Geotechnical Properties of Rock

by

R. Jackson[1], B. Gorski[2] and M. Gyenge[3]

Abstract

The mining industry in Canada requires increasingly more detailed information on both the pre- and post-failure support capabilities of rock, especially as companies move into deeper and more highly stressed ground. *Geotechnical Properties of Rock* offers a summary of results for many rock types typical of Canadian mine environments. These results include values for density, porosity, compressive and shear wave velocity, uniaxial compressive strength, Young's modulus and Poisson's ratio. More importantly, the data base contains *m* and *s* values determined using the Hoek and Brown failure criteria for both pre- and post-failure conditions. These are presented using detailed data sheets and summary tables.

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Key words
Rock properties, mechanical, Young's modulus, Poisson's ratio, uniaxial compressive strength, compressive wave velocity, shear wave velocity, Hoek and Brown.

Propriétés géotechniques des roches

par

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RÉSUMÉ

L'industrie minière du Canada a besoin de plus d'informations détaillées sur les capacités de soutènement de la roche avant et après rupture, notamment à mesure que les sociétés exploitent des terrains plus profonds, aux contraintes plus élevées. L'ouvrage *Propriétés géotechniques des roches* renferme un résumé de résultats pour un grand nombre de roches typiques des environnements miniers canadiens. Ces résultats comprennent des données sur la masse volumique, la porosité, la vitesse des ondes de compression et de cisaillement, la résistance à la compression uniaxiale, le module d'Young et le coefficient de Poisson. Plus important encore, la base de données contient des valeurs de m et s établies à l'aide du critère de rupture de Hoek et Brown, tant avant qu'après rupture. Ces données sont présentées dans des fiches techniques détaillées et des tableaux récapitulatifs.

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Mots-clés

Propriétés des roches, mécanique, module d'Young, coefficient de Poisson, résistance à la compression uniaxiale, vitesse des ondes de compression, vitesse des ondes de cisaillement, Hoek et Brown.

Contents

INTRODUCTION

The search for ore has occupied people since the beginning of recorded history. Relatively little time passed, however, before ever-increasing demands exhausted surface mineral deposits and the mining industry (such as it was) was forced to begin underground excavation for new sources of ore. Unfortunately, the success or failure of these early forays into underground mine design was measured as much in terms of loss of life as in tonnage recovered. Gradually, though, mining became safer; more as a result of accumulated experience than an understanding of underlying principles.

Today the industry is again faced with a similar dilemma, with relatively shallow reserves being quickly depleted. Companies are having to proceed deeper and into areas where stability is threatened by extremely high and complex stress fields. Consequently, both safety and economic concerns require that failure envelopes be more precisely and rigorously defined and the support capabilities of even failed material taken into consideration. The science of rock mechanics and its associated technologies have, in recent years, gone a long way to meeting the increasing needs for more specialized knowledge. The resources and necessary expertise required to determine the post-failure behaviour of rock, however, are often beyond the grasp of all but the largest mining companies.

In response, the Mining Research Laboratories (MRL) division of the Canada Centre for Mineral and Energy Technology (CANMET) has compiled a summary of the pre- and post-failure mechanical properties of rock types that were tested to provide design data for ground control programs within MRL and elsewhere. *Geotechnical Properties of Rock* presents these results in a single, concise and what is hoped to be easily understood volume. In addition, analyzed results, established by the Mohr-Coulomb and Hoek and Brown failure criteria, are included for preliminary design purposes.

The data base itself is divided into three sections. The first is a general description of the test procedures used in determining the mechanical properties of the various rock types. This includes outlines of methods used for direct and indirect tensile testing, uniaxial compression testing, and conventional, multi-stage, continuous failure state and extension triaxial testing.

Mechanical rock property characterization is an ongoing activity at MRL and, as such, new data are constantly being generated. Consequently, the data base is updated on an annual basis to include the results of programs that have been conducted during the previous year. The second section of the report comprises these results and they are summarized in detailed data sheets such as that shown in Figure 1. The sheets contain, when available, information under the following headings:

- **Origin:** the site from which the samples were obtained.

- **Reference No.:** the number(s) of the referenced report(s), listed in Table 3, from which the data sheet was assembled. The original report will generally contain the most detailed information on the specific rock type being considered.

- **Rock Type:** the rock types have been named according to the classification system developed by the Colorado School of Mines, which is summarized in Appendix A (Travis, 1955). This system identifies rock types solely in terms of petrography, and although this may not be universally accepted, it does represent a reasonably unified approach for effective communication.

- **Regional Geology, Structural Characteristics:** these refer to the gross characteristics supplied by the on-site personnel on the formation from which the samples were obtained.

- **Petrography:** the petrographic analysis of the rock type in question.

- **Mechanical Properties:** summarized here are the uniaxial mechanical properties of the rock including bulk density, γ_d; porosity, n; specimen diameter, ϕ; specimen length, l; compressive wave velocity, V_p; shear wave velocity, V_s; uniaxial compressive strength, Q_u; tensile strength, σ_t; 50% tangent Young's modulus, E; Poisson's ratio, v; and the confining pressure range over which triaxial testing was conducted, σ_3.

- **Hoek and Brown Material Constants:** includes m, s, r^2, m_r, s_r and r^2_r values for the intact and residual strength conditions, as well as the uniaxial compressive strength, Q_c, predicted by the model.

Origin	Reference No.	Rock Type

Regional Geology	Structural Characteristics
	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography	
Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties										
γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	v	σ_3 (MPa)

MOHR FAILURE ENVELOPES

Shear Stress (MPa)

Normal Stress (MPa)

Hoek and Brown Material Constants						
Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r

Borehole Information
Collar Elevation: Depth: Inclination: Latitude: Longitude:

Figure 1. Example of a detailed data sheet

- **Borehole Information:** this includes the collar elevation, its depth, the inclination of the borehole, and its latitude and longitude.

Finally, the data sheets contain a plot of the mean Mohr-Coulomb circles and the corresponding intact and residual strength failure envelopes determined using the Hoek and Brown failure criteria.

Results described in the data sheets are summarized in the accompanying tables, where they are arranged in alphabetical order according to rock type. Table 1 contains the mean values of the mechanical properties determined for each rock type. These include its origin, the reference number and corresponding data sheet for more detailed information, bulk density, tensile strength, uniaxial compressive strength, Young's modulus, Poisson's ratio, compressive wave velocities (both saturated and dry) and porosity.

Table 2 summarizes the Hoek and Brown constants m, s, r^2, m_r, s_r and r^2_r for both intact and residual conditions. For comparison, the actual and predicted uniaxial compressive strengths, Q_u and Q_c, respectively, have been included.

Table 3 is the list of references that contain detailed test program summaries, methodologies, results (complete with stress-strain histories) and observations and conclusions related to the test objectives. These may be obtained through MRL by quoting the appropriate title and report number.

TEST METHODS

The scope and sophistication of the tests available to the mine engineer have increased dramatically over the last number of years. This has been due largely to the introduction of computer-controlled, servo-hydraulic compression machines, such as the one shown in Figure 2.

These new technologies allow investigators to quickly adjust and readjust test conditions with great precision. As a consequence, methods such as multi-stage and continuous failure state testing have been developed to enable more information to be extracted from a single sample than was previously possible. In addition, servo-hydraulics give us the capability to determine post-failure properties of rock and avoid the violent, brittle fracture usually associated with softer, manually controlled machines. The following, then, is a general overview of the test types available at MRL and how they have been used to acquire the data summarized in this report.

TENSILE STRENGTH

It has been shown that for several types of rock tested in compression, failure is often the result of tensile forces generated in the specimen. It becomes important, therefore, to get some estimate of tensile strength, especially when complex stress conditions such as those surrounding deep underground openings are anticipated.

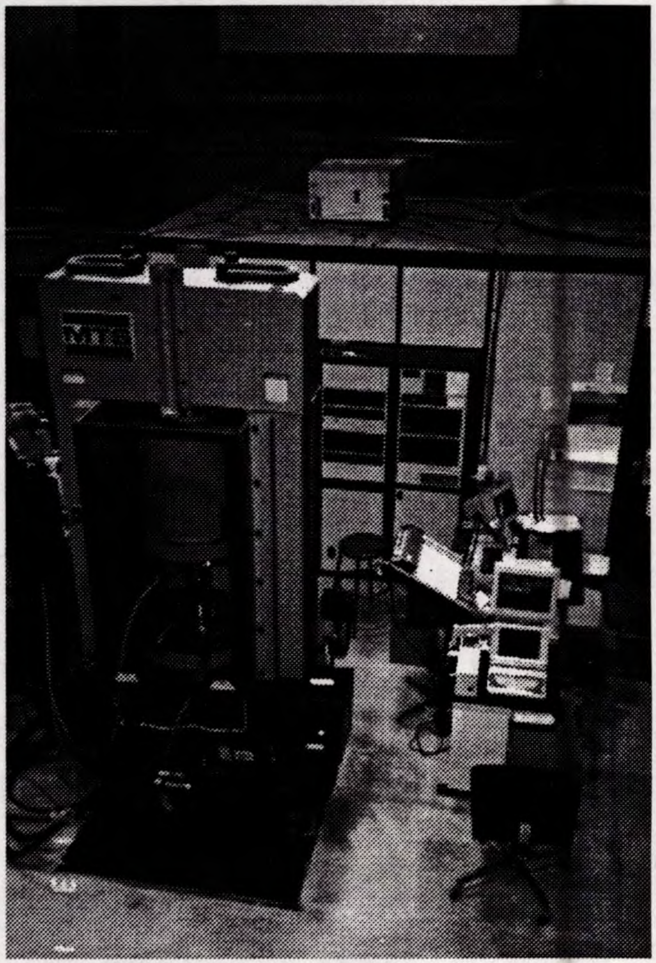

Figure 2. MRL rock mechanics test system

Direct Tensile Test: Direct measurement of the tensile strength is obviously the method of choice, but problems associated with misalignment when gripping the specimen can result in the development of bending forces within the rock. Great care must be taken to ensure that the axis of loading coincides with the specimen axis.

For average strength rocks, satisfactory results have been obtained using the plate and glue methods. The specimen is glued to two end loading caps that, in turn, are tensioned with suitable loading mechanisms (e.g., cable, chain, spherically seated joints, etc.) (Figure 3, Fairhurst, 1961). For higher strength rocks, both Hoek (1964) and Brace (1963) found that rock specimens machined down to a shape similar to that used for metals testing yielded good results.

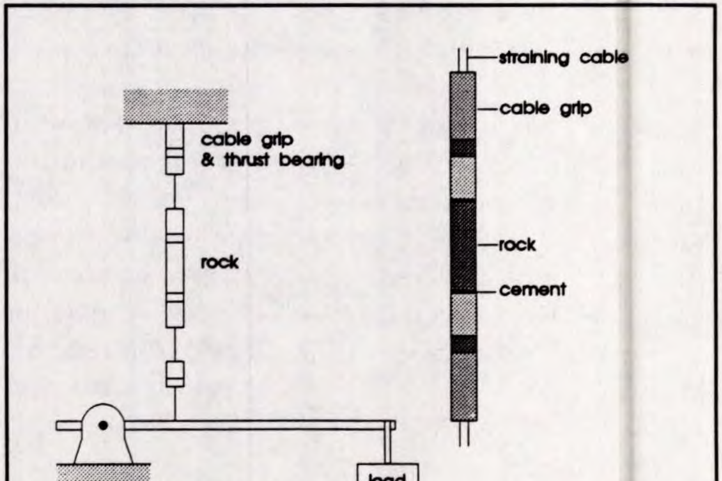

Figure 3. Tensile test apparatus and gripping arrangement (after Fairhurst, 1961)

Although direct methods for determining tensile strength are preferable, the complexity of sample preparation and care required for testing make them unsuitable for many engineering investigations. Indirect methods often provide adequate estimates with a minimum of trouble. Two such methods used extensively at MRL include Brazilian tensile and bending or flexural tests.

Brazilian Tensile Test: This test employs a solid circular disc that is compressed to failure along its diameter. It can be shown that the horizontal stress perpendicular to the axis of loading is uniform and tensile (Figure 4).

Although Brazilian testing is, perhaps, the most convenient method of determining tensile strength, some care must be taken with its use. Short fissures, which tend to lower the tensile strength when determined directly, do not have as pronounced an effect on splitting tension. Results obtained using the Brazilian test, therefore, can indicate a somewhat higher tensile strength than is actually the case.

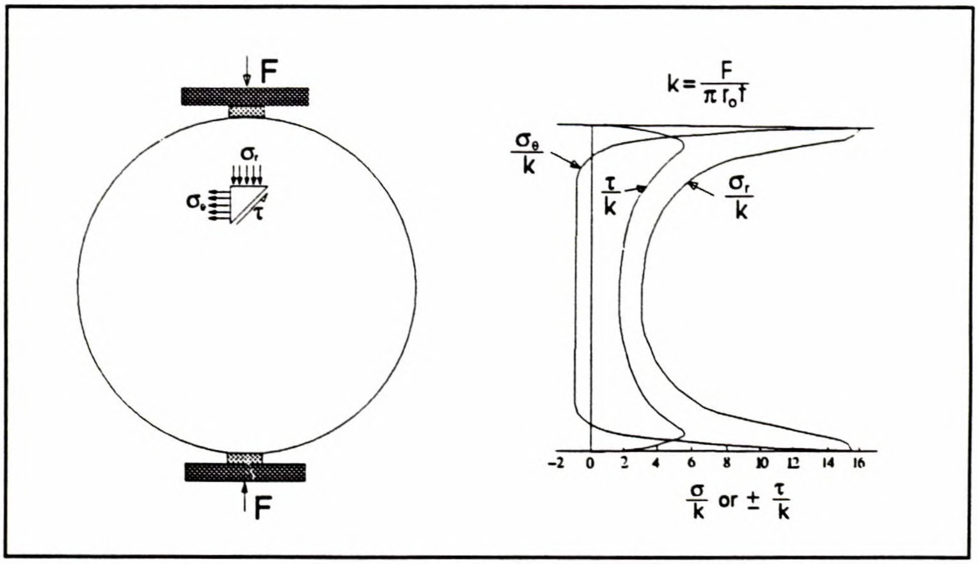

Figure 4. Stress distribution across the loaded diameter of a Brazilian test specimen (after Shook, 1963)

Bending or Flexural Test: A beam (prismatic or cylindrical), when subjected to bending, develops tensile stresses along its convex surface and compressive stresses along its concave surface (Figure 5). As such, failure in tension can be anticipated and the tensile strength estimated from simple beam theory.

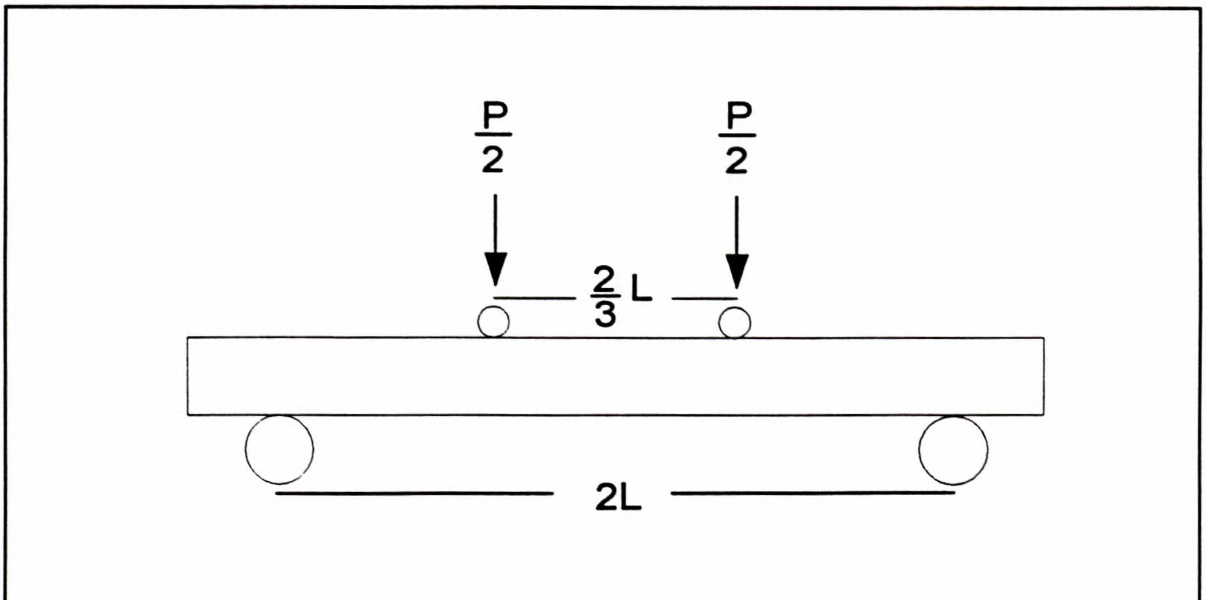

Figure 5. Bending or flexural test schematic

Again, caution is advised in using the results of bending tests. Some fundamental assumptions used in the analysis require that the material be homogeneous and the stress-strain behaviour be the same in both tension and compression. These obviously do not hold entirely true for rock, and the flexural strength is often two to three times the tensile strength determined by direct methods. Some deviation also exists because of the relatively small volume of rock failed in pure tension in a flexed beam.

Pre- and Post-failure Uniaxial Compressive Strength

Compression testing in the post-failure region has, historically, been conducted using very stiff testing machines, which minimized the transfer of stored strain energy from the load frame to the specimen at the point of failure. The entire stress-strain curve is then readily obtained for class 1 rocks (Figure 6) where axial strain increases monotonically throughout the loading cycle (i.e., σ or ε = constant * time). It is not so easily achieved, however, for borderline class 1/class 2 and class 2 rock types where the control signal becomes unstable shortly after point A (illustrated in Figure 7) is reached, causing violent failure.

The last two decades have seen the refinement of servo-control mechanisms that, when connected to the hydraulics of a frame actuator, enable loading to be controlled according to any number or combination of chosen analog outputs. This, coupled with increasingly sophisticated computer control, has allowed investigators to study post-failure of class 2 rocks using such properties as lateral strain, inelastic strain and acoustic emission as control signals.

MRL has experimented with three different methods of determining post-failure behaviour. These include using axial stroke, lateral strain and a modified axial strain signal as control modes.

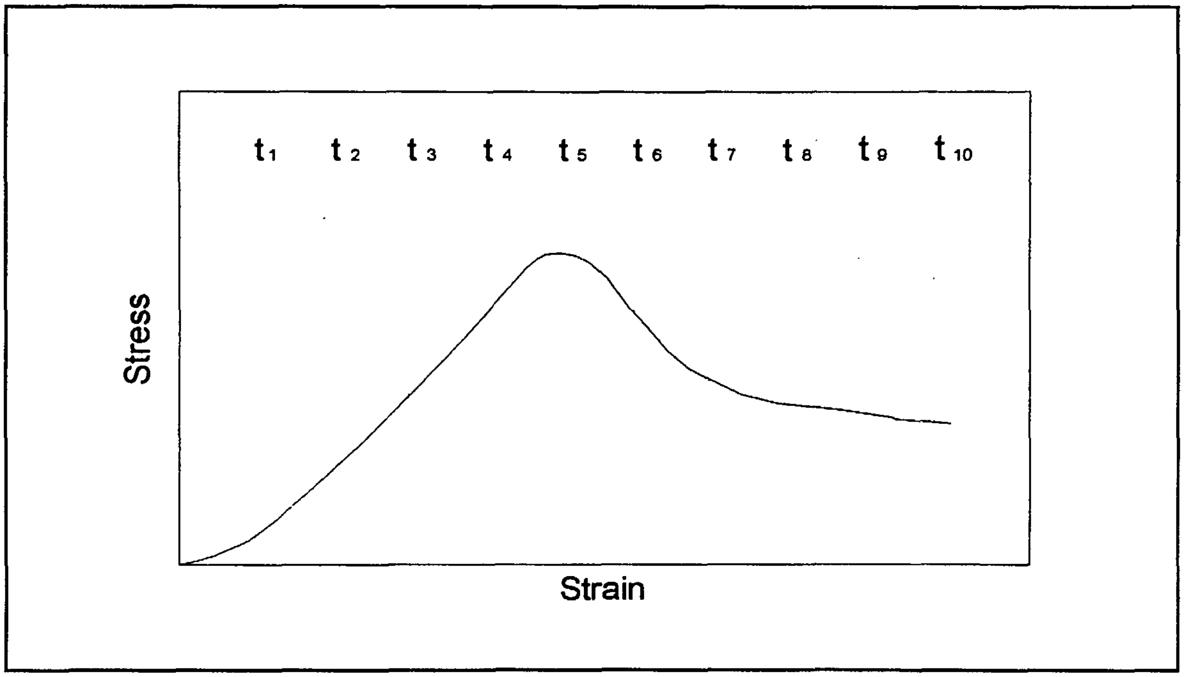

Figure 6. Class 1 strain rate-controlled uniaxial test

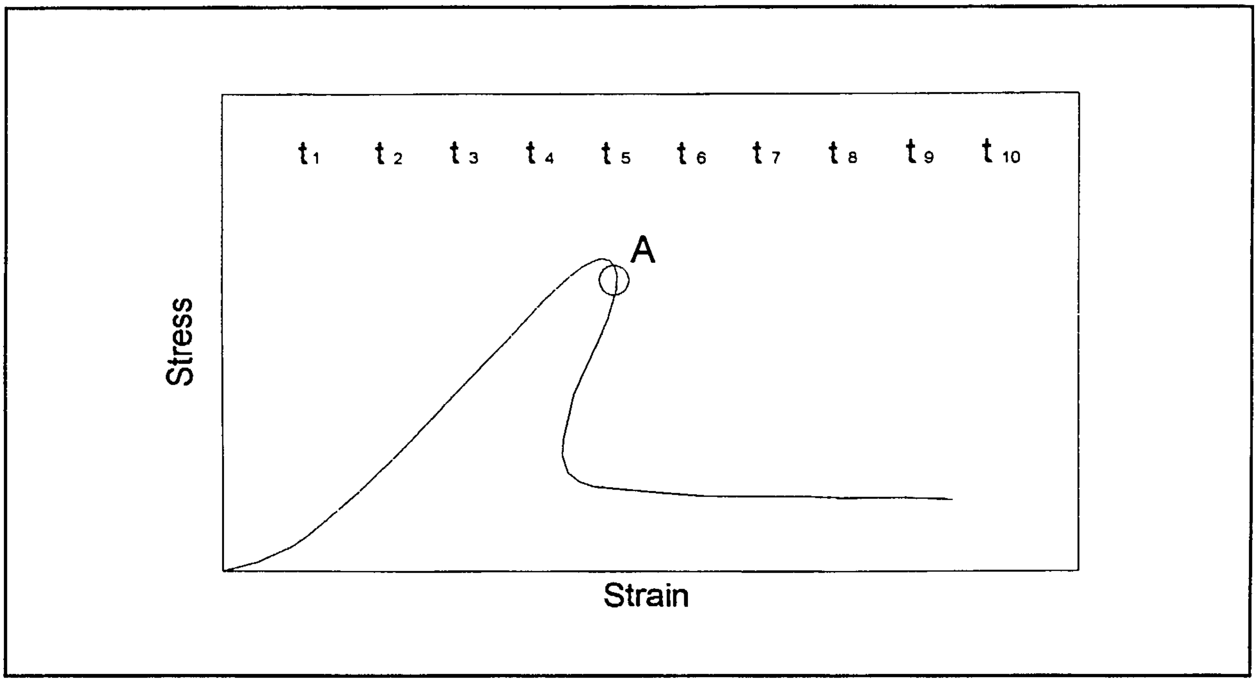

Figure 7. Class 2 strain rate-controlled uniaxial test

Axial Strain Control Mode: For class 1 rock, the entire pre- and post-failure stress-strain curve can be obtained using a single constant axial strain rate, which is maintained throughout the loading sequence. To obtain post-failure behaviour for class 2 rock, however, energy must be extracted from the system at ultimate strength to avoid violent failure.

This has been accomplished at MRL by monitoring, every second, the load required to maintain a specified axial strain rate. If the current load is equal to or less than the previous load reading (indicating imminent failure), then a command signal immediately causes the specimen to be unloaded to 60% of the last load level. The loading sequence is then re-initiated according to the originally specified strain rate. This pattern is repeated until an outline of the entire stress-strain curve can be traced using the maxima of each individual loading cycle (Figure 8).

Lateral Strain Control Mode: Lateral or circumferential strain provides a convenient means of control for post-failure testing since it increases monotonically throughout the loading range for both class 1 and 2 rock types. Feedback from a suitable transducer (e.g., a bicycle chain extensometer) enables computer-controlled servo-valves to either increase or decrease the load to maintain a constant lateral strain rate.

