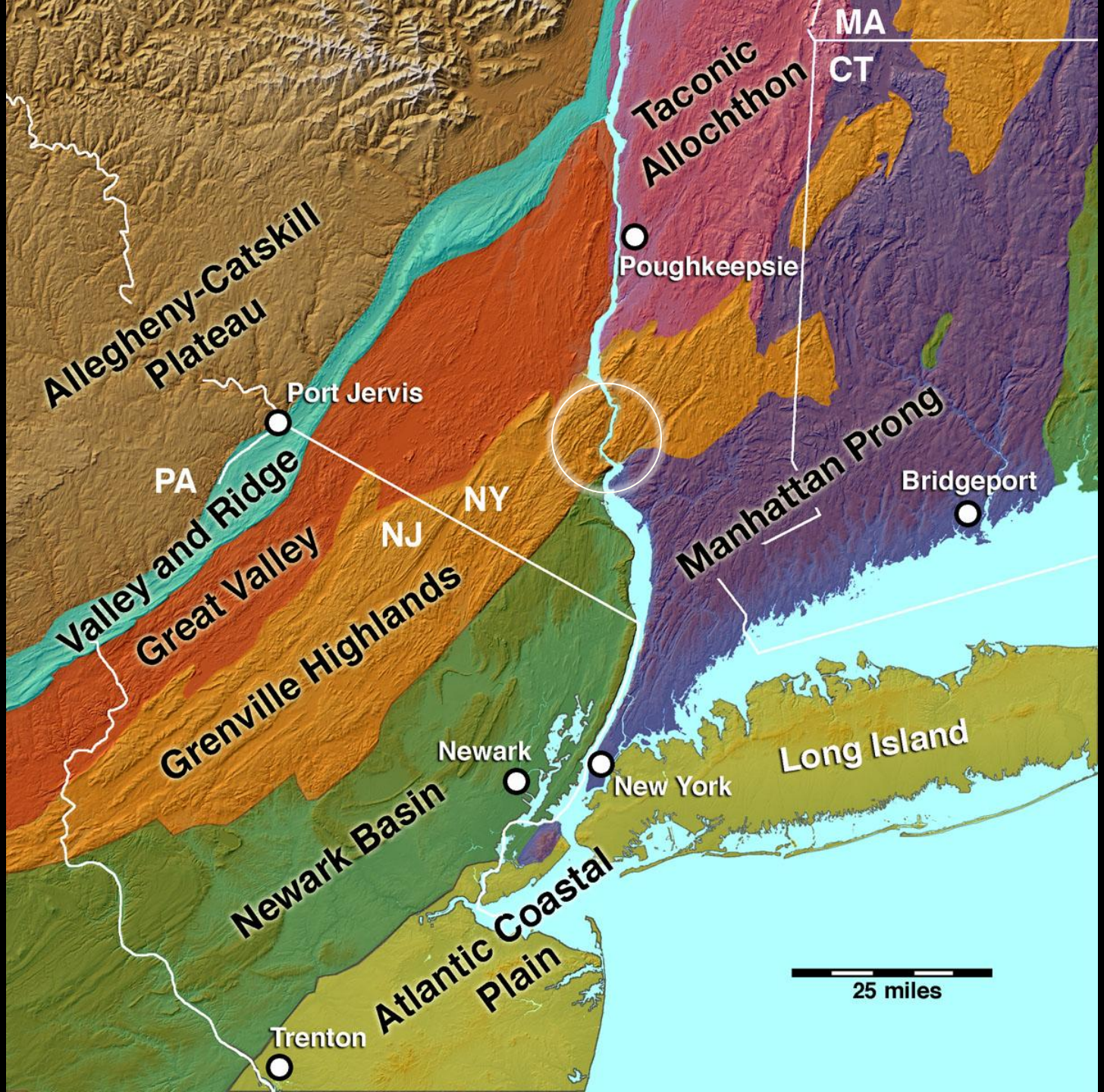
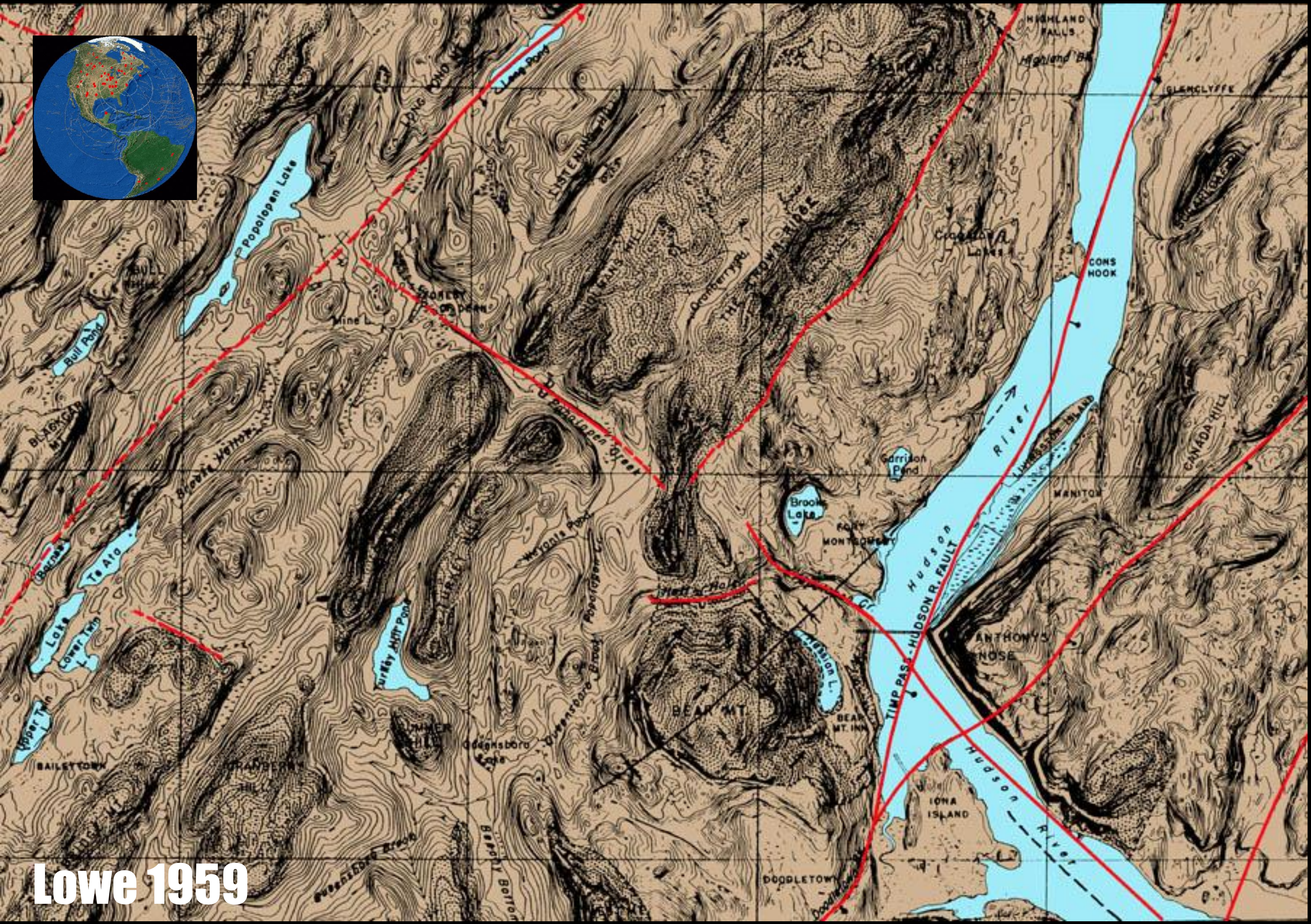
Review of New York City Bedrock with a Focus on Brittle Structures

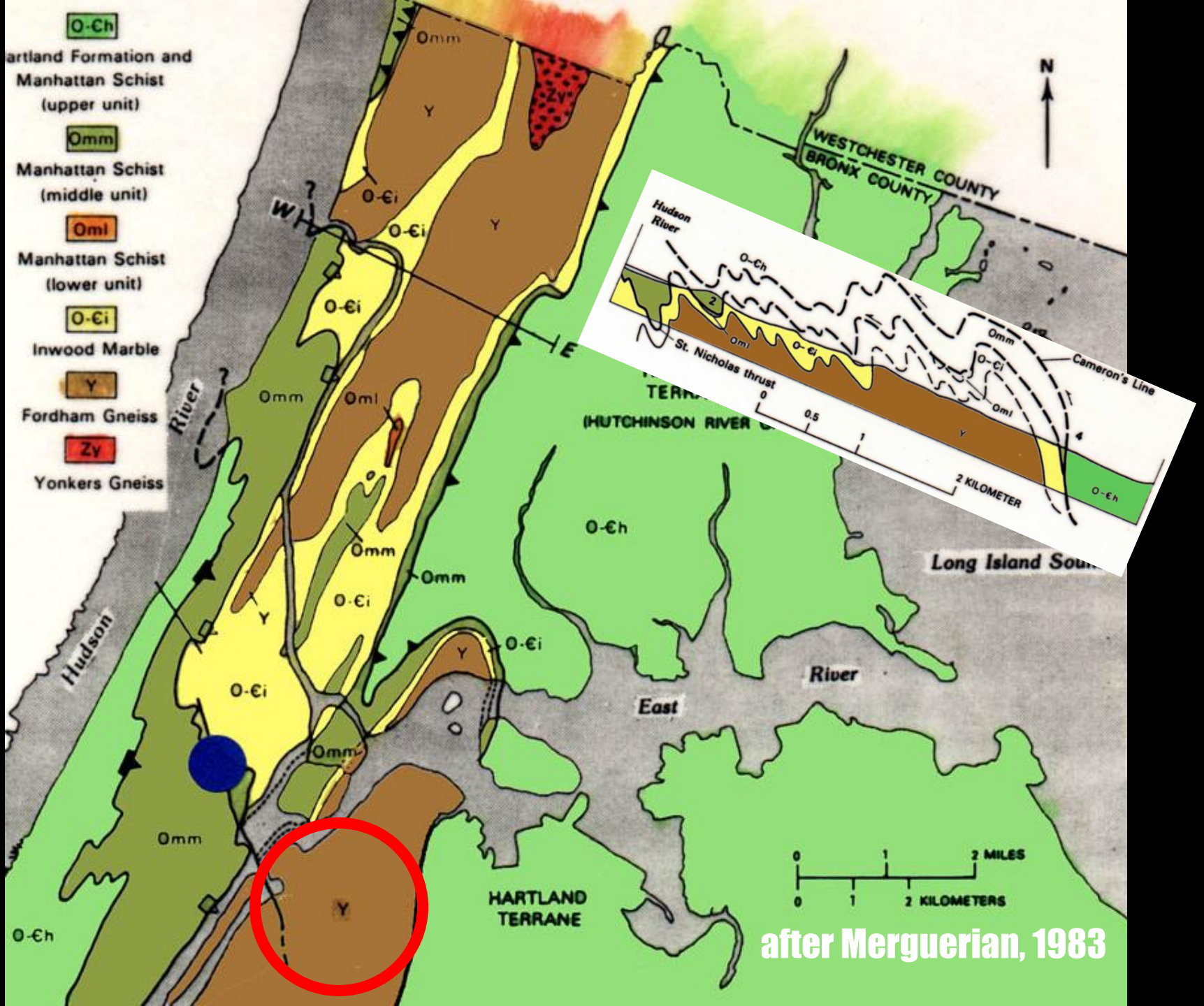
Charles Merguerian

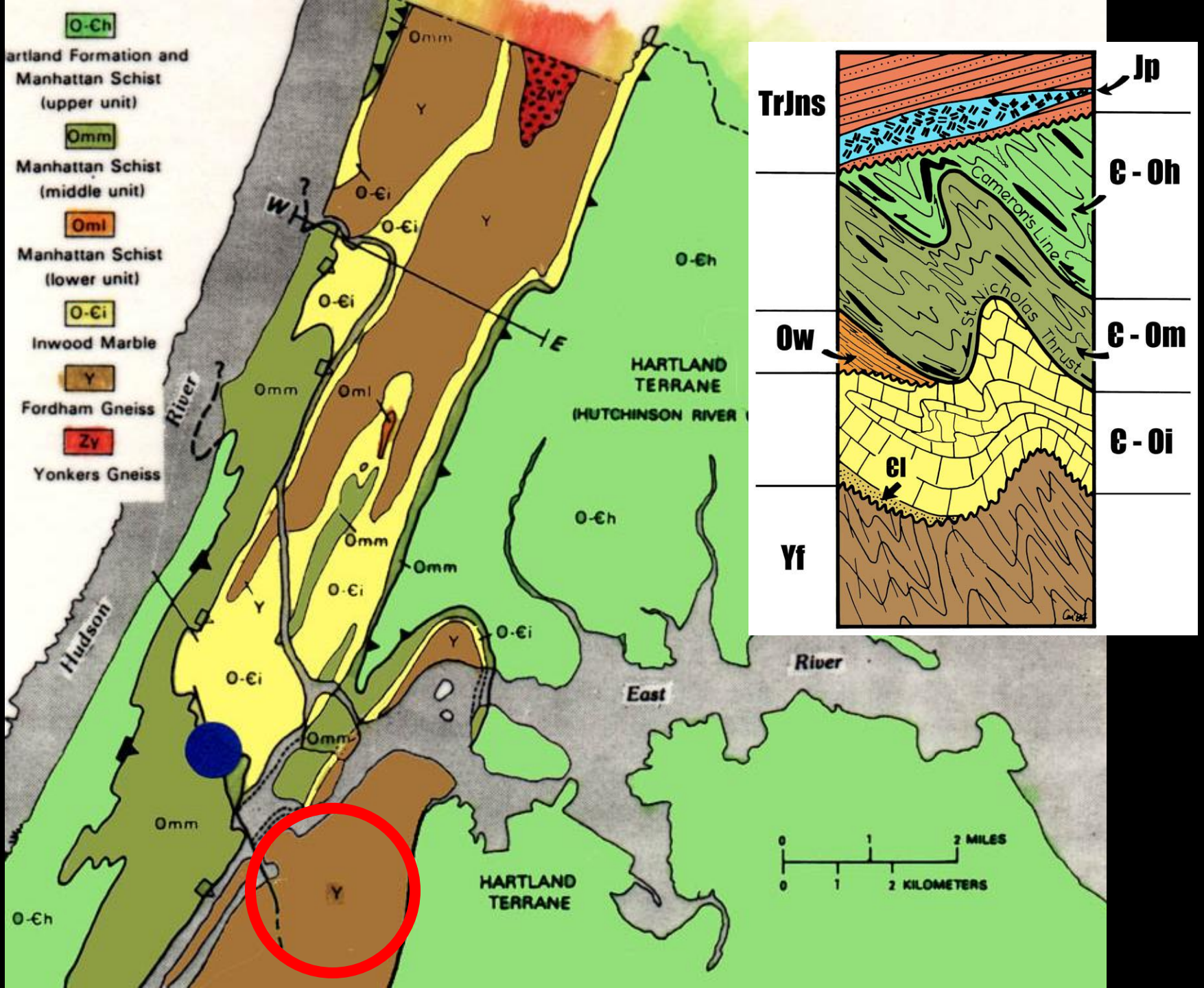
GANJ 2015

16 October 2015


MA
CT
Taconic Allochthon
Poughkeepsie
Allegheny-Catskill Plateau
Port Jervis
PA
NY
NJ
Valley and Ridge
Great Valley
Grenville Highlands
Manhattan Prong
Bridgeport
Newark
New York
Long Island
Newark Basin
Atlantic Coastal Plain
Trenton
25 miles


Lowe 1959
HIGHLAND FALLS
GLENCLYFFE
Long Pond
Popolopen Lake
Bull Pond
Mine L.
CONS HOOK
Garrison Pond
Brooks Lake
FORT MONTGOMERY
Hudson River
HUDSON R. FAULT
TIMP PASS
ANTHONY'S NOSE
BEAR MT.
BEAR MT. INN
MANITOU
CANADA HILL
IONA ISLAND
DOODLETOWN
BAILEYTOWN
Lake
Lower Twin
Upper Twin
Te Ata
SUMMER HILL
CRANBERRY HILL
Turkey Hill Pond


