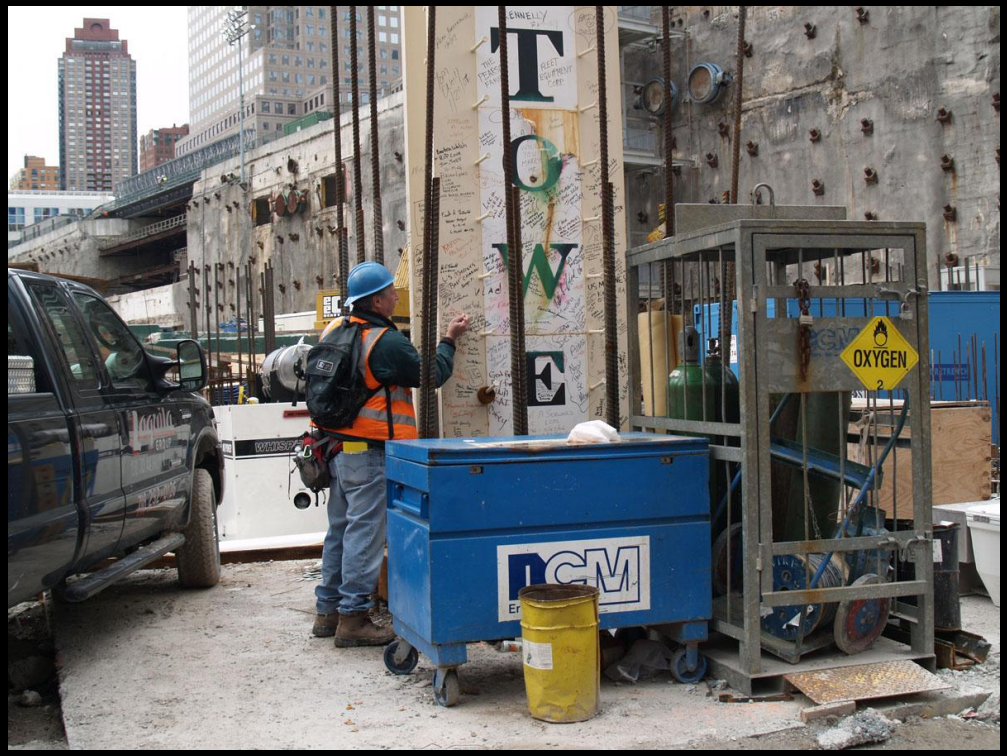
The World Trade Center Site

New Perspectives on the Geology of New York City

Charles Merguerian
Hofstra University Geology Dept.



Thanks To:

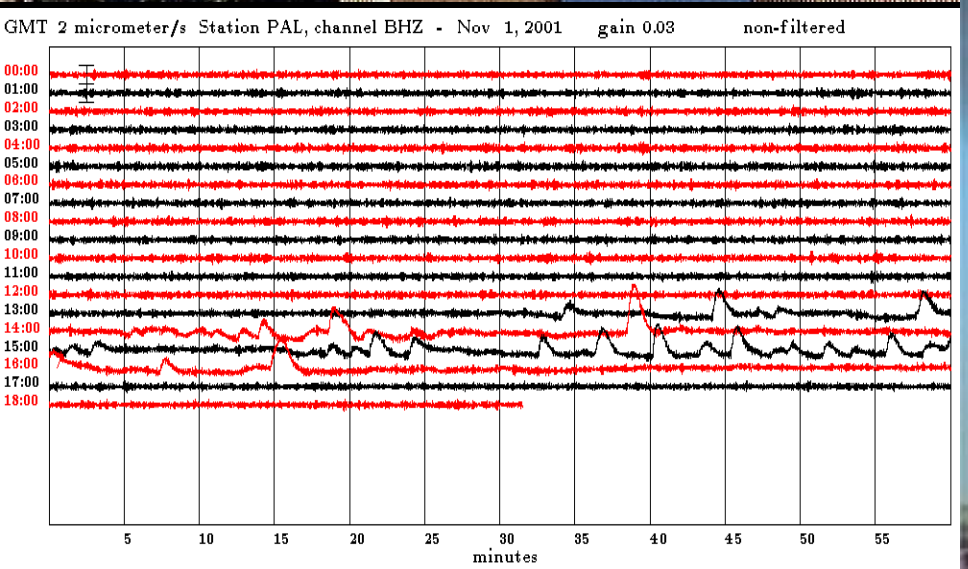
Cheryl Moss
Bob Reina
Pablo Lopez
Jim Tantalla
Mueser Rutledge
Consulting Engineers

- **Elizabeth Guise**
- **Mickey Merguerian**
- **Angel Ventrelli**
- **Courtney Melrose**
- **HCLAS FRDG Grants**
- **Many Students Over 29 Years at Hofstra**

Some Still With Us!

and, the "get-it-done" staff at Duke Geological Laboratory in Westbury, NY


Dukelabs
“We’re Not Good, But We’re Slow”

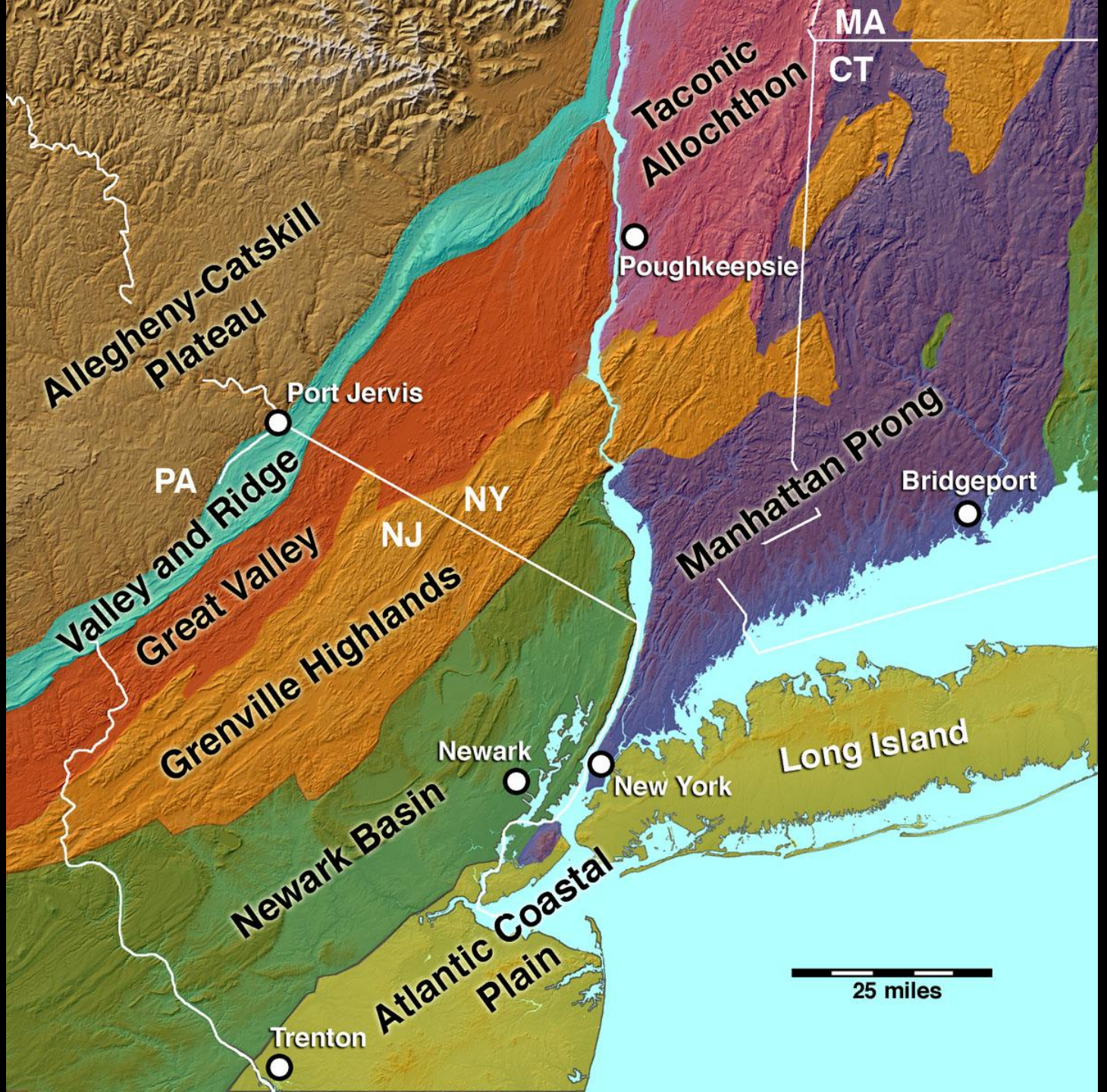

GMT 2 micrometer/s Station PAL, channel BHZ - Nov 1, 2001 gain 0.03 non-filtered
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
5
10
15
20
25
30
35
40
45
50
55
minutes

The New World Trade Center Plan

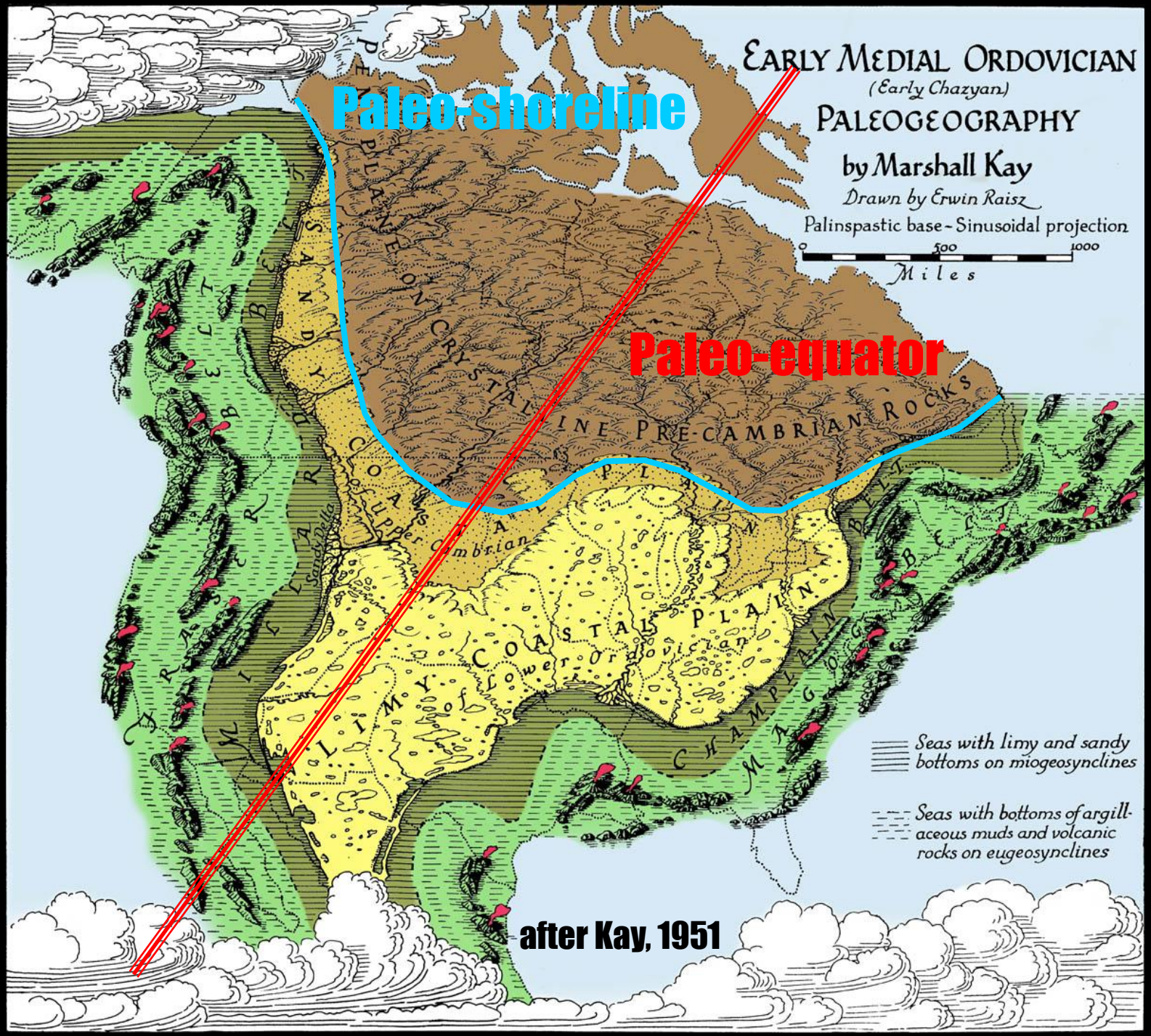
As Described by *Bela Lugosi* in "The Black Cat" (1934)

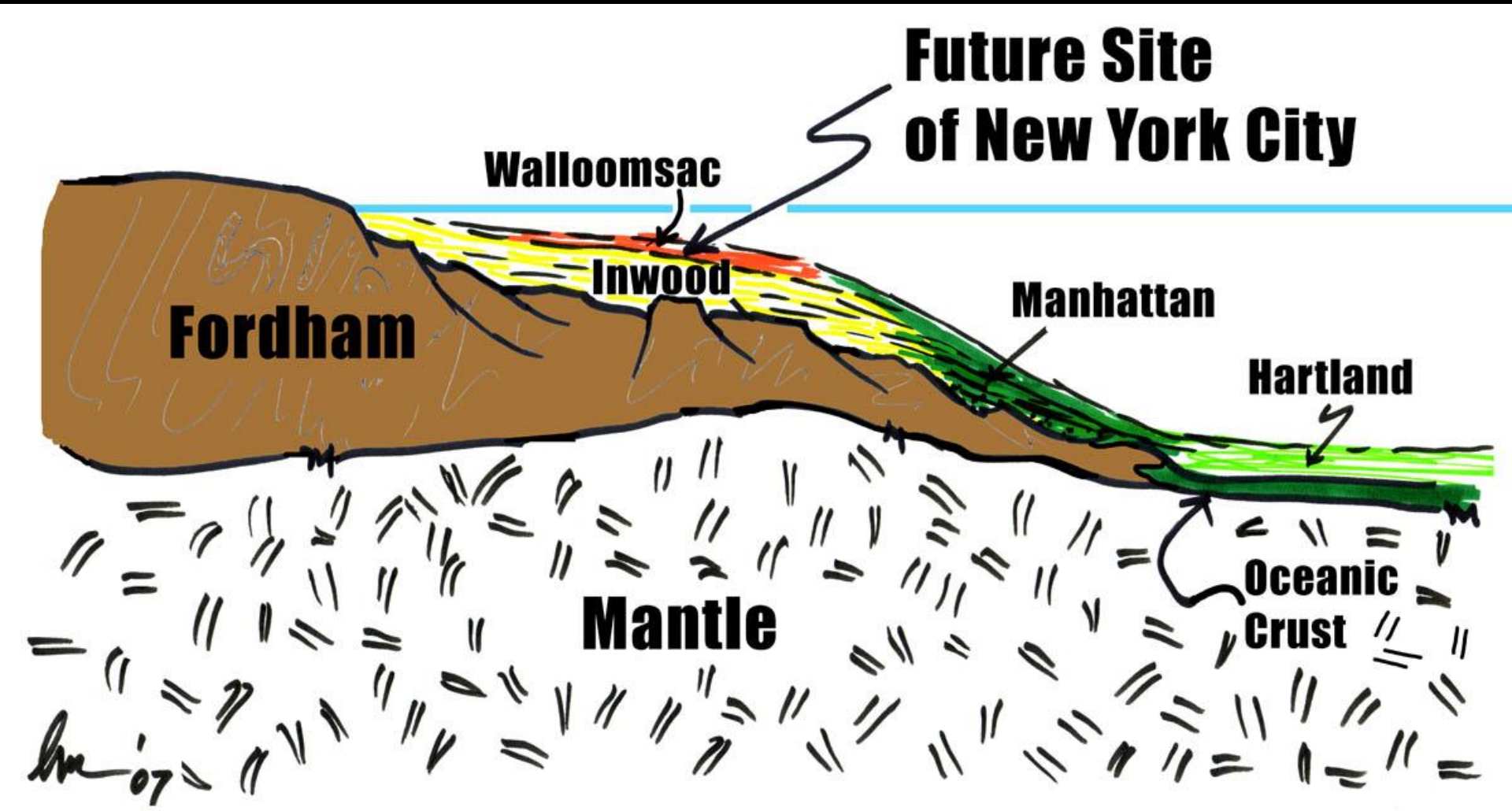
The History Channel: Super City – New York
22 September 2008

Hollywood Fat Cat Merguerian and Direcor of Opertions Genevieve Glasson at Geology Department “Hammy” Awards Presentation (2008)

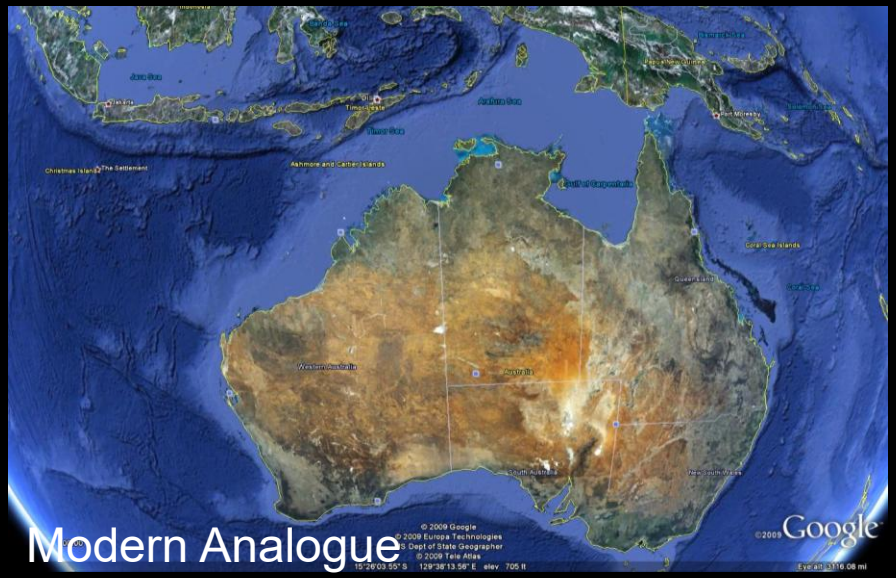

MA
CT
Taconic Allochthon
Poughkeepsie
Allegheny-Catskill Plateau
Port Jervis
PA
NY
NJ
Valley and Ridge
Great Valley
Grenville Highlands
Manhattan Prong
Bridgeport
Newark
New York
Long Island
Newark Basin
Atlantic Coastal Plain
Trenton
25 miles

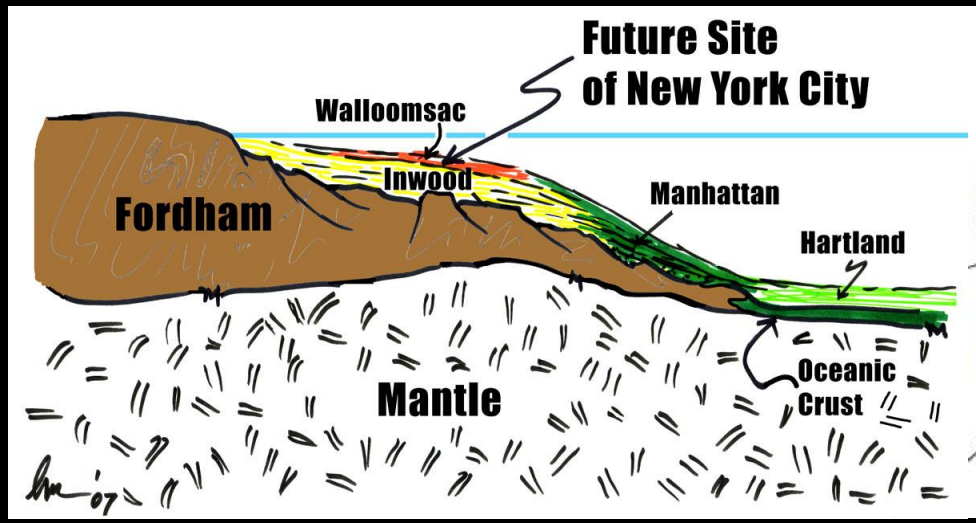
Let's Go Back In Time From Today to the Cambrian!

