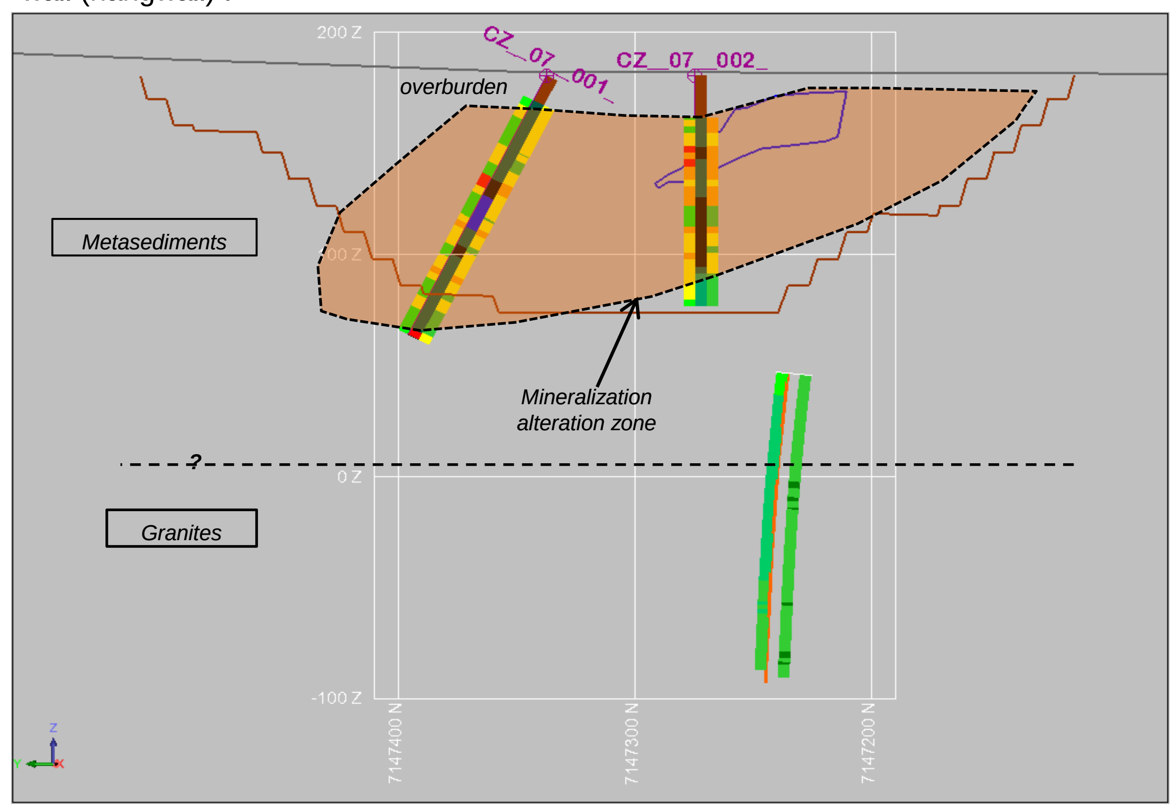
Borehole Legend



b) Section A – borehole projections of strength (R) and RMR with inferred alteration zones and lithological domains. Some mineralization alteration is inferred to occur on the end walls.



c) Section B – borehole projections of strength (R) and RMR with inferred alteration zones and lithological domains. Fault influenced alteration is inferred in the lower portion of the south wall. Some mineralization alteration is inferred to occur along the toe of the slope in the northwest wall (hangwall) .



Date: November 2009

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Drawn: BC

Chkd:: MR

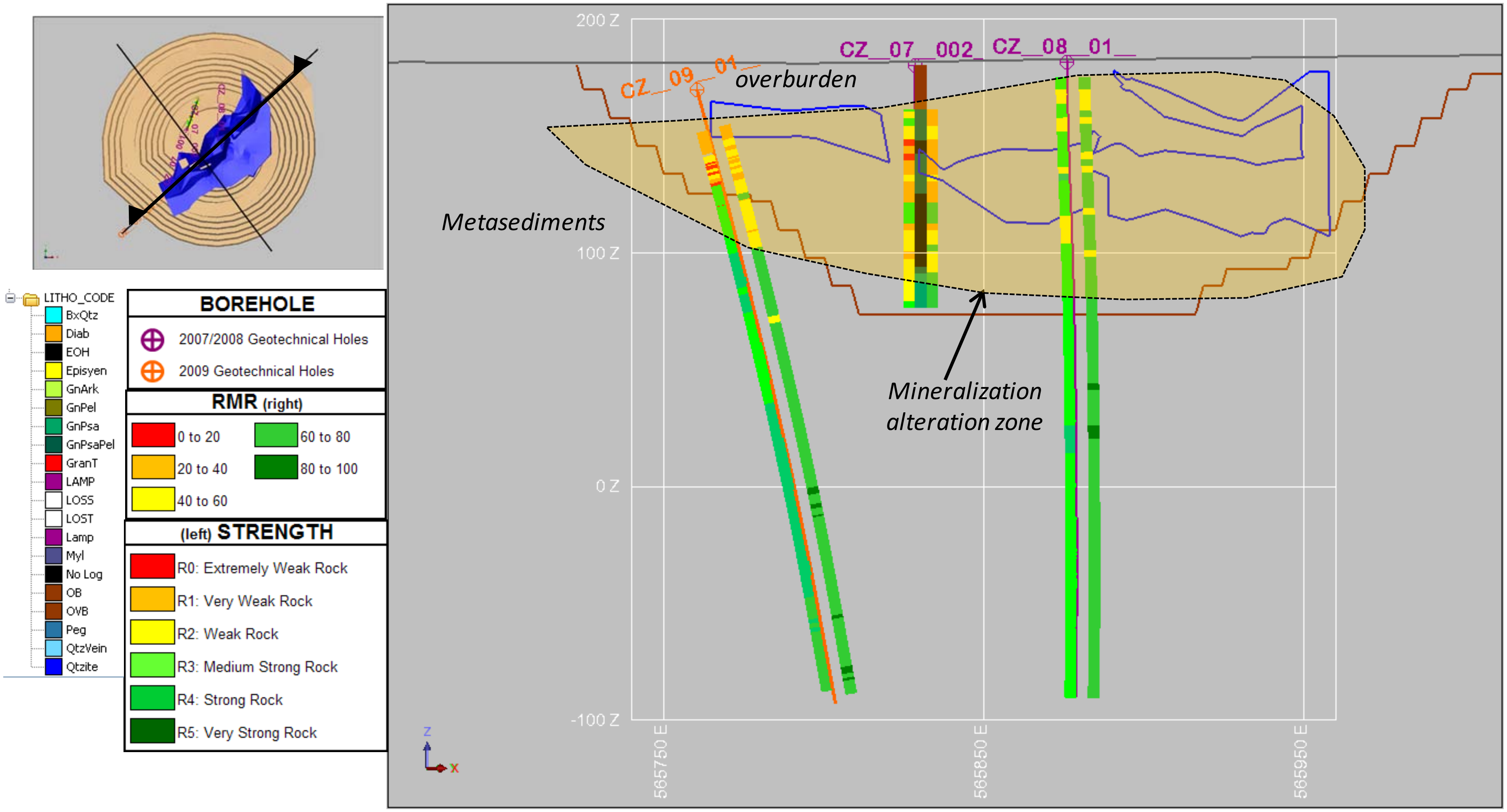

Figure B7: Kiggavik Centre Pit - Generalized Geotechnical Section (SW-NE). Inferred Fault and Mineralization Alteration Zones are Highlighted on the Figure.

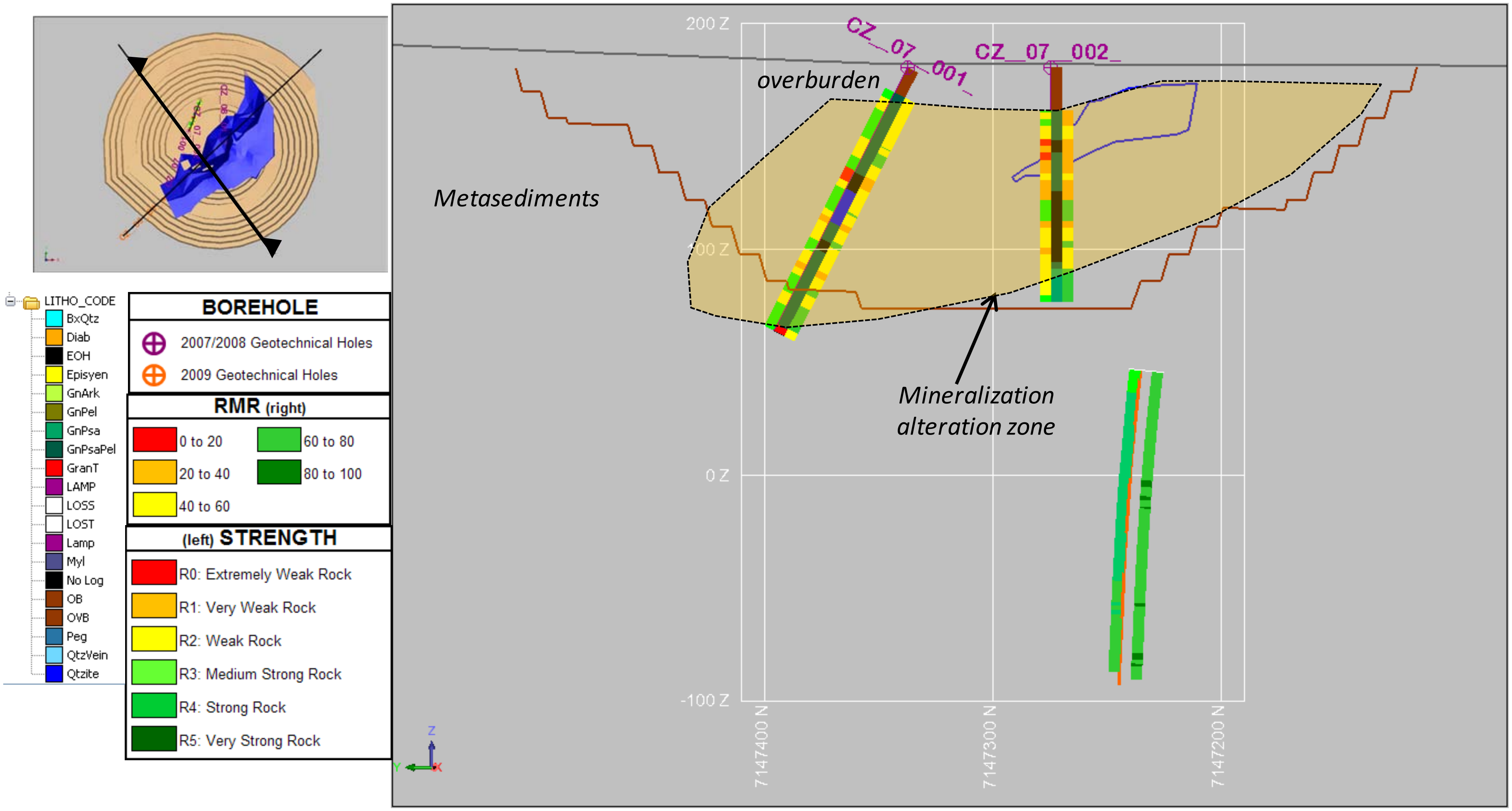

Figure B8: Kiggavik Centre Pit - Generalized Geotechnical Section (NW-SE). Inferred Fault and Mineralization Alteration Zones are Highlighted on the Figure.

3.3 Main and Centre Rock Mass Quality Distribution

Cumulative frequency distributions of RMR for the 2009 Kiggavik Main and Centre zone data are plotted on Figures B9 and B10. The upper bound, lower bound and average RMR values are given on the corresponding tables.

Figure B9 plots the RMR distributions by borehole, with the data summarized in Table B2. In general there is a fairly narrow range in RMR distributions between all boreholes. Lower bound RMR values range between 55 and 65, and upper bound values range between 67 and 74. The average RMR values range between 62 and 69 suggesting an overall good quality rock mass for both the Main Zone and Centre Zone pits.

Figure B10 plots the RMR distributions by rock type, with the data summarized in Table B3. The rock types have been divided into metasediments (less/greater than 75 m depth), and granites. The upper metasediments show notably lower qualities than the granites and deeper metasediments. This lower quality is potentially related to inferred mineralization of fault alteration (i.e., MZ09-02, CZ09-01), as well as some potential reduction in quality due to physical weathering. It is possible that the final pit walls, away from the faults and mineralization zones, do not show significant contrast in quality with depth.

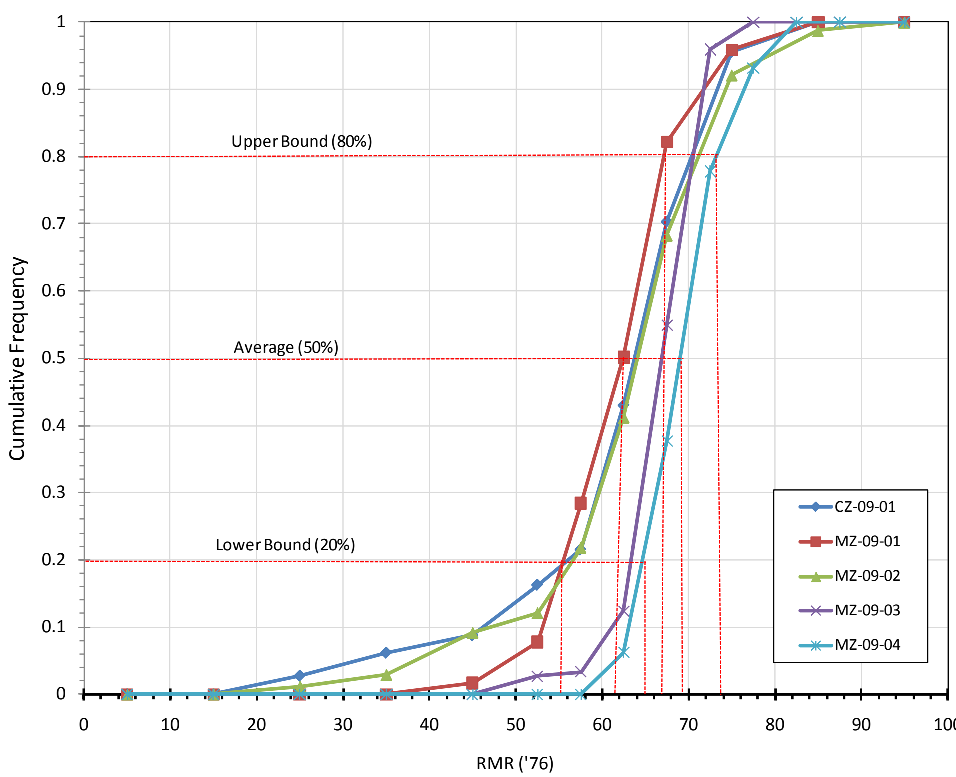

Figure B9: Kiggavik Main and Centre Zones – 2009 Boreholes. Cumulative Frequency Distribution of RMR by Borehole.

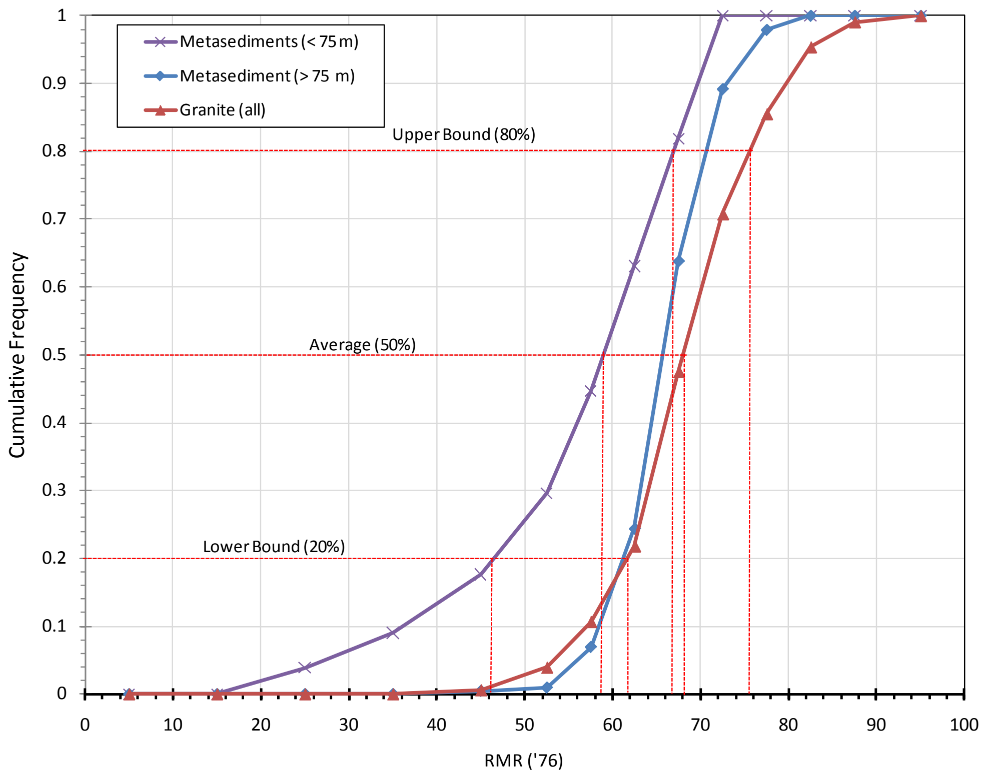

Figure B10: Kiggavik Main and Centre Zones – 2009 Boreholes. Cumulative Frequency Distribution of RMR by Rock Type.

Table B2: Kiggavik Main and Centre Zones – 2009 Boreholes. Summary of RMR values by borehole

Hole	RMR (1976)		
	Lower Bound	Upper Bound	Average
MZ09-01	55	67	62
MZ09-02	56	71	63
MZ09-03	63	70	66
MZ09-04	65	74	69
CZ09-01	56	70	63

Table B3: Kiggavik Main and Centre Zones – 2009 Boreholes. Summary of RMR values by rock type

Hole	Depth	RMR (1976)		
		Lower Bound	Upper Bound	Average
Metasediment (GnArk,GnPel,GnPsaPel)	< 75 m	46	66	59
	> 75 m	62	71	66
Granites (GranT)	all	62	76	68

GnArk, GnPel, GnPsaPel = Arkosic Gneiss, Pelitic Gneiss, Psammo-pelitic Gneiss; GranT = Granite

4.0 CONCLUSIONS AND RECOMMENDATIONS

The proceeding sections have presented the methodology and results of the rock mass classification work carried out for the 2009 geotechnical data for the Kiggavik Main Zone and Centre Zone Pits. Generalized interpretations were made based on the available information. Appreciably more geotechnical information should be collected to make better interpretations on rock mass quality and strength, predominantly for the final planned pit walls, where currently data is lacking.

The Kiggavik Main Zone and Centre Zone rock masses have been classified together. These rock units appear to be comprised of metasediments, underlain by granites. Some fault related alteration has been inferred at the Main Zone pit as shown on Figure B3. Mineralization related alteration is inferred both in the Main Zone and Centre Zone pits. Recommendations for RMR and strength parameters for the main rock units are given in Table B4. Assumptions for the various ratings are also given in the table.

Table B4: Kiggavik – Recommendations for RMR and strength parameters

Rock Unit	RMR (1976)	Comment	Strength	Comment
Upper Metasediments (<75 m depth)	**46 to 66** (fair to good)	Range of RMR from lower to upper bound limits for the 2009 Upper Metasediment data.	**R4/R5** (strong to very strong)	Average UCS = 93.4 MPa and average Is(50) = 7.9 MPa for slightly altered (Appendix A
Lower Metasediments (>75 m depth)	**62 to 71** (good)	Range of RMR from lower to upper bound limits for the 2009 Lower Metasediment data.	**R4/R5** (strong to very strong)	Average UCS = 93.4 MPa and average Is(50) = 8.4 MPa for fresh rock (Appendix A)
Granites (all)	**62 to 76** (good)	Range of RMR from lower to upper bound limits for the 2009 Granite data.	**R4/R5** (strong to very strong)	Average UCS = 112.3 MPa and average Is(50) = 10.1 MPa for fresh rock (Appendix A)
Fault or Mineralization Altered Zones	**46 to 62** (fair to good)	Lower Bound RMR for all 2009 lithology data.	**R3** (moderately strong)	Average UCS = 21.8 MPa for highly altered metasediments, and average UCS = 55.9 for slightly to moderately altered granites (Appendix A).

5.0 REFERENCES

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APPENDIX C

Stereonet Analysis from Oriented Core Data

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TABLES

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FIGURES

1.0 INTRODUCTION

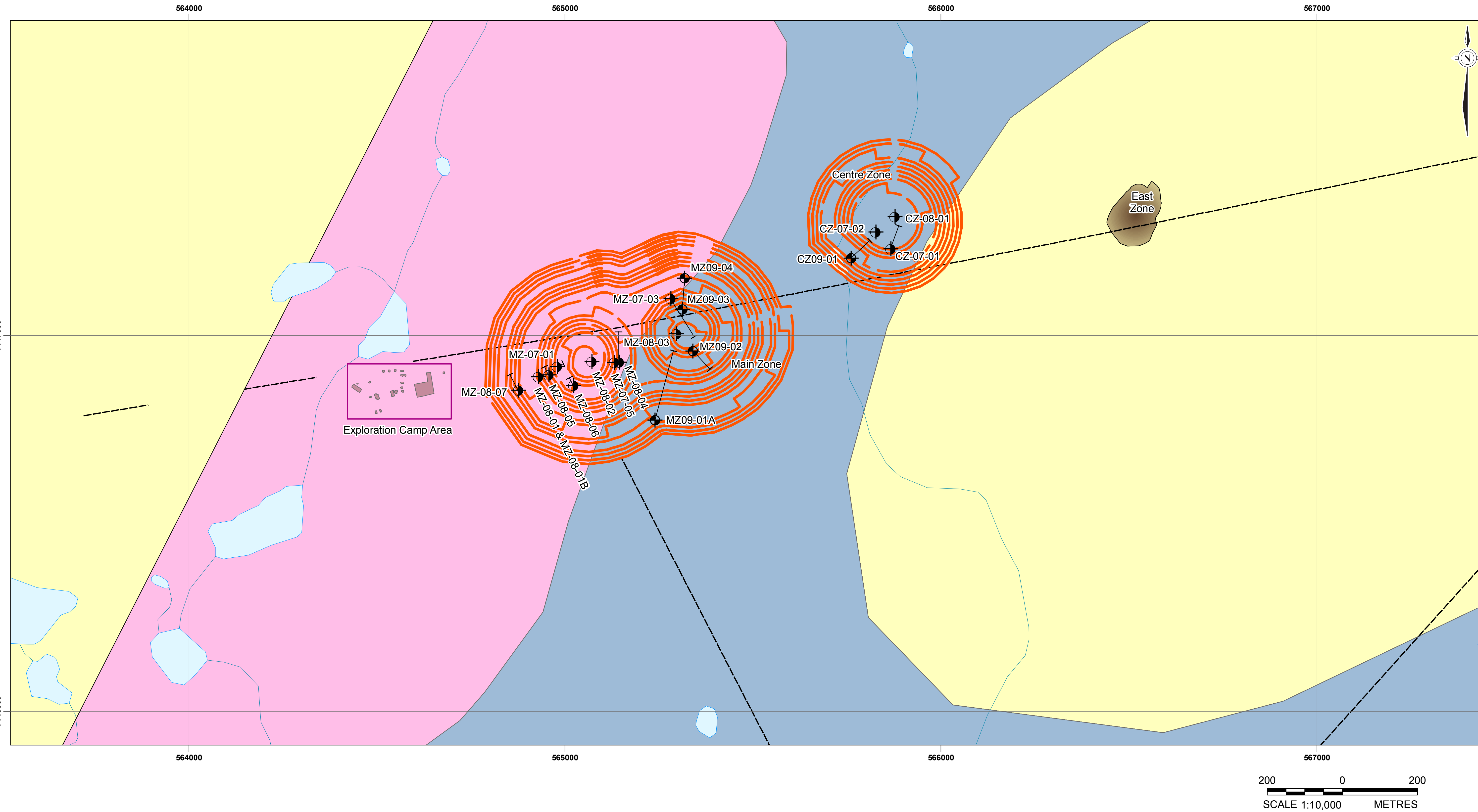
This appendix outlines the methodology used to select the major and minor discontinuity sets within the rock masses at Kiggavik Main and Centre Zones.

Details of the 2009 geotechnical drilling program that was conducted at Main Zone and Centre Zone has been presented in a geotechnical data report prepared by Golder entitled “2009 Kiggavik Geotechnical and Hydrogeological Investigation Data Report”. This data report outlines the drilling program conducted, and presents the data collected during the 2009 season. As reference, a total of 4 holes were oriented during the 2009 investigation at Main and Centre Zones. Oriented boreholes are shown on Figure C1, along with oriented boreholes logged by SRK Consulting (SRK) in 2007 and 2008, and are summarized on Table C1.

Table C1: Summary of Oriented Boreholes from 2007, 2008, and 2009 from Main Zone and Centre Zone

Borehole #	Year Drilled	Northing	Easting	Collar Elevation (masl)*	Azimuth	Dip	Drill Depth (mAH)	Vertical Depth (mbgs)	Bit Size
Main Zone									
MZ09-01A	2009 (G)	7146776	565239	173.73	015	-52	309	243	NQ3
MZ09-02	2009 (G)	7146959	565340	176.03	137	-75	260	251	NQ3
MZ09-03	2009 (G)	7147070	565312	184.48	004	-70	248	233	NQ3
MZ-08-04	2008 (SRK)	7146929	565143	179	244	-76	341	330	HQ/HQ3
MZ-08-05	2008 (SRK)	7146895	564956	187	333	-80	150	148	HQ
MZ-08-06	2008 (SRK)	7146867	565022	188	333	-75	96	93	HQ
MZ08-07	2008 (SRK)	7146854	564875	187.5	333	-67	126	116	HQ/NQ
MZ-07-01	2008 (SRK)	7146907	564969	185.93	065	-85	238	237	NQ3
MZ-07-03	2008 (SRK)	7147097	565282	187.85	148	-60	243	210	NQ3
Centre Zone									
CZ09-01	2009 (G)	7147207	565761	179.33	047	-75	270	261	NQ3
CZ-07-01	2007 (SRK)	7147336	565808	180.36	111	-60	135	117	NQ3

G = Golder (2009), SRK (2007/2008); Coordinates in UTM NAD 83 Zone 14, Collar elevation for 2009 boreholes are an estimate based on point data collected from a LiDAR survey, masl = metres above sea level; mAH = metres along hole; mbgs = metres below ground surface



G:\2009\1362\09-1362-0613 Areva Kiggavik Golder Internal Field Manual\GIS\Maps\Geotechnical\Kiggavik Site\GTI-09-1362-0613-3100-GEO-Drillhole Location Plan - Current and Historical - Main and Centre Zones_Appendix.mxd

Legend

- Borehole
- Historical Borehole
- Hole Trace
- Main and Centre Pit
- Camp Boundary
- Camp Infrastructure
- East Zone Pit
- Fault
- Granite (undivided)
- Orthoquartzite
- Supracrustal rocks (undifferentiated)

Reference:
Faults Courtesy of
AREVA Pre-feasability Study
Geological Structures Courtesy
of Natural Resources Canada 2002
NTS Mapsheets 56D, 66A, 66B
NAD83 UTM Zone 14

PROJECT
AREVA
AREVA RESOURCES CANADA INC.
KIGGAVIK PROJECT

TITLE
DRILLHOLE LOCATION PLAN
MAIN AND CENTRE ZONES

Golder Associates
Saskatoon, Saskatchewan

PROJECT	09-1362-0613		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	MD	21/12/09	FIGURE: C1	
CHECK	EM	21/12/09		
REVIEW	LG	22/12/09		

2.0 CORE ORIENTATION METHODOLOGY

In 2009, core orientation was undertaken by the drilling contractor using an Ace Core Orientation Tool (ACT), made by Reflex Instruments. ACT was a fully electronic system that used accelerometers to reference the low side of the borehole (Reflex, 2009). This information was then used by the drill staff to place a reference mark at the bottom of each drill run which corresponded to the low side of the borehole.

