APPENDIX A

Laboratory Rock Strength Testing Results and Rock Block Photographs
Petrographic Testing Results

NORMAN B. KEEVIL
INSTITUTE OF MINING ENGINEERING

Hatch Mott Macdonald

Project No.: 230748
Laboratory Testing Report

October 30, 2006

LABORATORY TESTING

October 2006

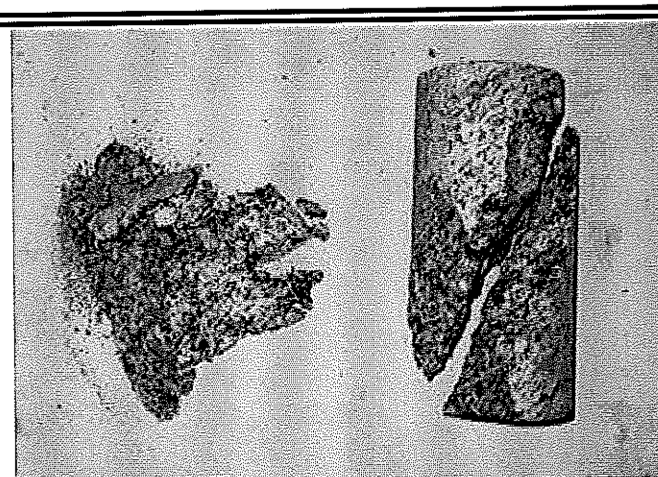
Testing Date:	October 13 – October 27, 2006
Tested by:	Cristian Caceres and Paul Hughes
Tested at:	Norman B Keevil Institute of Mining Engineering, University of British Columbia
Equipment:	MTS Electro-Hydraulic Testing Machine
Method:	ASTM D 2938-95 (UCS)
Procedure:	UCS Samples identified as competent were wet cut and polished and tested per ASTM specifications.
Comments:	

Summary

Elastic Modulus and Unconfined Compression Test Results

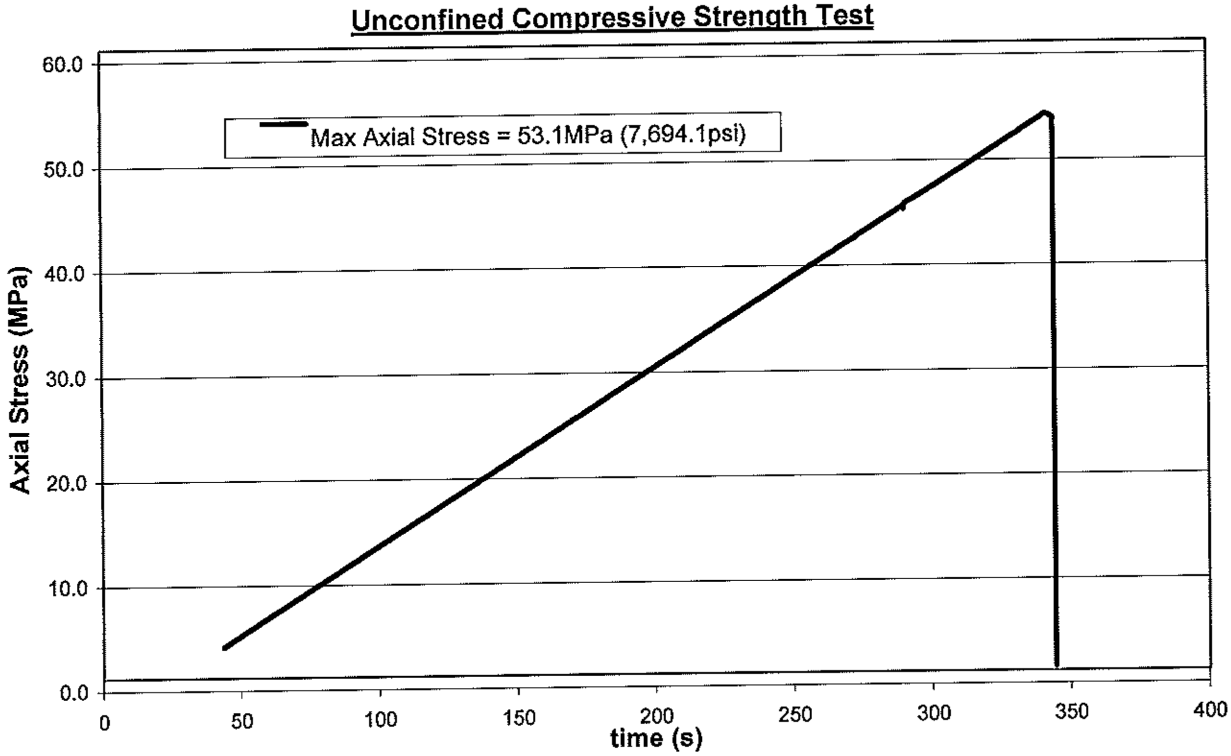
Sample No.	Borehole	Depth (m)	Rock Type	Diameter d (mm)	Height H (mm)	Ratio H/d	UCS (MPa)	UCS (psi)
1A	SCL-1 Portal	Boulder Sample	Granite	46.3	106.9	2.3	53.1	7694.1
1B	SCL-1 Portal	Boulder Sample	Granite	46.3	104.1	2.2	54.4	7894.3
2A	SCL-1 Intake	Boulder Sample	Granite	46.2	104.4	2.3	134.6	19519.8
2B	SCL-1 Intake	Boulder Sample	Granite	46.3	102.7	2.2	133.8	19397.4
3A	SCL-2	Boulder Sample	Granite	46.2	104.4	2.3	125.5	18202.6
3B	SCL-2	Boulder Sample	Granite	46.3	105.7	2.3	114.0	16528.2
4A	SCL-3	Boulder Sample	Granite	46.4	85.4	1.8	117.1	16983.9
4B	SCL-3	Boulder Sample	Granite	46.4	86.0	1.9	124.4	18037.4

Borehole:	SCL-1 Portal
Sample No:	1A
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear

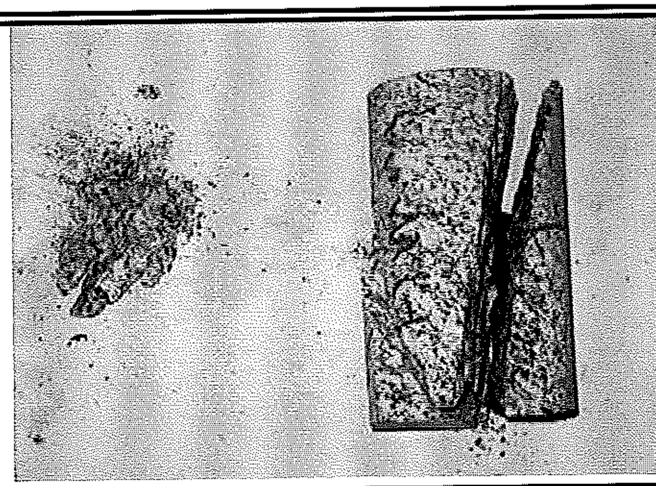


Diameter, (ϕ)	**Area, (A)**	**Height, (h)**	**Ratio**	**Peak Load**	**σ_{UCS}**	
(mm)	**(mm^2)**	**(mm)**	**h/ϕ**	**(kN)**	**(MPa)**	**(psi)**
46.29	1682.9	106.87	2.3	89.3	53.1	7,694.1

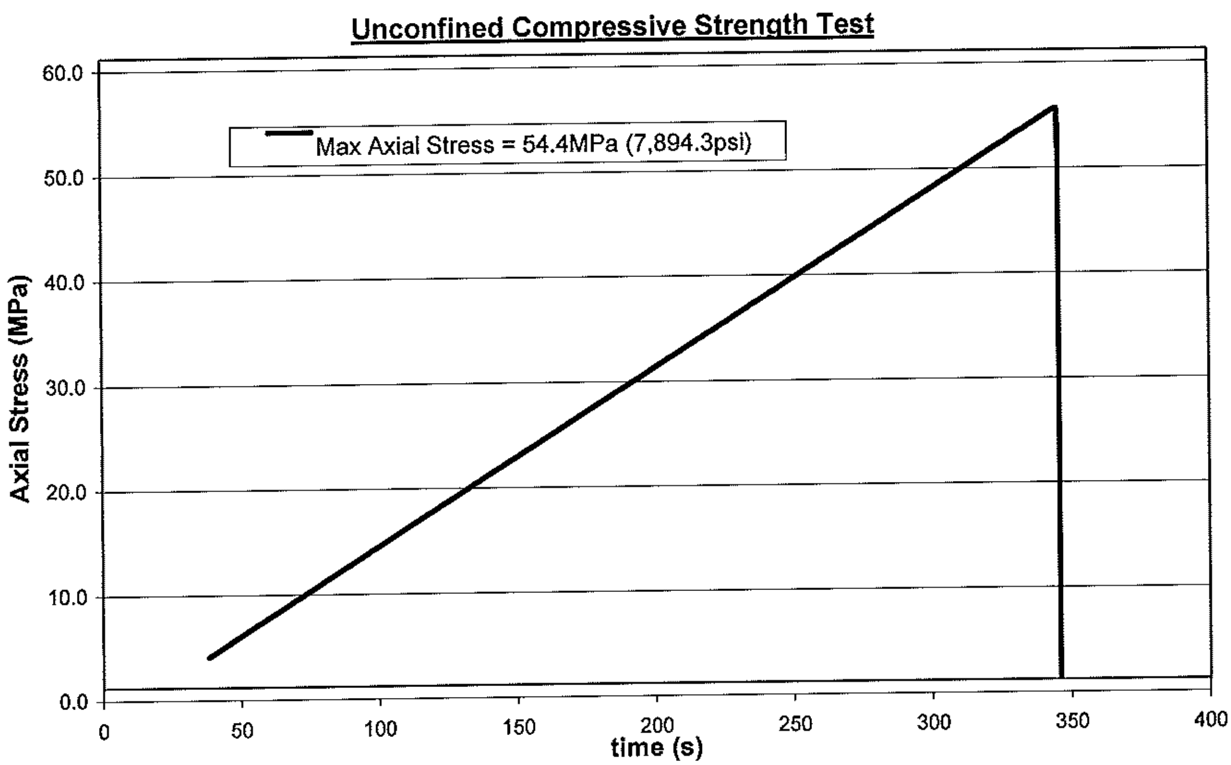
Unconfined Compressive Strength Test



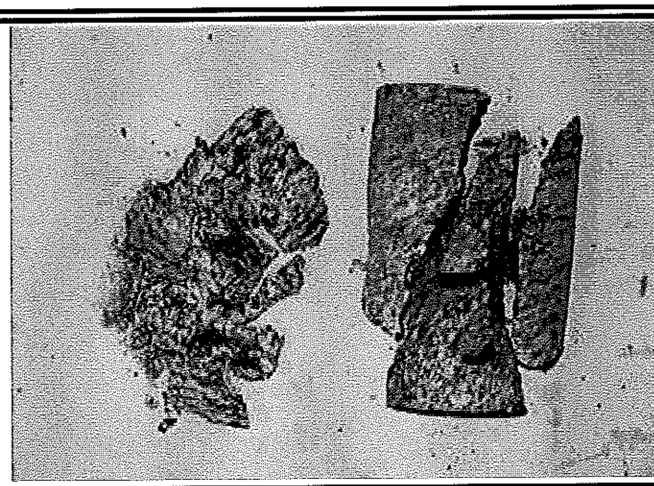
Borehole:	SCL-1 Portal
Sample No:	1B
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear/Explosive



