Orange County Mineral Society 10Apr26

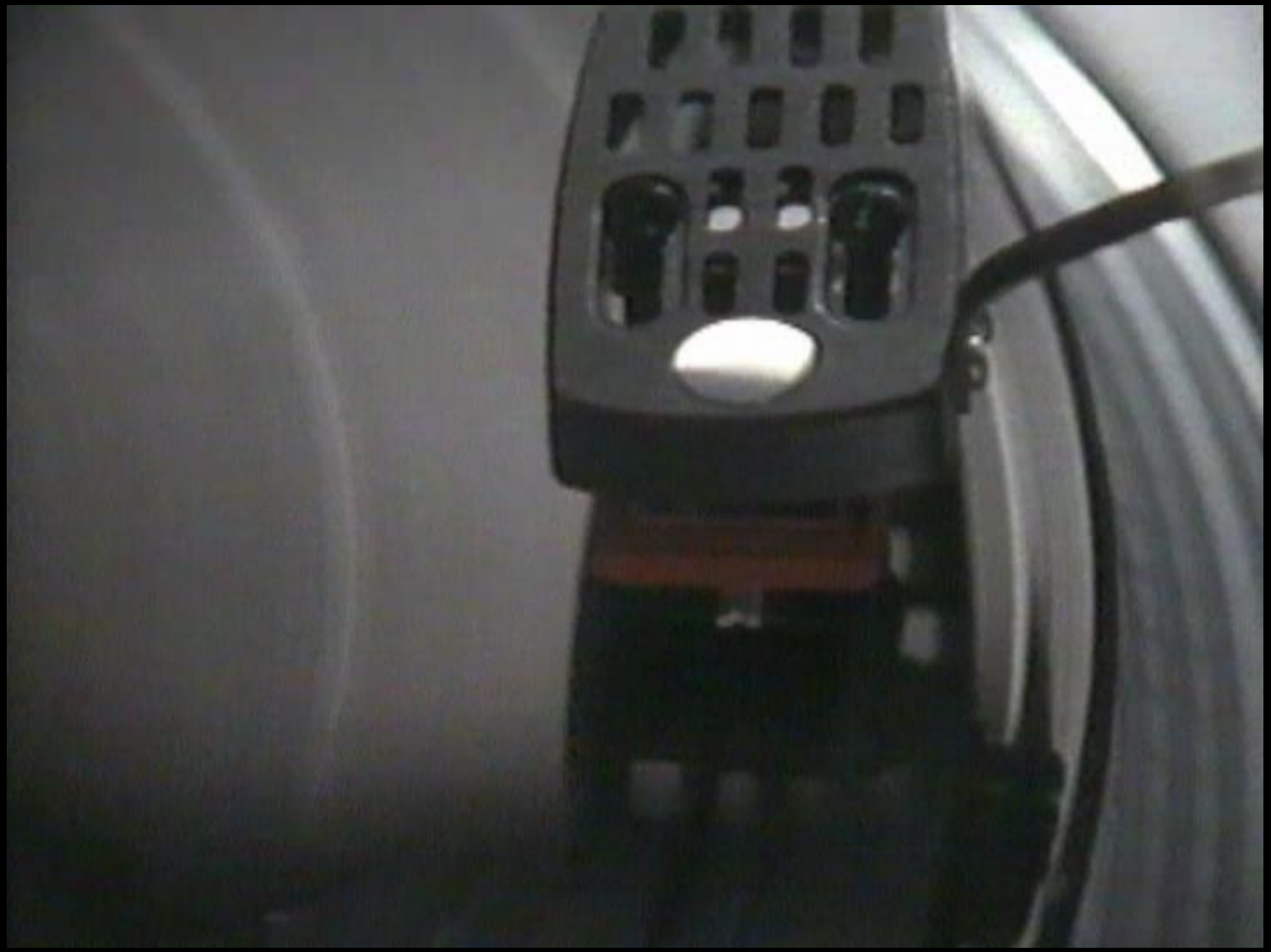
New York City Earthquakes - Can it Happen Here?

Charles Merguerian

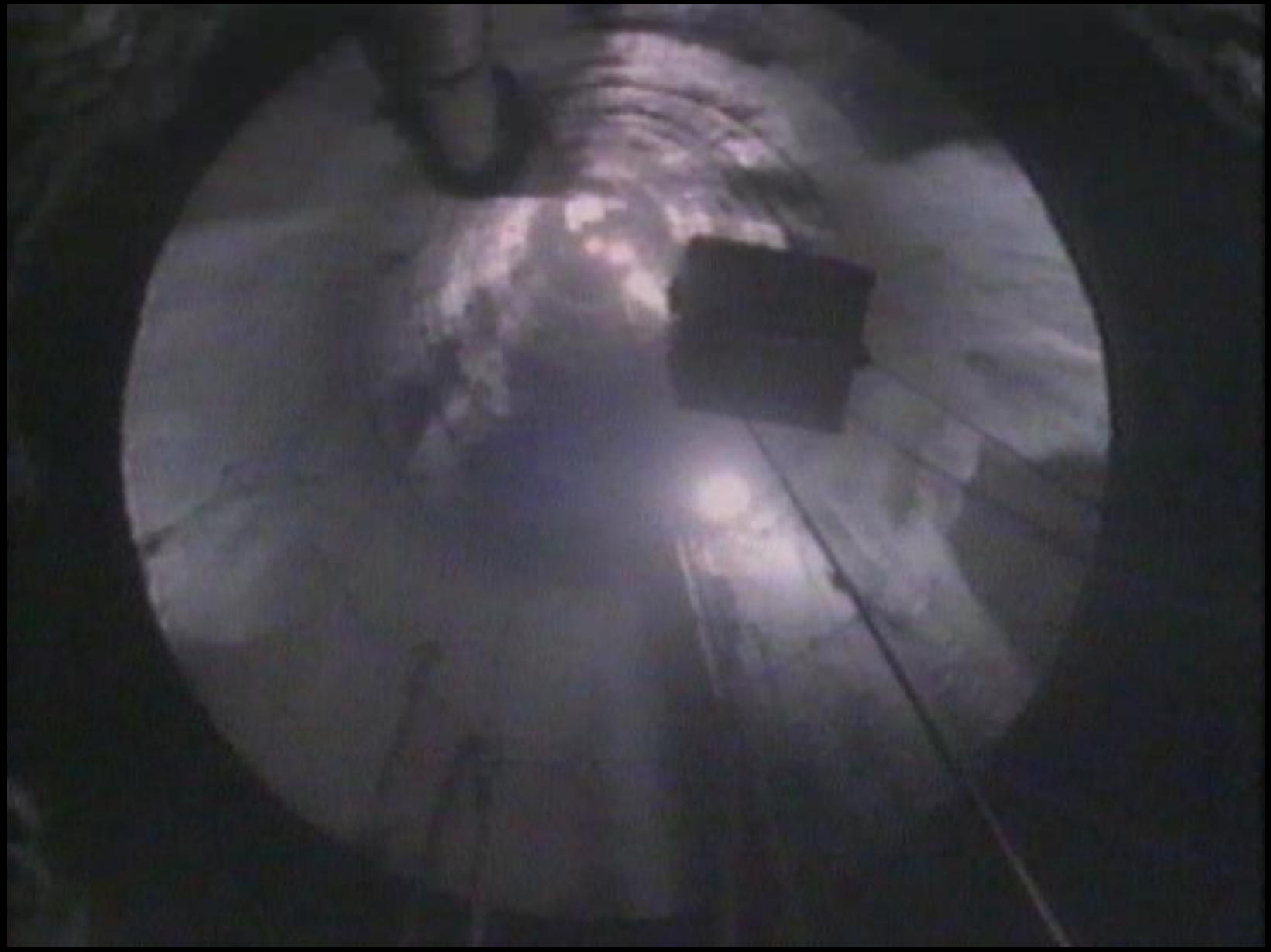
Duke Geological Lab
Stone Ridge, NY
www.dukelabs.com

DUKE

New York City Earthquakes - Fact or Fiction



From: Earthquakes – The Terrible Truth - ABC World of Discovery, 1994



From: Earthquakes – The Terrible Truth
ABC World of Discovery, 1994

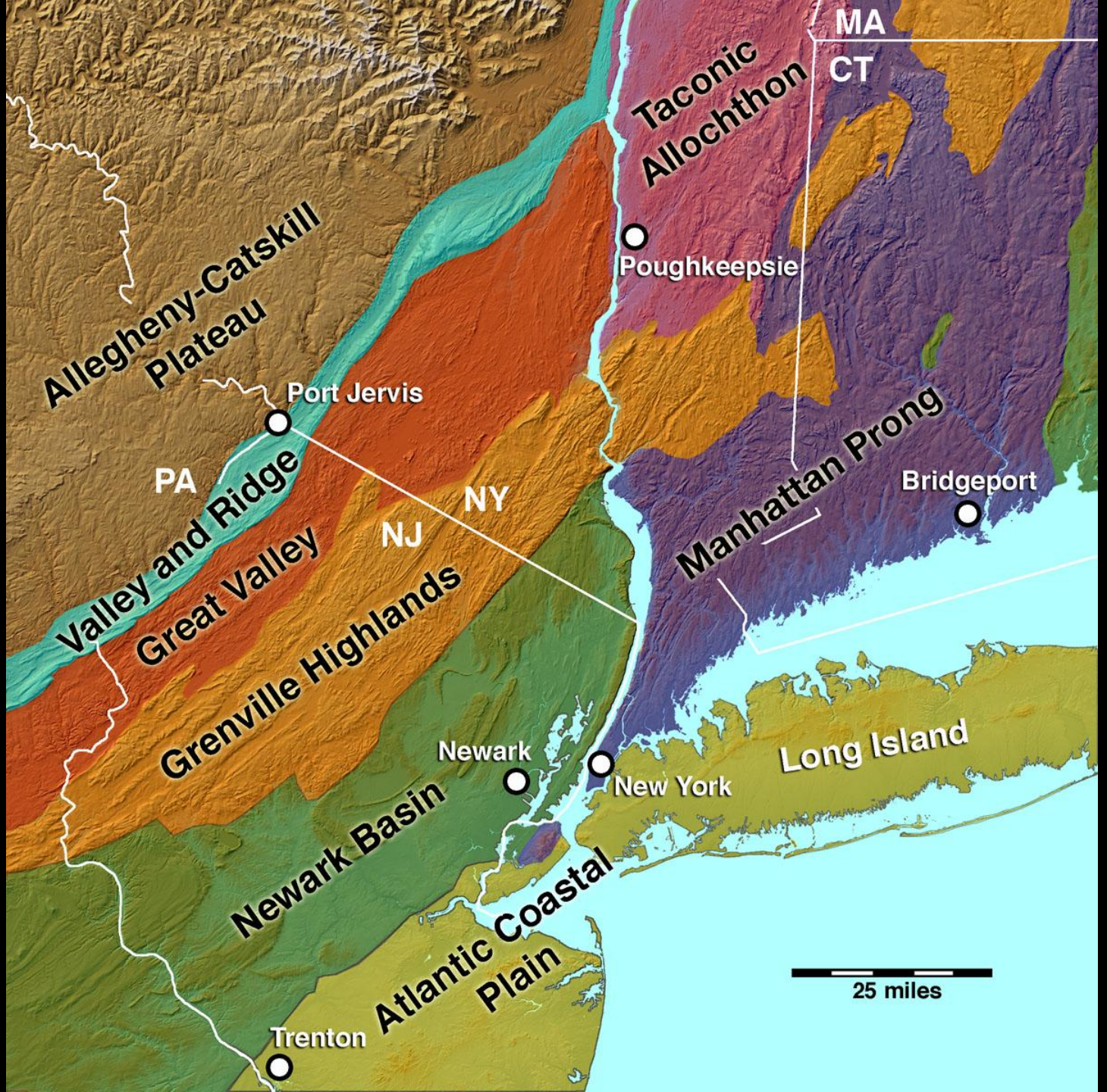
New York City Earthquake
When Might it Happen?

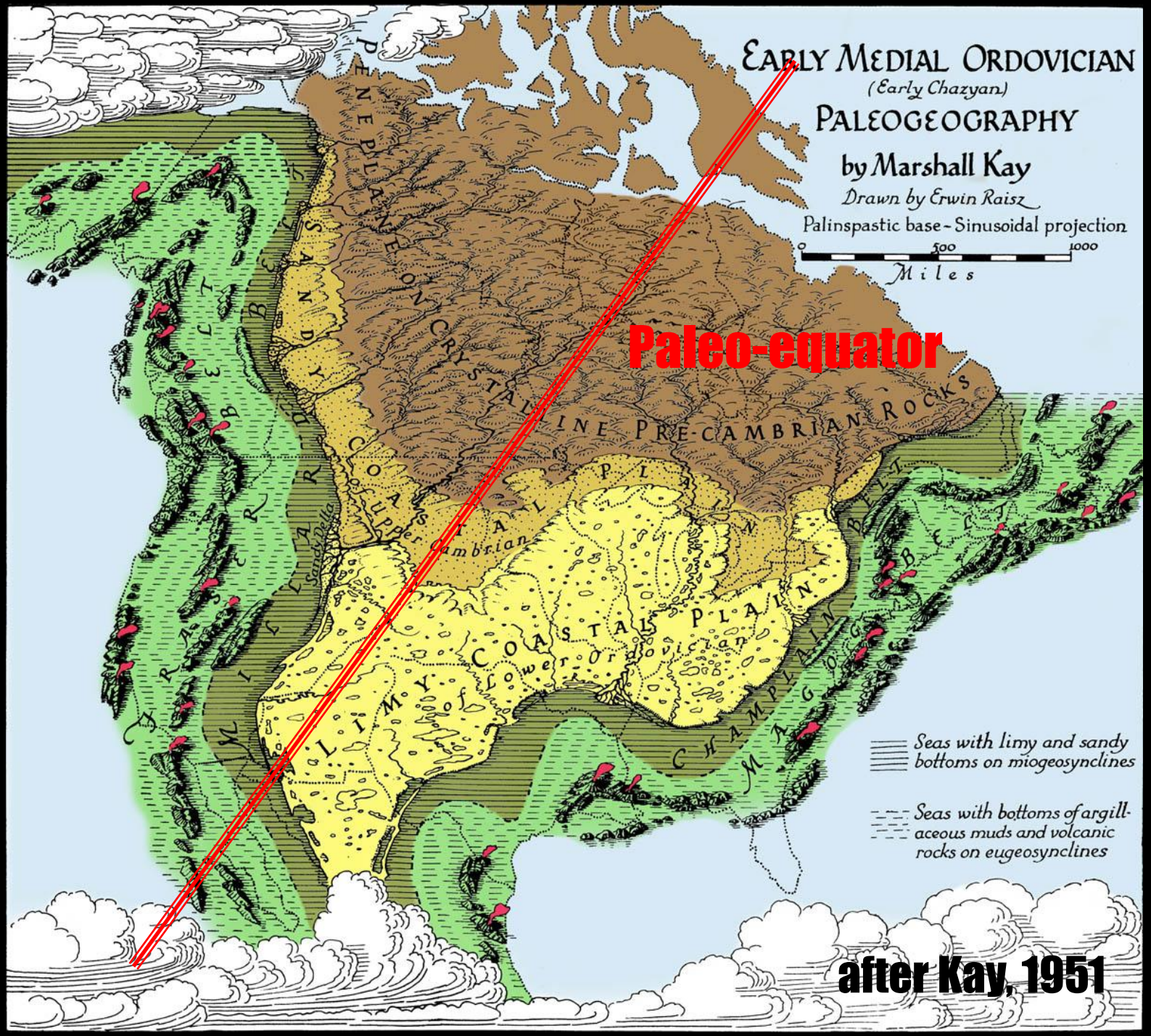
1737 5.2

1783 4.9

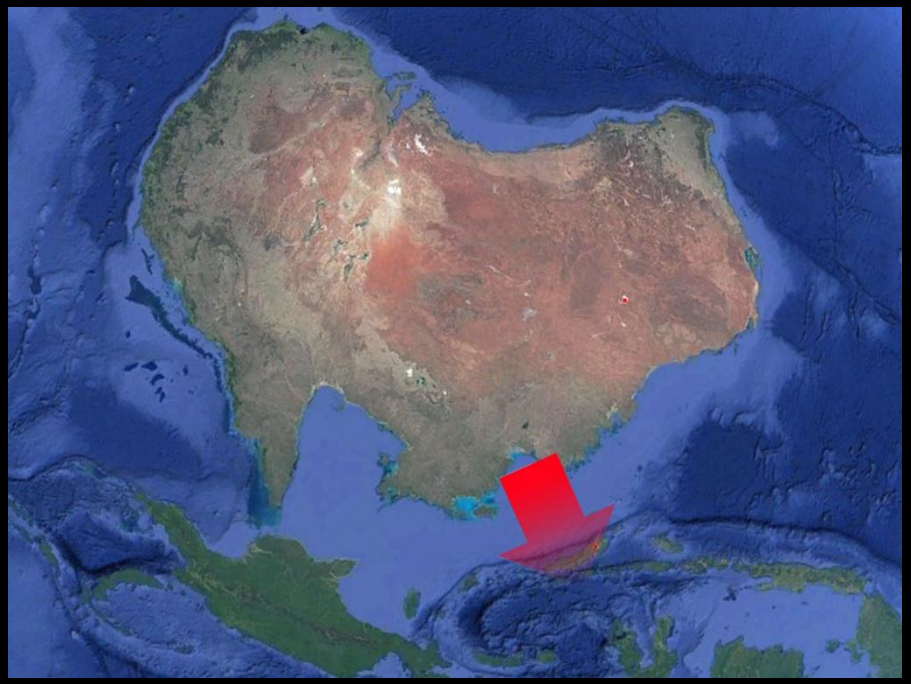
1884 5.2

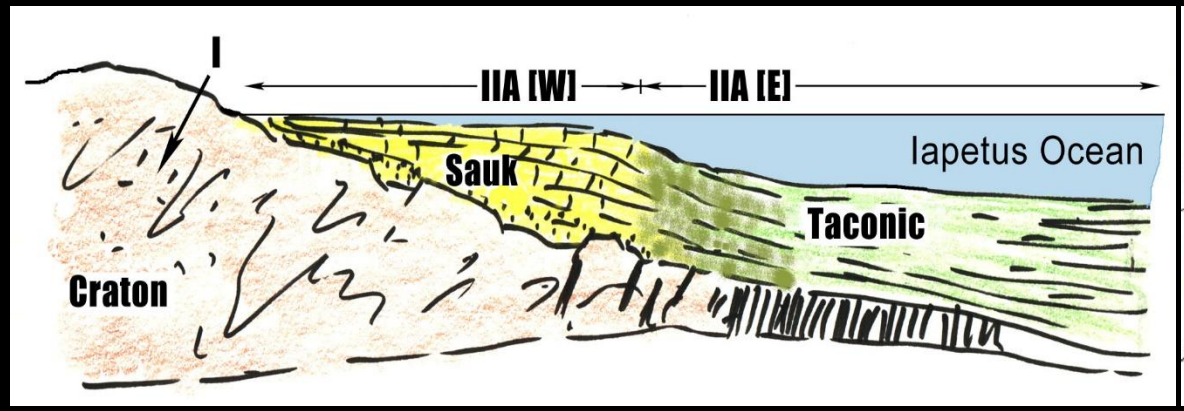
20xx ?

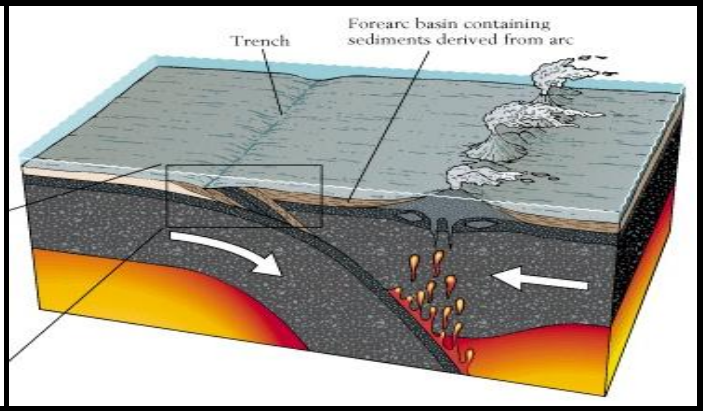

MA
CT
Taconic Allochthon
Poughkeepsie
Allegheny-Catskill Plateau
Port Jervis
PA
NY
NJ
Valley and Ridge
Great Valley
Grenville Highlands
Manhattan Prong
Bridgeport
Newark
New York
Long Island
Newark Basin
Atlantic Coastal Plain
Trenton
25 miles

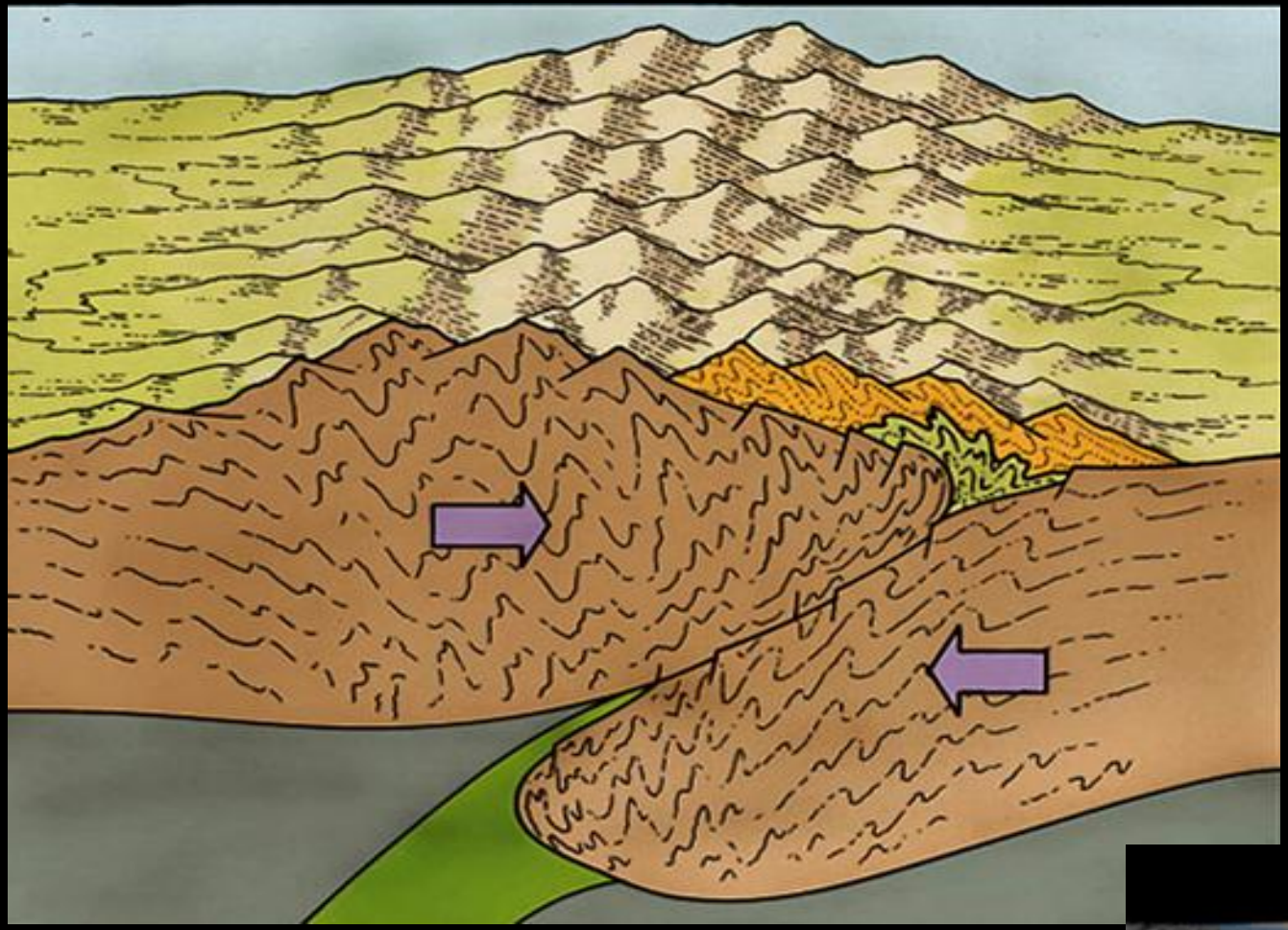

EARLY MEDIAL ORDOVICIAN
(Early Chazyan)
PALEOGEOGRAPHY
by Marshall Kay
Drawn by Erwin Raisz
Palinspastic base - Sinusoidal projection
500
1000
Miles
Paleo-equator
PENEPLANED CRYSTALLINE PRE-CAMBRIAN ROCKS
SANDY COASTAL PLAIN of Upper Cambrian
LIMY COASTAL PLAIN of Lower Ordovician
CHAMPLAIN MAGOG BELT
Seas with limy and sandy bottoms on miogeosynclines
Seas with bottoms of argillaceous muds and volcanic rocks on eugeosynclines
after Kay, 1951

~ 450 Ma Taconian Arc – Passive Margin Collision



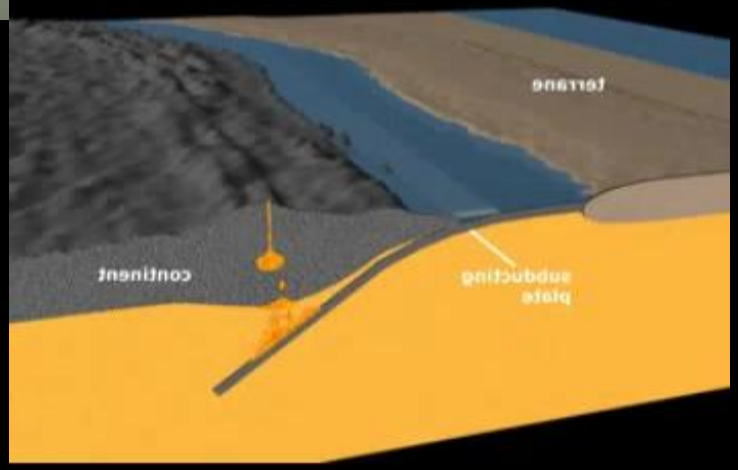






Beautiful!
Beau-ti-ful!

