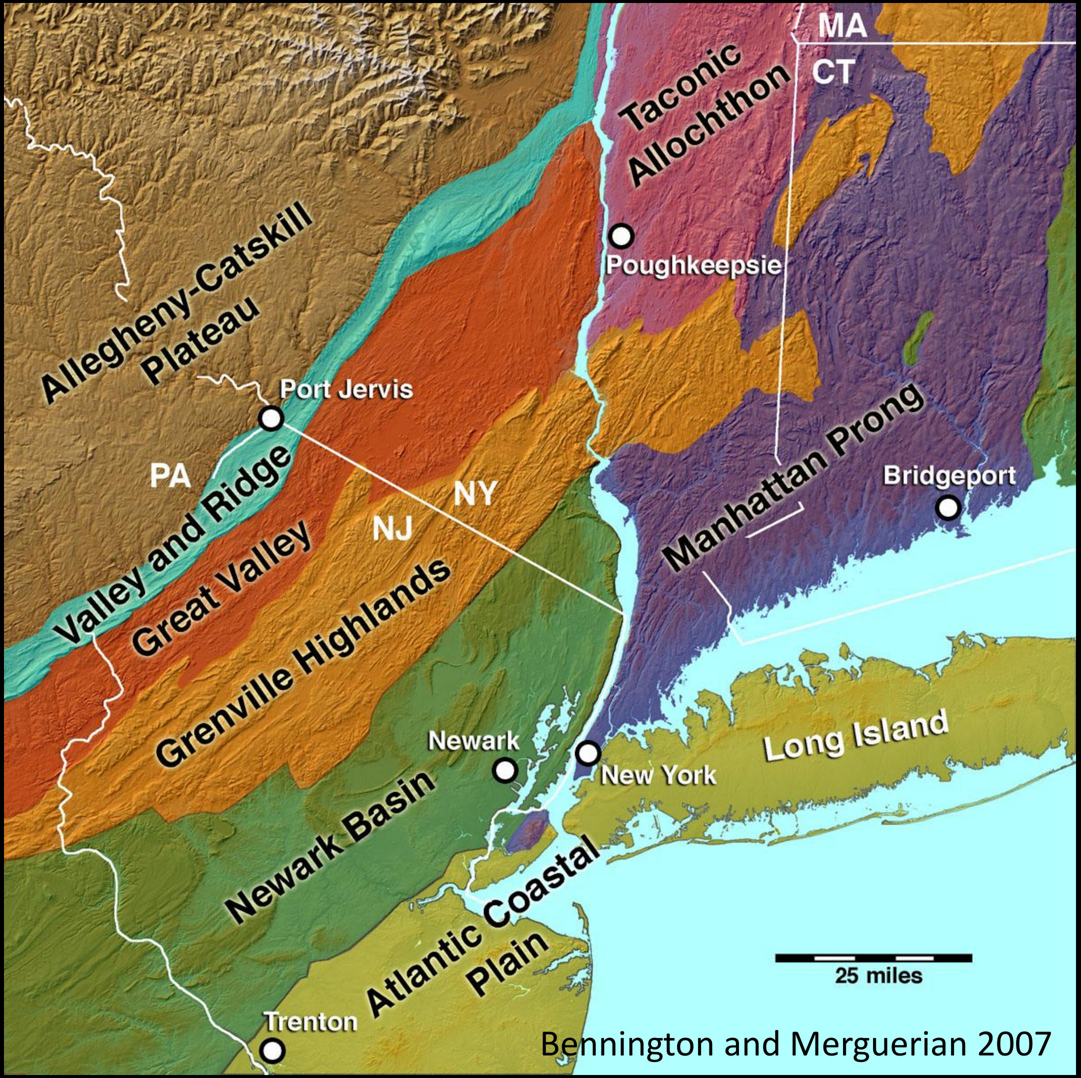
Geological Solutions Providing a Scientific Basis for Differing Site Condition (DSC) Claims

Charles Merguerian
Mickey Merguerian*

DUKE

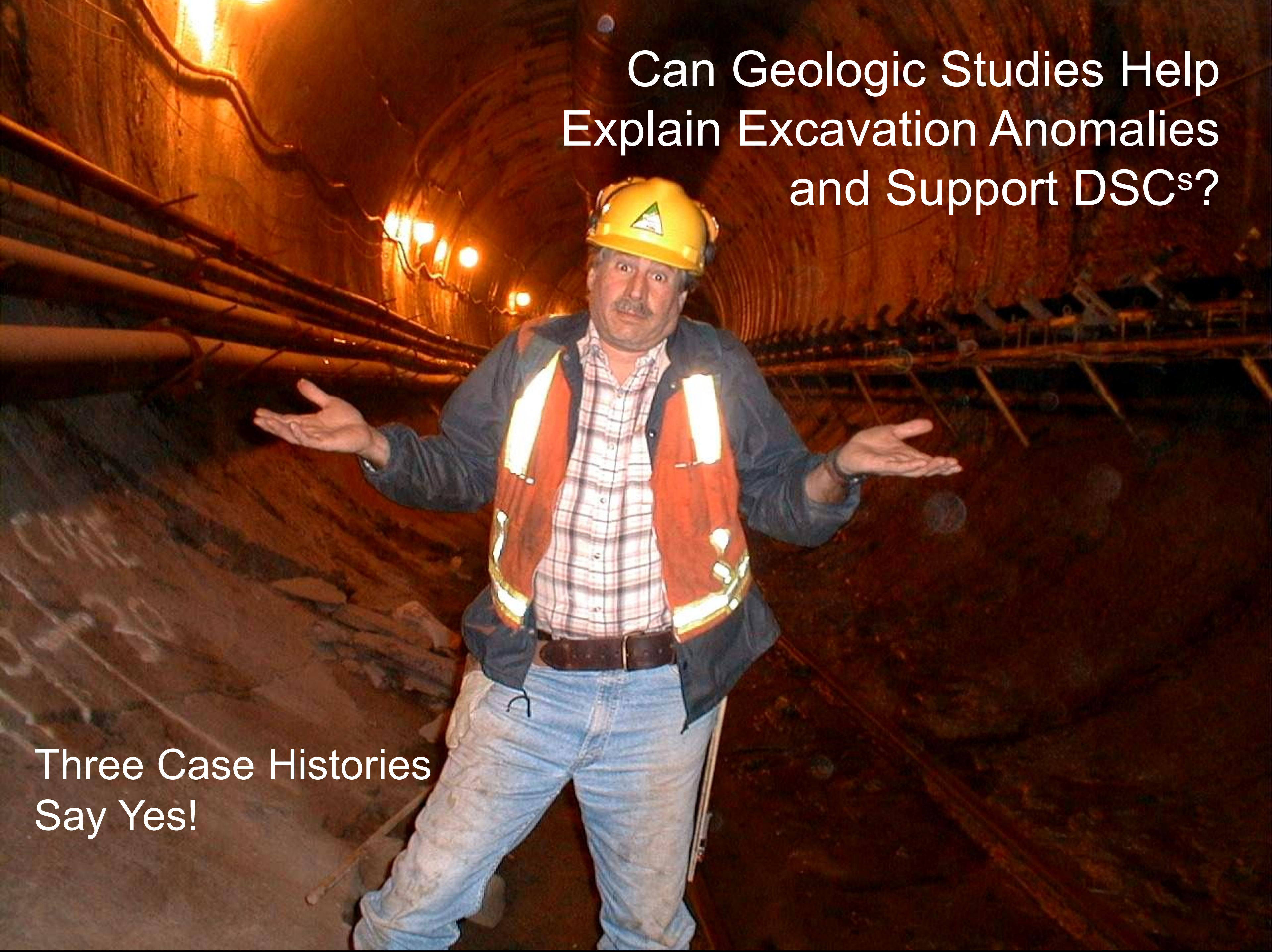
DUKELABS DSC INC.

ASCE Metro NY Conference
26 May 2022



Bennington and Merguerian 2007

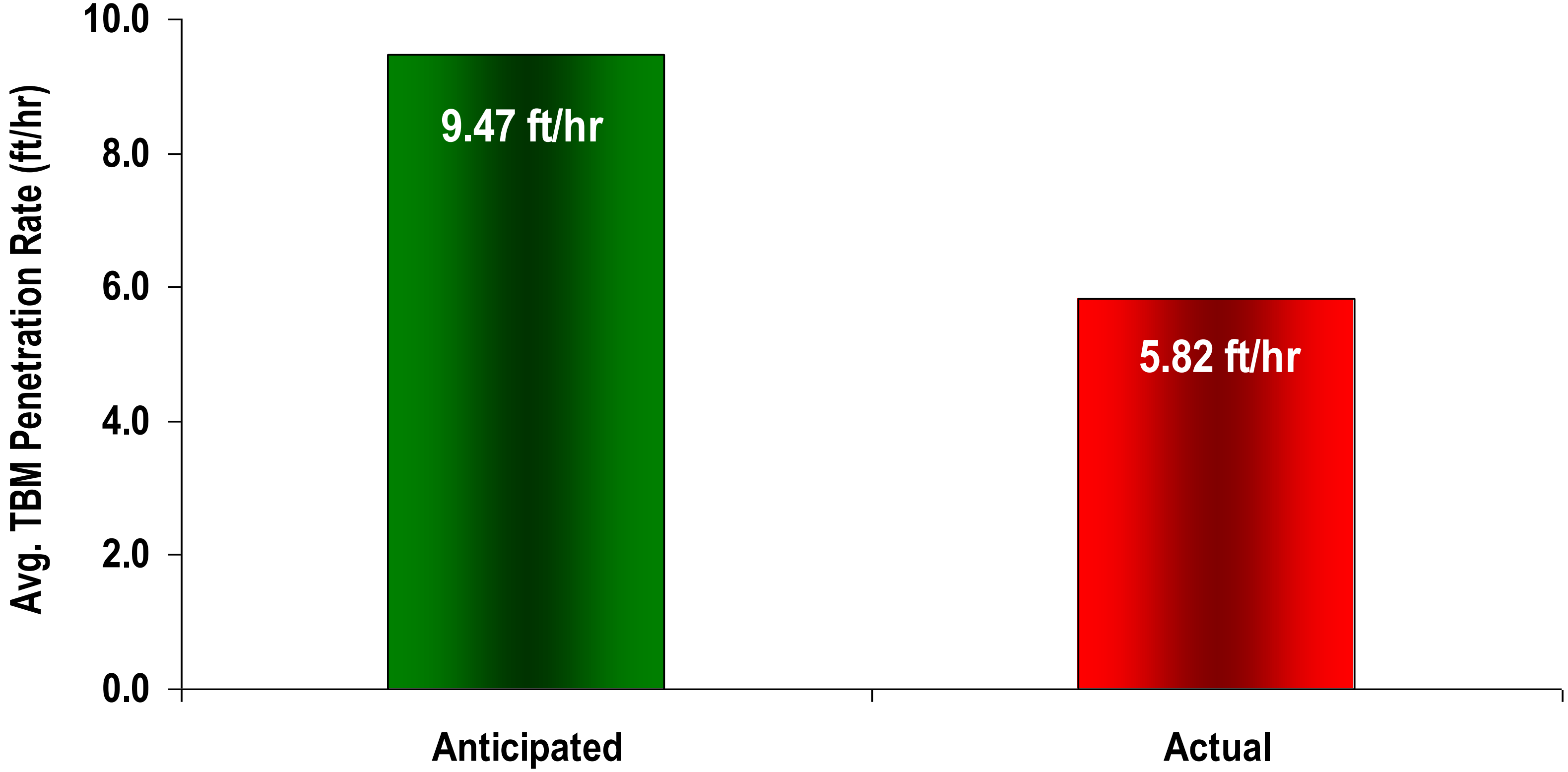
Can Geologic Studies Help Explain Excavation Anomalies and Support DSCs?



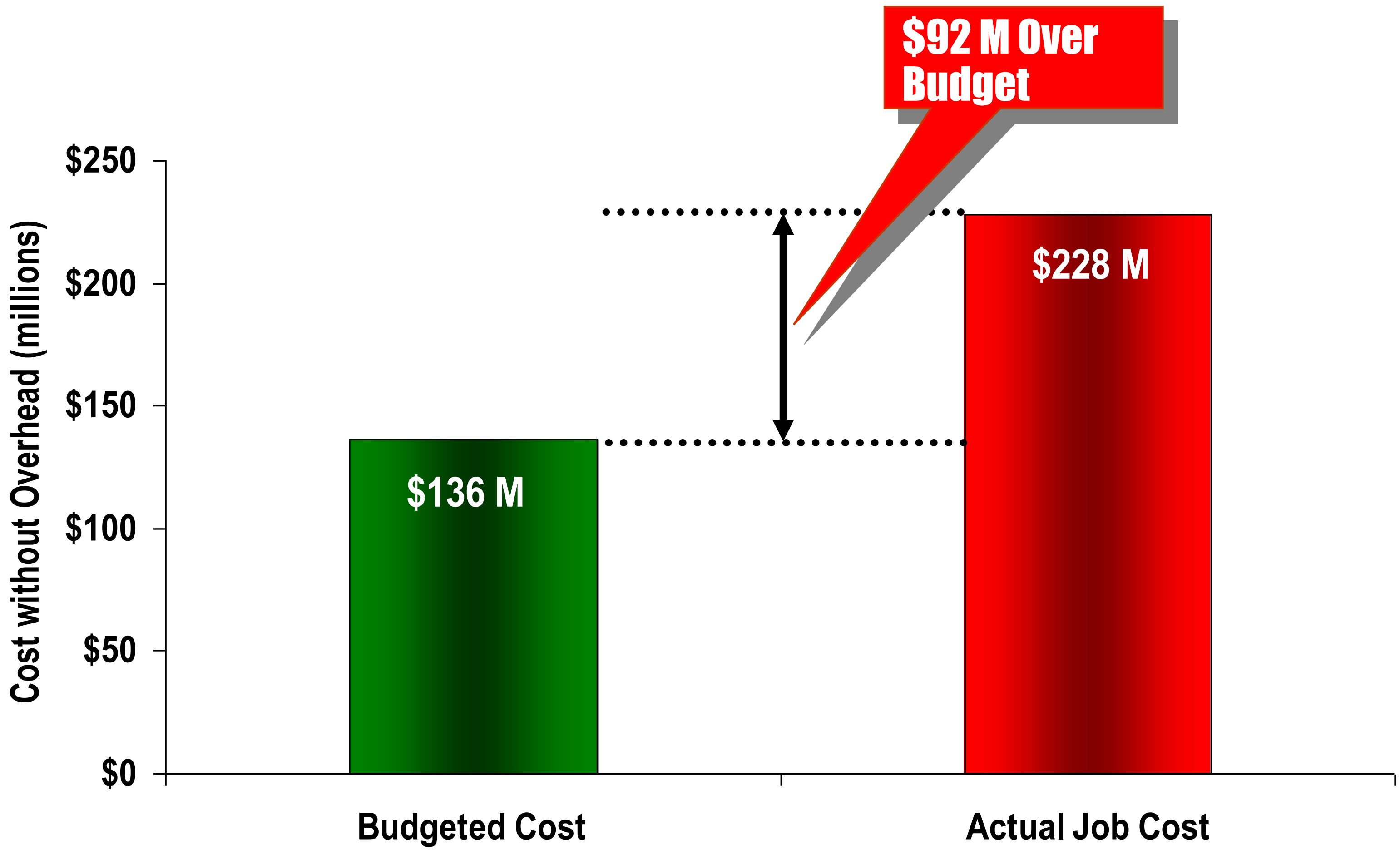
Three Case Histories
Say Yes!

TBM Tunnel #1

Anticipated vs. Actual Penetration Rate



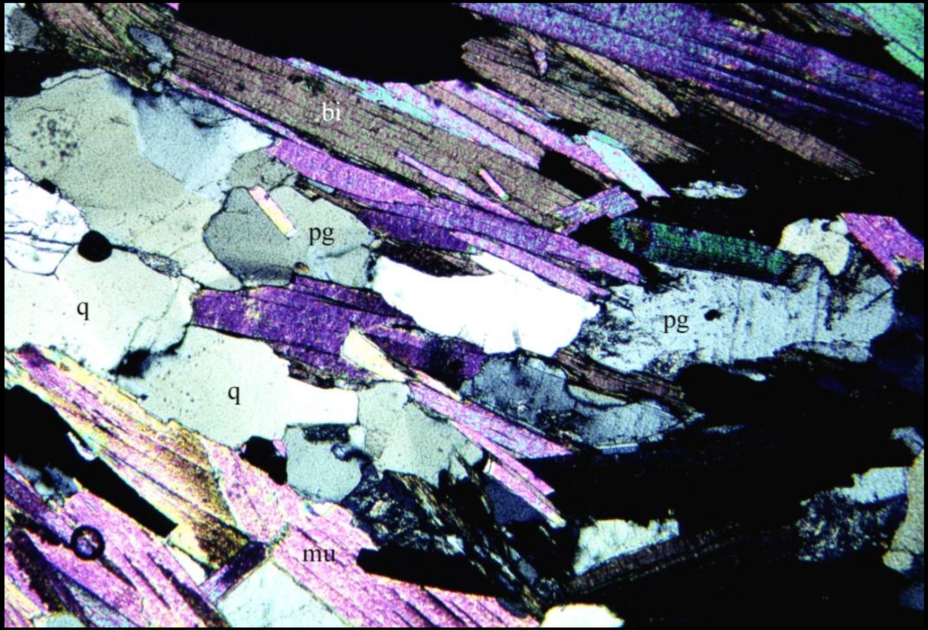
Anticipated vs. Actual Cost



Office Help

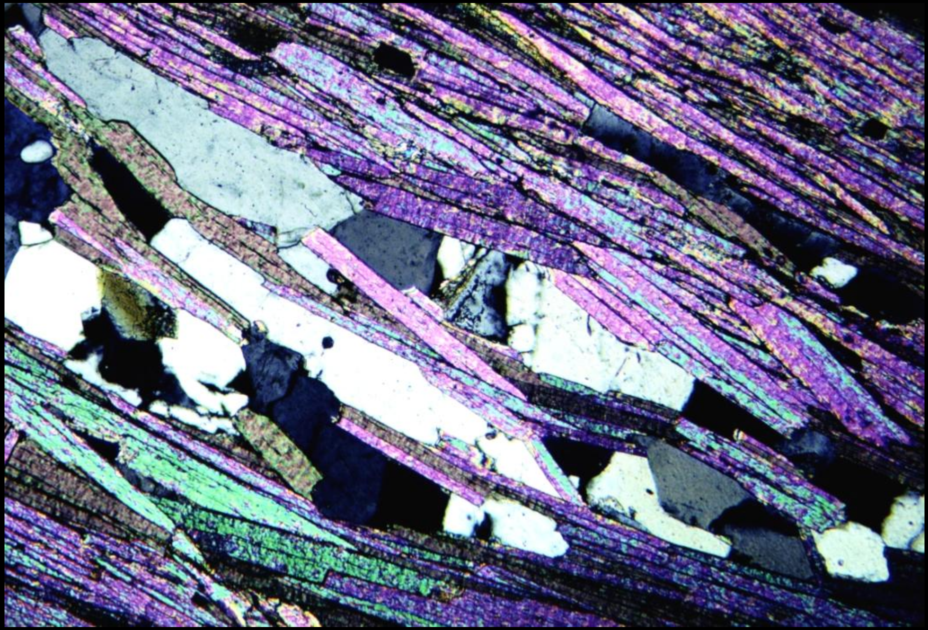
Dukelabs's Tunnel #1 Field Office

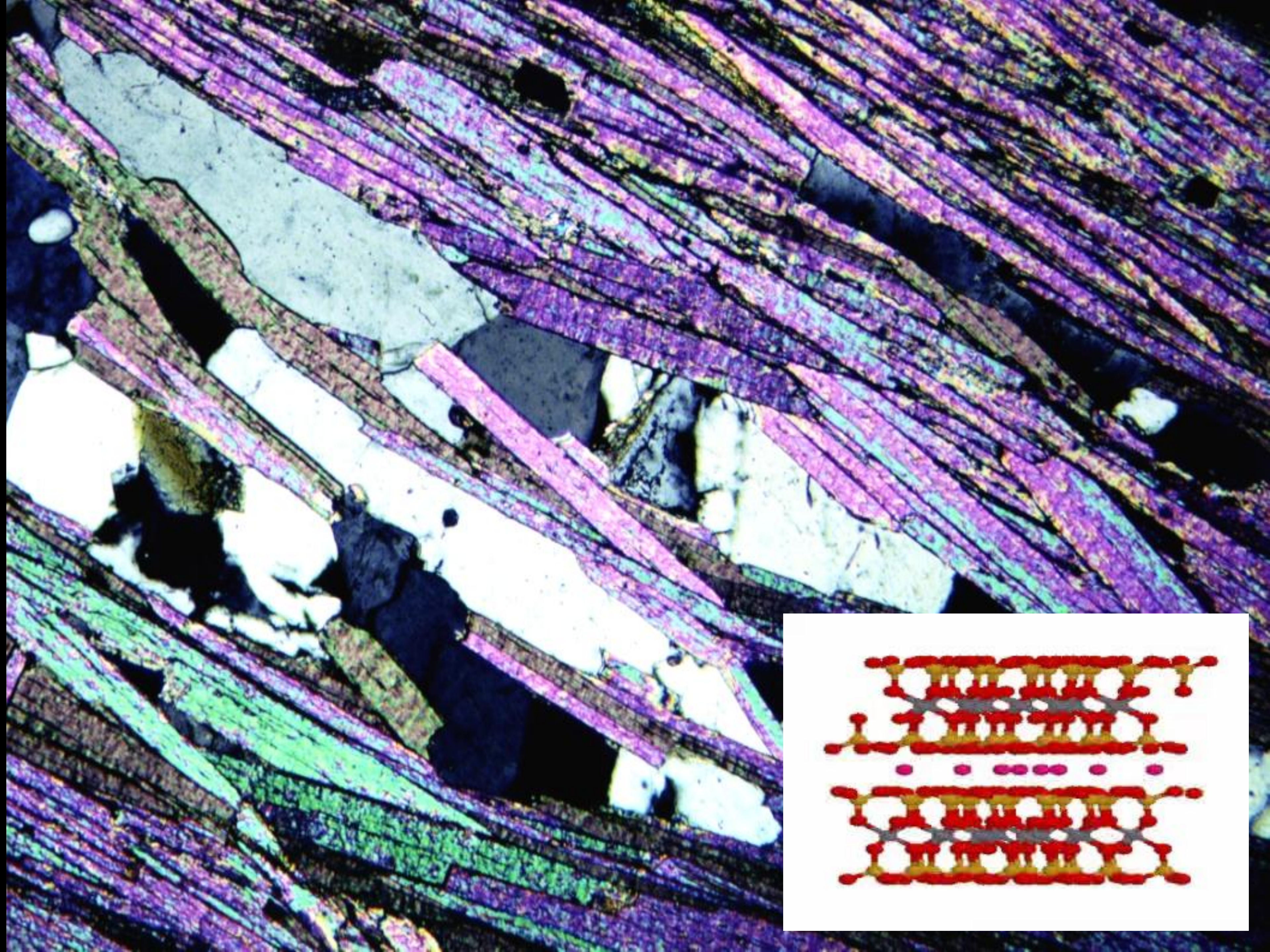
Foliated Textures Anticipated in Well-Layered Hartland Formation