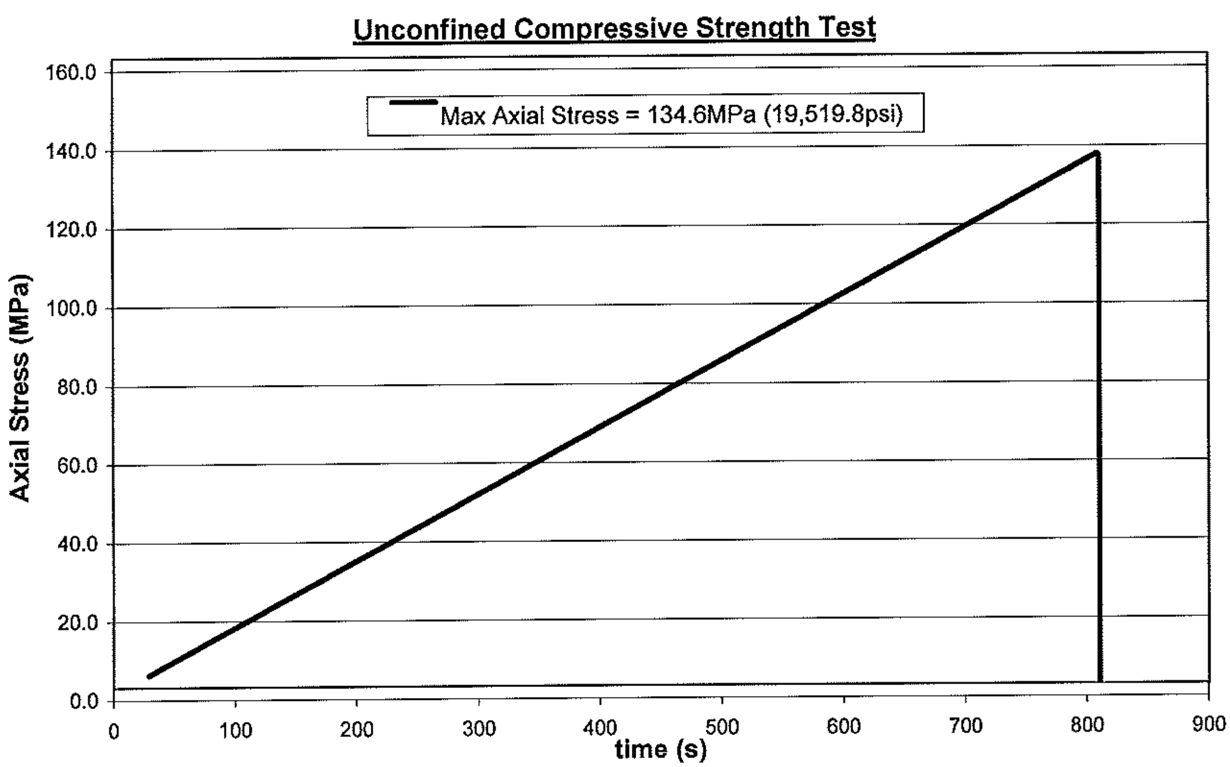
Diameter, (ϕ)	**Area, (A)**	**Height, (h)**	**Ratio**	**Peak Load**	**σ_{UCS}**	
(mm)	**(mm²)**	**(mm)**	**h/ϕ**	**(kN)**	**(MPa)**	**(psi)**
46.32	1685.1	104.11	2.2	91.7	54.4	7,894.3



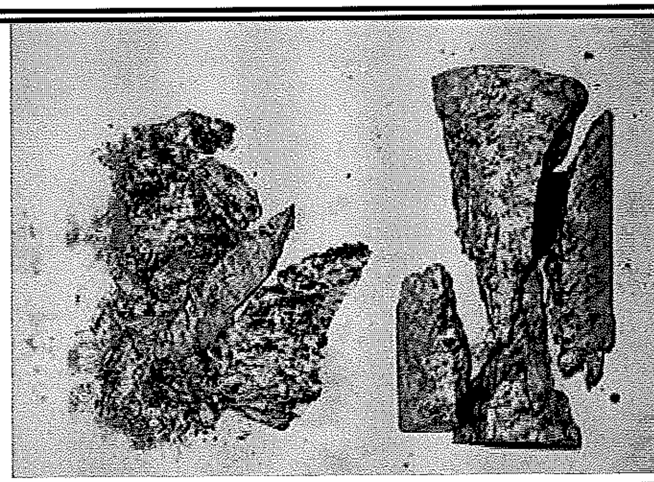
Borehole:	SCL-1 Intake
Sample No:	2A
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear



Diameter, (ϕ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm^2)	(mm)	h/ϕ	(kN)	(MPa)	(psi)
46.23	1678.6	104.36	2.3	226.0	134.6	19,519.8

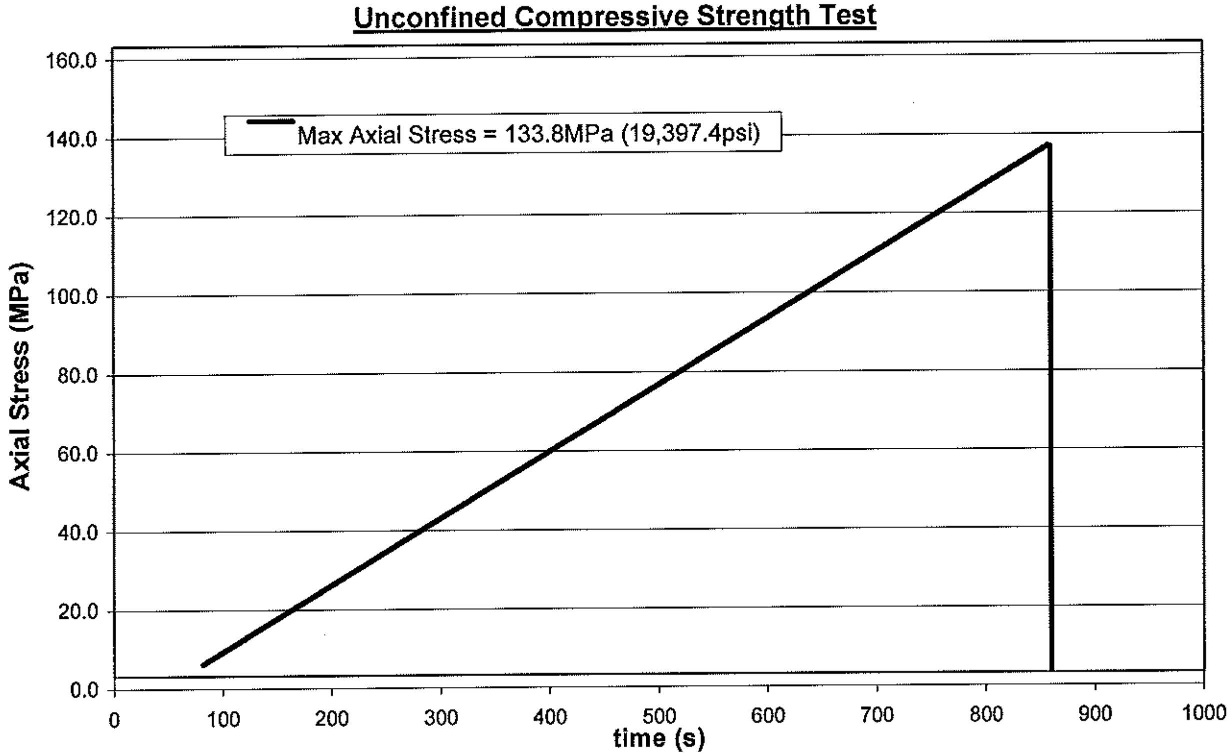


Borehole:	SCL-1 Intake
Sample No:	2B
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear/Explosive

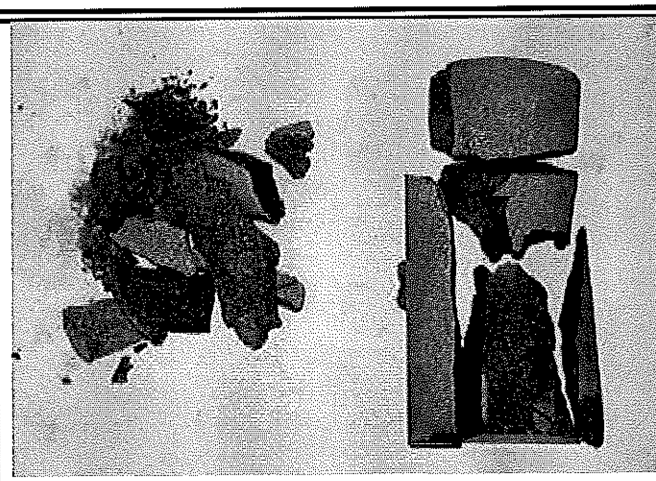


Diameter, (ϕ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm^2)	(mm)	h/ϕ	(kN)	(MPa)	(psi)
46.27	1681.5	102.70	2.2	224.9	133.8	19,397.4

