APPENDIX A

TABLE A.1 - Suggested support measures for the 38 categories (After Barton et al, 1977). Support measures for Rock Masses of "Exceptional', Extremely Good', 'Very Good' and Good Quality (Q range : 1000–10)

Support category	RQD/J_n	J_r/J_a	Span/ESR	Type of support	Note
1*	–	–	–	sb (utg)	–
2*	–	–	–	sb (utg)	–
3*	–	–	–	sb (utg)	–
4*	–	–	–	sb (utg)	–
5*	–	–	–	sb (utg)	–
6*	–	–	–	sb (utg)	–
7*	–	–	–	sb (utg)	–
8*	–	–	–	sb (utg)	–
9	≥ 20	–	–	sb (utg)	–
	< 20	–	–	B (utg) 2.5 – 3 m	–
10	≥ 30	–	–	B (utg) 2 – 3 m	–
	< 30	–	–	B (utg) 1.5 – 2 m + clm	–
11*	≥ 30	–	–	B (tg) 2 – 3 m	–
	< 30	–	–	B (tg) 1.5 – 2 m + clm	–
12*	≥ 30	–	–	B (tg) 2 – 3 m	–
	< 30	–	–	B (tg) 1.5 – 2 m + clm	–

Key to Support Tables:

sb = spot bolting
B = systematic bolting
(utg) = untensioned, grouted
(tg) = tensioned, (expanding shell type for competent rock masses, grouted post-tensioned in very poor quality rock masses; see Note XI)
S = shotcrete
(mr) = mesh reinforced
clm = chain link mesh
CCA = cast concrete arch
(sr) = steel reinforced

Bolt spacings are given in metres (m). Shotcrete, or cast concrete arch thickness is given in centimetres (cm).

Support category	RQD/J_n	J_r/J_a	Span/ESR	Type of support	Note
13	≥ 10	≥ 1.5	–	sb (utg)	I
	≥ 10	< 1.5	–	B (utg) 1.5 – 2 m	I
	< 10	≥ 1.5	–	B (utg) 1.5 – 2 m	I
	< 10	< 1.5	–	B (utg) 1.5 – 2 m + S 2 – 3 cm	I
14	≥ 10	–	≥ 15 m	B (tg) 1.5 – 2 m + clm	I, II
	< 10	–	≥ 15 m	B (tg) 1.5 – 2 m + S (mr) 5 – 10 cm	I, II
	–	–	< 15 m	B (utg) 1.5 – 2 m + clm	I, III
15	> 10	–	–	B (tg) 1.5 – 2 m + clm	I, II, IV
	≤ 10	–	–	B (tg) 1.5 – 2 m + S (mr) 5 – 10 cm	I, II, IV
16* See note XII	> 15	–	–	B (tg) 1.5 – 2 m + clm	I, V, VI
	≤ 15	–	–	B (tg) 1.5 – 2 m + S (mr) 10 – 15 cm	I, V, VI

* Authors' estimates of support. Insufficient case records available for reliable estimation of support requirements.

Note: The type of support to be used in categories 1 to 8 will depend on the blasting technique. Smooth wall blasting and thorough barring-down may remove the need for support. Rough wall blasting may result in the need for single applications of shotcrete, especially where the excavation height is > 25 m. Future case records should differentiate categories 1 to 8.

TABLE A.2 - Suggested support measures for the 38 categories (After Barton et al, 1977). Support measures for Rock Masses of 'Fair' and 'Poor' Quality (Q range : 10 – 1)

Support category	Conditional factors			Type of support	Note
	RQD/J_n	J_r/J_a	Span/ESR		
17	> 30	–	–	sb (utg)	I
	(≥ 10, ≤ 30)	–	–	B (utg) 1 – 1.5 m	I
	< 10	–	≥ 6 m	B (utg) 1 – 1.5 m + S 2 – 3 cm	I
	< 10	–	< 6 m	S 2 – 3 cm	I
18	> 5	–	≥ 10 m	B (tg) 1 – 1.5 m + clm	I, III
	> 5	–	< 10 m	B (utg) 1 – 1.5 m + clm	I
	≤ 5	–	≥ 10 m	B (tg) 1 – 1.5 m + S 2 – 3 cm	I, III
	≤ 5	–	< 10 m	B (utg) 1 – 1.5 m + S 2 – 3 cm	I
19	–	–	≥ 20 m	B (tg) 1 – 2 m + S (mr) 10 – 15 cm	I, II, IV
	–	–	< 20 m	B (tg) 1 – 1.5 m + S (mr) 5 – 10 cm	I, II

Key to Support Tables:

sb = spot bolting
B = systematic bolting
(utg) = untensioned, grouted
(tg) = tensioned, (expanding shell type for competent rock masses, grouted post-tensioned in very poor quality rock masses; see Note XI)
S = shotcrete
(mr) = mesh reinforced
clm = chain link mesh
CCA = cast concrete arch
(sr) = steel reinforced

Bolt spacings are given in metres (m). Shotcrete, or cast concrete arch thickness is given in centimetres (cm).

Support category	Conditional factors			Type of support	Note
	RQD/J_n	J_r/J_a	Span/ESR		
20* See note XII	–	–	≥ 35 m	B (tg) 1 – 2 m + S (mr) 20 – 25 cm	I, V, VI
	–	–	< 35 m	B (tg) 1 – 2 m + S (mr) 10 – 20 cm	I, II, IV
21	≥ 12.5	≤ 0.75	–	B (utg) 1 m + S 2 – 3 cm	I
	< 12.5	≤ 0.75	–	S 2.5 – 5 cm	I
	–	> 0.75	–	B (utg) 1 m	I
22	(> 10, < 30)	> 1.0	–	B (utg) 1 m + clm	I
	≤ 10	> 1.0	–	S 2.5 – 7.5 cm	I
	< 30	≤ 1.0	–	B (utg) 1 m + S (mr) 2.5 – 5 cm	I
	≥ 30	–	–	B (utg) 1 m	I
23	–	–	≥ 15 m	B (tg) 1 – 1.5 m + S (mr) 10 – 15 cm	I, II, IV, VII
	–	–	< 15 m	B (utg) 1 – 1.5 m + S (mr) 5 – 10 cm	I
24* See note XII	–	–	≥ 30 m	B (tg) 1 – 1.5 m + S (mr) 15 – 30 cm	I, V, VI
	–	–	< 30 m	B (tg) 1 – 1.5 m + S (mr) 10 – 15 cm	I, II, IV

* Authors' estimates of support. Insufficient case records available for reliable estimation of support requirements.

TABLE A.3 - Suggested support measures for the 38 categories (After Barton et al, 1977). Support measures for Rock Masses Of 'Very Poor' Quality (Q range : 1 – 0.1)

Support category	RQD/J_n	J_r/J_a	Span/ESR	Type of support	Note
	Conditional factors				
25	> 10	> 0.5	–	B (utg) 1 m + mr or clm	I
	> 10	> 0.5	–	B (utg) 1 m + S (mr) 5 cm	I
	–	≤ 0.5	–	B (tg) 1 m + S (mr) 5 cm	I
26	–	–	–	B (tg) 1 m + S (mr) 5 – 7.5 cm	VIII, X, XI
	–	–	–	B (utg) 1 m + S 2.5 – 5 cm	I, IX
27	–	–	≥ 12 m	B (tg) 1 m + S (mr) 7.5 – 10 cm	I, IX
	–	–	< 12 m	B (utg) 1 m + S (mr) 5 – 7.5 cm	I, IX
	–	–	> 12 m	CCA 20 – 40 cm + B (tg) 1 m	VIII, X, XI
	–	–	< 12 m	S (mr) 10 – 20 cm + B (tg) 1 m	VIII, X, XI

Key to Support Tables:

sb = spot bolting
B = systematic bolting
(utg) = untensioned, grouted
(tg) = tensioned, (expanding shell type for competent rock masses, grouted post-tensioned in very poor quality rock masses; see Note XI)
S = shotcrete
(mr) = mesh reinforced
clm = chain link mesh
CCA = cast concrete arch
(sr) = steel reinforced

Bolt spacings are given in metres (m). Shotcrete, or cast concrete arch thickness is given in centimetres (cm).

Support category	RQD/J_n	J_r/J_a	Span/ESR	Type of support	Note
	Conditional factors				
28*	–	–	≥ 30 m	B (tg) 1 m + S (mr) 30 – 40 cm	I, IV, V, IX
See note XII	–	–	(≥ 20 m, < 30 m)	B (tg) 1 m + S (mr) 20 – 30 cm	I, II, IV, IX
	–	–	< 20 m	B (tg) 1 m + S (mr) 15 – 20 cm	I, II, IX
	–	–	–	CCA (sr) 30 – 100 cm + B (tg) 1 m	IV, VIII, X, XI
29*	> 5	> 0.25	–	B (utg) 1 m + S 2 – 3 cm	–
	≤ 5	> 0.25	–	B (utg) 1 m + S (mr) 5 cm	–
	–	≤ 0.25	–	B (tg) 1 m + S (mr) 5 cm	–
30	≥ 5	–	–	B (tg) 1 m + S 2.5 – 5 cm	IX
	< 5	–	–	S (mr) 5 – 7.5 cm	IX
	–	–	–	B (tg) 1 m + S (mr) 5 – 7.5 cm	VIII, X, XI
31	> 4	–	–	B (tg) 1 m + S (mr) 5 – 12.5 cm	IX
	≤ 4, ≥ 1.5	–	–	S (mr) 7.5 – 25 cm	IX
	< 1.5	–	–	CCA 20 – 40 cm + B (tg) 1 m	IX
	–	–	–	CCA (sr) 30 – 50 cm + B (tg) 1 m	VIII, X, XI
32	–	–	≥ 20 m	B (tg) 1 m + S (mr) 40 – 60 cm	II, IV, IX
See note XII	–	–	< 20 m	B (tg) 1 m + S (mr) 20 – 40 cm	III, IV, IX
	–	–	–	CCA (sr) 40 – 120 cm + B (tg) 1 m	IV, VIII, X, XI

TABLE A.4 - Suggested support measures for the 38 categories (After Barton et al, 1977). Support measures for Rock Masses of 'Extremely Poor' and 'Exceptionally Poor' Quality (Q range : 0.1 – 0.001)

Support category	Conditional factors RQD/J_n	J_r/J_a	Span/ESR	Type of support	Note
33*	≥ 2	–	–	B (tg) 1 m	IX
				+ S (mr) 2.5 – 5 cm	
	< 2	–	–	S (mr) 5 – 10 cm	IX
	–	–	–	S (mr) 7.5 – 15 cm	VIII, X
34	≥ 2	≥ 0.25	–	B (tg) 1 m	IX
				+ S (mr) 5 – 7.5 cm	
	< 2	≥ 0.25	–	S (mr) 7.5 – 15 cm	IX
	–	< 0.25	–	S (mr) 15 – 25 cm	IX
	–	–	–	CCA (sr) 20 – 60 cm	VIII, X,
				+ B (tg) 1 m	XI
35	–	–	≥ 15 m	B (tg) 1 m	II, IX
				+ S (mr) 30 – 100 cm	
	–	–	≥ 15 m	CCA (sr) 60 – 200 cm	VIII, X,
See note				+ B (tg) 1 m	XI, II
XII	–	–	< 15 m	B (tg) 1 m	IX, III
				+ S (mr) 20 – 75 cm	
	–	–	< 15 m	CCA (sr) 40 – 150 cm	VIII, X,
				+ B (tg) 1 m	XI, III
36*	–	–	–	S (mr) 10 – 20 cm	IX
	–	–	–	S (mr) 10 – 20 cm	VIII, X,
				+ B (tg) 0.5 – 1.0	XI
37	–	–	–	S (mr) 20 – 60 cm	IX
	–	–	–	S (mr) 20 – 60 cm	VIII, X,
				+ B (tg) 0.5 – 1.0	XI
38	–	–	≥ 10 m	CCA (sr) 100 – 300 cm	IX
	–	–	≥ 10 m	CCA (sr) 100 – 300 cm	VIII, X,
See note				+ B (tg) 1 m	II, XI
XIII	–	–	< 10 m	S (mr) 70 – 200 cm	IX
	–	–	< 10 m	S (mr) 70 – 200 cm	VIII, X,
				+ B (tg) 1 m	III, XI

Supplementary notes by BARTON, LIEN *and* LUNDE

I. For cases of heavy bursting or 'popping', tensioned bolts with enlarged bearing plates often used, with spacing of about 1 m (occasionally down to 0.8 m). Final support when 'popping' activity ceases.

II. Several bolt lengths often used in same excavation, i.e. 3, 5 and 7 m.

III. Several bolt lengths often used in same excavation, i.e. 2, 3 and 4 m.

IV. Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 2 – 4 m.

V. Several bolt lengths often used in same excavation, i.e. 6, 8 and 10 m.

VI Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 4 – 6 m.

VII. Several of the older generation power stations in this category employ systematic or spot bolting with areas of chain link mesh, and a free span concrete arch roof (25—40 cm) as permanent support.

VIII. Cases involving swelling, for instance montmorillonite clay (with access of water). Room for expansion behind the support is used in cases of heavy swelling. Drainage measures are used where possible.

IX. Cases not involving swelling clay or squeezing rock.

X. Cases involving squeezing rock. Heavy rigid support is generally used as permanent support.

XI. According to the authors' experience, in cases of swelling or squeezing, the temporary support required before concrete (or shotcrete) arches are formed may consist of bolting (tensioned shell-expansion type) if the value of RQD/J_n is sufficiently high (i.e. > 1.5), possibly combined with shotcrete. If the rock mass is very heavily jointed or crushed (i.e. RQD/J_n < 1.5, for example a 'sugar cube' shear zone in quartzite), then the temporary support may consist of up to several applications of shotcrete. Systematic bolting (tensioned) may be added after casting the concrete, but it may not be effective when RQD/J_n < 1.5 or when a lot of clay is present, unless the bolts are grouted before tensioning. A sufficient length of anchored bolt might also be obtained using quick setting resin anchors in these extremely poor quality rock masses. Serious occurrences of swelling and/or squeezing rock may require that the concrete arches are taken right up to the face, possibly using a shield as temporary shuttering. Temporary support of the working face may also be required in these cases.

XII. For reasons of safety the multiple drift method will often be needed during excavation and supporting of roof arch. Categories 16, 20, 24, 28, 32, 35 (SPAN/ESR > 15 m only).

XIII. Multiple drift method usually needed during excavation and support of arch, walls and floor in cases of heavy squeezing. Category 38 (SPAN/ESR > 10 m only).

TABLE A.5 - Supplementary notes by Barton, Lien and Lunde (After Barton et al, 1977)

Supplementary notes by BARTON, LIEN *and* LUNDE

I For cases of heavy bursting or 'popping', tensioned bolts with enlarged bearing plates often used, with spacing of about 1 m (occasionally down to 0.8 m). Final support when 'popping' activity ceases.

II. Several bolt lengths often used in same excavation, i.e. 3, 5 and 7 m.

III. Several bolt lengths often used in same excavation, i.e. 2, 3 and 4 m.

IV. Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 2 – 4 m.

V. Several bolt lengths often used in same excavation, i.e. 6, 8 and 10 m.

VI. Tensioned cable anchors often used to supplement bolt support pressures. Typical spacing 4 – 6 m.

VII. Several of the older generation power stations in this category employ systematic or spot bolting with areas of chain link mesh, and a free span concrete arch roof (25—40 cm) as permanent support.