Terminal Phase Appalachian Orogeny



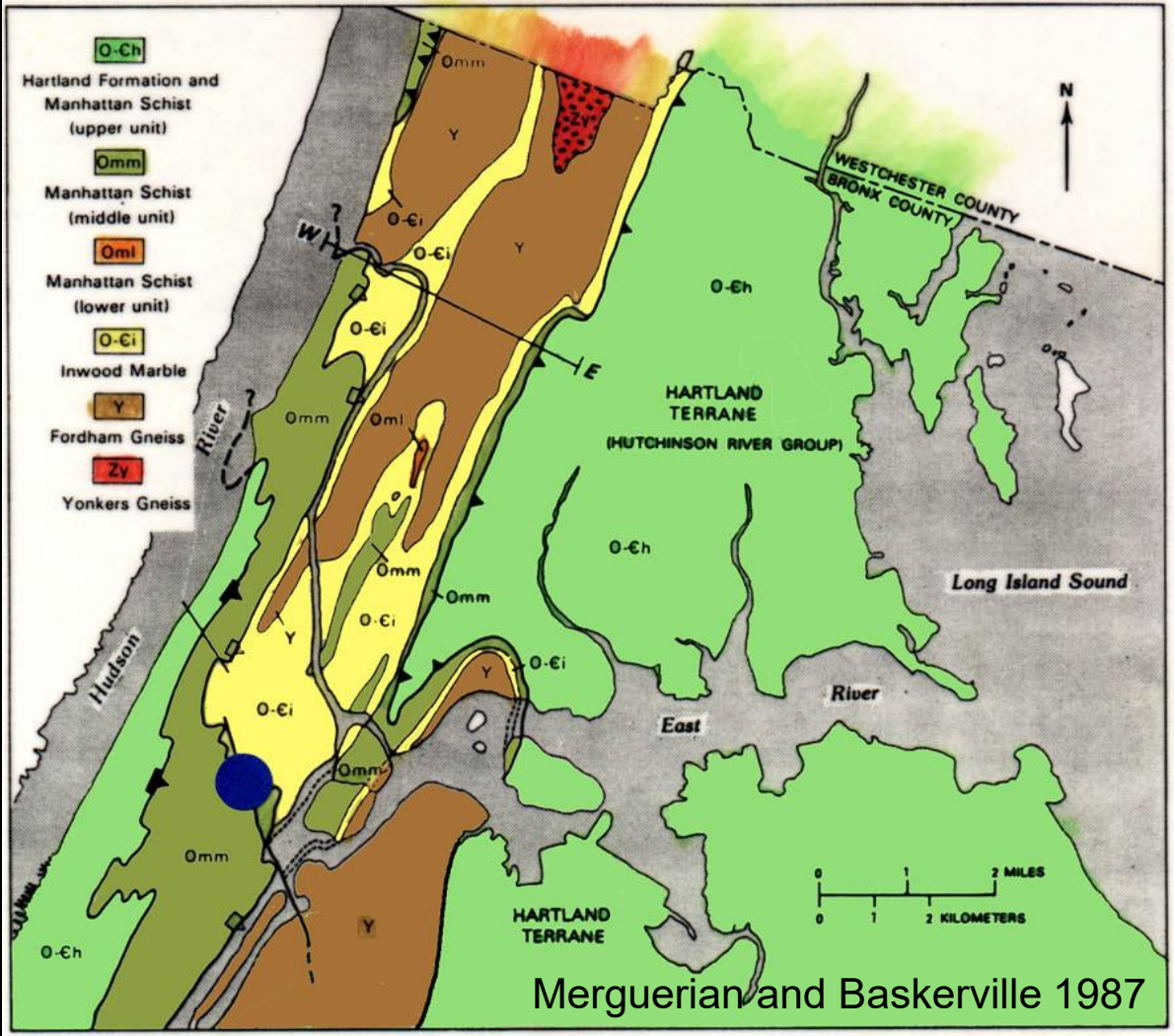
Merguerian's Early Field Work on Manhattan Island

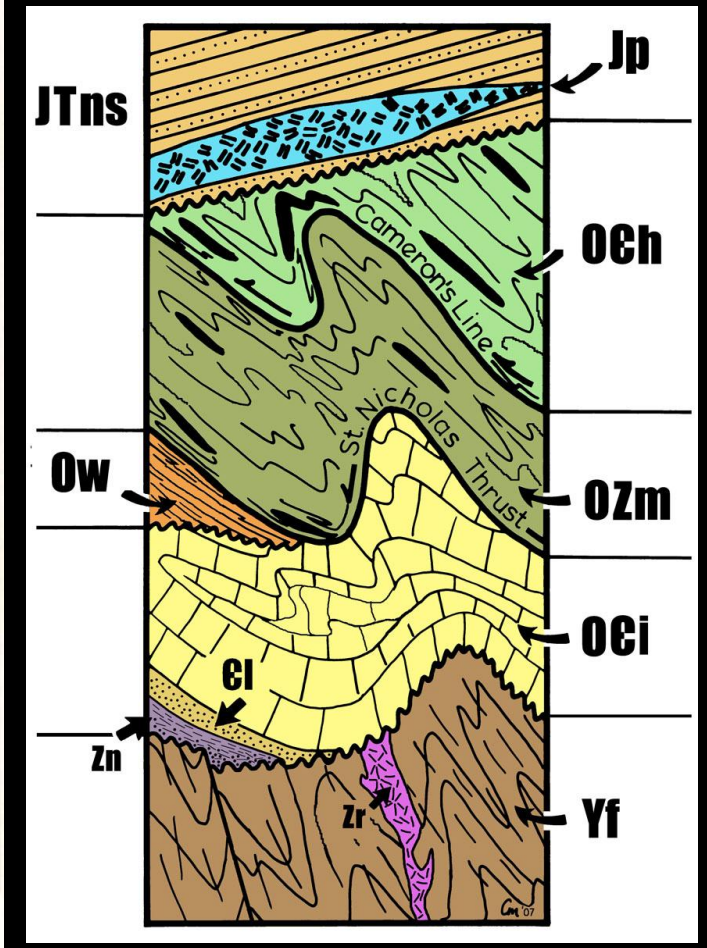
In the Days - When He Was Younger and Limber

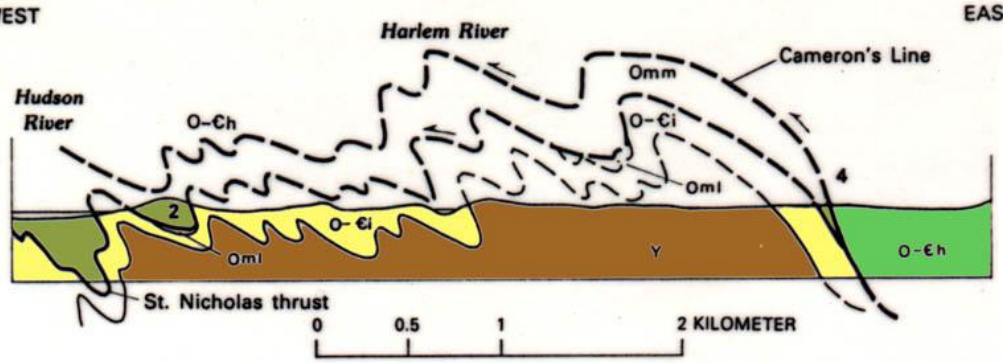
Merguerian Has Spent (Wasted?) Most of his Career Mapping the Surface and Subsurface Geology of NYC

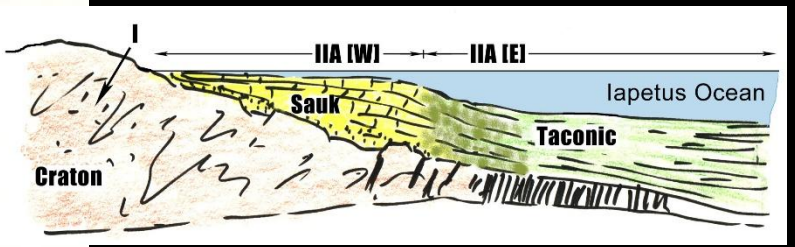
Proper Field Attire For NYC Field Work

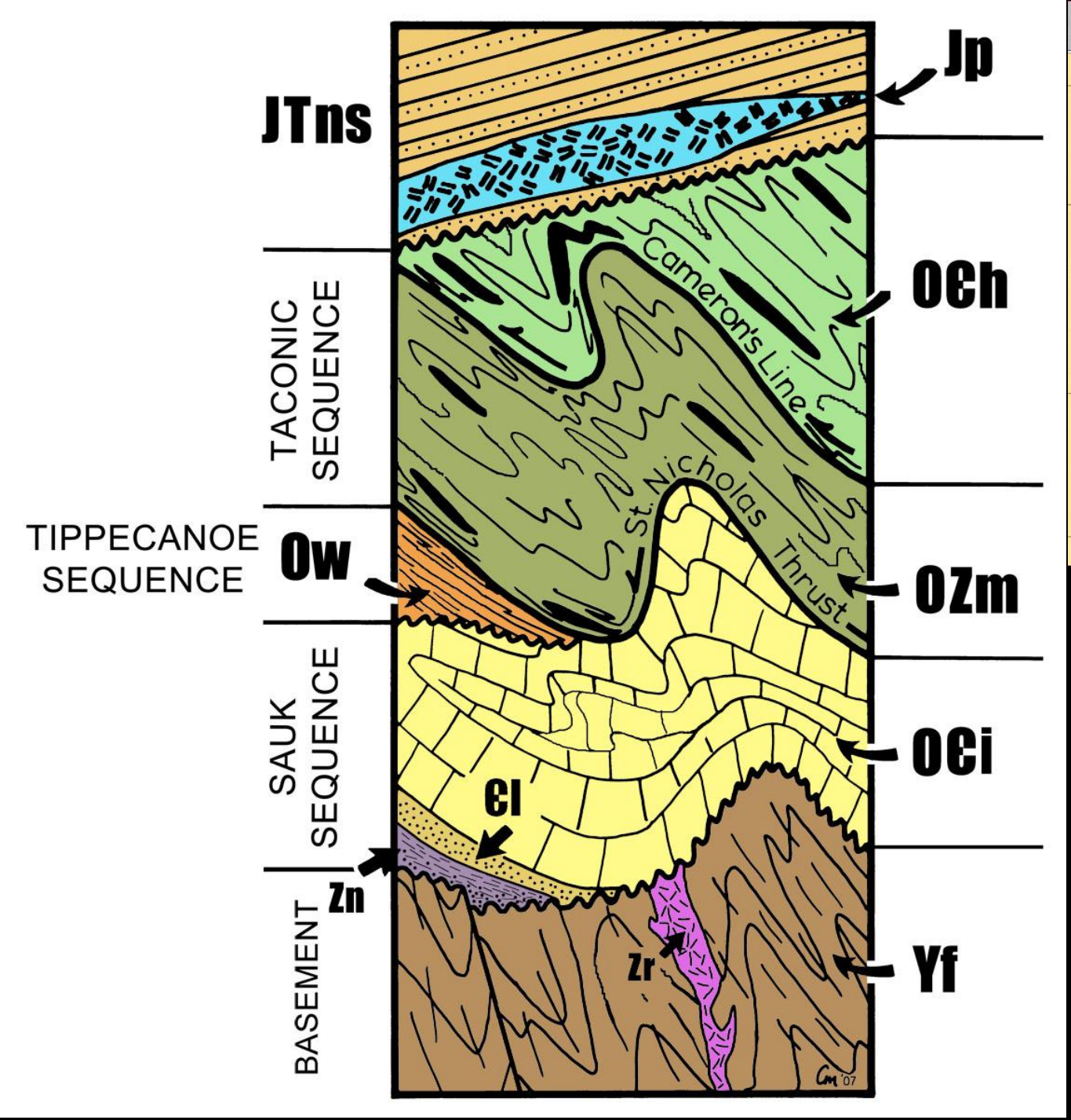
New York City

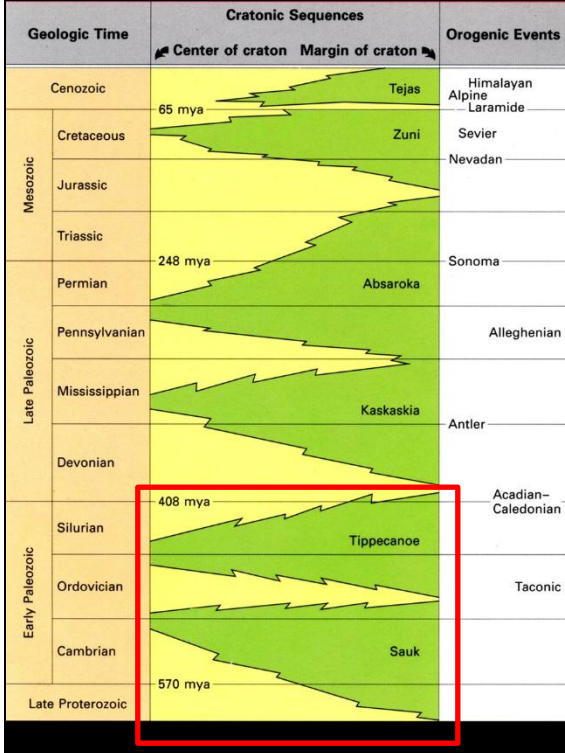












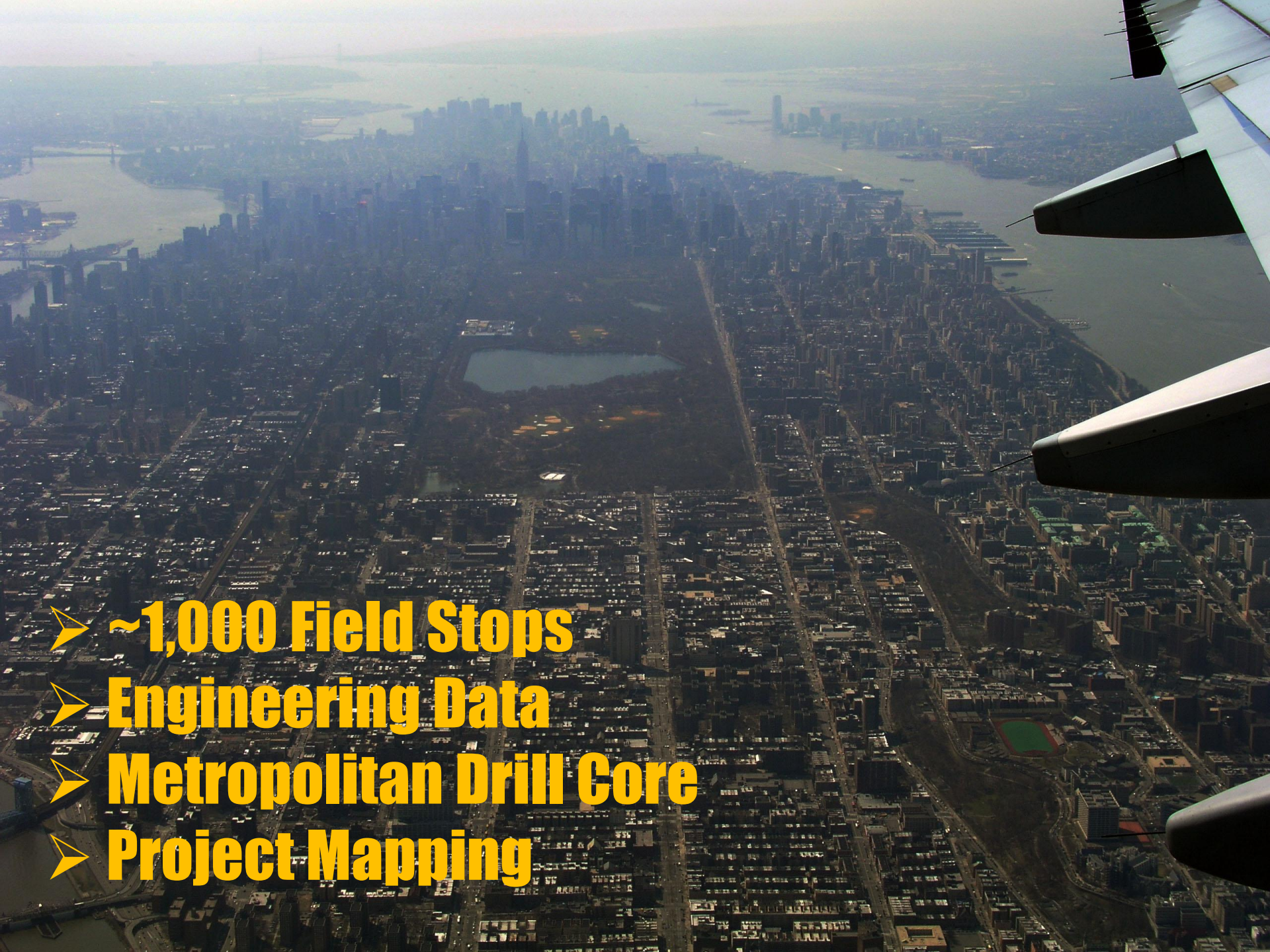
Sloss, 1963

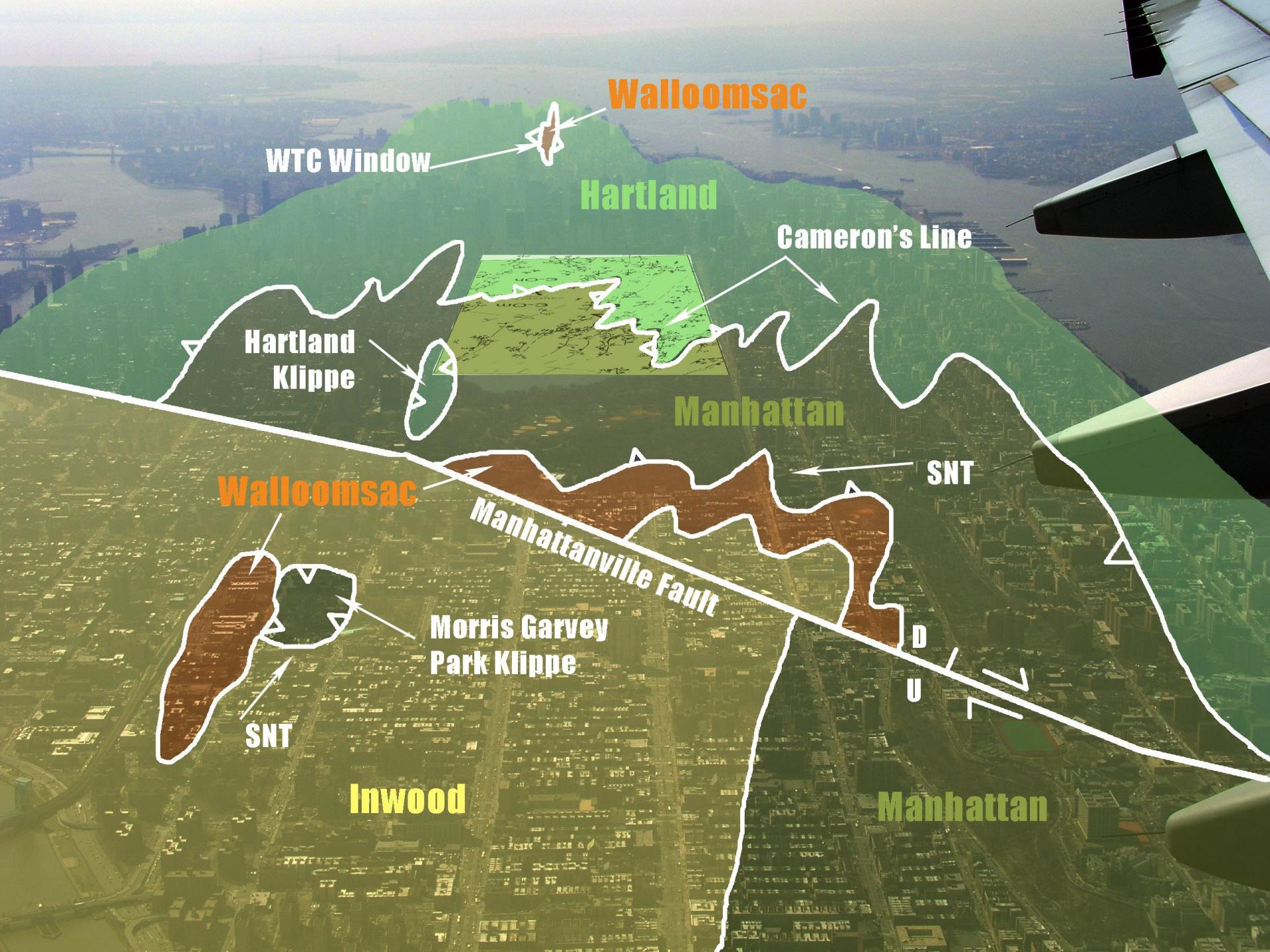
Taconic

Taconic

Tippecanoe

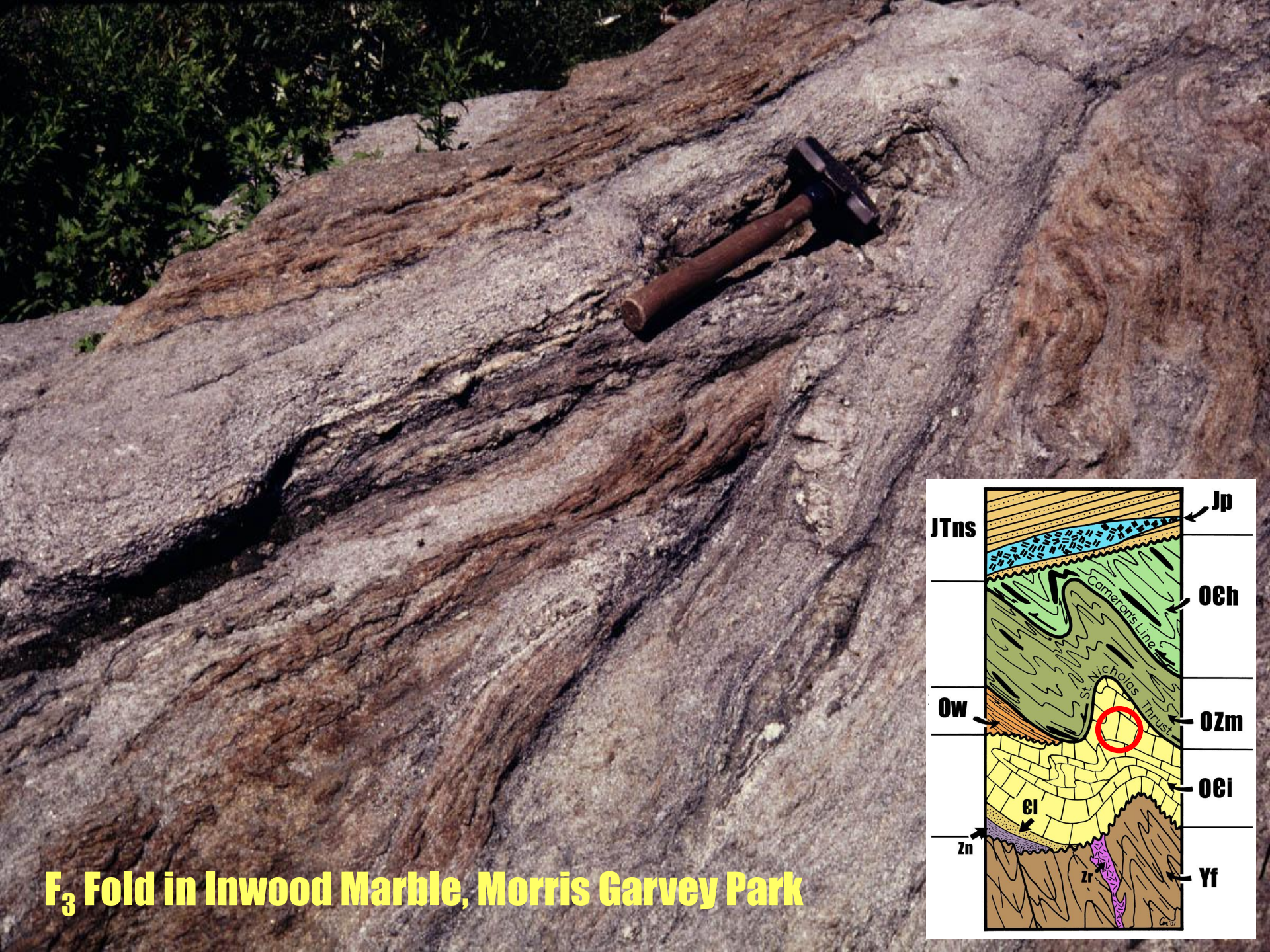
Sauk


~1,000 Field Stops
Engineering Data
Metropolitan Drill Core
Project Mapping


Walloomsac
WTC Window
Hartland
Cameron's Line
Hartland
Klippe
Manhattan
SNT
Walloomsac
Manhattanville Fault
Morris Garvey
Park Klippe
D
U
SNT
Inwood
Manhattan


Fordham Gneiss, Echo Park

JTns
Jp
Oeh
Cameron's Line
St. Nicholas Thrust
Ow
OZm
Oei
Cl
Zn
Zr
Yf



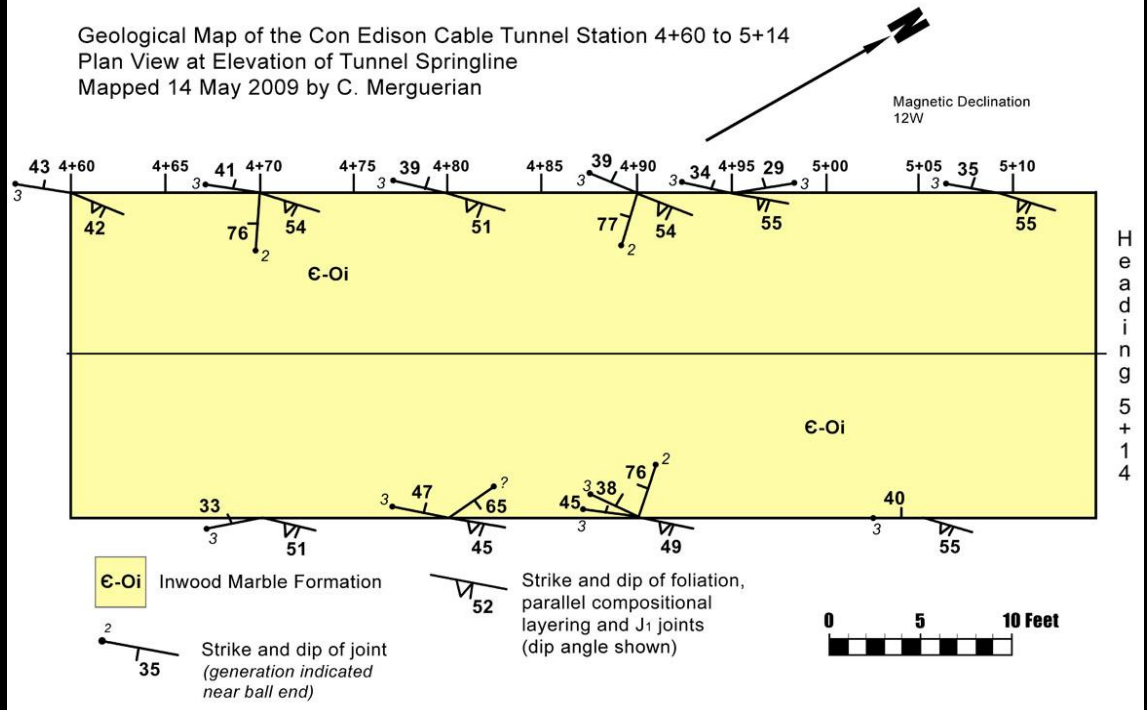
F_3 Fold in Inwood Marble, Morris Garvey Park