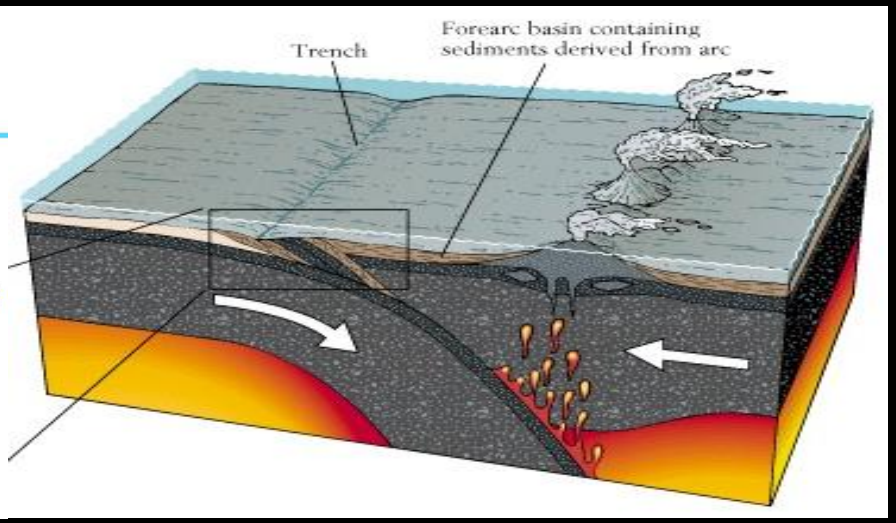

Paleo-shoreline
Paleo-equator
EARLY MEDIAL ORDOVICIAN
(Early Chazyan)
PALEOGEOGRAPHY
by Marshall Kay
Drawn by Erwin Raisz
Palinspastic base - Sinusoidal projection
500
1000
Miles
PENEPLANED CRYSTALLINE PRE-CAMBRIAN ROCKS
SANDY COASTAL PLAIN of Upper Cambrian
LIMY COASTAL PLAIN of Lower Ordovician
CHAMPLAIN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

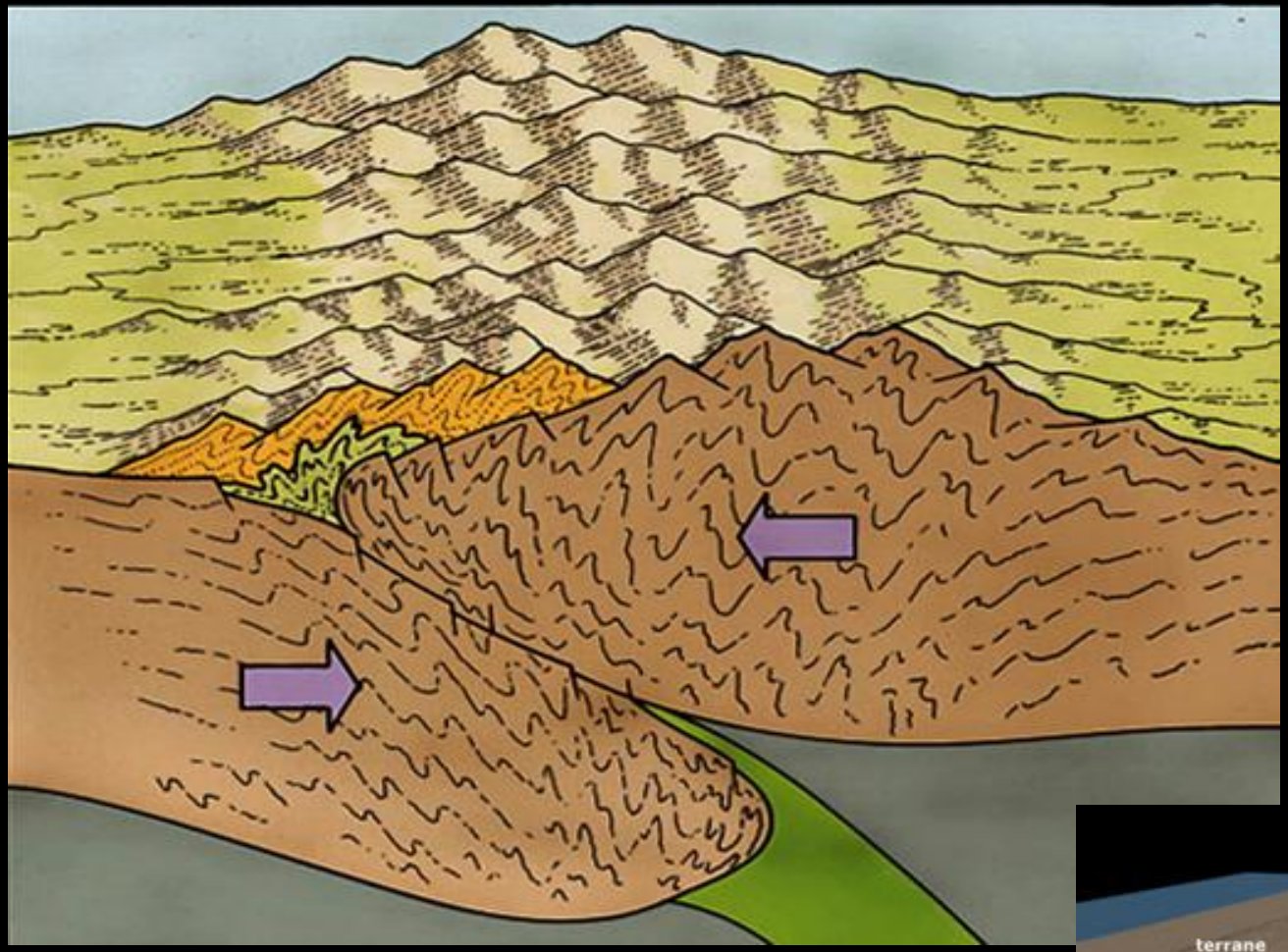

Future Site
of New York City
Walloomsac
Inwood
Fordham
Manhattan
Hartland
Oceanic
Crust
Mantle
'07

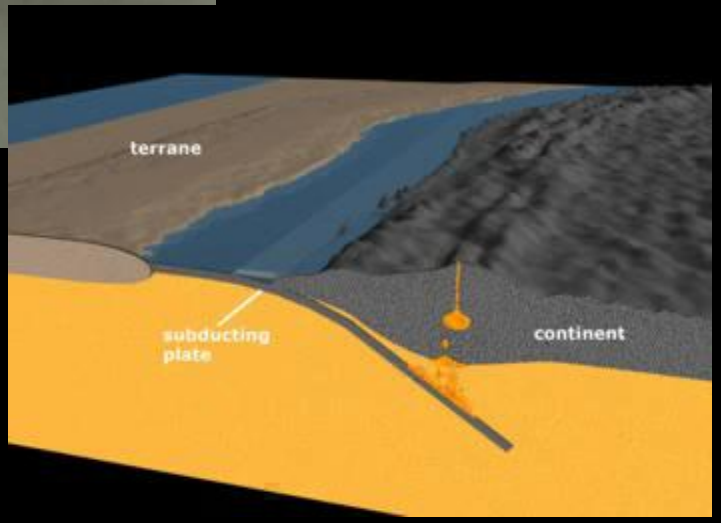
~ 480 Ma Taconian Arc – Passive Margin Collision





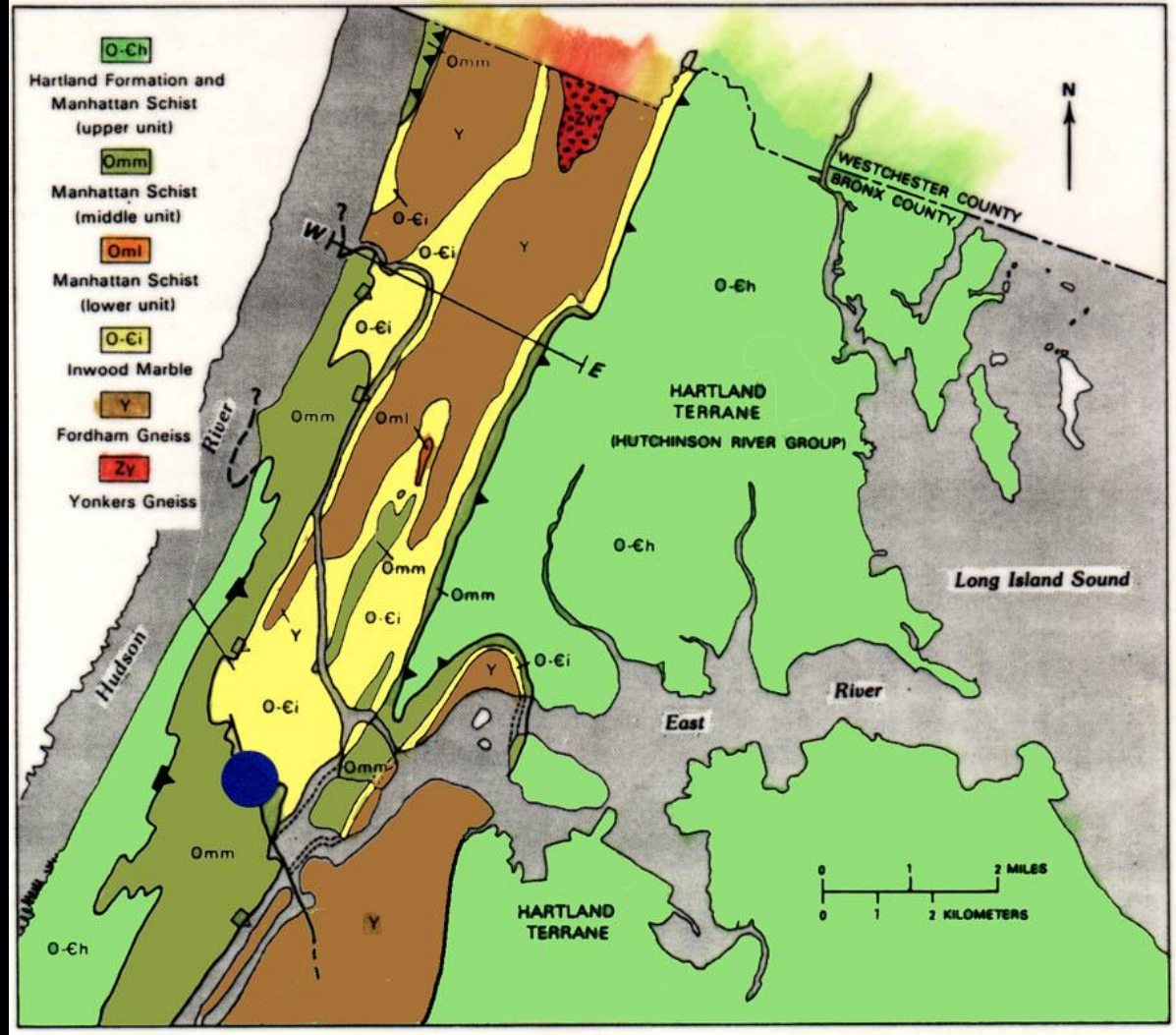


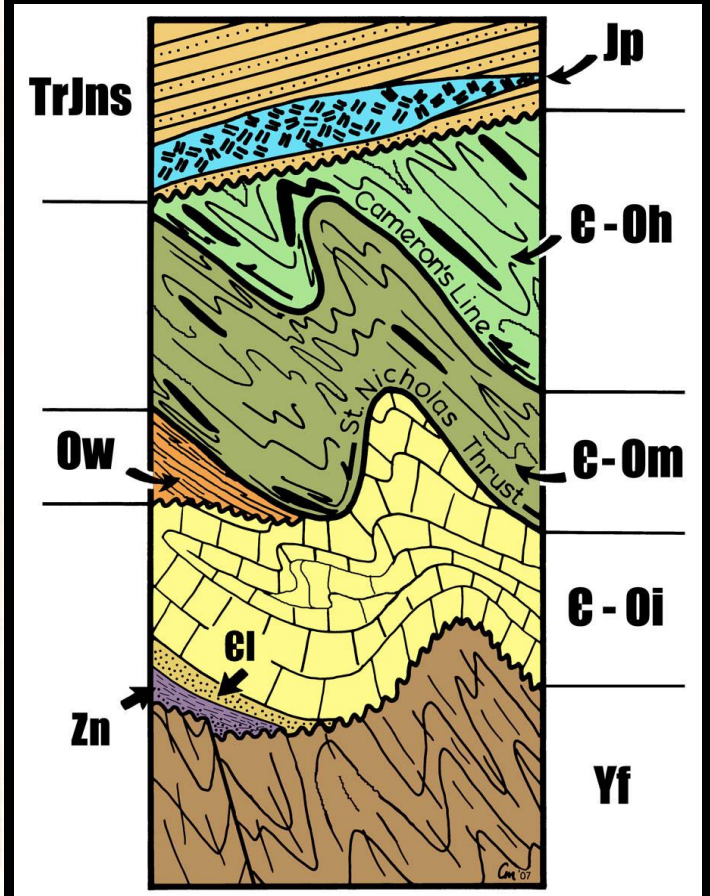


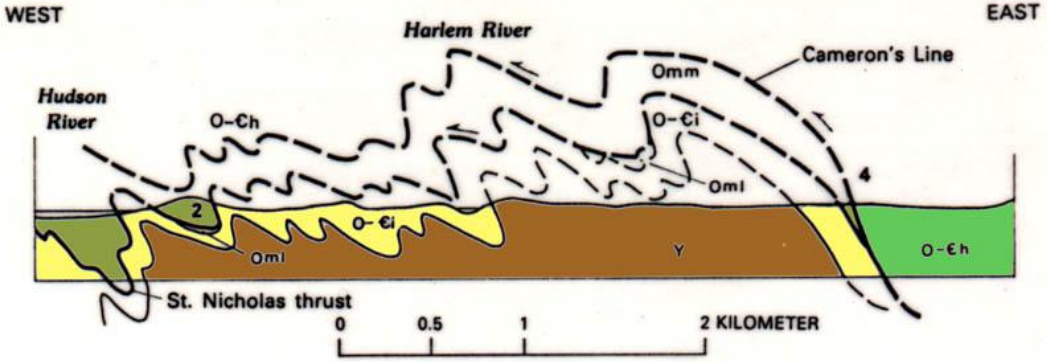


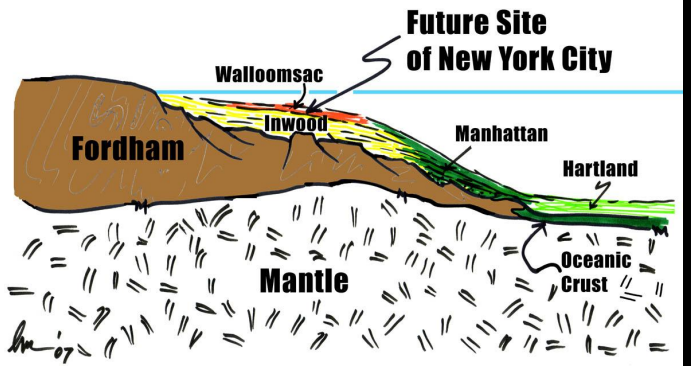
450 Ma to 250 Ma Protracted Plate Collisions Produce the Appalachians

New York City





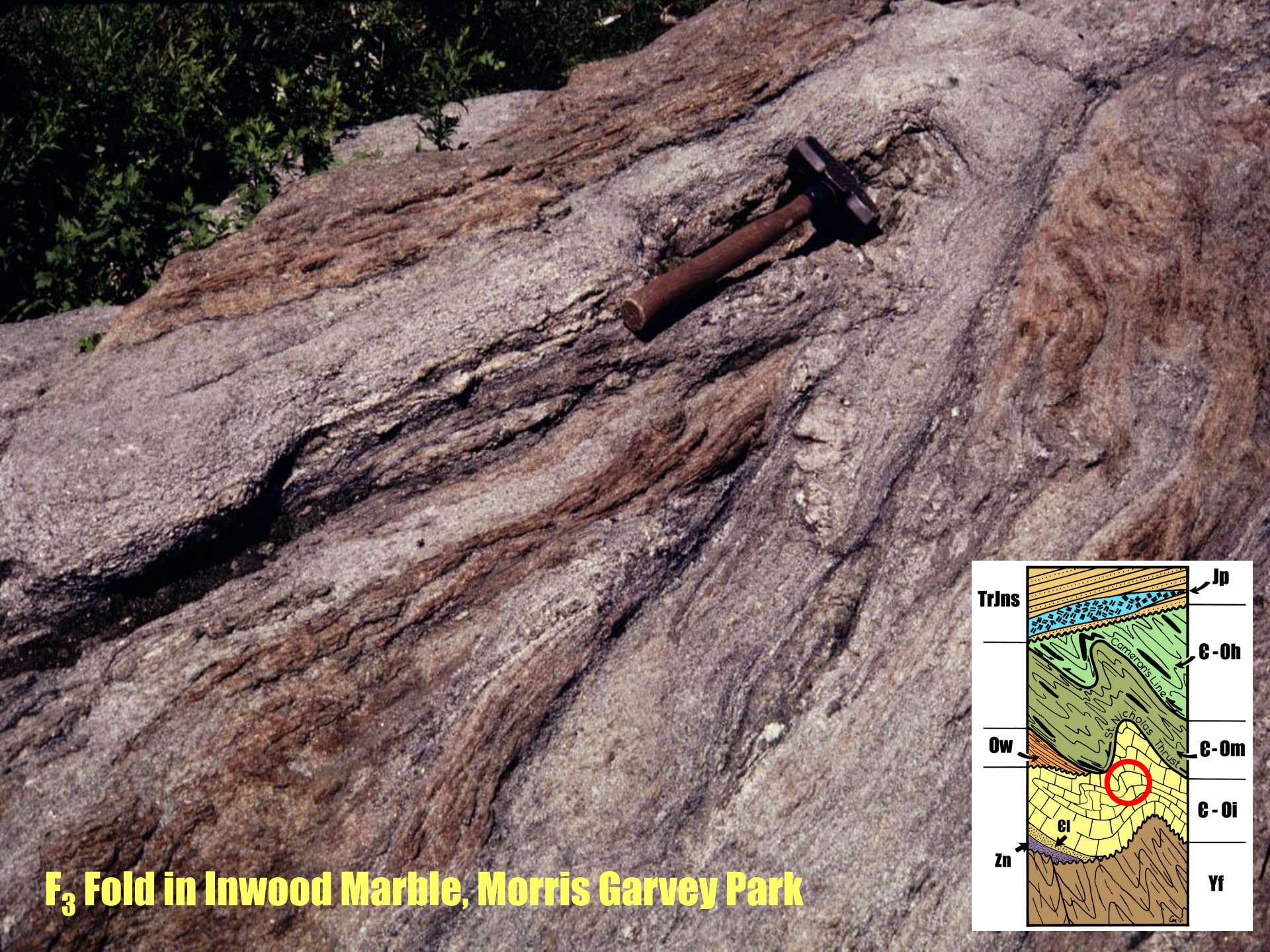





Fordham Gneiss, Echo Park

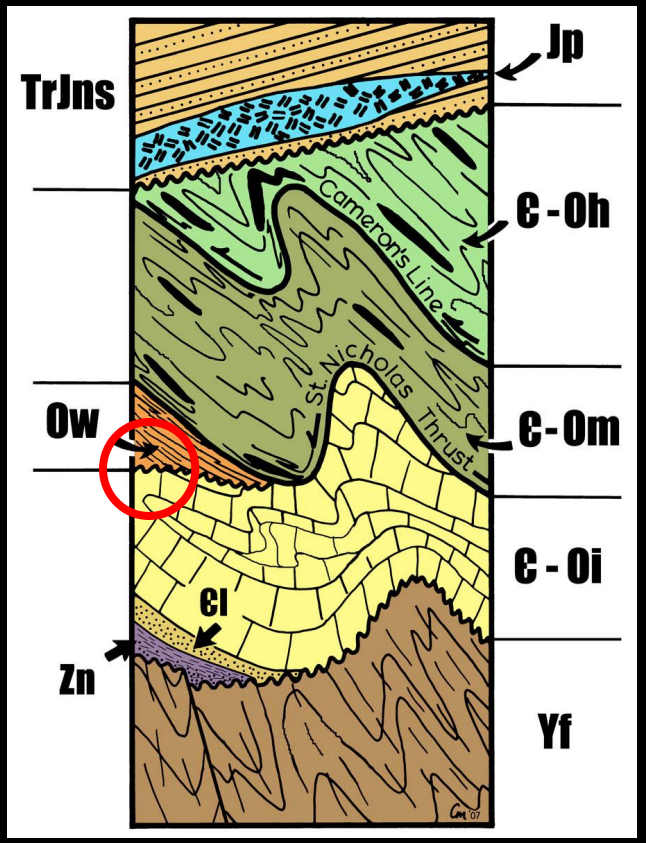
TrJns
Jp
Cameron's Line
Nicholas Thrust
Ow
Zn
Yf


108+30
108+35
Queens Tunnel Gneiss - Sta. 108+31 LW
TrJns
Jp
Cameron's Line
Nicholas Thrust
Ow
Zn
Yf



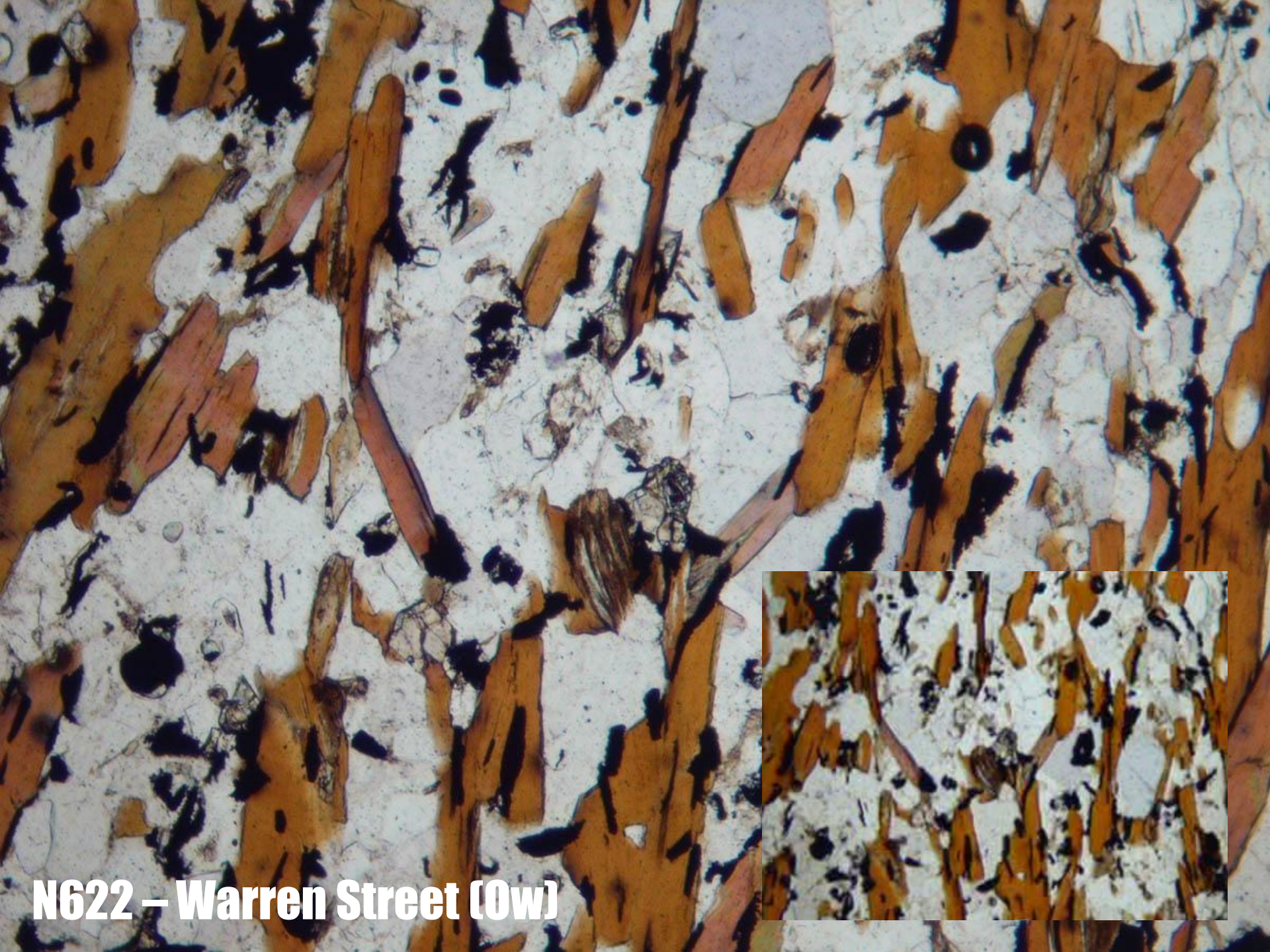
F_3 Fold in Inwood Marble, Morris Garvey Park

N631 – Warren Street (Ow)