VIII. Cases involving swelling, for instance montmorillonite clay (with access of water). Room for expansion behind the support is used in cases of heavy swelling. Drainage measures are used where possible.

IX. Cases not involving swelling clay or squeezing rock.

X. Cases involving squeezing rock. Heavy rigid support is generally used as permanent support.

XI. According to the authors' experience, in cases of swelling or squeezing, the temporary support required before concrete (or shotcrete) arches are formed may consist of bolting (tensioned shell-expansion type) if the value of RQD/J_n is sufficiently high (i.e. > 1.5), possibly combined with shotcrete. If the rock mass is very heavily jointed or crushed (i.e. RQD/J_n < 1.5, for example a 'sugar cube' shear zone in quartzite), then the temporary support may consist of up to several applications of shotcrete. Systematic bolting (tensioned) may be added after casting the concrete, but it may not be effective when RQD/J_n < 1.5 or when a lot of clay is present, unless the bolts are grouted before tensioning. A sufficient length of anchored bolt might also be obtained using quick setting resin anchors in these extremely poor quality rock masses. Serious occurrences of swelling and/or squeezing rock may require that the concrete arches are taken right up to the face, possibly using a shield as temporary shuttering. Temporary support of the working face may also be required in these cases.

XII. For reasons of safety the multiple drift method will often be needed during excavation and supporting of roof arch. Categories 16, 20, 24, 28, 32, 35 (SPAN/ESR > 15 m only).

XIII. Multiple drift method usually needed during excavation and support of arch, walls and floor in cases of heavy squeezing. Category 38 (SPAN/ESR > 10 m only).

Supplementary notes by HOEK *and* BROWN *(1980)*

A. Chainlink mesh is sometimes used to catch small pieces of rock which can become loose with time. It should be attached to the rock at intervals of between 1 and 1.5 m and short grouted pins can be used between bolts. Galvanized chainlink mesh should be used where it is intended to be permanent, e.g. in an underground powerhouse.

B. Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.

C. In poorer quality rock, the use of untensioned grouted dowels as recommended by BARTON, LIEN and LUNDE depends upon immediate installation of these reinforcing elements behind the face. This depends upon integrating the support drilling and installation into the drill-blastmuck cycle and many non-Scandinavian contractors are not prepared to consider this system. When it is impossible to ensure that untensioned grouted dowels are going to be installed immediately behind the face, consideration should be given to using tensioned rockbolts which can be grouted at a later stage. This ensures that support is available during the critical excavation stage.

D. Many contractors would consider that a 200 mm thick cast concrete arch is too difficult to construct because there is not enough room between the shutter and the surrounding rock to permit easy ac-

TABLE A.5 - (cont.) Supplementary notes by Barton, Lien and Lunde (After Barton et al, 1977)

cess for pouring concrete and placing vibrators. The US Army Corps of Engineers (1978) suggests 10 inches (254 mm) as a normal minimum while some contractors prefer 300 mm.

E. BARTON, LIEN and LUNDE suggest shotcrete thicknesses of up to 2 m. This would require many separate applications and many contractors would regard shotcrete thicknesses of this magnitude as both impractical and uneconomic, preferring to cast concrete arches instead. A strong argument in favour of shotcrete is that it can be placed very close to the face and hence can be used to provide early support in poor quality rock masses. Many contractors would argue that a 50 to 100 mm layer is generally sufficient for this purpose, particularly when used in conjunction with tensioned rockbolts as indicated by BARTON, LIEN and LUNDE, and that the placing of a cast concrete lining at a later stage would be a more effective way to tackle the problem. Obviously, the final choice will depend upon the unit rates for concreting and shotcreting offered by the contractor and, if shotcrete is cheaper, upon a practical demonstration by the contractor that he can actually place shotcrete to this thickness. In North America, the use of concrete or shotcrete linings of up to 2 m thick would be considered unusual and a combination of heavy steel sets and concrete would normally be used to achieve the high support pressures required in very poor ground.

Supplementary note by STILLBORG

Untensioned, grouted rockbolts are recommended in several support categories. At the time when BARTON et al. proposed their guide for support measures the friction anchored rockbolts were not yet available. The note under Table 6 in connection with BIENIAWSKI's guide for excavation and support in rock tunnels is therefore equally applicable here.

Supplementary notes by HOEK *and* BROWN *(1980)*

A. Chainlink mesh is sometimes used to catch small pieces of rock which can become loose with time. It should be attached to the rock at intervals of between 1 and 1.5 m and short grouted pins can be used between bolts. Galvanized chainlink mesh should be used where it is intended to be permanent, e.g. in an underground powerhouse.

B. Weldmesh, consisting of steel wires set on a square pattern and welded at each intersection, should be used for the reinforcement of shotcrete since it allows easy access of the shotcrete to the rock. Chainlink mesh should never be used for this purpose since the shotcrete cannot penetrate all the spaces between the wires and air pockets are formed with consequent rusting of the wire. When choosing weldmesh, it is important that the mesh can be handled by one or two men working from the top of a high-lift vehicle and hence the mesh should not be too heavy. Typically, 4.2 mm wires set at 100 mm intervals (designated 100 x 100 x 4.2 weldmesh) are used for reinforcing shotcrete.

C. In poorer quality rock, the use of untensioned grouted dowels as recommended by BARTON, LIEN and LUNDE depends upon immediate installation of these reinforcing elements behind the face. This depends upon integrating the support drilling and installation into the drill-blastmuck cycle and many non-Scandinavian contractors are not prepared to consider this system. When it is impossible to ensure that untensioned grouted dowels are going to be installed immediately behind the face, consideration should be given to using tensioned rockbolts which can be grouted at a later stage. This ensures that support is available during the critical excavation stage.

D. Many contractors would consider that a 200 mm thick cast concrete arch is too difficult to construct because there is not enough room between the shutter and the surrounding rock to permit easy ac-

APPENDIX B

E B.1 - CASE STUDY 1 - 10 LEVEL CROSSCUT NO. 9-SHAFT - IMPALA PLATINUM - 640m BELOW SURFACE

Depth bel. surf. (m)	Exc. Height	Exc. Width	Jt Vertical	Dip	Strike	RQD	Act. RQD	Description	Jn	Description	Jr	Description	Ja	Description	Jw	Description	SRF	Description	Q-value	Description	Photos	Supp. Installed & pattern/spacing - Photo No.
640	3	3	2	1	4	108.07	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good	Yes	Plate 19,20
640	3	3	1	0	4	109.5	100	Excellent	3	1 Joint Set Plus Random	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	3	2	1	2	110.27	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	15.0	Good		No Bolting
640	3	3	2	0	5	107.3	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	15.0	Good		No Bolting
640	3	3	5	3	2	106.31	100	Excellent	9	Three Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	6.7	Fair		No Bolting
640	3	3	4	5	3	105.65	100	Excellent	9	Three Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	6.7	Fair	Yes	Plate 14,15,16
640	3	3	2	1	0	112.47	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	No Bolting
640	3	3	1	5	2	110.05	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good	Yes	No Bolting
640	3	3	2	1	0	112.47	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	3	Silty, small clay fraction	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	3	1	1	4	109.17	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	1	4	2	110.38	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good		Spot Bolting
640	3	3	0	1	1	113.57	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	1	2	0	113.24	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	3	Silty, small clay fraction	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Extremely Good		No Bolting
640	3	3	0	1	0	114.67	100	Excellent	1	few	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	150.0	Extremely Good		No Bolting
640	3	3	1	0	6	107.3	100	Excellent	3	One Joint Set plus Random	1.5	Slickensided undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	10.0	Good		No Bolting
640	3	3	2	1	3	109.17	100	Excellent	4	Two Joint Sets	4	Discontinuous Joints	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	3	0	0	2	112.8	100	Excellent	2	One Joint Set	2	Smooth undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	5	0	0	4	112.36	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	10	O1 / O2 < 0,15	7.5	Fair	Yes	Plate 17,18
640	3	5	0	0	2	113.68	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	No Bolting
640	3	3	0	0	0	115	100	Excellent	1	few	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	666.7	Extremaly Good		No Bolting
640	3	3	0	1	0	114.67	100	Excellent	1	few	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	150.0	Extremaly Good		No Bolting
640	3	3	2	1	3	109.17	100	Excellent	6	Two Joint Sets Plus Random	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	0.66	Damp	2.5	Sing. Shear Zone, Compt. Rock, >50m	6.6	Fair		No Bolting
640	3	3	0	1	3	111.37	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	30.0	Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Extremaly Good		No Bolting
640	3	3	0	0	1	113.9	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	Plate 11,12,13
640	3	3	0	1	2	112.47	100	Excellent	2	One Joint set	1	Smooth planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	25.0	Good	Yes	50% Spotbolting
640	3	3	0	0	2	112.8	100	Excellent	2	One Joint Set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	50% Spotbolting
640	3	3	0	0	1	113.9	100	Excellent	2	One Joint set	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	30.0	Good		No Bolting
640	3	3	0	1	2	112.47	100	Excellent	3	One Joint Set plus Random	1	Smooth planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	16.7	Good		No Bolting
640	3	3	0	3	0	114.01	100	Excellent	2	One Joint Set	1	Smooth planar	4	Softening mineral coating	1	Dry Excavation	7.5	Multiple Shear Zone in competent, loose suurounding, any depth	1.7	Poor		No Bolting
640	3	3	0	0	0	115	100	Excellent	1	few	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	666.7	Extremely Good		No Bolting
640	3	3	1	1	1	112.47	100	Excellent	1	few	1	Smooth planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	50.0	Good		No Bolting
640	3	3	0	2	5	108.84	100	Excellent	4	Two Joint Sets	3	Rough/irregular undulating	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	1	1	2	111.37	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	0	0	1	113.9	100	Excellent	1	few	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	30.0	Good		No Bolting
640	3	3	0	0	2	112.8	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	0	0	4	110.6	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	15.0	Good		No Bolting
640	3	3	1	1	3	110.27	100	Excellent	3	One Joint Set plus Randum	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	25.0	Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Extremely Good		No Bolting
640	3	4,5	0	1	3	#VALUE!	100	Excellent	3	One Joint Set plus Randum	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	10.0	Fair/Good	Yes	Shepherd Crooks, 12mm diam, 1,8m long, 1m spacing
640	3	3	0	2	0	114.34	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	37.5	Good	Yes	Plate 9, 10
640	3	3	0	2	5	108.84	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	7.5	Fair		No Bolting
640	3	3	0	3	2	111.81	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	18.8	Good		No Bolting
640	3	3	0	2	4	109.94	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	18.8	Good		No Bolting
640	3	3	0	0	2	112.8	100	Excellent	2	One Joint set	1	Smooth planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	25.0	Good		No Bolting
640	3	3	0	0	1	113.9	100	Excellent	1	few	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Excessively Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Excessively Good		No Bolting
640	3	3	0	2	5	108.84	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	2	Slightly altered jw,non-soft, Min.coat	1	Dry Excavation	1	Medium Stress	18.8	Good		No Bolting
640	3	3	2	2	0	112.14	100	Excellent	4	Two Joint Sets	1	Smooth planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	25.0	Good		No Bolting
640	3	3	0	1	1	113.57	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	30.0	Good		No Bolting
640	3	3	0	4	0	113.68	100	Excellent	2	One joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	Plate 7, 8
640	3	3	0	0	6	108.4	100	Excellent	2	One joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	0	0	3	111.7	100	Excellent	2	One joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	30.0	Good	Yes	Plate 5
640	3	3	0	0	2	112.8	100	Excellent	2	One joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	1	0	0	113.9	100	Excellent	2	One joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good	Yes	Plate 6, Rockstuds, spaced 1m apart
640	3	3	0	2	3	111.04	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	0	1	0	114.67	100	Excellent	1	few	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	150.0	Extremely Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Excessively Good		No Bolting
640	3	3	0	0	0	115	100	Excellent	0.5	Massive	5	Joint spacing >3m	0.75	Tightly Healed	1	Dry Excavation	1	Medium Stress	1333.3	Excessively Good		No Bolting
640	3	3	2	1	4	108.07	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	0	0	2	112.8	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	0	2	3	111.04	100	Excellent	6	Two Joint sets plus random	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	10.0	Fair/Good		No Bolting
640	3	3	0	1	2	112.47	100	Excellent	3	One Joint Set plus Random	1.5	Rough/irregular planar	3	Silty, small clay fraction	1	Dry Excavation	1	Medium Stress	16.7	Good		No Bolting
640	3	3	2	2	3	108.84	100	Excellent	9	Three Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	16.7	Good		No Bolting
640	3	3	1	2	4	108.84	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	1	1	2	111.37	100	Excellent	3	One Joint Set plus Random	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	50.0	Very Good		No Bolting
640	3	3	2	1	3	109.17	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	2	2	4	107.74	100	Excellent	9	Three Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	2.5	Sing. Shear Zone, Compt. Rock, >50m	6.7	Fair		No Bolting
640	3	3	0	2	3	111.04	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good		No Bolting
640	3	3	2	1	1	111.37	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	75.0	Very Good		No Bolting
640	3	3	1	4	3	109.29	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	1	Unaltered joint walls	1	Dry Excavation	1	Medium Stress	37.5	Good	Yes	Plate 2,3,4
640	3	3	1	2	2	111.04	100	Excellent	4	Two Joint Sets	1.5	Rough/irregular planar	3	Silty, small clay fraction	1	Dry Excavation	1	Medium Stress	12.5	Good		No Bolting
640	3	3	1	1	2	111.37	100	Excellent	2	One Joint Set	1.5	Rough/irregular planar	1	[illegible]								

B.2 - CASE STUDY 2 - 23 LEVEL CONVEYOR DECLINE NO. 14-SHAFT - IMPALA PLATINUM - 1058m BELOW SURFACE

Depth bel. surf. (m)	Exc. Height	Exc. Width	Jt Vertical	Dip	Strike	RQD	Act. RQD	Description	Jn	Description	Jr	Description	Ja	Description	Jw	Description	SRF	Description	Q-value	Description	Photos	Supp. Installed & pattern/spacing
1058	9.5	7	2	16	15	101.954	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	6	Zones or bands of disintergrate or crushed	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	0.8	Very poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	3	16	14	102.078	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	4	16	17	100.316	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	0.5	Damp	5	Loose open joints, sugar cube, heavy jointed	0.6	Very poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	11	9	106.432	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	3	13	10	104.954	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	13	7	106.715	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	15	10	104.641	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	9	7	108.035	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	8	8	107.894	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	10	9	106.762	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	10	8	107.234	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
1058	9.5	7	2	13	8	106.244	100	Excellent	12	Three Joint Sets Plus Random	3	Rough/irregular undulating	4	Sandy particles, clay free, disintergated rock	1	Dry Excavation	5	Loose open joints, sugar cube, heavy jointed	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart

TABLE B.3 : Q-VALUE CATEGORIE DISTRIBUTION

Q-VALUE CATEGORIES	10 LEVEL CROSSCUT QUANTITIES	23 LEVEL CONVEYOR DECLINE QUANTITIES
Exceptionally Good	10	0
Extremely Good	3	0
Very Good	20	0
Good	35	0
Fair	7	0
Poor	1	10
Very Poor	0	2
Extremely Poor	0	0
Exceptionally poor	0	0