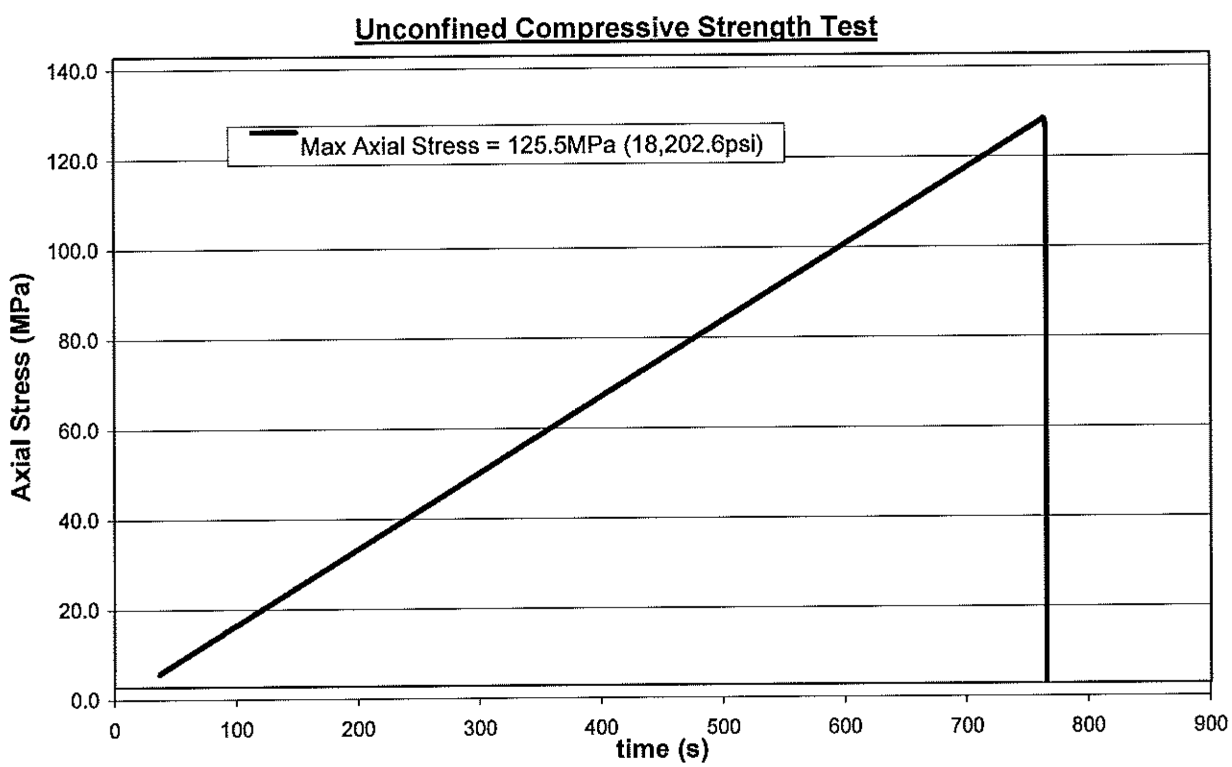
Unconfined Compressive Strength Test



Borehole:	SCL-2
Sample No:	3A
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear/Explosive

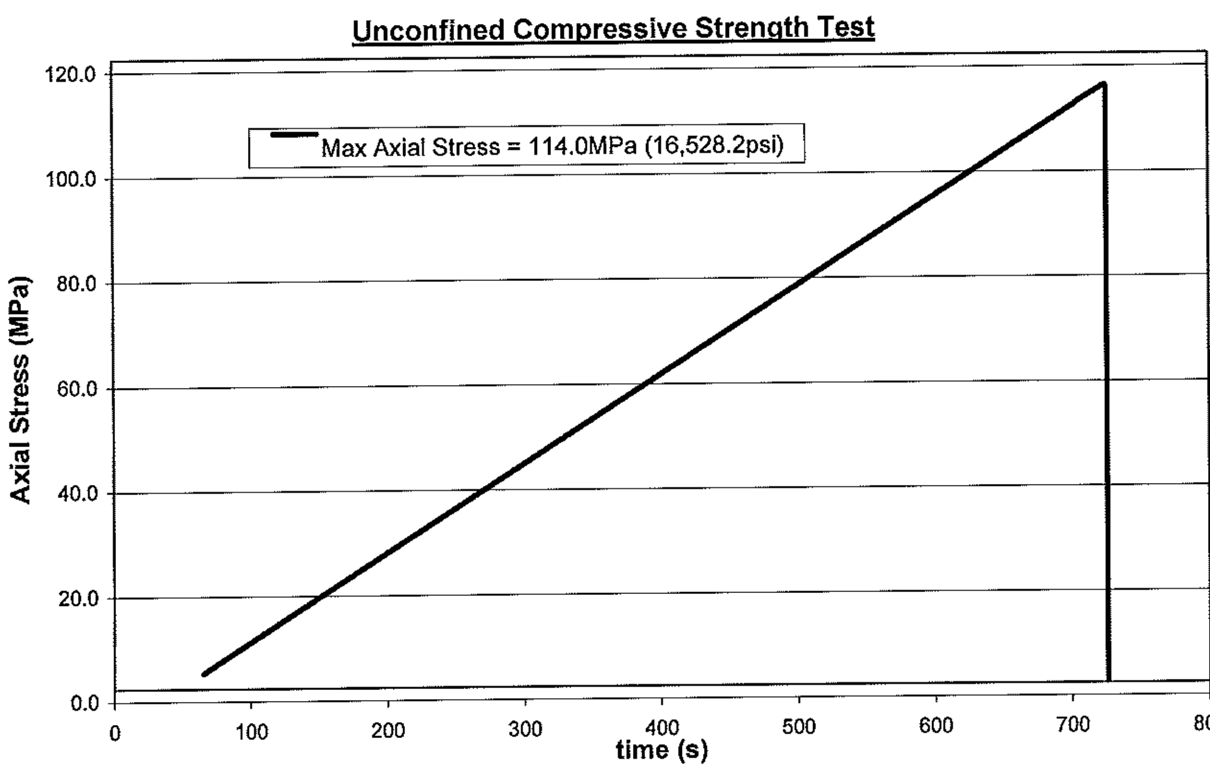


Diameter, (ϕ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm^2)	(mm)	h/ϕ	(kN)	(MPa)	(psi)
46.24	1679.3	104.37	2.3	210.8	125.5	18,202.6

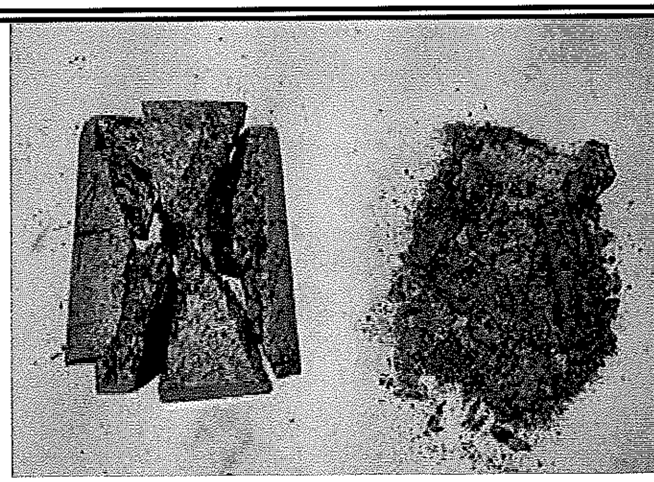


Borehole:	SCL-2	
Sample No:	3B	
Depth:	Boulder Sample	
Tested by:	C. Caceres P.Hughes	
Test Date:	24-Oct-06	
Geology:	Granite	
Failure Mode:	Shear/Explosive	

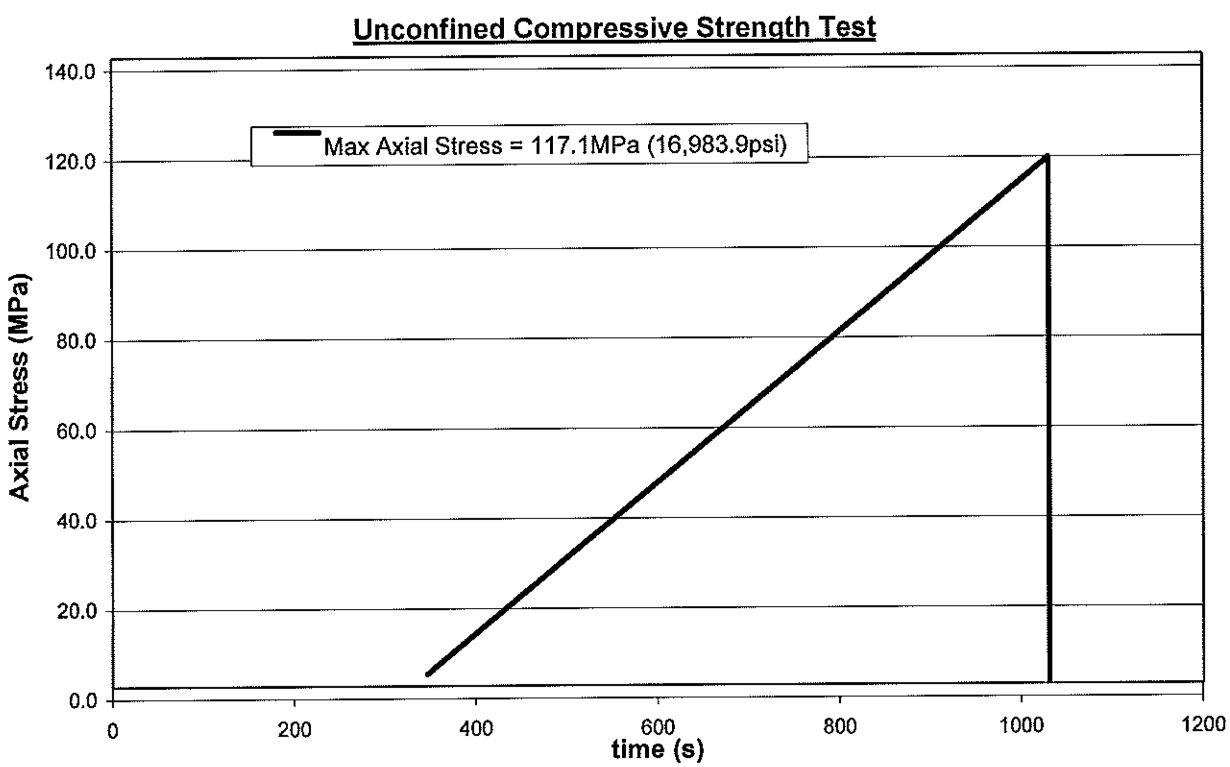
Diameter, (ϕ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm^2)	(mm)	h/ϕ	(kN)	(MPa)	(psi)
46.27	1681.5	105.72	2.3	191.7	114.0	16,528.2