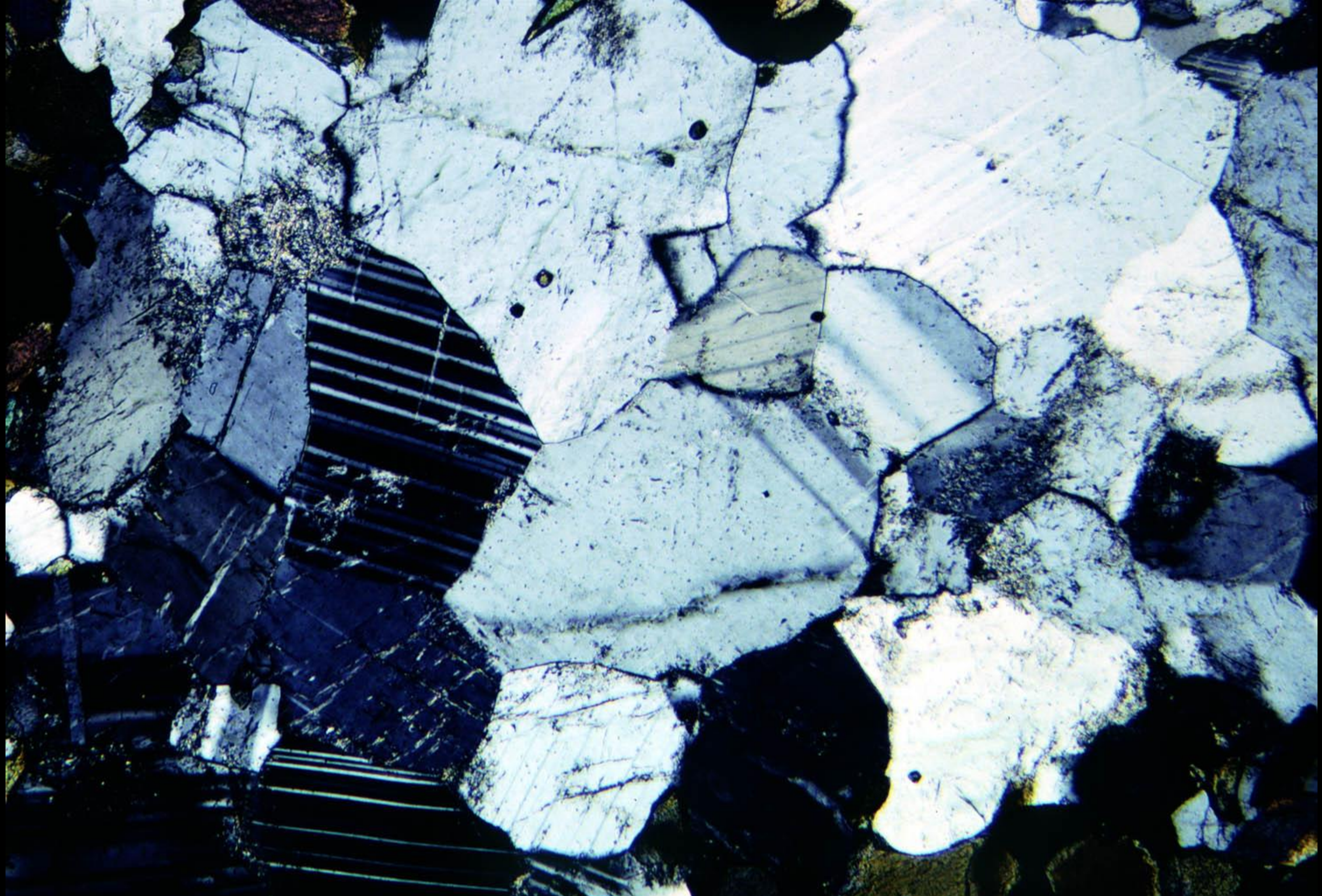


NYC Schist
Well-layered Hartland Fm.
Penetrative Foliated Textures

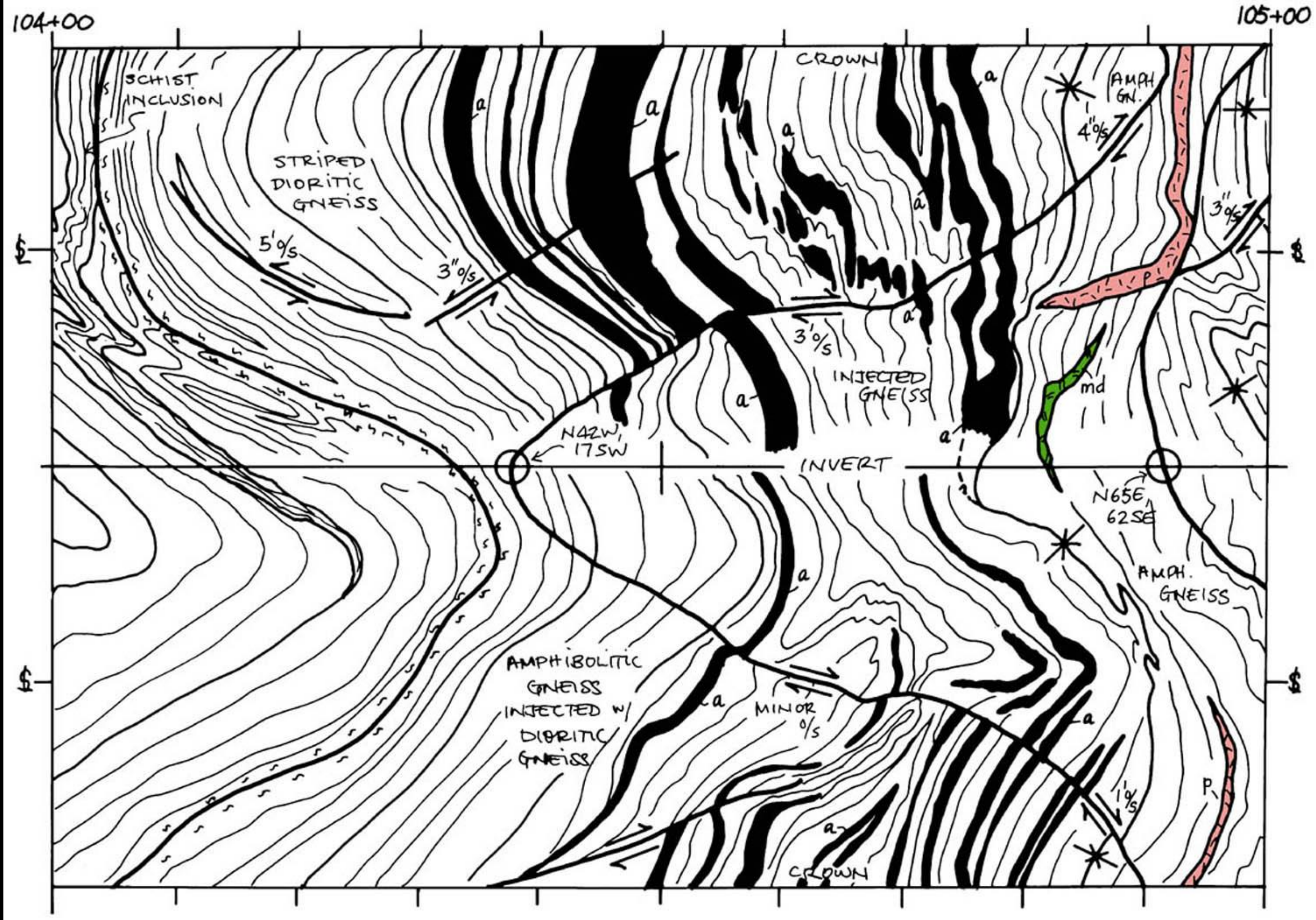
Great Rocks for Tunneling and Excavation!



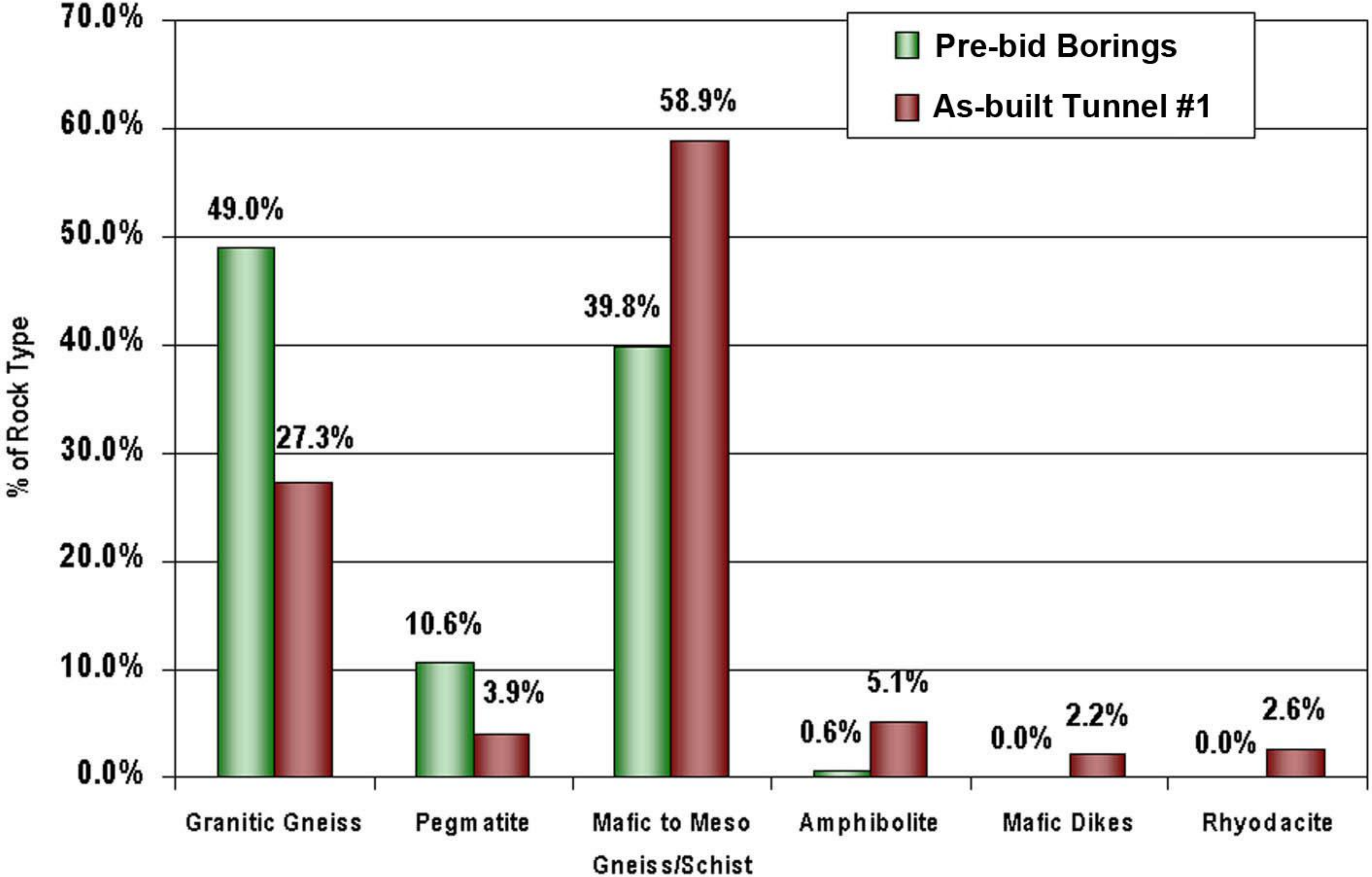




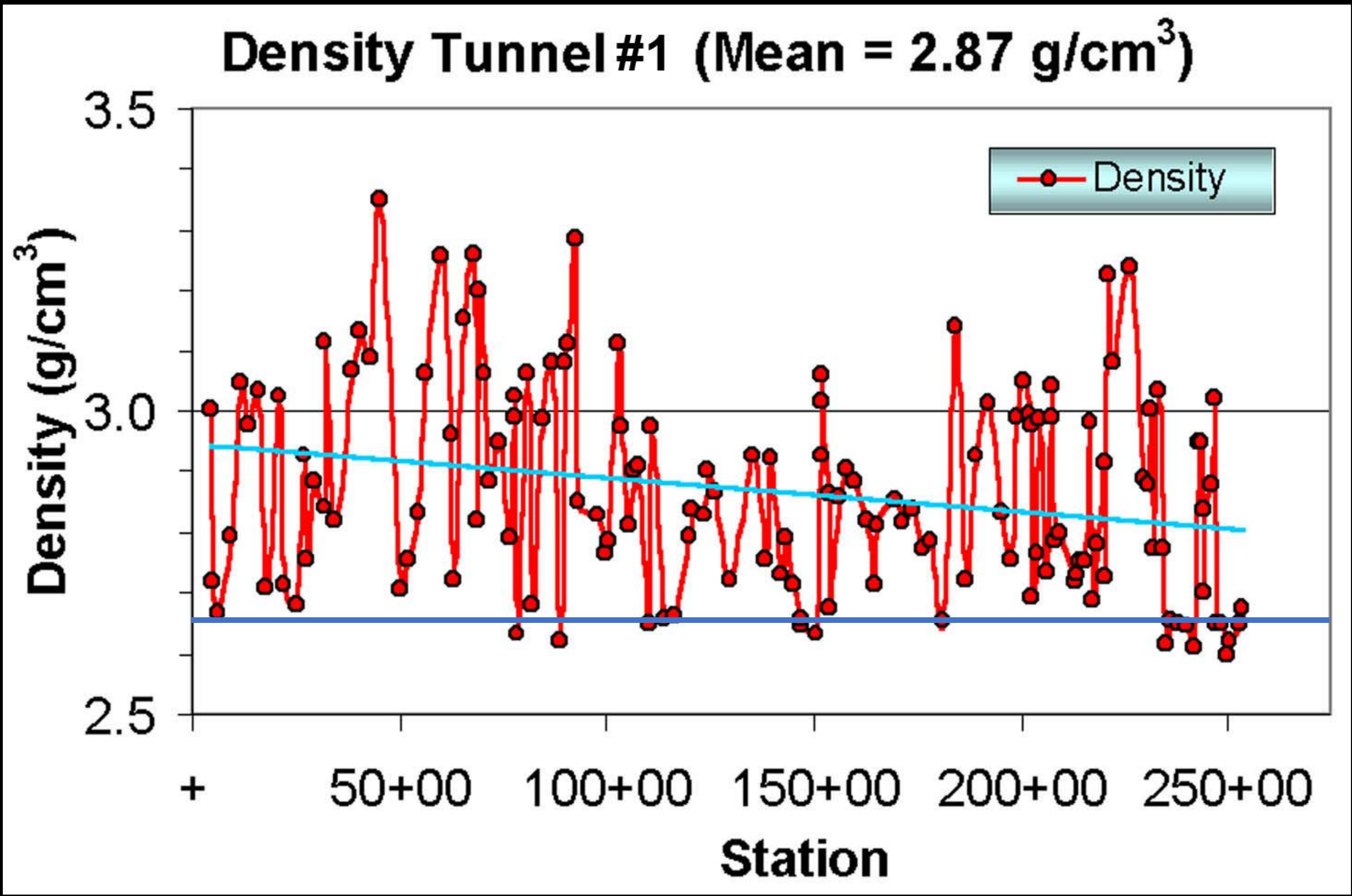
Tough, Granoblastic Textures Encountered in Orthogneiss



1” = 10’ Mapping Program 1997-1999



Incorrect Pre-Bid Anticipation Based on Tunnel-Horizon Borings



Density Analysis of > 100 Samples >> Schist (~2.65)