O-Ch
artland Formation and
Manhattan Schist
(upper unit)
Omm
Manhattan Schist
(middle unit)
Oml
Manhattan Schist
(lower unit)
O-€i
Inwood Marble
Y
Fordham Gneiss
Zy
Yonkers Gneiss
N
WESTCHESTER COUNTY
BRONX COUNTY
Hudson River
O-Ch
Oml
O-€i
Omm
Cameron's Line
St. Nicholas thrust
0
0.5
1
2 KILOMETER
O-€h
(HUTCHINSON RIVER
Long Island Sou
River
East
HARTLAND
TERRANE
0
1
2 MILES
0
1
2 KILOMETERS
after Merguerian, 1983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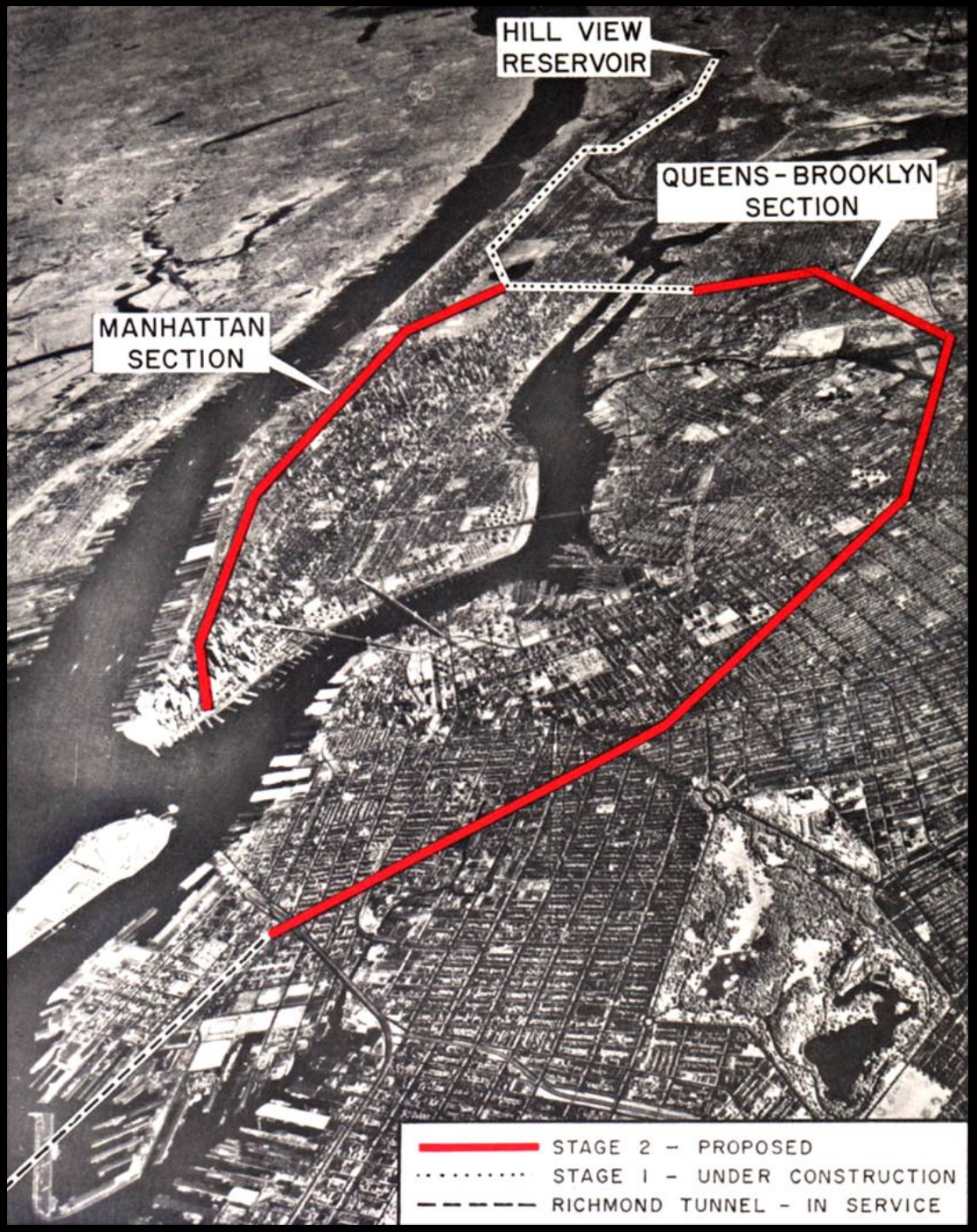
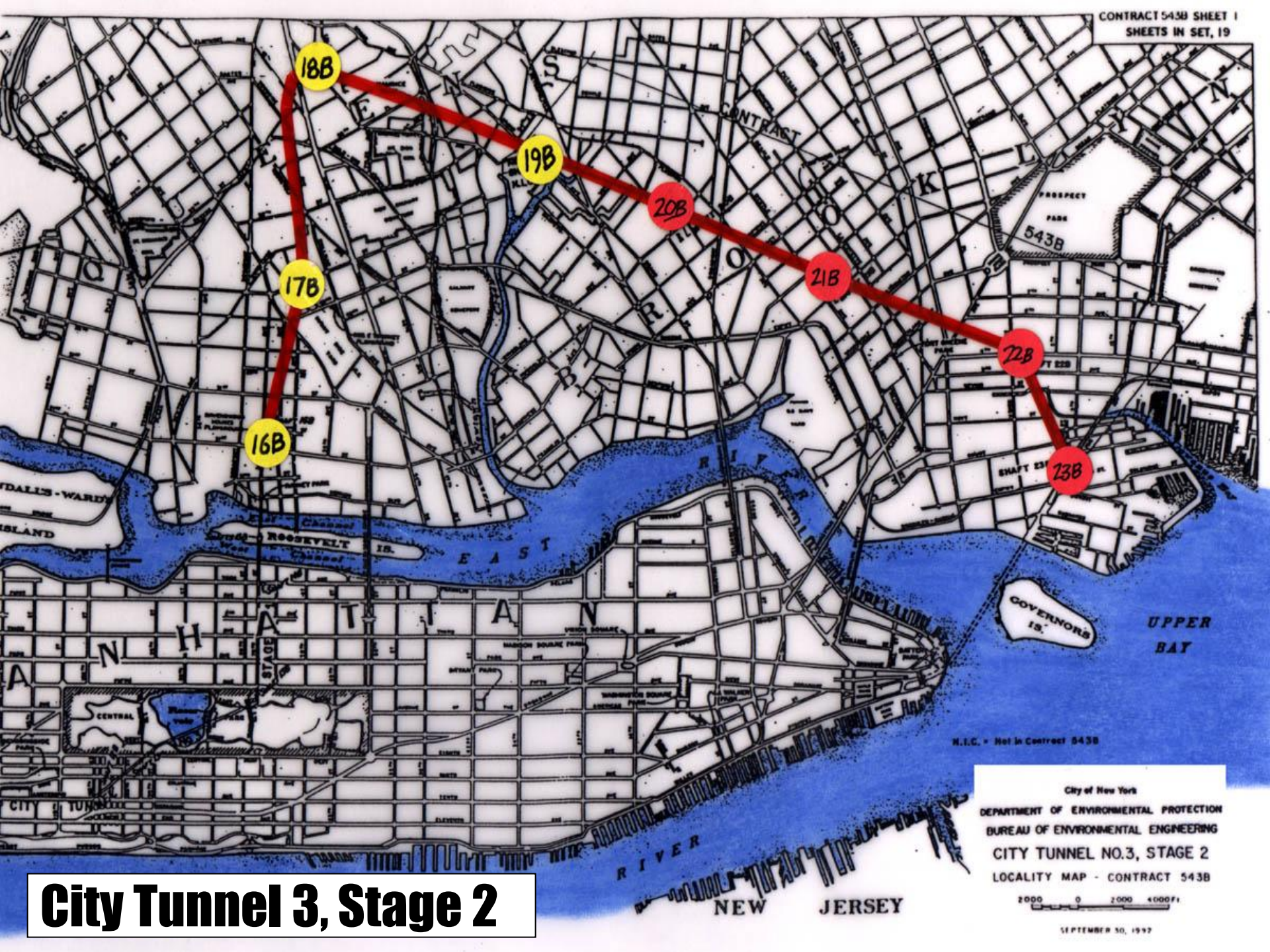
Cameron's Line
St. Nicholas Thrust
C - Oh
C - Om
C - Oi

City Tunnel 3
Stages 1 and 2



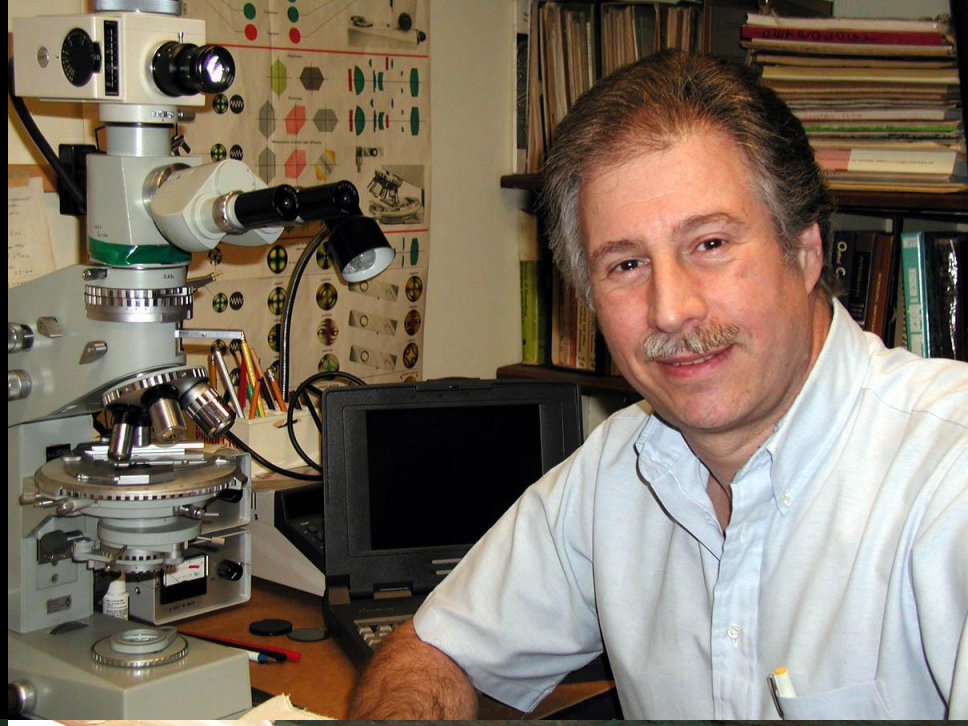


City Tunnel 3, Stage 2

Duke Geological Lab

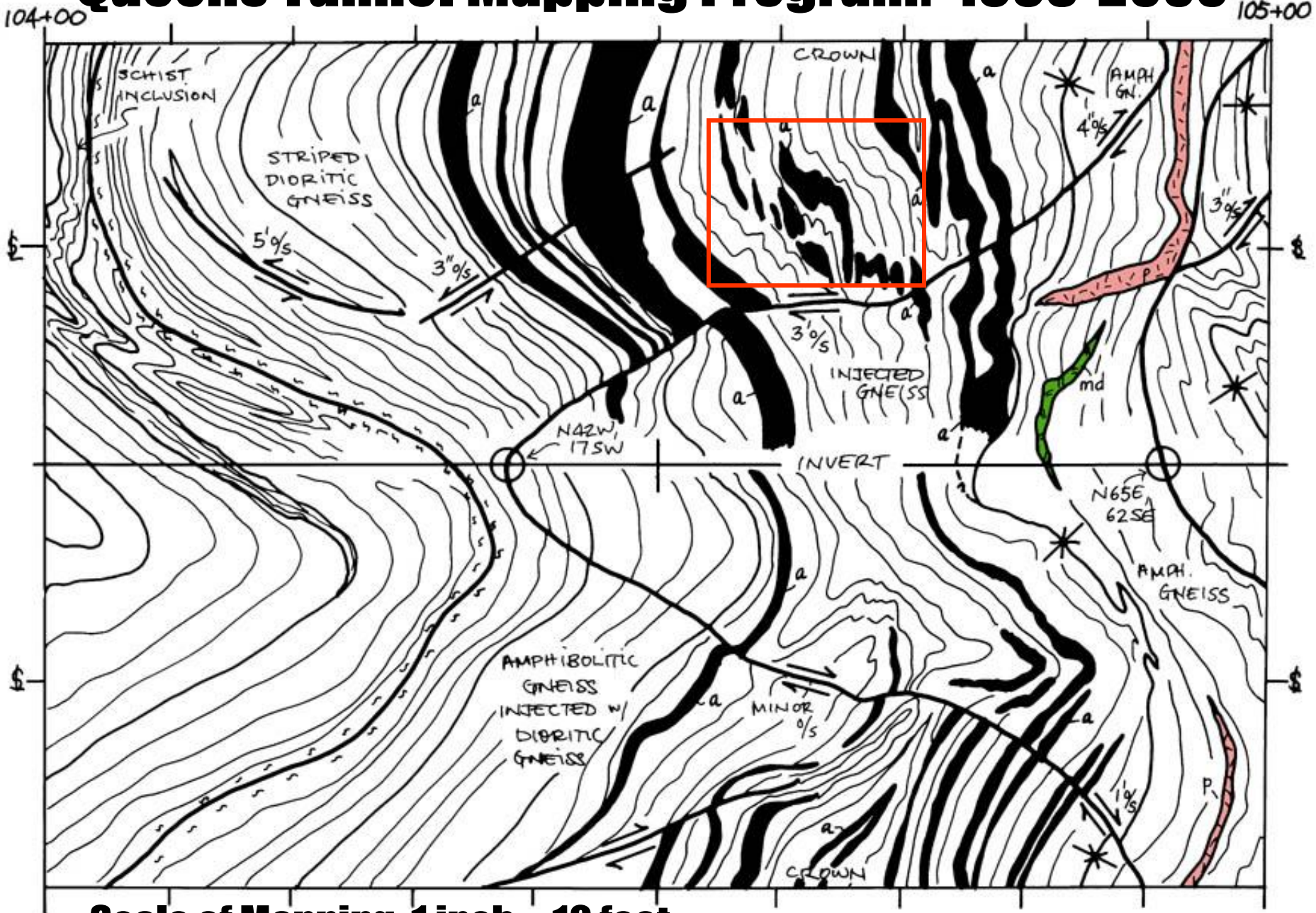
Full Service Geotechnical Tunneling Analysis

www.dukelabs.com



Dukelabs
Queens Tunnel
Field Office
No Windows!

Queens Tunnel Mapping Program: 1998-2000



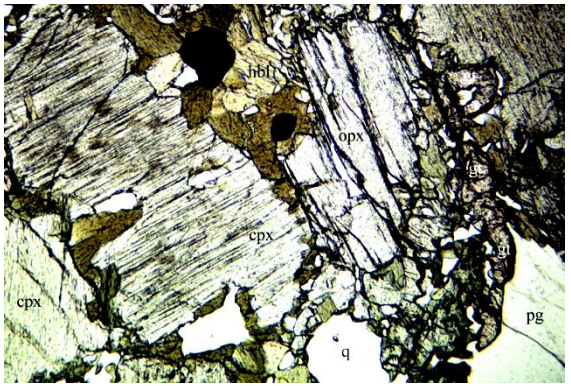
- Scale of Mapping: 1 inch = 10 feet

Mafic Gneiss Xenoliths in Tonalitic Gneiss


Folded Garnet Segregations in Mafic Gneiss
Sta 36+60

Petrographic Analysis (92 Samples)

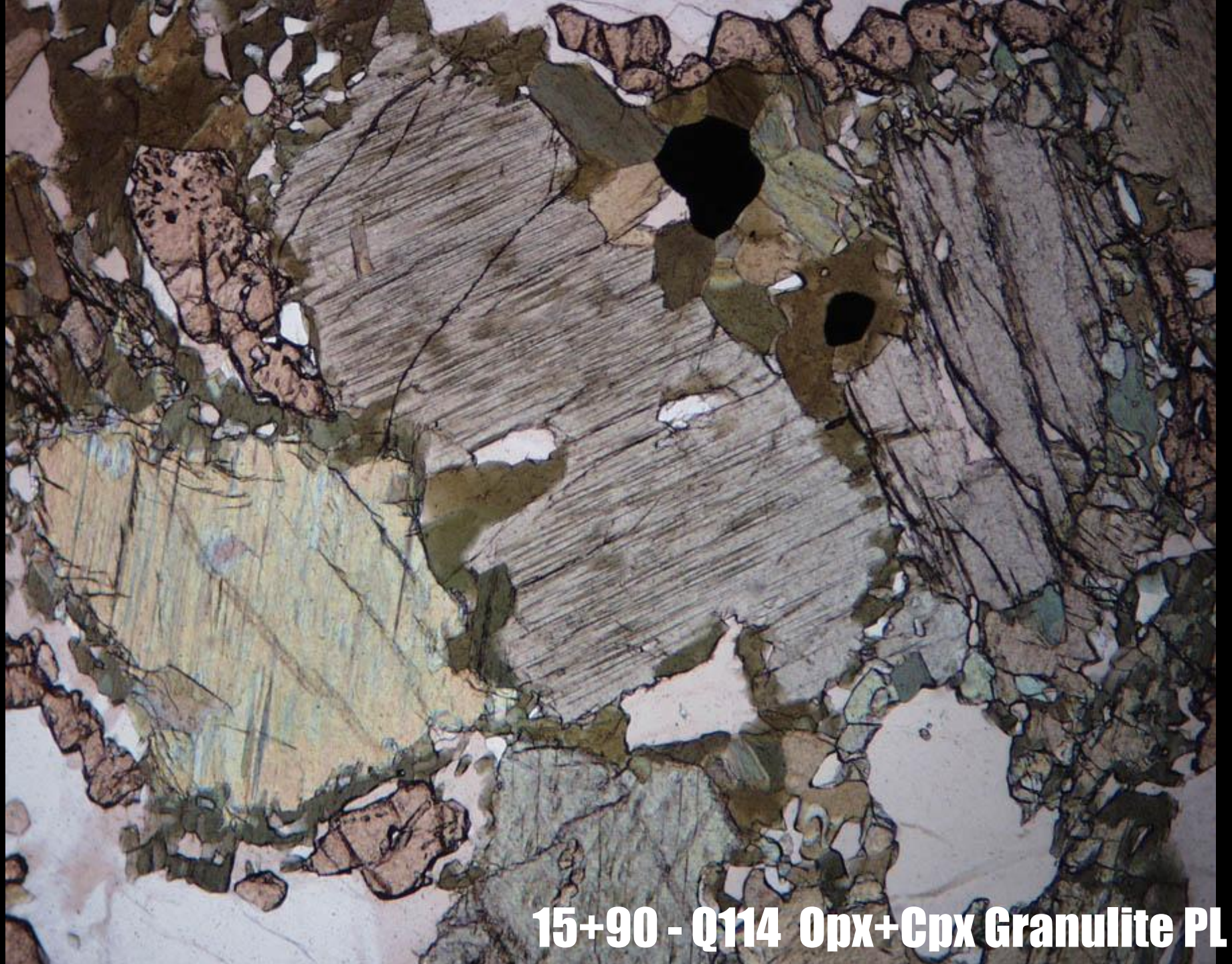
- Texture
- Mineralogy
- Internal Structure
- Metamorphism