Borehole:	SCL-3
Sample No:	4A
Depth:	Boulder Sample
Tested by:	C. Caceres P.Hughes
Test Date:	24-Oct-06
Geology:	Granite
Failure Mode:	Shear/Explosive



Diameter, (φ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm²)	(mm)	h/φ	(kN)	(MPa)	(psi)
46.44	1693.8	85.36	1.8	198.4	117.1	16,983.9



Borehole: SCL-3

Sample No: 4B

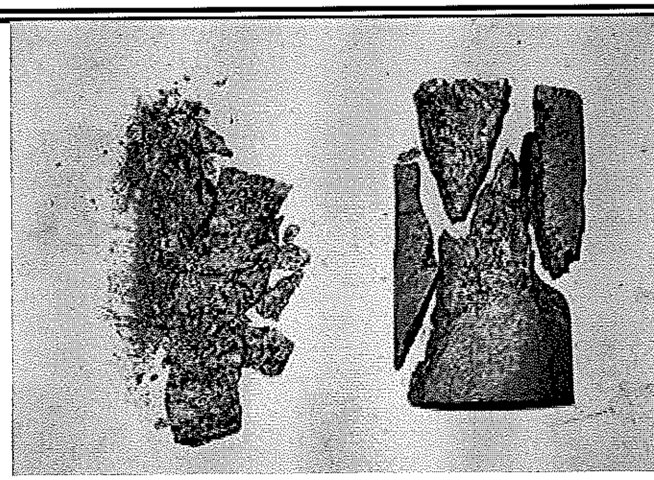
Depth: Boulder Sample

Tested by: C. Caceres P.Hughes

Test Date: 24-Oct-06

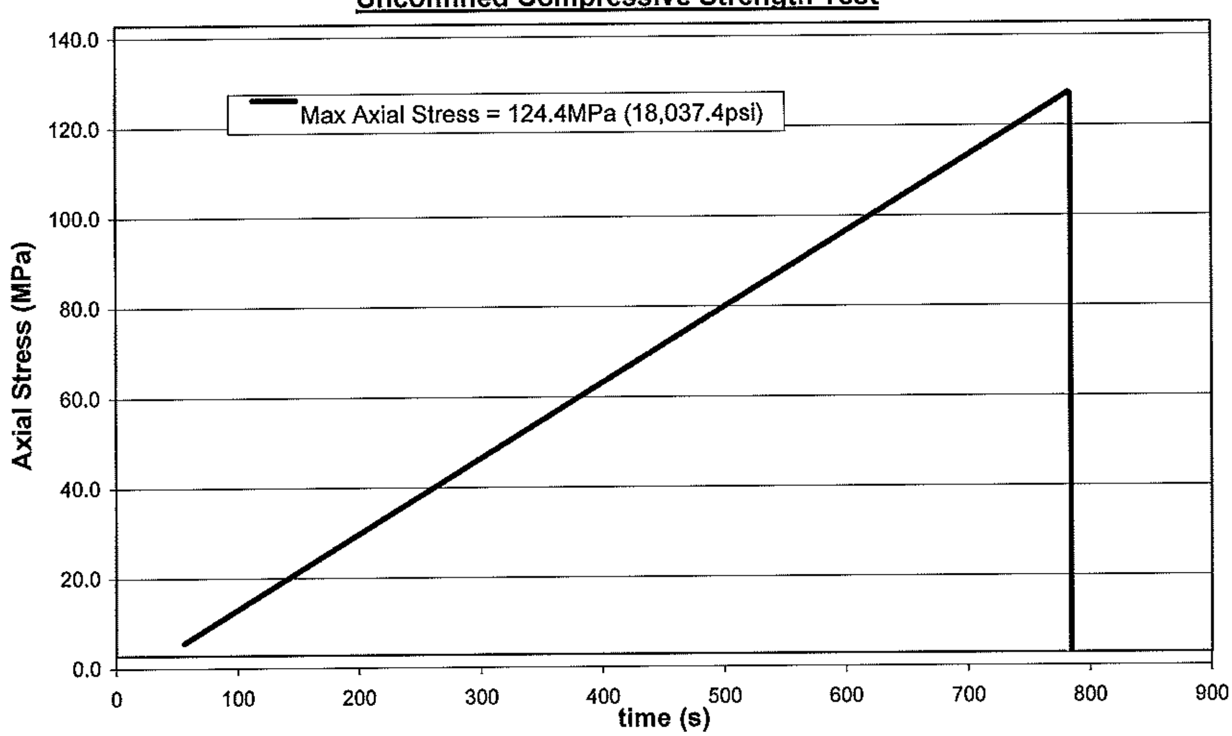
Geology: Granite

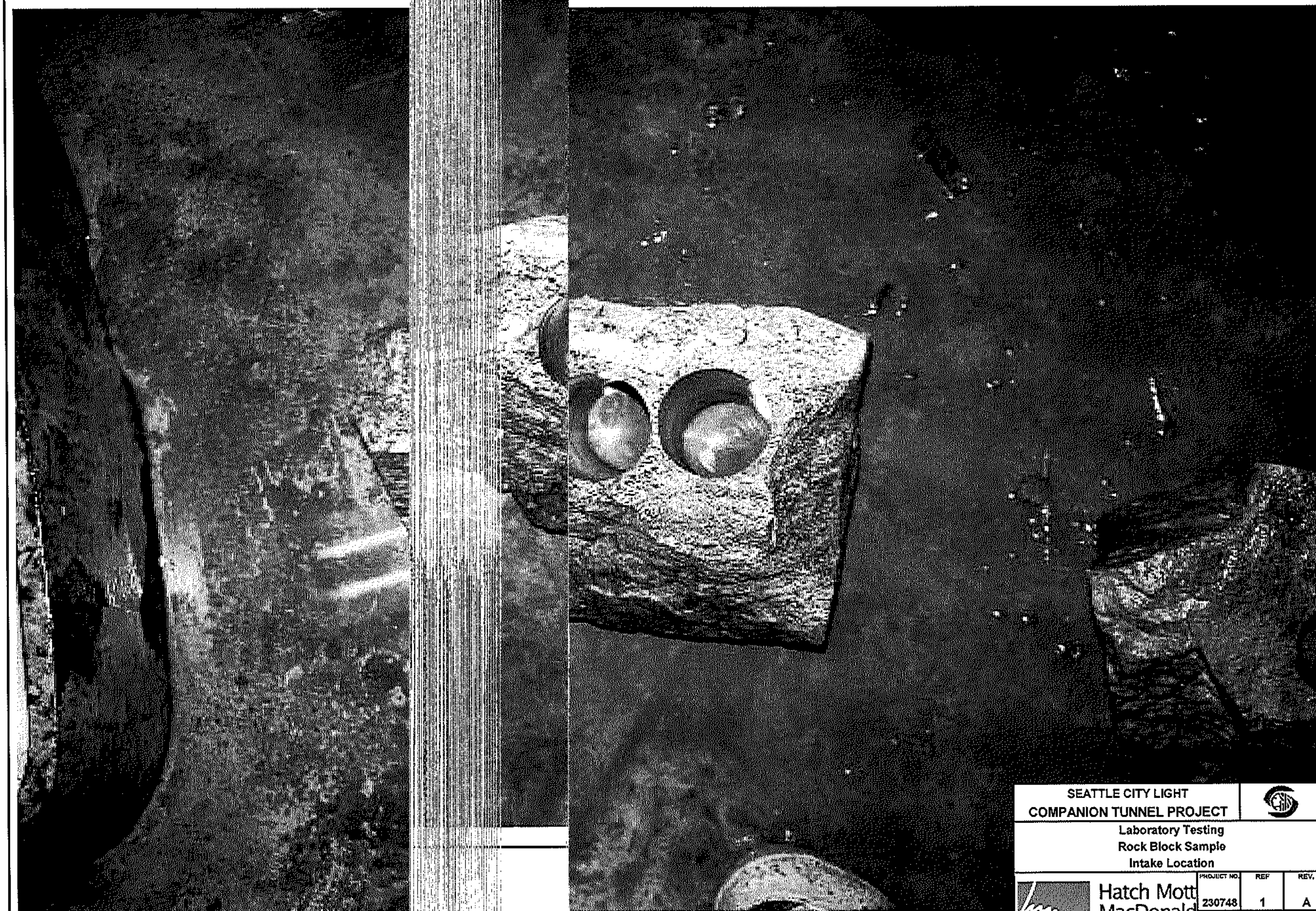
Failure Mode: Shear/Explosive



Diameter, (φ)	Area, (A)	Height, (h)	Ratio	Peak Load	σ_{UCS}	
(mm)	(mm^2)	(mm)	h/φ	(kN)	(MPa)	(psi)
46.42	1692.4	86.02	1.9	210.5	124.4	18,037.4