Geochemistry Geochronology

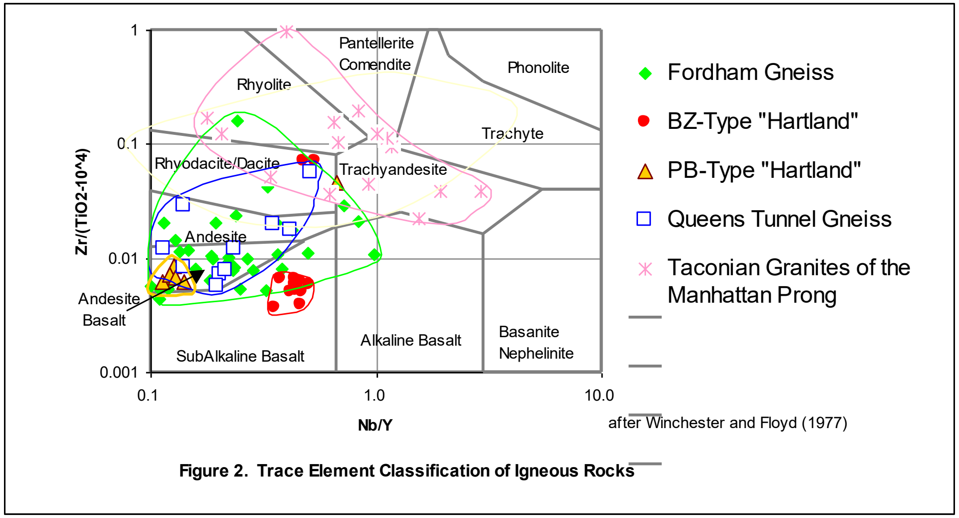


Figure 2. Trace Element Classification of Igneous Rocks

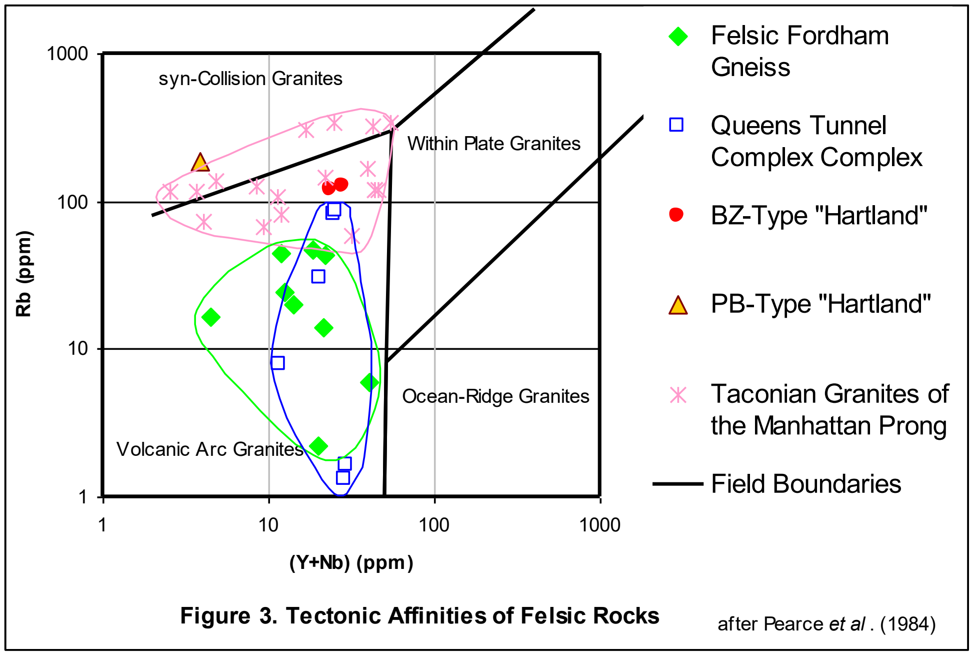
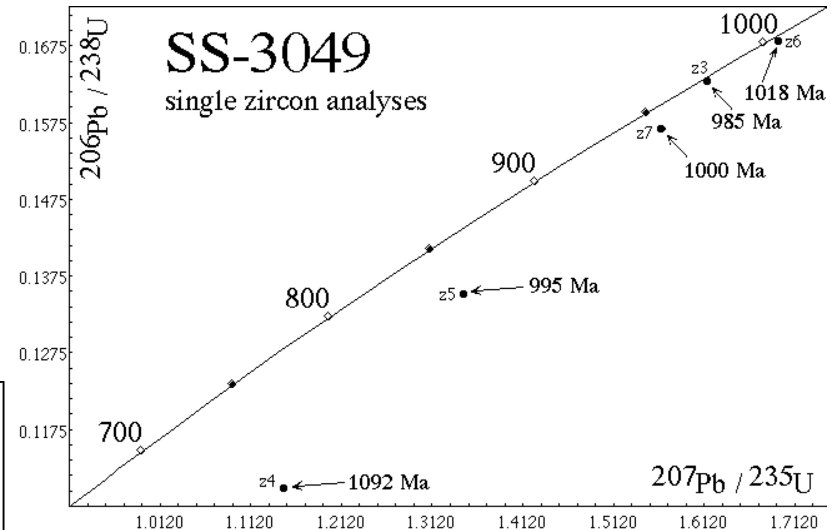
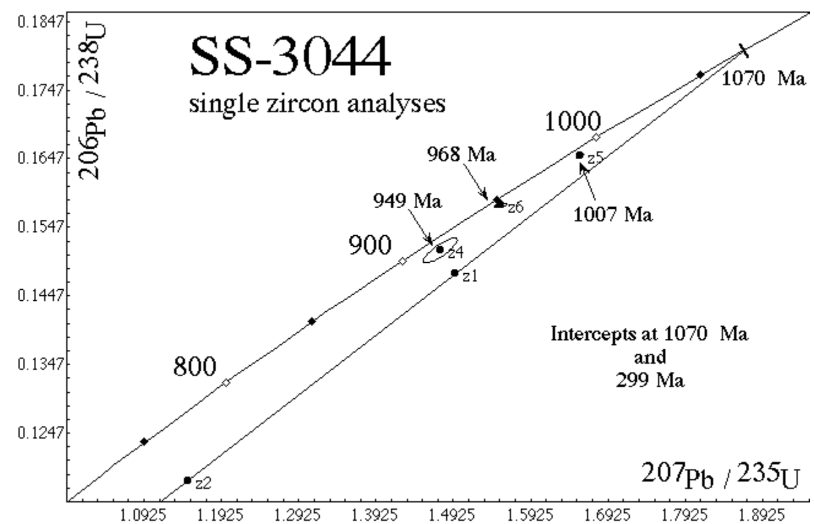


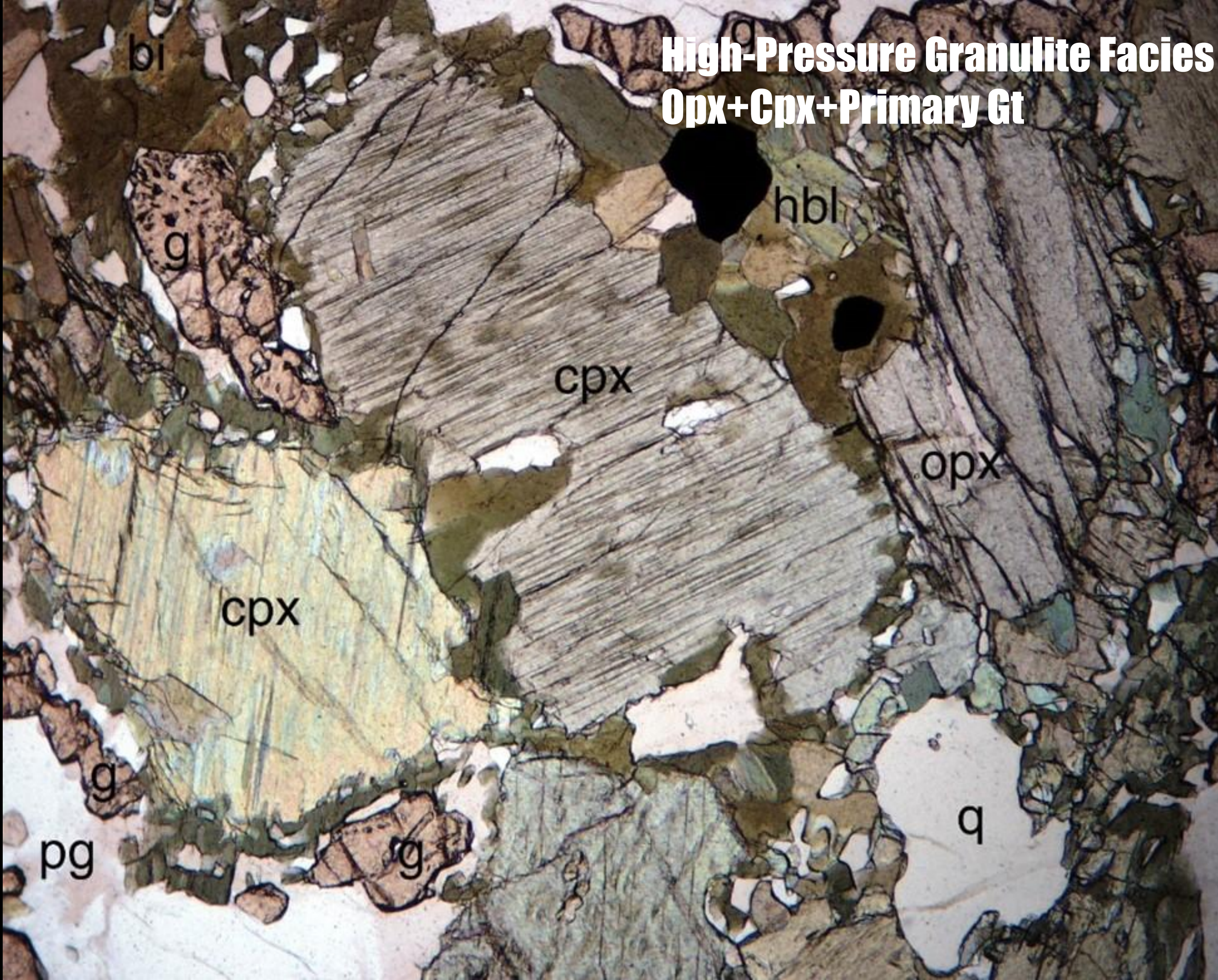
Figure 3. Tectonic Affinities of Felsic Rocks

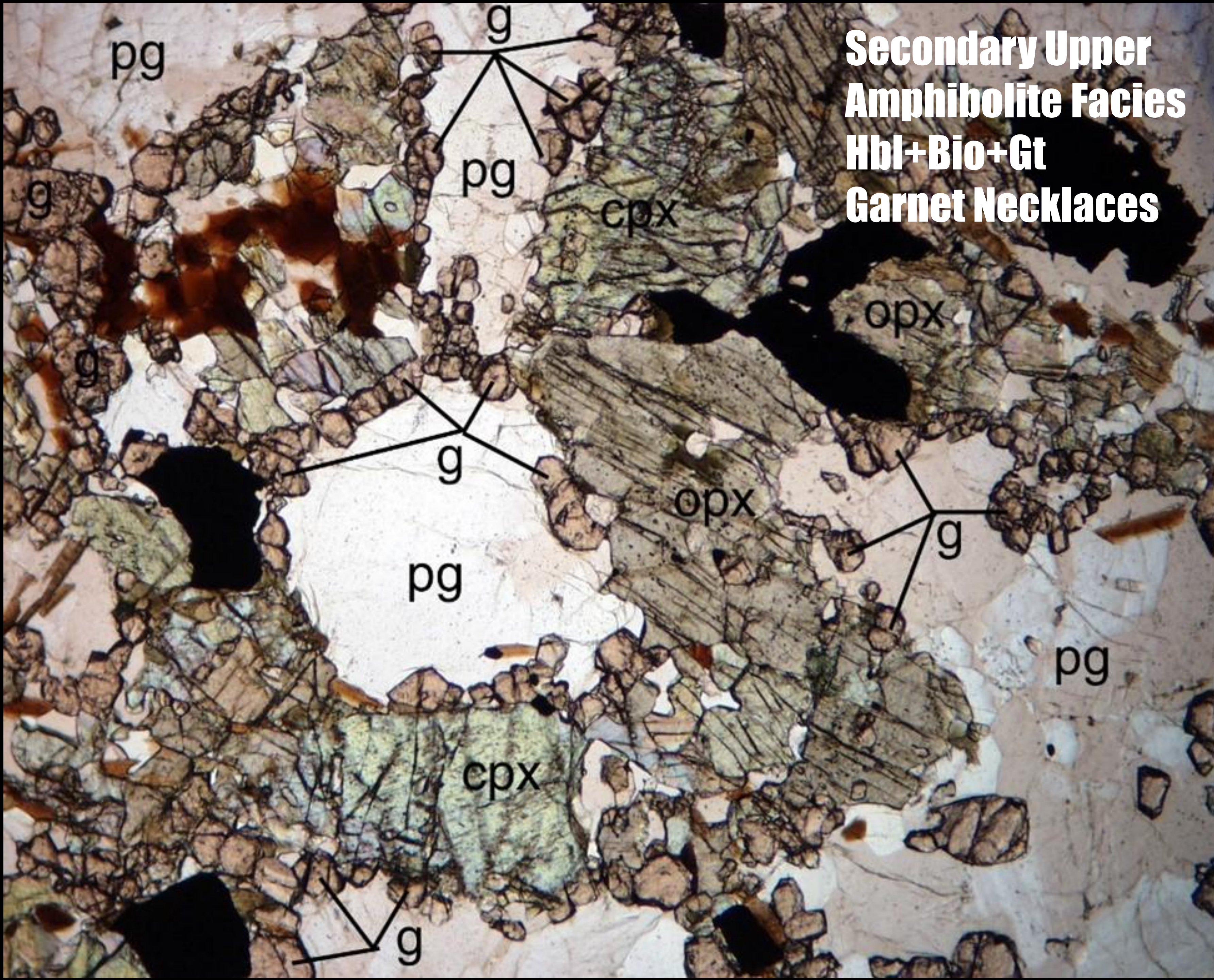




Unlike Hartland and Much Older

From Brock, Brock and Merguerian 2001


High-Pressure Granulite Facies
Opx+Cpx+Primary Gt
bi
g
g
hbl
cpx
opx
cpx
g
pg
g
q

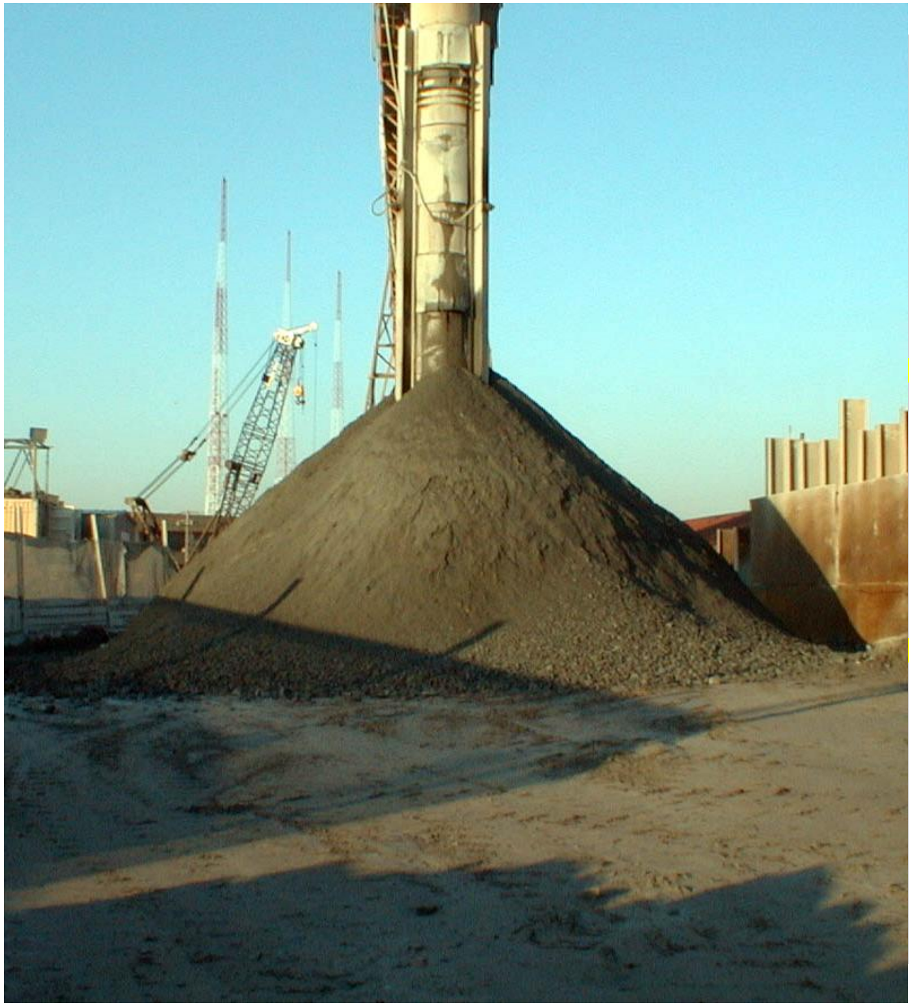

Secondary Upper
Amphibolite Facies
Hbl+Bio+Gt
Garnet Necklaces
g
pg
pg
g
cpx
g
opx
g
opx
g
pg
pg
cpx
g

High-Pressure Granulite Facies Metamorphism Produced Broad Zones of Anomalous Garnet, Higher Density, Lower Production, Excessive Fines

Anomalous Garnet Concentrations, Layers, Lenses, and Laminae

Tunnel #1

Tunnel Station Start	End	Length (Feet)	Garnet Zone No.	Field Description	Samples (Q-)
27+45	27+80	35	**1**	Garnet layer a few feet thick in migmatitic mafic gneiss, LW only	120
36+18	37+70	152	**2**	Garnet layers and laminae in injected mafic gneiss	
45+00	46+48	148	**3**	Garnetiferous mafic schist, gneiss and amphibolite	128
53+87	54+80	93	**4**	Two garnetiferous layers a few feet thick in mafic gneiss	131A, B
68+03	68+50	47	**5**	Garnetiferous zone in mafic gneiss, RW only	137, 138
68+78	69+84	106	**6**	Garnetiferous mafic schist, gneiss and amphibolite	139
70+27	70+78	51	**7**	10' thick garnet layer in mafic gneiss, schist, and amphibolite	140
71+01	71+18	17	**8**	Thin garnet lenses in mafic orthogneiss	
77+75	79+10	135	**9**	Broad zone of garnetiferous layers, lenses, and laminae	08, 144, 145
95+82	96+22	40	**10**	Garnetiferous leucosome in mafic gneiss, LW only	
96+77	99+25	248	**11**	Broad zone of garnetiferous mafic gneiss, schist, and amphibolite	153
100+13	102+46	233	**12**	Broad zone of garnetiferous mafic gneiss, schist, and amphibolite	155
103+43	103+62	19	**13**	Laminated garnet zone in mafic gneiss, schist, and amphibolite	
104+95	105+43	48	**14**	Laminated garnet zone in mafic gneiss, schist, and amphibolite	158
106+50	108+70	220	**15**	Broad zone of garnetiferous mafic gneiss, schist, and amphibolite	11
109+30	109+35	5	**16**	Blocks of garnetiferous gneissic rock in shear zone	
111+35	111+45	10	**17**	Laminated garnetiferous zone in mafic gneiss, LW only	
123+55	123+70	15	**18**	Laminated garnetiferous zone in mafic gneiss	101
151+80	152+20	40	**19**	Garnetiferous biotite schist and gneiss in contact with dacite	89A, B; 90A, B
171+15	173+78	263	**20**	Broad zone of highly garnetiferous migmatitic mafic rocks	80A, B
175+53	176+45	92	**21**	Broad zone of highly garnetiferous migmatitic mafic rocks	78
180+75	181+48	73	**22**	Garnet lenses and laminae in mafic schist, gneiss, and amphibolite	76
183+10	183+57	47	**23**	Garnet layer and laminae in mafic schist, gneiss, and amphibolite	
183+98	184+57	59	**24**	Garnet layer in mafic schist, gneiss, and amphibolite	75A, B
198+26	198+35	9	**25**	Sheared and rotated block containing garnet layers, RW only	
199+94	201+00	106	**26**	Garnetiferous layers in sheared mafic gneiss	68
201+80	202+05	25	**27**	Garnetiferous layer in mafic gneiss, RW only	14
207+18	207+95	77	**28**	Zone of garnet with layers, lenses, and laminae in mafic gneiss	20, 21
221+12	221+95	83	**29**	Thin garnet layers in mafic gneiss, schist, and amphibolite	33A, B
225+07	225+38	31	**30**	Garnetiferous granitoid at mafic gneiss/orthogneiss contact	
229+72	229+97	25	**31**	Garnetiferous zone in mafic gneiss and schist	
231+25	232+36	111	**32**	Laminated garnetiferous zone in mafic gneiss	38A, B
TOTAL ===>		**2663**	**Linear Feet of Tunnel #1 with Highly Garnetiferous Rocks = (2663/25035) = 10.64%**		