Unfortunately, crack formation in certain rock types causes the lateral strain to increase significantly just before failure. To compensate, the loading rate must be decreased, often to levels where visco-elastic or creep effects may begin to occur. This can result in decreases in apparent strength and modulus values determined at failure.

Modified Axial Strain Mode: Okubo and Nishimatsu (1985) controlled the failure of class 2 rocks by modifying the axial strain according to the equation:

$$\varepsilon - \frac{\sigma}{E'} = \text{constant} * \text{time}$$

E' represents an arbitrary modulus value that lies somewhere between the expected pre- and post-failure moduli for the rock type in question. $1/E'$ or the "gain" alters the signal in such a way as to allow control throughout the post-failure region even if the post-failure modulus is positive (Figure 9).

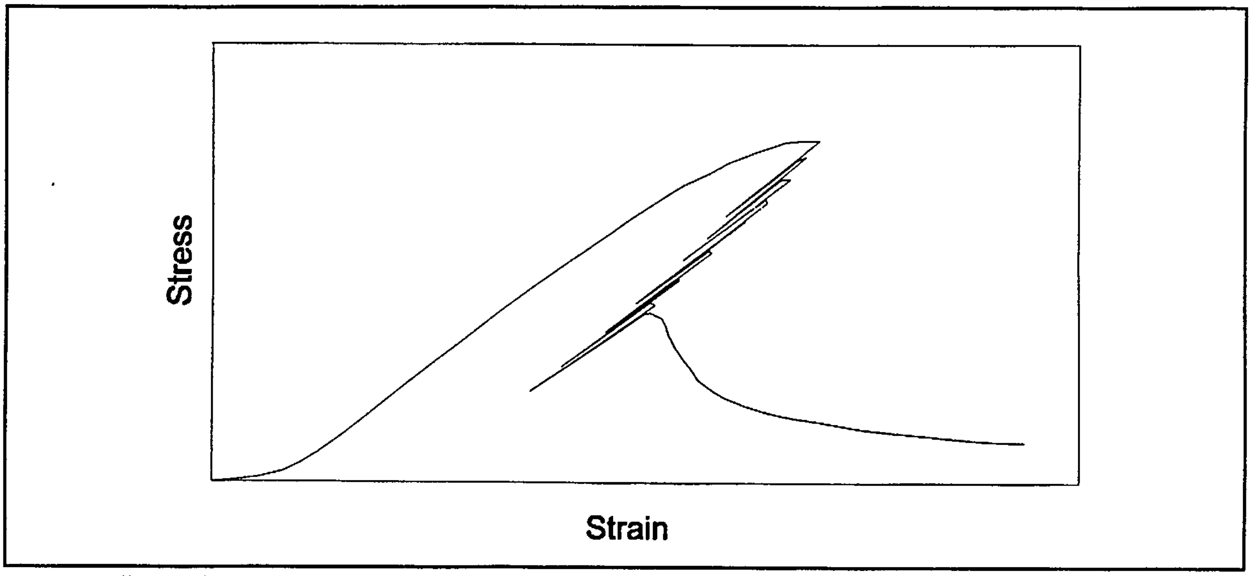

Figure 8. Typical class 2 post-failure longitudinal strain rate-controlled uniaxial test

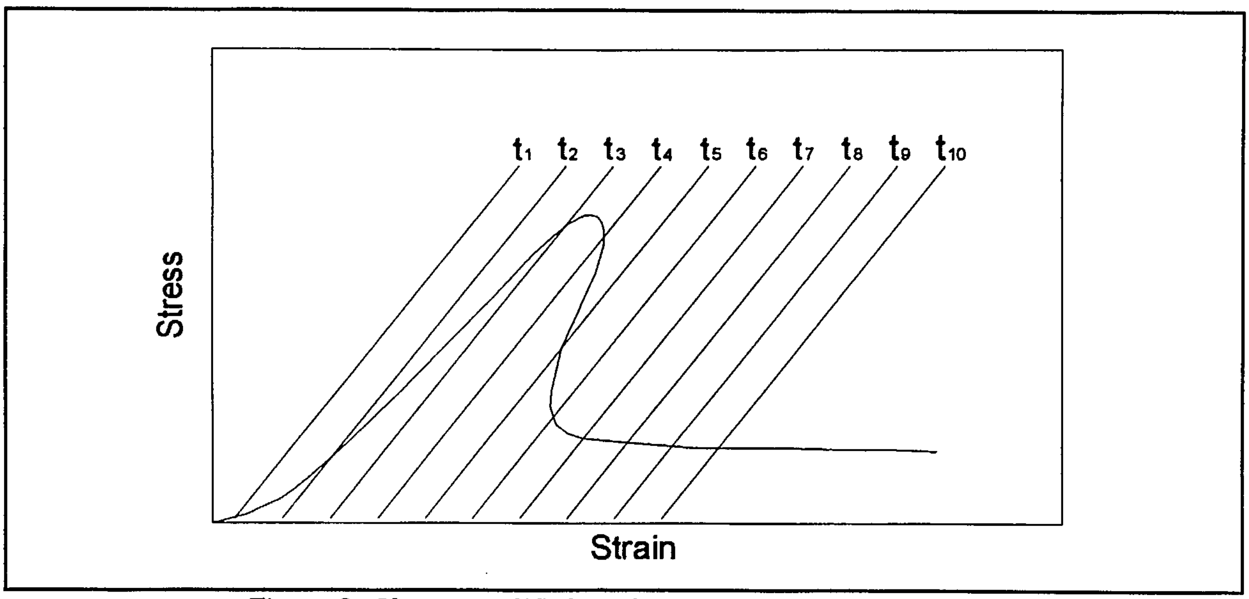

Figure 9. Class 2 modified strain rate-controlled uniaxial test

Pre- and Post-failure Triaxial Compressive Strength

Perhaps the greatest impact of computer-controlled servo-hydraulics has been felt in the area of triaxial compression testing. The ability to quickly and accurately adjust the confining pressure and loading rate applied to a sample enables the investigator to utilize a number of unconventional stress paths that are not possible with standard compression machines. So although the traditional single confining pressure triaxial test remains a staple fixture for rock mass characterization, the development of techniques such as multi-stage and continuous failure state testing has extended the range of information available from each sample.

Conventional Triaxial Test: In a conventional triaxial test, the specimen is loaded hydrostatically, generally by the simultaneous application of axial load and side pressure, to the desired confining pressure level. Axial loading then continues to failure according to the chosen control mode (e.g., load, axial strain, lateral strain, etc.). Post-failure behaviour can be determined using any of the methods mentioned for uniaxial testing given that the same caveats are observed.

Multi-stage Triaxial Test: Before testing begins, the confining pressures required to adequately describe a rock type's failure envelope for the anticipated ground conditions are determined by the investigator. The sample is then loaded hydrostatically to the lowest predetermined confining pressure. It is subsequently loaded axially according to the control mode chosen before testing.

As in post-failure uniaxial testing, the load is monitored every second until the current load reading is equal to or less than the previous reading, indicating the onset of failure. At this point, the confining pressure is immediately increased to the next level and loading continues. This process is repeated for each of the specified confining pressures until the maximum level is reached. Loading can then proceed into the post-failure region by any of the methods outlined for uniaxial testing. The residual strength, indicated by a plateauing of the stress-strain curve, can also be obtained for each of the lower confining pressures. This is accomplished by switching load control from the current mode to one that will maintain a specified axial displacement rate. The confining pressure is then reduced to the next lowest level and the stress-strain curve allowed to once again plateau out. This is repeated sequentially until the residual strength has been established for all desired confining pressures.

Continuous Failure State Test: The continuous failure state test is, essentially, a multi-stage test where very little time elapses between an incremental increase in confining pressure and the corresponding onset of failure. This is accomplished by setting the confining pressure steps sufficiently small so that only minimal additional loading is required to continue failing the specimen.

The main advantage of continuous failure state testing is that the resulting confining pressure versus failure stress curve is, in essence, a failure envelope for the specimen being tested.

Extension Test: The vast majority of mine designs are based on failure envelopes developed using the Griffith and Mohr-Coulomb criteria or modifications thereof. In brittle rock, however, it has been shown that slabbing of excavation walls has occurred at stress levels significantly less than those predicted by either model. It is also apparent from the orientation and condition of the observed fracture surfaces that failures have resulted in tensile rather than shear displacements. Stacey (1981) noted that failure in these materials can be caused by extensional strains arising from the Poisson's ratio effect.

Unsupported underground excavation results in a reorientation of local stress fields and, depending on tunnel configuration, can cause a reduction in confinement in some areas and stress concentrations in others. Under suitable conditions of compressive stress and reduced confinement, sufficient extension straining can occur to cause extension fracturing. Since this type of failure occurs at stress levels considerably less than traditionally predicted values, it is important to find a method of estimating the stress conditions that can result in extensional failures.

At MRL, this is accomplished by hydrostatically loading a specimen to the major principal stress anticipated for a particular ground condition and tunnel configuration. The axial load is then held constant and the confining pressure reduced so that a constant rate of longitudinal strain is maintained. The onset of extensional strain failure is indicated by a plateauing of the confining pressure versus axial strain curve.

Multi-stage Extension Test: For multi-stage extension testing, the specimen is loaded hydrostatically to the highest predetermined stress level. As in the single-stage test, the confining pressure is reduced according to a specified axial strain rate until the onset of failure. As the specimen begins to fail, the axial load is reduced to the next lower stress level of interest. The confining pressure is again reduced as described earlier. This sequence is repeated until all predetermined stress levels have been investigated.

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DATA SHEETS

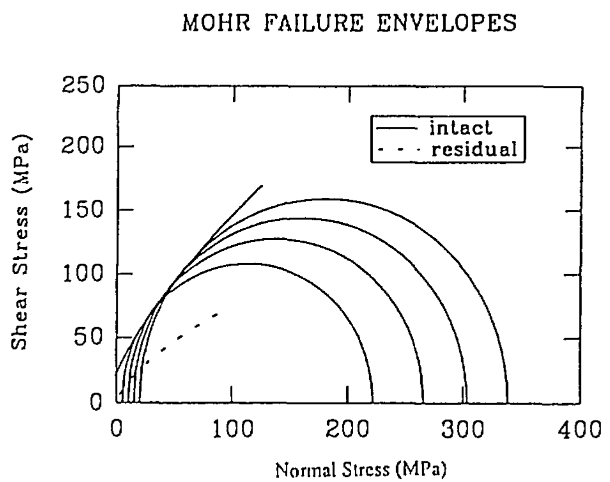
Origin	Reference No.	Rock Type
Montauban Mine, Quebec	2	amphibolite

Regional Geology	Structural CharacteristicsRegional Geology
Precambrian rock in the Grenville Provincial Series metavolcano-sedimentary rocks	Dip: Strike: NW – SE (orebody) Bedding Thickness: variable Fracture Spacing: Weathering:

Petrography	
Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.90	n/a	46	91	n/a	n/a	n/a	n/a	n/a	n/a	5.00– 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
170.06	21.36	1.00	1.00	3.05	0.00	0.66

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 55′
Longitude: 72° 10′

Data Sheet 2

Origin	Reference No.	Rock Type
Chimo Mine, Quebec	19	andesite

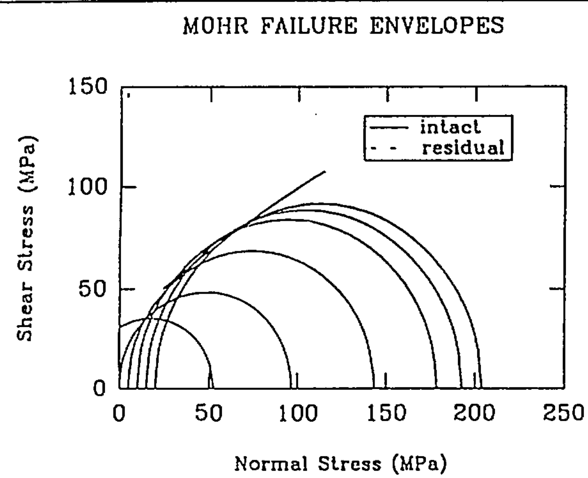
Regional Geology	Structural Characteristics
Upper Malartic Group, in the Abitibi Subprovince of the Superior Province (Archean age). W – NW belt of metasediments with contact metavolcanics at north	Dip: 70° to 80° Strike: 135° Bedding Thickness: 7.60 m Fracture Spacing: 5.00 30.00 cm Weathering: none

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	carbonates, basic minerals, quartz, corundum

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.80	n/a	46.00	91.00	n/a	n/a	96.70	-17.50	55.82	0.31	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
128.13	6.67	1.00	0.89	2.59	0.12	0.22

Borehole Information

Collar Elevation:
Depth: 36.90 m
Inclination: -90°
Latitude: 48° 2′ N
Longitude: 77° 10′ W

Data Sheet 3

Origin	Reference No.	Rock Type
Hislop Township, Ontario	3	andesite

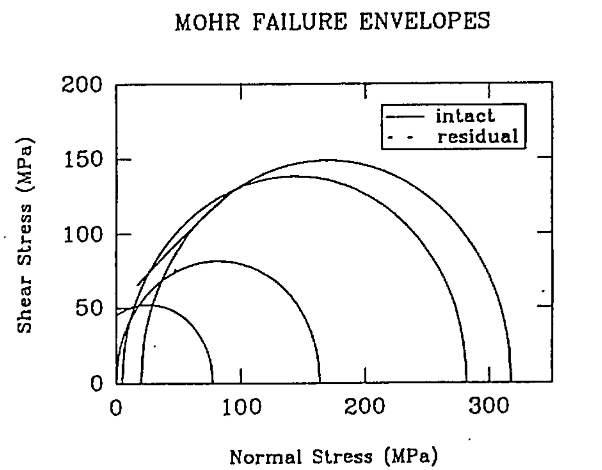
Regional Geology	Structural Characteristics
Archean, part of the Abitibi Subprovince, massive rock, with carbonate throughout	Dip: 75° to 80° NW Strike: NW – SE generally Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: smooth, undulating joints with calcite infilling	Composition
Texture: Grain Size: medium to fine Colour: medium to dark grey Grain Sorting: Grain Shape: Matrix:	1% pyrite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.90	<0.10	46.00	91.00	5.90	n/a	163.47	-25.96	73.21	0.28	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
226.12	7.75	1.00	0.79	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 30′ N
Longitude: 80° 15′ W

Data Sheet 4

Origin	Reference No.	Rock Type
Hislop Township, Ontario	3	breccia

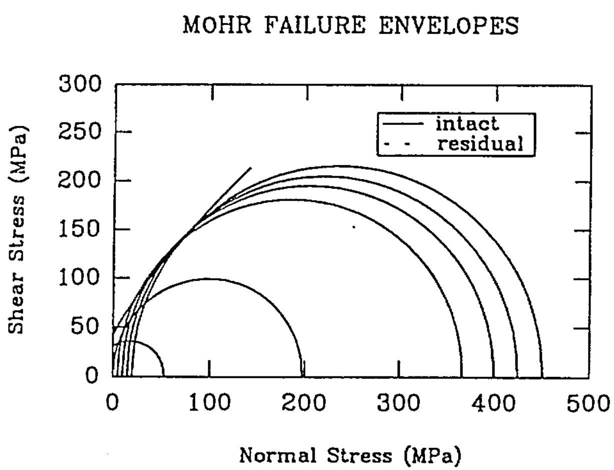
Regional Geology	Structural Characteristics
Archean, part of the Abitibi Subprovince	Dip: 75° – 80° NE Strike: NW – SE generally Bedding Thickness: 7.60 30.50 m Fracture Spacing: Weathering:

Petrography

Structure: massive	Composition
Texture: Grain Size: 1.60 25.40 mm Colour: medium to dark grey Grain Sorting: Grain Shape: angular to subangular Matrix: grey coloured	chlorite, carbonates, silicates 1-10% pyrite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.89	n/a	46.00	91.00	n/a	n/a	197.63	-17.72	87.22	0.26	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
291.86	17.89	1.00	0.89	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 30′ N
Longitude: 80° 15′ W

Origin	Reference No.	Rock Type
Lingan Mine, Nova Scotia	7	coal

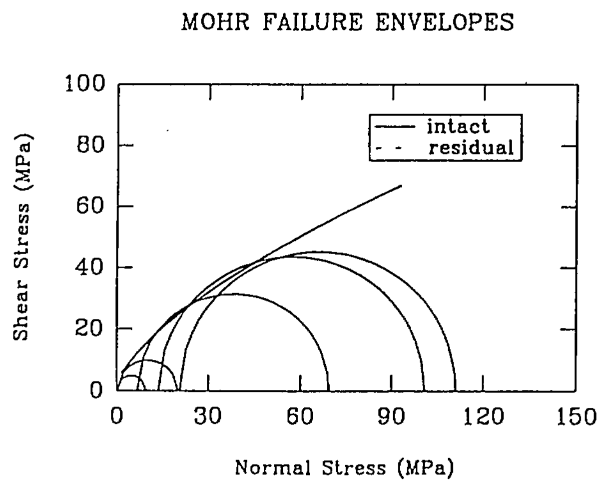
Regional Geology	Structural Characteristics
Morien Group, Glace Bay Sub-basin of the Carboniferous Sydney Basin	Dip: 4° – 15° seaward Strike: E – NE Bedding Thickness: 2.30 m Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
1.24	n/a	46.00	91.00	n/a	n/a	9.78	-0.43	1.76	0.34	0.30 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
20.96	20.26	1.00	0.95	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 60° 5′ W

Origin	Reference No.	Rock Type
Pamour Mine, Ontario	20	conglomerate

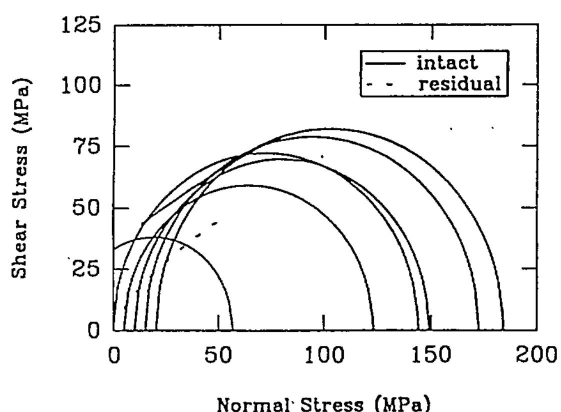
Regional Geology	Structural Characteristics
Mineralized zone, north of the Destor-Porcupine Fault; close to the contact of sedimentary and volcanic rocks of the Superior Province	Dip: 70° – 80° N Strike: 270° W Bedding Thickness: 10.40 m Fracture Spacing: <5.00 cm to 1.00 m Weathering: little to none

Petrography	
Structure: tight joints, rough planar and undulated surfaces	Composition
Texture: Grain Size: variable Colour: Grain Sorting: Grain Shape: rounded Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.76	n/a	46.00	91.00	n/a	n/a	144.28	-18.97	64.41	0.25	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
126.36	4.07	1.00	0.84	3.51	0.00	0.24

Borehole Information

Collar Elevation:
Depth: 9.00 m (to conglomerate)
Inclination: -64° S
Latitude: 48° 30′ N
Longitude: 81° 20′ W

Data Sheet 7

Origin	Reference No.	Rock Type
Creighton Mine, Ontario	6	norite

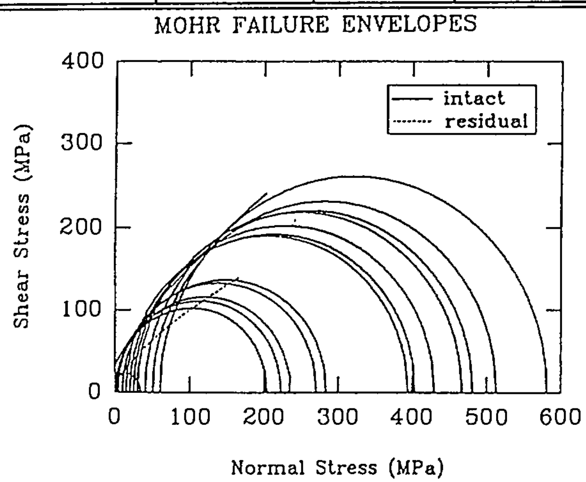
Regional Geology	Structural Characteristics
Huronian Supergroup, Elliot Lake Group, Copper Cliff Formation, Precambrian rocks, southern rim of the norite deposit, in the Sudbury Basin	Dip: Strike: 75° SW Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: tight, unaltered joints; uniform, rough to smooth joint surfaces	Composition
Texture: Grain Size: coarse Colour: dark Grain Sorting: Grain Shape: Matrix: uniform	50 – 60% labradorite, 18 – 30% ferromagnesians hornblende and biotite, <5% sulphide minerals, called "norite" due to An content, quartz

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.03	n/a	55.00	109.00	n/a	n/a	203.40	-11.53	59.74	0.18	2.00 – 60.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
222.67	17.14	1.00	0.95	5.40	0.04	0.49

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 25′ N
Longitude: 8° 20′ W

Data Sheet 8

Origin	Reference No.	Rock Type
Lac St-Jean, Quebec	9	diabase (fine-grained)

Regional Geology	Structural Characteristics
intrusive diabase dike	Dip: Strike: Bedding Thickness: Fracture Spacing: none Weathering: none

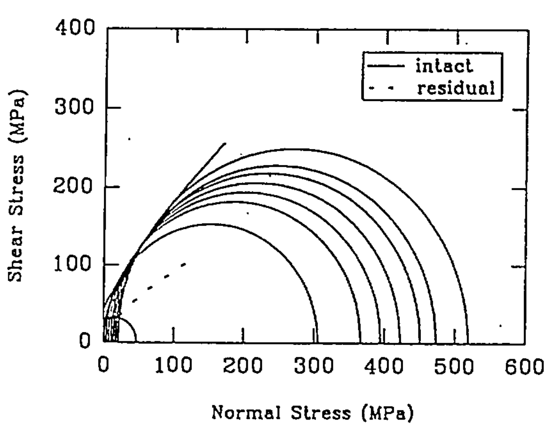
Petrography

Structure: homogeneous, unmetamorphosed aphanitic; massive	Composition
Texture: Grain Size: fine Colour: dark to greyish dark Grain Sorting: Grain Shape: Matrix:	56% light brown plagioclase, 44% pale brown augite, actinolite, biotite, prehnite, quartz, opaque minerals

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.97	<0.1	42.00	84.00	5.34	n/a	306.00	-15.69	89.54	0.30	3.50 – 20.70

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
321.27	20.40	1.00	0.99	3.03	0.00	0.81

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 30′ N
Longitude: 7°1 45′ W

Origin	Reference No.	Rock Type
Eldrich Mine, Quebec	10	diorite

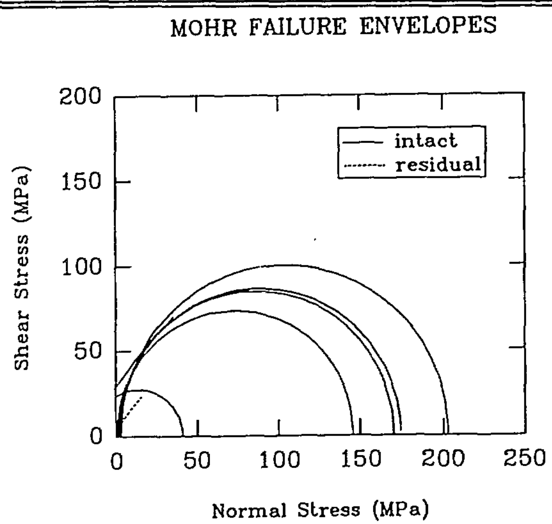
Regional Geology	Structural Characteristics
Southern volcanic zone of the Abitibi Subprovince altered rocks from the NW sector of the Flavarian batholith Blake River Group, Archean age, also called Eldrich gabbro, results of incomplete mixing of two magmas in a turbulent region	Dip: 30° to 45° Strike: 30° SE Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: homogeneous, primary ophitic	Composition
Texture: Grain Size: fine Colour: grey-green Grain Sorting: Grain Shape: Matrix:	40 – 50% plagioclase (saussuritized), 35 – 45% hornblende, 3 – 15% quartz, accessory minerals: albite, sericite, calcite, chlorite, sphene, opaques

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.85	0.15	46.00	91.00	6.62	n/a	143.13	-13.57	79.86	0.29	1.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
165.47	11.45	1.00	0.88	3.86	0.01	0.28