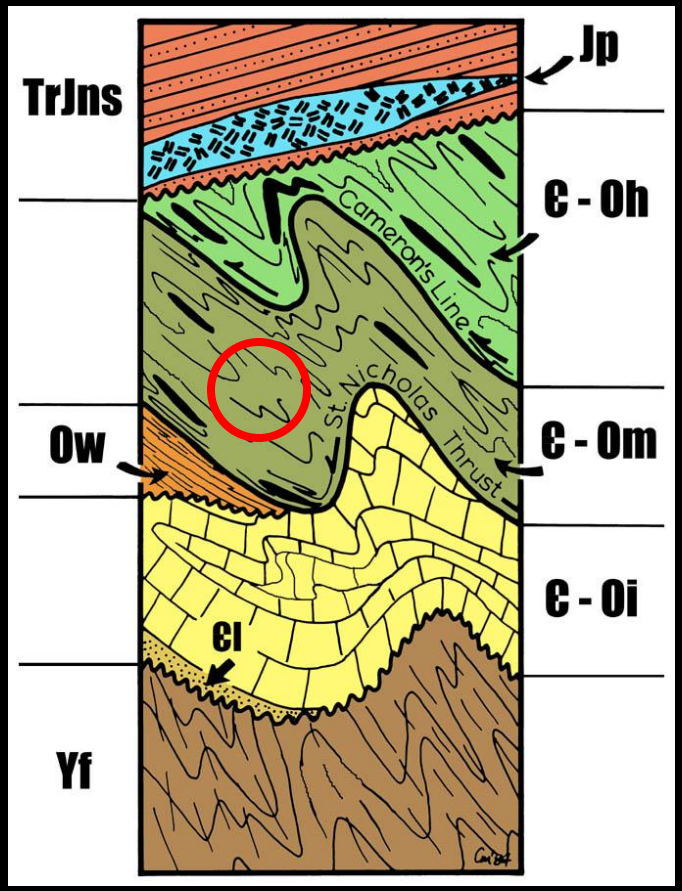


Schist
Granofels
Calc-silicate
Calcite Marble

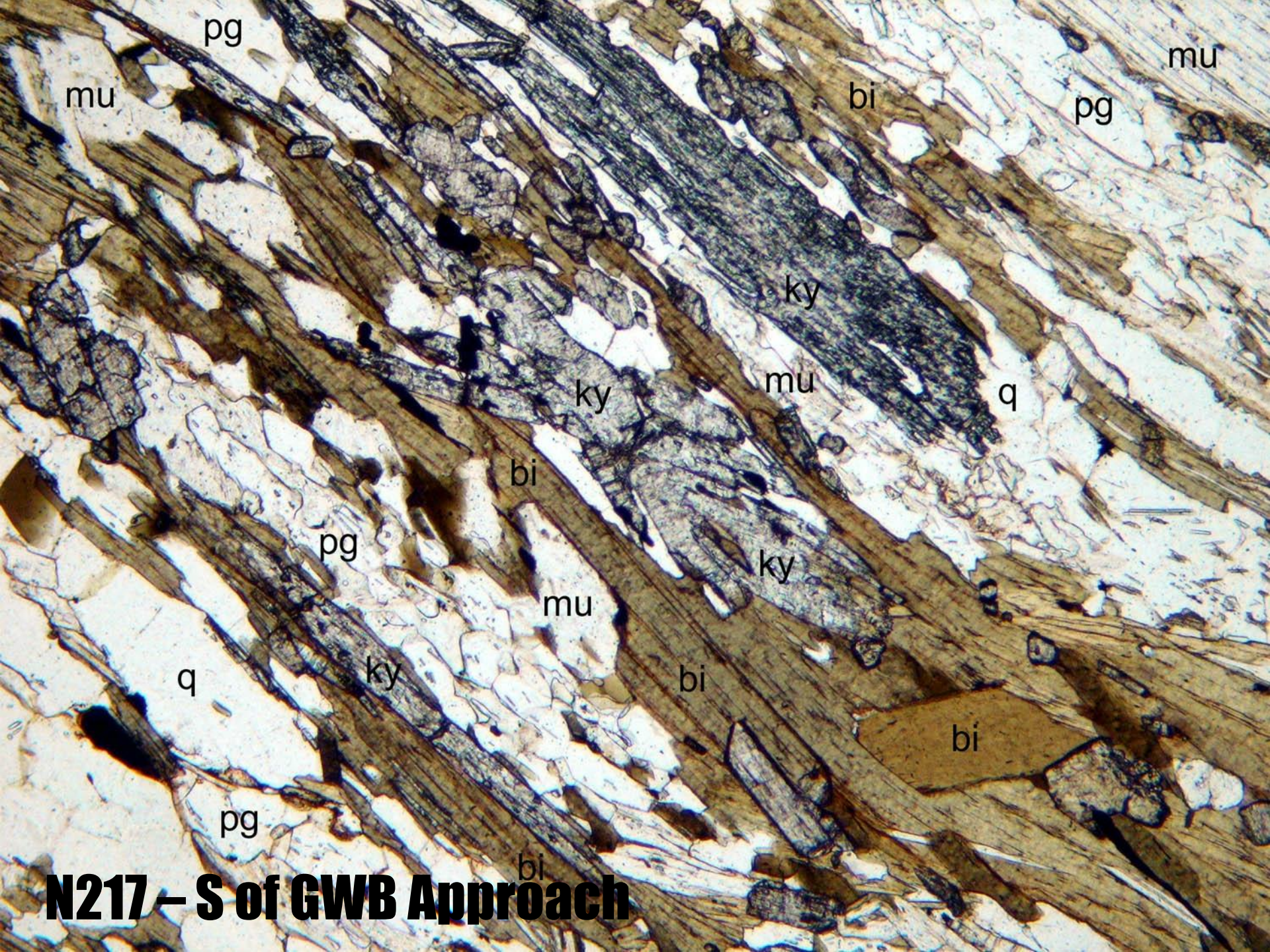
Walloomsac "Balmville" Contact, Grand Concourse, Bronx, NY



N622 – Warren Street (Ow)

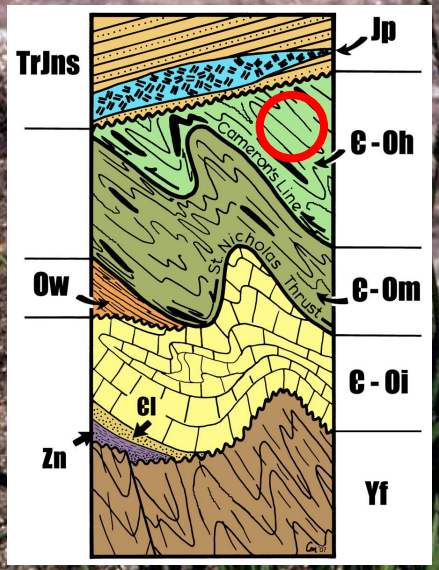


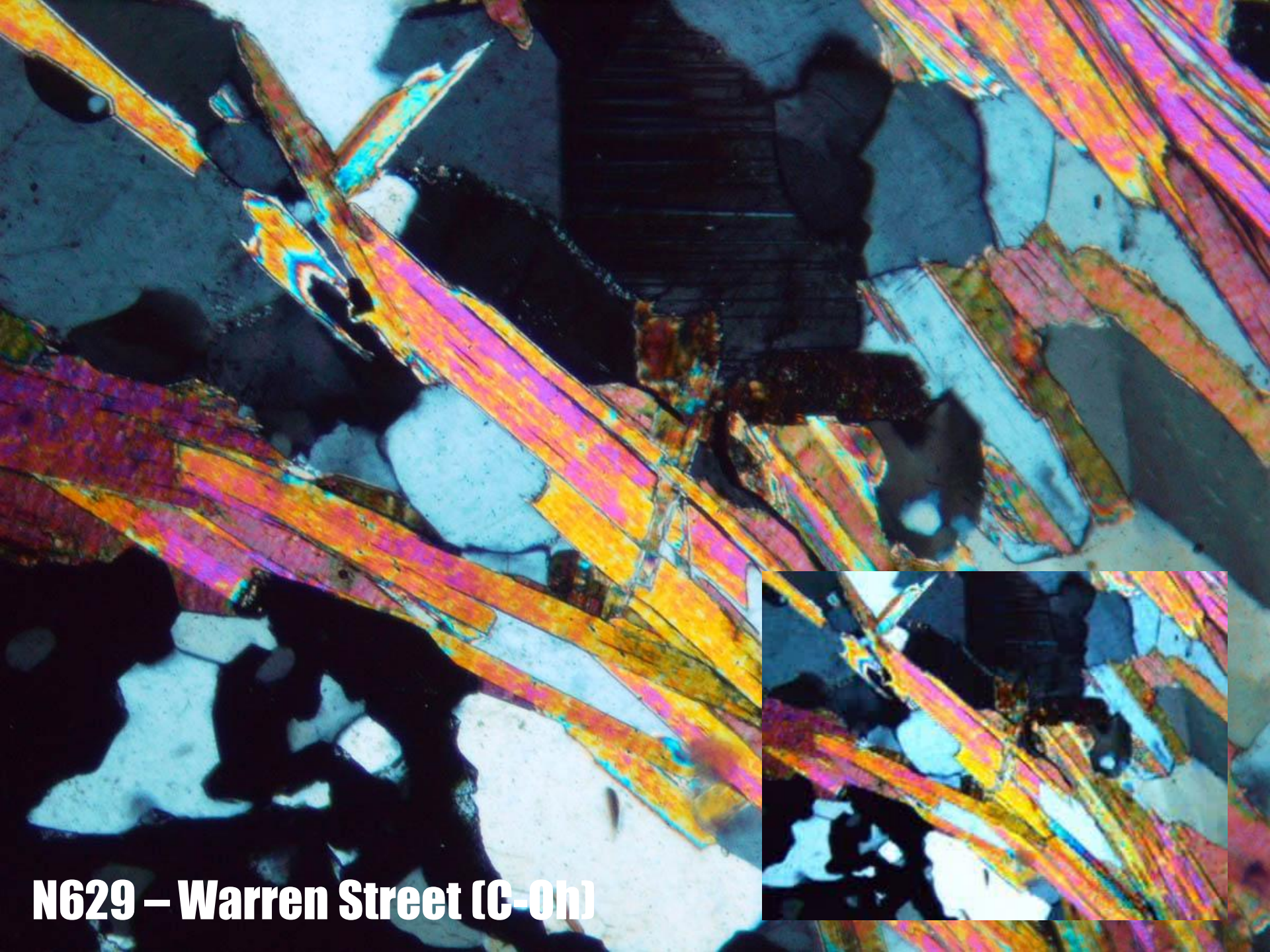
Manhattan Schist
F_3 Folds of S_2
Central Park, NYC

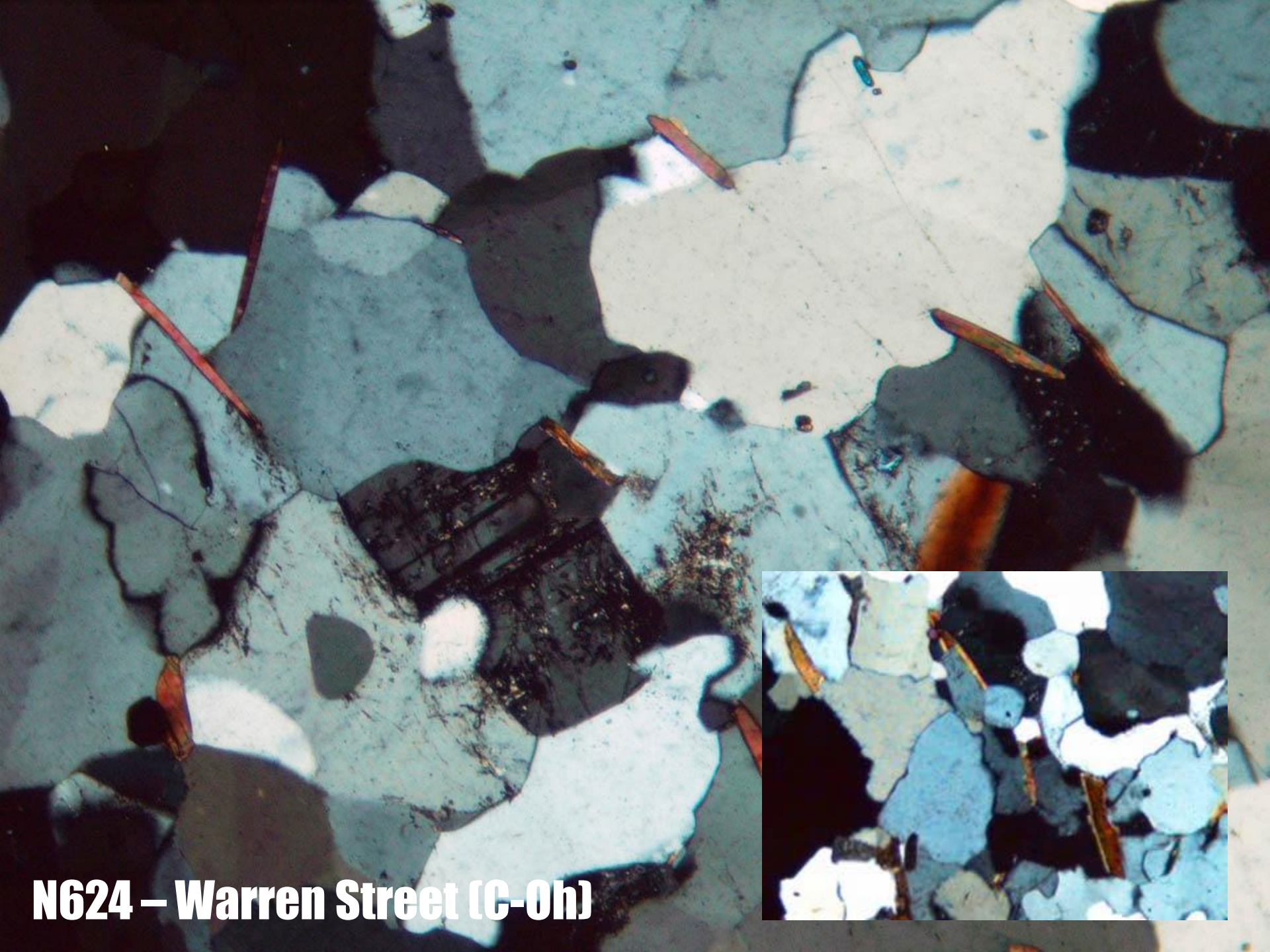


N217 – S of GWB Approach

Hartland Schist, Riverside Park

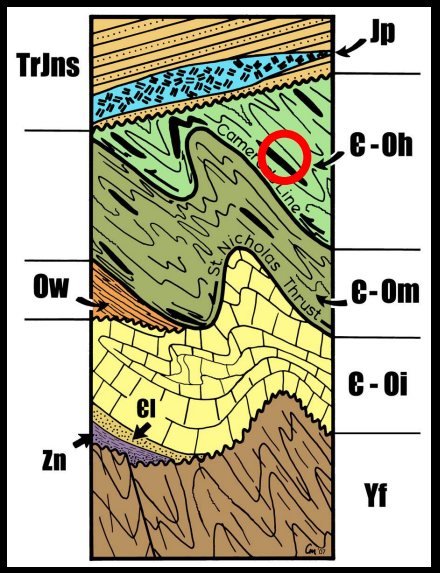



N629 – Warren Street (C-Oh)



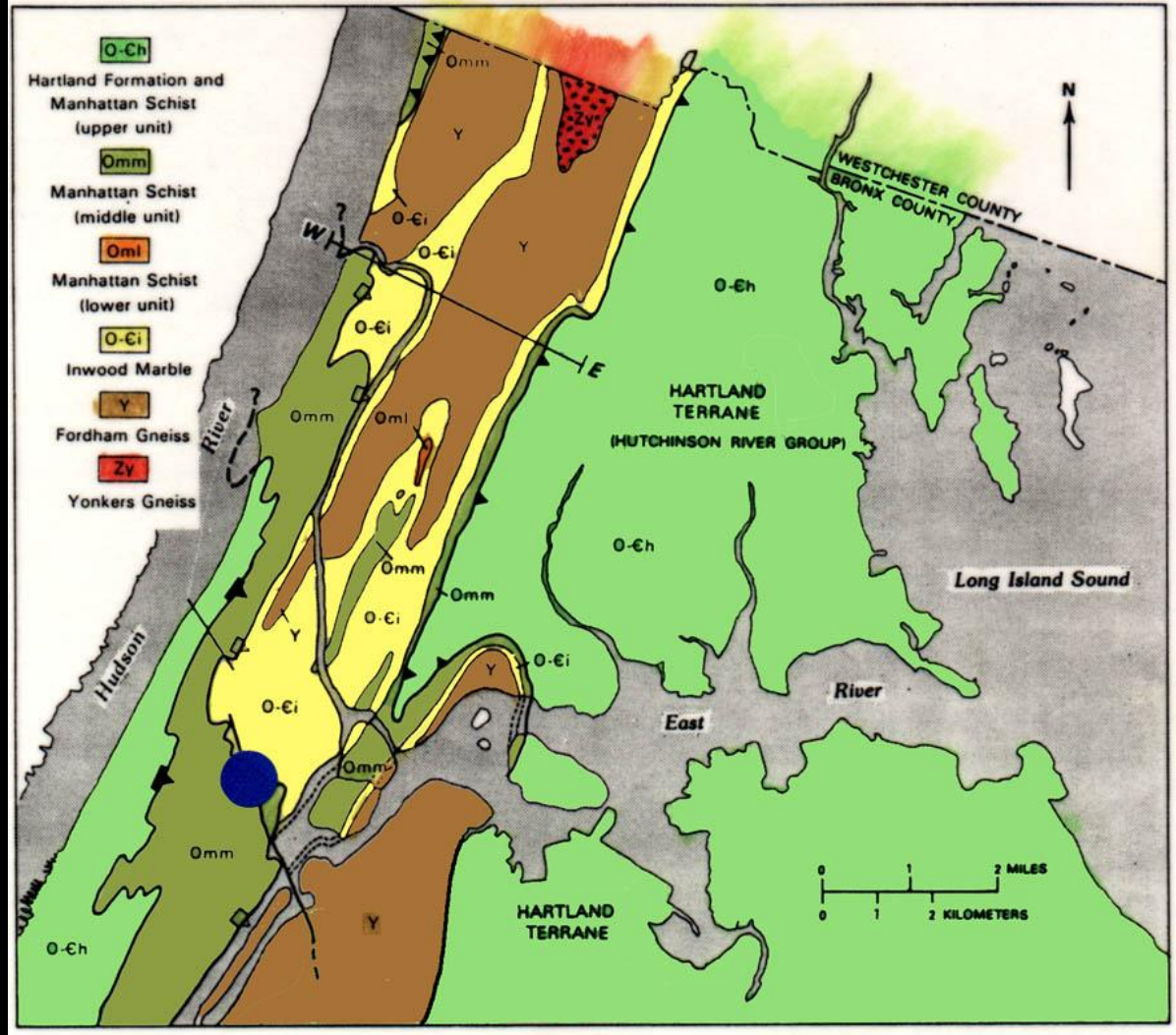
N624 – Warren Street (C-Oh)