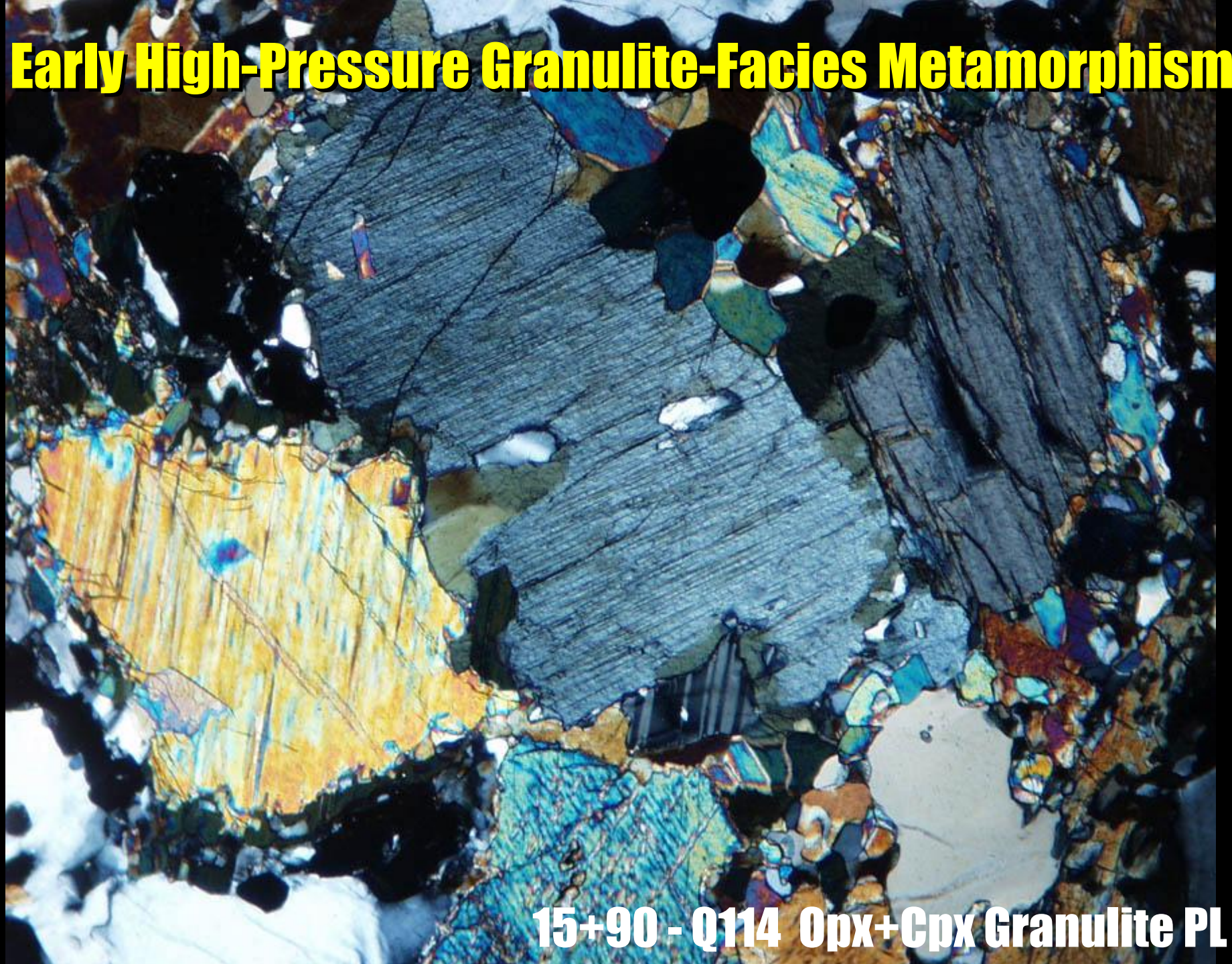
Thin section photomicrograph

Number	Location	Color	Density	Qtz	Kspar	Plagio/	An	Opx	Cpx	Hbld	Bio	Garnet	Opaque
Q109	004+80					M	35	M		M			
Q109	004+80	25	2.72	M		M	35			m	m	m	
Q110	006+42	10	2.66	M	tr+AP	M					m gnbk	tr	tr
Q111	009+25	25	2.79	M		M		m		tr	m	M py encl Q	tr
Q112	011+60	35	3.05	m		M	51		M exsol	m gnkh		M py	
Q114	015+90	45	3.03	m		M	53-39	MinsomeExsol	MExsol	mgnkh		*m necklace*	tr
Q115	017+70	10	2.71	M	tr AP	M				m **bugn** sieve	m rbn	m porange	tr
Q117a	022+25	15	2.72	M	tr	m	27			m **dgygn**	m rbn	m porange sieve	tr
Q119	026+65	45	2.93	m 10-15		M	27			M khgn	tr rdbn	m	m
Q123	032+15	60	3.11	m		m	44	m		m gnHB	m rbn	M sieve	tr
Q127	042+67	60	3.09	m		M		tr	M	M gnkh	m red	M	m
Q129	049+95	25	2.71	M	M	M	low				M kh	M	
Q130	051+83	15	2.76	40	tr	M					m obn	M.vermic/sieve	trms
Q133	059+95	55	3.26	m		M	38-29		M	Mkhtan	m	M	m
Q134	062+45	60	3.17	m		M	28-40	RevZoning	M	M **bugn** some	vermic wi Qtz	M fine sieve/verm	c vermi
068+10	068+10	5:50		M		M	55	m	M	m gn		*m vermic with pla*	ag
070+60	070+60	45		M		M	45+	?	core?	m. Gn	m	M	m
Q141	071+80	30	2.9	5		M sieve		M sieve		tr gn	M okh	M sieve	2

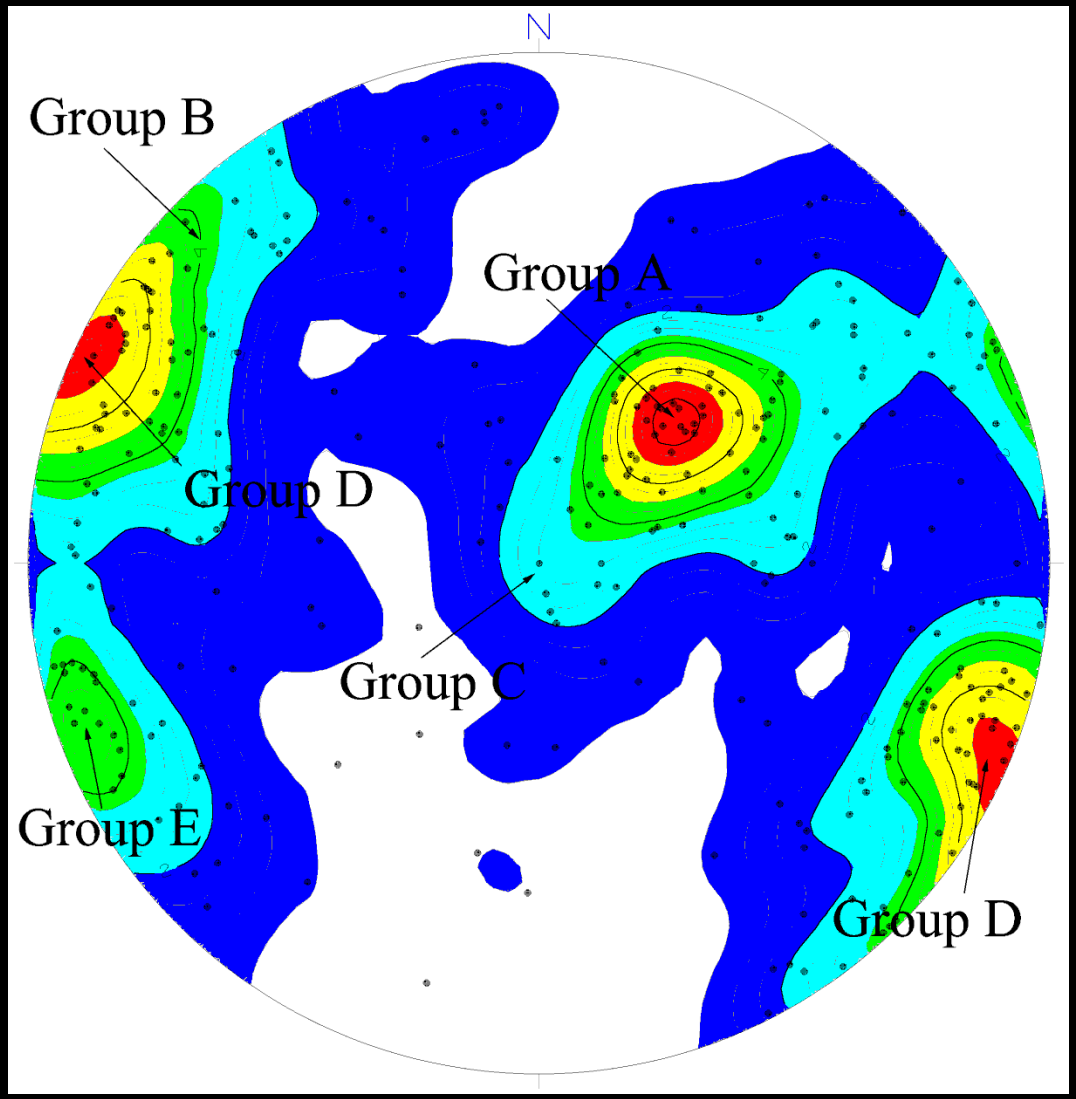
Typical Petrographic Data Sheet


15+90 - Q114 Opx+Cpx Granulite PL

Early High-Pressure Granulite-Facies Metamorphism



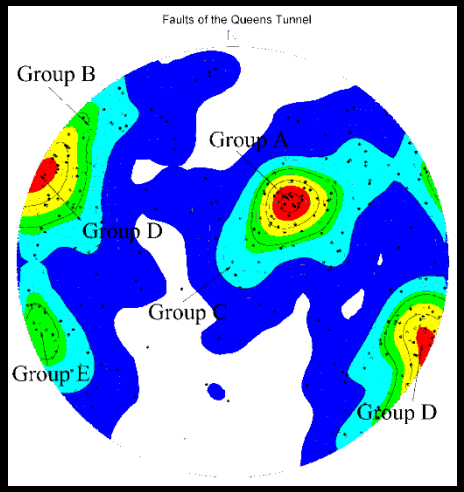
15+90 - Q114 Opx+Cpx Granulite PL



So, tell them about the Faults!

Queens Tunnel Faults

Queens Tunnel Faults



Hundreds of faults mapped in five groups

From oldest to youngest:

Group A = NW strike and gentle SW dipping faults

Group B = ENE-trending steeply dipping faults

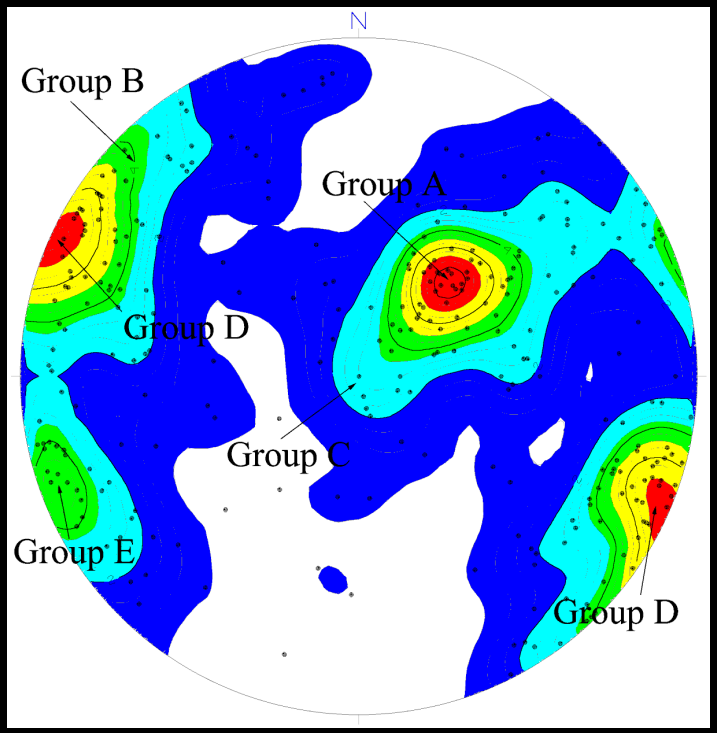
Group C = Subhorizontal fractures and faults

Group D = NNE-trending steeply dipping fault system

Group E = NNW-trending “Manhattanville” fault system

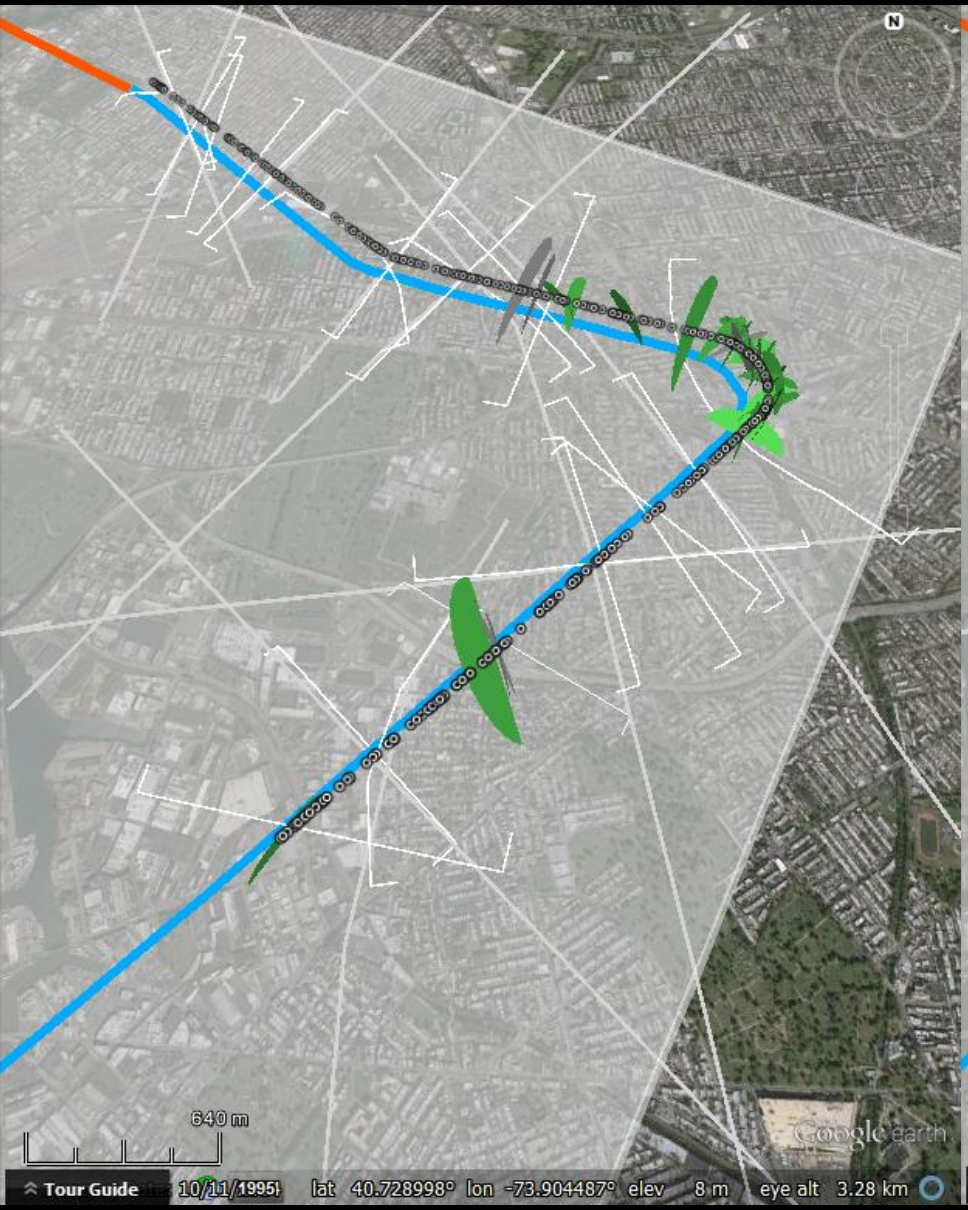
Database on GANJ webpage

QT Faults


N
Group B
Group A
Group D
Group C
Group E
Group D

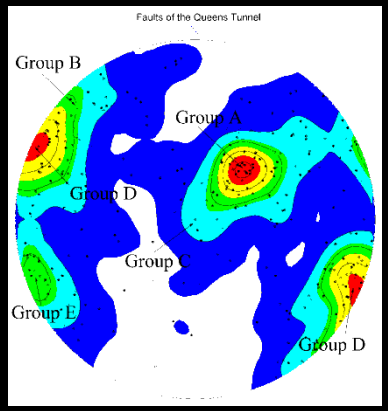

640 m
Google earth
Tour Guide
10/11/1995
lat 40.728998° lon -73.904487° elev 8 m eye alt 3.28 km