TABLE B.4 : JOINT NUMBER CRITICAL PARAMETERS DISTRIBUTION

	10 LEVEL CROSSCUT		23 LEVEL CONVEYOR DECLINE	
Joint Number	Quantity	Ave. Q-Value	Quantity	Ave. Q-Value
Massive	8	500	0	0
Few	8	242.3	0	0
1 Joint Set	27	52.75	0	0
1 Joint Set Plus Random	7	25.5	0	0
Two Joint Sets	20	25.9	0	0
Two Joint Sets Plus Random	3	12.9	0	0
Three Joint Sets	4	9.2	0	0
Three Joint Sets Plus Random	0	0	12	1.2

TABLE B.5 : JOINT ROUGHNESS CRITICAL PARAMETERS DISTRIBUTION

	10 LEVEL CROSSCUT		23 LEVEL CONVEYOR DECLINE	
Joint Roughness	Quantity	Ave. Q-Value	Quantity	Ave. Q-Value
Joint Spacing >3m	10	500	0	0
Discontinuous Joints	1	50	0	0
Rough / irregular undulating	23	45.18	12	1.2
Smooth Undulating	1	50	0	0
Slickensided undulating	1	10	0	0
Rough / irregular planar	35	40.76	0	0
Smooth planar	6	23.6	0	0

TABLE B.6 : JOINT ALTERATION CRITICAL PARAMETERS DISTRIBUTION

	10 LEVEL CROSSCUT		23 LEVEL CONVEYOR DECLINE	
Joint Alteration	Quantity	Ave. Q-Value	Quantity	Ave. Q-Value
Tightly Healed	10	500	0	0
Unaltered Joint Walls	22	53.58	0	0
Slightly Altered,jw, non soft min. coat	40	42.22	0	0
Silty, small clay fraction	4	32.3	0	0
Softening mineral coating	1	1.7	0	0
Sandy particles, clay free, disintegrated rock	0	0	11	1.23
Zones or Bands of disintegrated rock	0	0	1	0.8

TABLE B.7 : STRESS REDUCTION FACTOR CRITICAL PARAMETERS DISTRIBUTION

	10 LEVEL CROSSCUT		23 LEVEL CONVEYOR DECLINE	
Stress Reduction Factor	Quantities	Ave. Q-Value	Quantities	Ave. Q-Value
Medium Stress	60	265	0	0
Sing. Shear, Compt Rock >50m Depth	16	16.2	0	0
Multiple Shear Zone in Comp., Loose Surr.	1	1.7	0	0
Loose open joints, sugar cube, heavy jointed	0	0	12	1.2

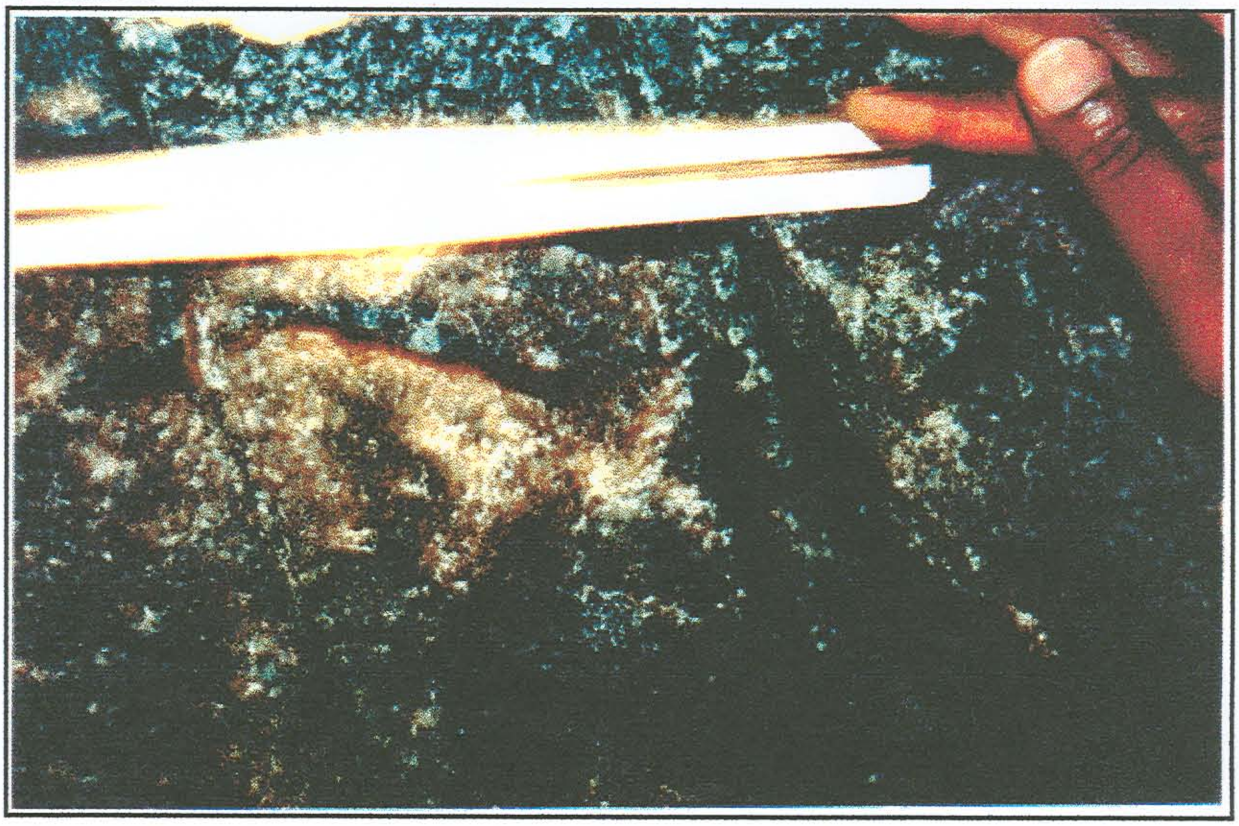
Table B.8 : Barton Comparison - Scatterplot Equivalent Dimension vs Q-values Data Base - 10 Level Crosscut

Site No.	Exc. Width	De	Q-value	Description	Photos	Supp. Installed & pattern/spacing - Photo No.
1	3	1.9	37.5	Good	Yes	Plate 19, 20
2	3	1.9	50.0	Very Good		No Bolting
3	3	1.9	15.0	Good		No Bolting
4	3	1.9	15.0	Good		No Bolting
5	3	1.9	6.7	Fair		No Bolting
6	3.2	2.0	6.7	Fair	Yes	Plate 14,15,16
7	3.2	2.0	75.0	Very Good	Yes	No Bolting
8	3	1.9	37.5	Good	Yes	No Bolting
9	3	1.9	50.0	Very Good		No Bolting
10	3	1.9	75.0	Very Good		No Bolting
12	3	1.9	37.5	Good		No Bolting
13	3	1.9	50.0	Very Good		No Bolting
15	3	1.9	150.0	Extremely Good		No Bolting
16	2.7	1.7	10.0	Good		No Bolting
17	2.7	1.7	50.0	Very Good		No Bolting
18	3	1.9	50.0	Very Good		No Bolting
19	5	3.1	7.5	Fair	Yes	Plate 17, 18
20	5	3.1	75.0	Very Good	Yes	No Bolting
22	3	1.9	150.0	Extremely Good		No Bolting
23	3.1	1.9	6.6	Fair		No Bolting
24	3	1.9	30.0	Good		No Bolting
29	3	1.9	30.0	Good		No Bolting
30	3	1.9	16.7	Good		No Bolting
31	3	1.9	1.7	Poor		No Bolting
33	3	1.9	50.0	Good		No Bolting
34	3	1.9	37.5	Good		No Bolting
35	3	1.9	37.5	Good		No Bolting
36	3	1.9	30.0	Good		No Bolting
37	3	1.9	37.5	Good		No Bolting
38	3	1.9	15.0	Good		No Bolting
39	3.2	2.0	25.0	Good		No Bolting
40	3	1.9	37.5	Good	Yes	Plate 9, 10
41	3	1.9	7.5	Fair		No Bolting
42	3	1.9	18.8	Good		No Bolting
43	3	1.9	18.8	Good		No Bolting
44	3	1.9	25.0	Good		No Bolting
45	3	1.9	75.0	Very Good		No Bolting
46	3	1.9	18.8	Good		No Bolting
47	3	1.9	25.0	Good		No Bolting
48	3.3	2.1	30.0	Good		No Bolting
49	3.3	2.1	75.0	Very Good	Yes	Plate 7, 8
50	3	1.9	75.0	Very Good		No Bolting
51	3.1	1.9	30.0	Good	Yes	Plate 5
52	3	1.9	75.0	Very Good		No Bolting
53	5	3.1	37.5	Good		No Bolting
54	3	1.9	150.0	Extremely Good		No Bolting
55	3	1.9	37.5	Good		No Bolting
56	3	1.9	75.0	Very Good		No Bolting
57	3	1.9	10.0	Fair/Good		No Bolting
58	3	1.9	16.7	Good		No Bolting
59	3	1.9	16.7	Good		No Bolting
60	3	1.9	37.5	Good		No Bolting
61	3	1.9	50.0	Very Good		No Bolting
62	3	1.9	37.5	Good		No Bolting
63	3	1.9	6.7	Fair		No Bolting
64	3	1.9	37.5	Good		No Bolting
65	3	1.9	75.0	Very Good		No Bolting
66	3	1.9	37.5	Good	Yes	Plate 2,3,4
67	3	1.9	12.5	Good		No Bolting
68	3	1.9	75.0	Very Good		No Bolting
69	3.1	1.9	22.9	Good	Yes	Plate 1

TABLE B.9 : CASE STUDY 2 - 23 LEVEL CONVEYOR DECLINE NO. 14-SHAFT - CALCULATED CONDITIONAL FACTORS - BARTON et al (1977).

Site No.	Exc. Width	De - Span/ESR	Act. RQD	Description	Jn	Description	RQD / Jn	Jr	Description	Ja	Description	Jr/Ja	Jw	Q-value	Description	Photos	Supp. Installed & pattern/spacing
1	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	6	Zones or bands of disintergrate or crushed	0.5	1	0.8	Very poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
2	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
3	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	0.5	0.6	Very poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
4	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
5	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
6	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
7	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
8	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
9	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
10	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
11	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart
12	7	4.4	100	Excellent	12	Three Joint Sets Plus Random	8.3	3	Rough/Irregular undulating	4	Sandy particles, clay free, disintegrated rock	0.75	1	1.3	Poor	Yes	3,0m Long, 16mm Diameter Shepherd Crook, Spaced 1m apart

PLATE 1



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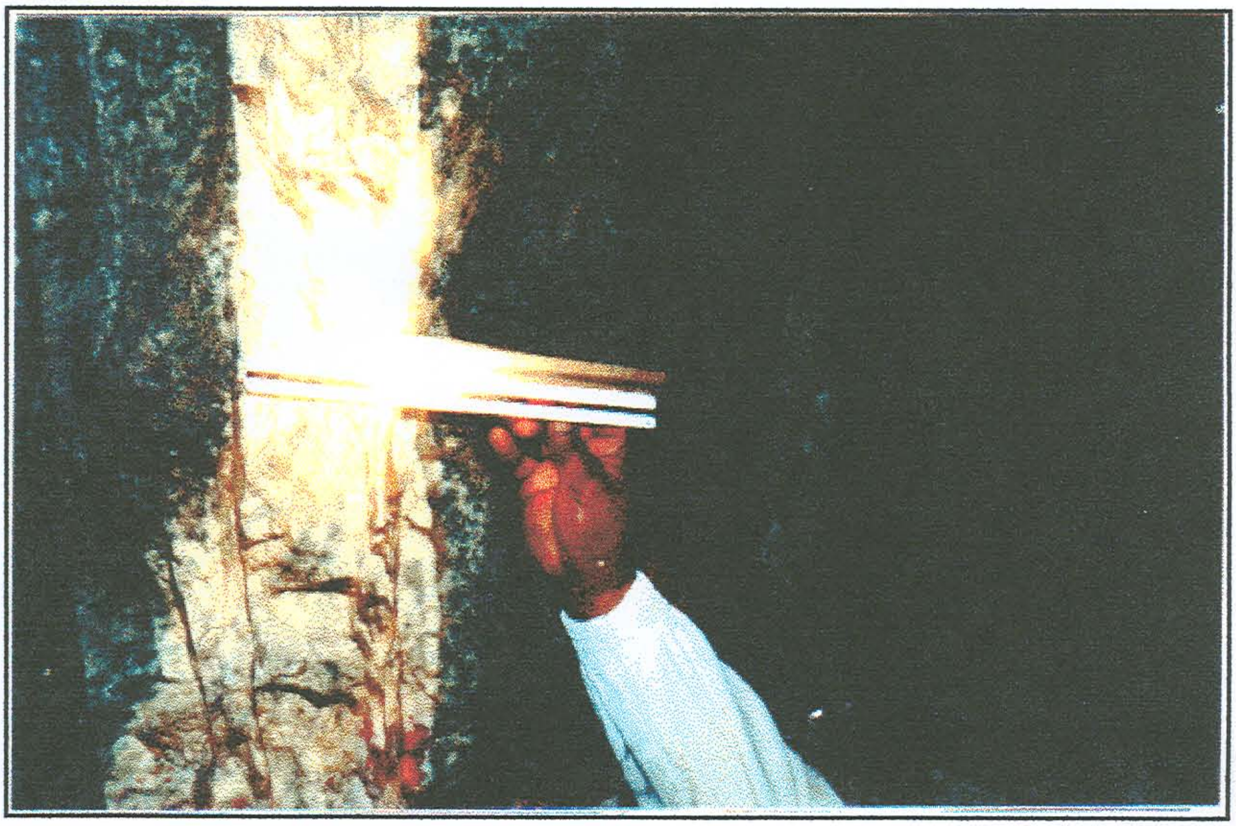