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 19′ N
Longitude: 79° 1″ W

Data Sheet 10

Origin	Reference No.	Rock Type
Montauban Mine, Quebec	2	gneiss (quartz-mica-biotite)

Regional Geology	Structural Characteristics
Precambrian rocks in the Grenville Provincial Series metavolcano-sedimentary rocks	Dip: Strike: NW – SE (orebody) Bedding Thickness: Fracture Spacing: Weathering:

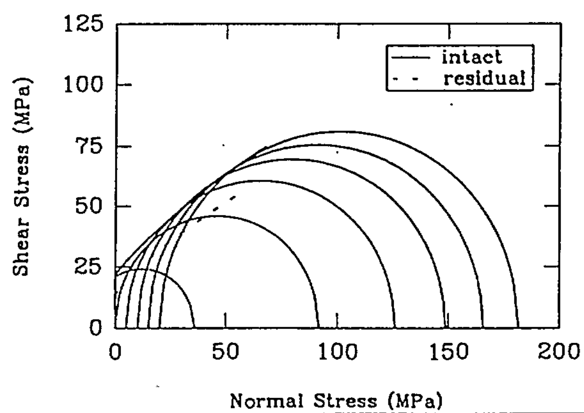
Petrography

Structure: well-developed gneissic banding	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	50 – 70% quartz, 30 – 50% muscovite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.75	n/a	46.00	91.00	n/a	n/a	93.17	-12.00	41.72	0.25	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
103.21	7.57	1.00	0.98	4.78	0.40	0.01

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 55′
Longitude: 72° 10′

Data Sheet 11

Origin	Reference No.	Rock Type
Montauban Mine, Quebec	2	gneiss (quartz-biotite)

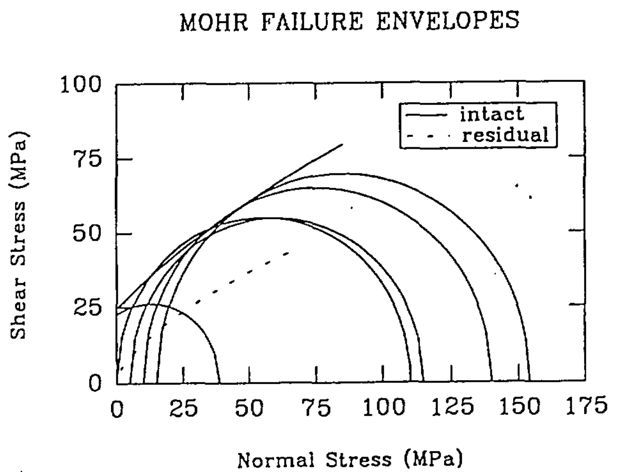
Regional Geology	Structural Characteristics
Precambrian rocks in the Grenville Provincial Series, metavolcano-sedimentary rocks	Dip: Strike: NW – SE (orebody) Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: well-developed gneissic banding	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	50 – 70% quartz, 30 – 50% biotite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.69	n/a	46.00	91.00	n/a	n/a	110.28	-12.97	40.99	0.49	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
103.20	5.68	1.00	0.97	2.27	0.02	0.33

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 55′
Longitude: 72° 10′

Data Sheet 12

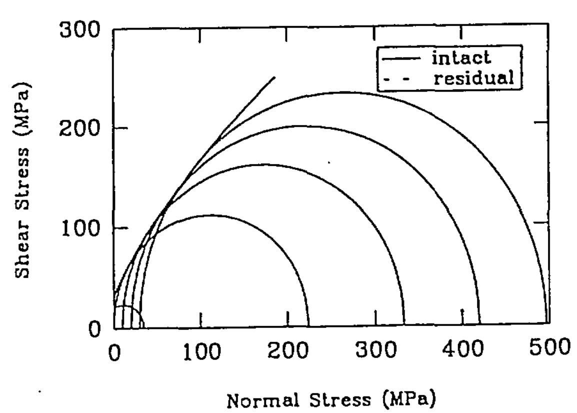
Origin	Reference No.	Rock Type
Blue Beach North, Newfoundland	4	granite (pink)

Regional Geology	Structural Characteristics
St. Lawrence granite, Devonian, also called Red Alaskite, from a Carboniferous pluton, host rock for fluorite veins	Dip: generally steep to the west Strike: 135° Bedding Thickness: Fracture Spacing: Weathering:

Petrography	
Structure: porphyritic	Composition
Texture: Grain Size: medium to coarse; phenocrysts up to 1 cm diameter Colour: pink Grain Sorting: Grain Shape: Matrix:	30 – 60% alkali feldspar, 20 – 40% quartz, 0 – 20% albite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.55	1.43	38.00	76.00	5.17	n/a	223.86	-11.53	63.61	0.27	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
236.87	22.10	1.00	1.00	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 55′
Longitude: 55° 23′

Data Sheet 13

Origin	Reference No.	Rock Type
Pinawa, Manitoba	11	granite (pink and grey)

Regional Geology	Structural Characteristics
Originates from the Lac Du Bonnet pluton (Archean age) in the Englis River Subprovince, pink colour caused by submicroscopic iron-oxide coatings and fillings, from hydrothermal fluids	Dip: 50 – 55° N Strike: Bedding Thickness: 137.00 – 400.00 m Fracture Spacing: 2.0 – 22.00 m Weathering:

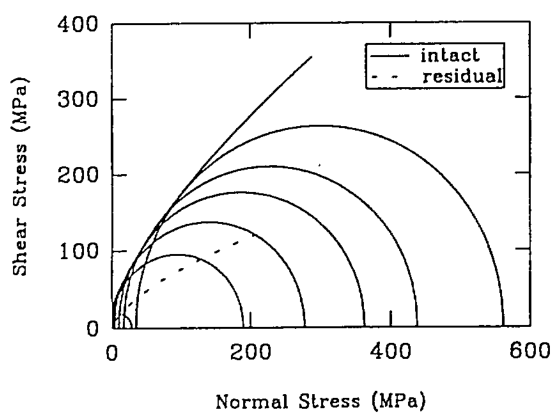
Petrography

Structure: massive, porphyritic, few fractures, medium-coarse grained	Composition
Texture: Grain Size: microscopic to 20 mm Colour: grey, pink Grain Sorting: Grain Shape: Matrix:	plagioclase (oligoclase) 37.5%, microcline 27.3%, quartz 30.6%, biotite 3.5%, muscovite 0.5%, sphene, apatite, calcite, epidote, iron oxide, allanite 0.6%

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.63	0.36	44.00	98.00	4.43	n/a	190.00	-9.56	65.30	0.27	3.50 – 35.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
234.15	27.75	1.00	0.99	2.26	0.00	0.97

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 50° 25′ N
Longitude: 96° 00′ W

Origin	Reference No.	Rock Type
Belmoral Mine, Quebec	17	granodiorite

Regional Geology	Structural Characteristics
Bourlamaque batholith, cutting the Malartic Group in the Abitibi Subprovince of the Superior Province (Archean age)	Dip: 65° SE Strike: 70° Bedding Thickness: 5.2 m Fracture Spacing: 30 cm to 1 m Weathering: none

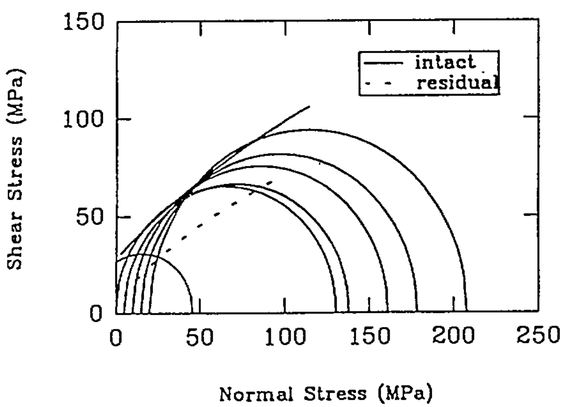
Petrography

Structure: cross-jointed, vertical joints, unaltered, smooth planar to slickenside joint surfaces	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	feldspar, hornblende, altered diorite, quartz, some hematitic and sericitic alteration

Mechanical Properties

γ_d (Mg/m^3)	n (%)	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.78	0.22	46.00	91.00	6.06	n/a	130.37	-15.13	69.47	0.28	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
125.37	6.64	1.00	0.97	3.64	0.00	0.15

Borehole Information

Collar Elevation:
Depth: 19.2 m
Inclination: -90°
Latitude: 48° 8′ N
Longitude: 77° 38′ W

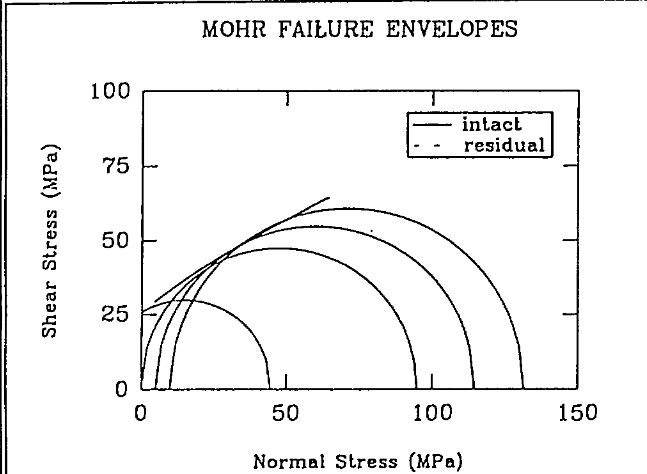
Origin	Reference No.	Rock Type
Pamour Mine, Ontario	20	greywacke

Regional Geology	Structural Characteristics
North of the Destor-Porcupine Fault; close to the contact of sedimentary and volcanic rocks of the Superior Province	Dip: 70° – 80° N Strike: 270° W Bedding Thickness: 3.40 m – 9.10 m Fracture Spacing: <5 cm – 30 cm Weathering: slight

Petrography	
Structure: tight, closely spaced joints, smooth to rough planar surfaces	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.76	n/a	46.00	91.00	n/a	n/a	134.10	-14.89	44.20	0.29	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
99.14	4.49	1.00	0.98	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth: 5.2 – 19.4 m
Inclination: -52° S
Latitude: 48° 30′ N
Longitude: 81° 20′ W

Data Sheet 16

Origin	Reference No.	Rock Type
Central Canada Potash, Saskatchewan	16	limestone (bituminous)

Regional Geology	Structural Characteristics
Dawson Bay Formation, middle Devonian period	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

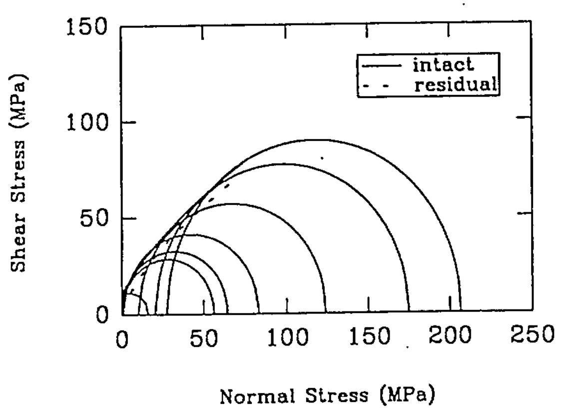
Petrography

Structure: bituminous, calcite-filled vugs, sugary	Composition
Texture: Grain Size: Colour: dark brown to black Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.46	n/a	44.00	89.00	n/a	n/a	56.37	-5.43	29.80	0.30	0.10 – 27.60

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
66.71	14.40	1.00	0.99	13.05	0.00	0.98

Borehole Information

Collar Elevation: 459 m
Depth:
Inclination: 53° SW
Latitude: 51° 55′
Longitude: 105° 45′ W

Origin	Reference No.	Rock Type
Central Canada Potash, Saskatchewan	16	limestone (fine-grained)

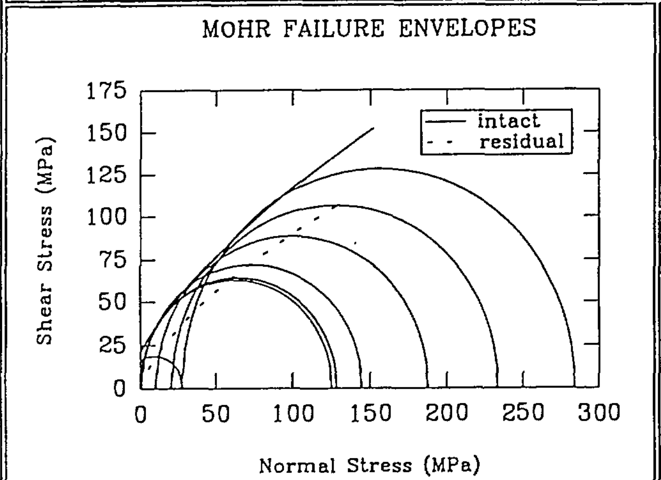
Regional Geology	Structural Characteristics
Dawson Bay Formation, middle Devonian period	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: competent, few fractures, mottled	Composition
Texture: Grain Size: fine Colour: dark to medium grey, brownish grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.61	n/a	44.00	89.00	n/a	n/a	125.70	-9.40	40.08	0.26	0.10 – 27.60



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
127.97	12.76	1.00	0.98	7.02	0.00	0.87

Borehole Information

Collar Elevation: 459 m
Depth:
Inclination: 53° SW
Latitude: 51° 55′ N
Longitude: 105° 45′ W

Data Sheet 18

Origin	Reference No.	Rock Type
Indiana, USA	8	limestone (oolitic)

Regional Geology	Structural Characteristics
	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

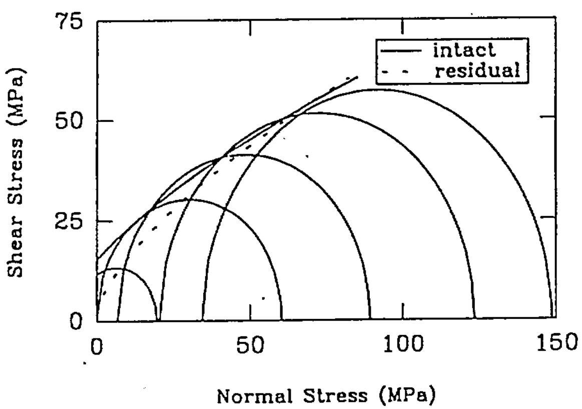
Petrography

Structure: faint bedding trace, orthogonal to core axis, soft	Composition
Texture: Grain Size: Colour: buff coloured Grain Sorting: Grain Shape: Matrix:	30 – 50% pelecypods, gastropods, bryozoans observed in a soft, moderately cemented ooid and fossil mass

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.34	13.76	42.00	84.00	3.80	n/a	59.70	-4.76	40.80	0.25	6.90 – 34.50

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
60.50	4.90	1.00	0.96	6.40	0.14	0.99

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: approx 40° N
Longitude: approx 88° W

Origin	Reference No.	Rock Type
Central Canada Potash, Saskatchewan	16	limestone (sugary)

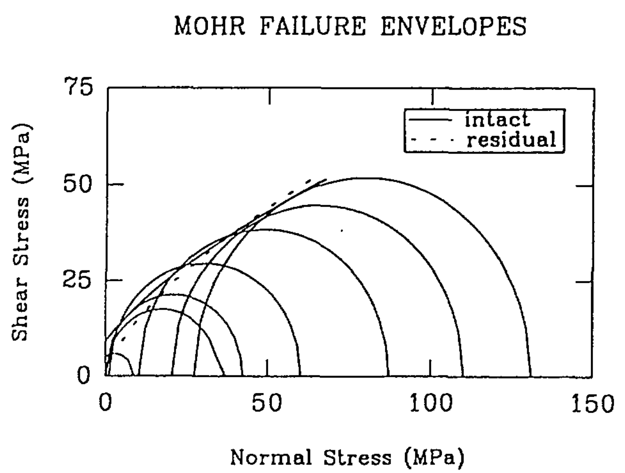
Regional Geology	Structural Characteristics
Dawson Bay Formation, middle Devonian period	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: few fractures, some fossilization, mottled appearance, sugary	Composition
Texture: Grain Size: fine Colour: light grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.20	n/a	44.00	89.00	n/a	n/a	42.55	-2.91	18.03	0.28	0.10 – 27.60



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
43.07	7.49	1.00	0.96	9.86	0.00	1.00

Borehole Information

Collar Elevation: 459 m
Depth:
Inclination: 53° SW
Latitude: 51° 55′ N
Longitude: 105° 45′ W

Data Sheet 20

Origin	Reference No.	Rock Type
Detour Lake Mine, Ontario	5	mafic flow

Regional Geology	Structural Characteristics
Archean rocks, of volcanic origin, Abitibi Subprovince located on the James Bay Highlands, on the hanging wall of the excavation, basaltic flow	Dip: 35° – 40° W (orebody) Strike: avg. N 70° E Bedding Thickness: Fracture Spacing: Weathering:

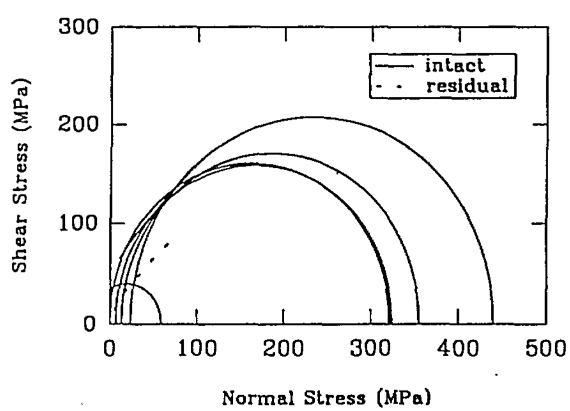
Petrography

Structure: tight fractures, brittle	Composition
Texture: Grain Size: Colour: dark green Grain Sorting: Grain Shape: Matrix:	iron, magnesium rich, plagioclase, pyroxene, quartz

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.95	<0.10	44.00	89.00	4.65	n/a	316.91	-19.99	88.00	0.25	6.90 – 24.10

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
287.22	12.27	1.00	0.95	5.01	0.00	0.98

Borehole Information

Collar Elevation: 259.00 m above sea level
Depth: >38 m
Inclination:
Latitude: 50° 0′ N
Longitude: 79° 45′ W

Origin	Reference No.	Rock Type
Detour Lake Mine, Ontario	5	mafic flow ore

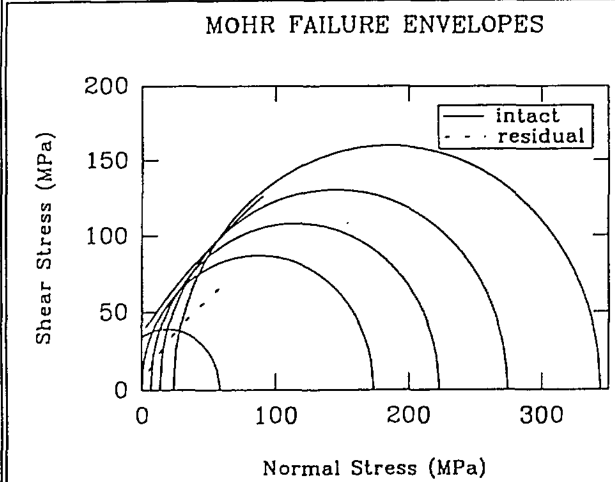
Regional Geology	Structural Characteristics
Archean rocks of volcanic origin located on the James Bay Highlands, on the hanging wall of the excavation, pillowed amygdaloidal basalt flow	Dip: 35° – 40° W (orebody) Strike: avg. N 70° E Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: tight fractures, brittle, sulphide-filled amygdules	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	iron, magnesium rich

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.99	n/a	44.00	89.00	n/a	n/a	173.91	-19.53	92.69	0.26	6.90 – 24.10



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
199.22	10.87	1.00	0.94	5.36	0.00	0.56

Borehole Information

Collar Elevation: 259.0 m above sea level
Depth: >38 m
Inclination:
Latitude: 50° 0′ N
Longitude: 79° 45′ W

Origin	Reference No.	Rock Type
Donkin-Morien, Nova Scotia	13	mudstone

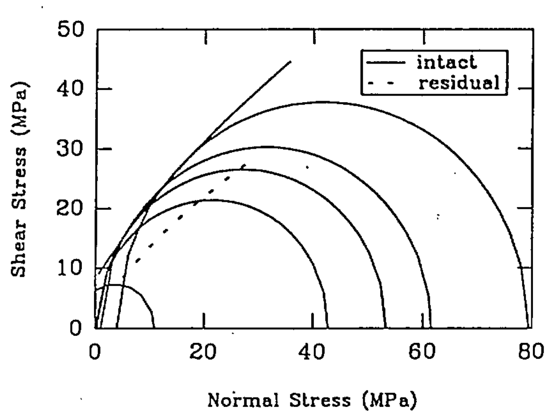
Regional Geology	Structural Characteristics
Originates from the Carboniferous Morien Group, Sydney Basin	Dip: 4° to 15° Strike: NE – E Bedding Thickness: thinly laminated medium Fracture Spacing: Weathering: little or none

Petrography

Structure: fissile, frequently containing clasts	Composition
Texture: Grain Size: Colour: light to dark grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.61	n/a	46.00	91.00	n/a	n/a	33.92	-3.63	1.93	0.49	0.40 – 5.20



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
50.84	14.39	1.00	0.95	6.65	0.00	0.55

Borehole Information

Collar Elevation: approx. -200 m
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 59° 50′ W

Data Sheet 23

Origin	Reference No.	Rock Type
Lingan Mine, Nova Scotia	7	mudstone

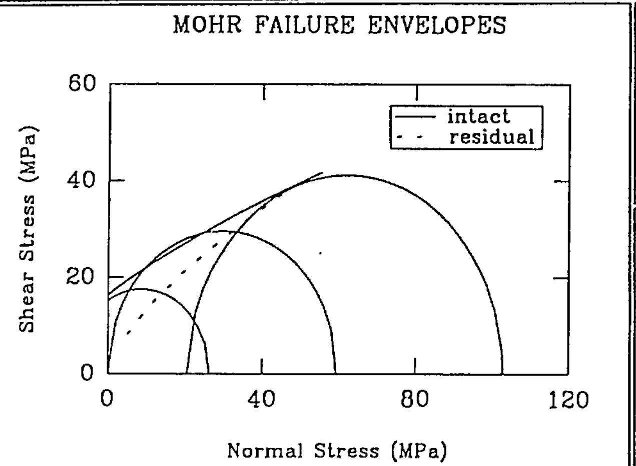
Regional Geology	Structural Characteristics
Morien Group, Glace Bay Sub-basin of the Carboniferous Sydney Basin	Dip: 4° – 15° seaward Strike: E – NE Bedding Thickness: 0.4 – 1.5 m Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.70	n/a	46.00	91.00	n/a	n/a	59.40	-8.78	15.49	0.11	3.50 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
55.85	3.26	1.00	0.98	5.59	0.00	0.98

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 60° 5′ W

Data Sheet 24

Origin	Reference No.	Rock Type
Springhill Coal Mine, Nova Scotia	14	mudstone

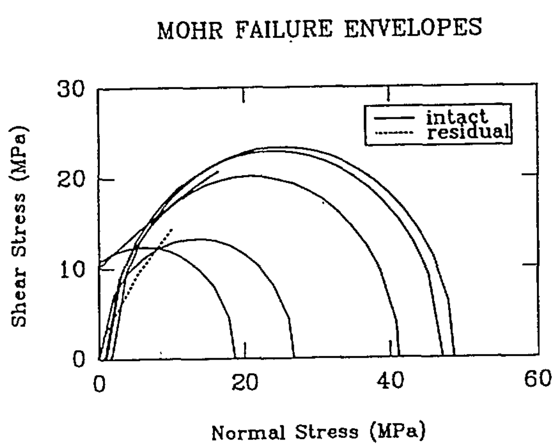
Regional Geology	Structural Characteristics
Pennsylvanian Cumberland Group, from the Cumberland Basin in the Appalachian Orogen	Dip: SW (Springhill Anticline axis) Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
n/a	n/a	46.00	91.00	n/a	n/a	26.71	-6.21	n/a	n/a	0.40 – 3.50



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
39.35	4.44	1.00	0.56	9.83	0.08	0.44

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 45° 35′ N
Longitude: 64° 5′ W

Data Sheet 25

Origin	Reference No.	Rock Type
Central Canada Potash, Saskatchewan	16	mudstone (dolomitic)

Regional Geology	Structural Characteristics
Dawson Bay Formation, middle Devonian period	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