During the core logging process, Golder personnel used the driller's reference mark to scribe an orientation line on the low side of the drill core along the length of the drill run. A good match of reference lines between consecutive drill core runs was considered valid with 'high confidence'. When the orientation lines varied at approximately 40˚ to 60˚ from one another, this data was considered valid with 'moderate confidence'. In some cases, poor core conditions in zones of highly fractured or altered core prevented the line from being extended the length of the drill run and the core orientation line was lost. When there was no match between orientation lines, or no continuity between oriented zones, the data was considered invalid or 'low' confidence.

Using the orientation line, alpha and beta angles were measured for each logged discontinuity. Alpha angles were a measurement of the apparent dip of the feature with respect to the core axis. These measurements were taken at the steepest part of the discontinuity, and ranged from 0˚ (i.e., horizontal to the core axis) to 90° (i.e., perpendicular to the core axis). Beta angles were the measurement of the apparent trend of the discontinuity, with respect to the orientation reference line. Beta angles were measured using linear protractors, where the zero degree mark was held on the reference line, with the measurement being taken in a clockwise direction on the "down dip" end (i.e., bottom of the discontinuity when looking downhole) of the discontinuity surface. Measurements ranged between 0˚ to 360˚. A summary of all orientation measurements taken from the 2009 boreholes are shown in Table C2. The use of this data is discussed further in the following sections.

Core drilled in 2007 and 2008 was oriented using ACT in a similar manner to that used in 2009 (based on SRK 2009).

Table C2: Summary of Oriented Features from 2009 boreholes

2009 Borehole	# of Features Oriented	% of Features Oriented	# of Intervals Oriented	% Intervals Oriented
Main Zone				
MZ09-01A	622	64%	83	76%
MZ09-02	443	63%	65	71%
MZ09-03	518	63%	61	72%
Centre Zone				
CZ09-01	412	57%	67	64%

3.0 ASSESSMENT OF ROCK MASS FABRIC

3.1 Major Geological Structure

The major geological structures at Main Zone and Centre Zone deposits have been summarized below:

3.1.1 Fault Trends

Regional fault trends have been identified at the Kiggavik Main and Centre Zones. The Kiggavik deposits occur between two major regional faults (the Thelon Fault and the Sissons fault) (AREVA 2007). The Main Zone and Centre Zone deposits follow the same 065 degree east-northeast trending shear zone. At Main Zone, the ore body lies in a graben structure (Golder 1989), created by the intersection of this shear zone with a 095 degree east trending fault that dips at 55˚ to the north (AREVA 2007).

A plot of the identified fault structures at Main and Centre Zones from the geological model (AREVA 2009) is shown on Figure C2 below. It was noted that the identified fault traces in the geological model do not necessarily follow the inferred regional fault trends, which were provided by AREVA and based on geophysical data (after Figure 3 – main text). At Kiggavik Main, the north-south striking regional fault appears to coincide with a dyke feature in the geological model. The Centre Zone pit does not show any faulting within the pit boundary in the geological model but a regional fault trend does appear to intersect the upper slope footwall of the pit. The regional fault trends have been approximated on Figure C2.

Further clarification as the locations and orientations of major fault structures should be carried out by AREVA.

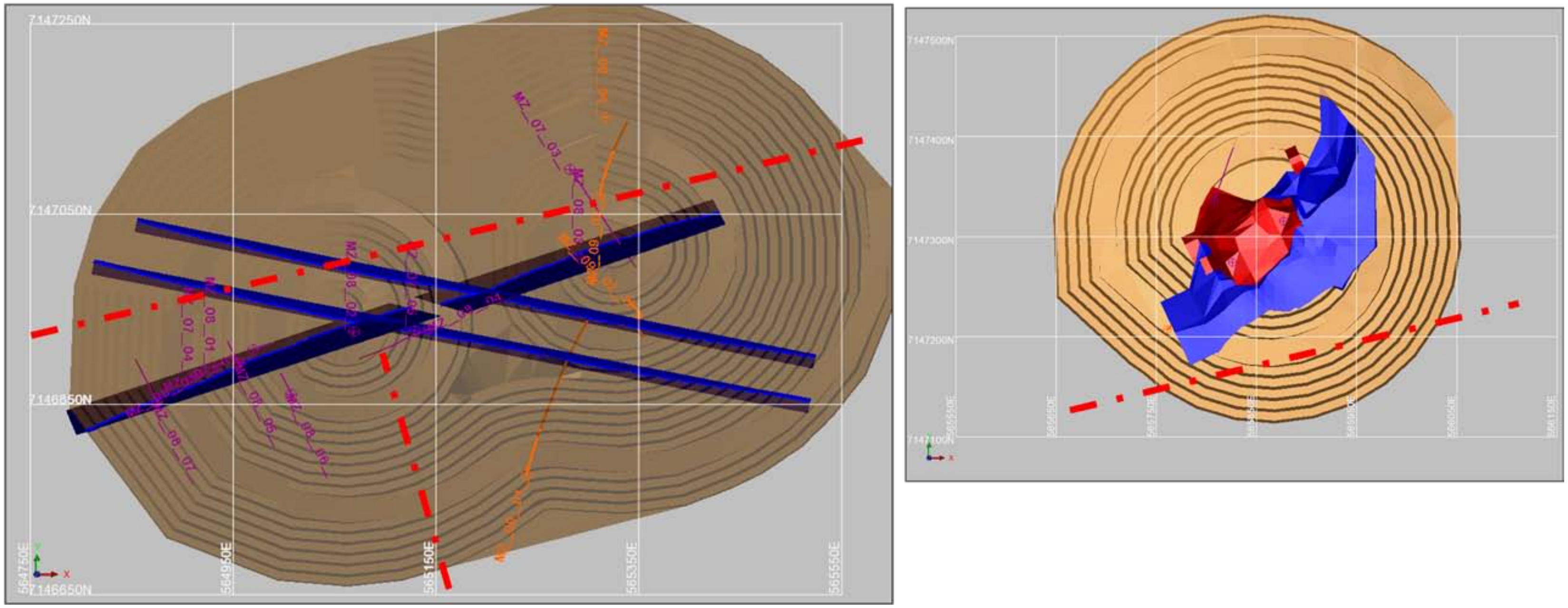


Figure C2: Kiggavik Main Zone and Centre Zone Pits Showing the Inferred Fault Outlines (blue) and Regional Fault Trends (red).

3.1.2 Foliation/Bedding

Two apparent foliation/bedding trends were identified at the Kiggavik Main and Centre Zones (see Figure C3). The main trend is shown to be sub-horizontal, dipping between 0˚ to 30˚ towards the northwest or southeast. Some inferred bedding features were also identified following this trend. This bedding/foliation trend was identified in the metasediments. The granite rock units do show a similar sub-horizontal feature set, although these features were identified as joints as the granites are mainly non-foliated.

A second foliation trend was identified, striking east-west and steeply dipping to the south. This set was identified in both the metasediments and the granite rock units. This foliation set could be related to a secondary deformational event, or veining in the granites.

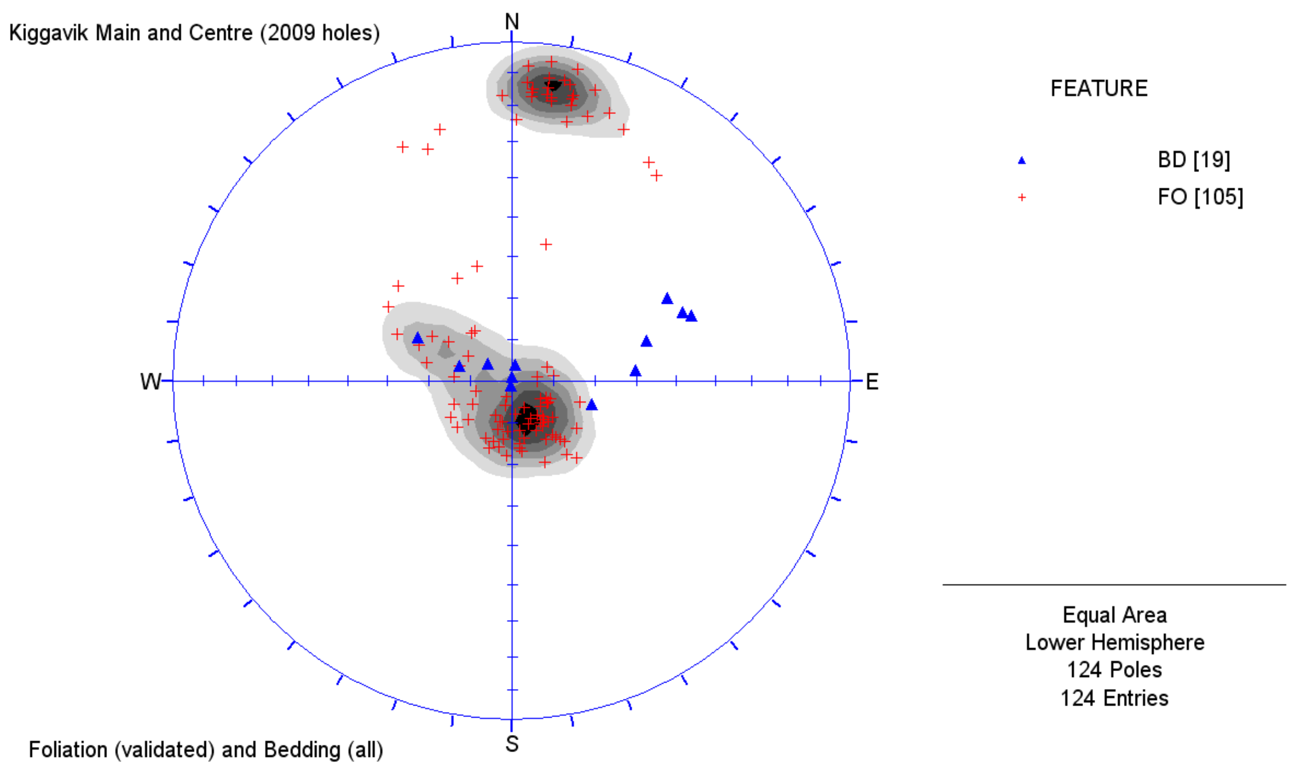


Figure C3: Kiggavik Main and Centre Zones- 2009 Oriented Core Data for Foliation (FO) and Bedding (BD) Features.

3.2 Stereonets from Oriented Core Data

Discontinuity data was analysed statistically using the software DIPS©, distributed by Rocscience. DIPS© allows the user to analyze and visualize structural geological data using the same techniques developed for manual stereonet analysis (Rocscience, 2009a). It also allows the user to contour data, analyze discontinuity statics, and select discontinuity sets.

In order to enter borehole discontinuity data (alpha and beta angles) into DIPS©, the borehole orientation had to be input as traverses. Borehole traverses were selected based on downhole surveys that were conducted by the drilling contractor as the hole was advanced. The downhole surveys were conducted using a Reflex EZ-Shot tool, manufactured by Reflex Instruments. These surveys recorded borehole dip and dip direction at specific depth points along the borehole, with the survey interval generally every 51 m. This survey data was entered into DIPS© as separate traverses, to which the discontinuity data was assigned. This allowed for the incorporation of any borehole deviation into the analysis of the discontinuity data. As the reflex tool provided measurements relative to magnetic north, a correction for magnetic declination was applied in DIPS©. The magnetic declination was calculated based on the Geological Survey of Canada online magnetic declination calculator, and was found to be 1.4° west for the Kiggavik site.

The pole to a plane is a convenient geomechanical construction that can be used to uniquely define the inclination and orientation of the plane of a discontinuity on the stereonet projection. As each pole is located 90° from its plane, a plot of poles represent the dip and dip direction of all measured discontinuities. Thus in turn, statistical contouring allows the pole density for a given discontinuity fabric to be delineated on the stereonet, which provides a 3D representation of structural data. The analysis of the structural data from the Main Zone and Centre Zone deposits were carried out using lower hemisphere equal area stereonet projections, and a Fisher distribution. Discontinuity sets are represented on the stereonets as areas with high pole densities or concentrations as indicated by the contours.

As much of the data was from line sources (boreholes), a bias correction (referred to in DIPS© as the Terzaghi correction) was applied to the oriented core data to help eliminate the problem of data misrepresentation. The bias correction calculates a geometrical weighting factor to each discontinuity measured, with the highest correction applied to the structures that are subparallel to the borehole orientation. Discontinuities that are perpendicular to the core axis receive the smallest weighting factor, since these features are intersected more often in the borehole, and are therefore measured more frequently during the core logging. Since the weighting function tends to infinity as the angle between the discontinuity and the borehole axis (α) approaches zero, a maximum weighting corresponding to a 15° bias angle was applied to any plane with $\alpha \leq 15°$ orientation (Rocscience 2009b).

3.3 Definitions of Pole Concentrations

For the definition of the major and minor discontinuity sets from the stereonets, the following was used:

- When treating the data per hole for Main and Centre Zones – A pole density or concentration of approximately 1% to 3% was selected to represent a minor discontinuity set. A pole density greater than approximately 3% was selected to indicate major or dominant joint sets.
- When combining all the holes for Main and Centre Zones – In these cases the number of poles increased to more than 1000 for each analysis and, consequently, pole densities of 1% to 2% and >2% were used in the statistical treatment to define the minor and major discontinuity sets, respectively.

The discontinuity sets for Main Zone and Centre Zone were selected manually by identifying the peak concentrations and recording the orientation of that point. This was done using a Terzaghi weighted contour plot of all the borehole data in DIPS©, using the “add plane” function.

The discontinuity sets were numbered and labelled with upper and lower case fonts representing, respectively, major and minor discontinuity sets. For example, ‘JN’ or ‘jn’ was used to differentiate major or minor discontinuity sets. Since these major and minor sets show some variations in terms of both dip and dip directions, for the kinematics analyses, these variations have been addressed by considering sub-sets, which were labelled with the letter ‘A’ (or ‘a’) and ‘B’ (or ‘b’).

3.4 Results from Stereonet Analysis

3.4.1 Assessment of Oriented Core Data

Figures C8 to C12 appended to this text show the stereographic projections for Main and Centre Zones. These figures show the oriented core data plotted by the individual borehole, as well as data symbolic pole plots of grouped data showing types of features logged (i.e., bedding, foliation, joints, shears, etc.) as well as the joint alteration index value referring to the degree of alteration of the joint surface (Draft – Golder Factual Report, 2009). Some additional comments and interpretation are included on these figures.

As discussed previously, there was some difficulty maintaining orientation in the drilled core, particularly in zones of highly fractured or mechanically broken rock. Assessment was made in the field as to the high, moderate, and low confidence based on alignment of consecutive orientation reference lines.

For the Kiggavik Main and Centre Zones, comparing all measured data (1,995 features) and the high confidence data only (755 features), there shows to be reasonable agreement between the two data sets (see Figure C4). This suggests that the majority of unvalidated data is likely oriented correctly. All data combined was used in the analyses discussed in the following sections. The approximate borehole directions for CZ09-01 and MZ09-01 to -03 are also shown on Figure C4. It is noted that boreholes trend between an azimuth of 010˚ and 145˚ which can result in some bias in the data. Future boreholes should be drilled in complimentary orientations in order to minimize the potential bias due to borehole orientations.

The SRK 2007-2008 data is also plotted on a separate stereonet on Figure C4. A total of 638 poles from 7 boreholes (CZ-07-01, MZ-07-01,-03, and MZ-08-04 to -07) are plotted. The borehole orientations are also shown for reference. There generally shows to be a higher degree of low angle features (30° to 60°) as compared to the 2009 data, and there also shows considerable scatter in this data. It is interpreted that the relatively steep angle of these boreholes resulted in a reduced number of high angle features, as four out of seven of the boreholes were drilled at an inclination of greater than 75°.

Because there is uncertainty as to the validation and processing of the SRK data, it was not included with the 2009 data for assessment of discontinuity sets. However, SRK's reported discontinuity sets have been taken into consideration in delineating the major and minor sets comprising the overall rock mass fabric, as discussed later sections.

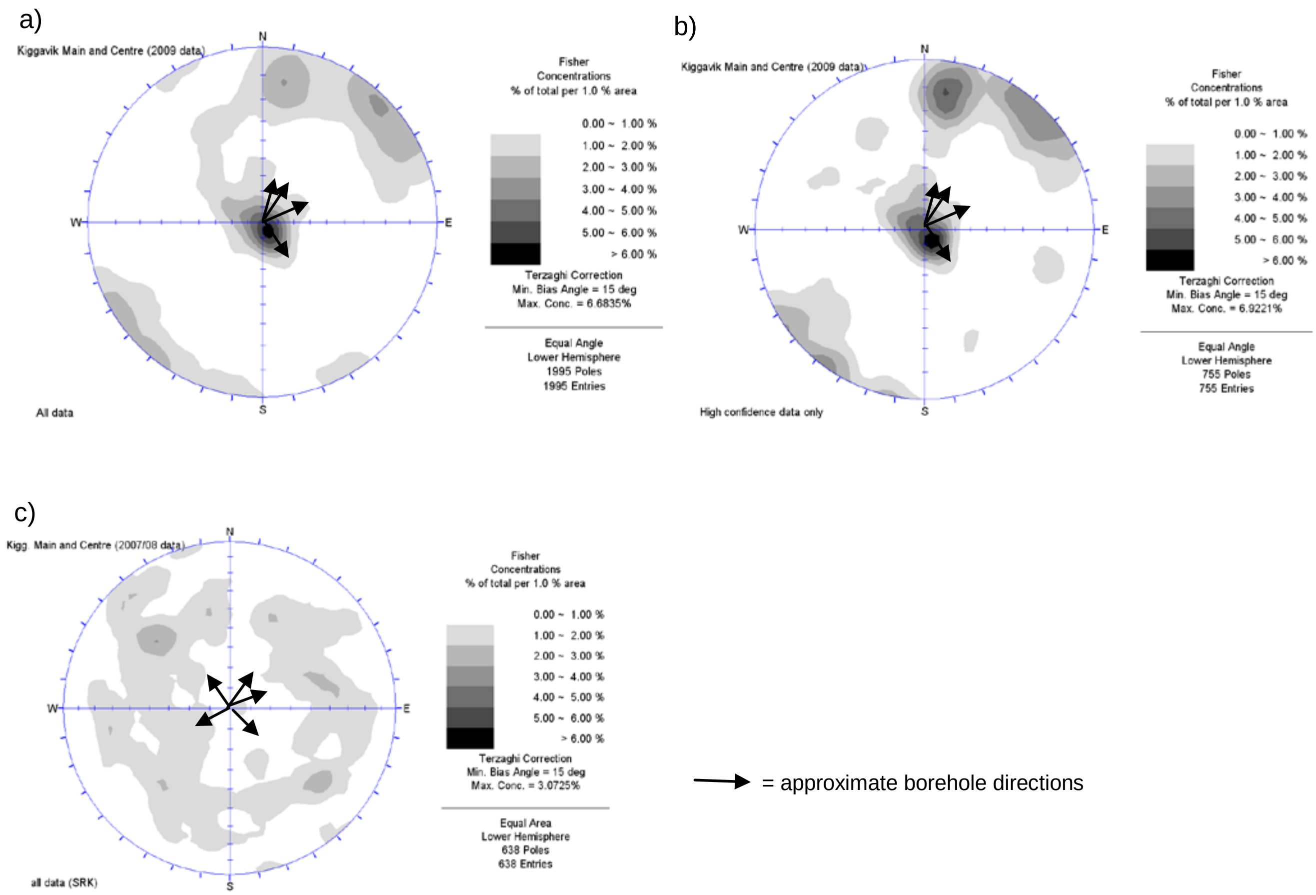


Figure C4: Kiggavik Main and Centre Zones - Oriented Core Data Contoured; a) All 2009 data, b) High Confidence 2009 data, and c) All 2007-2008 data (SRK).

3.4.2 Selected Discontinuity Sets

The selected discontinuity sets for the Main Zone and Centre Zone 2009 boreholes are summarised in Table C3 below. The inferred major sets in each borehole have been highlighted on this table, and the selected major and minor sets are plotted on a stereonet in Figure C5. A total of 59 sets were selected in the four geotechnical holes following the criteria discussed previously. A total of 22 sets were identified as major in all boreholes.

Table C3 plots the selected sets by trend, dip, and dip direction. Set identifications (i.e. FO1, JN1, etc.) have been given to the various data clusters. Some of the sets are inferred as sub-sets, which accounts for the slight variations in the major trends of the data (i.e., FO1A, FO1B).

Also summarised in Table C3 are the selected sets from the 2007-2008 boreholes (SRK 2009) and the 1989 geotechnical borehole (Golder 1989). These sets are plotted on separate stereonets in Figure C5. The top six identified sets for the 2007-2008 data have been highlighted as major. The 1989 sets were previously highlighted as major and minor.

There is generally shown to be good agreement between the 2009 data and historical data. As commented on previously, the 2007-2008 data shows greater feature concentrations for some of the inclined sets, which were not seen to be significant in the 2009 boreholes. The 1989 data identifies two major sets striking north-south (i.e. jn2a, jn2b) which were only seen as minor in the 2009 data. The 1989 data also suggests an east-west striking fault set (i.e., flt2) which was seen as minor in the 2009 data. This fault set was likely inferred from the regional fault trends.

Three to four major sets are inferred at the Kiggavik Main and Centre Zones. These major sets are mainly flat and associated with bedding, or sub-vertical and associated with foliation or jointing. Some interpretation on these sets is as follows:

- B1A/B1B/b1c – the mainly flat, slightly dipping to the northwest or southwest, inferred bedding set was seen as a major set in all 2009 holes, as well as the 2007-2008 and 1989 data. The bedding, also associated with foliation, is associated with the metasediments. A similar trend is also seen in the granites; however this trend is interpreted as a stress relief joint set in the granite rock units. Other identified features in this set include joints, veins, and shears.
- FO1A/FO1B – inferred foliation set striking east-west and dipping steeply to the south or north. Seen as a possible secondary foliation or veinlet set related to deformation in the metasediment and granite rock units. Other identified features include joints and shears. FO1A was identified as a major set in 3 of the 4 2009 boreholes as well as the 1989 data. FO1B, a possible variation or scatter to FO1A was identified in 2 of the 4 2009 boreholes as well as the 1989 data. This set was not identified in the 2007-2008 data which might be related to borehole orientation bias, although this is uncertain.
- JN1A/JN1B – inferred joint set striking southeast-northwest, and dipping steeply northeast or southwest. Identified as a major set in 3 of the 4 2009 boreholes, and also identified in the 2007-2008 boreholes. This set is possibly related to major deformational events, trending nearly orthogonal to the main trend of the mineralization shear zone. It also trends near-parallel to the identified northwest-southeast trending fault/dyke structure. Other features within this set include veins and shears.
- FLT1A/FLT1B/FLT1C – inferred joint set related to faulting, as this set trends northeast-southwest, near parallel to the inferred regional fault trend for the Main and Centre Zones. Other features associated with this set include shears and veins. FLT1A and FLT1B dips sub-vertical and associated sets were identified in all 2009 boreholes, as well as the 2007-2008 SRK data and 1989 data. FLT1C dips inclined towards the southeast, and was identified as a major set in 2 of the 4 2009 boreholes, as well as a major set in the 2007-2008 data.

Overall, the fairly wide distribution of the selected sets from all programs does suggest that additional data collection would be required. In particular, the 2007-2008 data illustrates a couple of major inclined dipping sets which were not identified in the 2009 or 1989 data sets. Confirmatory drilling at complimentary borehole orientations would be useful to validate or disqualify the presence of these major sets.

Table C3: Summary of discontinuity sets for the 2009, 2007-2008, and 1989 geotechnical investigations at the Kiggavik Main and Centre Zones.

Trend	North-South				Northeast-Southwest				East-West				Southeast-Northwest				Sub-Horizontal (dip 0˚ to 30˚)
Dip	Sub-Vertical (dip 60˚ to 90˚)		Inclined (dip 30˚ to 60˚)		Sub-Vertical (dip 60˚ to 90˚)		Inclined (dip 30˚ to 60˚)		Sub-Vertical (dip 60˚ to 90˚)		Inclined (dip 30˚ to 60˚)		Sub-Vertical (dip 60˚ to 90˚)		Inclined (dip 30˚ to 60˚)		
Dip Direction	Dip East	Dip West	Dip East	Dip West	Dip SE	Dip NW	Dip SE	Dip NW	Dip North	Dip South	Dip North	Dip South	Dip NE	Dip SW	Dip NE	Dip SW	
Set ID	jn2b	jn2a	jn4	-	FLT1A	FLT1B	FLT1C	jn3a/jn3b	FO1B	FO1A	flt2	fr1	JN1B	JN1A	b1c	-	B1A/B1B/b1c
CZ-09-01	-	78/282	47/097	-	-	66/333	49/141	34/296	-	**77/195**	-	-	-	**82/229**	53/028	33/207	**09/350** **20/130** 30/052
MZ-09-01	-	73/266	**53/093**	48/288	**85/147**	**84/333**	**50/137**	39/334	79/360	**74/183**	-	40/173	**85/055**	**84/234**	-	-	**05/312** **18/120** 29/055
MZ-09-02	74/094	69/284	-	-	85/137	81/312	**58/154**	38/312	-	-	53/343 56/008	57/197	**86/035** **77/055**	76/244	32/043	-	**12/320** 23/173
MZ-09-03	-	81/281	53/083	-	69/146 74/116	85/333	-	51/309	**84/014**	**77/189** 84/163	52/339	**36/185**	87/056	79/235	44/025	-	**08/268** **19/123** 19/064
SRK 2007/2008	86/103	-	-	**58/272**	**62/131**	61/313	44/149 **49/150**	-	-	-	40/001	-	-	63/245 79/220	**40/060**	-	**07/025** **33/077** 18/173
Golder 1989	**82/094**	**82/275**	-	-	79/140 **79/154**	78/318	-	-	**78/022**	**81/198**	**59/001**	-	-	-	-	-	**12/308**

Upper case set names indicate major sets, lower case set names indicate minor sets. Major sets highlighted in grey. Sets given by dip/dip direction.

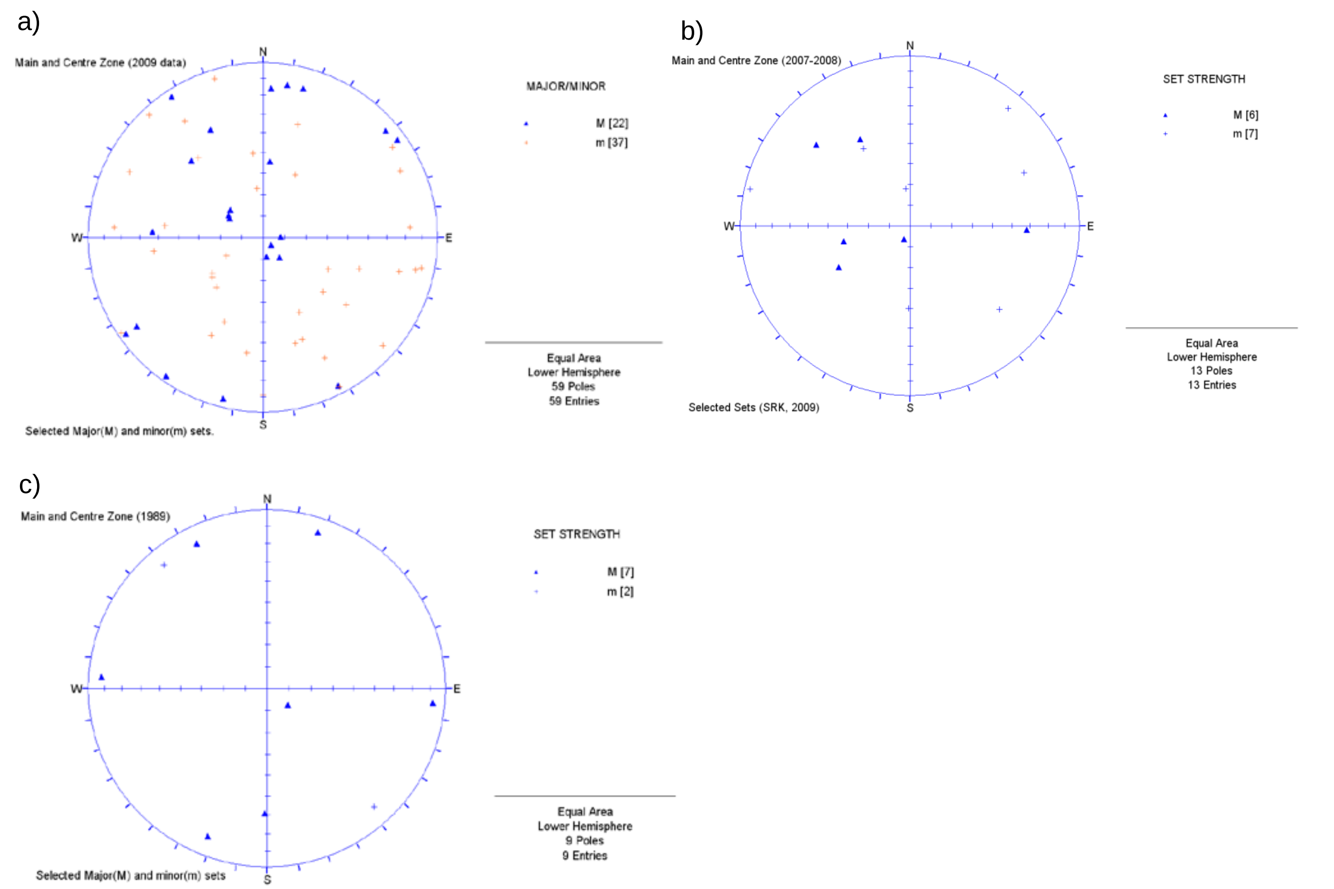


Figure C5: Kiggavik Main Zone and Centre Zone – Selected Major and Minor sets; a) 2009 Data, b) 2007-2008 Data, c)1989 Data.