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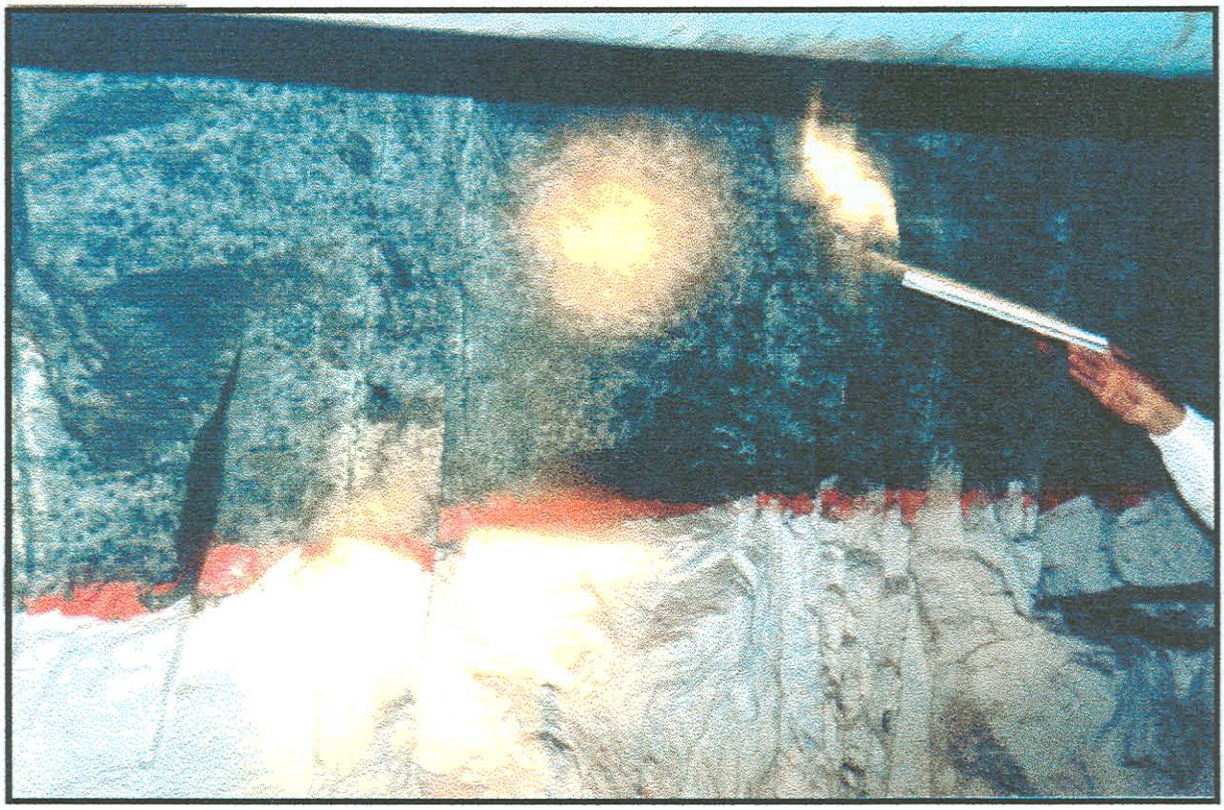


PLATE 4

PLATE 5

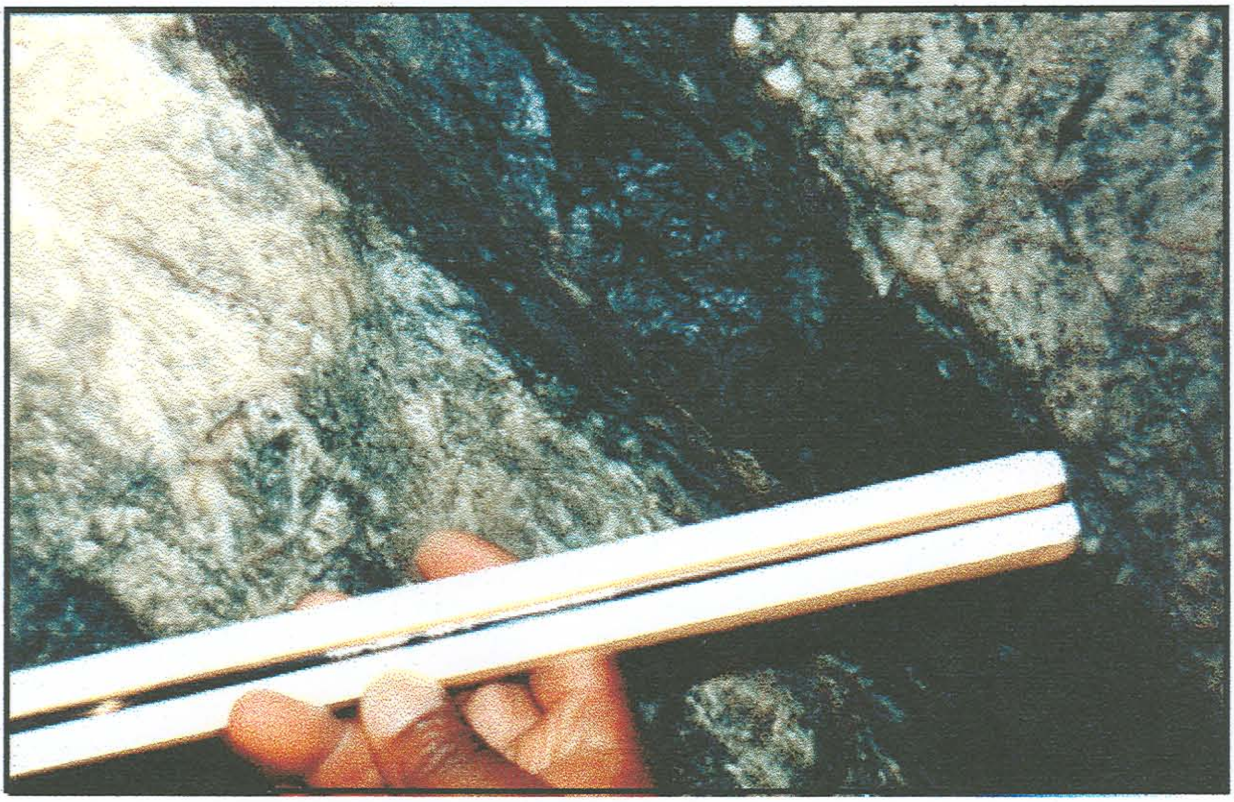
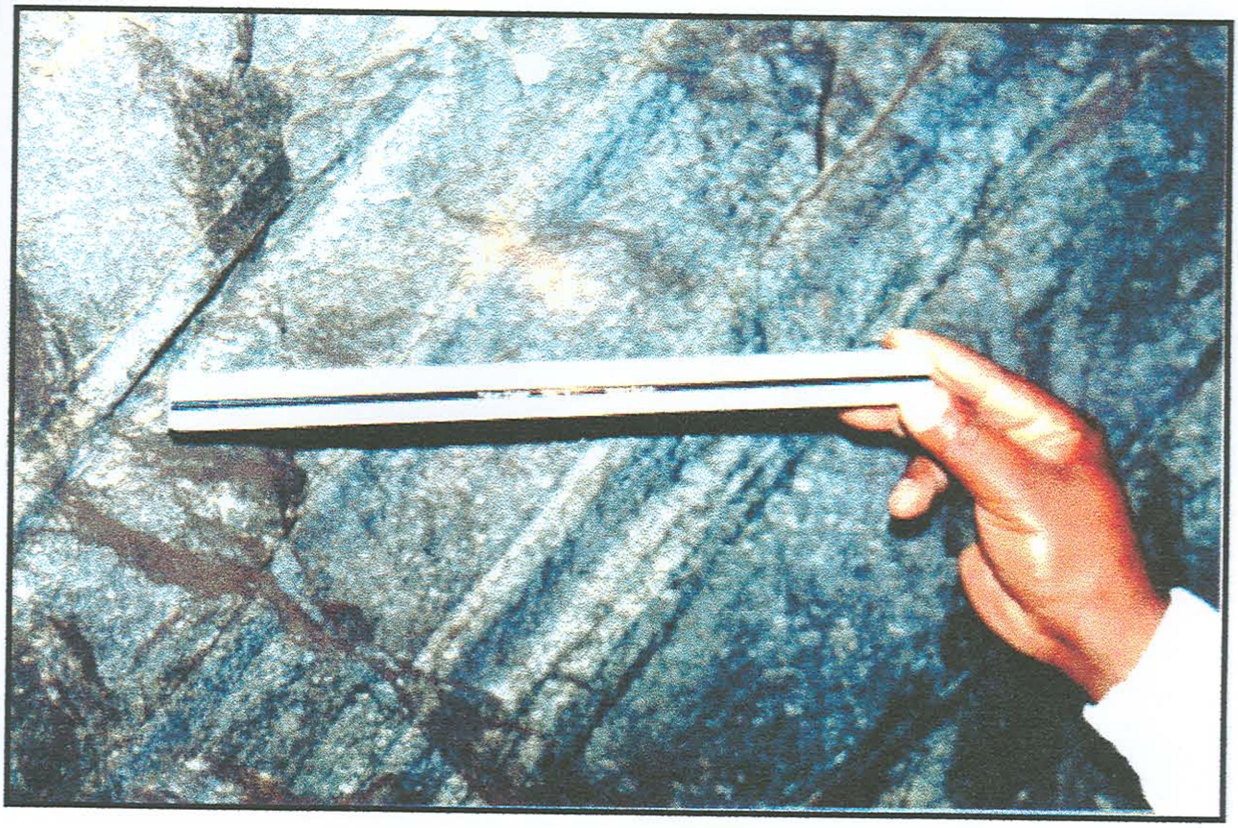


PLATE 6

PLATE 7



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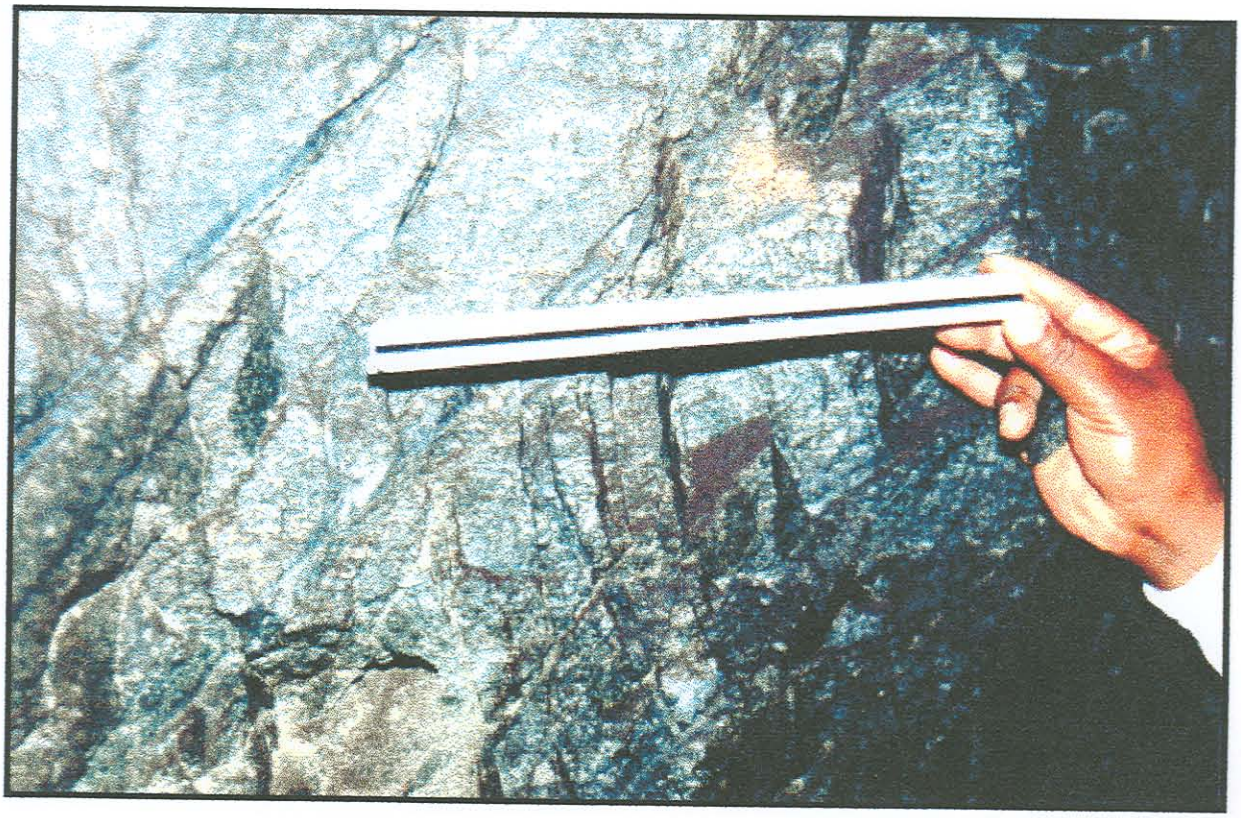

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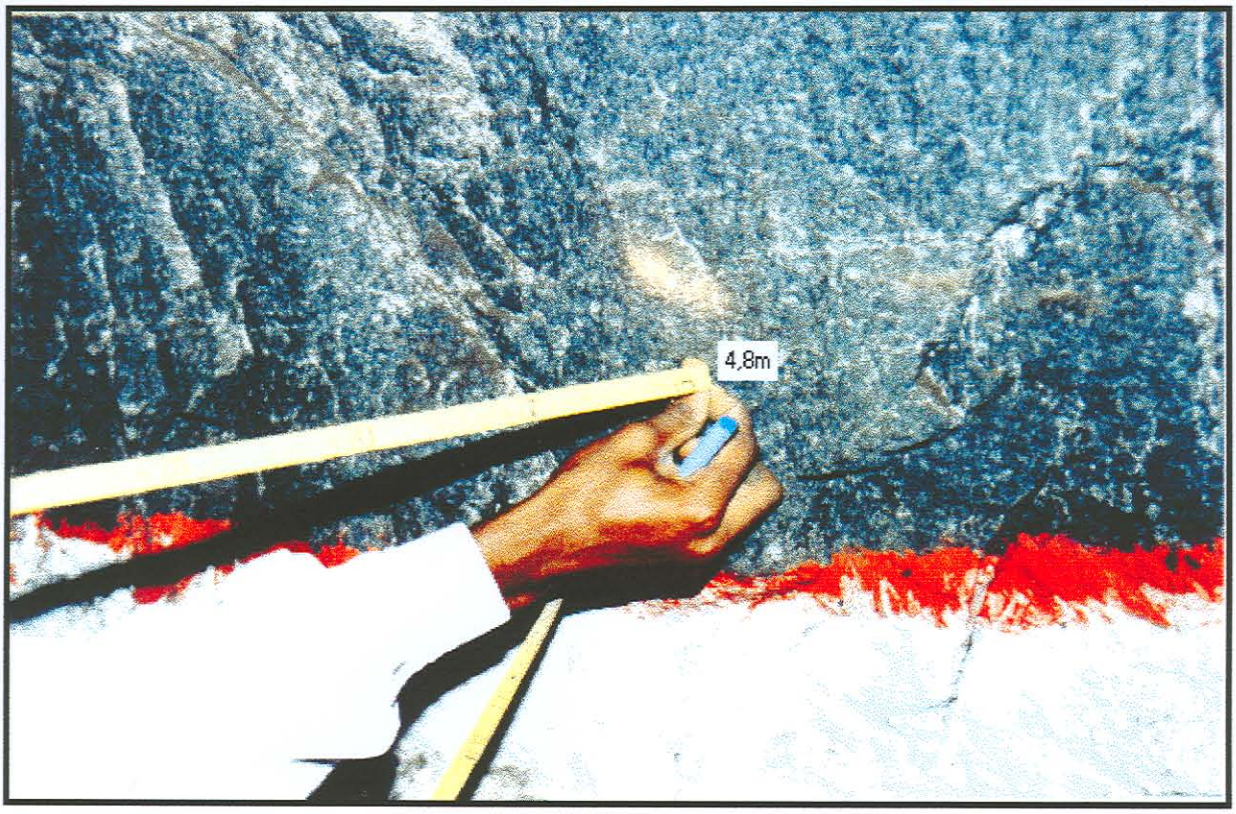