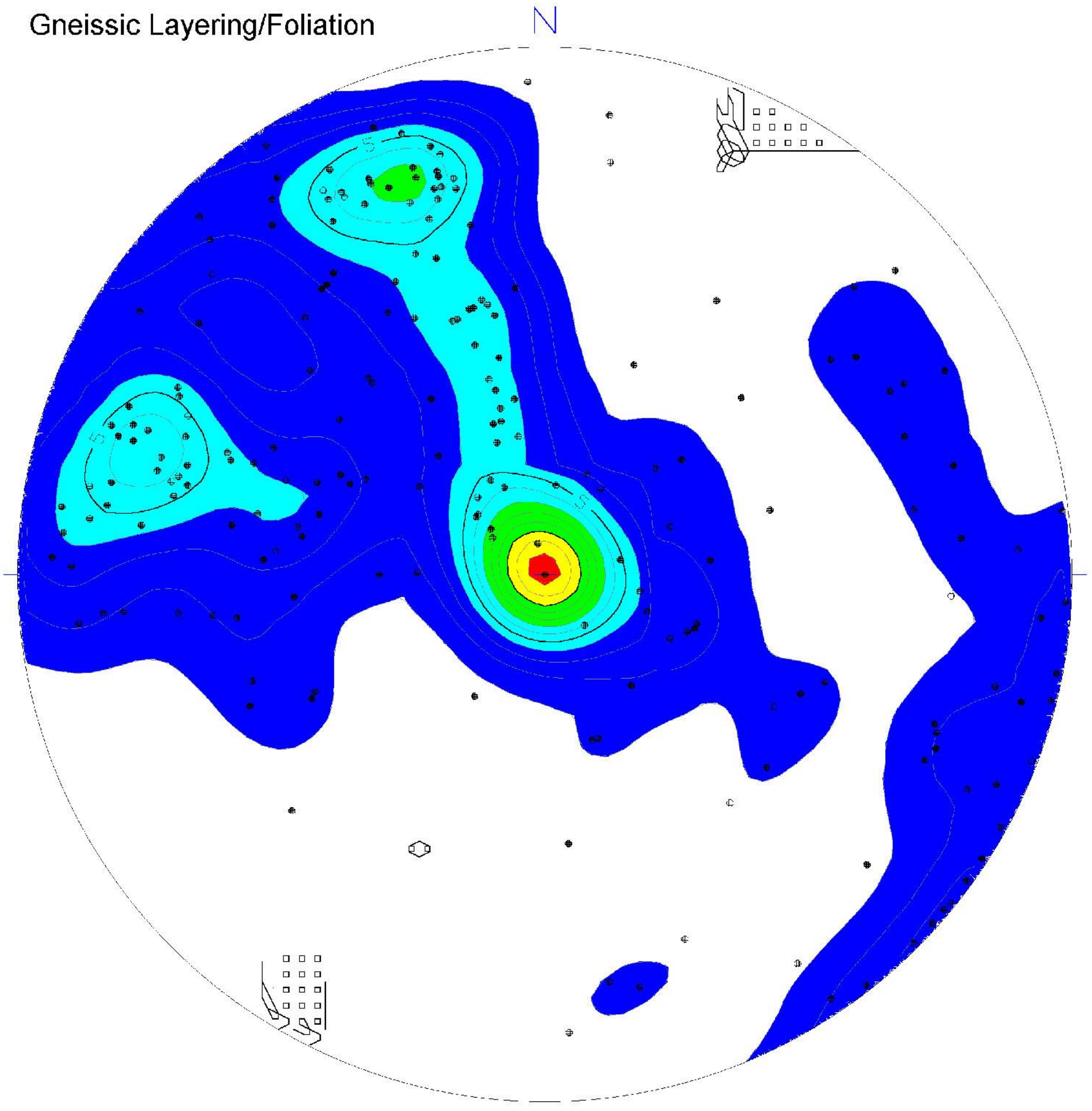
~11% of Tunnel up to 50% Garnet
in 32 Zones (= Ore Deposit!!)
Abrasive, Tough Granoblastic Rock Mass =
Low Penetration Rate of <6'/hour vs.
9'/hour Anticipated and Excessive Fines
Bimodal Blocks and Dust

Pre-bid Data = NE-trending Steep SE Dip of Foliation

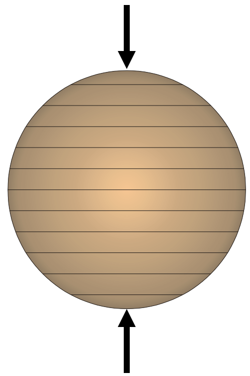
Very Favorable Tunnel Drive Orientation!!

Instead:
11% ~ 0°
<u>27%</u> <30°
38% Gentle Dips

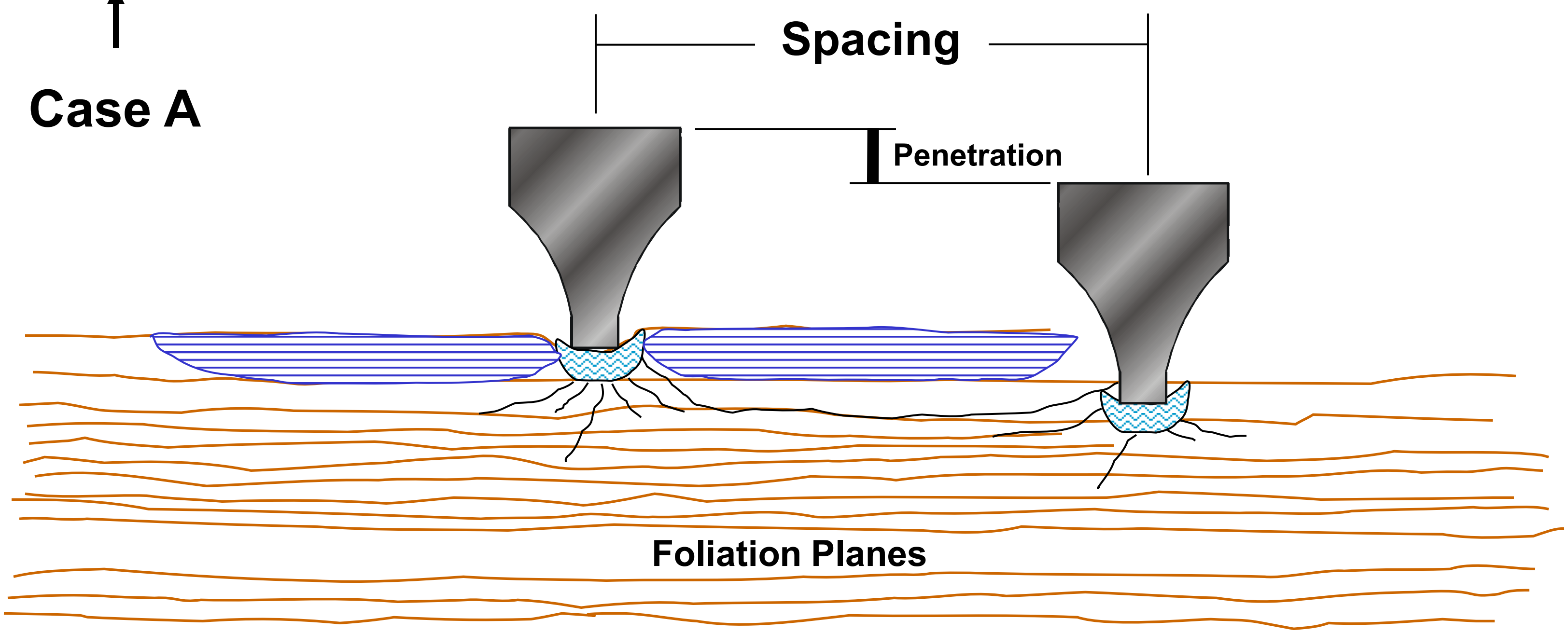
Very <u>Unfavorable</u> TBM Drive Orientation!!



Foliation Planes Perpendicular

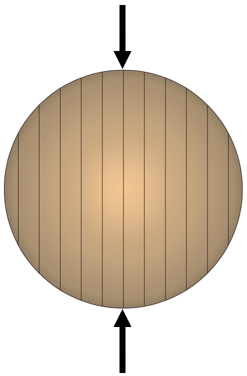


Case A

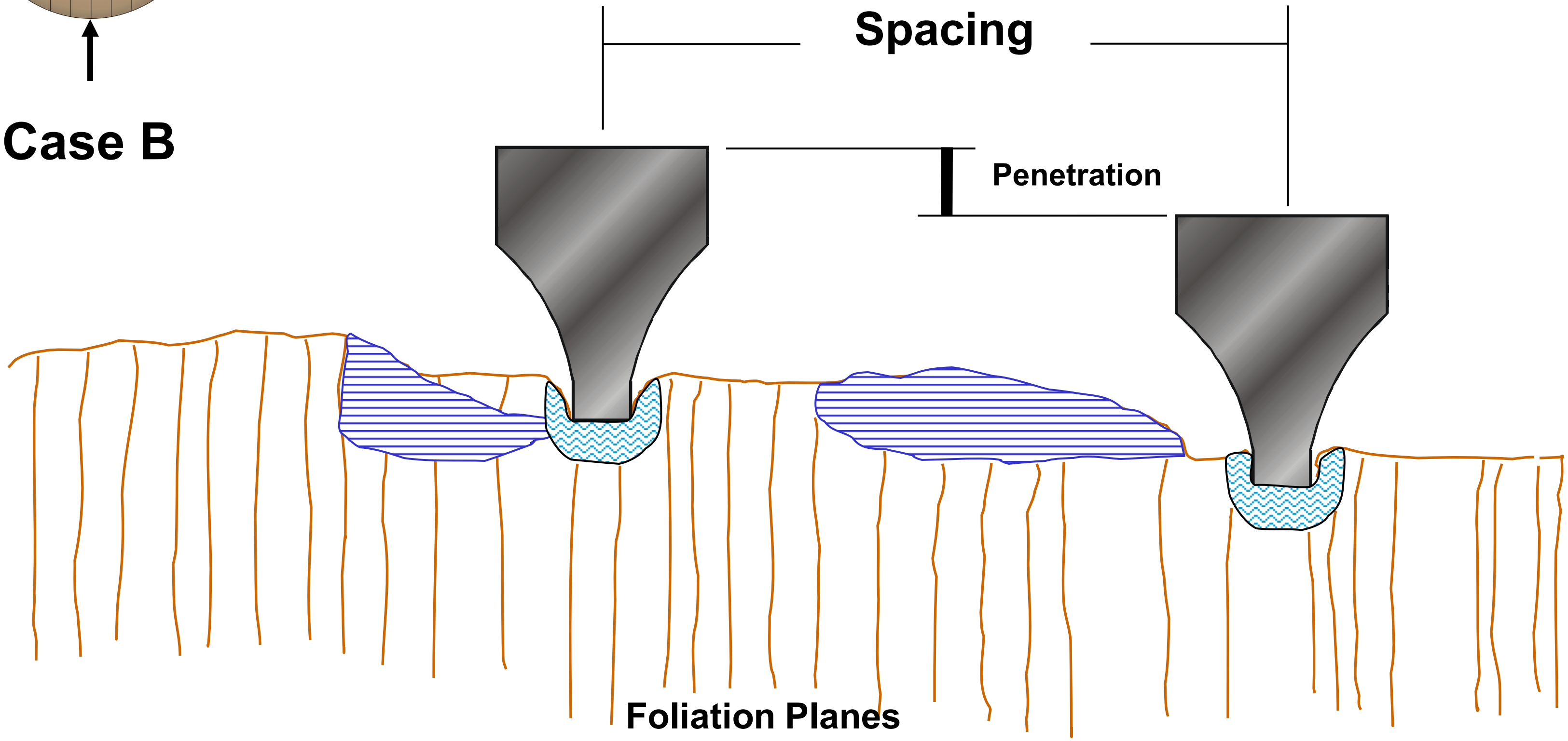


Chipping mechanism when TBM advancing perpendicular to foliation (Case A)

Foliation Planes Parallel



Case B



Chipping mechanism when TBM advancing parallel to foliation (Case B)

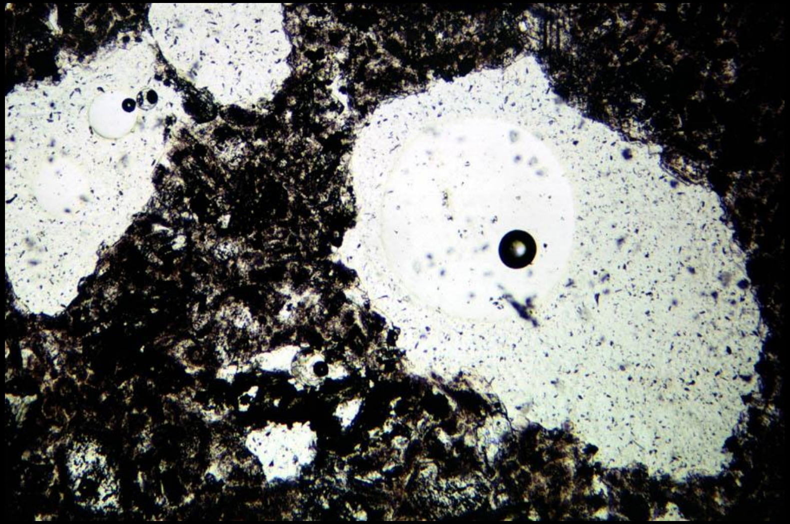

Normal TBM Chips


Excessive Fines
Mineralogy
Metamorphism
Fabric
Garnet

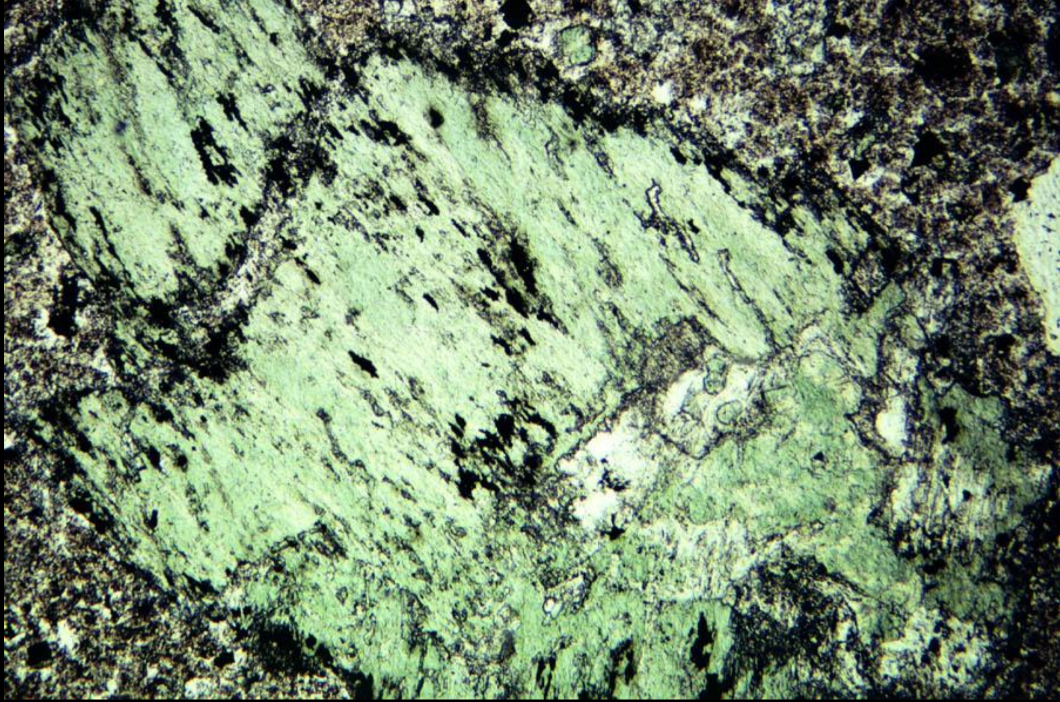
Five Laterally Extensive Dikes

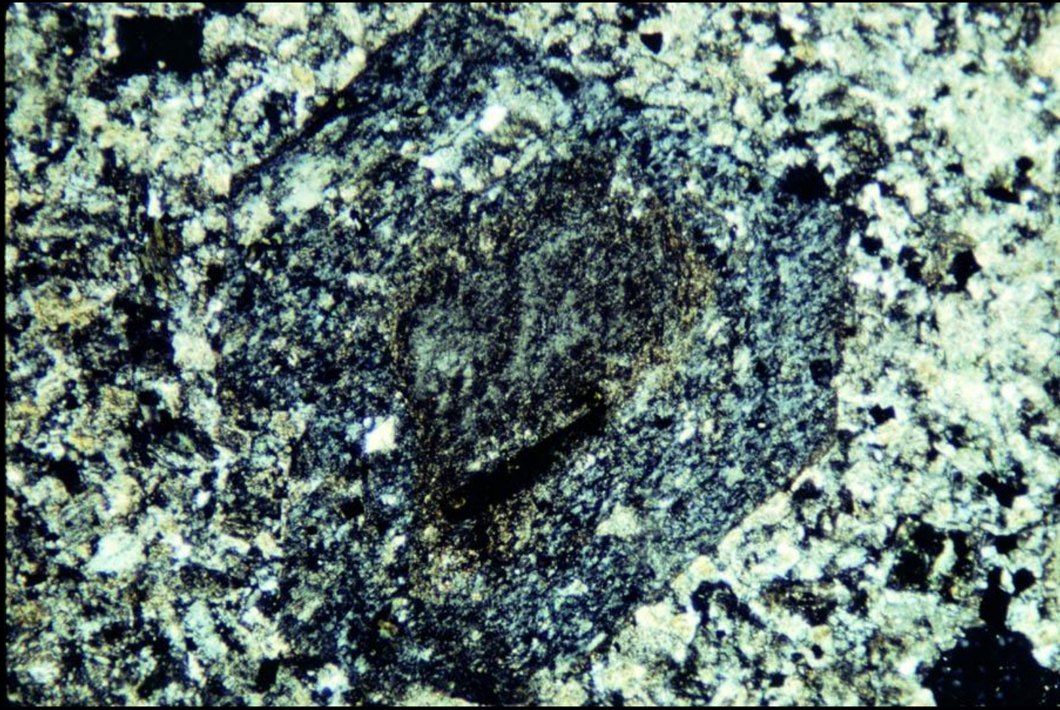
Dike	Stations	Orientation	Exposed Length	Thick-ness	Brief Comments
1	109+20 - 109+52	N65°W, 57°NE	32'	12'	cuts N58°E, 83°NW normal fault
2	117+58 - 118+24	? - RW Only	66'	>8'	cuts N52°E, 76°NW normal fault and shear zone
3	128+70 - 129+21	? - LW Only	51'	7'	cuts D_3 shear zone
	129+53 - 130+41	N48°W, 78°SW	88'	11'	cuts N20°E, 10°NW thrusts and older F_3 fold
4	131+70 - 132+42	? - LW Only	72'	6'	cuts N30°W, 23°SW thrust fault
	132+40 - 132+56	? - RW Only	16'	3'	thin selvage cuts thrust fault and shear zone
	132+58 - 133+62	N61°W, 81°NE	104'	5'-10'	cuts N44°E, 83°SE reverse shear zone; fractured
5	149+93 - 151+36	N52°W, 90°	143'	16'	cut by N20°E, 70°NW normal fault; clay-rich gouge
	151+45 - 152+40	N40°W, 83°SW	95'	14'	cut by N18°E, 70°NW normal fault; clay-rich gouge

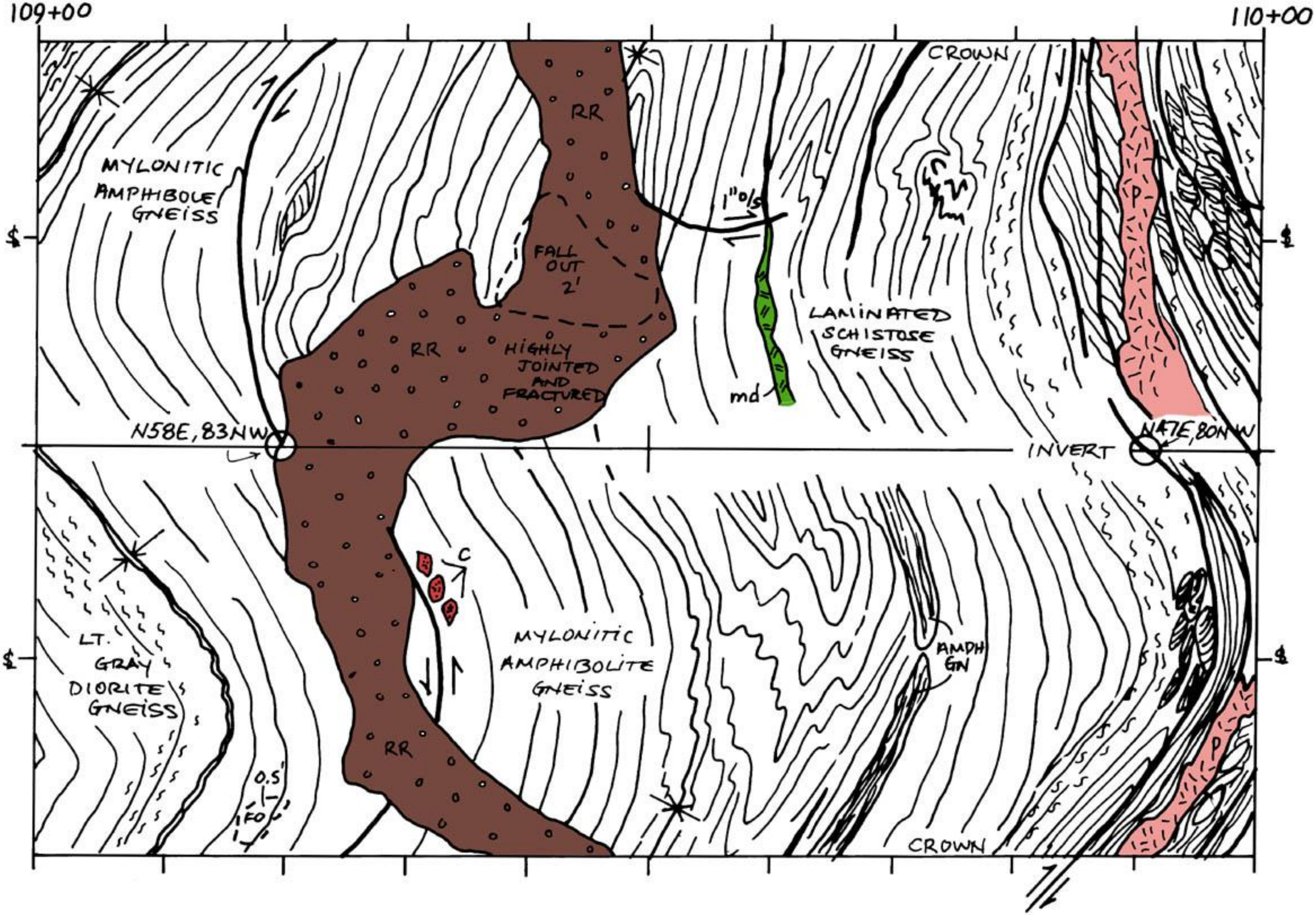
Glassy Textures
Vesiculated
Hornblende Phenocrysts
Plagioclase Phenocrysts
Typical Rhyodacite Features
Geochemical Confirmation