Unconfined Compressive Strength Test





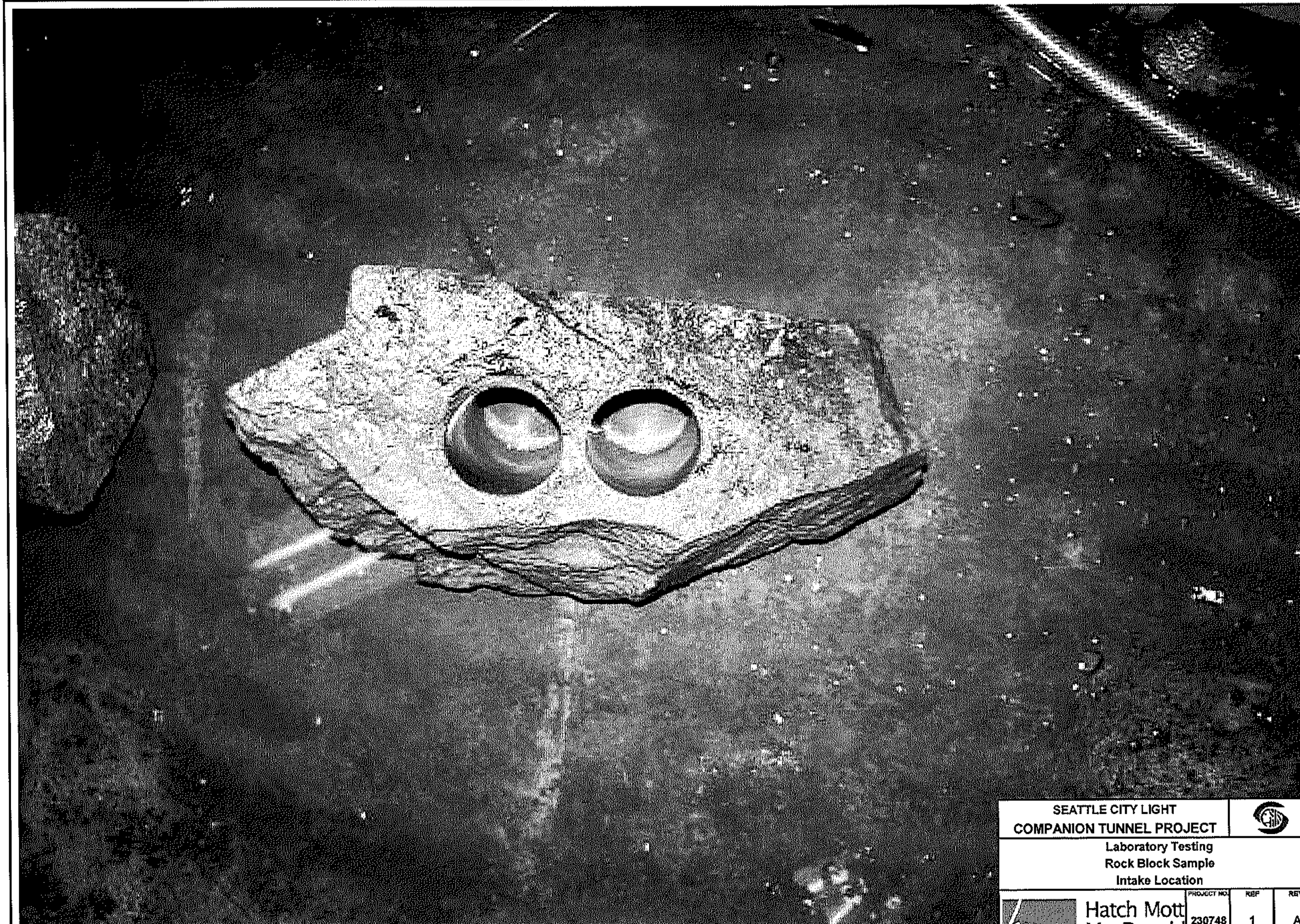
SEATTLE CITY LIGHT
COMPANION TUNNEL PROJECT

Laboratory Testing
Rock Block Sample
Intake Location

Hatch Mott MacDonald

PROJECT NO.	REF	REV.
230748	1	A

Figure A1



SEATTLE CITY LIGHT COMPANION TUNNEL PROJECT		
Laboratory Testing Rock Block Sample Intake Location		
PROJECT NO.	REF	REV.
230748	1	A

Hatch Mott MacDonald

Figure A2

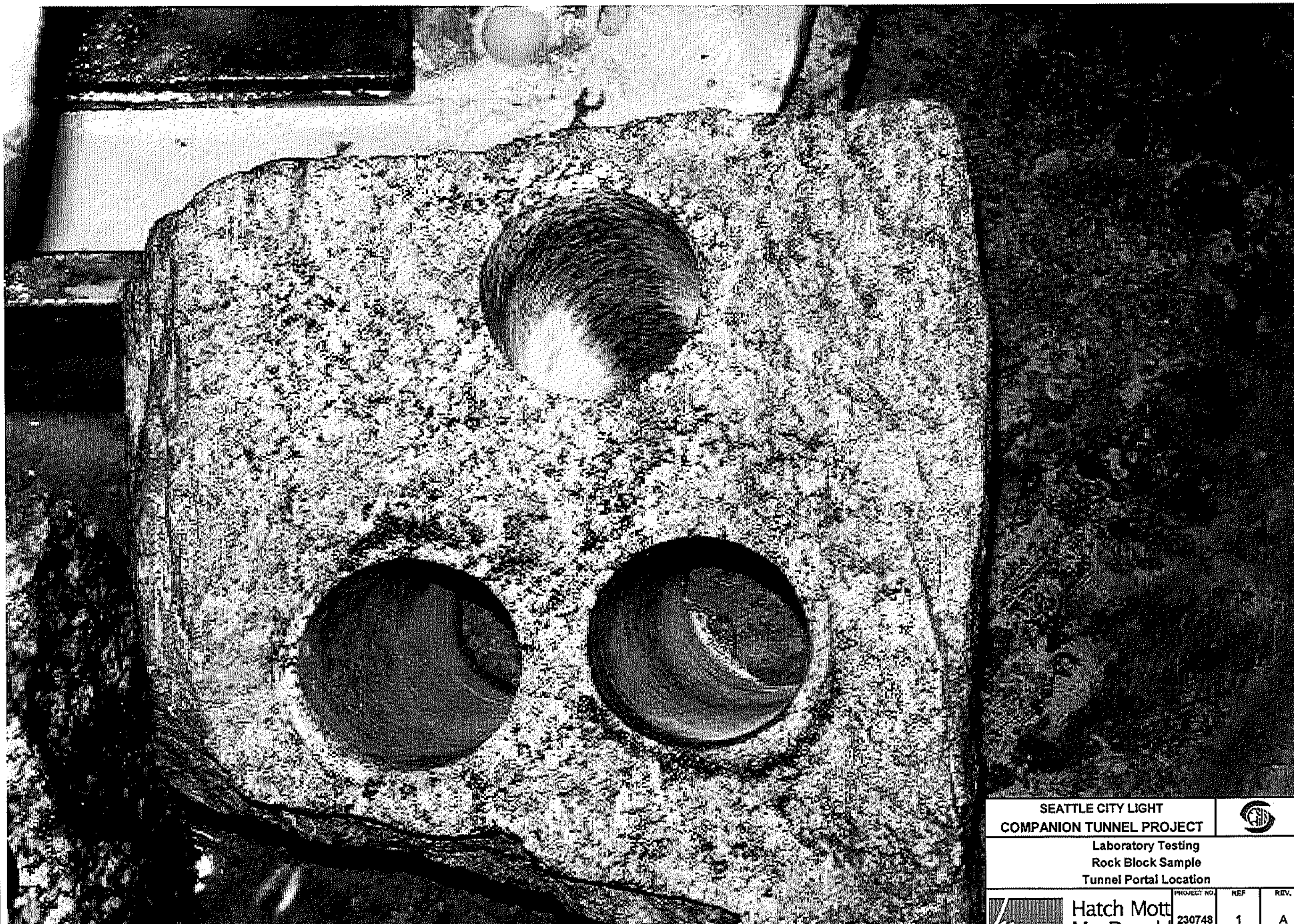
SEATTLE CITY LIGHT
COMPANION TUNNEL PROJECT

Laboratory Testing
Rock Block Sample
Intake Location

Hatch Mott MacDonald

PROJECT NO.	REF	REV.
230748	1	A

Figure A3



SEATTLE CITY LIGHT COMPANION TUNNEL PROJECT			
Laboratory Testing Rock Block Sample Tunnel Portal Location			
Hatch Mott MacDonald	PROJECT NO. 230748	REF 1	REV. A
	Figure A4		

VANCOUVER PETROGRAPHICS

PETROGRAPHIC REPORT ON 7 SAMPLES FROM SEATTLE CITY LIGHT GORGE PROJECT

Report for: Dean Brox, P. Eng. Invoice 060848
Hatch Mott MacDonald
1066 W. Hastings Street, 10th Floor
Vancouver, B.C. V6E 3X2 (604) 629-1736 Nov. 3, 2006.

SUMMARY:

Samples reported to be from near Seattle City Light's Gorge powerhouse, Skagit River valley near Newhalem, Washington (south of Manning Park/Ross Lake), in an area mapped by the USGS as orthogneiss, locally including mafic orthogneiss and migmatite. Main focus of the petrographic investigation is hard mineral content and alteration of the samples submitted, to prepare for possible TBM excavation of a second power generating tunnel.

The samples submitted are generally weakly to moderately foliated, and may be divided into 1) biotite-hornblende quartz diorite orthogneiss, 2) mafic orthogneiss (generally finer-grained, more melanocratic, biotite (±garnet, hornblende) quartz diorite, and 3) leucocratic, pegmatitic garnet-biotite granodiorite orthogneiss. Almost all samples contain accessory opaques (possibly mainly ilmenite, minor magnetite, rutile, rare sulfides now oxidized to limonite), sphene, and apatite, plus local rutile, allanite (?), monazite (?), and zircon (?).

Hard minerals noted in this suite include significant quartz (10-25%, commonly 20%) in all samples studied, and local garnet (2-3%, locally 8-10%) in two samples. Trace to minor alteration (<5%) is mainly to very fine-grained clay-sericite, rare carbonate (after feldspars), and chlorite (after biotite). Kspar is generally minor, and may be partly secondary, except in the pegmatitic granodiorite (SCL-6). Most quartz, and to a lesser degree plagioclase, is weakly to moderately (rarely strongly) strained. Microfracturing or less commonly micro-shearing, especially in plagioclase and to a lesser degree quartz, is locally significant and affects five of the seven samples submitted. Minor limonite, or locally Fe-carbonate or Kspar, is locally found along these microfractures.

Capsule descriptions are as follows:

SCL-1 Portal: weakly foliated biotite-hornblende quartz diorite ("tonalite") orthogneiss, accessory sphene, opaques (possibly ilmenite?), and apatite. It is moderately strained and microfractured, but essentially unaltered (only traces of clay-sericite and chlorite, plus trace limonite, likely due to surface weathering).

SCL-1 Intake: weakly foliated biotite quartz diorite orthogneiss is in contact with finer-grained, somewhat more mafic biotite quartz diorite orthogneiss; slight alteration to clay-sericite, carbonate and chlorite, and accessory minerals including apatite and rutile (?) are similar in both, although allanite (?) and zircon also occur in the coarser-grained orthogneiss phase.

SCL-1 Surge: moderately foliated biotite-hornblende quartz diorite orthogneiss (accessory sphene, apatite) cut by narrow fractures of quartz-Kspar with envelopes of Kspar-sericite-chlorite, and later microfractures that are mainly open or locally filled with limonite transported from nearby sites of oxidizing minor sulfides.