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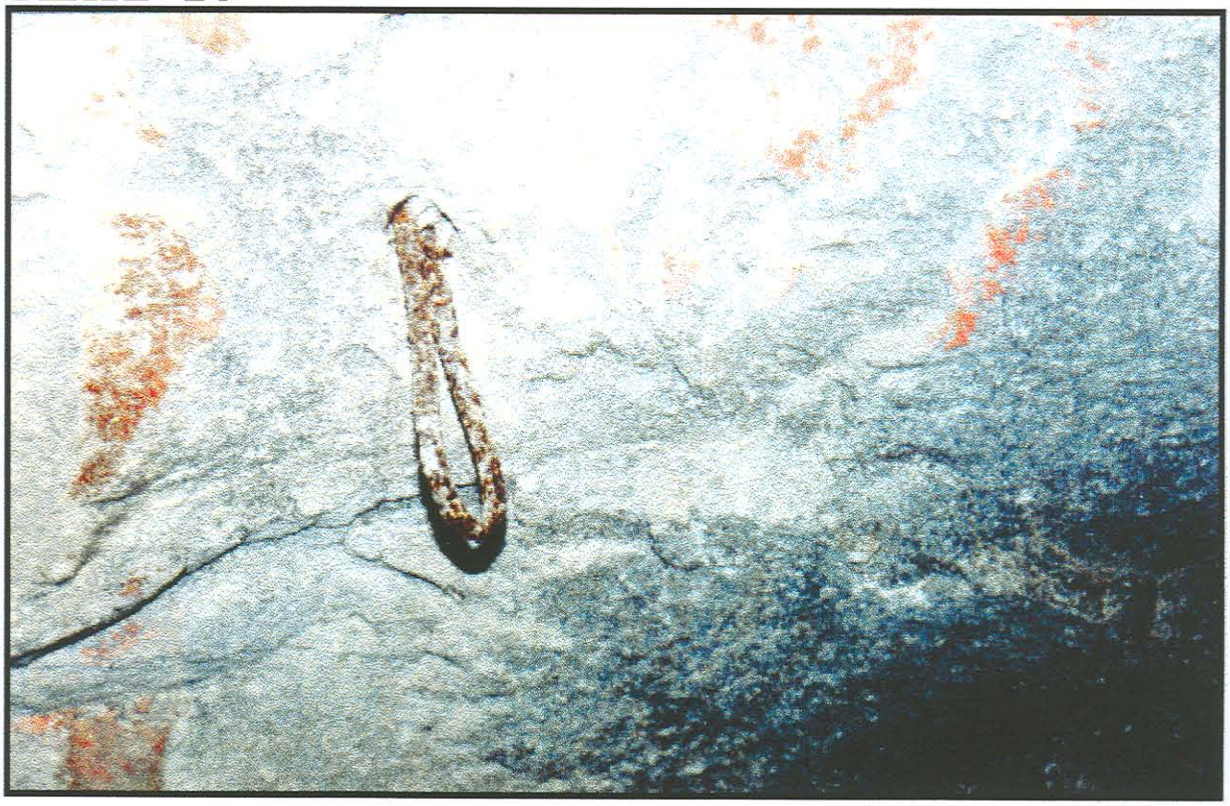

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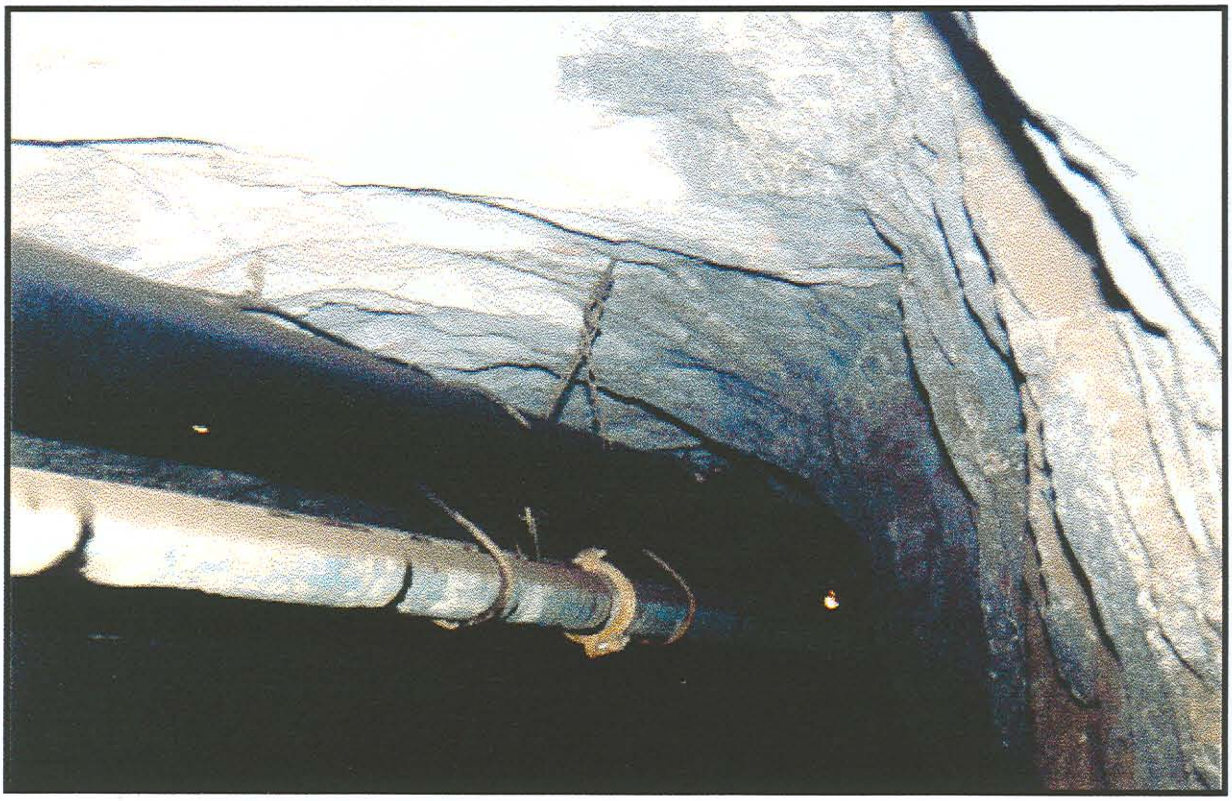
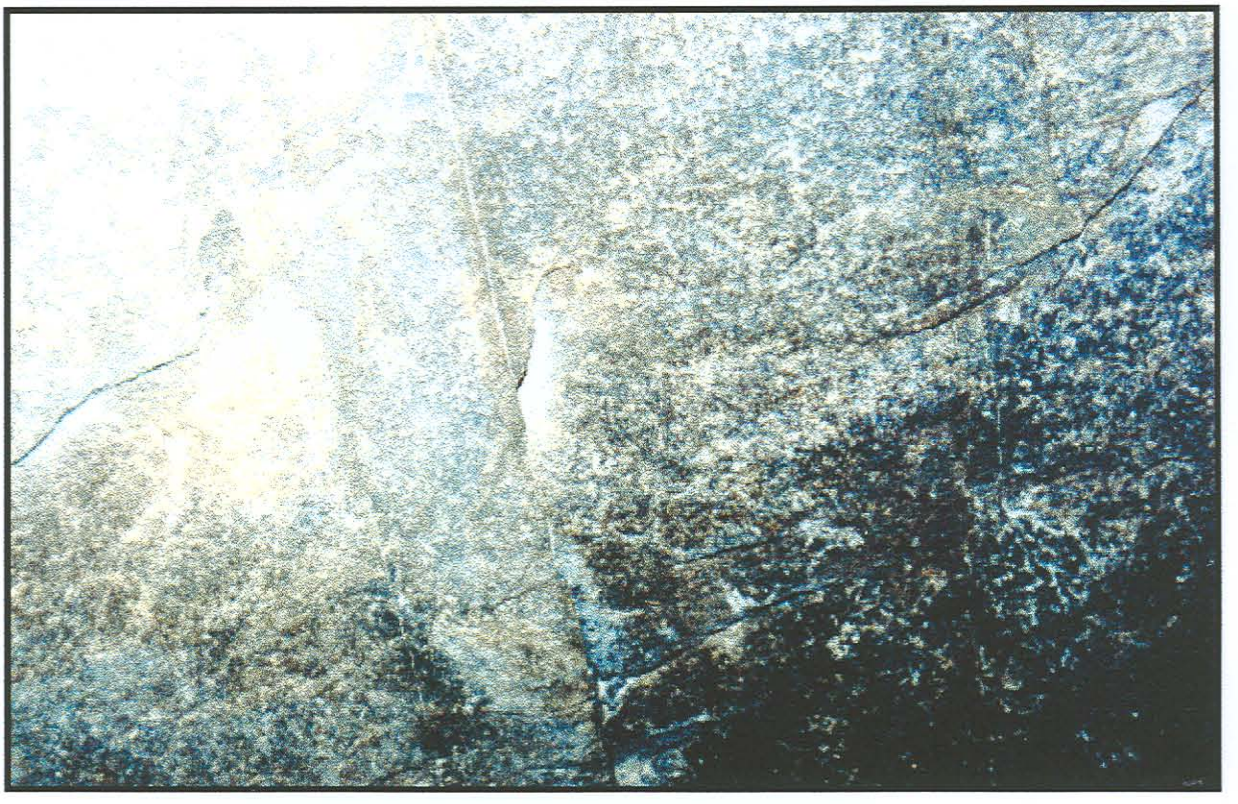


PLATE 12

PLATE 13



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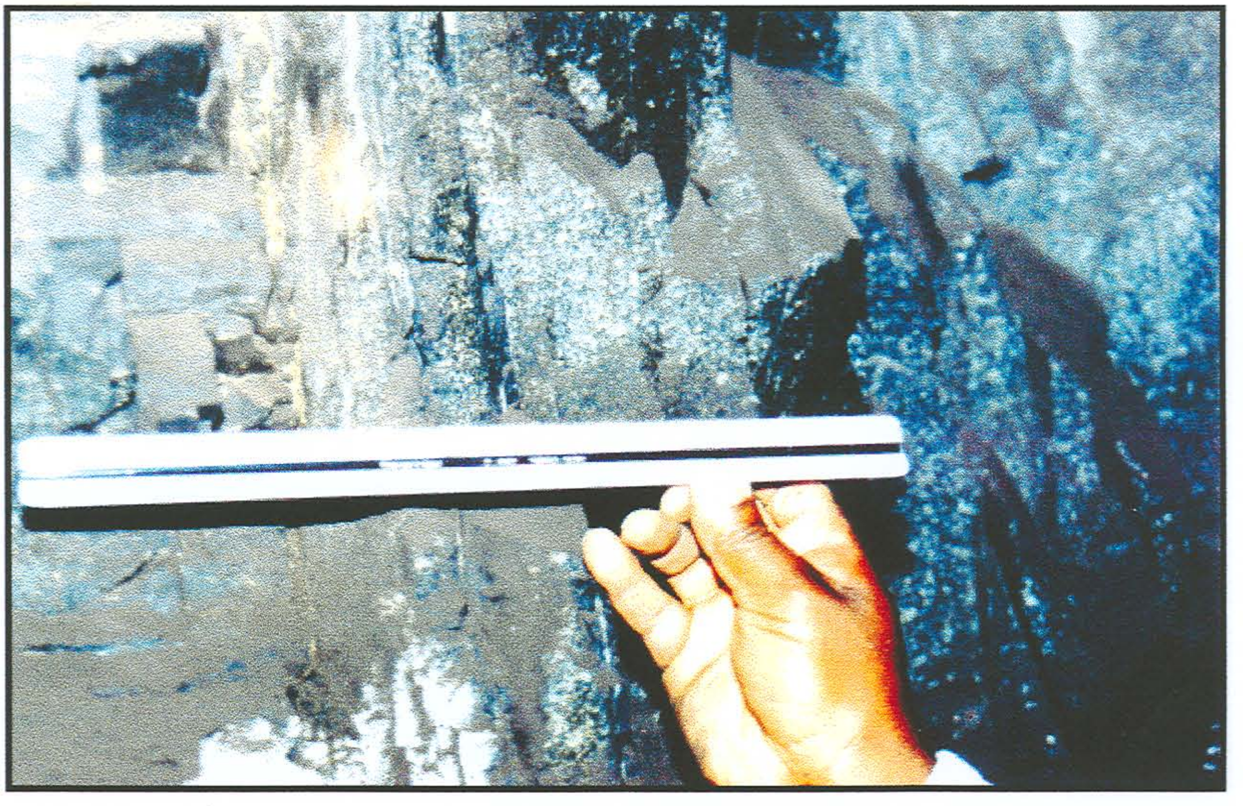

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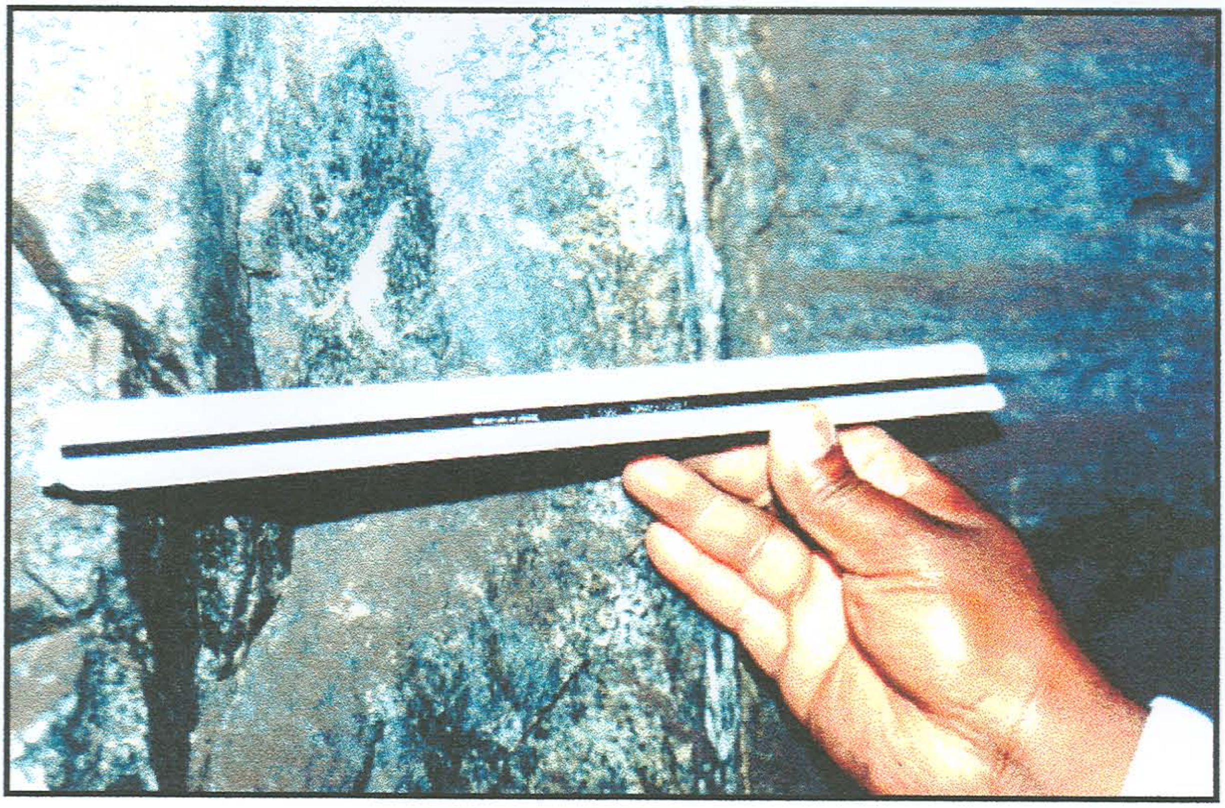