3.5 Structural Domains

As part of the analysis of the structural stereonet data, an assessment of structural domains that may be present at each deposit was conducted. A structural domain is an area within the deposit which has different structural conditions from other areas within the deposit. This could be due to a change in rock type, hanging wall versus footwall rocks, proximity to major features, etc.

At Main and Centre Zones, an assessment was made for the 2009 data between the two distinct rock units; metasediments (1426 features) and granites (569 features). Figure C6 presents contoured structural data for either rock type. There appears to be generally good agreement between the rock units in terms of the distribution of the major discontinuity sets. The metasediments show a higher concentration for the sub-horizontal inferred bedding set as compared to the granites, however this set still appears to be persistent in the granites. Insufficient verifiable data was available to assess the potential spatial variability of the rock mass structure, therefore it was decided that a single structural domain that would reflect the discontinuity sets in both the metasediments and granites will be assigned to the rock masses for the Main Zone and Centre Zone pits.

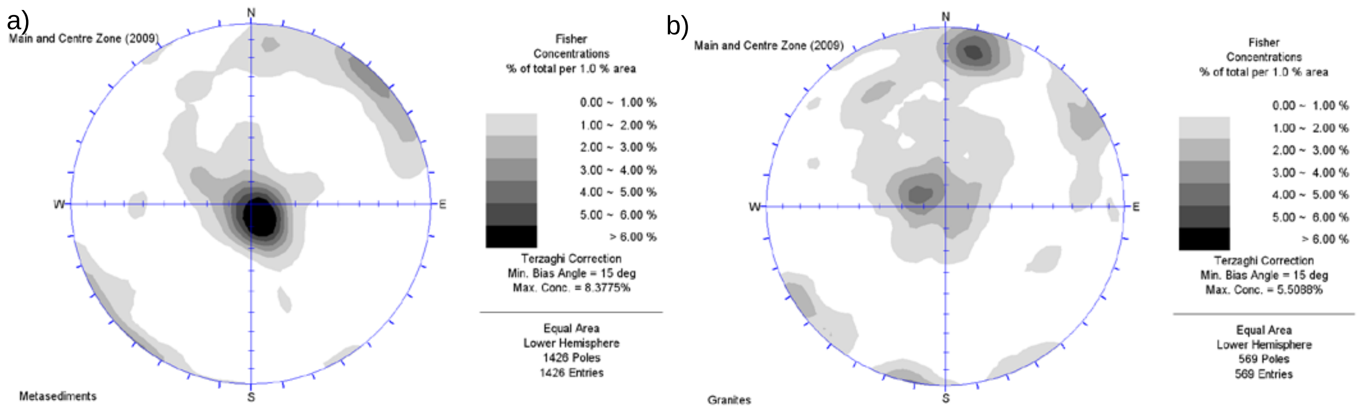


Figure C6: Kiggavik Main Zone and Centre Zone – All 2009 Data Contoured; a) Metasediments, and b) Granites.

4.0 DETERMINATION OF STRUCTURAL SETS FOR KINEMATIC ANALYSES

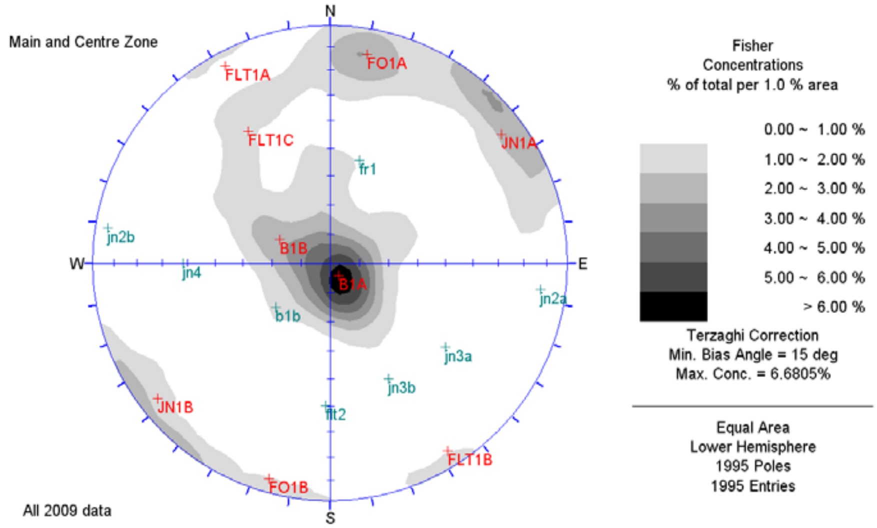
Based on the proceeding discussions related to the oriented core data obtained from the 2009 geotechnical investigation, with data supplemented from the 1989 (Golder) and 2008 (SRK) investigations, as assessment was made of major and minor structural sets to be used for kinematic analyses for pit slope design.

For the Main Zone and Centre Zone pits, because of limited oriented core data for the Centre Zone pit, and its close proximity to Main Zone, a single structural domain was assumed for both the Main Zone and Centre Zone pits. Also, there showed to be good agreement between the metasediment and granite rock units for the Main Zone and Centre Zone boreholes, therefore a single structural domain was assumed for all rock types. Supplementary data for the 2009 investigation included regionally identified fault trends (provided by AREVA, and based on identified geophysical anomalies), as well as discontinuity data from boreholes completed in 2007 and 2008 by SRK, as well as structural data developed from a geotechnical investigation conducted by Golder in 1989. The selected major and minor structural sets for the Main and Centre Zones are presented in Table C4. The selected sets are plotted with the 2009 oriented core data (contoured) on Figure C7 for comparison.

Table C4: Structural Sets for Kinematic Analysis from Main and Centre Zones (inferred major sets shown in bold).

Major Fabric Trends		Structural			Type
Strike/Trend	Dip	Set	Dip	Dip Dir	
NW-SE	SW (sub-vertical)	**JN1A**	79	233	**Major** Joint Set - observed as major joint set in 3 of 4 2009 boreholes, as well as identified in the SRK 2008 data. It is considered continuous throughout the pit area.
	NE (Sub-vertical)	**JN1B**	81	52	
E-W	S (sub-vertical)	**FO1A**	78	190	**Major** Foliation Set - observed in the 1989 and 2009 data sets shown to be related to a foliation or veining trend in both the metasediments and granites. It is considered continuous throughout the pit region.
	N (sub-vertical)	**FO1B**	83	16	
NE-SW	SE (sub-vertical)	**FLT1A**	83	152	**Major** Fault Sets - observed in the 1989, 2007-2008, and 2009 data. These discontinuity sets possibly correspond with and may be related to the regional NE-SW shear zone that controls mineralization at Main and Centre Zones. They are expected to be continuous within the pit areas.
	NW (sub-vertical	**FLT1B**	82	328	
	SE (inclined)	**FLT1C**	55	148	
NE-SW	NW (sub-horizontal)	**B1A**	5	326	**Major** Bedding Set - observed in 1989, 2007-2008 and 2009 data. Dominant as bedding in the metasediments but also seen as a major set in the granites as a possible stress-relief joint set.
	SE (sub-horizontal)	**B1B**	19	115	
NW-SE	NE (sub-horizontal)	b1c	24	51	Minor bedding subset - related to B1, oriented perpendicular to the major bedding set. Not expected to be continuous within the pit area.
E-W	N (inclined)	flt2	50	2	Minor fault dipping to the north. This feature may be related the E-W trending graben structures that control mineralization within Main Zone. It was identified in the 1989 report as an expected major trend related to faulting, however was not observed as a major discontinuity set in the 2008 and 2009 data.
N-S	W (sub-vertical)	jn2a	78	277	Minor joint set which is nearly orthogonal to FO1 and JN1. A possible local variation to JN1. It was identified as a major set in the 1989 data, however was not seen to have considerable persistence in the 2008 and 2009 data. It is not expected to be continuous throughout the pit area.
	E (sub-vertical)	jn2b	84	99	
NE-SW	NW (inclined)	jn3a	50	306	Minor joint set, inclined to the NW identified in the 2009 data. Not expected to be continuous throughout the pit area.
	NW(inclined)	jn3b	45	333	
N-S	E (inclined)	jn4	52	90	Minor joint set inclined dipping east. Identified as a major set in one of the 2009 boreholes, but not identified in the 1989 and 2009 data. Not expected to be continuous throughout the pit area.
E-W	S (inclined)	fr1	37	196	Minor fracture set inclined dipping south. Identified as a major set in one of the 2009 boreholes, likely related to scatter from the bedding set B1. Not expected to be continuous throughout the pit area.

Dip Dir = dip direction; Structural dip and dip direction shown in degrees; JN = joint, FO = foliation, FLT = fault, B = bedding, fr = fracture



Set	Dip	Dip Dir
JN1A	79	233
JN1B	81	52
FO1A	78	190
FO1B	83	16
FLT1A	83	152
FLT1B	82	328
FLT1C	55	148
B1A	5	326
B1B	19	115
b1c	24	51
flt2	50	2
jn2a	78	277
jn2b	84	99
jn3a	50	306
jn3b	45	333
jn4	52	90
fr1	37	196

Figure C7: Main and Centre Zones - 2009 Oriented Core Data (contoured) with Selected MAJOR and minor Structural Sets.

5.0 REFERENCES

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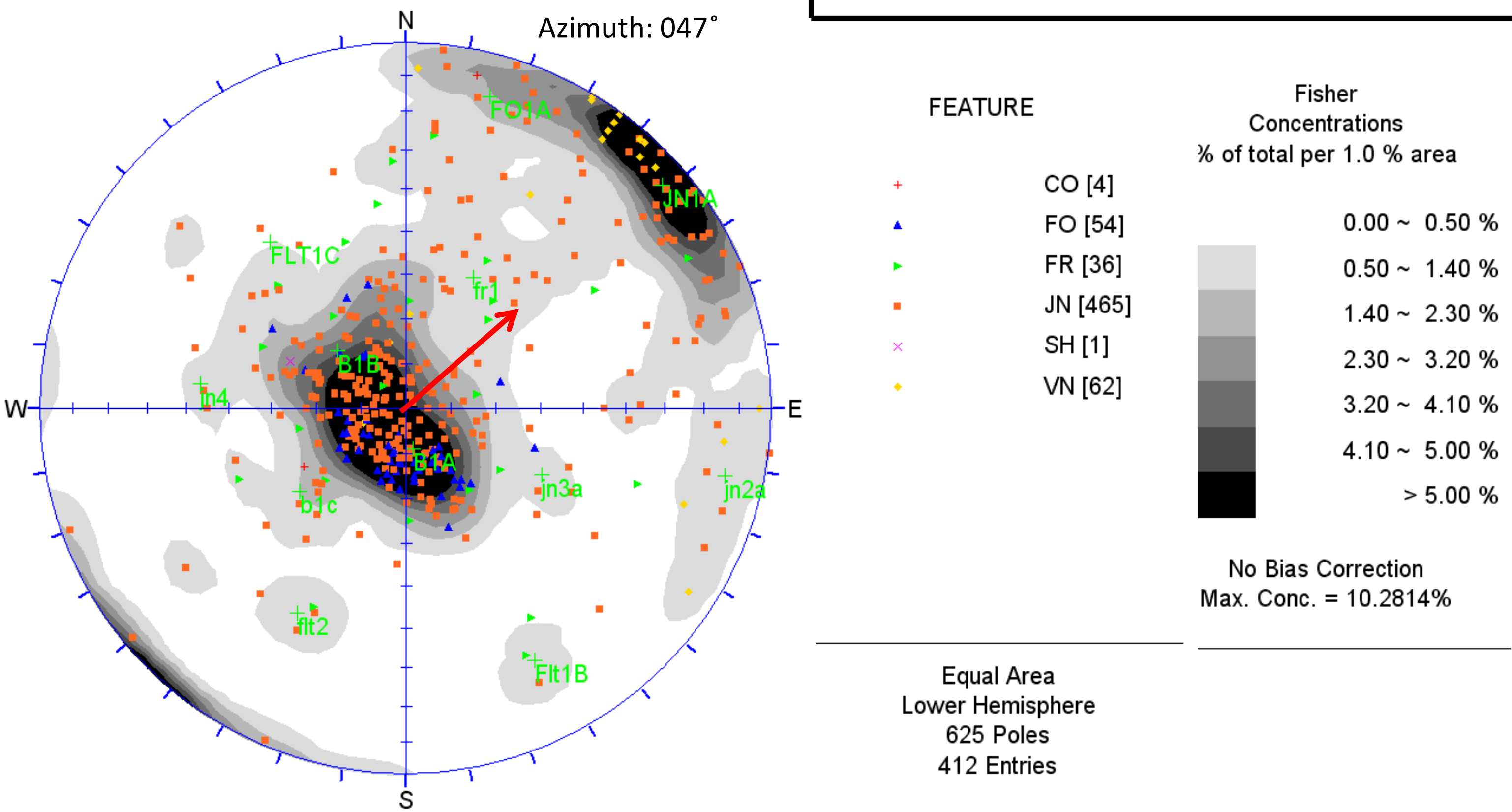
\\sas1-s-filesrv1\data\active\2009\1362\09-1362-0613 areva kiggavik geotechnical baker lake nunavut\pit slope report\final reports - february 2011\main and centre\app c\app 11 feb 17 main and centre zone appendix c - stereonet analysis final_eam.docx

Kiggavik – Main and Centre Zone
Identified Sets By Each Borehole – CZ09-01

Figure C8

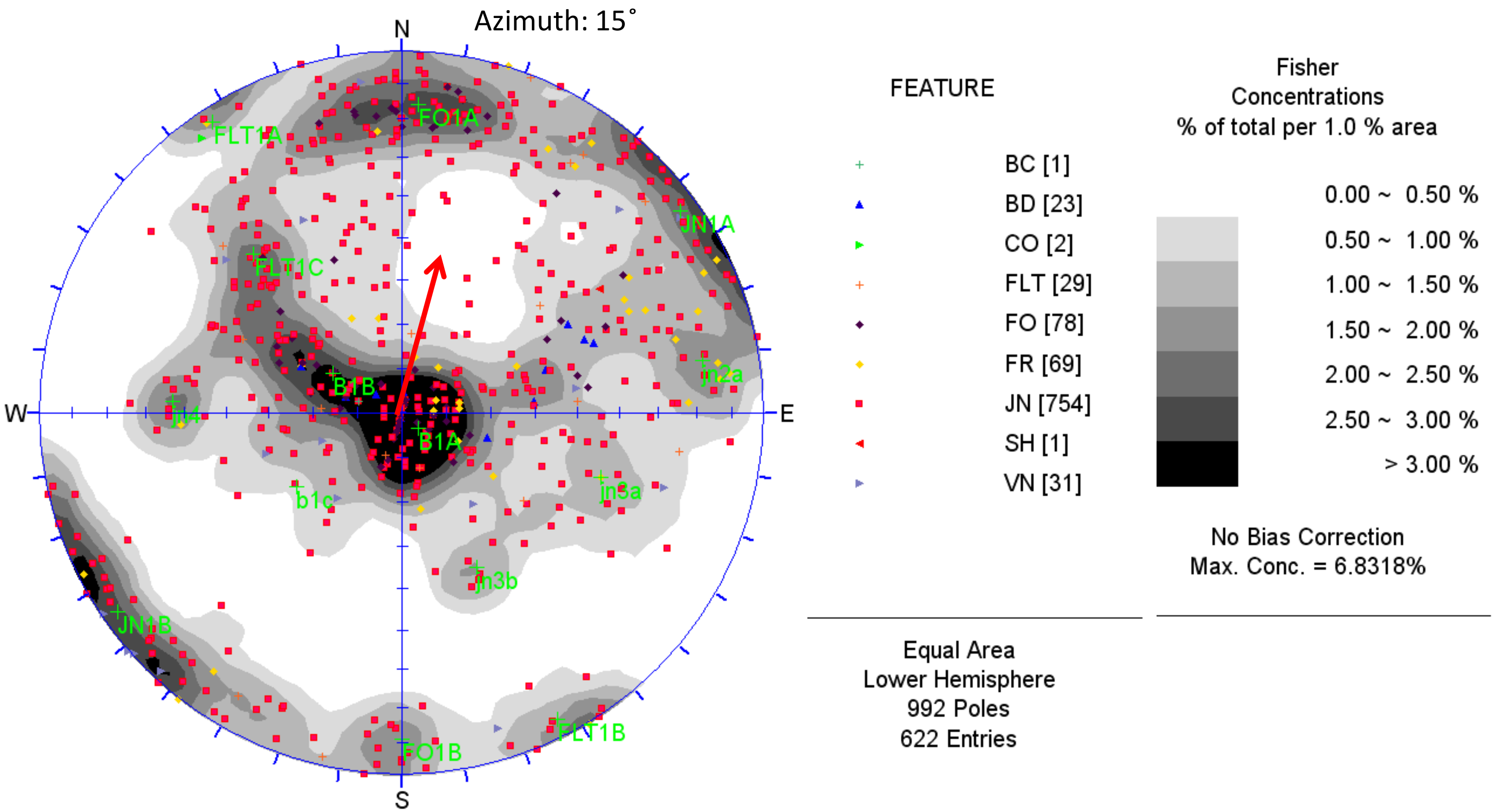


Set	Dip	Dip Dir
JN1A	82	229
FO1A	77	195
FLT1B	66	333
FLT1C	49	141
B1A	9	350
B1B	20	130
b1c	30	52
flt2	53	28
jn2a	78	282
jn3a	34	296
jn4	47	97
fr1	33	207

- Shown are the processed data files with a Terzaghi weighting applied. The number of entries indicate the total number of data points considered, which are shown as poles in the stereonet. The number of poles shown is the Terzaghi weighted value that the Fisher concentration contours are based on.
- Upper case indicates major sets, lower case indicates minor sets
- FO = foliation, JN = joint set, CJN = conjugate joint set, Dip Dir = Dip Direction
- Orientations (Dip and Dip Direction) are based on selected peak pole concentrations, based on the Fisher Concentration contours
- Major sets were selected based on its continuity between boreholes, and its orientation with respect to regional structure
- Major sets with a lower case letter following the name (i.e., FO1Aa) indicate different peaks which were interpreted to occur within the same set due to inherent scatter within the data.
- the arrow indicates the borehole orientation

Kiggavik – Main and Centre Zone
Identified Sets By Each Borehole – MZ09-01A

Figure C9

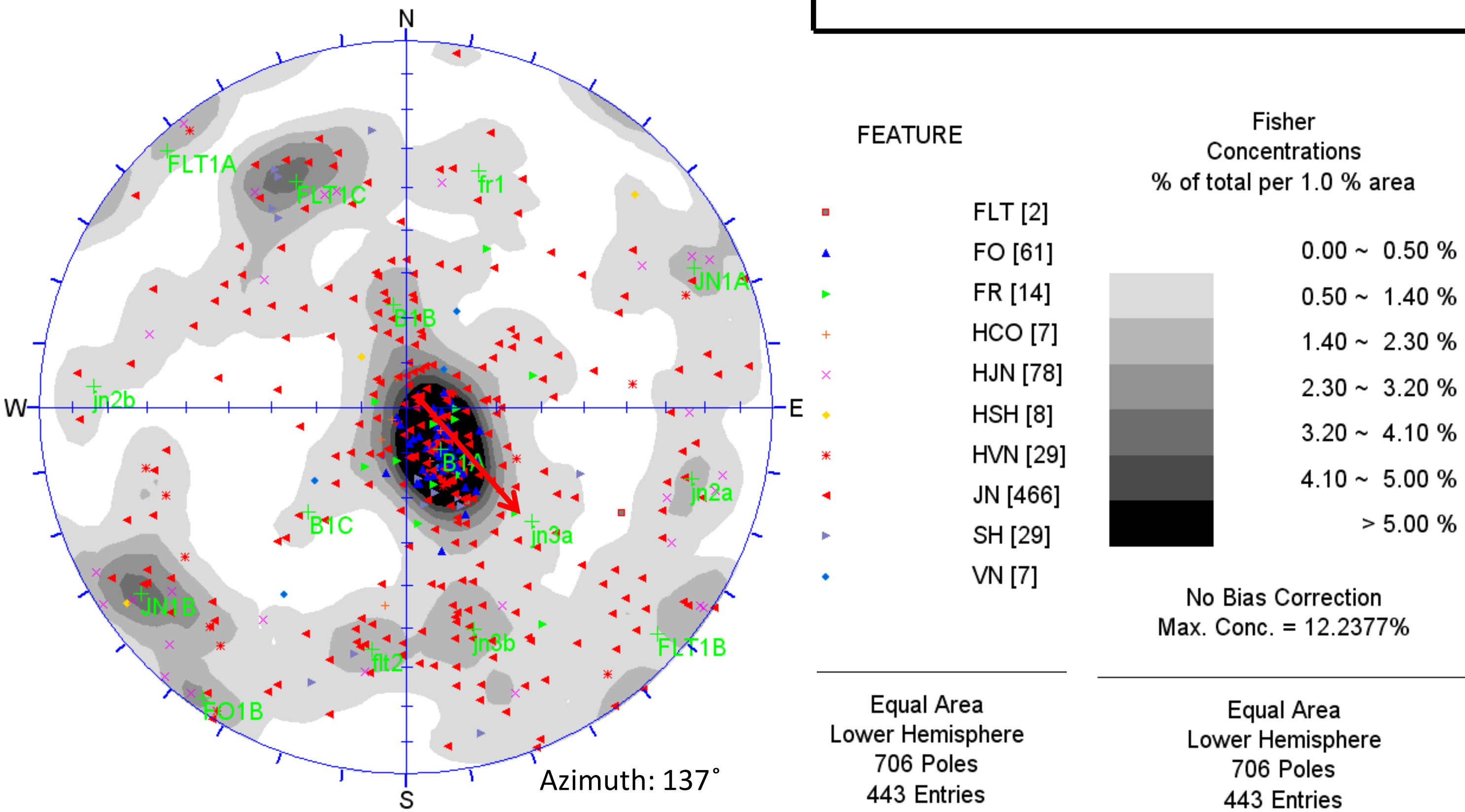


Set	Dip	Dip Dir
JN1A	84	234
JN1B	85	55
FO1A	74	183
FO1B	79	360
FLT1A	85	147
FLT1B	84	333
FLT1C	50	137
B1A	5	312
B1B	18	120
b1c	29	55
jn2a	73	266
jn3a	48	288
jn3b	39	334
jn4	53	93

- Shown are the processed data files with a Terzaghi weighting applied. The number of entries indicate the total number of data points considered, which are shown as poles in the stereonet. The number of poles shown is the Terzaghi weighted value that the Fisher concentration contours are based on.
- Upper case indicates major sets, lower case indicates minor sets
- FO = foliation, JN = joint set, CJN = conjugate joint set, Dip Dir = Dip Direction
- Orientations (Dip and Dip Direction) are based on selected peak pole concentrations, based on the Fisher Concentration contours
- Major sets were selected based on its continuity between boreholes, and its orientation with respect to regional structure
- Major sets with a lower case letter following the name (i.e., FO1Aa) indicate different peaks which were interpreted to occur within the same set due to inherent scatter within the data.
- the arrow indicates the borehole orientation

Kiggavik – Main and Centre Zone
Identified Sets By Each Borehole – MZ09-02

Figure C10

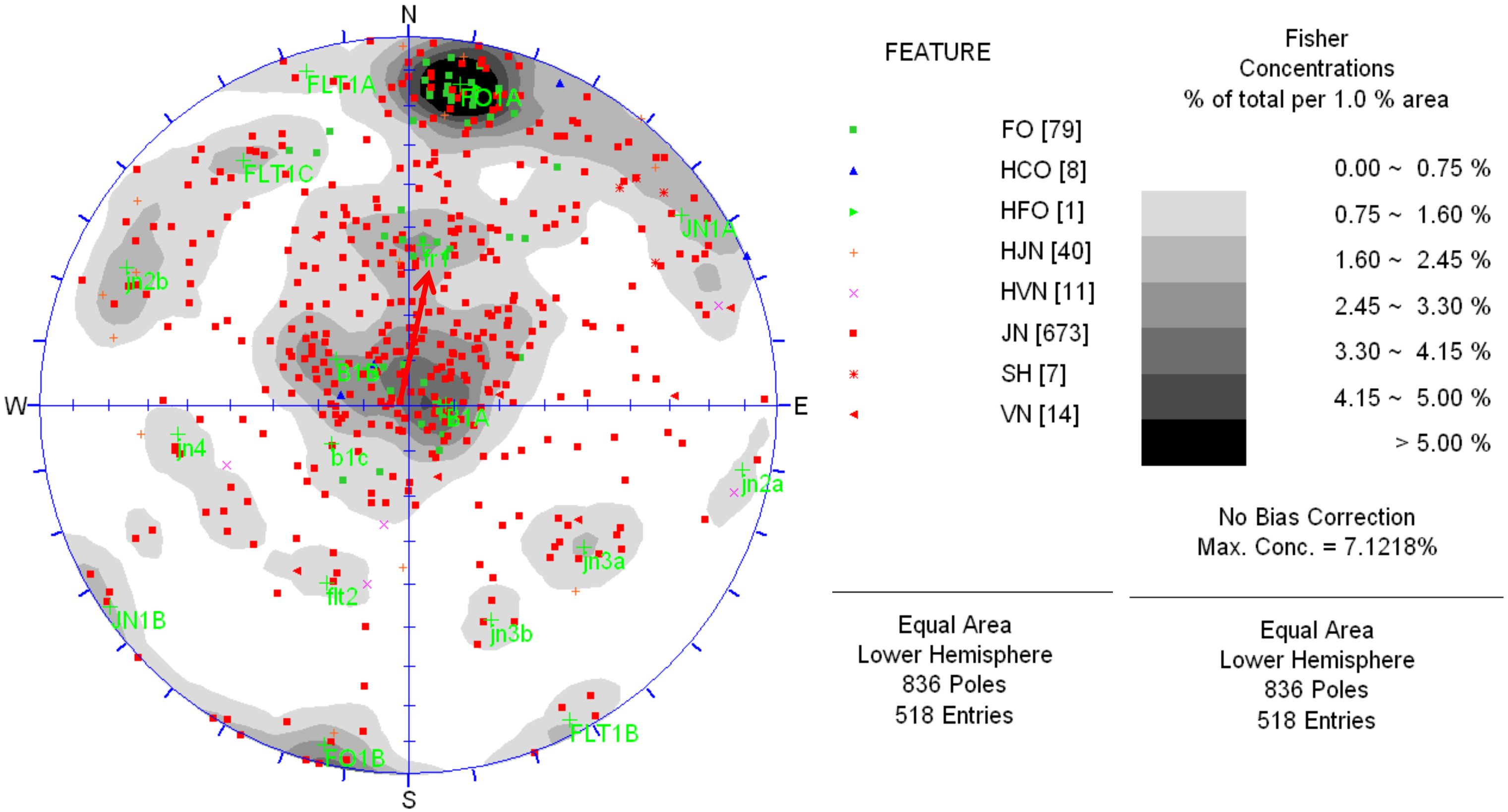


Set	Dip	Dip Dir
FO1B	86	36
JN1A	76	244
JN1B	77	55
FLT1A	85	137
FLT1B	81	312
FLT1C	58	154
B1A	12	320
B1B	23	173
b1c	32	43
flt2	56	8
jn2a	69	284
jn2b	74	94
jn3a	38	312
jn3b	53	343
fr1	57	197

