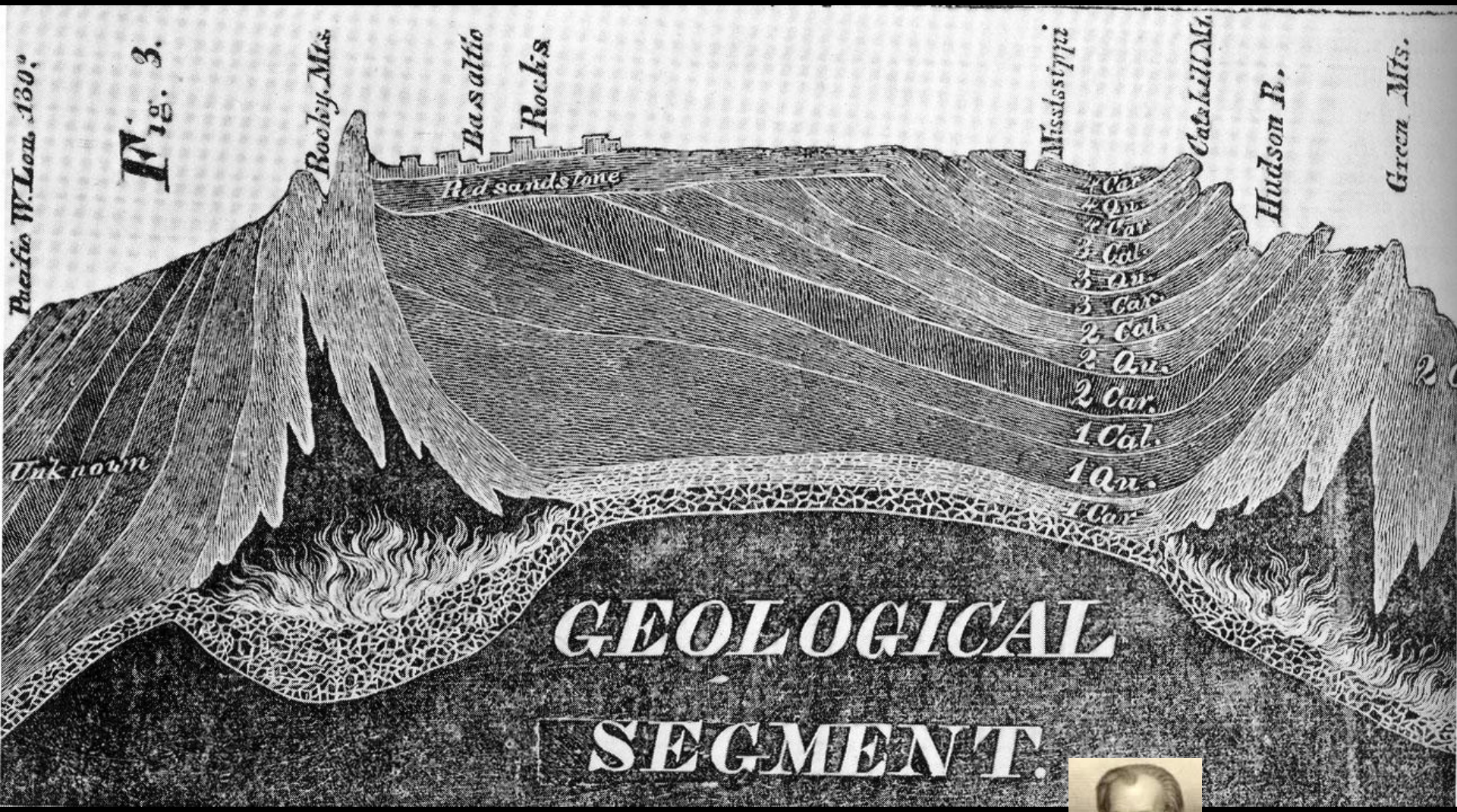
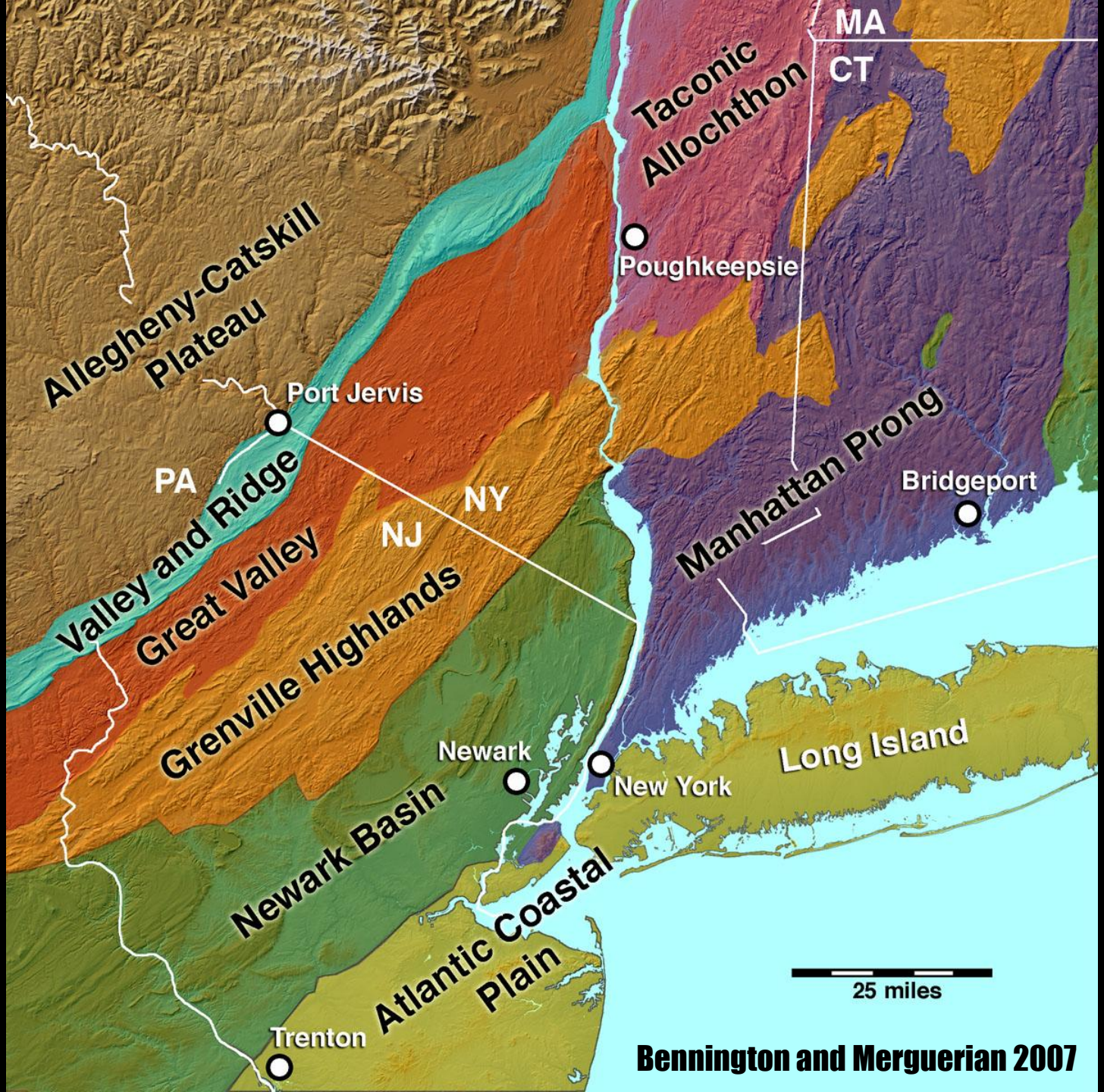
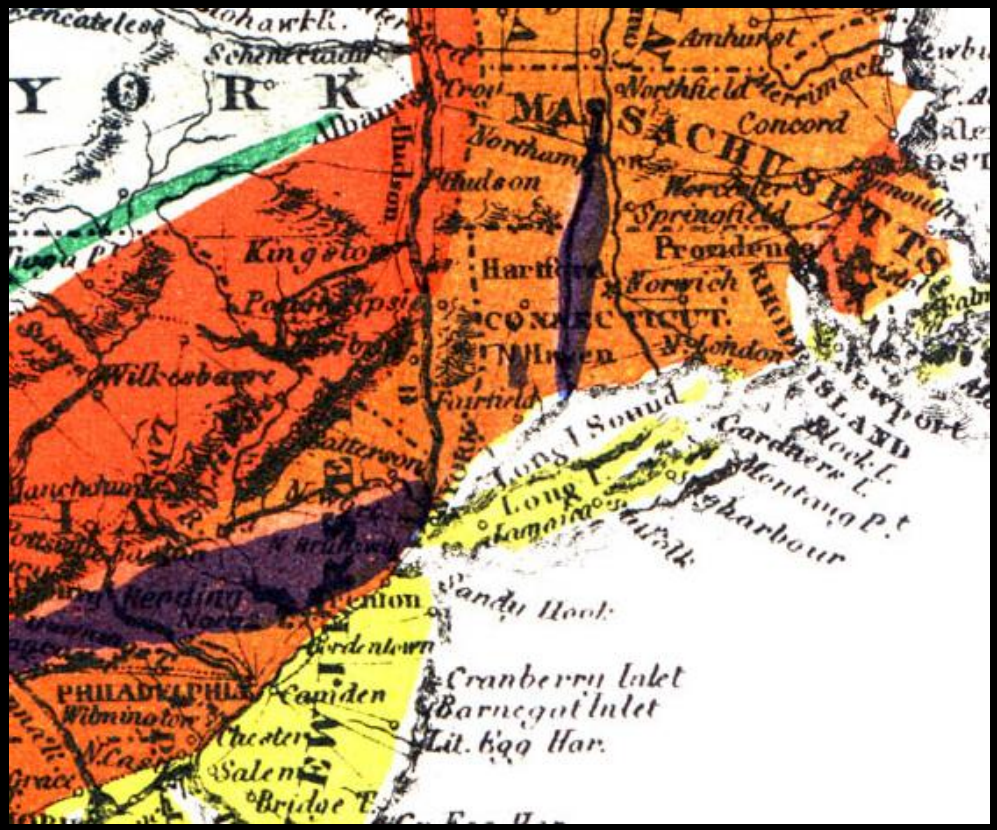
Manhattan Prong Overview and NYC Bedrock Tribulations
Charles Merguerian



Eaton 1820

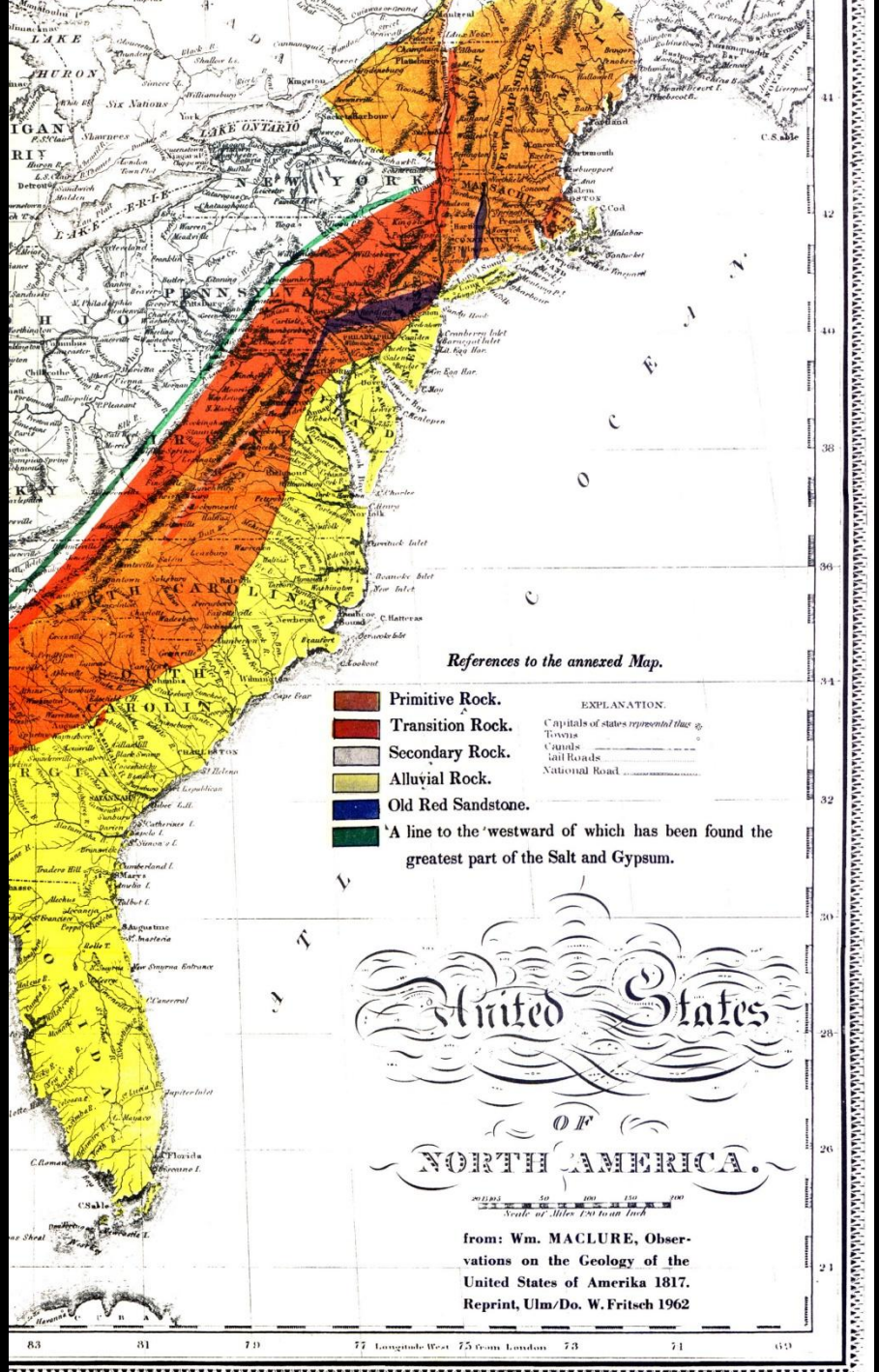


Bennington and Merguerian 2007



References to the annexed Map.

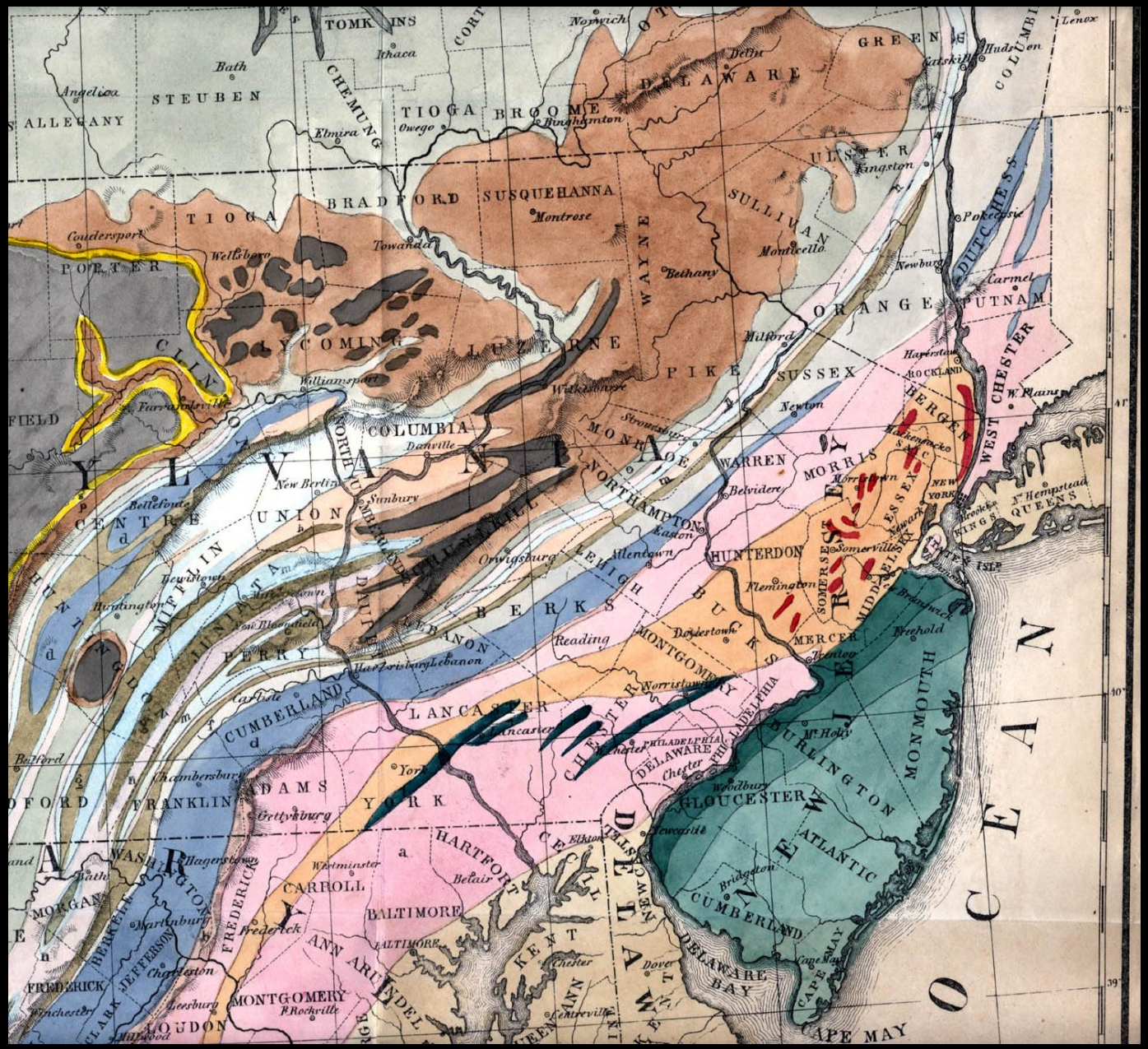
- Primitive Rock.
- Transition Rock.
- Secondary Rock.
- Alluvial Rock.
- Old Red Sandstone.
- A line to the westward of which has been found the greatest part of the Salt and Gypsum.

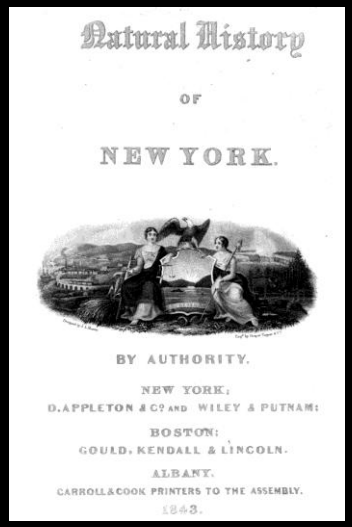


Maclure 1817

Natural History of New York

1843





Hall
Mather
Emmons
Beck
Vanuxem

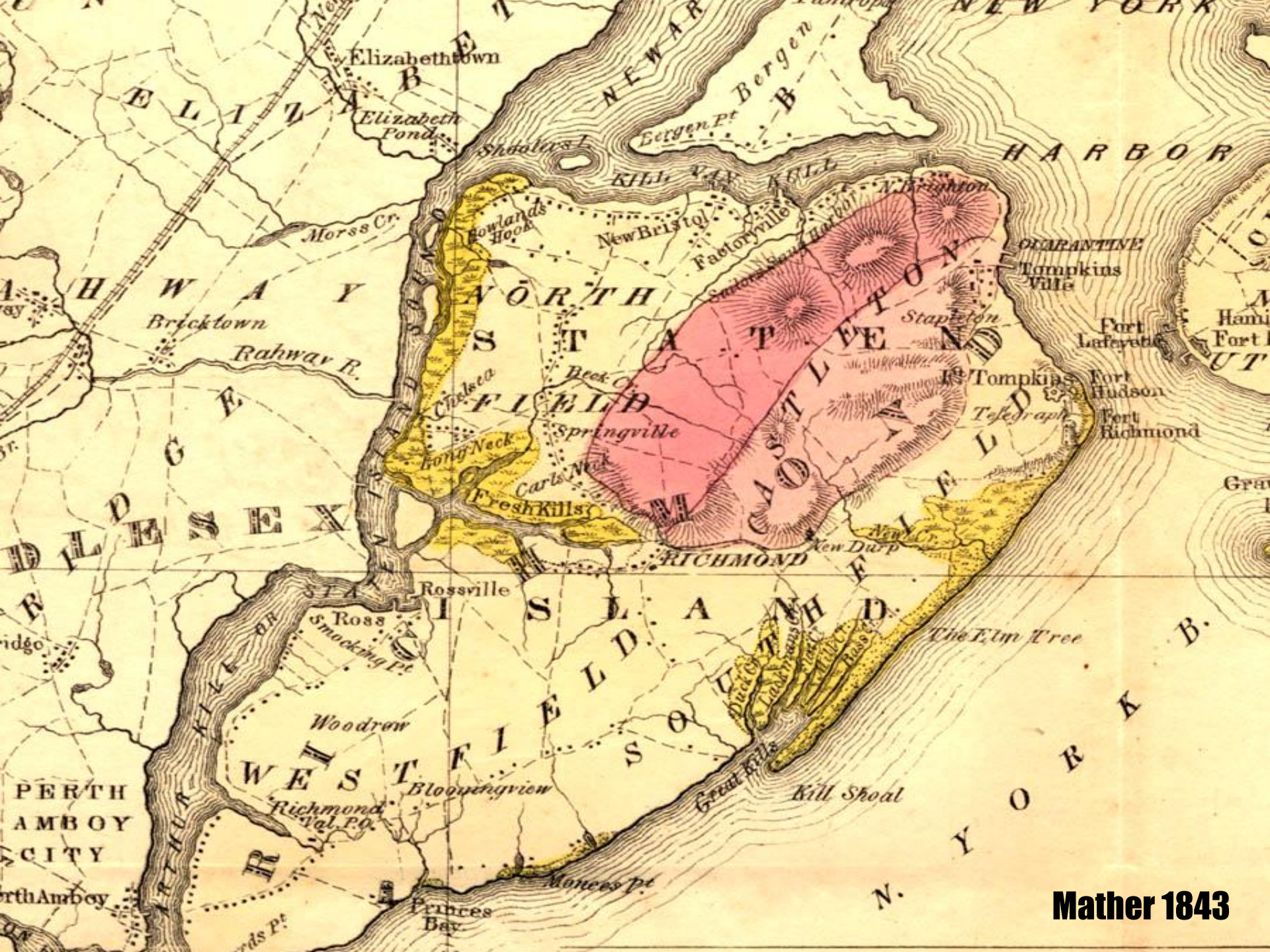
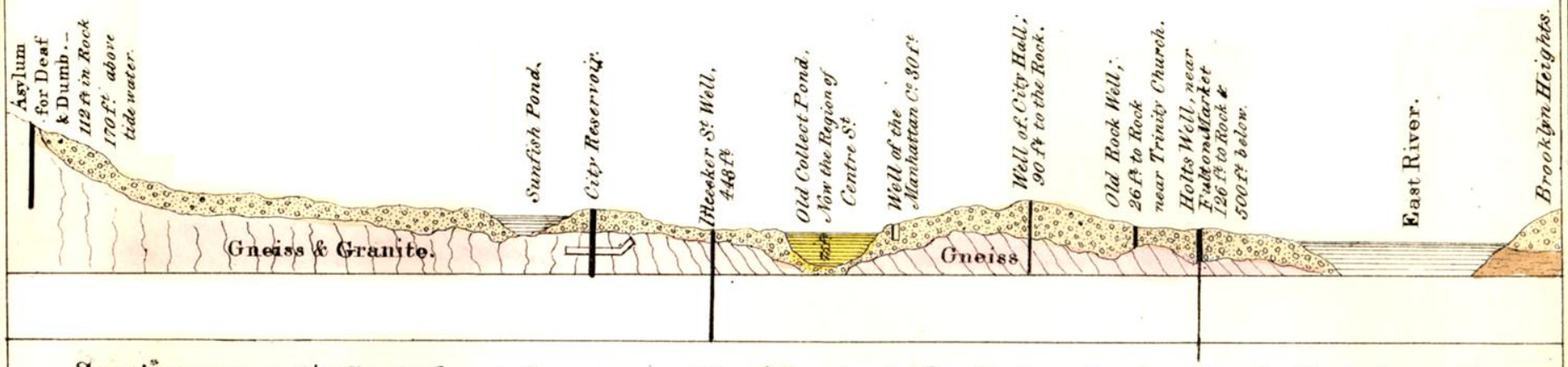

Elizabethtown
Elizabeth Pond
Shooters I.
Bergen Pt
Bergen
HARBOR
NEW YORK
KILL VAN KULL
N. Brighton
Morss Cr.
Bowlands Hook
New Bristol
Factoryville
Sailors Snug Harbor
QUARANTINE
Tompkins Ville
Stapleton
Fort Lafayette
Fort Hudson
Fort Richmond
Tompkins
Telegraph
Bricktown
Rahway R.
NORTH
STATEN
ISLAND
Chelsea
Springville
Long Neck
Carls Neck
Fresh Kills
RICHMOND
New Dorp
Rossville
Ross
Smocking Pt
ISLAND
The Elm Tree
Woodrew
WESTFIELD
SOUTHFIELD
Bloomingview
Richmond Val. P.O.
Great Kills
Kill Shoal
Monces Pt
Princes Bay
PERTH AMBOY CITY
N. YORK B.
Mather 1843

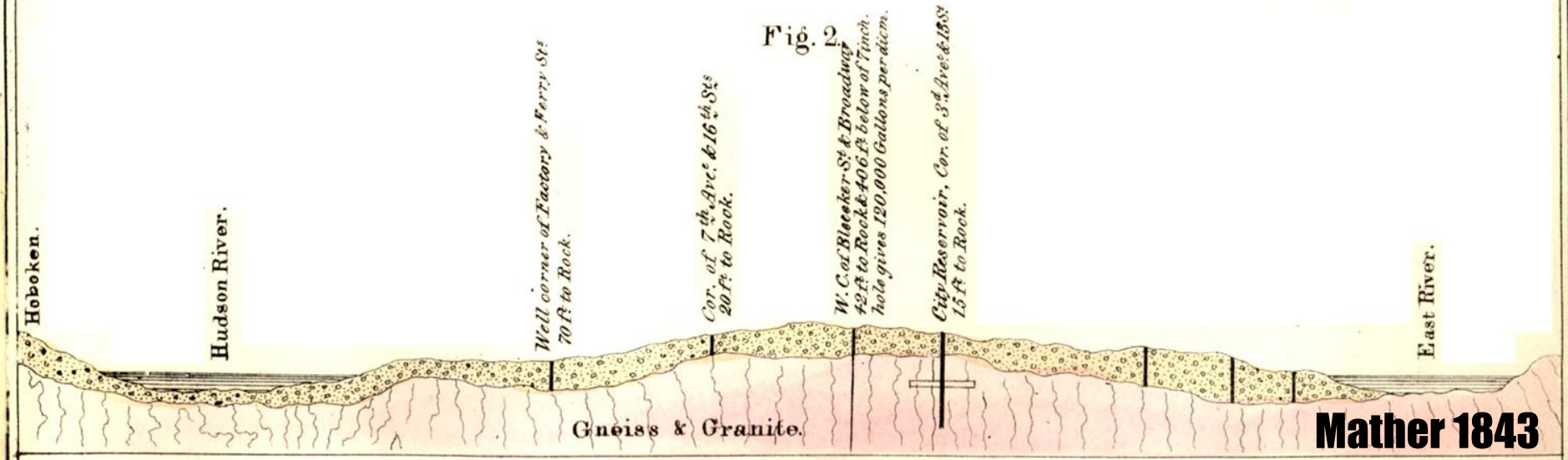
Fig. 1.

Geological Section, *on the Island of New-York parallel to the strike of the strata from near 50th Street on the North to Brooklyn Heights on the South shewing the depths of earth and rock perforated in boring wells.*



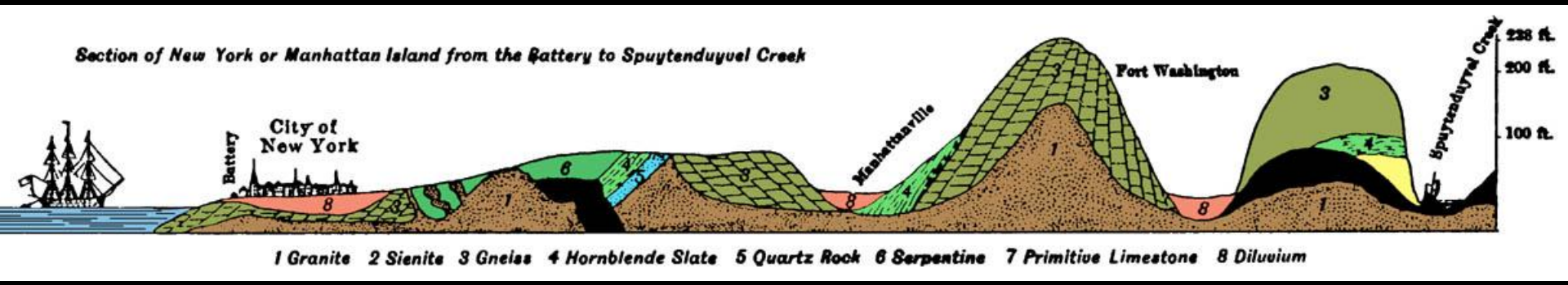
Section *perpendicular to the strike; across the Island of New-York, shewing the depth to the rock.*

Fig. 2.



Mather 1843

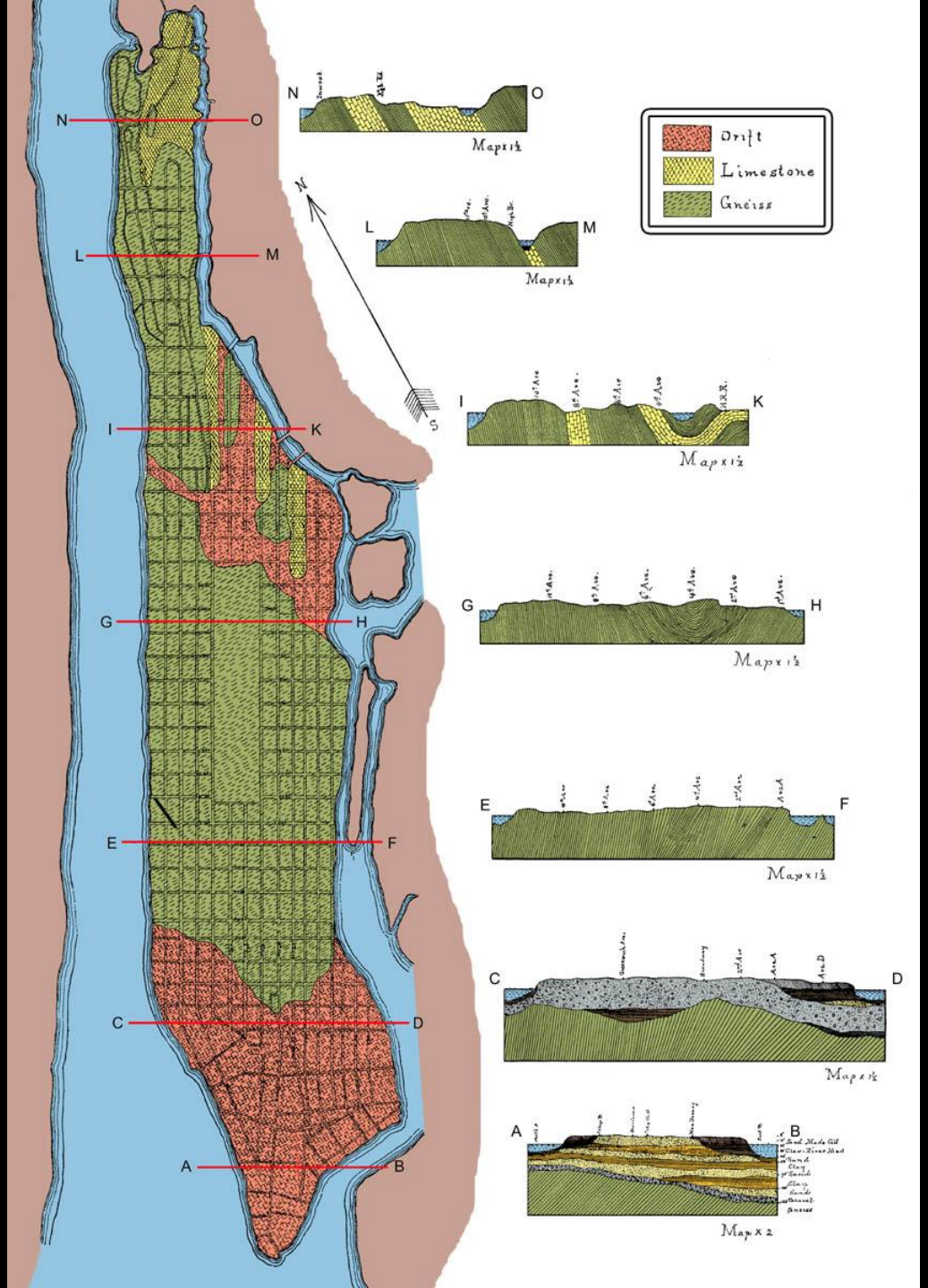
Geological Section – Manhattan Island



Gneiss, Limestone, Hornblende Slate and Serpentinite
Over a Crystalline Substrate of Primitive Granite
Covered by Diluvium

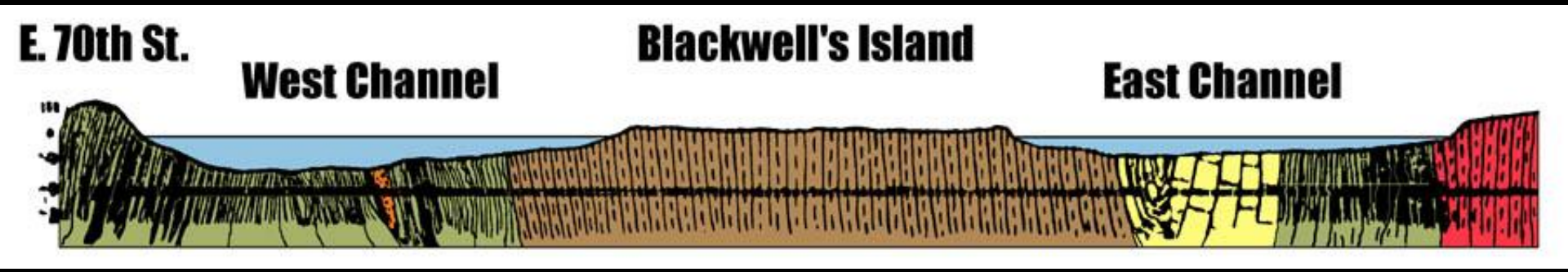
after Cozzens 1848

First Geologic Map of Manhattan Island



after Kemp 1887

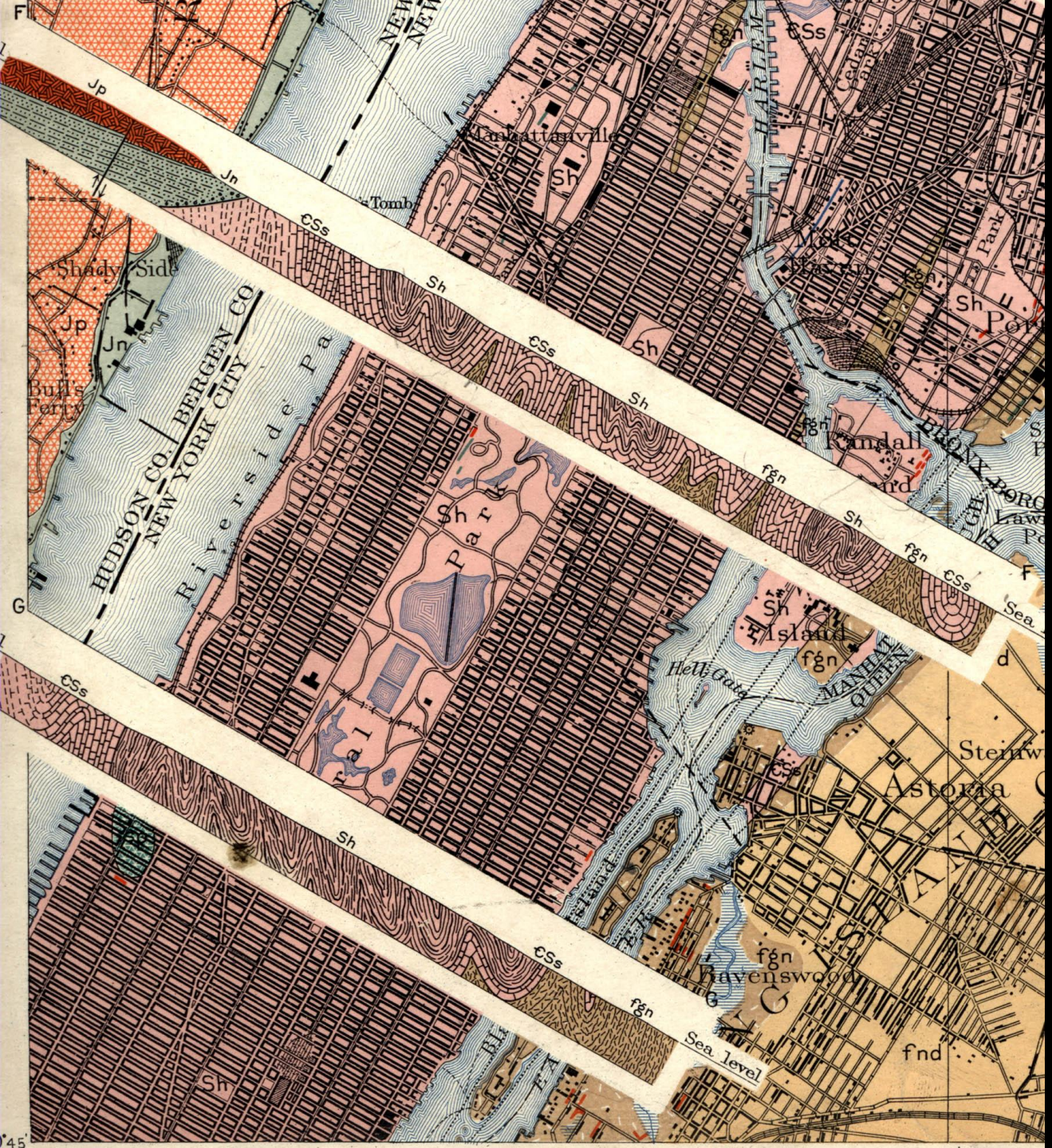
East River Gas Company Tunnel



after Kemp 1895

Davenport Neck Serpentinite

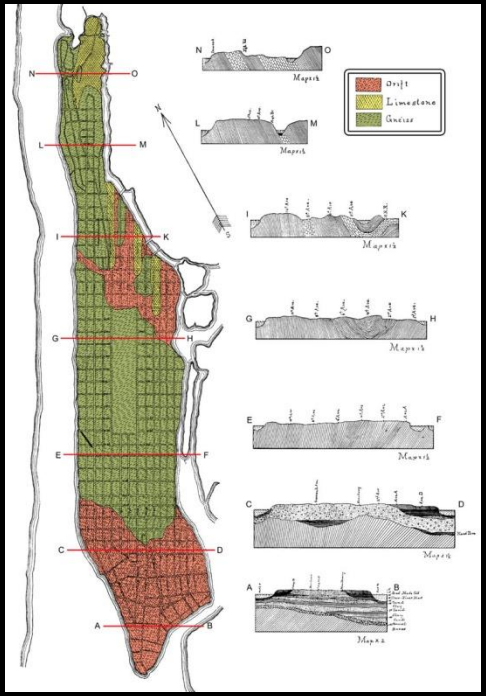
Merrill 1898

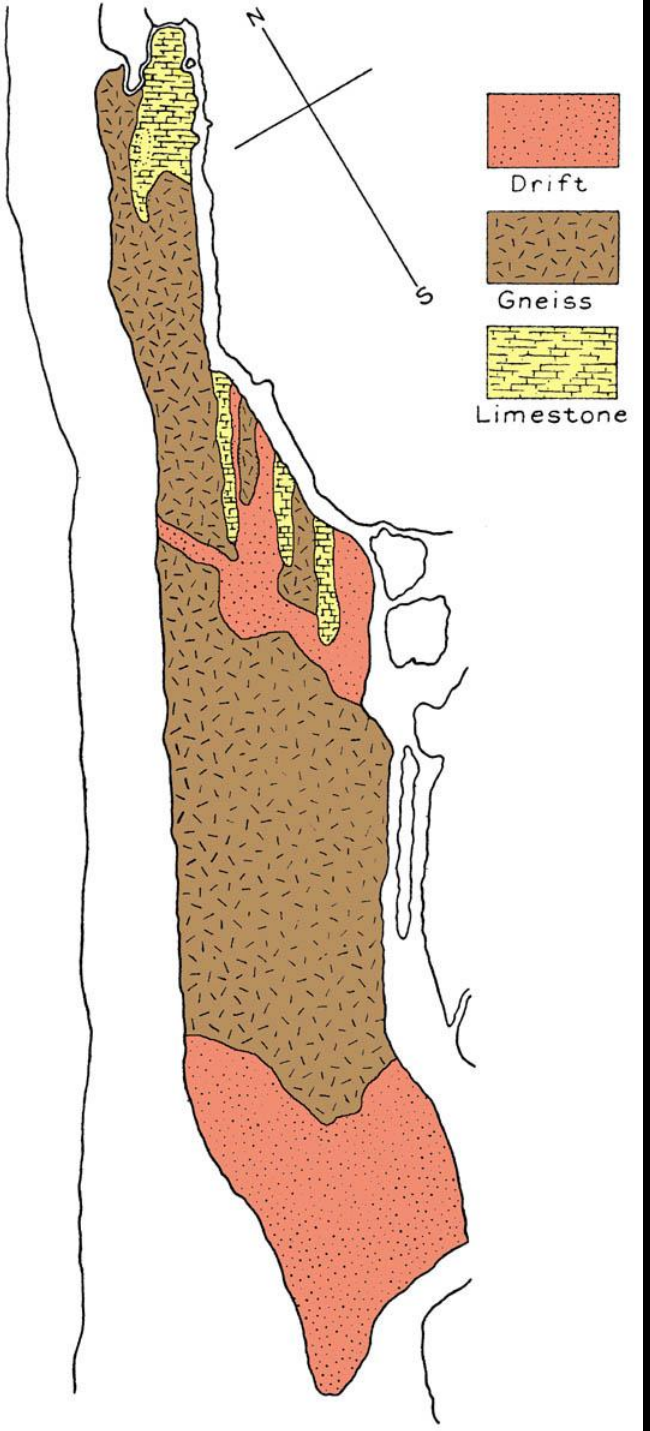


Geologic Maps and Sections New York City USGS Folio 83

Merrill et al. 1902

Geologic Map of Manhattan *(after Kemp and Merrill)*



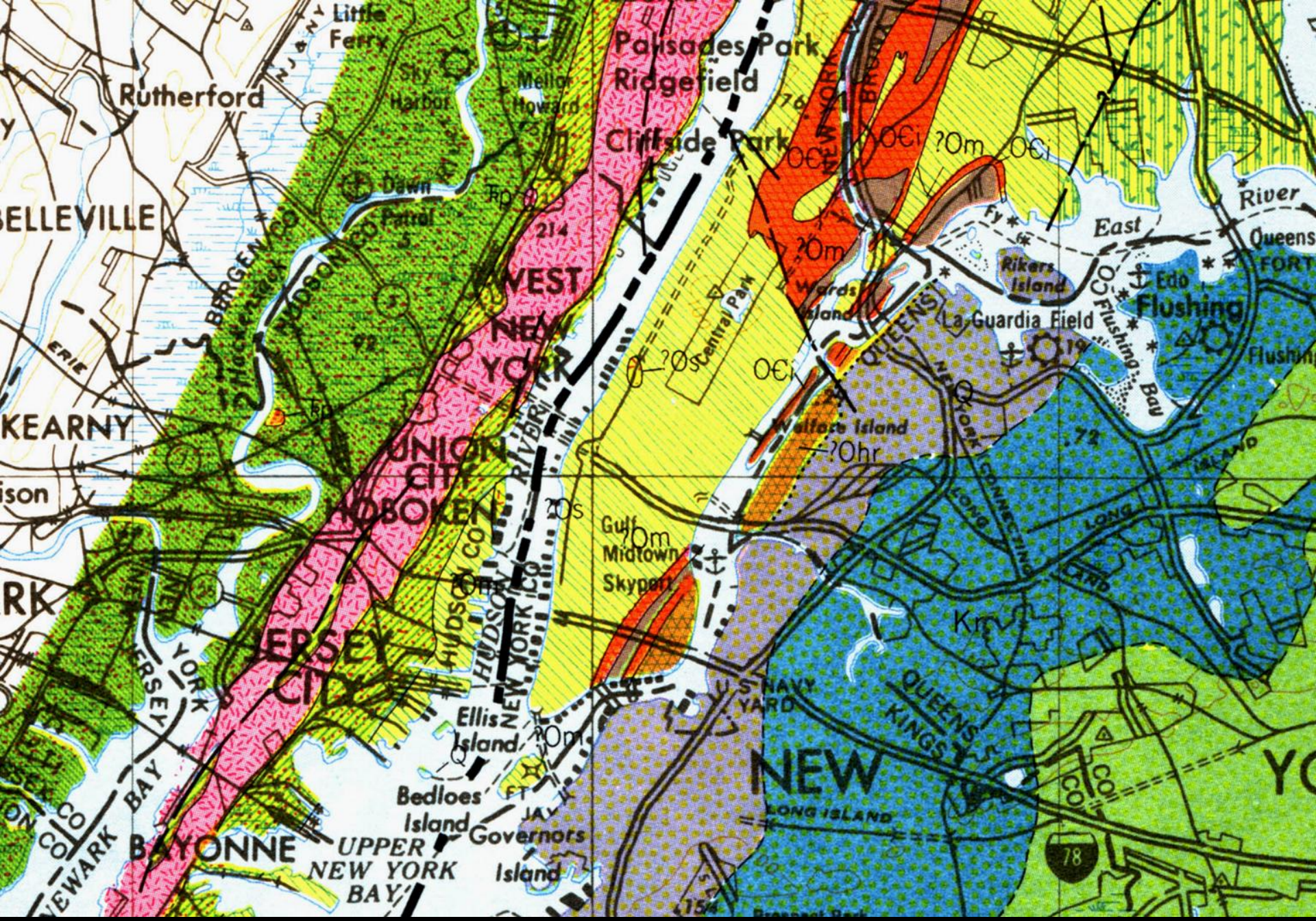


Hobbs 1905

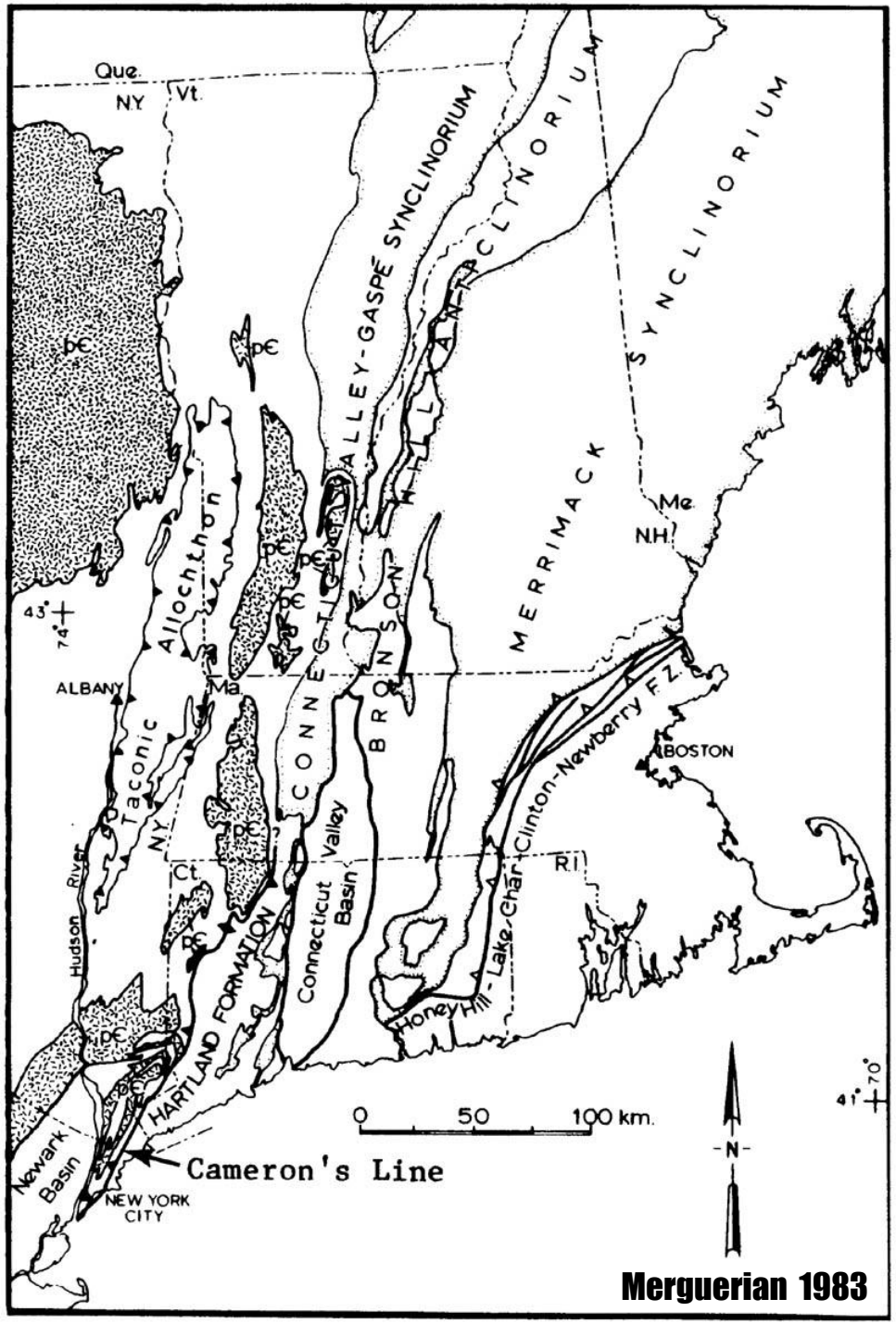
Berkey 1911

LEGEND
HOBOKEN SERPENTINE A metamorphosed basic intrusive cutting the Manhattan schist.
MANHATTAN SCHIST Chiefly a coarse mica schist.
INWOOD LIMESTONE A coarsely crystalline dolomitic marble.
RAVENSWOOD GRANODIORITE A gneissoid intrusive belonging to the Fordham Gneiss Series.
INTERBEDDED LIMESTONES Associated with a schistose gneiss belonging to the Fordham Gneiss Series.
FORDHAM GNEISS Chiefly a black and white banded granitic gneiss.
WALLABOUT BAY
WALLABOUT CHANNEL
UNITED STATES NAVY YARD