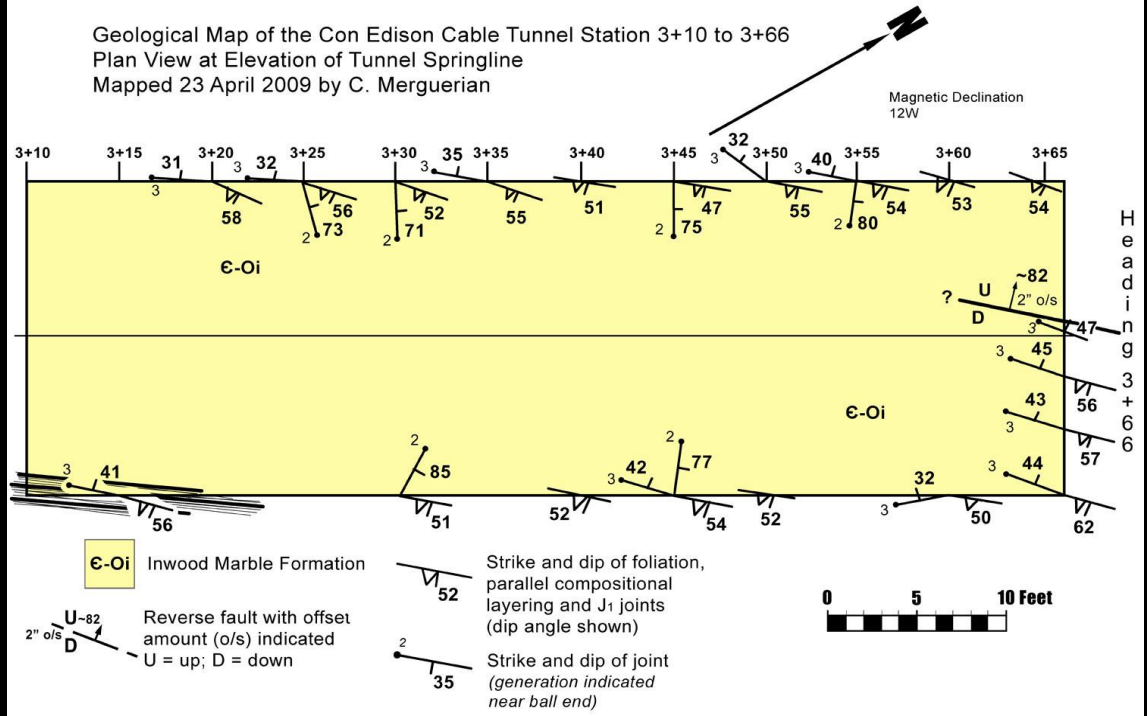
Con Edison Cable Tunnel
2009 D&B Tunnel – 700’

Harlem River Tunnel - 2009

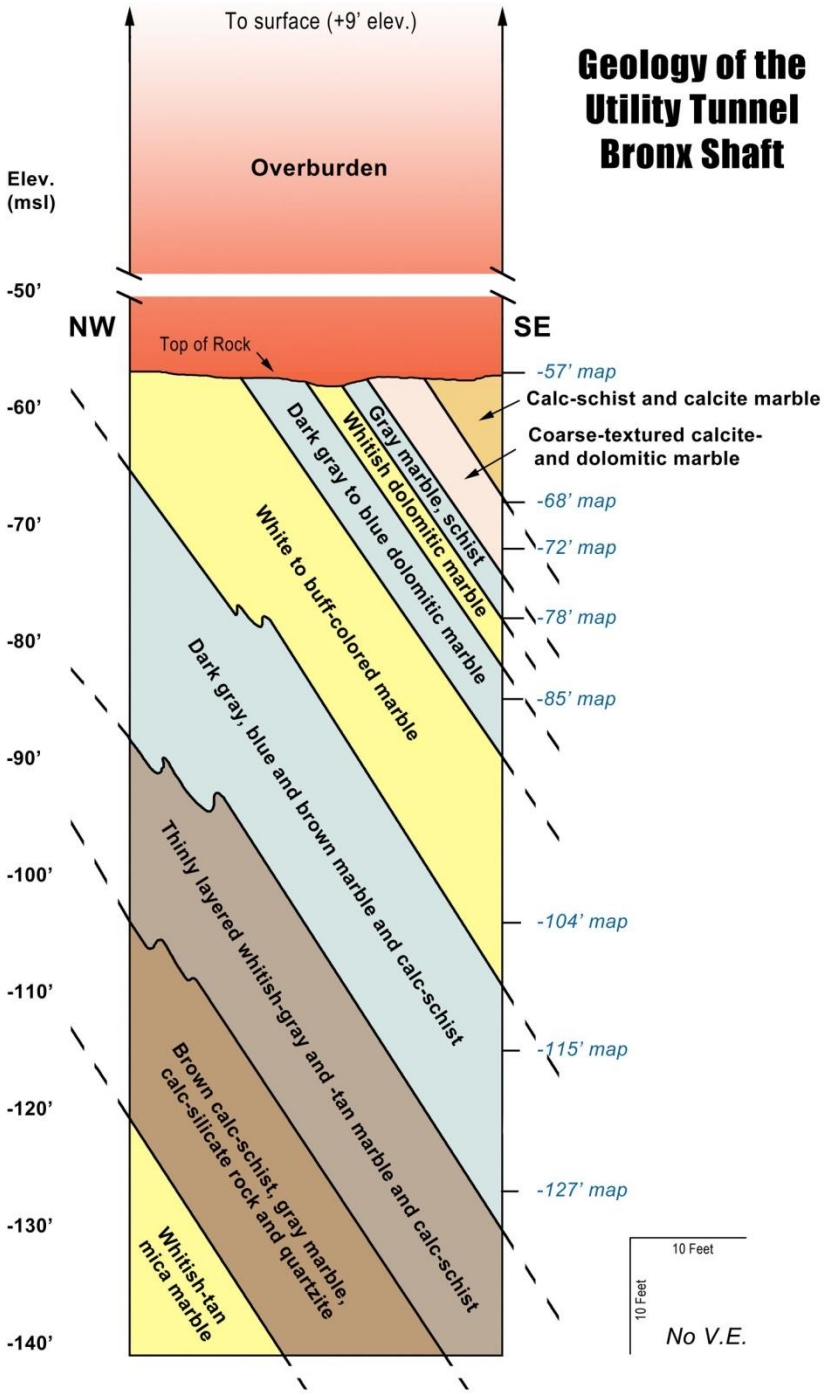
Con Edison Cable Tunnel
2009 D&B Tunnel – 700’

Elev. -150’





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’

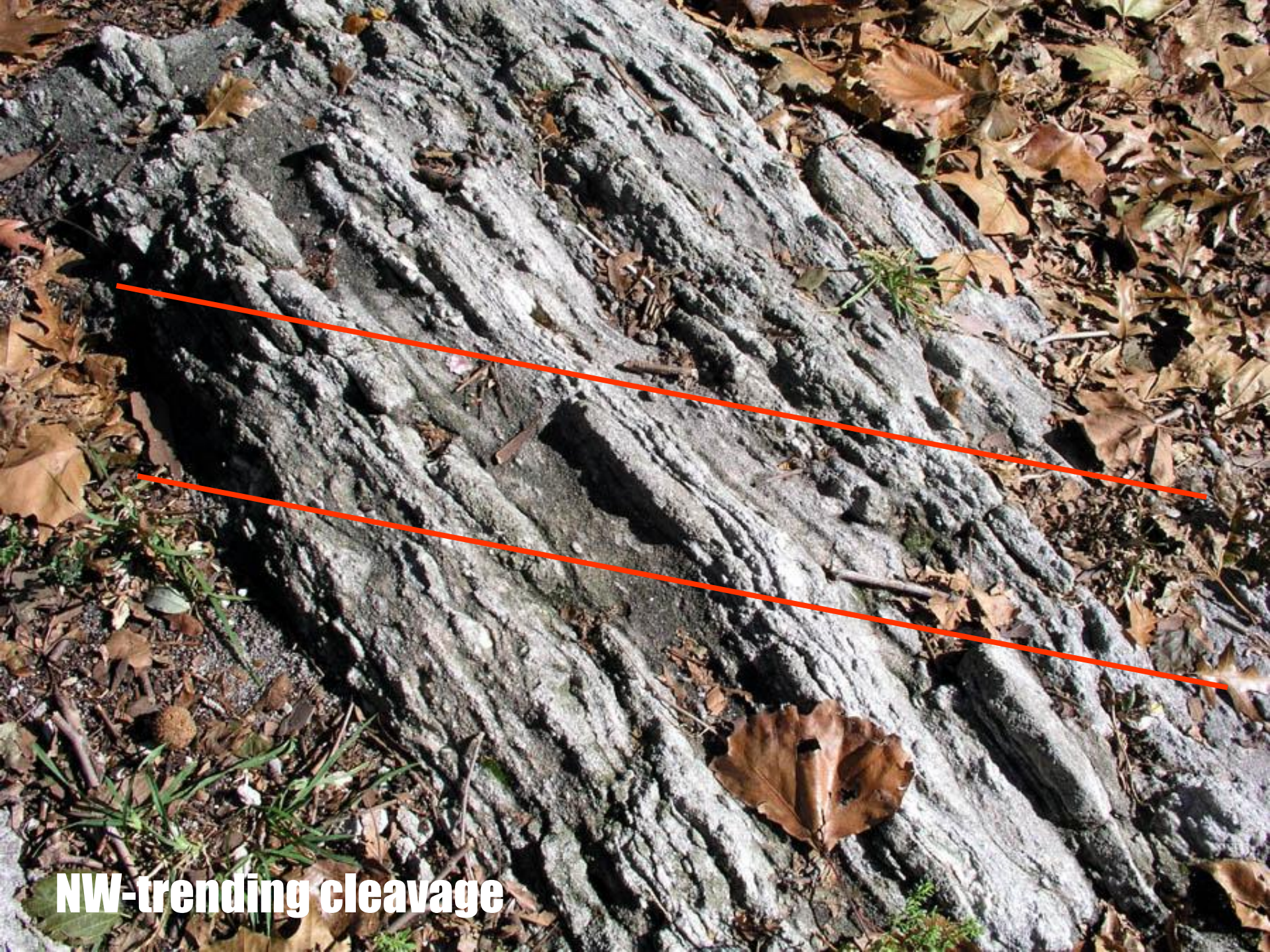


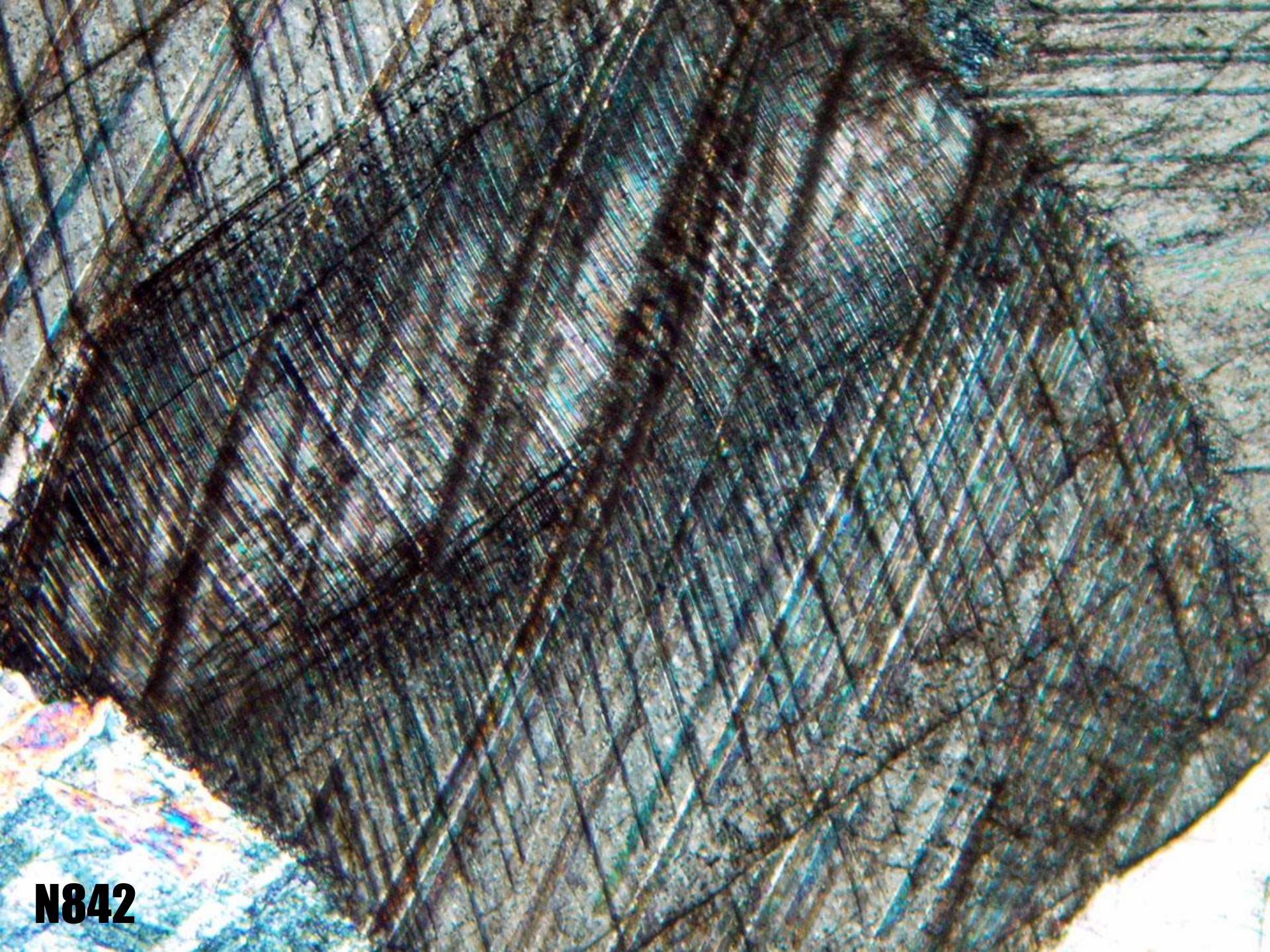
Isham Park, NYC


Preliminary Geological Map of Isham Park, No. Manhattan, NY
SEAMAN AVENUE
PARK TERRACE EAST
ISHAM STREET
Well-layered White to Gray Dolomitic Marble
Marble, Schist, and Calc-silicate
White to Gray Dolomitic and Calcite Marble
White Coarse-Textured Calcite Marble
S0 x S1
S2
S3
S4
S2
S3
S4
F2
F3
F4
N
0'
20'
40'
60'
80'
100'


Coarse-textured Calcite Marble

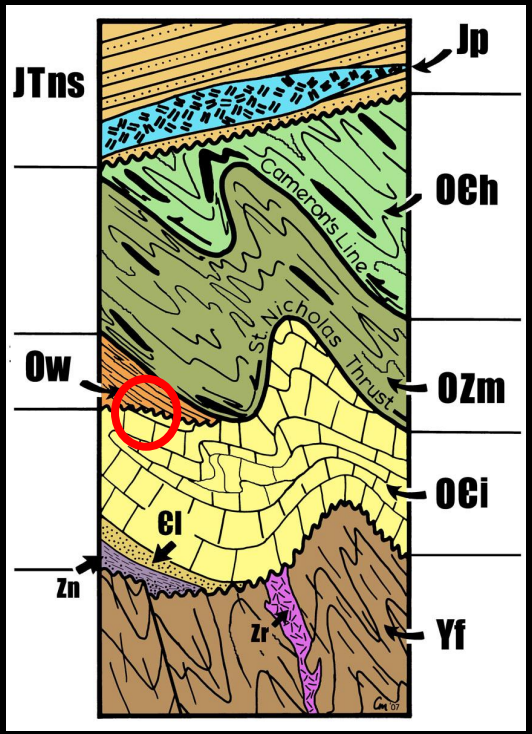
L3 Lineated Tremolite after Diopside Porphyroblasts


NW-trending cleavage


N842


Inwood Hill Park, NYC
Utility Tunnel
and Bronx Shaft
(approx.)
Isham
Park
NW
SE
Є-Oh
Ow
Є-Om
Є-Oi
Є-Om
Є-Oi
Є-Oi
Yf
Yf
Inwood Hill Park
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Tippecanoe



Inwood Hill, Boro Hall, FDR, Verplanck Pt., Stony Point

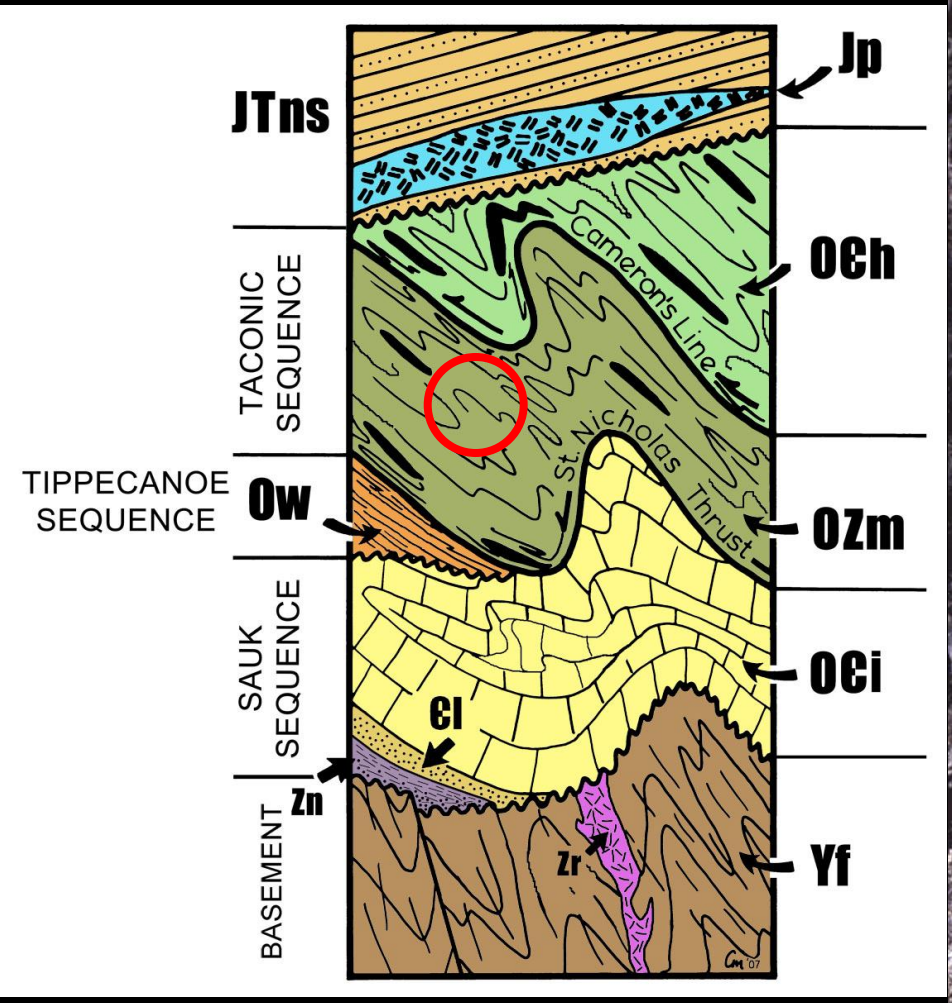
Annsville, Manhattan A, Martinsburg, Normanskill +

454 Ma base VT - Fossils

N293 - I-95 Grand Concourse, Bronx - Walloomsac ("Balmville")

Tippecanoe

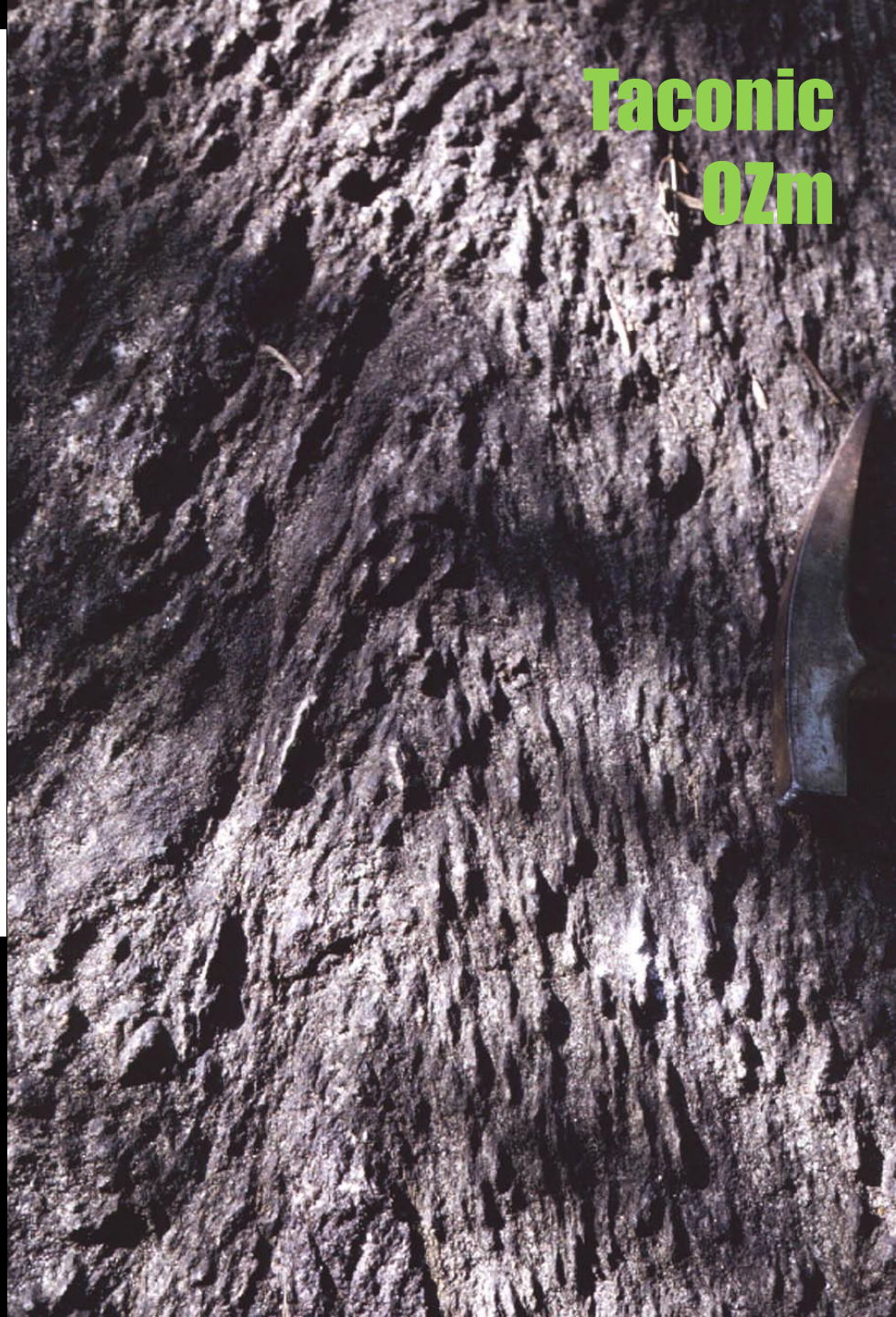
N622 – Warren Street, So. Manhattan (Ow)