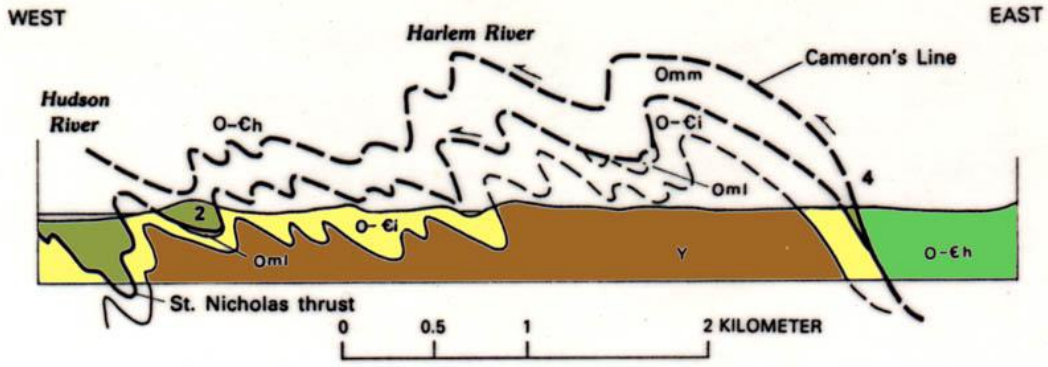
Hartland Amphibolite N567

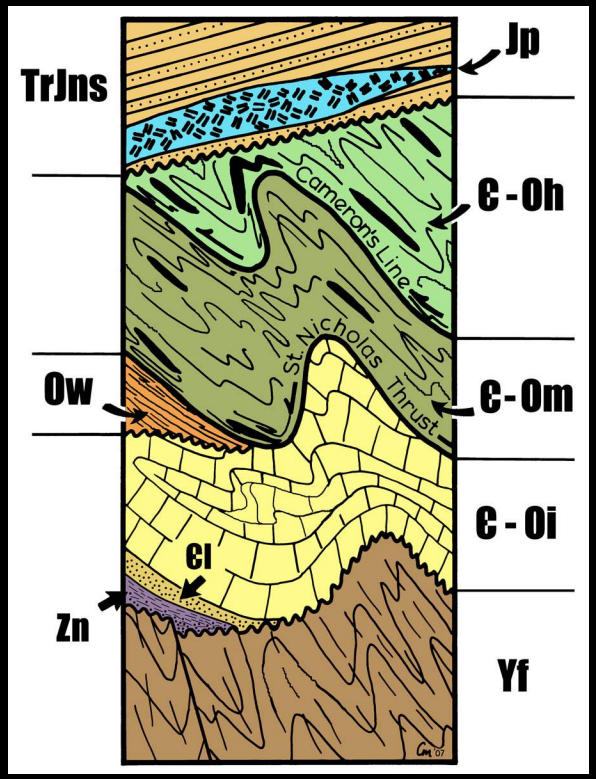


Hartland Coticule

New York City



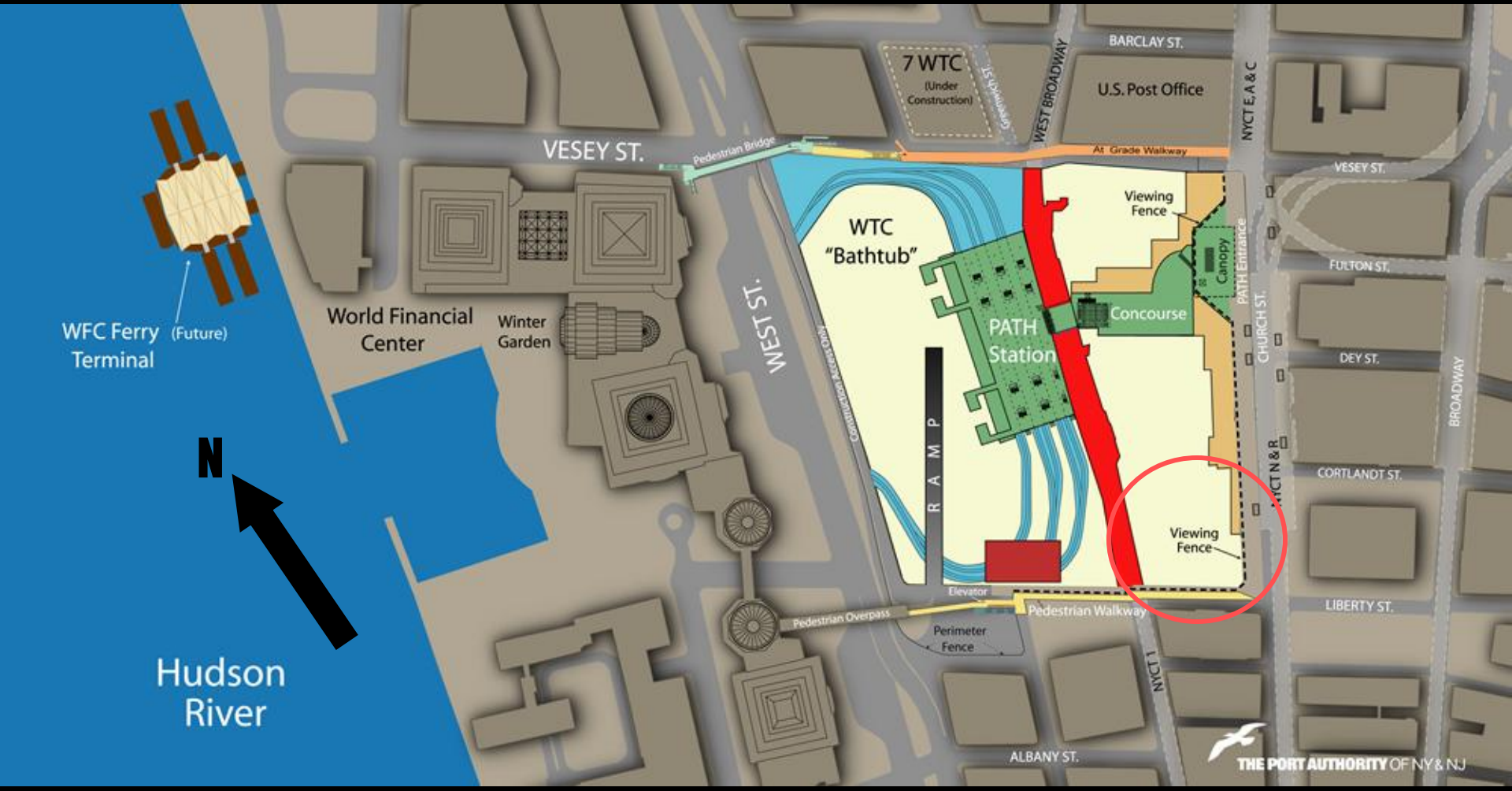




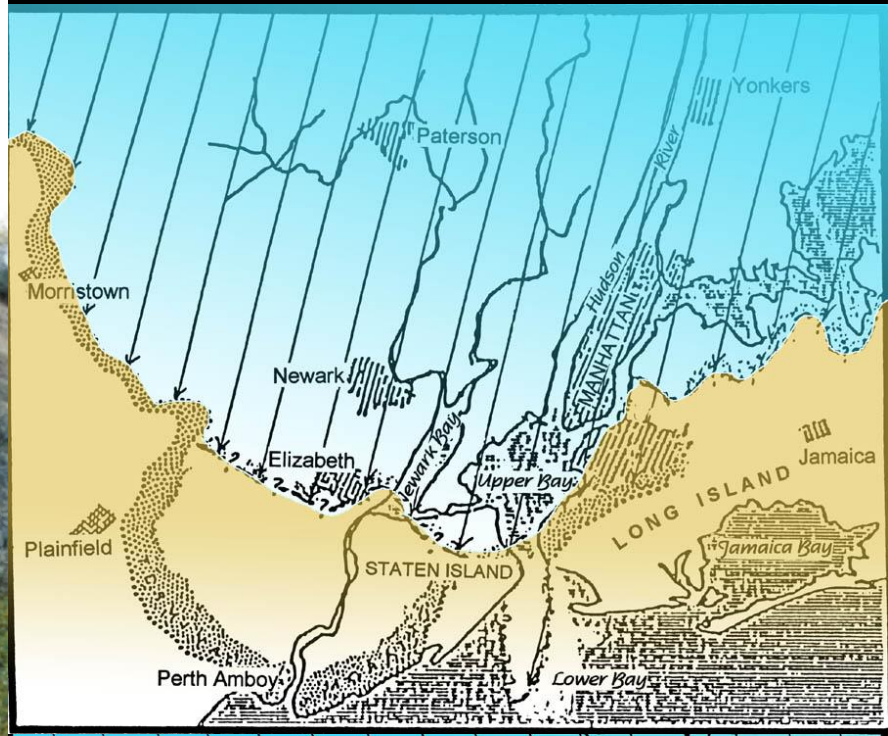
Merguerian and Merguerian, 2004

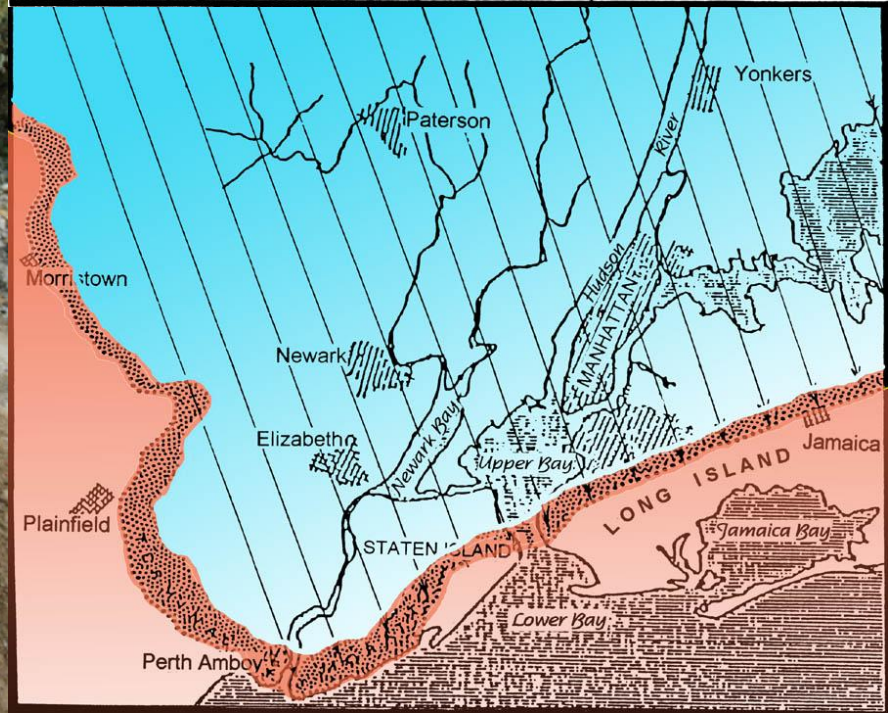

Remember CM, You're Nothing Without Me!
Finally! He's Going to Talk About the World Trade Center Site

The World Trade Center Site



Pleistocene Glaciation


Yonkers
Paterson
Hudson River
Morristown
MANHATTAN
Newark
Elizabeth
Newark Bay
Upper Bay
Jamaica
LONG ISLAND
Plainfield
Jamaica Bay
STATEN ISLAND
Perth Amboy
Lower Bay

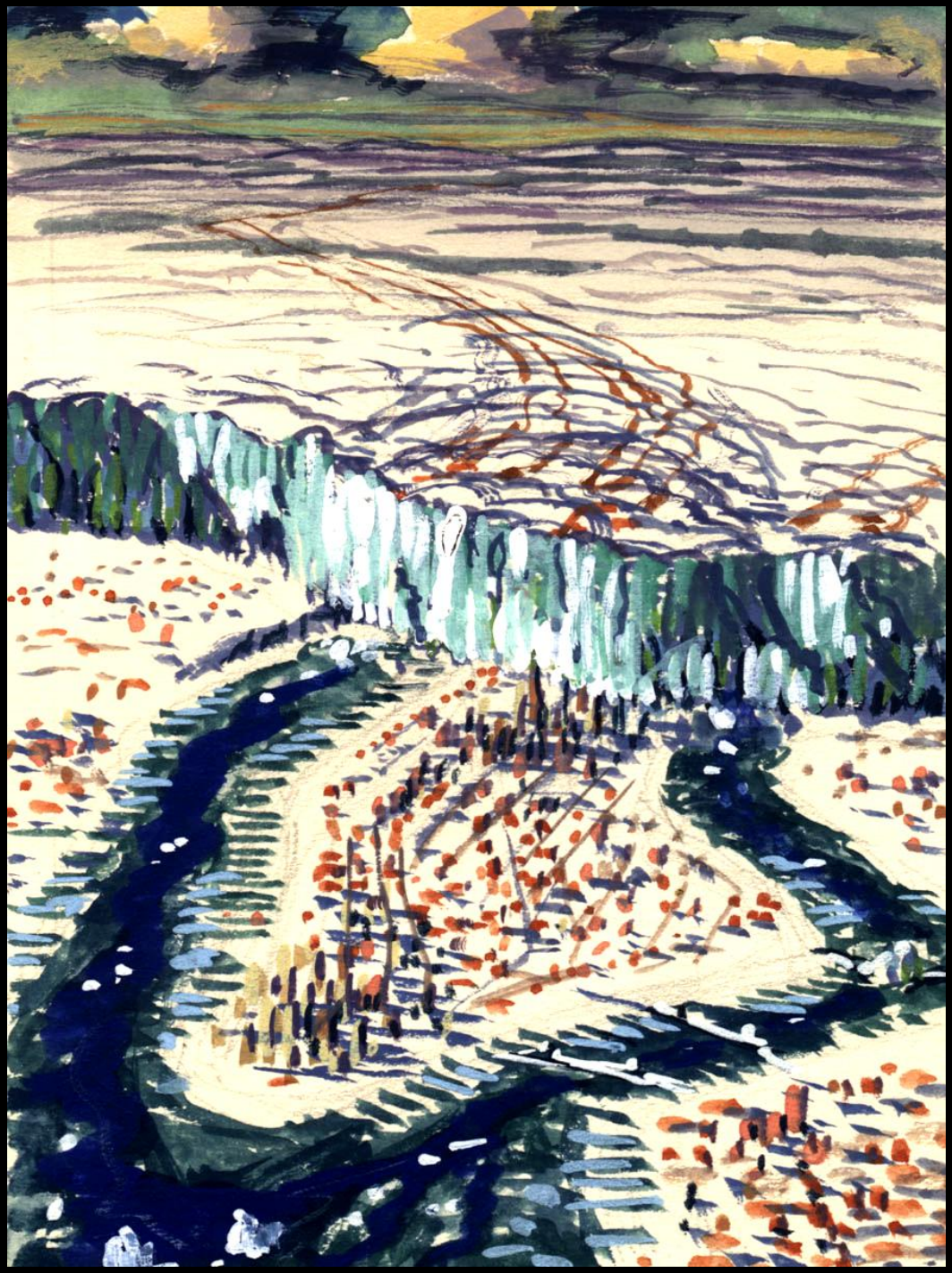

Yonkers
Paterson
Hudson River
Morristown
MANHATTAN
Newark
Elizabeth
Newark Bay
Upper Bay
Jamaica
LONG ISLAND
Plainfield
Jamaica Bay
STATEN ISLAND
Lower Bay
Perth Amboy

Rock - Paper - Scissors

Paper Covers Rock

Glacier Covers NYC

Not a One-Shot Deal!
Multiple Glaciers
Sculpted and Supplied
Sediment to the
NYC and LI Region

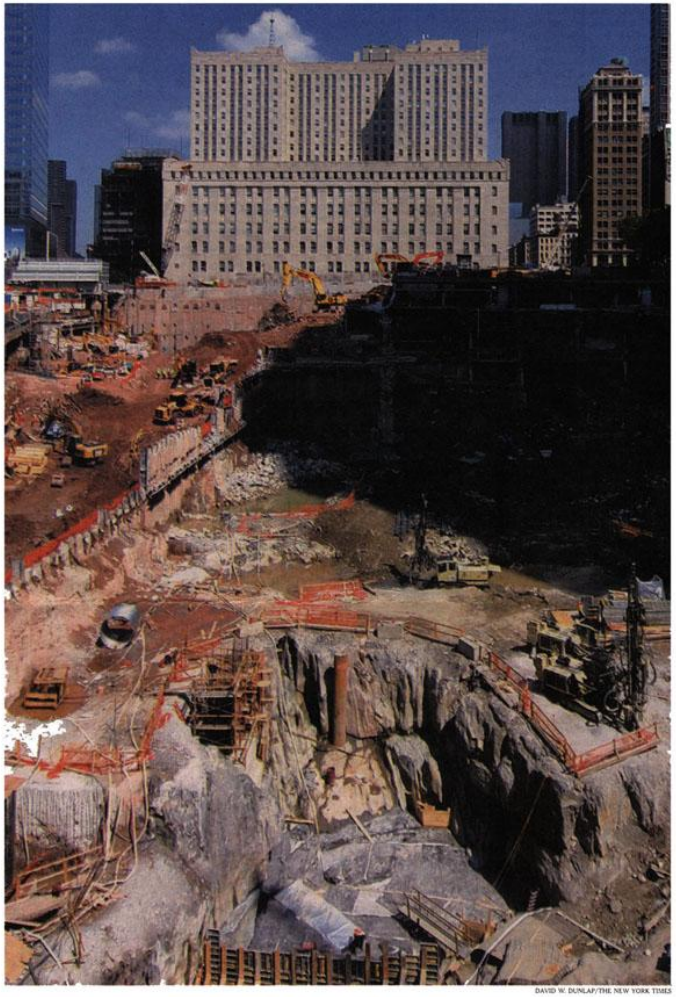


The Metro Section

The New York Times
MONDAY, SEPTEMBER 22, 2008

At Ground Zero, Scenes From the Ice Age

Trade Center Excavation Uncovers a Landscape Carved by Glaciers

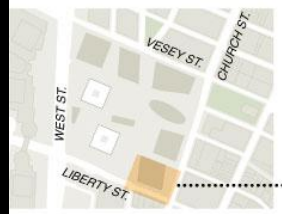


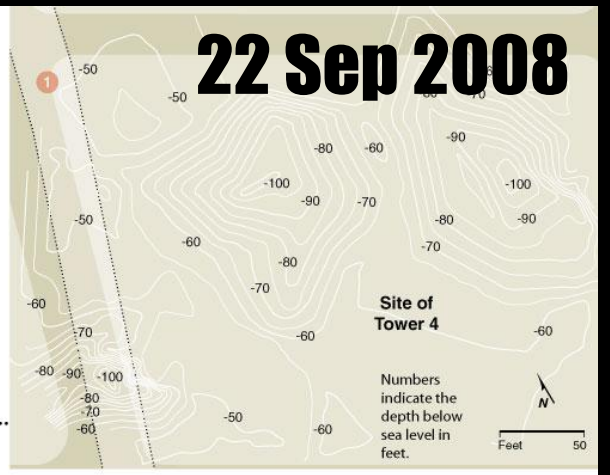
DAVID W. DUNLAP/THE NEW YORK TIMES

A Glimpse of New York City, 18,000 B.C.
Excavation at the World Trade Center site has uncovered, among other geologic features, a 40-foot glacial pothole. Page B4.

Glacial Terrain At Ground Zero

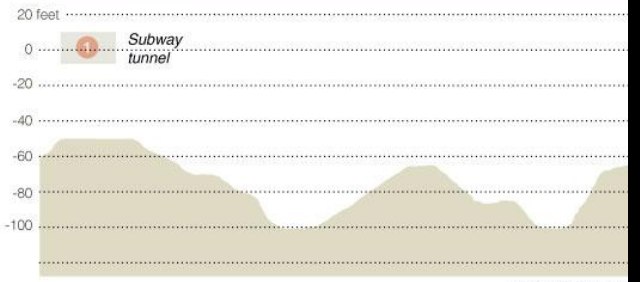
Excavations for Tower 4 at the southeast corner of the World Trade Center site uncovered a landscape carved by glaciers out of bedrock at least 20,000 years ago, with deep pools known as potholes.





BELOW CITY STREETS

Map at upper right shows bedrock contours of the Tower 4 site from above. At right is a cross section. In the measurement scale, 0 is close to sea level and is10 to 20 feet below street level. That means the bottoms of the potholes (-100) are about 110 feet to 120 feet below the street.



THE NEW YORK TIMES

22 Sep 2008

World Trade Center
100’ Deep Plunge Pools


CAT

From Moss and Merguerian 2009

NW to SE-Directed Glacial Flow Provenance of a ~50 ka Till Determined from the World Trade Center Site (WTC), NYC

Ventrelli, Angelica; Merguerian, J. Mickey; Melrose, Courtney; Moss, Cheryl; and Merguerian, Charles.
Geology Department, 114 Hofstra University, Hempstead, NY 11549.

Samples-Angelica, Mickey, and Courtney identifying samples from the WTC site

WTC Site Location- site covers 12 city blocks. Samples were recovered from the beneath the Tower 4 site

Site-View of a large plunge pool depression beneath the Tower 4 location

Whirlpool-NW face of western depression showing a "cave" carved by a circular whirlpool

WTC Till- contains rock clearly native to NJ – Palisades diabase, Hoboken serpentinite, Newark Basin redbeds, indicating that the glaciation responsible for filling the basins flowed from the NW

Trapped Wood - sent out for C14 dating. Most recent references agree that the Harbor Hill event affected the NYC area roughly between 25,000 and 19,000 years ago. There is not a consistent date associated with the Ronkonkoma event with ages of 70,000 or >130,000 years usually mentioned. The date on the wood found embedded within the till is roughly 50,000 BP

During terminal stages of excavation for the new World Trade Center site a series of major glacial features were discovered in steeply dipping metamorphic and intrusive rocks of the Walloomsac and Hartland formations. The excavated SE corner of the WTC site is underlain by 2 large plunge pools (-100' elevation), waterslides, and scores of potholes formed by stream erosion and later filled with glacial till rich in boulders, cobbles, and pebbles. (See NY Times article dated 22 September 2008). The unusually deep erosion (-100' elevation) found at the WTC site is a testimonial to the drop in sea-level and oceanward migration of the shoreline that accompanies glaciation as such deep erosion usually takes place far from the shoreline in coastal areas.

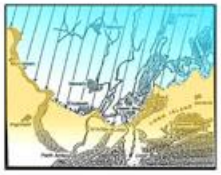
Our analysis of the shapes and lithology of about 220 pebbles and cobbles randomly collected from the potholes indicate that the clast population consists of well-rounded far-traveled rocks from varied bedrock sources. We were able to interpret a wide variety of lithologies, although due to obvious constraints, collecting every clast in the plunge pools was impossible. The clasts arranged by decreasing percentage consist of quartzite, reddish sandstone, orthogneiss/granite/granitoid, greywacke, quartz fragments, siltstone, syenite, aplite, black chert, metaconglomerate, schist, diorite, amphibolite, slate, basalt, phyllite, and rare contact hornfels from the Palisades intrusive sheet.

The clasts include indicator stones that can be traced back to specific physiographic provinces, all to the NW of the WTC site. In addition to the Palisades contact hornfels, these include basalt from the Watchung lava or the chilled margin of the Palisades sheet of the Newark Basin and coarse-textured metaquartzite of the Shawangunk formation, from the Valley and Ridge physiographic province. Orthogneiss/granite/granitoid, syenite, diorite, and amphibolite are from the Hudson Highlands. Taconic strata (slate, phyllite, greywacke) are also represented, together indicating glacial transport from the NW to SE.

By contrast to prevailing thoughts that Pleistocene ice descended from the NNE down the Hudson River valley, our studies indicate that glacial ice advanced from the NW (across the Hudson valley), picking up rocks and red soil distinctly native to New Jersey and New York.

The age of the till has been determined to be unexpectedly old (~50 ka), obtained by C14 dating of a piece of wood trapped within a silt lens within the potholes. The date obtained was 49,500 +3050/-2205 BP (Moss and Merguerian 2009). Importantly, these ages clearly indicate the till filling the lower 2/3 (and likely upper third) of the depression was deposited by an older than recognized glaciation from the NW developed prior to the ~20 ka Harbor Hill event.

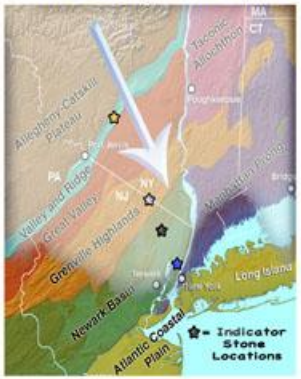
Glaciations



Left- Predominant theory that the Pleistocene ice traveled in a NNE flow direction.

Right- Based on our research results, the Pleistocene ice traveled in a NNW flow direction.

Physiographic Provinces of NY



Provenance of Till Pebbles from NW to SE

Allegheny-Catskill Plateau - Devonian sandstones/shales (may be present at site - further petrographic analysis needed).

Valley/Ridge - Silurian Shawangunk coarse sandstone, quartzite, and metaconglomerate.

Great Valley - Cambro-ordovician black shale, carbonates, and greywacke (no representatives of shale or carbonates as they would not last but graywackes and gray slates are persistent).

Grenville Highlands- Proterozoic orthogneiss, granite, granitoid, aplite, syenite, diorite, amphibolite, Cambrian quartzite, Ordovician phyllite, and black chert (from Devonian limestones).

Taconic Allochthon- Cambro-ordovician strata may have overlapped Grenville until eroded (Greywackes and slates: green, purple, gray).

Newark Basin - Jurassic red siltstones, sandstone, Palisades contact aureole, and basalt. Hoboken serpentinite also present in field.

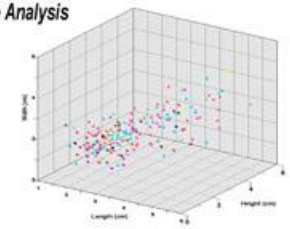
Manhattan Prong - Proterozoic to Ordovician metamorphic rocks locally derived.

*Sampling error - larger stones left uncollected.

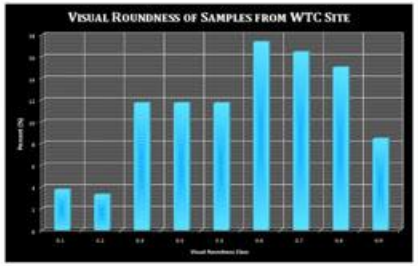
Till-Closer view of the matrix supported till. The large, red angular rock in the upper-left corner is serpentinite from the area of Hoboken, NJ.