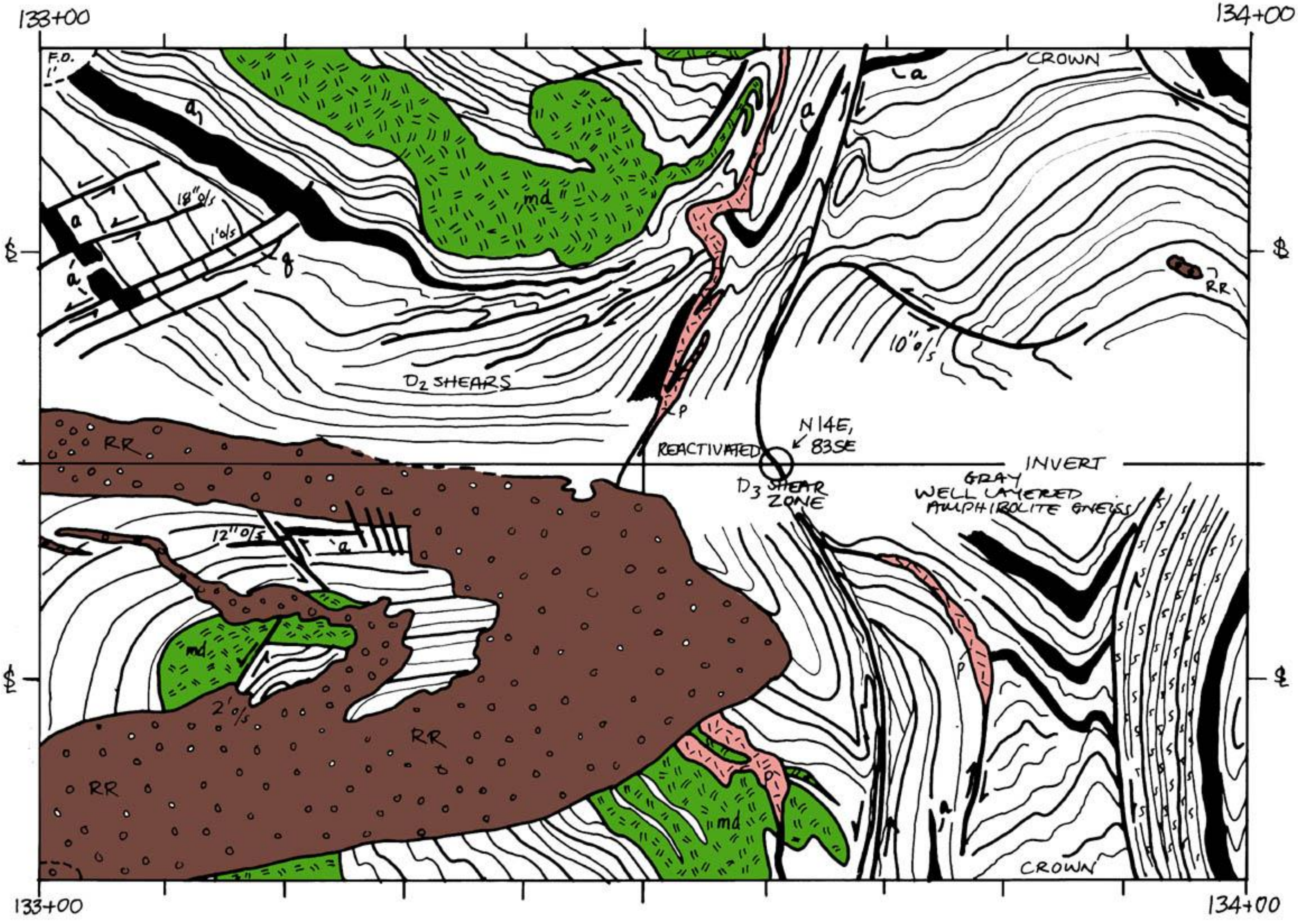
Major Elements	QTR-1	Q01-B	Q02-B	Average
SiO2	64.89	66.16	63.06	64.70
TiO2	0.58	0.51	0.62	0.57
Al2O3	14.54	14.83	14.78	14.72
FeO*	3.73	3.31	4.35	3.80
MnO	0.07	0.08	0.08	0.08
MgO	1.62	1.77	2.22	1.87
CaO	3.97	4.40	5.54	4.64
Na2O	4.80	5.07	4.48	4.78
K2O	4.52	3.26	4.35	4.04
P2O5	0.40	0.41	0.54	0.45
Total	99.12	99.80	100.01	99.64
LOI	0.87	3.81	2.86	2.51
*Total Iron as FeO				



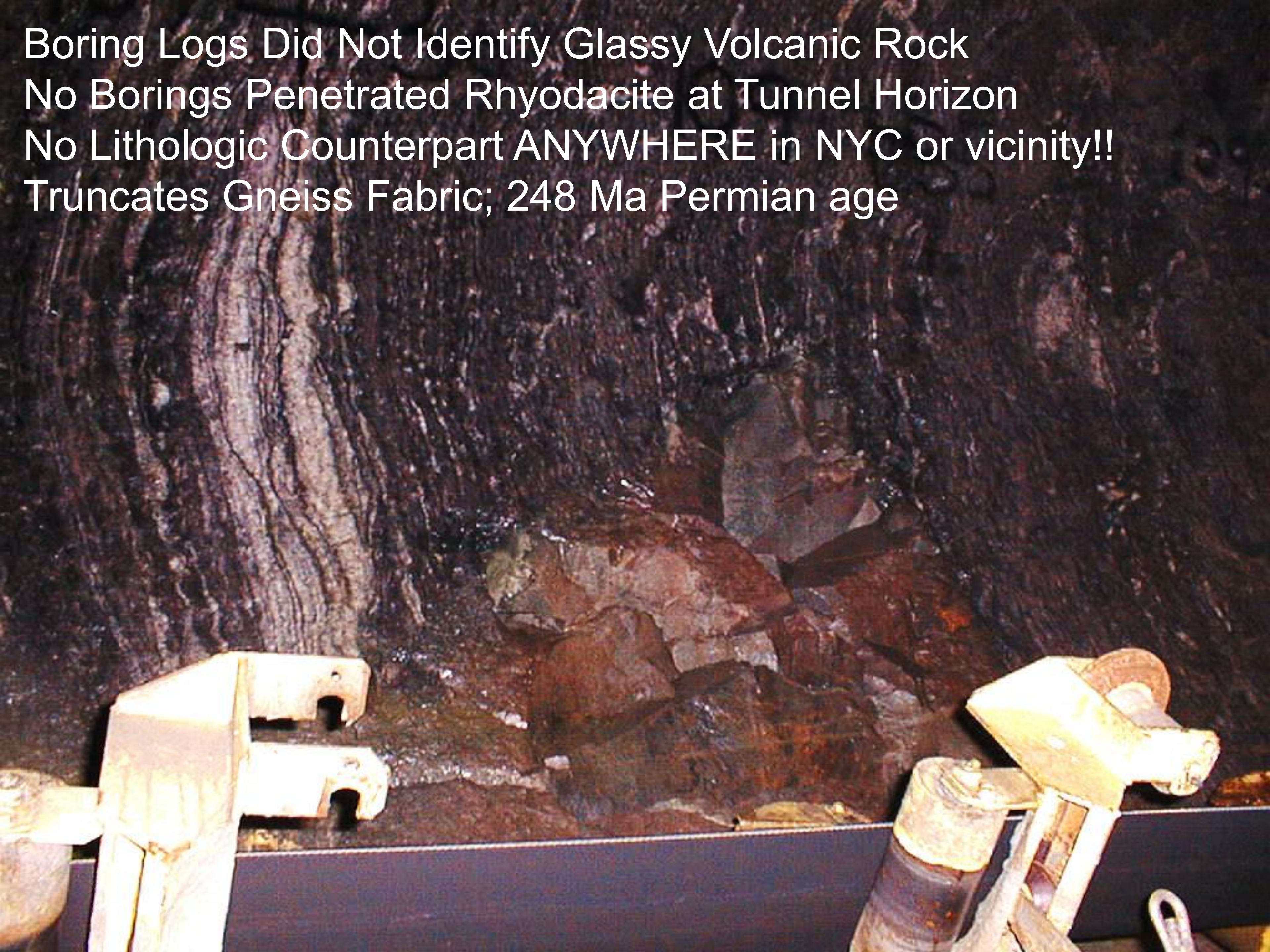




109+00
110+00
CROWN
RR
MYLONITIC AMPHIBOLE GNEISS
FALL OUT 2'
1"o/s
LAMINATED SCHISTOSE GNEISS
md
RR
HIGHLY JOINTED AND FRACTURED
N58E, 83NW
N47E, 80NW
INVERT
P
C
MYLONITIC AMPHIBOLITE GNEISS
AMPH GN
LT. GRAY DIORITE GNEISS
0.5'
1FO
RR
P
CROWN


133+00
134+00
F.O.
1'
CROWN
a
a_1
a
18" o/s
a
1' o/s
g
a
md
RR
10" o/s
D2 SHEARS
P
RR
N14E,
83SE
REACTIVATED
INVERT
D3 SHEAR
ZONE
GRAY
WELL LAYERED
AMPHIBOLITE GNEISS
12" o/s
a
md
2' o/s
RR
P
P
RR
md
a
CROWN
133+00
134+00

Boring Logs Did Not Identify Glassy Volcanic Rock
No Borings Penetrated Rhyodacite at Tunnel Horizon
No Lithologic Counterpart ANYWHERE in NYC or vicinity!!
Truncates Gneiss Fabric; 248 Ma Permian age




Station 109+20, Right Wall
Produced Mechanical Weakness
Cooling joints extend 10' into country rock

Collapsing Crown and Sidewalls

Detailed Mapping
Lithological Analyses (Mineralogy, Petrography, Density)
Structural Analyses
Metamorphic Analyses
Geochemistry
Geochronology

Indicated Tunnel #1 Rock Mass Not Anticipated Hartland
Rather, High-Pressure Granulite Facies Metamorphic
Rocks Correlative with Older, Tougher Fordham Gneiss

Added Impediments to Anticipated Production
Rhyodacite Dike Swarm
Anomalous Garnet Content

Combined Research Showed Clear DSC

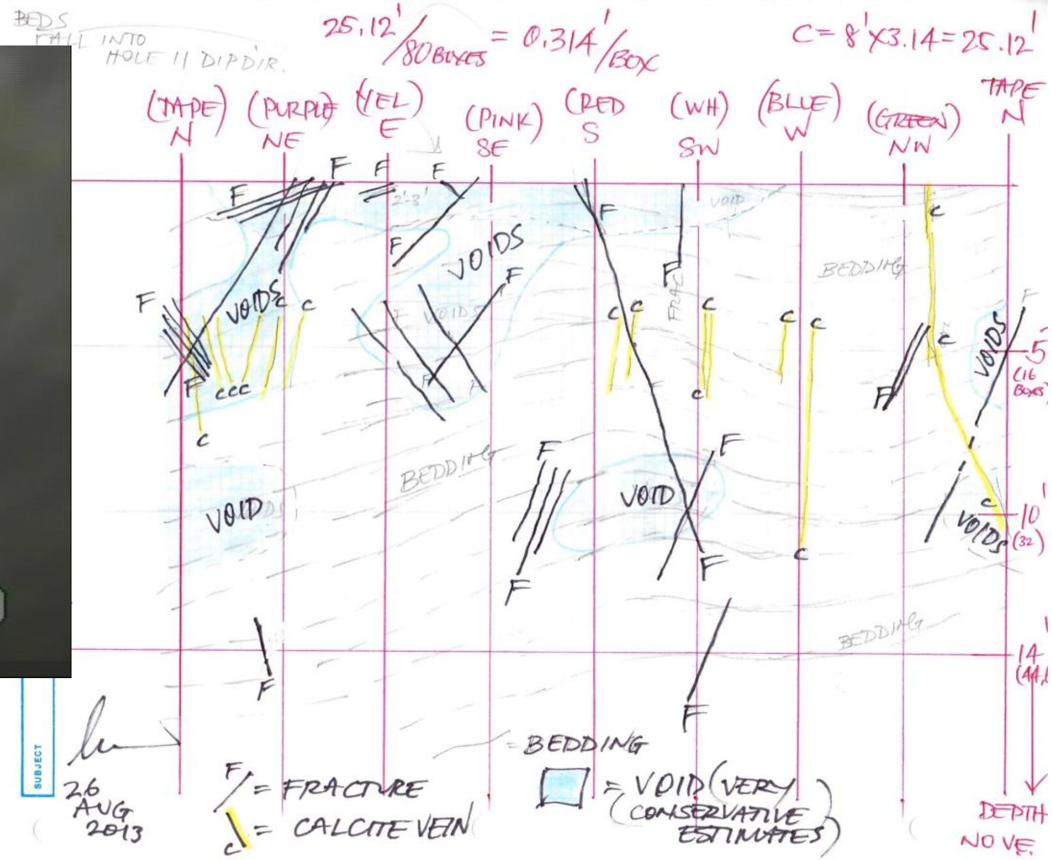

Subaqueous Bridge Shafts
Equipment Rental

Mucking Operations


Passaic Fm Sandstone
Angular not Rounded
Sidewall Collapse
Water + Material + Aquatic Life = Hydrologic Connectivity with River

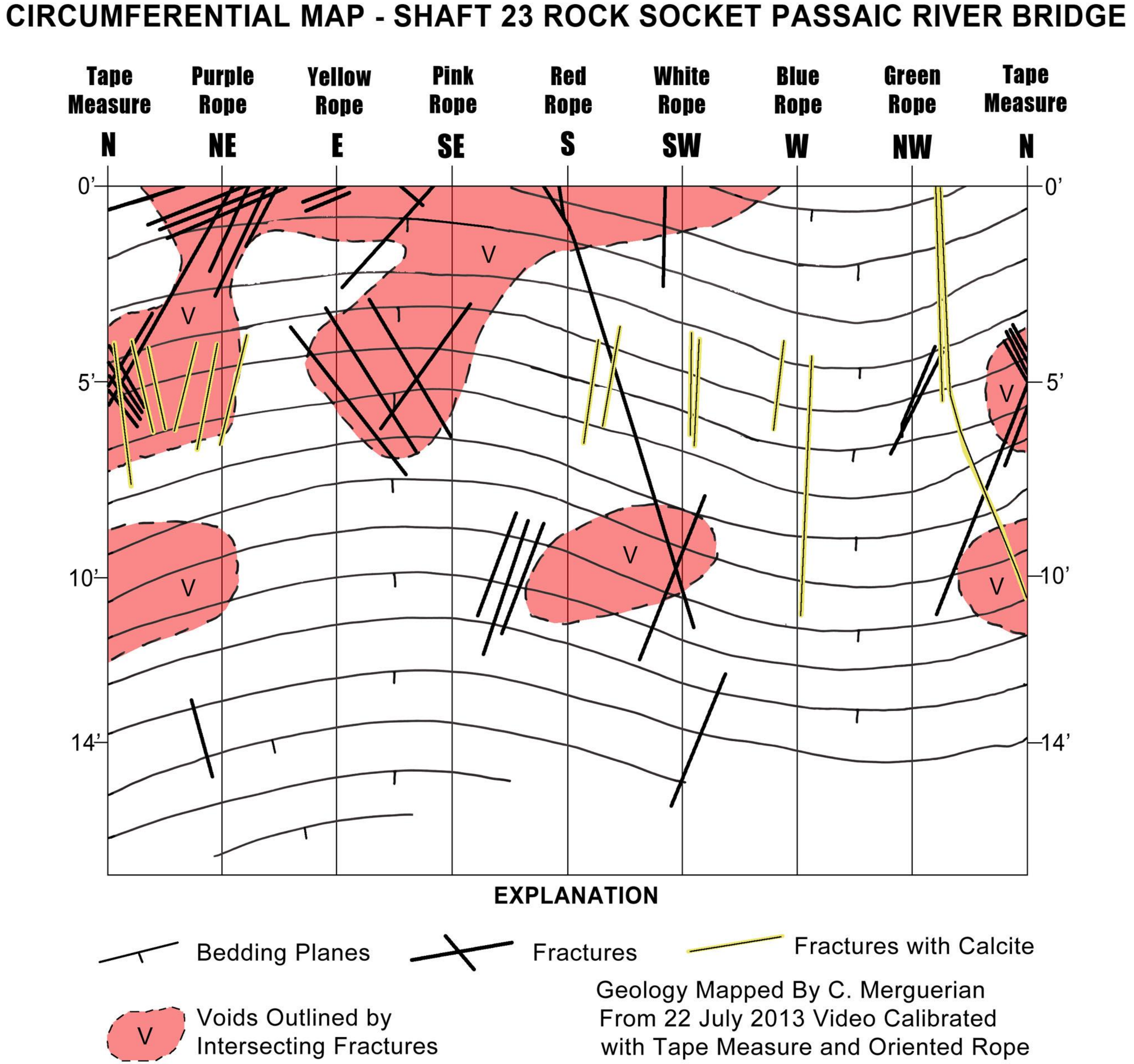
Video Mapping System


Video Mapping System



1:06:17	Bedding sub-horizontal	Beds dip NW	Bedding subhorizontal
1:06:26	Veining	Sub-vertical	Sinuous light-colored (calcite?) vein
1:06:35	Veining	Vertical	Light-colored (calcite?) vein; high-angle fracture dips right
1:07:01	Rope with beds	Beds dip NW	Red Rope = Mag S; Sub-horizontal bedding
1:07:37	Bedding sub-horizontal	Beds dip NW	Sub-horizontal bedding (apparent dip)
1:07:48	Rope; Steep fractures		Pink Rope = Mag SE
1:07:57	Steep fractures	Fractures trend NW	Fractures dip right and left; Angular blocks and voids; Steep NE jnts
1:08:20	Steep fracture	Fracture trends NW	High-angle fracture dips right
1:08:35	Rope	Beds dip NW	Yellow Rope = Mag E; Sub-horizontal bedding (app. dip)
1:08:54	Bedding gently inclined	Beds dip NW	Beds dip gently left
1:09:09	Veining		Vertical calcite (?) vein