Joints



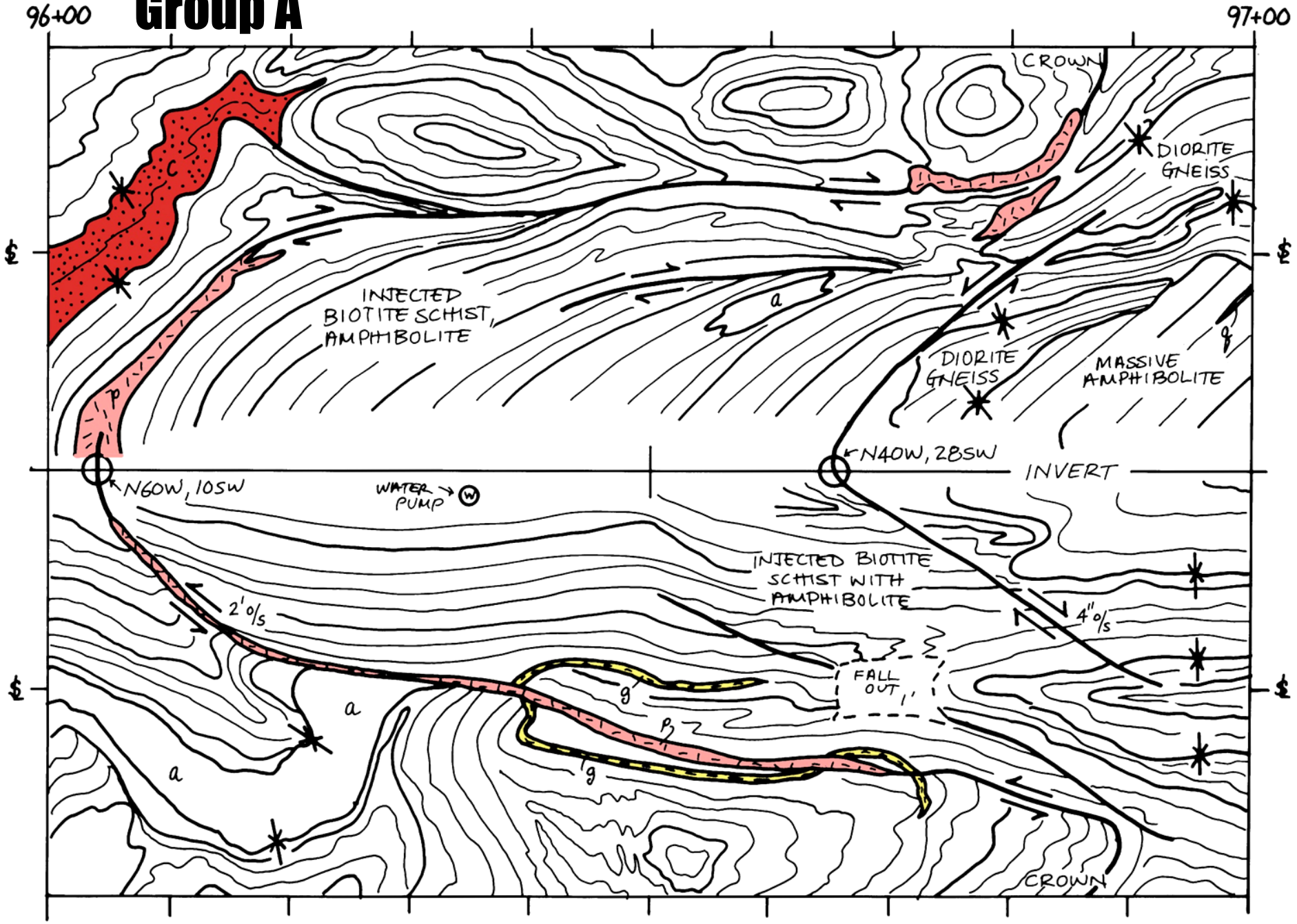
Pegmatites

Gently-dipping Faults of Group A



- NW strike and gentle SW dip
- Both normal and reverse offset
- Typically reactivate older, D_4 ductile shears
- Thin zones of fault breccia and crush zones
- Commonly contain sheared pegmatite
- Laterally extensive features that persist for 100s of feet
- Abruptly terminate by ramping steeply into crown and down into invert
- Wet features that resulted in collapsed tunnel heading

Group A


96+00
97+00
CROWN
DIORITE GNEISS
INJECTED BIOTITE SCHIST, AMPHIBOLITE
DIORITE GNEISS
MASSIVE AMPHIBOLITE
N40W, 28SW
INVERT
N60W, 10SW
WATER PUMP
INJECTED BIOTITE SCHIST WITH AMPHIBOLITE
2'0/s
4"0/s
FALL OUT
CROWN

Queens Tunnel Station 196+85

Steeply-dipping Brittle Faults of Group B

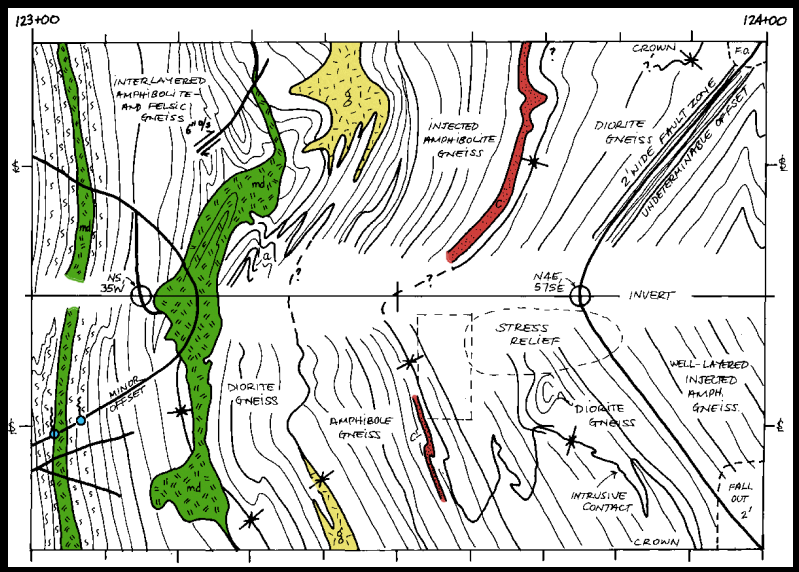
- ENE strike and steep NW and SE dips
- Reactivate Group A faults and older ductile shears
- Thin zones of fault breccia and crush zones
- Cut by subhorizontal fractures (Group C) and younger faults (Groups D and E)

Subhorizontal Brittle Faults of Group C

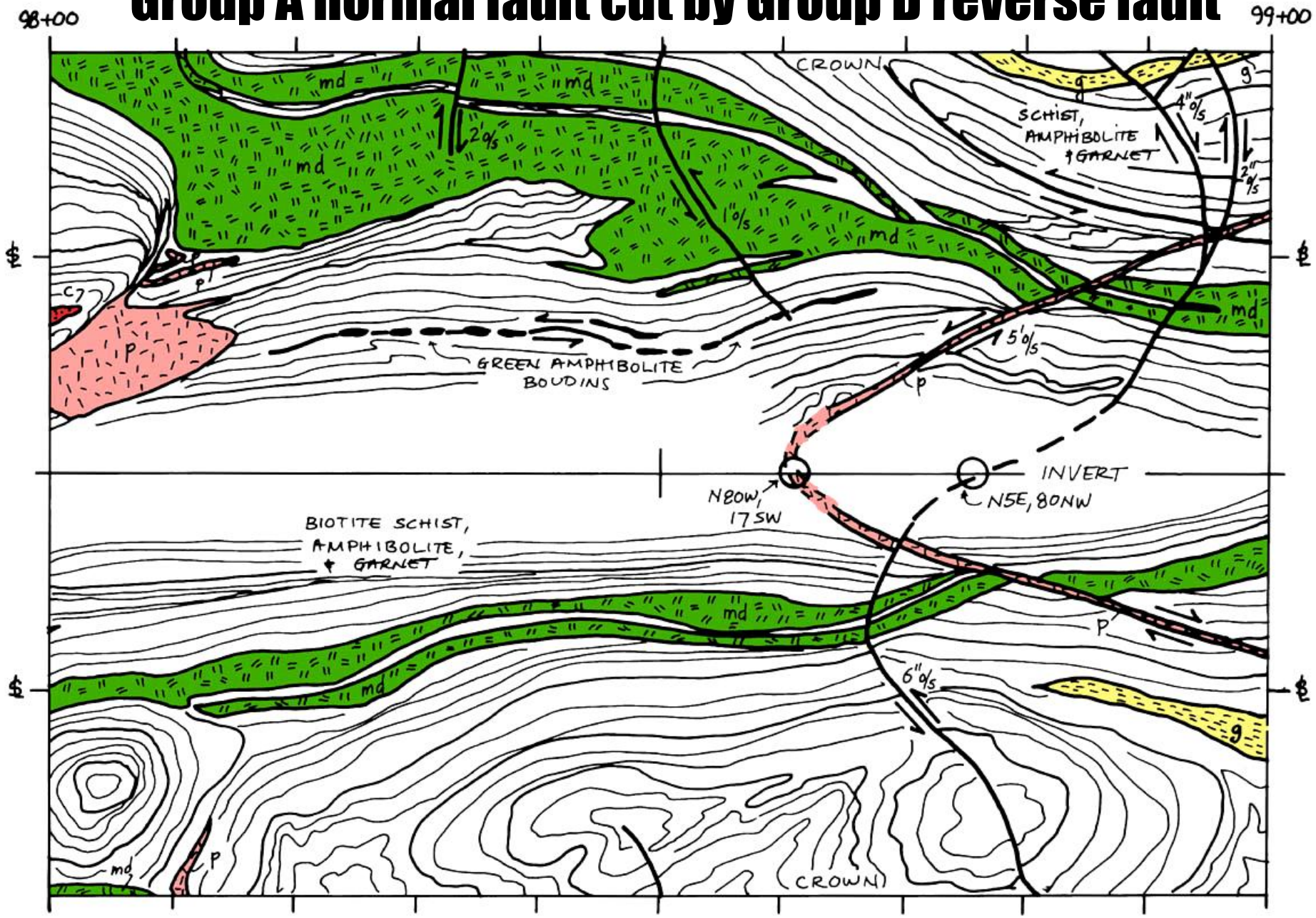
- Cut Group A and B faults and older ductile shears
- Thin zones of fault breccia and crush zones
- Cut by Group D and E faults

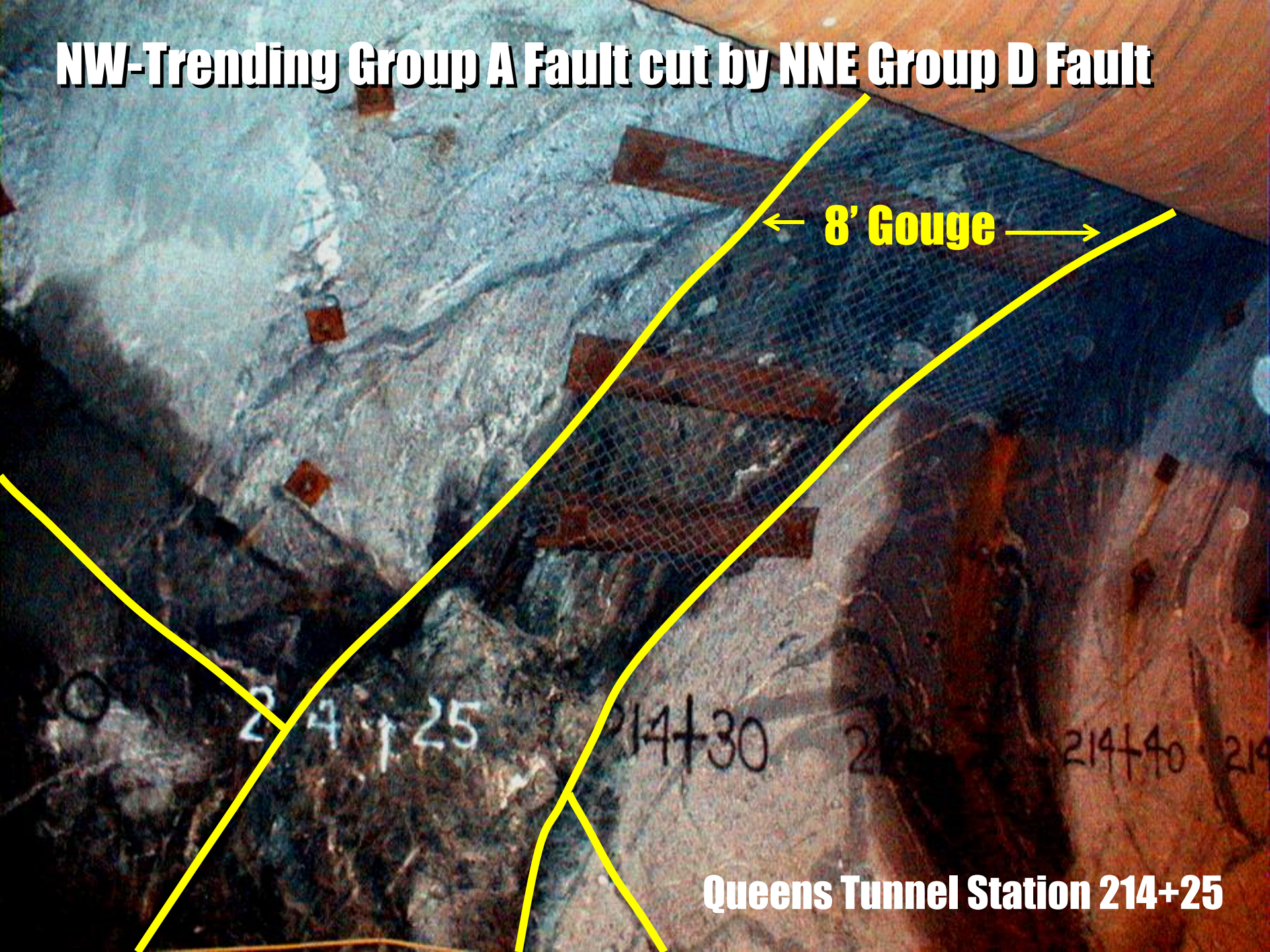
NNE-Trending Fault System of Group D

- NNE strike and steep dips; dip-slip mechanisms
- Structural control – parallel to Pz regional S_3 foliation
- Thick zones of fault gouge and breccia
- Clay-, zeolite-, and chlorite-rich gouge zones
- Stilbite – Calcite – Chabazite – Analcime - Apophyllite
- Relatively young – they cut 295 Ma rhyodacite dikes



Group A normal fault cut by Group D reverse fault




NW-Trending Group A Fault cut by NNE Group D Fault
8' Gouge
214+25
214+30
214+40
Queens Tunnel Station 214+25