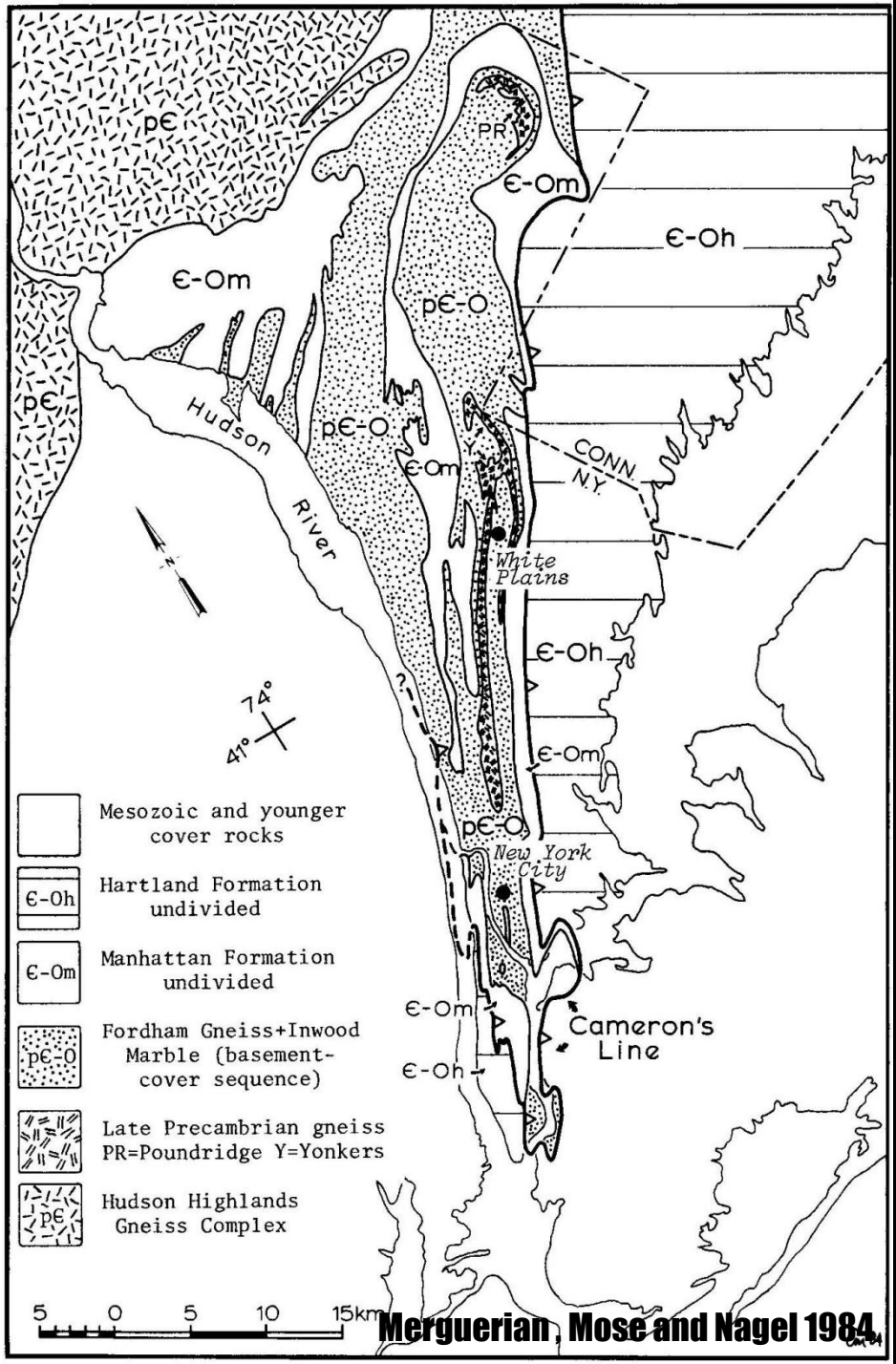
LITTLE HELL GATE
JEFFERSON PARK
RECREATION PIER
HELL GATE
GREAT HELL ROCK
LITTLE HELL ROCK
CROTON RESERVOIR
Line E



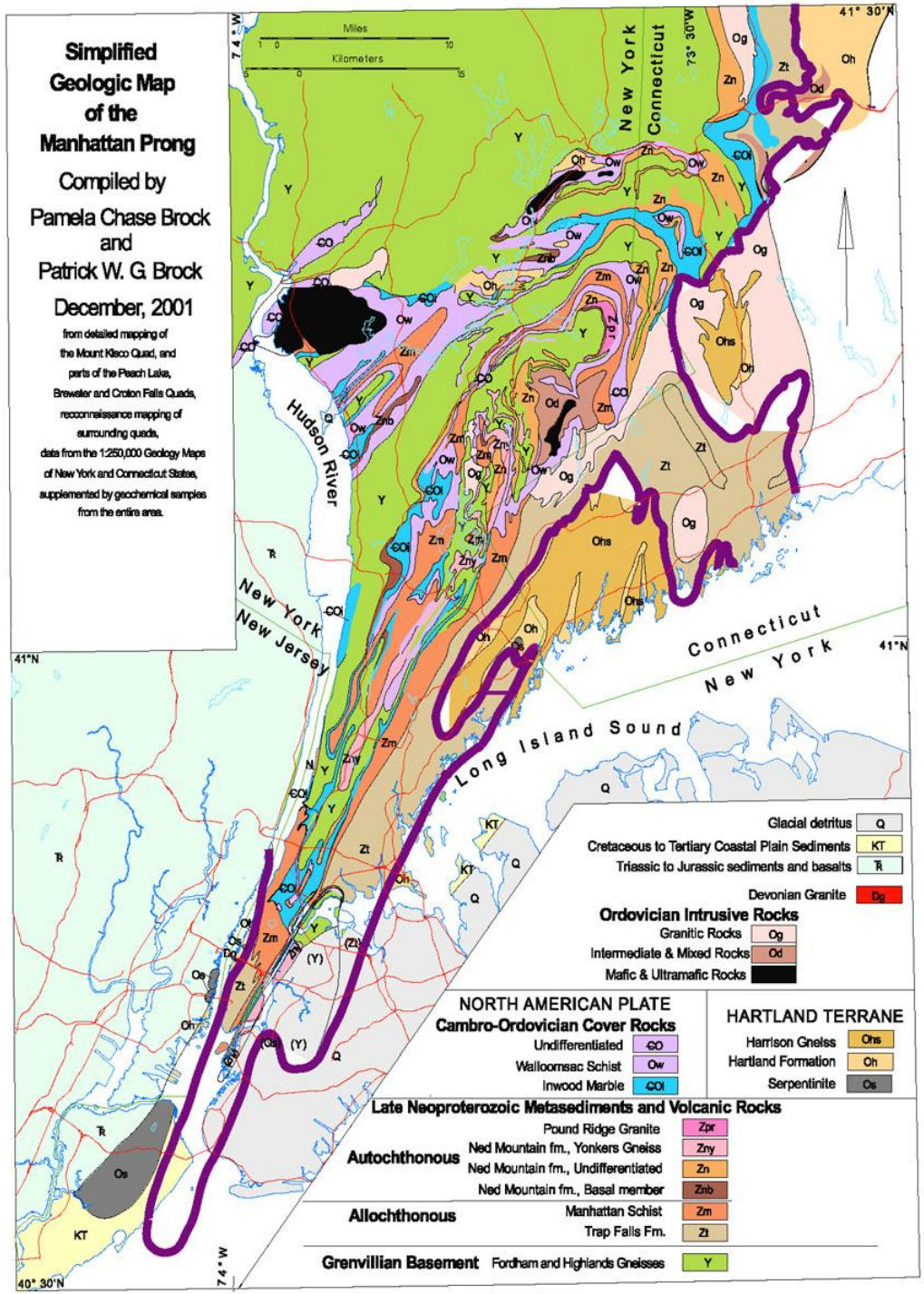
Fisher et al. 1970



Merguerian 1983

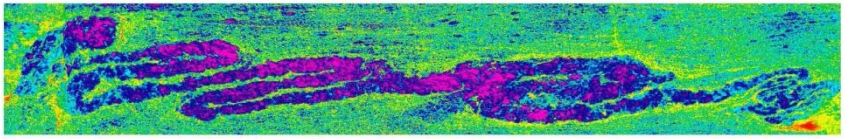


Merguerian, Mose and Nagel 1984



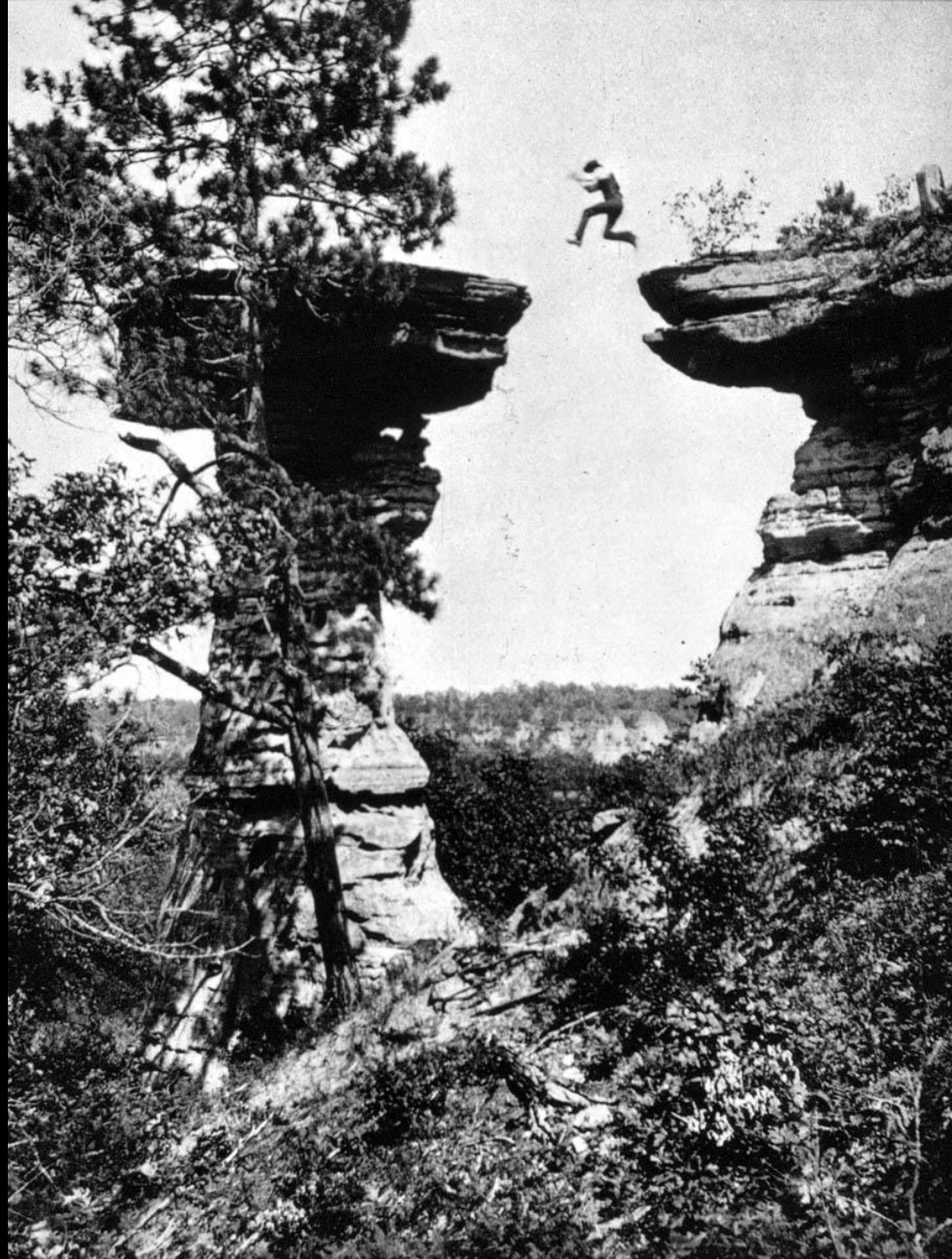
Main Questions:

1) Position/Geometry of Cameron's Line & St. Nicholas Thrust
2) Age/Provenance of Schistose Rocks
3) Proterozoic Rocks
4) P-T History of All
5) Mafic Rocks
6) Plutons/Dikes
7) Serpentinites
8) Geochem/Age Dating



Merguerian's Early Field Work on Manhattan Island

In The Days When He Was More Limber



>1,000 Field Data Points
Hundreds of Academic Field Trips
NYC Parks
Tunnels
Geotechnical Data/Borings
Access via Consulting

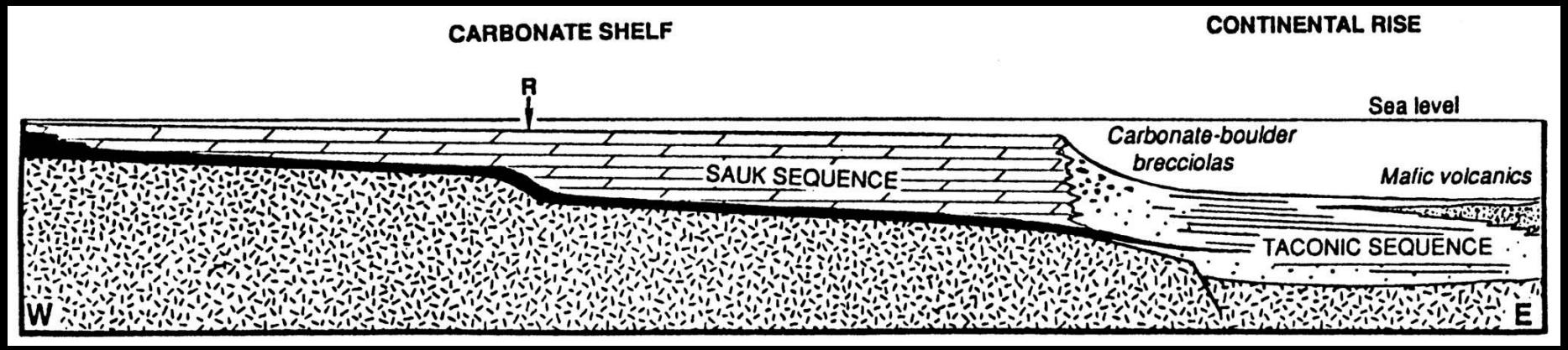
Merguerian Has Spent Most of his Career Mapping the Surface and Subsurface Geology of NYC

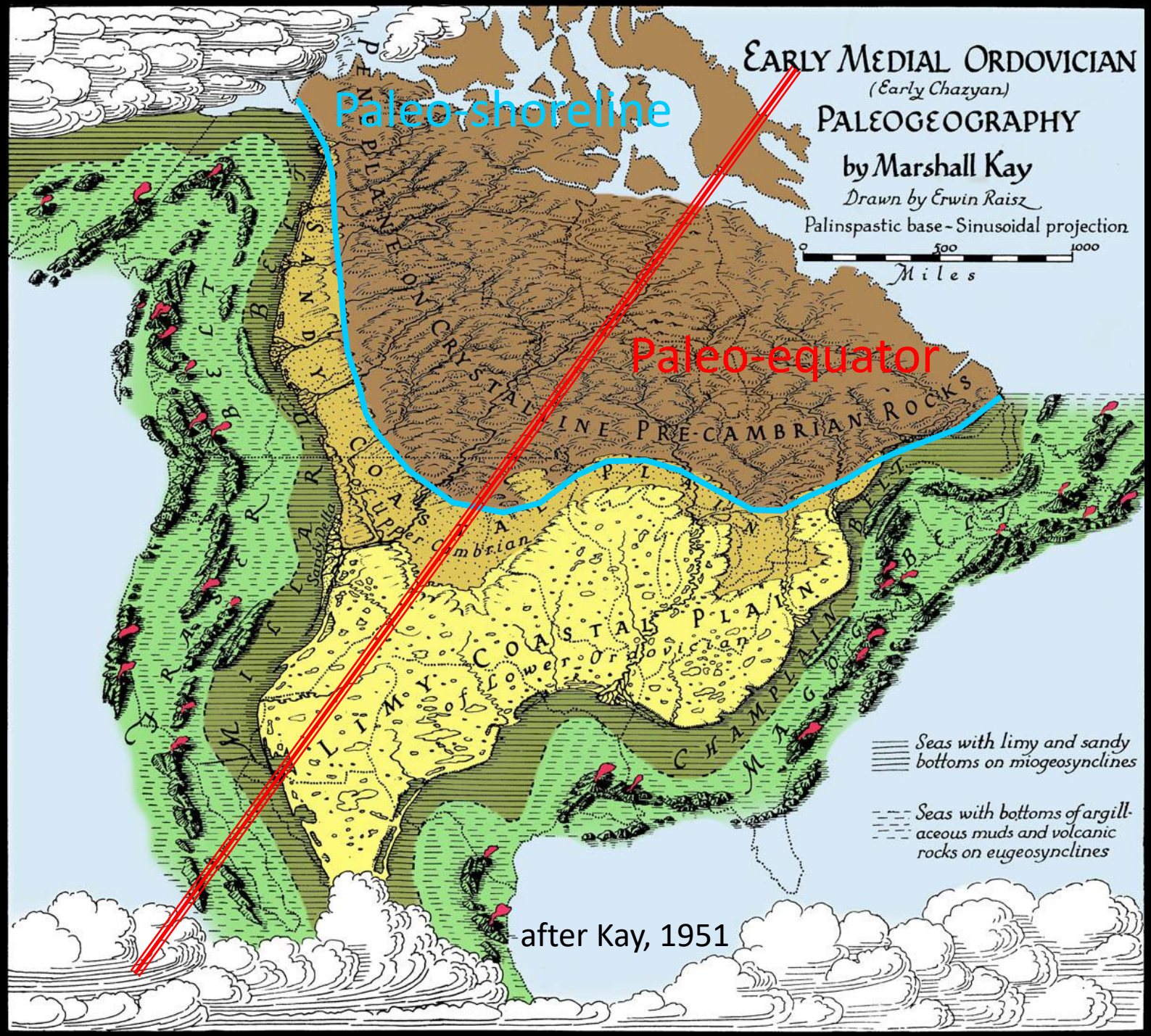
Proper Field Attire For NYC Work

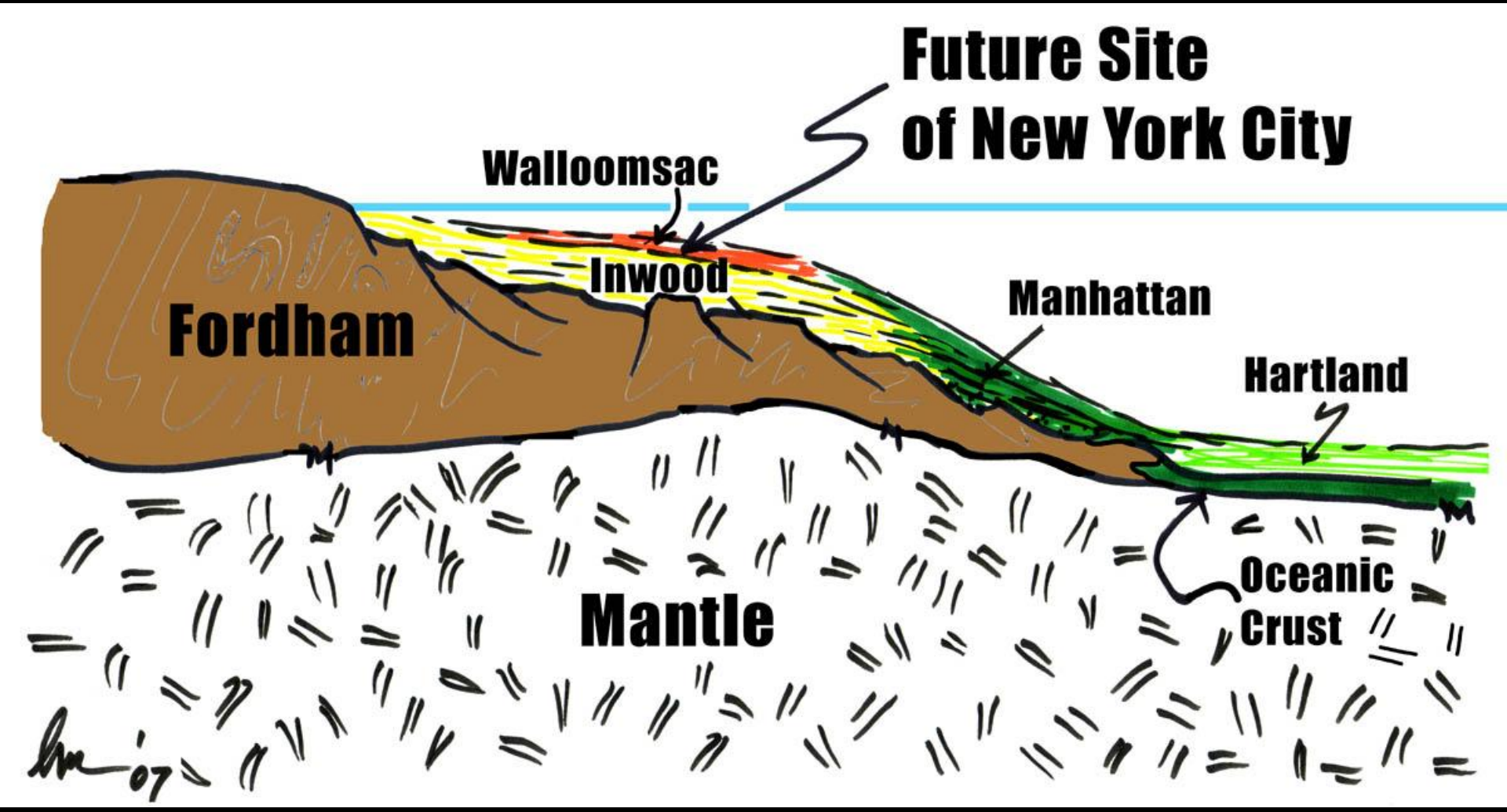
51 Connections

Sequence Stratigraphy

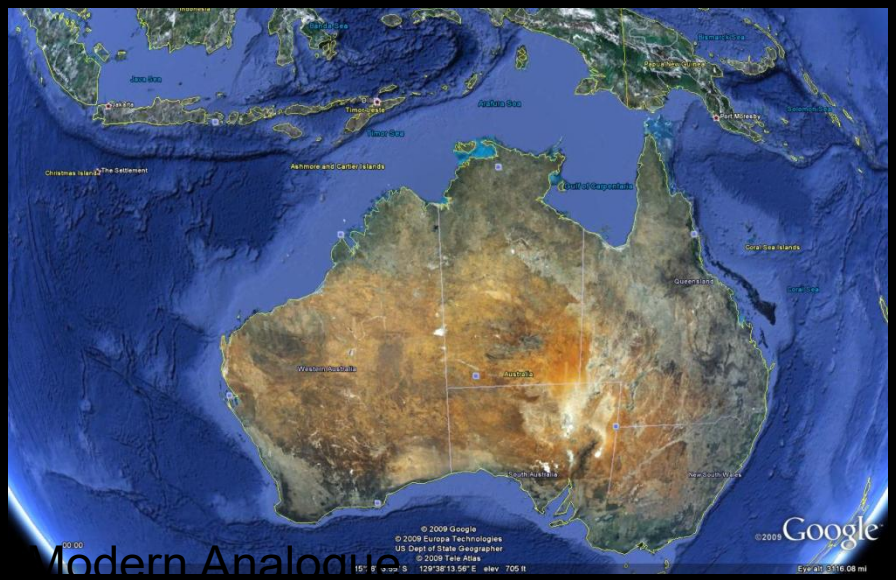
Tippecanoe
Sauk
Taconic

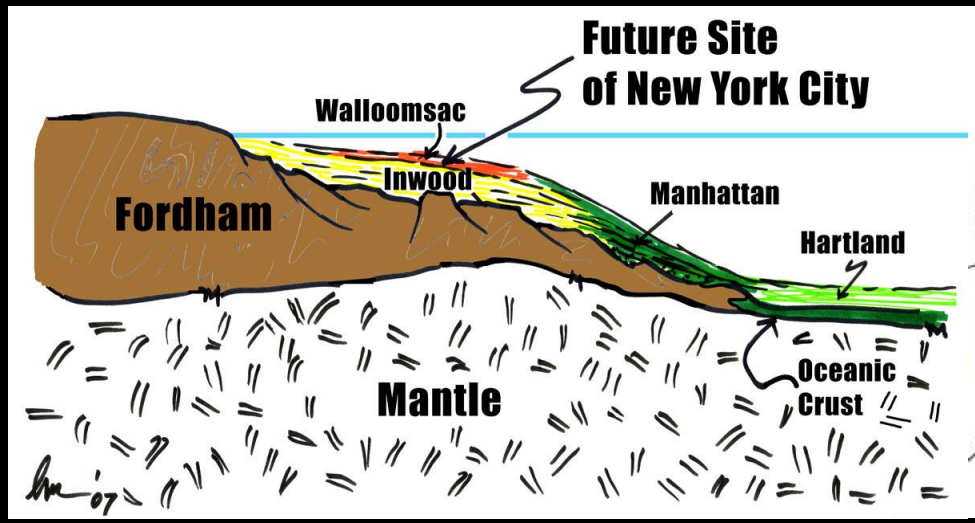


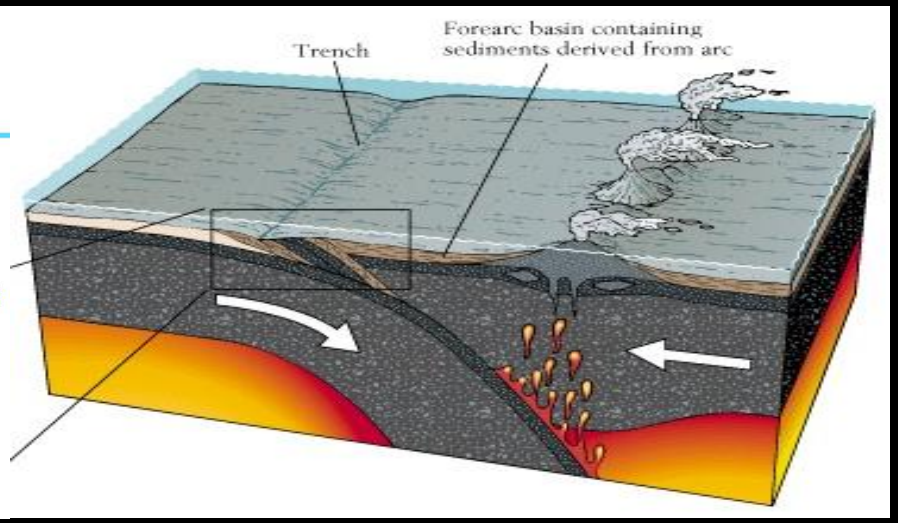

Early Medial Ordovician
(Early Chazyan)
Paleogeography
by Marshall Kay
Drawn by Erwin Raisz
Palinspastic base - Sinusoidal projection
0
500
1000
Miles
Paleo-shoreline
Paleo-equator
Peneplanation Crystalline Pre-Cambrian Rocks
Coastal Plain of Upper Cambrian
Coastal Plain of Lower Ordovician
Limy
Champlain Magnesian Belt
Appalachian Belt
Seas with limy and sandy bottoms on miogeosynclines
Seas with bottoms of argillaceous muds and volcanic rocks on eugeosynclines
after Kay, 1951

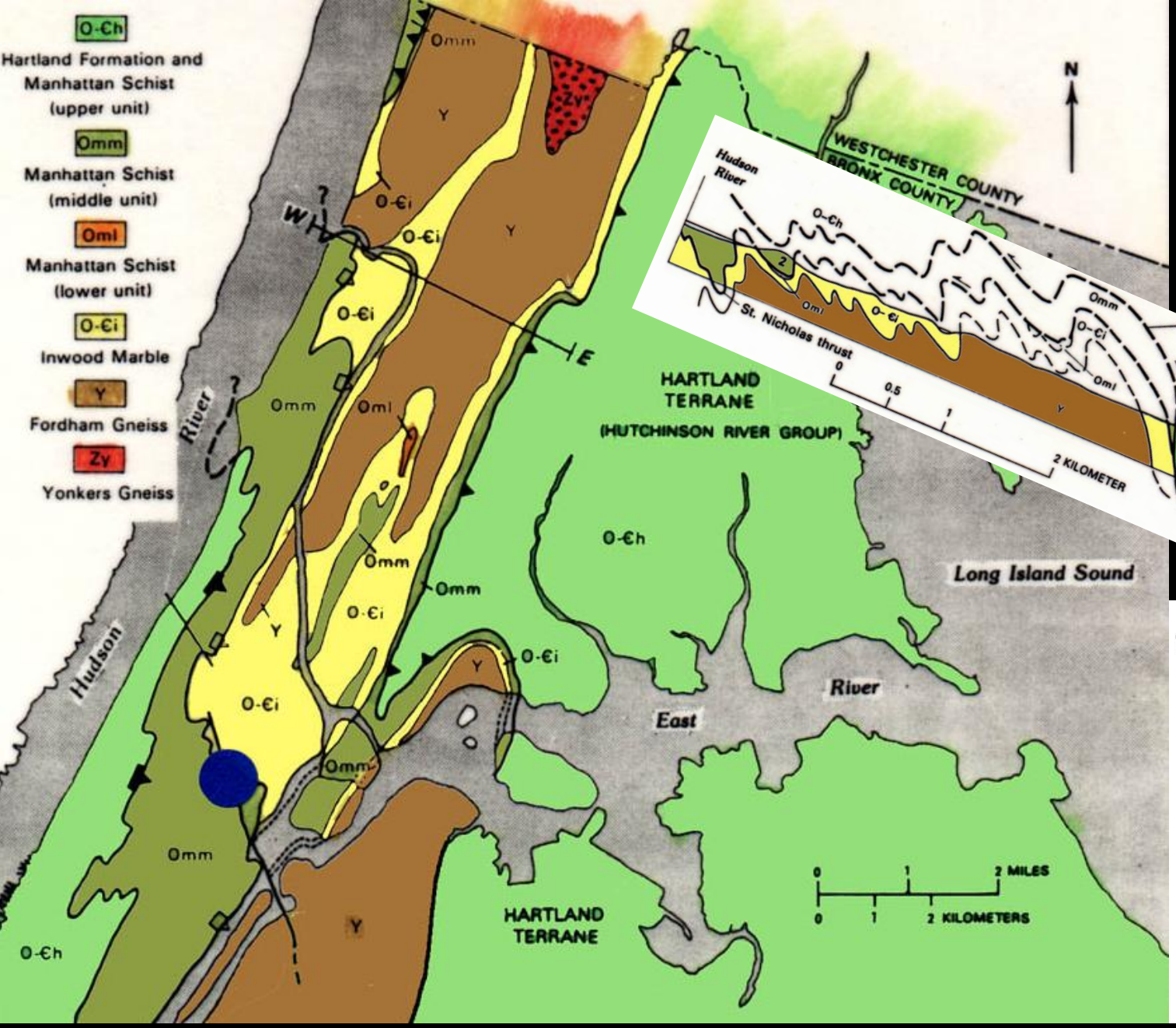

Future Site
of New York City
Walloomsac
Inwood
Fordham
Manhattan
Hartland
Oceanic
Crust
Mantle

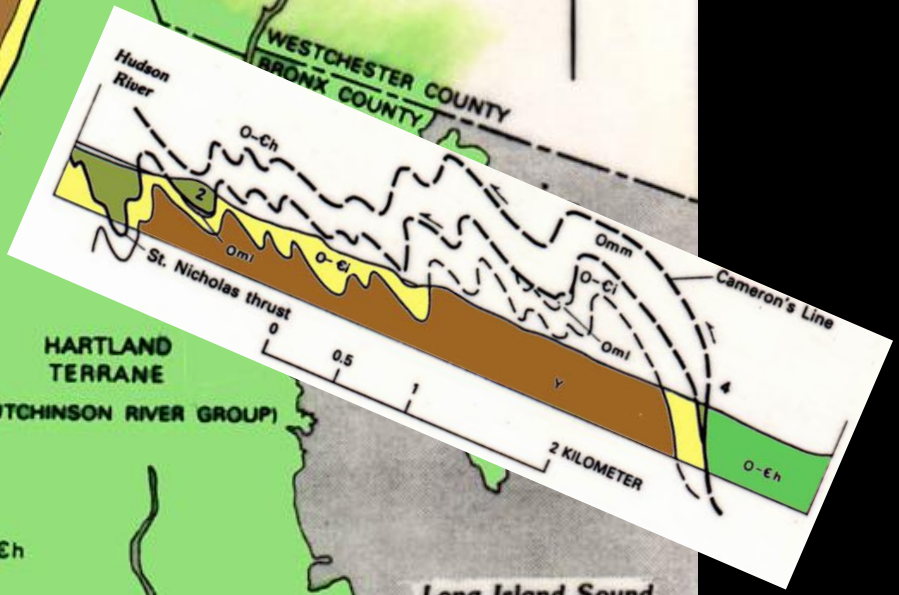
~ 450 Ma Taconian Arc – Passive Margin Collision

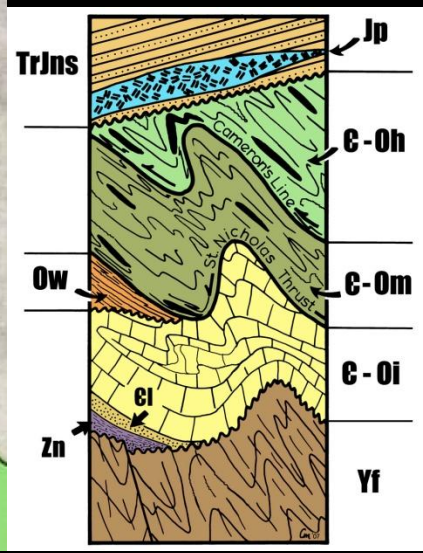




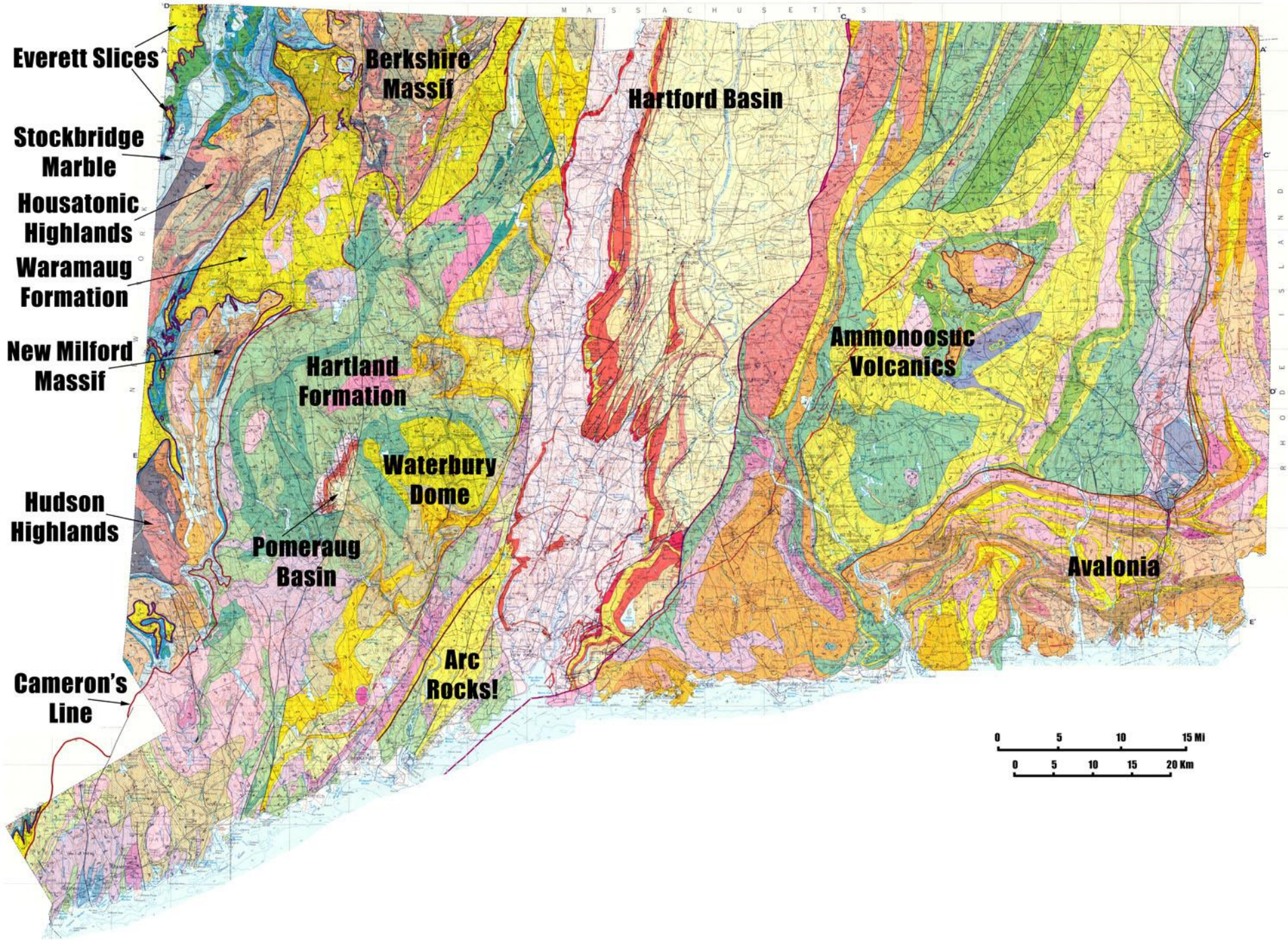




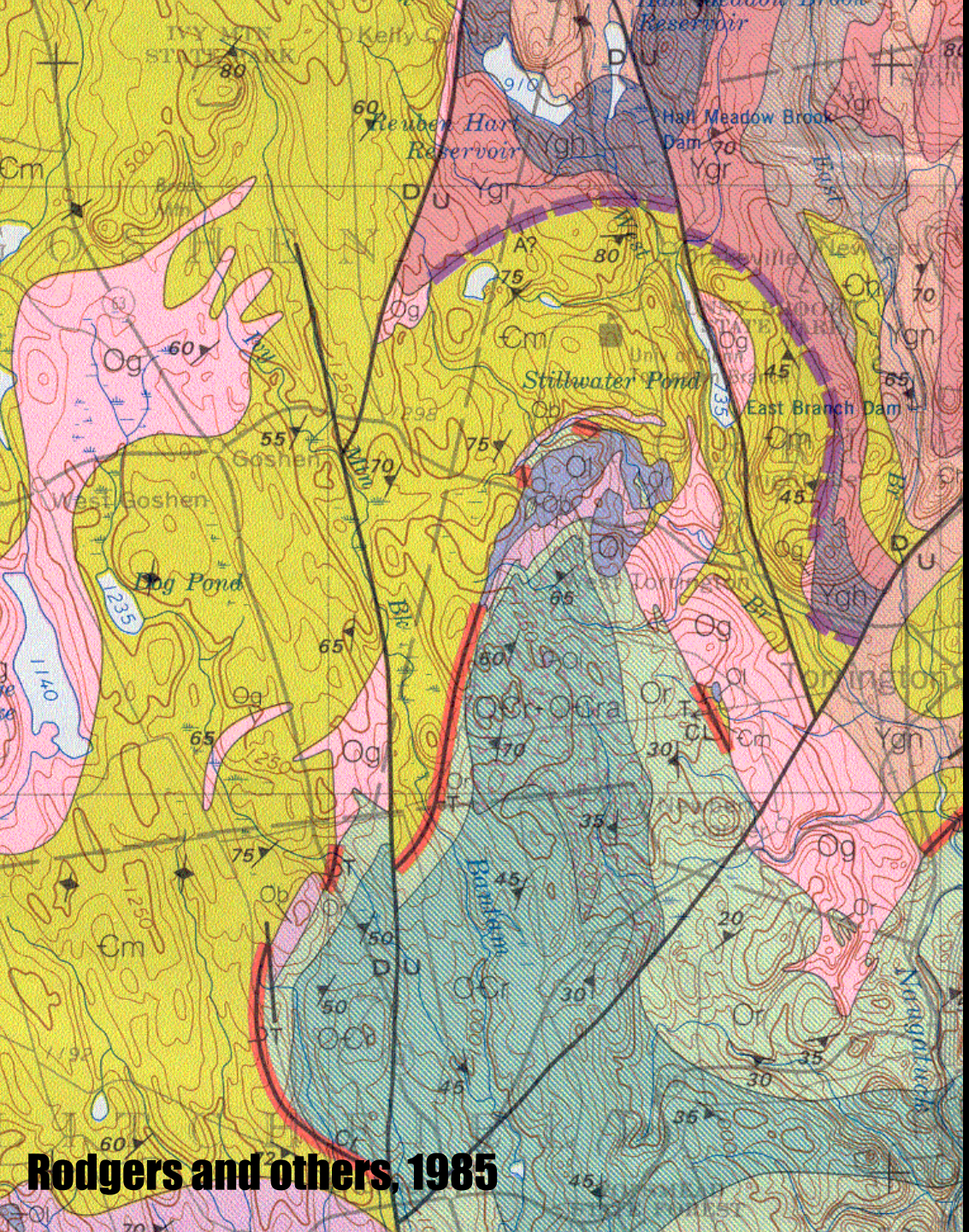




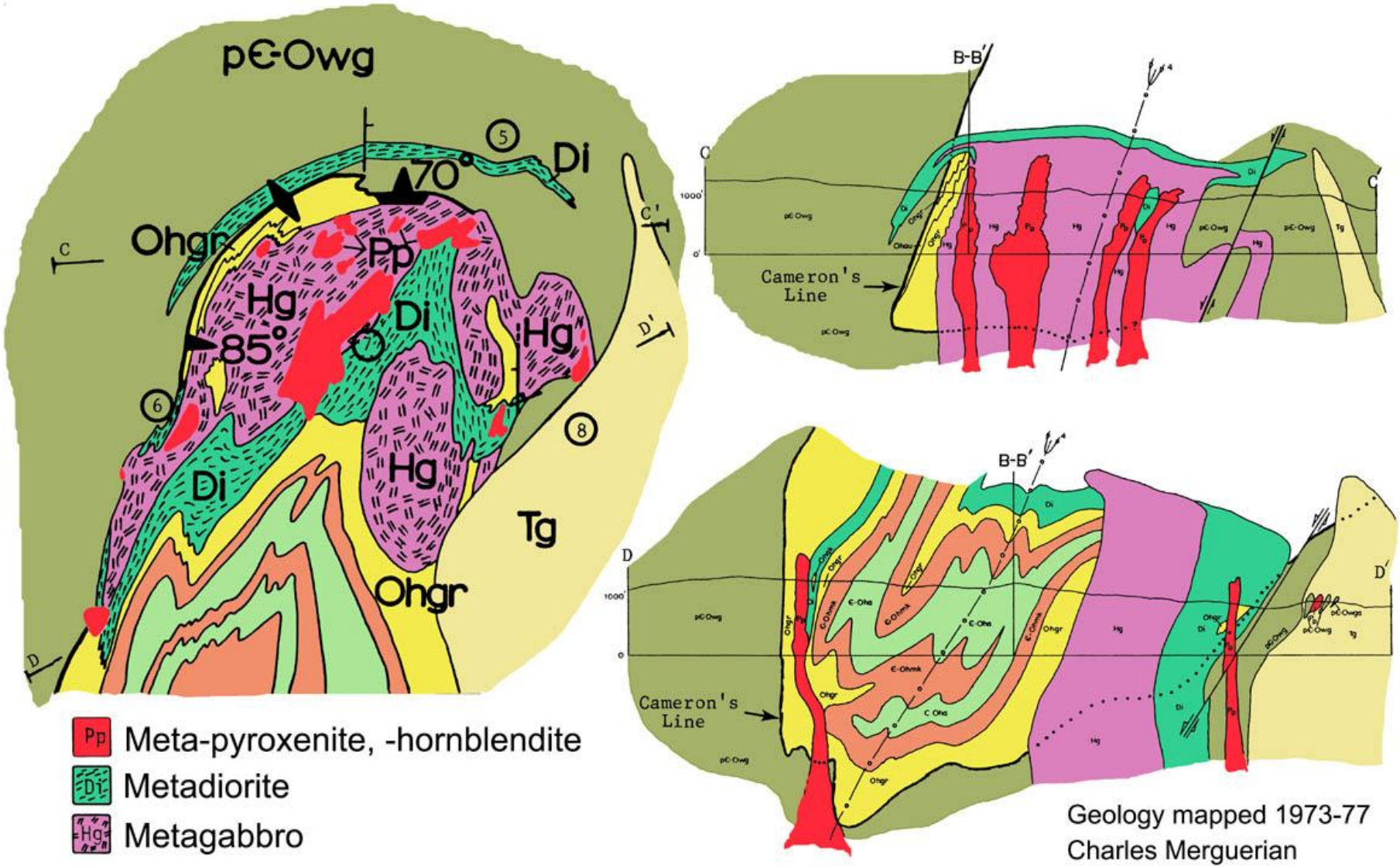
Merguerian and Merguerian, 2004


Everett Slices
Stockbridge Marble
Housatonic Highlands
Waramaug Formation
New Milford Massif
Hudson Highlands
Cameron's Line
Berkshire Massif
Hartford Basin
Hartland Formation
Waterbury Dome
Pomeraug Basin
Arc Rocks!
Ammonoosuc Volcanics
Avalonia
MASSACHUSETTS
NEW YORK
RHODE ISLAND
0 5 10 15 Mi
0 5 10 15 20 Km