- Shown are the processed data files with a Terzaghi weighting applied. The number of entries indicate the total number of data points considered, which are shown as poles in the stereonet. The number of poles shown is the Terzaghi weighted value that the Fisher concentration contours are based on.
- Upper case indicates major sets, lower case indicates minor sets
- FO = foliation, JN = joint set, CJN = conjugate joint set, Dip Dir = Dip Direction
- Orientations (Dip and Dip Direction) are based on selected peak pole concentrations, based on the Fisher Concentration contours
- Major sets were selected based on its continuity between boreholes, and its orientation with respect to regional structure
- Major sets with a lower case letter following the name (i.e., FO1Aa) indicate different peaks which were interpreted to occur within the same set due to inherent scatter within the data.
- the arrow indicates the borehole orientation

Kiggavik – Main and Centre Zone
Identified Sets By Each Borehole – MZ09-03

Figure C11



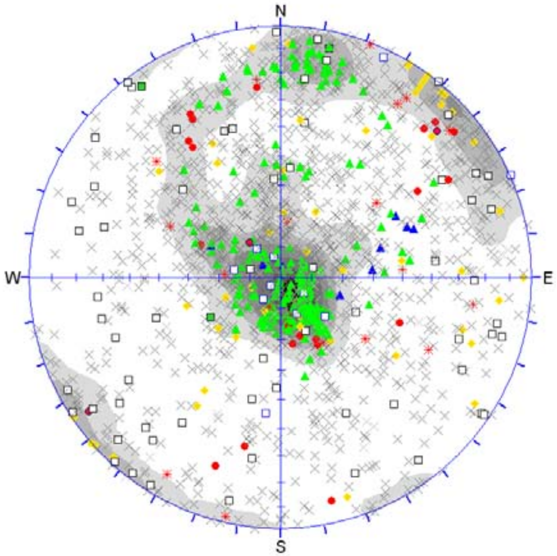
Set	Dip	Dip Dir
JN1A	79	235
JN1B	87	56
FO1A	77	189
FO1B	84	14
FLT1A	84	163
FLT1B	85	333
FLT1C	69	146
B1A	8	268
B1B	19	123
b1c	19	64
flt2	44	25
jn2a	81	281
jn2b	74	116
jn3a	51	309
jn3b	52	339
jn4	53	83
fr1	36	185

- Shown are the processed data files with a Terzaghi weighting applied. The number of entries indicate the total number of data points considered, which are shown as poles in the stereonet. The number of poles shown is the Terzaghi weighted value that the Fisher concentration contours are based on.
- Upper case indicates major sets, lower case indicates minor sets
- FO = foliation, JN = joint set, CJN = conjugate joint set, Dip Dir = Dip Direction
- Orientations (Dip and Dip Direction) are based on selected peak pole concentrations, based on the Fisher Concentration contours
- Major sets were selected based on its continuity between boreholes, and its orientation with respect to regional structure
- Major sets with a lower case letter following the name (i.e., FO1Aa) indicate different peaks which were interpreted to occur within the same set due to inherent scatter within the data.
- the arrow indicates the borehole orientation

Kiggavik – Main and Centre Zone
All Validated Data with Symbolic Pole Plots
Feature Type & Discontinuity Alteration Index

Figure C12

a) All valid data – Type of Feature

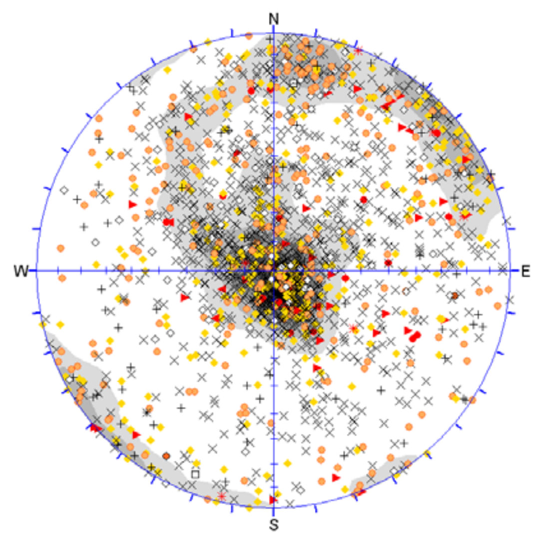


FEATURE

BD [19]	Bedding
CO [3]	Contact
FLT [22]	Fault
FO [230]	Foliation
FR [81]	Fracture
HCO [11]	Healed Contact
HSH [3]	Healed Shear
JN [1488]	Joint
SH [21]	Shear
VN [54]	Vein
Others [63]	

Equal Area
Lower Hemisphere
1995 Poles
1995 Entries

b) All valid data – Discontinuity Alteration Index (Ja)



JA

0.75 [76]	Healed
1 [1166]	Clean
10 [9]	Clay Infilled
15 [3]	Clay Infilled
2 [98]	Slightly altered
3 [317]	Hard coating
4 [264]	Soft coating
5 [7]	Hard infilling
6 [35]	Clay Infilling
8 [17]	Clay Infilling
Others [3]	

Equal Area
Lower Hemisphere
1995 Poles
1995 Entries

APPENDIX D

Rock Mass Stability Analysis

Table of Contents

TABLES

Table of Contents

FIGURES

1.0 INTRODUCTION

This appendix presents the results of the rock mass stability assessments carried out for the Main Zone and Centre Zone pits. The stability assessments included limit equilibrium slope stability analyses, as well as floor heave stability analyses. The slope stability analyses were conducted for generalized two-dimensional rock mass slope configurations developed from the information and interpretations presented and developed in the previous appendices. Various rock mass strengths and qualities were assessed in order to estimate pit slope angles which would achieve a reasonable and representative factor of safety against deep-seated rock mass failure.

The floor heave stability analyses were developed to assess the potential for floor heave due to the high artesian water pressures acting at depths below the permafrost line within the pit floors. The floor heave stability analysis results are intended to provide a range of conservative thicknesses of pit floor above the permafrost zone at which time remedial measures such as vertical drains could be installed to depressurize the pit floor.

The following appendix presents the methodology and results of the rock mass stability assessments.

2.0 SLOPE STABILITY ANALYSES

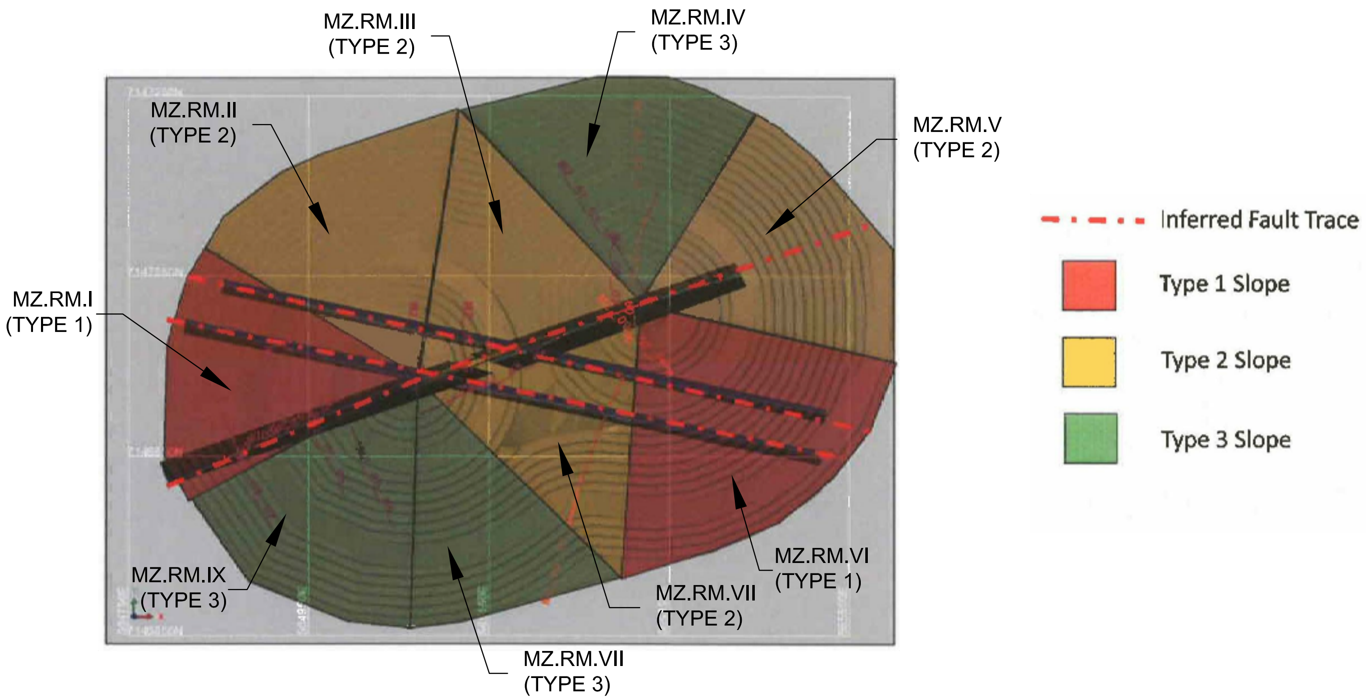
2.1 Slope Model Configurations

2.1.1 Generalized Rock Mass Slope Configurations

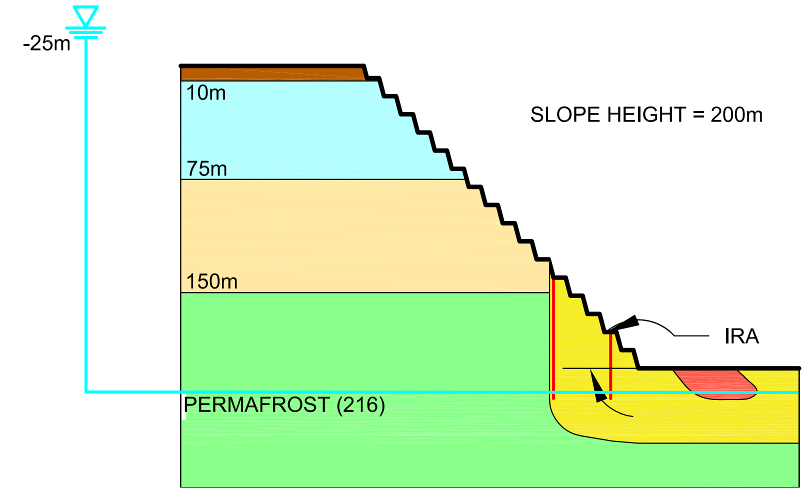
The limit equilibrium slope stability analysis software Slide® v.5 (Rocscience Inc.) was used for assessing the stability of the design slopes against deep seated rock mass failure. Parametric trials assessing the factor of safety versus slope inclination were conducted for the various slope geometries and material configurations.

The slope configurations and engineering geology conditions used for slope stability analyses for Kiggavik Main Zone and Centre Zone pits are presented in Figure D1. The material properties for the various slope configurations were inferred from the results of the rock strength (Appendix A) and rock mass classification work (Appendix B).

KIGGAVIK MAIN PIT - INFERRED ROCK MASS DESIGN SECTORS



TYPE 2 - LOWER SLOPE ALTERATION

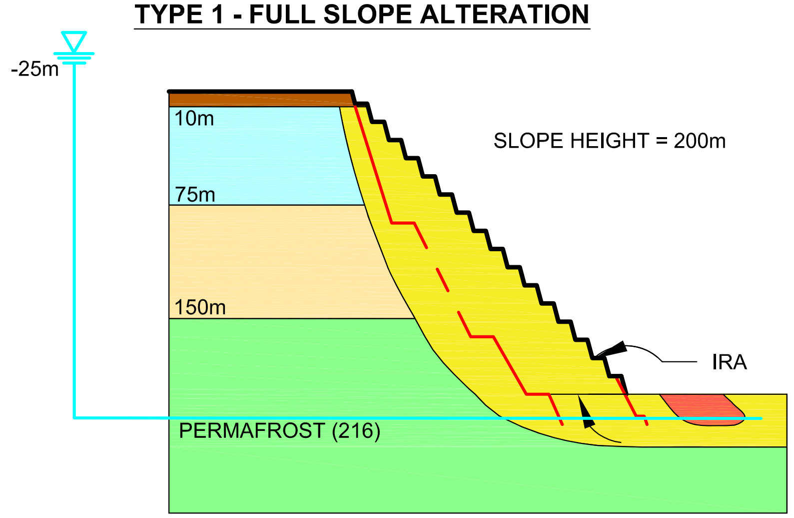


LOWER SLOPE AND FLOOR IS COMPRISED OF
FAULTING AND ORE ZONE HALO ALTERATION

ROCK MASS DOMAINS:

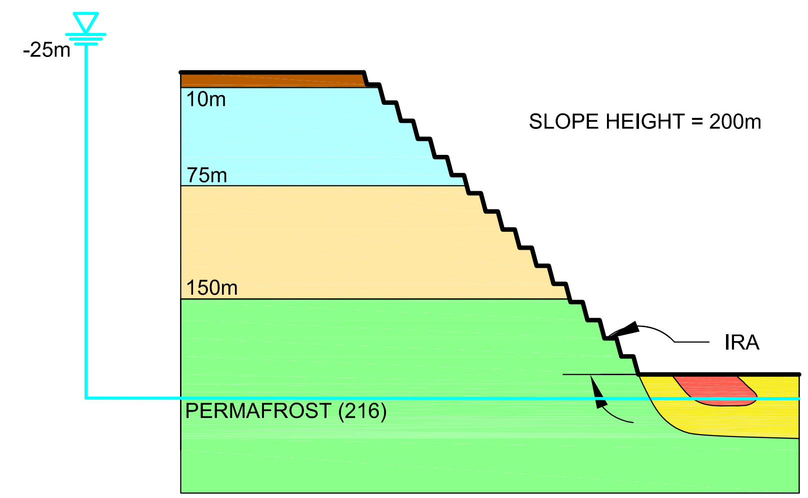
ZONE		RMR (1976)	UCS (MPa)
UPPER METASEDIMENTS	(light blue)	55 (fair)	100 (strong to very strong)
LOWER METASEDIMENTS	(tan)	65 (good)	100 (strong to very strong)
GRANITE	(green)	65 (good)	110 (very strong)
FAULT ZONE ALTERATION	(yellow)	50 (fair)	35 (moderately strong)
ORE HALO ALTERATION	(red)	50 (fair)	25 (weak to moderately strong)

TYPE 1 - FULL SLOPE ALTERATION



SLOPE AND FLOOR IS ENTIRELY COMPRISED OF
FAULTING AND ORE ZONE HALO ALTERATION

TYPE 3 - NO SLOPE ALTERATION

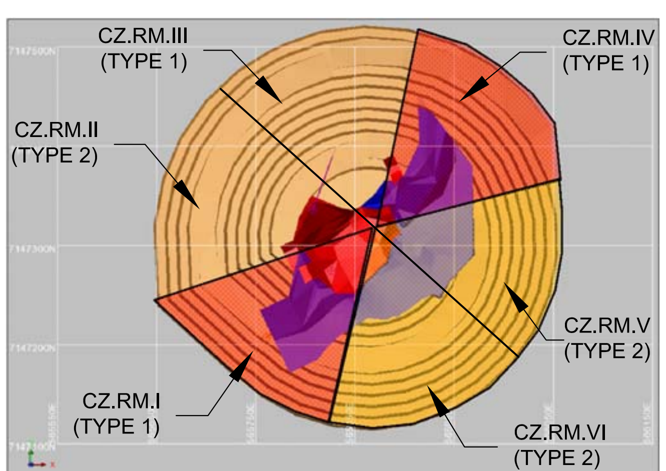


SLOPE IS MAINLY UNALTERED. FLOOR IS
FAULTED AND ALTERED

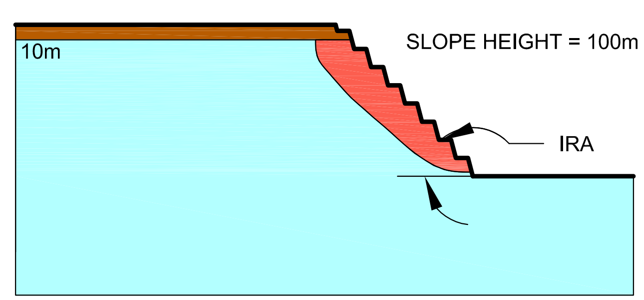
REFERENCES:

1. SURPAC GEOLOGY MODEL RECEIVED FROM AREVA (2009).

KIGGAVIK CENTRE PIT - INFERRED ROCK MASS DESIGN SECTORS

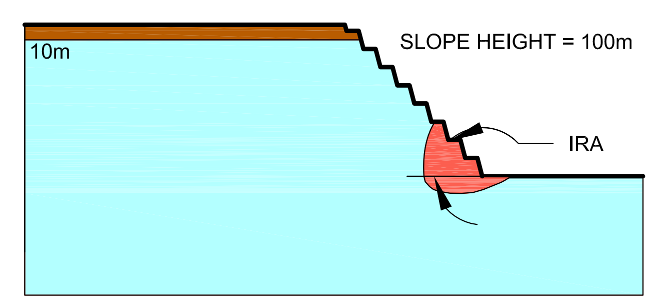


TYPE 1 - FULL SLOPE ALTERATION



SLOPE IS ENTIRELY COMPRISED OF
ORE ZONE HALO ALTERATION

TYPE 2 - LOWER SLOPE ALTERATION



LOWER SLOPE IS COMPRISED OF
ORE ZONE HALO ALTERATION

100 0 100
SCALE 1:5000 METRES

PROJECT	AREVA RESOURCES INC. 2009 KIGGAVIK PRELIMINARY PIT SLOPE DESIGN		
TITLE	KIGGAVIK MAIN AND CENTRE ZONES GENERALIZED PIT SLOPE CONFIGURATION FOR STABILTY ANALYSES		
PROJECT No.	09-1362-0613	FILE No. 0913620613AB0D2.dwg	
DESIGN		11/19/2009	SCALE AS SHOWN REV. A
CAD	JS	22/12/2009	FIGURE
CHECK	EAM	22/12/2009	
REVIEW	MR	22/12/2009	D1

Golder Associates
Saskatoon, Saskatchewan, Canada

PLOT DATE: February 25, 2011
FILENAME: G:\2009\1362\09-1362-0613 Areva Kiggavik Golder Internal Field Manual\CAD\from Mississauga\-AB-\0913620613AB0D2.dwg

Each pit was assumed to be comprised of two or three types of slopes, with varying degrees of rock mass alteration. The altered rock slopes included zones of the rock mass in close proximity to interpreted faulting or ore zone halo alteration. The non-altered rock zones assumed a generalized distribution of lithological domains (i.e., upper metasediments, lower metasediments, and granites) with depth. The slope configuration models, denoted Type 1, Type 2, and Type 3, are described as follows:

- ***Type 1 – Full Slope Alteration:*** Assumes the majority of the slope is altered and weakened due to the presence of faulting or ore zone halo alteration. For the Kiggavik Main Zone slopes, Type 1 slopes have been assumed and assigned to pit walls where faulting and associated alteration halos, in particular where more than one fault in close proximity, are interpreted to control the material properties of the open pit wall. At Kiggavik Centre, no major fault zones have been identified, however the ore zone halo alteration is interpreted to potentially affect the majority of the slope height in the end walls.
- ***Type 2 – Lower Slope Alteration:*** Assumes the lower slope, being the lower one half to one quarter of the overall slope height (depending on wall inclination), is altered and weakened due to the presence of faulting or the ore zone alteration halo. This includes fault zone exposures on the lower portions of pit walls, or interpreted ore zone alteration halos that extend to the lower portions of the walls and to the open pit floors. The upper portions of the slope, away from the faulting or alteration halos are assumed to be relatively unaltered country rock of better strength and quality.
- ***Type 3 – No Slope Alteration:*** Assumes predominantly non-altered rock mass conditions throughout the full slope height. This includes zones of the pit wall away from faulting and mineralization. For the Main Zone pit, the pit floor can still be assumed altered and weaker due to faulting or due to alteration. These slopes can include the paleo-weathered metasediments.

The rock mass design sectors for the Main Zone and Centre Zone pits are summarised on Figure D1.

The Kiggavik Main Zone pit is interpreted to be predominantly Type 2 or Type 3 rock mass slopes. The three identified major fault trends strike east-northeast-west-southwest to east-southeast-west-northwest. In the pit walls on strike with these trends, the rock mass is inferred to be Type 1.

The Kiggavik Centre Zone pit is interpreted to be predominantly Type 1 or Type 2 slopes due to the relatively shallow depth of excavation and the inferences made on the extents of the ore halo alteration. This is a relatively conservative estimation of the pit wall quality; however the shallow depth of excavation significantly reduces the likelihood of rock mass instability.

2.1.2 Material Parameters

The SLIDE stability model 2D geometries and geotechnical units are outlined on Figure D2 and the material properties used in the slope stability analyses are presented in Table D1. These parameters were developed from the results of the strength testing and rock mass classification work presented in the earlier appendices. Due to a lack of data, some of the parameters are estimates, derived from review of the trends of rock mass quality or strength with depth.

The rock mass strength was estimated following the generalized Hoek-Brown failure criterion (Hoek et al. 2002). This criterion uses the rock mass GSI (Geological Strength Index) which is approximated from the Rock Mass Rating (RMR) 1976 to estimate the rock mass strength from its intact material strength (UCS). The Hoek-Brown material coefficient, m_i values, were estimated from the approximated ratio of compressive strength to the materials tensile strength, which, in the absence of other data, can be considered as a value slightly greater than the PLT to UCS correlation factor K. These inferred m_i values correspond to recommended values for moderately strong to strong, crystalline metasedimentary rocks (RocLab, Rocscience 2007). Brazilian tensile strength testing, which was not carried out as part of this assessment, would be required to confirm this assumption.

In general, the Main Zone and Centre Zone pits show a mainly good quality rock mass, with intact rock strength generally varying from strong to very strong. Fault or ore halo alteration is assumed to considerably reduce the intact rock strengths and rock mass quality to a lesser extent than at other deposits within the Kiggavik project location.

A disturbance factor (D) is used in the Hoek-Brown criterion to downgrade the rock mass strength for considerations related to rock mass damage and disturbance such as blasting or stress relief due to excavation. This disturbance factor might also be considered for potential deterioration of the rock mass quality due to thawing and unravelling of the exposed frozen ground in warmer months. There is uncertainty estimating a relevant value of D for the rock mass comprising these pit slopes. Because of this uncertainty, the models were analysed with both disturbance factors in order to produce a range of results, from conservative to optimistic assumptions. Slope performance observations and study of the effects of blasting will help reduce blast damage to the walls, with potential for slope steepening if successful. Should the damage factor to slopes be high, slope flattening may be required.

Material unit weights were estimated from the density of the rock samples. Overburden was assumed to be cohesionless with an angle of friction representative of a dense sandy material. However, the overburden units in these models carry no resistance to failure due to assumed tension cracking extending through the upper portions of rock into the overburden. The overburden essentially acts as load imparted to the rock mass.

Table D1: Slope Stability Analyses - Rock mass parameters.

Rock Mass Units	GSI = RMR	UCS (MPa)	m_i	D	γ (kN/m^3)	c (MPa)	φ (˚)
KIGGAVIK MAIN & CENTRE							
Overburden	-	-	-	-	-	0	35
Upper Metasediments	55	100	12	0.5 or 1	26	-	-
Lower Metasediments	65	100	12	0.5 or 1	26	-	-
Granites	65	110	12	0.5 or 1	26	-	-
Fault Alteration	50	35	12	0.5 or 1	24	-	-
Ore Halo Alteration	50	25	12	0.5 or 1	24	-	-

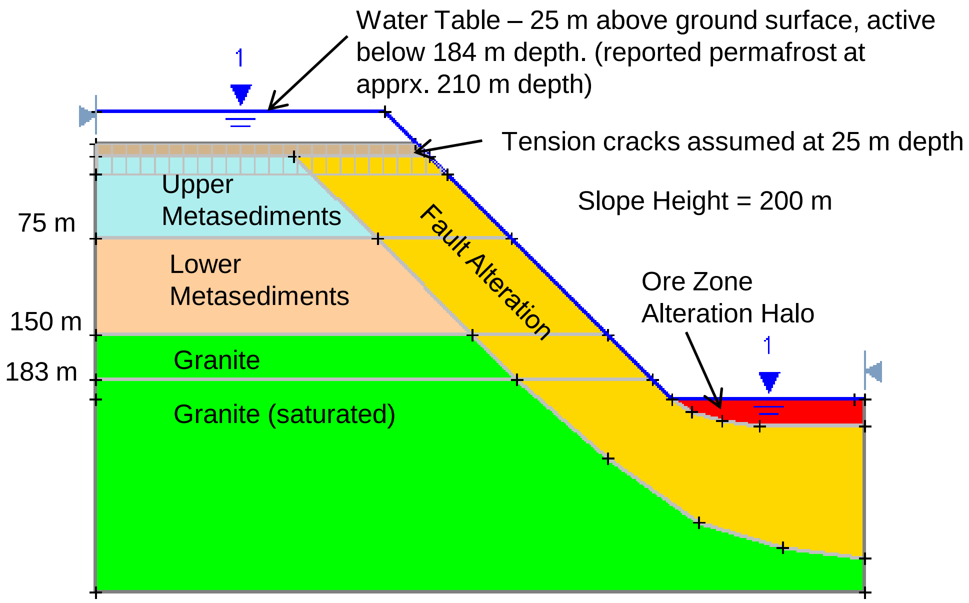
*GSI = Geological Strength Index (Hoek-Brown), RMR = Rock Mass Rating 1976, UCS = unconfined compressive strength, m_i = Hoek-Brown material coefficient, γ = unit weight, D = Hoek-Brown disturbance factor, c = cohesion (Mohr-Coulomb), ϕ = angle of friction (Mohr-Coulomb).

ANDREW LAKE & KIGGAVIK
SLOPE STABILITY ASSESSMENT
SLIDE MODEL CONFIGURATIONS

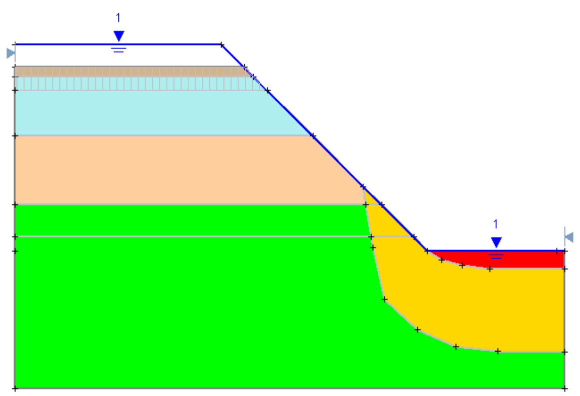
FIGURE D2

KIGGAVIK MAIN

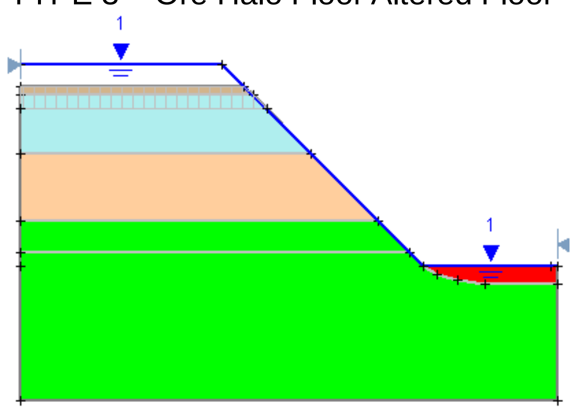
TYPE 1 – Fault Altered Slope



TYPE 2 – Fault Altered Lower Slope

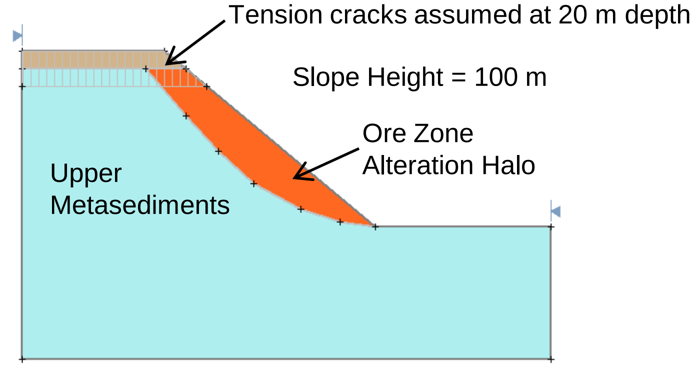


TYPE 3 – Ore Halo Floor Altered Floor

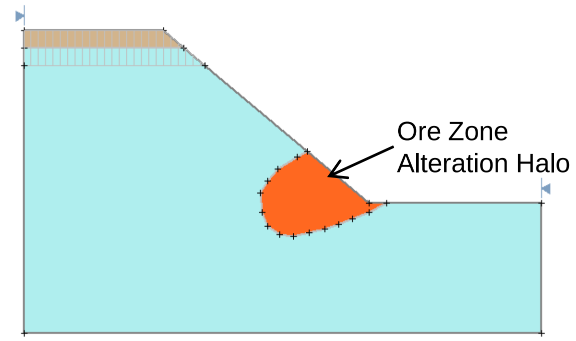


KIGGAVIK CENTRE

TYPE 1 – Full Slope Ore Zone Halo Alteration



TYPE 2 –Ore Zone Halo Alteration at Toe of Slope.