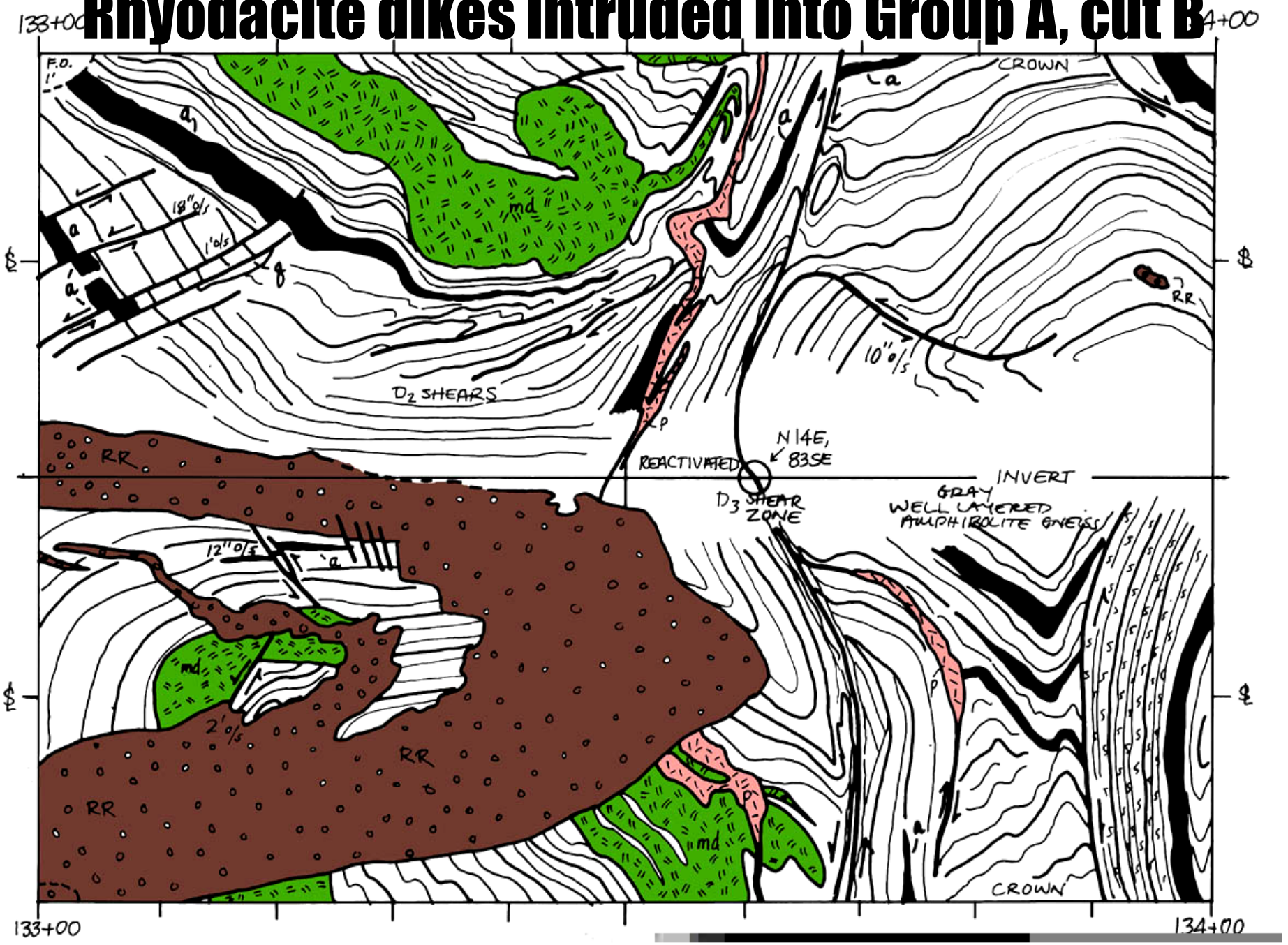
Crush Breccia NNE Fault

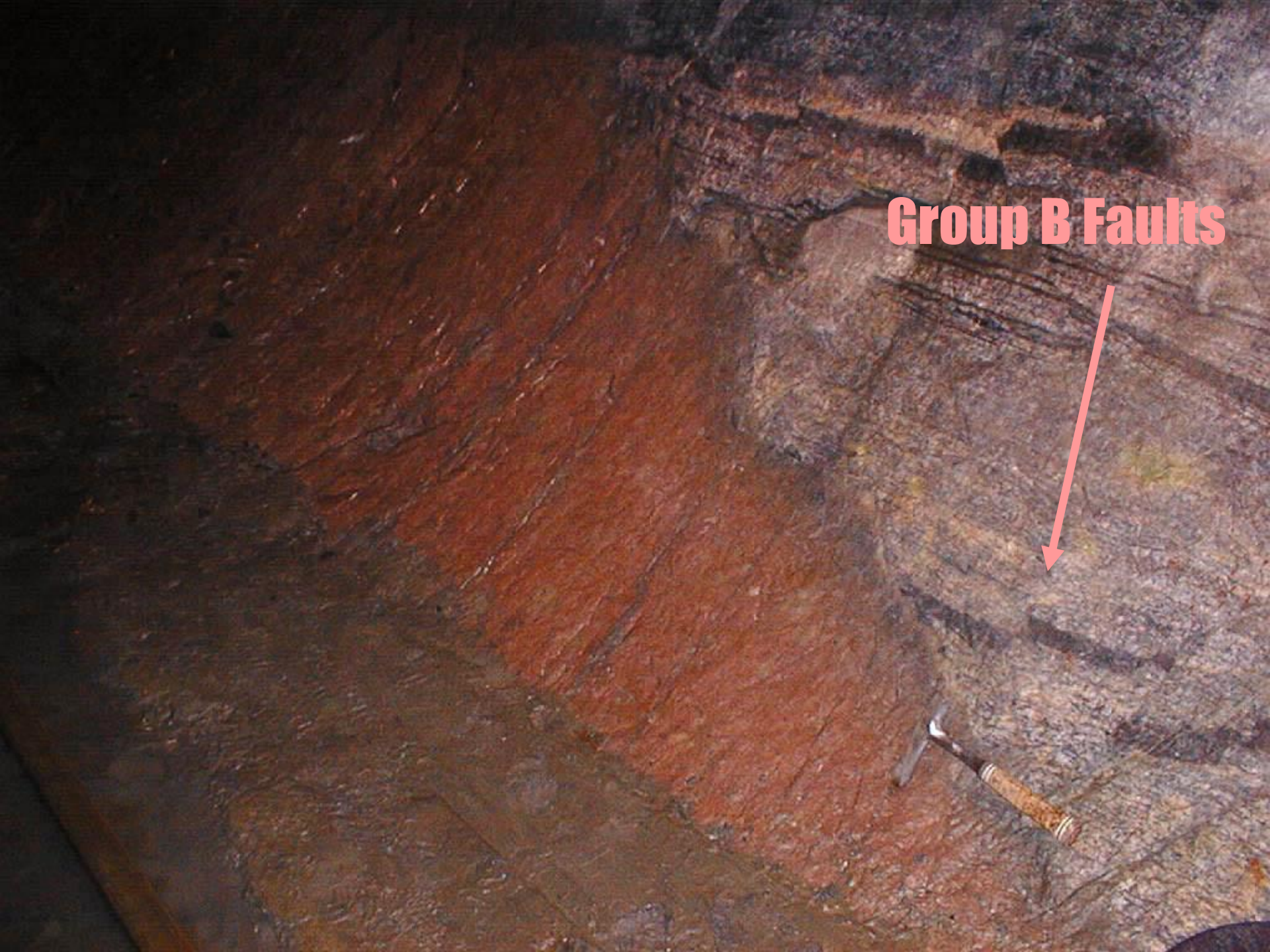
Sta. 137+30

Queens Tunnel Sta. 93+60

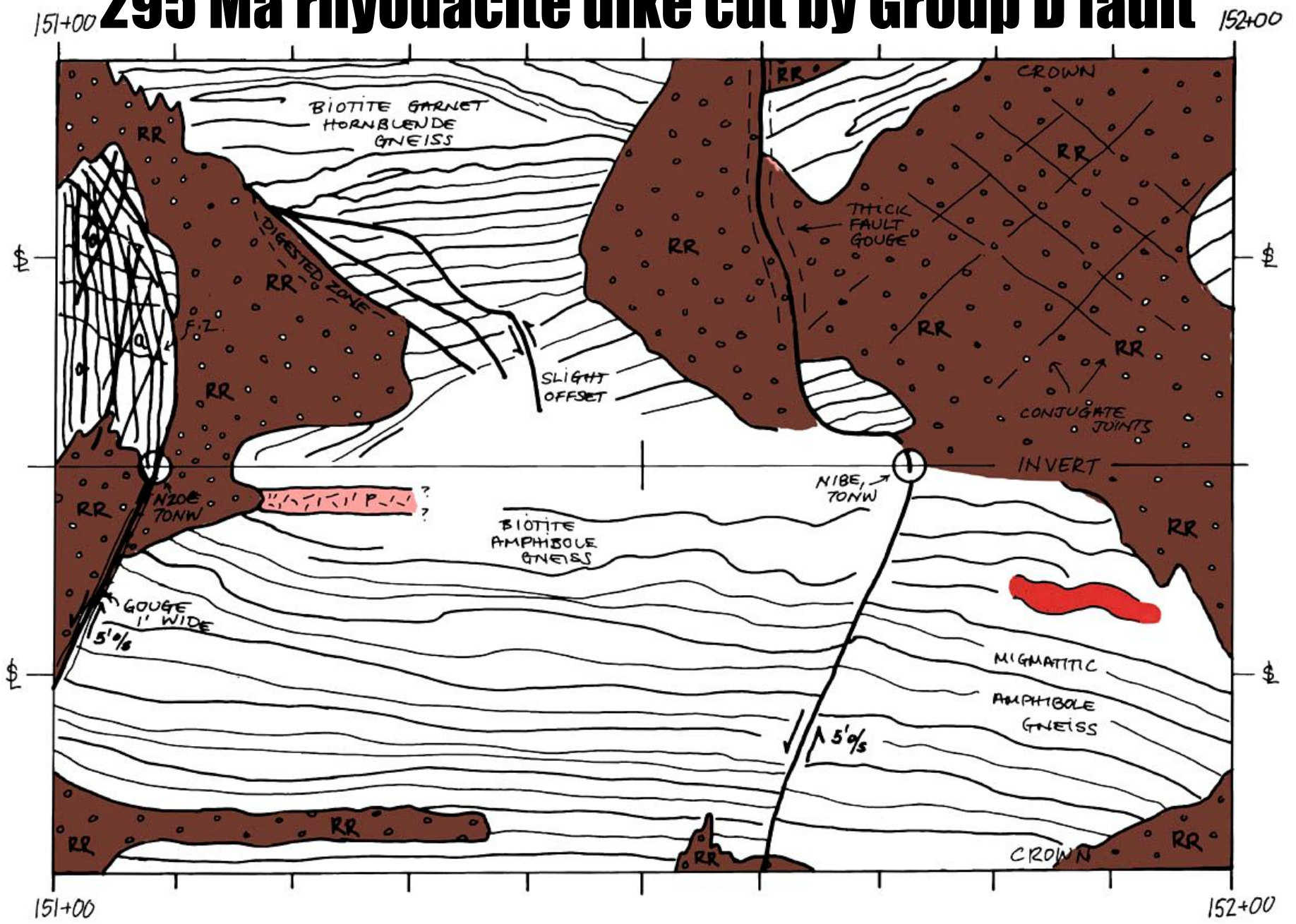

Station 130+40, Right Wall
Multidirectional cooling joints in rhyodacite

Rhyodacite dikes intruded into Group A, cut B




Group B Faults

295 Ma rhyodacite dike cut by Group D fault

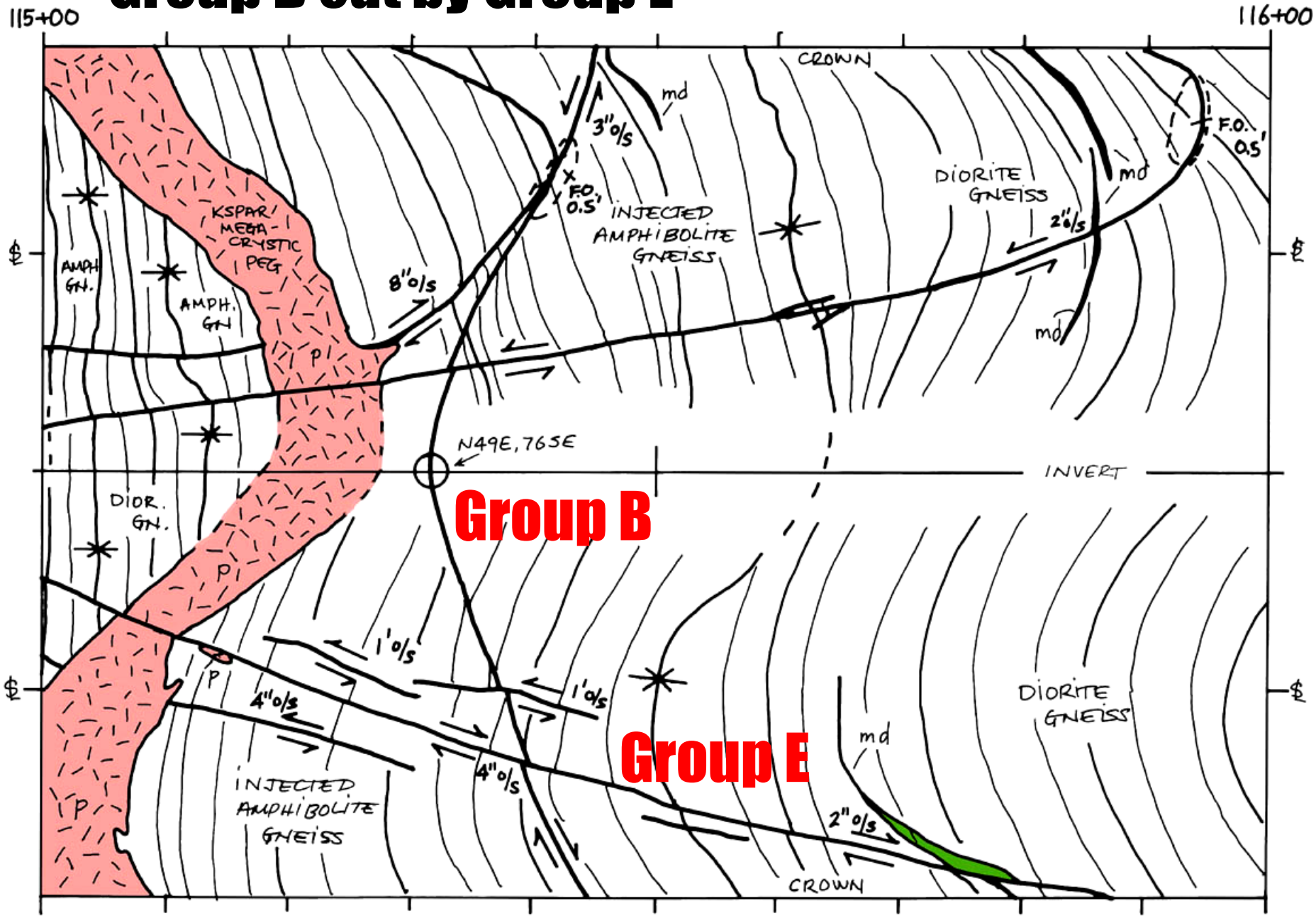


NNW-Trending Fault System of Group E

- NNW strike with steep dips; R/L and L/L strike-slip offset
- Follow S_4 traces of open cross folds (F_4)
- Commonly healed with quartz +/- pyrite
- Youngest fault group – they cut all tunnel structures
- Reactivate many older faults
- Persistent features in west part of NW-leg of tunnel
- Associated with areas of stress relief
- Produce wet zones in areas of fault convergence


NNW-Trending “Manhattanville” Strike-Slip Faults
Splays and Conjugate Joints
Queens Tunnel Sta. 75+85
156+40
156+35
156+30
156+20

Group B cut by Group E



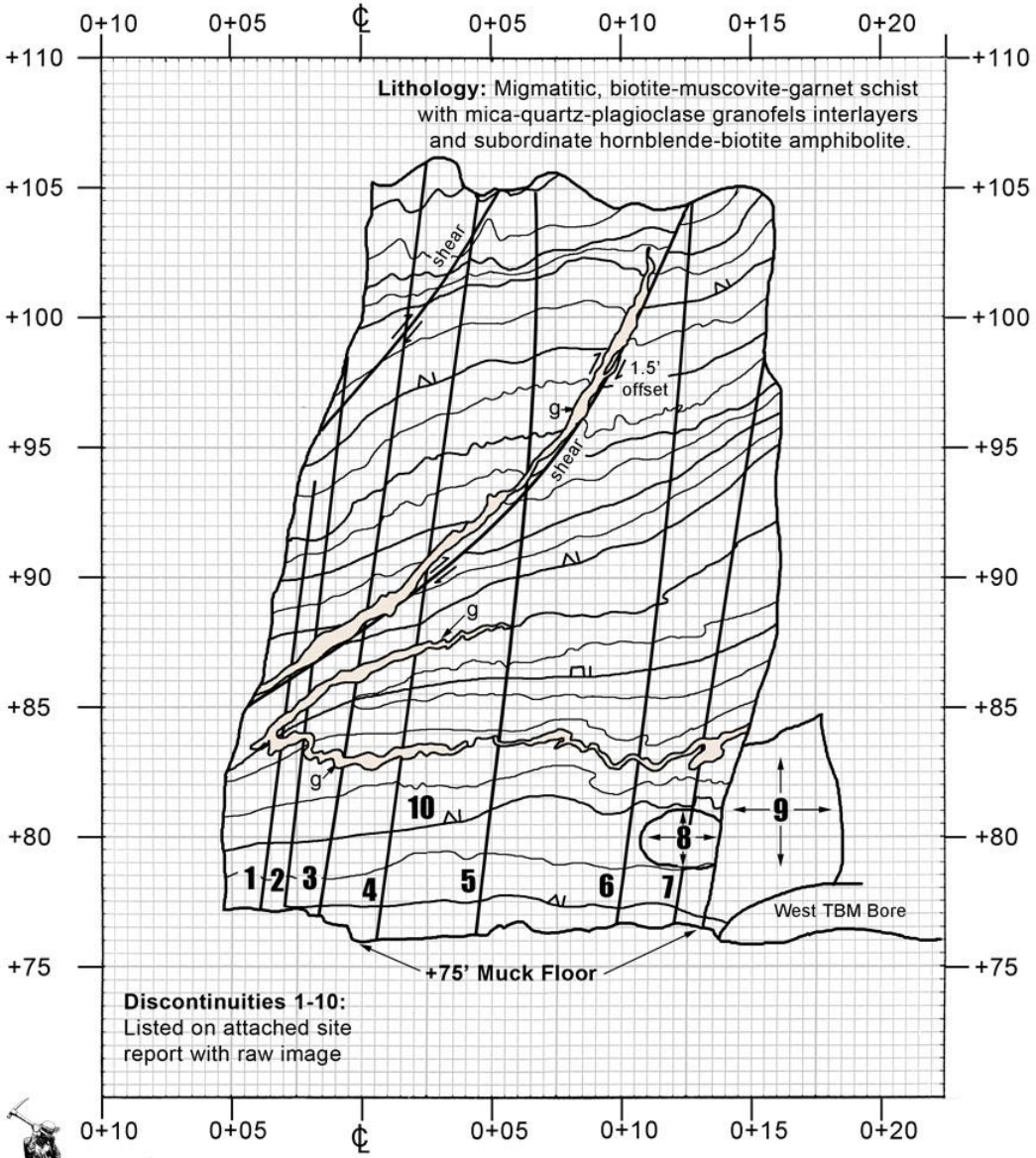

Second Avenue Subway
Sta ~1205+00 – North Cavern

Second Avenue Subway

Sta 1204+90

North Cavern Center Slash

Second Avenue Subway - North Cavern Center Slash
Working Face at Sta. 1204+90; Elev. +75' to +108'