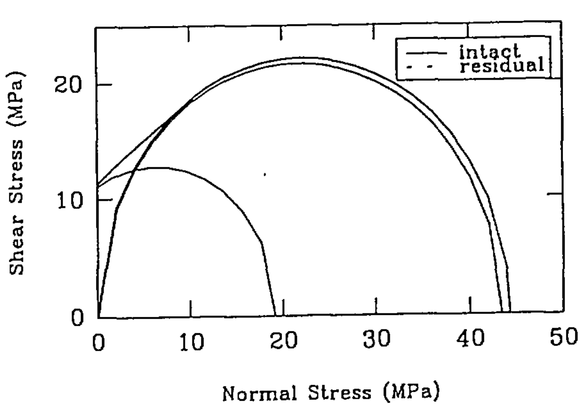
Petrography

Structure: argillaceous. dolomitic	Composition
Texture: Grain Size: fine Colour: grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n (%)	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.50	n/a	44.00	89.00	n/a	n/a	44.31	-6.39	9.34	0.15	0.10 – 27.60

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
43.71	4.50	1.00	0.99	n/a	n/a	n/a

Borehole Information

Collar Elevation: 459 m
Depth:
Inclination: 53° SW
Latitude: 51° 55′ N
Longitude: 105° 45′ W

Data Sheet 26

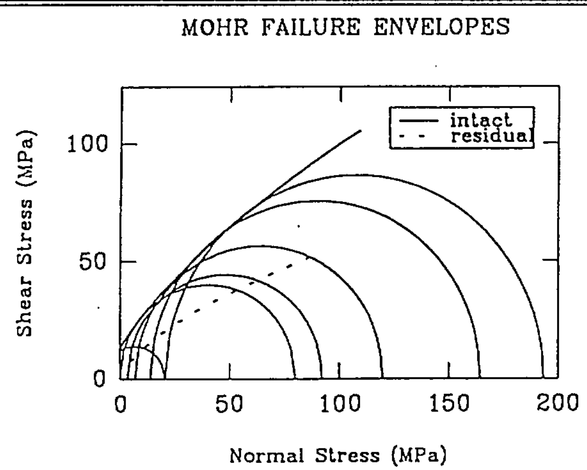
Origin	Reference No.	Rock Type
Lingan Mine, Nova Scotia	7	sandstone

Regional Geology	Structural Characteristics
Morien Group, Glace Bay Sub-basin of the Carboniferous Sydney Basin	Dip: 4° – 15° seaward Strike: E – NE Bedding Thickness: 0.8 – 4.6 m Fracture Spacing: Weathering:

Petrography	
Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.66	n/a	46.00	91.00	n/a	n/a	80.02	-6.87	30.37	0.18	3.50 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
80.25	13.68	1.00	0.98	3.00	0.00	0.79

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 60° 5′ W

Data Sheet 27

Origin	Reference No.	Rock Type
Central Canada Potash, Saskatchewan	16	sandstone (2nd redbed)

Regional Geology	Structural Characteristics
Dawson Bay Formation, middle Devonian period	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

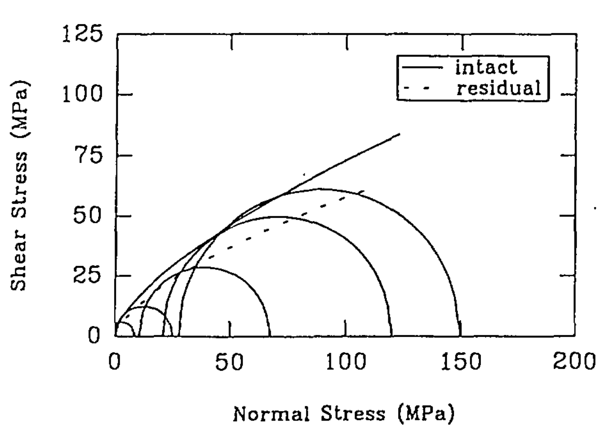
Petrography

Structure: poorly consolidated; salt inclusions	Composition
Texture: Grain Size: Colour: reddish brown Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.53	n/a	44.00	89.00	n/a	n/a	24.90	-2.91	n/a	n/a	0.10 – 27.60

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
19.92	24.12	1.00	0.95	12.83	0.00	0.97

Borehole Information

Collar Elevation: 459 m
Depth:
Inclination: 53° SW
Latitude: 51° 55′ N
Longitude: 105° 45′ W

Data Sheet 28

Origin	Reference No.	Rock Type
Donkin-Morien, Nova Scotia	13	sandstone (fine-grained)

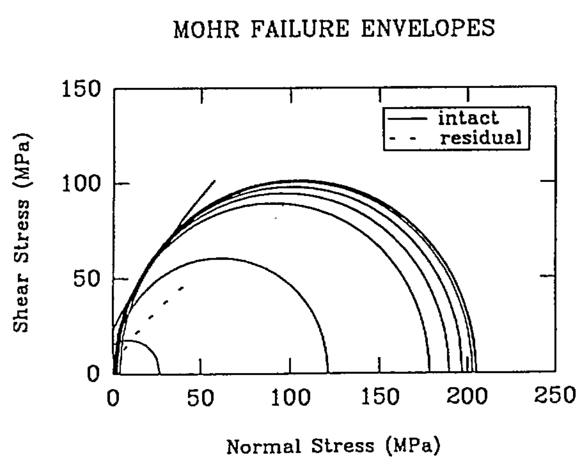
Regional Geology	Structural Characteristics
Originates from the Carboniferous Morien Group, Sydney Basin	Dip: 4° – 15° Strike: NE – E Bedding Thickness: laminated to thick Fracture Spacing: none Weathering: little or none

Petrography

Structure: no fractures; massive, homogeneous, no stratification	Composition
Texture: Grain Size: 0.1 – 0.2 mm Colour: light to dark grey Grain Sorting: Grain Shape: angular to subangular Matrix: kaolinite cement	58.5% quartz 23.3% shale 10.5% kaolinite 3.6% quartz and feldspar fragments 4.1% chert, chlorite, zircon, mica, opaques

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.46	1.36	46.00	91.00	4.43	n/a	121.25	-8.96	19.04	0.14	0.40 – 5.20



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
171.49	19.64	1.00	0.82	4.41	0.01	0.94

Borehole Information

Collar Elevation: -200 m
Depth: 16.8 m
Inclination:
Latitude: 46° 15′ N
Longitude: 59° 50′ W

Data Sheet 29

Origin	Reference No.	Rock Type
Prince Mine, Nova Scotia	1	sandstone (fine-grained)

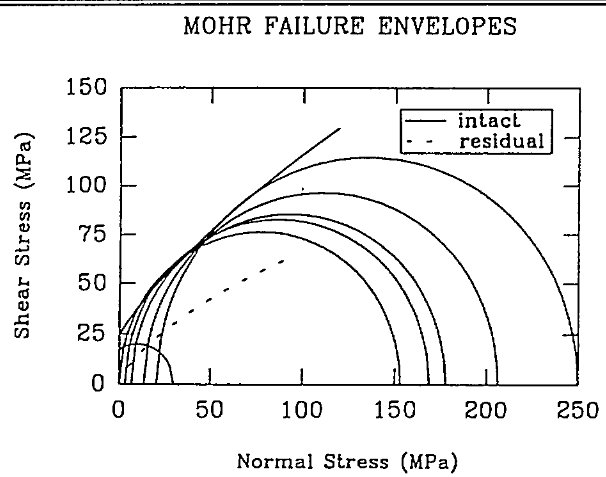
Regional Geology	Structural Characteristics
Located in the Carboniferous Sydney basin, Morien Group	Dip: 4° – 15° seaward Strike: NE – E Bedding Thickness: 1.5 – 2.3 m, mixed with siltstone Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: fine Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.63	n/a	46.00	91.00	n/a	n/a	142.87	-9.97	41.79	0.18	0.30 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
139.38	11.08	1.00	0.97	2.71	0.00	0.87

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 10′ N
Longitude: 60° 5′ W

Data Sheet 30

Origin	Reference No.	Rock Type
Springhill Coal Mine, Nova Scotia	14	sandstone (fine-grained)

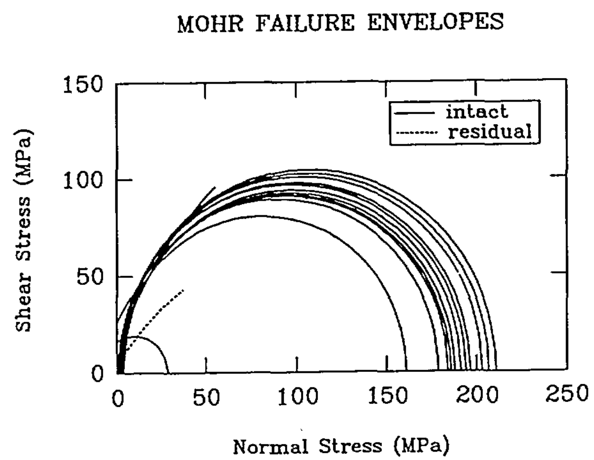
Regional Geology	Structural Characteristics
Pennsylvanian Cumberland Group, from the Cumberland Basin in the Appalachian Orogen	Dip: SW (Springhill Anticline axis) Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: fine Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n (%)	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
n/a	n/a	46.00	91.00	n/a	n/a	160.76	-9.47	32.86	0.15	0.40 – 3.50



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
175.37	16.32	1.00	0.78	4.14	0.01	0.79

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 45° 35′ N
Longitude: 64° 5′ W

Origin	Reference No.	Rock Type
Niagara Falls, Ontario	15	sandstone (Grimsby)

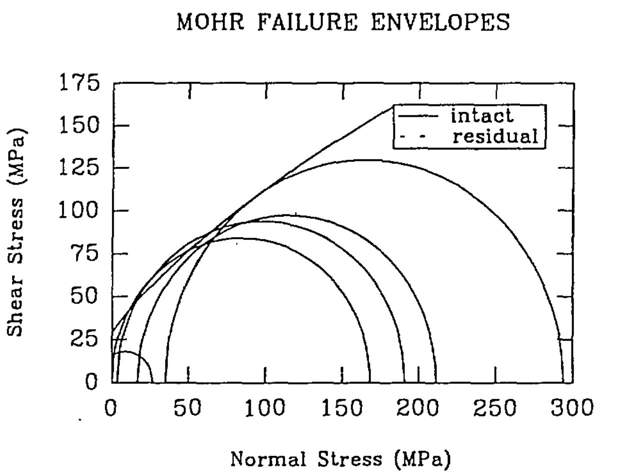
Regional Geology	Structural Characteristics
Lower Silurian, Medina Group, Grimsby Formation	Dip: Strike: Bedding Thickness: 12.3 m Fracture Spacing: Weathering:

Petrography

Structure: quartzose, mottled	Composition
Texture: Grain Size: Colour: red Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.53	6.60	44.00	98.00	3.30	n/a	168.20	-8.98	24.88	0.36	3.50 – 35.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
147.83	8.78	1.00	0.89	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth: 143.7 – 235.3 m
Inclination:
Latitude: 43° 10′ N
Longitude: 79° 35′ W

Data Sheet 32

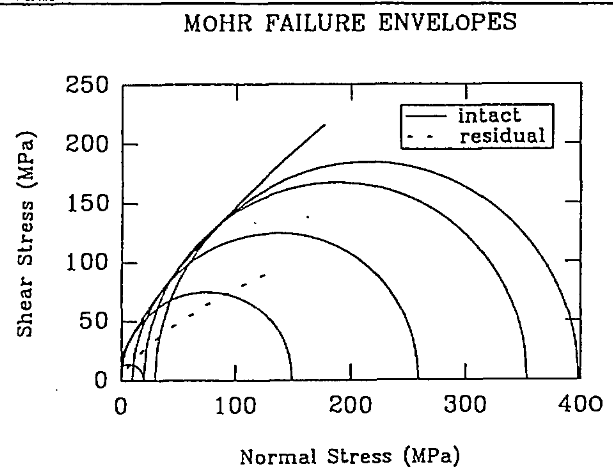
Origin	Reference No.	Rock Type
Campbell's Quarry, Ontario	21	sandstone (medium-grained)

Regional Geology	Structural Characteristics
Nepean Formation, Chazy period, upper Cambrian age	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering: advanced

Petrography	
Structure: mature quartz arenite, with some quartzite bands	Composition
Texture: Grain Size: 0.14 mm (medium-grained) Colour: beige-orangy Grain Sorting: well sorted Grain Shape: well rounded Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.40	8.15	44.00	111.00	4.09	n/a	145.78	-6.82	39.24	0.50	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
159.93	23.98	1.00	0.99	3.62	0.00	0.85

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 45° 20′ N
Longitude: 75° 40′ W

Origin	Reference No.	Rock Type
Donkin-Morien, Nova Scotia	13	sandstone (medium-grained)

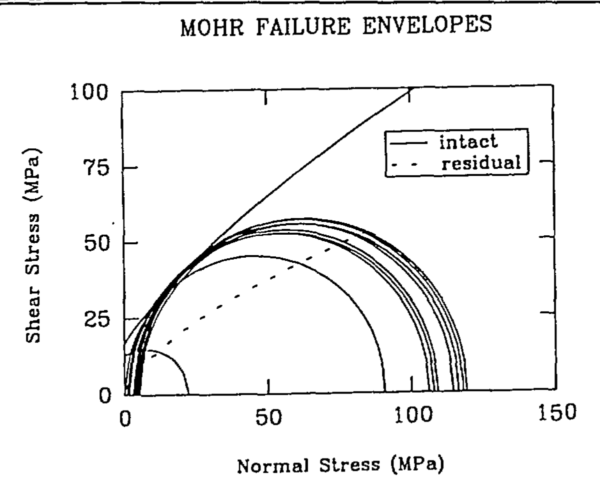
Regional Geology	Structural Characteristics
Originates from the Carboniferous Morien Group, Sydney basin	Dip: 4° – 15° Strike: NE – E Bedding Thickness: laminated to thick Fracture Spacing: Weathering: little or none

Petrography

Structure: some fracturing, clastic grains and lithic fragments	Composition
Texture: Grain Size: 0.15 – 0.30 mm Colour: light to medium grey Grain Sorting: Grain Shape: Matrix: knolinite	60.8% quartz grains and fragments 20.2% shale 3.5% quartz-feldspar fragments 2.6% chert 4.9% mica, chlorite, sphene, etc.

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.42	n/a	46.00	91.00	n/a	n/a	88.23	-7.46	20.38	0.21	0.40 – 5.20



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
94.00	10.64	1.00	0.95	2.79	0.01	0.75

Borehole Information

Collar Elevation: approx. -200 m
Depth: 5.2 m
Inclination:
Latitude: 46° 15′ N
Longitude: 59° 50′ W

Origin	Reference No.	Rock Type
Prince Mine, Nova Scotia	1	sandstone (medium-grained)

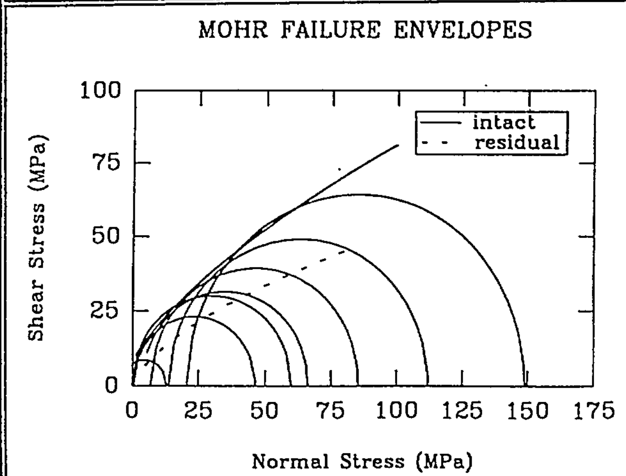
Regional Geology	Structural Characteristics
Located in the Carboniferous Sydney basin, Morien Group	Dip: 4° – 15° seaward Strike: NE – E Bedding Thickness: 1.5 – 2.3 m, mixed with siltstone Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: medium Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.31	n/a	46.00	91.00	n/a	n/a	56.25	-4.35	15.41	0.18	0.30 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
49.42	12.49	1.00	0.97	3.87	0.00	0.87

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 10′ N
Longitude: 60° 5′ W

Origin	Reference No.	Rock Type
Springhill Coal Mine, Nova Scotia	14	sandstone (medium-grained)

Regional Geology	Structural Characteristics
Pennsylvanian Cumberland Group, from the Cumberland Basin in the Appalachian Orogen	Dip: SW (Springhill Anticline axis) Strike: Bedding Thickness: Fracture Spacing: Weathering:

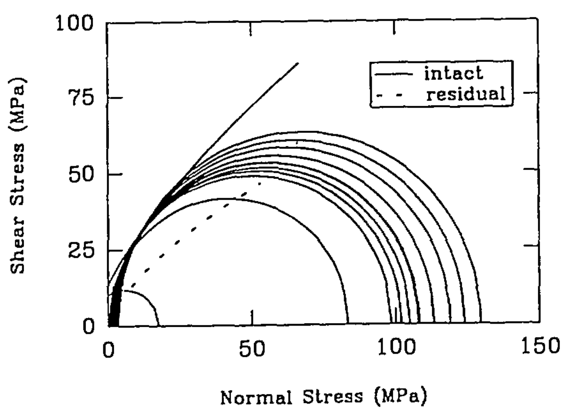
Petrography

Structure:	Composition
Texture: Grain Size: medium Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
n/a	n/a	46.00	91.00	n/a	n/a	83.30	-5.91	24.00	0.20	0.40 – 3.50

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
93.94	16.72	1.00	0.94	4.70	0.01	0.80

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 45° 35′ N
Longitude: 64° 5′ W

Data Sheet 36

Origin	Reference No.	Rock Type
Niagara Falls, Ontario	15	sandstone (whirlpool)

Regional Geology	Structural Characteristics
Lower Silurian, Cataract Group, Whirlpool Formation	Dip: Strike: Bedding Thickness: 4.6 m Fracture Spacing: Weathering:

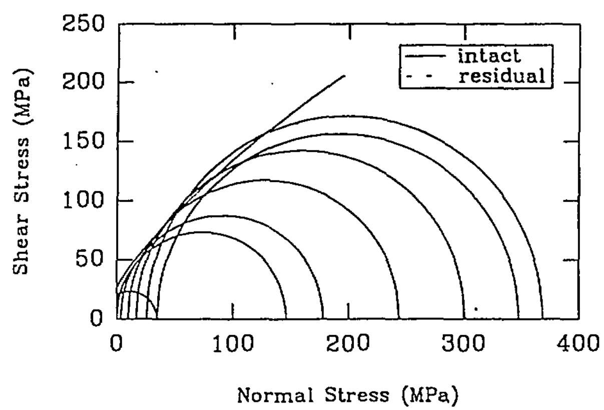
Petrography

Structure: orthoquartzic	Composition
Texture: Grain Size: fine Colour: white and grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.50	n/a	44.00	98.00	n/a	n/a	146.42	-11.61	n/a	n/a	3.50 – 35.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
170.15	14.84	1.00	0.90	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth: 183.8 – 256.3 m
Inclination:
Latitude: 43° 10′ N
Longitude: 79° 35′ W

Origin	Reference No.	Rock Type
Prince Mine, Nova Scotia	1	shale

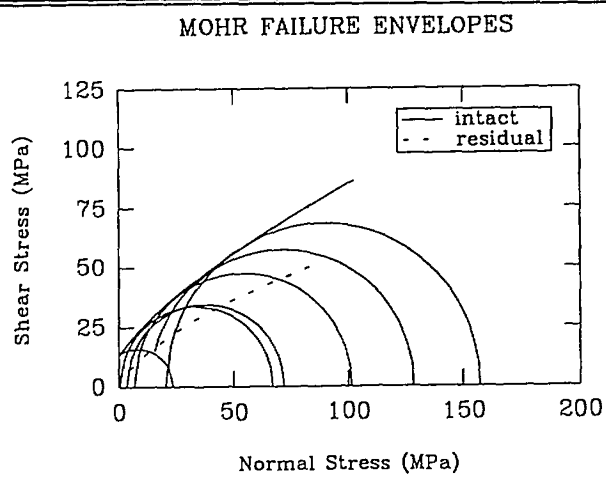
Regional Geology	Structural Characteristics
Located in the Carboniferous Sydney basin, Morien Group	Dip: 4° – 15° seaward Strike: NE – E Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.60	n/a	46.00	91.00	n/a	n/a	89.30	-7.96	17.40	0.18	0.30 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
69.53	9.39	1.00	0.96	3.37	0.00	0.99

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 10′ N
Longitude: 60° 5′ W

Origin	Reference No.	Rock Type
Donkin-Morien, Nova Scotia	13	siltstone

Regional Geology

Originates from the Carboniferous Morien Group, Sydney basin

Structural Characteristics

Dip: 4° – 15°
Strike: NE – E
Bedding Thickness: laminated to thin
Fracture Spacing:
Weathering: fresh to slightly weathered

Petrography

Structure: argillaceous partings, closely spaced, sandy

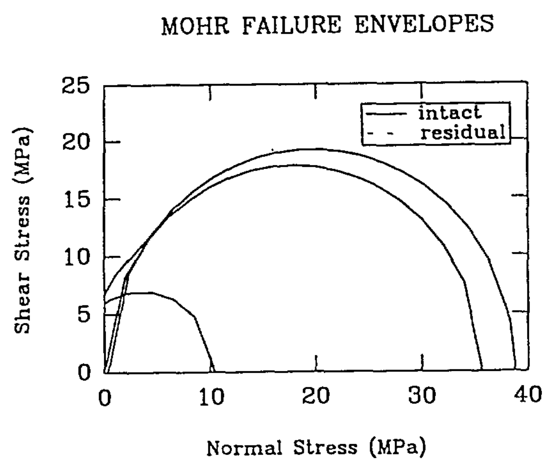
Texture: Grain Size: 0.04 – 0.1 mm
Colour: dark greenish grey
Grain Sorting:
Grain Shape: subangular
Matrix:

Composition

35.0% siderite, 33.6% clays (illite, smectite), 20.0% quartz, 6.4% calcite, 2.8% mica, 2.1% chlorite and opaques

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.86	n/a	46.00	91.00	n/a	n/a	35.68	-3.48	22.38	0.20	0.40 – 5.20



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
36.36	8.95	1.00	1.00	4.41	0.01	0.94

Borehole Information

Collar Elevation: approx. -200 m
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 59° 50′ W

Data Sheet 39

Origin	Reference No.	Rock Type
Lingan Mine, Nova Scotia	7	siltstone

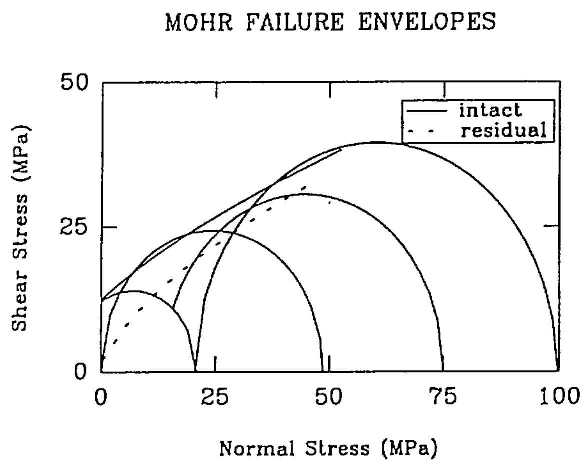
Regional Geology	Structural Characteristics
Morien Group, Glace Bay Sub-basin of the Carboniferous Sydney basin	Dip: 4° – 15° seaward Strike: E – NE Bedding Thickness: 1.1 m to 3.0 m Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.70	n/a	46.00	91.00	n/a	n/a	48.64	-6.97	36.58	0.21	3.50 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
45.35	3.92	1.00	0.94	4.43	0.03	0.86

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 15′ N
Longitude: 60° 5′ W

Origin	Reference No.	Rock Type
Prince Mine, Nova Scotia	1	siltstone

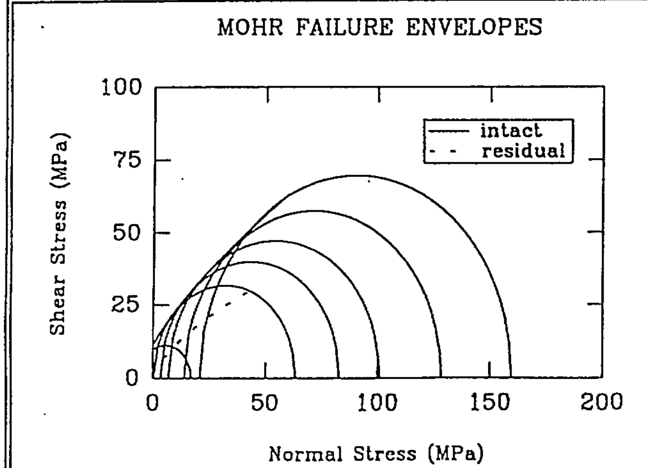
Regional Geology	Structural Characteristics
Located in the Carboniferous Sydney basin, Morien Group	Dip: 4° – 15° seaward Strike: NE – E Bedding Thickness: 1.5-2.3 m, mixed with sandstone Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: grey Grain Sorting: Grain Shape: Matrix:	90% quartz, 10% opaque minerals, phlogopite and obsidian, several 0.5 mm thick coal bands