Notes: See text for material strength parameters information. Material strength parameters considered high blast damage (D=1) or low disturbance conditions (D=0.5). Kiggavik Main Zone models were assessed for dry and saturated conditions (within toe of slope). Kiggavik Centre Zone was assumed dry as depth of permafrost boundary significantly exceeds pit depth.

Date: November 2009
Project: 09-1362-0613

Golder Associates

Drawn: BC
Chkd:: MR

2.1.3 Tension Cracking and Water Conditions

Figure D2 shows the various slope model configurations, with tension cracking and piezometric surfaces.

Tension cracking was assumed to develop in the upper slope to depths of between 20 m and 30 m for the varying pit slope heights. The tension cracks carry no shear strength, and act as release planes from which failure surfaces would develop into the rock mass. The tension cracks were assumed to be unfilled, with no water pressure acting within the fractures.

Both wet and dry conditions were analysed for the Main Zone slope configurations. The “wet” conditions considered a piezometric surface along the face of the pit slope, and extending to above the ground surface to represent artesian pressure conditions which were measured at depth below the permafrost boundary during the geotechnical investigation. A differential pressure head of approximately 25 m above ground surface was measured at Main Zone (Golder 2009).

In the wet models, the water pressures are assumed to act within the lower portions of the slopes only, either below or slightly above the permafrost boundary. The Main Zone pit shows the base of permafrost to be at approximately 210 m which would put it below the pit floor elevation, however in the models a water pressure was assumed to act at 17 m above the slope toe to assess the effect of water pressure on the lower slope stability. The use of the water table in the Slide models might be considered conservative, as the full hydrostatic pressures acting from above ground surface were applied to the models. In reality, ground water depressurization through the drilling of drain holes would considerably reduce the water pressures acting in the slope.

The Kiggavik Centre model assumed only dry conditions, as mining would occur appreciably above the base of the permafrost.

2.2 Kiggavik Main Zone Pit Slope Stability

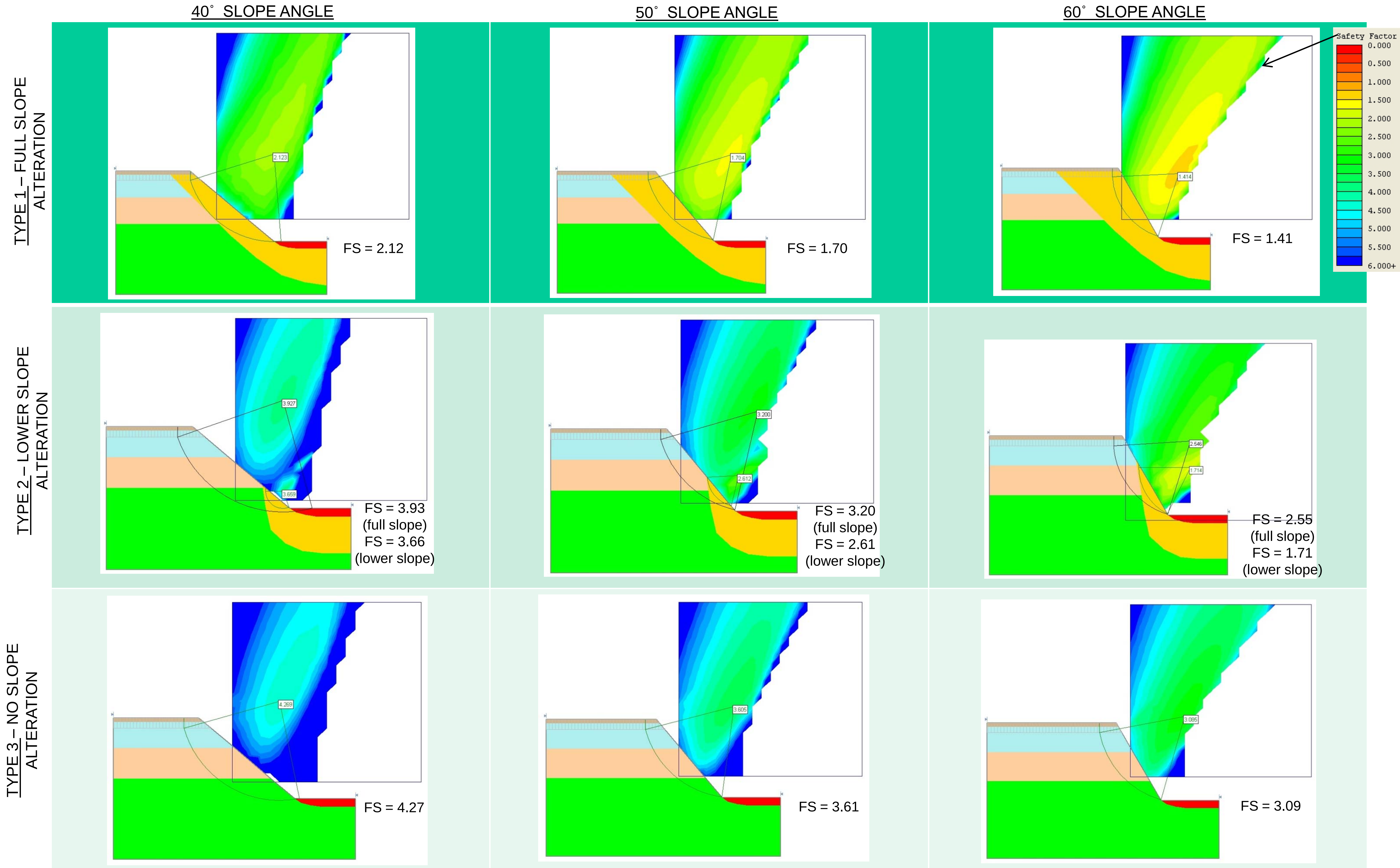
The Kiggavik Main Zone pit Type 1, Type 2, and Type 3 rock mass slope configurations were analysed with varying degrees of slope inclination, ranging from 35° to 60°. Several screen captures from the Slide models are plotted on Figure D3 which illustrate the ranges of factor of safety (FS), and relative decrease in FS with increased inclination.

The FS versus the overall slope angle results for the Main Zone Type 1 slope are plotted on Figure D4. The FS for the Type 1 slope is relatively high, due to the reduced slope height and stronger rock mass conditions at Kiggavik Main. Water pressures acting within the toe of the slope were shown to have a slight effect on stability, however the assumptions related to slope disturbance (D factor) is the main contributor to variability. The stable slope angles show high sensitivity to rock mass parameters disturbance. A low and moderate risk slope angle was inferred from these results, ranging from 45° to 55°. A slope angle of 50° appears to be achievable with the adoption of good blasting practices.

KIGGAVIK MAIN PIT
SLOPE STABILITY ASSESSMENT
SLIDE ANALYSES RESULTS*

FIGURE D3

*Slide results shown are dry, with damage factor, D = 0.5.



Date: November 2009

Project: 09-1362-0613

Golder Associates

Drawn: BC

Chkd:: MR

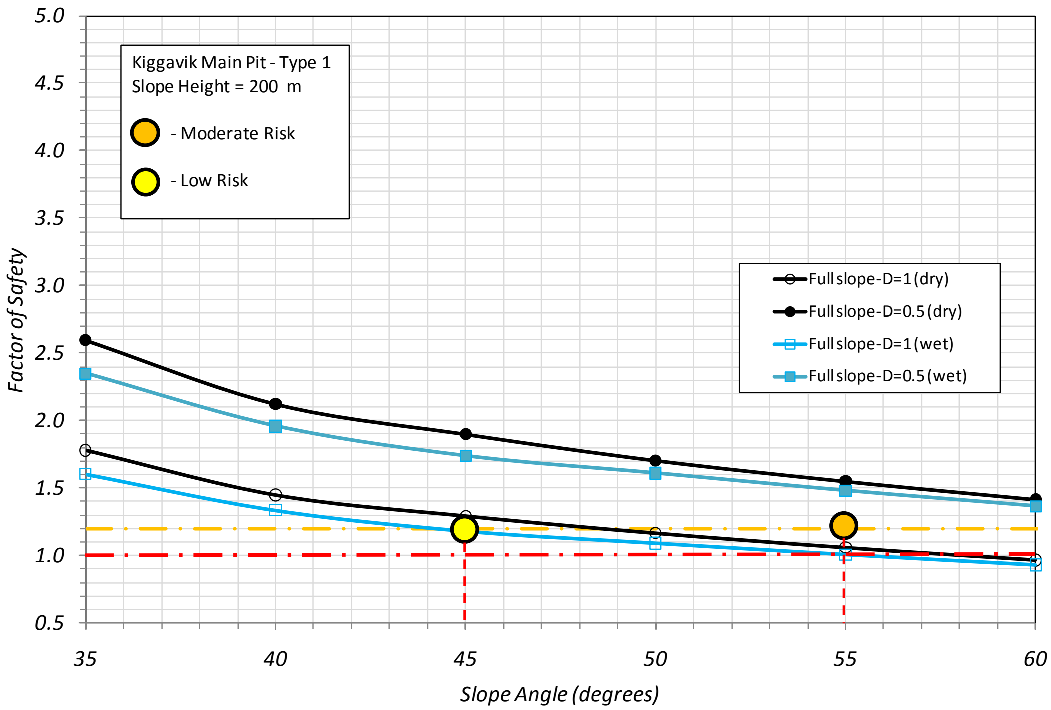


Figure D4: Main Zone Type 1 Slope - Slope Angle versus Factor of Safety for the Full Slope Altered Rock Mass Configuration.

The FS versus the overall slope angle results for the Main Zone Type 2 slope are plotted on Figure D5. Two modes of failure were assessed: failure occurring through the full slope height, and failure occurring mainly with the altered rock at the base of the slope. A lower factor of safety was seen in the altered rock in the toe of the slope. Based on these results, a slope angle of 55° would be achievable in the lower slope within the altered rock mass, and a higher slope angle would likely be achievable in the upper slope within the non-altered rock mass.

The FS versus the overall slope angle results for the Main Zone Type 3 slope are plotted on Figure D6. Rock mass slope instability does not appear to be a concern for the relatively strong rock mass conditions in this slope configuration.

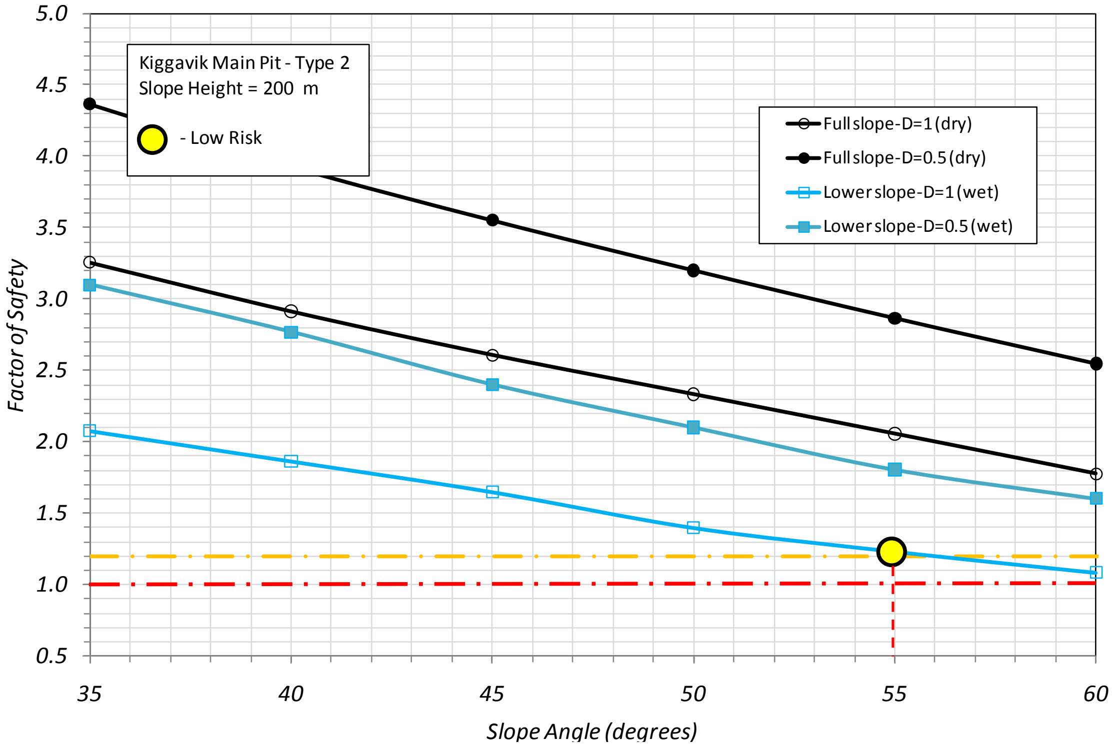


Figure D5: Main Zone Type 2 Slope - Slope Angle versus Factor of Safety for the Lower Slope Altered Rock Mass Configuration.

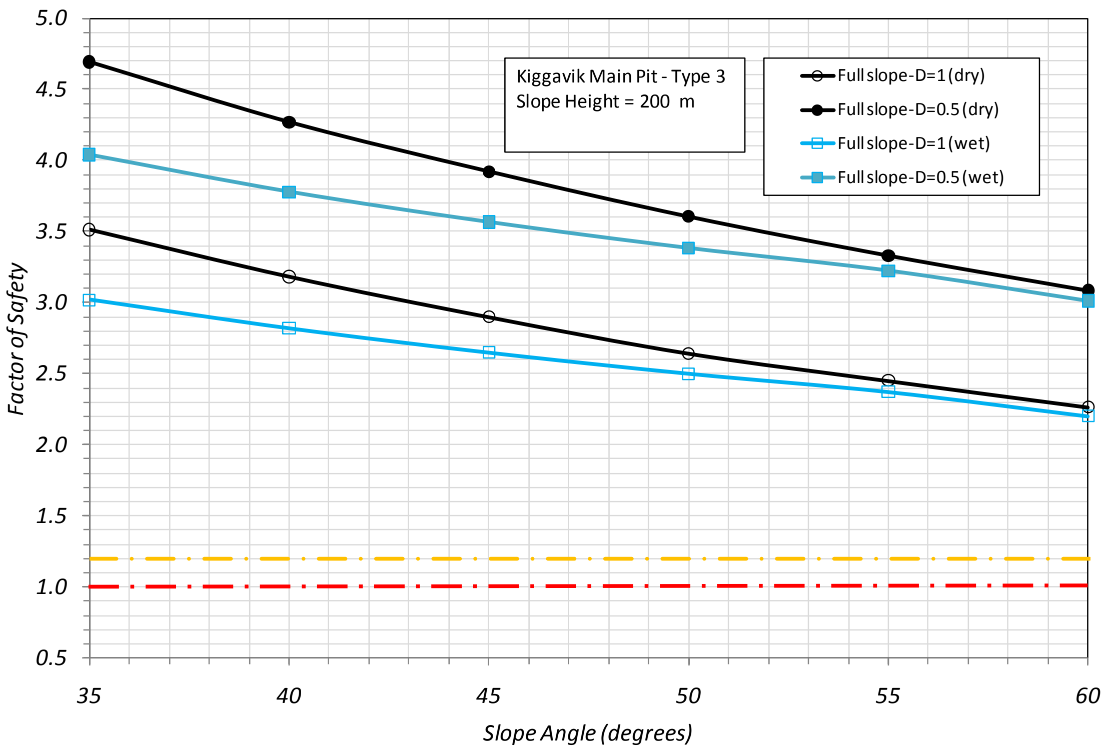


Figure D6: Main Zone Type 3 Slope - Slope Angle versus Factor of Safety for the Non-altered Rock Mass Configuration.

The slope stability results for the Main Zone configurations have been tabulated in Table D2. Recommended slope angles for the upper, lower, and full slope conditions are given along with the perceived level of risk for either configuration. Generally a low to moderate risk of rock mass instability is expected for the Main Zone pit. Deep seated rock mass failure would likely only be of concern within the weakened and altered rock units associated with faulting or ore zone halo alteration. A maximum slope angle of 50° is recommended for full slope altered rock mass conditions. A maximum slope angle of 60° has been assumed for the non-altered rock mass units. This appears to be conservative based on the stability analysis results and will have to be compared with the results of the kinematics assessment to assess the applicability of this angle.

Table D2: Main Zone Pit - Recommended maximum slope angles for rock mass slope stability.

Rock Mass Slope Configuration		Overall Slope Net of Upper and lower slope (0 m to 200 m)	Upper Slope (0 m to 125 m)	Lower Slope (125 m to 200 m)	Perceived Risk/Sensitivity of the design to variations in strength
Type 1	Full slope alteration	50°	50°	50°	Moderate risk.
Type 2	Lower slope alteration	58°	60°	55°	Low risk.
Type 3	No slope alteration	60°	60°	60°	Low risk.

2.3 Kiggavik Centre Zone Pit Slope Stability

The Centre Zone pit Type 1, and Type 2 rock mass slope configurations were analysed with varying degrees of slope inclination, ranging from 35° to 60°. Several screen captures from the Slide models are plotted on Figure D7 which illustrate the ranges of factor of safety (FS), and relative decrease in FS with increased inclination. As mentioned previously, the Centre Zone pit was assumed to be dry, with the full slope excavation occurring well above the permafrost boundary.

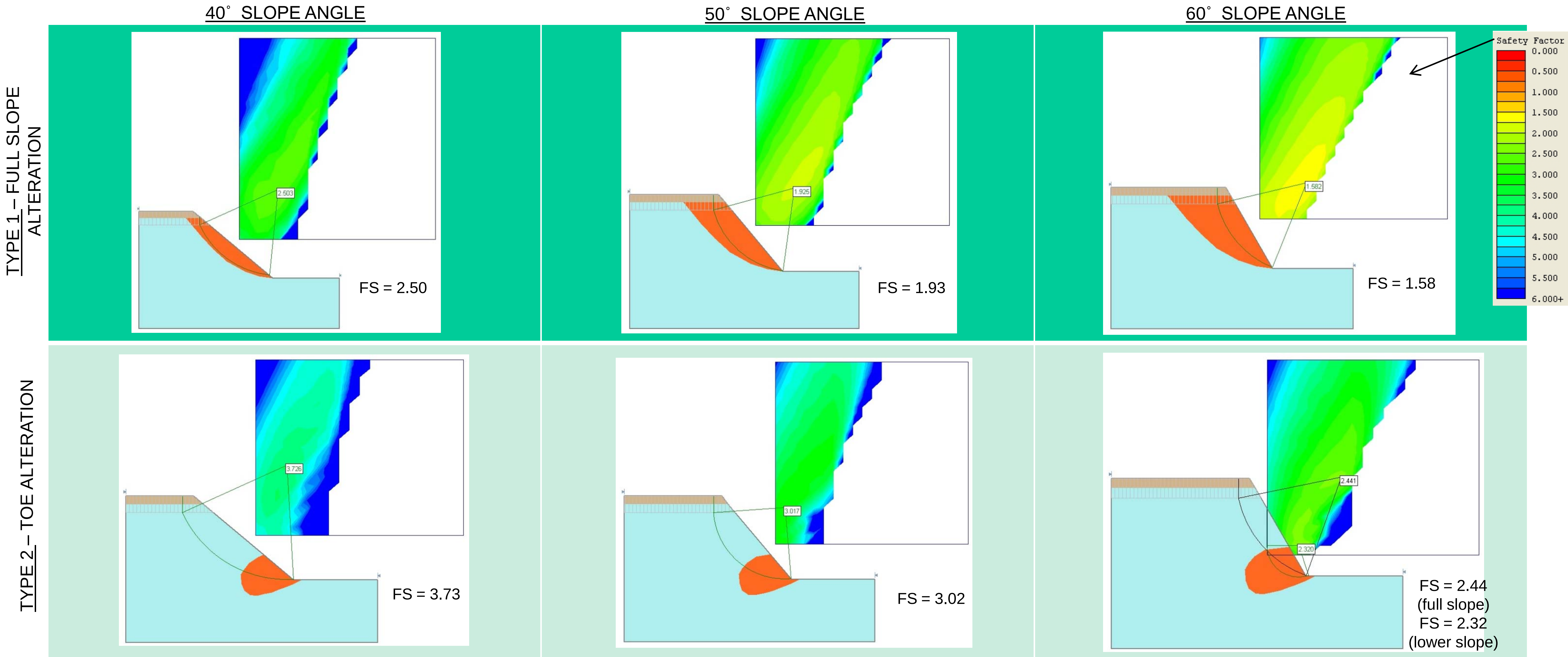
The Centre Zone Type 1 results are plotted on Figure D8. Acceptable slope angles for low to moderate level of risk ranged between 55° and 60°. A slope angle of 55° appears to be achievable with good blasting practices.

The Centre Zone Type 2 results are plotted on Figure D9. Overall there does not appear to be a significant risk of failure for the assumed rock mass conditions.

*Slide results shown are dry, with damage factor, D = 0.5.

KIGGAVIK CENTRE PIT
SLOPE STABILITY ASSESSMENT
SLIDE ANALYSES RESULTS*

FIGURE D7



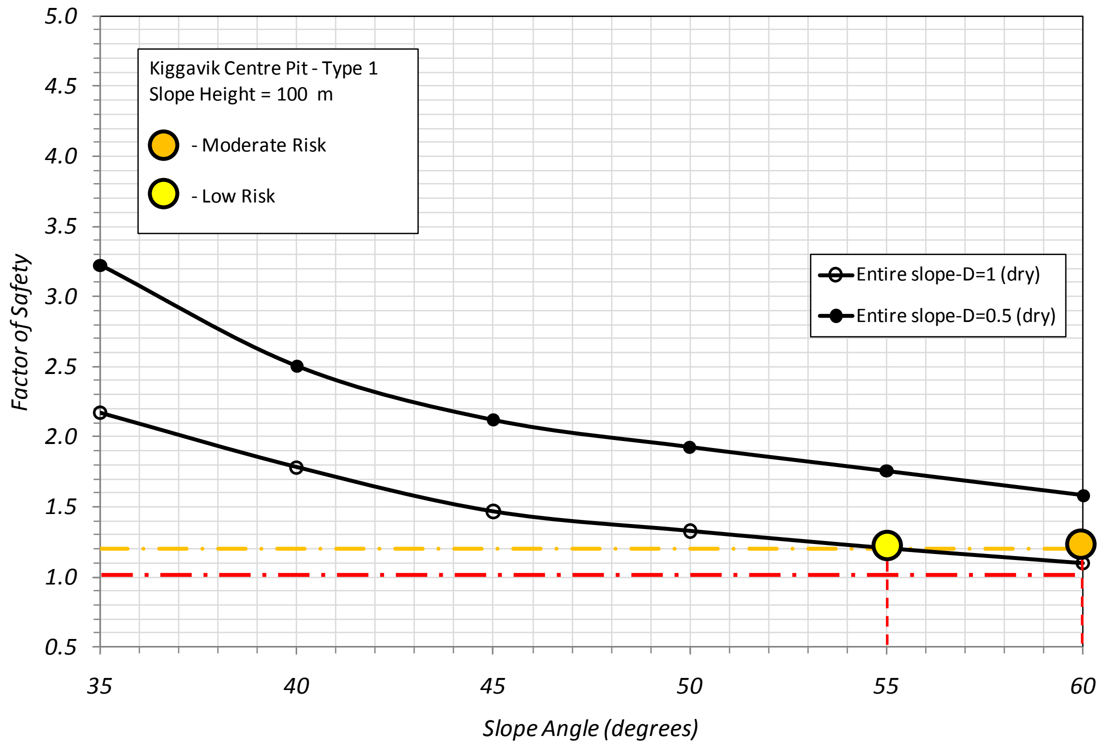


Figure D8: Centre Zone Type 1 Slope - Slope Angle versus Factor of Safety for the Full Slope Altered Rock Mass Configuration.

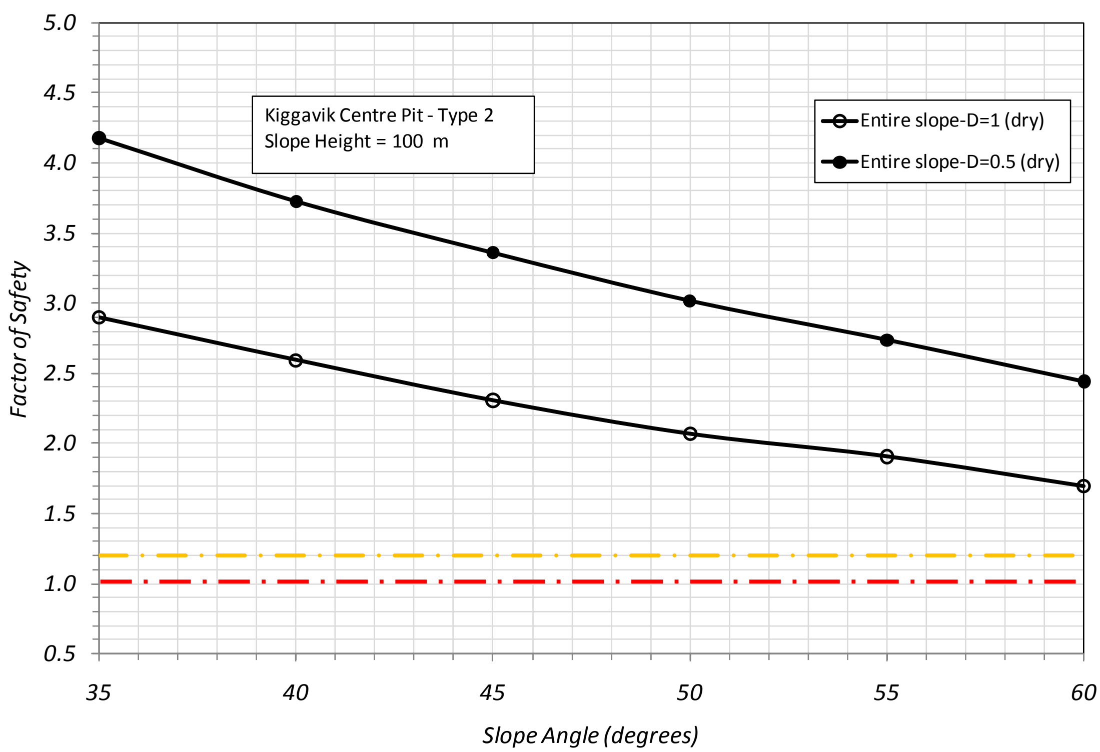


Figure D9: Centre Zone Type 2 Slope - Slope Angle versus Factor of Safety for the Lower Slope Altered Rock Mass Configuration.

The slope stability results for the Centre Zone configurations have been tabulated in Table D3. Recommended slope angles for the upper, lower, and full slope heights are given along with the perceived level of risk for either slope type. Generally a low to moderate risk of rock mass instability is expected for the Centre Zone pit. A maximum slope angle of 60° has been assumed for the non-altered and partially altered rock mass slope configurations. This appears to be conservative based on the stability analysis results and will have to be compared with the results of the kinematics assessment to assess the applicability of this angle.

Table D3: Centre Zone Pit - Recommended maximum slope angles for rock mass slope stability.