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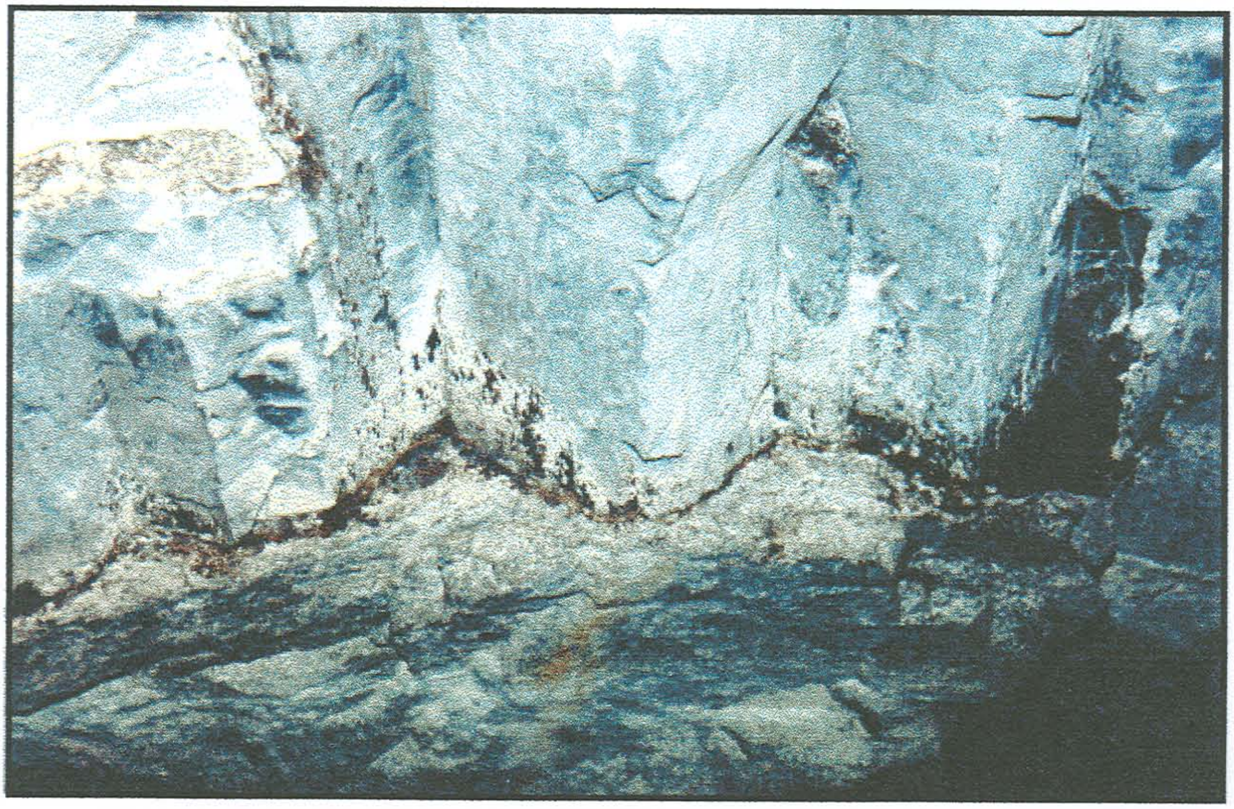

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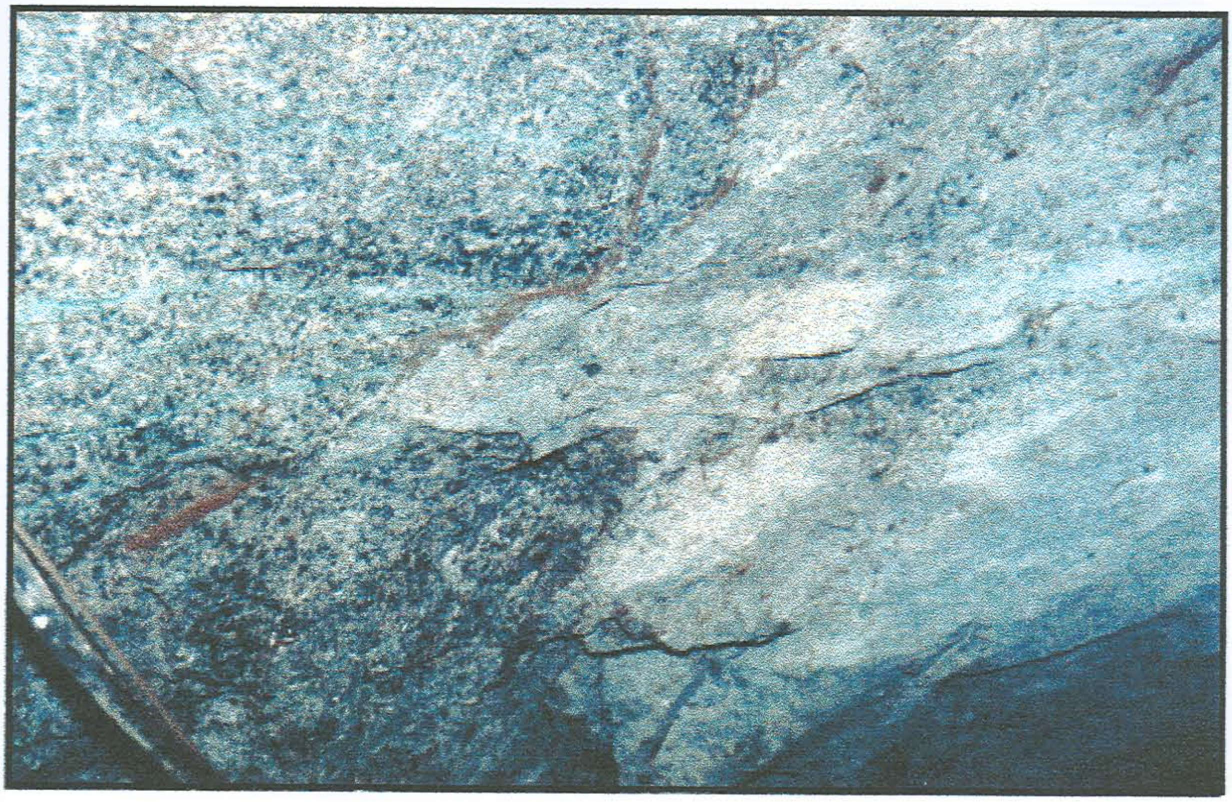

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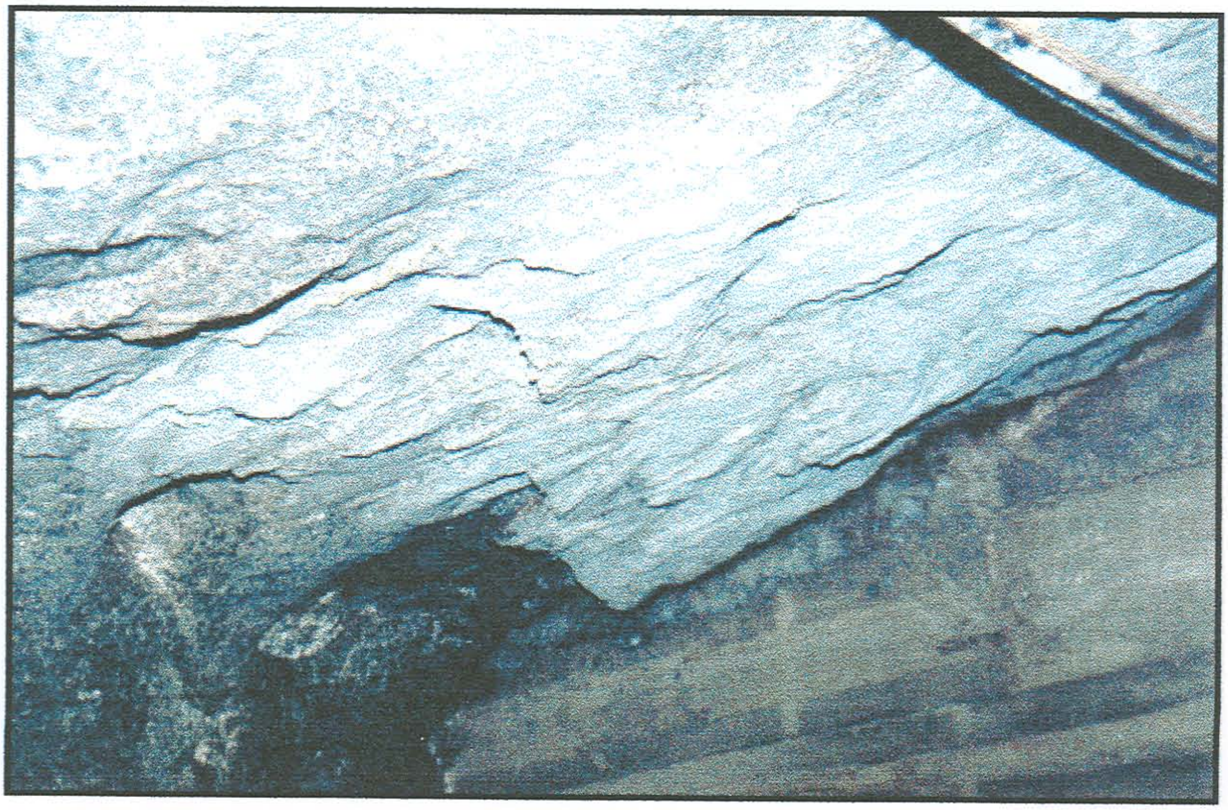

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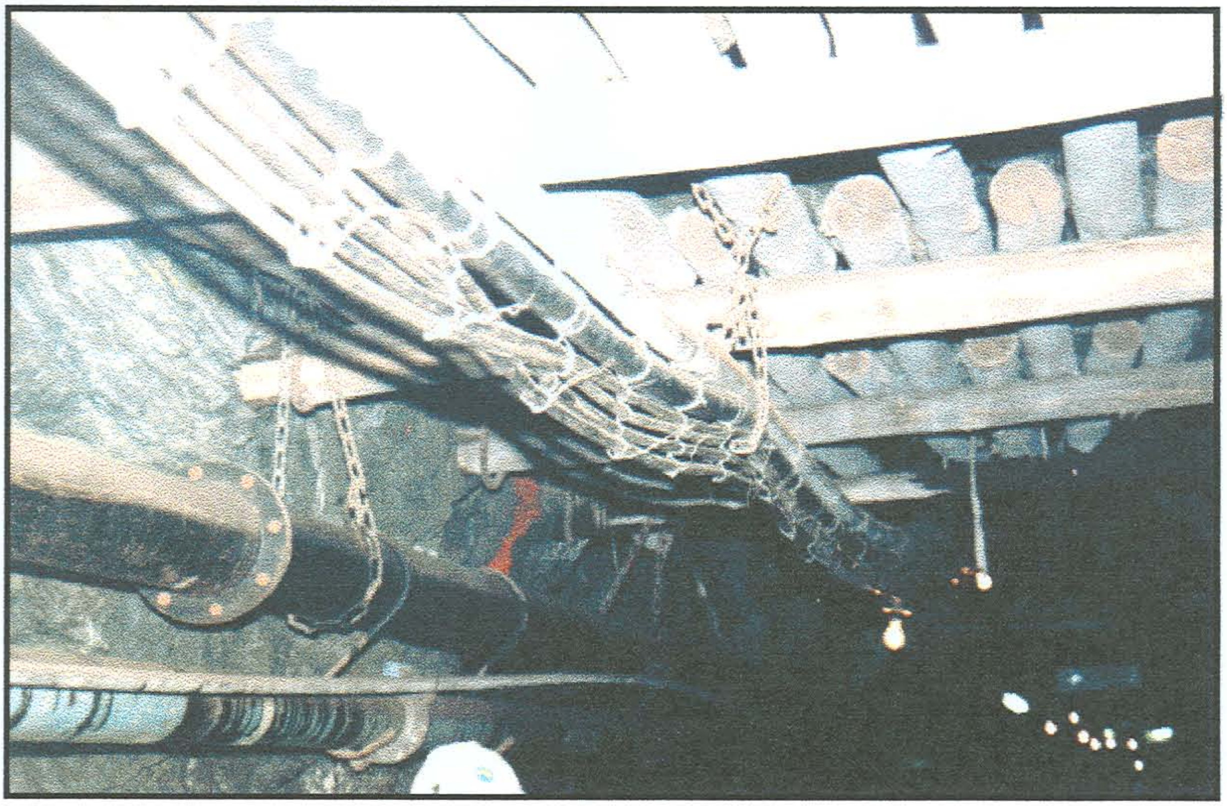