Pothole-View of till filled pothole that may have been scoured by sediment laden water

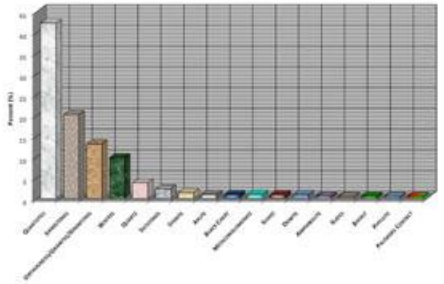
Sample Size Analysis



Visual Roundness of Samples from WTC Site

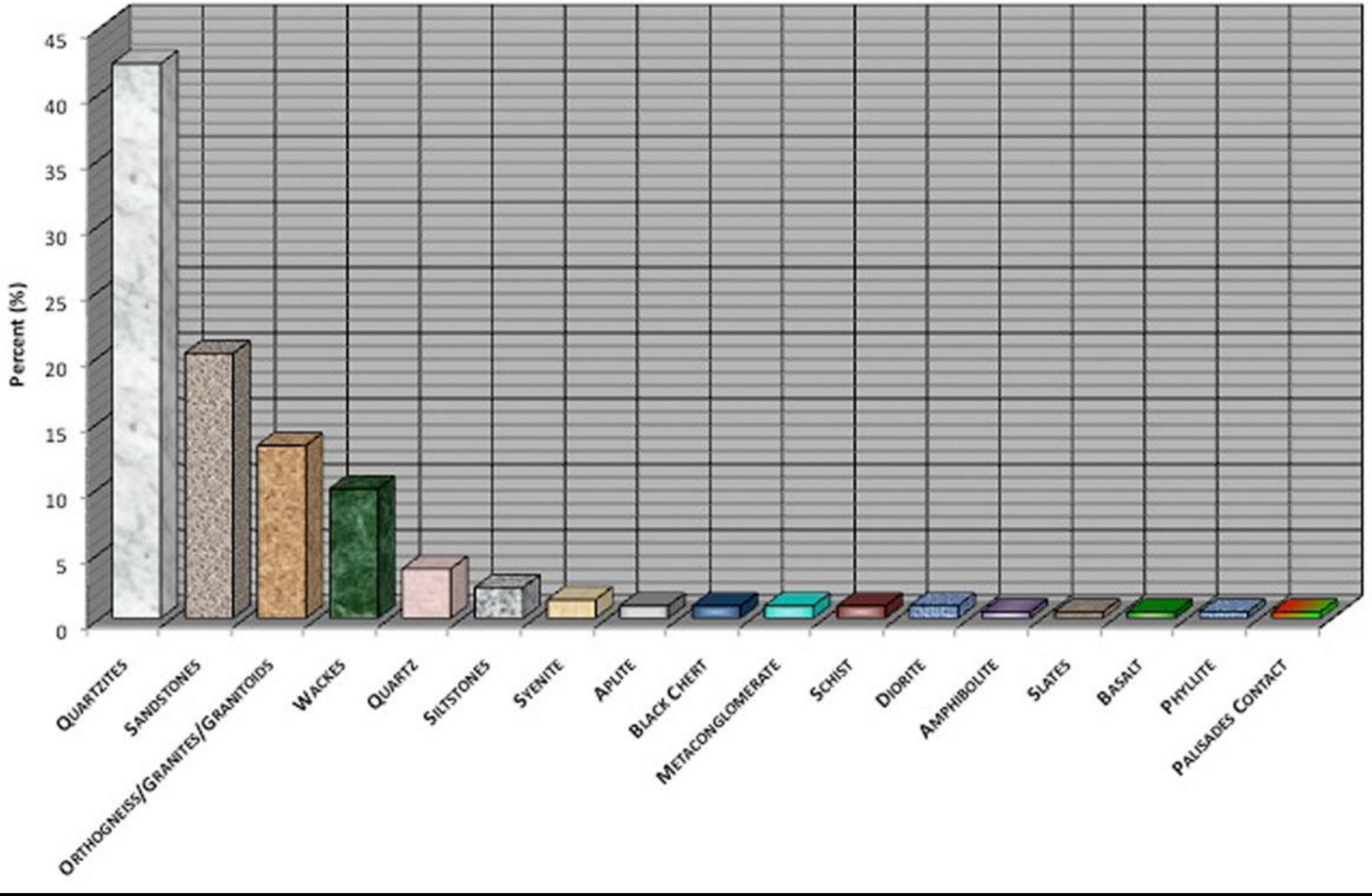


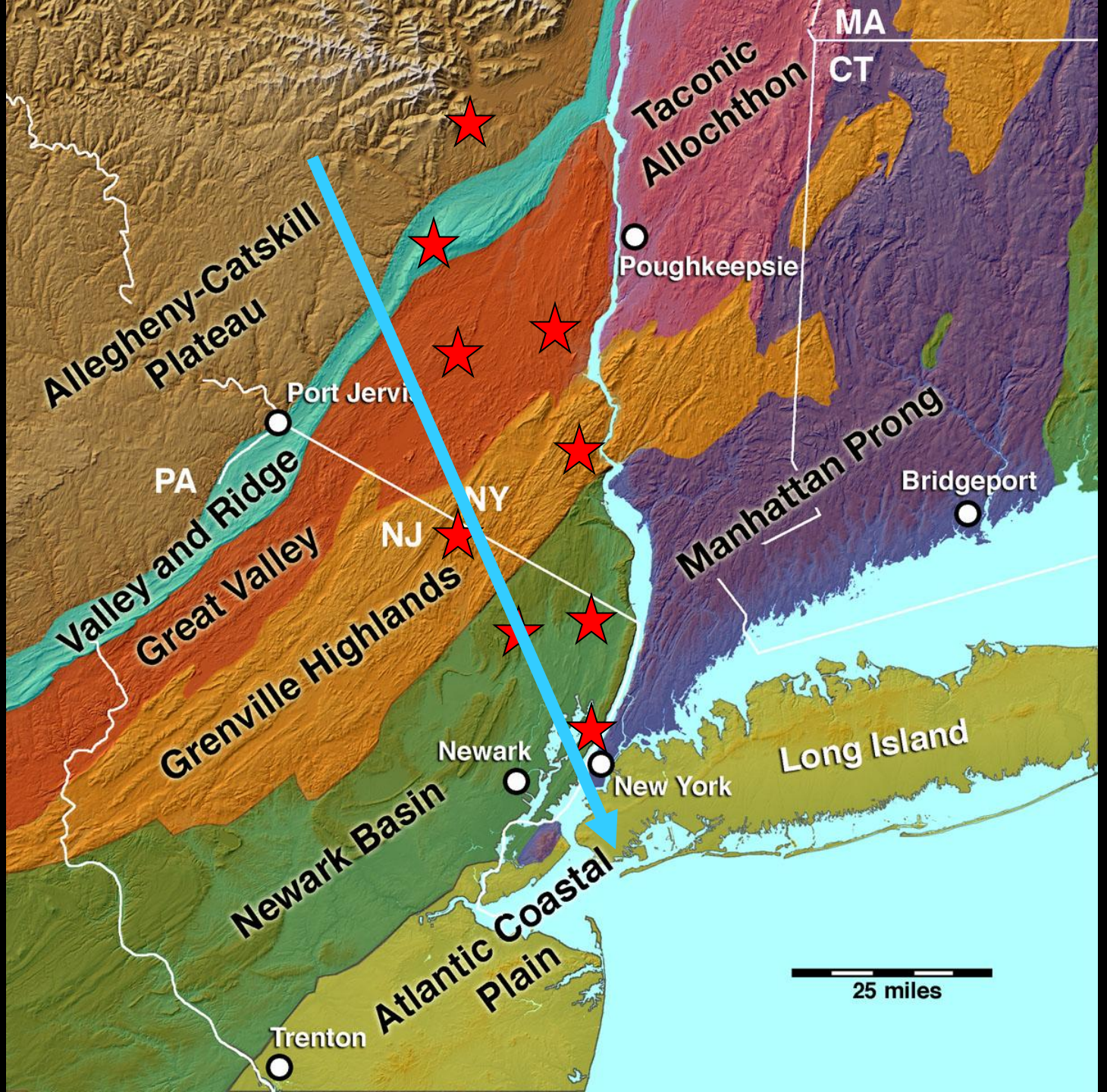
Lithology Percent of Samples from WTC Site



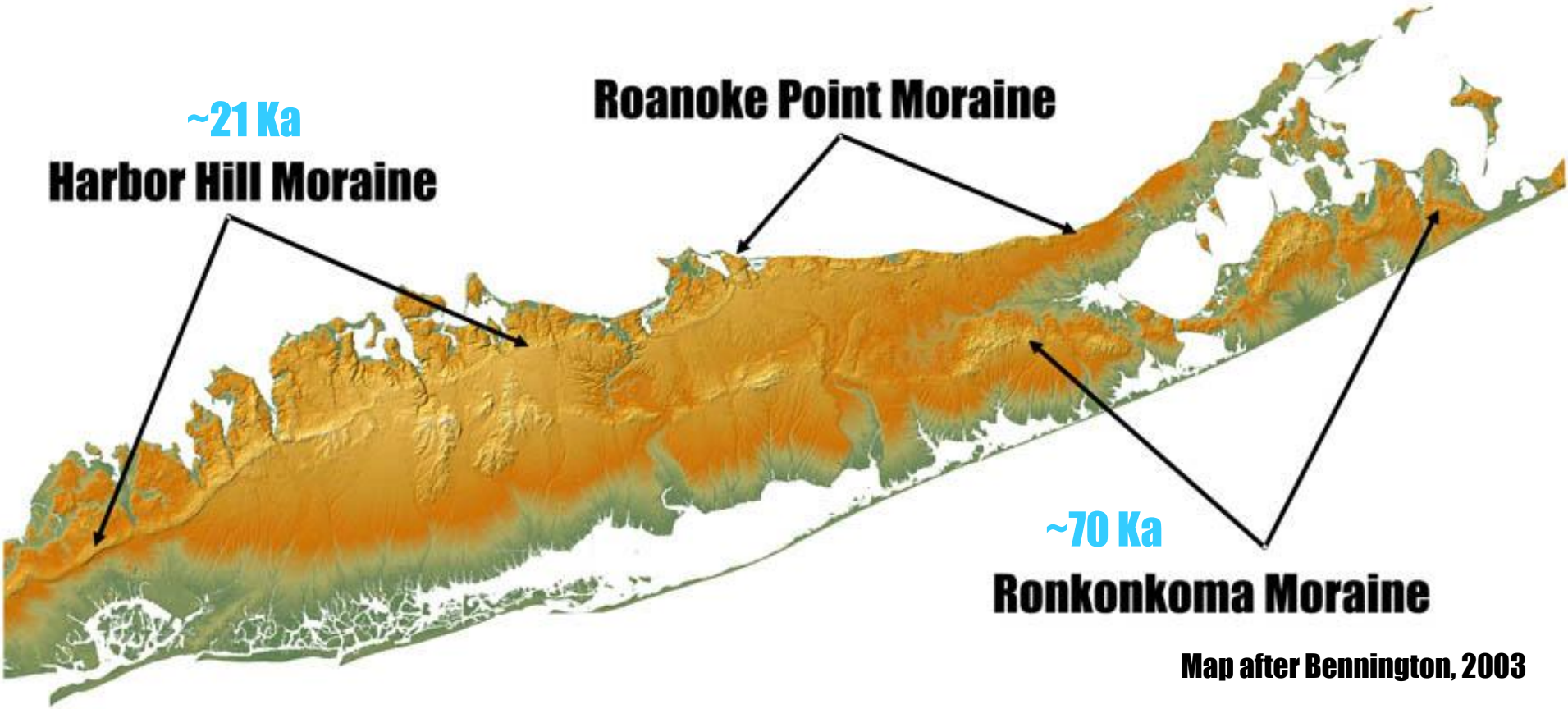
Student Poster at Colonial Alliance Conference – April 2010

Lithology Percent of Samples from WTC Site




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

Long Island's Glacial Moraines



Most NY Area Glacial Features or Erosion and Deposition Are the Product of NW Advances


Existing caisson
Location Where Wood Was Found
X
Silt Lens
Surrounding Till

FRDG Funding = 49,500 BP +3050/-2205

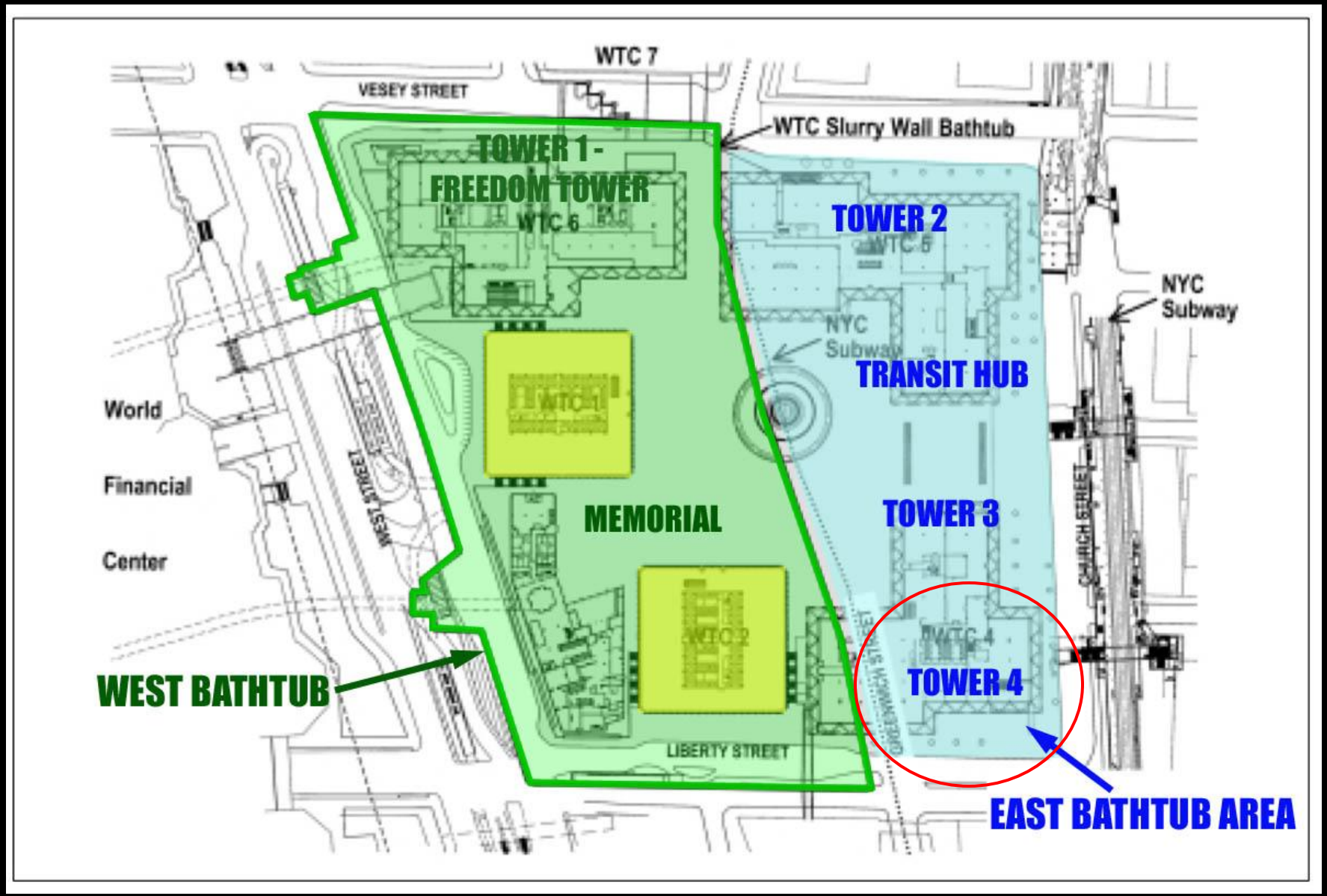
Harbor Hill 25 - 19 Ka

Ronkonkoma ~70 Ka

Question is: WHICH GLACIATION?

From Moss and Merguerian 2009

World Trade Center Site



From Moss and Merguerian 2009


World Trade Center
Field Stops
32
33
31
37
21
18
17
34
20
16
15
19
14
22
13
8
12
7
11
9
30
10
35
28
29
27
6
5
26
4
25
23
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

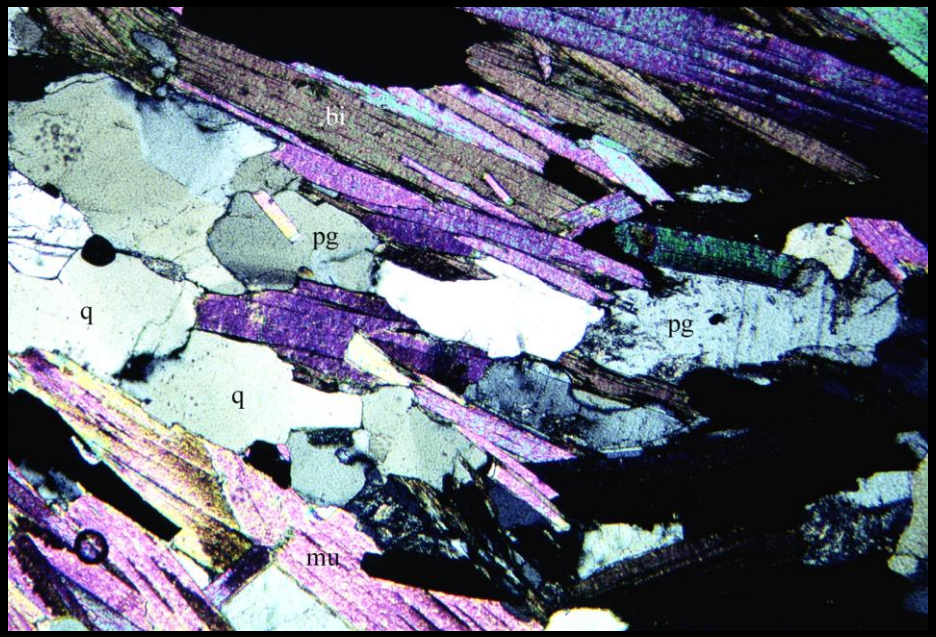
On The Rocks

2004

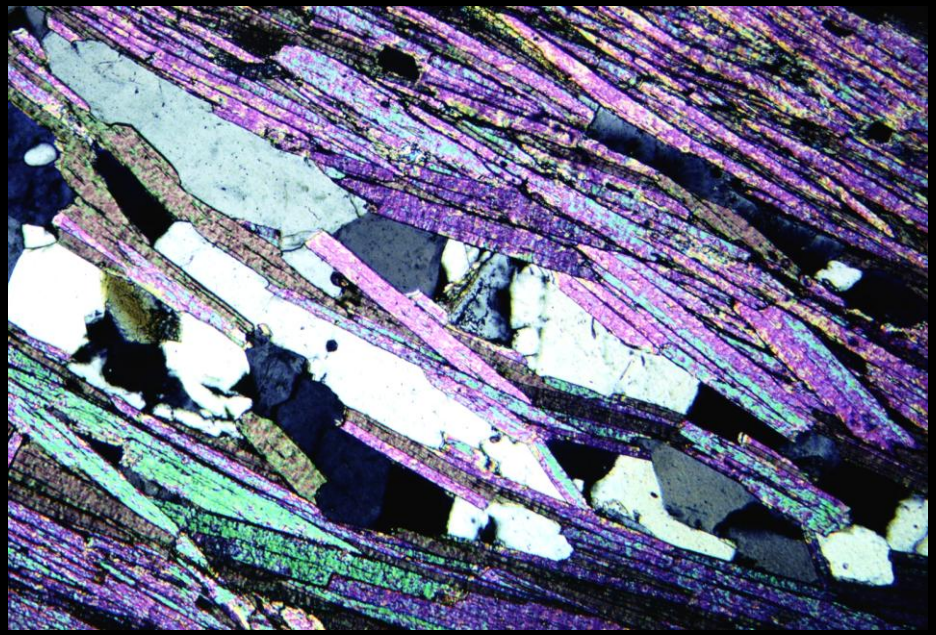
Geology Department

New York City
Rock Sample Archive
Gittleson Hall

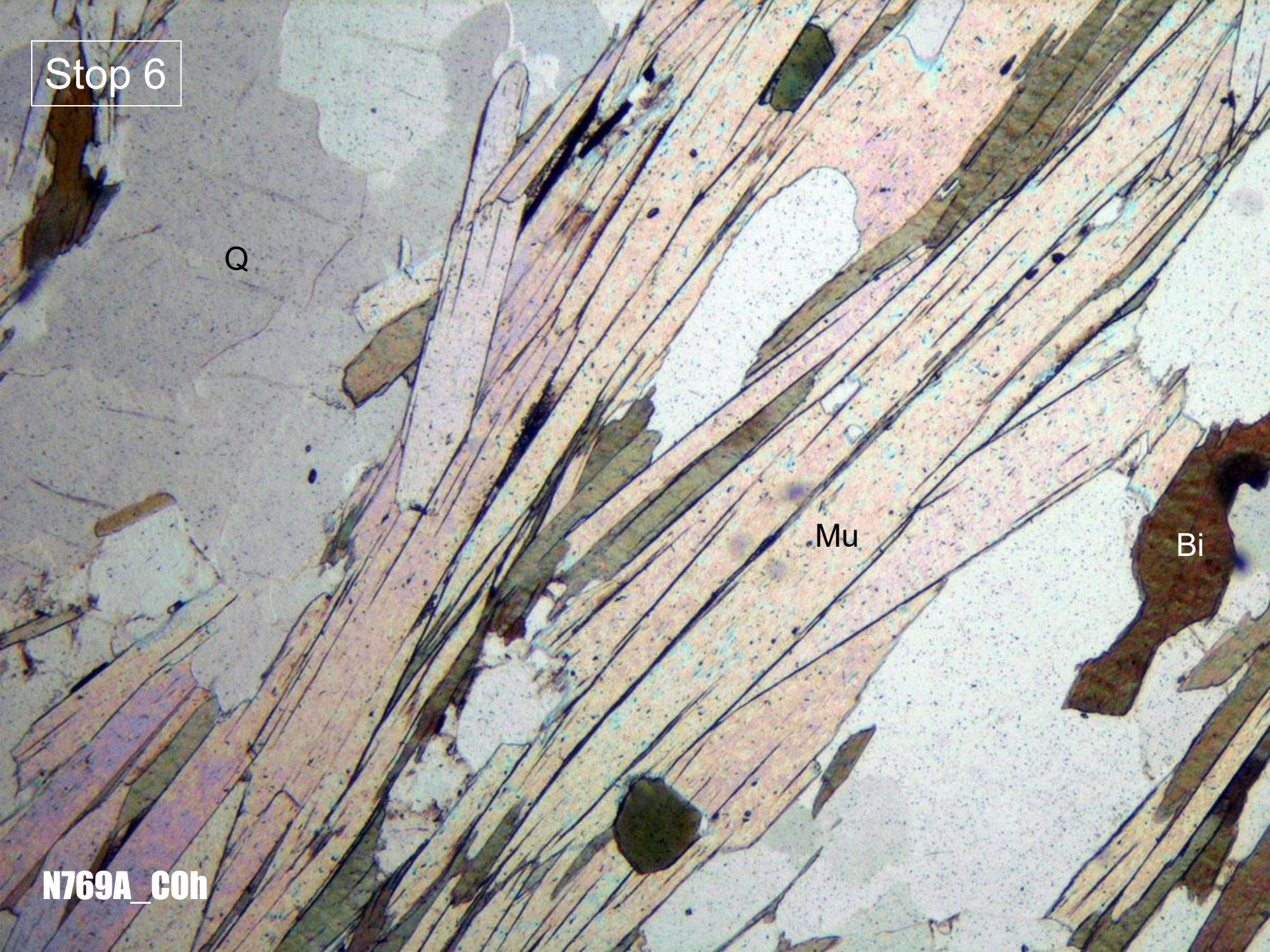
So, Let's Take a Peek at Some Rocks

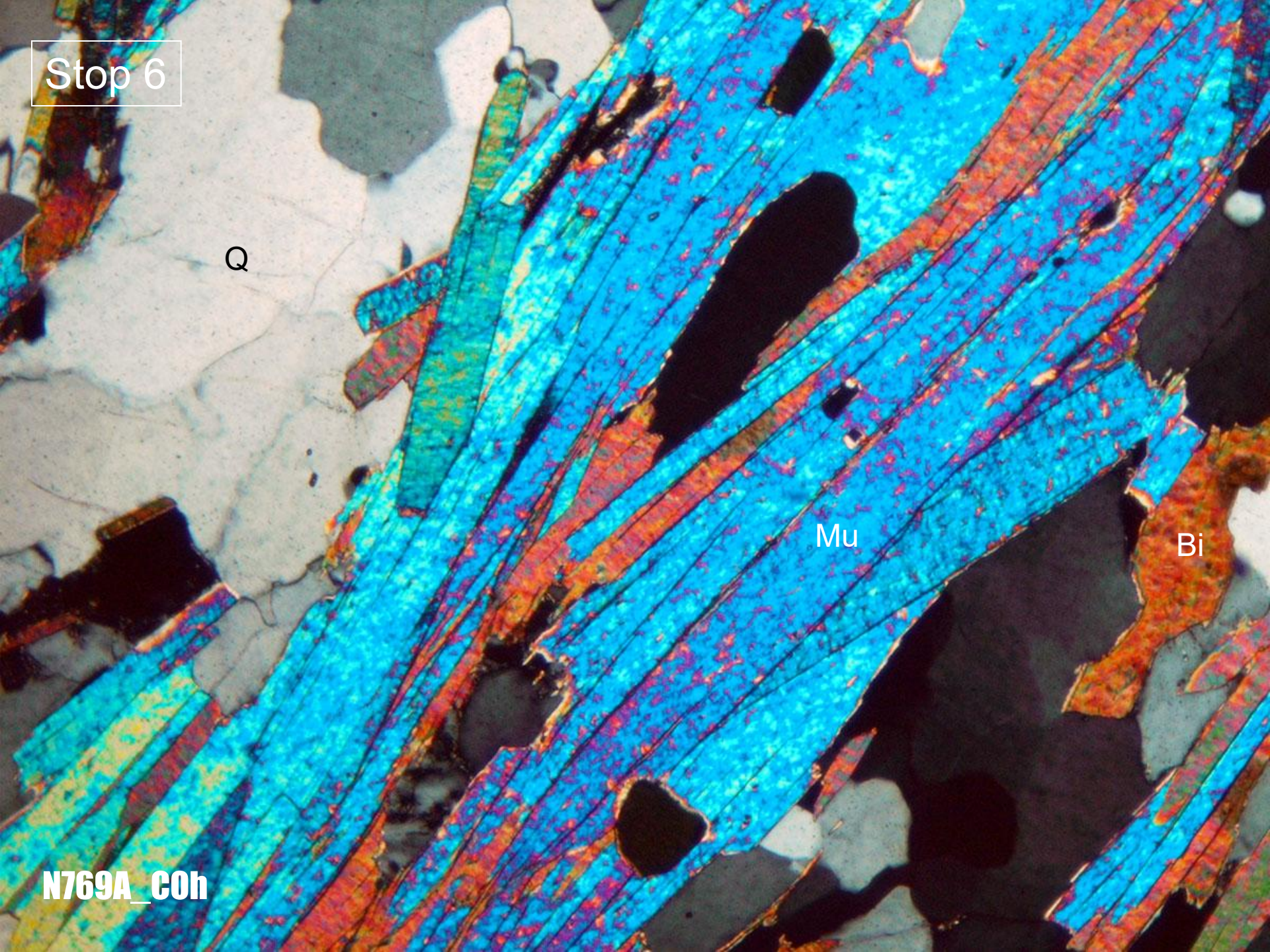


In Western and Central Manhattan:
Amphibolite Facies Schist
Well-layered Hartland Fm.
Penetrative Foliated Textures
Great Rocks for Tunneling and Excavation!