Rock Mass Slope Configuration		Full Slope (0 m to 100 m)	Perceived Risk/Sensitivity of the design to variations in strength
Type 1	Full slope alteration	55°	Moderate risk
Type 2	Lower slope alteration	60°	Low risk
Type 3	No slope alteration	60°	Low risk

3.0 FLOOR HEAVE STABILITY ANALYSES

3.1 Methodology

A simple analysis was carried out to assess the depth at which floor heave due to artesian water pressures would become an issue at the Main Zone and Centre Zone sites. These analyses follow the assumption that the presence of pressurized water might be encountered below the permafrost boundary. At either site, during mining of the open pit, the excavation of the rock mass will reduce the overburden pressure counteracting the water pressure at depth. If a critical depth is reached without the reduction in water pressure, the potential exists for floor heave and water infiltration into the base of the pit. This could present considerable problems for mine operations, as well as potentially reducing the stability of the pit walls. The floor heave analyses follow previous work conducted by Golder (1989), except that both self weight resistance to floor heave, as well as rock mass failure were both considered.

The depth of the permafrost boundary, and assumed water pressure conditions used in the analyses are summarised in Table D4. This data was cited from the geotechnical investigation data report (Golder 2009). An assumed value was used in the analyses where a range of values was recorded.

Table D4: Permafrost depths and hydraulic heads used in the floor heave analyses.

Site	Depth of Permafrost – Measured (Assumed)	Hydraulic Head above ground surface
Kiggavik	207 to 216 m (210 m)	25.2 m

Rock mass strength parameters and density were required to assess the rock mass pressure and strength for resistance to floor heave. The rock mass in the floor of the planned open pits is inferred to be predominantly altered and faulted, therefore the weakest material parameters were assumed in the analyses (Table D5). A disturbance factor (D) of 0.5 and 1 was also considered due to potential reduction in rock mass strength related to blasting and stress relief. This is likely a conservative estimation, particularly when considering the rock mass at considerable depth away from the pit floor.

Table D5: Floor Heave Analyses - Rock mass parameters

Rock Type	GSI = RMR	UCS (MPa)	m_i	D	ρ(kg/m^3)
Ore Halo Alteration	50	25	12	0.5 or 1	2,450

*GSI = Geological Strength Index (Hoek-Brown), RMR = Rock Mass Rating (1976), UCS = unconfined compressive strength, mi = Hoek-Brown material coefficient, ρ = bulk density, D = Hoek-Brown disturbance factor

The general layout of the pit and hydraulic/permafrost considerations is shown on Figure D10 below. The water pressure (Pw) acting at depth below the permafrost boundary is calculated from the depth of the permafrost (Dp) and hydraulic head above ground surface (Hw). The rock pressure (Pr) resisting the potential floor heave and water infiltration are assessed from the depth of the rock from the floor to the permafrost boundary (Dr). The rock pressure considered both the weight of the rock mass only, as well as the weight and strength components of the rock mass. The strength component was calculated from the rock mass shear strength (τ_{rm}), derived from the H-B criterion. A confining pressure of two-thirds of the depth of the rock (2/3Dr) was used in calculating the rock mass shear strength. A pressure differential (dP=Pr-Pw), being rock pressure minus the water pressure is calculated for varying pit slope depths (Ho). As the depth of the pit increases, the pressure differential decreases. When the water pressure exceeds the rock pressure (negative differential pressure), there exists the risk for floor heave and water infiltration.

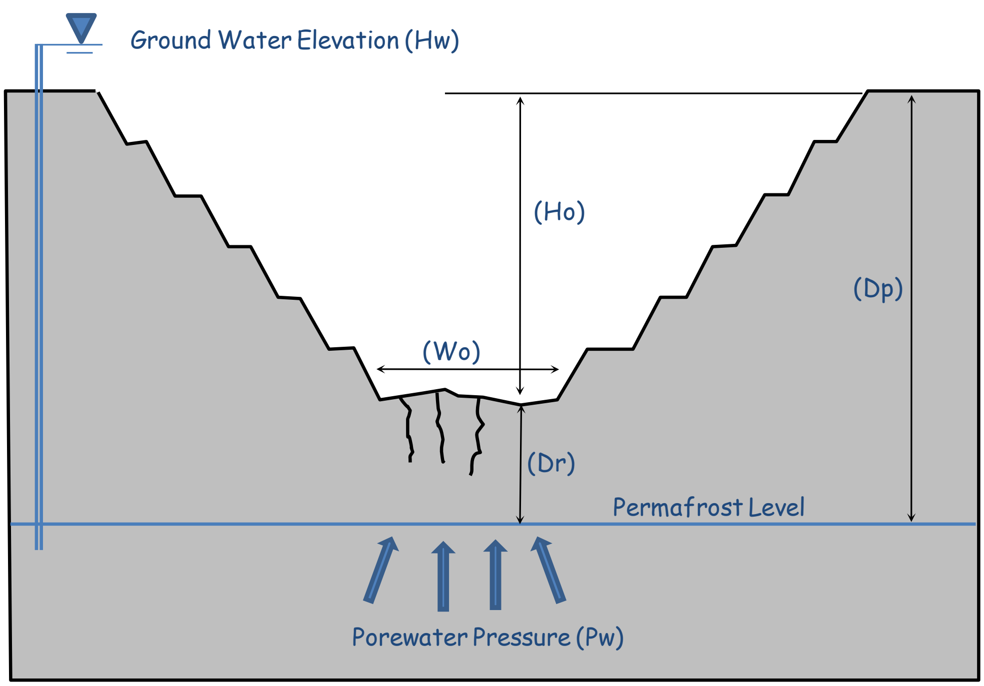


Figure D10: General Representation of the Components Used in the Floor Heave Analyses.

3.2 Floor Heave Analysis Results

The floor heave analysis results for Main Zone and Centre Zone, plotting the differential pressure versus pit depth, is shown on Figure D11. Negative differential pressures, related to unstable conditions, are shown to occur at between 110 m and 160 m. A pit depth of 110 m is recommended for consideration of alleviation of floor water pressures, which corresponds to approximately one half of the planned pit depth at Main Zone. The Centre Zone pit has a planned depth of 105 m, therefore drainage considerations are not likely required.

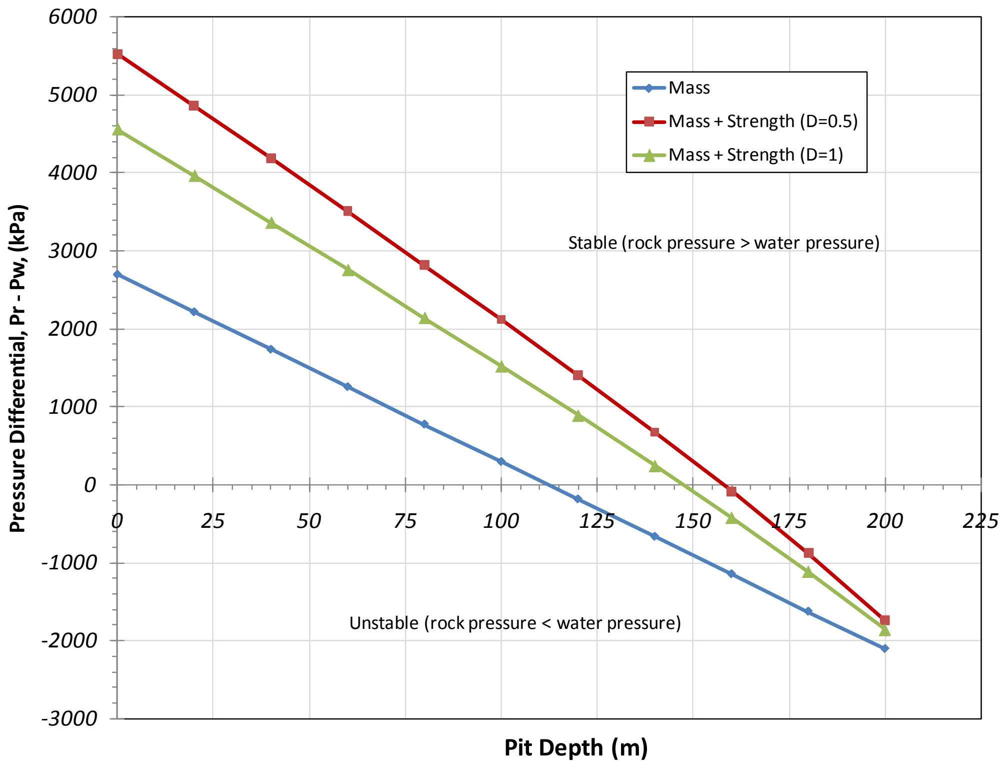


Figure D11: Main and Centre Zones – Floor Heave Analysis Results Showing Differential Pressure versus Pit Depth.

The recommended critical depths of mining for floor heave drainage considerations are given on Table D6. These depths represent the rock mass components of resisting pressure only. The strength components of the rock mass are assumed to be an additional factor of safety. If floor drainage systems are proven to be effective at reducing the water pressures below the permafrost boundary, full depth of mining would be achievable without risk of floor heave.

Table D6: Recommended critical depths at which remedial measures such as vertical pressure relief drains may be required to prevent floor heave – self weight and rock mass failure

Site	Planned Depth of Pit (m)	Expected Depth to Permafrost (m)	Critical Depth[a] (m) – Self Weight	Critical Depth (m) – Rock Mass Failure
Main Zone	200	210	110	150
Centre Zone	105	210	-	-

a = Critical depth of the pit floor at which floor pore water pressure reductions should start assuming self weight resistance only. Consideration should be given to establishing a geotechnical bench at this depth for depressurization.

4.0 REFERENCES

Golder Associates Ltd. 1989. Report to Urangesellschaft Canada Limited on the Mining Geotechnical Aspects of the Proposed Kiggavik Uranium Operations. Volume I of II and Volume II of II. Project #882-1421/881-1814G. August 1989.

Golder Associates Ltd. 2009. Draft 2009 Kiggavik Geotechnical and Hydrogeological Investigation Data Report. November, 2009. Project #09-1362-0613. November 2009.

Hoek, E., Carranza-Torres, C., Corkum, B. 2002. Hoek-Brown Failure Criterion – 2002 Edition. www.rocscience.com

RocLab v.1031 (www.rocscience.com)

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APPENDIX E

Kinematic Analysis

Table of Contents

TABLES

FIGURES

1.0 INTRODUCTION

The slopes in the Main Zone and Centre Zone pits will be susceptible to kinematic structurally controlled failure. Kinematics were analyzed using the structural data for each deposit, outlined in Appendix C. The methodology used to analyze the potential kinematic controls was deterministic in nature, and results are presented below.

2.0 STRUCTURALLY CONTROLLED FAILURE MECHANISMS

Structurally controlled failure in rock occurs as the result of movement along pre-existing geological discontinuities. The three basic mechanisms of structurally controlled failure in rock slopes are planar failures, wedge failures, and toppling failures, as described below.

A **planar failure** may occur when a geological discontinuity dips out of a rock slope at an angle that is shallower than the inclination of the slope and steeper than the effective angle of friction on the discontinuity. Planar failures will generally only develop to a significant extent if the strike of the geologic discontinuity is within $\pm 20^\circ$ of the strike of the rock slope. In some cases, this range was expanded in the analyses to $\pm 30^\circ$ to account for variability in slope dip direction for each design sector.

Wedge failure may occur when two or more geological discontinuities intersect to form an unstable wedge. In order for a wedge to fail, the line of intersection of the wedge must dip out of the slope at an inclination that is shallower than the inclination of the slope face, but steeper than the effective angle of friction along the discontinuities. Wedge failures will only develop to a significant extent if the azimuth of the line of intersection is within $\pm 45^\circ$ of the dip direction of the slope face.

Toppling failure may develop when a rock mass contains multiple, parallel, steeply dipping continuous geologic structures, that strike nearly parallel to the strike of the face of the rock slope. Toppling failure will generally only develop when the strike of the structures is within $\pm 10^\circ$ of the azimuth of the slope face. Kinematically, the potential for toppling failure is determined by the spacing (separation), inclination and continuity of the toppling blocks and the slope angle. Wide spacing and/or discontinuous structures will mitigate the potential for toppling. At a bench scale, this failure mechanism is controlled by berm width and/or the inclusion of mid-slope catch berms, both which improve stability by reducing the effective length of the toppling blocks.

All structurally controlled failure modes are aggravated by water pressures within the slope, particularly toppling failures. Water pressure was not included in the kinematic analysis, as dry conditions were assumed in all pit slopes. It will be important to monitor the groundwater elevations at each deposit and, where required, install long horizontal drains.

The magnitude and frequency of structurally controlled failures are directly related to the continuity and spacing of the structures along which sliding can occur. Rock mass structures that exhibit limited continuity, such as joints, may result in small bench scale failures that are rarely of consequence to overall slope stability but may adversely affect access ramps or equipment installations. Conversely, larger scale failures can occur along continuous, through-going structures, such as faults. It is, therefore, these more continuous structures that are of primary concern.

2.1 Design Sectors

Figure E2 presents the kinematic design sectors for Main Zone and Centre Zone. At Main Zone, the kinematic design sectors were broken down into east wall, west wall, foot wall and hanging wall components. The footwall and hanging wall sectors were further sub-divided to account for pit geometry. At Centre Zone, the pit geometry is essentially circular allowing use of a sub-set of the kinematic sectors at Main Zone.

2.2 Slope Design Definitions

A pit slope has three major components: bench configuration, inter-ramp slope and overall slope, as illustrated on Figure E1. The bench configuration is defined by vertical bench separation (or bench height), catch berm width (or berm width) and bench face angle (or batter). The inter-ramp slope is formed by a series of uninterrupted benches and the overall slope is formed by a series of inter-ramp slopes separated by haul roads.

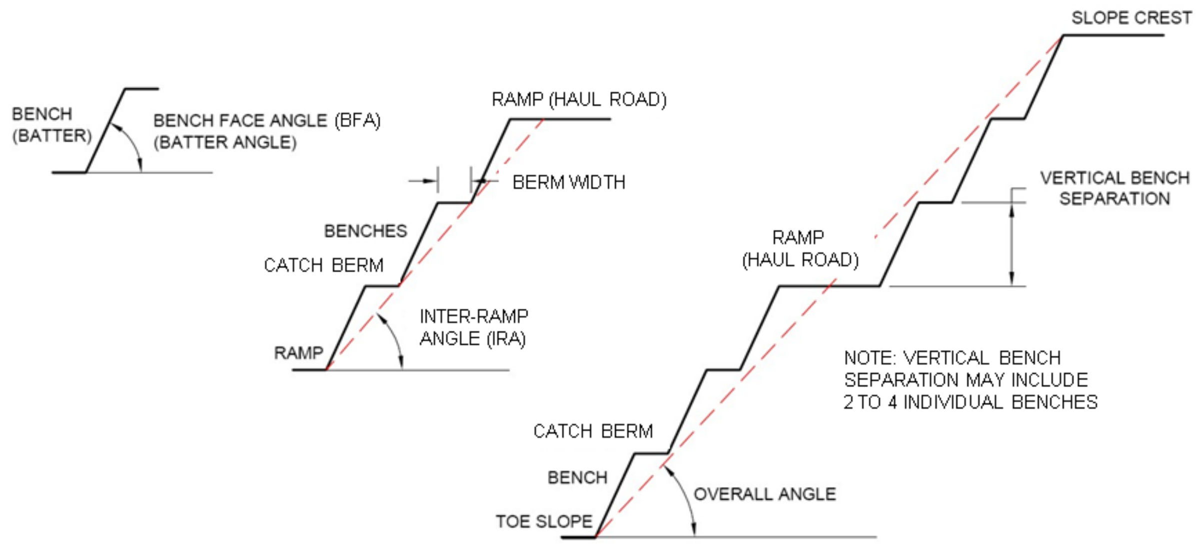
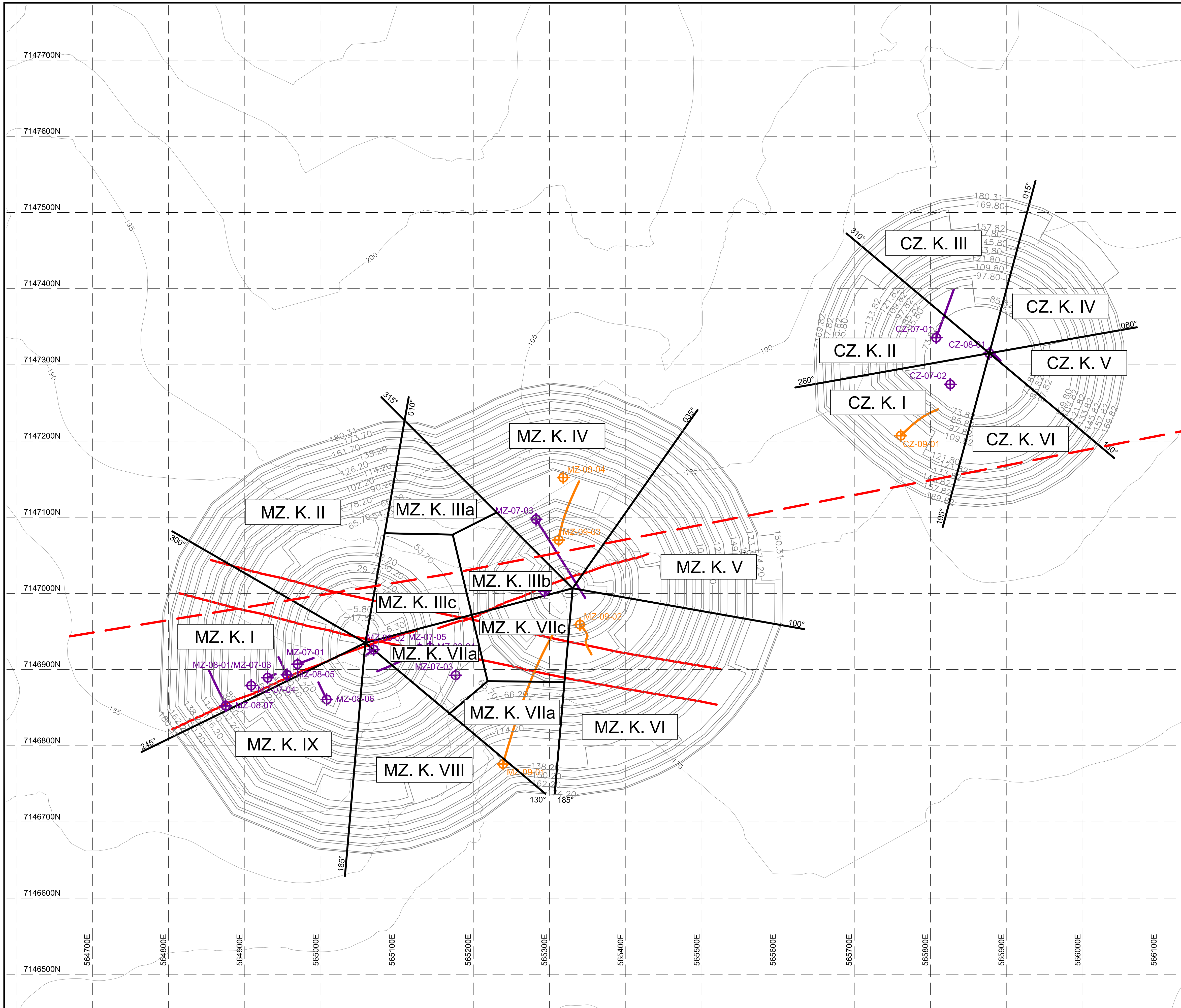


Figure E1: Schematic Representation of Bench Face Angle (BFA) and Inter-ramp Angle (IRA).



LEGEND:

ANDW-08-01 DRILLHOLES FROM 2007 & 2008 INVESTIGATIONS (SRK)

AND-09-01 DRILLHOLES FROM 2009 INVESTIGATIONS (GOLDER)

REGIONAL FAULT TREND (REF. 1)

INFERRED FAULT INTERSECTION ON PIT WALL (REF. 2)

REFERENCES:

1. BASED ON REGIONAL GEOLOGY DRAWINGS (MAIN TEXT FIGURES 4 & 5).
2. AREVA GEOLOGICAL MODEL (2009).

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SCALE 1:5000 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

AREVA

AREVA RESOURCES CANADA INC.
KIGGAVIK PROJECT

TITLE

KINEMATIC DESIGN SECTORS
MAIN ZONE AND CENTRE ZONE

Golder Associates
Saskatoon, Saskatchewan, Canada

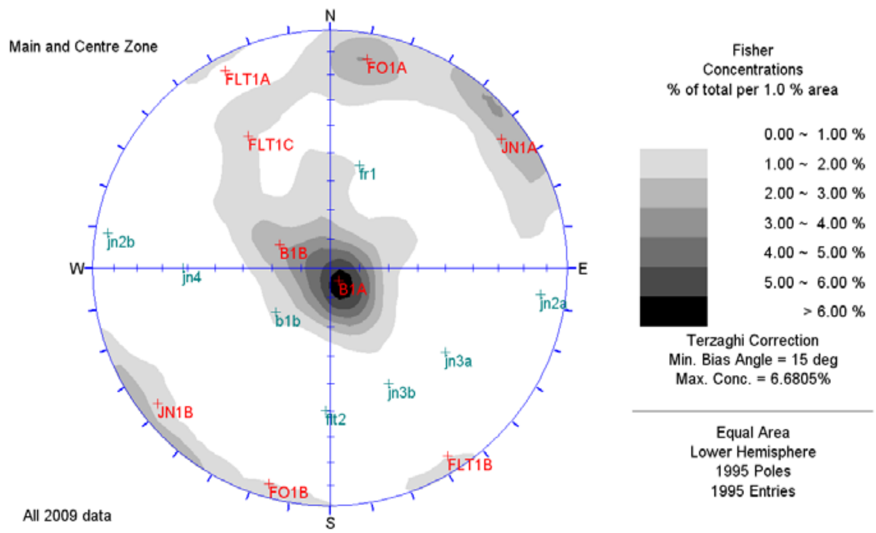
PROJECT No.		09-1362-0613	FILE No.	0913620613AB0E1.dwg
DESIGN		12/06/2009	SCALE AS SHOWN	REV. A
CAD	JS	12/22/2009	FIGURE	
CHECK	EAM	12/22/2009		
REVIEW	MR	12/22/2009		E2

PLOT DATE: February 25, 2011
FILENAME: G:\2009\1362\09-1362-0613 Areva Kiggavik Golder Internal Field Manual\CAD\from Mississauga\-AB-\0913620613AB0E1.dwg

2.3 Kinematic Assessment

2.3.1 Rock Mass Fabrics

The structural rock mass fabrics for the Main Zone and Centre Zone deposits are shown on Figure E3. This figure presents the major and minor discontinuity sets that will be used in the kinematic analysis. The selection of discontinuity sets for the kinematic analyses are discussed in Appendix C.



Set	Dip	Dip Dir
JN1A	79	233
JN1B	81	52
FO1A	78	190
FO1B	83	16
FLT1A	83	152
FLT1B	82	328
FLT1C	55	148
B1A	5	326
B1B	19	115
b1c	24	51
flt2	50	2
jn2a	78	277
jn2b	84	99
jn3a	50	306
jn3b	45	333
jn4	52	90
fr1	37	196

Figure E3: Main and Centre Zones - 2009 Oriented Core Data (contoured) with Selected MAJOR and minor Sets.

It is recognized that one of the limitations of core orientation is the interpretation of continuity and frequency for a given discontinuity set. Large scale characteristics can only reasonably be assessed from actual mining exposures. For example, when a discontinuity set is very continuous but widely spaced, it would show a low concentration of poles and be classified as minor set in the stereonet, whereas a closely spaced, but discontinuous set would show a high concentration of poles and be classified as a major set in the stereographic projections, based on the frequency of data measurements. In addition, for identically spaced discontinuities, the smaller the angle at which the structures intersect the borehole axis, the fewer the number of structures that will be encountered. An effect of this condition is that boreholes have a “blind zone”, such that structures that are approximately parallel to the borehole are rarely encountered. Engineering judgement is therefore required for selecting the sets that would be considered continuous with the potential to affect multiple benches (i.e., be more than 20 m to 30 m long), for the application of the kinematic analysis. For this judgment, the following information is used:

- regional and local geology;
- interpretation of orientation of the mineralized zones;
- occurrence and the orientation of the major geological structures, such as fault, shear zones and dykes;
- outcrop exposures;

- pole concentrations in the stereographic projections; and
- type of discontinuity (e.g., vein, foliation, bedding, etc.).

At Main and Centre Zones, and according to the criteria discussed in Appendix C, certain sets were considered to be major, while others were considered minor.

Similar to the discussion of structural domains in Appendix C, the determination of the continuity of the sets identified at Main Zone and Centre Zone was based on a relatively small data set. This should be reassessed as more orientation data for each deposit becomes available.

2.3.2 Shear Strength

Direct shear testing was not conducted for the Kiggavik project; therefore, discontinuity shear strength properties were estimated based on core log data. Friction angles at both Main and Centre Zones were estimated based on the logged Joint Roughness Number (Jr) and Joint Alteration Number (Ja) parameters for each discontinuity. Jr and Ja are numerical values used in Barton's Q rock mass classification system, and they attempt to describe the friction and strength conditions along the discontinuity face. Jr, and Ja are described in detail in the geotechnical data report prepared by Golder entitled "2009 Kiggavik Geotechnical and Hydrogeological Investigation Data Report".

Two methods were used to estimate the friction angle for each discontinuity set. The ratio of Jr/Ja developed by Barton et al. (1974) for the Q system attempts to quantify the strength of the discontinuity surface. A rough estimate of the peak discontinuity friction angle can be made using $\tan^{-1}$ (Jr/Ja). The second method utilized correlations developed between the Ja parameter and the residual friction angle, as presented by Barton and Grimstad (1994). Generally, the two methods were comparable to each other, however, estimating the friction angle based on $\tan^{-1}$ (Jr/Ja) tended to overestimate the friction angle when the discontinuity surface was clean or rough. If there was a discrepancy between the two methods used to estimate the friction angle, the residual friction angle estimated based on Barton and Grimstad (1994) was used, as it was the more conservative value.

For the current kinematic analyses under dry slope conditions, a shear strength along the discontinuity sets identified at each deposit was assumed to be represented by zero cohesion and a friction angle ϕ = 30°, as summarized on Table E1. Given that the cohesion component can be reduced or eliminated by freeze-thaw, dilation related to blasting or stress relief, or other factors, the assumption of zero cohesion along discontinuities is reasonable. The friction angle can be considered as a conservative value for some of the discontinuities with clean and slightly altered surfaces, however, it is considered representative of the relatively high frequency of coated joints (predominantly calcite and quartz, with some chlorite and clay coatings).

It must be recognized that for faults and shear zones, the friction angle is likely to be lower than 35° due to soft material infilling on these features. It is possible in these zones that the shear strength would typically vary from 20° to 25°. Therefore, it is important to properly locate the known faults and shear zones on the geological model when designing the pit shell, particularly for the location of the access ramps.

Table E1: Main Zone and Centre Zone Kinematic Sets Showing Friction Angle and Spacing

Set	Dip	Dip Dir	Φ(˚)	Spacing (m)*
JN1A	79	233	35	
JN1B	81	52	35	0.89
FO1A	78	190	35	
FO1B	83	16	35	0.99
FLT1A	83	152	35	
FLT1B	82	328	35	
FLT1C	55	148	35	1.38
B1A	5	326	35	
B1B	19	116	35	
b1c	24	51	35	0.72
flt2	50	2	35	1.49
jn2a	78	277	35	
jn2b	84	99	35	0.86
jn3a	50	306	35	
jn3b	45	333	35	4.24
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Dip Dir = Dip Direction; Φ = friction angle. Spacing taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

2.3.3 Set Spacing

As shown in Table E1, the discontinuity spacing for each set was estimated from the oriented core data. This was done by identifying features that were part of the same discontinuity set, based on the stereonet analysis from each borehole. These sets were then grouped, and the average spacing between them was calculated. It should be noted that the actual spacing between discontinuities may vary significantly from the average spacing presented, as there are a number of limitations and biases associated with this approach.

2.3.4 Kinematic Design Criteria

The following criteria have been used to define the potential level for planar, wedge and toppling modes of failure, based on the major and minor sets identified at each deposit location:

2.3.4.1 Planar Failure

Major Potential – When involving a major set, as it is assumed to be continuous and could impact both the bench face (BFA) and inter-ramp (IRA) angles, with potential to affect multiple benches.

Minor Potential – When involving a minor set, as it is considered to be discontinuous compared to the bench height.

A planar failure is considered if the following conditions are met:

- the plane on which sliding occurs must strike within approximately ±30˚ to the slope face;

- the dip of the sliding plane is less than the dip of the slope face (daylights on the slope face); and
- the dip of the sliding plane is greater than the angle of friction of this plane.