2-D Map From Videos

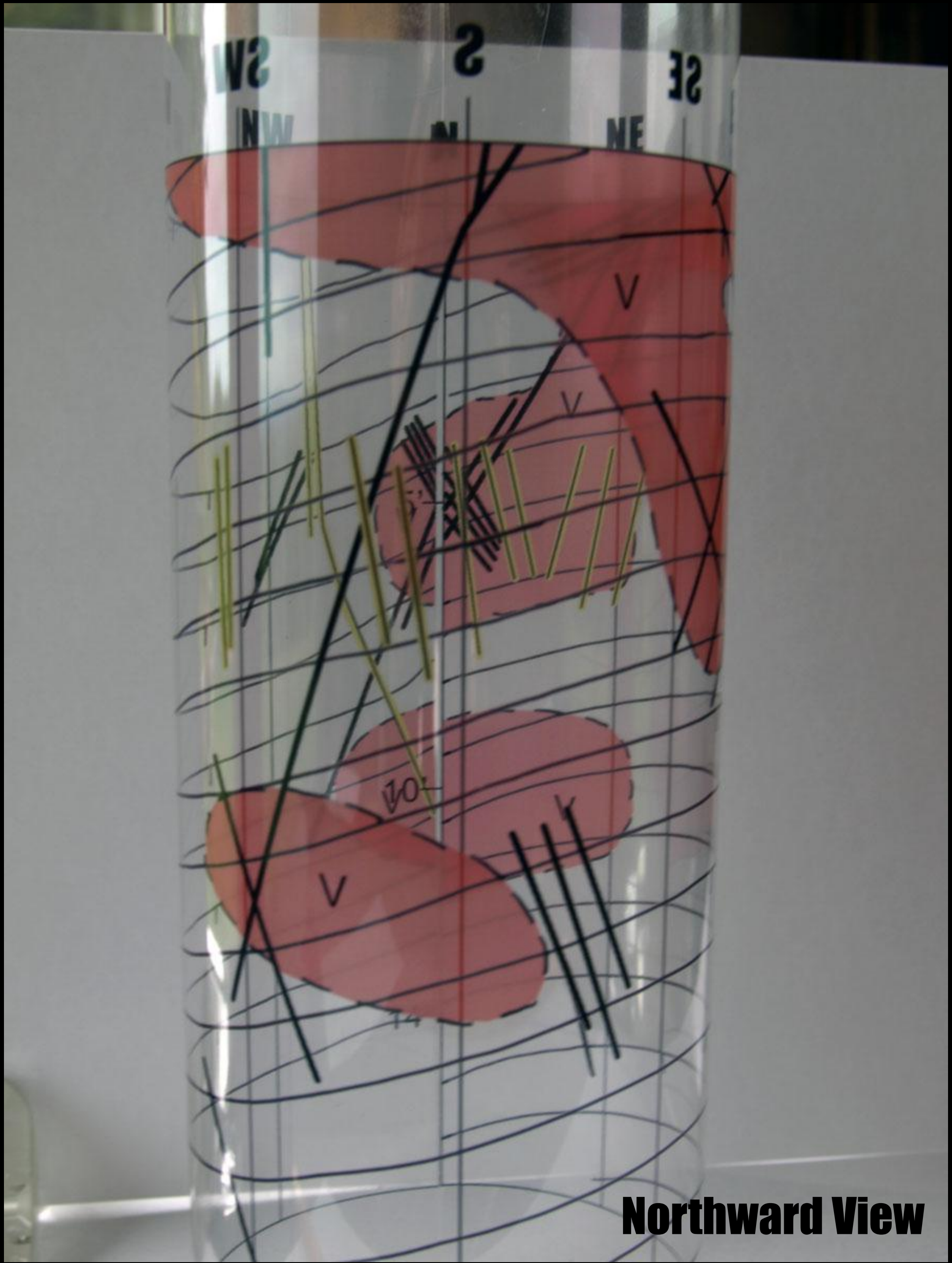


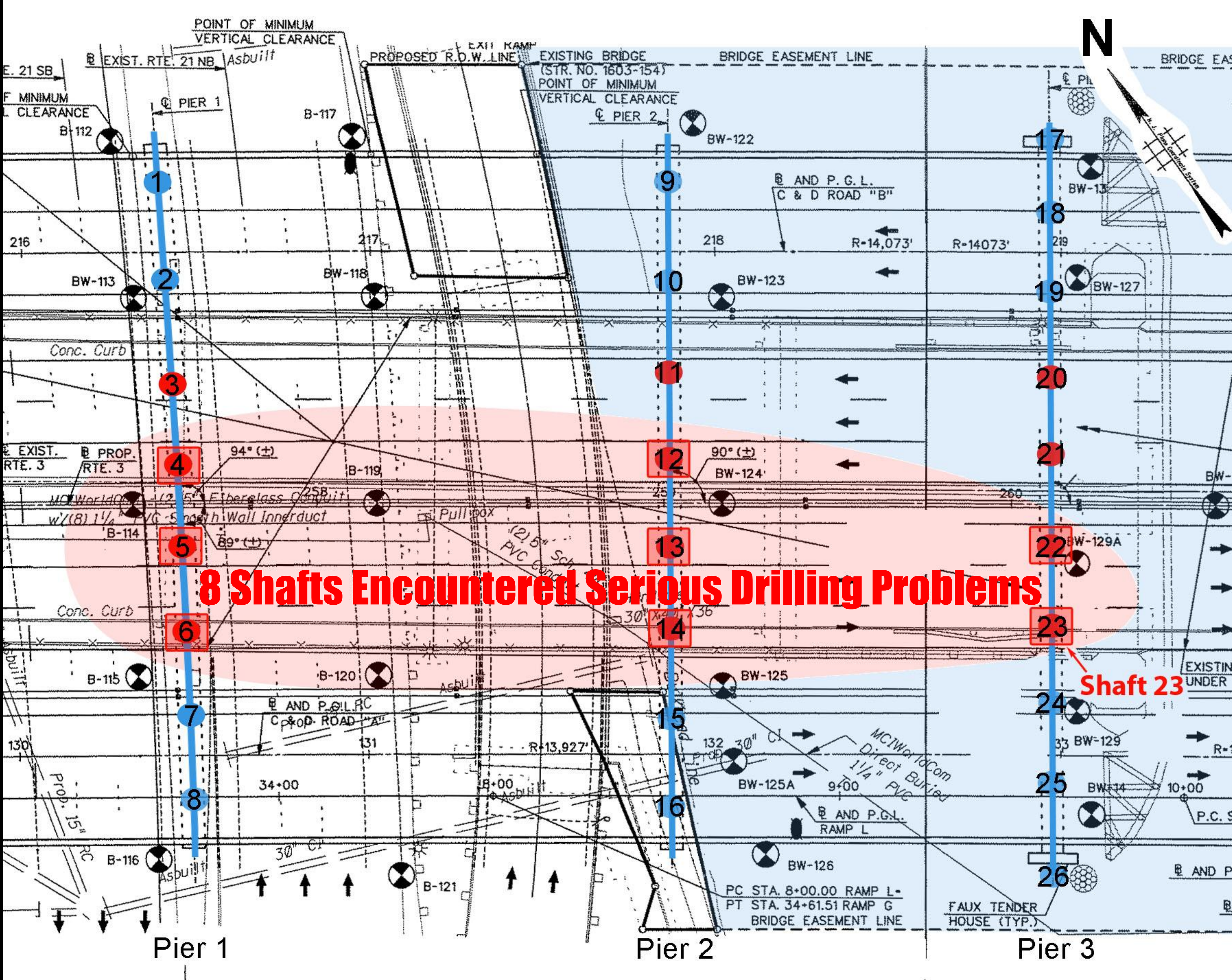
Shaft 23 – Curled 3-D Map on Acetate Detected Three Intersecting Fault Systems

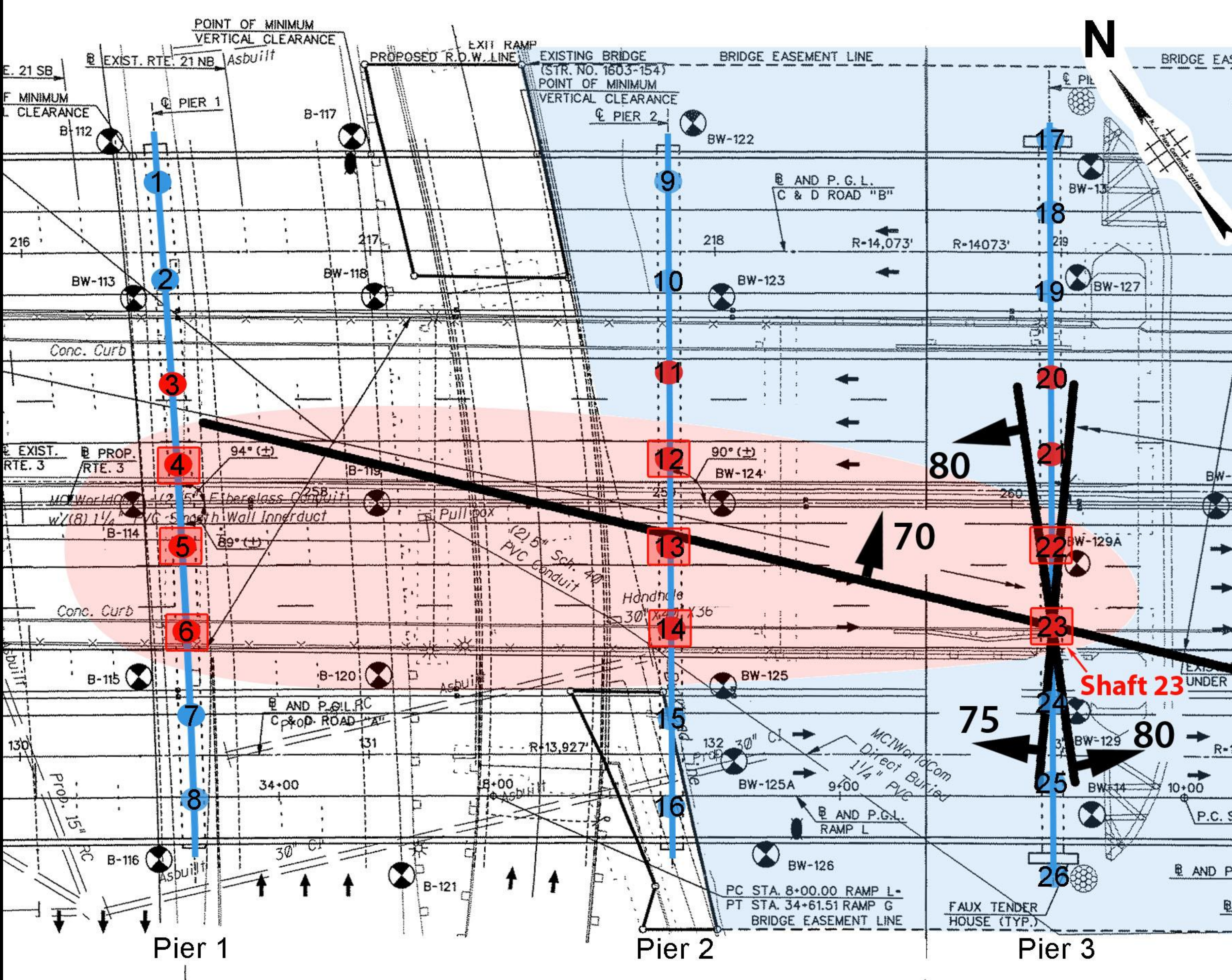
1) N35°E, 75° NW

2) N25°E, 80° SE - 80° NW - Conjugate Set

3) N40°W, 70° NE




N
8 Shafts Encountered Serious Drilling Problems
Shaft 23
Pier 1
Pier 2
Pier 3
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
POINT OF MINIMUM
VERTICAL CLEARANCE
PROPOSED R.O.W. LINE
EXISTING BRIDGE
(STR. NO. 1603-154)
POINT OF MINIMUM
VERTICAL CLEARANCE
BRIDGE EASEMENT LINE
℄ PIER 1
℄ PIER 2
B-112
B-117
BW-122
BW-113
BW-118
BW-123
BW-127
B-119
BW-124
B-114
BW-129A
B-115
B-120
BW-125
BW-129
BW-125A
B-116
B-121
BW-126
℄ AND P.G.L.
C & D ROAD "B"
R=14,073'
R=14073'
Conc. Curb
94° (±)
90° (±)
89° (±)
℄ AND P.G.L.
C & D ROAD "A"
R=13,927'
34+00
9+00
10+00
℄ AND P.G.L.
RAMP L
PC STA. 8+00.00 RAMP L-
PT STA. 34+61.51 RAMP G
BRIDGE EASEMENT LINE
FAUX TENDER
HOUSE (TYP.)
MCIWorldCom
Direct Buried
1 1/4" PVC
Pull box



N
POINT OF MINIMUM VERTICAL CLEARANCE
EXIT RAMP
PROPOSED R.O.W. LINE
EXISTING BRIDGE (STR. NO. 1603-154)
POINT OF MINIMUM VERTICAL CLEARANCE
BRIDGE EASEMENT LINE
℄ EXIST. RTE. 21 NB Asbuilt
℄ PIER 1
℄ PIER 2
B-112
B-117
BW-122
BW-113
BW-118
BW-123
BW-127
℄ AND P.G.L. C & D ROAD "B"
R=14,073'
R=14073'
216
217
218
219
Conc. Curb
℄ EXIST. RTE. 3
℄ PROP. RTE. 3
94° (±)
90° (±)
B-119
BW-124
BW-129A
B-114
89° (±)
Pull box
(2) 5" Sch. 40 PVC Conduit
Handhole
Fiberglass Conduit
Smooth Wall Innerduct
B-115
B-120
BW-125
℄ AND P.G.L. C & D ROAD "A"
R=13,927'
BW-125A
BW-129
BW-14
MCIWorldCom Direct Buried 1¼" PVC
34+00
9+00
10+00
℄ AND P.G.L. RAMP L
B-116
B-121
BW-126
30" CI
PC STA. 8+00.00 RAMP L-
PT STA. 34+61.51 RAMP G
BRIDGE EASEMENT LINE
FAUX TENDER HOUSE (TYP.)
P.C. ST
Shaft 23
80
70
75
80
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
Pier 1
Pier 2
Pier 3

Terrestrial Caissons

As-Built Contractor Experience -

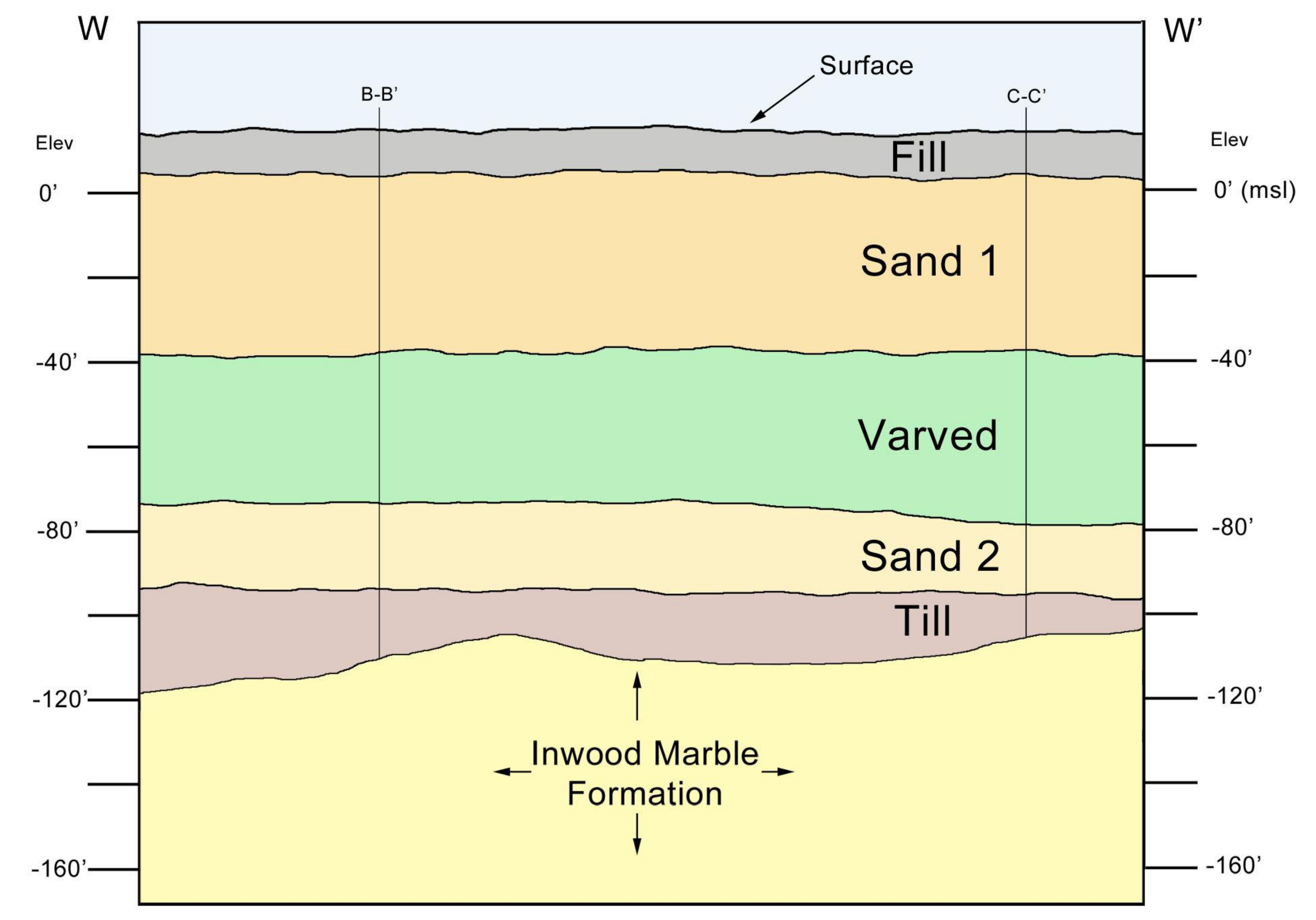
Terrestrial Caissons

As-Built Contractor Experience -

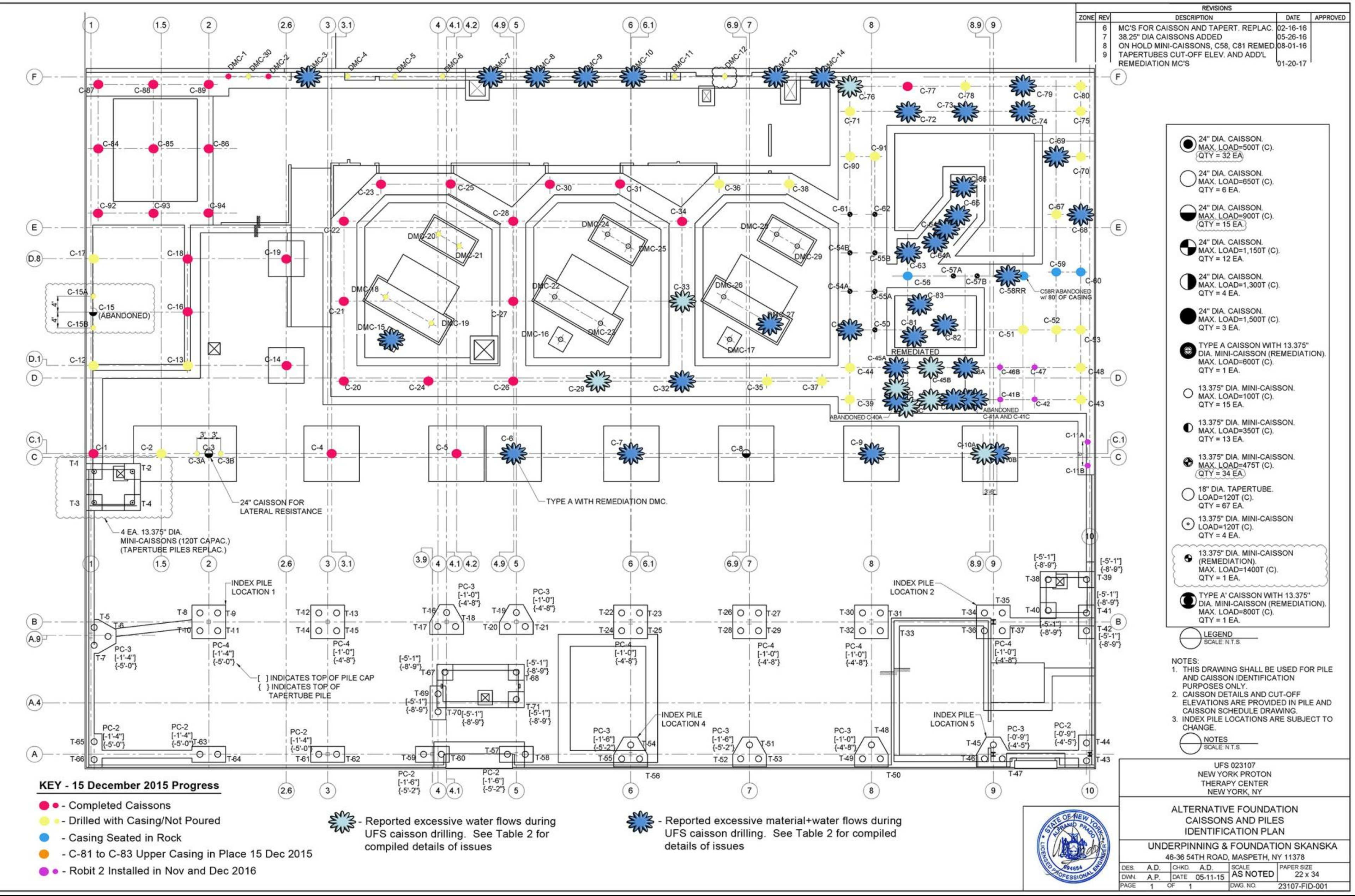
- "heavy water, sand, and rock”
- “excessive water from casing”
- “thick (heavy) sediment inflows up to 25 feet”
- “seams and rock ledges”
- “large rocks and dirty discharge”
- “socket making water”
- “communication between open drill sites”
- “flooding of the jobsite”
- “spoils on the ground”
- “equipment damage including broken shoes, rig tilting, hammer clogging and unanticipated hammer firing“