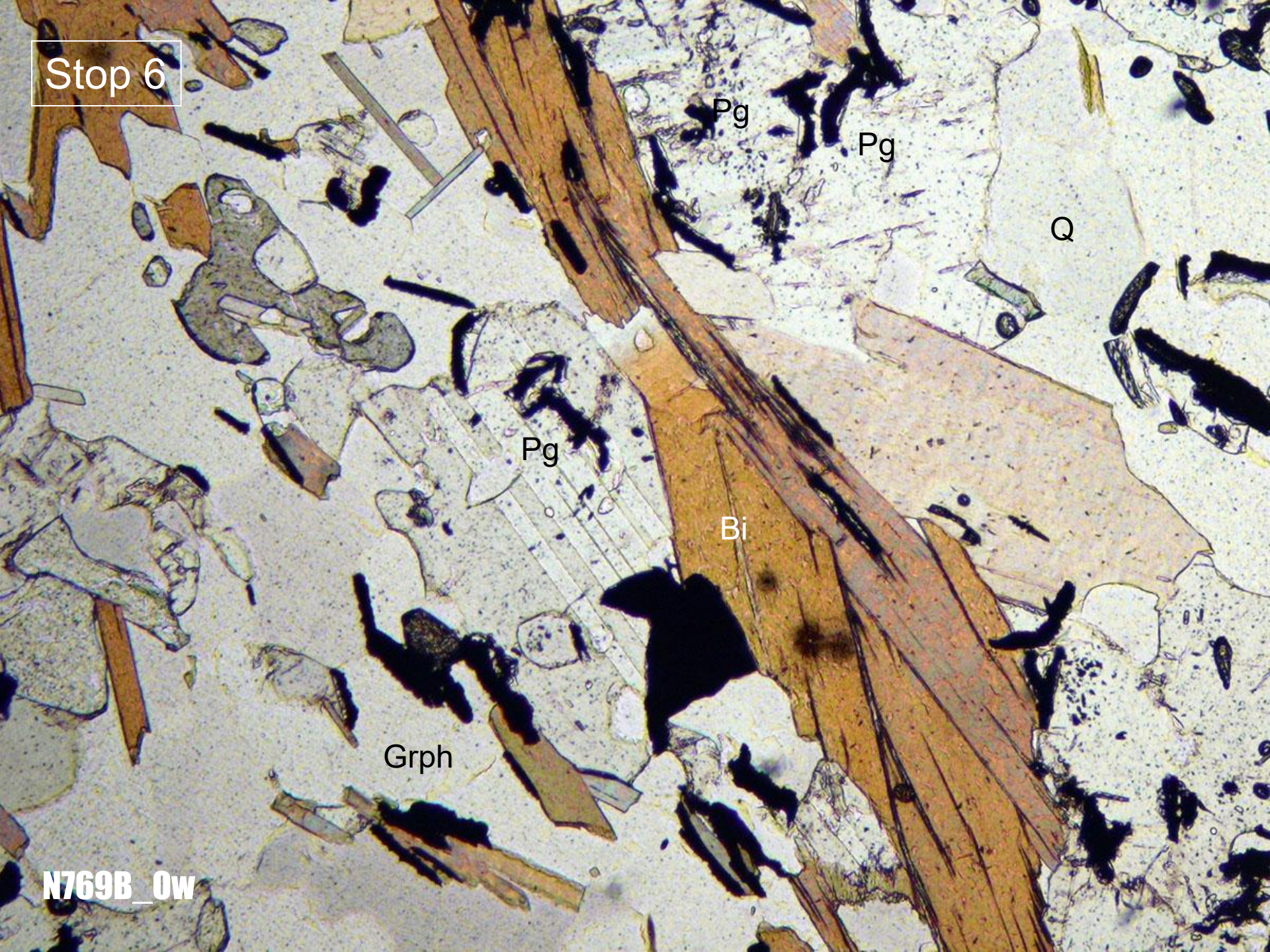


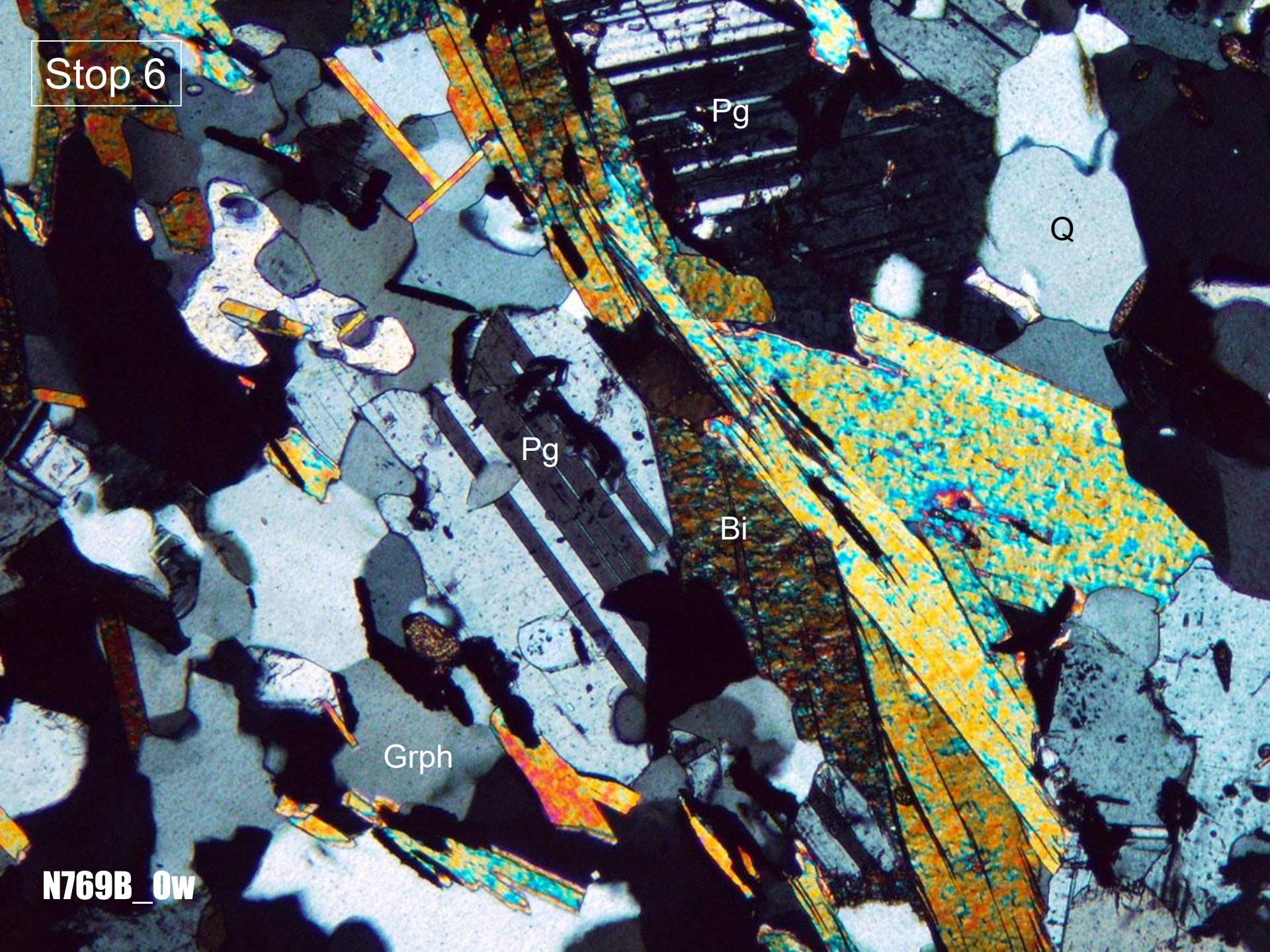

Stop 6
COh


Stop 6
Q
Mu
Bi
N769A_COh

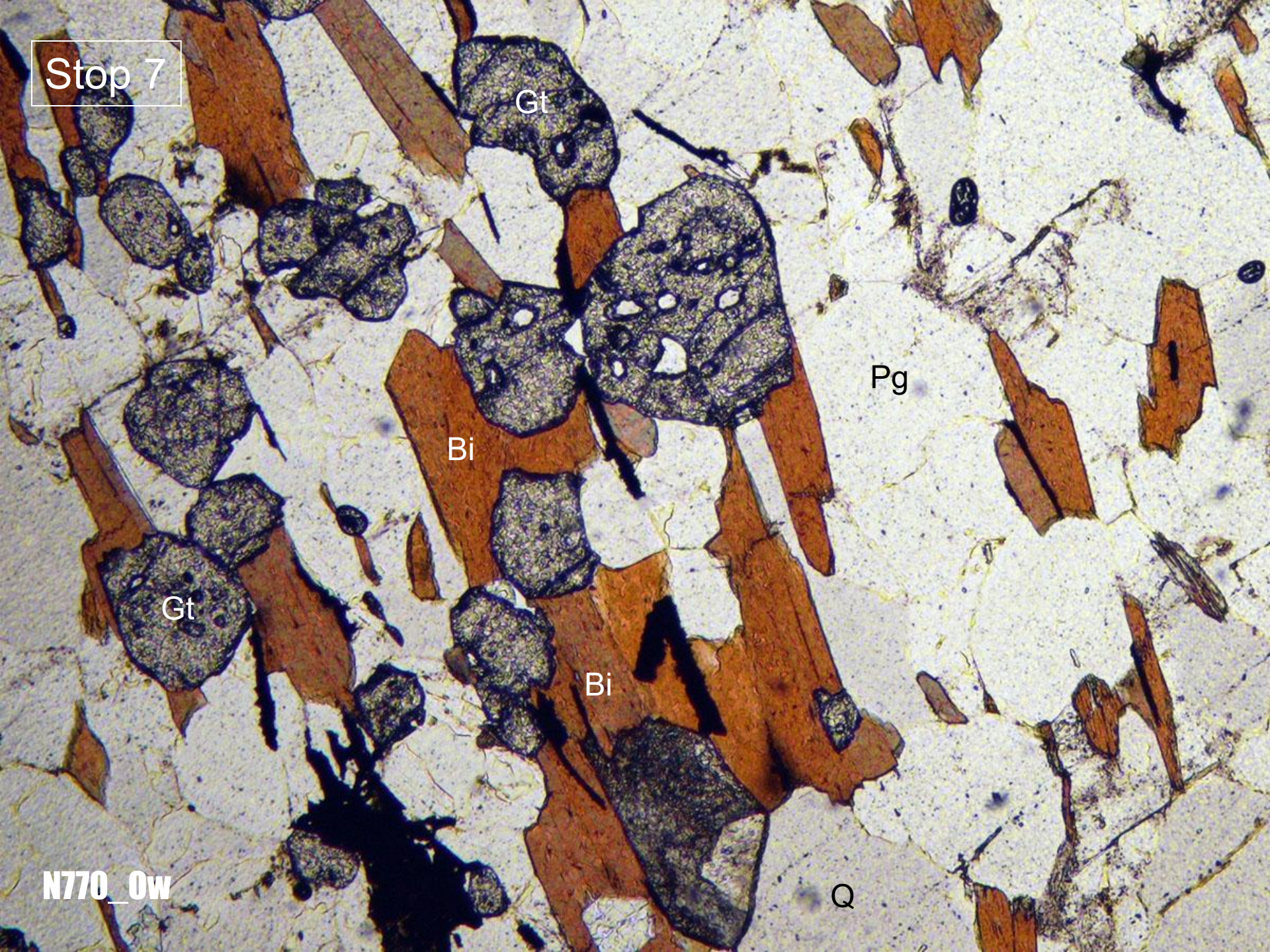

Stop 6
Q
Mu
Bi
N769A_COh

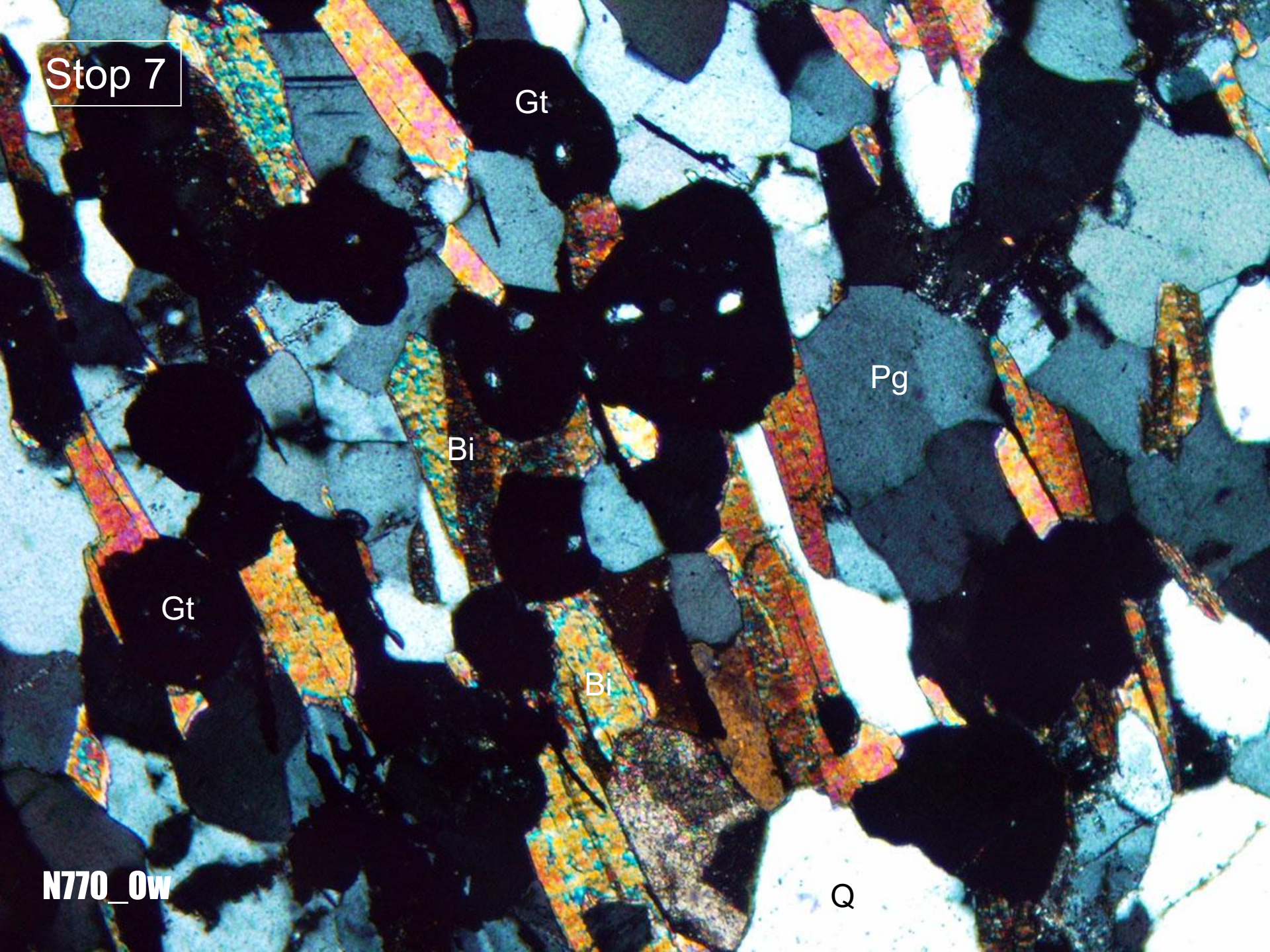

Stop 6
Ow
COh
COh+Ow


Stop 6
Pg
Pg
Q
Pg
Bi
Grph
N769B_0w


Stop 6
Pg
Q
Pg
Bi
Grph
N769B_Ow

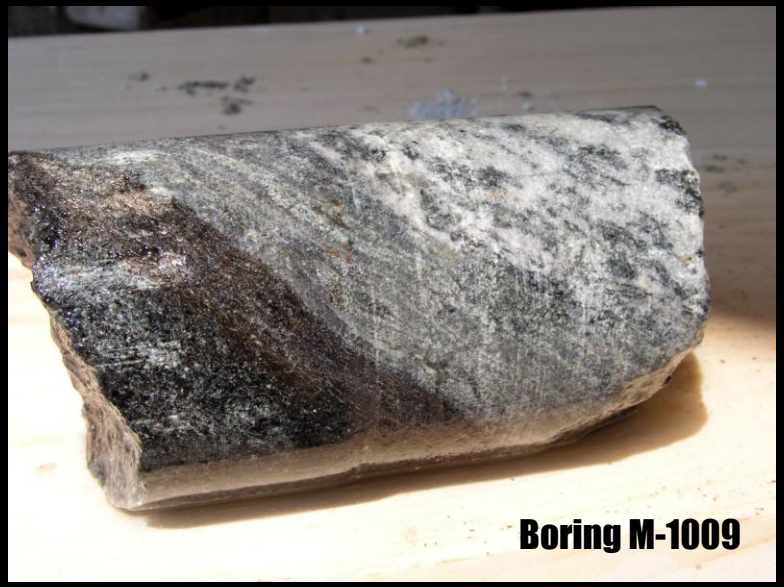

Stop 7
Ow


Stop 7
Gt
Pg
Bi
Gt
Bi
N770_0w
Q


Stop 7
Gt
Pg
Bi
Gt
Bi
N77O_Ow
Q

Near Stop 13

Sub-vertical F_3 Folds with Steep, NE-trending Axial Surfaces in Walloomsac Schist and Calc-Silicate Unit