SCL-2: moderately foliated, relatively melanocratic (mafic) biotite-hornblende quartz diorite orthogneiss containing intermediate plagioclase and accessory opaques, sphene, apatite and rare allanite (?). It is only slightly altered to clay-sericite, but appears to be cut by abundant micro-shears subparallel to the foliation.

SCL-3: moderately foliated hornblende-biotite quartz diorite (tonalite) orthogneiss (accessory apatite, sphene, and opaques; possible allanite, monazite, zircon?), with minor alteration to clay-sericite, Fe-carbonate, possible Kspar, and chlorite associated with minute fractures or micro-fractures, affecting perhaps 10% of the rock.

SCL-5: weakly to moderately foliated, garnet-biotite quartz diorite orthogneiss with accessory opaques (ilmenite, magnetite?) and apatite, possible trace monazite (?), and slight alteration to clay-sericite and K-feldspar.

SCL-6: leucocratic, garnet-biotite granodiorite orthogneiss with a pegmatitic aspect (accessory muscovite and opaques, plus traces sphene/monazite/zircon?) and minor alteration to clay-sericite, chlorite and trace carbonate.

Detailed petrographic descriptions and photomicrographs are appended (on CD). If you have any questions regarding the petrography, please do not hesitate to contact me.

Craig H.B. Leitch, Ph.D., P. Eng. (250) 653-9158 craig.leitch@gmail.com
492 Isabella Point Road, Salt Spring Island, B.C. Canada V8K 1V4

SCL-1 Portal: WEAKLY FOLIATED BIOTITE-HORNBLENDE QUARTZ DIORITE (TONALITE) ORTHOGNEISS, ACCESSORY SPHENE-OPAQUE-APATITE; TRACE SERICITE, CHLORITE

Hand specimen is white to greyish, medium-grained, weakly foliated felsic to intermediate plutonic rock (orthogneiss) with local irregular poorly defined biotite-rich foliae and local irregular fractures partly coated with minor limonite. The rock is not magnetic, shows no reaction to cold dilute HCl, and only trace stain for K-feldspar in the etched offcut (part of the yellow stain is due to potassium in biotite). Modal mineralogy in thin section is approximately:

Plagioclase (oligoclase?)	60%
Quartz (mainly primary)	20%
Amphibole (hornblende?)	8%
Biotite	7%
K-feldspar (mainly primary)	2-3%
Sphene	<1%
Apatite	<1% 0.5 mm
Opaques (ilmenite?)	<1%
(limonite)	<1%
Clay/sericite	<1%
Chlorite (after biotite)	<1%

This sample consists mainly of plagioclase with interstitial quartz-minor K-feldspar and mafic minerals (amphibole, biotite) associated with accessory sphene, apatite and opaques. Foliation indicated by alignment of biotite flakes is very weakly developed.

Plagioclase forms somewhat irregular subhedral to anhedral crystals up to about 4.5 mm in maximum dimension, commonly with moderate microfracturing (mostly <10 microns thick, possibly filled with epoxy?). Although there is local undulose extinction, zoning appears to be absent, and twinning is not particularly well developed, indicating that the observed composition near An27 (calcic oligoclase), based on extinction Y^010 = 10 degrees, X^001 = 2 degrees, and relief almost indistinguishable from quartz, is likely a metamorphic re-equilibration. In general, the plagioclase shows only traces of clay-sericite alteration (minute flakes mostly <10 microns in diameter, along microfractures). Minor K-feldspar forms sub- to anhedral crystals mostly <0.1 mm in diameter, mainly interstitial to plagioclase and quartz, or locally apparently partly replacing plagioclase.

Quartz generally occurs as irregular, anhedral to locally subhedral crystals mostly <1.5 mm in diameter, but commonly in shapeless to ellipsoid aggregates up to about 3 m long, somewhat elongated in the plane of weak foliation. The crystals are commonly moderately to locally strongly strained, as indicated by undulose extinction, minor sub-grain development, and rare suturing of grain boundaries, and are weakly to moderately microfractured (mainly <10 microns thick, also partly filled with epoxy?).

Amphibole forms somewhat ragged subhedral crystals up to about 2 mm in maximum dimension, with extinction angle around 19 degrees and medium olive-green pleochroism (likely hornblende). Biotite forms somewhat ragged, subhedral flakes rarely over about 1.5 mm in diameter (locally glomeratic) with medium to dark red-brown pleochroism, locally partly altered to chlorite as subhedral flakes to 0.25 mm with pale green pleochroism and weak anomalous blue, length-slow birefringence indicating moderate Fe:Fe+Mg (F:M) ratio possibly near 0.6 (?). Accessory sphene, forming rounded subhedral to irregular aggregates up to 0.6 mm across (commonly cored by aggregates of rounded subhedral opaques, likely ilmenite, to 0.4 mm), and apatite, forming euhedral prisms up to 0.5 mm long, are closely associated with the mafic mineral aggregates. Traces of amorphous limonite are locally found along microfractures.

In summary, this is a weakly foliated biotite-hornblende quartz diorite ("tonalite") orthogneiss, with accessory sphene, opaques (possibly ilmenite?), and apatite. It is moderately strained and microfractured, but essentially unaltered (only traces of clay-sericite and chlorite, plus trace limonite, likely due to surface weathering).

SCL-1 Intake: CONTACT: WEAKLY FOLIATED BIOTITE QUARTZ DIORITE ORTHOGNEISS AND BIOTITIC ORTHOGNEISS (MINOR ALTERATION TO SERICITE-CHLORITE-CARBONATE, ACCESSORY APATITE, RUTILE, ALLANITE?, ZIRCON

Hand specimen is large block of mixed, medium-grained moderately foliated grey/black orthogneiss, and fine-grained, dark grey to black, mafic orthogneiss. The rock is not magnetic, and shows no reaction to cold dilute HCl, but there is modest yellow stain for fine-grained, interstitial K-feldspar in the etched offcut. Modal mineralogy in thin section is approximately:

Orthogneiss		Mafic orthogneiss	
Plagioclase (andesine?)	45%	Plagioclase (andesine?)	40%
Quartz (mainly primary?)	20%	Biotite	25%
Biotite	20%	Quartz (mainly primary?)	15%
K-feldspar (mainly primary?)	5%	K-feldspar (mainly primary?)	10%
Clay-sericite (after feldspars)	5%	Clay-sericite (after feldspars)	5-7%
Chlorite (after biotite)	1%	Chlorite (after biotite)	1%
Opaque (mainly rutile?)	1%	Opaque (partly rutile?)	1%
Apatite	1%	Apatite	1%
Allanite (?)	<1%	Carbonate	<1%
Carbonate	<1%		
Zircon	trace		

This section consists of roughly equal proportions of orthogneiss and mafic orthogneiss, separated by a relatively well-defined, biotitic contact zone generally <1 mm thick. Weakly developed foliation in the mafic orthogneiss is sub-parallel to this contact; very weakly developed foliation in the more felsic orthogneiss is oblique or sub-perpendicular to the contact.

The relatively coarser-grained orthogneiss consists mainly of rounded subhedral plagioclase crystals up to about 1.5 mm in diameter, with ragged scalloped margins, slight undulose extinction, and relatively rare twinning with extinction on 010 up to about 15 degrees and relief slightly positive compared to quartz indicating composition likely near An30 (sodic andesine). Weak alteration to minute flakes of clay-sericite (mostly <15 microns in size) is common, especially near interstitial Kspar (subhedra to 0.2 mm). Interstitial quartz is also generally finer-grained, forming ragged interlocking sub- to anhedra mostly <0.5 mm in diameter that are weakly to moderately strained (show undulose extinction, but only rare sub-grain development, minor suturing of grain boundaries). Biotite forms subhedral red-brown flakes with ragged terminations up to about 1 mm diameter (locally aggregating to almost 2 mm and showing minor partial alteration to chlorite similar to that described for SCL-1 Portal), generally associated with the accessory minerals (minute opaque needles <20 microns long that are likely mostly rutile?), and apatite as euhedral prisms mostly <0.15 mm long. Rare coarse-grained allanite? (REE-bearing epidote) forms euhedral crystals up to 0.7 mm in size, with pale red-brown pleochroism. Minor carbonate forming irregular subhedra mostly <0.25 mm in diameter is locally associated with microfracturing (and clay-sericite alteration of feldspars).

The relatively finer-grained, more mafic orthogneiss is composed of essentially the same minerals but is somewhat richer in biotite (subhedral flakes mostly <0.5 mm with dark greenish brown pleochroism, rarely chloritized as described above) and Kspar (subhedra to 0.25 mm), with somewhat lesser plagioclase (rounded subhedra mostly <1 mm in diameter) and quartz (aggregates with irregular outlines of tightly interlocking sub- to anhedra mostly <0.15 mm in diameter). Feldspars, particularly plagioclase, show slight to locally moderate alteration to clay-sericite as minute flakes up to 20 microns in diameter; minor carbonate occurs as subhedra to 0.2 mm along narrow fractures or in interstices. Accessory opaques (subhedra to 0.2 mm) and apatite (euhedra mostly <0.1 mm) are generally associated with the biotite.

In summary, weakly foliated biotite quartz diorite orthogneiss is in contact with finer-grained, somewhat more mafic biotite quartz diorite orthogneiss; slight alteration to clay-sericite, carbonate and chlorite, and accessory minerals including apatite and rutile (?) are similar in both, although allanite (?) and zircon also occur in the coarser-grained orthogneiss phase.

SCL-1 Surge: FOLIATED BIOTITE-HORNBLENDE QUARTZ DIORITE ORTHOGNEISS (ACCESSORY SPHENE, APATITE, TRACE SULFIDE OXIDIZED TO LIMONITE) CUT BY QUARTZ-KSPAR FRACTURES WITH KSPAR-SERICITE-CHLORITE ENVELOPES

Hand specimen is grey-white, moderately foliated orthogneiss marked by small rusty spots of limonite associated with mafic (mostly biotite) concentrations. The rock is not magnetic, and shows no reaction to cold dilute HCl, but there is minor yellow stain for K-feldspar in the etched offcut, particularly along a narrow fracture zone (therefore secondary). Modal mineralogy in thin section is approximately:

Plagioclase (oligoclase?)	60%
Quartz (mainly primary?)	15%
Amphibole (hornblende?)	8%
Biotite	7%
K-feldspar (partly secondary)	5%
Clay-sericite (after feldspars)	2-3%
Chlorite (after biotite)	1-2%
Apatite	<1%
Sphene	<1%
Limonite (partly after former sulfides?)	<1%

This sample consists mainly of granular plagioclase, with lesser interstitial quartz and minor, very fine-grained K-feldspar, scattered clotty aggregates of hornblende and biotite, and accessory apatite and sphene, cut by narrow quartz-filled fractures with Kspar-sericite envelopes, and later (mainly open or epoxy-filled) microfractures.