Duke Geological Lab
Westbury, NY 11590
(516) 280-7144
www.dukelabs.com

← Stationing East and West of Second Avenue Centerline →

Mapped 19 December 2012

Second Avenue Subway

Sta 1204+90

North Cavern Center Slash

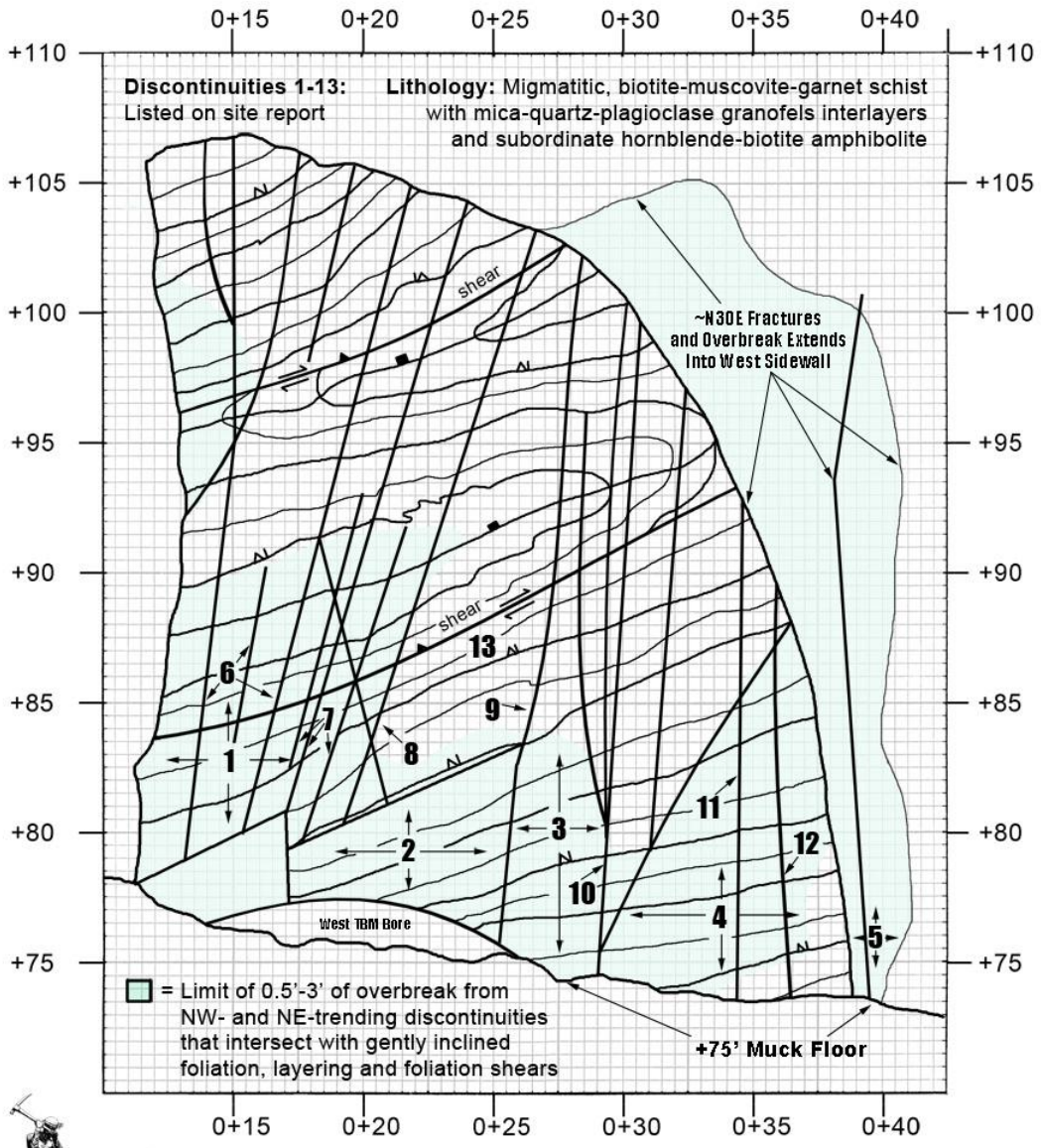

Second Avenue Subway
Sta ~1205+00 – North Cavern

Second Avenue Subway

Sta 1205+10

North Cavern West Slash

Second Avenue Subway



Duke Geological Lab
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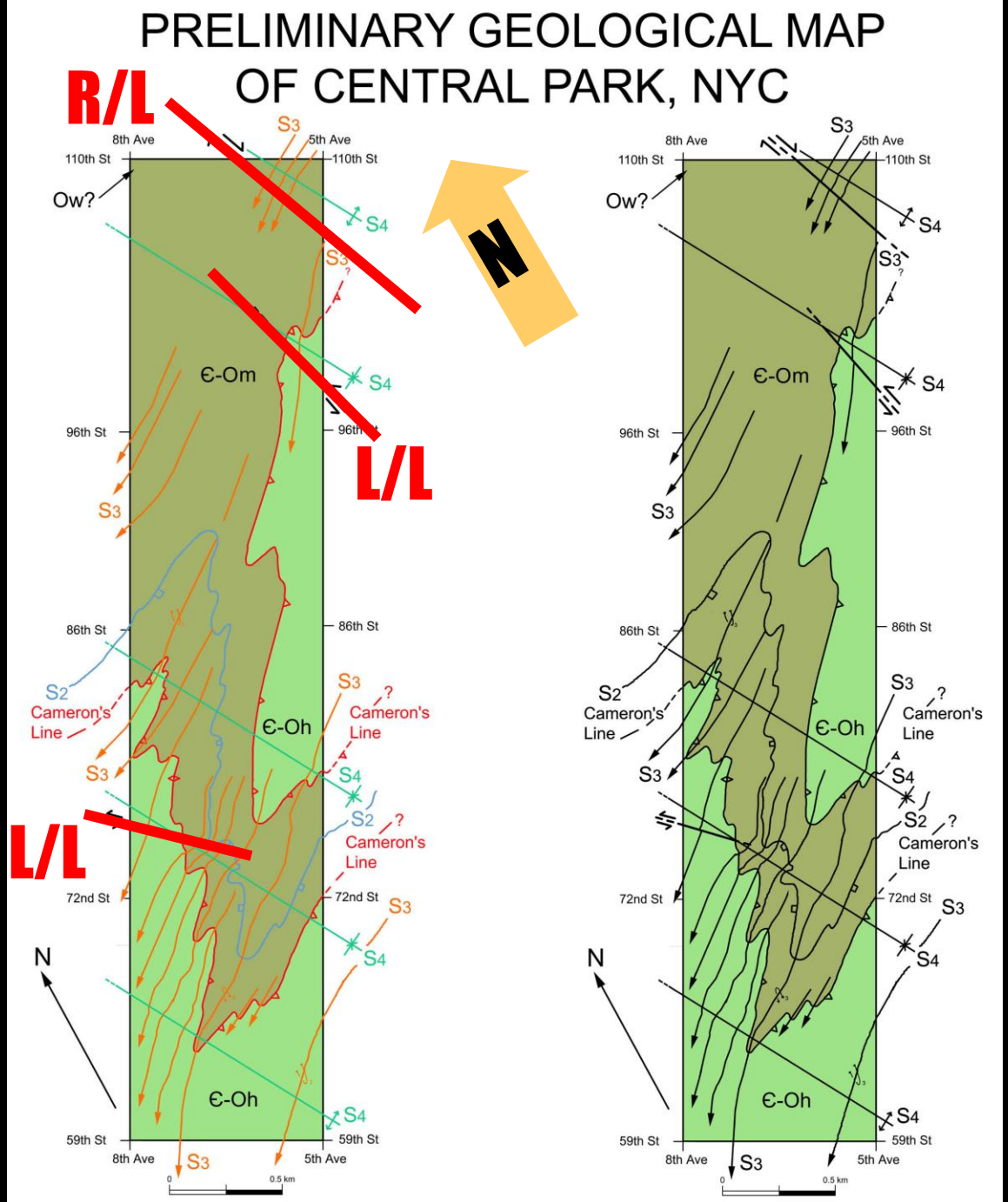
Mapped 19 December 2012