All From “Job Field Reports”

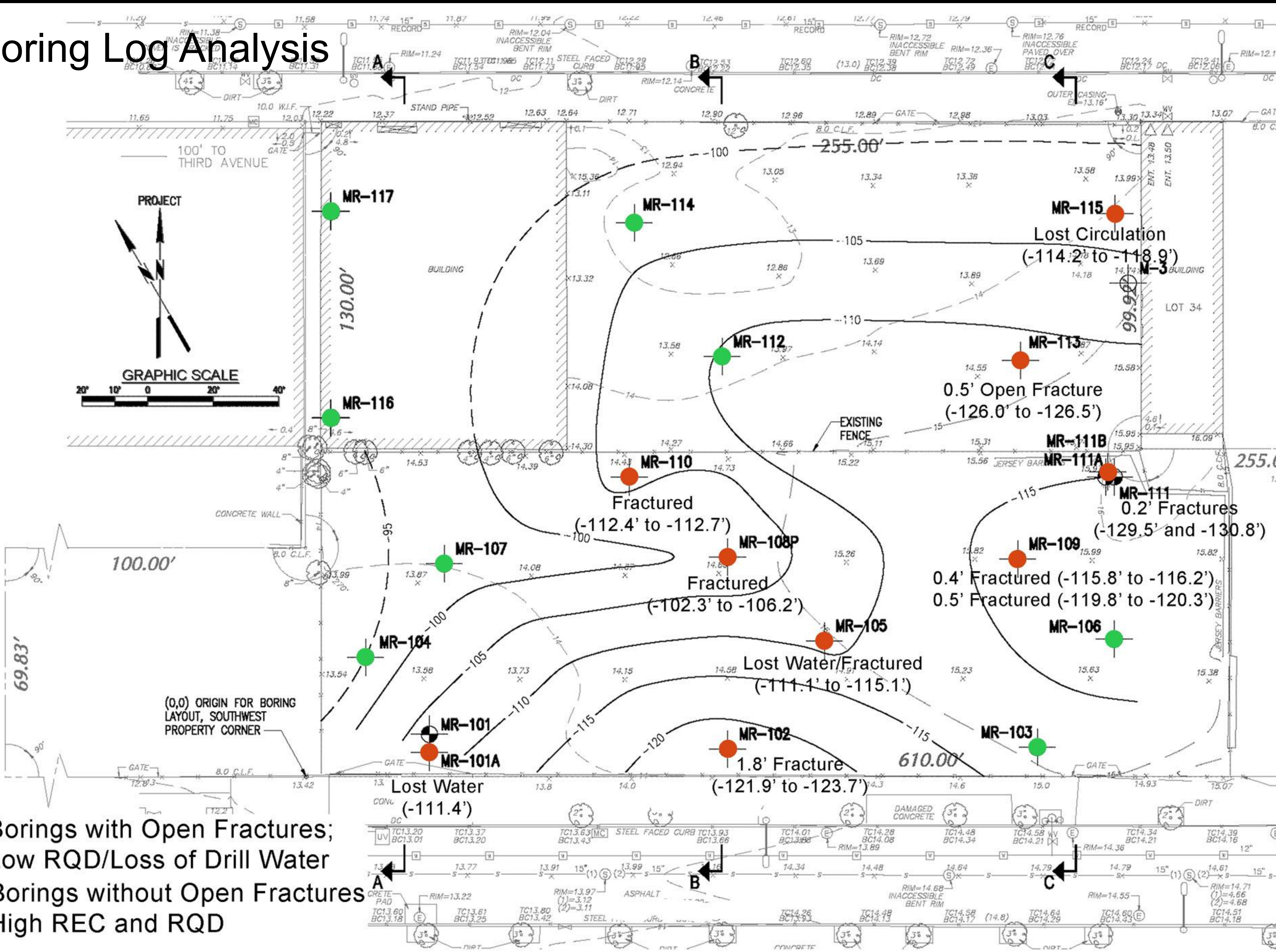
Expectation: Roughly 100' of unconsolidated overburden covering competent marble bedrock – the softest and easiest to drill rock type in NYC!



44 (29.7%) of 148 Caisson Drilling Issues – Same Means/Methods

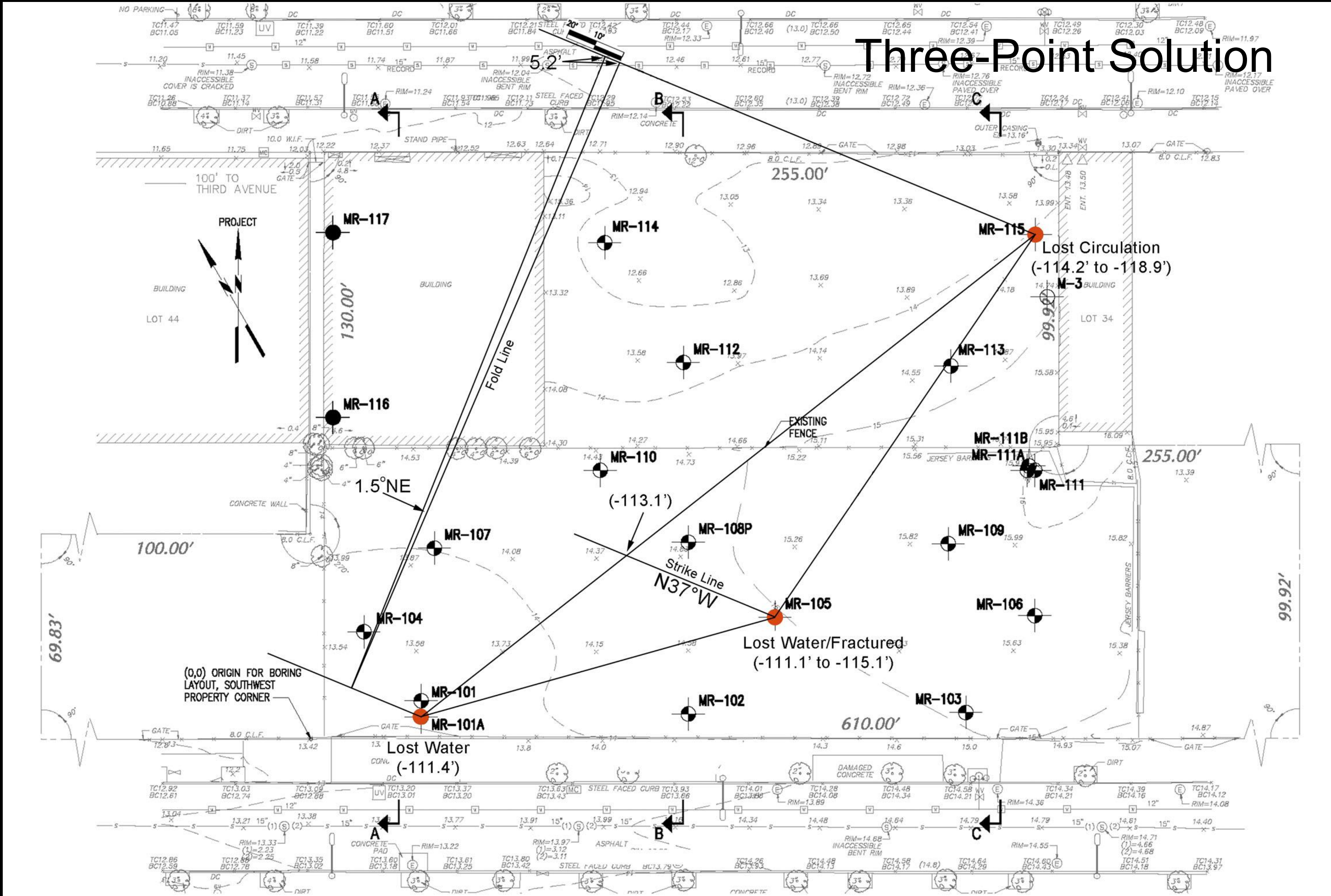


Boring Log Analysis



- Borings with Open Fractures; Low RQD/Loss of Drill Water
- Borings without Open Fractures High REC and RQD

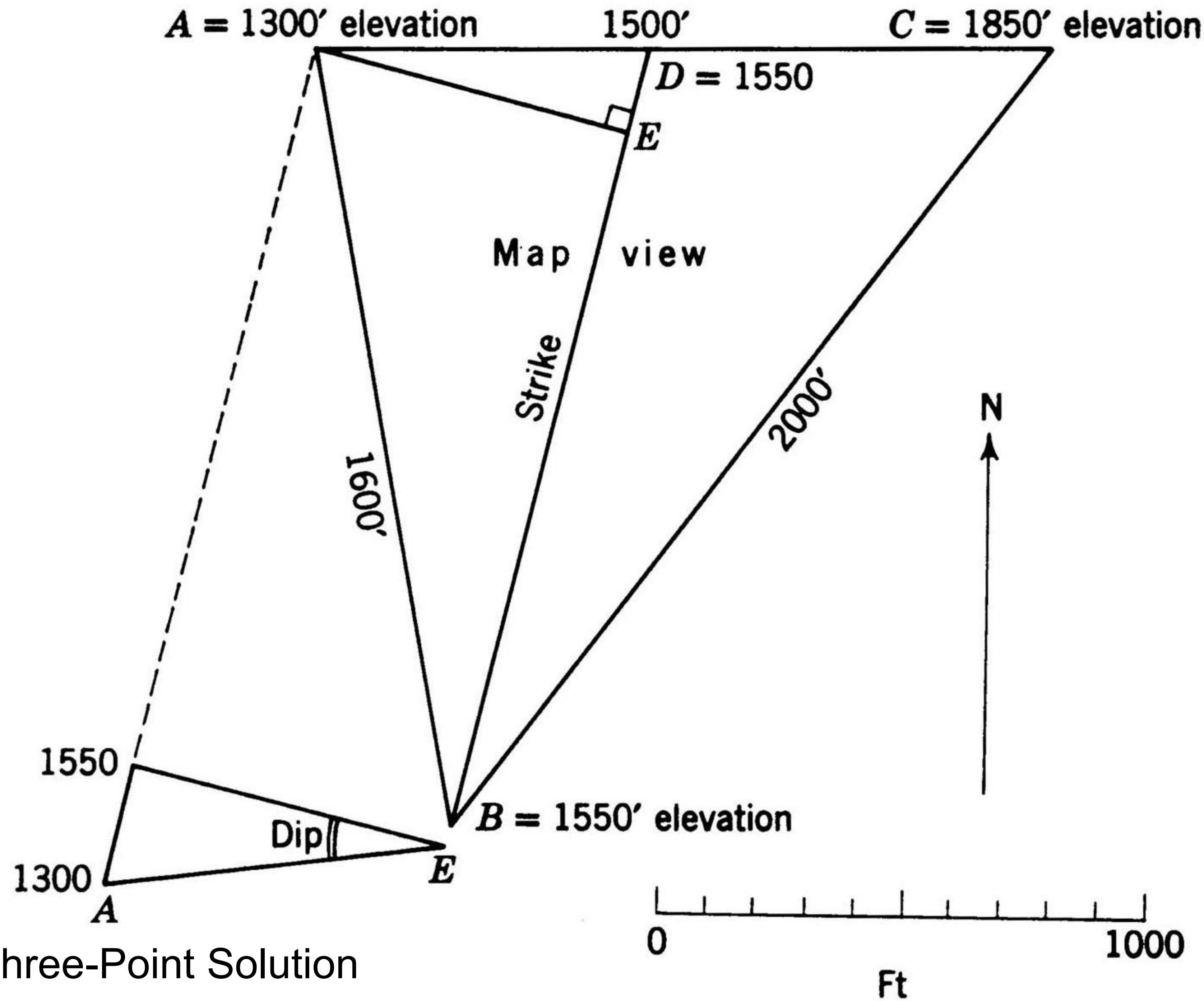
Three-Point Solution



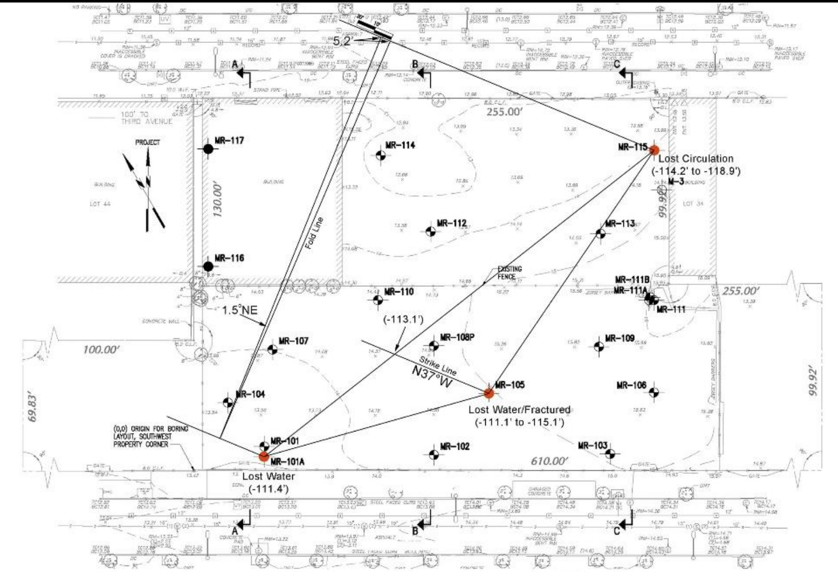
Upper Fracture
Three-Point Problem #1
MR-101A/MR-105/MR-115
Solution = N37°W, 1.5°NE

GRAPHIC SCALE
20' 10' 0 20' 40'

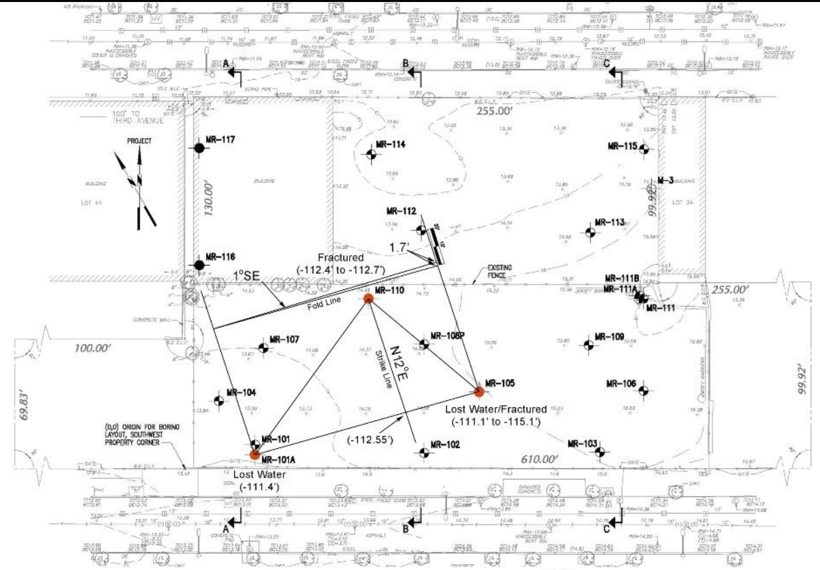
LEGEND:
M-3 – PREVIOUS BORING MADE IN JUNE 2007
MR-101 – BORING MADE IN JUNE 2013
P – PIEZOMETER
MR-117 – PROPOSED ADDITIONAL BORING
Borings with Open Fractures; Low RQD/Loss of Drill Water



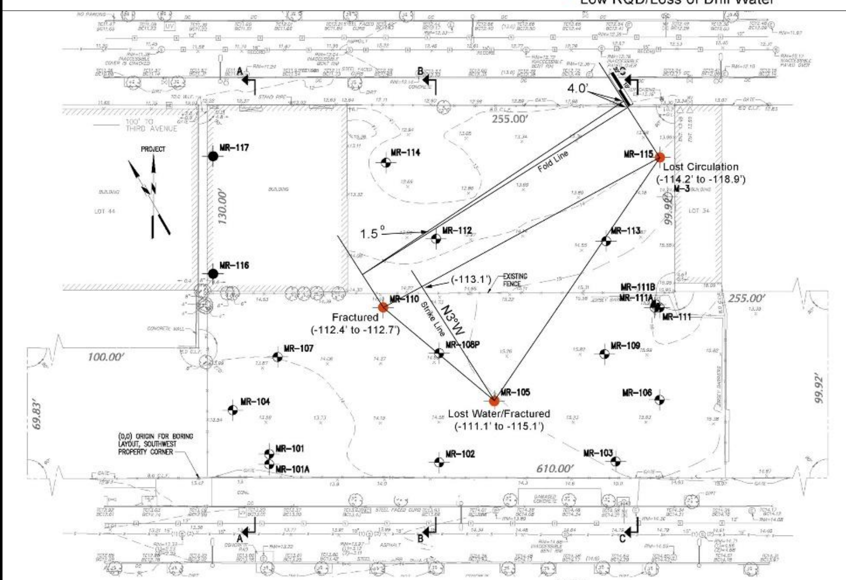
Three-Point Solution



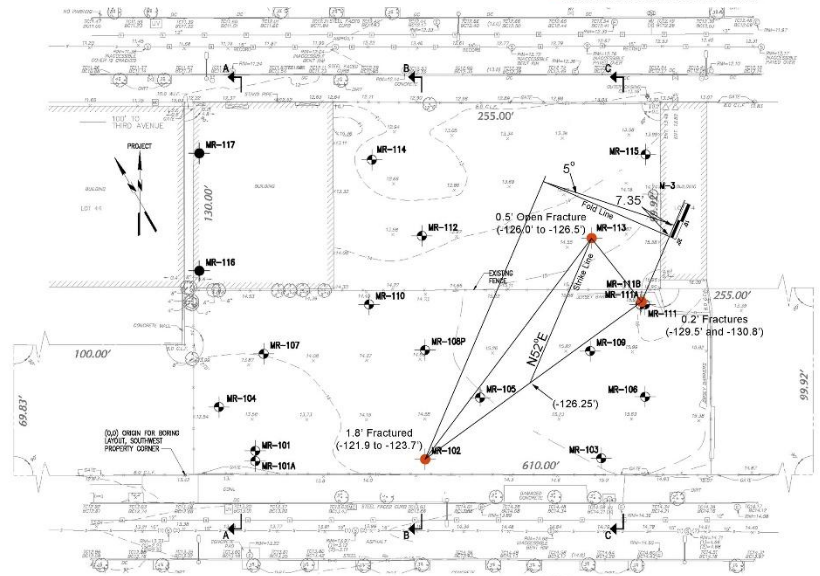
Upper Fracture
Three-Point Problem #1
MR-101A/MR-105/MR-115
Solution = N37°W, 1.5°NE



Upper Fracture
Three-Point Problem #2
MR-101A/MR-105/MR-110
Solution = N12°E, 1°SE



Upper Fracture
Three-Point Problem #3
MR-105/MR-110/MR-115
Solution = N3°W, 1.5°NE