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.48	n/a	46.00	91.00	n/a	n/a	82.08	-5.59	14.16	0.17	0.30 – 20.70



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
63.26	11.24	1.00	1.00	2.86	0.00	0.95

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 10′ N
Longitude: 60° 5′ W

Data Sheet 41

Origin	Reference No.	Rock Type
Springhill Coal Mine, Nova Scotia	14	siltstone

Regional Geology	Structural Characteristics
Pennsylvanian Cumberland Group, from the Cumberland Basin in the Appalachian Orogen	Dip: SW (Springhill Anticline axis) Strike: Bedding Thickness: Fracture Spacing: Weathering:

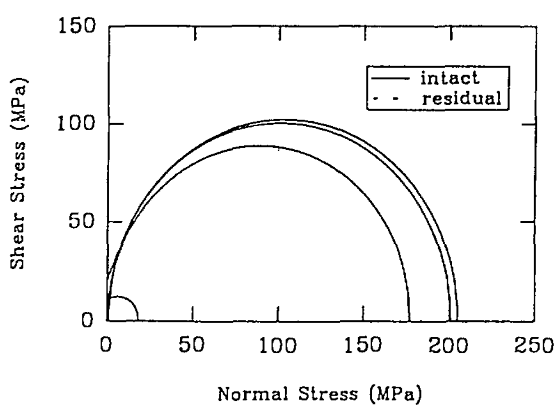
Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
n/a	n/a	46.00	91.00	n/a	n/a	177.20	-6.14	30.00	0.14	0.40 – 3.50

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
189.38	30.61	1.00	0.97	3.34	0.00	1.00

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 45° 35′ N
Longitude: 64° 5′ W

Data Sheet 42

Origin	Reference No.	Rock Type
Copper Cliff South Mine, Ontario	12	sulphide ore

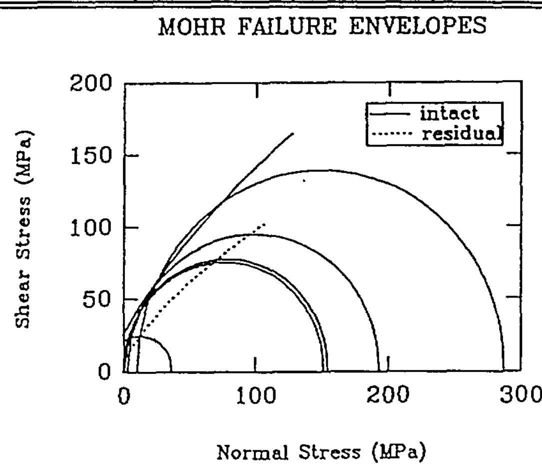
Regional Geology	Structural Characteristics
Southern rim of the Sudbury Irruptive, in the Middle Precambrian McKim pelites, Southern Province, sulphide-bearing crystal tuff unit	Dip: 65° W Strike: NS Bedding Thickness: up to 15 m Fracture Spacing: 36 cm Weathering:

Petrography

Structure: crystalline	Composition
Texture: Grain Size: very fine grained Colour: metallic yellow-bronze, grey Grain Sorting: Grain Shape: Matrix:	pyrite chalcopyrite pyrrhotite quartz 4% nickel 2% copper

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.99	<0.10	42-292	84-584	4.03	n/a	155.10	-12.32	77.20	0.26	1.00 – 10.30



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
175.66	17.49	1.00	0.84	6.43	0.06	0.92

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 46° 25′ N
Longitude: 81° 10′ W

Origin	Reference No.	Rock Type
Hislop Township, Ontario	3	syenite

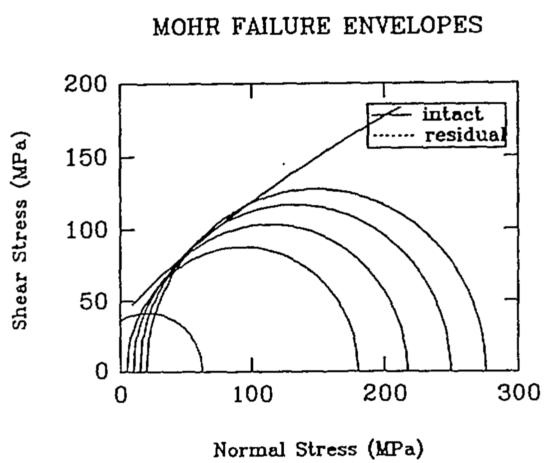
Regional Geology	Structural Characteristics
Archean, part of the Abitibi Subprovince, from a chloritic, silicified dike and stock that have been mixed with breccia	Dip: 75° – 80° NE Strike: NW – SE generally Bedding Thickness: dike-7.6 – 39.6 m, stock-48.8 m Fracture Spacing: 0.3 – 1.0 m Weathering:

Petrography

Structure: rough, irregular joints	Composition
Texture: Grain Size: medium to coarse Colour: pink-purple-grey Grain Sorting: Grain Shape: Matrix:	albite with some sericite alteration sulphides (pyrite), hematite little or no quartz or ferromagnesians

Mechanical Properties

γ_d (Mg/m³)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.66	0.14	46.00	91.00	5.80	n/a	253.62	-20.87	76.49	0.36	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
179.25	7.65	1.00	0.94	n/a	n/a	n/a

Borehole Information

Collar Elevation:
Depth: 24.4 m
Inclination:
Latitude: 48° 30′ N
Longitude: 80° 15′ W

Data Sheet 44

Origin	Reference No.	Rock Type
Detour Lake Mine, Ontario	5	talc-chlorite

Regional Geology	Structural Characteristics
Altered Archean rocks of volcanic origin located on the James Bay Highlands, on the footwall of the excavation	Dip: 35° – 40° W (orebody) Strike: avg. N 70° E Bedding Thickness: Fracture Spacing: Weathering: fresh

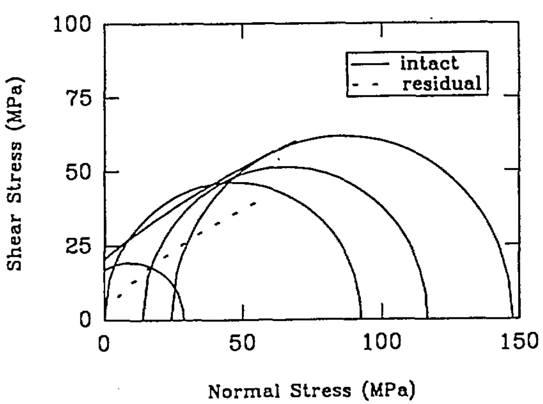
Petrography

Structure: massive, irregularly foliated, finely banded	Composition
Texture: Grain Size: fine Colour: dark green, light greyish green Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.97	n/a	44.00	89.00	n/a	n/a	92.43	-9.58	50.82	0.34	6.90 – 24.10

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
79.56	4.65	1.00	0.92	3.22	0.00	0.85

Borehole Information

Collar Elevation: 259.0 m above s. l
Depth: >38 m
Inclination:
Latitude: 50° 0′ N
Longitude: 79° 45′ W

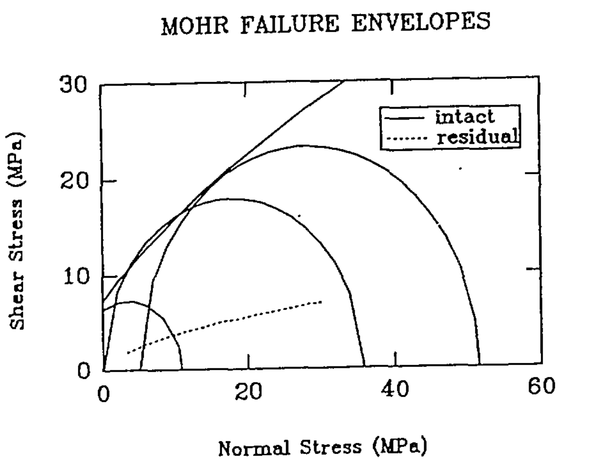
Origin	Reference No.	Rock Type
Hislop Township, Ontario	3	talc-chlorite-schist

Regional Geology	Structural Characteristics
Archean, part of the Abitibi Subprovince altered ultramafic flow; intermittent clay, and pyrite is disseminated throughout	Dip: 75° – 80° NE Strike: NW – SE generally Bedding Thickness: 91.4 m Fracture Spacing: Weathering:

Petrography	
Structure: closely spaced joints; no visible foliation, soft	Composition
Texture: Grain Size: Colour: bluish black Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.84	n/a	46.00	91.00	n/a	n/a	35.79	-3.61	35.82	0.29	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
33.37	6.70	1.00	0.98	0.24	0.00	0.99

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 30′ N
Longitude: 80° 15′ W

Data Sheet 46

Origin	Reference No.	Rock Type
Eldrich Mine, Quebec	10	tonalite

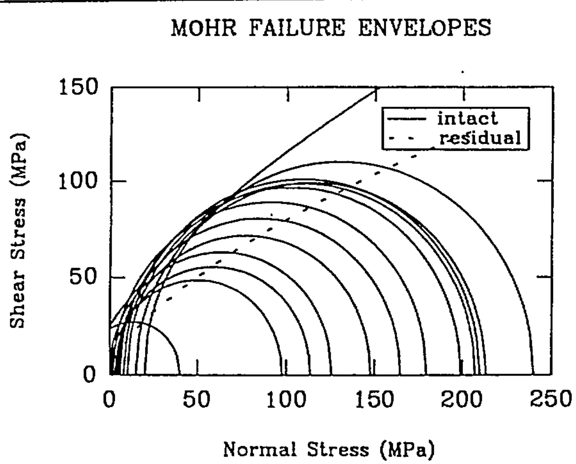
Regional Geology	Structural Characteristics
Southern volcanic zone of the Abitibi Subprovince, altered rocks from the NW sector of the Flavarian batholith, Blake River Group, Archean age, result of the complete mixing of mafic and felsic magmas	Dip: 30° – 45° Strike: 30° SE Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: frequent fractures, heterogenous composition, fine to grainy	Composition
Texture: Grain Size: Colour: pinkish Grain Sorting: Grain Shape: Matrix:	50 – 60% oligoclase, 15 – 30% quartz, hornblende, accessory minerals: pistachite, chlorite, amphibole, sericite, opaque minerals

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.74	0.14	46.00	91.00	6.27	n/a	123.42	-13.54	73.58	0.23	1.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
138.72	10.92	1.00	0.74	4.42	0.04	0.36

Borehole Information

Collar Elevation:
Depth:
Inclination:
Latitude: 48° 19′ N
Longitude: 79° 11′ W

Origin	Reference No.	Rock Type
Bousquet Mine, Quebec	18	tuff

Regional Geology	Structural Characteristics
Upper Blake River Group, in Abitibi Subprovince, Superior Province (Archean age), veins of quartz, garnets in some areas, schistose appearance, sericite concenctrated along schist planes	Dip: 85° Strike: 100° Bedding Thickness: 18.3 m – 36.6 m Fracture Spacing: 5 – 30 cm Weathering: some

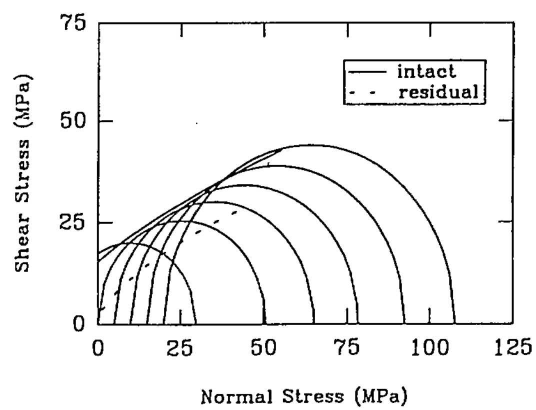
Petrography

Structure: tightly banded; joints vertical, smooth planar to slickenside planar	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	siliceous, contains pyrite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.92	n/a	46.00	91.00	n/a	n/a	50.83	-9.95	58.79	0.29	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
54.78	3.72	1.00	0.95	2.72	0.04	0.17

Borehole Information

Collar Elevation:
Depth: 18.3 m
Inclination: -72° N
Latitude: 48° 15′ N
Longitude: 78° 28′ W

Origin	Reference No.	Rock Type
Chimo Mine, Quebec	19	tuff

Regional Geology	Structural Characteristics
Upper Malartic Group, in the Abitibi Subprovince of the Superior Province (Archean age), W – NW belt of metasediments with contact metavolcanics at north, chloritized amphiboles and calcified alterations observed	Dip: 70° – 80° Strike: 135° Bedding Thickness: 12.2 m Fracture Spacing: 5 – 30 cm Weathering: little to none

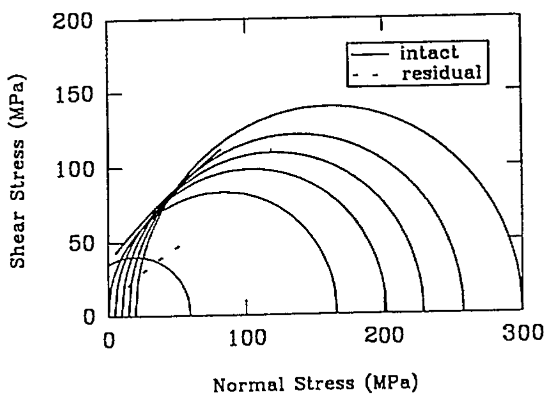
Petrography

Structure: tight, cross-jointed joints, smooth, planar joints	Composition
Texture: Grain Size: fine to medium Colour: white to light grey Grain Sorting: Grain Shape: Matrix:	siliceous

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.86	n/a	46.00	91.00	n/a	n/a	165.92	-19.91	95.49	0.23	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
185.43	9.23	1.00	0.93	2.63	0.00	0.62

Borehole Information

Collar Elevation:
Depth: 24.7 m
Inclination: -90°
Latitude: 48° 2′ N
Longitude: 77° 10′ W

Origin	Reference No.	Rock Type
Kidd Creek Mine, Ontario	22	andesite (foliated)

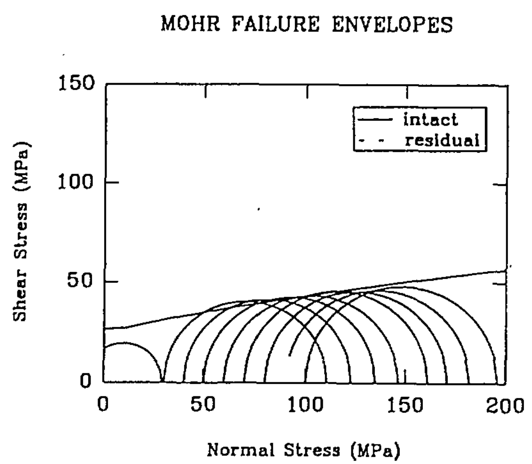
Regional Geology	Structural Characteristics
Abitibi orogenic belt N – W facing felsic tuffs and breccia	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: structural foliation	Composition
Texture: Grain Size: fine Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.82	n/a	47.00	110.00	n/a	6.30	n/a	-9.73	n/a	n/a	30.00 – 100.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
59.88	1.04	1.00	0.87	n/a	n/a	n/a

Borehole Information

Collar Elevation: 1956 m
Depth: 273 – 275 m
Inclination: 0°
Latitude: 48° 41′ 30′′ N
Longitude: 81° 22′ W

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Origin	Reference No.	Rock Type
Kidd Creek Mine, Ontario	22	andesite

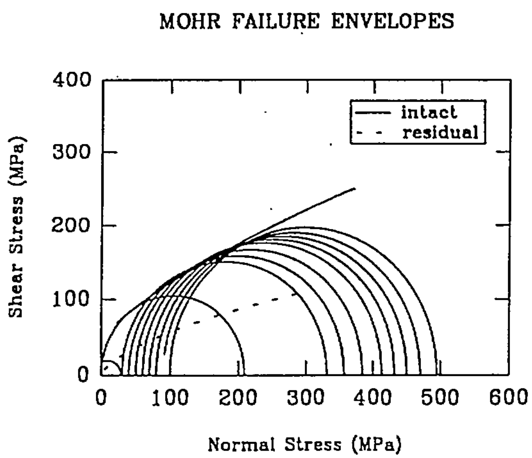
Regional Geology	Structural Characteristics
Abitibi orogenic belt N – W facing felsic tuffs and breccia	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: medium Colour: dark grey Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.05	n/a	47.00	110.00	6.40	n/a	209.50	-9.73	95.76	0.26	30.00 – 100.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
208.96	5.83	1.00	0.93	1.16	0.00	0.46

Borehole Information

Collar Elevation: 1956 m
Depth: 486 – 793 m
Inclination: 0°
Latitude: 48° 41′ 30′′ N
Longitude: 81° 22′ W

Origin	Reference No.	Rock Type
Béliveau Mine, Québec	24	basalt

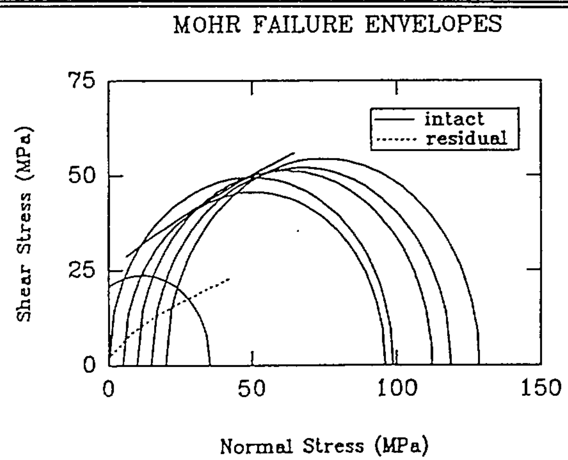
Regional Geology	Structural Characteristics
E – W trending Archean volcanics and pyroclastics of the lower Malartic subgroup	Dip: 85° S Strike: 90° E Bedding Thickness: >200 m Fracture Spacing: ±1 m Weathering: intense

Petrography

Structure: intense alterations	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	chlorite, quartz, white mica, carbonate, albite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.85	n/a	47.00	110.00	n/a	n/a	98.87	-11.83	62.93	0.38	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
84.87	3.26	1.00	0.82	1.02	0.008	0.67

Borehole Information

Collar Elevation: -49 m (1st level)
Depth: 9.5 m
Inclination: horizontal
Latitude: 48° 08′ 24′′ N
Longitude: 77° 31′ W

Data Sheet 52

Origin	Reference No.	Rock Type
Strathcona Mine, Ontario	26	breccia (late granite)

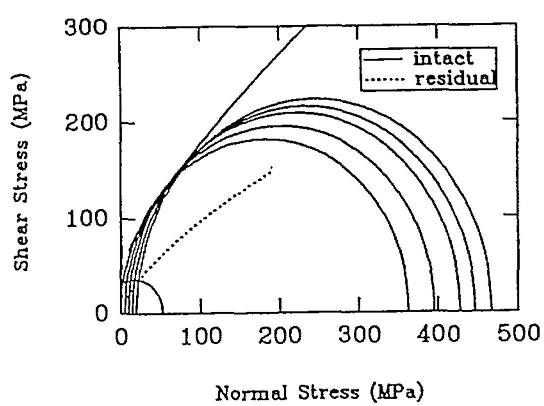
Regional Geology	Structural Characteristics
North rim of the Sudbury Basin between gneiss complex and irruptive, retrogressive metamorphism is widespread	Dip: Strike: Bedding Thickness: 9 – 60 m Fracture Spacing: Weathering:

Petrography

Structure: rock fragments in fine grained matrix	Composition
Texture: Grain Size: fragments 20 mm to 3000 mm Colour: light grey Grain Sorting: gap sorted Grain Shape: subangular Matrix: fine grained, light coloured	pyrrhitite, pentlandite, chalcopyrite, sulphides, silicates

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.71	n/a	45.00	110.00	n/a	n/a	362.97	-17.77	84.31	0.27	5.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
337.00	15.39	1.00	0.95	3.26	0.00	0.86

Borehole Information

Collar Elevation:
Depth: 783 m
Inclination:
Latitude: 9900 N (mine co-ordinate)
Longitude: 22200 E (mine co-ordinate)

Data Sheet 53

Origin	Reference No.	Rock Type
Béliveau Mine, Québec.	24	diorite

Regional Geology	Structural Characteristics
S – E of the Abitibi orogenic belt within the Malartic group, part of the Val d'Or and Dubuisson formations, contact with Bourlamaque batholith on west side	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

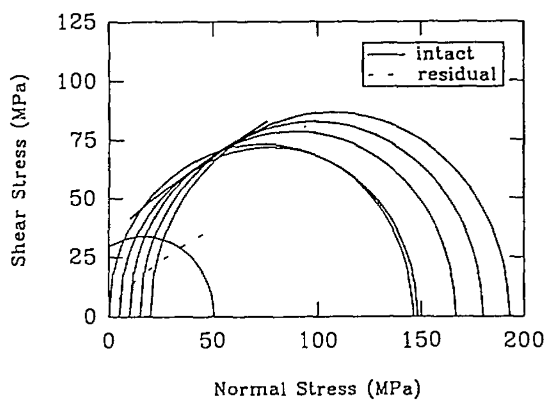
Petrography

Structure: mineralized dyke	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	albite 15 – 60%, quartz 10 – 50%, chlorite 5 – 40%, carbonate 5 – 25%, sericite 0 – 25%

Mechanical Properties

γ_d (Mg/m³)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.80	n/a	47.00	110.00	n/a	n/a	146.11	-16.87	70.26	0.34	10.00 – 30.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
132.95	5.05	1.00	0.95	1.89	0.00	0.53

Borehole Information

Collar Elevation: -50 m (1st level)
Depth: 13.5 m
Inclination: vertical
Latitude: 48° 08′ 24′′ N
Longitude: 77° 31′ W

Origin	Reference No.	Rock Type
Gays River Mine, Nova Scotia	25	dolomite (micrite)

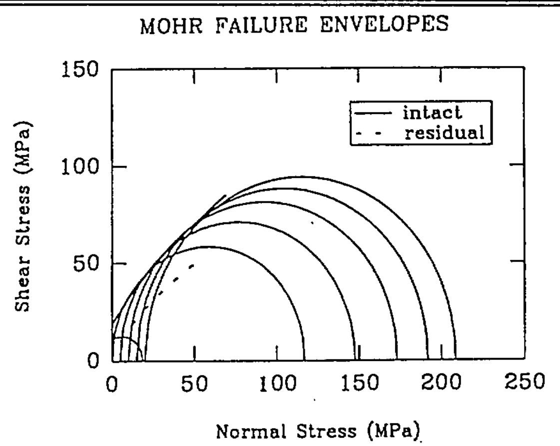
Regional Geology	Structural Characteristics
Carboniferous (Visean sub-system) dolomitized carbonate reef structure	Dip: 45° Strike: E – W Bedding Thickness: well developed, irregular Fracture Spacing: Weathering:

Petrography

Structure: algal, skeletal, coral bearing, micritic	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	carbonate

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.73	n/a	45.00	100.00	n/a	n/a	116.91	-6.42	55.42	0.45	1.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
108.97	11.94	1.00	0.97	5.70	0.00	0.98

Borehole Information

Collar Elevation:
Depth: 30 m
Inclination: horizontal, due north
Latitude: 45° 0′ N
Longitude: 63° 0′ W

Data Sheet 55

Origin	Reference No.	Rock Type
Strathcona Mine, Ontario	26	gneiss (mafic)

Regional Geology	Structural Characteristics
North rim of the Sudbury Basin `granite' gneiss complex derived as the result of regional metamorphism and metasomatism	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

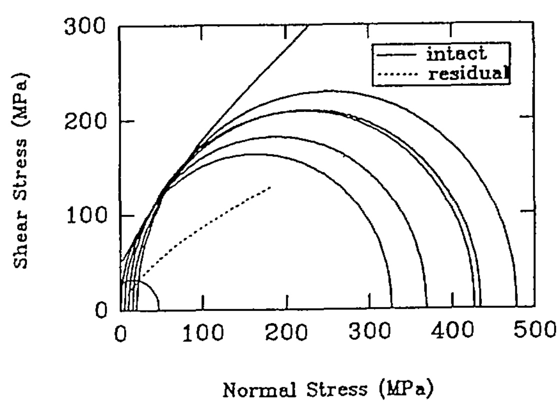
Petrography

Structure: irregular gneissosity, curved, folded	Composition
Texture: Grain Size: medium Colour: light grey Grain Sorting: Grain Shape: Matrix:	Streaks of pyroxene and amphibole banded with andesine and quartz