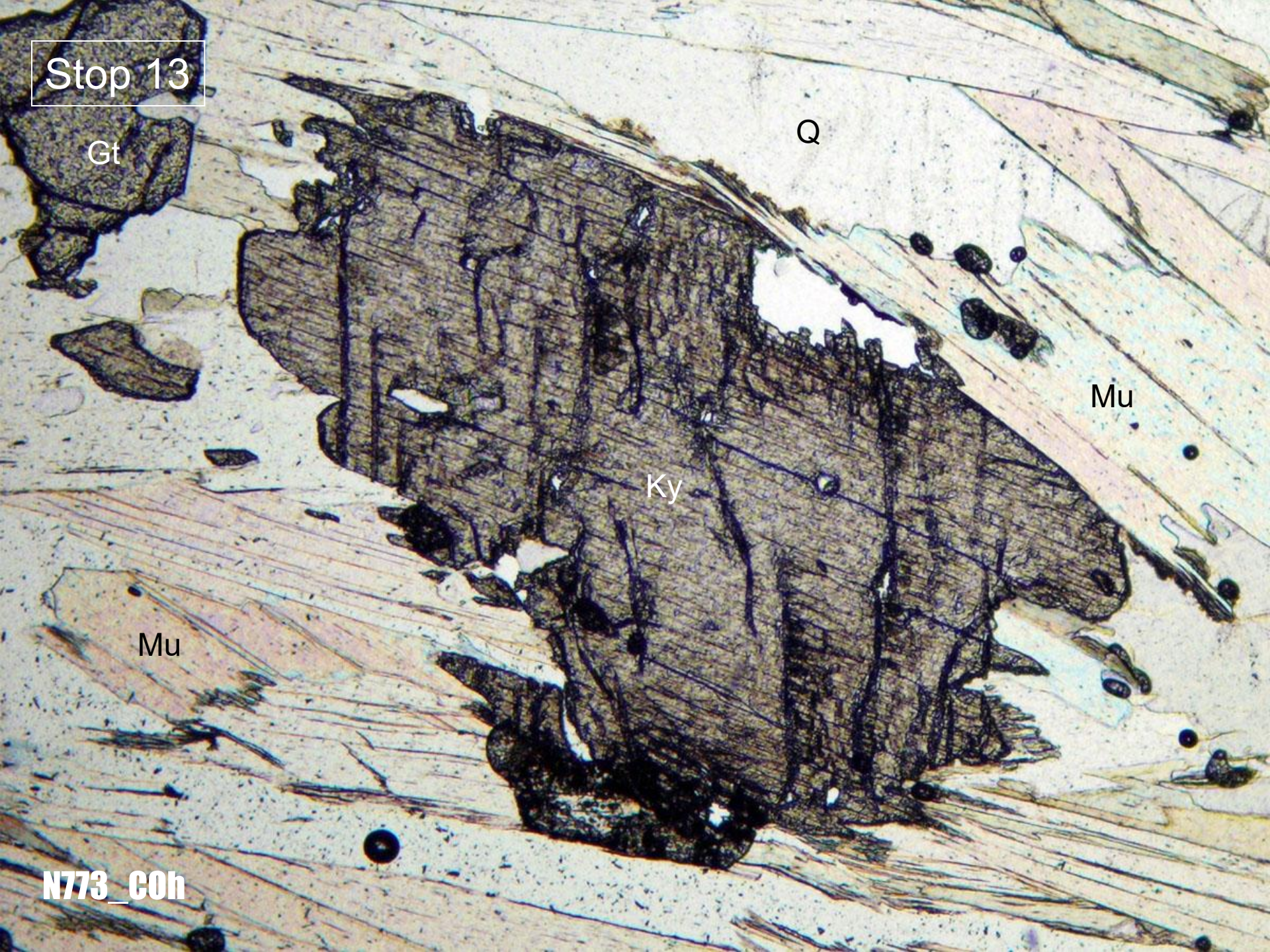
Ow+Owc

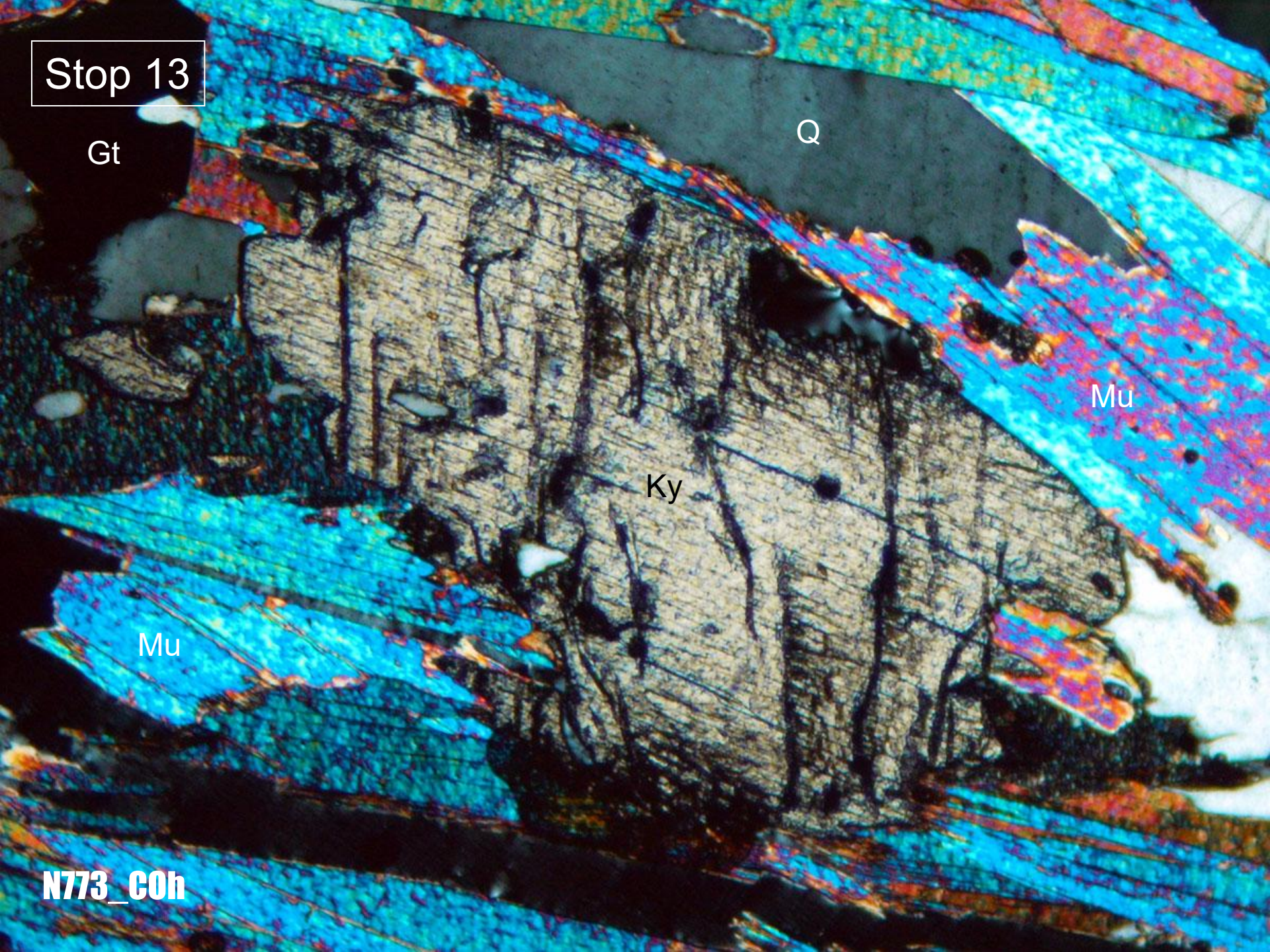
Image by C. Moss

Stop 13

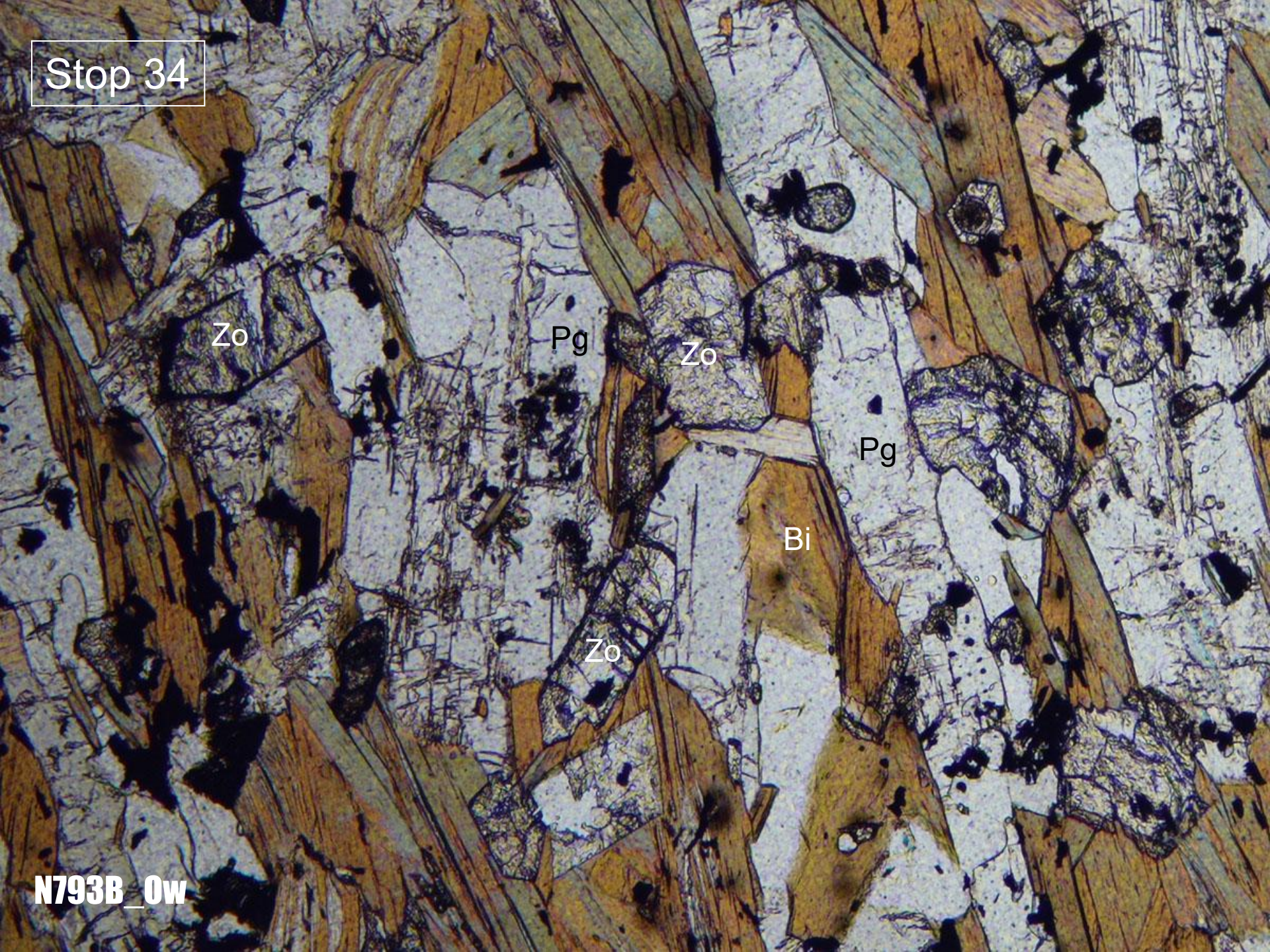
Scale = 22.2’ Hamster

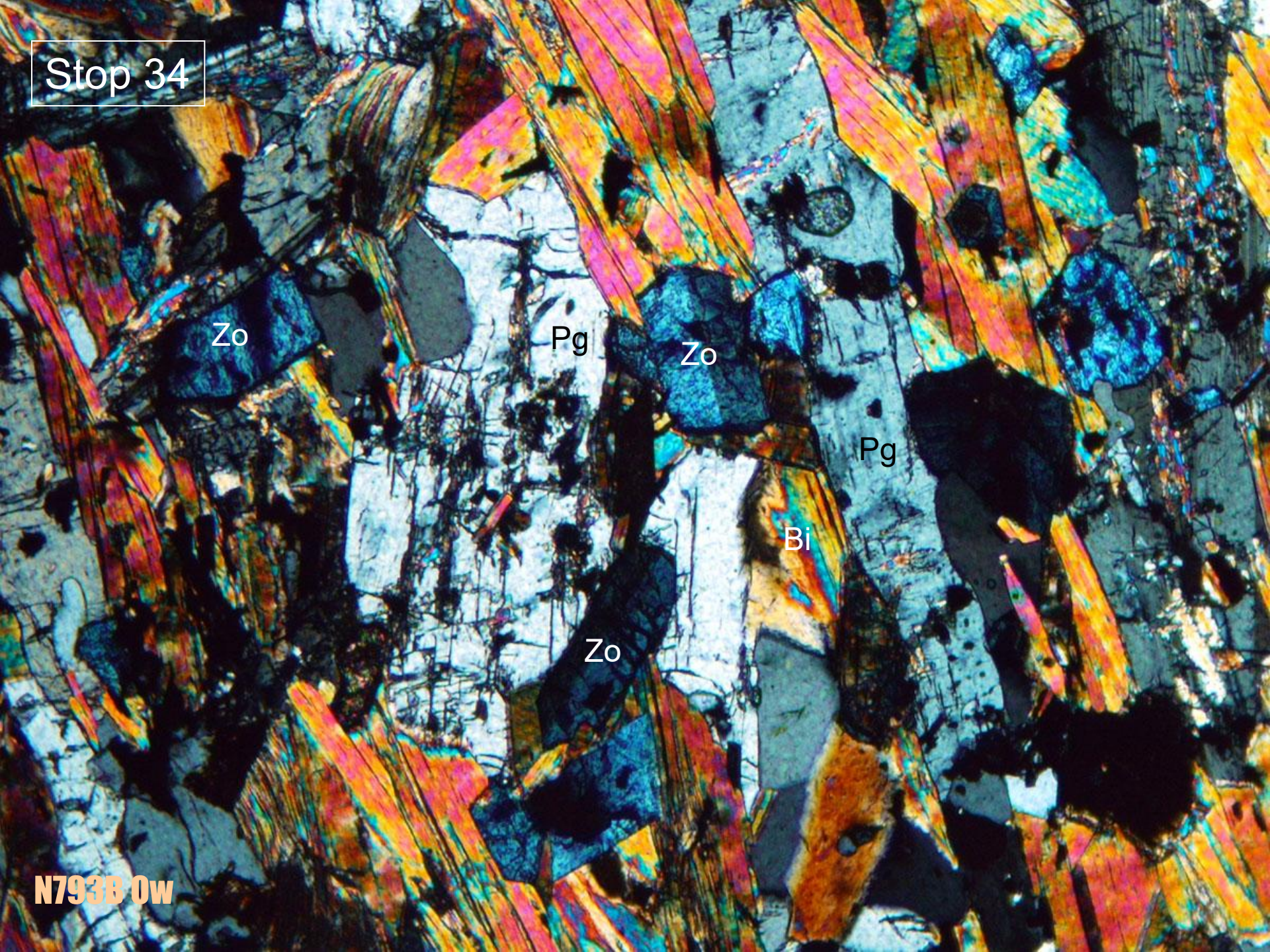
C-Oh


Stop 13
Gt
Q
Mu
Ky
Mu
N773_COh

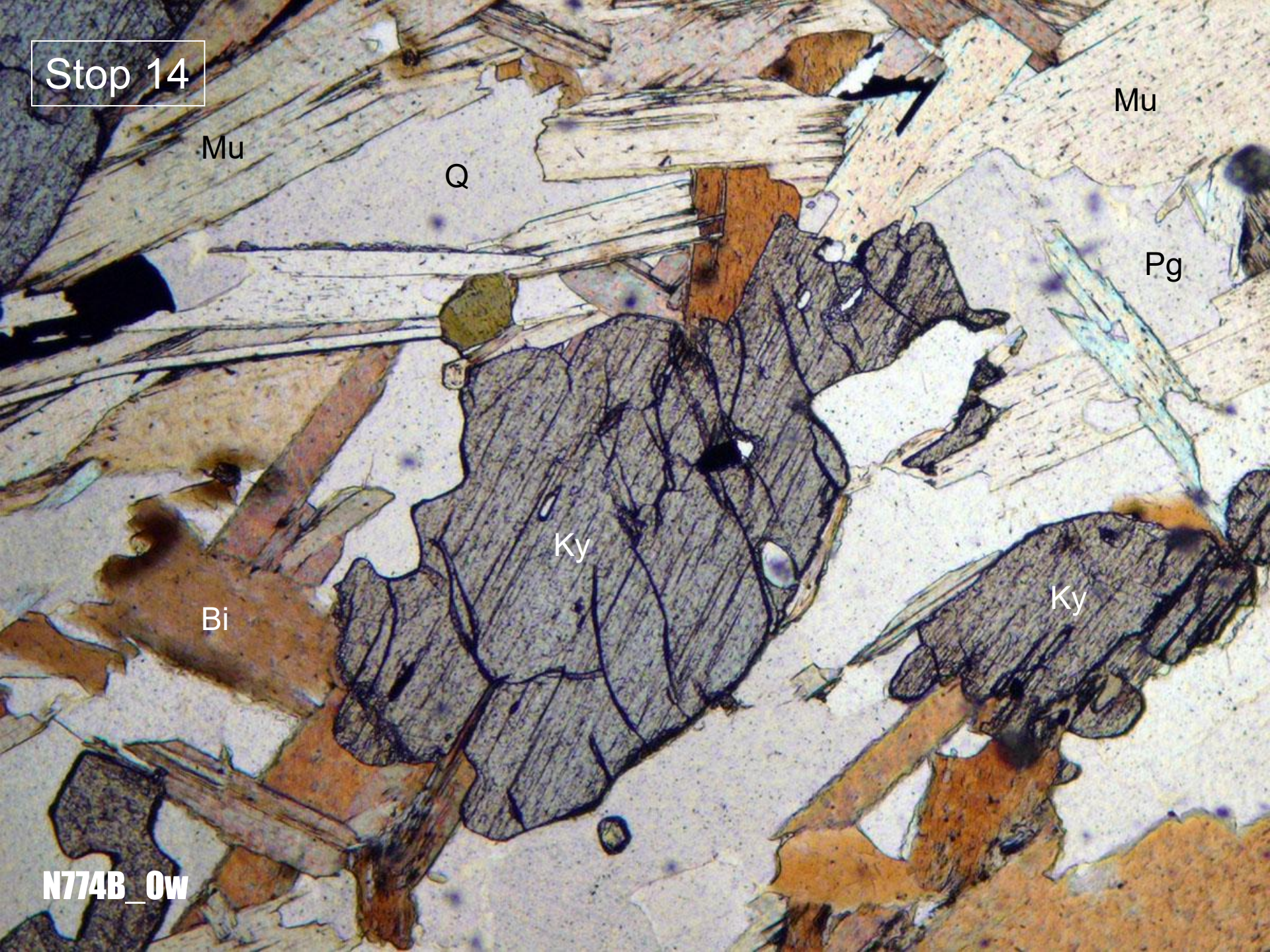

Stop 13
Gt
Q
Mu
Ky
Mu
N773_COh

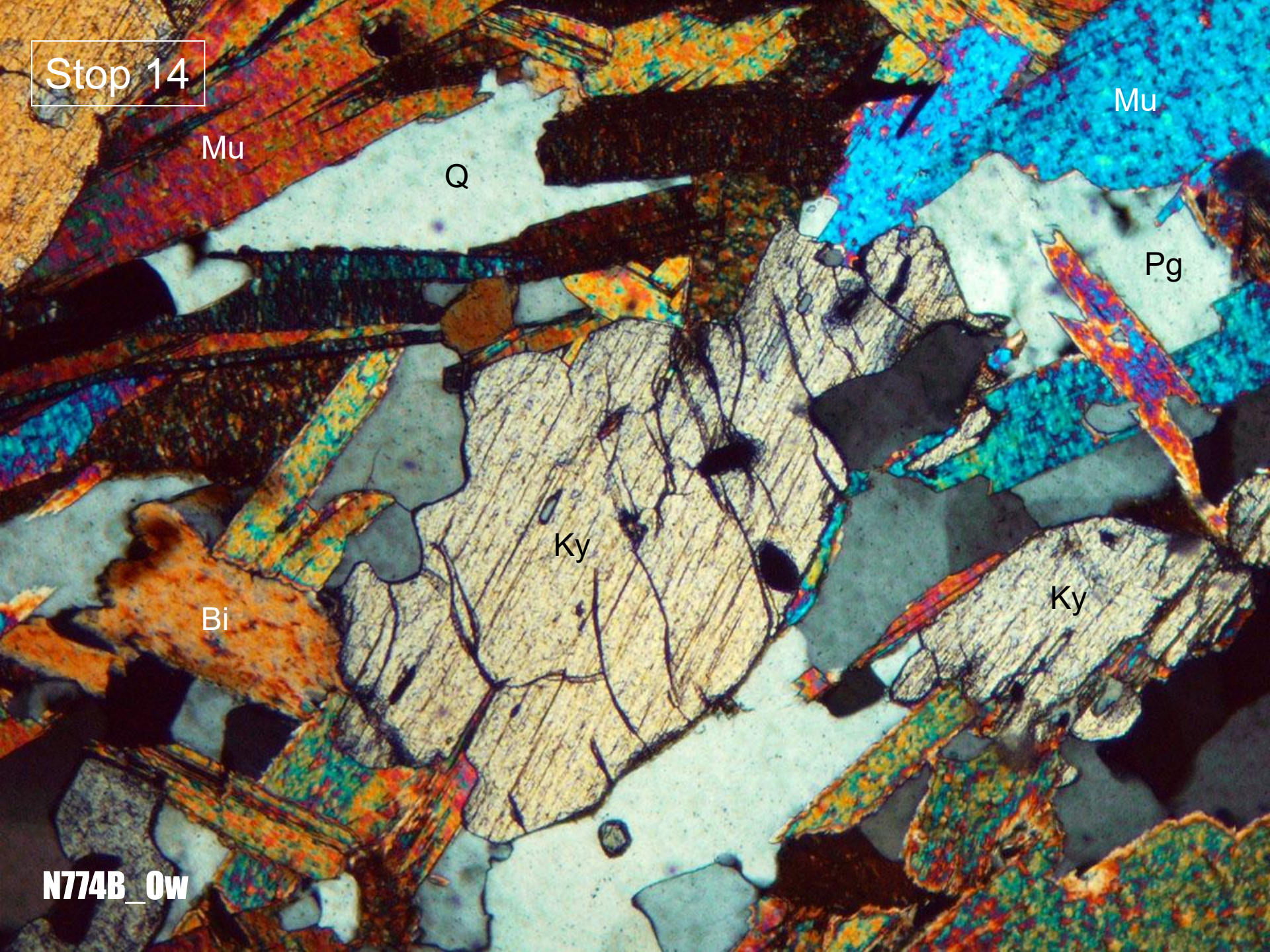

Stop 34
Owc

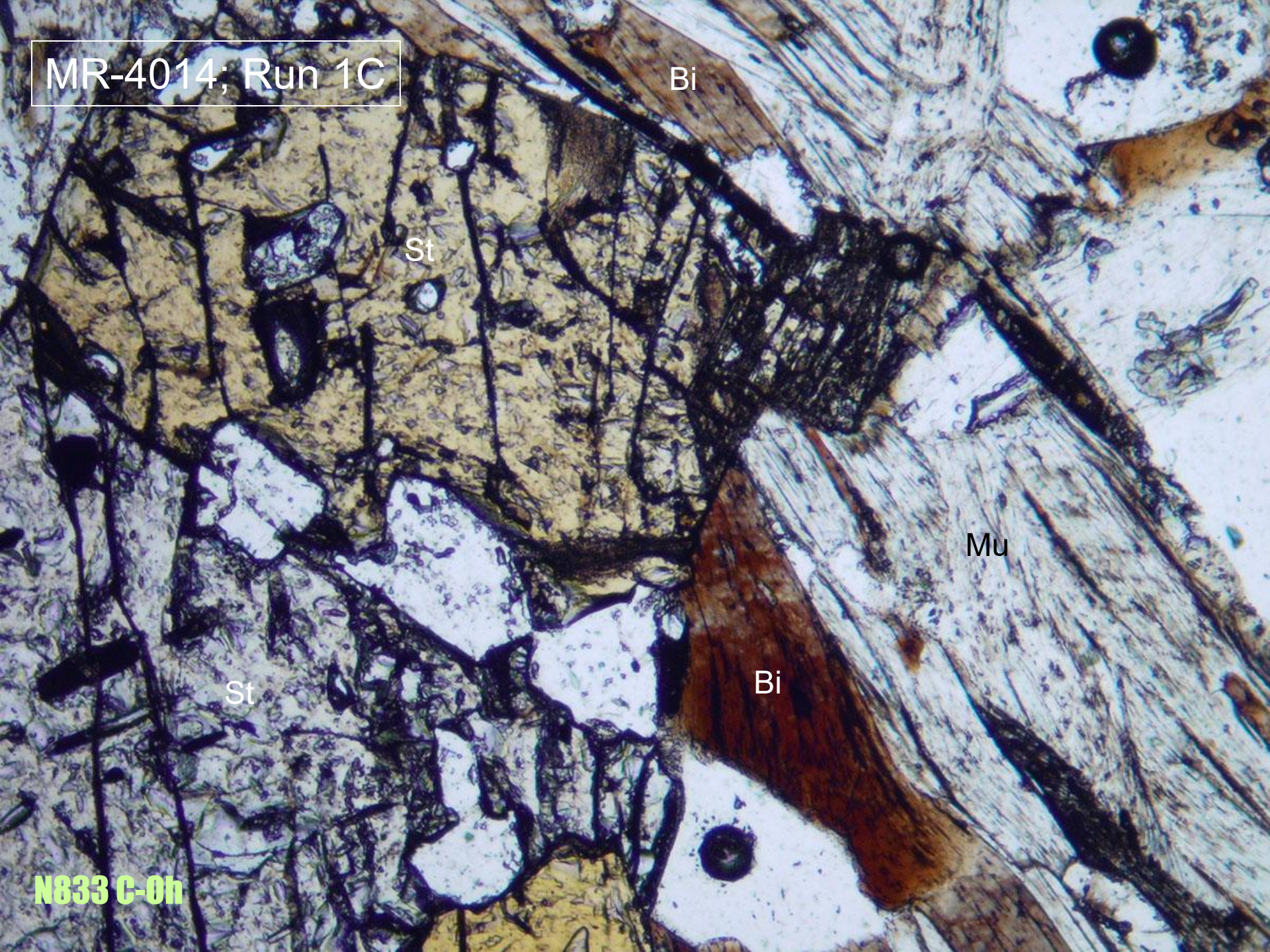

Stop 34
Zo
Pg
Zo
Pg
Bi
Zo
N793B_Ow


Stop 34
Zo
Pg
Zo
Pg
Bi
Zo
N793B Ow


Stop 14
Ow


Stop 14
Mu
Q
Mu
Pg
Ky
Bi
Ky
N774B_Ow

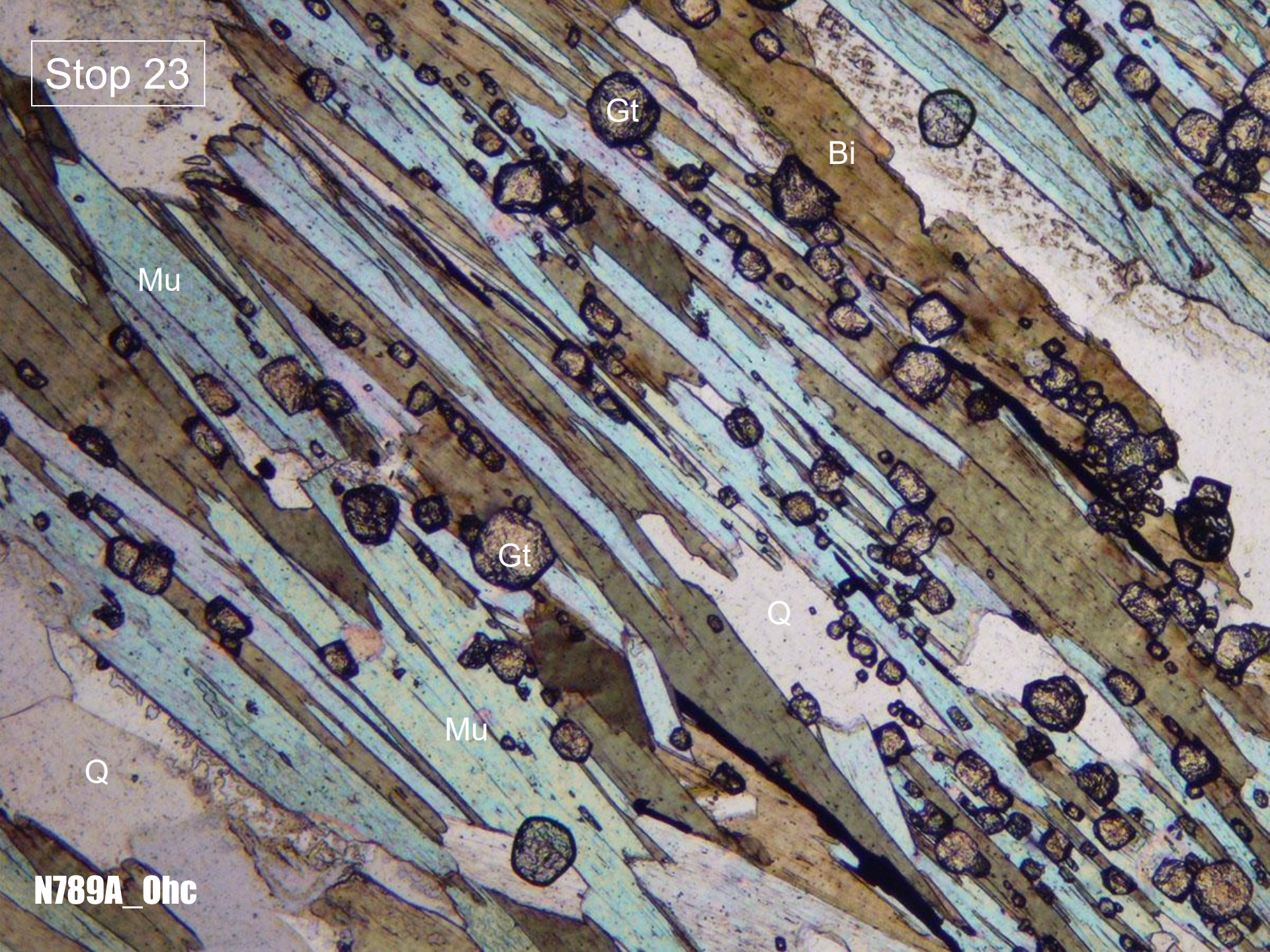

Stop 14
Mu
Q
Mu
Pg
Ky
Ky
Bi
N774B_Ow

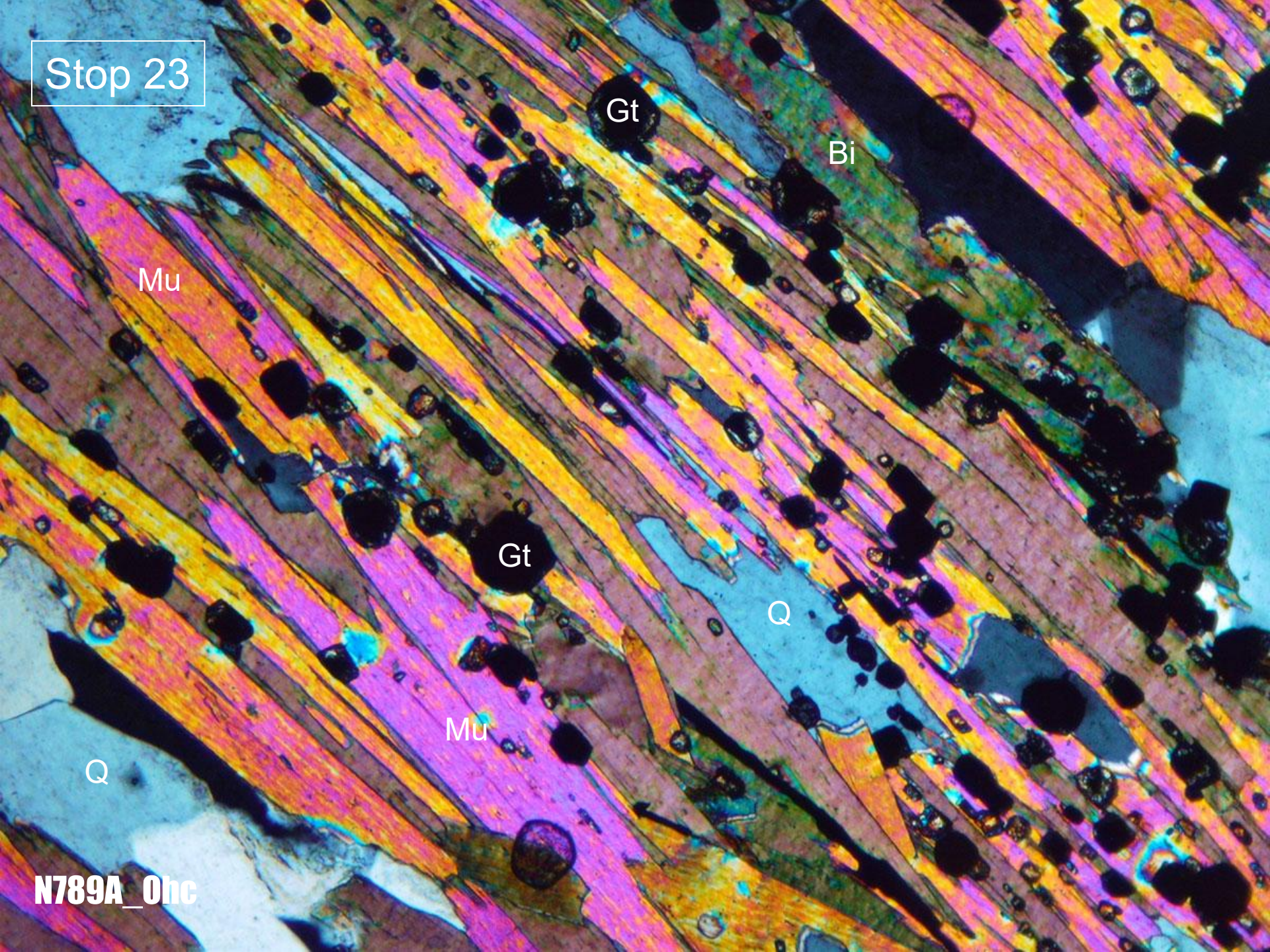

MR-4014; Run 1C
Bi
St
Mu
Bi
St
N833 C-0h

Hartland Coticule Found w/ Spessartine Garnet

C-Ohc


Stop 23
COh

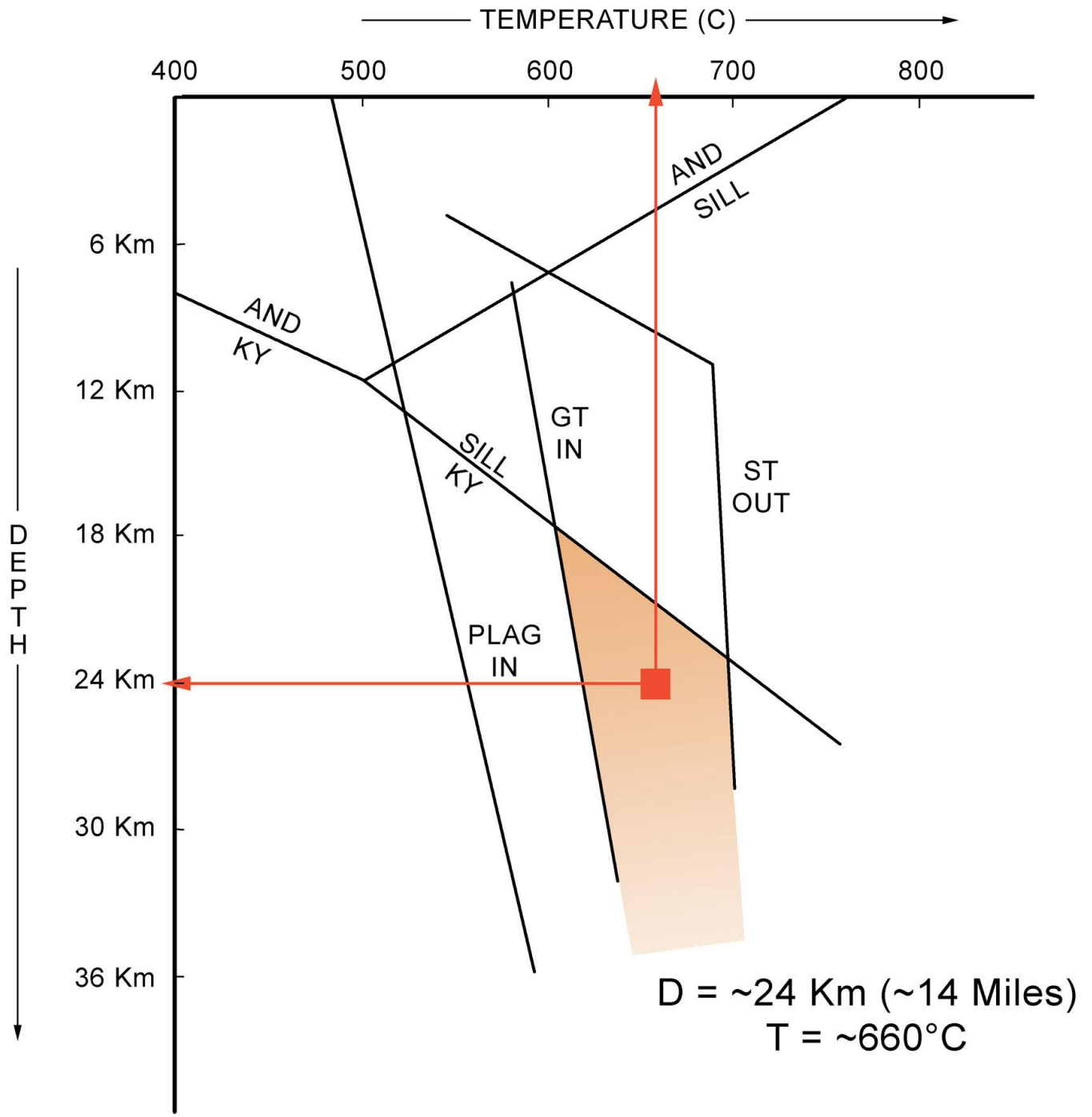

Stop 23
Gt
Bi
Mu
Gt
Q
Mu
Q
N789A_Ohc

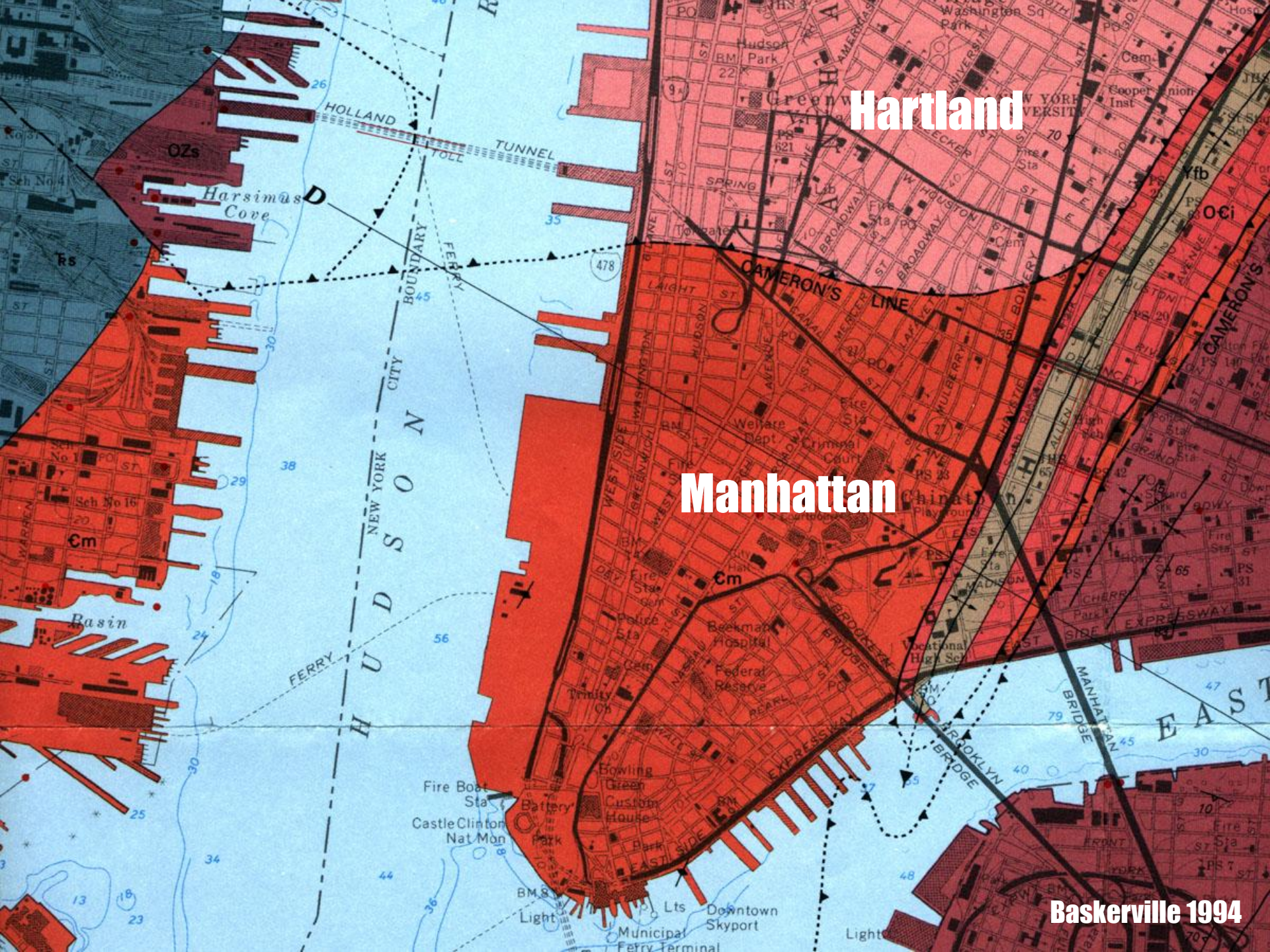