2.3.4.2 Wedge Failure

Factors of safety (FS) were calculated for the potential wedges that could form by the intersection of any two discontinuity sets. A wedge would be considered stable for a factor of safety greater than 1.2. A wedge with a FS less than 1.2 would require additional consideration (flatten the bench face angle or widening the benches, depending upon whether the wedge is created by major or minor fabric as discussed below). The FS for wedges was calculated using a deterministic limiting equilibrium approach detailed in Appendix 3 of Rock Slope Engineering 4th Edition (Wyllie 2007). In the deterministic approach the major and minor peak set orientations established through the structural fabric analysis represented the orientation of the failure surfaces. The deterministic approach considered:

- shear strength represented by cohesion and angle of friction (ϕ), as presented in Table E1, was used for the analyses and served as a screening process to identify the critical wedges (i.e., those that showed FS less than or equal to 1.2); and
- dry conditions without excess pore water pressure acting within the discontinuity surface.

The following are the potential levels used in the kinematic analysis of wedges:

Major Potential – When the wedge has a FS less than 1.2 and is formed by the intersection of two major sets (i.e., formed by major rock mass fabric), and at least one of them is considered to be very persistent (i.e., foliation or parallel to fault sets). It is considered that it can impact the stability of both the BFA and IRA. In general, consideration is given to flatten the BFA and IRA.

Moderate Potential – When the wedge is formed by the intersection of a major and a minor set, it is considered that it would locally impact the BFA stability and could also impact the IRA. If the wedge is sliding along the plane of the major set, then the IRA should, as much as practically possible be within the plunge of this wedge. Subsequent structural mapping of the exposed bench faces during the initial production stage should confirm if the minor set is discontinuous as assumed in the analysis.

Minor Potential – When the wedge is formed by the intersection of two minor sets, which are considered to be discontinuous, then it may only locally affect the bench face (or batter) stability and it is considered that the wedge will be retained by the catch-berm. Consideration is given to widening the benches, particularly, if a steeper BFA is used.

2.3.4.3 Toppling

The following was considered in assessing toppling potential for the kinematic design sectors:

Major Potential – When it involves a major steeply dipping set and a shallow dipping set, which would facilitate toppling. In addition, the major discontinuity set also shows small spacing between the planes, and have a preferential orientation to the slope face for toppling.

Moderate Potential – When it involves a major set, but there is no shallow dipping set, or the orientation of the major set compared to the slope face was not preferential to toppling. Development of toppling becomes more difficult in this case.

Minor Potential, Minor Likelihood or Not Likely – When involving a major or minor set that has wide spacing or a minor set, which is assumed discontinuous.

The potential for toppling was assessed based on the shape of the blocks (block shape test), the relationship between the dip of the planes forming the slabs and the face angle (inter-layer slip test) and the orientation of the toppling set with respect to the wall (block alignment test). The block shape test states that if the ratio of the width of the block to the height of the block is less than the tangent of the base plane angle, then the centre of gravity of the block lies outside the base of the block, and the block is susceptible to toppling. The condition for inter-layer slip states that for toppling to occur, the dip of the wall must be greater than or equal to ninety degrees minus the dip of the toppling set plus the friction angle of the toppling set. The block alignment kinematic condition for toppling is that the steep inwardly dipping toppling set should strike approximately parallel to the wall face. The dip direction of the toppling set should be within approximately ± 10° of the wall dip direction (Wyllie 2007).

2.4 Results of Kinematic Assessment

Figures E4 to E12 illustrate the planar, wedge, and toppling potentials in terms of the major and minor set arrangements at Main/Centre Zone. Tables E2 and E3 present the results of the kinematic analyses for each deposit location.

General observations from the kinematic analyses from the Main and Centre Zones include:

- a number of high angle major discontinuity sets dipping at 77° to 83° (FO1, JN1, FLT1A/FLT1B and JN2) likely to limit BFA for controls on planar and toppling failures;
- the risk of toppling is likely reduced due to the relatively tight spacing of the flat bedding set (B1) which would reduce the column height of toppling blocks; and
- a number of major wedge combinations plunging from 50° to 82° along kinematically favourable wall orientations likely to require controls on both the BFA and IRA.

3.0 REFERENCES

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\\sas1-s-filesrv1\data\active\2009\1362\09-1362-0613 areva kiggavik geotechnical baker lake nunavut\pit slope report\final reports - february 2011\main and centre\app e\app 11 feb 17 main and centre zone appendix e - kinematics analysis fianl_eam.docx

Table E2: Main Zone - Kinematic Design Sectors and Slope Stability Controls

Main Zone Walls			Kinematic Controls							
Kinematic Sectors			Toppling		Planar		Wedge (F.S. ≤1.2)			Comments
			Set	Dip (°)	Set	Dip (°)	Combination		Dip (°)	
WEST WALL	MZ.K.I	Dip Dir: 100˚ (65˚ to 120˚)	jn2a	78	jn2b	84	jn4	**FO1A**	49	Strong control through JN1B. 6 major wedge combinations dipping 54 to 81 likely to limit IRA or BFA. Toppling low likelihood as minor sets; Toppling limit: 47˚+5˚ = 52˚ (for the assumed worst case of continuous columns).
			jn3a	50	jn4	52	jn4	**FLT1C**	50	
					B1B(s)	40	**FLT1C**	**FO1A**	50	
							jn4	**FO1B**	52	
							FLT1C	**JN1B**	54	
							FO1A	**JN1B**	63	
							FO1B	**FLT1A**	72	
							JN1B	**FLT1A**	78	
							JN1B	**FO1B**	81	
							FLT1A	jn2b	83	
HANGWALL	MZ.K.II	Dip Dir: 160˚ (120˚ to 190˚)	**FLT1B**	82	**FLT1A**	83	fr1	jn2a	37	Strong Control through FLT1C dipping at 55˚. 3 major wedge combinations dipping 54 to 63 likely to influence IRA and BFA. 1 potential major planar set dipping at 55 likely to limit BFA and IRA. Toppling limit: 43˚+5˚ = 48˚ (for assumed worst case of continuous columns)
			flt2	50	**FLT1C**	55	**FLT1C**	jn2b	50	
					FO1A(s)	77	**FLT1C**	**JN1B**	54	
					fr1(s)	37	**FLT1C**	**JN1A**	55	
							FO1A	**JN1B**	63	
							JN1A	jn2b	69	
							FO1A	jn2b	77	
							FLT1A	jn2b	83	
	MZ.K.IIIa	Dip Dir: 160˚ (135˚ to 190˚)	**FLT1B**	82	**FLT1A**	83	fr1	jn2a	37	Strong control through FLT1C. 3 major wedge combinations dipping 54 to 63 likely to lower BFA. 1 potential major planar set dipping at 55 likely to limit BFA and IRA. Toppling limit: 43˚+5˚ = 48˚ (for the assumed worst cast of continuous columns).
			flt2	50	**FLT1C**	55	**FLT1C**	jn2b	50	
					FO1A(s)	77	**FLT1C**	**JN1B**	54	
					ft1(s)	37	**FLT1C**	**JN1A**	55	
							FO1A	**JN1B**	63	
							JN1A	jn2b	69	
							FO1A	jn2b	77	
							FLT1A	jn2b	83	
	MZ.K.IIIb	Dip Dir: 100˚ (70˚ to 135˚)	jn2a	78	jn2b	84	jn4	**FO1A**	49	Strong control through JN1B. 6 major wedge combinations dipping 54 to 81 likely to limit BFA, IRA and berm width. Toppling limit: 47˚+5˚ = 52˚ (for the assumed worst case of continuous columns).
			jn3a	50	jn4	52	jn4	**FLT1C**	50	
					B1B(s)	40	**FLT1C**	**FO1A**	50	
							jn4	**FO1B**	52	
							FLT1C	**JN1B**	54	
							FO1A	**JN1B**	63	
							FO1B	**FLT1A**	72	
							JN1B	**FLT1A**	78	
							JN1B	**FO1B**	81	
							FLT1A	jn2b	83	
	MZ.K.IIIc	Dip Dir: 215˚ (190˚ to 250˚)	**FO1B**	83	**FO1A**	77	fr1	jn2b	36	2 major planar sets and 2 major toppling sets dipping 77 to 81 likely to limit BFA. Toppling limit: 42˚+5˚ = 47˚ (for the assumed worst case of continuous columns).
			JN1B	81	**JN1A**	77	fr1	jn2a	37	
					fr1(s)	37	**FLT1C**	jn2b	50	
							FO1A	**FLT1B**	64	
							JN1A	jn2b	69	
							jn2a	**FLT1A**	70	
							FO1A	jn2a	74	
							FO1A	**FLT1A**	77	
							FO1A	**JN1A**	78	
							JN1A	**FLT1A**	78	
	MZ.K.IV	Dip Dir: 175˚ (135˚ to 215˚)	**FLT1B**	82	**FO1A**	77	fr1	jn2b	36	1 major wedge combination dipping 55 and 3 major wedge combinations dipping 77 to 78 likely to limit IRA and BFA respectively. Toppling and planar controls dipping at 77 to 82. Toppling limit: 43˚+5˚ = 48˚ (for assumed worst case of continuous columns)
			flt2	50	FLT1A(s)	83	fr1	jn2a	37	
					FLT1C(s)	55	**FLT1C**	jn2b	50	
					fr1(s)	37	**FLT1C**	**JN1A**	55	
							JN1A	jn2b	69	
							FO1A	jn2b	77	
							FO1A	**FLT1A**	77	
							FO1A	**JN1A**	78	
							JN1A	**FLT1A**	78	
							FLT1A	jn2b	83	

Table E2: Main Zone - Kinematic Design Sectors and Slope Stability Controls (continued)

Main Zone Walls			Kinematic Controls							
Kinematic Sectors			Toppling		Planar		Wedge (F.S. ≤1.2)			Comments
			Set	Dip (°)	Set	Dip (°)	Combination		Dip (°)	
EAST WALL	MZ.K.V	Dip Dir: 235˚ (215˚ to 280˚)	**JN1B**	81	**JN1A**	77	fr1	jn2a	37	1 major toppling and planar set dipping 77 to 81 likely limit to BFA. 5 major wedge combinations dipping 64 to 78 likely to influence BFA and berm width. Toppling limit: 44˚+5˚ = 49˚ (for the assumed worst case of continuous columns).
							jn3a	**FO1A**	43	
							FO1A	**FLT1B**	64	
							jn2a	**FLT1A**	70	
							FO1A	jn2a	74	
							JN1A	**FLT1B**	76	
							FO1A	**FLT1A**	77	
							jn2a	**JN1A**	78	
							FO1A	**JN1A**	78	
							JN1A	**FLT1A**	78	
							jn2a	**FLT1B**	78	
FOOTWALL	MZ.K.VI	Dip Dir: 325˚ (280˚ to 005˚)	**FLT1A**	83	**FLT1B**	82	jn3b	jn2a	43	1 major toppling and planar set dipping 82 to 83 likely limiting BFA. 1 potential toppling set at 55. 1 major wedge combination dipping at 63 likely to influence BFA or berm width. 1 major wedge combination dipping at 82. Toppling limit: 42˚+5˚ = 47˚ (for the assumed worst case of continuous columns).
			FLT1B	55	jn3a	50	jn3b	**JN1A**	43	
					jn3b	45	jn3b	jn3a	45	
							jn3b	flt2	45	
							jn3b	**JN1B**	45	
							flt2	**JN1B**	46	
							flt2	jn3a	46	
							jn3a	**JN1B**	47	
							jn3a	**FO1B**	49	
							flt2	jn2a	50	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							jn2a	**JN1B**	64	
							jn2a	**FO1B**	75	
							FLT1B	**FO1B**	82	
	MZ.K.VIIa	Dip Dir: 340˚ (310˚ to 005˚)	**FLT1A**	83	**FLT1B**	82	jn3b	Jn2a	43	1 major planar and toppling set dipping 82 to 83 likely limiting BFA. 1 major low angle toppling set dipping at 55. 1 major wedge combination dipping at 64 likely influencing BFA and berm width, and 2 major wedge combinations dipping at 79 to 82. Toppling limit: 42˚+5˚ = 47˚ (for the assumed worst case of continuous columns).
			FLT1C	55	jn3b	45	jn3b	**JN1A**	43	
					flt2	45	jn3b	Jn3a	45	
							jn3b	Flt2	45	
							jn3b	**JN1B**	45	
							flt2	**JN1B**	46	
							flt2	jn3a	46	
							jn3a	**JN1B**	47	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							jn2a	**JN1B**	64	
							jn2a	**FO1B**	75	
							JN1B	**FLT1B**	79	
							FLT1B	**FO1B**	82	
	MZ.K.VIIb	Dip Dir: 285˚ (250˚ to 310˚)	jn2b	84	jn2a	78	jn3b	**JN1A**	43	2 major wedge combinations dipping 63 to 64 likely influencing BFA and berm width. 1 major wedge combination dipping at 76 likely limiting BFA. Toppling limit: 41˚+5˚ = 46˚ (for the assumed worst case of continuous columns).
			FLT1C(s)	50			jn3a	**FO1A**	43	
							jn3b	flt2	45	
							jn3a	**FO1B**	49	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							FO1A	**FLT1B**	64	
							jn2a	**FO1B**	75	
							JN1A	**FLT1B**	76	
							jn2a	**JN1A**	78	
							jn2a	**FLT1B**	78	

Table E2: Main Zone - Kinematic Design Sectors and Slope Stability Controls (continued)

Main Zone Walls			Kinematic Controls							
Kinematic Sectors			Toppling		Planar		Wedge (F.S. ≤1.2)			Comments
			Set	Dip (°)	Set	Dip (°)	Combination		Dip (°)	
FOOTWALL	MZ.K.VIIc	Dip Dir: 040˚ (005˚ to 070˚)	**JN1A**	79	**JN1B**	81	flt2	jn4	42	2 major planar sets dipping 81 to 83 and 2 major toppling sets dipping 78 to 79 likely limiting BFA. 1 major wedge combination dipping at 72, and 3 major wedge combinations dipping 79 to 82 likely influencing BFA. Toppling limit: 46˚+5˚ = 51˚ (for the assumed worst case of continuous columns).
			FO1A	78	**FO1B**	83	jn3b	jn2a	43	
							jn4	**FLT1B**	44	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn4	**FLT1A**	50	
							jn2a	**JN1B**	64	
							FO1B	**FLT1A**	72	
							FLT1B	jn2b	73	
							JN1B	**FLT1B**	79	
							JN1B	**FO1B**	81	
							JN1B	jn2b	81	
							FO1B	jn2b	81	
							FLT1B	**FO1B**	82	
	MZ.K.VIII	Dip Dir: 340˚ (310˚ to 005˚)	**FLT1A**	83	**FLT1B**	82	jn3b	Jn2a	43	1 major planar and toppling set dipping 82 to 83 likely limiting BFA. 1 major low angle toppling set dipping at 55. 1 major wedge combination dipping at 64 likely influencing BFA and berm width, and 2 major wedge combinations dipping at 79 to 82. Toppling limit: 42˚+5˚ = 47˚ (for the assumed worst case of continuous columns).
			FLT1C	55	jn3b	45	jn3b	**JN1A**	43	
					flt2	45	jn3b	Jn3a	45	
							jn3b	Flt2	45	
							jn3b	**JN1B**	45	
							flt2	**JN1B**	46	
							flt2	jn3a	46	
							jn3a	**JN1B**	47	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							jn2a	**JN1B**	64	
							jn2a	**FO1B**	75	
							JN1B	**FLT1B**	79	
							FLT1B	**FO1B**	82	
	MZ.K.IX	Dip Dir: 040˚ (005˚ to 065˚)	**JN1A**	79	**JN1B**	81	flt2	jn4	42	2 major planar sets dipping 81 to 83 and 2 major toppling sets dipping 78 to 79 likely limiting BFA. 1 major wedge combination dipping at 72, and 3 major wedge combinations dipping 79 to 82 likely influencing BFA. Toppling limit: 46˚+5˚ = 51˚ (for the assumed worst case of continuous columns).
			FO1A	78	**FO1B**	83	jn3b	jn2a	43	
							jn4	**FLT1B**	44	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn4	**FLT1A**	50	
							jn2a	**JN1B**	64	
							FO1B	**FLT1A**	72	
							FLT1B	jn2b	73	
							JN1B	**FLT1B**	79	
							JN1B	**FO1B**	81	
							JN1B	jn2b	81	
							FO1B	jn2b	81	
							FLT1B	**FO1B**	82	

Table E3: Centre Zone - Kinematic Design Sectors and Slope Stability Controls

Centre Zone Walls			Kinematic Controls							
Kinematic Sectors			Toppling		Planar		Wedge (F.S. ≤1.2)			Comments
			Set	Dip (°)	Set	Dip (°)	Combination		Dip (°)	
WEST WALL	CZ.K.I	Dip Dir: 040˚ (015˚ to 080˚)	**JN1A**	79	**JN1B**	81	flt2	jn4	42	2 major planar sets dipping 81 to 83 and 2 major toppling sets dipping 78 to 79 likely limiting BFA. 1 major wedge combination dipping at 72, and 3 major wedge combinations dipping 79 to 82 likely influencing BFA. Toppling limit: 46˚+5˚ = 51˚. (for assumed worst case of continuous columns)
			FO1A	78	**FO1B**	83	jn3b	jn2a	43	
							jn4	**FLT1B**	44	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn4	**FLT1A**	50	
							jn2a	**JN1B**	64	
							FO1B	**FLT1A**	72	
							FLT1B	jn2b	73	
							JN1B	**FLT1B**	79	
							JN1B	**FO1B**	81	
							JN1B	jn2b	81	
							FO1B	jn2b	81	
							FLT1B	**FO1B**	82	
HANG WALL	CZ.K.II	Dip Dir: 100˚ (080˚ to 130˚)	jn2a	78	jn2b	84	jn4	**FO1A**	49	Strong control through JN1B. 6 major wedge combinations dipping 54 to 81 likely to influence BFA, IRA and berm width. Toppling limit: 47˚+5˚ = 52˚ (for assumed worst case of continuous columns)
			jn3a	50	jn4	52	jn4	**FLT1C**	50	
					B1B(s)	40	**FLT1C**	**FO1A**	50	
							jn4	**FO1B**	52	
							FLT1C	**JN1B**	54	
							FO1A	**JN1B**	63	
							FO1B	**FLT1A**	72	
							JN1B	**FLT1A**	78	
							JN1B	**FO1B**	81	
							FLT1A	jn2b	83	
	CZ.K.III	Dip Dir: 160˚ (130˚ to 195˚)	**FLT1B**	82	**FLT1A**	83	fr1	jn2a	37	Strong control through FLT1C. 3 major wedge combinations dipping 54 to 63 likely to lower BFA. 1 potential major planar set dipping at 55 likely to influence BFA and IRA. Toppling limit: 43˚+5˚ = 48˚ (for assumed worst case continuous columns).
			flt2	50	**FLT1C**	55	**FLT1C**	jn2b	50	
					FO1A(s)	77	**FLT1C**	**JN1B**	54	
					ft1(s)	37	**FLT1C**	**JN1A**	55	
							FO1A	**JN1B**	63	
							JN1A	jn2b	69	
							FO1A	jn2b	77	
							FLT1A	jn2b	83	
EAST WALL	CZ.K.IV	Dip Dir: 235˚ (195˚ to 260˚)	**JN1B**	81	**JN1A**	77	fr1	jn2a	37	1 major toppling and planar set dipping 77 to 81 likely limit to BFA. 5 major wedge combinations dipping 64 to 78 likely to influence BFA and berm width. Toppling limit: 44˚+5˚ = 49˚ (for assumed worst case of continuous columns)
							jn3a	**FO1A**	43	
							FO1A	**FLT1B**	64	
							jn2a	**FLT1A**	70	
							FO1A	jn2a	74	
							JN1A	**FLT1B**	76	
							FO1A	**FLT1A**	77	
							jn2a	**JN1A**	78	
							FO1A	**JN1A**	78	
							JN1A	**FLT1A**	78	
							jn2a	**FLT1B**	78	
FOOT WALL	CZ.K.V	Dip Dir: 285˚ (260˚ to 310˚)	jn2b	84	jn2a	78	jn3b	**JN1A**	43	2 major wedge combinations dipping 63 to 64 likely influencing BFA and berm width. 1 major wedge combination dipping at 76 likely limiting BFA. Toppling limit: 41˚+5˚ = 46˚ (for assumed worst case of continuous columns).
			FLT1C(s)	50			jn3a	**FO1A**	43	
							jn3b	flt2	45	
							jn3a	**FO1B**	49	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							FO1A	**FLT1B**	64	
							jn2a	**FO1B**	75	
							JN1A	**FLT1B**	76	
							jn2a	**JN1A**	78	
							jn2a	**FLT1B**	78	

Table E3: Centre Zone - Kinematic Design Sectors and Slope Stability Controls (continued)

Centre Zone Walls			Kinematic Controls							
Kinematic Sectors			Toppling		Planar		Wedge (F.S. ≤1.2)			Comments
			Set	Dip (°)	Set	Dip (°)	Combination		Dip (°)	
FOOT WALL	CZ.K.VI	Dip Dir: 340˚ (310˚ to 015˚)	**FLT1A**	83	**FLT1B**	82	jn3b	Jn2a	43	1 major planar and toppling set dipping 82 to 83 likely limiting BFA. 1 major low angle toppling set dipping at 55. 1 major wedge combination dipping at 63 may locally influence BFA and berm width, and 2 major wedge combinations dipping at 79 to 82. Toppling limit: 42˚+5˚ = 47˚ (for assumed worst case of continuous columns)
			FLT1C	55	jn3b	45	jn3b	**JN1A**	43	
					flt2	45	jn3b	Jn3a	45	
							jn3b	Flt2	45	
							jn3b	**JN1B**	45	
							flt2	**JN1B**	46	
							flt2	jn3a	46	
							jn3a	**JN1B**	47	
							flt2	jn2b	49	
							flt2	jn2a	50	
							jn3a	**JN1A**	50	
							JN1A	**FO1B**	63	
							jn2a	**JN1B**	64	
							jn2a	**FO1B**	75	
							JN1B	**FLT1B**	79	
							FLT1B	**FO1B**	82	

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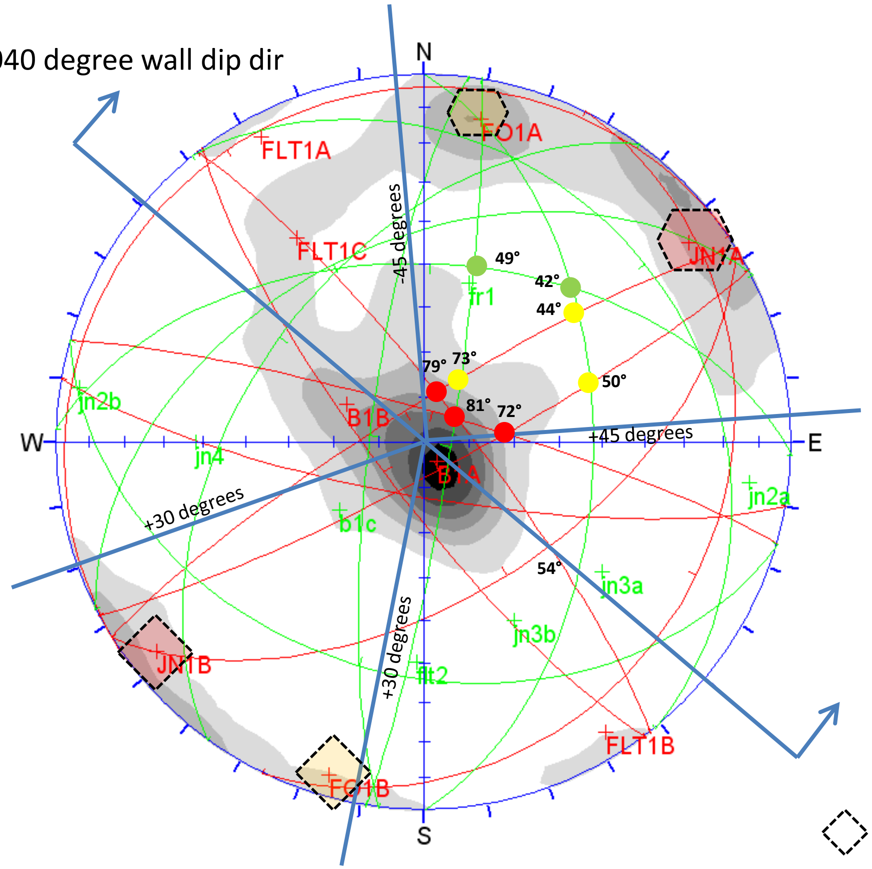
Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 040 degrees

Figure E4

Kinematic Design Sectors:
MZ.K.IX
MZ.K.VIIc
CZ.KI



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
b1c	**FLT1C**	22	75	1.86
b1c	**FLT1A**	23	65	1.77
b1c	jn3b	23	37	1.68
b1c	**FLT1B**	24	54	1.62
jn3b	jn4	30	27	1.55
jn3b	jn2b	37	14	1.42
flt2	jn4	42	44	0.94
jn3b	jn2a	43	356	1.11
jn4	**FLT1B**	44	50	1.12
flt2	jn2b	49	16	0.71
flt2	jn2a	50	353	0.65
jn4	**FLT1A**	50	71	0.81
jn2a	**JN1B**	64	341	0.81
FO1B	**FLT1A**	72	84	0.59
FLT1B	jn2b	73	30	0.48
JN1B	**FLT1B**	79	14	0.19
JN1B	**FO1B**	81	55	0.13
JN1B	jn2b	81	51	0.12
FO1B	jn2b	81	52	0.14
FLT1B	**FO1B**	82	343	0.11

Planar Failures

Major Potential - Set JN1B (81˚)
Moderate Potential – Set FO1B (83˚)

Toppling Failures

Major Potential – Set JN1A (79˚)
Moderate Potential - Set FO1A (78˚)

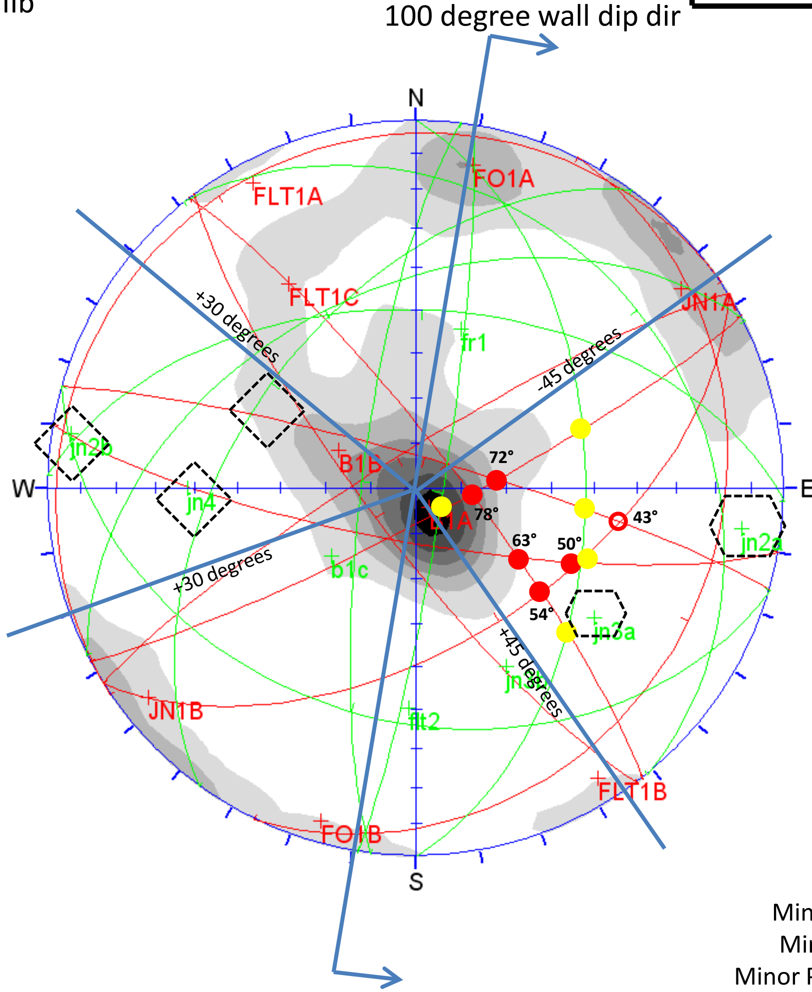
- Potential Wedge Failures FS < 1.2 (Major-Major) (red dot)
- Potential Wedge Failures FS < 1.2 (Major-minor) (yellow dot)
- Potential Wedge Failures FS < 1.2 (minor-minor) (green dot)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major) (red circle)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 100 degrees