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.93	n/a	45.00	110.00	n/a	n/a	326.75	-15.85	95.00	0.28	5.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
318.18	17.92	1.00	0.98	2.51	0.00	0.60

Borehole Information

Collar Elevation:
Depth: 747 m
Inclination:
Latitude: 11500 N (mine co-ordinate)
Longitude: 21700 E (mine co-ordinate)

Data Sheet 56

Origin	Reference No.	Rock Type
Gays River Mine, Nova Scotia	25	greywacke (massive)

Regional Geology	Structural Characteristics
Ordovican Goldenville Formation, basement complex	Dip: 45° Strike: E – W Bedding Thickness: thick, folded Fracture Spacing: highly jointed Weathering:

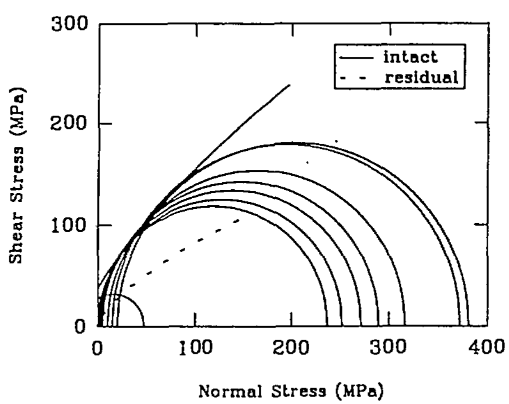
Petrography

Structure: massive	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	quartzite

Mechanical Properties

γ_d (Mg/m³)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.69	n/a	45.00	100.00	n/a	n/a	236.72	-15.93	60.81	0.26	2.00 – 20.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
244.28	15.25	1.00	0.98	2.81	0.00	0.86

Borehole Information

Collar Elevation:
Depth: 17 m
Inclination: horizontal, due north
Latitude: 45° 0′
Longitude: 63° 0′

Data Sheet 57

Origin	Reference No.	Rock Type
Lupin Mine, Northwest Territories	23	phyllite

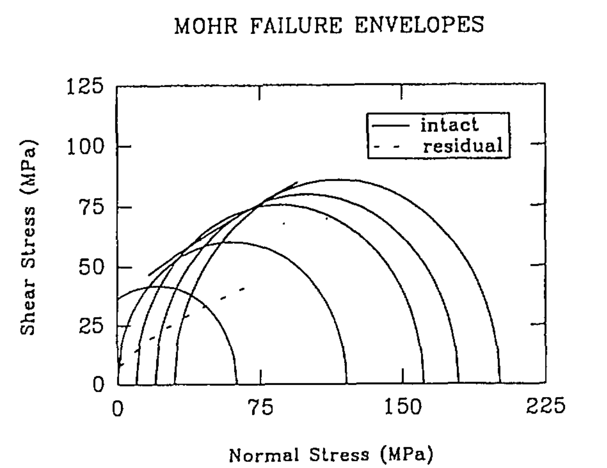
Regional Geology	Structural Characteristics
Contwoyto Formation turbidites of the Archean Yellowknife Supergroup metamorphic – lower amphibolite facies	Dip: -80° Strike: 30° Bedding Thickness: 5 – 30 m Fracture Spacing: 1 m Weathering: none

Petrography

Structure: schistose	Composition
Texture: Grain Size: fine Colour: grey Grain Sorting: Grain Shape: Matrix:	quartz, chlorite, muscovite, biotite, garnet, cordierite, graphite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.87	n/a	35.00	85.00	4.98	n/a	120.60	-20.89	52.30	0.21	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
127.55	3.57	1.00	0.98	1.39	0.05	0.30

Borehole Information

Collar Elevation: 1365 m
Depth: 11.0 m
Inclination: 06°
Latitude: 10180 N
Longitude: 1045 E

Data Sheet 58

Origin	Reference No.	Rock Type
Lupin Mine, Northwest Territories	23	quartzite (metagreywacke)

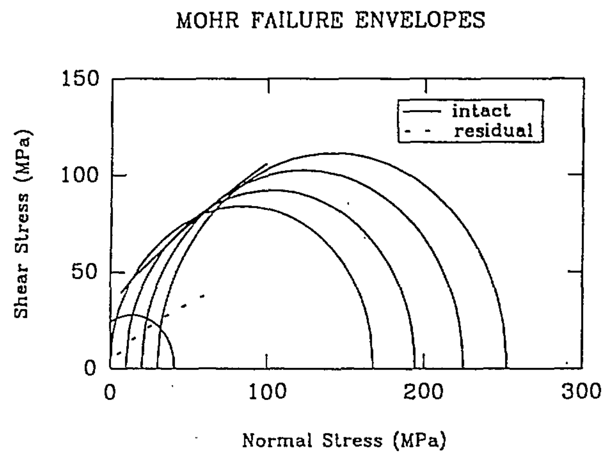
Regional Geology	Structural Characteristics
Contwoyto Formation turbidites of the Archean Yellowknife Supergroup metamorphic – lower amphibolite facies	Dip: -80° Strike: 30° Bedding Thickness: 5 – 30 Fracture Spacing: 1.5 Weathering: none

Petrography

Structure: homogeneous interbeaded	Composition
Texture: Grain Size: coarse Colour: grey Grain Sorting: homogenous Grain Shape: subangular Matrix: quartz	quartz, feldspar, biotite, sericite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.70	n/a	35.00	85.00	3.54	n/a	168.06	-13.68	49.19	0.42	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
148.16	6.81	1.00	0.94	1.29	0.00	0.60

Borehole Information

Collar Elevation: 1365 m
Depth: 82 m
Inclination: 0°
Latitude: 10170 N
Longitude: 10120 E

Origin	Reference No.	Rock Type
Kidd Creek Mine, Ontario	22	rhyolite

Regional Geology	Structural Characteristics
Abitibi orogenic belt N – W facing felsic tuffs and breccia	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

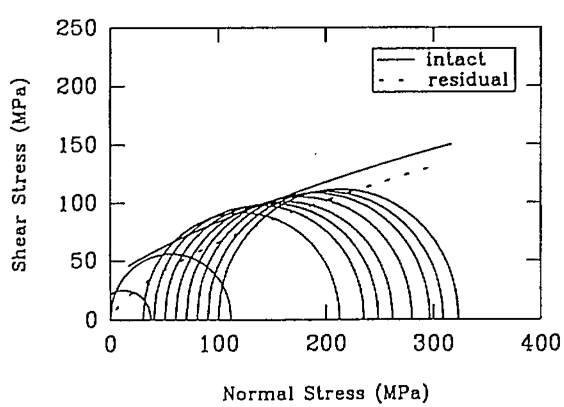
Petrography

Structure: fragmented	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.75	n/a	36.00	90.00	6.16	n/a	111.98	-12.48	80.75	0.39	10.00 –100.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
122.77	3.29	1.00	0.90	2.98	0.00	0.85

Borehole Information

Collar Elevation: 2045 m
Depth: 403 – 408 m
Inclination: 0°
Latitude: 48° 41′ 30′′ N
Longitude: 81° 22′ W

Data Sheet 60

Origin	Reference No.	Rock Type
Lupin Mine, Northwest Territories	23	sulphide iron

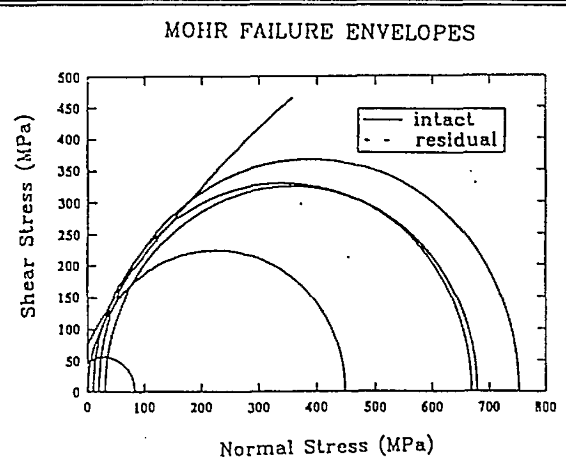
Regional Geology	Structural Characteristics
Contwoyto Formation turbidites of the Archean Yellowknife Supergroup, metamorphic – lower amphibolite facies	Dip: -80° Strike: 10° Bedding Thickness: 8 m Fracture Spacing: 0.4 m Weathering: none

Petrography

Structure: interbanded	Composition
Texture: Grain Size: coarse, 0.4 mm Colour: dark green, brown Grain Sorting: Grain Shape: subangular Matrix:	quartz, hornblende, pyrrhotite, arsenopyrite, grunerite, chlorite, chert

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.21	n/a	35.00	90.00	6.26	n/a	447.73	-27.90	101.10	0.24	10.00 –30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
515.26	16.78	1.00	0.82	n/a	n/a	n/a

Borehole Information

Collar Elevation: 1365 m
Depth: 2 m
Inclination: 0°
Latitude: 10° 16′ 5″ N
Longitude: 10° 11′ 8″ E

Data Sheet 61

Origin	Reference No.	Rock Type
Kidd Creek Mine, Ontario	22	sulphide zinc

Regional Geology	Structural Characteristics
Abitibi orogenic belt N – W facing felsic tuffs and breccia	Dip: 75° N Strike: N 20° E Bedding Thickness: Fracture Spacing: Weathering:

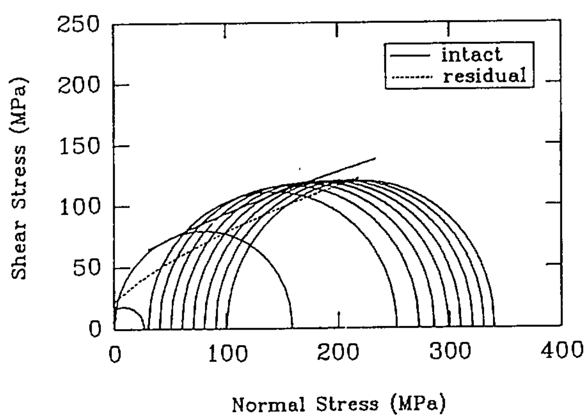
Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	massive chalcopyrite and sphalerite, breccia ore of chalcopyrite replacing rhyolite breccia

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.72	n/a	36.00	70.00	5.81	n/a	158.54	-8.86	82.16	0.16	10.00–100.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
157.47	2.80	1.00	0.71	2.88	0.30	0.75

Borehole Information

Collar Elevation: 2045 m
Depth: 423 m
Inclination: 0°
Latitude: 48° 41′ 30′′ N
Longitude: 81° 22′ W

Origin	Reference No.	Rock Type
Kidd Creek Mine, Ontario	22	talc-carbonate

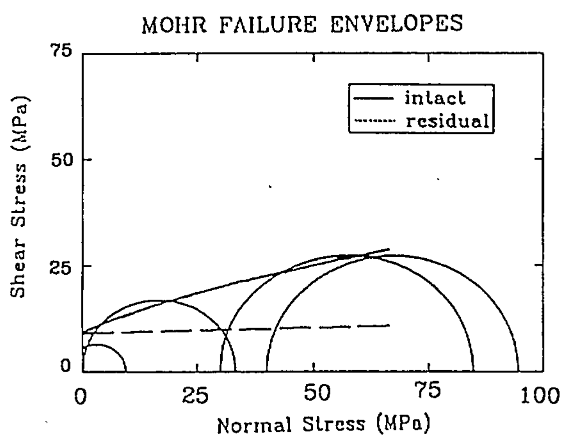
Regional Geology	Structural Characteristics
Abitibi orogenic belt N – W facing felsic tuffs and breccia	Dip: Strike: Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure:	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.84	n/a	47.00	110.00	4.85	n/a	33.34	-3.17	28.55	0.58	10.00 – 100.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
27.64	2.27	1.00	0.92	0.06	0.30	n/a

Borehole Information

Collar Elevation: 1956 m
Depth: 979 – 983 m
Inclination: 0°
Latitude: 48° 41′ 30′′ N
Longitude: 81° 22′ W

Origin	Reference No.	Rock Type
Béliveau Mine, Québec	24	tuff

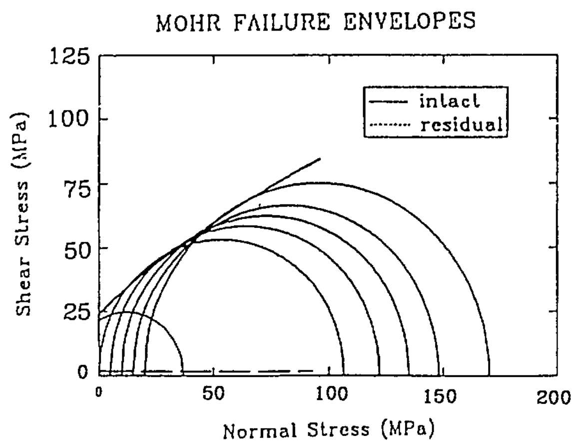
Regional Geology	Structural Characteristics
S – E of the Abitibi orogenic belt within the Malartic Group, part of the Val d'Or and Dubuisson formation, contact with Bourlamaque batholith on west side	Dip: vertical Strike: 90° E Bedding Thickness: 200 m Fracture Spacing: 1 – 1.5 m Weathering: average to intense

Petrography

Structure: agglomerate	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	carbonate, chlorite, sericite, quartz (volcanic sediments)

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.74	n/a	47.00	110.00	n/a	n/a	106.38	-12.32	68.65	0.34	10.00 – 20.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
101.09	5.77	1.00	0.98	4.00	0.00	0.82

Borehole Information

Collar Elevation: -49 m (1st level)
Depth: 9.3 m
Inclination: horizontal
Latitude: 48° 8.4′ N
Longitude: 77° 31′ W

Origin	Reference No.	Rock Type
Pinawa, Manitoba	27	granite (pink)

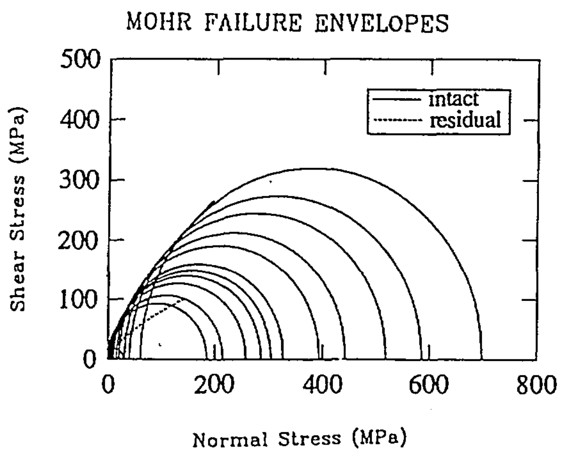
Regional Geology	Structural Characteristics
Originates from the Lac du Bonnet Pluton (Archean age) in the English River Subprovince, pink colour caused by submicroscopic iron-oxide coatings and fillings from hydrothermal fluids.	Dip: Strike: Bedding Thickness: 220 m Fracture Spacing: Weathering:

Petrography

Structure: massive, prophyritic, few fractures	Composition
Texture: Grain Size: microscopic to 20 mm Colour: Grain Sorting: Grain Shape: Matrix:	quartz 30.6% plagioclase 37.5% microline 27.3% muscovite 0.5% sphene, apatite, calcite, epidote iron oxide, allanite 0.6%

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.63	<0.3	45.00	115.00	5.28	n/a	186.10	-9.48	75.17	0.31	10.00 – 60.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
210.13	29.54	1.00	0.99	3.04	0.00	0.70

Borehole Information

Collar Elevation: 130 m level
Depth: 36.05 – 43.65 m
Inclination: trend = 59.8°, plunge = 61.3°
Latitude: 50° 25′ N
Longitude: 96° 00′ W

Data Sheet 65

Origin	Reference No.	Rock Type
Pinawa, Manitoba	28	granodiorite

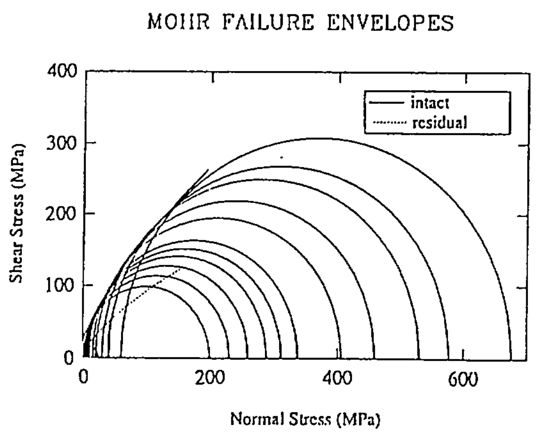
Regional Geology	Structural Characteristics
Originates from the Lac du Bonnet Pluton (Archean age) in the English River Subprovince	Dip: Strike: Bedding Thickness: Fracture Spacing: 5 – 22 m Weathering:

Petrography

Structure: massive, porphyritic, tew fractures	Composition
Texture: Grain Size: microscopic to 20 mm Colour: Grain Sorting: equigranular Grain Shape: hypidiomorphic Matrix:	quartz 30.6% plagioclase 37.5% microline 27.3% muscovite 0.5% biotite 3.5% opaques 0.4%

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.66	<0.30	61.00	150.00	3.70	n/a	198.50	-8.14	57.14	0.21	2.00 – 60.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
223.45	26.30	1.00	0.98	4.47	0.00	0.82

Borehole Information

Collar Elevation: 420 m level
Depth: 36.07 – 37.81 m
Inclination: trend = 225.5°, plunge = 0.9°
Latitude: 50° 25′ N
Longitude: 96° 00′ W

Origin	Reference No.	Rock Type
Dumagami Mine, Québec	29	sulphide (massive)

Regional Geology	Structural Characteristics
Cadillac Group overlying felsic volcanics with pyrrhotite mineralization together with alternating layers of massive and ribboned rhyolite; the ore zone that underlies the rhyolite units consists of andalusite schists with pyrite, sphalerite and galena mineralization interbedded with sercite schists; below the sulphide ore zone lies a mafic tuff unit	Dip: 80 – 85° S Strike: E – W Bedding Thickness: Fracture Spacing: Weathering:

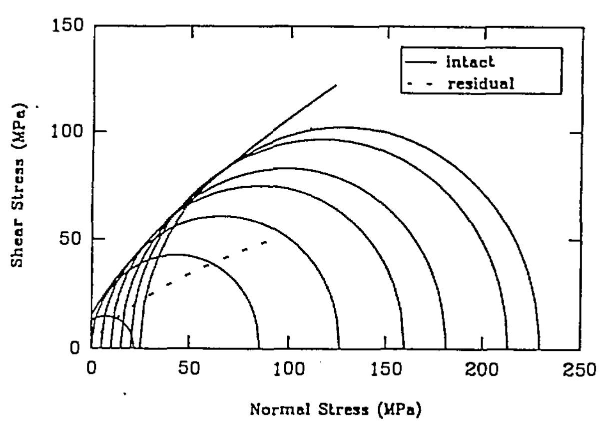
Petrography

Structure: volcanics	Composition
Texture: Grain Size: Colour: green-brown Grain Sorting: Grain Shape: Matrix:	pyrite, chalcopyrite, sphalerite, gold, petzite, calaverite, galena, arsenopyrite, tetrahedrite, magnetite

Mechanical Properties

γ_d (Mg/m^3)	n (%)	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
4.56	n/a	47.00	100.00	n/a	n/a	85.58	-7.36	84.26	0.54	5.00 – 25.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
94.47	14.00	1.00	0.99	2.14	0.00	0.91

Borehole Information

Collar Elevation: stope
Depth: 32.16 – 54.45 m
Inclination: horizontal
Latitude: 48° N
Longitude: 78° W

Data Sheet 67

Origin	Reference No.	Rock Type
Dumagami Mine, Québec	29	sulphide (semi-massive)

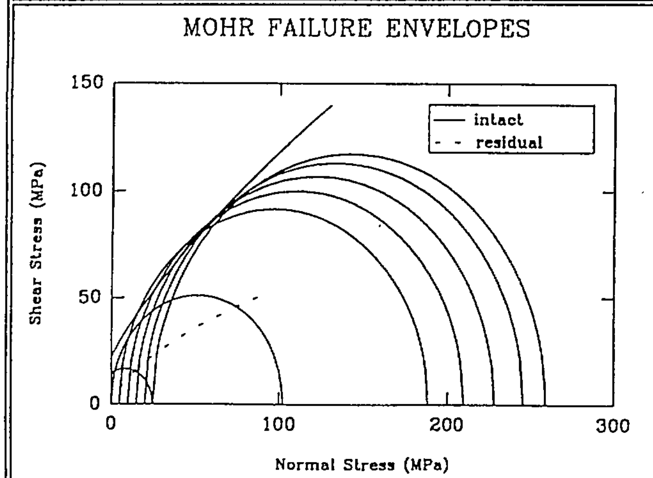
Regional Geology	Structural Characteristics
Cadillac Group overlying felsic volcanics with pyrrhotite mineralization together with alternating layers of massive and ribboned rhyolite; the ore zone that underlies the rhyolite units consists of andalusite schists with pyrite, sphalerite and galena mineralization interbedded with sercite schists; below the sulphide ore zone lies a mafic tuff unit	Dip: 80 – 85° S Strike: E – W Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: volcanics	Composition
Texture: Grain Size: Colour: green-brown Grain Sorting: Grain Shape: Matrix:	pyrite, chalcopyrite, sphalerite, gold, petzite, calaverite, galena, arsenopyrite, tetrahedrite, magnetite

Mechanical Properties

γ_d (Mg/m³)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.88	n/a	47.00	100.00	n/a	n/a	102.22	-8.22	79.36	0.40	5.00 – 25.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
132.19	12.93	1.00	0.93	1.69	0.00	0.78

Borehole Information

Collar Elevation: stope
Depth: 48.71 – 54.62 m
Inclination: horizontal
Latitude: 48° N
Longitude: 78° W

Data Sheet 68

Origin	Reference No.	Rock Type
Dumagami Mine, Québec	29	rhyolite (sulphide)

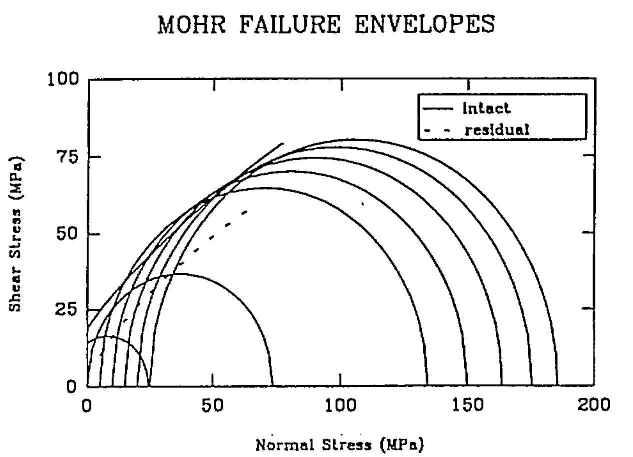
Regional Geology	Structural Characteristics
Cadillac Group overlying felsic volcanics with pyrrhotite mineralization together with alternating layers of massive and ribboned rhyolite; the ore zone that underlies the rhyolite units consists of andalusite schists with pyrite, sphalerite and galena mineralization interbedded with sercite schists; below the sulphide ore zone lies a mafic tuff unit	Dip: 80 – 85° S Strike: E – W Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: volcanics	Composition
Texture: Grain Size: Colour: green-brown Grain Sorting: Grain Shape: Matrix:	stringer sulphide

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
3.35	n/a	47.00	100.00	n/a	n/a	73.40	-8.15	75.96	0.42	5.00 – 25.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
94.17	8.40	1.00	0.91	6.27	0.00	0.61

Borehole Information

Collar Elevation: stope
Depth: 44.87 – 52.22 m
Inclination: horizontal
Latitude: 48° N
Longitude: 78° W