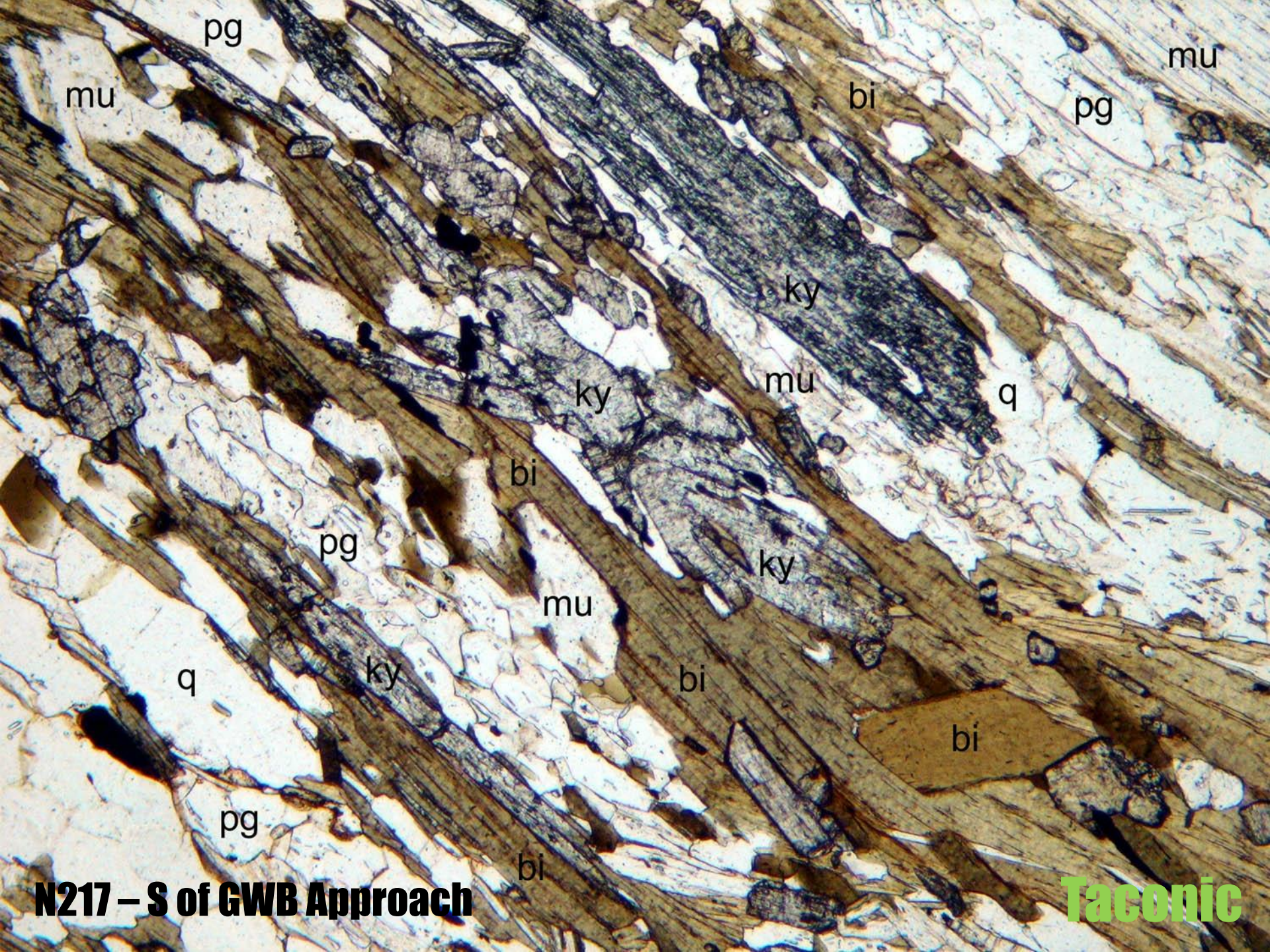


Manhattan Gneiss, Schist, Granofels, Amphibolite - OZm

F_3 Folds of S_2 ---------→

Waramaug, Manhattan C, Hoosac

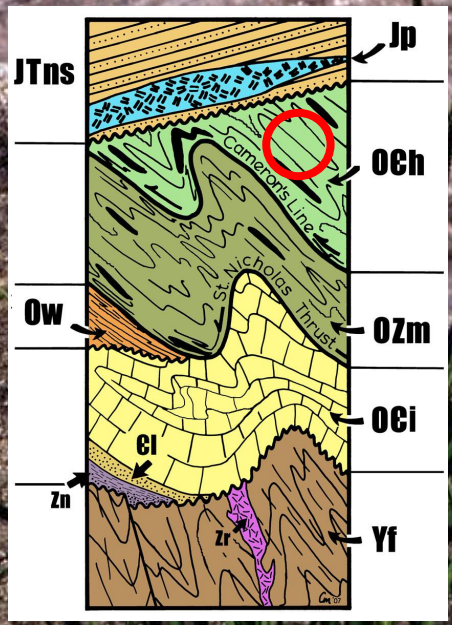




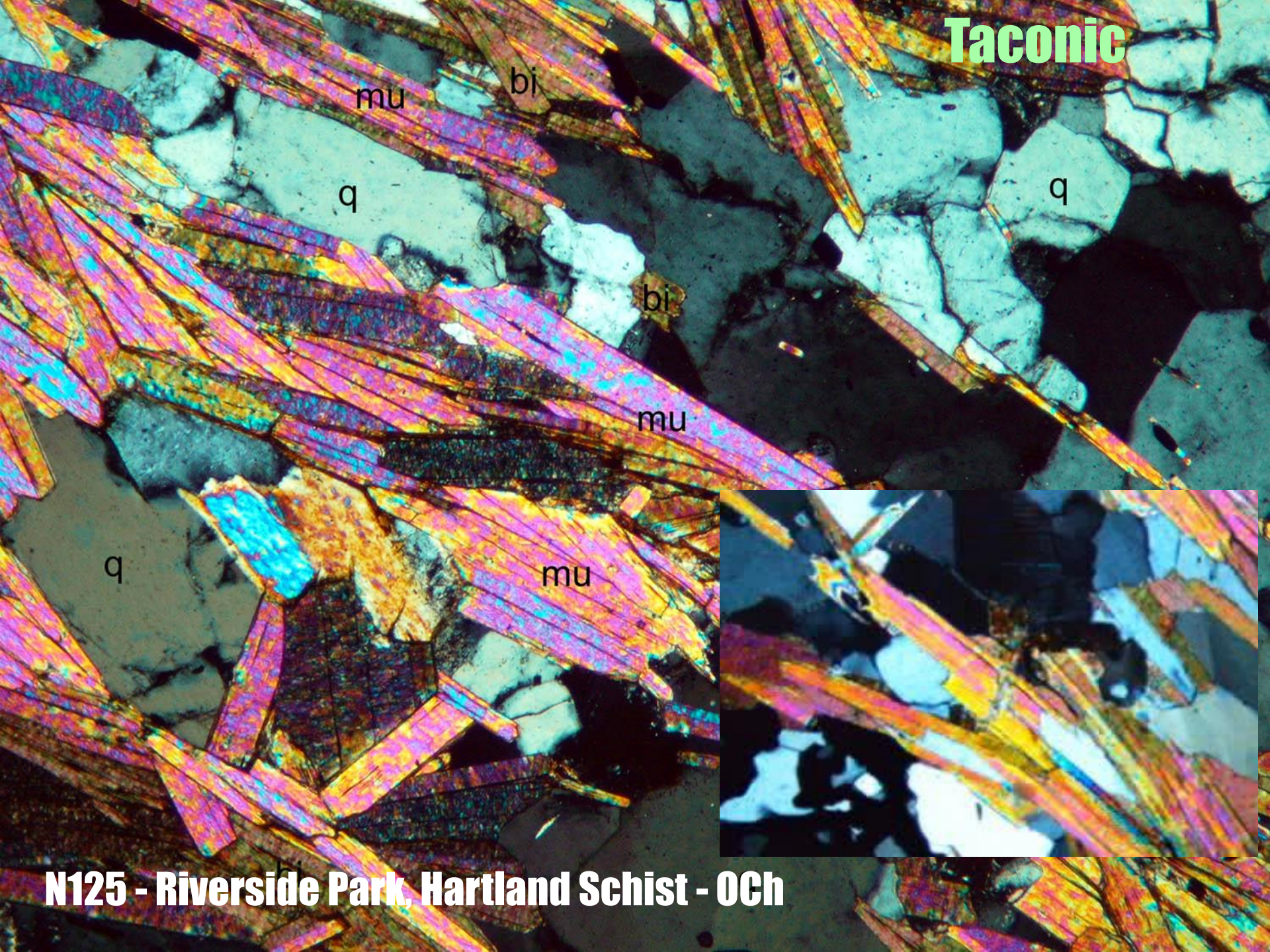
N217 – S of GWB Approach

Taconic

Taconic
OCh



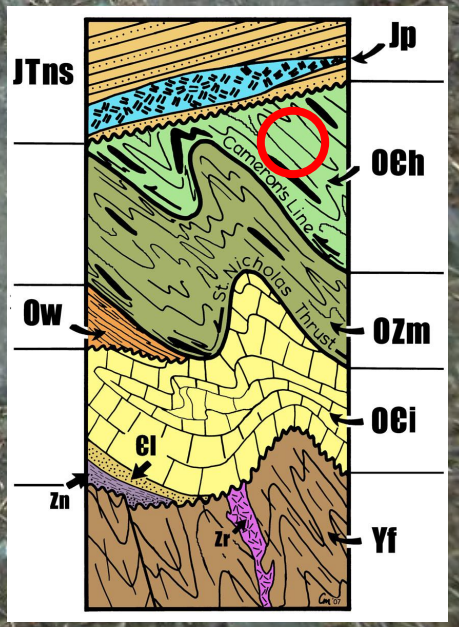
N114 - Riverside Park, Hartland Schist



N125 - Riverside Park, Hartland Schist - OCh

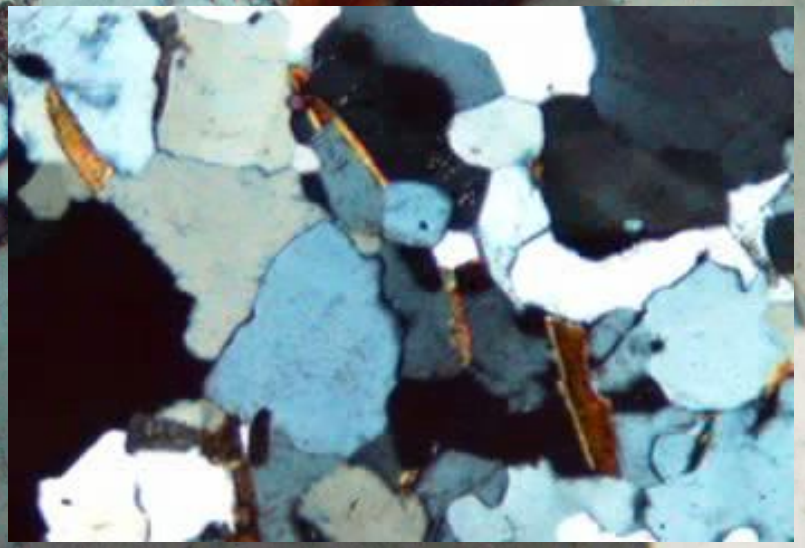
Taconic
OCh

SW Central Park, Hartland Granofels



N624 – Warren Street. NYC

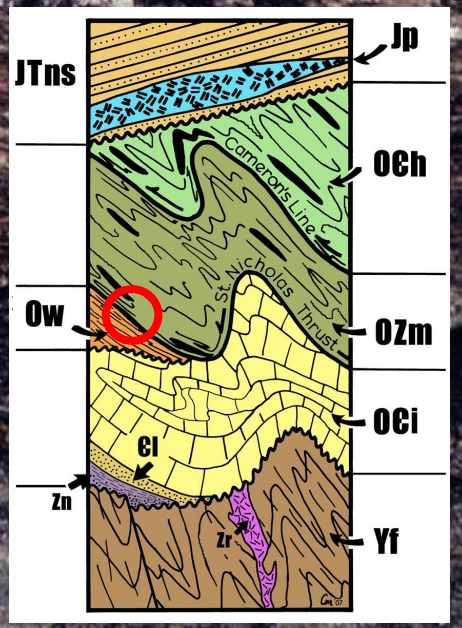
Taconic
OCh



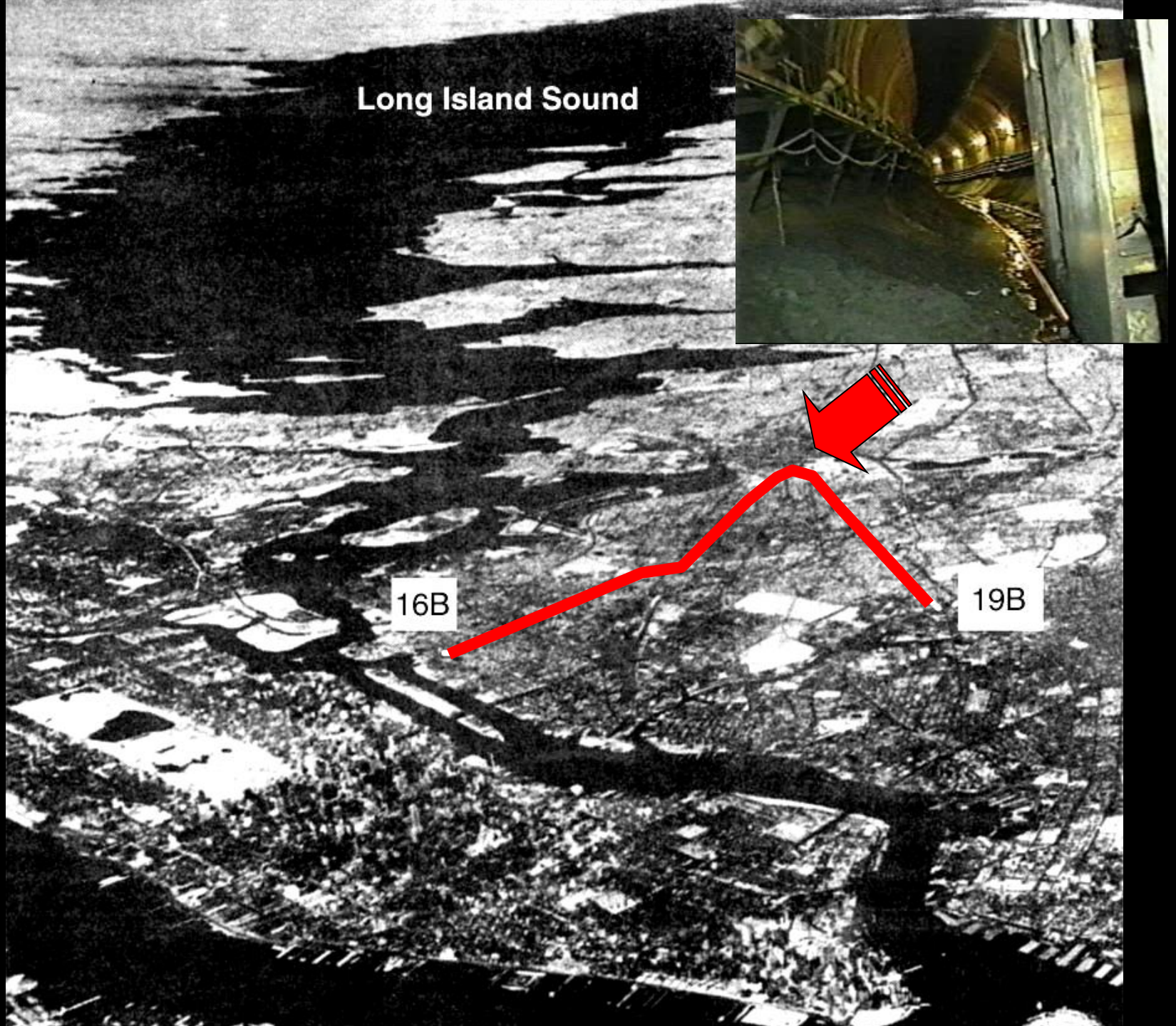

Taconic
OCha
N567 - Central Park, Hartland Amphibolite

CL and SNT Structural Features

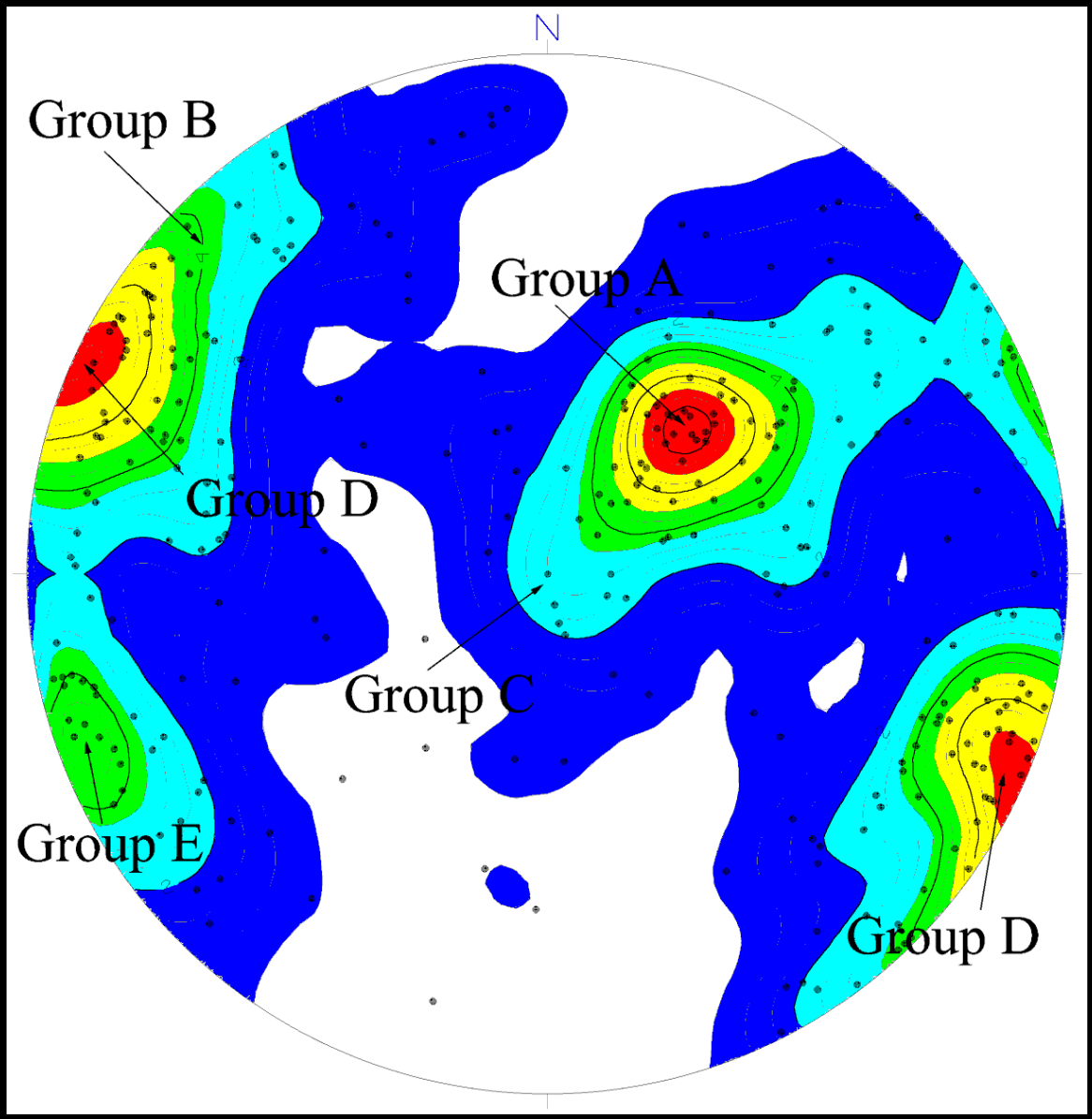
Taconic
OZm



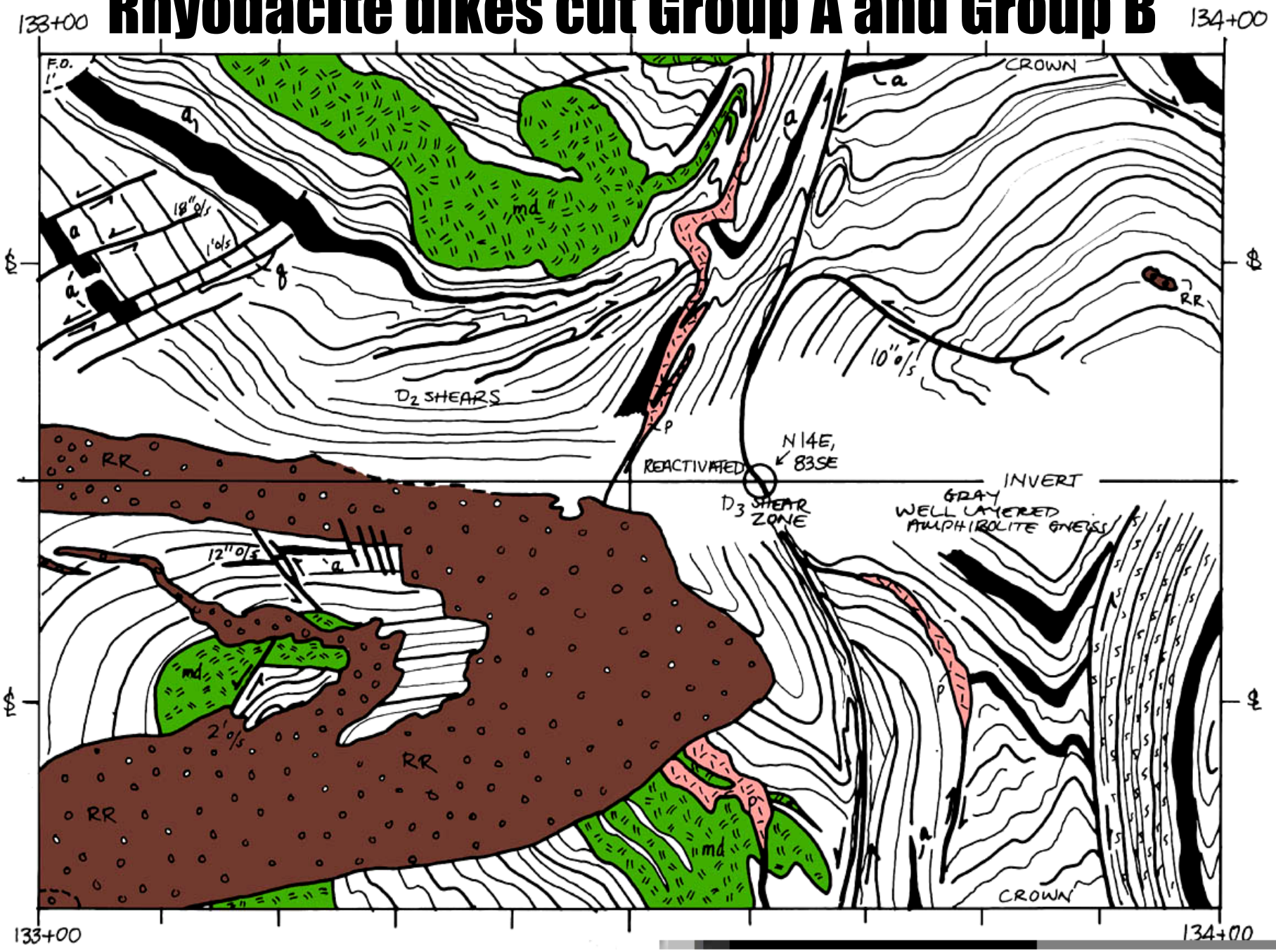
N177 - St. Nicholas Park - Sheared Manhattan Schist