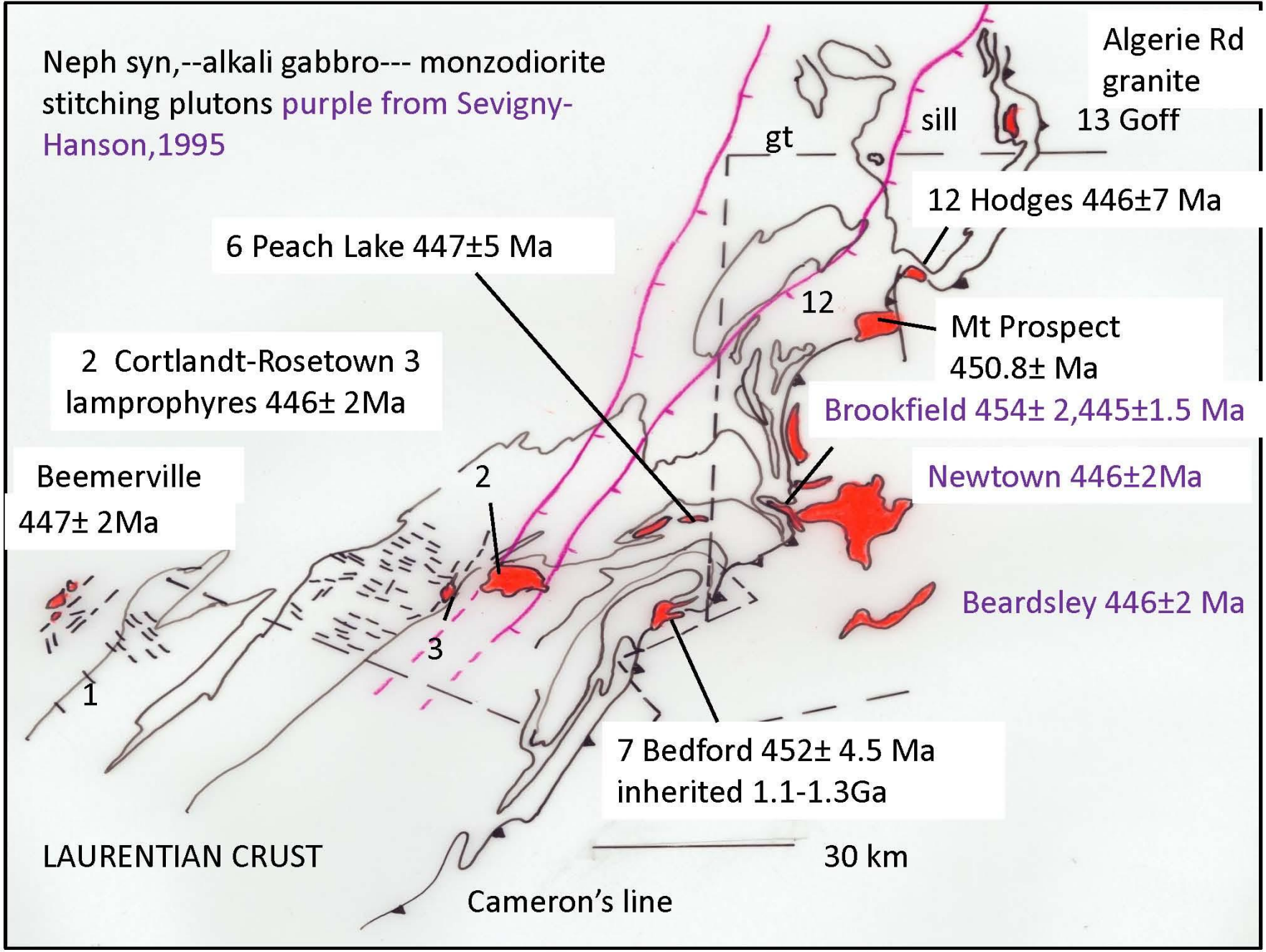
Hodges Complex and Cameron's Line



Rodgers and others, 1985

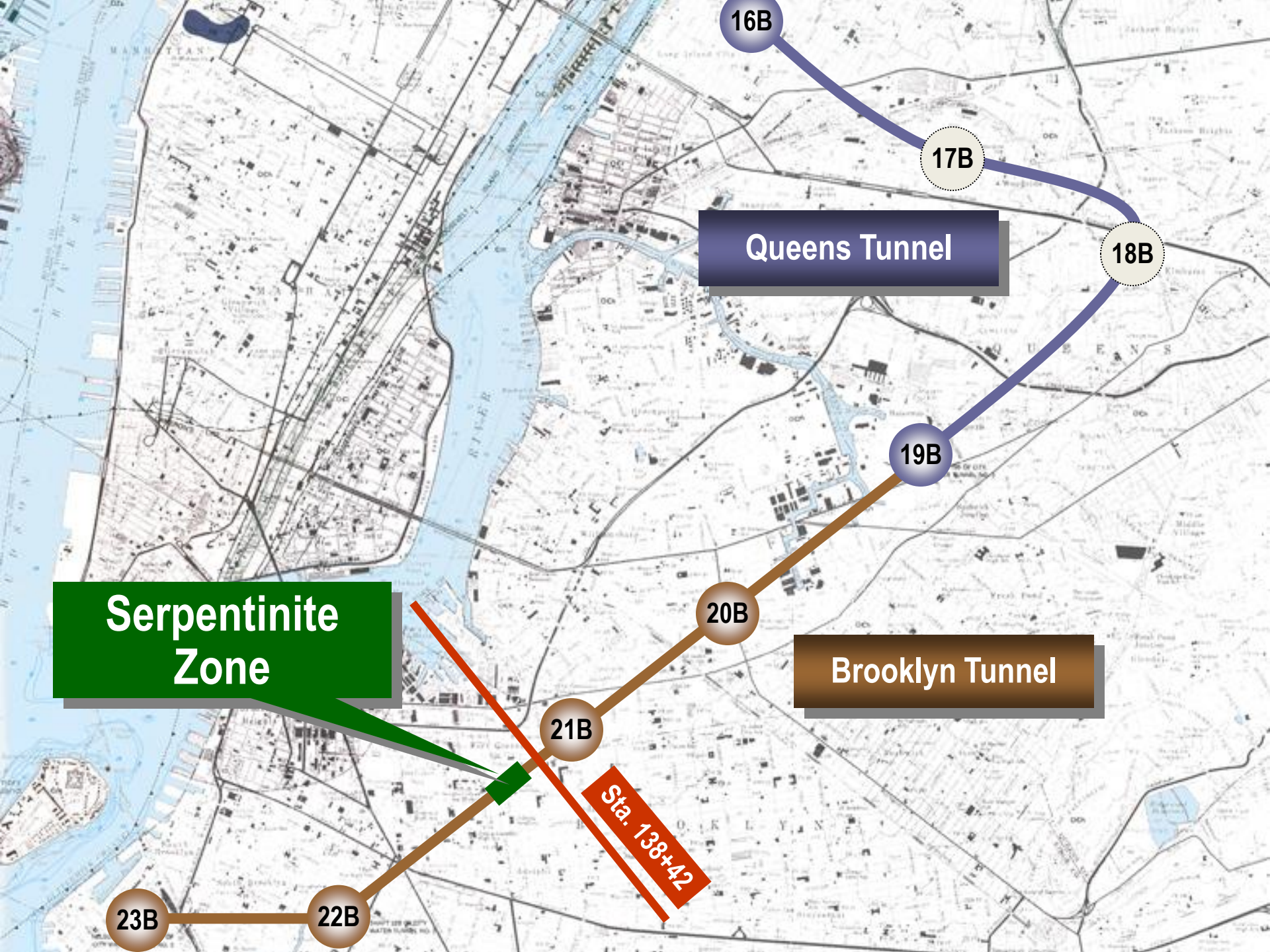


Merguerian 1977, 1985



Ratcliffe and others, 2012

S2
Merguerian 1977


16B
17B
18B
19B
20B
21B
22B
23B
Queens Tunnel
Brooklyn Tunnel
Serpentinite Zone
Sta. 138+42

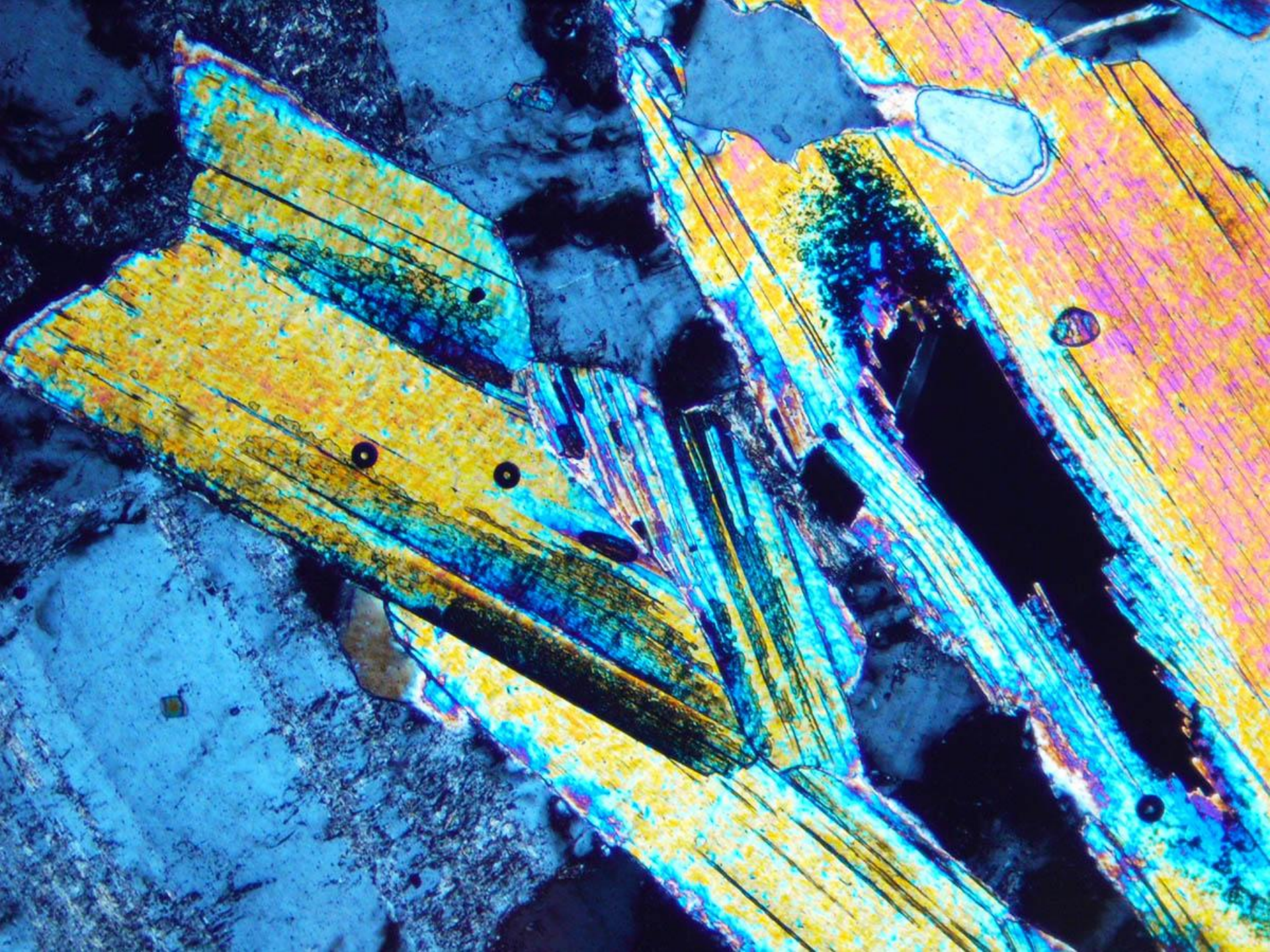
Major Serpentinite Zone
Brooklyn Tunnel – Sta. 128+30

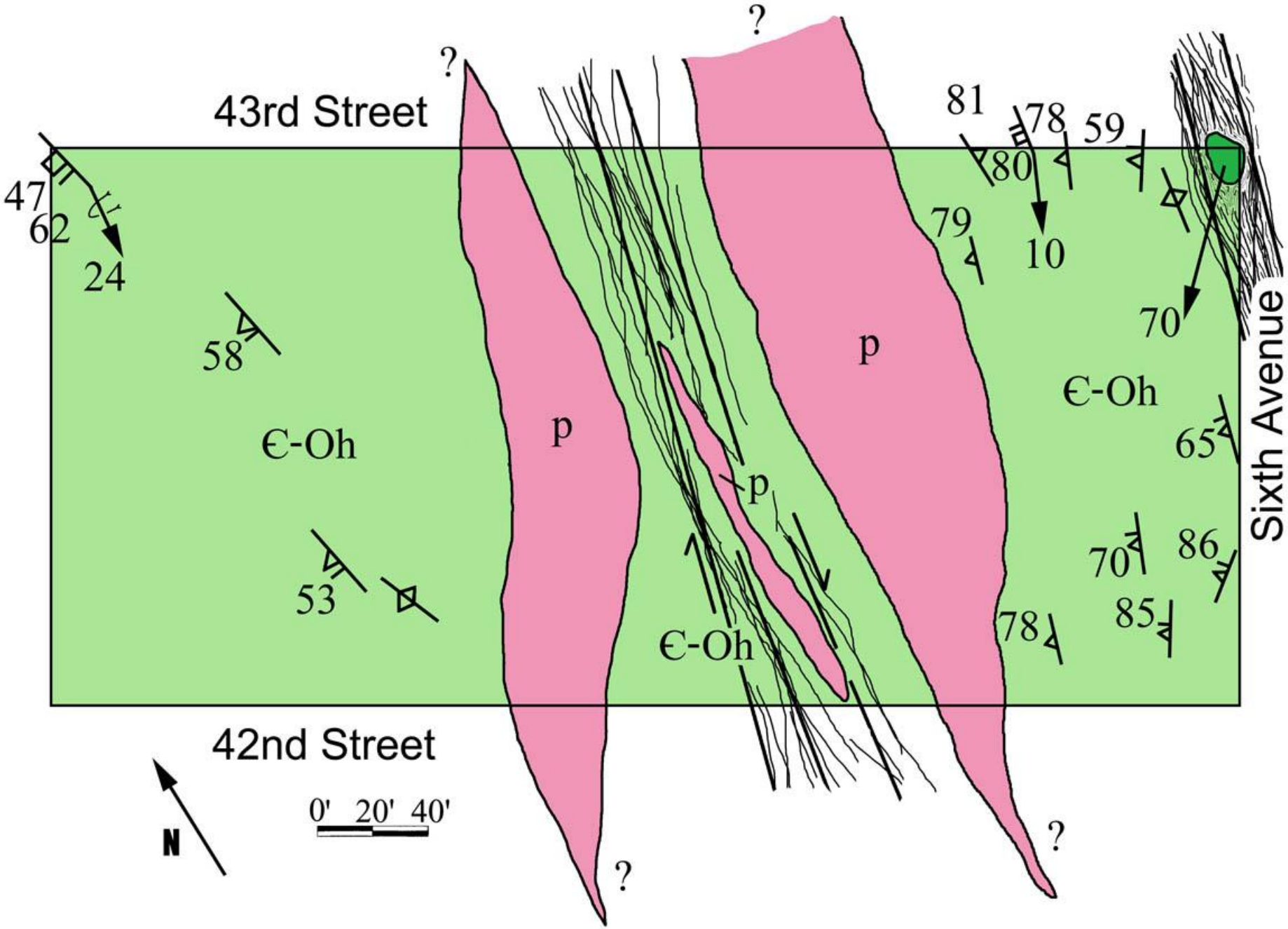
42nd Street Serpentinite

Talc-Chlorite-Biotite Shear Envelope

Cigar-Shaped Mass with Steep Plunge Southward
Base Not Exposed
>10 m Long Dimension
70º

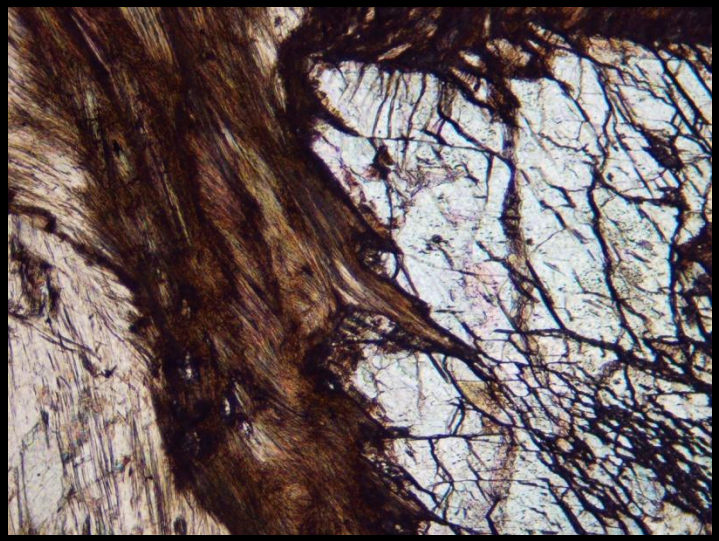
Sheared Western Margin
Gently Plunging Slicks

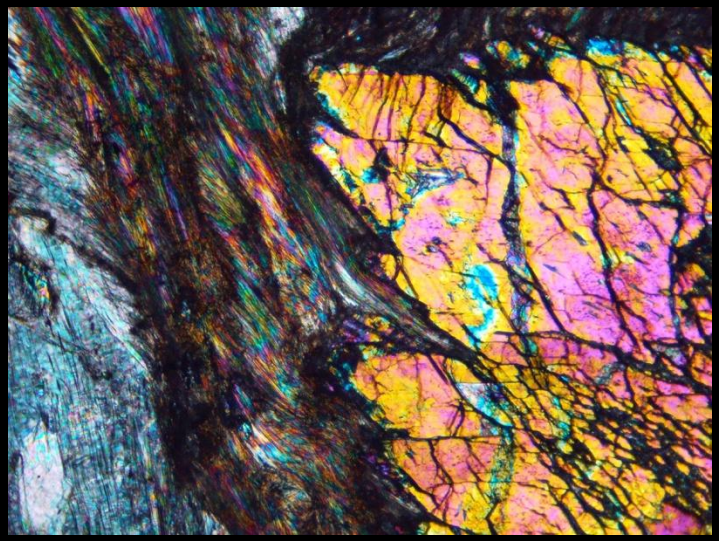


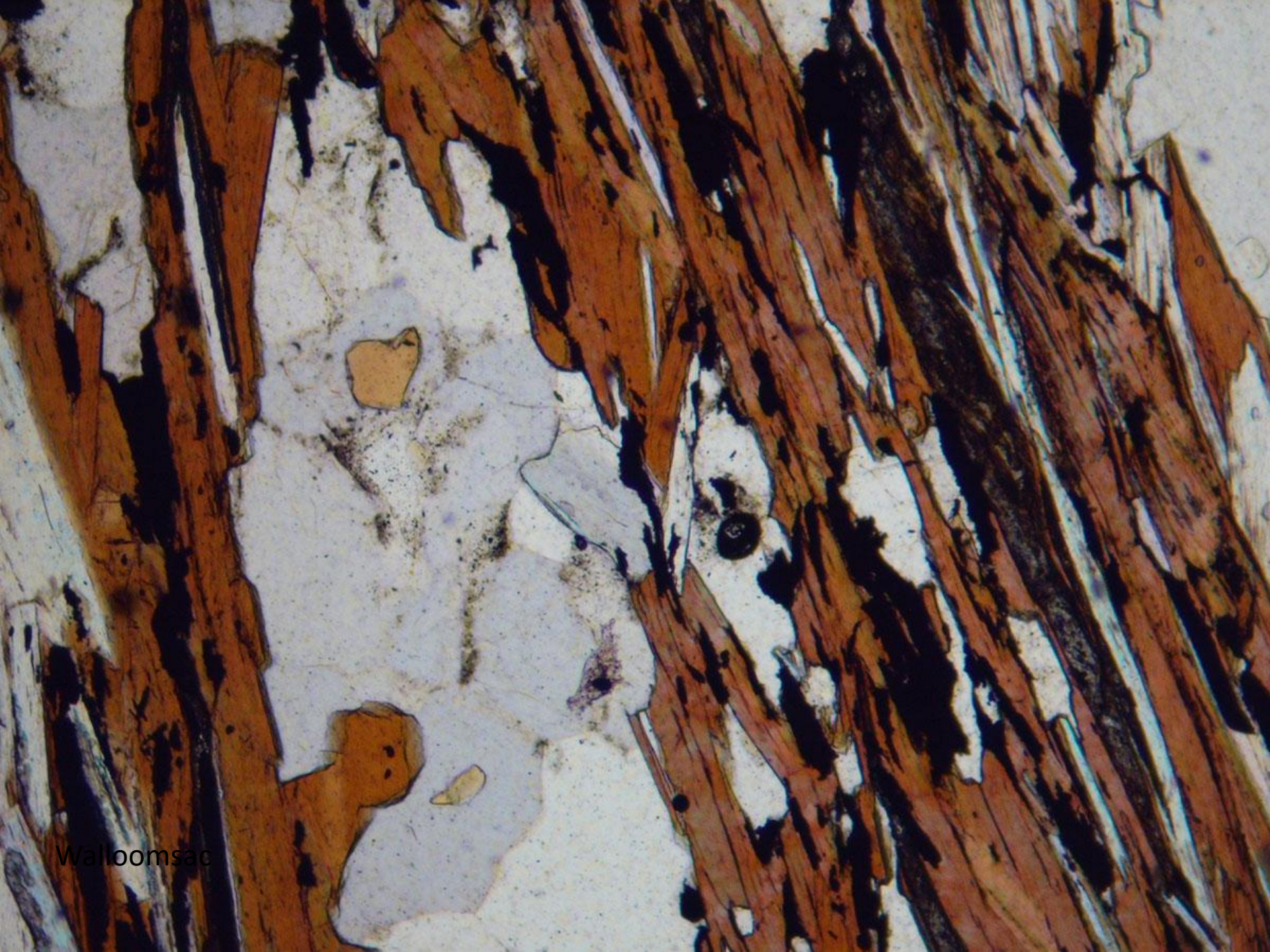

43rd Street
42nd Street
Sixth Avenue
Є-Oh
Є-Oh
Є-Oh
p
p
p
?
?
?
?
47
62
24
58
53
81
78
59
80
79
10
70
65
70
86
85
78
N
0' 20' 40'

165th Street Serpentinite

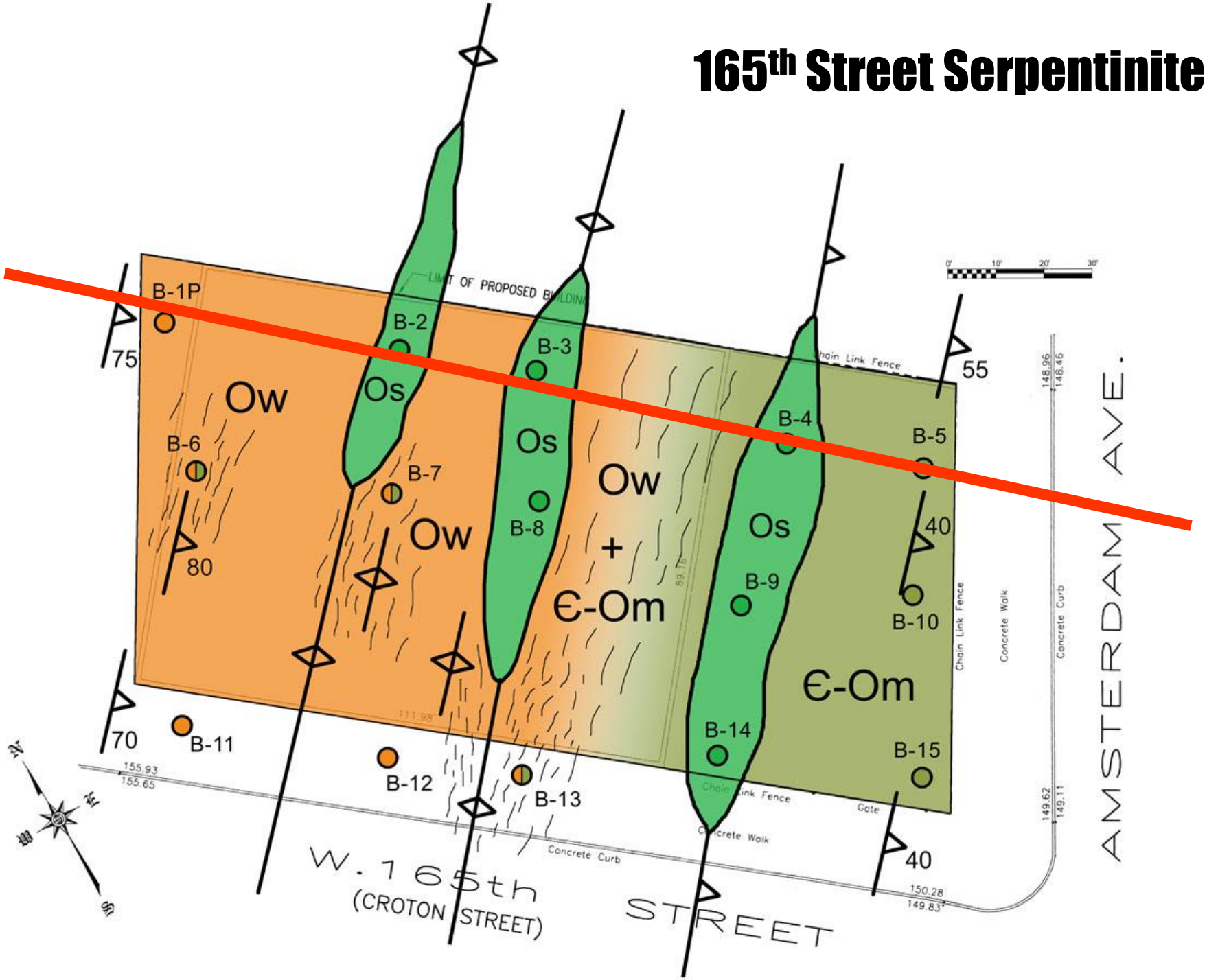
Serpentinite Found
in 40% of Borings
B-2 B-3 B-4 B-8 B-9 B-14