Data Sheet 69

Origin	Reference No.	Rock Type
Dumagami Mine, Québec	29	rhyolite

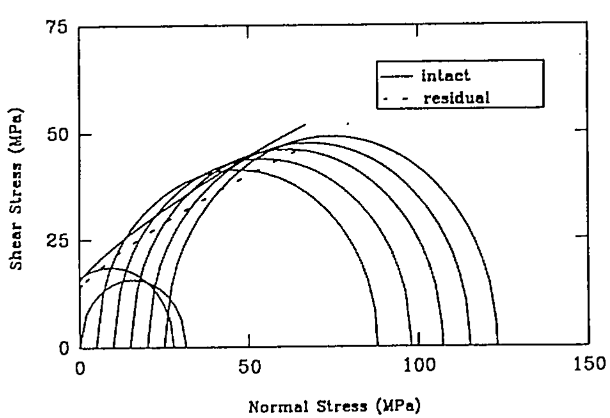
Regional Geology	Structural Characteristics
Cadillac Group overlying felsic volcanics with pyrrhotite mineralization together with alternating layers of massive and ribboned rhyolite; the ore zone that underlies the rhyolite units consists of andalusite schists with pyrite, sphalerite and galena mineralization interbedded with sercite schists; below the sulphide ore zone lies a mafic tuff unit	Dip: 80 – 85° S Strike: E – W Bedding Thickness: Fracture Spacing: Weathering:

Petrography	
Structure: volcanics, massive to ribboned	Composition
Texture: Grain Size: Colour: green-brown Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.84	n/a	47.00	100.00	n/a	n/a	31.45	-9.26	28.42	0.20	5.00 – 25.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
60.87	4.57	1.00	0.83	3.47	0.73	0.71

Borehole Information

Collar Elevation: stope
Depth: 37.86 – 45.90 m
Inclination: horizontal
Latitude: 48° N
Longitude: 78° W

Data Sheet 70

Origin	Reference No.	Rock Type
Dumagami Mine, Québec	29	tuff

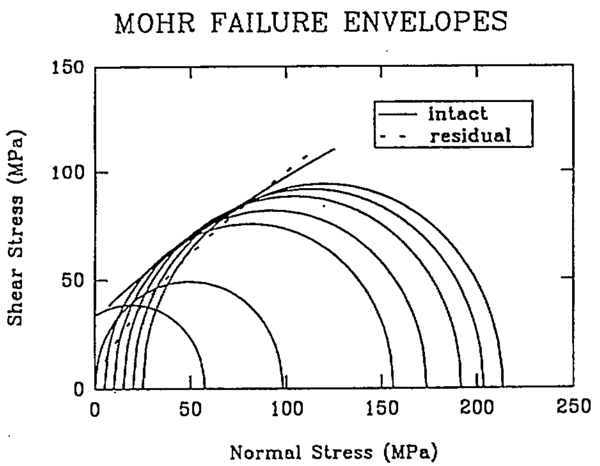
Regional Geology	Structural Characteristics
Cadillac Group overlying felsic volcanics with pyrrhotite mineralization together with alternating layers of massive and ribboned rhyolite; the ore zone that underlies the rhyolite units consists of andalusite schists with pyrite, sphalerite and galena mineralization interbedded with sercite schists; below the sulphide ore zone lies a mafic tuff unit	Dip: 80 – 85° S Strike: E – W Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: volcanics, mafic	Composition
Texture: Grain Size: Colour: green-brown Grain Sorting: Grain Shape: Matrix:	

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.74	n/a	47.00	100.00	n/a	n/a	98.17	-19.12	32.14	0.44	5.00 – 25.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
132.76	5.69	1.00	0.90	9.35	0.00	1.00

Borehole Information

Collar Elevation: stope
Depth: 62.82 – 84.06 m
Inclination: horizontal
Latitude: 48° N
Longitude: 78° W

Data Sheet 71

Origin	Reference No.	Rock Type
Rideau Quarry, Alymer, Québec	30	limestone (intra-bio-sparite)

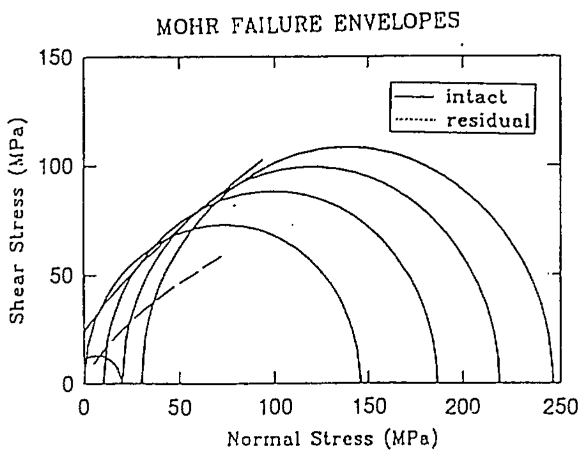
Regional Geology	Structural Characteristics
Trenton group, Ottawa formation, Ordivician to early Palaeozoic	Dip: 0° Strike: 0° Bedding Thickness: Fracture Spacing: 0.3 m Weathering:

Petrography

Structure: massive	Composition
Texture: Grain Size: microscopic Colour: grey Grain Sorting: Grain Shape: Matrix: calcium carbonate	intra-bio-sparite calcite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.70	n/a	45.00	110.00	6.80	2.70	145.84	-6.52	74.76	0.32	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
124.92	9.32	1.00	0.91	3.93	0.00	0.95

Borehole Information

Collar Elevation: surface
Depth: 0.3 m
Inclination: vertical
Latitude: 45° 26′ N
Longitude: 75° 49′ W

Data Sheet 72

Origin	Reference No.	Rock Type
Rideau Quarry, Québec	30	limestone (bio-pel-sparite)

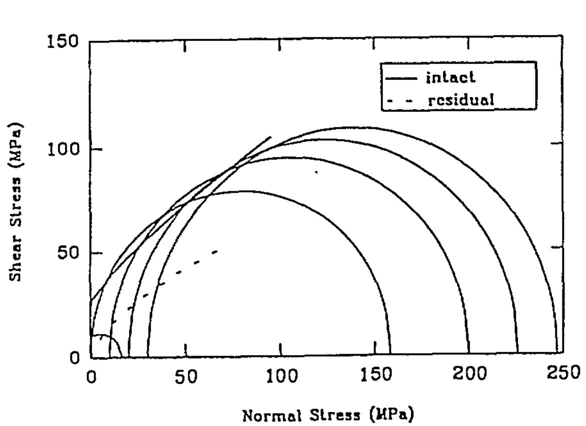
Regional Geology	Structural Characteristics
Trenton group, Ottawa formation, Ordivician to early Palaeozoic	Dip: 0° Strike: 0° Bedding Thickness: Fracture Spacing: 0.3 m Weathering:

Petrography

Structure: massive	Composition
Texture: Grain Size: microscopic Colour: grey Grain Sorting: Grain Shape: Matrix: calcium carbonate	bio-pel-sparite calcite

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.71	n/a	45.00	110.00	6.80	2.70	158.16	-5.51	67.62	0.31	10.00 – 30.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
132.40	8.76	1.00	0.82	2.74	0.00	0.94

Borehole Information

Collar Elevation: surface
Depth: 0.3 m
Inclination: vertical
Latitude: 45° 26′ N
Longitude: 75° 49′ W

Data Sheet 73

Origin	Reference No.	Rock Type
Myra Falls Mine, British Columbia	31	sulphide pyrite (massive)

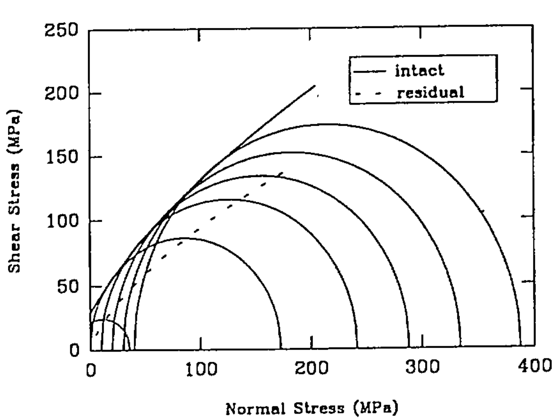
Regional Geology	Structural Characteristics
Orebody occurs at the base of the lowest of a series of mineralized rhyolite beds in the Myra formation of the Sicker group (Palaeozoic age). The orebody was formed as mineral-bearing hydrothermal fluids percolated through and were precipitated out on a sea floor bed of volcaniclastic andesites. The ore is overlain by rhyolite tuffs and flows with interbedded volcanic greywacke, argillite and chert. This unit, termed the HW Rhyolite, is typically capped by a massive andesite flow. Volcanic rocks adjacent to the HW and FW of the main zone orebody have undergone intense sercite-chlorite alteration.	Dip: 40° NE Strike: plunge = 10° SE Bedding Thickness: Fracture Spacing: Weathering:

Petrography	
Structure: Folded, metmosphosed in the lower greenschist facies	Composition
Texture: Grain Size: Colour: green brown Grain Sorting: Grain Shape: Matrix: polymetallic sulphide	sphalerite chalcopyrite gold silver

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
4.78	n/a	54.00	125.00	n/a	n/a	172.08	-11.99	166.30	0.15	10.00 – 40.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
170.83	13.01	1.00	1.00	6.03	0.00	0.94

Borehole Information

Collar Elevation: 23-366, 540 m
Depth:
Inclination:
Latitude: 49° N
Longitude: 125° W

Origin	Reference No.	Rock Type
Myra Falls Mine, British Columbia	31	rhyolite (footwall)

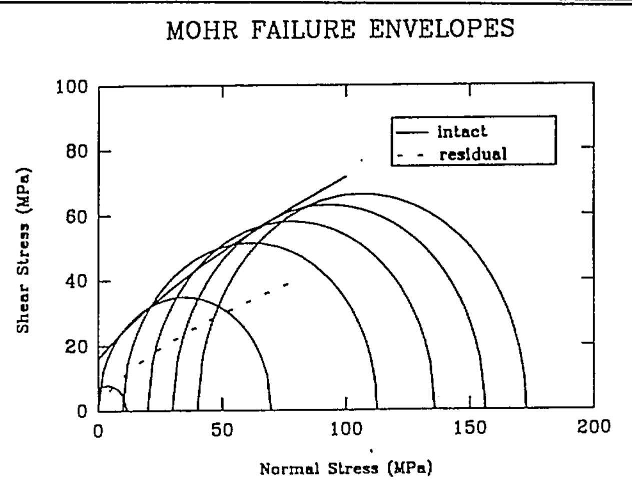
Regional Geology	Structural Characteristics
Orebody occurs at the base of the lowest of a series of mineralized rhyolite beds in the Myra formation of the Sicker group (Palaeozoic age). The orebody was formed as mineral-bearing hydrothermal fluids percolated through and were precipitated out on a sea floor bed of volcaniclastic andesites. The ore is overlain by rhyolite tuffs and flows with interbedded volcanic greywacke, argillite and chert. This unit, termed the HW Rhyolite, is typically capped by a massive andesite flow. Volcanic rocks adjacent to the HW and FW of the main zone orebody have undergone intense sercite-chlorite alteration.	Dip: Strike: anticline Bedding Thickness: interbedded Fracture Spacing: Weathering:

Petrography

Structure: folded, metamorphosed in the lower greenschist facies	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	tuffs flows

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.80	n/a	54.00	125.00	n/a	n/a	69.64	-3.90	63.03	0.12	10.00 – 40.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
66.64	5.62	1.00	0.92	2.07	0.00	0.98

Borehole Information

Collar Elevation: 23 level, FW
Depth: 540 m
Inclination:
Latitude: 49° N
Longitude: 125° W

Data Sheet 75

Origin	Reference No.	Rock Type
Myra Falls Mine, British Columbia	31	rhyolite (hangingwall)

Regional Geology	Structural Characteristics
Orebody occurs at the base of the lowest of a series of mineralized rhyolite beds in the Myra formation of the Sicker group (Palaeozoic age). The orebody was formed as mineral-bearing hydrothermal fluids percolated through and were precipitated out on a sea floor bed of volcaniclastic andesites. The ore is overlain by rhyolite tuffs and flows with interbedded volcanic greywacke, argillite and chert. This unit, termed the HW Rhyolite, is typically capped by a massive andesite flow. Volcanic rocks adjacent to the HW and FW of the main zone orebody have undergone intense sercite-chlorite alteration.	Dip: Strike: anticline Bedding Thickness: interbedded Fracture Spacing: Weathering:

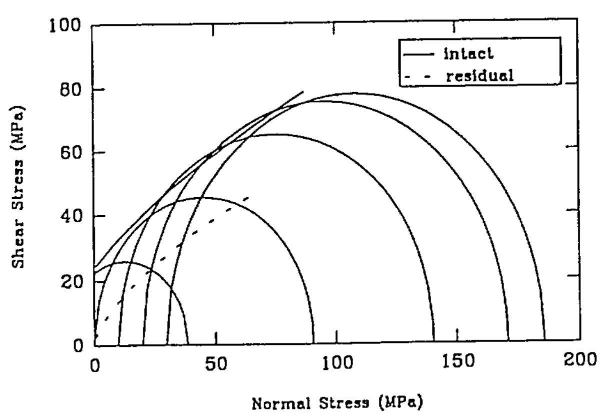
Petrography

Structure: folded, metamorphosed in the lower greenschist facies	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	tuffs flows

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.80	n/a	54.00	125.00	n/a	n/a	90.56	-12.89	45.42	0.26	10.00 – 40.00

MOHR FAILURE ENVELOPES



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r_r^2
99.09	5.50	1.00	0.96	2.86	0.01	0.92

Borehole Information

Collar Elevation: 3190 E, 3660 N, HW
Depth: 455 m
Inclination:
Latitude: 49° N
Longitude: 125° W

Origin	Reference No.	Rock Type
Myra Falls Mine, British Columbia	31	andesite, altered

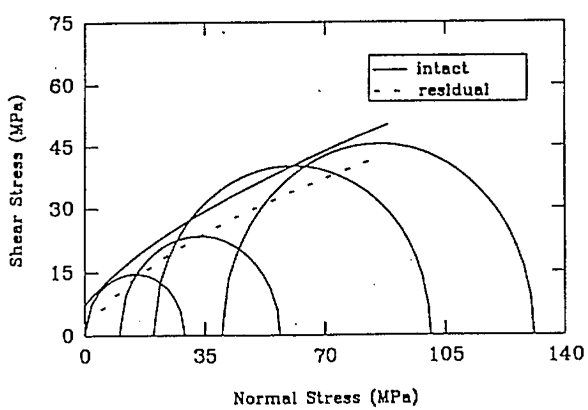
Regional Geology	Structural Characteristics
Orebody occurs at the base of the lowest of a series of mineralized rhyolite beds in the Myra formation of the Sicker group (Palaeozoic age). The orebody was formed as mineral-bearing hydrothermal fluids percolated through and were precipitated out on a sea floor bed of volcaniclastic andesites. The ore is overlain by rhyolite tuffs and flows with interbedded volcanic greywacke, argillite and chert. This unit, termed the HW Rhyolite, is typically capped by a massive andesite flow. Volcanic rocks adjacent to the HW and FW of the main zone orebody have undergone intense sercite-chlorite alteration.	Dip: Strike: anticline Bedding Thickness: massive Fracture Spacing: Weathering:

Petrography

Structure: folded, metamorphosed in the lower greenschist facies	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	flows

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.80	n/a	45.00	90.00	n/a	n/a	29.14	-12.65	23.63	0.32	10.00 – 40.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
32.13	6.08	1.00	0.91	4.46	0.00	1.00

Borehole Information

Collar Elevation: 3150 E, 3670 N, FW
Depth: 440 m
Inclination:
Latitude: 49° N
Longitude: 125° W

Origin	Reference No.	Rock Type
Myra Falls Mine, British Columbia	31	feldspar (porphyry)

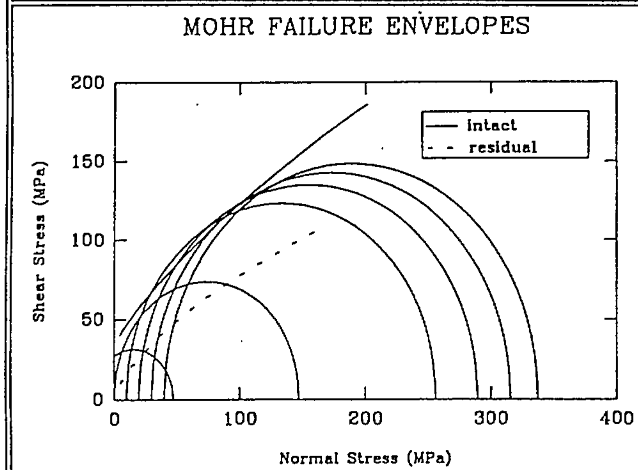
Regional Geology	Structural Characteristics
Orebody occurs at the base of the lowest of a series of mineralized rhyolite beds in the Myra formation of the Sicker group (Palaeozoic age). The orebody was formed as mineral-bearing hydrothermal fluids percolated through and were precipitated out on a sea floor bed of volcaniclastic andesites. The ore is overlain by rhyolite tuffs and flows with interbedded volcanic greywacke, argillite and chert. This unit, termed the HW Rhyolite, is typically capped by a massive andesite flow. Volcanic rocks adjacent to the HW and FW of the main zone orebody have undergone intense sercite-chlorite alteration.	Dip: Strike: anticline Bedding Thickness: Fracture Spacing: Weathering:

Petrography

Structure: folded, metamorphosed in the lower greenschist facies	Composition
Texture: Grain Size: Colour: Grain Sorting: Grain Shape: Matrix:	dyke

Mechanical Properties

γ_d (Mg/m^3)	n %	ϕ (mm)	l (mm)	V_p (km/s)	V_s (km/s)	Q_u (MPa)	σ_t (MPa)	E (GPa)	ν	σ_3 (MPa)
2.79	n/a	45.00	90.00	n/a	n/a	147.07	-15.75	70.85	0.25	10.00 – 40.00



Hoek and Brown Material Constants

Q_c (MPa)	m	s	r^2	m_r	s_r	r^2_r
178.84	9.09	1.00	0.93	3.25	0.00	0.84

Borehole Information

Collar Elevation: 3790 E, 3500 N
Depth: 470 m
Inclination:
Latitude: 49° N
Longitude: 125° W

TABLES

Table 1 - Physical Rock Properties

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
amphibolite	Montauban Mine (P.Q.)	2/1	2.90	n/a	n/a	n/a	n/a	n/a	n/a	n/a
andesite	Chimo Mine (P.Q.)	19/2	2.80	-17.50	96.70	55.82	0.31	n/a	n/a	n/a
andesite	Hislop Township (Ont.)	3/3	2.90	-25.96	163.47	73.21	0.28	6.0	5.90	<.10
andesite (foliated)	Kidd Creek Mine (Ont.)	22/49	2.82	-9.73	n/a	n/a	n/a	6.3	n/a	n/a
andesite	Kidd Creek Mine (Ont.)	22/50	3.05	-9.73	209.50	95.76	0.26	6.4	6.40	n/a
andesite (altered)	Myra Falls Mine (B.C.)	31/76	2.80	-12.65	29.14	23.63	0.32	n/a	n/a	n/a
basalt	Béliveau Mine (P.Q.)	24/51	2.85	-11.83	98.87	62.93	0.38	n/a	n/a	n/a
breccia	Hislop Township (Ont.)	3/4	2.89	-17.72	197.63	87.22	0.26	n/a	n/a	n/a
breccia (late granite)	Strathcona Mine (Ont.)	26/52	2.71	-17.77	362.97	84.31	0.27	n/a	n/a	n/a
coal	Lingan Mine (N.S.)	7/5	1.24	-0.43	9.78	1.76	0.34	n/a	n/a	n/a

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
conglomerate	Pamour Mine (Ont.)	20/6	2.76	-18.97	144.28	64.41	0.25	n/a	n/a	n/a
diabase (fine grained)	Lac St Jean (P.Q.)	9/8	2.97	-15.69	306.00	89.54	0.30	5.63	5.34	<10
diorite	Eldrich Mine (P.Q.)	10/9	2.85	-13.57	143.13	79.86	0.29	7.00	6.62	0.15
diorite	Béliveau Mine (P.Q.)	24/53	10.00 -30.00	-16.87	146.11	70.26	0.34	n/a	n/a	n/a
dolomite (micritic)	Gays River Mine (N.S.)	25/54	2.73	-6.24	116.91	55.42	0.45	n/a	n/a	n/a
feldspar (porphyry)	Myra Falls Mine (B.C.)	31/77	2.79	-15.75	147.07	70.85	0.25	n/a	n/a	n/a
gneiss (qz-mica-biotite)	Montauban Mine (P.Q.)	2/10	2.75	-12.00	93.17	41.72	0.25	n/a	n/a	n/a
gneiss (qz-biotite)	Montauban Mine (P.Q.)	2/11	2.69	-12.97	110.28	40.99	0.49	n/a	n/a	n/a
gneiss (mafic)	Strathcona Mine (Ont.)	26/55	2.93	-15.85	326.75	95.00	0.28	n/a	n/a	n/a
granite (pink)	Blue Beach North (Nfld.)	4/12	2.55	-11.53	223.86	63.61	0.27	4.57	5.17	1.43

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
granite (pink, grey)	Pinawa (Man.)	11/13	2.63	-9.56	190.00	65.30	0.27	n/a	4.43	0.36
granite (pink)	Pinawa (Man.)	27/64	2.63	-9.48	186.10	75.17	0.31	n/a	5.28	<.30
granodiorite	Pinawa (Man.)	28/65	2.66	-8.14	198.50	57.14	0.21	n/a	3.70	<.30
granodiorite	Belmoral Mine (P.Q.)	17/14	2.78	-15.13	130.37	69.47	0.28	6.09	6.06	0.22
greywacke	Pamour Mine (Ont.)	20/15	2.76	-14.89	134.10	44.20	0.29	n/a	n/a	n/a
greywacke (massive)	Gays River Mine (N.S.)	25/56	2.69	-15.93	236.72	60.81	0.26	n/a	n/a	n/a
limestone (bituminous)	Central Canada Potash (Sask.)	16/16	2.46	-5.43	56.37	29.80	0.30	n/a	n/a	n/a
limestone (fine-grained)	Central Canada Potash (Sask.)	16/17	2.61	-9.41	125.70	40.08	0.26	n/a	n/a	n/a
limestone (oolitic)	Indiana (U.S.A.)	8/18	2.34	-4.76	59.70	40.80	0.25	3.87	3.80	13.76
limestone (sugary)	Central Canada Potash (Sask.)	16/19	2.20	-2.91	42.55	18.03	0.28	n/a	n/a	n/a

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	v	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
limestone (intra-bio-sparite)	Rideau Quarry (P.Q.)	30/71	2.70	-6.52	145.84	74.76	0.32	n/a	6.80	n/a
limestone (bio-pel-sparite)	Rideau Quarry (P.Q.)	30/72	2.71	-5.51	158.16	67.62	0.31	n/a	6.80	n/a
mafic flow	Detour Lake Mine (Ont.)	5/20	2.95	-19.99	316.91	88.00	0.25	4.68	4.65	<0.10
mafic flow ore	Detour Lake Mine (Ont.)	5/21	2.99	-19.53	173.91	92.69	0.26	n/a	n/a	n/a
mudstone	Donkin-Morien Mine (N.S.)	13/22	2.61	-3.63	33.92	1.93	0.49	n/a	n/a	n/a
mudstone	Lingan Mine (N.S.)	7/23	2.70	-8.78	59.40	15.49	0.11	n/a	n/a	n/a
mudstone	Springhill Coal Mine (N.S.)	14/24	n/a	-6.21	26.71	n/a	n/a	n/a	n/a	n/a
mudstone (dolomitic)	Central Canada Potash (Sask.)	16/25	2.50	-6.39	44.31	9.34	0.15	n/a	n/a	n/a
norite	Creighton Mine (Ont.)	6/7	3.03	-11.53	203.40	59.74	0.18	n/a	n/a	n/a

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
phyllite	Lupin Mine (N.W.T.)	23/57	2.87	-20.89	120.60	52.30	0.21	n/a	4.98	n/a
quartzite (metagrey-wacke)	Lupin Mine (N.W.T.)	23/58	2.70	-13.68	168.06	49.19	0.42	n/a	3.54	n/a
rhyolite	Kidd Creek Mine (Ont.)	22/59	2.75	-12.48	111.98	80.75	0.39	n/a	6.16	n/a
rhyolite	Dumagami Mine (P.Q.)	29/69	2.84	-9.26	31.45	28.42	0.20	n/a	n/a	n/a
rhyolite (sulphide)	Dumagami Mine (P.Q.)	29/68	3.35	-8.15	73.40	75.96	0.42	n/a	n/a	n/a
rhyolite (footwall)	Myra Falls Mine (B.C.)	31/74	2.80	-3.90	69.64	63.03	0.12	n/a	n/a	n/a
rhyolite (hangingwall)	Myra Falls Mine (B.C.)	31/75	2.80	-12.89	90.56	45.42	0.26	n/a	n/a	n/a
sandstone	Lingan Mine (N.S.)	7/26	2.66	-6.87	80.02	30.37	0.18	n/a	n/a	n/a
sandstone (2nd redbed)	Central Canada Potash (Sask.)	16/27	2.53	-2.91	24.90	n/a	n/a	n/a	n/a	n/a
sandstone (fine-grained)	Donkin-Morien Mine (N.S.)	13/28	2.46	-8.96	121.25	19.04	0.14	4.89	4.43	1.36