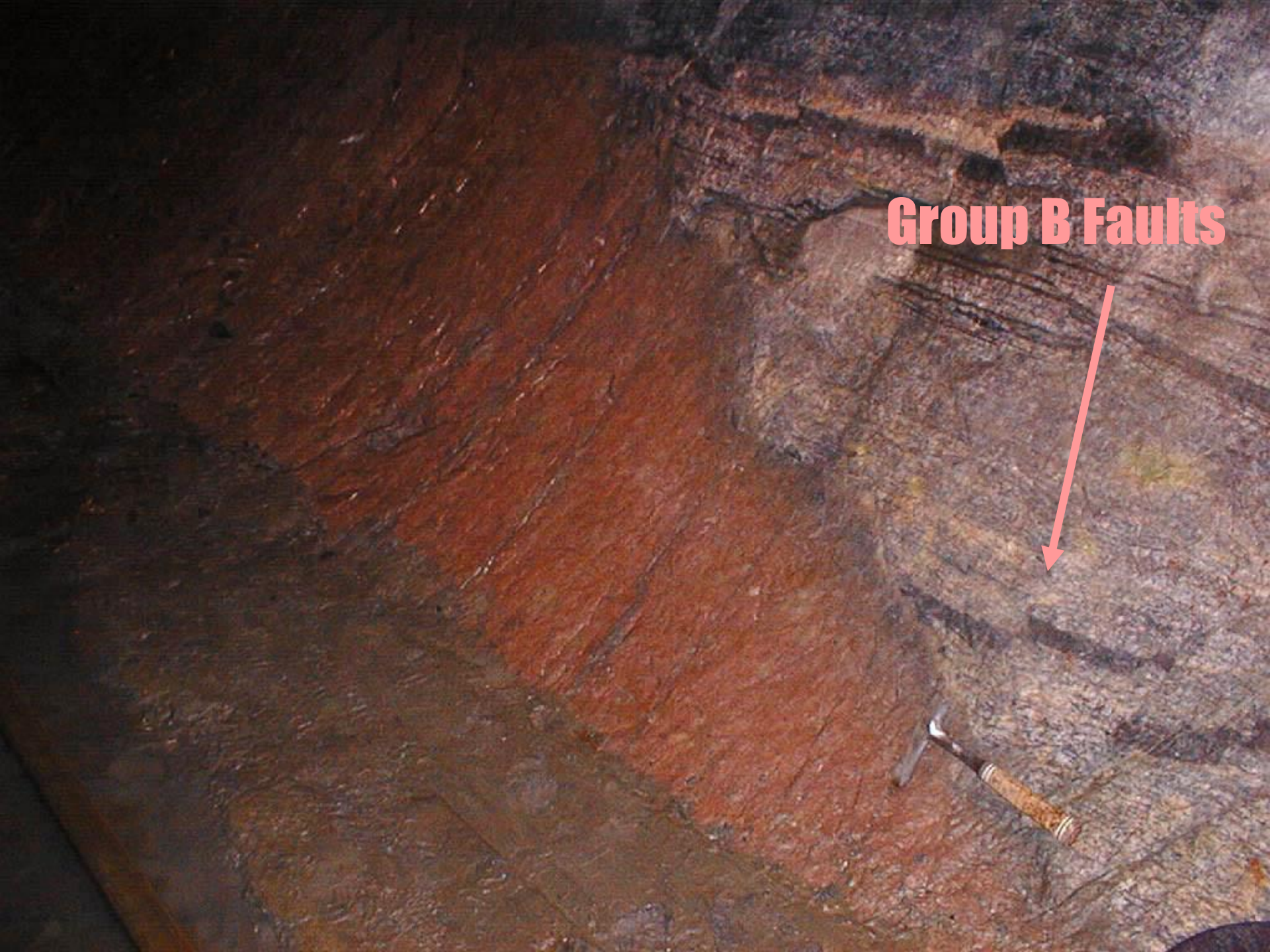

Long Island Sound
16B
19B

Queens Tunnel Faults

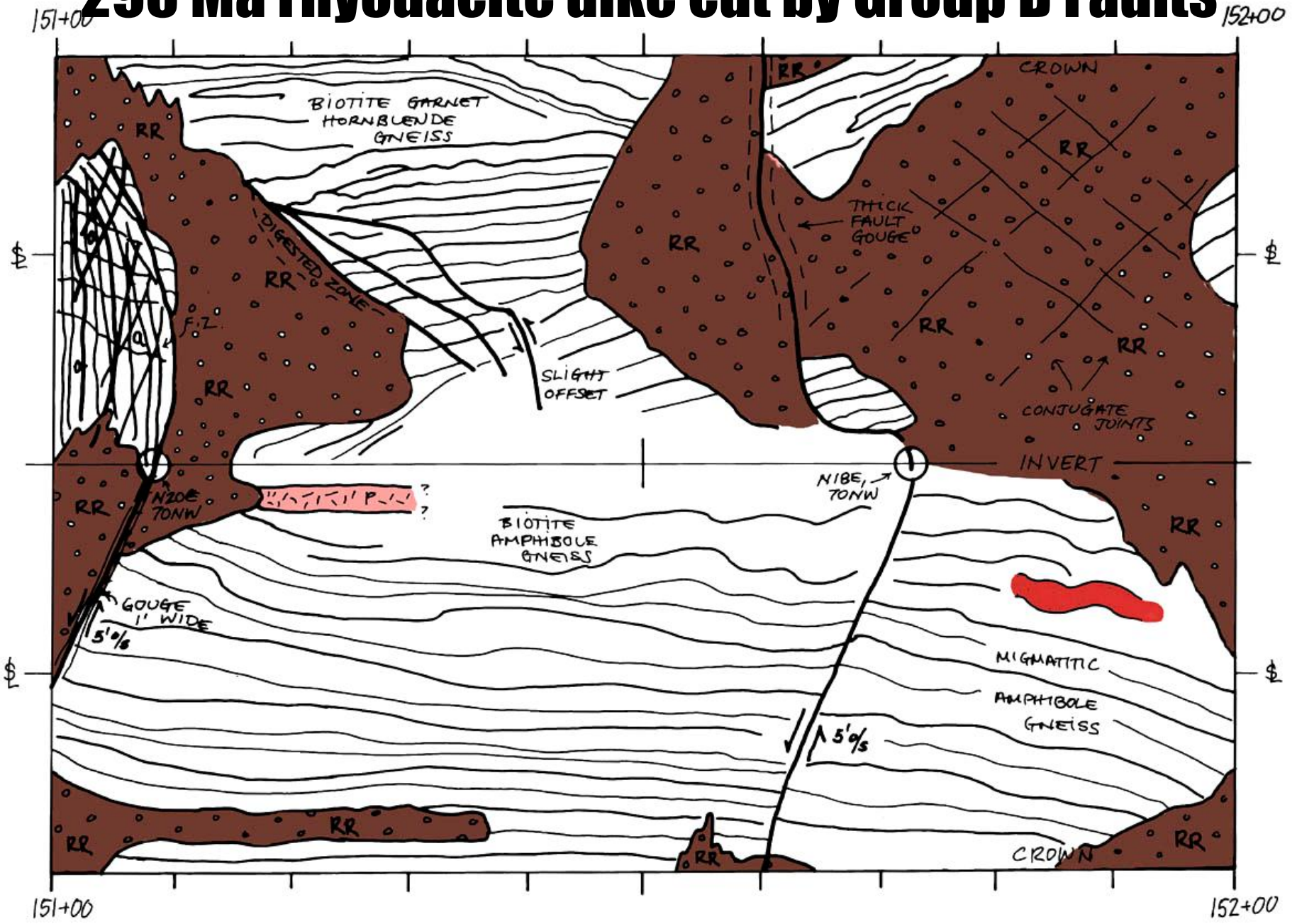


Rhyodacite dikes cut Group A and Group B

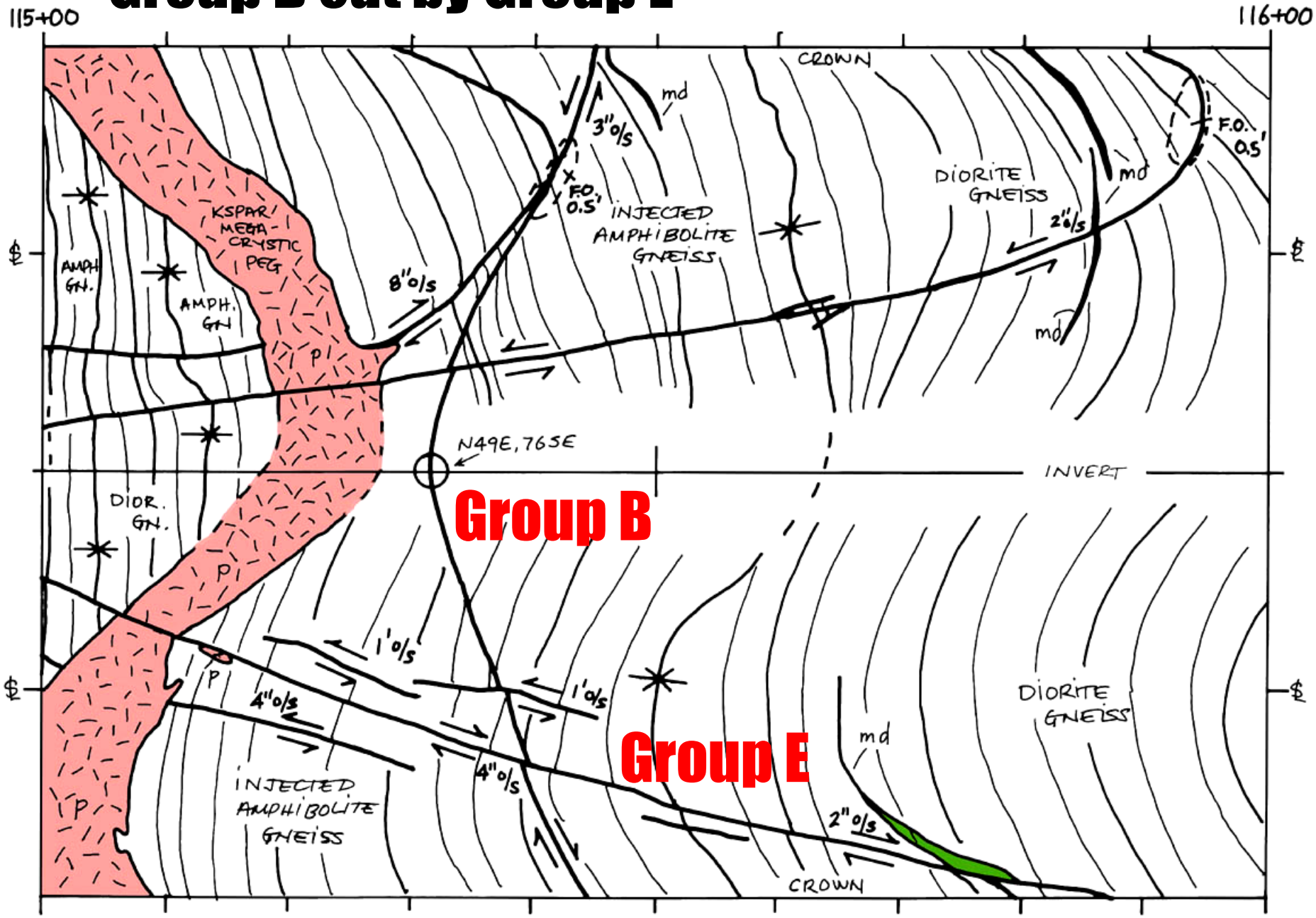



Group B Faults

295 Ma rhyodacite dike cut by Group D Faults



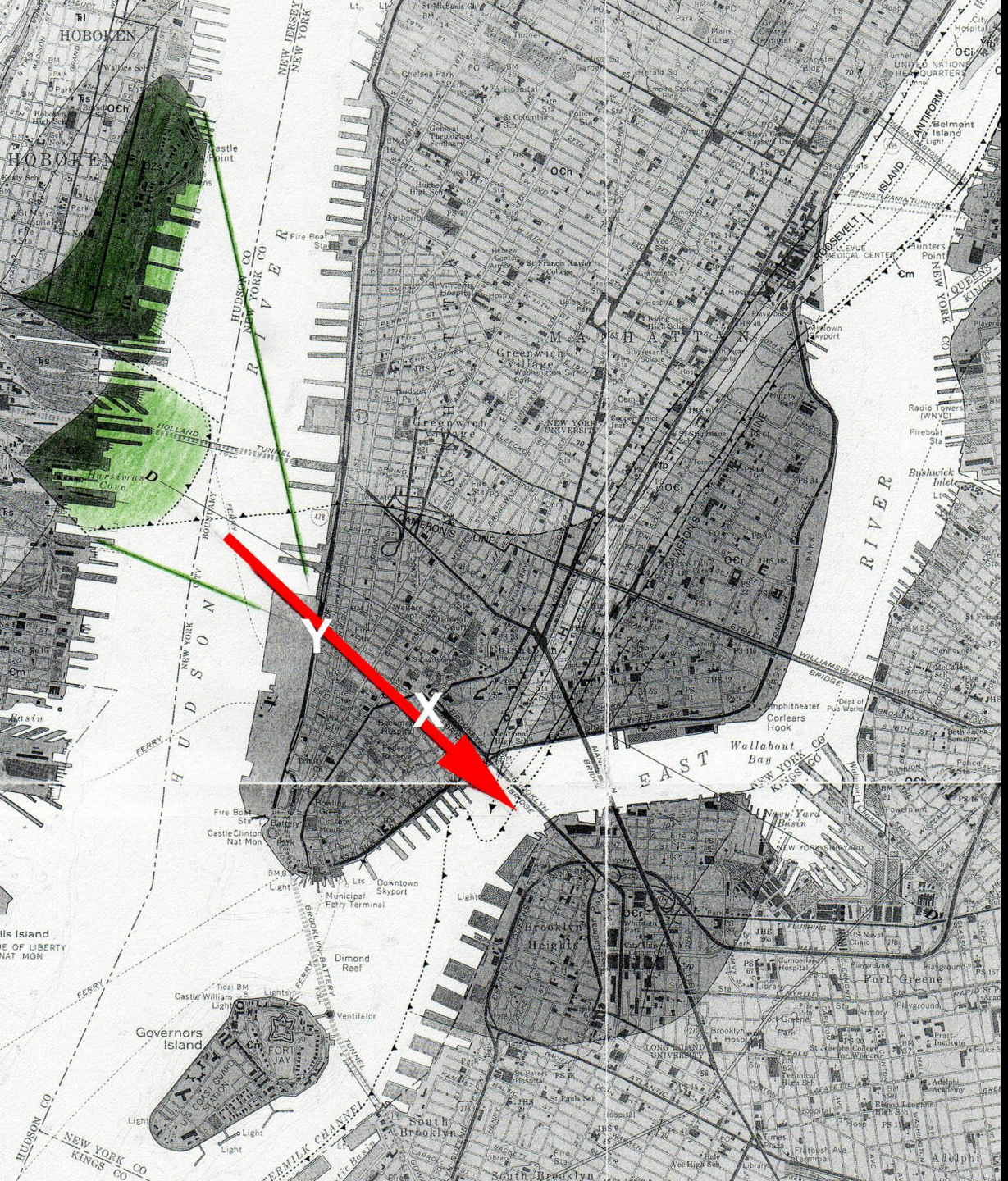
Group B cut by Group E



NNW-Trending Fault System of Group E

- NNW strike and 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 NW-leg of tunnel
- Associated with areas of stress relief
- Produce wet zones in areas of fault convergence

Buried Valley = Low Building Heights



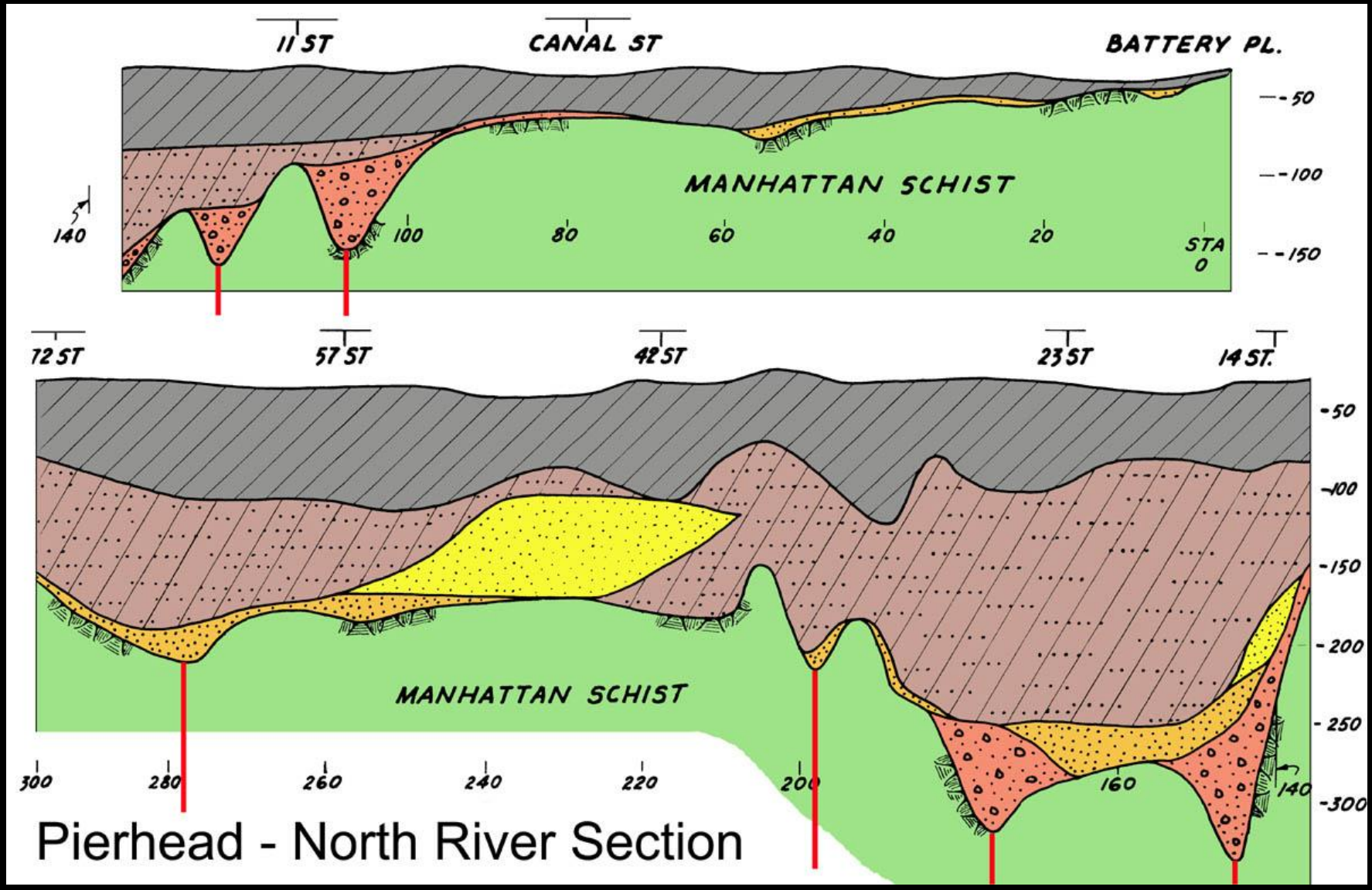
Buried Valley

Carved By Old Glacier

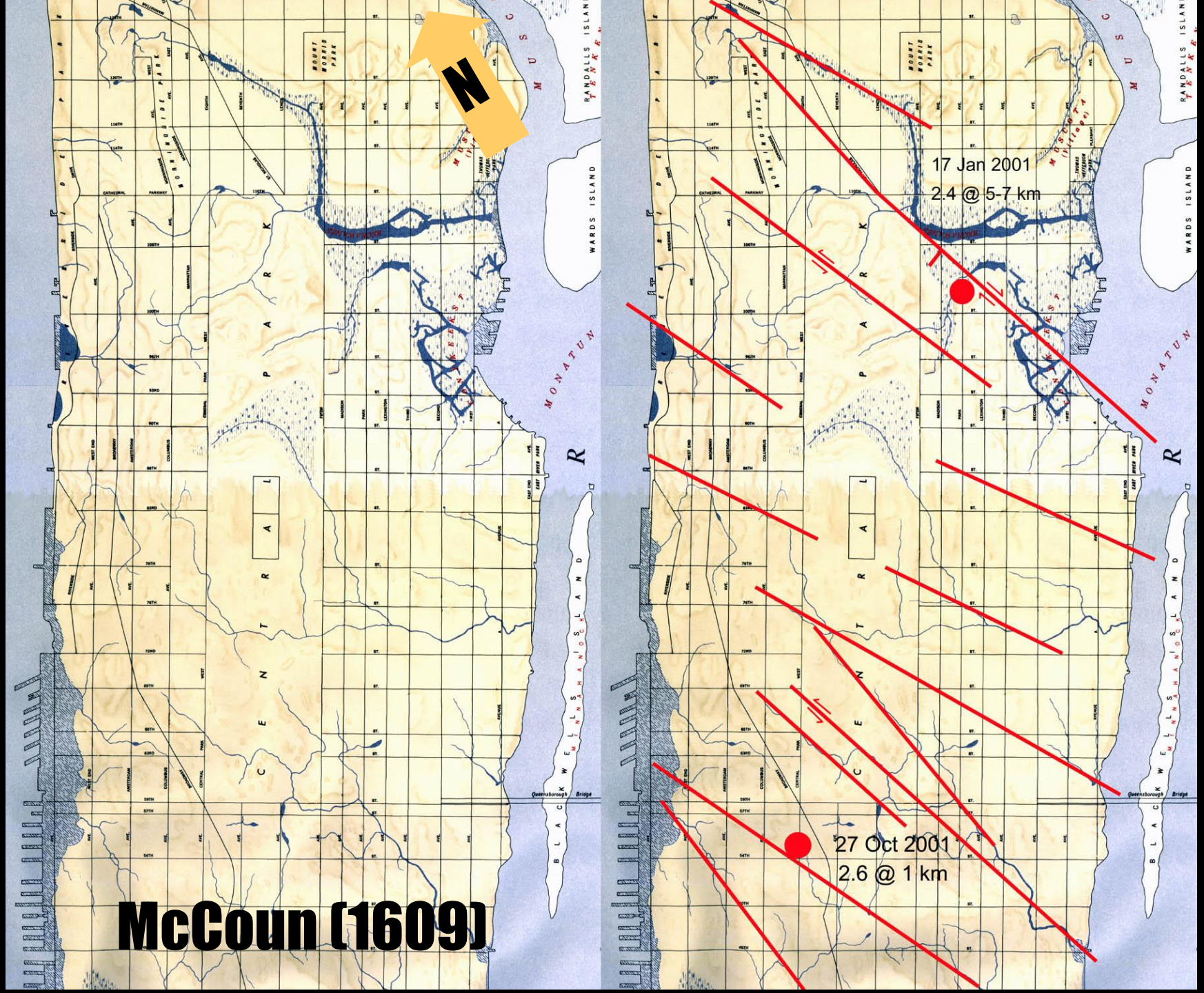
Backfilled by Younger Glaciers

Sites in Valley Contain NJ Serpentinite in Till; Wood Found in Till at WTC (49 Ka)

Longitudinal Profile - Manhattan



Base diagram after Mueser-Rutledge Consultants

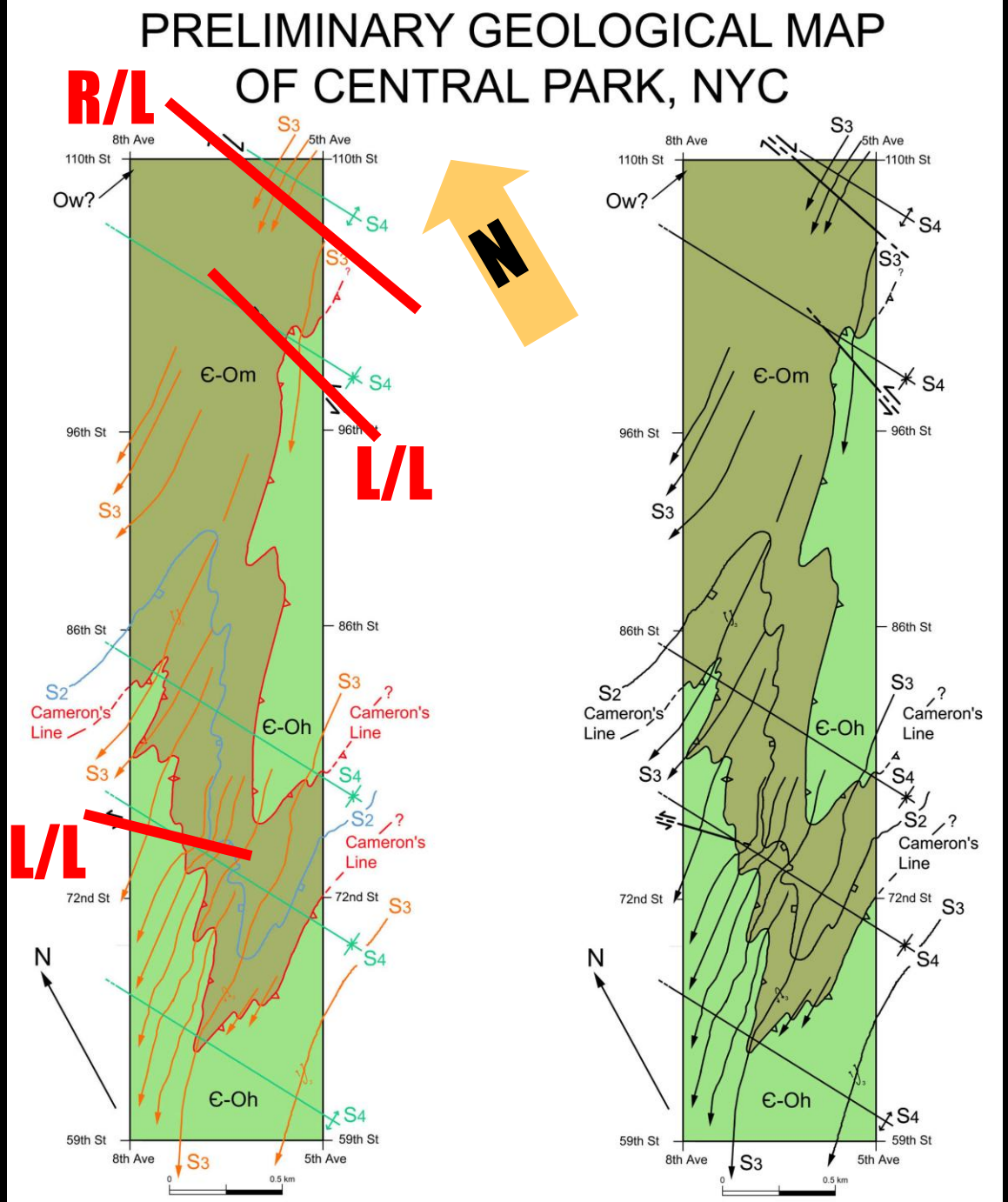

N
17 Jan 2001
2.4 @ 5-7 km
27 Oct 2001
2.6 @ 1 km
McCoun (1609)

Manhattan
Schist -OZm

Offsets F_3
Synform

N537

Group E - N12°W, L/L Fault

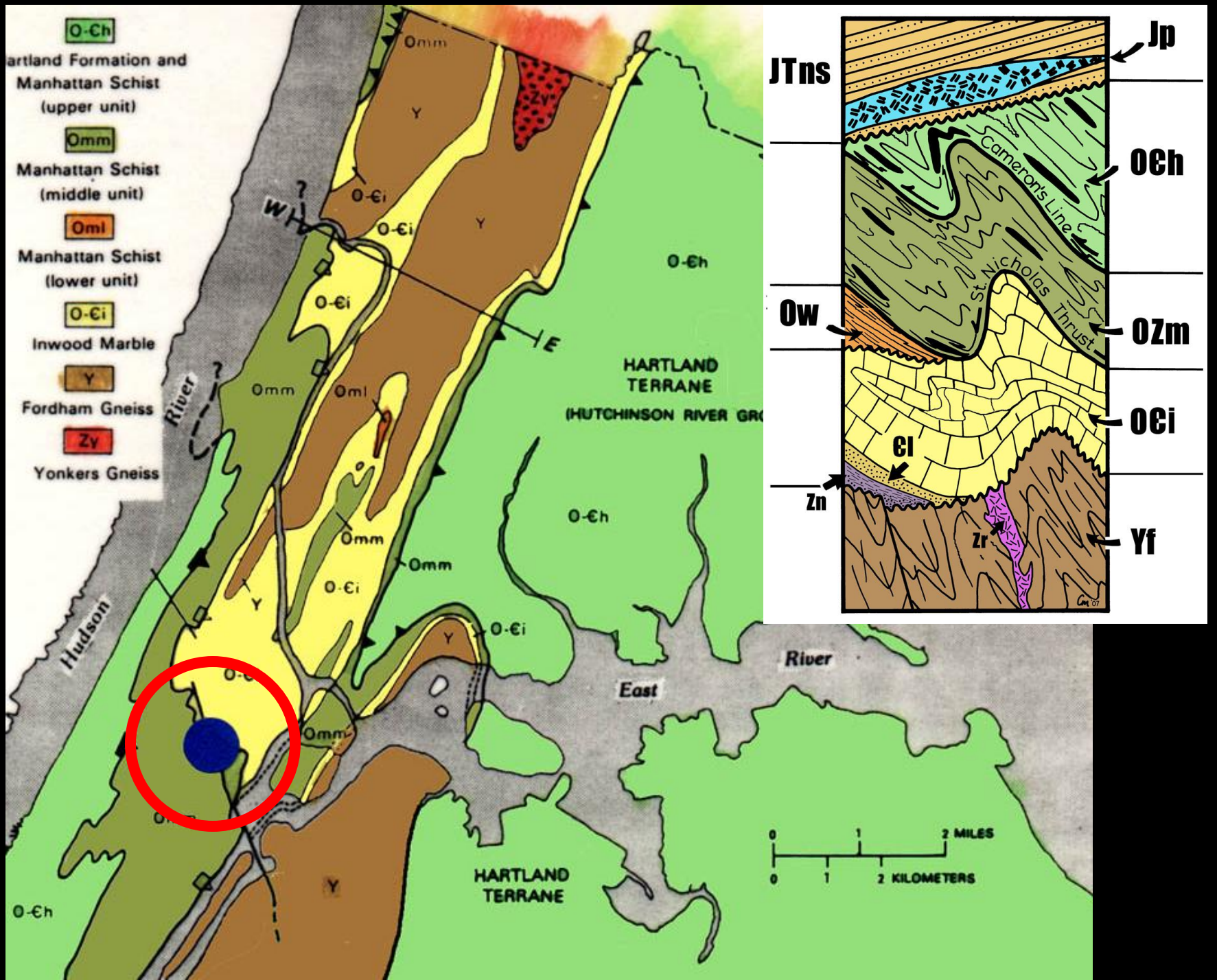


Group E Faults In Central Park

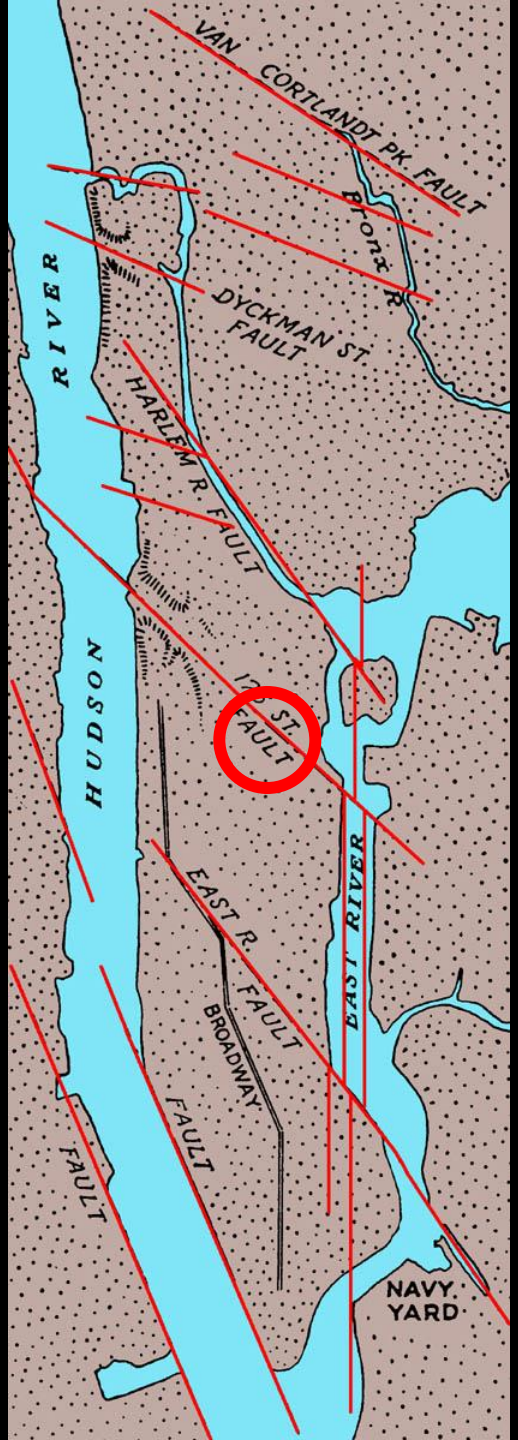
Merguerian and Merguerian, 2004

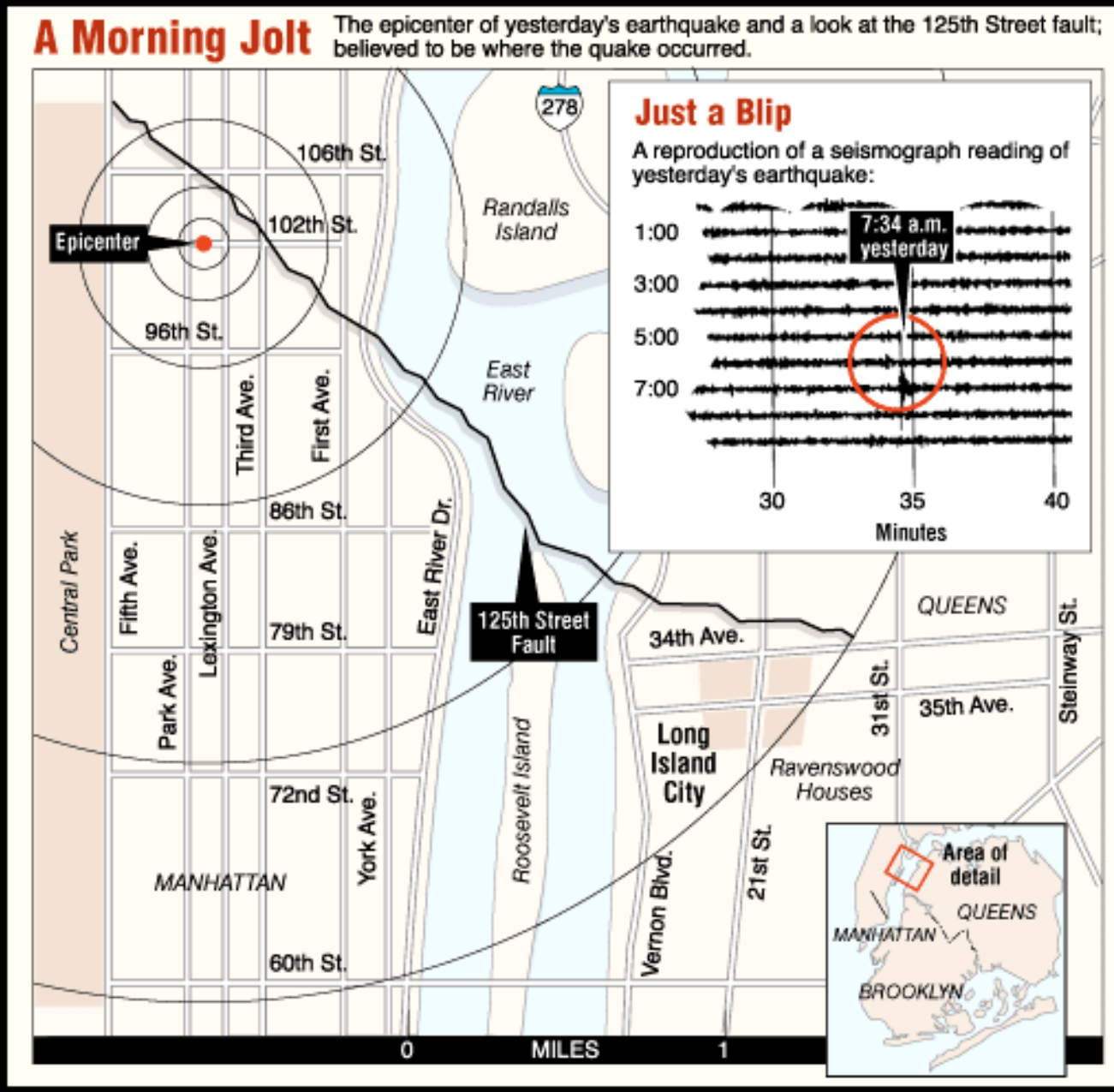
Group E - N45°W, 80°S L/L Fault

N296 - Central Park, Hartland Fm


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
Hudson
River
HARTLAND
TERRANE
(HUTCHINSON RIVER GR
HARTLAND
TERRANE
East
River
0 1 2 MILES
0 1 2 KILOMETERS
JTns
Jp
Och
Ow
OZm
Oci
Cl
Zn
Zr
Yf
Cameron's Line
St. Nicholas Thrust