Sta 1205+10

North Cavern West Slash


Second Avenue Subway
Sta 1205+10 – North Cavern



Group E Faults In Central Park

Merguerian and Merguerian, 2004

Manhattan Schist

Offsets F_3 Syncline

N537

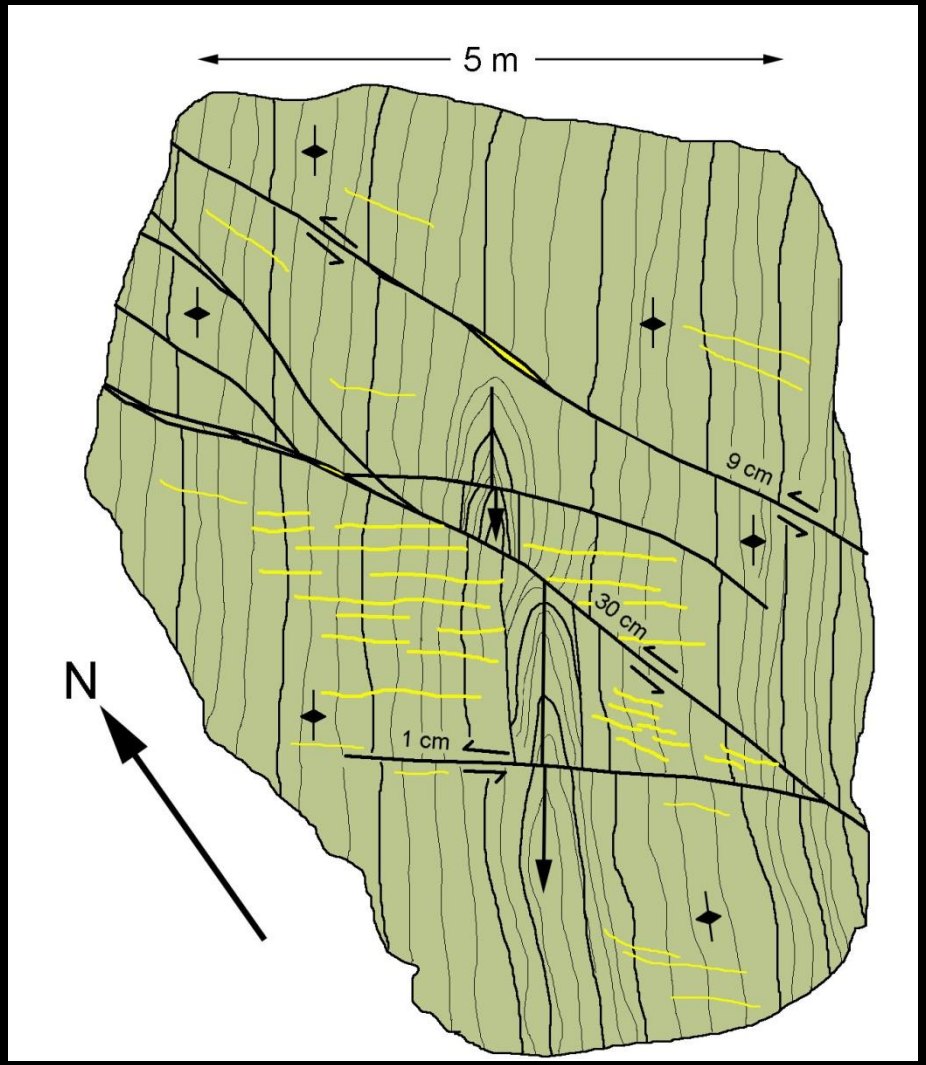
Group E - N12°W, L/L Fault

Manhattan Schist

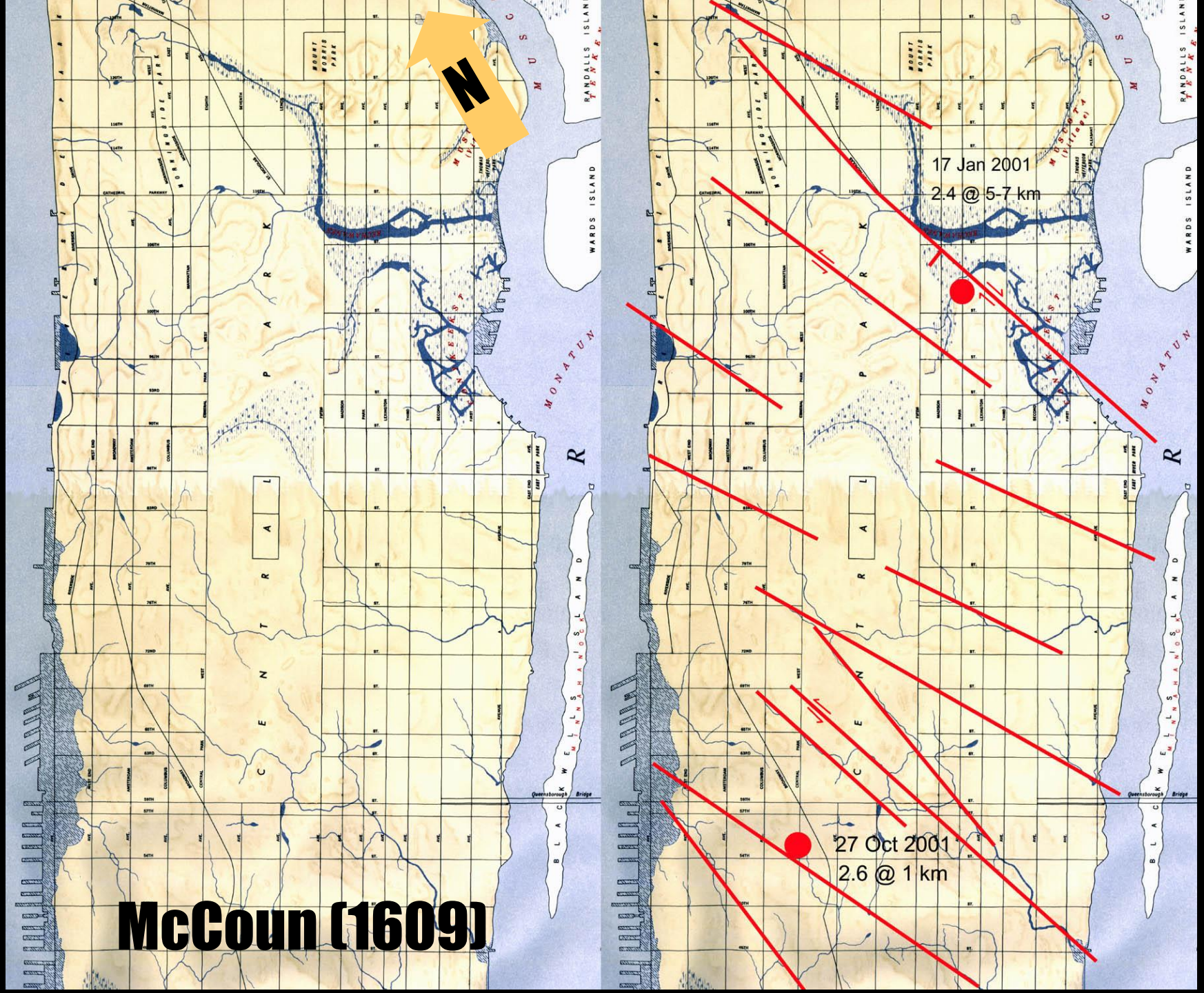
Offsets F_3 Syncline

N537

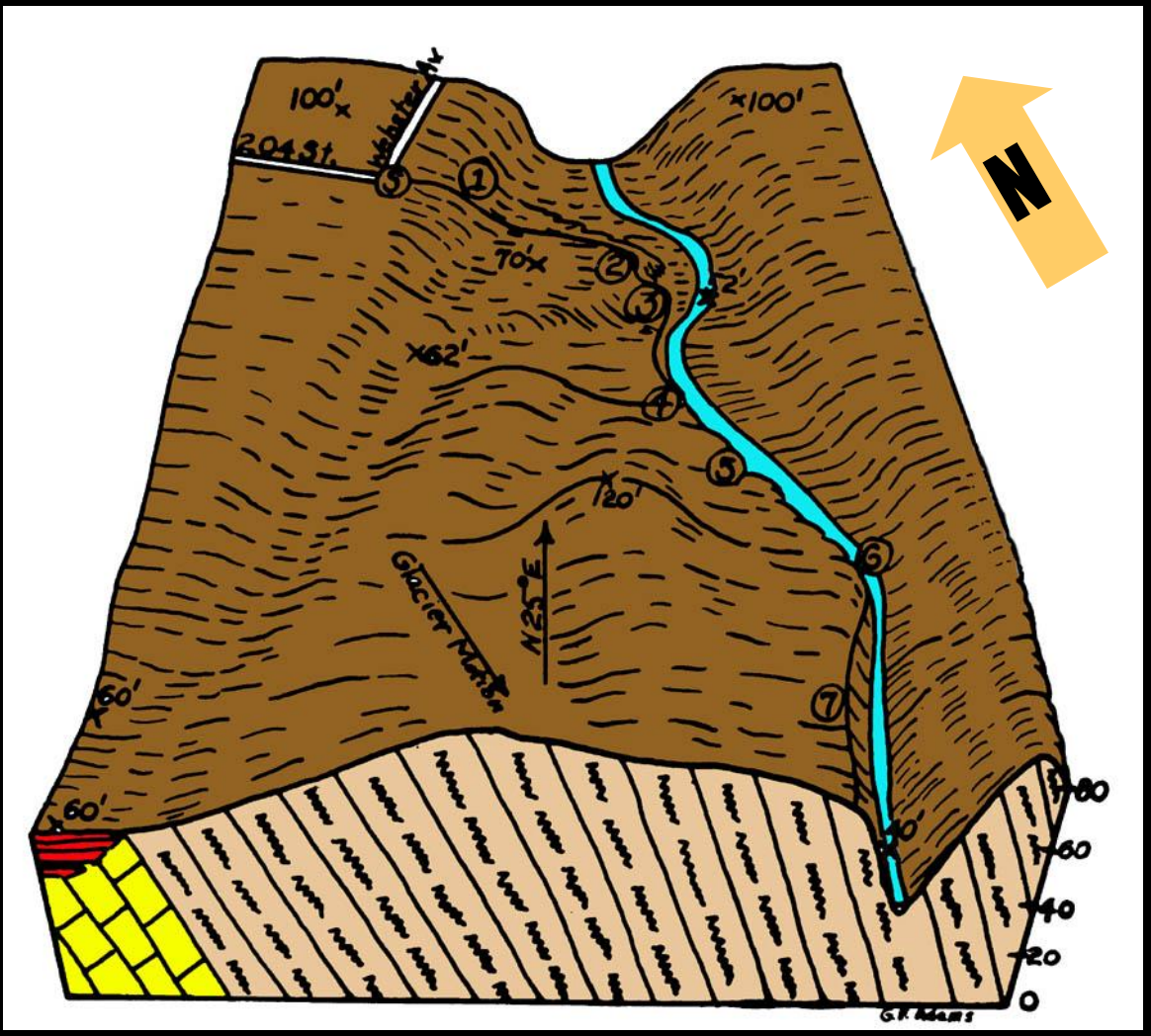
Group E - N12°W, L/L Fault

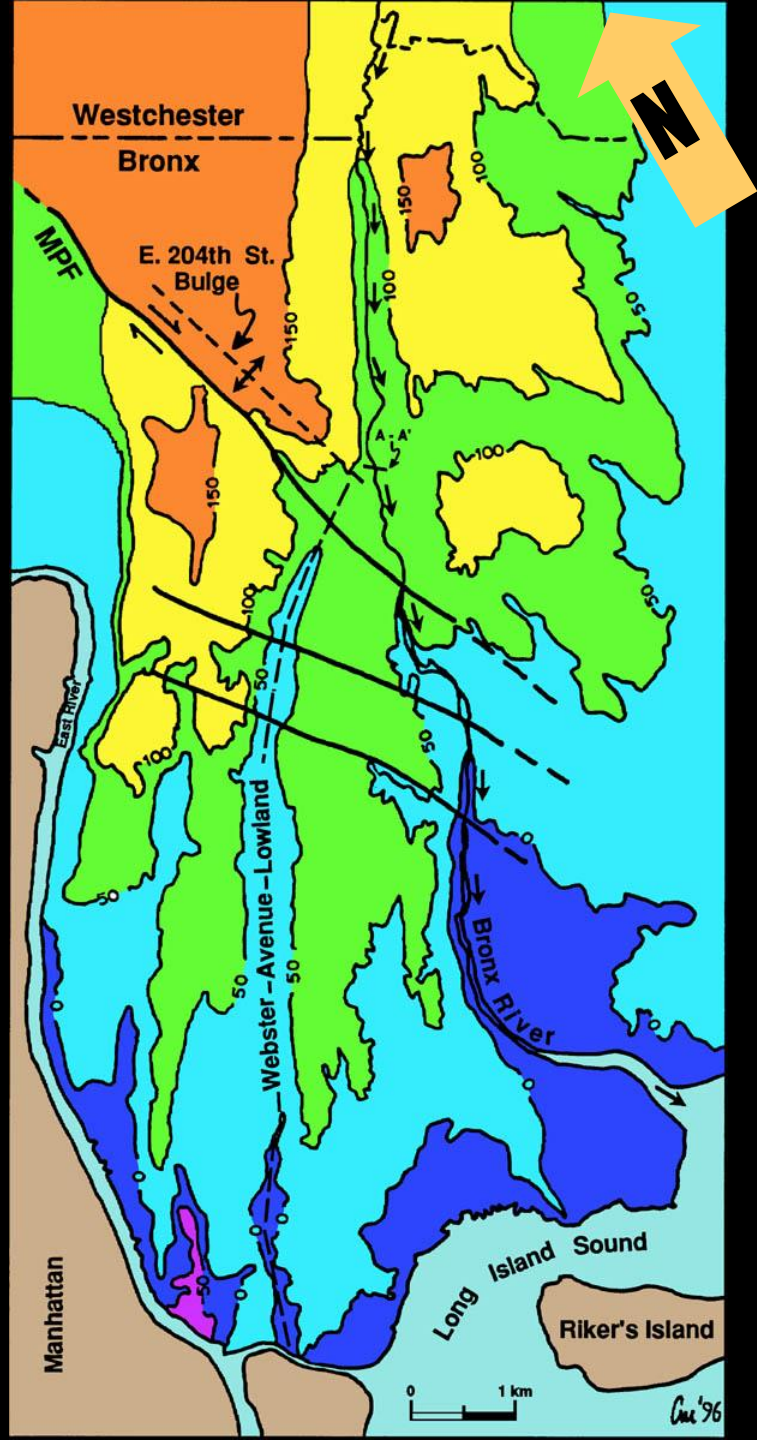


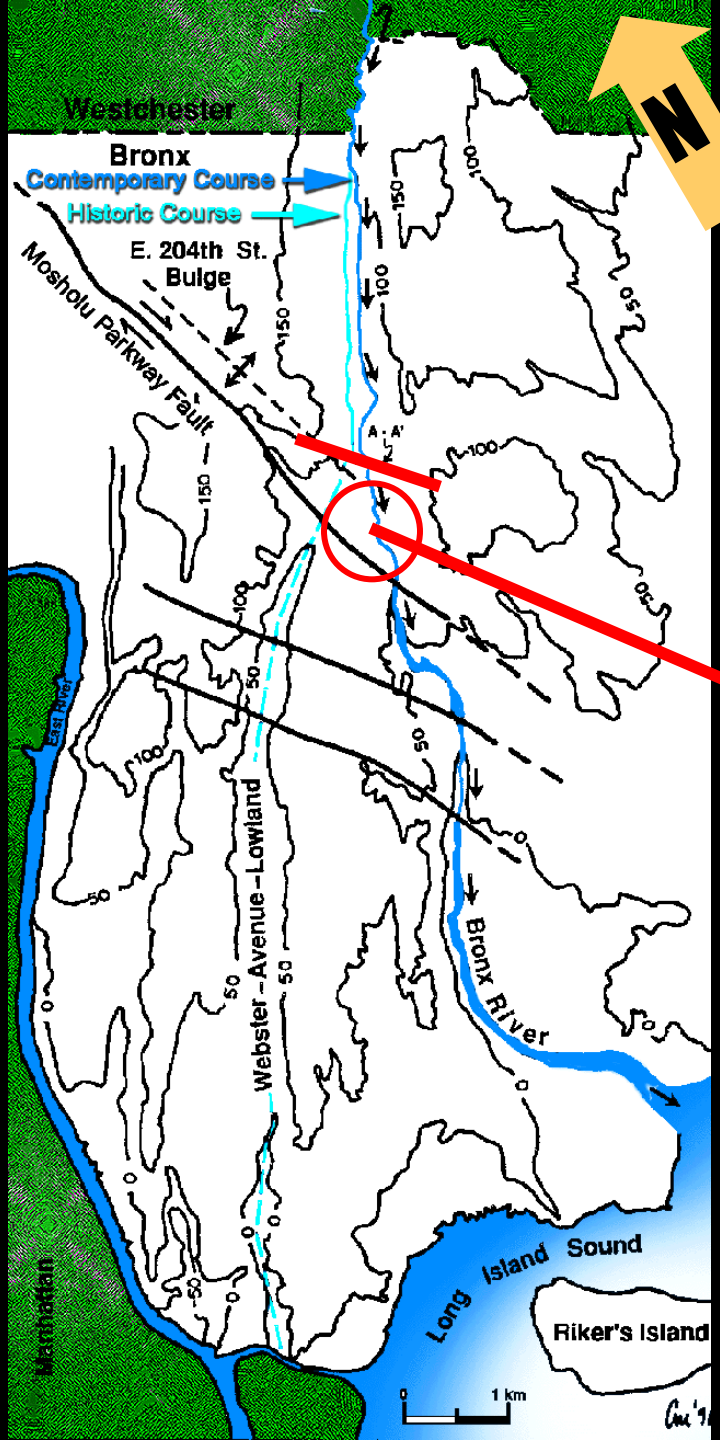
Group E - N45°W, 80°S L/L Fault


N
17 Jan 2001
2.4 @ 5-7 km
27 Oct 2001
2.6 @ 1 km
McCoun (1609)