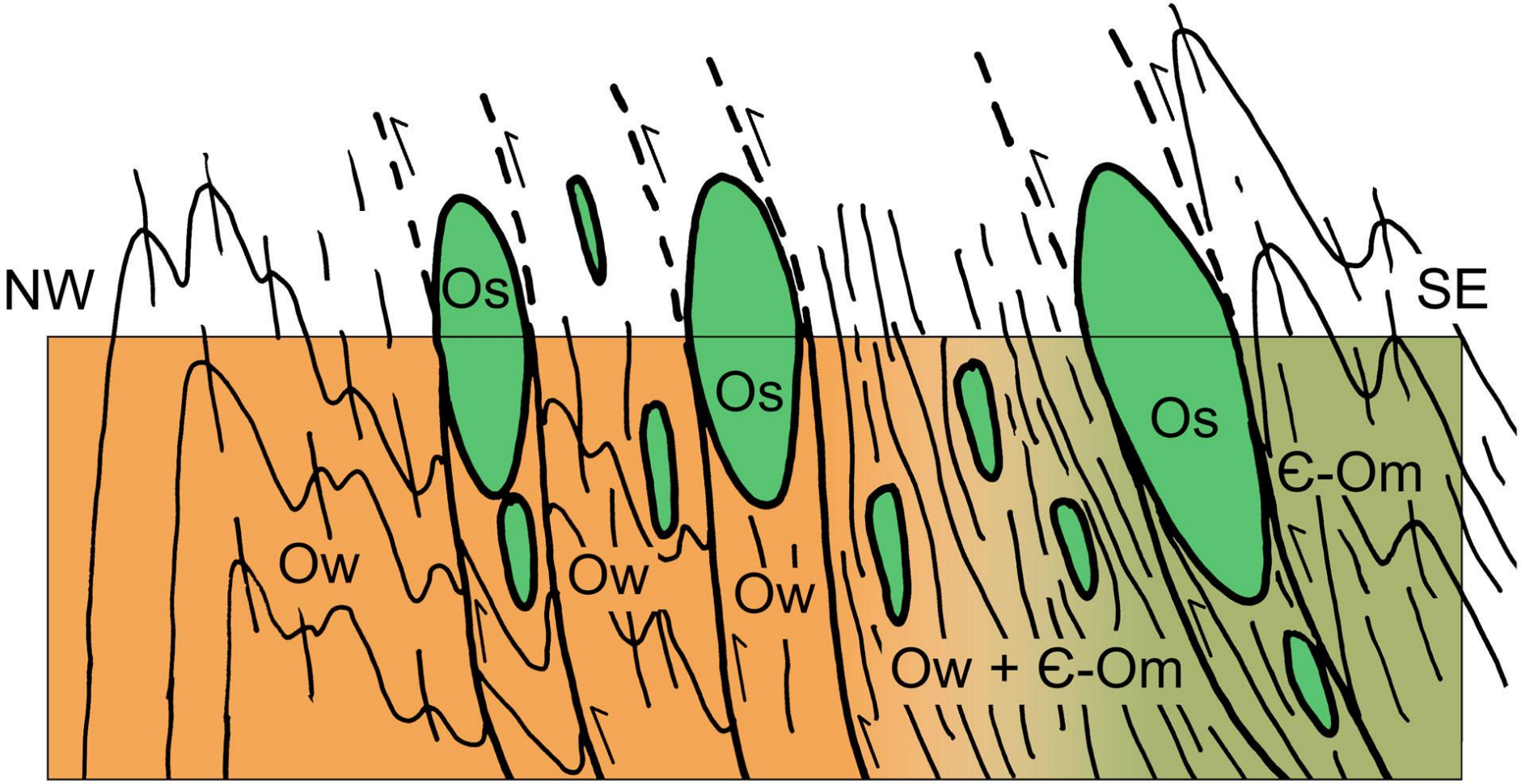


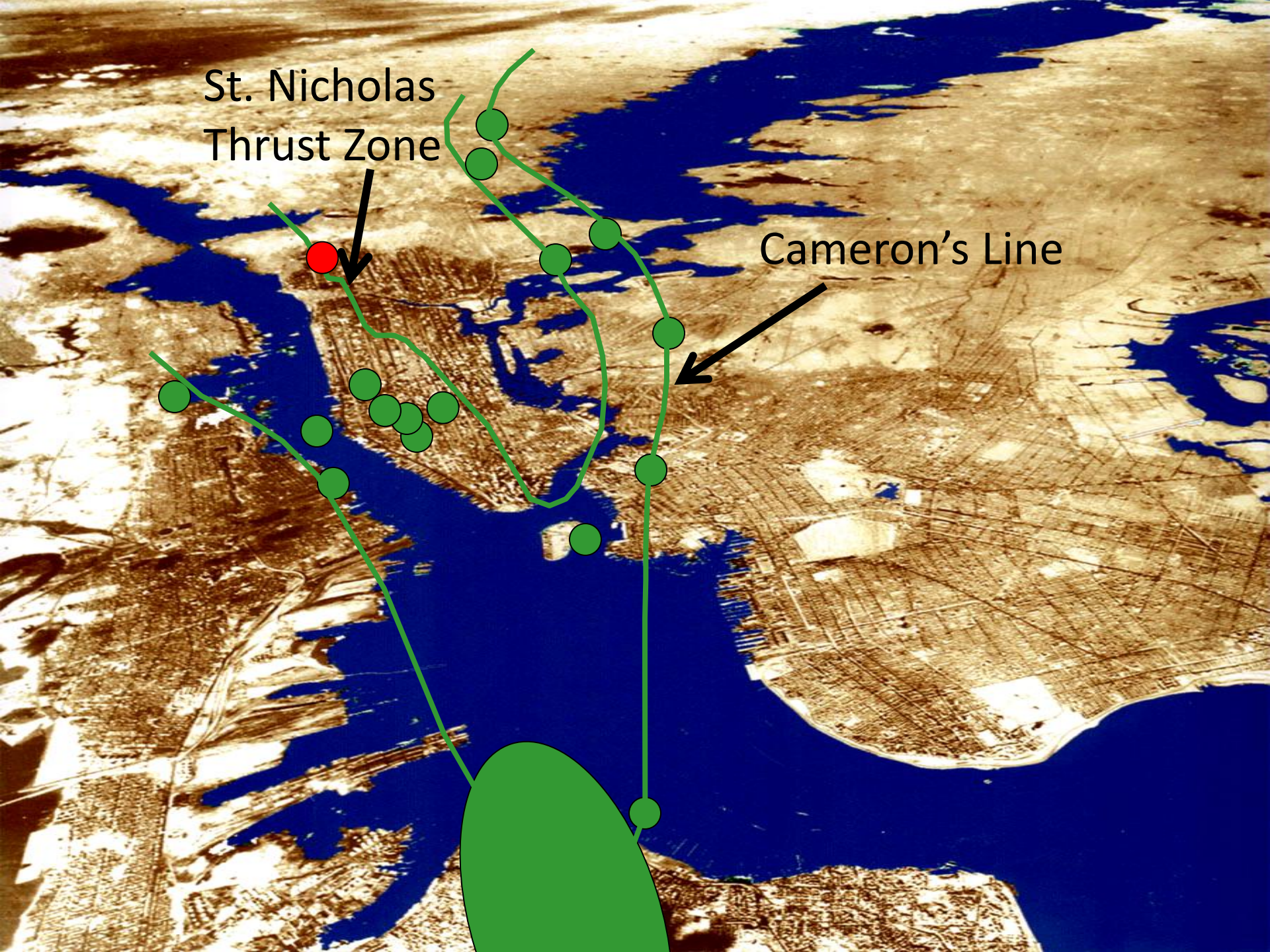


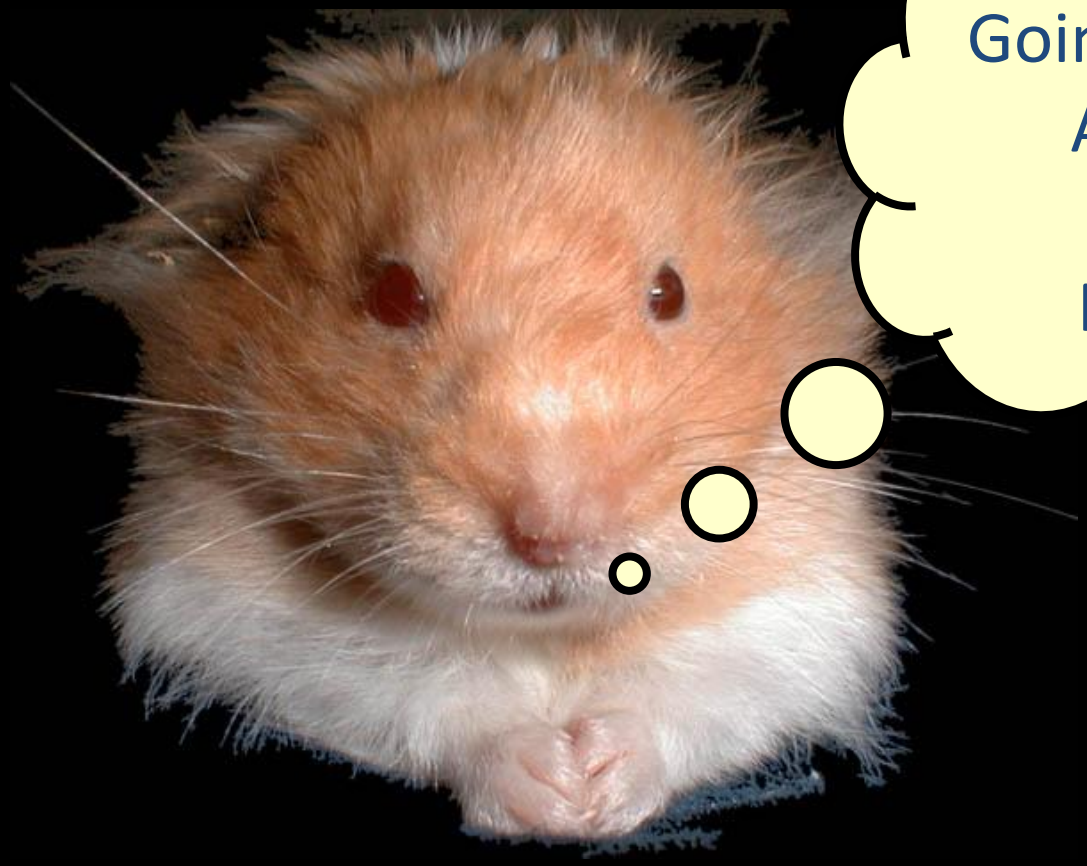

Walloomsac

165th Street Serpentinite

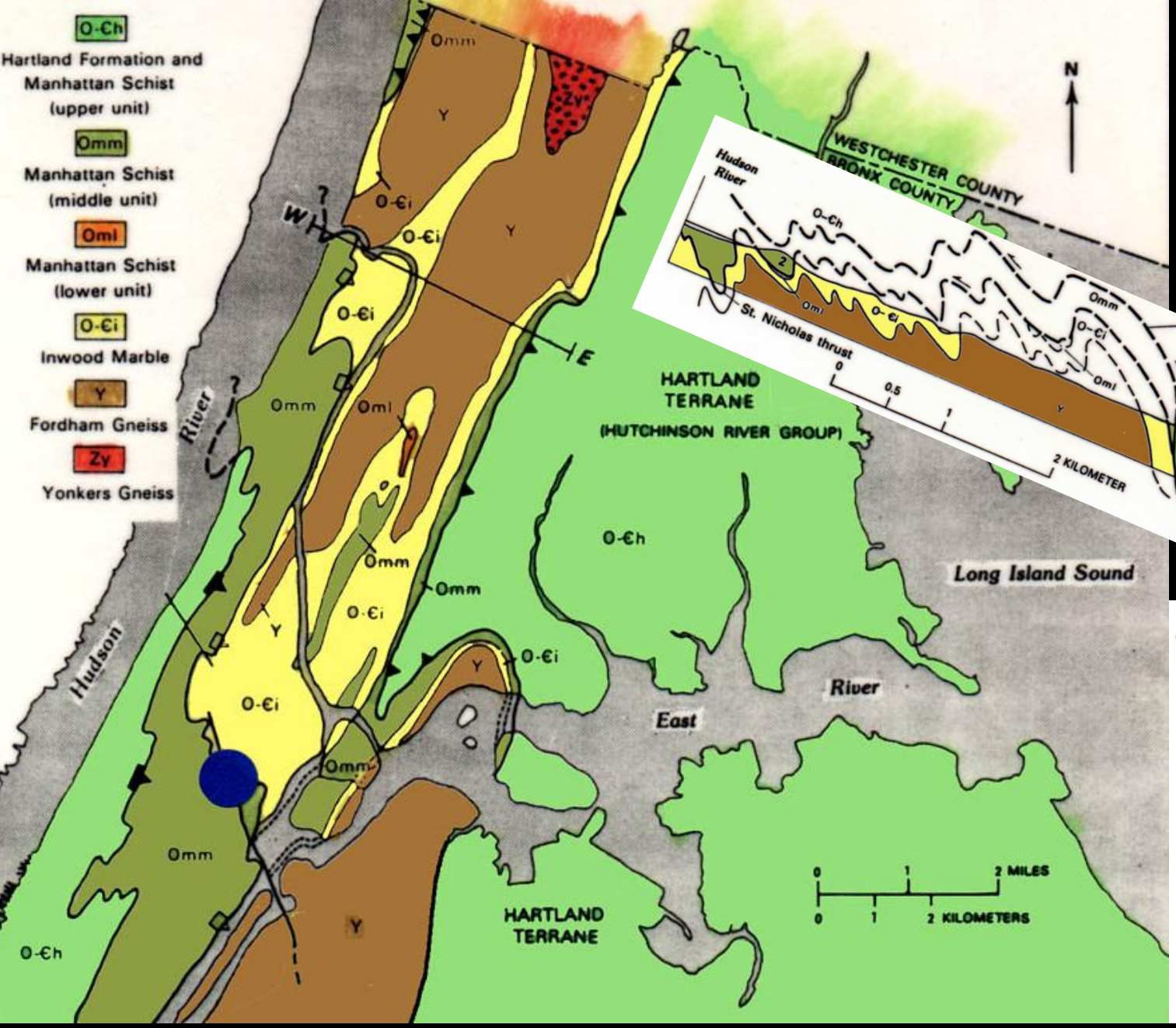


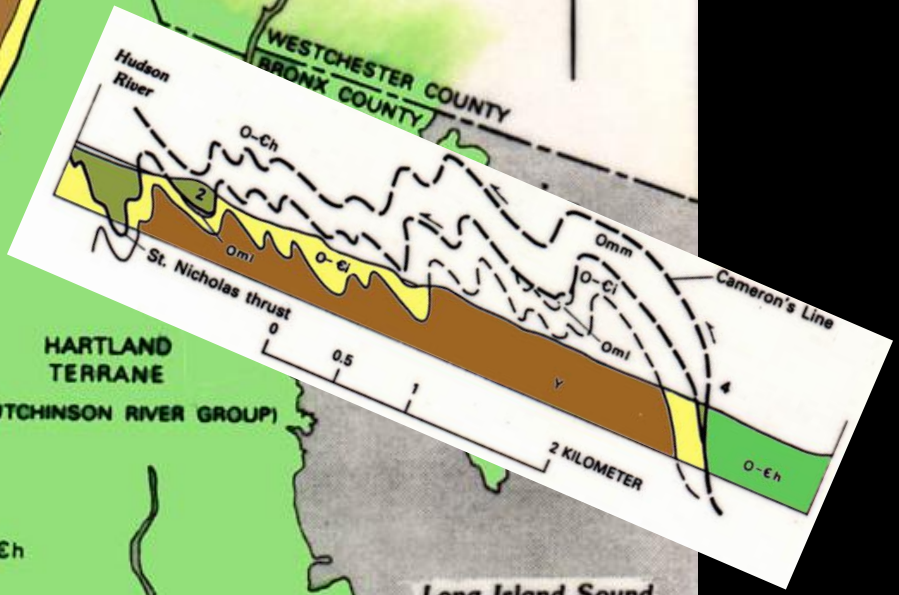

NW
SE
Os
Os
Os
Ow
Ow
Ow
Ow + Є-Om
Є-Om

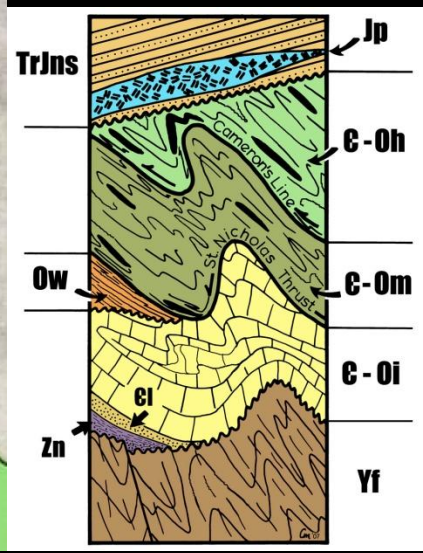

St. Nicholas
Thrust Zone
Cameron's Line



Finally, He's Going to Talk About NYC Rocks





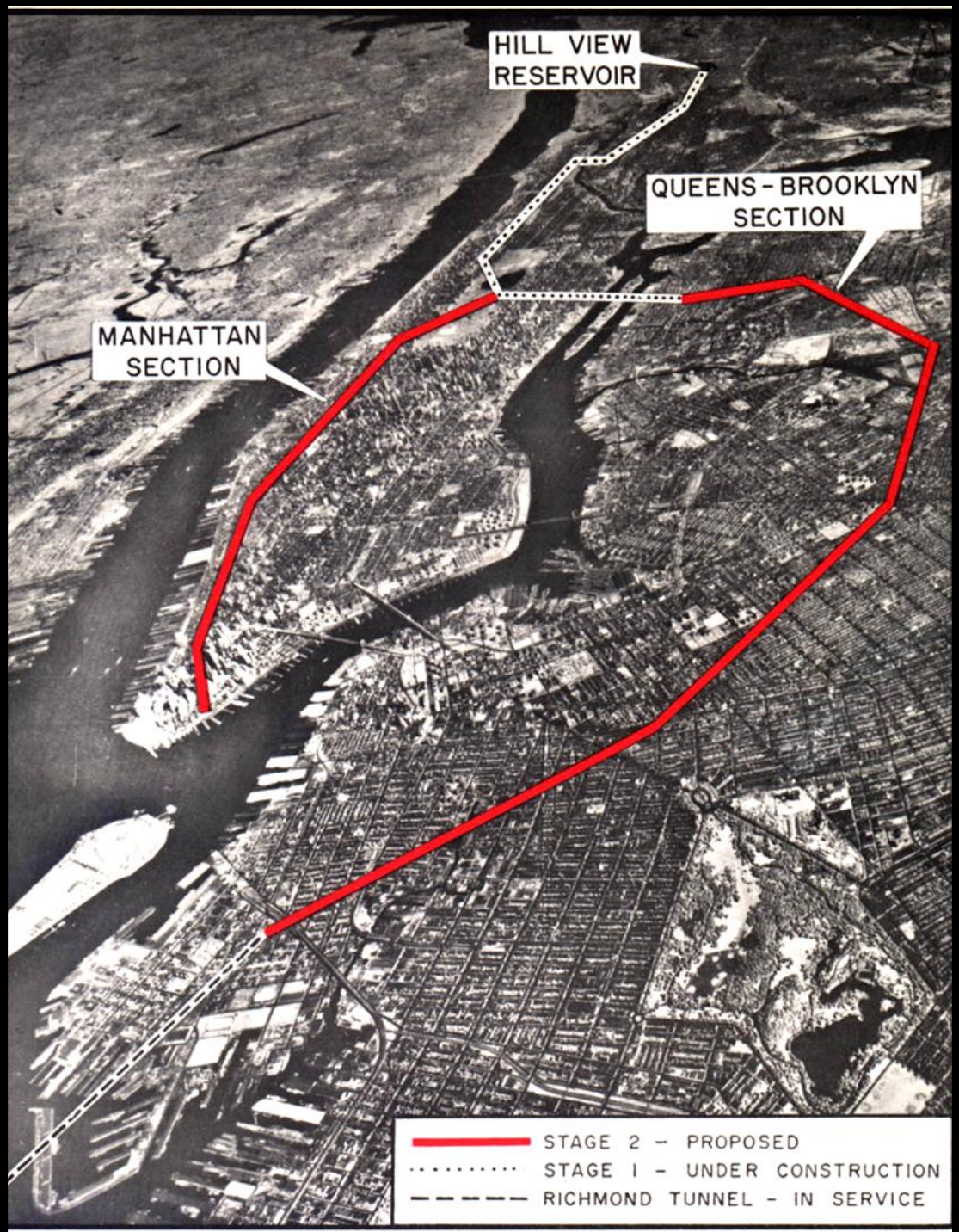


Merguerian and Merguerian 2004

Basement

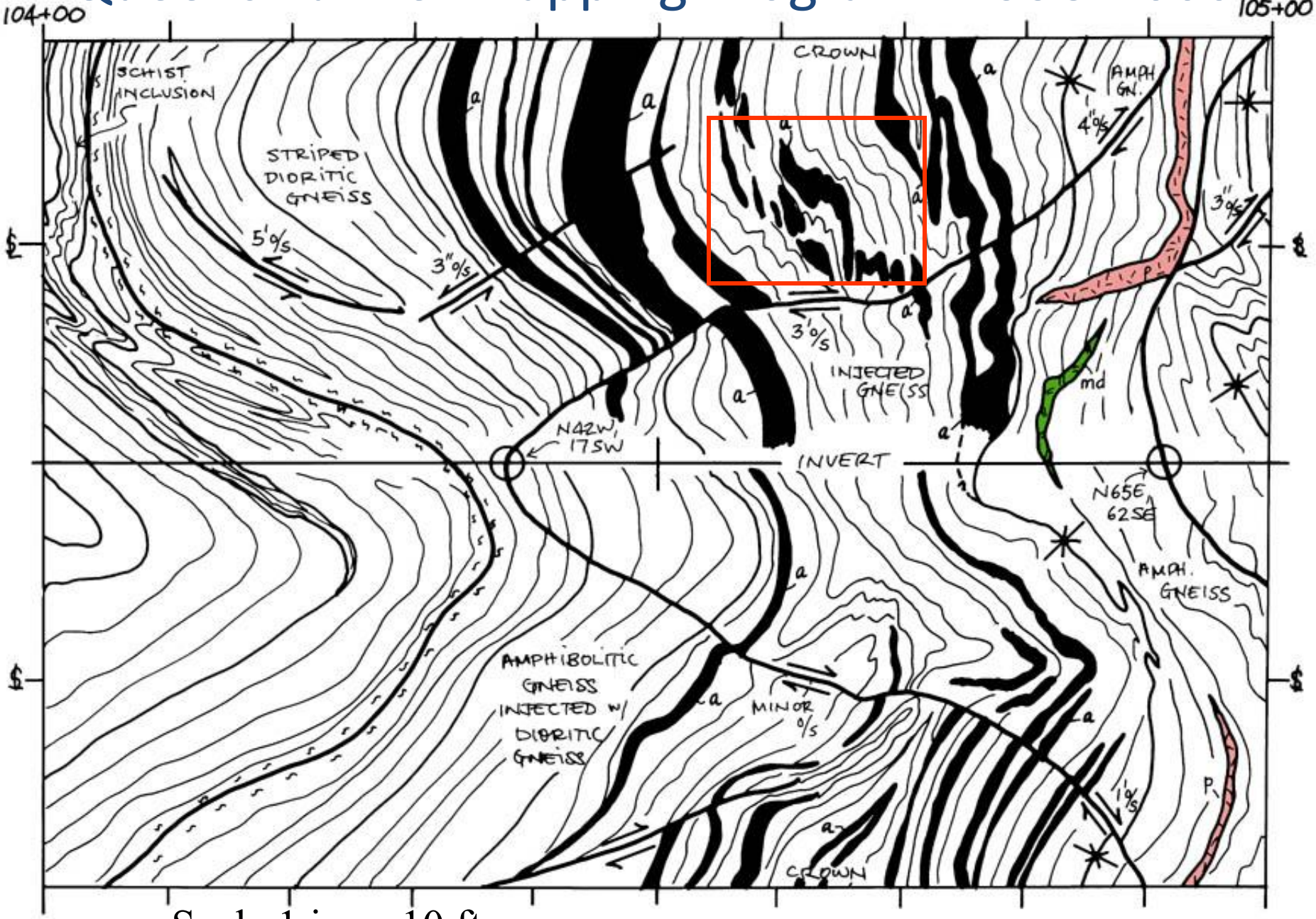
Yf Fordham Gneiss, Echo Park

CT3, Stages 1 and 2



Merguerian's Queens Tunnel Field Office

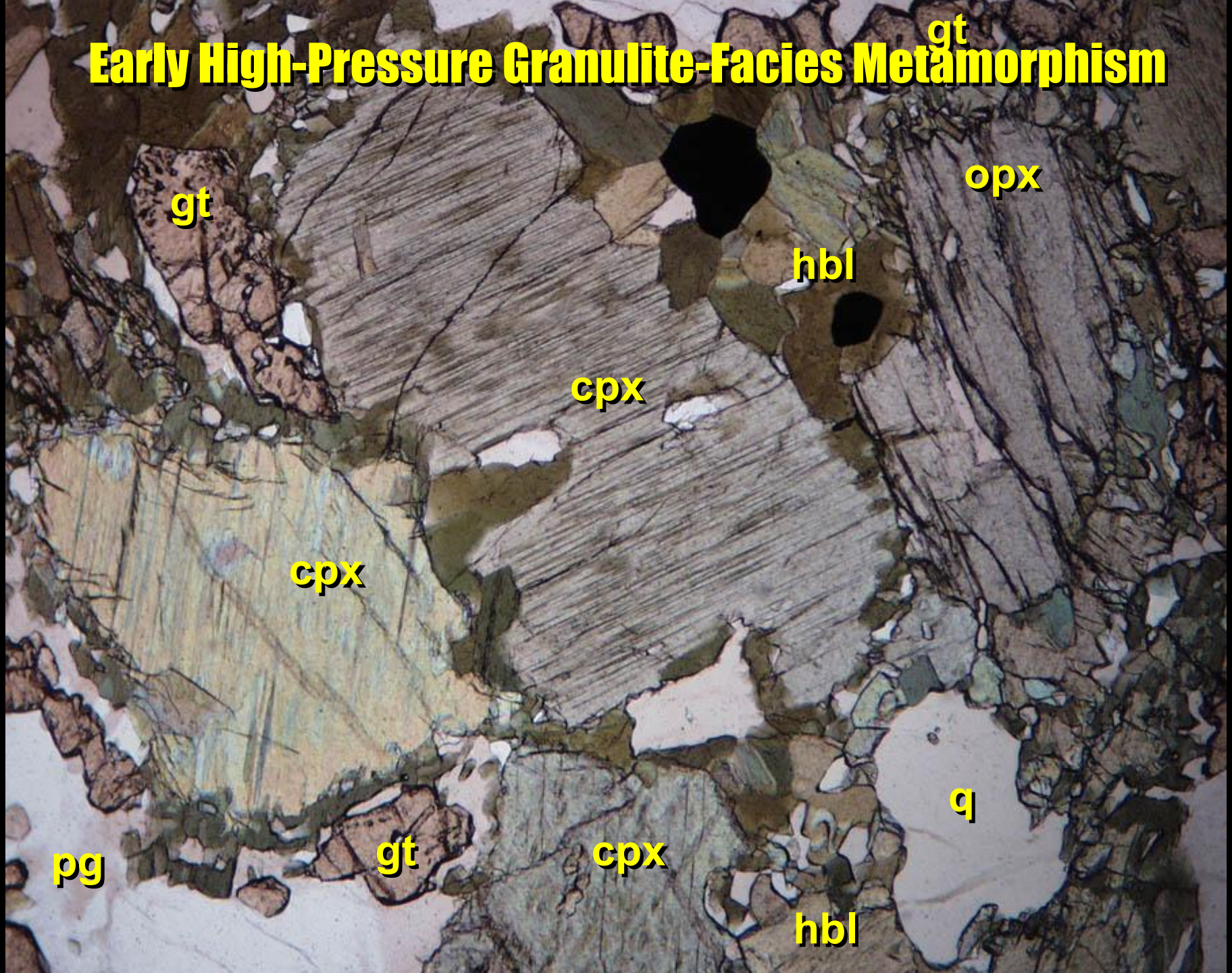
Queens Tunnel Mapping Program: 1998-2000



- Scale 1 in. = 10 ft

Basement

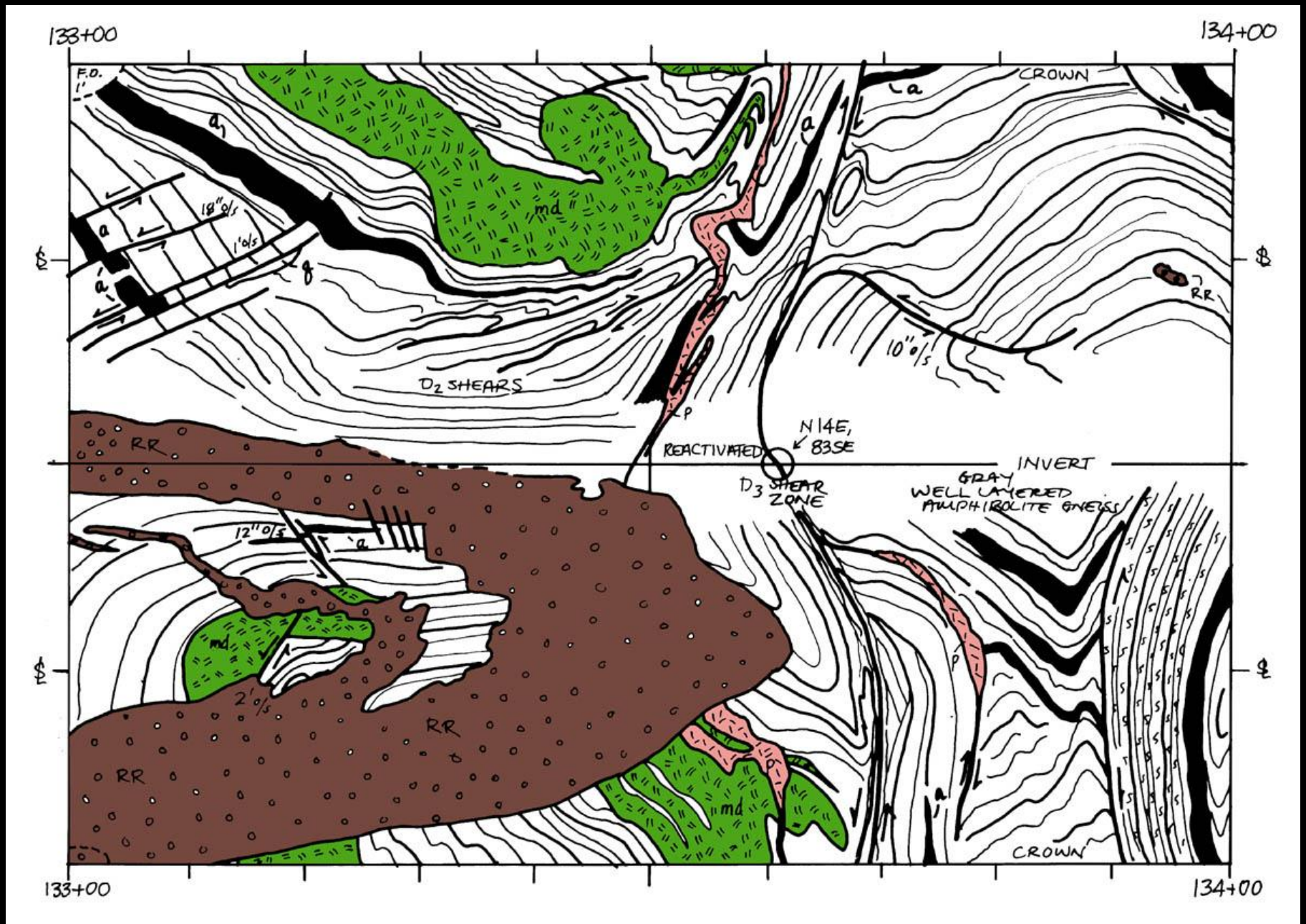
Early High-Pressure Granulite-Facies Metamorphism



Anomalous Garnet Content

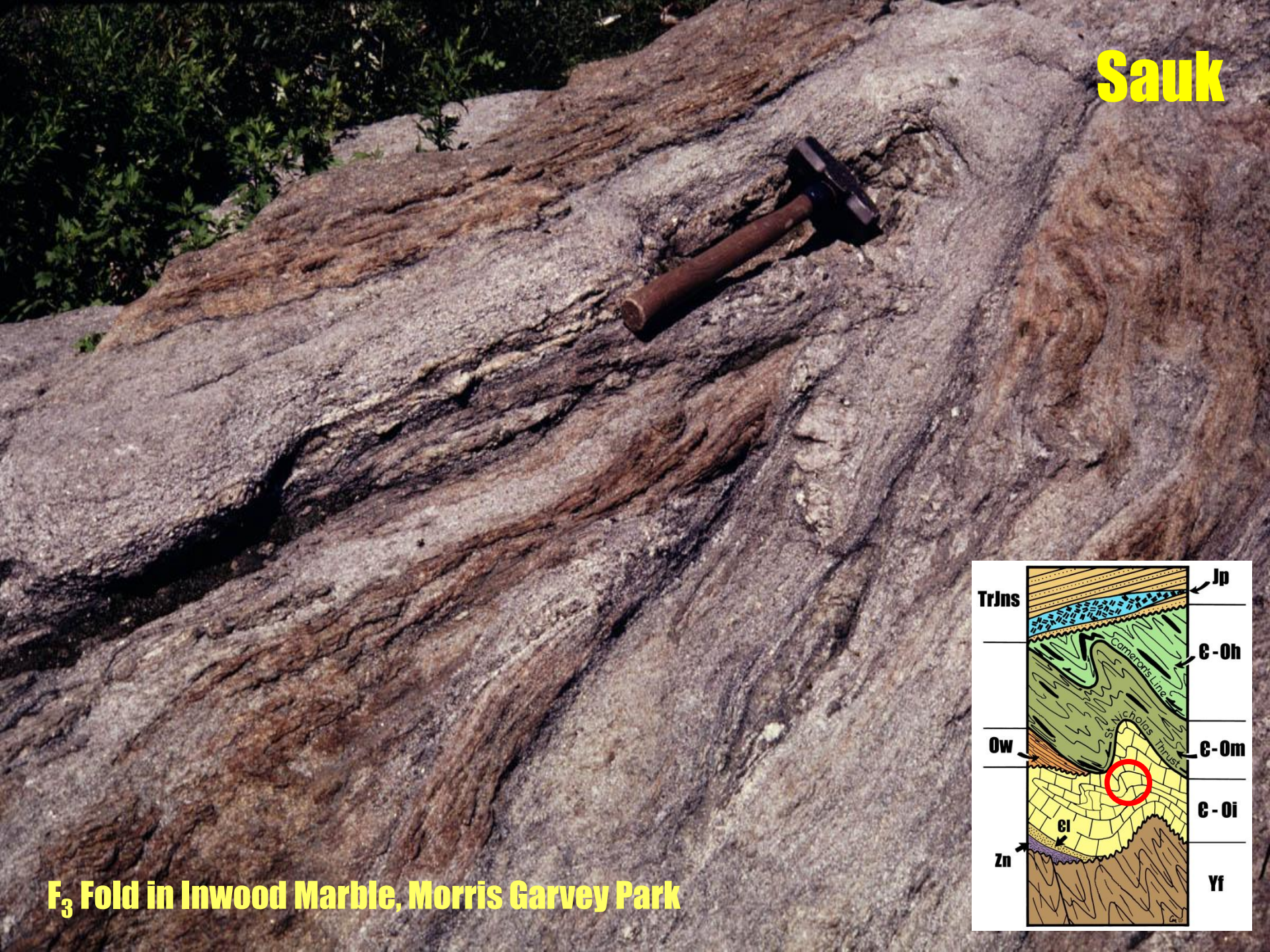
Increased Density and Abrasivity of Rock Mass

Woodside Rhyodacite Dike Swarm



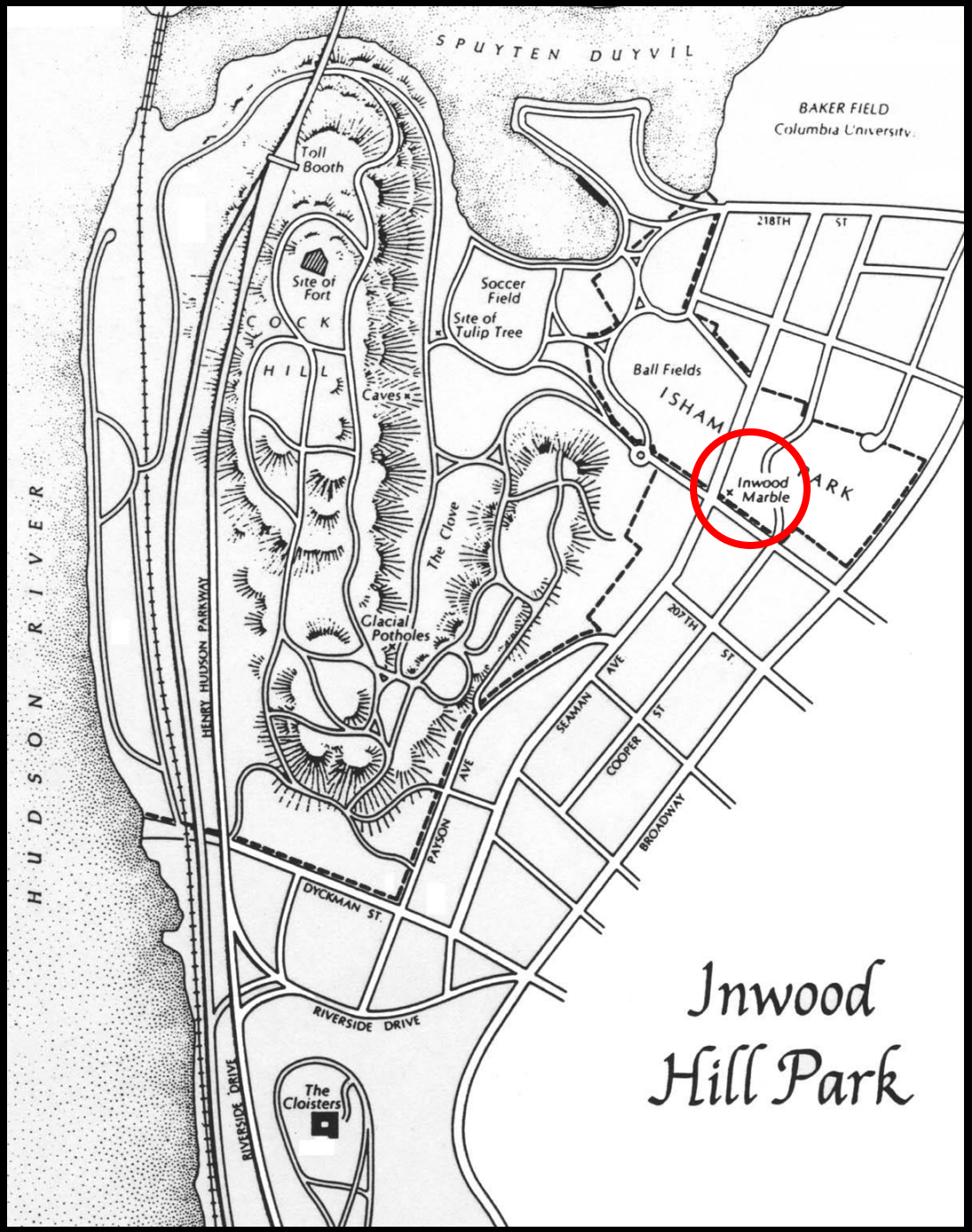
12:05PM
5/15/1998
00:15

Major Lithologic Contrast
No Counterpart in NYC!

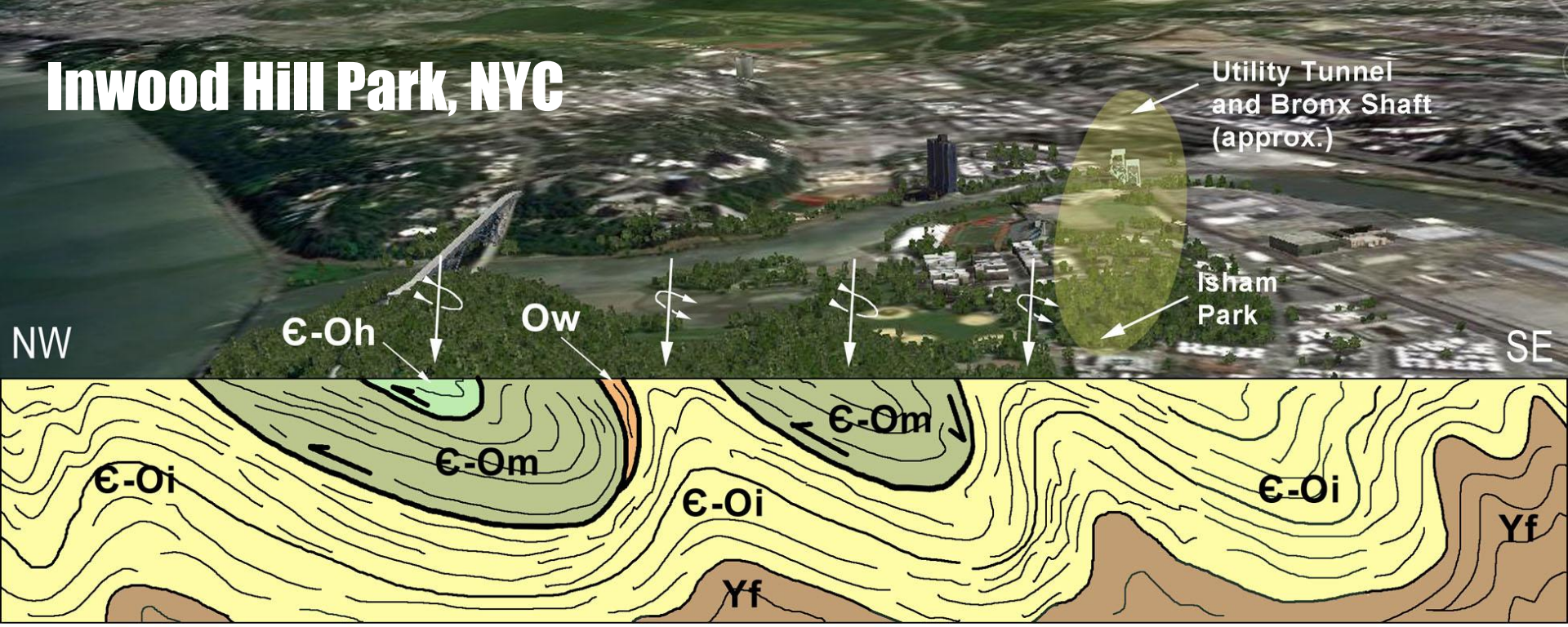


F_3 Fold in Inwood Marble, Morris Garvey Park

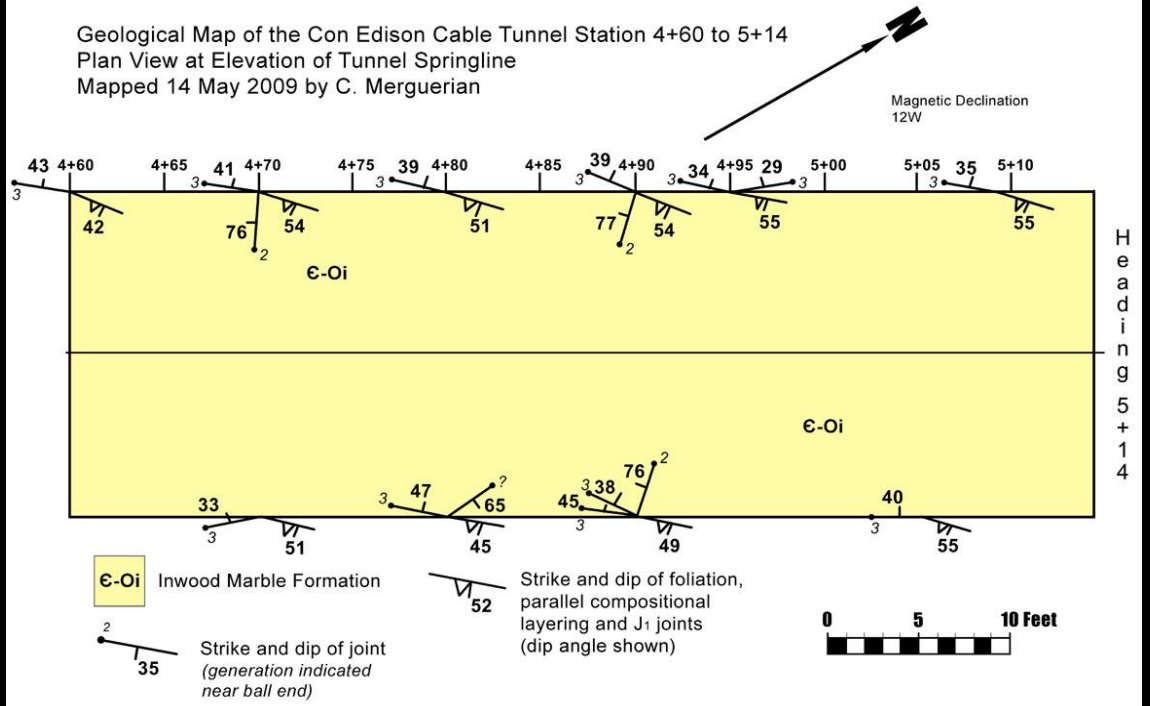
Sauk

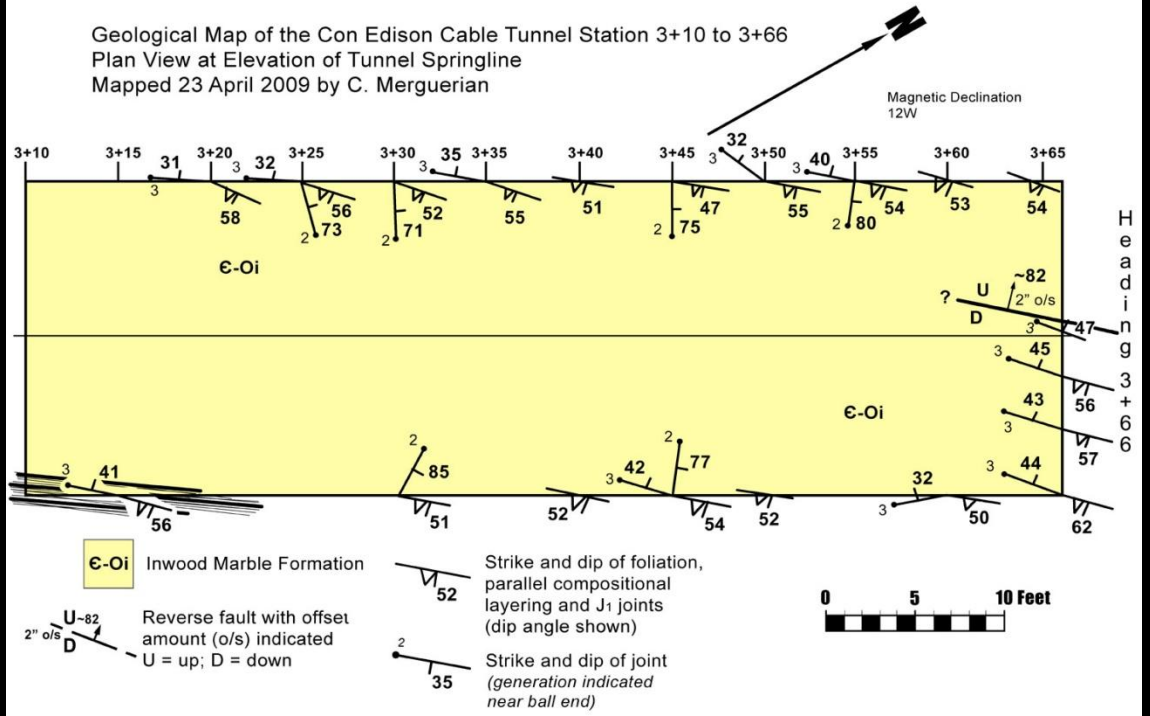

SPUYTEN DUYVIL
BAKER FIELD
Columbia University
Toll Booth
Site of Fort
COCK HILL
Caves
Soccer Field
Site of Tulip Tree
Ball Fields
ISHAM PARK
Inwood Marble
The Clove
Glacial Potholes
218TH ST
207TH ST
SEAMAN AVE
COOPER ST
BROADWAY
PAYSON AVE
DYCKMAN ST.
RIVERSIDE DRIVE
RIVERSIDE DRIVE
HENRY HUDSON PARKWAY
HUDSON RIVER
The Cloisters
Inwood Hill Park

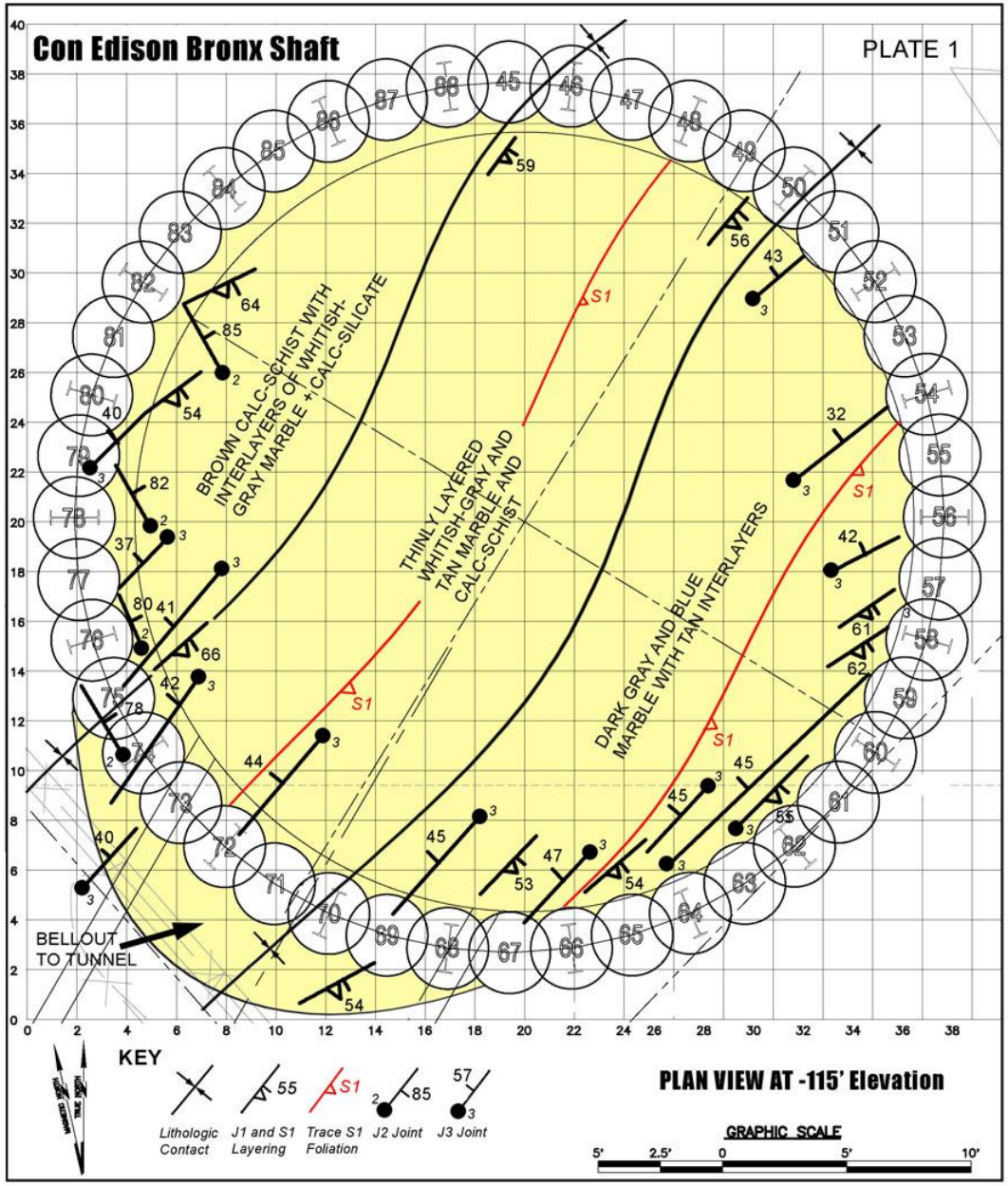
Inwood Hill Park, NYC

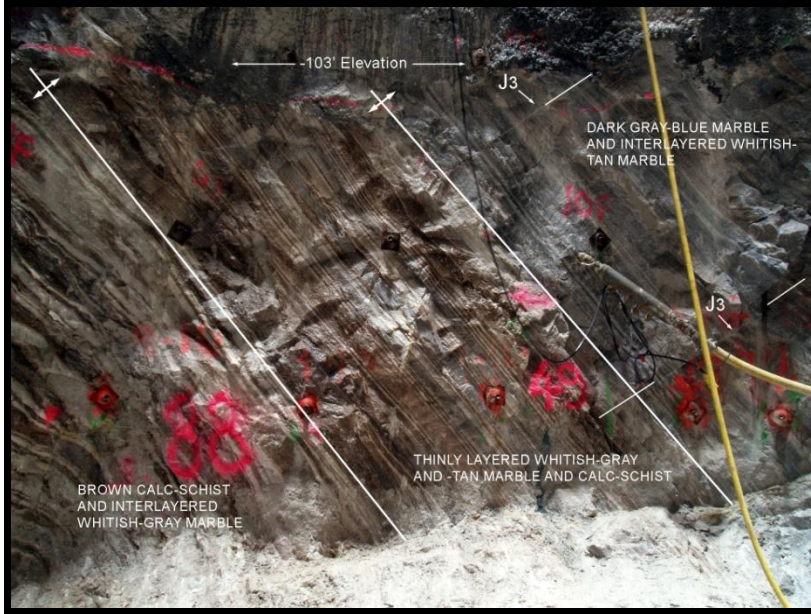


Con Edison Cable Tunnel
2009 D&B Tunnel – 700'









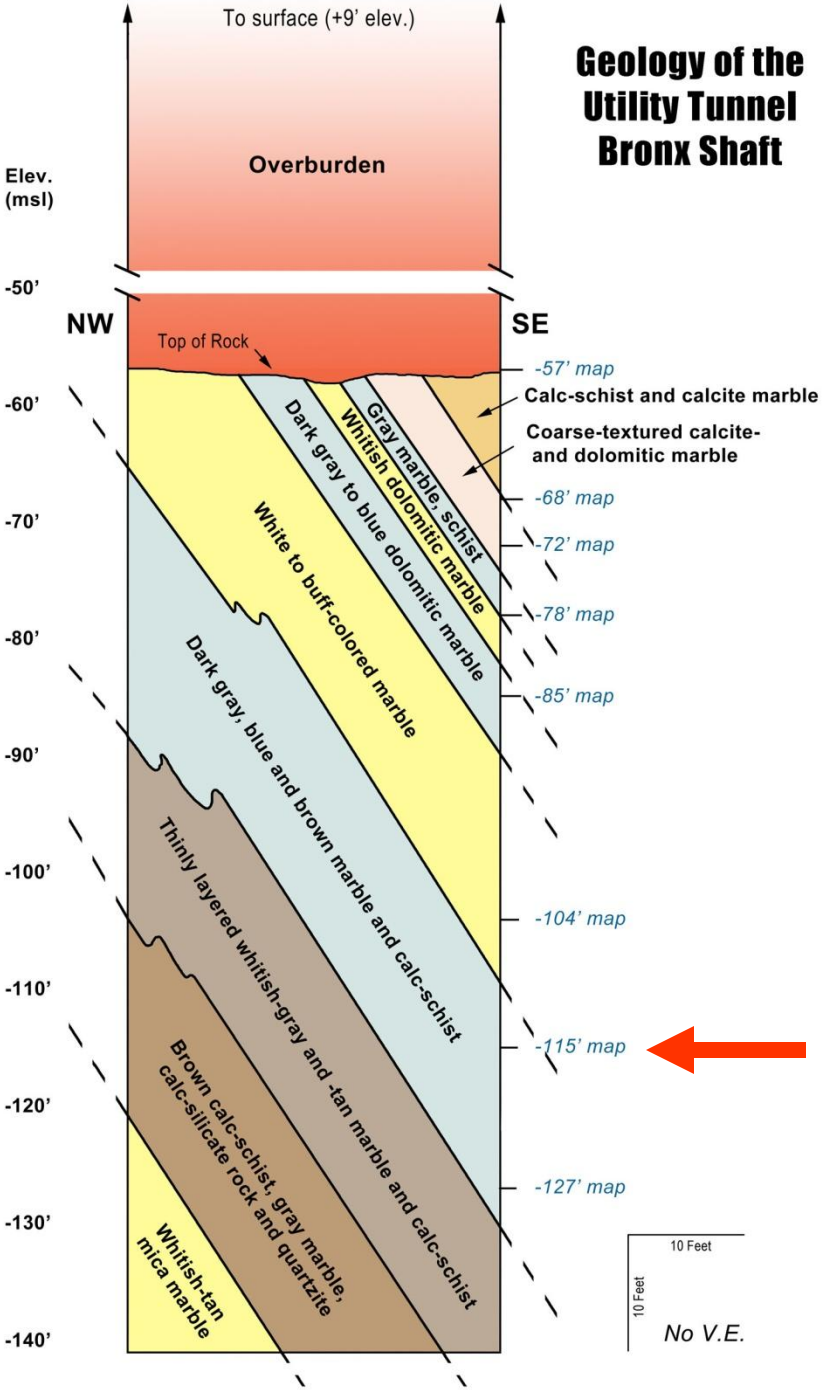
DUKE GEOLOGICAL LABORATORY
36 Fawn Lane
Westbury, NY 11590

Map Prepared By:

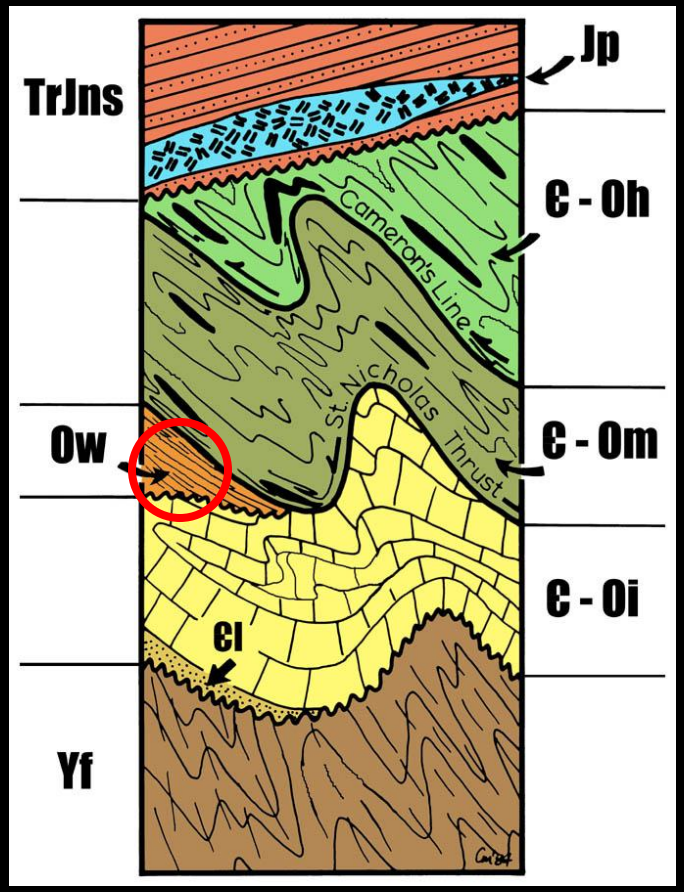
Date: 22 September 2009

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'