PLATE 20

APPENDIX D

PLATE 21

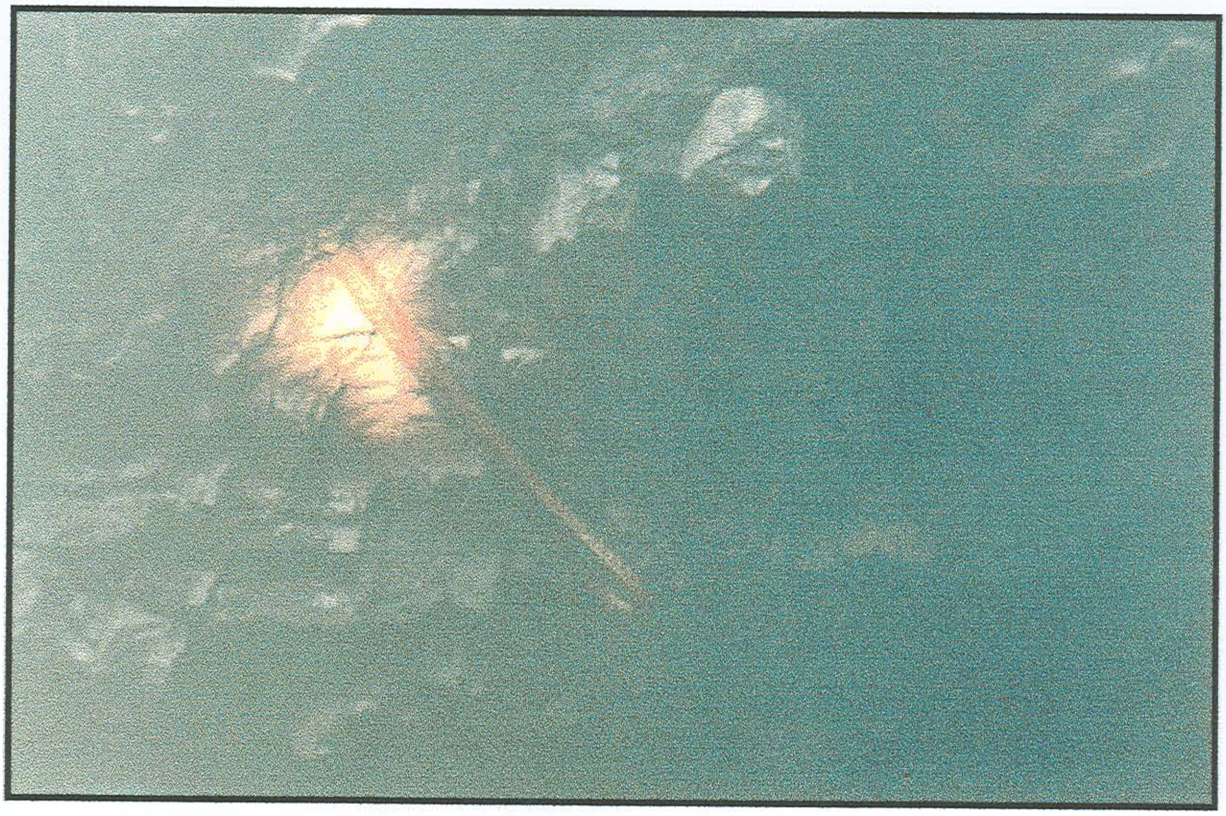


PLATE 22

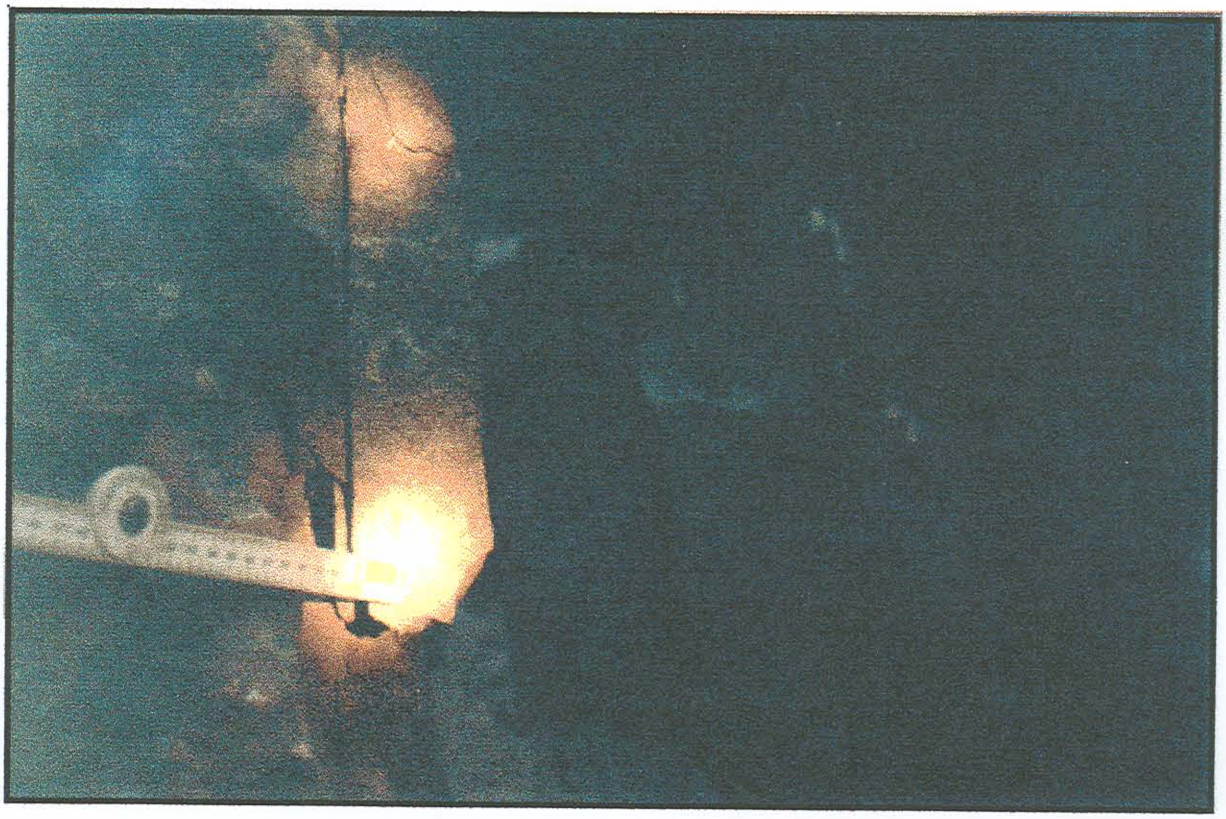
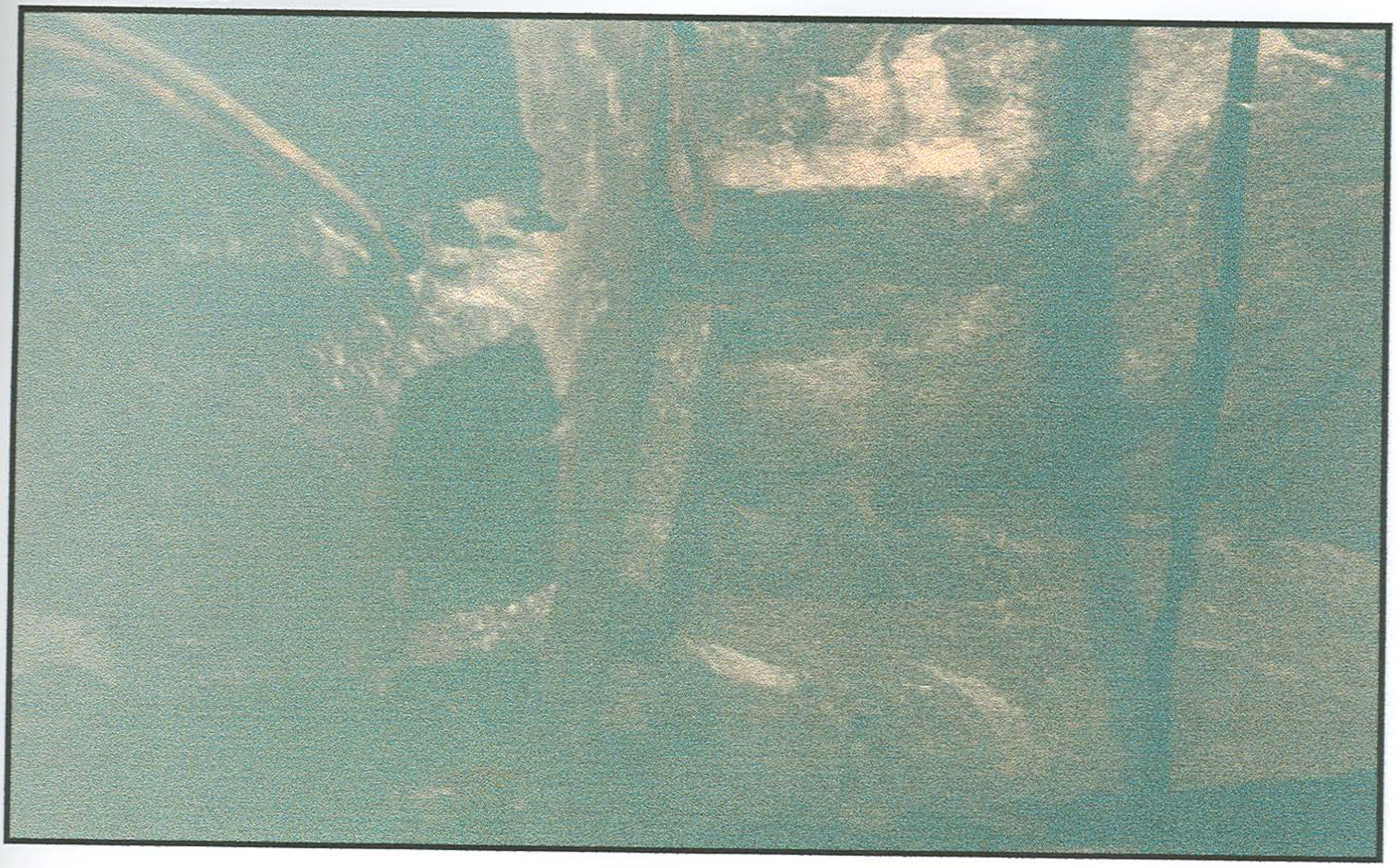


PLATE 23



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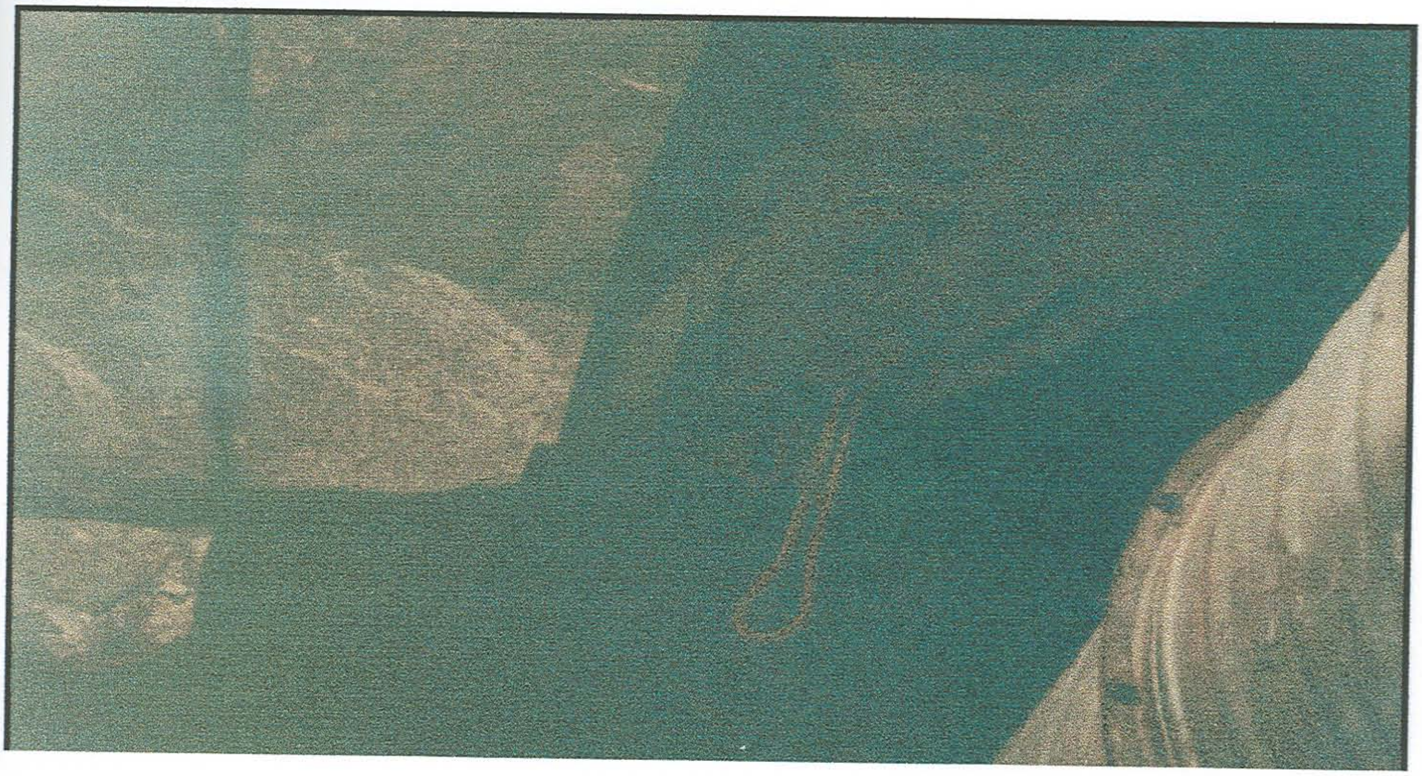

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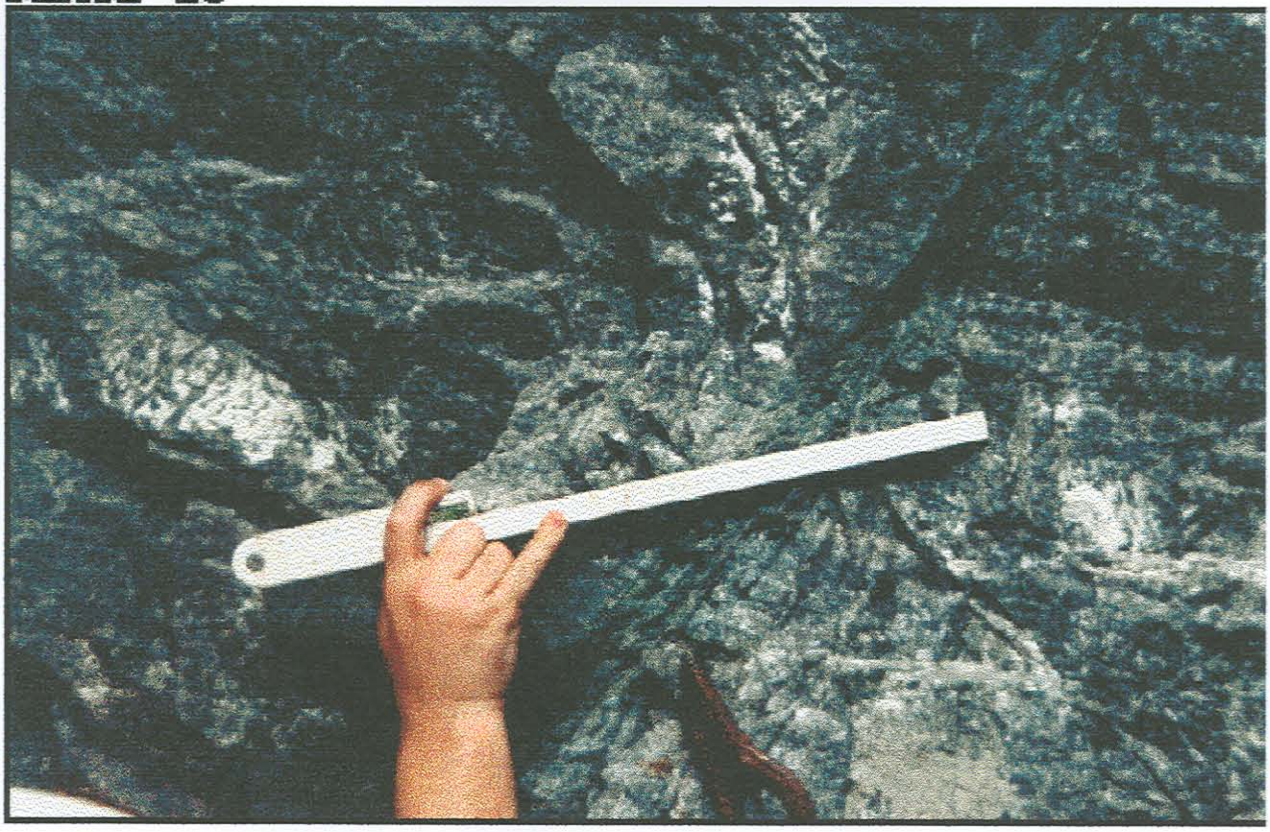