Plagioclase forms sub- to locally euhedral crystals up to about 2 mm in diameter, with local faint compositional zoning generally suggestive of metamorphic re-equilibration, locally in the outer 20% of the crystal, but all close to a composition of calcic oligoclase (An27) based on extinction Y^010 =8 degrees, Z^001 = 10 degrees and relief virtually indistinguishable from quartz. Locally the plagioclase contains minor K-feldspar inclusions (mostly <0.2 mm in size) in a sort of antiperthite or possibly replacement texture.

Quartz forms generally small, ragged, anhedral crystals rarely over about 0.5 mm in diameter but locally in irregular shaped aggregates up to 1.5 mm across. The crystals generally show evidence of moderate strain (undulose extinction, minor sub-grain development, and rare suturing of grain boundaries).

Amphibole forms ragged subhedra up to about 2 mm in maximum dimension, with optical properties as described for SCL-1 Portal (likely hornblende). Biotite is subordinate to hornblende, forming raggedly terminated, dark brown subhedral flakes mostly <1 mm in diameter, commonly intergrown with the hornblende and with accessory minerals such as sphene (subhedra to 1.1 mm long) and apatite (euhedral prisms up to 0.5 mm long). The only opaques present appear to be limonite as aggregates to 0.4 mm long (likely after former sulfides such as pyrite), surrounded by amorphous, probably transported limonite found as stains or filling microfractures in shattered areas. These areas cause the rusty spots seen in hand specimen, probably the result of oxidation of minor sulfides.

Minor alteration of feldspars to clay-sericite (minute flakes mostly <20 microns in diameter) or locally coarser-grained sericite (subhedral flakes to 70 microns) is in part related to fractures filled with ribbons of quartz and/or K-feldspar, surrounded by envelopes of (secondary) Kspar forming subhedral crystals up to 0.7 mm in diameter, apparently replacing plagioclase, and associated with pseudomorphous chlorite replacement of biotite as subhedral flakes up to 0.35 mm in diameter with optical properties similar to those described for the previous samples, possibly indicating F:M 0.6 (?).

In summary, this is a moderately foliated biotite-hornblende quartz diorite orthogneiss with accessory sphene and apatite, cut by narrow fractures of quartz-Kspar with envelopes of Kspar-sericite-chlorite, and later microfractures that are mainly open or locally filled with limonite transported from nearby sites of oxidizing minor sulfides.

SCL-2: FOLIATED, FINE-GRAINED MELANOCRATIC BIOTITE-HORNBLENDE ORTHO-GNEISS (ACCESSORY SPHENE-OPAQUES-APATITE-ALLANITE), MINOR CLAY-SERICITE

From intake; hand specimen shows a dark grey, fine-grained, weakly foliated, more mafic rock (mafic orthogneiss?) compared to the bulk of the SCL-1 samples. The rock is not magnetic, shows no reaction to cold dilute HCl, and no stain for K-feldspar in the etched offcut. Modal mineralogy in thin section is approximately:

Plagioclase (andesine?)	50%
Amphibole	20%
Biotite	15%
Quartz	10%
Clay-sericite (after feldspar)	2-3%
Sphene	1%
Opaque	1%
Apatite	<1%
Allanite (?)	<1%

This sample consists of granular plagioclase with interstitial quartz, mafic minerals (amphibole, biotite) and accessory sphene, opaques, apatite and scattered large crystals of allanite (?). Weak foliation is developed due to alignment of crystals of plagioclase, amphibole and biotite.

Plagioclase forms mostly subhedral, rounded to locally euhedral crystals up to about 1.5 mm long, commonly with sub-parallel alignment. Compositional zoning is relatively well developed compared to other samples of orthogneiss (possibly better preserved from initial magmatic zoning?) with a range from cores of calcic andesine (An45) to rims of sodic andesine (An33) based on extinction Y^010 of 25 and 15 degrees respectively. Many crystals show partial (<5-60%) replacement by fine-grained clay-sericite as minute flakes mostly <15 microns in diameter, particularly in smaller, interstitial crystals, or at fringes or margins of larger crystals.

Amphibole and biotite are commonly closely intermixed. Amphibole forms ragged, irregular subhedra up to 1.5 mm long that commonly appear offset along narrow micro-shears that mostly wrap around plagioclase crystals. Extinction angle about 15 degrees and pale to medium olive-green pleochroism suggest the amphibole is most likely hornblende. Biotite forms subhedral to ragged, medium greenish brown flakes mostly <1 mm in diameter that mainly (but not always) are sub-parallel and serve to define the foliation. Smaller biotite flakes, mostly <0.1 mm in diameter, also tend to be smeared out into and along the micro-shears. Locally, near these shears, amphibole is partly altered at terminations to a paler green, likely actinolitic, amphibole.

Quartz forms aggregates mostly <1 mm across (locally elongated and aligned sub-parallel or oblique to the foliation) composed of interlocking anhedra mostly <0.25 mm in diameter. The crystals are generally moderately to strongly strained, as evidenced by strong undulose extinction, sub-grain development, and suturing of grain boundaries.

Accessory opaques around the borders of biotite are mostly very fine-grained (irregular subhedra <0.1 mm long, commonly in aggregates to 0.3 mm long aligned with the foliation). Sphene forms subhedral, also somewhat elongated, crystals or aggregates up to 0.35 mm long, aligned sub-parallel to the foliation. Apatite forms slender prismatic or needle-like crystals mostly <0.15 mm long that are not always aligned parallel to foliation. Rare or scattered allanite (?) forms large euhedral crystals up to almost 1 mm long with strong red-brown to pale brown pleochroism.

In summary, this is a moderately foliated, relatively melanocratic (mafic) biotite-hornblende quartz diorite orthogneiss containing intermediate plagioclase and accessory opaques, sphene, apatite and rare allanite (?). It is only slightly altered to clay-sericite, but appears to be cut by abundant micro-shears subparallel to the foliation.

SCL-3: FOLIATED HORNBLENDE-BIOTITE QUARTZ DIORITE ORTHOGNEISS (ACCESSORY APATITE, SPHENE), MINOR CLAY-SERICITE/CARBONATE/CHLORITE ALTERED

From intake; hand sample shows a moderately foliated, medium-grained, black and white orthogneiss of felsic/intermediate composition similar to the SCL-1 samples. The rock is not magnetic, shows no reaction to cold dilute HCl, and only very minor yellow stain for K-feldspar in the etched offcut (apparently mainly along numerous microfractures, barely visible with a hand lens). Modal mineralogy in thin section is approximately:

Plagioclase (oligoclase?)	50%
Quartz (mainly primary)	20%
Biotite	20%
Amphibole (hornblende?)	5%
Clay-sericite (after feldspars)	2-3%
Carbonate (ankerite/siderite?)	1%
K-feldspar (partly secondary?)	1%
Chlorite (after biotite)	<1%
Apatite	<1%
Sphene (could include trace allanite, monazite, zircon?)	<1%
Opaque (ilmenite, rutile??)	<1%

This sample consists mainly of granular, interlocking crystals of plagioclase and lesser interstitial quartz, with clots or locally irregular foliae of biotite (minor amphibole) and accessory apatite, sphene and opaques. Minor clay-sericite-carbonate-chlorite alteration is associated with fractures and microfractures.

Plagioclase forms somewhat rounded to irregular subhedral crystals up to 3.5 mm in diameter that are mainly unzoned or locally show gradual, somewhat undulose zoning from core to rim (likely metamorphic). Composition appears to be about oligoclase (An27) based on extinction Y^010 about 10 degrees, and relief virtually indistinguishable from quartz. Most crystals show trace to minor alteration to very fine-grained clay-sericite (flakes mostly from <5 to 35 microns, rarely to 0.1 mm in diameter), particularly at margins and grain boundaries, or to carbonate (subhedra mostly <20 microns in diameter), particularly along or near micro-veinlets (mainly <30 microns thick) also filled with carbonate. Carbonate is either clear or more commonly Fe-stained, and may be partly ankerite or even siderite (?). In places, patches of the Fe-carbonate up to 0.6 mm across are surrounded by clay-sericite alteration, suggesting they are contemporaneous, and related to fracturing. Traces of Kspar, mostly as subhedra <25 microns in diameter, are also locally associated with the fracturing and clay-sericite alteration; they may in part replace plagioclase. Locally, minor chlorite replacement of adjacent biotite also appears to be associated with this alteration.

Quartz occurs in irregular to ellipsoid aggregates up to about 3 mm across, composed of tightly interlocking sub- to anhedral crystals up to about 2 mm in diameter. Moderate strain is indicated by modest undulose extinction, sub-grain development, and suturing of grain boundaries.

Biotite forms sub- to euhedral flakes rarely over 1.5 mm in diameter, with somewhat ragged terminations and dark brown pleochroism; aggregates to 3 mm are common, locally strung together to form vaguely defined foliae with crude sub-parallel orientation. Amphibole is subordinate, forming highly ragged, irregular crystals mainly <1.5 mm with extinction angle around 17 degrees and medium to dark olive-green pleochroism (likely hornblende). Accessory apatite forms sub-to euhedral prisms up to 0.3 mm long, and sphene forms sub- to euhedral crystals mostly <0.25 mm long (rare square-looking crystals <0.15 mm in size could be monazite; prismatic crystals to 0.1 mm could be zircon; red-brown euhedra to 0.2 mm could be allanite?). Opaques closely associated with biotite are rod- to plate-like, <30 microns in size; they might be ilmenite or rutile (?).

In summary, this is a moderately foliated hornblende-biotite quartz diorite (tonalite) orthogneiss (accessory apatite, sphene, and opaques; possible allanite, monazite, zircon?), with minor alteration to clay-sericite, Fe-carbonate, possible Kspar, and chlorite associated with minute fractures or micro-fractures, affecting perhaps 10% of the rock.