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
sandstone (fine-grained)	Prince Mine (N.S.)	1/29	2.63	-9.97	142.87	41.79	0.18	n/a	n/a	n/a
sandstone (fine-grained)	Springhill Coal Mine (N.S.)	14/30	n/a	-9.47	160.76	32.86	0.15	n/a	n/a	n/a
sandstone (Grimsby)	Niagara Falls (Ont.)	15/31	2.53	-8.98	168.20	24.88	0.36	4.25	3.30	6.60
sandstone (med-grained)	Campbell's Quarry (Ont.)	21/32	2.40	-6.82	145.78	39.24	0.50	4.66	4.09	8.15
sandstone (med-grained)	Donkin-Morien Mine (N.S.)	13/33	2.42	-7.46	88.23	20.38	0.21	n/a	n/a	n/a
sandstone (med-grained)	Prince Mine (N.S.)	1/34	2.31	-4.35	56.25	15.41	0.18	n/a	n/a	n/a
sandstone (med-grained)	Springhill Coal Mine (N.S.)	14/35	n/a	-5.91	83.30	24.00	0.20	n/a	n/a	n/a
sandstone (whirlpool)	Niagara Falls (Ont.)	15/36	2.50	-11.61	146.42	n/a	n/a	n/a	n/a	n/a
shale	Prince Mine (N.S.)	1/37	2.60	-7.96	89.30	17.40	0.18	n/a	n/a	n/a
siltstone	Donkin-Morien Mine (N.S.)	13/38	2.86	-3.48	35.68	22.38	0.20	n/a	n/a	n/a

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
siltstone	Lingan Mine (N.S.)	7/39	2.70	-6.97	48.64	36.58	0.21	n/a	n/a	n/a
siltsone	Prince Mine (N.S.)	1/40	2.48	-5.59	82.08	14.16	0.17	n/a	n/a	n/a
siltstone	Springhill Coal Mine (N.S.)	14/41	n/a	-6.14	177.20	30.00	0.14	n/a	n/a	n/a
sulphide (massive)	Dumagami Mine (P.Q.)	29/66	4.56	-7.36	85.58	84.26	0.54	n/a	n/a	n/a
sulphide (semi-massive)	Dumagami Mine (P.Q.)	29/67	3.88	-8.22	102.22	79.36	0.40	n/a	n/a	n/a
sulphide iron	Lupin Mine (N.W.T.)	23/60	3.21	-27.90	447.73	101.10	0.24	n/a	6.62	n/a
sulphide ore	Copper Cliff S. Mine (Ont.)	12/42	2.99	-12.32	155.10	77.20	0.26	4.03	4.03	$<.10$
sulphide zinc	Kidd Creek Mine (Ont.)	22/61	3.72	-8.86	158.54	82.16	0.16	n/a	5.81	n/a
sulphide pyrite (massive)	Myra Falls Mine (B.C.)	31/73	4.78	-11.99	172.08	166.30	0.15	n/a	n/a	n/a

Table 1 - (continued)

Rock type	Origin	Ref.#/ data sht.	γ_d (Mg/m^3)	σ_t (MPa)	Q_u (MPa)	E (GPa)	ν	V_p(sat.) (km/s)	V_p(dry) (km/s)	n (%)
syenite	Hislop Township (Ont.)	3/43	2.66	-20.87	253.62	76.49	0.36	5.80	5.80	0.14
talc-carbonate	Kidd Creek Mine (Ont.)	22/62	2.84	-3.17	33.34	28.55	0.58	n/a	4.85	n/a
talc-chlorite	Detour Lake Mine (Ont.)	5/44	2.97	-9.58	92.43	50.82	0.34	n/a	n/a	n/a
talc-chlorite-schist	Hislop Township (Ont.)	3/45	2.84	-3.61	35.79	35.82	0.29	n/a	n/a	n/a
tonalite (qz diorite)	Eldrich Mine (P.Q.)	10/46	2.74	-13.54	123.42	73.58	0.23	6.23	6.27	0.14
tuff	Bousquet Mine (P.Q.)	18/47	2.92	-9.95	50.83	58.79	0.29	n/a	n/a	n/a
tuff	Chimo Mine (P.Q.)	19/48	2.86	-19.91	165.92	95.49	0.23	n/a	n/a	n/a
tuff	Béliveau Mine (Val d'Or, P.Q.)	24/63	2.74	-12.32	106.38	68.65	0.34	n/a	n/a	n/a
tuff	Dumagami Mine (P.Q.)	29/70	2.74	-19.12	98.17	32.14	0.44	n/a	n/a	n/a

n/a = not available

Table 2 - Hoek and Brown Material Constants

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	m	s	r^2	m_r	s_r	r^2_r
amphibolite	Montauban Mine (P.Q.)	2/1	5.00 -20.00	n/a	n/a	170.06	21.36	1.00	1.00	3.05	0.00	0.66
andesite	Chimo Mine (P.Q.)	19/2	5.00 -20.00	-17.50	96.70	128.73	6.67	1.00	0.89	2.59	0.12	0.22
andesite	Hislop Township (Ont.)	3/3	5.00 -20.00	-25.96	163.47	226.12	7.75	1.00	0.79	n/a	n/a	n/a
andesite (foliated)	Kidd Creek Mine (Ont.)	22/49	30.00 -100.00	-9.73	n/a	59.88	1.04	1.00	0.87	n/a	n/a	n/a
andesite	Kidd Creek Mine (Ont.)	22/50	30.00 -100.00	-9.73	209.50	208.96	5.83	1.00	0.93	1.16	0.00	0.46
andesite (altered)	Myra Falls Mine (B.C.)	31/76	10.00 -40.00	-12.65	29.14	32.13	6.08	1.00	0.91	4.45	1.10	1.00
basalt	Béliveau Mine (P.Q.)	24/51	10.00 -30.00	-11.83	98.87	84.87	3.26	1.00	0.82	1.02	0.01	0.67
breccia	Hislop Township (Ont.)	3/4	5.00 -20.00	-17.72	197.63	291.86	17.89	1.00	0.89	n/a	n/a	n/a
breccia (late granite)	Strathcona Mine (Ont.)	26/52	5.00 -20.00	-17.77	362.97	337.00	15.39	1.00	0.95	3.26	0.00	0.86
coal	Lingan Mine (N.S.)	7/5	0.30 -20.70	-0.43	9.78	20.96	20.26	1.00	0.95	n/a	n/a	n/a

Table 2 - (continued)

Rock type	Origin	Ref. #/ data sht.	σ_3 (MPa)	σ_t (MPa)	Q_u (MPa)	Q_c (MPa)	Intact			Residual		
							m	s	r^2	m_r	s_r	r^2_r
conglomerate	Pamour Mine (Ont.)	20/6	5.00 20.00	-18.97	144.28	126.36	4.07	1.00	0.84	3.51	0.00	0.24
diabase (fine-grained)	Lac St Jean (P.Q.)	9/8	3.00 20.70	-15.69	306.00	321.27	20.40	1.00	0.99	3.03	0.00	0.81
diorite	Eldrich Mine (P.Q.)	10/9	1.00 20.00	-13.57	143.13	165.47	11.45	1.00	0.88	3.86	0.01	0.28
diorite	Béliveau Mine (P.Q.)	24/53	10.10 30.00	-16.87	146.11	132.95	5.05	1.00	0.95	1.89	0.00	0.53
dolomite (micritic)	Gays River Mine (N.S.)	25/54	1.00 20.00	-6.24	116.91	108.97	11.94	1.00	0.97	5.70	0.00	0.98
feldspar (porphyry)	Myra Falls Mine (B.C.)	31/77	10.00 40.00	-15.75	147.07	178.84	9.09	1.00	0.93	3.25	0.00	0.84
gneiss (qz-mica-biotite)	Montauban Mine (P.Q.)	2/10	5.00 20.00	-12.00	93.17	103.21	7.57	1.00	0.98	4.78	0.40	0.01
gneiss (qz-biotite)	Montauban Mine (P.Q.)	2/11	5.00 20.00	-12.97	110.28	103.20	5.68	1.00	0.97	2.27	0.02	0.33
gneiss (mafic)	Strathcona Mine (Ont.)	26/55	5.00 20.00	-15.85	326.75	318.18	17.92	1.00	0.98	2.51	0.00	0.60
granite (pink)	Blue Beach North (NFLD.)	4/12	10.00 30.00	-11.53	223.86	236.87	22.10	1.00	1.00	n/a	n/a	n/a

Table 2 - **(continued)**

Rock type	Origin	Ref. #/ data sht.	σ_3 (MPa)	σ_t (MPa)	Q_u (MPa)	Q_c (MPa)	Intact			Residual		
							m	s	r^2	m_r	s_r	r^2_r
granite (pink, grey)	Pinawa (Man.)	11/13	3.50 35.00	-9.56	190.0	234.15	27.75	1.00	0.99	2.26	0.00	0.97
granite (pink)	Pinawa (Man.)	27/64	10.00 60.00	-9.48	186.10	210.13	29.54	1.00	0.99	3.04	0.00	0.70
granodiorite	Pinawa (Man.)	28/65	2.00 60.00	-8.14	198.50	223.45	26.30	1.00	0.98	4.47	0.00	0.82
granodiorite	Belmoral Mine (P.Q.)	17/14	5.00 20.00	-15.13	130.37	125.37	6.64	1.00	0.97	3.64	0.00	0.15
greywacke	Pamour Mine (Ont.)	20/15	5.00 20.00	-14.89	134.10	99.14	4.49	1.00	0.98	n/a	n/a	n/a
greywacke (massive)	Gays River Mine (N.S.)	25/56	2.00 20.00	-15.93	236.72	244.28	15.25	1.00	0.98	2.81	0.00	0.86
limestone (bituminous)	Central Canada Potash (Sask.)	16/6	.10 27.60	-5.43	56.37	66.71	14.40	1.00	0.99	13.05	0.00	0.98
limestone (fine-grained)	Central Canada Potash (Sask.)	16/17	.10 27.60	-9.40	125.70	127.97	12.76	1.00	0.98	7.02	0.00	0.87
limestone (oolitic)	Indiana (U.S.A.)	8/18	7.00 34.50	-4.76	59.70	60.50	4.90	1.00	0.96	6.40	0.14	0.99
limestone (sugary)	Central Canada Potash (Sask.)	16/19	.10 27.60	-2.91	42.55	43.07	7.49	1.00	0.96	9.86	0.00	1.00

Table 2 - (continued)

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	m	s	r^2	m_r	s_r	r^2_r
limestone (intra-bio-sparite)	Rideau Quarry (P.Q.)	30/71	10.00 30.00	-6.52	145.84	124.42	9.32	1.00	0.91	3.93	0.00	0.95
limestone (bio-pel-sparite)	Rideau Quarry (P.Q.)	30/72	10.00 30.00	-5.51	158.16	132.40	8.76	1.00	0.82	2.74	0.00	0.94
mafic flow	Detour Lake Mine (Ont.)	5/20	7.00 24.10	-19.99	319.91	287.22	12.27	1.00	0.95	5.01	0.00	0.98
mafic flow ore	Detour Lake Mine (Ont.)	5/21	7.00 24.10	-19.53	173.91	199.22	10.87	1.00	0.94	5.36	0.00	0.56
mudstone	Donkin-Morien Mine (N.S.)	13/22	0.40 5.20	-3.63	33.92	50.84	14.39	1.00	0.95	6.65	0.00	0.55
mudstone	Lingan Mine (N.S.)	7/23	3.50 21.00	-8.78	59.40	55.85	3.26	1.00	0.98	5.59	0.00	0.98
mudstone	Springhill Coal Mine (N.S.)	14/24	0.40 -3.50	-6.21	26.71	39.35	4.44	1.00	0.56	9.83	0.08	0.44
mudstone (dolomitic)	Central Canada Potash (Sask.)	16/25	0.10 27.60	-6.39	44.31	43.71	4.50	1.00	0.99	n/a	n/a	n/a
norite	Creighton Mine (Ont.)	6/7	2.00 60.00	-11.53	203.40	222.67	17.14	1.00	0.95	5.40	0.04	0.49
phyllite	Lupin Mine (N.W.T.)	23/57	10.00 30.00	-20.89	120.60	127.55	3.57	1.00	0.98	1.39	0.05	0.30

Table 2 - (continued)

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	m	s	r^2	m_r	s_r	r^2_r
quartzite (metagreywacke)	Lupin Mine (N.W.T.)	23/58	10.00 30.00	-13.68	168.06	148.16	6.81	1.00	0.94	1.29	0.00	0.60
rhyolite	Kidd Creek Mine (Ont.)	22/59	10.00 100.00	-12.48	111.98	122.77	3.29	1.00	0.90	2.98	0.00	0.85
rhyolite	Dumagami Mine (P.Q.)	29/69	5.00 25.00	-9.26	31.45	60.87	4.57	1.00	0.83	3.47	0.73	0.71
rhyolite (sulphide)	Dumagami Mine (P.Q.)	29/68	5.00 25.00	-8.15	73.40	94.17	8.40	1.00	0.91	6.27	0.00	0.61
rhyolite (footwall)	Myra Falls Mine (B.C.)	31/74	10.00 40.00	-3.90	69.64	66.59	5.62	1.00	0.92	2.07	0.00	0.98
rhyolite (hangingwall)	Myra Falls Mine (B.C.)	31/75	10.00 40.00	-12.89	90.56	99.09	5.50	1.00	0.96	2.86	0.01	0.92
sandstone	Lingan Mine (N.S.)	7/26	3.50 20.70	-6.87	80.02	80.25	13.68	1.00	0.98	3.00	0.00	0.79
sandstone (2nd redbed)	Central Canada Potash (Sask.)	16/27	0.10 27.60	-2.91	24.90	19.92	24.12	1.00	0.95	12.83	0.00	0.97
sandstone (fine-grained)	Donkin-Morien Mine (N.S.)	13/28	0.4- 5.20	-8.96	121.25	171.49	19.64	1.00	0.82	4.41	0.01	0.94
sandstone (fine-grained)	Prince Mine (N.S.)	1/29	0.30 20.70	-9.97	142.87	139.38	11.08	1.00	0.97	2.71	0.00	0.87

Table 2 - **(continued)**

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	*m*	*s*	r^2	m_r	s_r	r^2_r
sandstone (fine-grained)	Springhill Coal Mine (N.S.)	14/30	0.40 3.50	-9.47	160.7	175.37	16.32	1.00	0.78	4.14	0.01	0.79
sandstone (Grimsby)	Niagara Falls (Ont.)	15/31	3.50 35.00	-8.98	168.20	147.83	8.78	1.00	0.89	n/a	n/a	n/a
sandstone (med-grained)	Campbell's Quarry (Ont.)	21/32	10.00 30.00	-6.82	145.78	159.93	23.98	1.00	0.99	3.62	0.00	0.85
sandstone (med-grained)	Donkin-Morien Mine (N.S.)	13/33	0.40 5.20	-7.46	88.23	94.00	10.64	1.00	0.95	2.79	0.01	0.75
sandstone (med-grained)	Prince Mine (N.S.)	1/34	0.30 20.70	-4.35	56.25	49.42	12.49	1.00	0.97	3.87	0.00	0.87
sandstone (med-grained)	Springhill Coal Mine (N.S.)	14/35	0.40 3.50	-5.91	83.30	93.94	16.72	1.00	0.94	4.70	0.01	0.80
sandstone (whirlpool)	Niagara Falls (Ont.)	15/36	3.50 35.00	-11.61	146.42	170.15	14.84	1.00	0.90	n/a	n/a	n/a
shale	Prince Mine (N.S.)	1/37	0.30 20.70	-7.96	89.30	69.53	9.39	1.00	0.96	3.37	0.00	0.99
siltstone	Donkin-Morien Mine (N.S.)	13/38	0.40 5.20	-3.48	35.68	36.36	8.95	1.00	1.00	4.41	0.01	0.94
siltstone	Lingan Mine (N.S.)	7/39	3.50 21.00	-6.97	48.64	45.35	3.92	1.00	0.94	4.43	0.03	0.86

Table 2 - (continued)

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	m	s	r^2	m_r	s_r	r^2_r
siltstone	Prince Mine (N.S.)	1/40	0.30 21.00	-5.59	82.08	63.26	11.24	1.00	1.00	2.86	0.00	0.95
siltstone	Springhill Coal Mine (N.S.)	14/41	0.40 3.50	-6.14	177.20	189.38	30.61	1.00	0.97	3.34	0.00	1.00
sulphide (massive)	Dumagami Mine (P.Q.)	29/66	5.00 25.00	-7.36	85.58	94.47	14.00	1.00	0.99	2.14	0.00	0.91
sulphide (semi-massive)	Dumagami Mine (P.Q.)	29/67	5.00 25.00	-8.22	102.22	132.19	12.93	1.00	0.93	1.69	0.00	0.78
sulphide iron	Lupin Mine (N.W.T.)	23/60	10.00 30.00	-7.73	447.73	515.26	16.78	1.00	0.82	n/a	n/a	n/a
sulphide ore	Copper Cliff S. Mine (Ont.)	12/42	1.00 10.30	-12.32	155.10	175.66	17.49	1.00	0.84	6.43	0.06	0.92
sulphide zinc	Kidd Creek Mine (Ont.)	22/61	10.00 100.00	-8.86	158.54	157.47	2.80	1.00	0.71	2.88	0.30	0.75
sulphide pyrite (massive)	Myra Falls Mine (B.C.)	31/73	10.00 40.00	-11.99	172.08	170.83	13.01	1.00	1.00	6.03	0.00	0.94
syenite	Hislop Township (Ont.)	3/43	5.00 20.00	-20.87	253.62	179.25	7.65	1.00	0.94	n/a	n/a	n/a
talc-carbonate	Kidd Creek Mine (Ont.)	22/62	10.00 100.00	-3.17	33.34	27.64	2.27	1.00	0.92	0.06	0.30	n/a

Table 2 - (continued)

Rock type	Origin	Ref. #/ data sht.	σ_3	σ_t	Q_u	Q_c	Intact			Residual		
			(MPa)	(MPa)	(MPa)	(MPa)	m	s	r^2	m_r	s_r	r^2_r
talc-chlorite	Detour Lake Mine (Ont.)	5/44	6.90 24.10	-9.58	92.43	79.56	4.65	1.00	0.92	3.22	0.00	0.85
talc-chlorite-schist	Hislop Township (Ont.)	3/45	5.00 20.00	-3.61	35.79	33.37	6.70	1.00	0.98	0.24	0.00	0.99
tonalite (qz-diorite)	Eldrich Mine (P.Q.)	10/46	1.00 20.00	-13.54	123.42	138.72	10.92	1.00	0.74	4.42	0.04	0.36
tuff	Bousquet Mine (P.Q.)	18/47	5.00 20.00	-9.95	50.83	54.78	3.72	1.00	0.95	2.72	0.04	0.17
tuff	Chimo Mine (P.Q.)	19/48	5.00 20.00	-19.91	165.92	185.43	9.23	1.00	0.93	2.63	0.00	0.62
tuff	Béliveau Mine (P.Q.)	24/63	10.00 20.00	-12.32	106.38	101.09	5.77	1.00	0.98	4.00	0.00	0.82
tuff	Dumagami Mine (P.Q.)	29/70	5.00 25.00	-19.12	98.17	132.76	5.69	1.00	0.90	9.35	0.00	1.00

Table 3 - List of MRL reports referred to in Data Sheets and Tables 1 and 2

Ref. no.	Report number	Title	Author(s)	Data sheet(s)
1	86-33(INT) 85-128(INT)	Strength Determinations of Prince Mine Rocks 1 Strength Determinations of Prince Mine Rocks 2	B. Gorski B. Gorski	29, 34, 37, 40
2	87-169(TR)	Strength Determinations of Montauban Mine Rocks	B. Gorski et al	1, 10, 11
3	88-77(INT)	Strength Determinations of Hislop Township Deposit Rocks	B. Gorski	3, 4, 43, 45
4	88-74(INT)	Strength Determinations of Blue Beach North Deposit Rocks	B. Gorski	12
5	85-45(INT) 85-108(INT)	Strength Determinations of Detour Lake Mine Rocks Additional Strength Determinations of Detour Lake Mine Rocks	B. Gorski B. Gorski	20, 21, 44
6	88-18(INT)	Rock Material Constants in Function of Stress Path Dependency Using a Computer Controlled Servo-Hydraulic Test System	B. Gorski	7
7	86-34(INT)	Uniaxial Strength Determinations of Lingan Mine Rocks	B. Gorski	5, 23, 26, 39
8	83-99(TR)	Triaxial Properties of Indiana Limestone	M. Bétournay T. Shimotani	18
9	83-19(INT)	Evaluation of Testing Procedures for Minimizing Rock Sample Requirement	T. Shimotani	8
10	88-34(INT) 88-111(INT)	Strength Determinations of Eldrich Mine Rocks - Phase I Strength Determinations of Eldrich Mine Rocks - Phase II	B. Gorski B. Gorski	9, 46
11	84-48(TR)	Mechanical Properties of Samples from Pinawa, Manitoba	A. Annor	13

Table 3 - (continued)

Ref. no.	Report number	Title	Author(s)	Data sheets(s)
12	82-141(TR)	Stiff Triaxial Tests on Copper Cliff South Mine Orebody Rock	J. Molson	42
13	84-90(TR)	A Study of Rock Behaviour for the Donkin-Morien Rock/Support Interaction Contract	M. Bétournay	22, 28, 33, 38
14	84-89(TR)	Strength and Deformation of Various Rocks from the Springhill Coal Mine, Nova Scotia	M. Bétournay	24, 30, 35, 41
15	85-134(TR)	Preliminary Results of High Temperature and High Pressure Triaxial Testing on Ontario Hydro Specimens	R. Jackson	31, 36
16	85-124(INT)	Strength Determinations of Central Canada Potash Rocks	B. Gorski	16, 17, 19, 25, 27
17	88-136(INT) 89-22(INT)	Strength Determinations of Belmoral Mine Rocks Strength Determinations of Belmoral, Pamour, Chimo and Bousquet Mine Rocks	B. Gorski et al	14
18	89-22(INT)	Strength Determinations of Belmoral, Pamour, Chimo and Bousquet Mine Rocks	B. Gorski et al	47
19	89-22(INT)	Strength Determinations of Belmoral, Pamour, Chimo and Bousquet Mine Rocks	B. Gorski et al	2, 48
20	89-22(INT)	Strength Determinations of Belmoral, Pamour, Chimo and Bousquet Mine Rocks	B. Gorski et al	6, 15
21	89-118(TR)	The Geological and Engineering Classification of Nepean Sandstone	B. Gorski	32

Table 3 - (continued)

Ref. no.	Report number	Title	Author(s)	Data sheets(s)
22	90-097(TR)	Strength Determinations of Kidd Creek Mine No. 3 Rocks	B. Gorski	49, 50, 59, 61, 62
23	90-100(TR)	Strength Determinations of Lupin Mine Rocks	B. Gorski	57, 58, 60
24	90-113(TR)	Strength Determinations of Lucien C. Béliveau Mine Rocks	B. Gorski	51, 53, 63
25	91-004(TR)	Strength Determinations of Gays River Mine Rocks	B. Gorski J. Folta	54, 56
26	90-133(INT)	Strength Determinations of Strathcona Mine Rocks	B. Gorski	52, 55
27	91-103(TR)	The Post-Failure Behaviour of the Lac Du Bonnet Pink Granite	J. Lau B. Gorski	64
28	91-098(TR)	The Post-Failure Behaviour of the Lac du Bonnet Granodiorite	J. Lau B. Gorski	65
29	91-093(INT)	Strength Determinations of Dumagami Mine Rocks	B. Gorski J. Folta	66, 67, 68, 69, 70
30	92-024(INT)	Strength Determinations of Pamelia Limestone	B. Gorski B. Conlon	71, 72
31	92-027(INT)	Strength Determination of Myra Falls Mine Rocks	B. Gorski B. Conlon	73, 74, 75, 76, 77