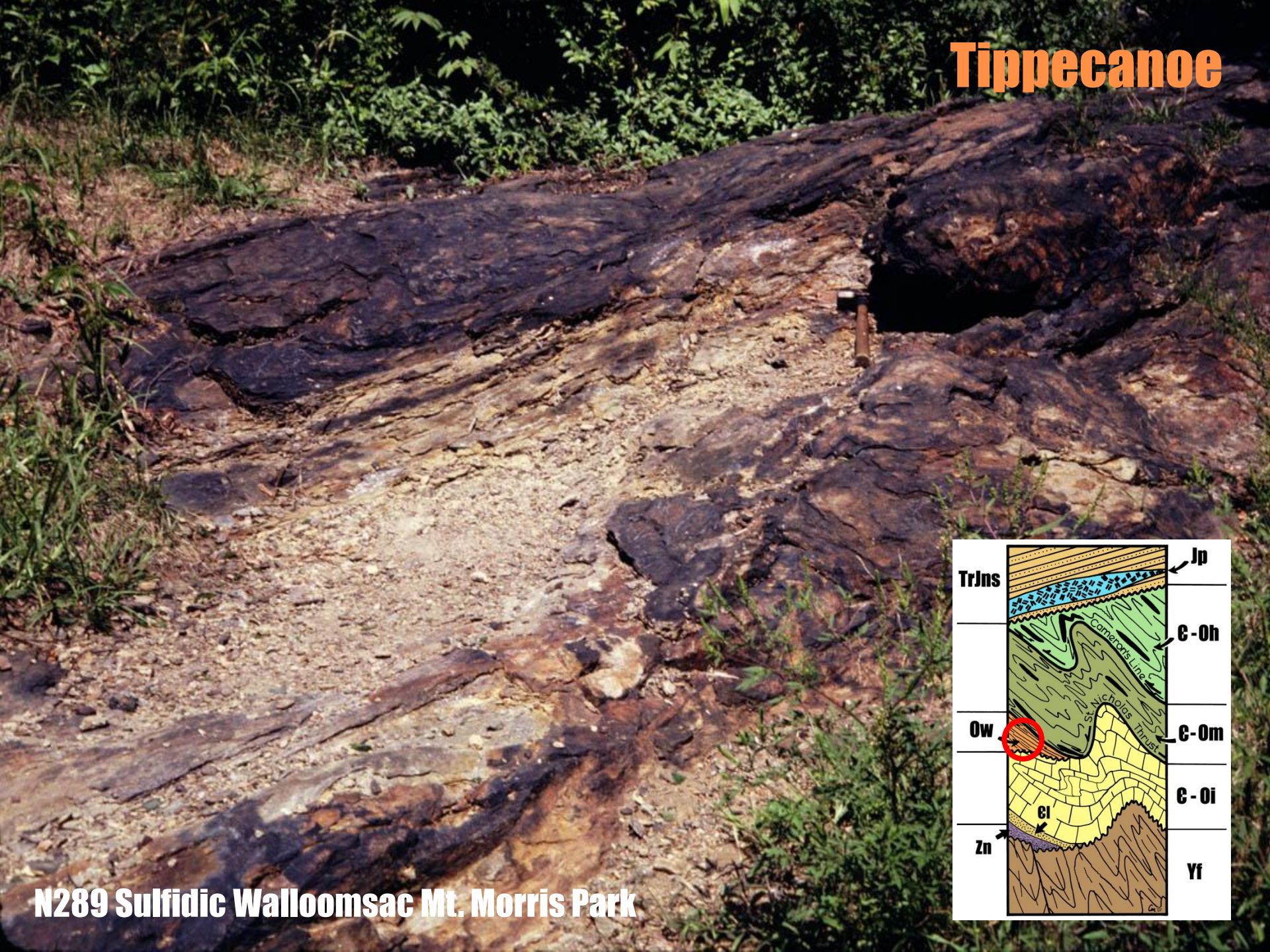


Tippecanoe

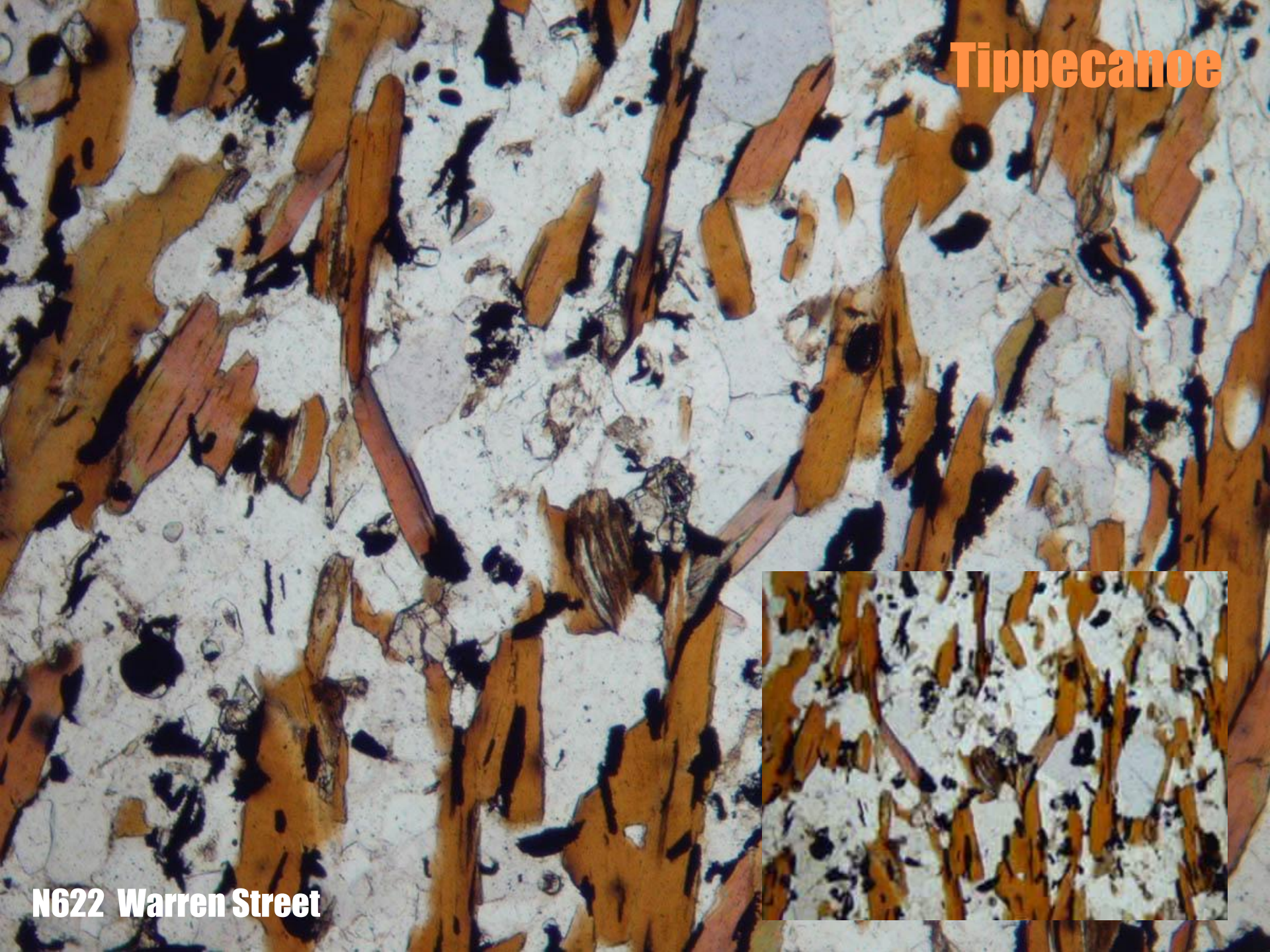


Walloomsac "Balmville" Contact, Grand Concourse, Bronx, NY

Tippecanoe



N289 Sulfidic Walloomsac Mt. Morris Park

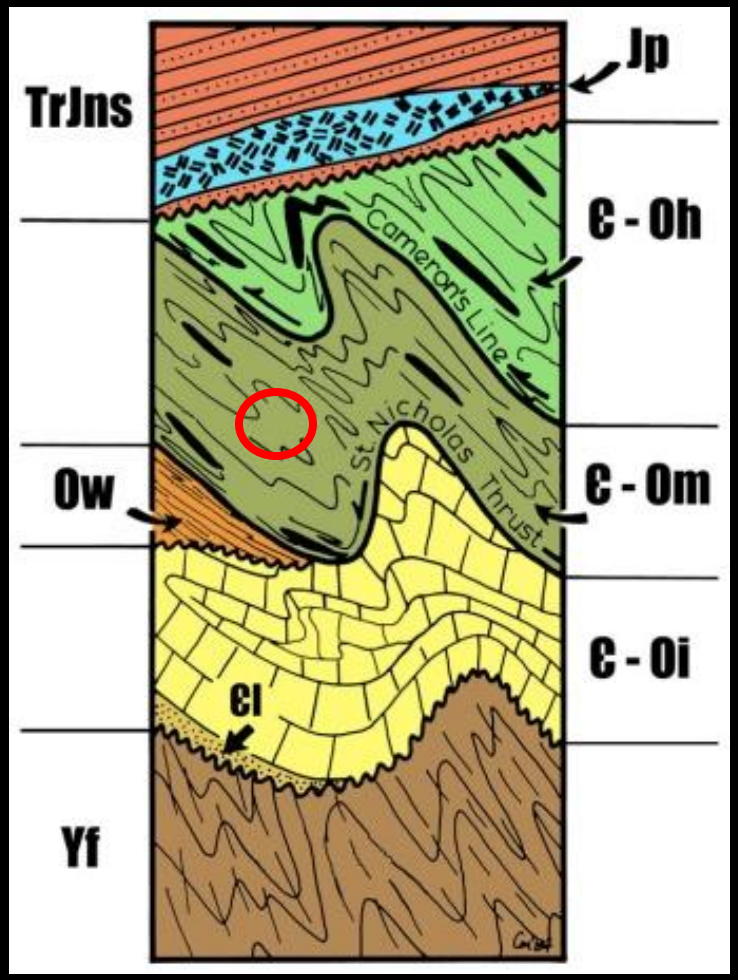

Tippecanoe
N622 Warren Street

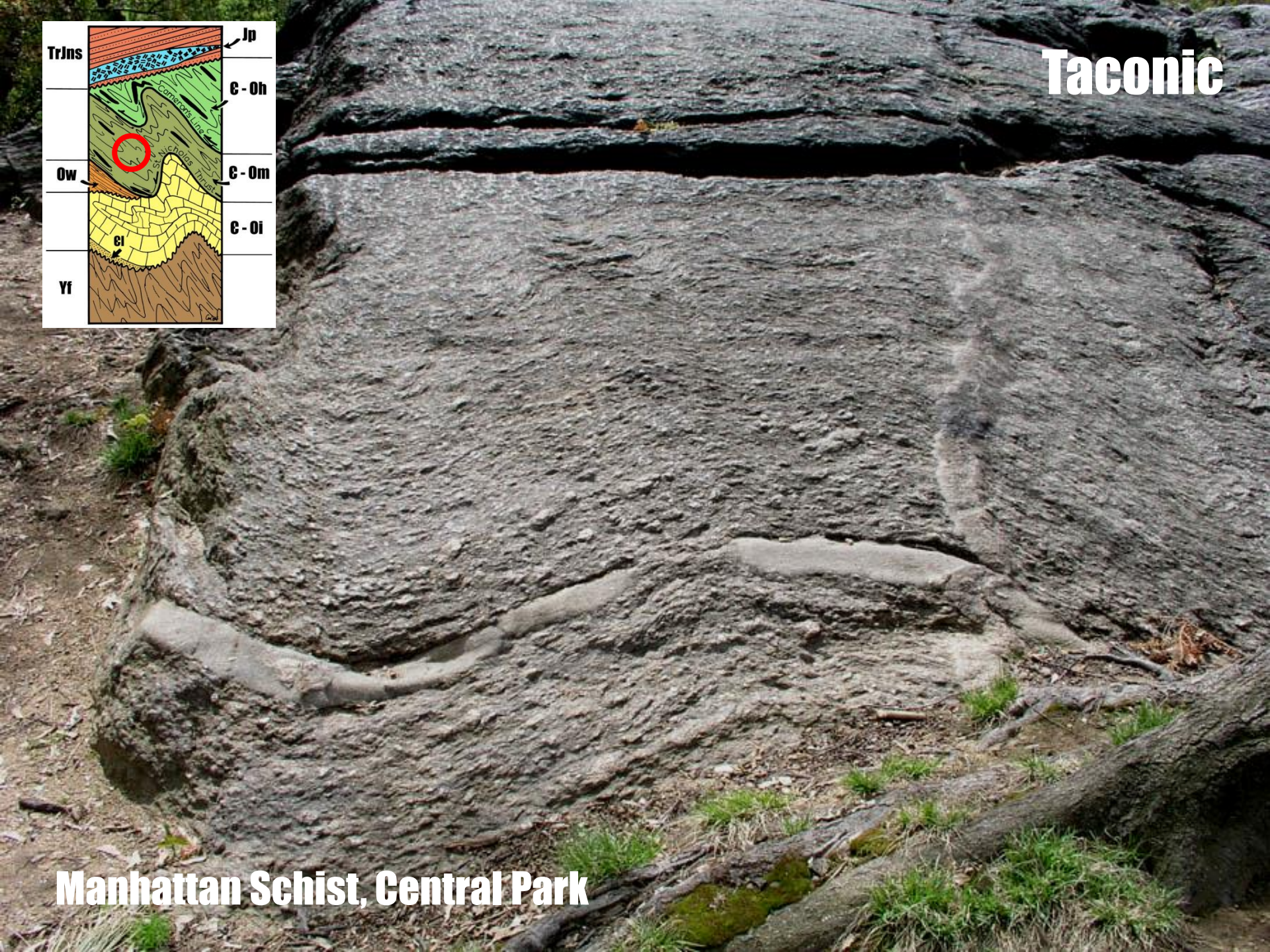
Near Stop 13

Sub-vertical F3 Folds with Steep, NE-trending Axial Surfaces in Walloomsac Schist and Calc-Silicate Unit

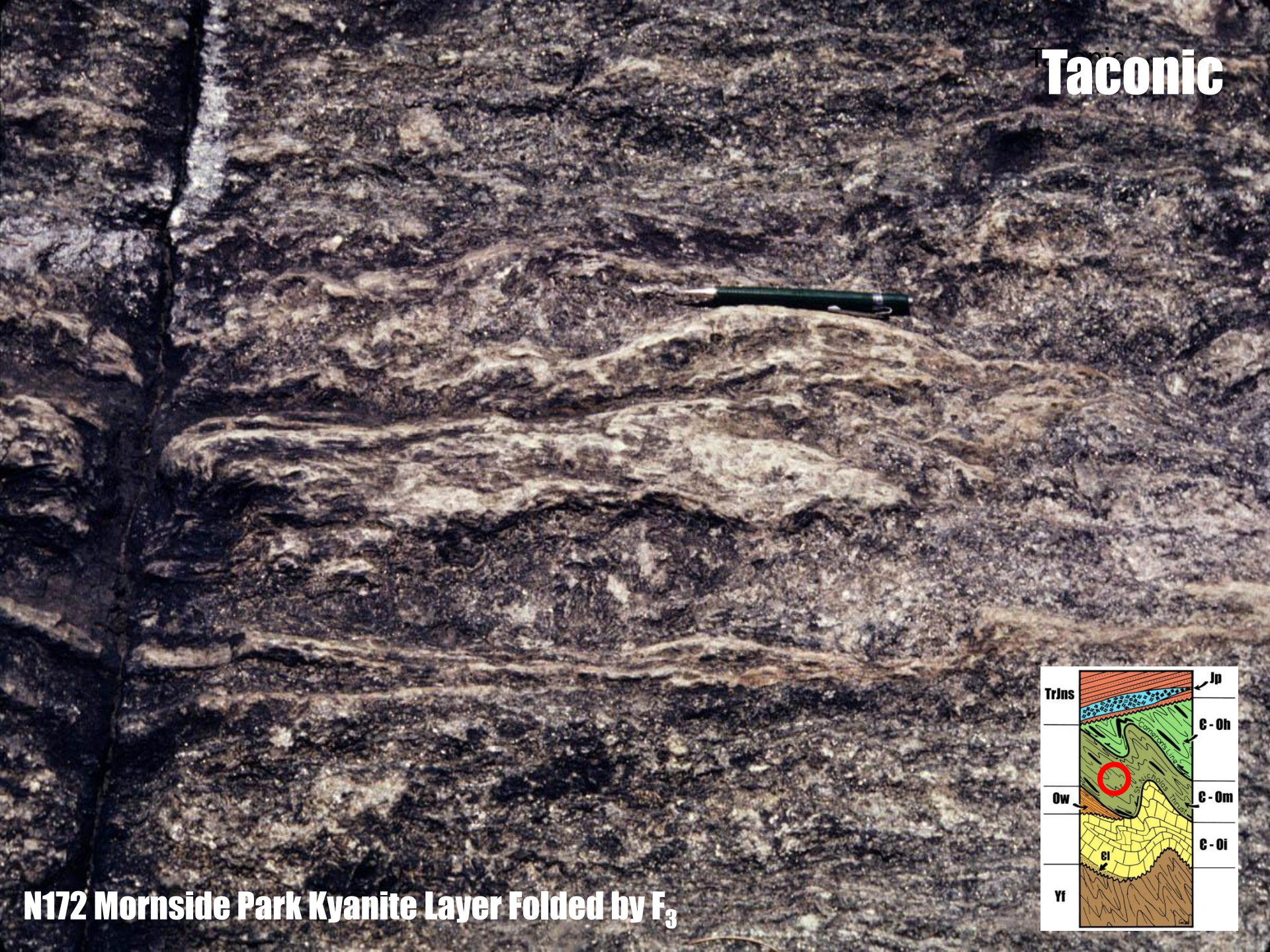
Ow + Owc

Manhattan Schist
F_3 Folds of S_2
Central Park, NYC

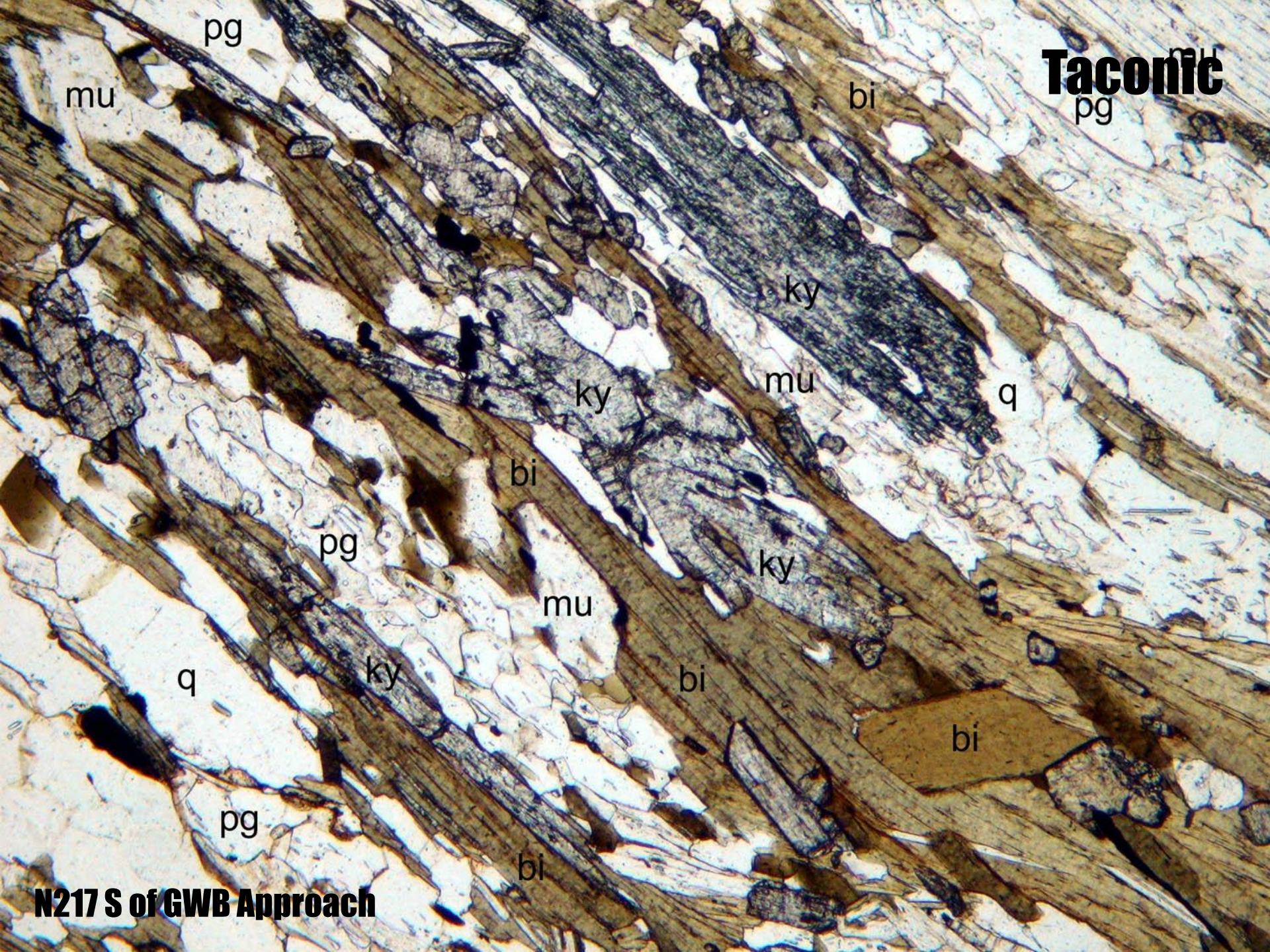



Taconic
Manhattan Schist, Central Park
TrJns
Jp
Є - Oh
Cameron's Line
St. Nicholas Thrust
Ow
Є - Om
Є - Oi
Єl
Yf

Taconic

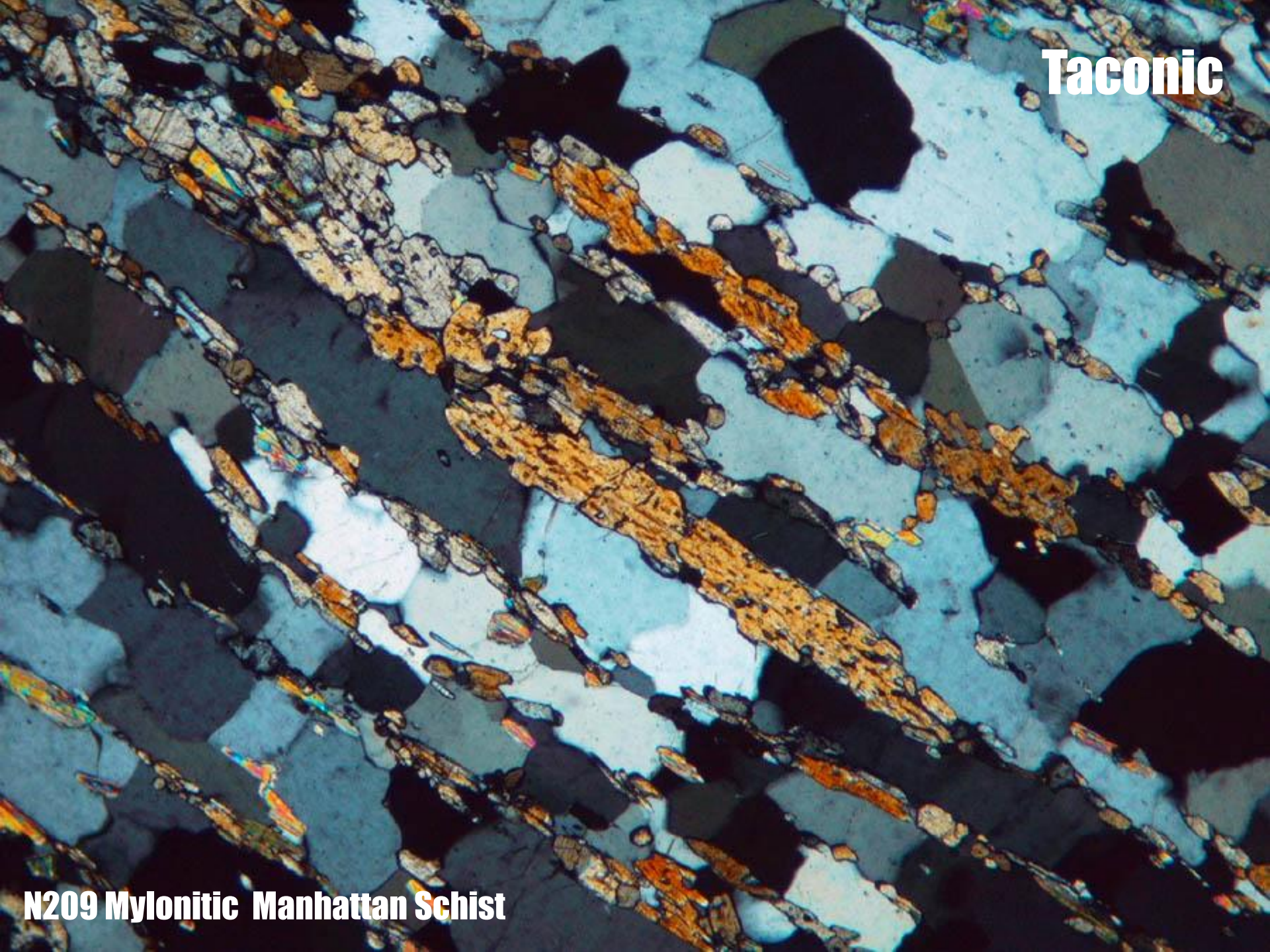


N172 Mornside Park Kyanite Layer Folded by F_3

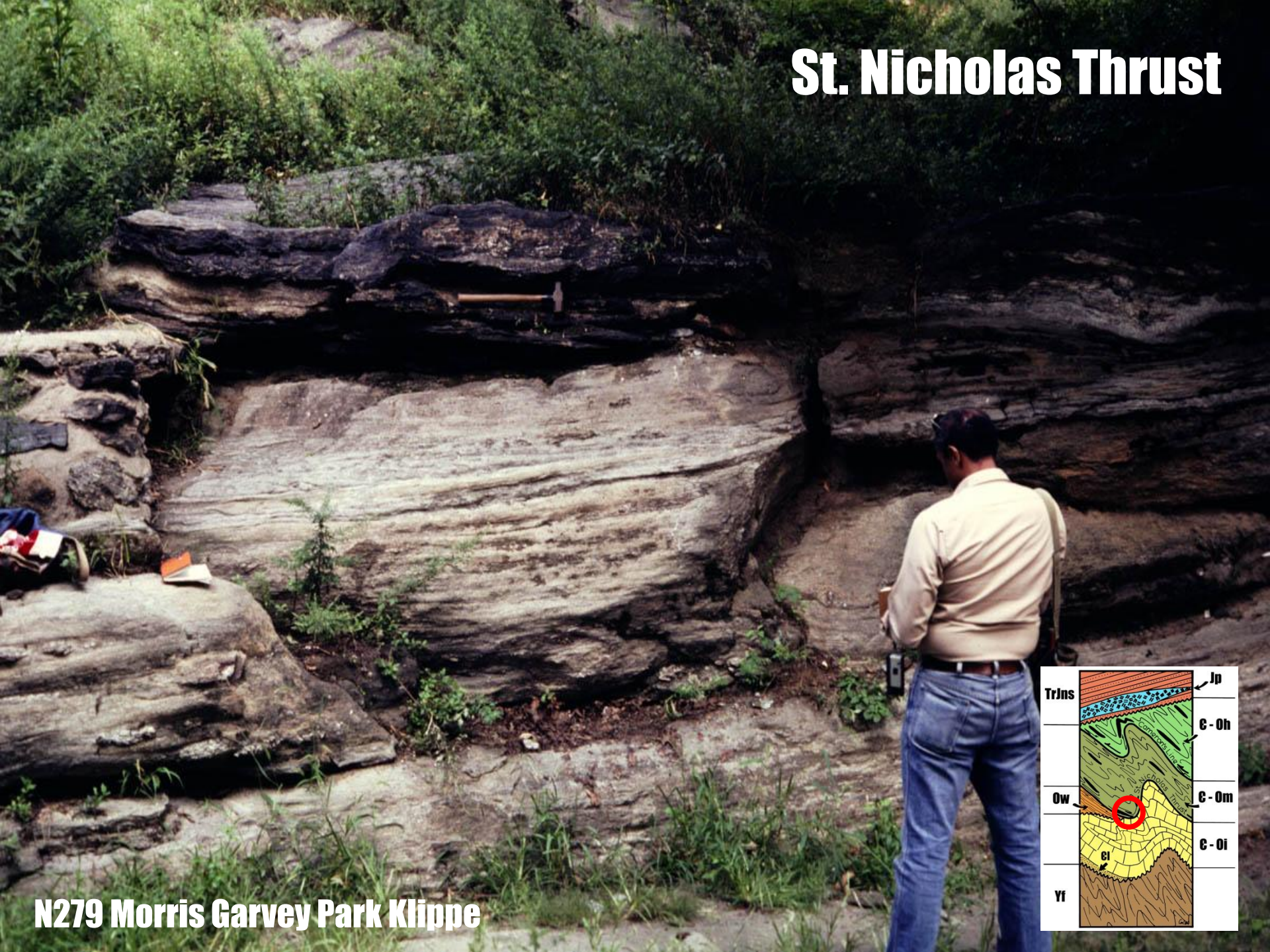

Taconic
pg
mu
bi
pg
mu
ky
mu
q
ky
bi
pg
ky
mu
q
ky
bi
bi
pg
bi
N217 S of GWB Approach

Taconic

Sheared Manhattan Schist, St. Nicholas Park


Taconic
N209 Mylonitic Manhattan Schist

St. Nicholas Thrust

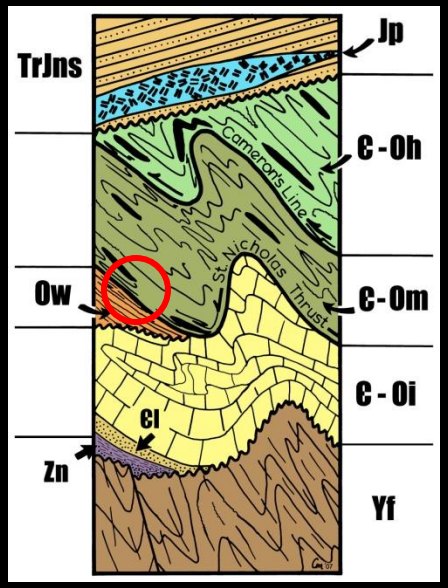


N279 Morris Garvey Park Klippe

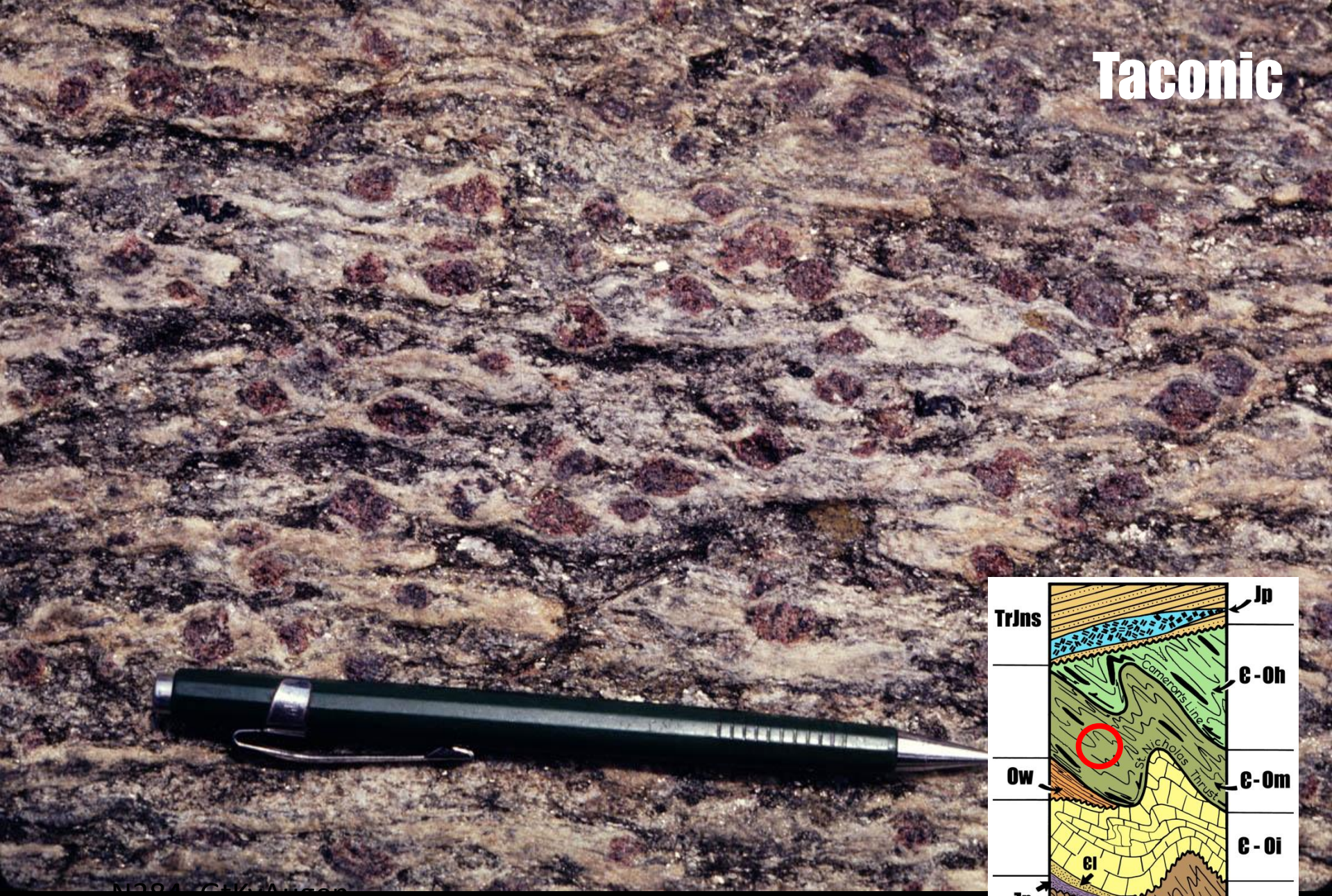
St. Nicholas Thrust

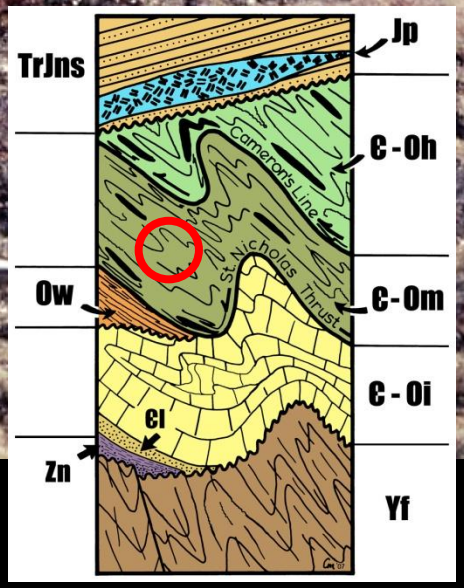
Taconic

Tippecanoe



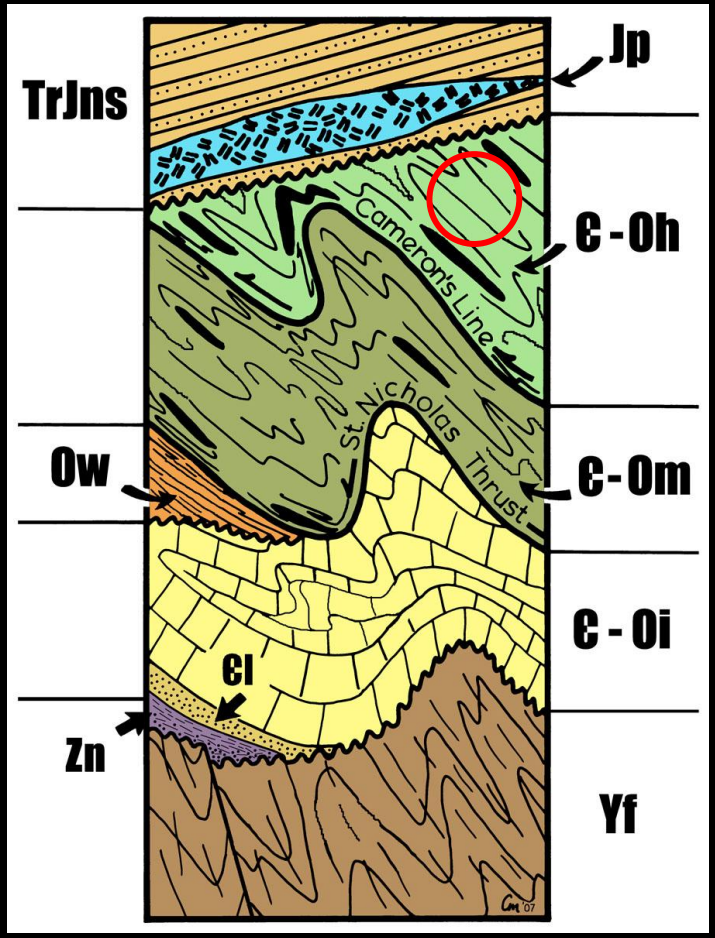
Taconic





Garnet-Sillimanite Augen Gneiss, Mt. Morris Park Klippe

Taconic



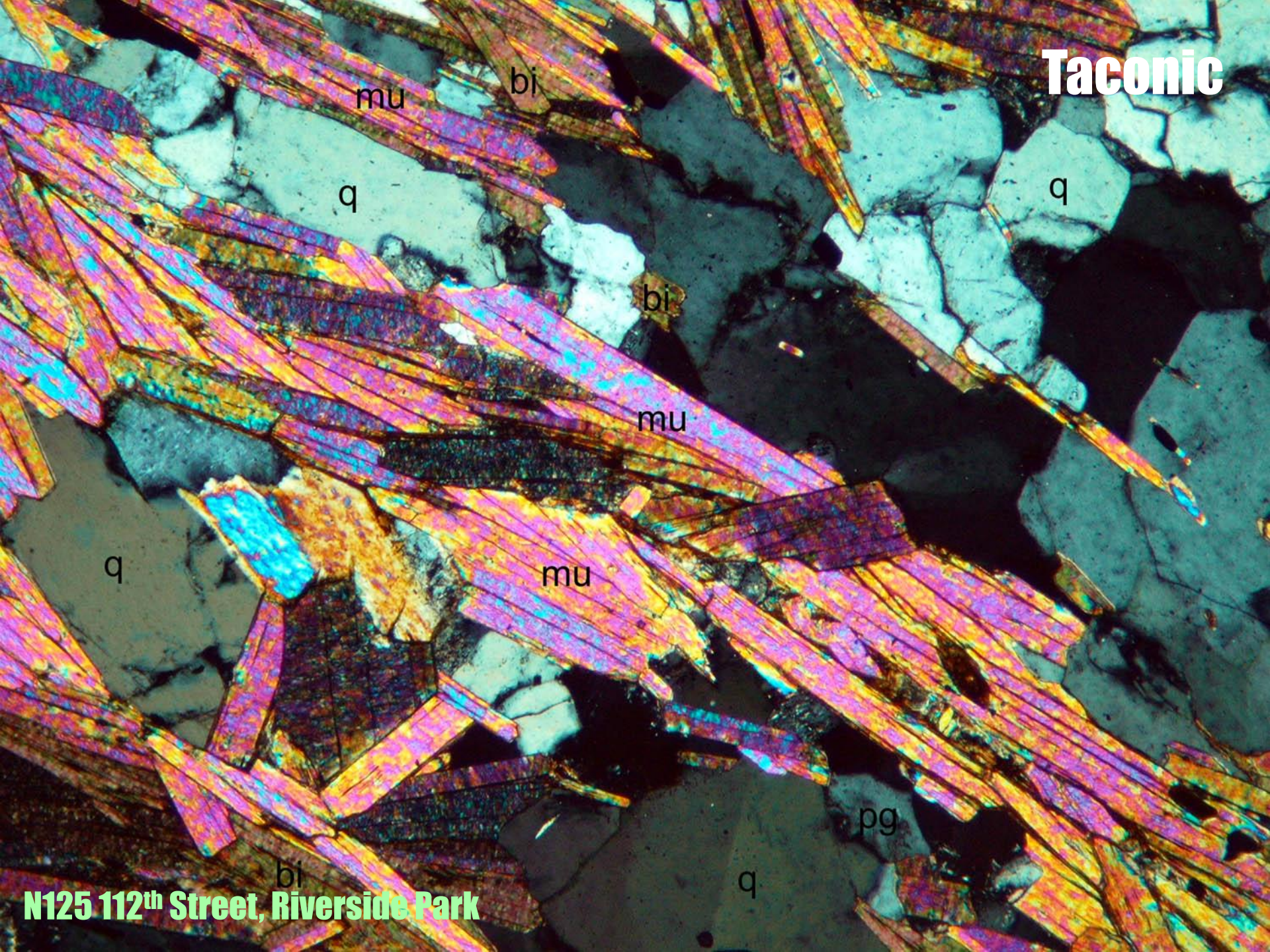
SW-Plunging F_3 Folds
Hartland Formation
Riverside Park, NYC

Taconic

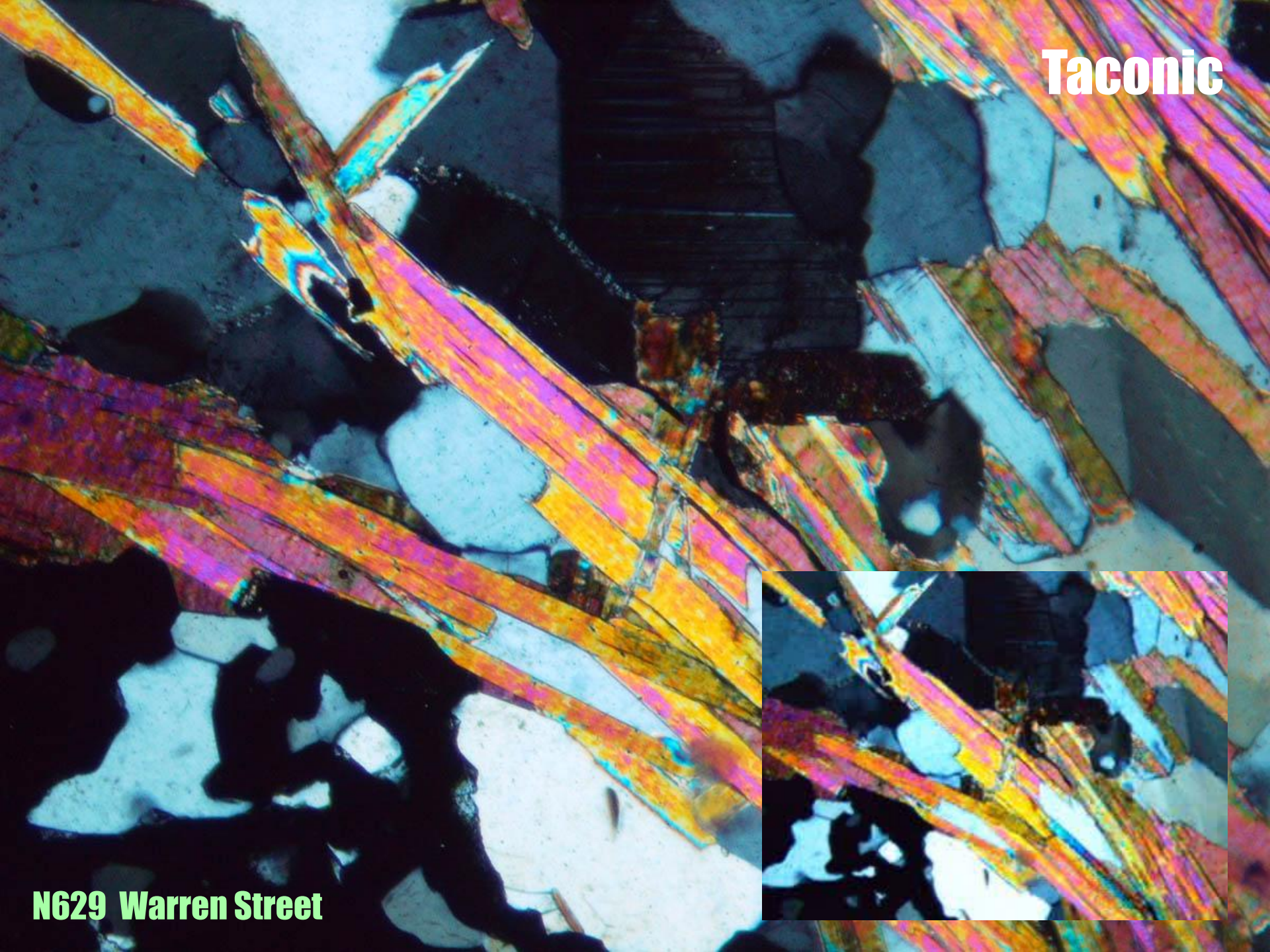
N125 Hartland Schist, Riverside Park

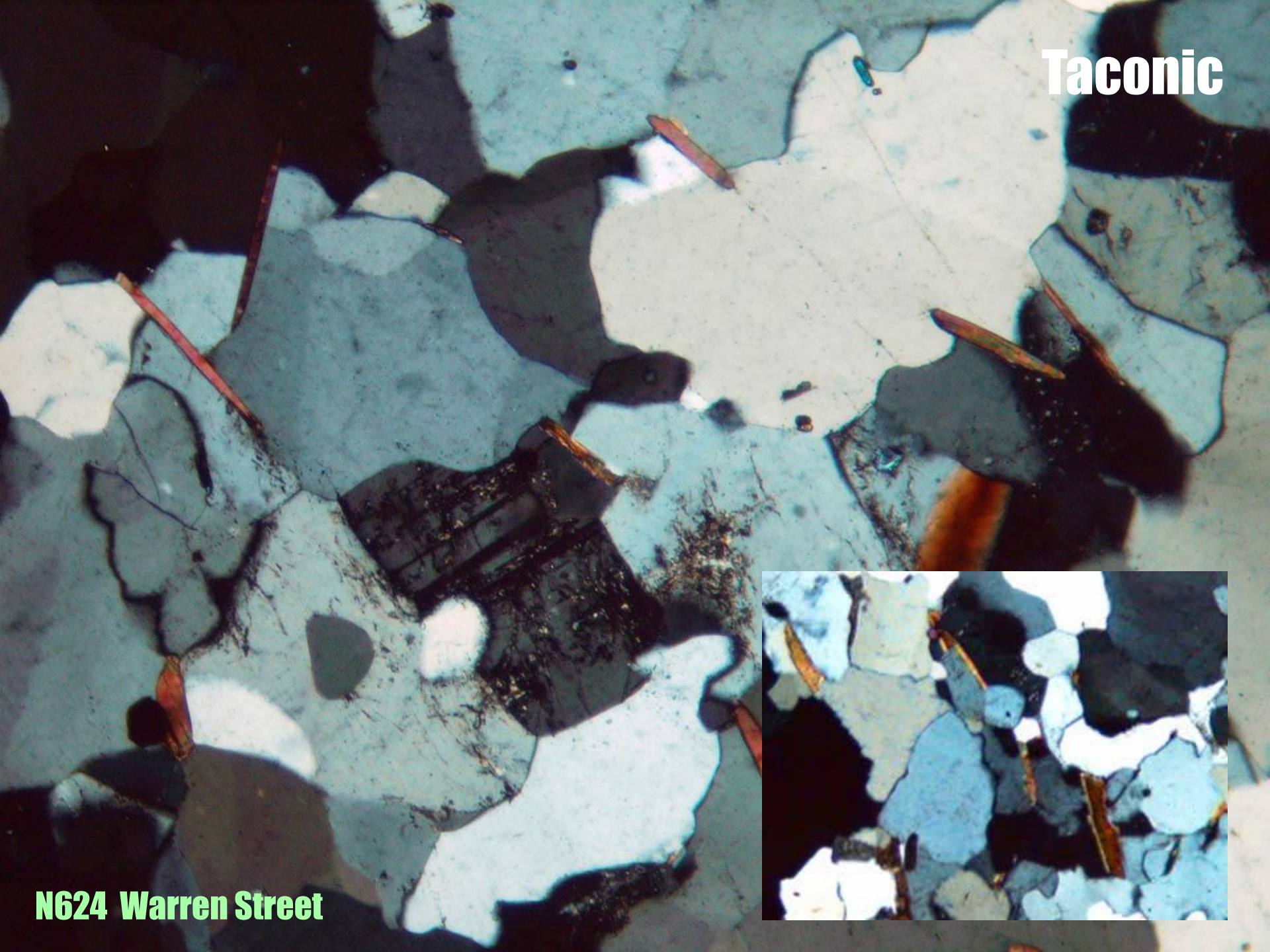
Taconic

N361 Hartland Schist and Granofels, Central Park



N125 112th Street, Riverside Park


Taconic
N629 Warren Street


Taconic
N624 Warren Street

Taconic

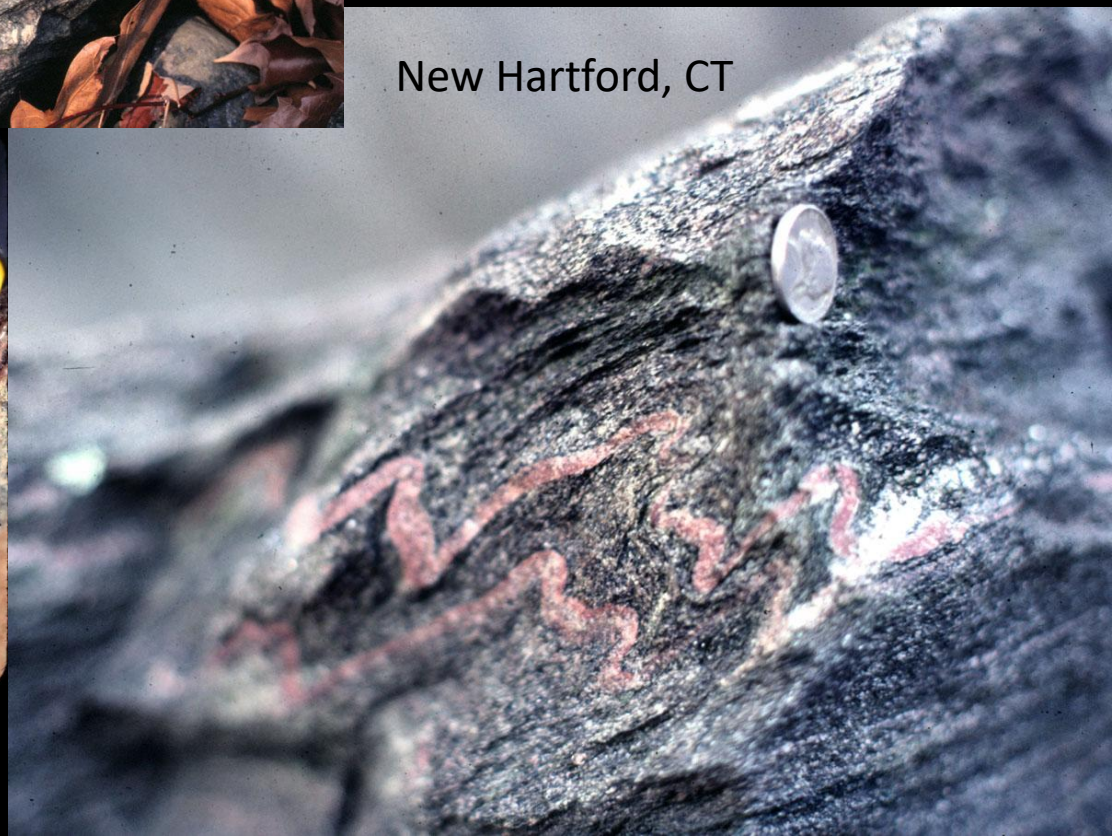
N296 Hartland Schist and Granitoid, Central Park