SCL-5: WEAKLY FOLIATED GARNET-BIOTITE QUARTZ DIORITE ORTHOGNEISS (ACCESSORY OPAQUES, APATITE; SLIGHT CLAY-SERICITE, KSPAR ALTERATION)

Not located; hand specimen is small, showing a relatively fine-grained, moderately foliated, purplish-brown, mafic orthogneiss with common disseminated pink (manganiferous?) garnets and minor rusty limonite stain on the outer weathered surfaces/fractures. The rock is not magnetic, shows no reaction to cold dilute HCl, and no significant stain for K-feldspar in the etched offcut. Modal mineralogy in thin section is approximately:

Plagioclase (andesine?)	45%
Quartz	25%
Biotite	20%
Garnet	8-10%
Opaques (magnetite/ilmenite?)	1-2%
Apatite	<1%
Clay-sericite (after feldspars)	<1%
K-feldspar (partly secondary?)	<1%
Chlorite (after biotite?)	<1%
Monazite (?)	trace

This sample consists largely of granular plagioclase separated by interstitial quartz, biotite and accessory opaques and apatite, hosting scattered disseminated euhedral garnet crystals. Trace alteration to clay-sericite and K-feldspar affects plagioclase, and rare chlorite affects biotite.

Plagioclase forms granular aggregates of subhedral, rounded to irregular crystals up to almost 2 mm in diameter, generally unzoned but with distinct twinning (extinction on 010 up to 16 degrees, and relief close to or slightly positive compared to quartz, suggests a composition near sodic andesine, An33). Most crystals are virtually unaltered, but in places the smaller, interstitial crystals associated with quartz and traces of K-feldspar show very minor alteration to minute flakes (mostly <15 microns in size) of clay-sericite. K-feldspar forms irregular, almost vein-like anhedra mostly <60 microns long by <20 microns thick.

Quartz occurs as aggregates with irregular to ellipsoidal outlines up to 2 mm across, composed of sub- to anhedral interlocking crystals mostly <0.5 mm in diameter. The crystals display indications of moderate strain (undulose extinction, minor sub-grain development, and rare suturing of grain boundaries).

Biotite forms mainly euhedral, medium red-brown flakes <1 mm in diameter, but commonly in loose, poorly defined aggregates up to about 3 mm across, interstitial to plagioclase and associated with quartz and scattered garnets plus accessory opaques and apatite. Rarely, biotite appears to be pseudomorphed by traces of chlorite as subhedral flakes to 0.1 mm with optical properties (virtually colourless, first-order greyish white, length-fast birefringence) that indicate a relatively magnesian composition (F:M perhaps 0.3-0.4).

Garnet forms mainly euhedral crystals up to about 1.5 mm in diameter, colourless or with very pale pink colour, but no detectable zoning or anomalous anisotropism; minor inclusions <75 microns in diameter are mostly quartz. The opaques mostly form somewhat tabular to irregular, subhedra <0.25 mm long that are likely ilmenite or ilmenite and magnetite (?); apatite forms sub- to euhedral prismatic crystals up to 0.25 mm long. Rare small sub- to euhedral crystals <35 microns in diameter of monazite (?) are also locally associated with biotite.

In summary, this appears to be a weakly to moderately foliated, garnet-biotite quartz diorite orthogneiss with accessory opaques (ilmenite, magnetite?) and apatite, possible trace monazite (?), and slight alteration to clay-sericite and K-feldspar.

SCL-6: LEUCOCRATIC, PEGMATITIC GARNET-BIOTITE GRANODIORITE ORTHOGNEISS (ACCESSORY MUSCOVITE OPAQUE-SPHENE/MONAZITE?), SERICITE/CHLORITE ALT'N

Hand specimen is a weakly foliated, white, medium-grained, pegmatitic-looking rock characterized by local flakes of muscovite and clotty patches, lenses or foliae of fine-grained purplish-brown biotite (locally green and chloritized). The rock is not magnetic, and shows no reaction to cold dilute HCl, but there is extensive yellow stain for K-feldspar in the etched offcut (which also reveals several pale pink, possibly manganiferous, garnets). Modal mineralogy in thin section is approximately:

Plagioclase (oligoclase?)	45%
K-feldspar (orthoclase?)	20%
Quartz	20%
Biotite (partly chloritized)	10%
Garnet	2-3%
Clay-sericite, muscovite (after feldspars)	1-2%
Opaque	<1%
Sphene (?)	<1%
Monazite (?), zircon (?)	<1%
Chlorite (after biotite)	<1%
Carbonate	<15

This sample consists essentially of a granular intergrowth of feldspars (plagioclase, Kspar) and quartz, with lesser, vaguely defined, irregular foliae of biotite, garnet and accessories (opaques, sphene?, monazite?, zircon?); there is slight alteration of feldspars to clay-sericite and of biotite to chlorite.

Plagioclase forms relatively coarse-grained, subhedral to rounded, irregular or lensoidal crystals up to 4.5 mm long, commonly but by no means all oriented sub-parallel to the foliation defined by clusters of biotite crystals. Weak, gradual zoning from core to rim, typical of metamorphic re-equilibration, varies little about a composition near An20-25 (oligoclase) based on extinction Y^010 about 0-5 degrees, and relief indistinguishable from quartz. In general, minor alteration to very fine (<35 micron) flakes of sericite, or even finer (<5 micron) clay (?) is concentrated along grain boundaries, twin planes and microfractures in plagioclase. Locally, coarser-grained flakes of muscovite up to 0.2 mm in diameter, associated with traces of carbonate as ragged subhedra <0.1 mm in size, appear to be related to irregular veinlets, <0.5 mm thick, of quartz and Kspar that cut plagioclase.

Quartz mainly occurs as irregular, sub- to anhedral crystals up to about 1 mm in diameter, confined to veinlet-like zones (commonly mixed with Kspar) between the larger plagioclase crystals. The quartz shows moderate to locally strong strain, indicated by undulose extinction, sub-grain development, and suturing of grain boundaries, or locally fracturing.

K-feldspar is mostly finer-grained and interstitial to plagioclase, forming subhedra mainly <1 mm in diameter (aggregating to 2.5 mm), or much finer-grained material (<30 microns) along grain boundaries around or microfractures in plagioclase and quartz. Lack of "grid" twinning and moderate (negative) 2V suggests Kspar is likely orthoclase. It is locally slightly perthitic (with string-like inclusions of plagioclase) or contains quartz inclusions in graphic (myrmekitic) texture.

Biotite forms mainly sub- to euhedral flakes up to about 1 mm in size, but in aggregates up to 4 mm long, in places associated with colourless to pale reddish, completely isotropic garnet as euhedra up to just over 1 mm diameter, and accessory opaques (subhedra to 0.3 mm, aggregating to 0.6 mm), sphene (subhedra to 0.3 mm) and possible monazite (?) and zircon (?) as euhedral crystals <0.1 mm in size marked by dark pleochroic haloes in surrounding biotite. Locally the biotite is replaced by chlorite as similar-sized flakes with optical properties (pale green, anomalous blue, length-slow birefringence) indicating F:M perhaps 0.5-0.6?).

In summary, this is a leucocratic, garnet-biotite granodiorite orthogneiss with a pegmatitic aspect (accessory muscovite and opaques, plus traces sphene/monazite/zircon?) and minor alteration to clay-sericite, chlorite and trace carbonate.

PHOTOMICROGRAPH CAPTIONS

SCL-1 Portal: Quartz diorite (tonalite) orthogneiss composed of plagioclase (pl), quartz (qz), hornblende (hb), biotite (bi, partly altered to chlorite, ch), trace interstitial K-feldspar (Kf), and accessory sphene (sp) cored by opaque (ilmenite?) and apatite (ap). Note microfractures in quartz and plagioclase. Transmitted plane light, field of view 3 mm wide.

SCL-1 Surge: Quartz diorite orthogneiss composed of quartz (qz), plagioclase (pl) partly altered to clay-sericite (cl-ser) or Kspar (Kf), near ribbon veinlets of quartz-Kspar, where biotite (bi) is concurrently altered to chlorite (ch). Later micro-fractures are mostly open or filled with epoxy. Transmitted plane light, field of view 3 mm wide.

SCL-1 Intake: Quartz diorite (tonalite) orthogneiss composed of plagioclase (pl, partly altered to clay-sericite near microfractures that also locally contain carbonate (ca), interstitial quartz (qz) and minor K-feldspar (Kf), brown biotite (bi) or chlorite (ch) associated with minute opaques and apatite (ap), local allanite? (al?). Transmitted plane light, field of view 3 mm wide.

SCL-1 Intake-M: More mafic, finer-grained orthogneiss composed of twinned plagioclase (pl) with interstitial quartz (qz), biotite (bi) and K-feldspar (difficult to distinguish) and accessory opaques, trace apatite; note minor clay-sericite and carbonate (ca) alteration along grain boundaries and microfractures. Transmitted light, crossed polars, field of view 3 mm.

SCL-2: Relatively fine-grained, foliated, melanocratic (mafic) orthogneiss composed of plagioclase (pl), hornblende (hb), biotite (bi), rare large allanite? (al?) crystals, and a micro-sheared, very fine-grained matrix of quartz (qz), biotite and opaques plus accessory sphene (sp), minute apatite (ap). Transmitted plane light, field of view 3 mm wide.

SCL-3: Moderately foliated quartz diorite orthogneiss composed of granular plagioclase (pl) and interstitial quartz (qz), or biotite (bi) rich layers (with accessory apatite, ap, opaques, op, and possible allanite?, al?, zircon?, zr?); note alteration to clay-sericite (cl-ser), Fe-carbonate (cb) at grain boundaries or associated with fractures partly filled with carbonate and trace Kspar (Kf). Transmitted plane light, field of view 3 mm wide.

SCL-5: Weakly foliated quartz diorite orthogneiss composed of plagioclase (pl, with slight alteration to clay-sericite and Kspar, Kf), quartz (qz), biotite (bi), and euhedral, locally fractured garnet (gt) plus accessory opaques and apatite (ap). Transmitted plane light, field of view 3 mm wide.

SCL-6: Leucocratic, pegmatitic granodiorite orthogneiss composed of coarse plagioclase (pl, slightly altered to minute flakes of clay-sericite) and fine-grained interstitial quartz (qz), Kspar (Kf), biotite (bi), garnet (gt), associated with accessory sphene (sp). Transmitted light, crossed polars, field of view 3 mm wide.