PLATE 26

PLATE 27

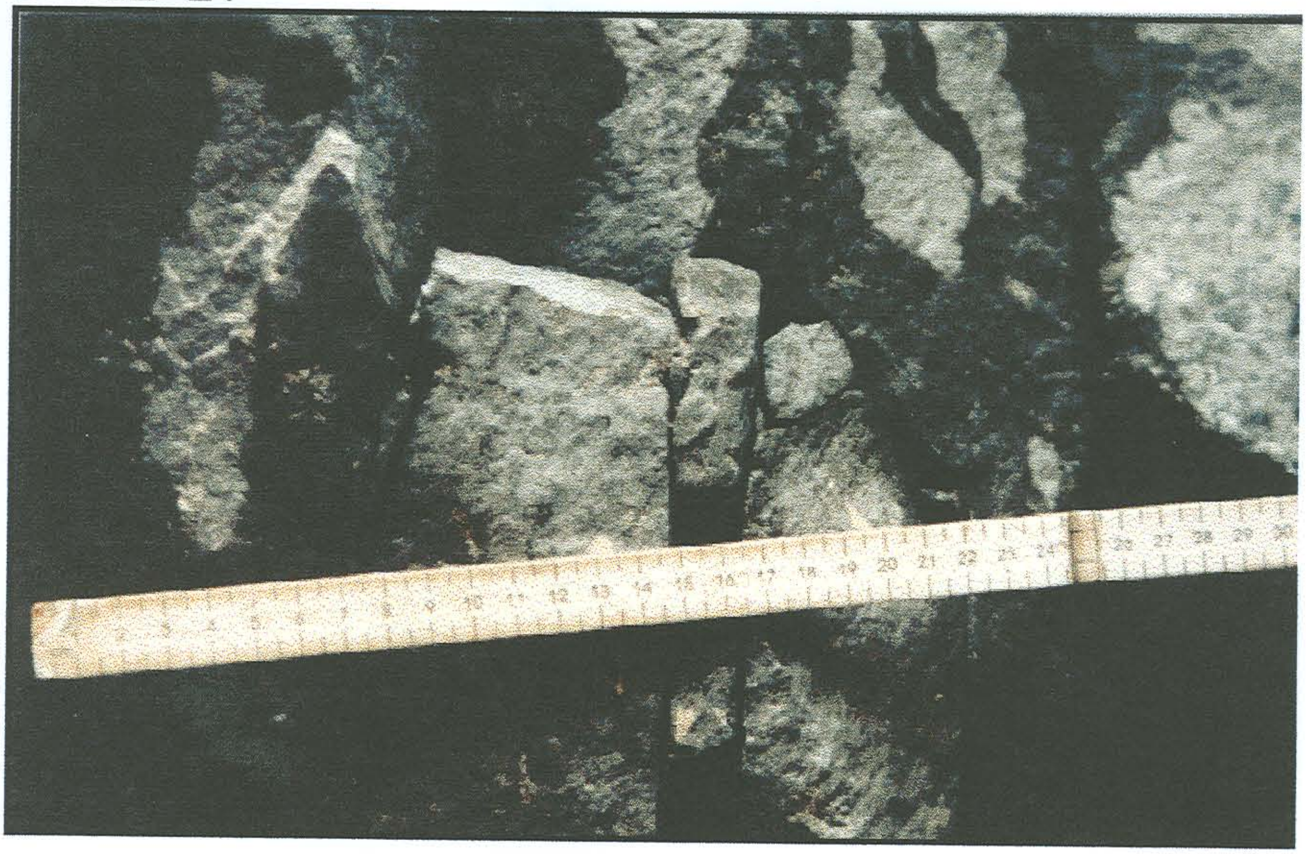
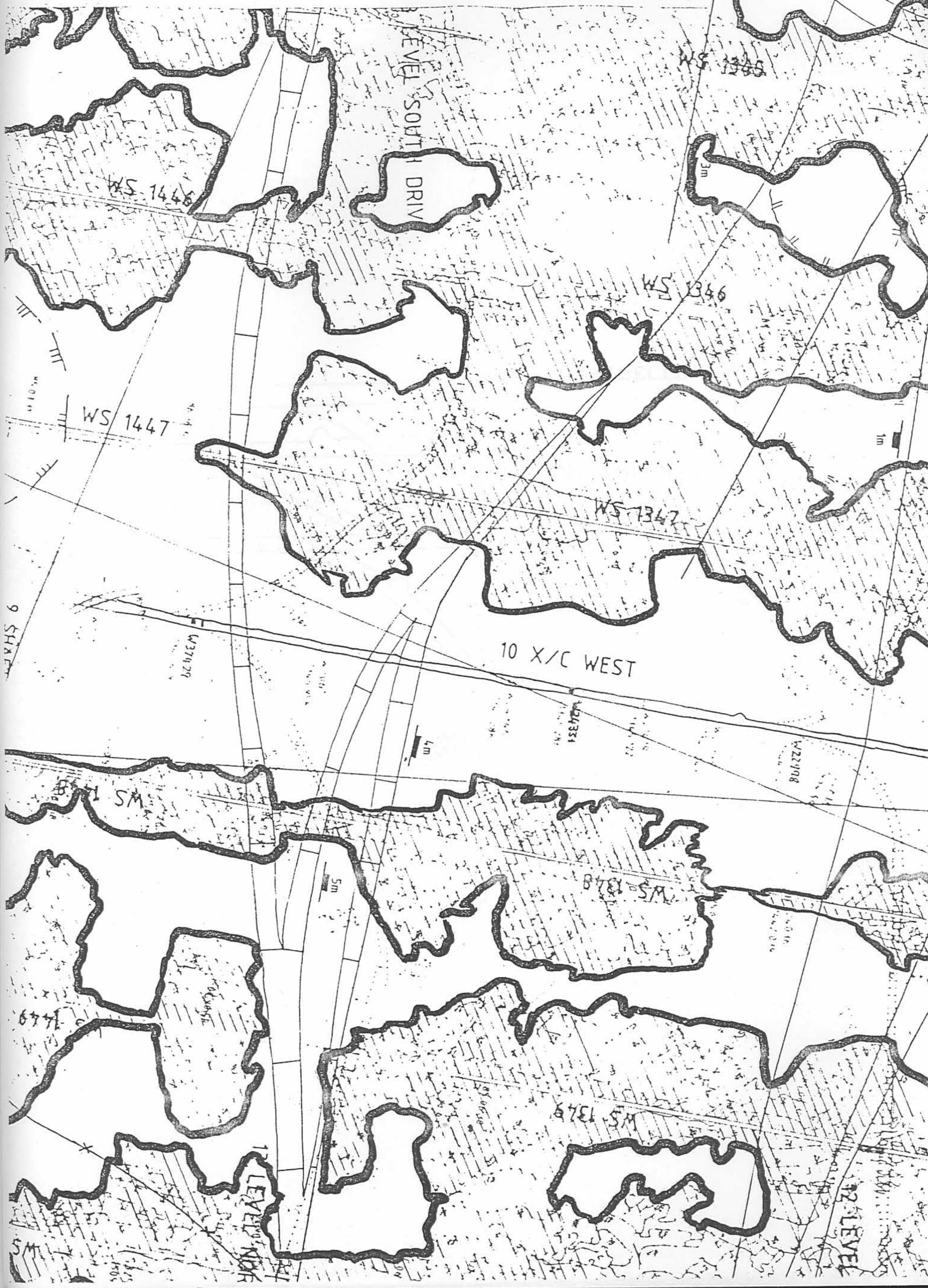
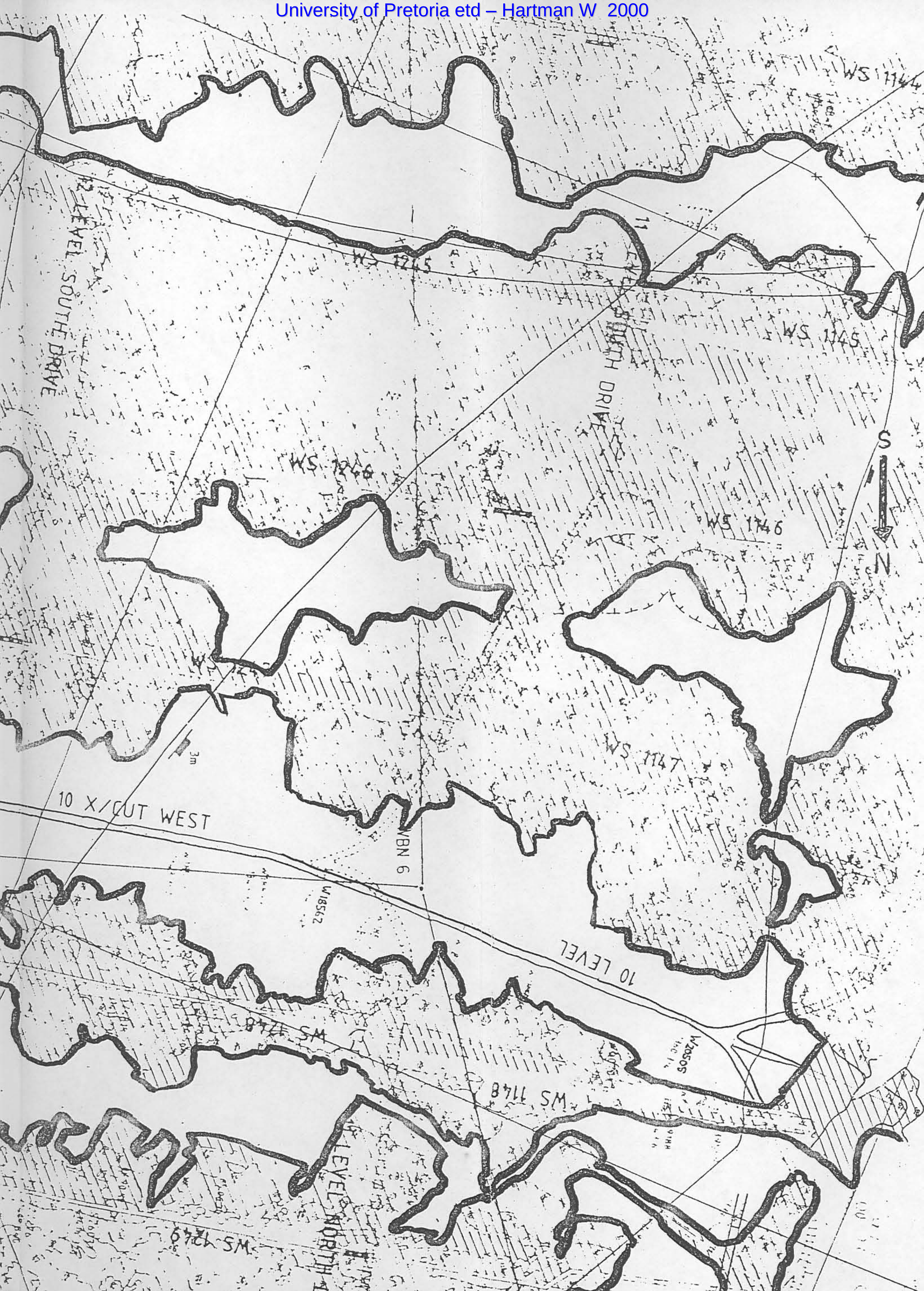


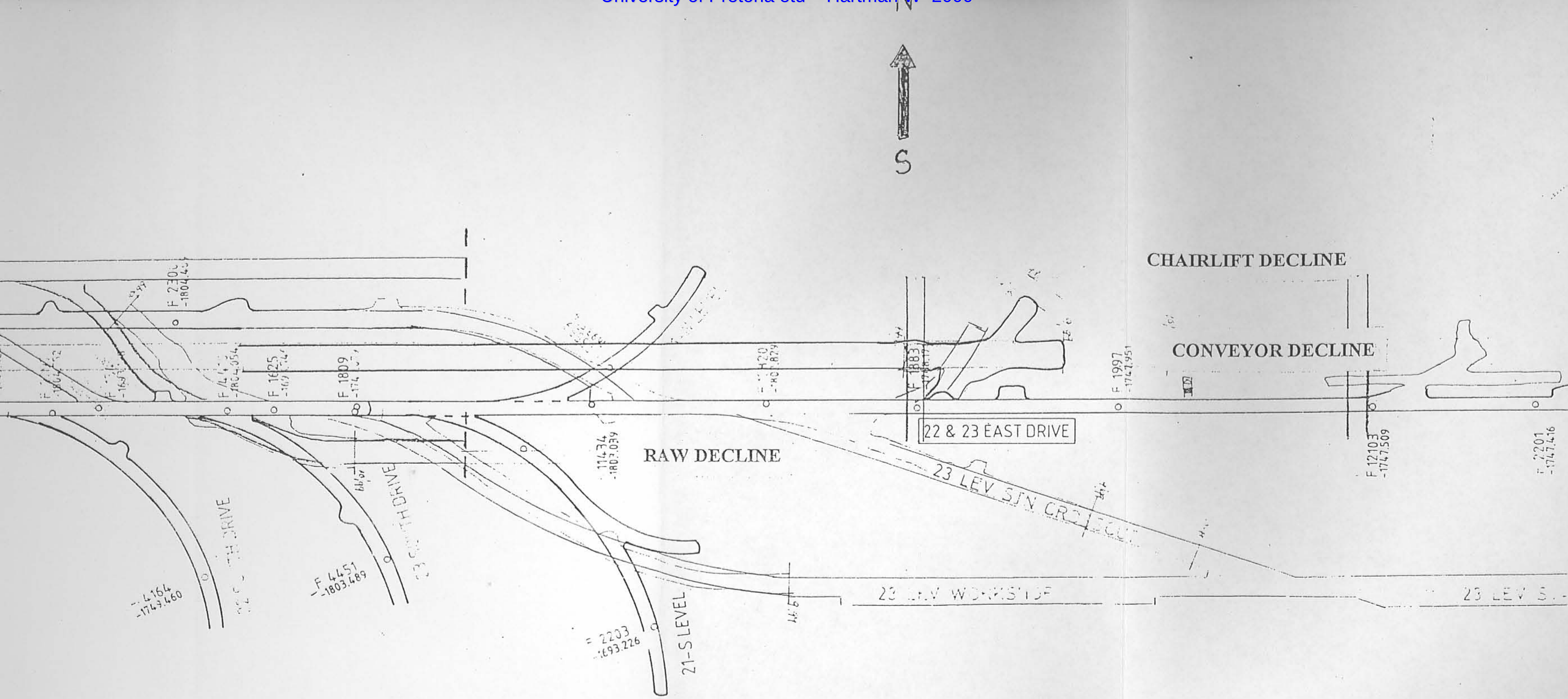
PLATE 28

APPENDIX E

PLAN 1 - 10 LEVEL CROSSCUT – N0. 9-SHAFT
SCALE : 1 : 1000




WS 1144
WS 1245
11 LEVEL SOUTH DRIVE
12 LEVEL SOUTH DRIVE
WS 1145
WS 1246
WS 1146
S
N
WS 1147
3m
10 X/CUT WEST
VBN 6
W18562
10 LEVEL
WS 1148
W20505
WS 1249
LEVEL NORTH


N
S
CHAIRLIFT DECLINE
CONVEYOR DECLINE
RAW DECLINE
22 & 23 EAST DRIVE
23 LEV STN CROSSCUT
23 LEV WORKSHOP
21-S LEVEL
F 1625
F 1809
F 1883
F 1997
F 12103
-1747.509
F 2201
-1747.416
F 4451
-1803.489
F 2203
-1693.226
F 2300
F 11434
-1747.951