N123 Hartland Schist and Amphibolite, Riverside Park

Taconic
TrJns
Jp
Є - Oh
Ow
Є - Om
Є - Oi
Єl
Yf
N567 Hartland Amphibolite

Taconic

Hartland Coticule

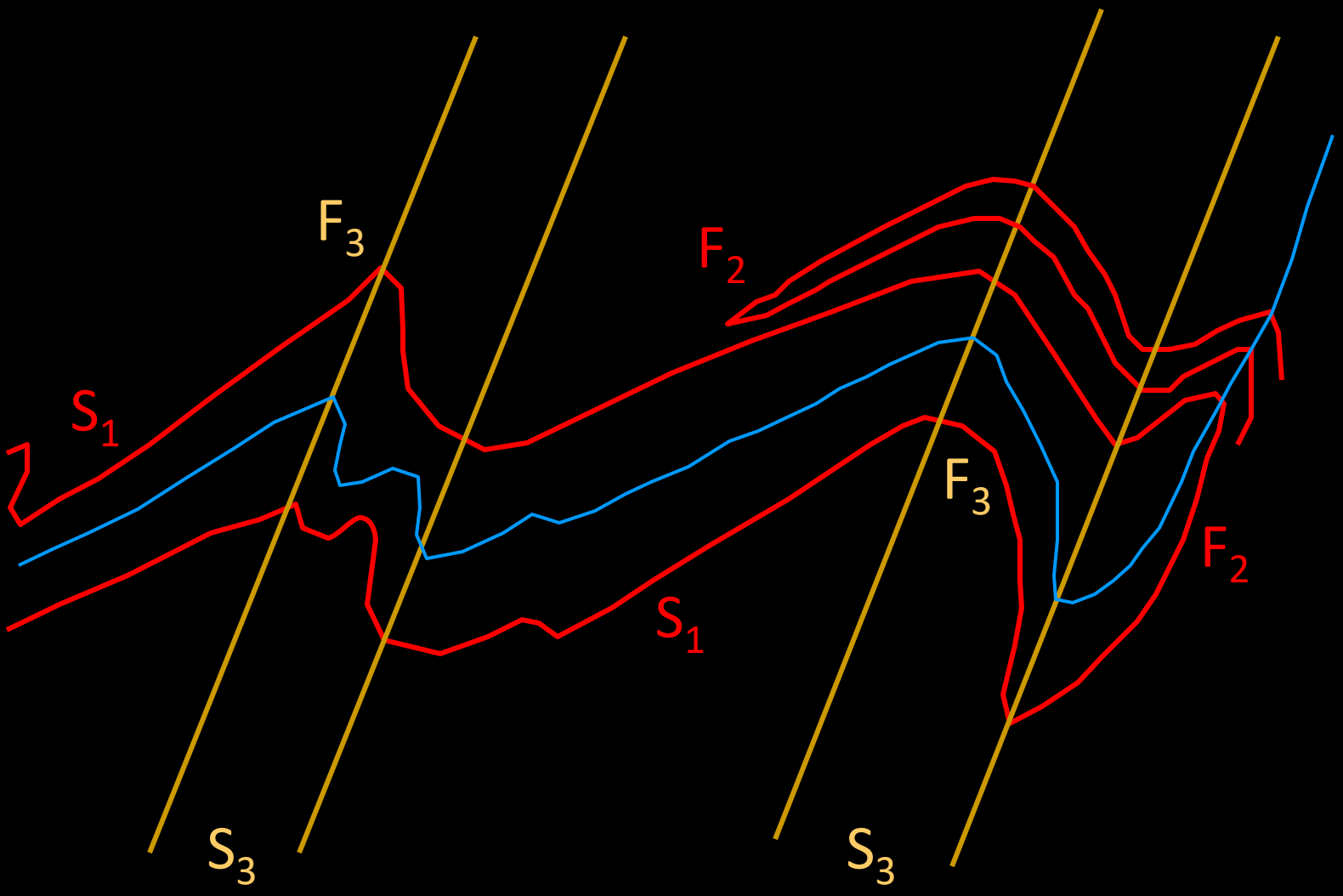


Hartland Coticule Found w/ Spessartine Garnet

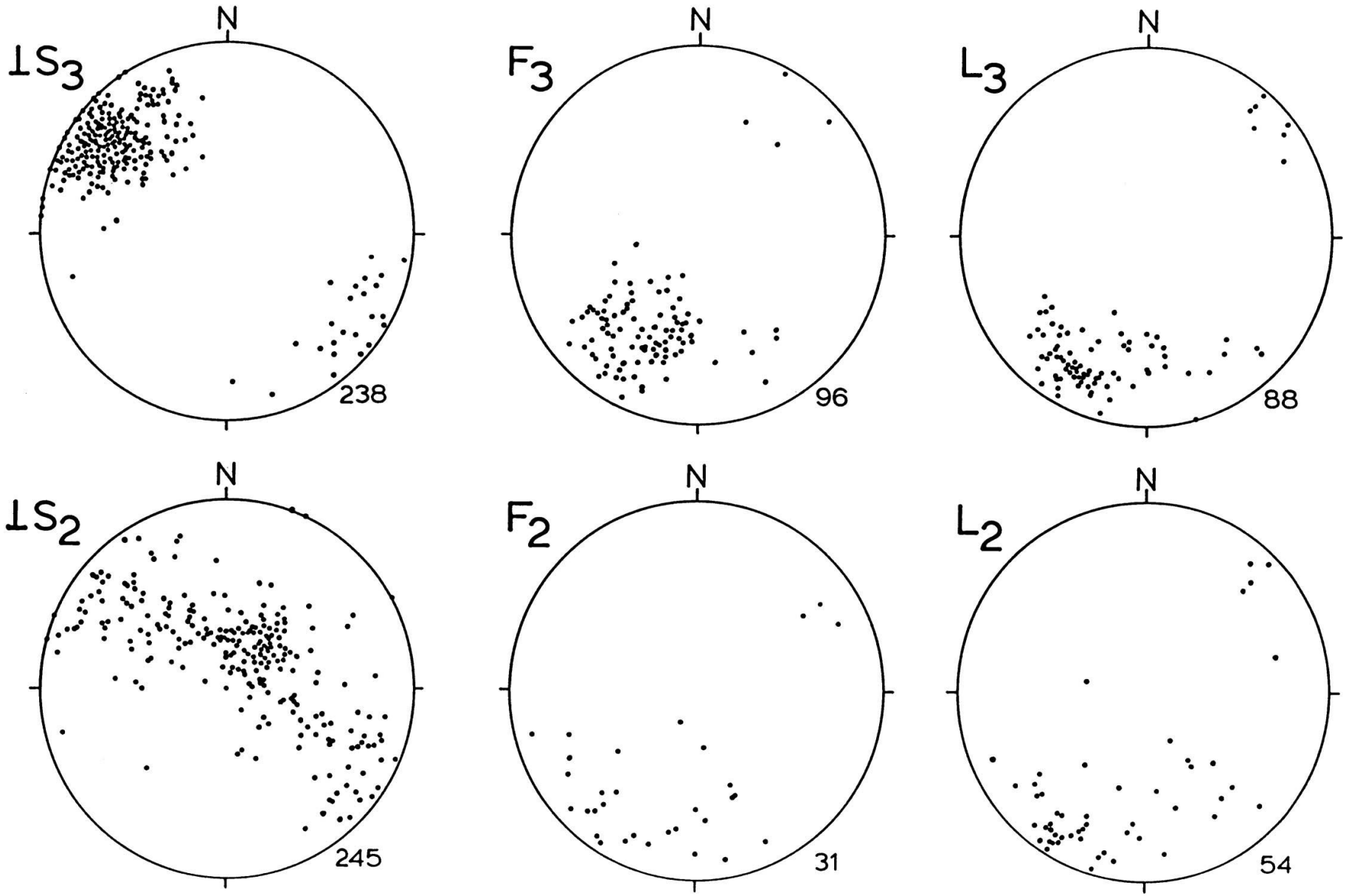
C-Ohc

Polydeformed Bedrock

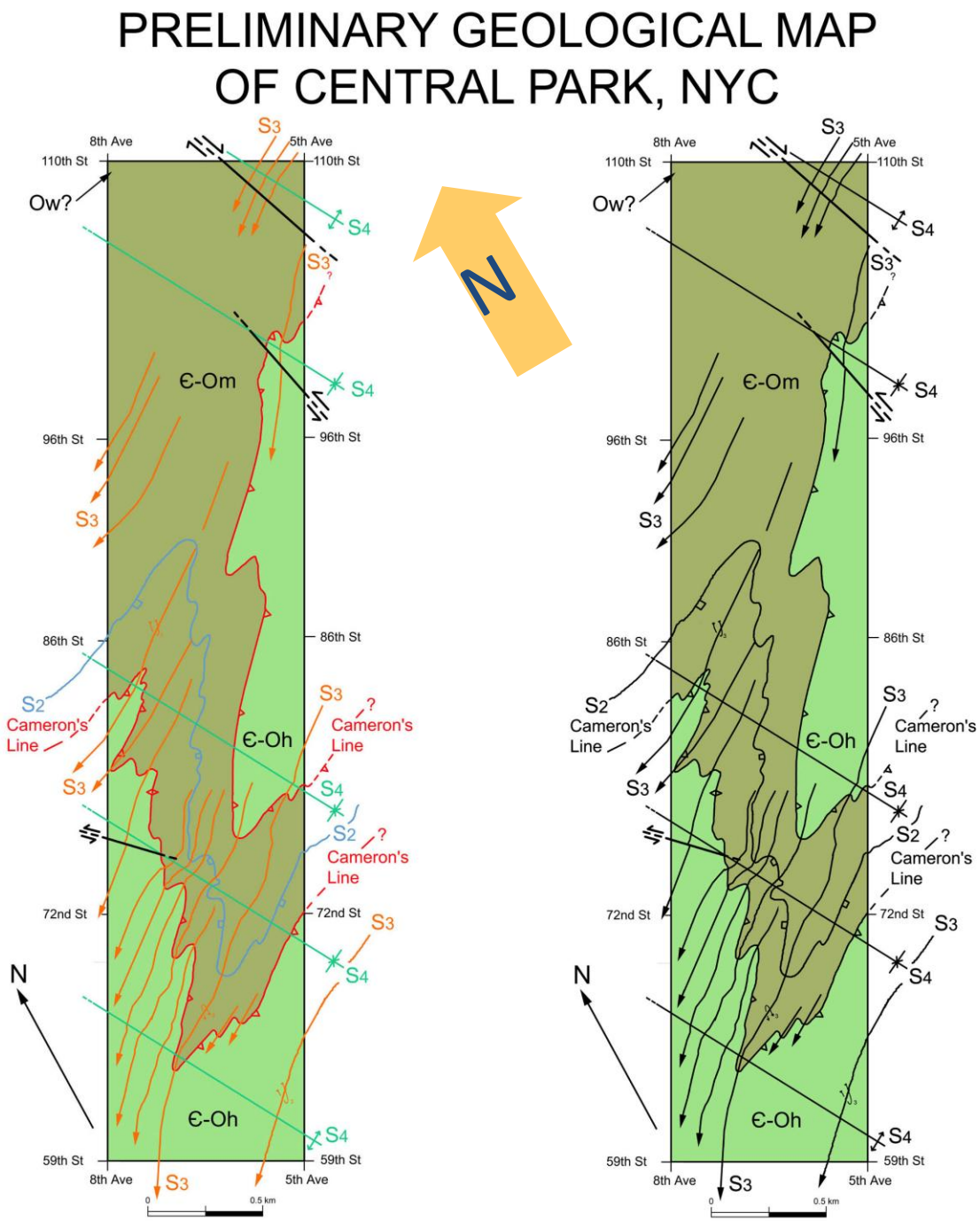
F3
F2
S1
F3
F2
S1
S3
S3


F3
F2
S1
F3
F2
S1
S3
S3

D2 x D3 Interference Patterns

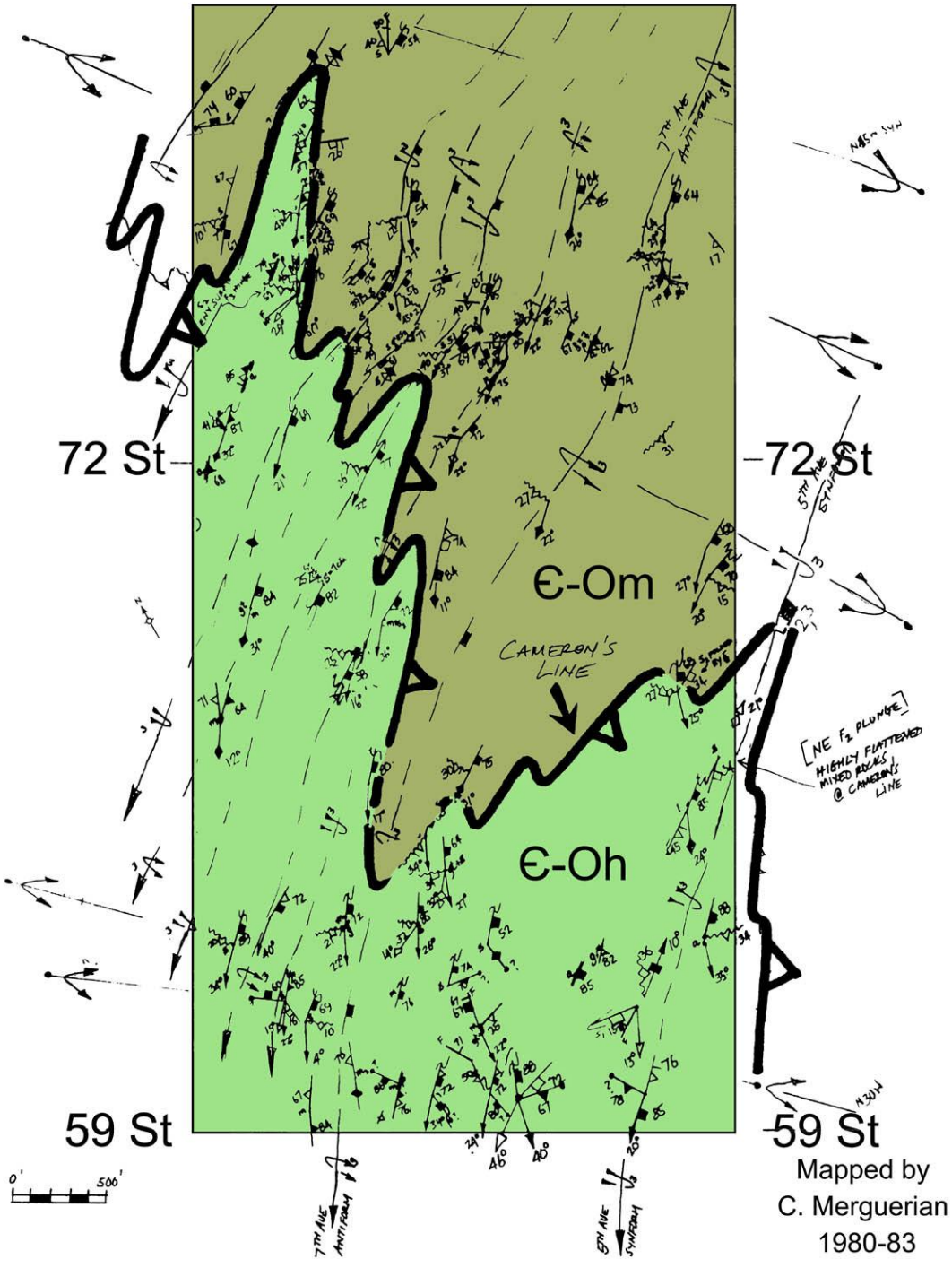

⊥S3
N
238
F3
N
96
L3
N
88
⊥S2
N
245
F2
N
31
L2
N
54

Cameron's Line in Central Park

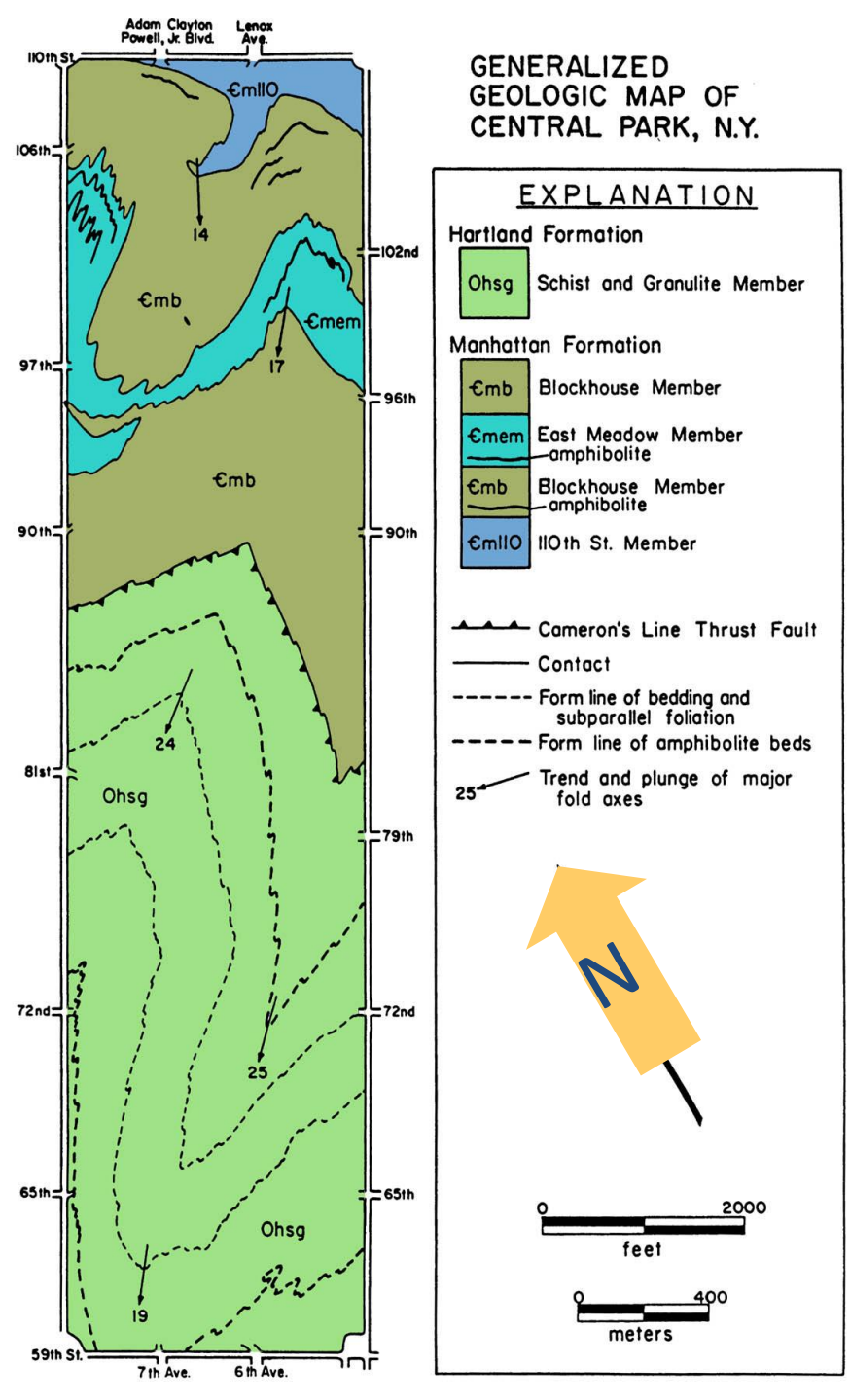


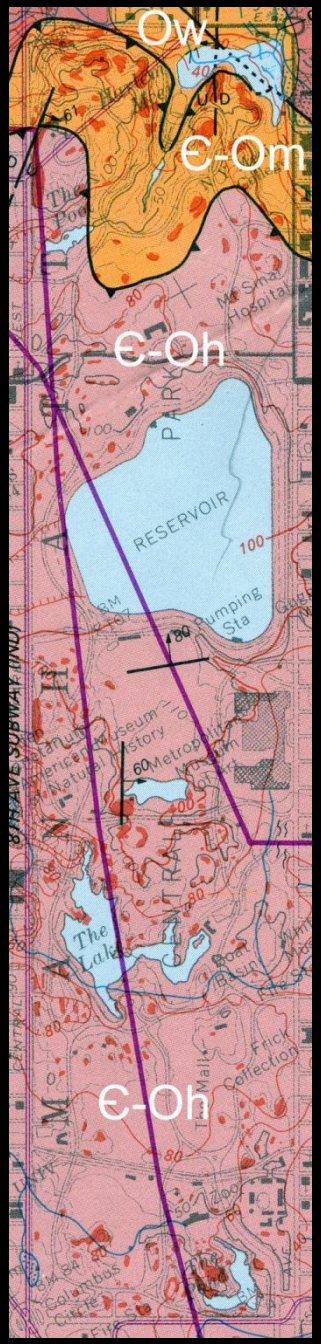
Merguerian and Merguerian, 2004

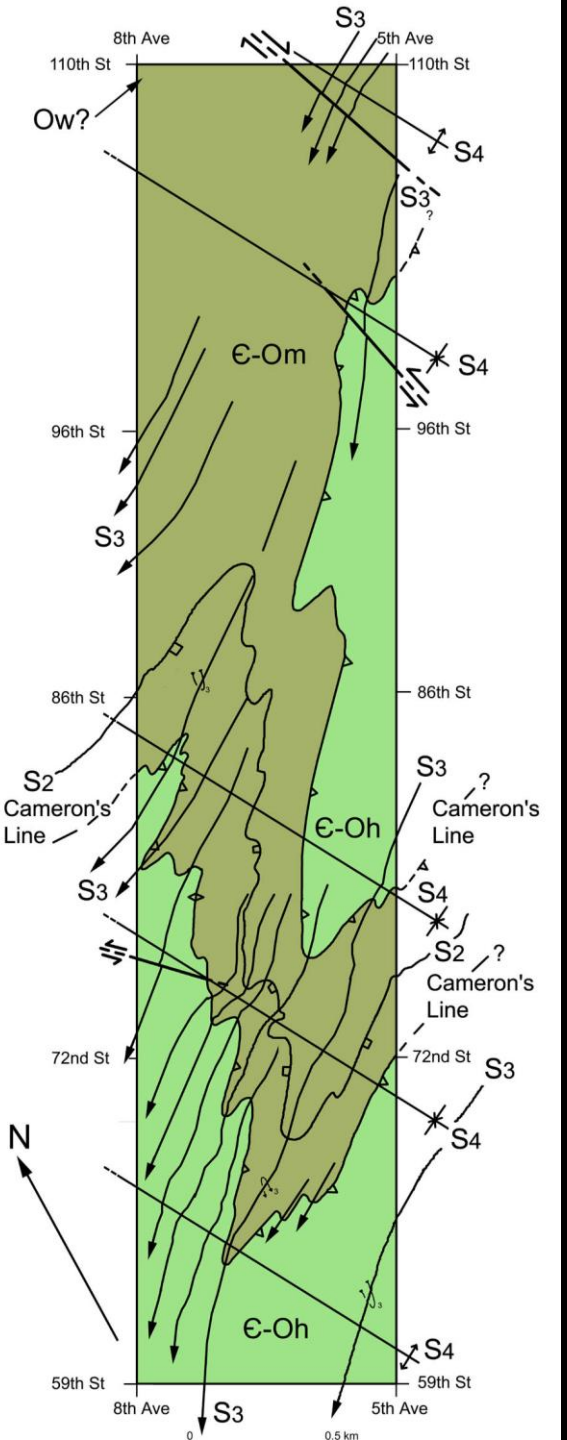
Cameron's Line in Central Park

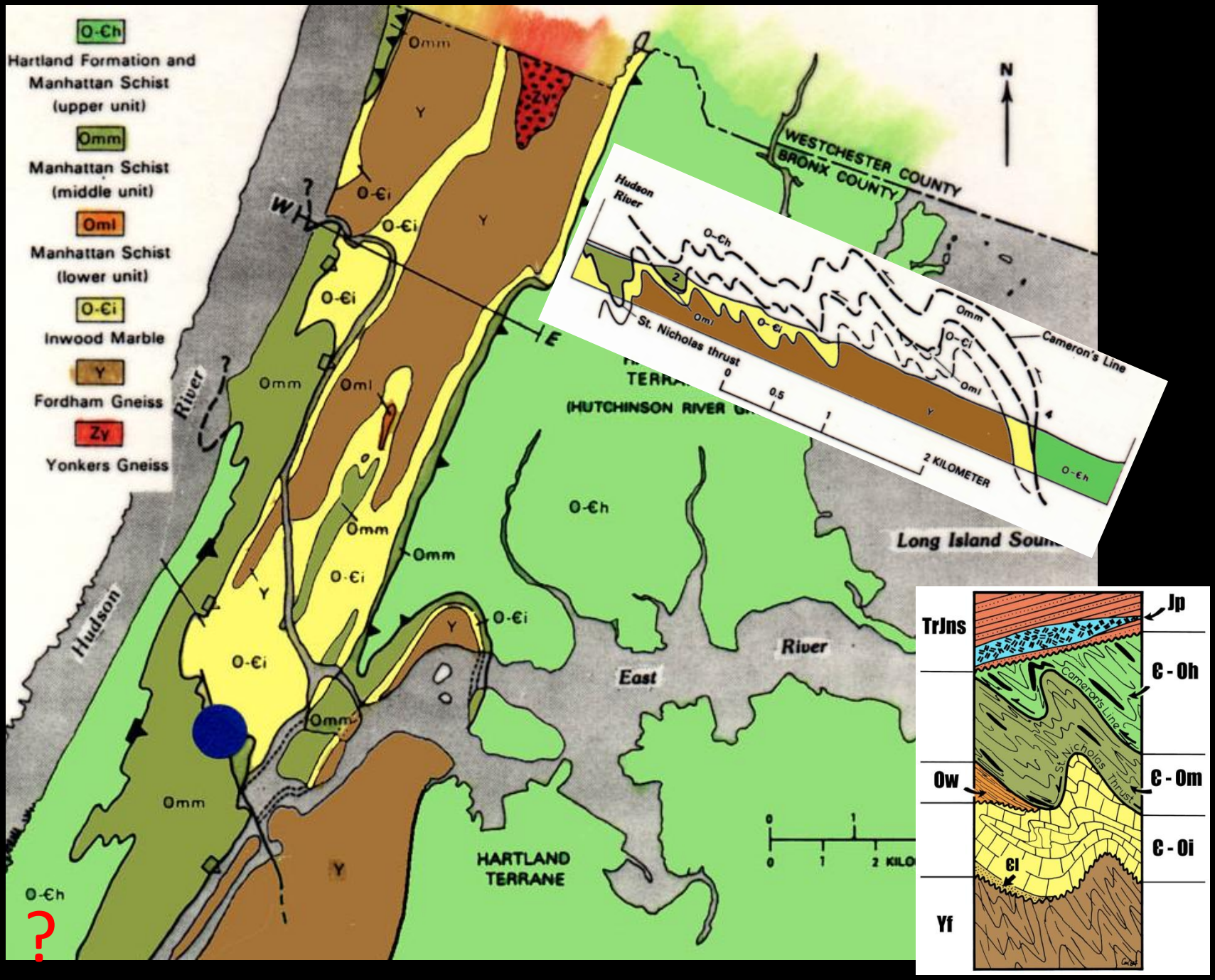


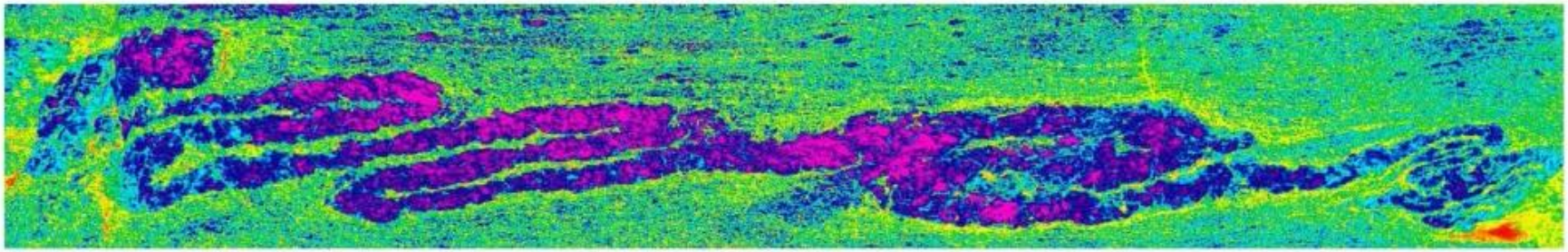
Merguerian and Merguerian, 2004


GENERALIZED GEOLOGIC MAP OF CENTRAL PARK, N.Y.
EXPLANATION
Hartland Formation
Ohsg Schist and Granulite Member
Manhattan Formation
€mb Blockhouse Member
€mem East Meadow Member
amphibolite
€mb Blockhouse Member
amphibolite
€m110 110th St. Member
Cameron's Line Thrust Fault
Contact
Form line of bedding and subparallel foliation
Form line of amphibolite beds
Trend and plunge of major fold axes
N
0 2000
feet
0 400
meters
Adam Clayton Powell, Jr. Blvd.
Lenox Ave.
110th St
106th
102nd
97th
96th
90th
81st
79th
72nd
65th
59th St.
7th Ave.
6th Ave.
€m110
€mb
€mem
Ohsg
14
17
24
25
19


Ow
€-Om
€-Oh
RESERVOIR
€-Oh


8th Ave
5th Ave
110th St
Ow?
S3
S4
S3?
€-Om
S4
96th St
S3
86th St
S2
Cameron's Line
S3
?
Cameron's Line
€-Oh
S3
S4
S2
?
Cameron's Line
72nd St
S3
S4
N
€-Oh
S4
59th St
8th Ave
S3
5th Ave
0
0.5 km


O-Ch
Hartland Formation and Manhattan Schist (upper unit)
Omm
Manhattan Schist (middle unit)
Oml
Manhattan Schist (lower unit)
O-Ci
Inwood Marble
Y
Fordham Gneiss
Zy
Yonkers Gneiss
N
WESTCHESTER COUNTY
BRONX COUNTY
Hudson River
O-Ch
St. Nicholas thrust
Cameron's Line
2 KILOMETER
Long Island Sound
HARTLAND TERRANE
(HUTCHINSON RIVER
Hudson River
East River
W
E
?
TrJns
Jp
Ꞓ - Oh
Ow
Ꞓ - Om
Ꞓ - Oi
Ꞓl
Yf
Cameron's Line
St. Nicholas Thrust



MANHATTAN PRONG WORKSHOP SEPTEMBER 6-7, 2014

Main Questions:

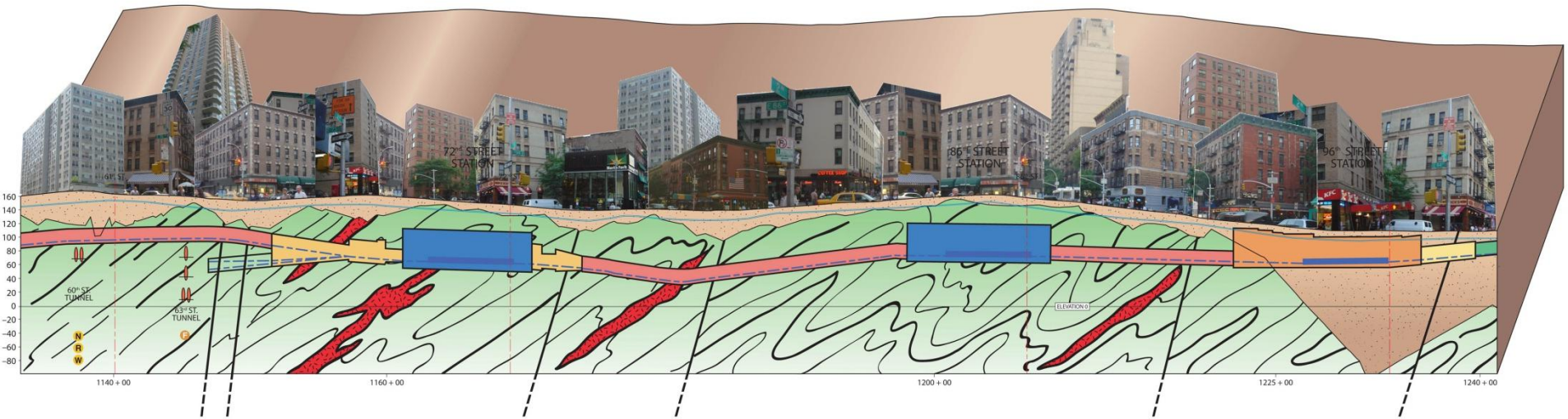
1) Position/Geometry of Cameron's Line & St. Nicholas Thrust
2) Age/Provenance of Schistose Rocks
3) Proterozoic Rocks
4) P-T History of All
5) Mafic Rocks
6) Plutons/Dikes
7) Serpentinites
8) Geochem/Age Dating