Figure E5

Kinematic Design Sectors:
MZ.K.I
MZ.K.IIIb
CZ.K.II



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
b1c	FLT1C	22	75	1.86
b1c	FLT1A	23	65	1.77
jn4	JN1B	43	134	1.63
FLT1C	FO1B	43	99	1.35
jn4	FO1A	49	114	0.76
jn4	FLT1C	50	113	0.65
FLT1C	FO1A	50	115	1.17
jn4	FLT1A	50	71	0.81
jn4	FO1B	52	97	0.62
FLT1C	JN1B	54	130	0.63
FO1A	JN1B	63	124	0.91
FO1B	FLT1A	72	84	0.59
JN1B	FLT1A	78	96	0.24
JN1B	FO1B	81	55	0.13
FLT1A	jn2b	83	134	0.10

Planar Failures

Minor Potential - Set jn2b (84˚)
Minor Potential – Set jn4 (52˚)
Minor Potential – Set B1B scatter (40˚)

Toppling Failures

Minor Potential - Set jn2a (78˚)
Minor Potential – Set jn3a (50˚)

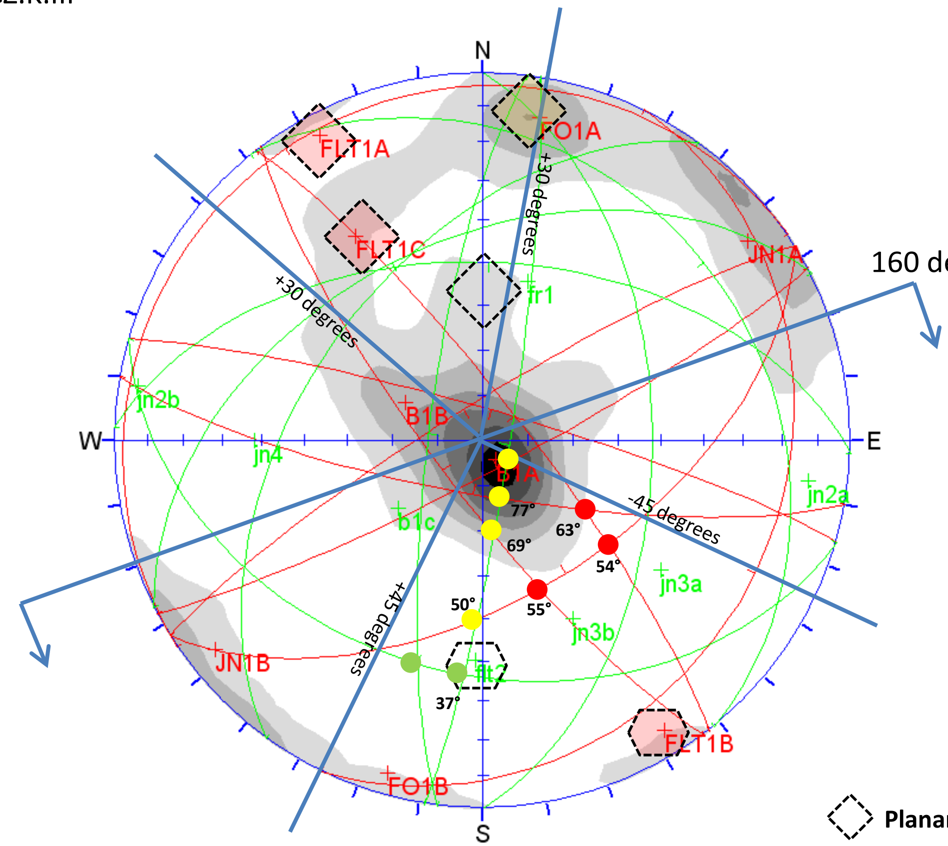
- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 160 degrees

Figure E6

Kinematic Design Sectors:
MZ.K.II
MZ.K.IIIa
CZ.K.III



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
fr1	jn4	29	154	1.49
fr1	jn2b	36	185	1.05
fr1	jn2a	37	196	0.93
FLT1C	jn2a	42	198	1.32
jn4	**JN1B**	43	134	1.63
FLT1C	jn2b	50	182	1.06
FLT1C	**JN1B**	54	130	0.63
FLT1C	**JN1A**	55	159	0.56
FO1A	**JN1B**	63	124	0.91
JN1A	jn2b	69	173	0.65
FO1A	jn2b	77	163	0.22
FLT1A	jn2b	83	134	0.10

Planar Failures

Major Potential - Set FLT1A (83˚)
Major Potential – Set FLT1C (55˚)
Moderate Potential – Set FO1A scatter (77˚)
Minor Potential – Set fr1 scatter (37˚)

Toppling Failures

Major Potential - Set FLT1B (82˚)
Minor Potential – Set flt2 (50˚)

- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

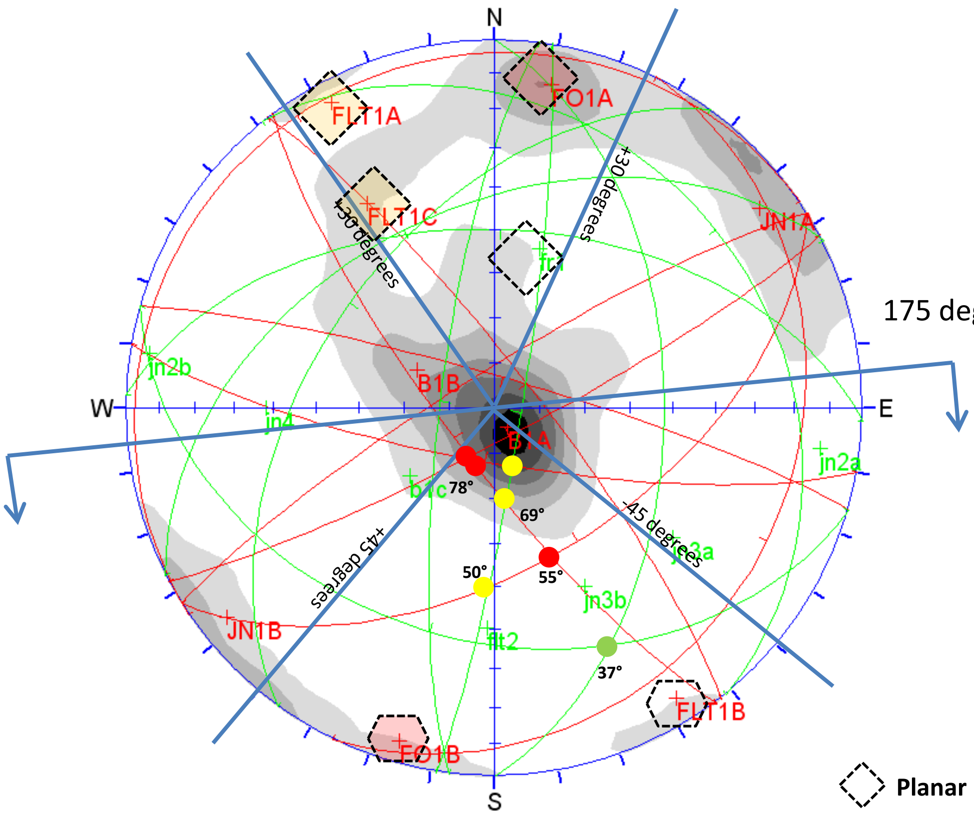
•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kinematic Design Sectors:
MZ.K.IV

Kiggavik – Main and Centre Zone Kinematic Assessment Wall Dip 175 degrees

Figure E7

Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18



Planar Failures

Moderate Potential - Set FLT1A (83˚)
Moderate Potential – Set FLT1C (55˚)
Major Potential – Set FO1A (77˚)
Minor Potential – Set fr1 scatter (37˚)

Toppling Failures

Major Potential - Set FLT1B (82˚)
Minor Potential – Set flt2 (50˚)

Potential Wedge Failures FS < 1.2 (Major-Major)
Potential Wedge Failures FS < 1.2 (Major-minor)
Potential Wedge Failures FS < 1.2 (minor-minor)
Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
fr1	jn4	29	154	1.49
fr1	jn2b	36	185	1.05
fr1	FLT1C	37	207	1.25
fr1	jn2a	37	196	0.93
FLT1C	jn2a	42	198	1.32
jn4	JN1B	43	134	1.63
FLT1C	jn2b	50	182	1.06
FLT1C	JN1A	55	159	0.56
JN1A	jn2b	69	173	0.65
FO1A	jn2b	77	163	0.22
FO1A	FLT1A	77	209	0.29
FO1A	JN1A	78	205	0.16
JN1A	FLT1A	78	207	0.19
FLT1A	jn2b	83	134	0.10

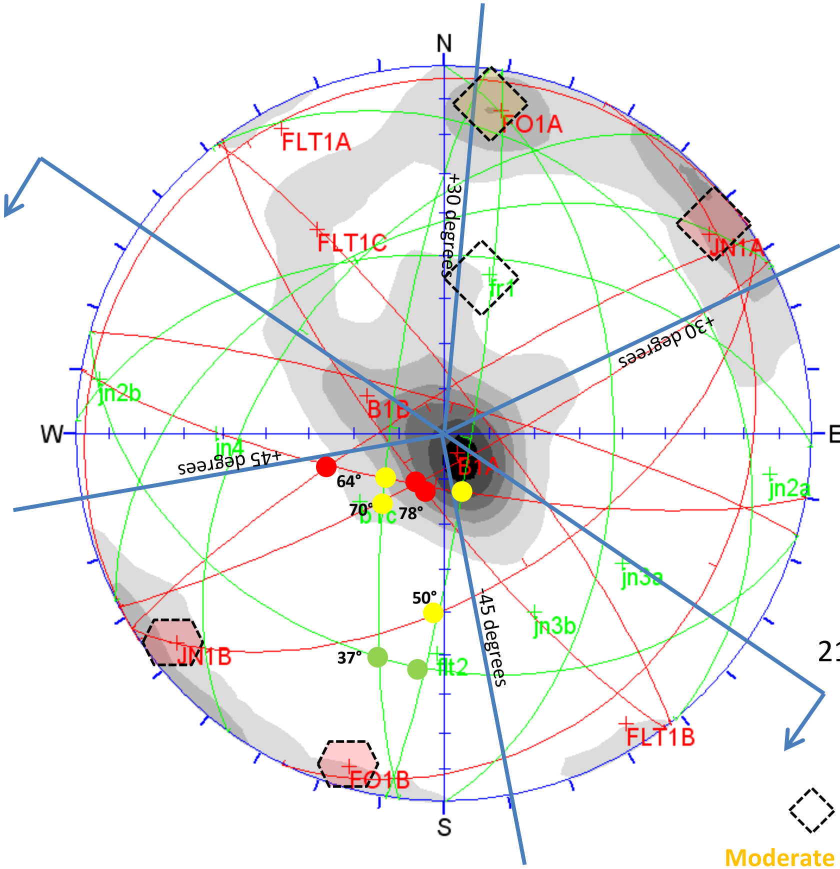
•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kinematic Design Sectors:
MZ.K.IIIc

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 215 degrees

Figure E8

Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18



215 degree wall dip dir

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
fr1	**FLT1B**	28	242	1.99
fr1	jn3a	28	242	1.61
fr1	jn2b	36	185	1.05
fr1	**FLT1C**	37	207	1.25
fr1	jn2a	37	196	0.93
FLT1C	jn2a	42	198	1.32
FLT1C	jn2b	50	182	1.06
FO1A	**FLT1B**	64	255	0.88
JN1A	jn2b	69	173	0.65
jn2a	**FLT1A**	70	222	0.52
FO1A	jn2a	74	234	0.28
FO1A	**FLT1A**	77	209	0.29
FO1A	**JN1A**	78	205	0.16
JN1A	**FLT1A**	78	207	0.19

Planar Failures

Moderate Potential – Set FO1A (77˚)
Major Potential – Set JN1A (77˚)
Minor Potential – Set fr1 scatter (37˚)

Toppling Failures

Major Potential - Set FO1B (83˚)
Major Potential - Set JN1B (81˚)

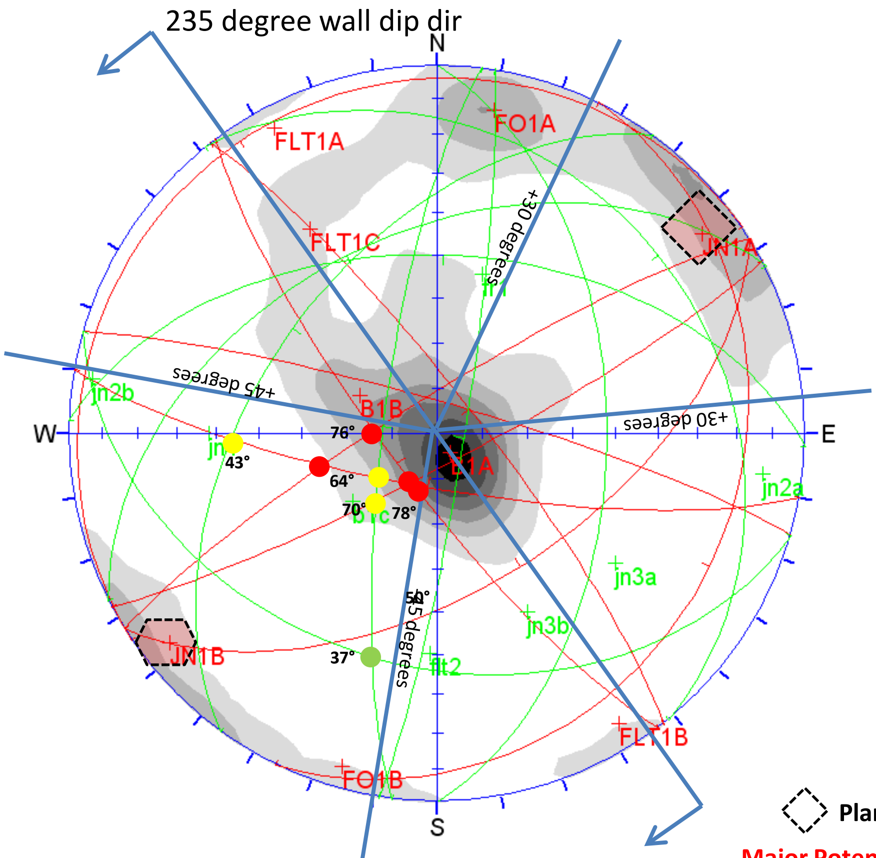
- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 235 degrees

Figure E9

Kinematic Design Sectors:
MZ.K.V
CZ.K.IV



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
fr1	FLT1B	28	242	1.99
fr1	jn3a	28	242	1.61
fr1	FLT1C	37	207	1.25
fr1	jn2a	37	196	0.93
FLT1C	jn2a	42	198	1.32
jn3a	FO1A	43	268	1.08
FO1A	FLT1B	64	255	0.88
jn2a	FLT1A	70	222	0.52
FO1A	jn2a	74	234	0.28
JN1A	FLT1B	76	272	0.25
FO1A	FLT1A	77	209	0.29
jn2a	JN1A	78	261	0.17
FO1A	JN1A	78	205	0.16
JN1A	FLT1A	78	207	0.19
jn2a	FLT1B	78	279	0.15

Planar Failures
Major Potential – Set JN1A (77°)

Toppling Failures
Major Potential - Set JN1B (81°)

- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

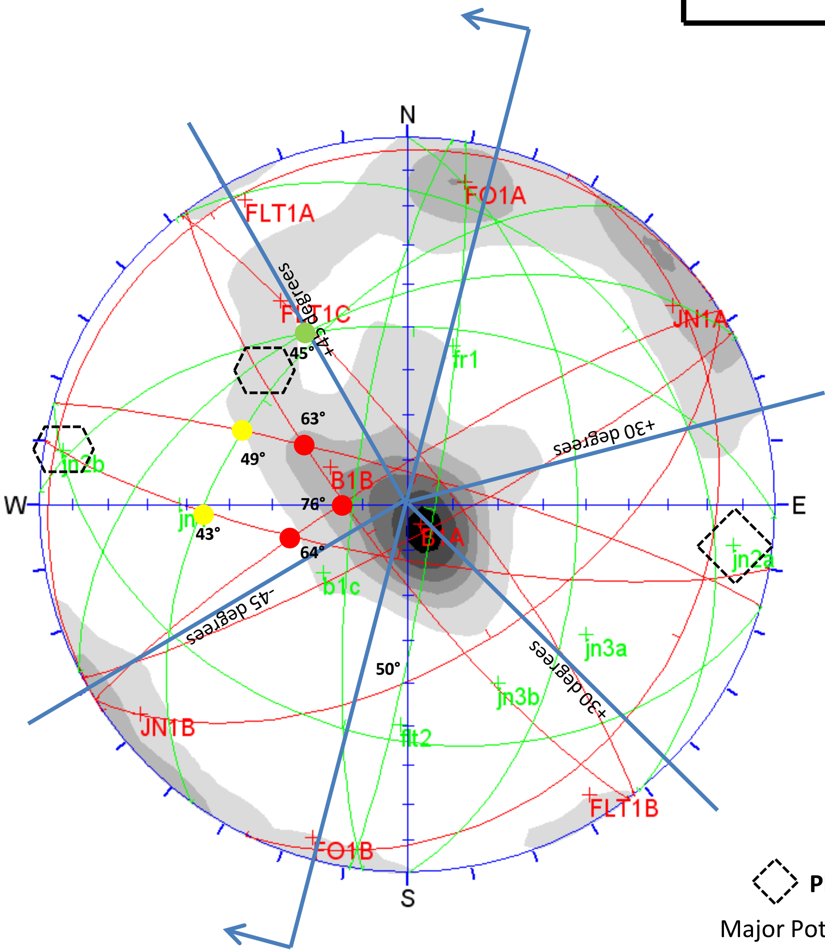
•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 285 degrees

Figure E10

Kinematic Design Sectors:
MZ.K.VIIb
CZ.K.V

285 degree wall dip dir



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
fr1	**FLT1B**	28	242	1.99
fr1	jn3a	28	242	1.61
jn3b	**FO1B**	37	291	1.71
flt2	**JN1A**	39	314	1.44
jn3b	**JN1A**	43	313	0.91
jn3a	**FO1A**	43	268	1.08
jn3b	flt2	45	329	0.89
jn3a	**FO1B**	49	294	0.73
jn3a	**JN1A**	50	310	0.63
JN1A	**FO1B**	63	300	1.00
FO1A	**FLT1B**	64	255	0.88
jn2a	**FO1B**	75	314	0.27
JN1A	**FLT1B**	76	272	0.25
jn2a	**JN1A**	78	261	0.17
jn2a	**FLT1B**	78	279	0.15

Planar Failures

Major Potential – Set jn2a (78˚)

Toppling Failures

Minor Potential – Set jn2b (84˚)
Minor Potential – Set FLT1C scatter (~50˚)

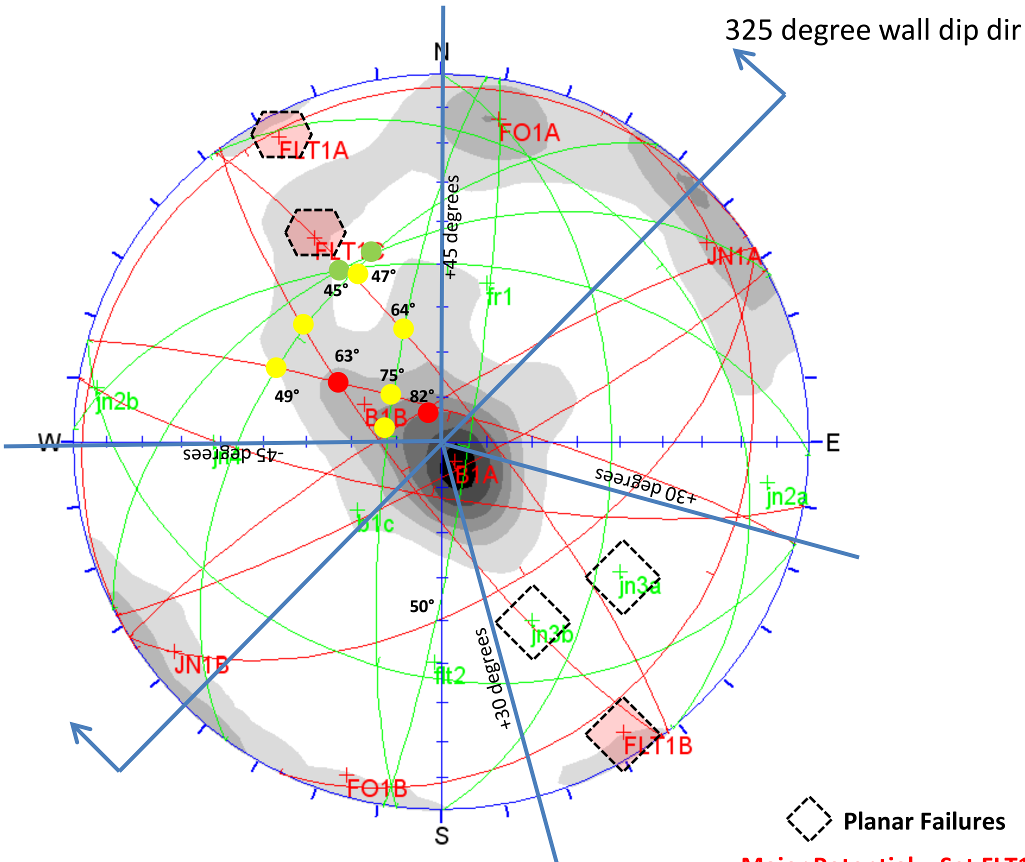
- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 325 degrees

Figure E11

Kinematic Design Sectors:
MZ.K.VI



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
jn3b	**FO1B**	37	291	1.71
flt2	**JN1A**	39	314	1.44
jn3b	jn2a	43	356	1.11
jn3b	**JN1A**	43	313	0.91
jn3b	jn3a	45	340	1.02
jn3b	flt2	45	329	0.89
jn3b	**JN1B**	45	331	0.72
flt2	**JN1B**	46	331	1.15
flt2	jn3a	46	334	0.71
jn3a	**JN1B**	47	332	0.86
jn3a	**FO1B**	49	294	0.73
flt2	jn2a	50	353	0.65
jn3a	**JN1A**	50	310	0.63
JN1A	**FO1B**	63	300	1.00
jn2a	**JN1B**	64	341	0.81
jn2a	**FO1B**	75	314	0.27
FLT1B	**FO1B**	82	343	0.11

Planar Failures

Major Potential – Set FLT1B (82˚)

Minor Potential – Set jn3a/jn3b (45˚ to 50˚)

Toppling Failures

Major Potential – Set FLT1A (83˚)

Major Potential – Set FLT1C (55˚)

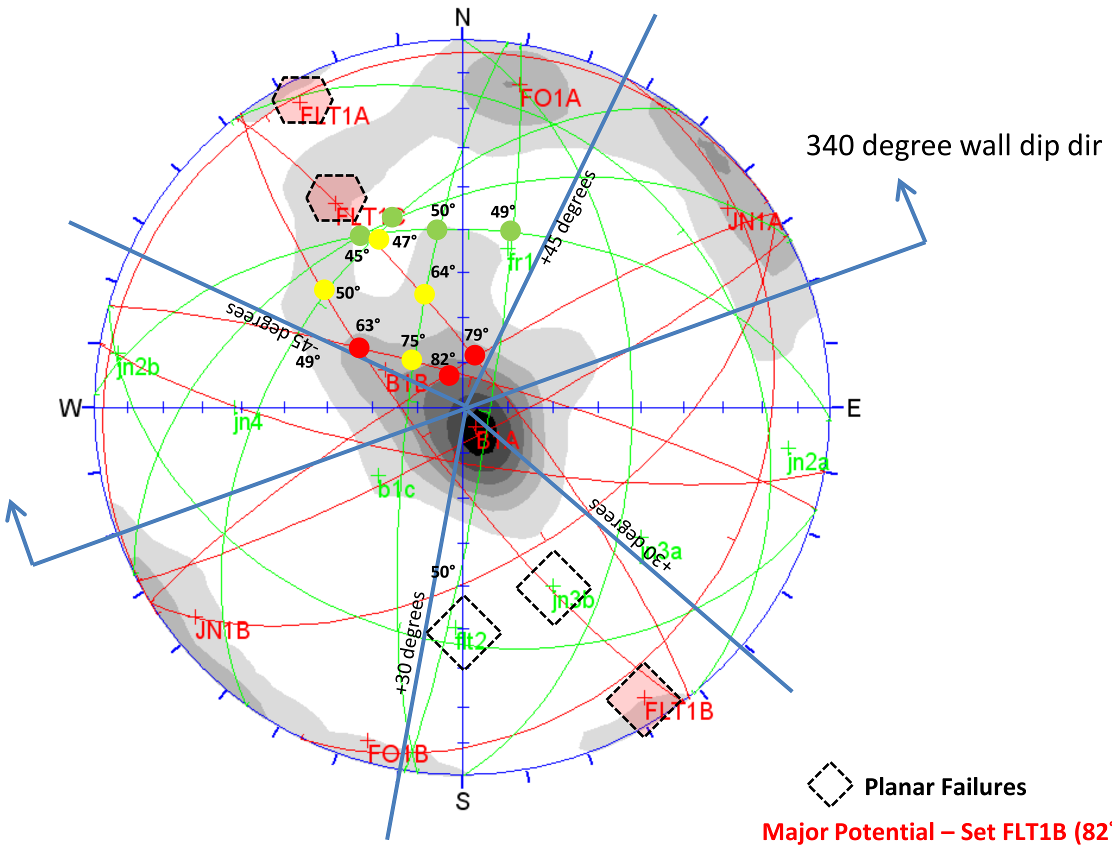
- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

Kiggavik – Main and Centre Zone
Kinematic Assessment
Wall Dip 340 degrees

Figure E12

Kinematic Design Sectors:
MZ.K.VIII
MZ.K.VIIa
CZ.K.VI



Set	Dip	Dip Dir	ϕ	Spacing (m)*
JN1A	79	233	35	0.89
JN1B	81	52	35	
FO1A	78	190	35	0.99
FO1B	83	16	35	
FLT1A	83	152	35	1.38
FLT1B	82	328	35	
FLT1C	55	148	35	
B1A	5	326	35	0.72
B1B	19	116	35	
b1c	24	51	35	
flt2	50	2	35	1.49
jn2a	78	277	35	0.86
jn2b	84	99	35	
jn3a	50	306	35	4.24
jn3b	45	333	35	
jn4	52	90	35	4.29
fr1	37	196	35	2.18

Wedge Analysis

Set 1	Set 2	Plunge	Trend	FS
jn3b	jn4	30	27	1.55
jn3b	Jn2b	37	14	1.42
flt2	JN1A	39	314	1.44
jn3b	Jn2a	43	356	1.11
jn3b	JN1A	43	313	0.91
jn3b	Jn3a	45	340	1.02
jn3b	Flt2	45	329	0.89
jn3b	JN1B	45	331	0.72
flt2	JN1B	46	331	1.15
flt2	jn3a	46	334	0.71
jn3a	JN1B	47	332	0.86
flt2	jn2b	49	16	0.71
flt2	jn2a	50	353	0.65
jn3a	JN1A	50	310	0.63
JN1A	FO1B	63	300	1.00
jn2a	JN1B	64	341	0.81
jn2a	FO1B	75	314	0.27
JN1B	FLT1B	79	14	0.19
FLT1B	FO1B	82	343	0.11

Planar Failures

Major Potential – Set FLT1B (82˚)
Minor Potential – Set jn3b (45˚)
Minor Potential – Set flt2 (45˚)

Toppling Failures

Major Potential – Set FLT1A (83˚)
Major Potential – Set FLT1C (55˚)

- Potential Wedge Failures FS < 1.2 (Major-Major)
- Potential Wedge Failures FS < 1.2 (Major-minor)
- Potential Wedge Failures FS < 1.2 (minor-minor)
- Potential Wedge Failures 1.2 < FS < 2 (Major-Major)

•Spacings taken as average for discontinuity sets indicated. Actual spacing may vary significantly.

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