Bronx River Drainage Anomaly



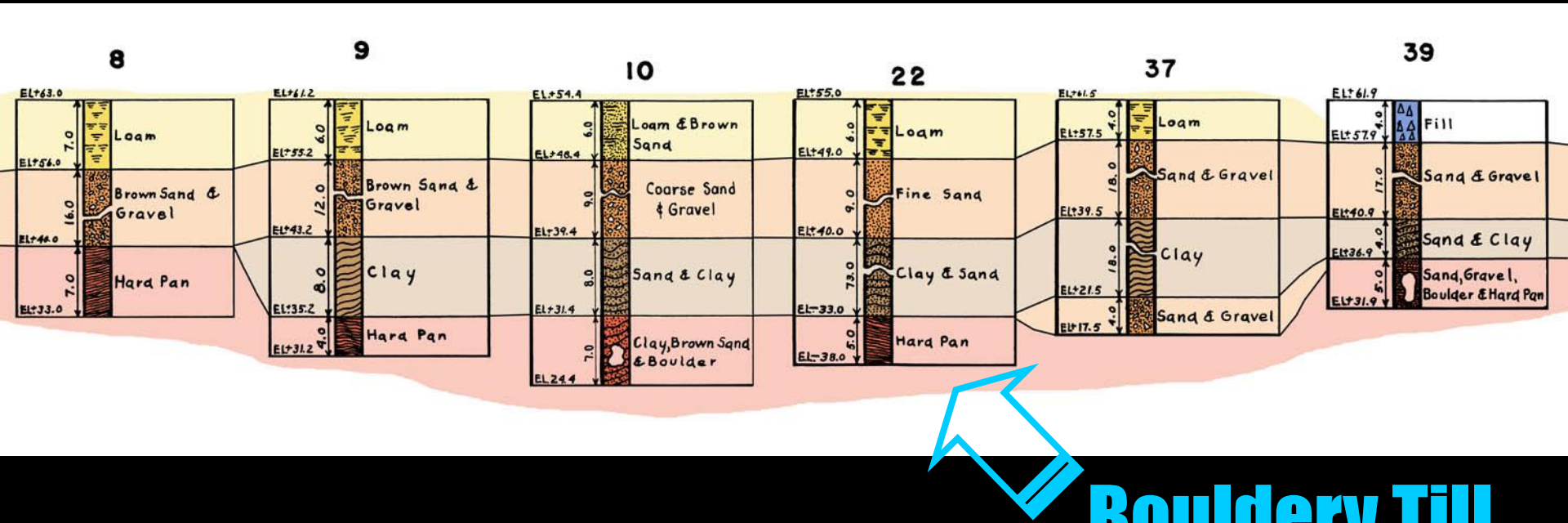




Non-glaciated V-Shaped Bronx River Valley at Snuff Mill, NY Botanical Garden

NW Joints, Mosholu Fault, Bronx, NY

Burke Avenue Profile – Bronx WPA



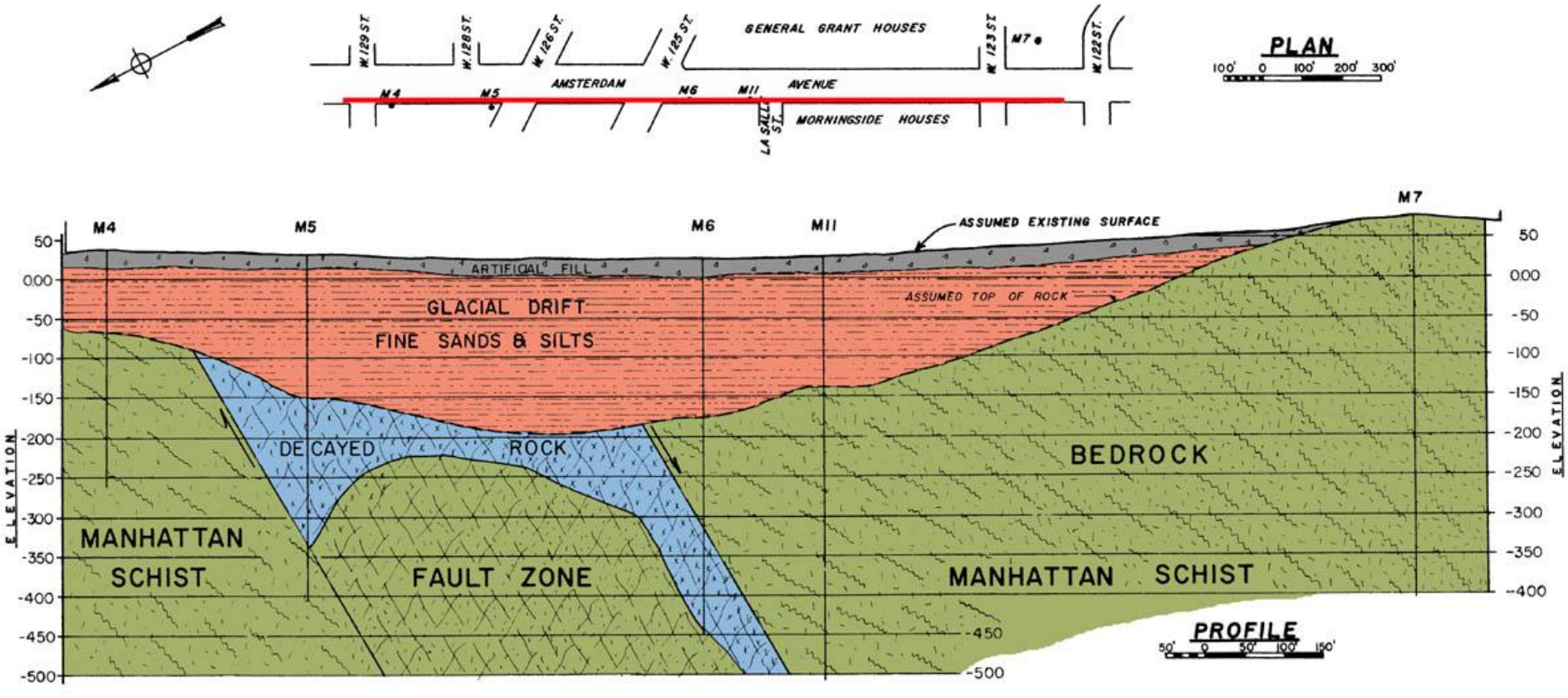
Bouldery Till

Stratified Lake Sediment Overlies "Hard Pan" Glacial Drift

Supports hypothesis that blockage of Bronx River was post-glacial


DESPATCH
MOVING & STORAGE

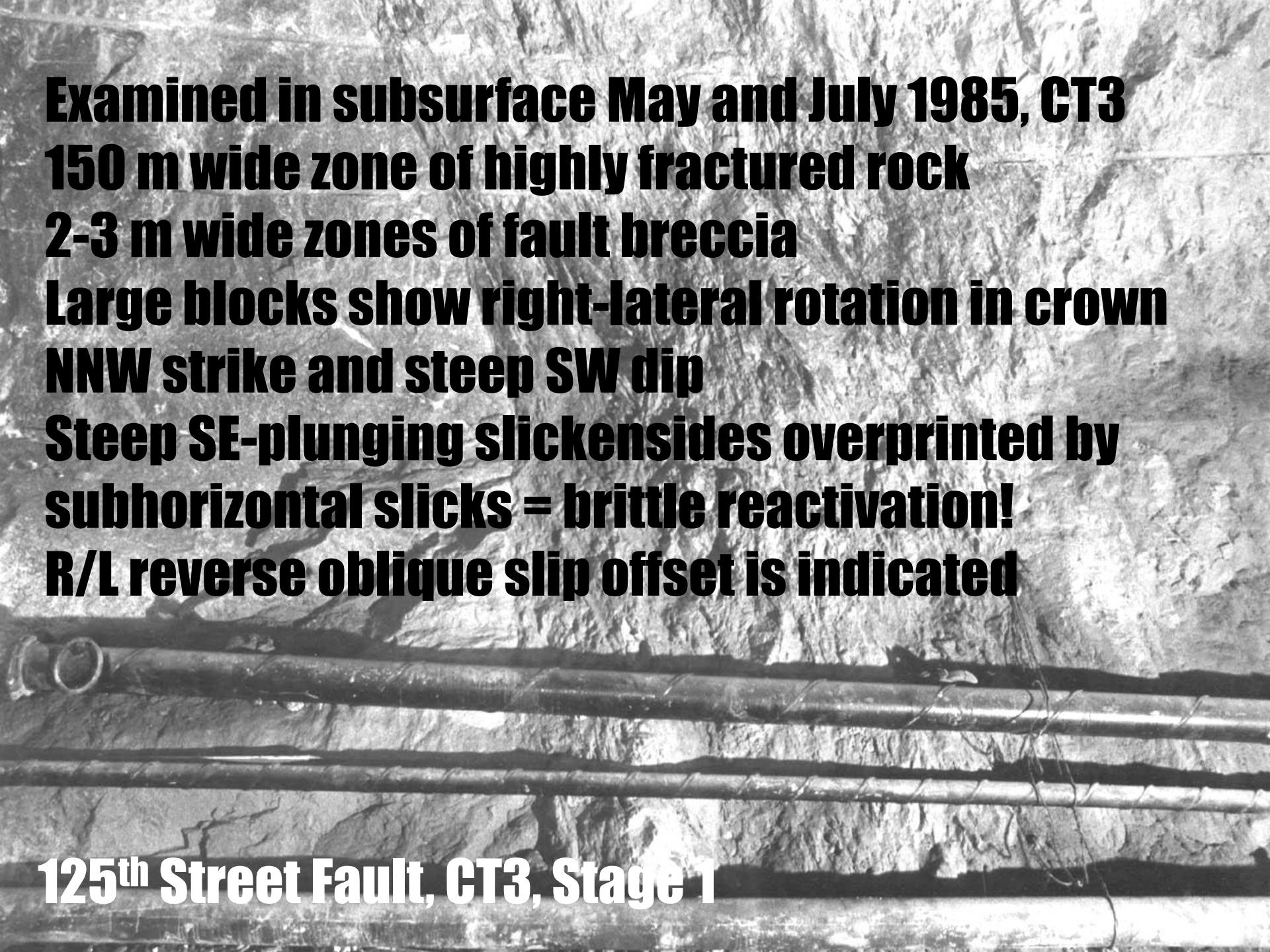
Manhattanville "125th Street" Fault



CT3, Stage 1

after Fluhr, 1969


125th Street Fault, CT3, Stage 1



125th Street Fault, CT3, Stage 1

New York City Earthquake Can it Happen Here?

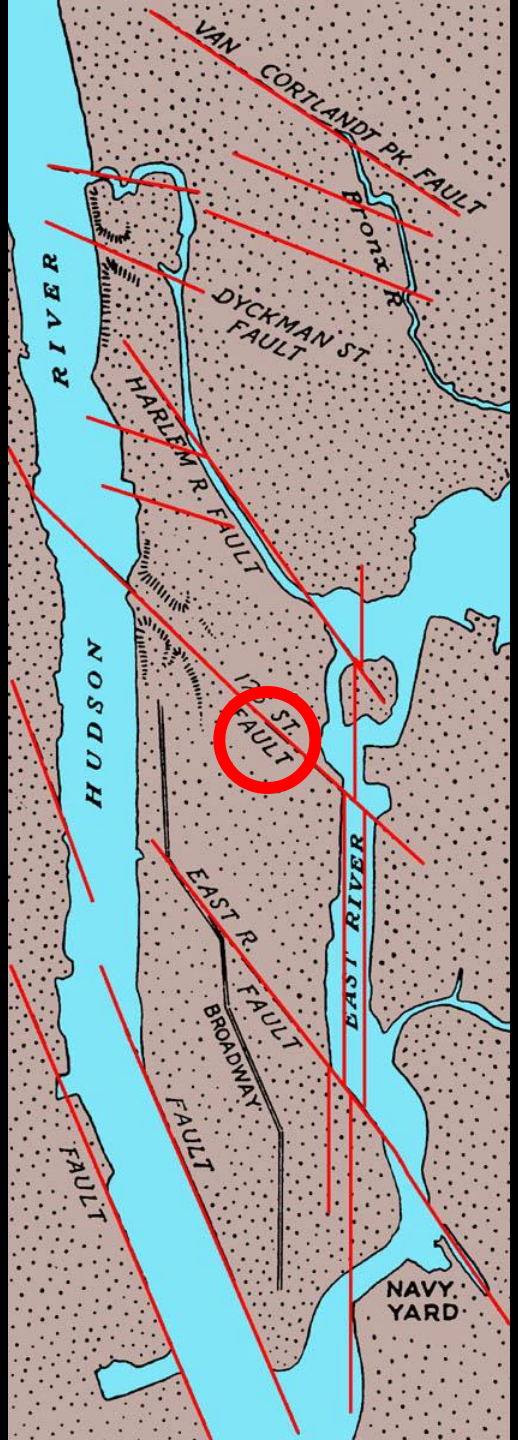
1737 5.2

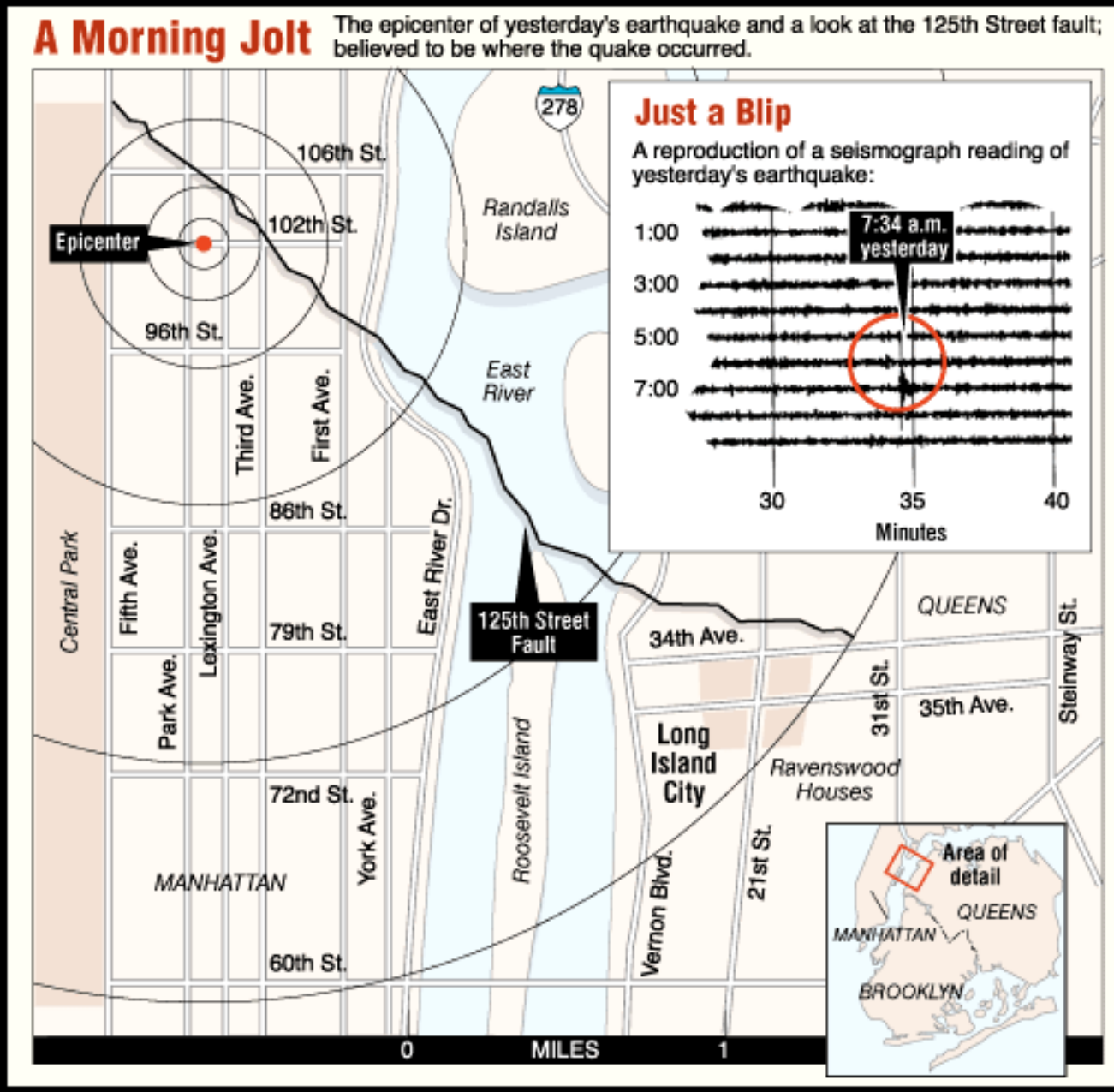
1783 4.9

1884 5.2

200? ?

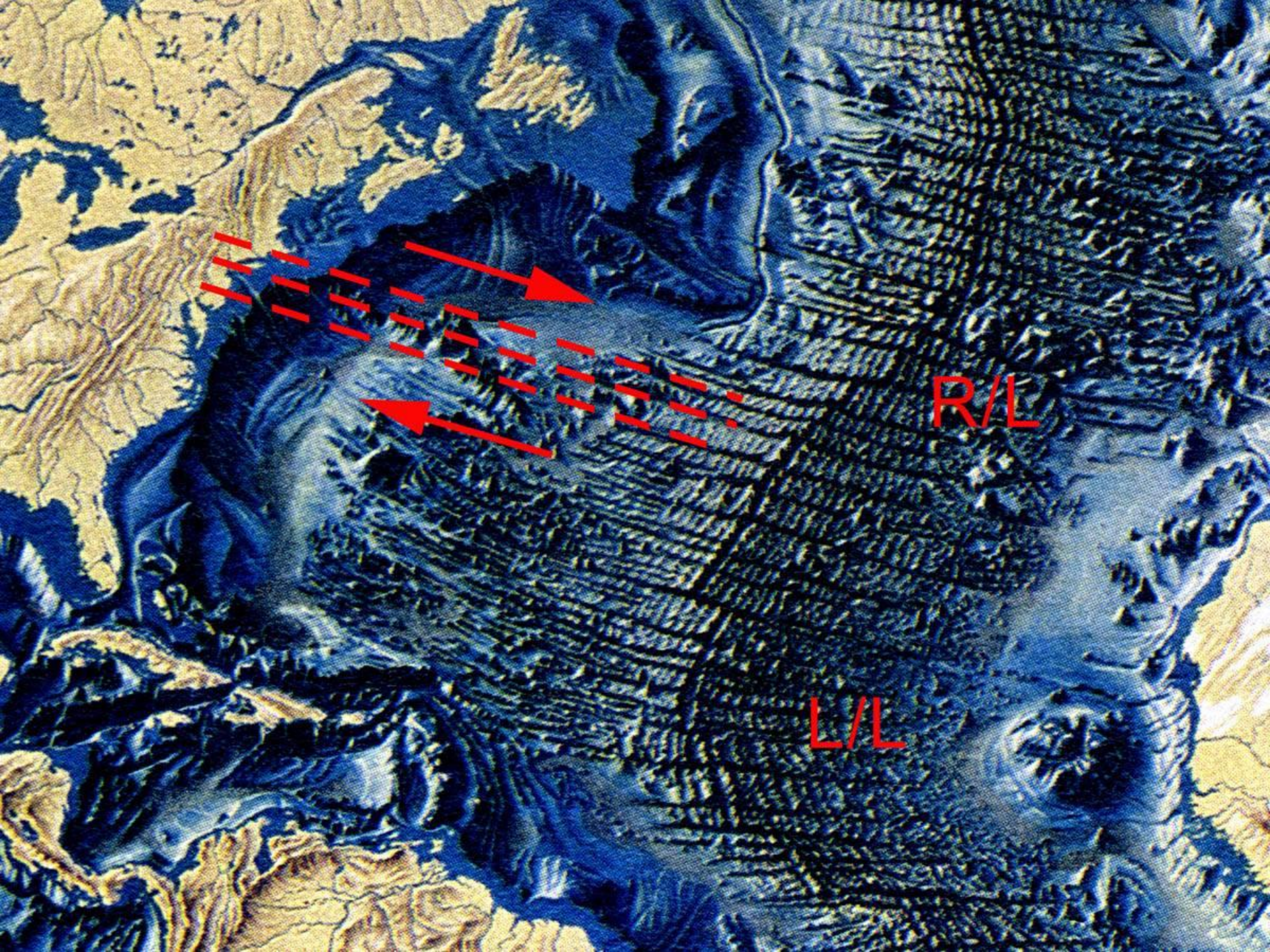
17 January 2001, M = 2.4





How Well Will NYC Withstand A Moderate Earthquake?

How is NYC Built?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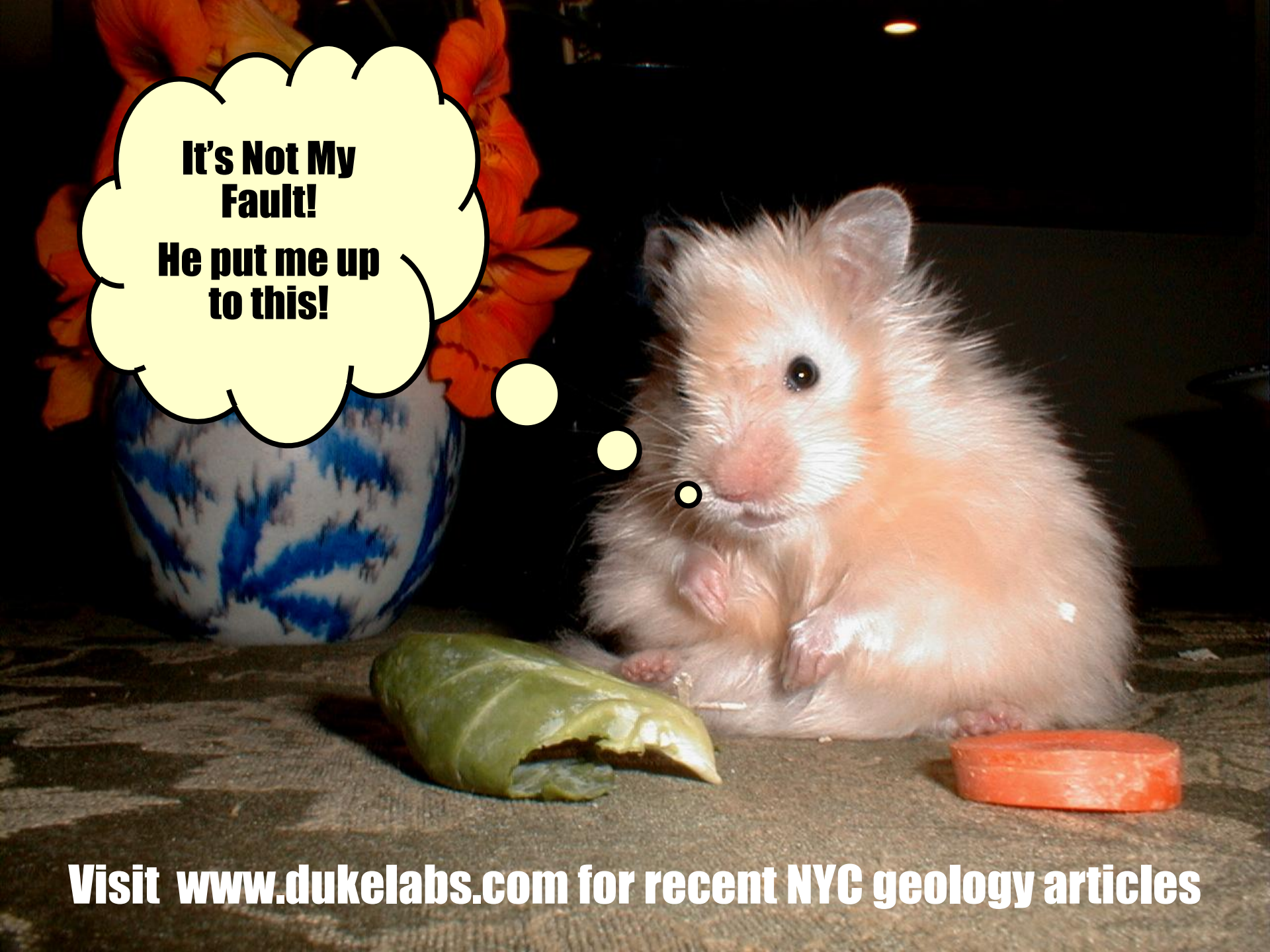
It's Not My Fault!
He put me up to this!
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