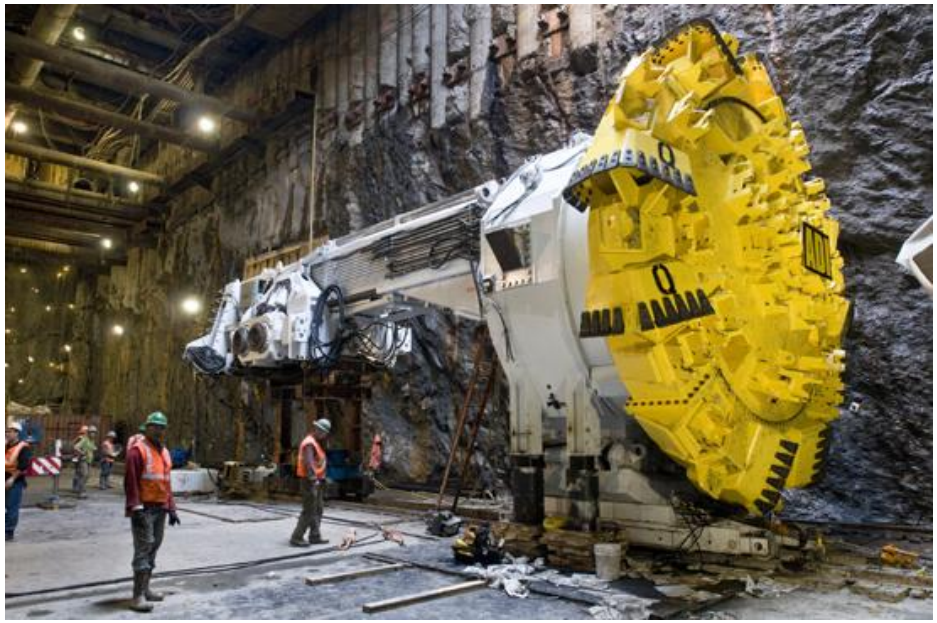
Download NYC Geology Publications @

www.dukelabs.com

www.hofstra.edu

Phase 1 - Threading The Needle





April 2010

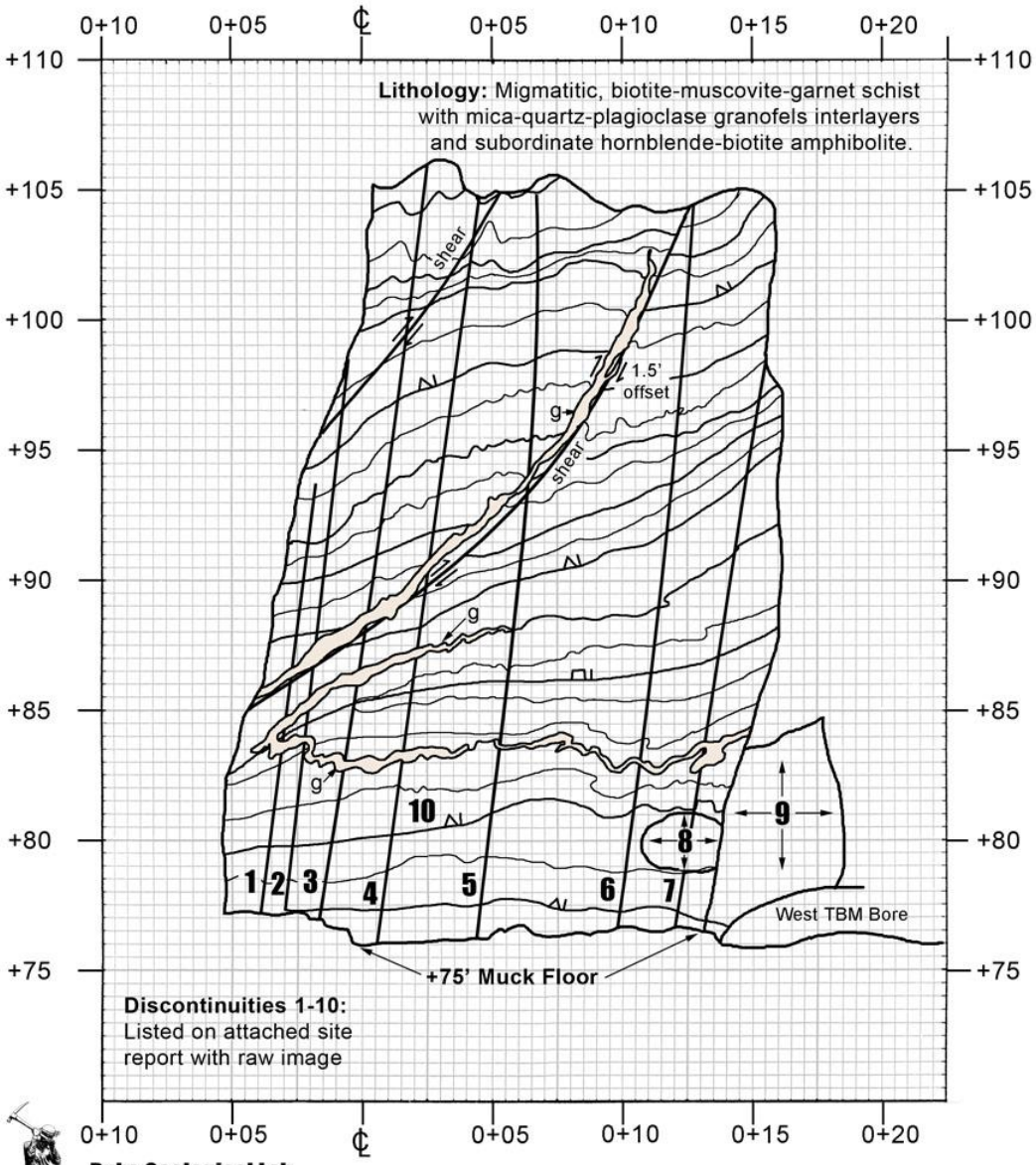
May 2010

Second Avenue Subway
Sta ~1205+00 – North Cavern

Second Avenue Subway

Sta 1204+90
North Cavern Center Slash

Second Avenue Subway



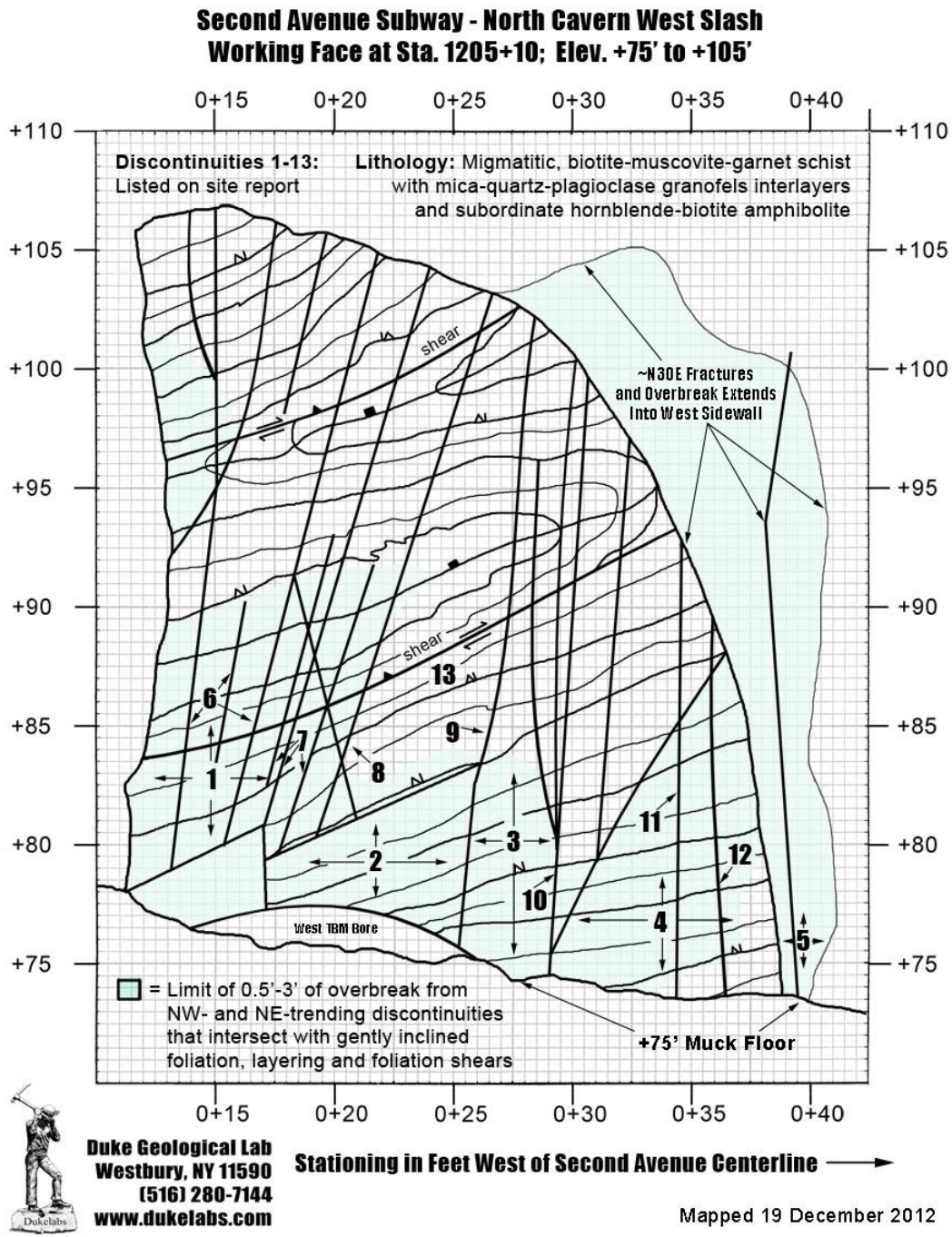
Sta 1204+90
North Cavern Center Slash

Sta ~1205+00 – North Cavern

Second Avenue Subway

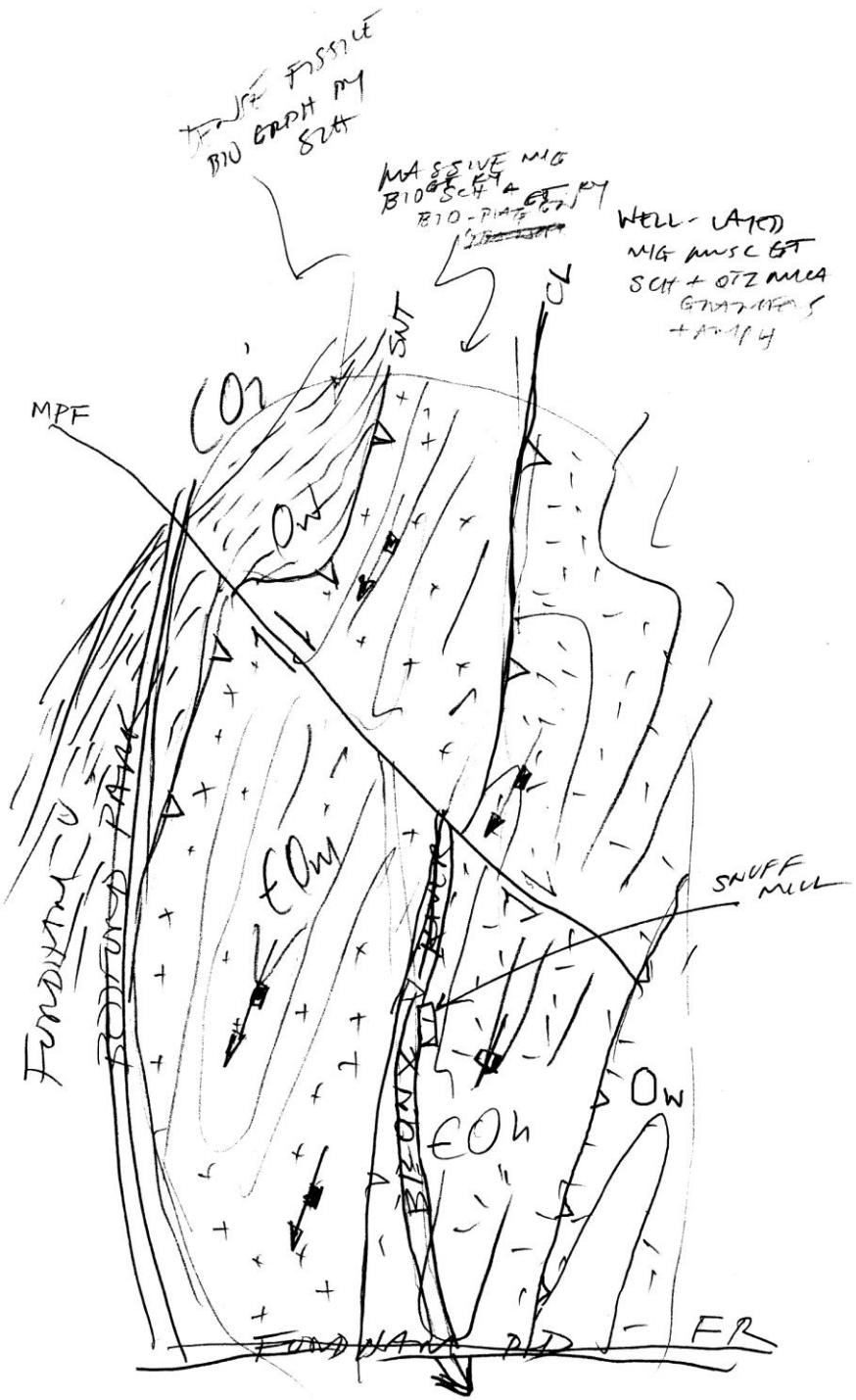
Sta 1205+10 – North Cavern

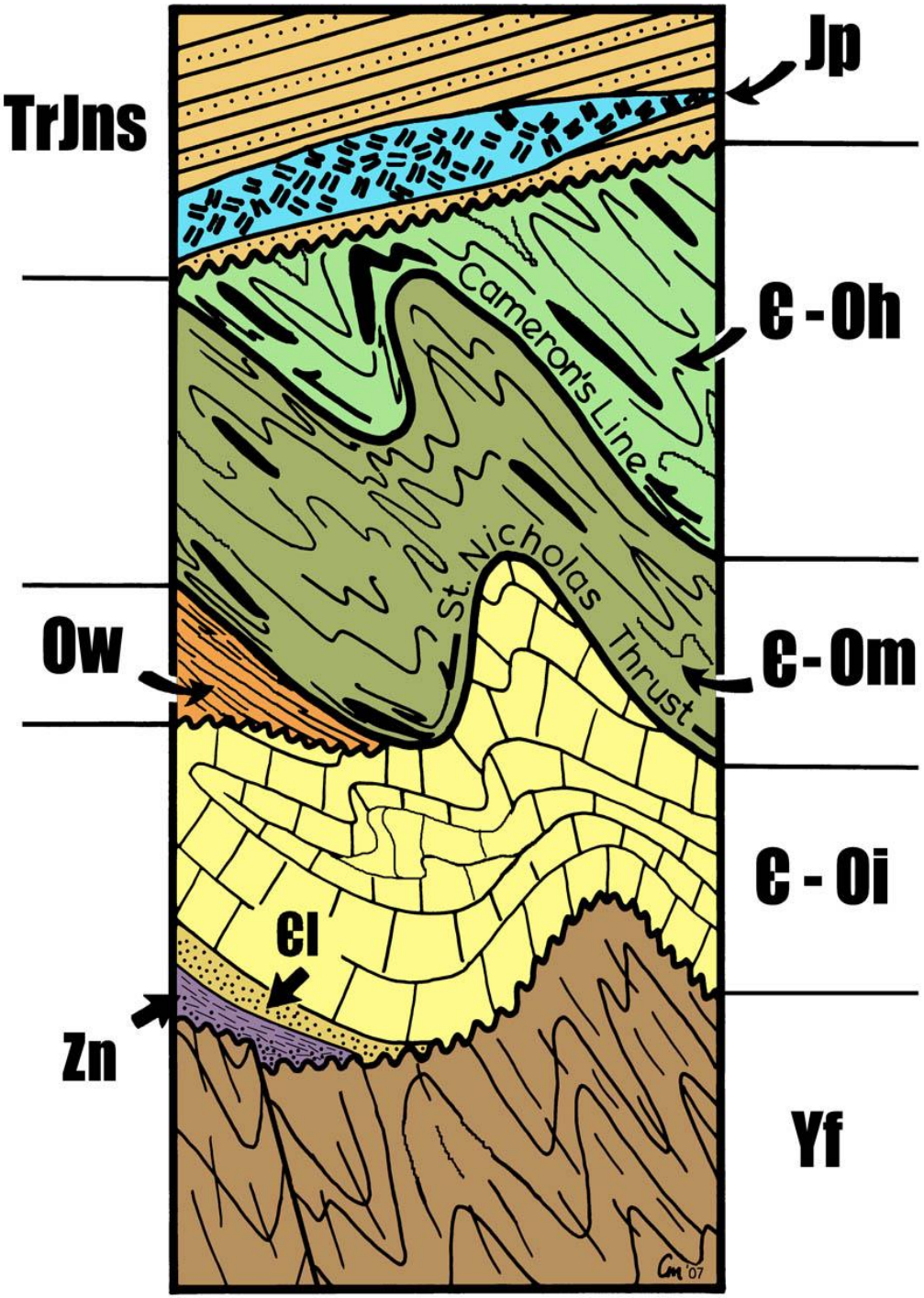
Second Avenue Subway



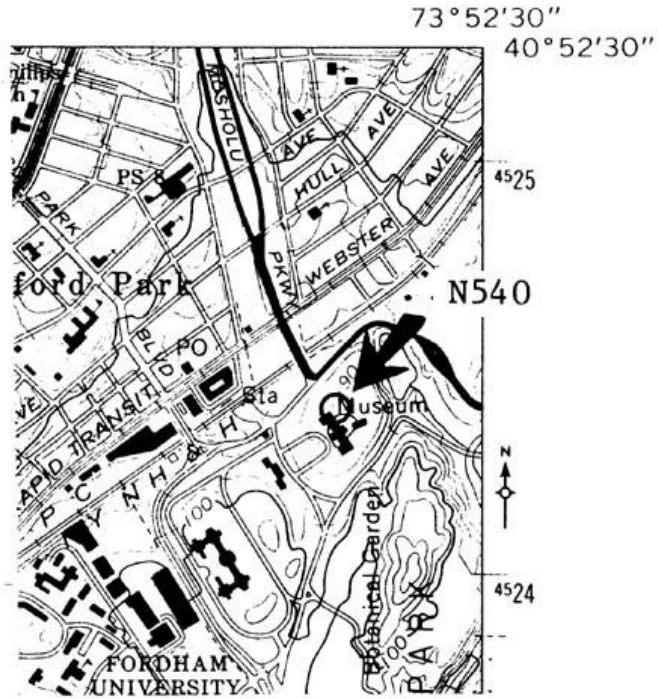
Sta 1205+10 – North Cavern

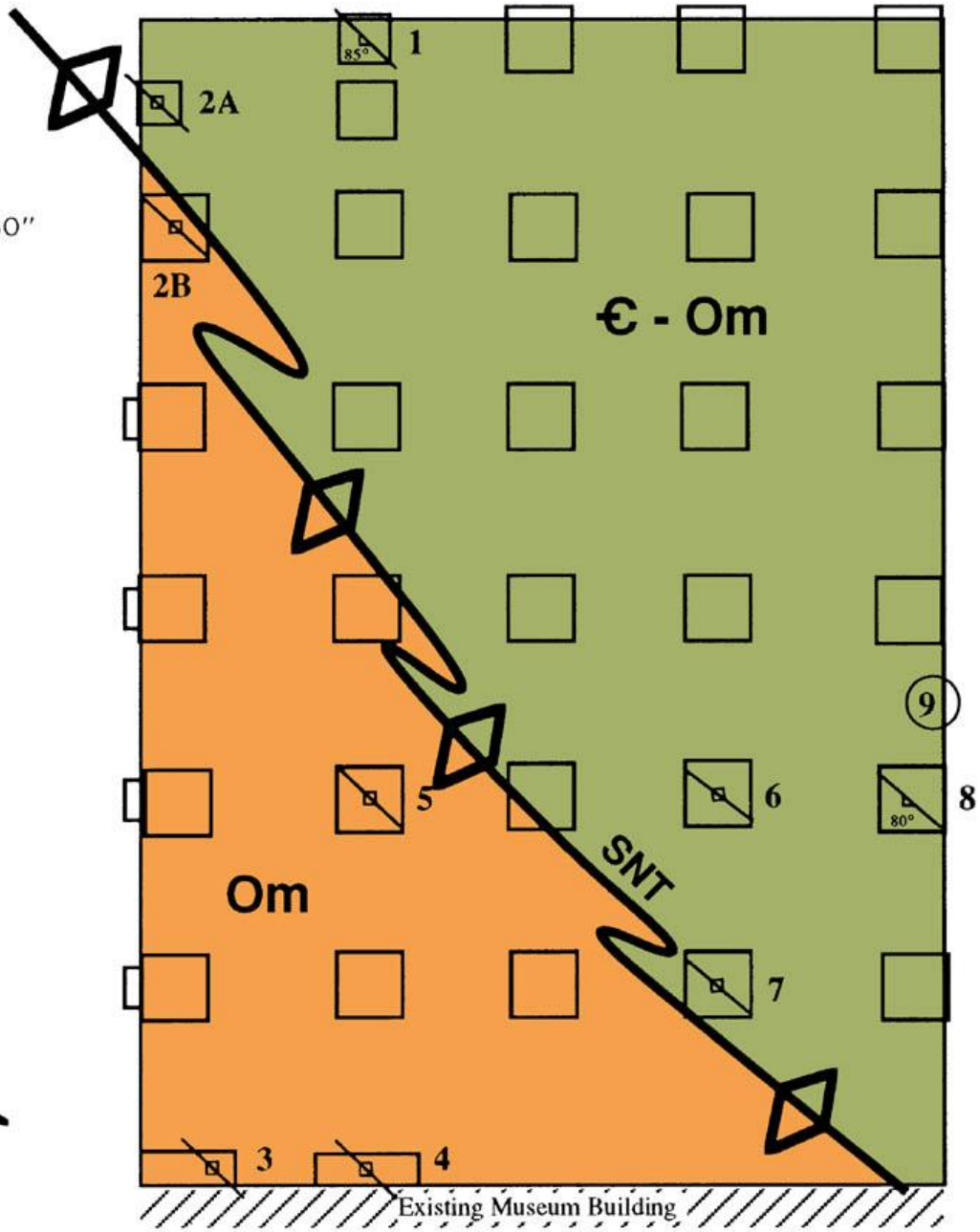
Second Avenue Subway
Sta 1205+10 – North Cavern

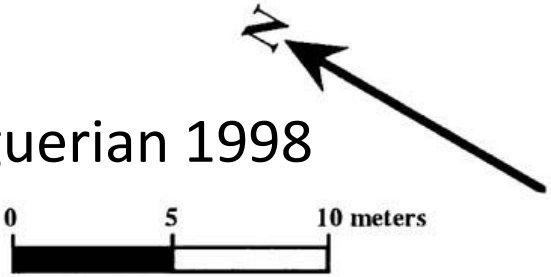

MPF
SNUFF MILL
FR


TrJns
Jp
Cameron's Line
St. Nicholas Thrust
Є-Oh
Ow
Є-Om
Є-Oi
Єl
Zn
Yf

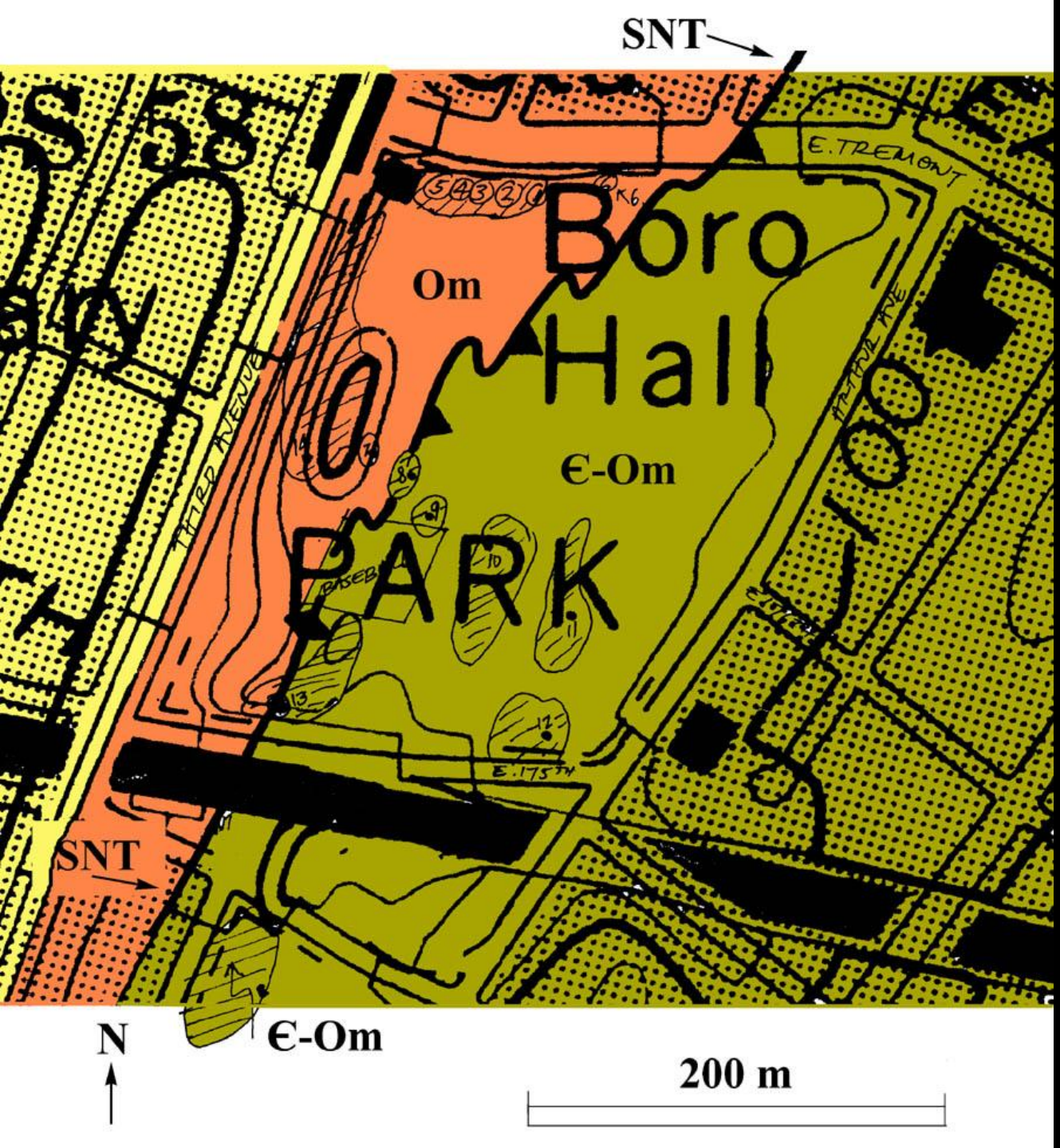
New York Botanical Garden Site N540





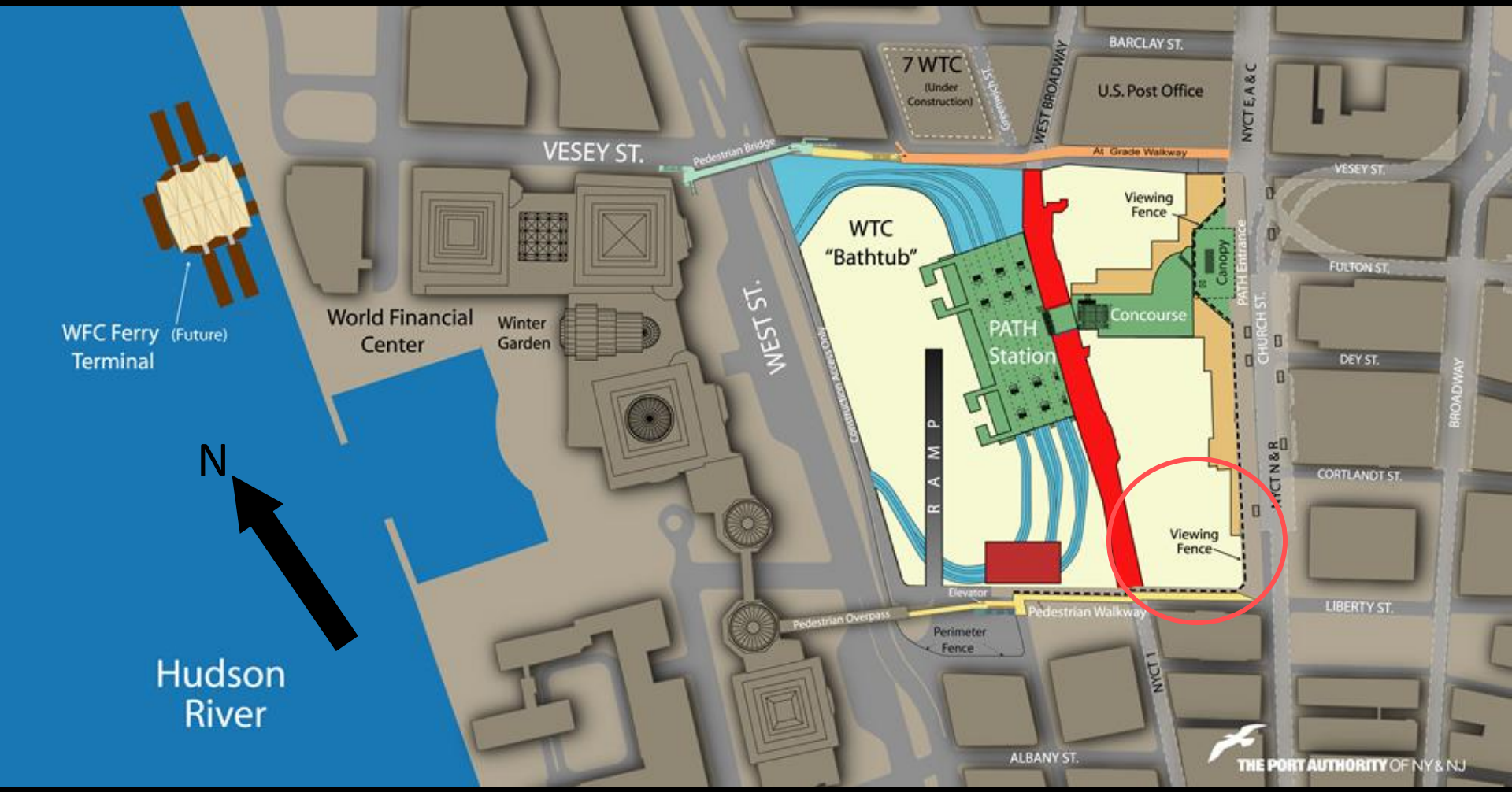


Merguerian 1998



Merguerian 1997

The World Trade Center Site



On The Rocks

2004

Mostly Hartland Schist and Granofels

WITH

Walloomsac Schist and calc-silicate rocks

Near Stop 13

Sub-vertical F3 Folds with Steep, NE-trending Axial Surfaces in Walloomsac Schist and Calc-Silicate Unit

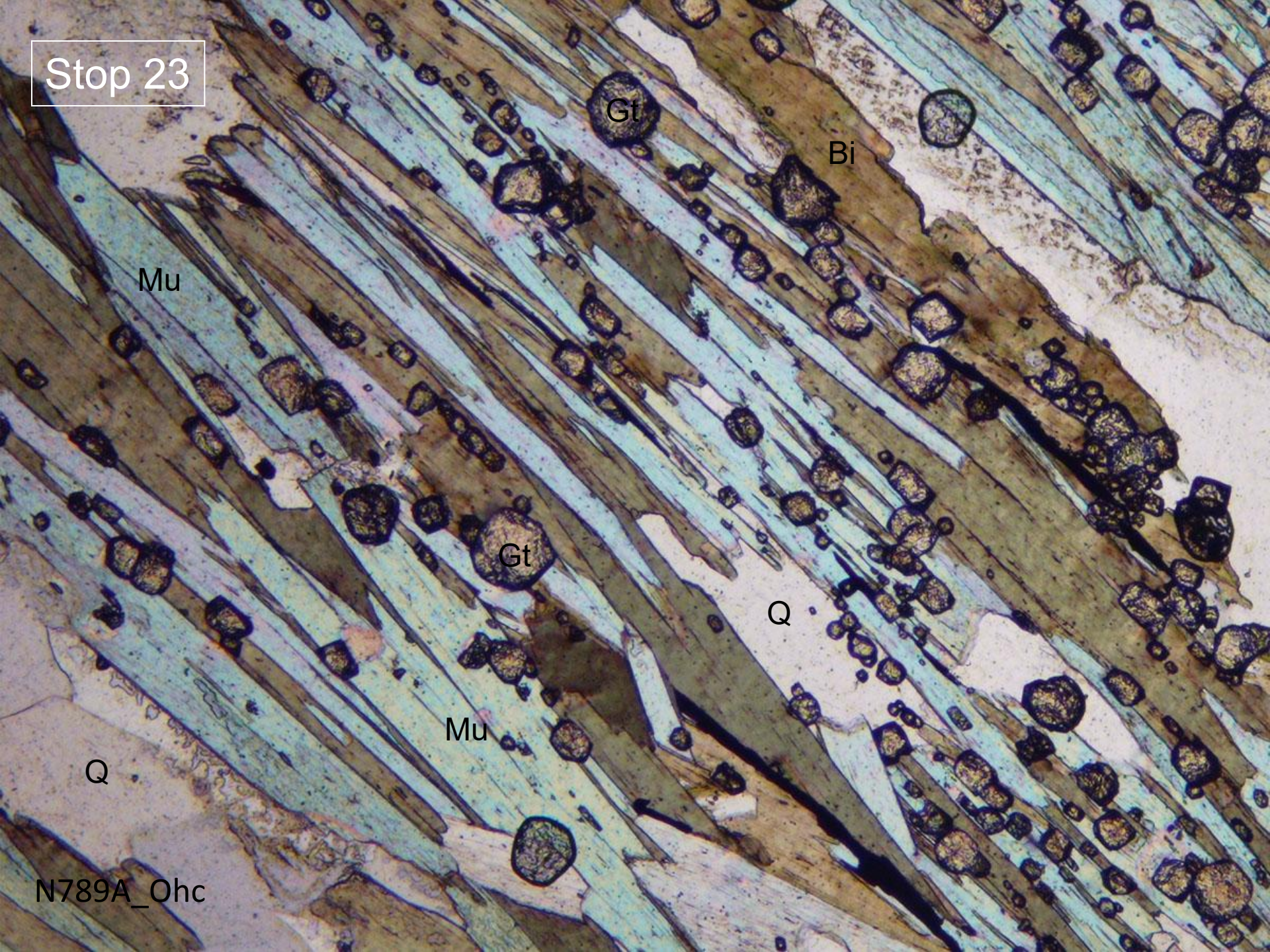
Ow+Owc

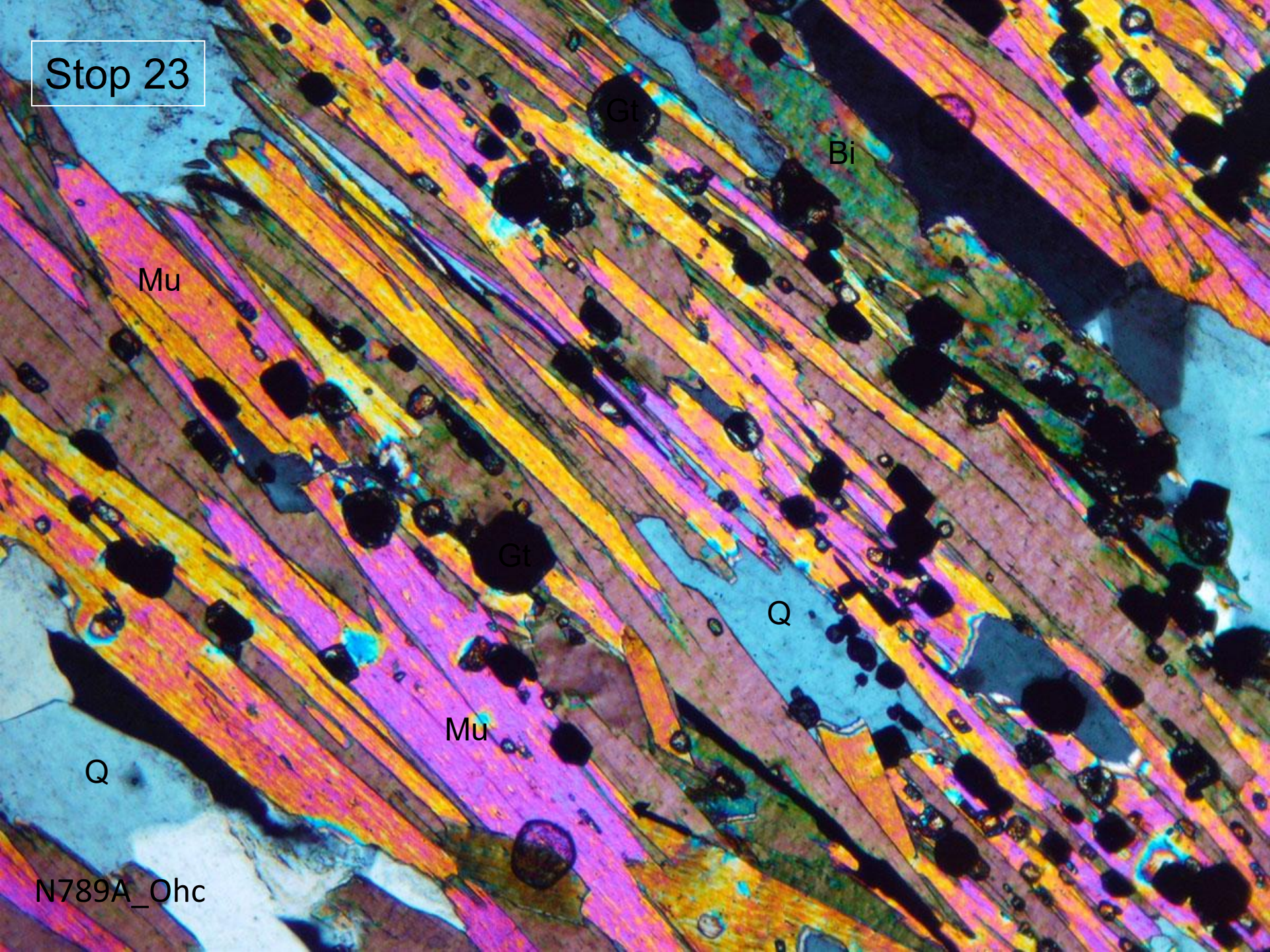
Image by C. Moss

Hartland Coticule Found w/ Spessartine Garnet

C-Ohc

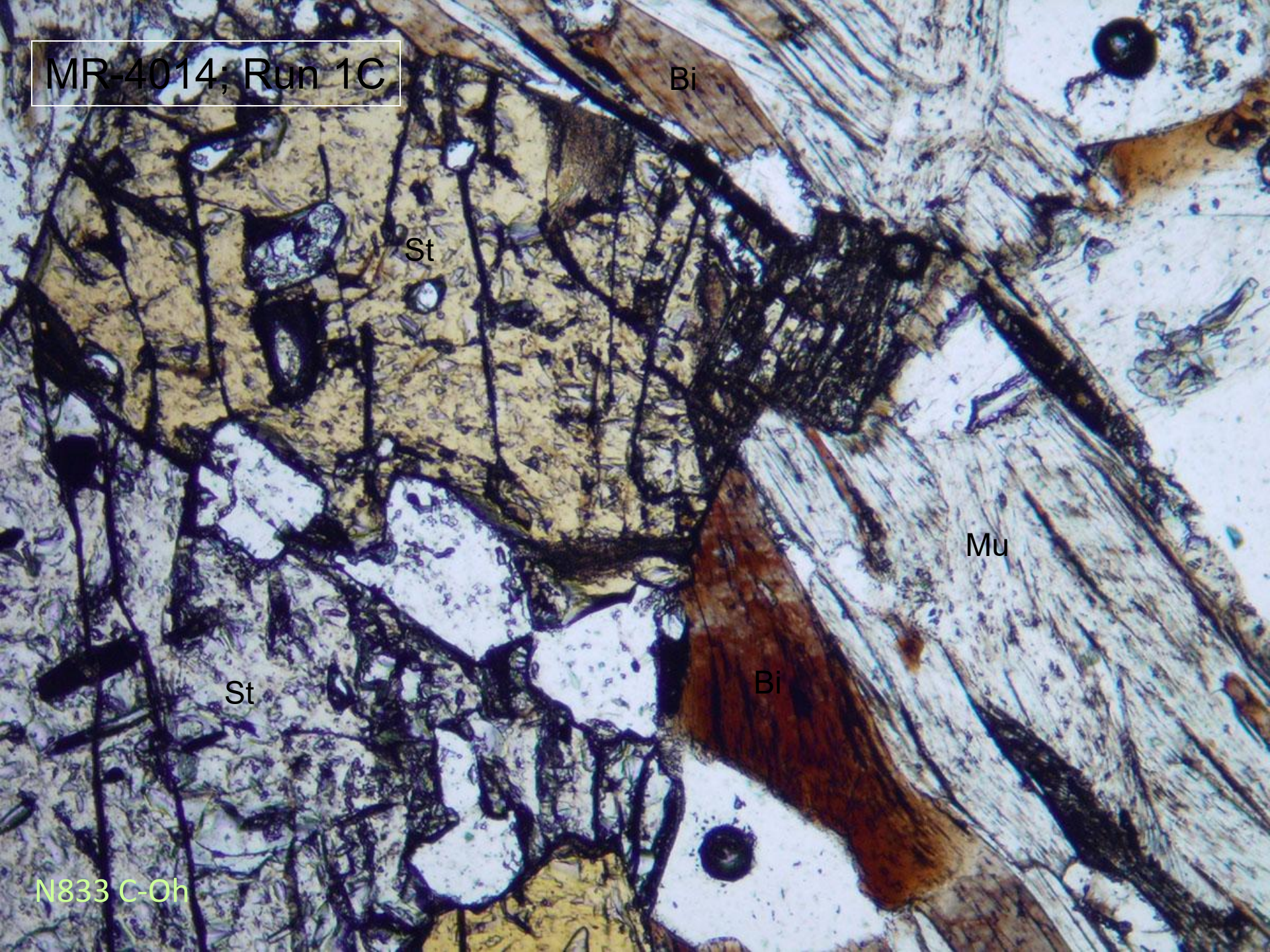
Stop 23
COh


Stop 23
Gt
Bi
Mu
Gt
Q
Mu
Q
N789A_Ohc


Stop 23
Gt
Bi
Mu
Gt
Q
Mu
Q
N789A_Ohc

World Trade Center
Field Stops
32
33
31
37
21
20
18
17
34
16
15
19
14
22
13
8
12
7
11
9
30
10
35
28
29
27
6
26
5
4
23
25
24
36
1
2
3
44
45
46
43
47
42
41
40
49
38
39
48
FULTON STREET
CHURCH STREET
FULTON STREET
DEY STREET
CORTLAND STRE

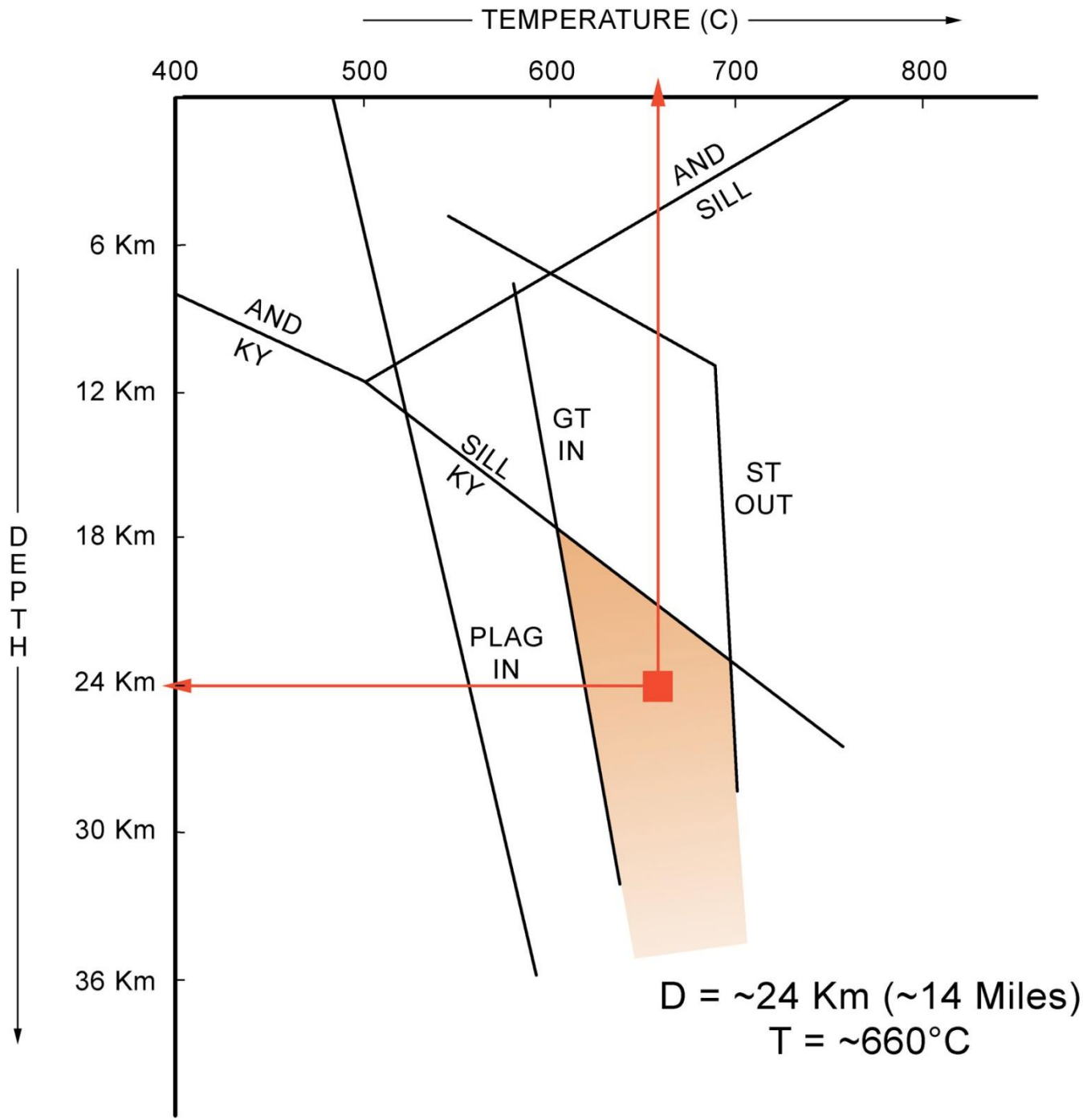
World Trade Center
Field Stops
C-Oh
Ow
Ow
C-Oh
Merguerian 2009

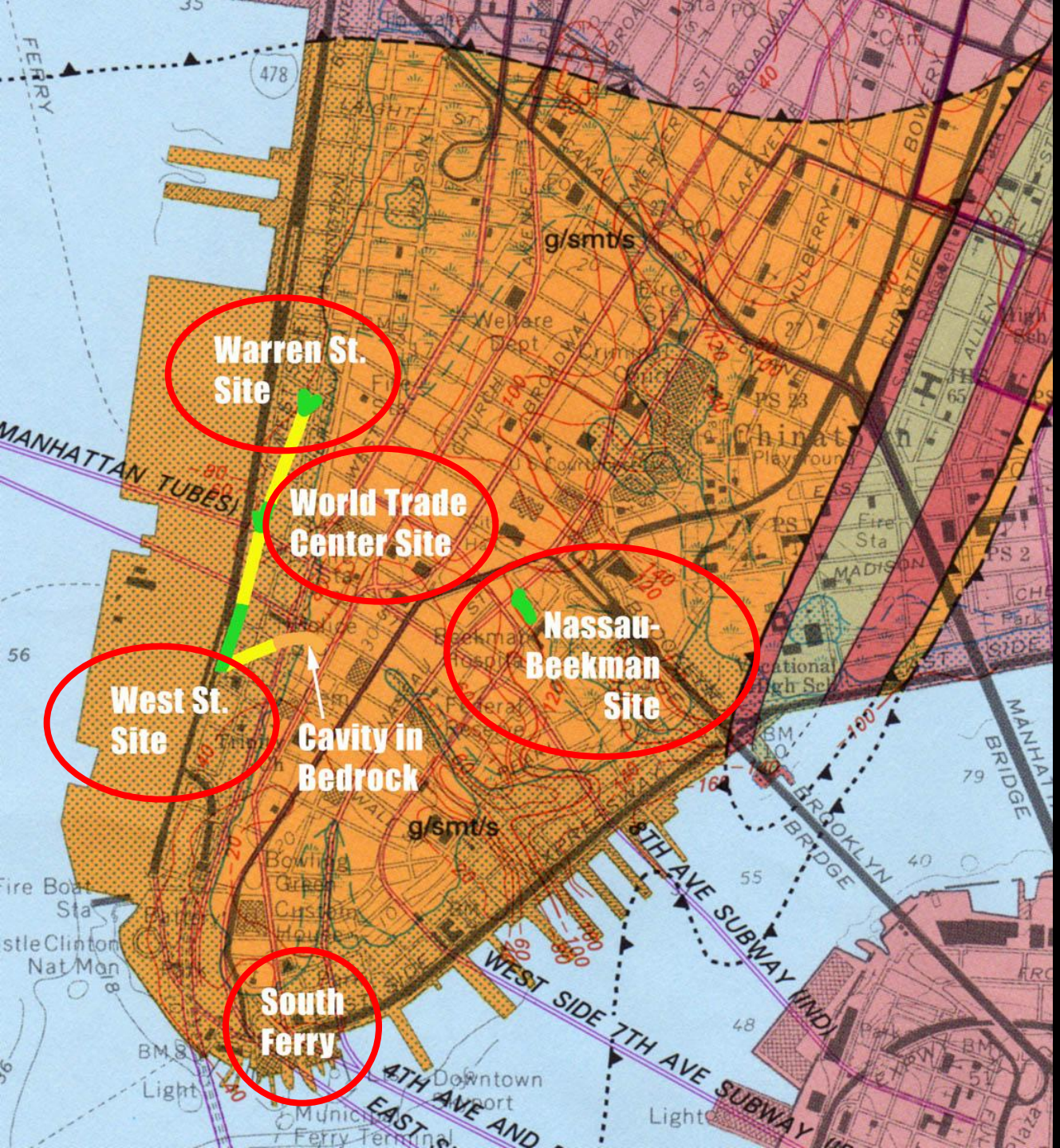

MR-4014; Run 1C
Bi
St
Mu
Bi
St
N833 C-Oh

Minerals Are Your Pals!

WTC Minerals

Plagioclase
Garnet
Staurolite
Kyanite



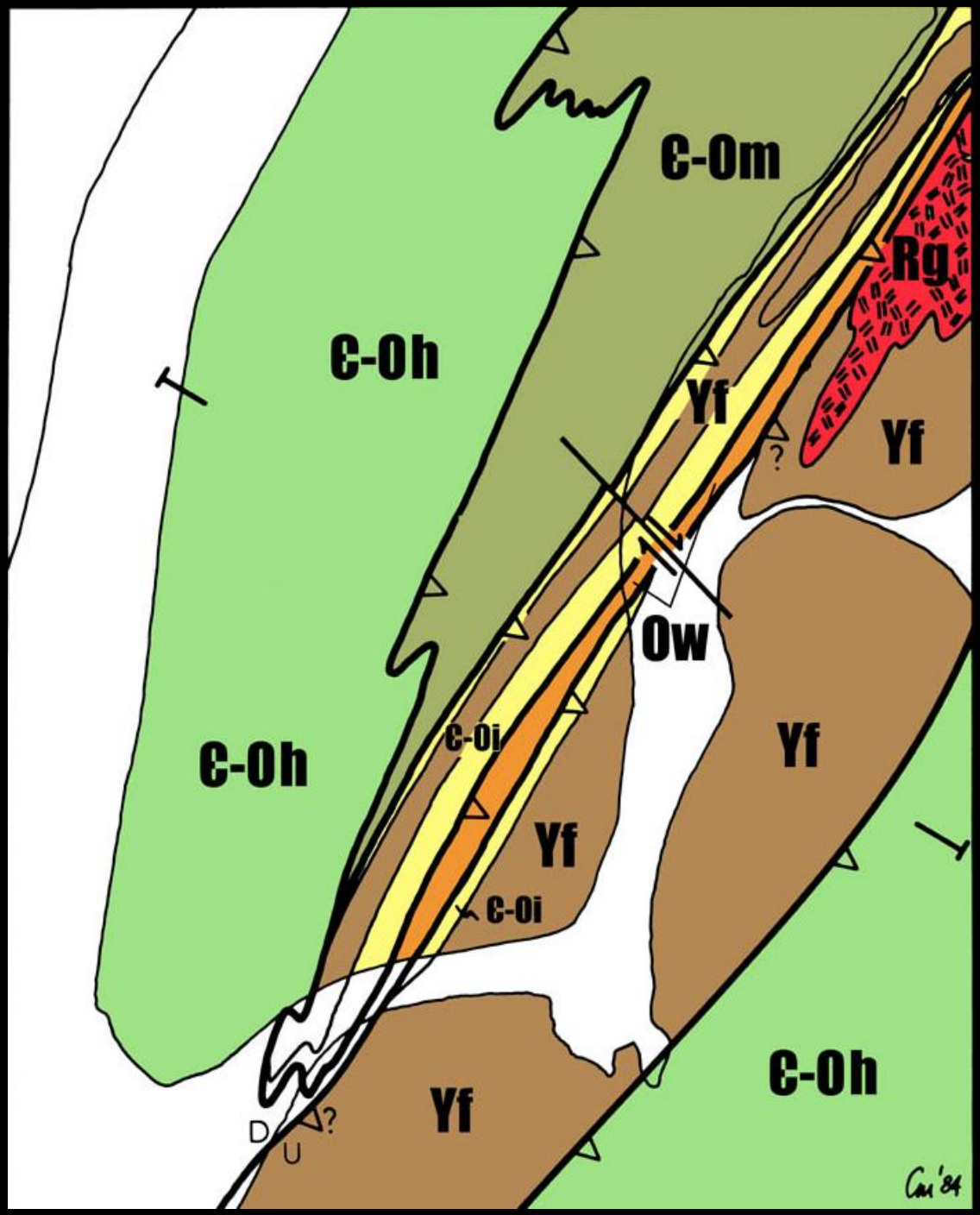


Four Main Localities South of Canal Street

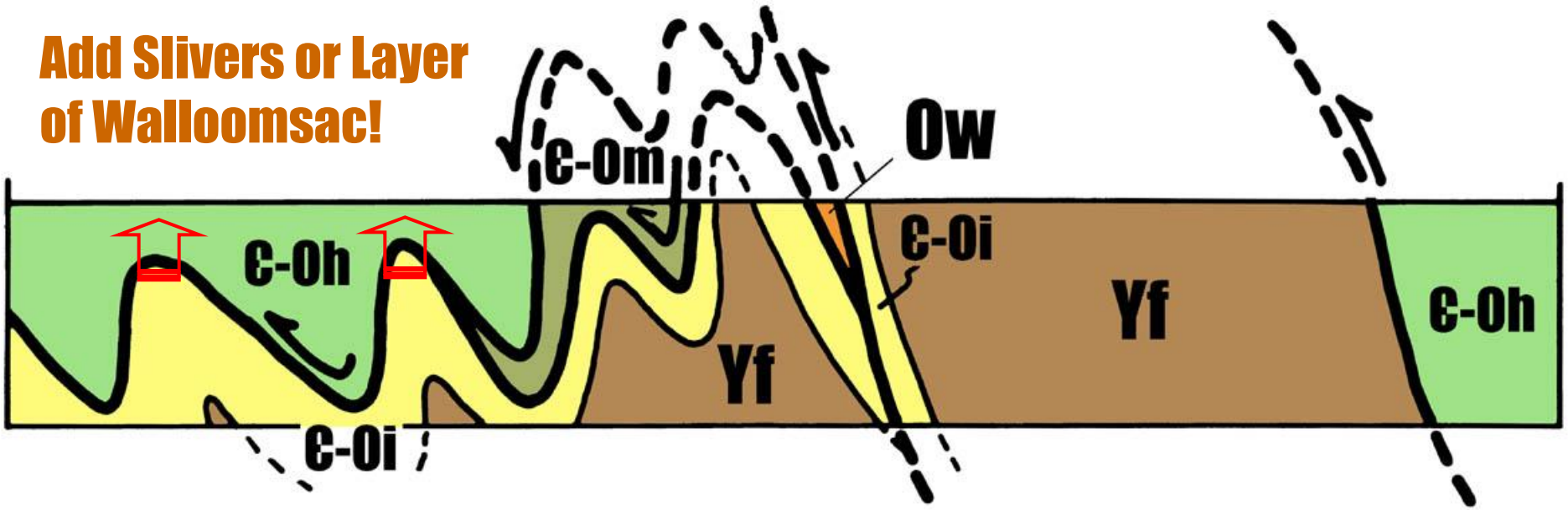
All Display Sheared Walloomsac Rocks!