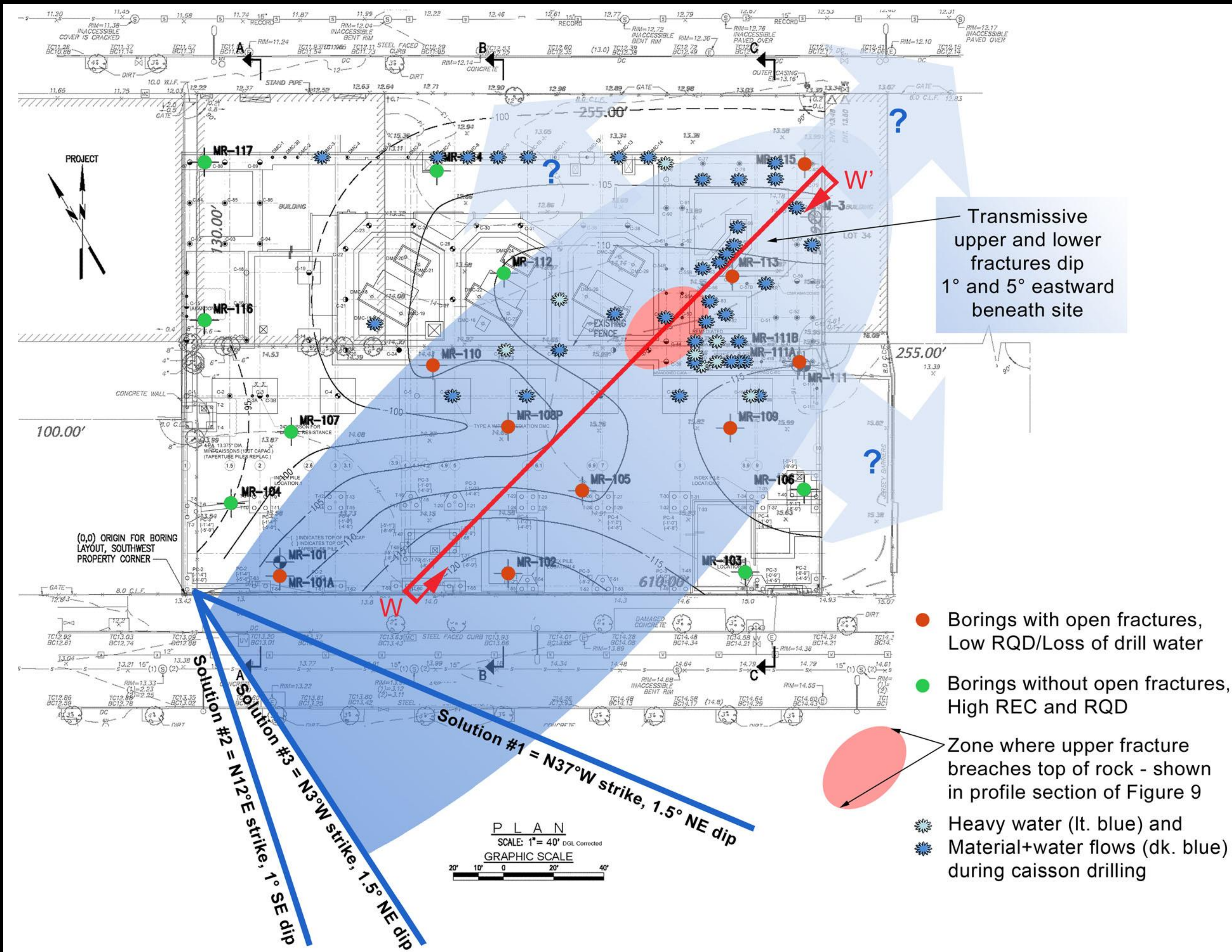
Lower Fracture
Three-Point Problem #4
MR-102/MR-111B/MR-113
Solution = N52°E, 5°SE

• Inspection Videos – Coarse-Textured Calcite Marble

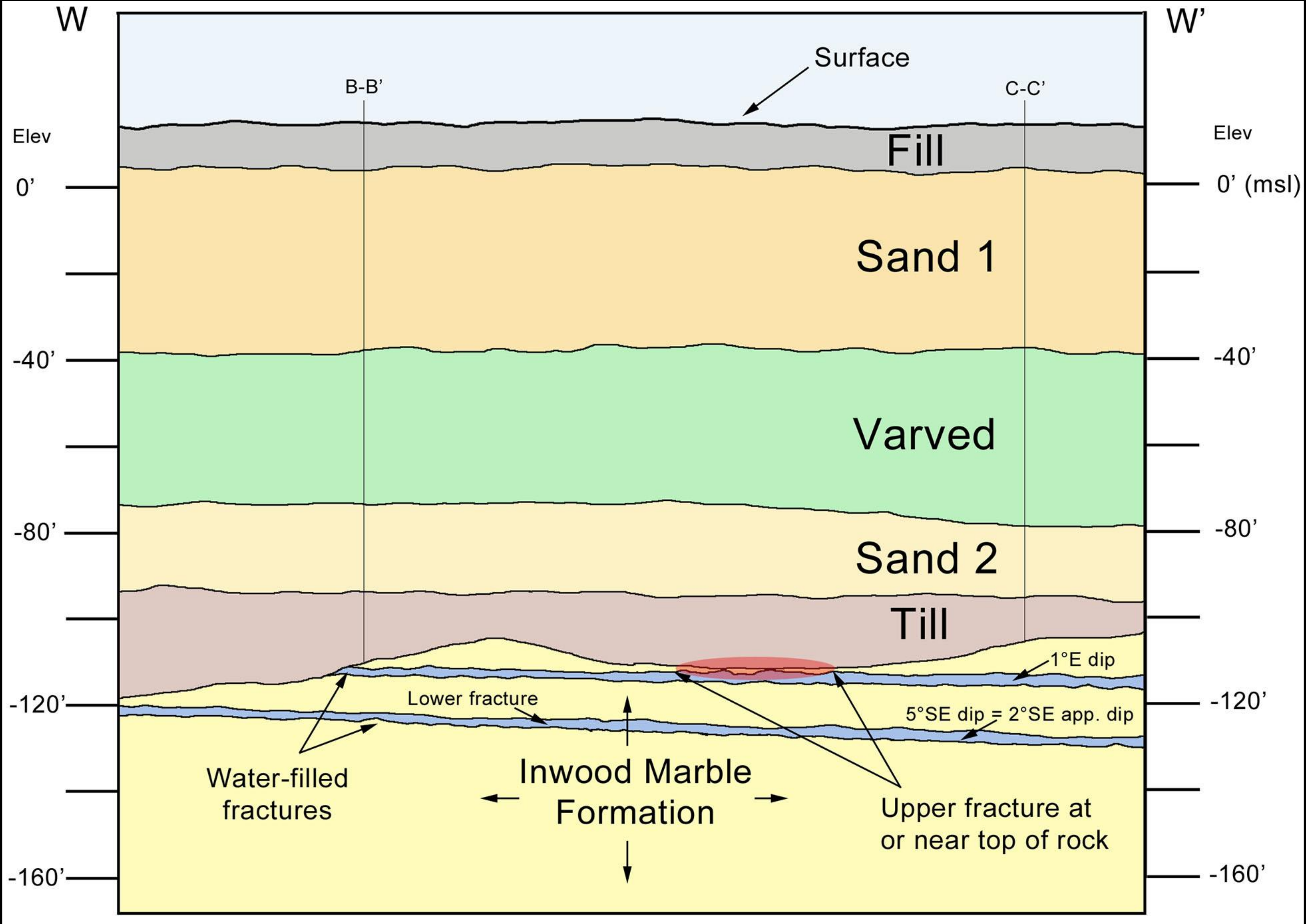
C-5 Socket

Upper Fracture Zone

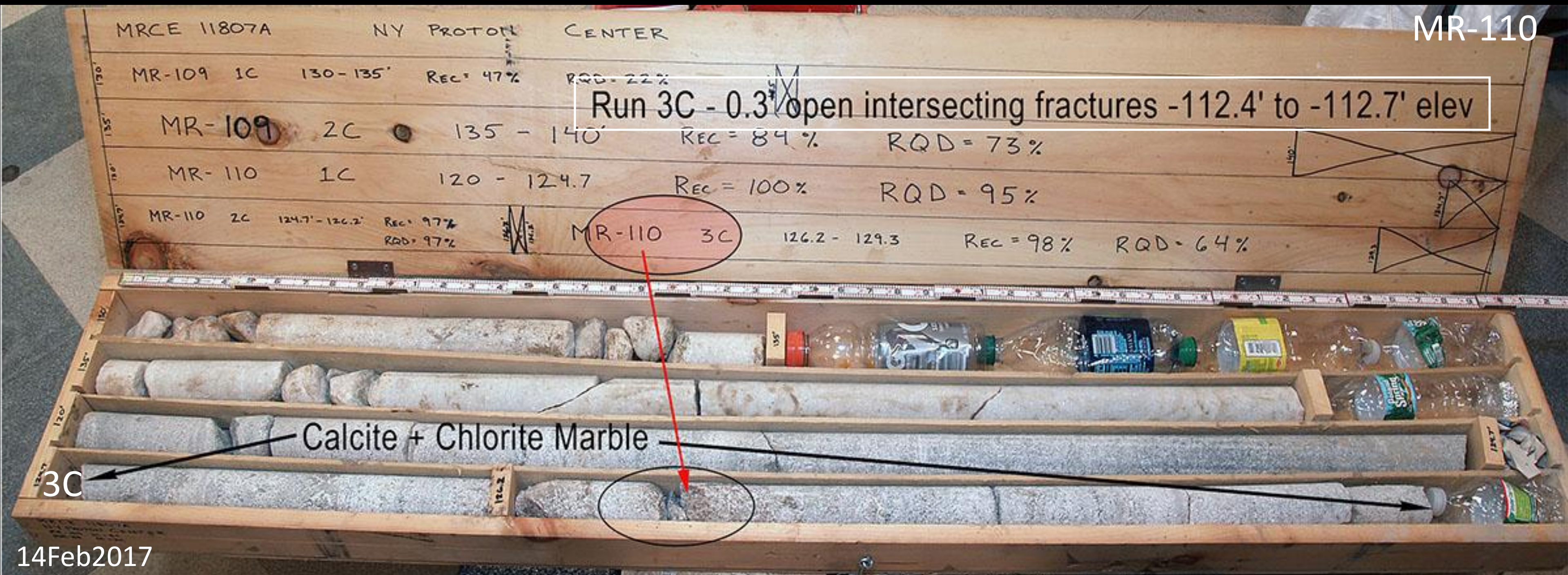
Lower Fracture Zone



Transmissive upper and lower fractures dip 1° and 5° eastward beneath site
W
W'
?
MR-117
MR-116
MR-112
MR-113
MR-115
MR-110
MR-111B
MR-111A
MR-111
MR-107
MR-108P
MR-109
MR-105
MR-106
MR-104
MR-101
MR-101A
MR-102
MR-103
N-3
LOT 34
BUILDING
EXISTING FENCE
CONCRETE WALL
PROJECT
(0,0) ORIGIN FOR BORING LAYOUT, SOUTHWEST PROPERTY CORNER
255.00'
130.00'
100.00'
610.00'
Solution #1 = N37°W strike, 1.5° NE dip
Solution #2 = N12°E strike, 1° SE dip
Solution #3 = N3°W strike, 1.5° NE dip
PLAN
SCALE: 1"= 40' DGL Corrected
GRAPHIC SCALE
20' 10' 0 20' 40'
Borings with open fractures, Low RQD/Loss of drill water
Borings without open fractures, High REC and RQD
Zone where upper fracture breaches top of rock - shown in profile section of Figure 9
Heavy water (lt. blue) and Material+water flows (dk. blue) during caisson drilling



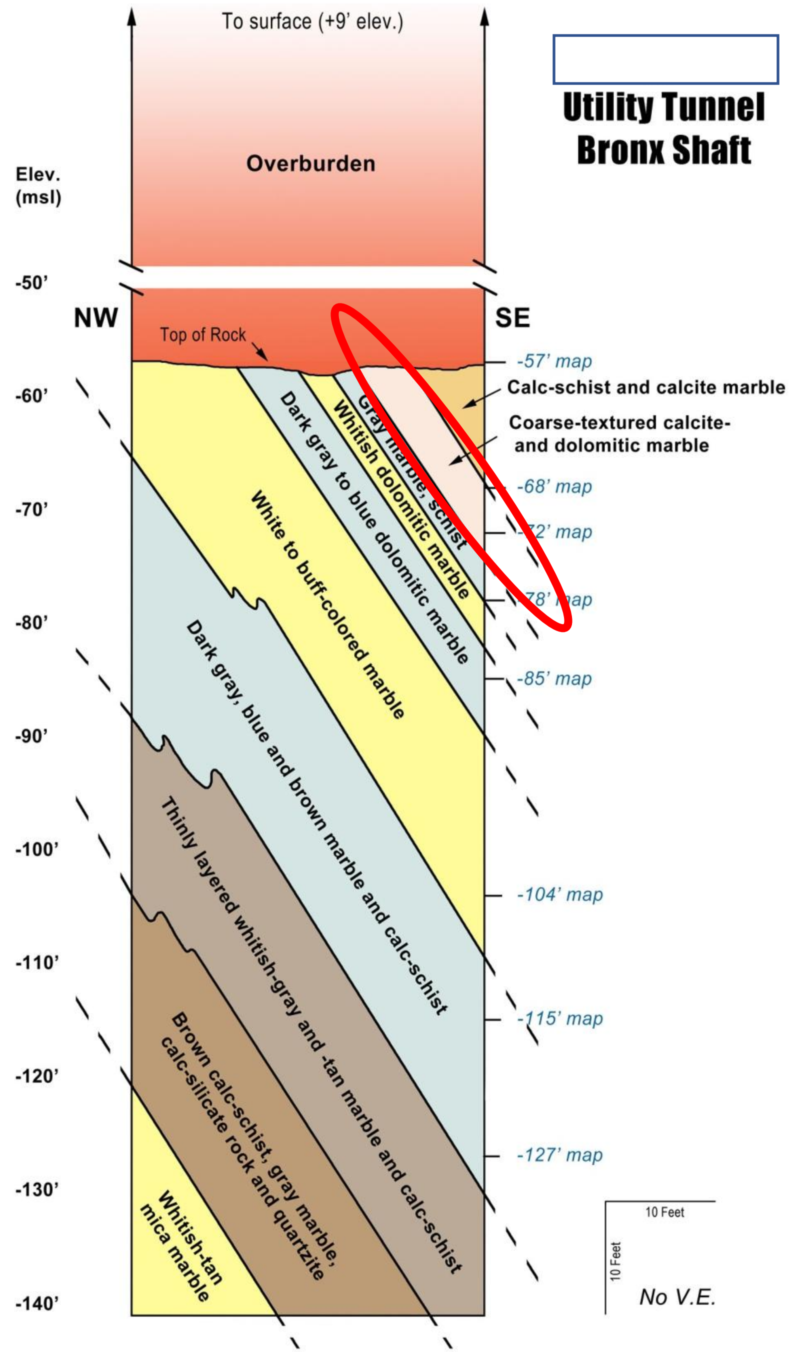
W
W'
Surface
B-B'
C-C'
Elev
Elev
Fill
0'
0' (msl)
Sand 1
-40'
-40'
Varved
-80'
-80'
Sand 2
Till
1°E dip
-120'
-120'
Lower fracture
5°SE dip = 2°SE app. dip
Water-filled fractures
Inwood Marble Formation
Upper fracture at or near top of rock
-160'
-160'


MR-110
MRCE 11807A NY PROTON CENTER
MR-109 1C 130-135' REC= 47% RQD= 22%
MR-109 2C 135 - 140' REC = 84% RQD = 73%
MR-110 1C 120 - 124.7 REC = 100% RQD = 95%
MR-110 2C 124.7'-126.2' REC= 97% RQD= 97%
MR-110 3C 126.2 - 129.3 REC = 98% RQD = 64%
Run 3C - 0.3' open intersecting fractures -112.4' to -112.7' elev
Calcite + Chlorite Marble
3C
14Feb2017


MR-115
MRCE 11807A NY PROTON CENTER
RUN 1C 118.3 to 123.3 REC= 97% RQD= 83%
RUN 2C 123.3 to 127.8 REC 100% RQD= 85%
RUN 3C 127.8 to 132.8 REC=100% RQD= 92%
RUN 4C 132.8 to 134.3 REC= 83% RQD= 83%
EMPTY
Run 3C - Loss of circulation -114.2' to -118.9' elev.
3C
Calcite Marble
14Feb2017

Sub-unit	Thickness (Feet)
1 - Calc-schist and calcite marble	> 6’; top not exposed
2 - Coarse-textured calcite- and dolomitic marble	4.0
3 - Dark gray marble and calc-schist	3.0
4 - White to buff-colored dolomitic marble	2.0
5 - Dark gray to blue dolomitic marble	5.0
6 - White to buff-colored marble	11.0
7 - Dark gray, blue and brown marble, calc-schist	11.0
8 - Thinly layered whitish-gray and -tan marble and calc-schist	10.5
9 - Brown calc-schist, gray marble, calc-silicate rock and quartzite	11.5
10 - Whitish-tan micaceous marble	>11.5’; base not exposed

Aggregate thickness exposed > 75.5’



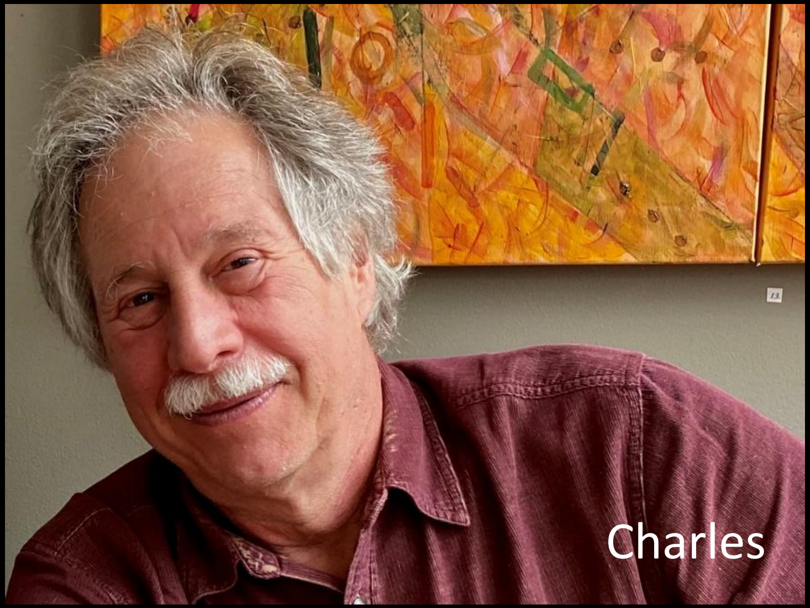
Merguerian, Merguerian and Cherukupalli 2011

100' of Water Saturated Overburden + Coarse Calcite Marble + Unanticipated Fractured Bedrock Breaching Top of Rock = Water, Water, Everywhere = Valid Differing Site Condition Claim

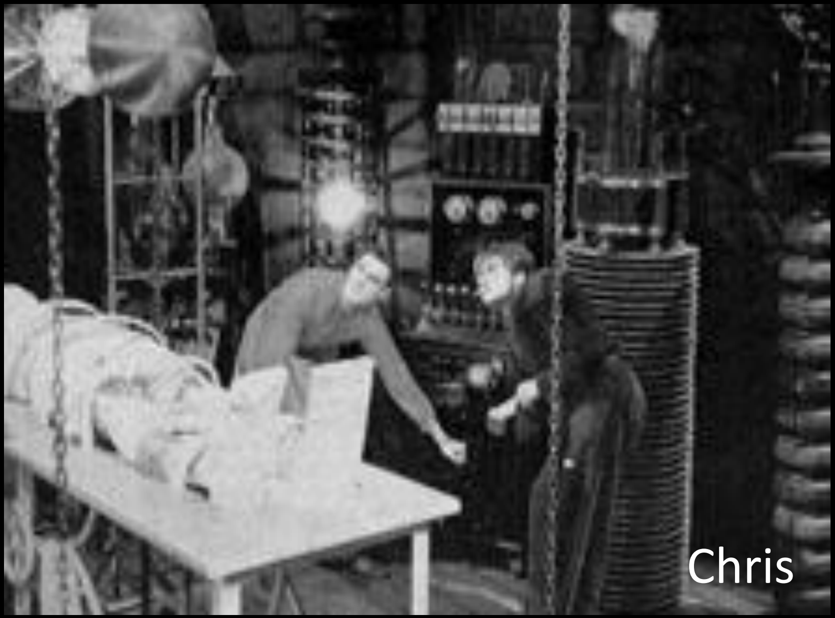
Duke Geological Lab

Full Service Geotechnical Analysis

www.Dukelabs.com
www.DukelabsDSC.com



Charles



Chris

Mickey