17 January 2001, M = 2.4



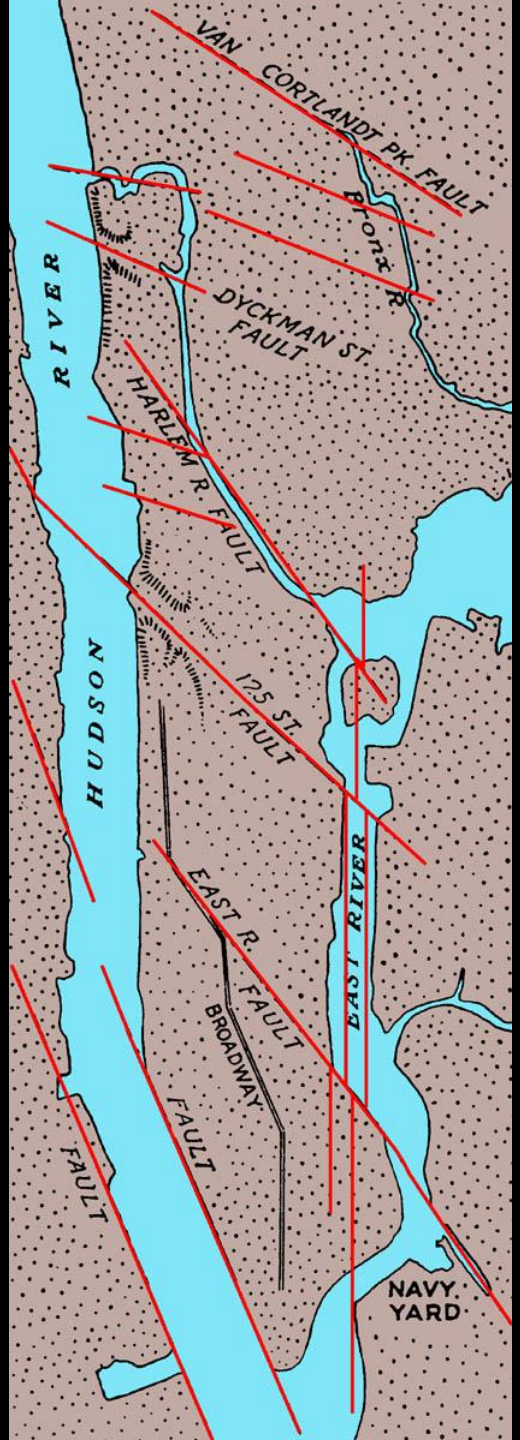


27 October 2001; M = 2.6

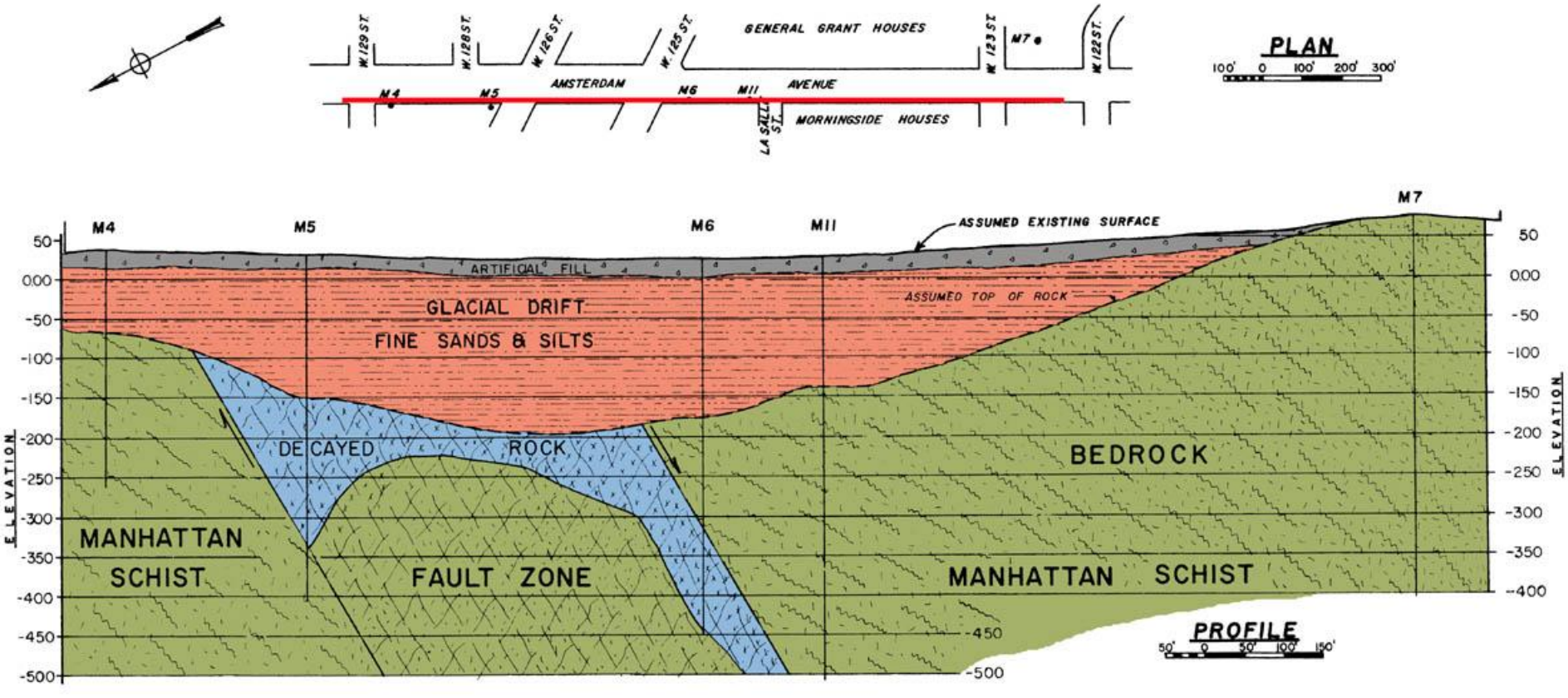
125th Street Manhattanville Fault


DESPATCH
MOVING & STORAGE

Group E Faults - Manhattanville



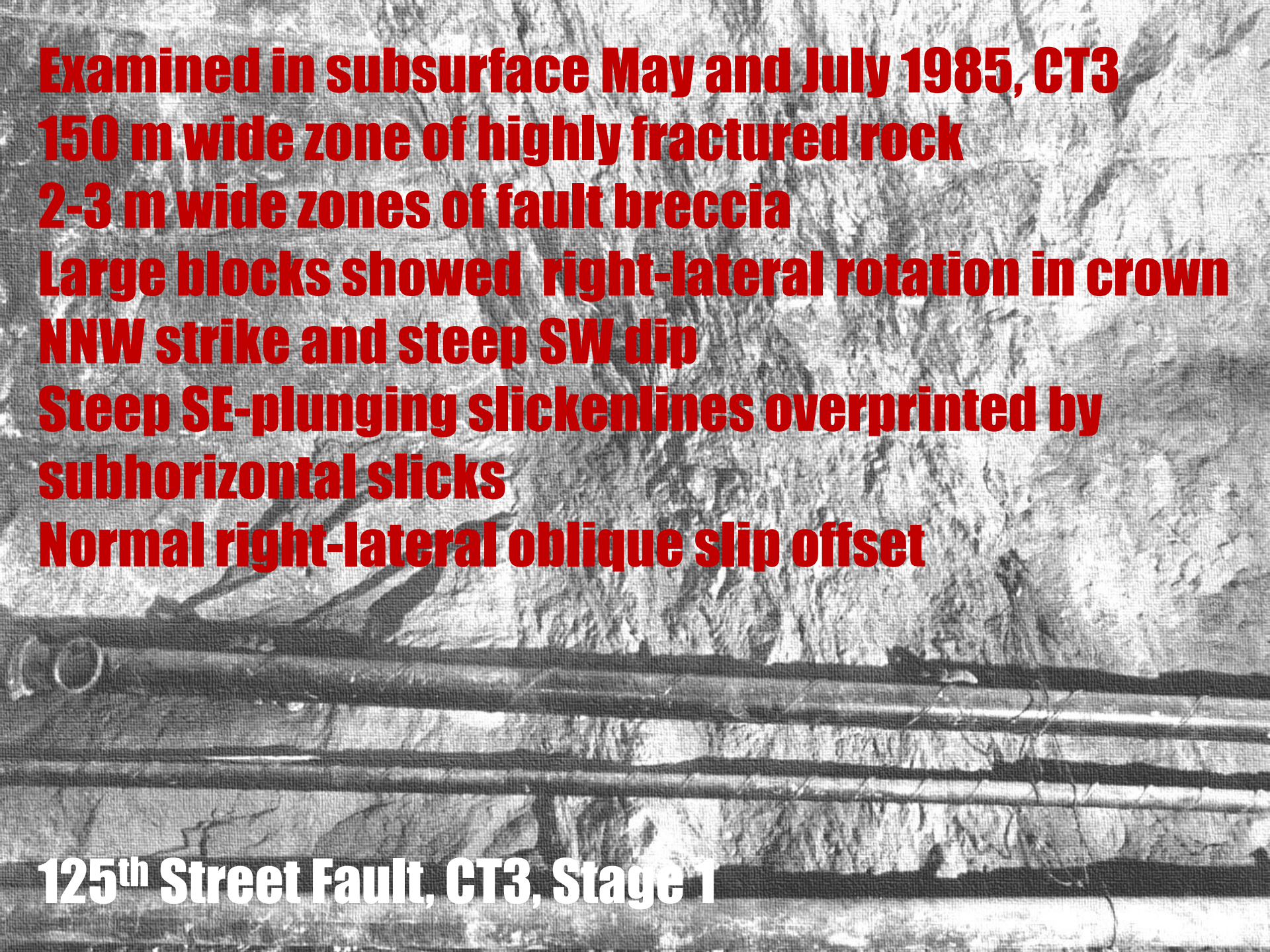
Manhattanville "125th Street" Fault Zone is 400' in width



CT3, Stage 1

after Fluhr, 1969


125th Street Fault, CT3, Stage 1


Examined in subsurface May and July 1985, CT3
150 m wide zone of highly fractured rock
2-3 m wide zones of fault breccia
Large blocks showed right-lateral rotation in crown
NNW strike and steep SW dip
Steep SE-plunging slickenlines overprinted by subhorizontal slicks
Normal right-lateral oblique slip offset
125th Street Fault, CT3, Stage 1

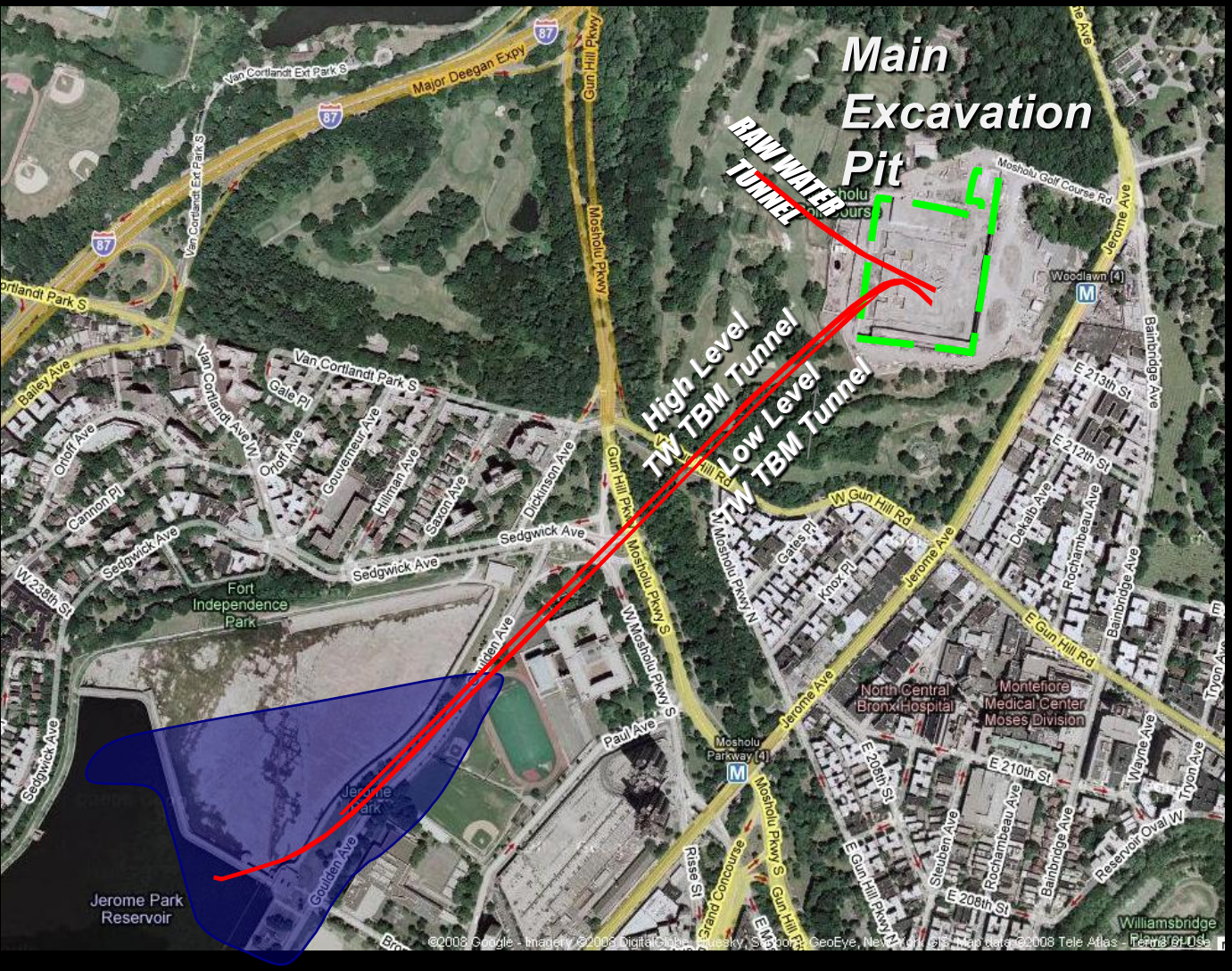
Manhattanville Bridge Construction, circa 1898

Manhattanville Bridge, circa 1900

REDEFINING THE SOUTHERN TERMINUS OF THE INTRUSIVE CONTACT BETWEEN THE YONKERS AND FORDHAM GNEISS IN VAN CORTLANDT PARK, NEW YORK CITY, NEW YORK

ISLER, Douglas, E.,
VELLONE, Daniel, A.,
MERGUERIAN, Charles; and
MERGUERIAN, J. Mickey
2009

Croton Water Tunnel Alignment

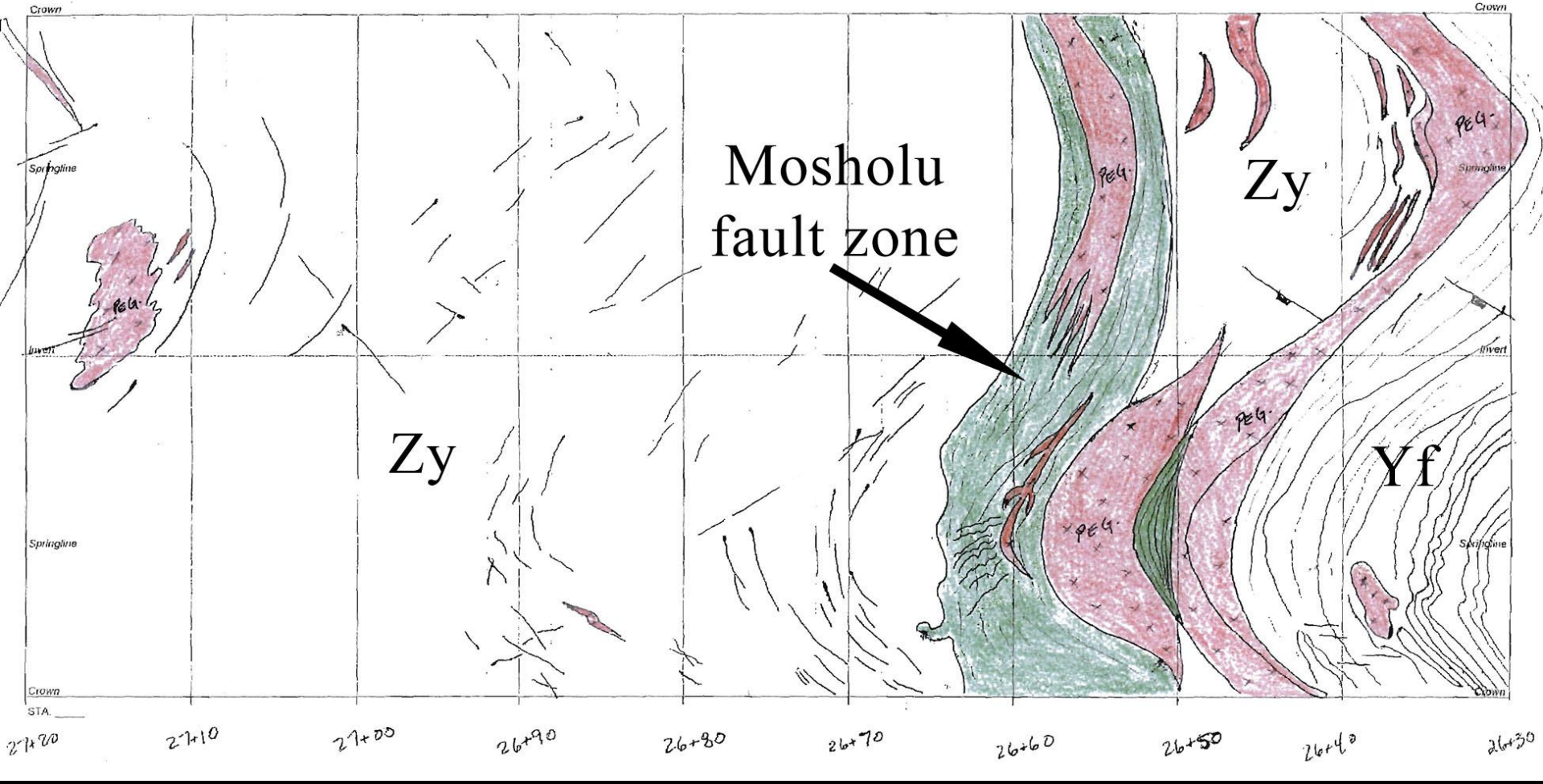


- Croton System Water flows into TW's via RWT of New Croton Aqueduct
- Distribution via two TWT's to Bronx and Manhattan