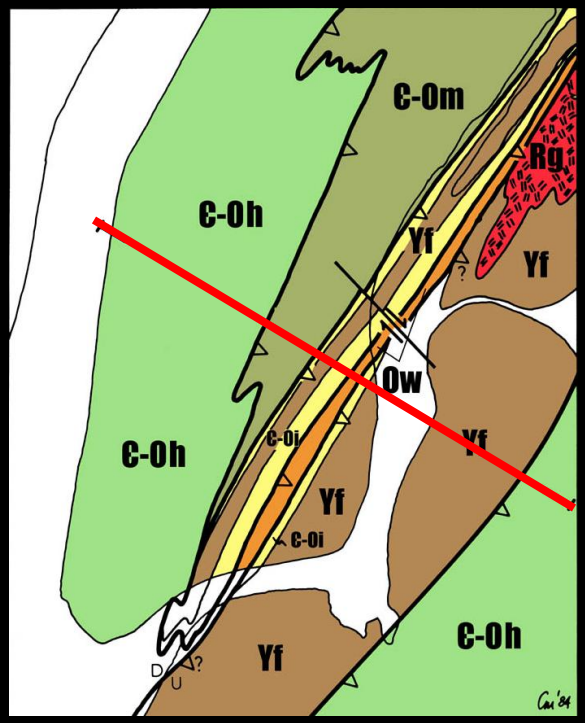
after Baskerville 1994

Berkey, 1911



Interpretive Geologic Map of SE Manhattan, Brooklyn, and Queens Based on Borings of Berkey (1910)

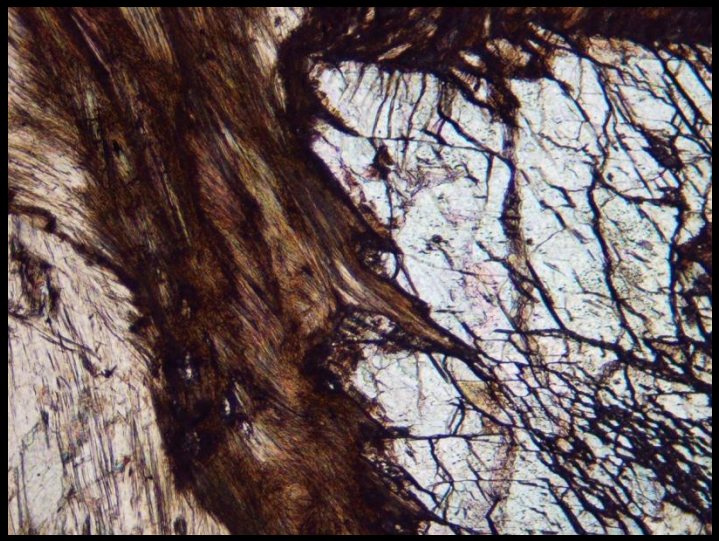


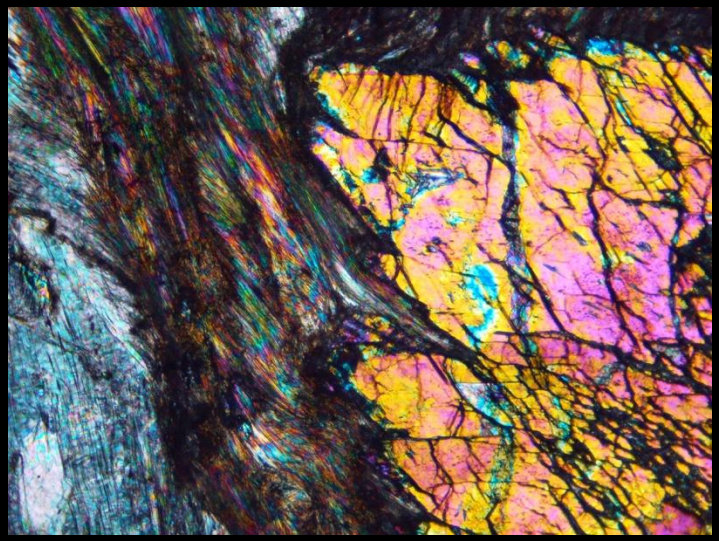


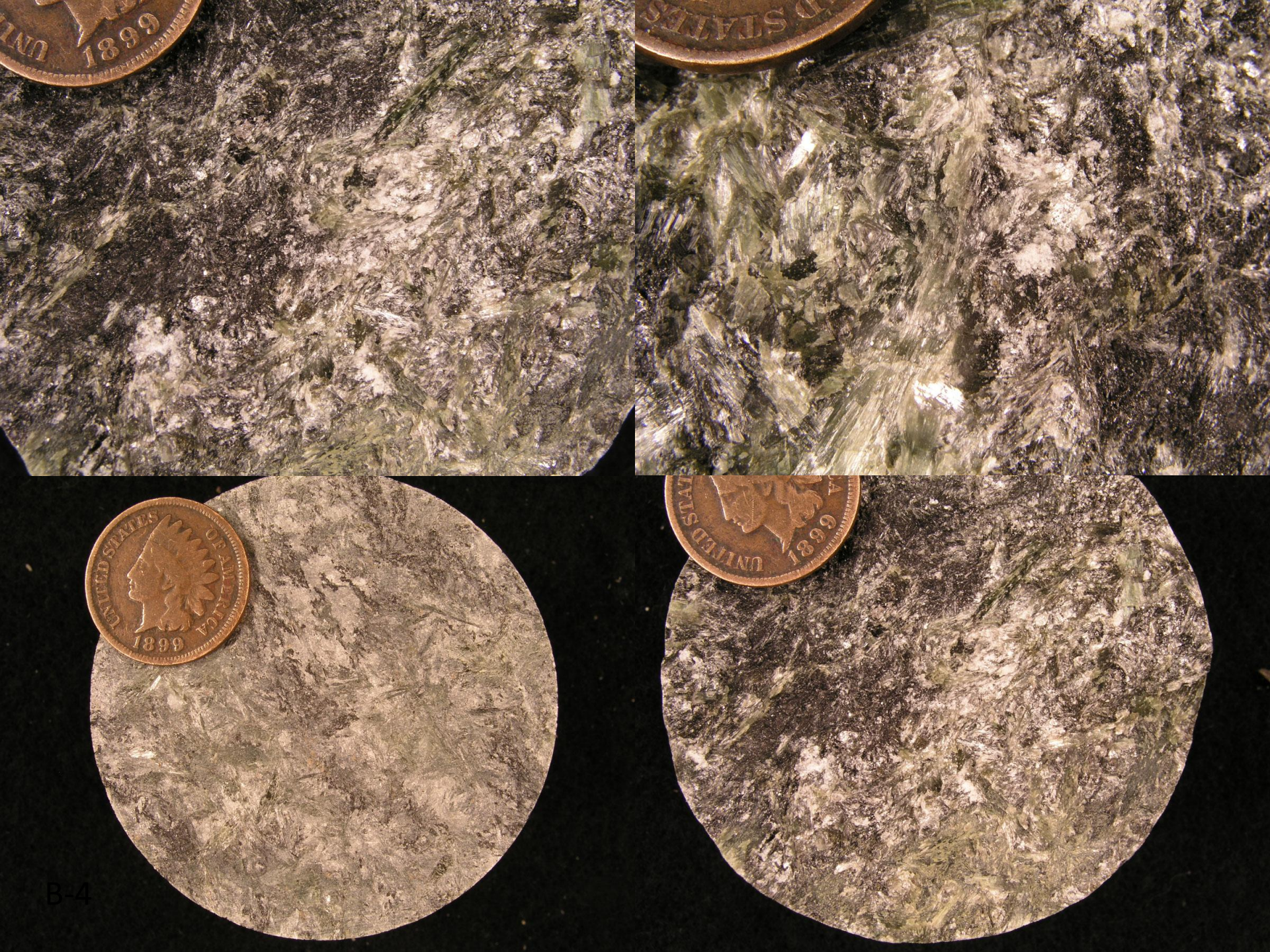
Interpretive NW-SE Geologic Section Based on Berkey 1910 Boring Data

Serpentinite Found in 40% of Borings

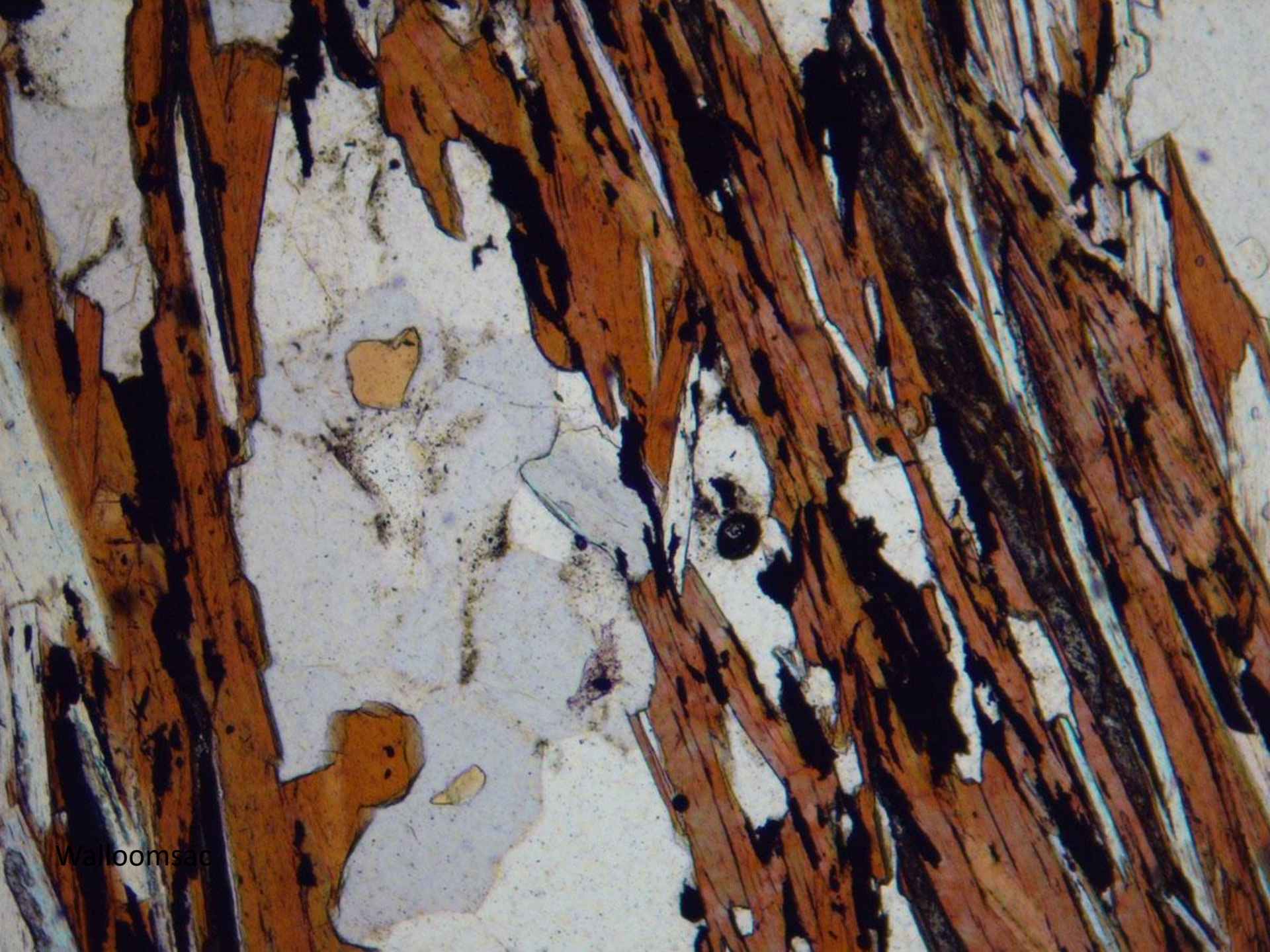
B-2 B-3 B-4 B-8 B-9 B-14

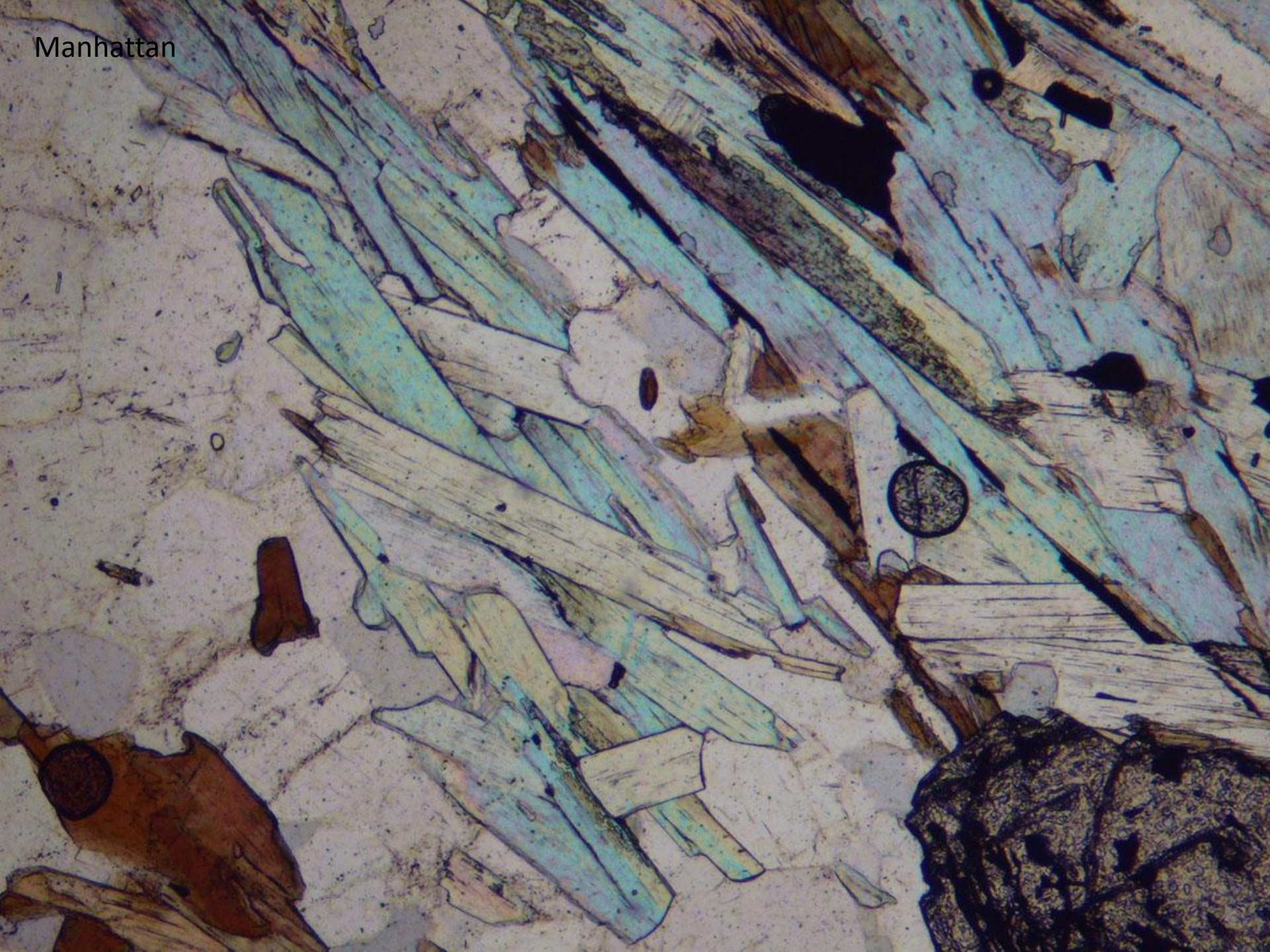


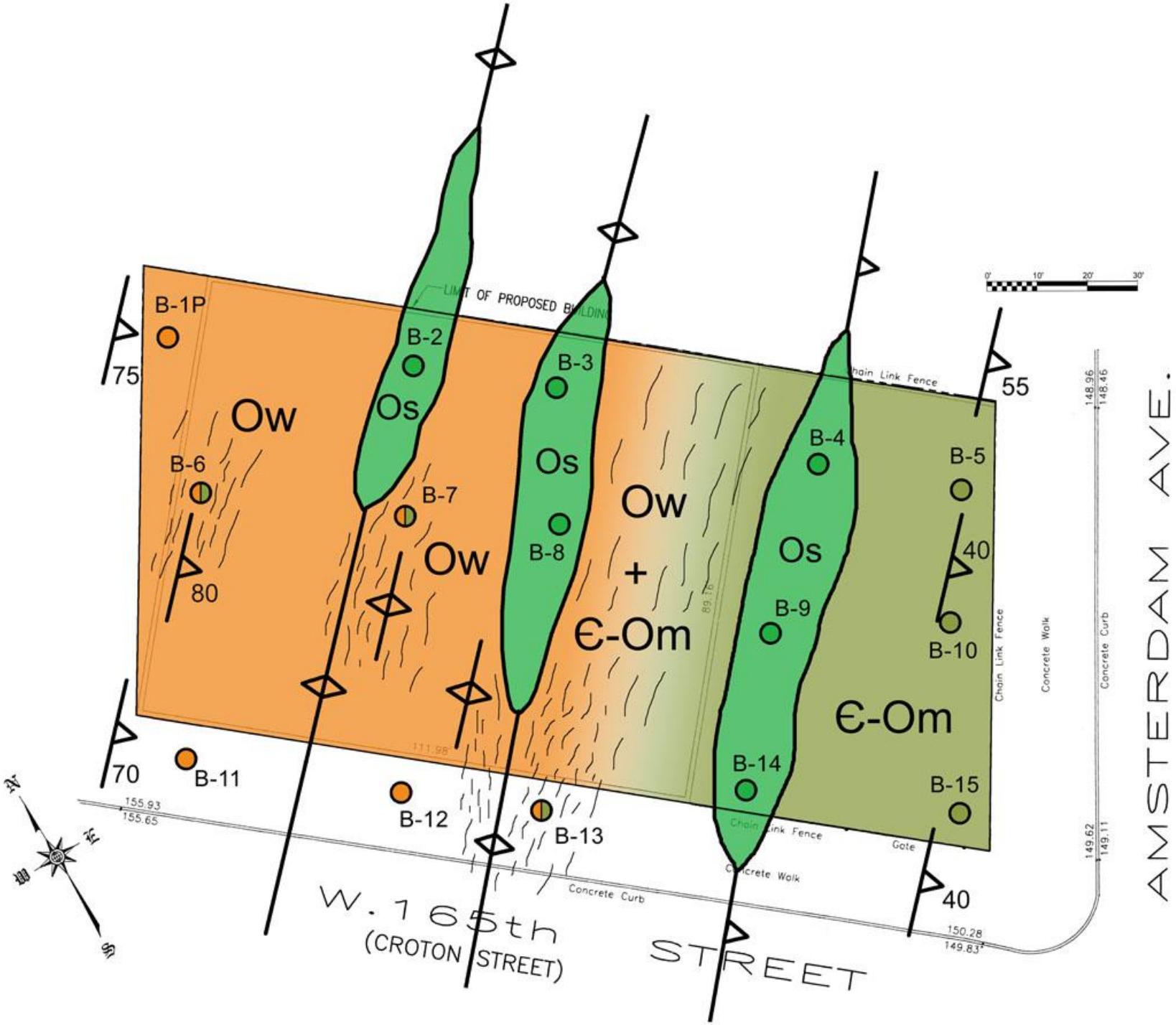


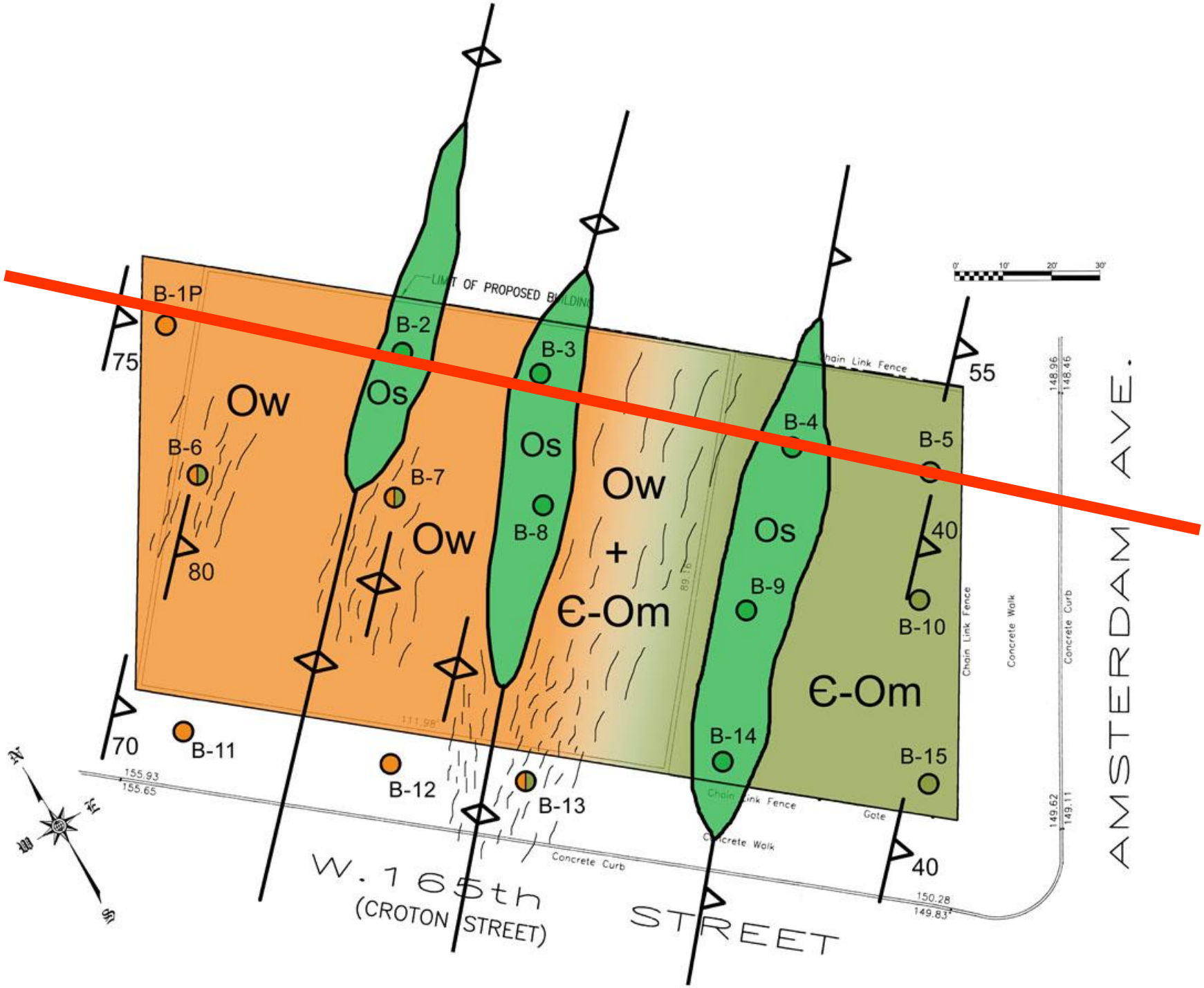


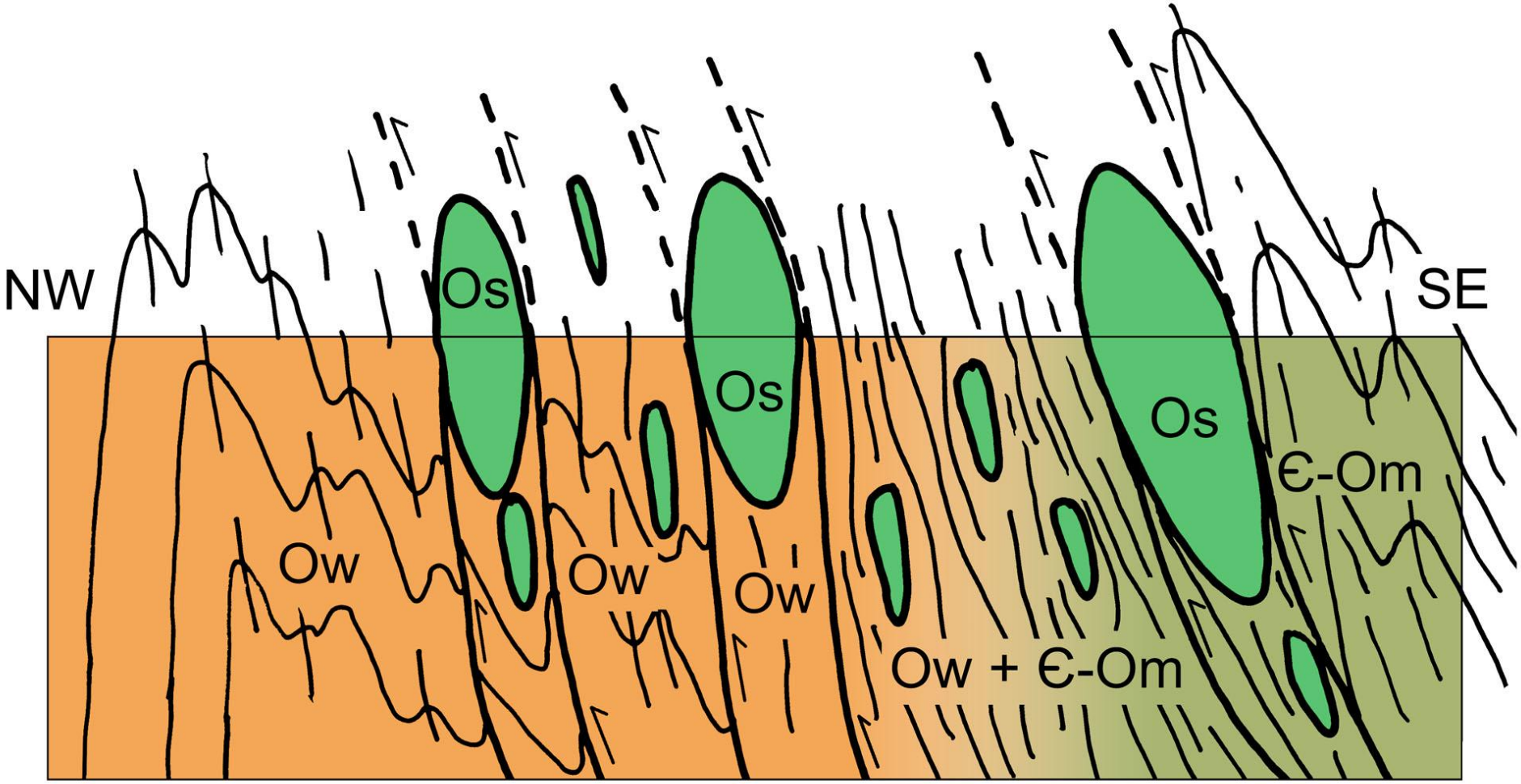
B-4


Walloomsac


Manhattan

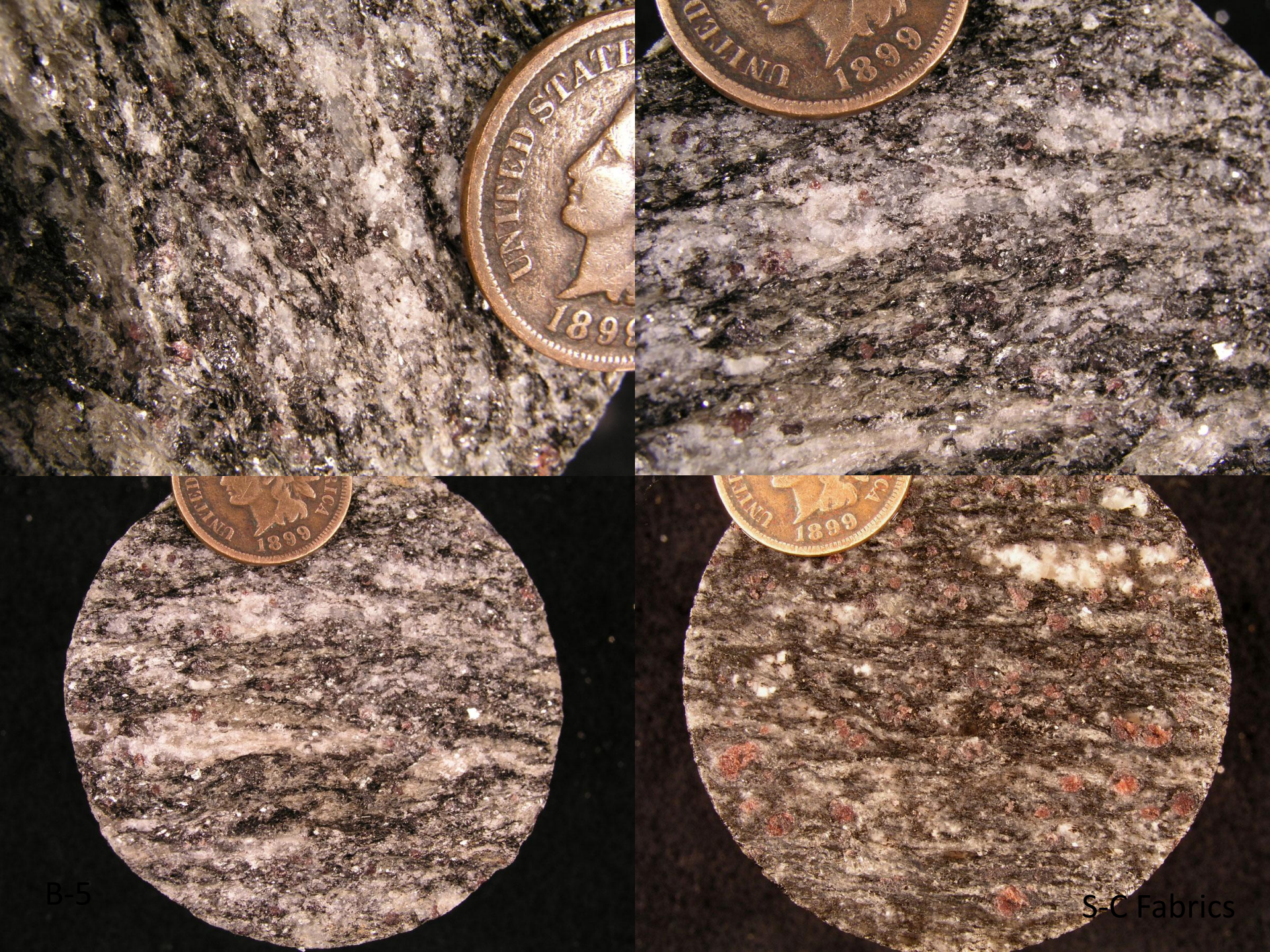

LIMIT OF PROPOSED BUILDING
B-1P
B-2
B-3
B-4
B-5
B-6
B-7
B-8
B-9
B-10
B-11
B-12
B-13
B-14
B-15
Ow
Os
Ow
Os
Ow
+
Є-Om
Os
Є-Om
75
80
70
55
40
40
Chain Link Fence
Concrete Walk
Concrete Curb
Gate
155.93
155.65
150.28
149.83
148.96
148.46
149.62
149.11
W. 165th STREET
(CROTON STREET)
AMSTERDAM AVE.
0' 10' 20' 30'

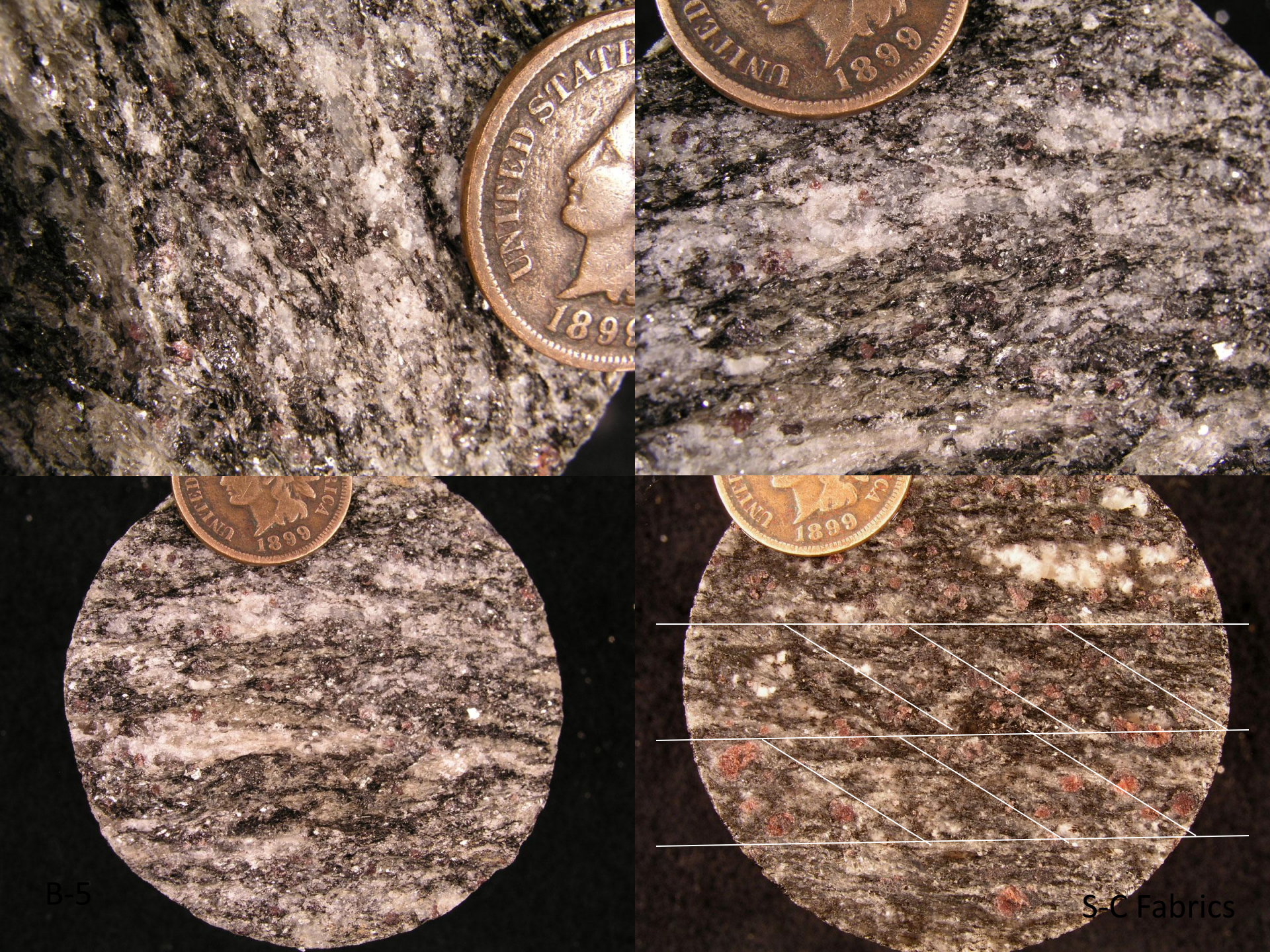

LIMIT OF PROPOSED BUILDING
B-1P
B-2
B-3
B-4
B-5
B-6
B-7
B-8
B-9
B-10
B-11
B-12
B-13
B-14
B-15
Ow
Os
Ow
Os
Ow
+
Є-Om
Os
Є-Om
75
55
80
40
70
40
Chain Link Fence
Concrete Walk
Concrete Curb
Gate
155.93
155.65
150.28
149.83
149.62
149.11
148.96
148.46
W. 165th
(CROTON STREET)
STREET
AMSTERDAM AVE.


NW
SE
Os
Os
Os
Ow
Ow
Ow
Ow + Є-Om
Є-Om

1899

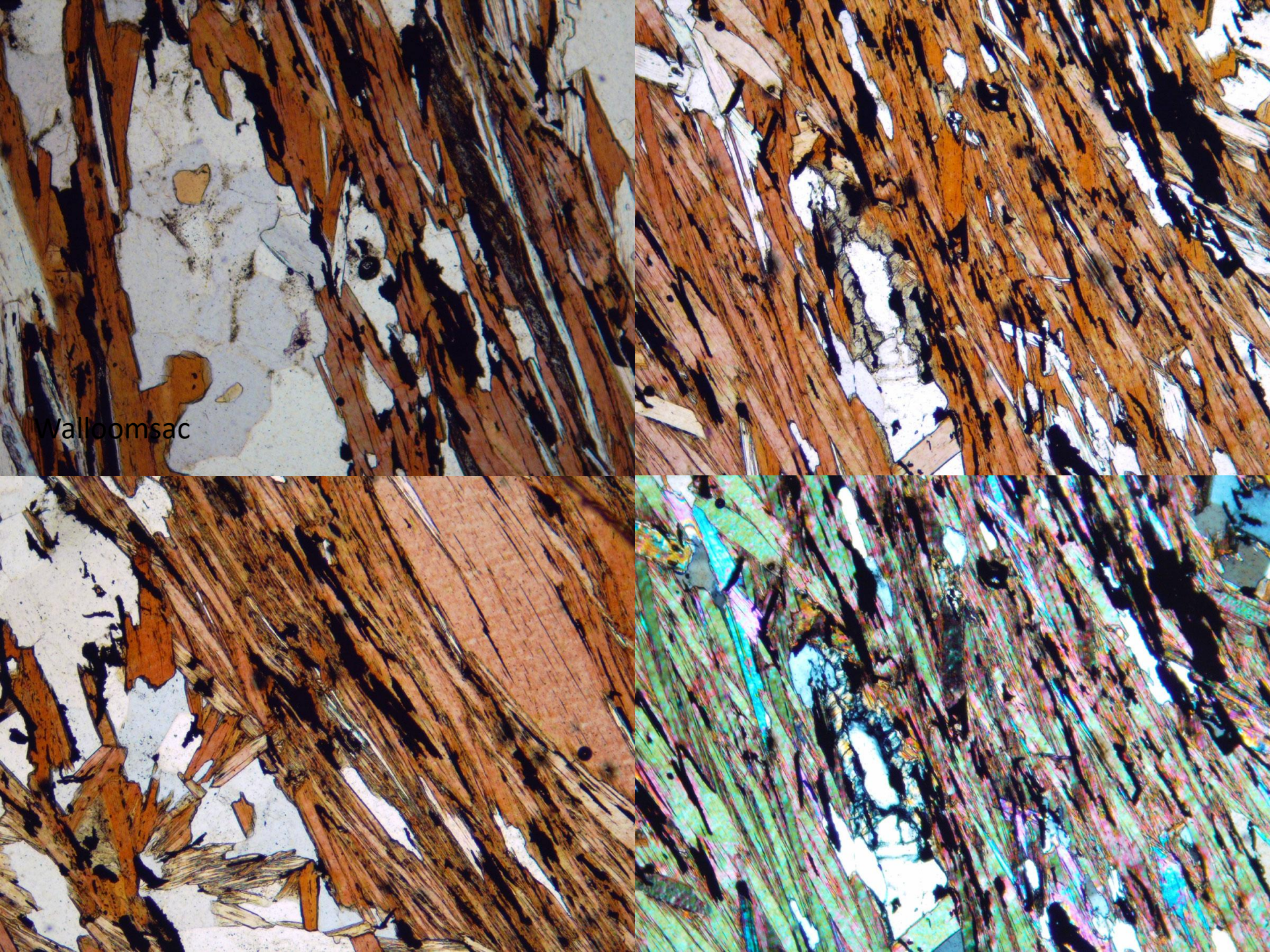
1899

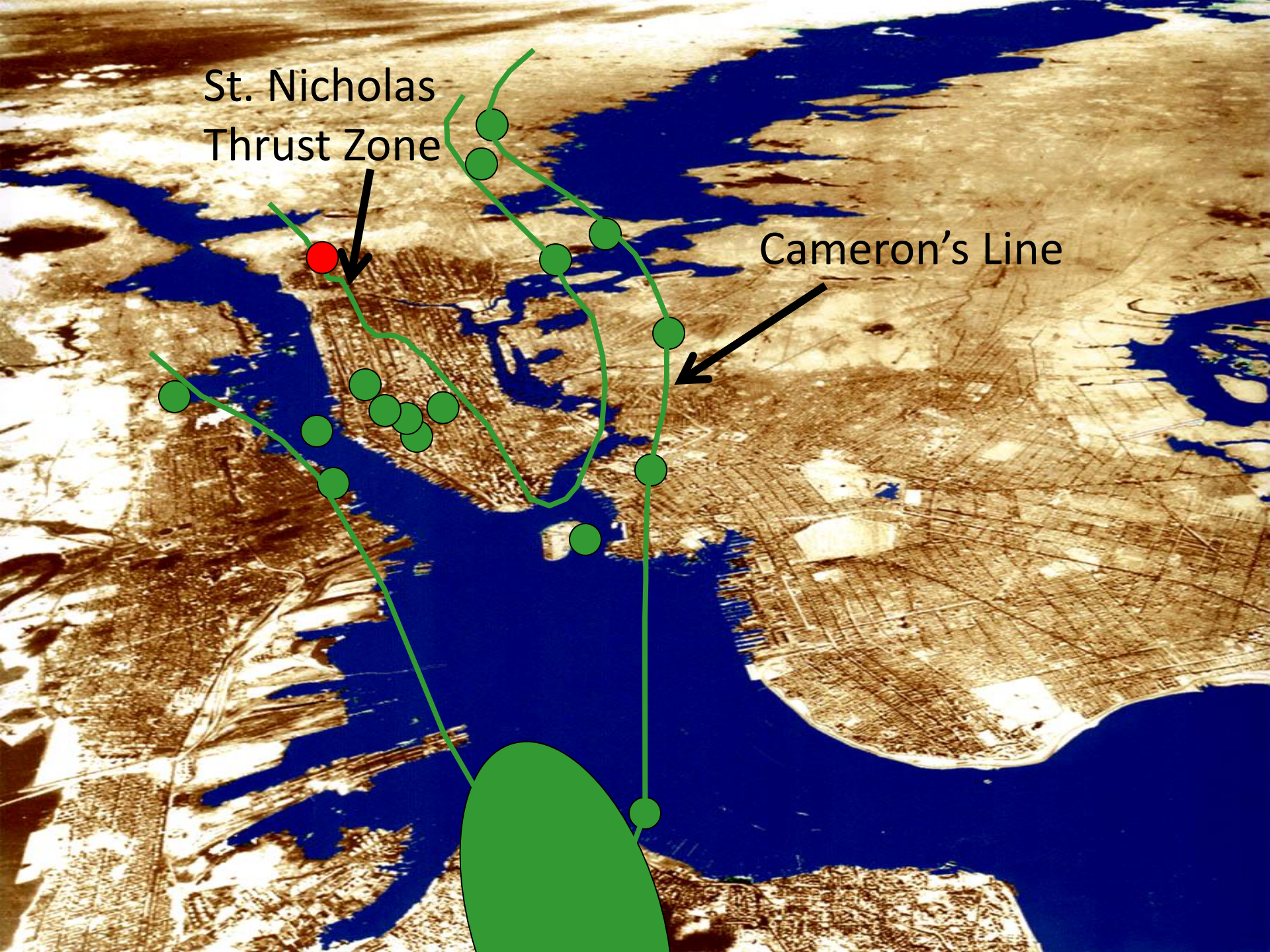

B-5
S-C Fabrics


B-5
S-C Fabrics

B-13

B-13


Walloomsac


St. Nicholas
Thrust Zone
Cameron's Line