Isler et al 2009


High Water Treatment Tunnel

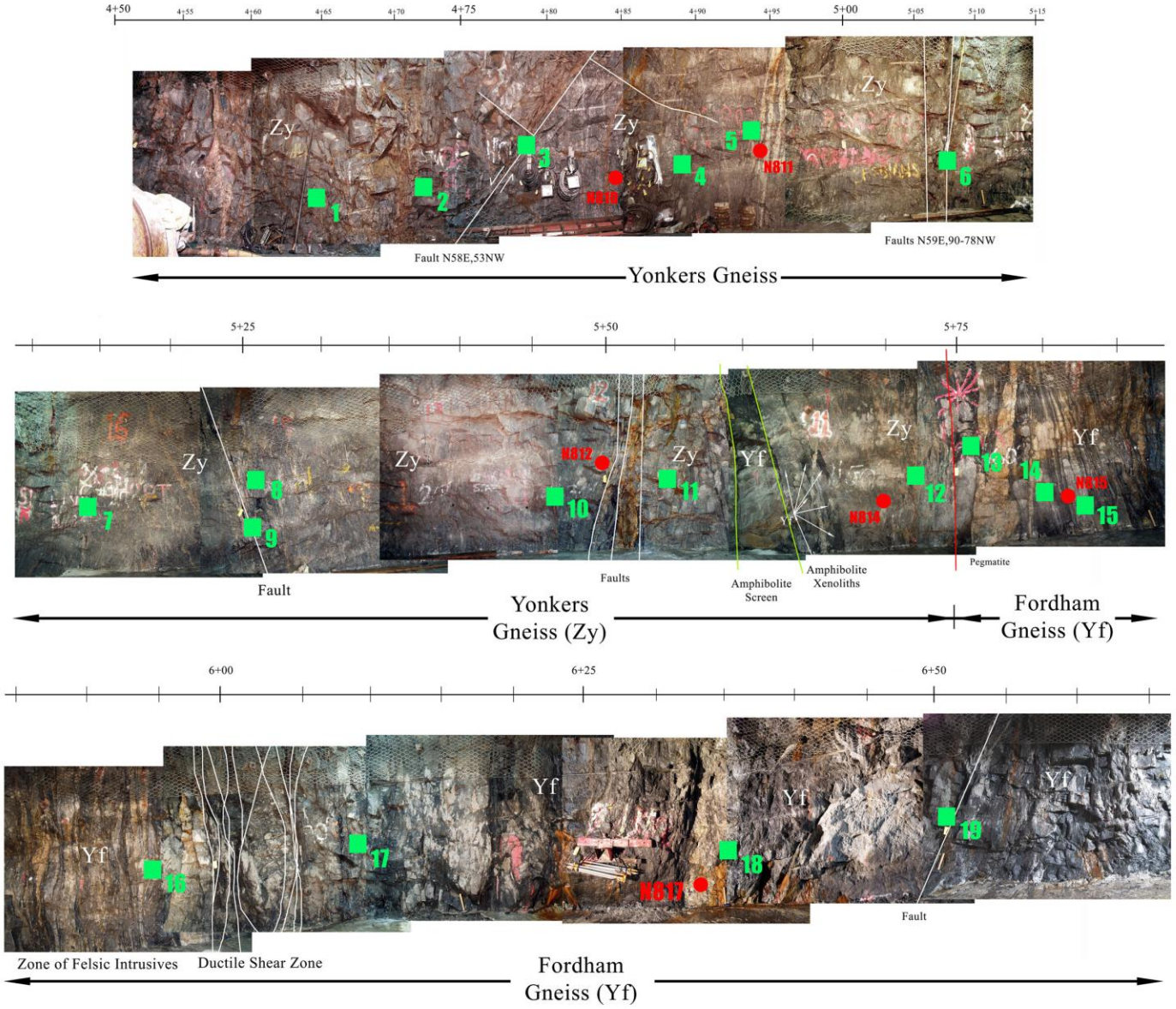

Mosholu Fault
HWT Sta 26+75



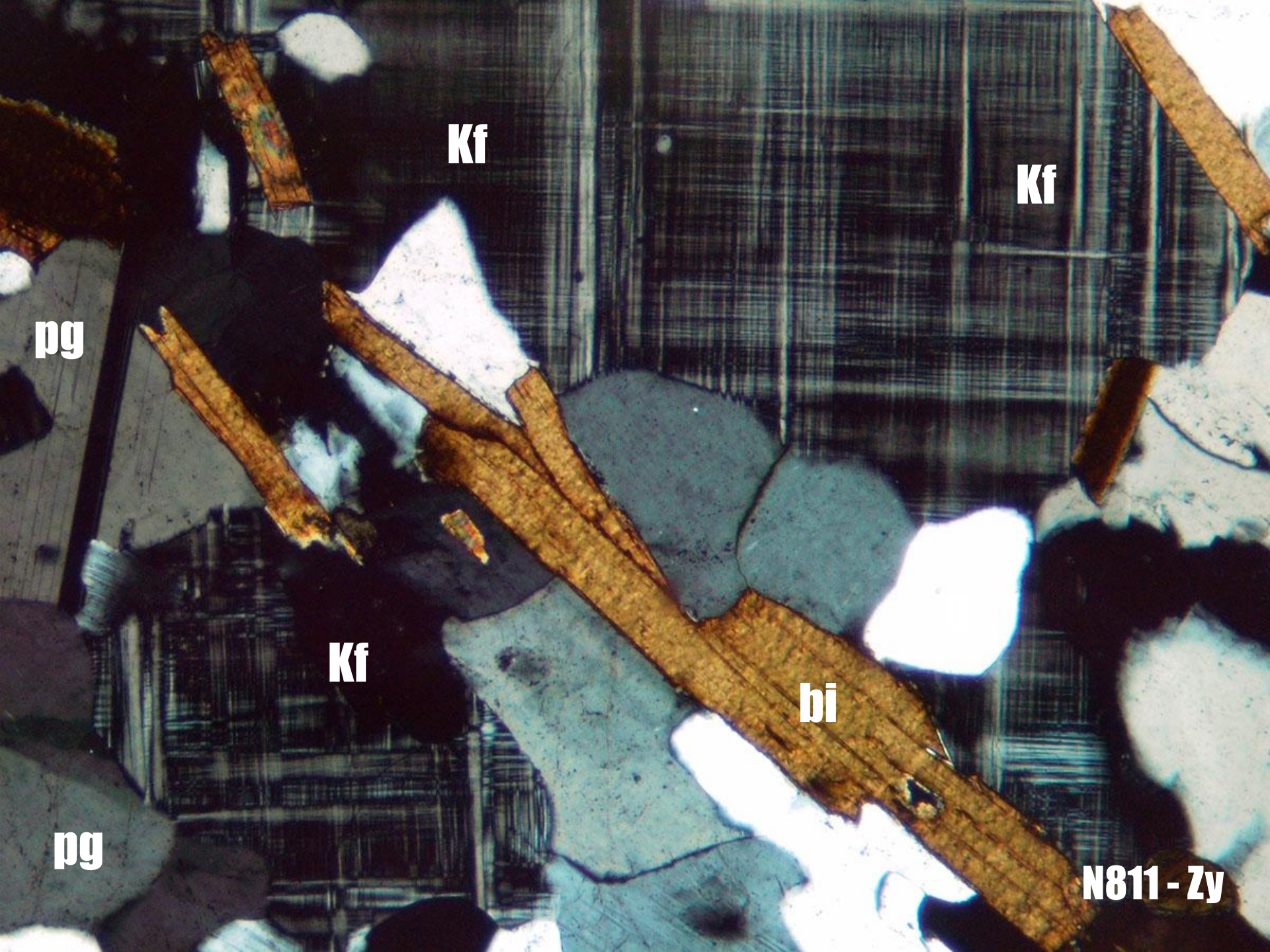
LWT Sta 27+20 - 26+30

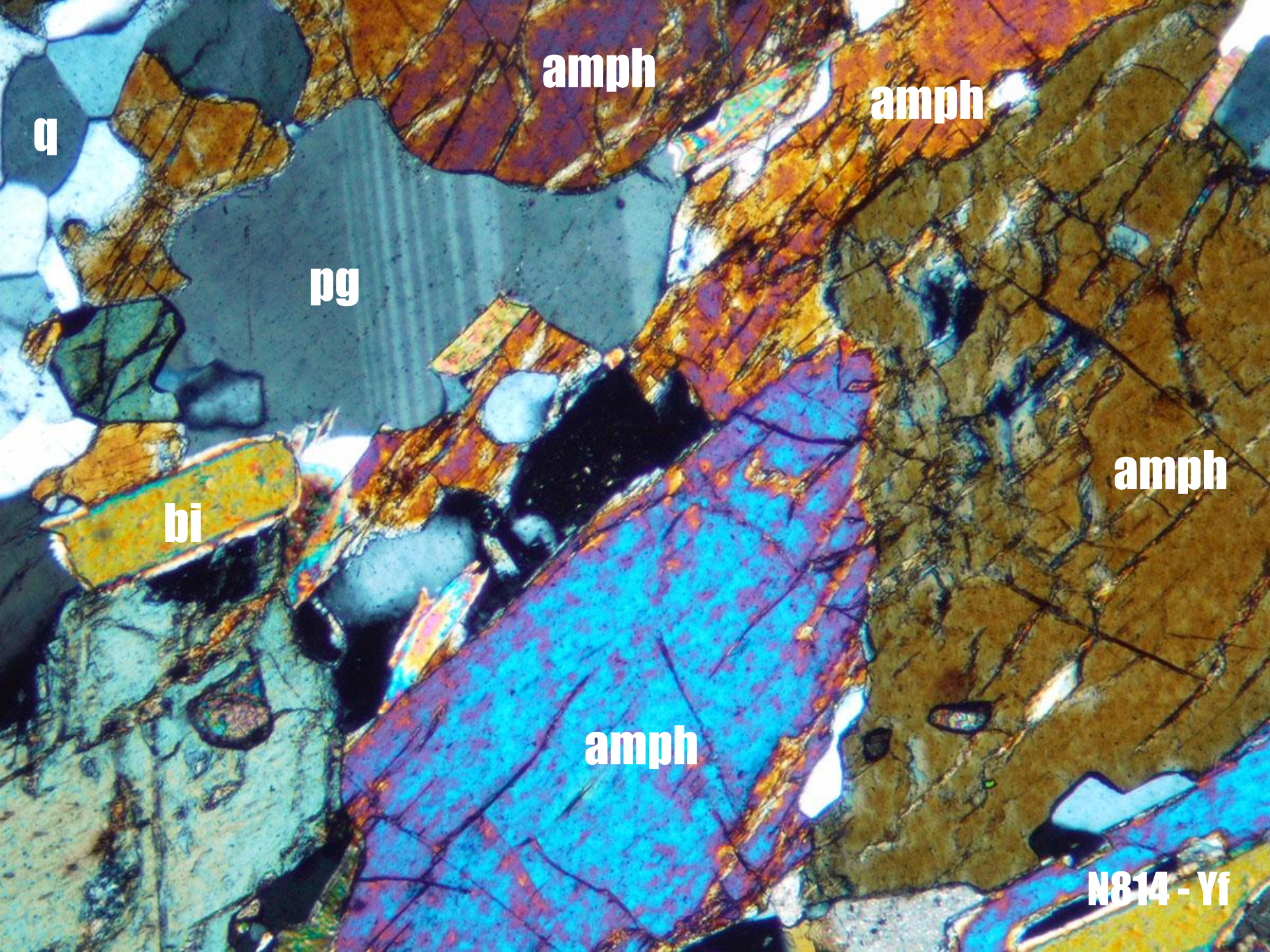

Yf
Zy
Zy
Yf
HWT Sta 26+95

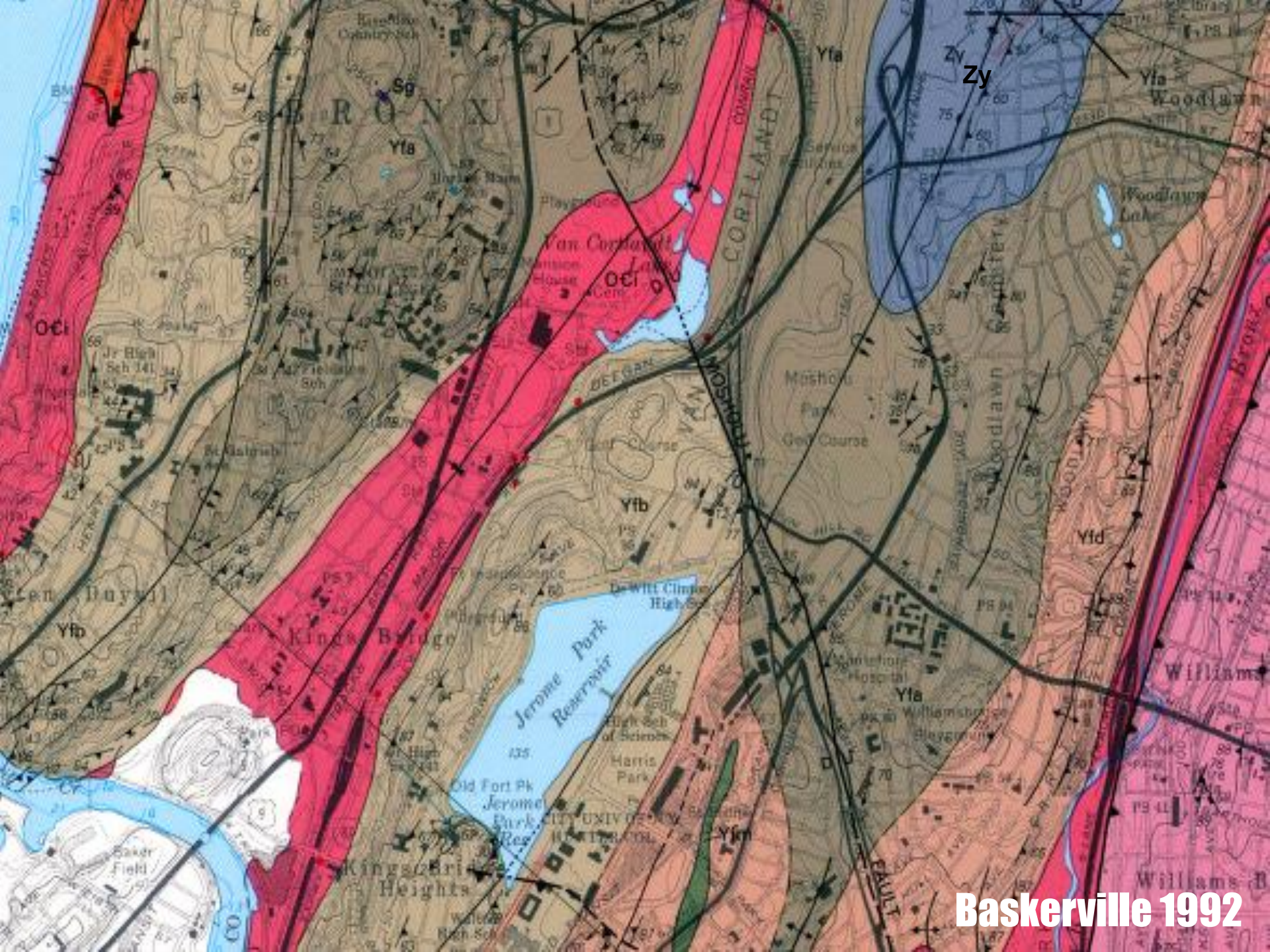
New Croton Water Treatment Plant, Bronx New York - North Wall Raw Water Tunnel, Stations 4+50 to 6+65



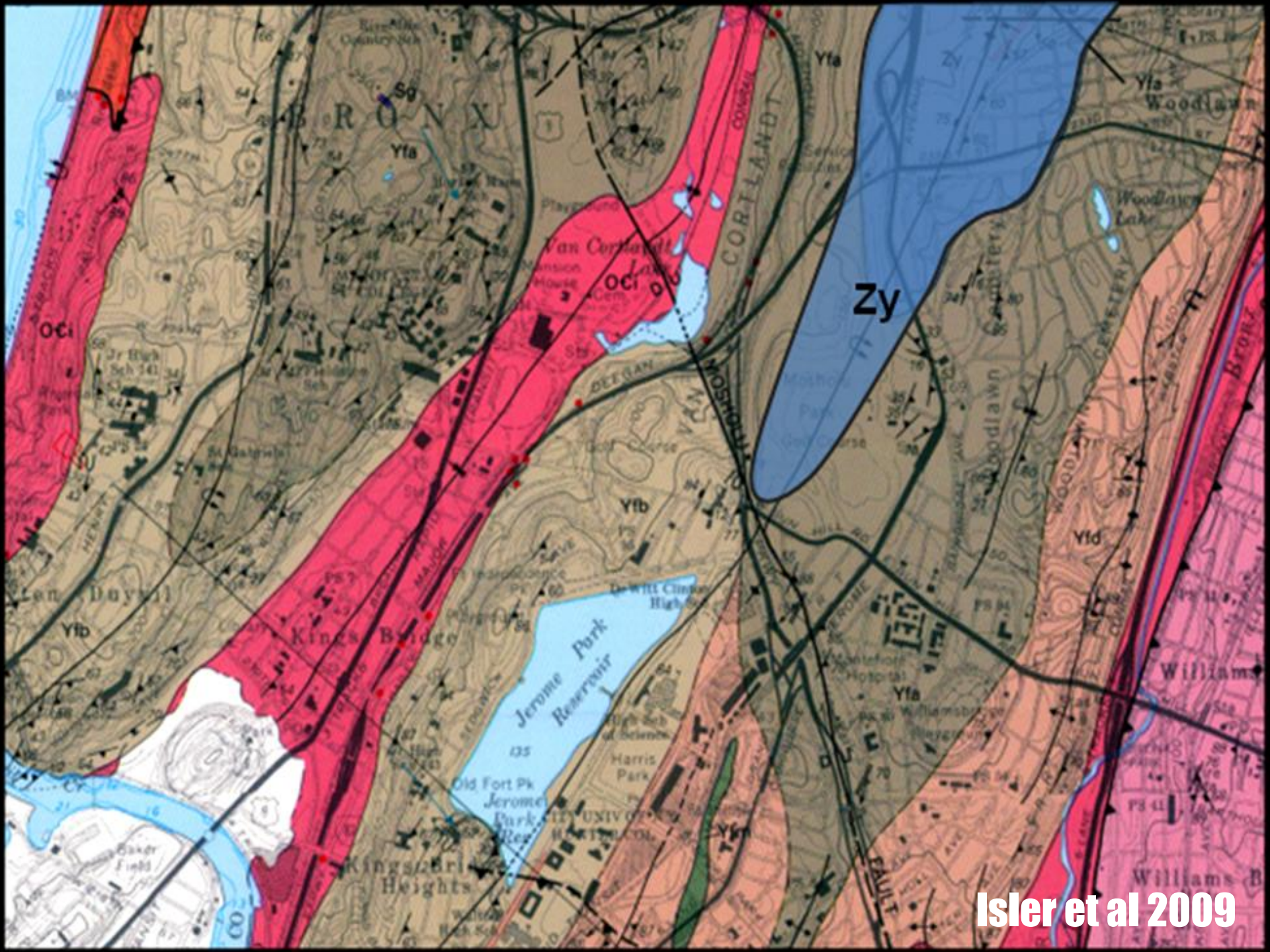
Mapping by C. Merguerian 2009

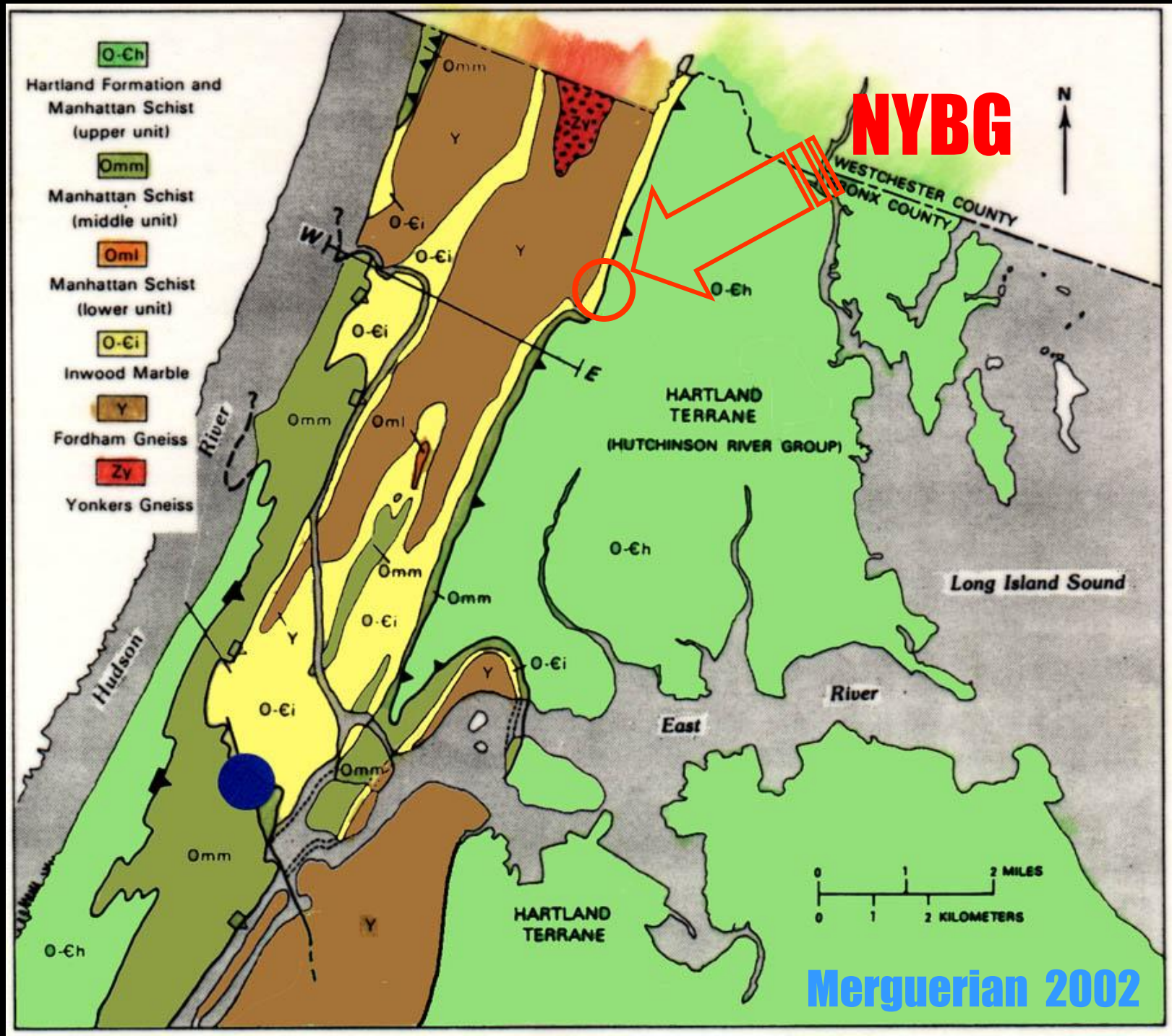

Kf
Kf
pg
Kf
bi
pg
N811 - Zy


amph
amph
q
pg
amph
bi
amph
N814 - Yf

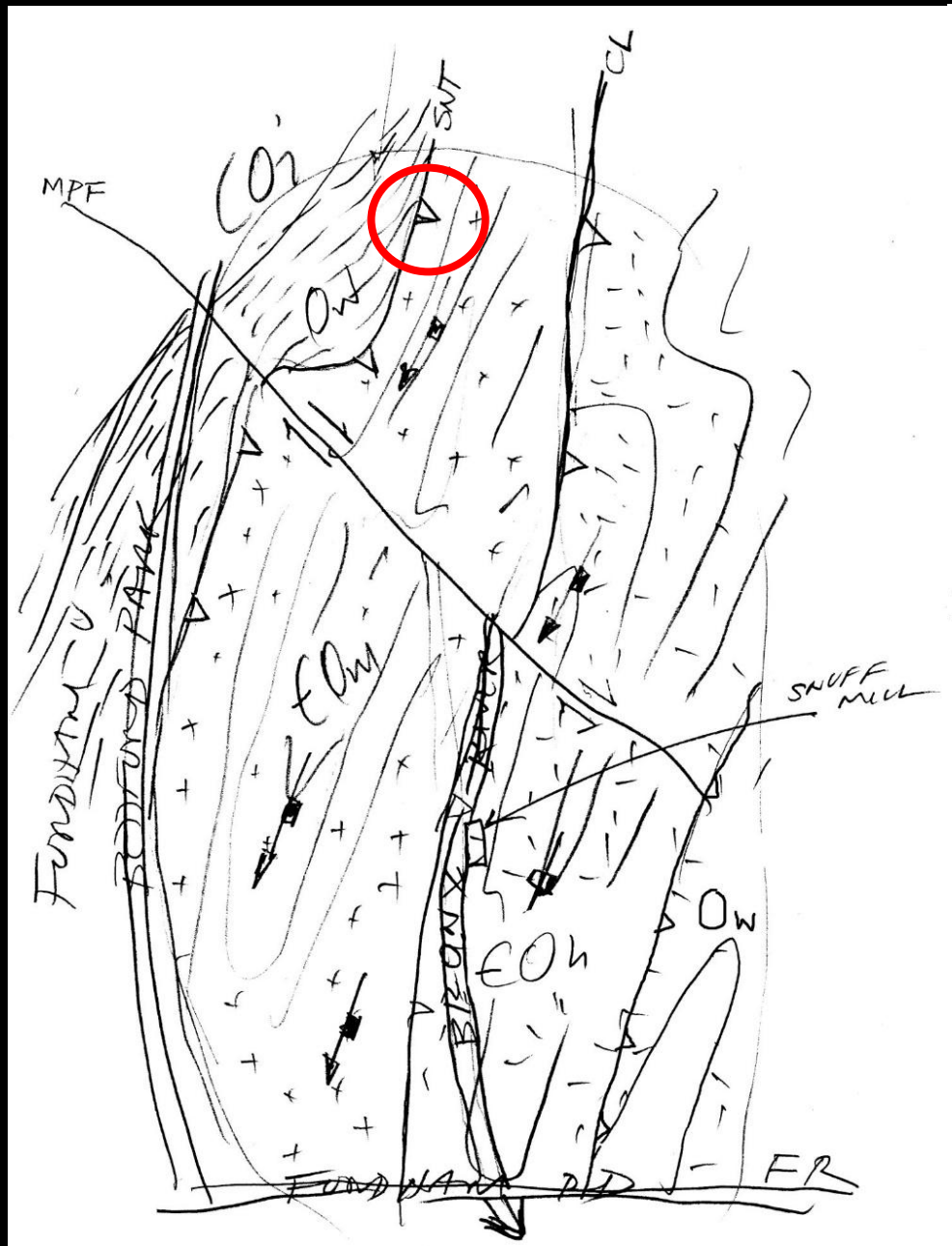


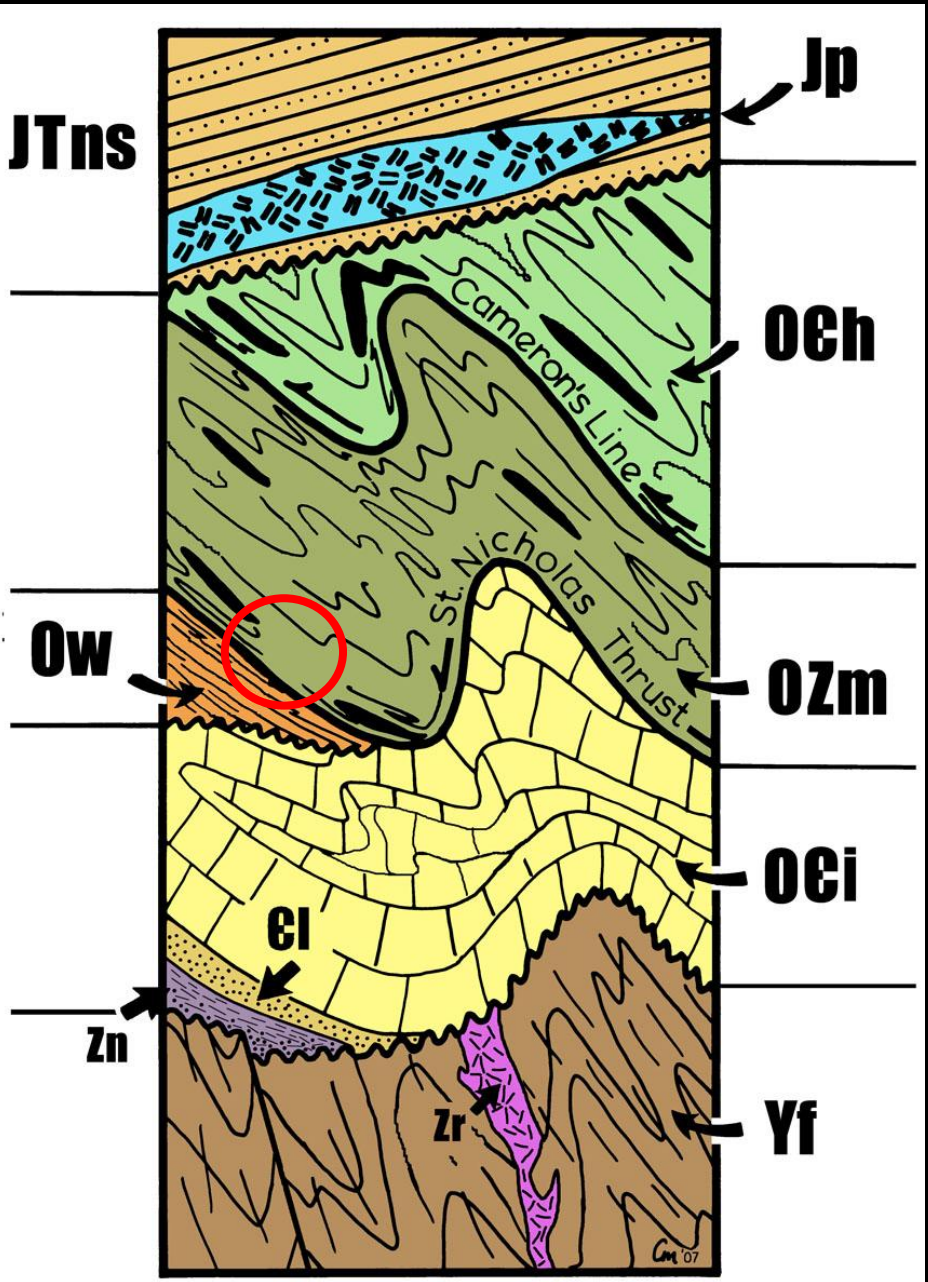
Baskerville 1992


Zy
Yfa
Yfb
Yfd
Oci
Sg
Jerome Park Reservoir
Isler et al 2009

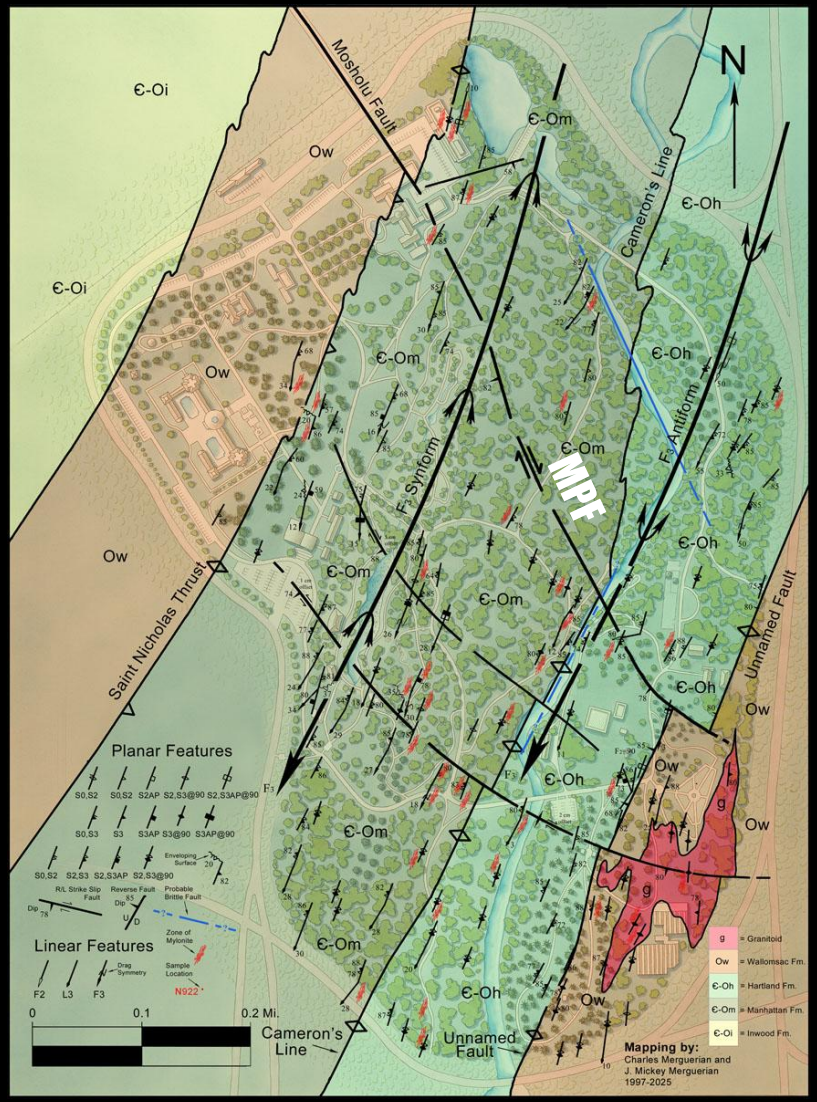

O-Ch
Hartland Formation and Manhattan Schist (upper unit)
Omm
Manhattan Schist (middle unit)
Oml
Manhattan Schist (lower unit)
O-Ei
Inwood Marble
Y
Fordham Gneiss
Zy
Yonkers Gneiss
NYBG
N
WESTCHESTER COUNTY
BRONX COUNTY
HARTLAND TERRANE
(HUTCHINSON RIVER GROUP)
HARTLAND TERRANE
Long Island Sound
East River
Hudson River
W
E
0 1 2 MILES
0 1 2 KILOMETERS
Merguerian 2002

NY Botanical Garden Mapping Project 2011

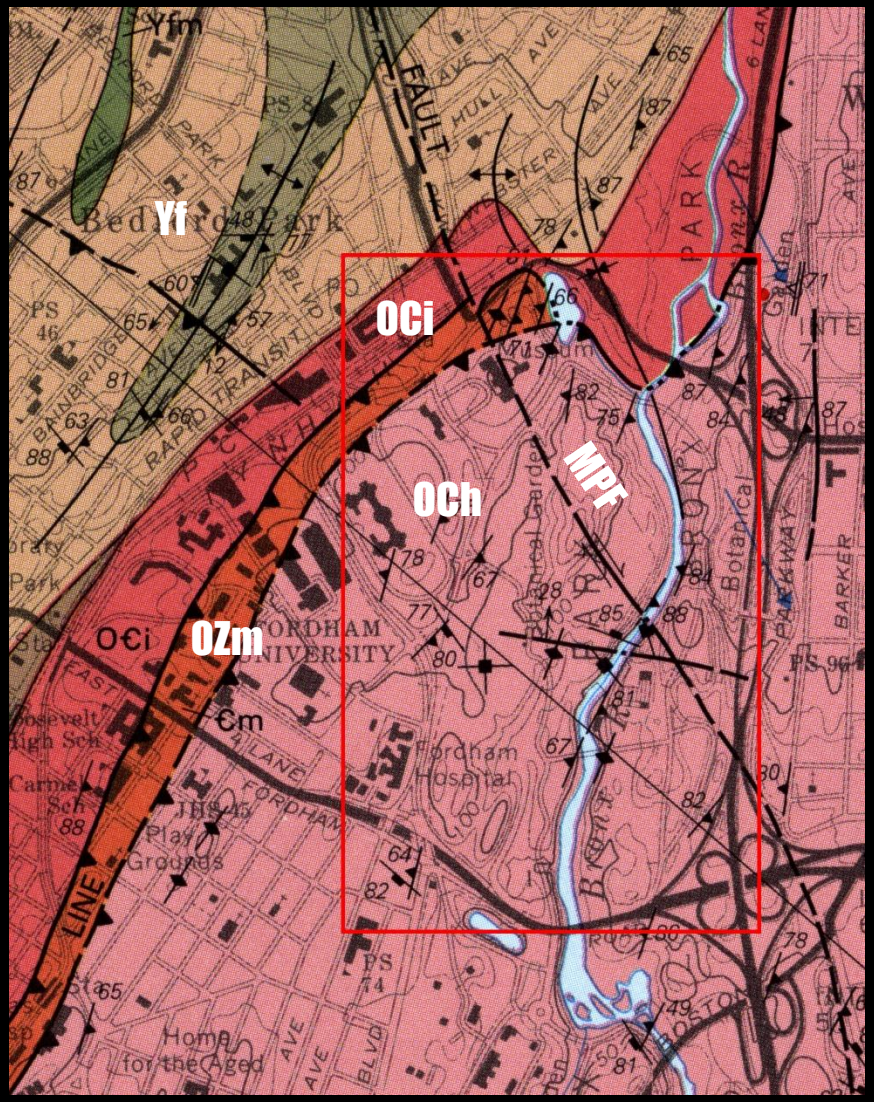




NY Botanical Garden

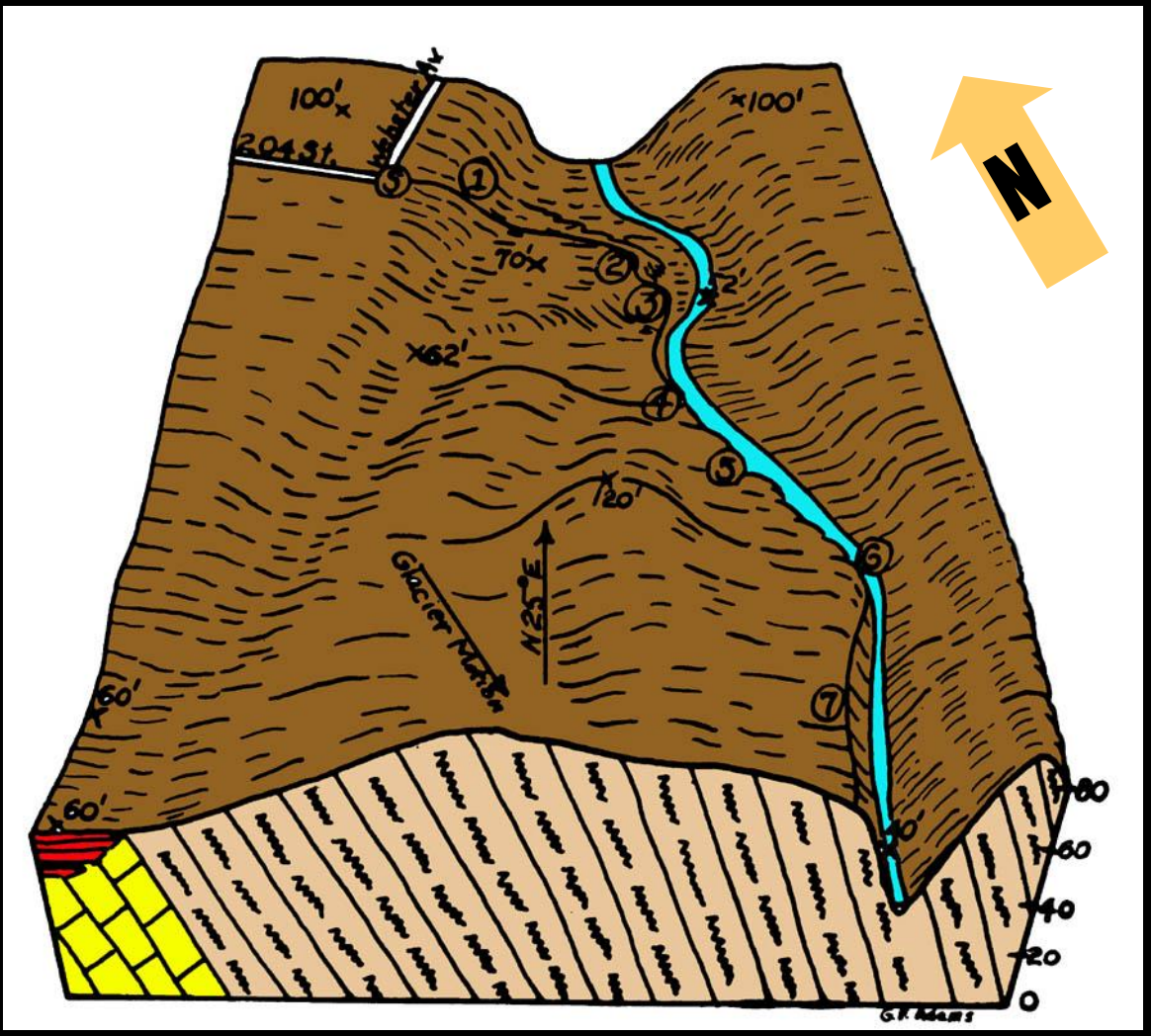


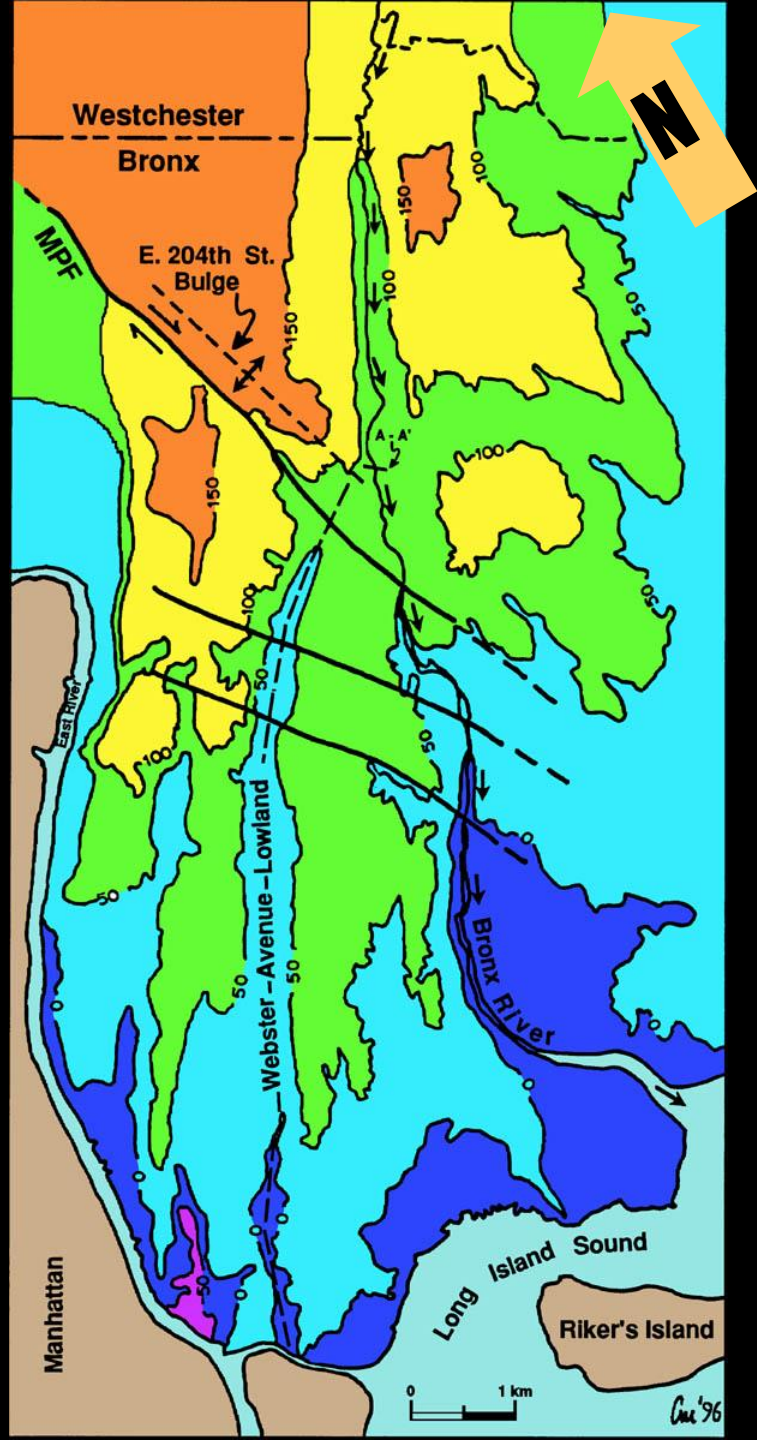
CM+MM 2024, 2025

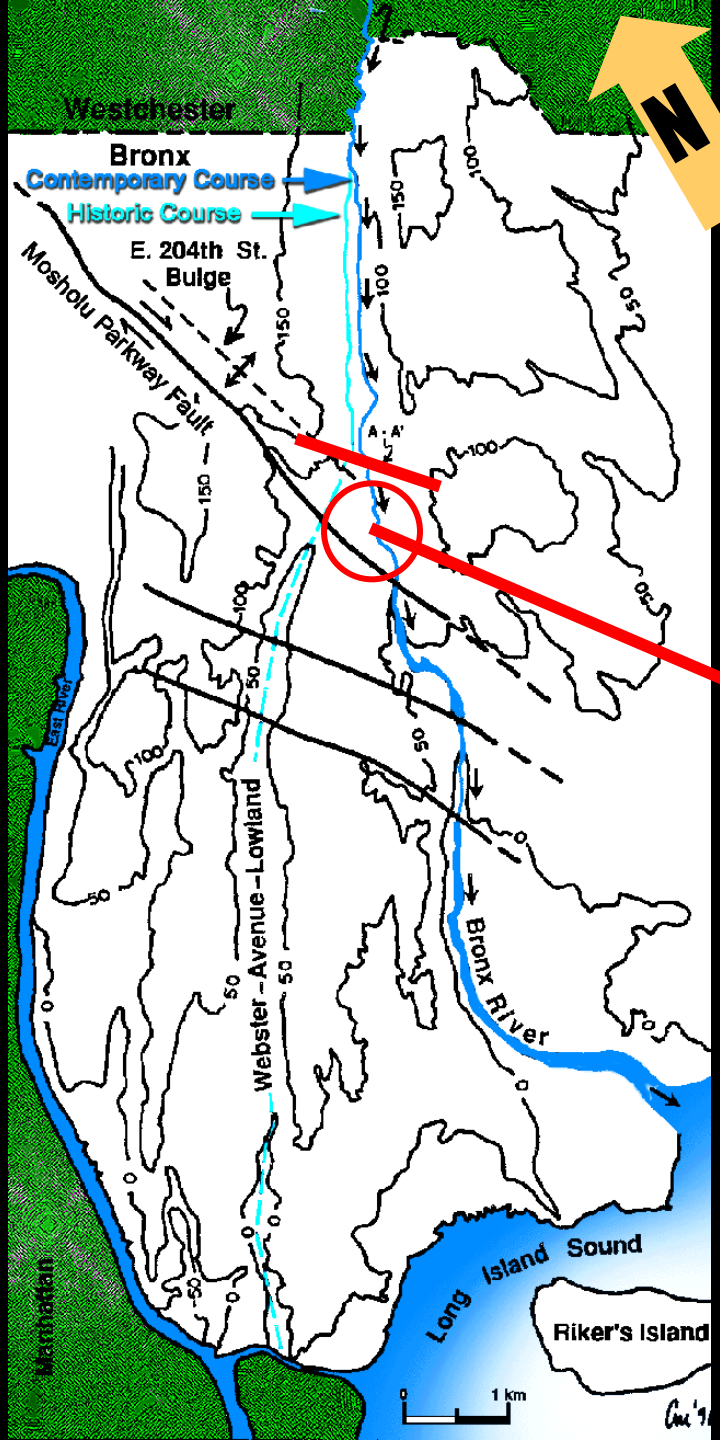


Baskerville 1992

Bronx River Drainage Anomaly



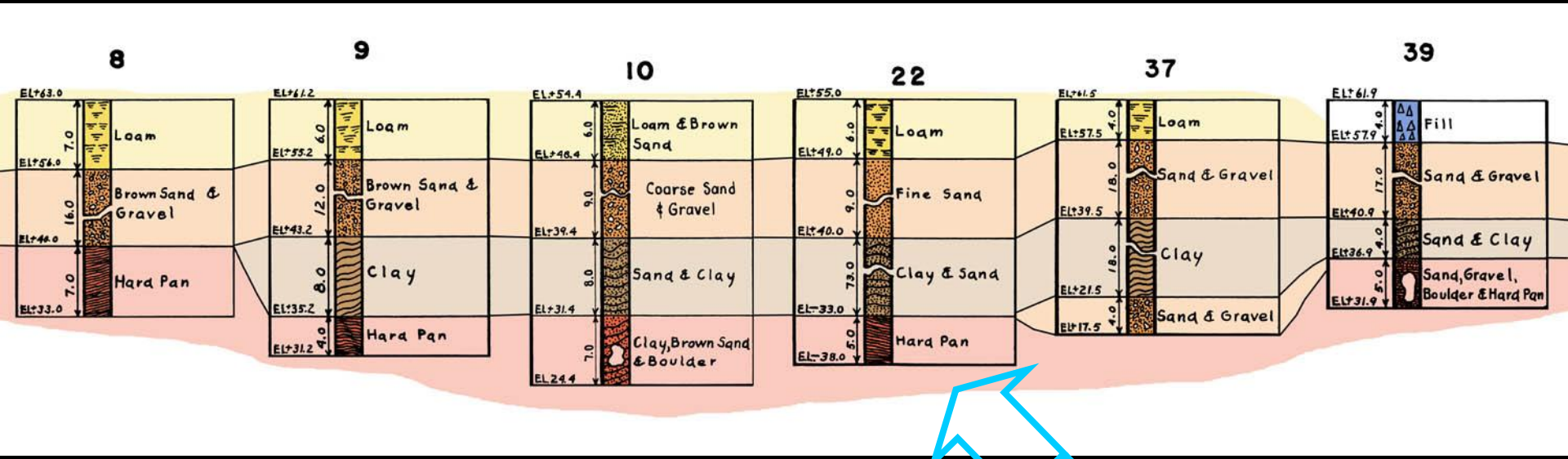




Non-glaciated v-shaped Bronx River Valley at Snuff Mill, NY Botanical Garden


NW-Trending
Joints
Mosholu Fault, Bronx, NY

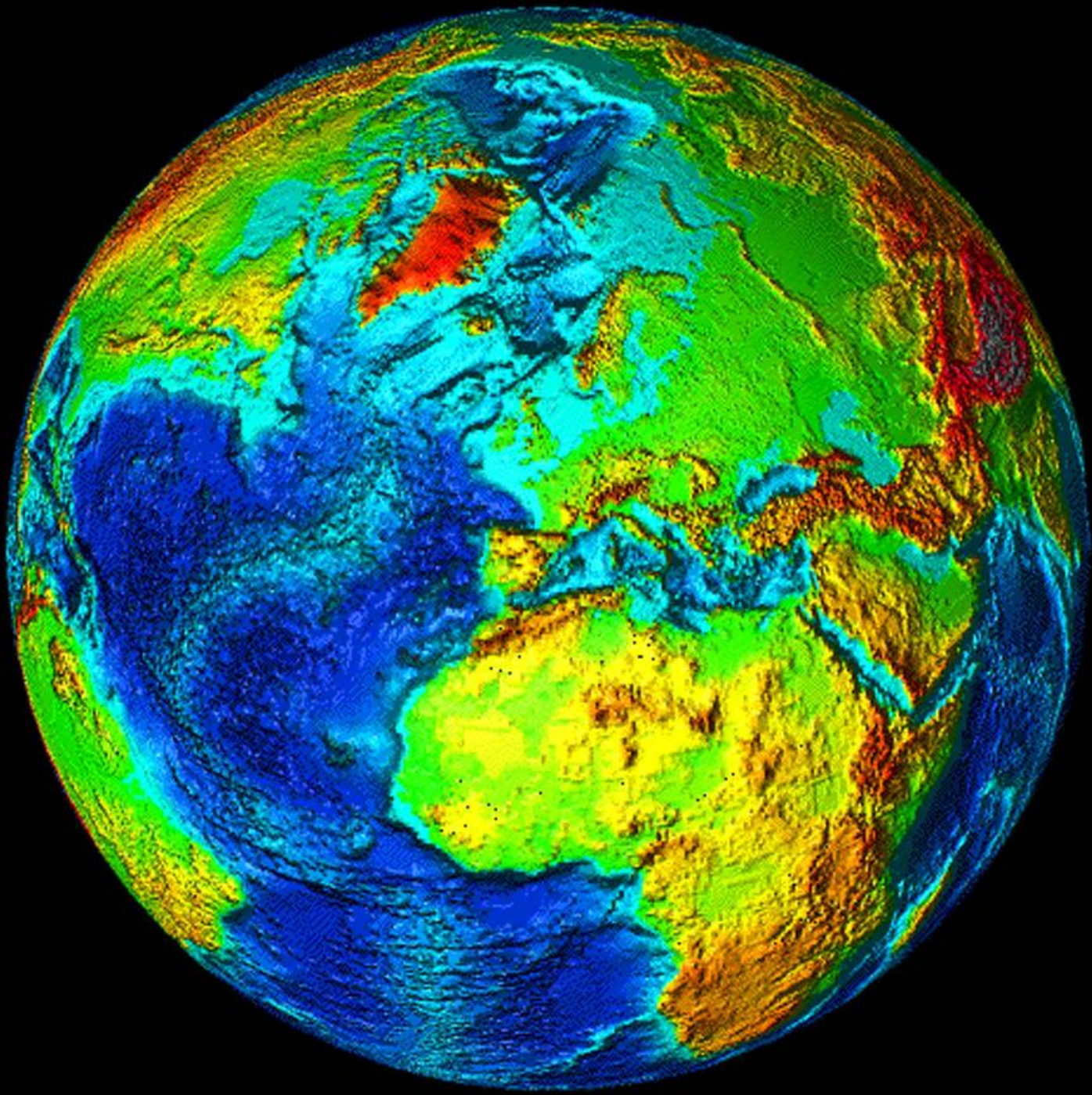
Burke Avenue Profile – Bronx WPA

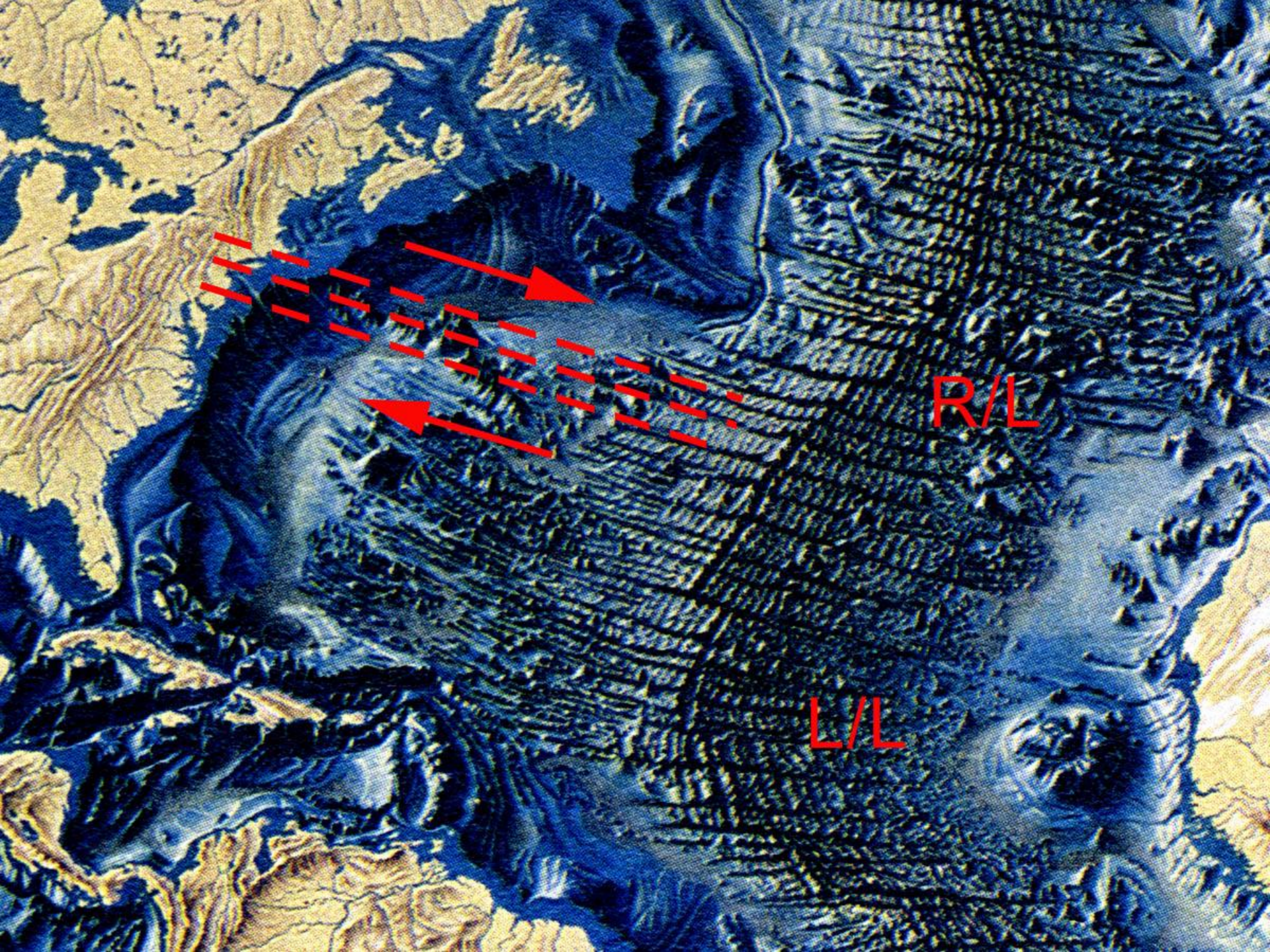


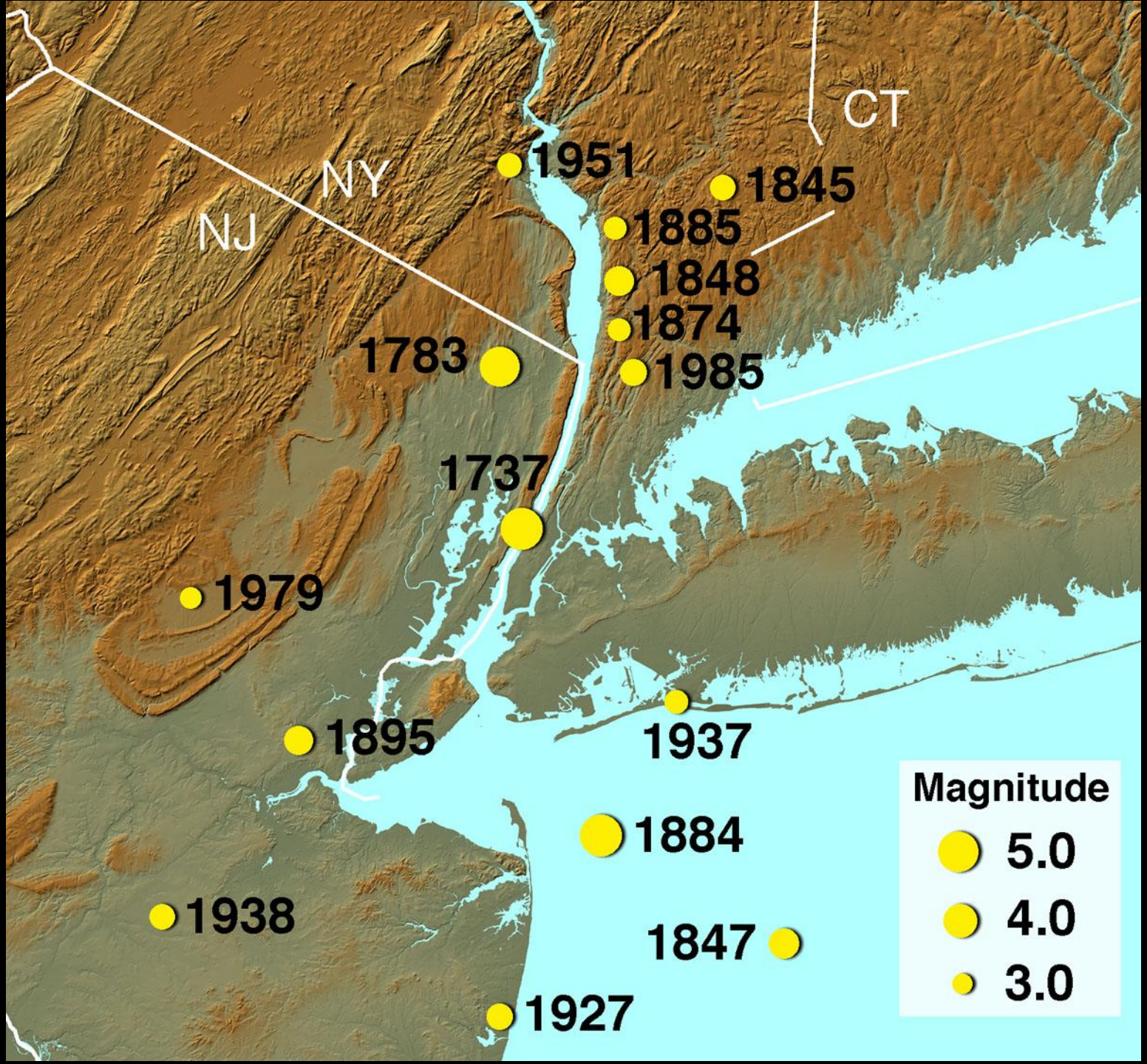
Bouldery Till

Stratified Lake Sediment Overlie Glacial Drift

Supports Geomorphic Evidence that Diversion of Bronx River was indeed Post-Glacial (<50,000 ybp)




R/L
L/L


CT
NY
NJ
1951
1845
1885
1848
1874
1783
1985
1737
1979
1895
1937
1884
1938
1847
1927
Magnitude
5.0
4.0
3.0

How Well Will NYC Withstand A Moderate or Severe Earthquake?

How is NYC Built?

DUKE

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It’s Not My Fault! He put me up to this!

EXTRA SLIDES