Stop 23
Gt
Bi
Mu
Gt
Q
Mu
Q
N789A_Ohc

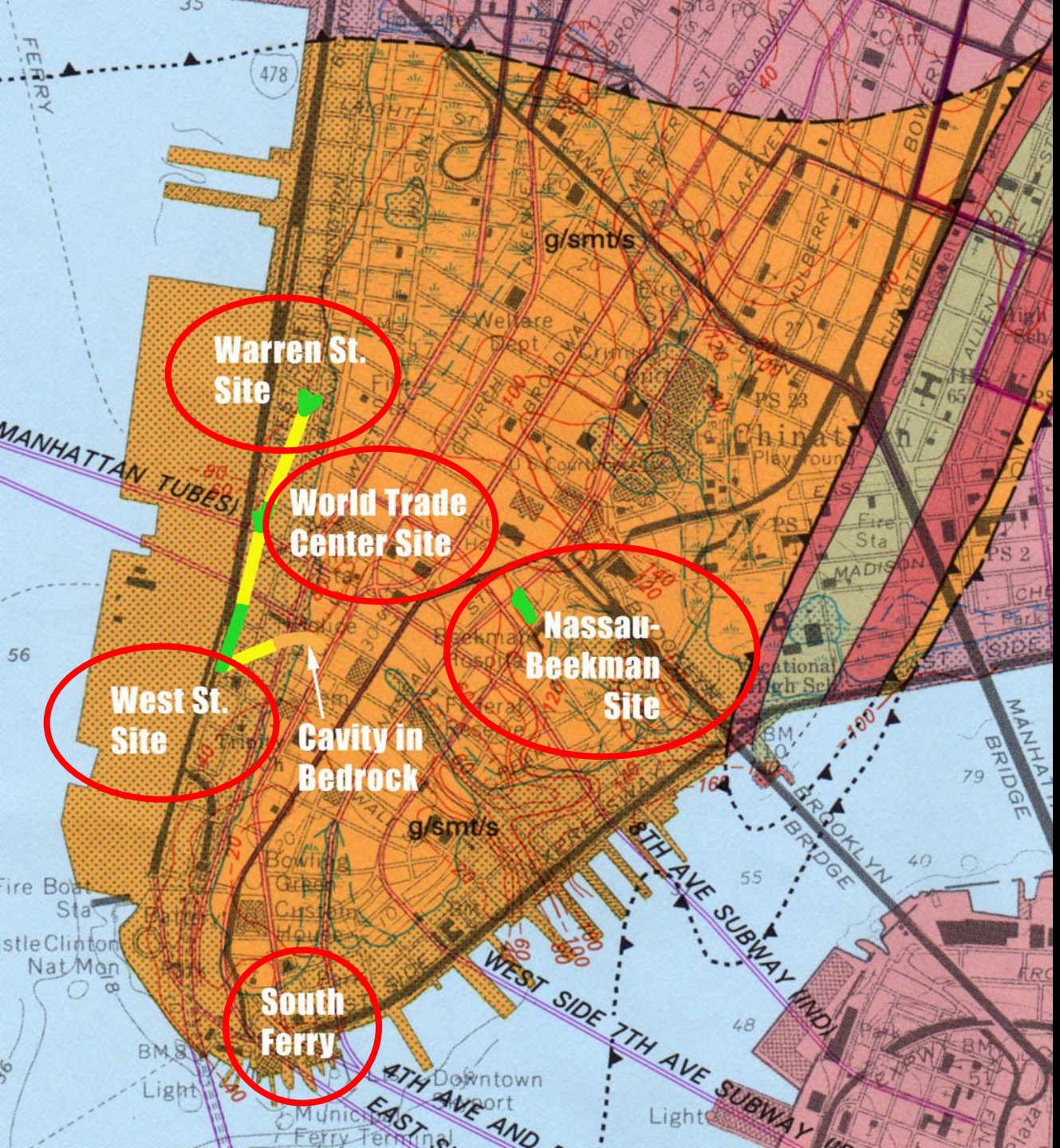
Minerals Are Your Pals!

WTC Minerals

Plagioclase
Garnet
Staurolite
Kyanite




Hartland
Manhattan
Baskerville 1994
HOLLAND TUNNEL
TOLL
Harsimus Cove
BOUNDARY
FERRY
CITY
NEW YORK
HUDSON
CAMERON'S LINE
CAMERON'S
Basin
FERRY
Fire Boat Sta
Castle Clinton Nat Mon
Battery Park
Bowling Green
Custom House
Municipal Ferry Terminal
Downtown Skyport
Lts
Light
BROOKLYN BRIDGE
MANHATTAN BRIDGE
EXPRESSWAY
Washington Sq Park
Hudson Park
Cooper Union
Welfare Dept
Criminal Court
Police Sta
Beekman Hospital
Federal Reserve
Trinity Ch
Vocational High Sch
Chinatown
Playground
Sch No 1
Sch No 16
Sch No 4
OZs
Rs
€m
Yfb
O€i



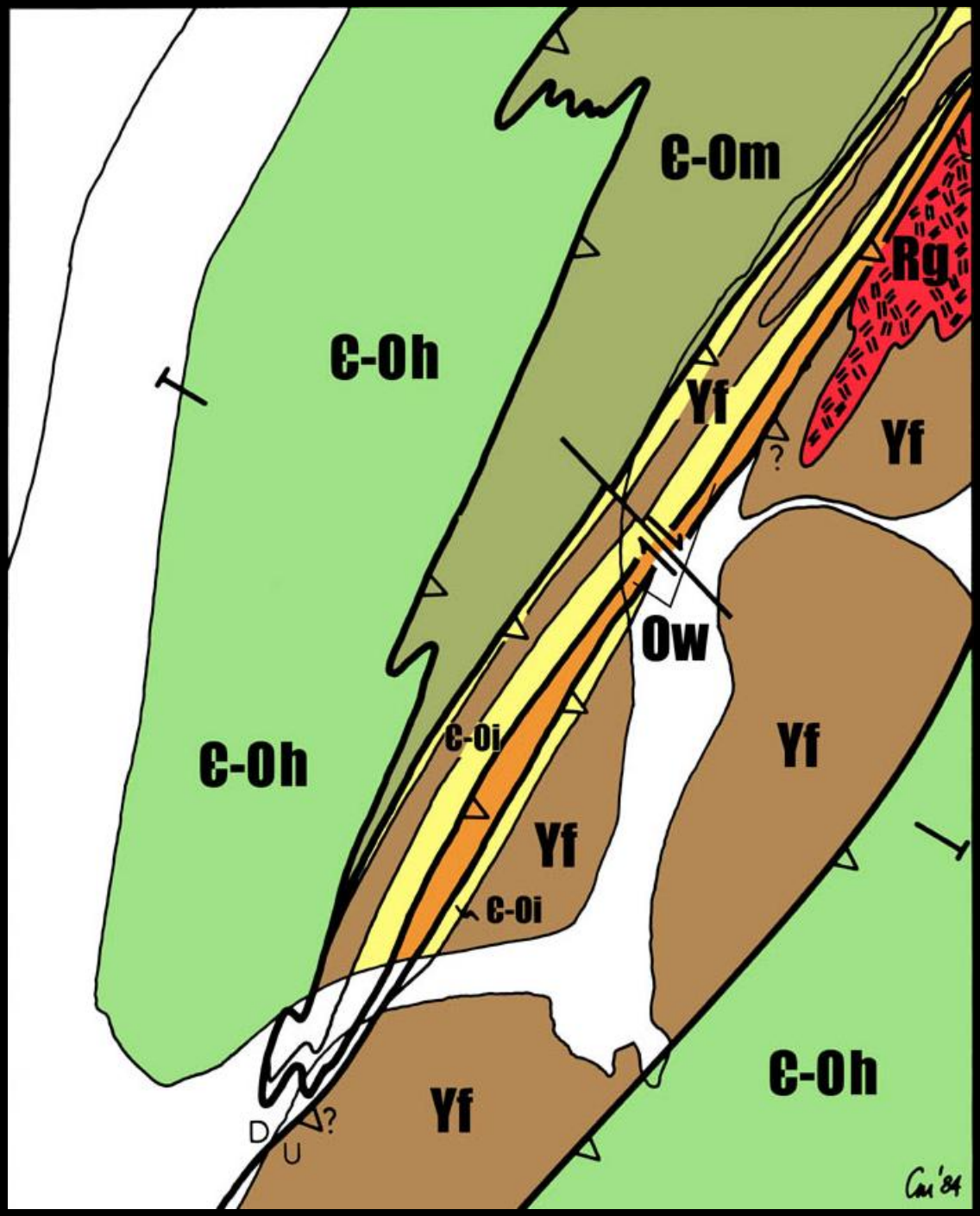
Five Localities South of Canal Street

Display Sheared Manhattan, Hartland, and Walloomsac Rocks!

after Baskerville 1994, Merguerian and Moss 2007


World Trade Center
Field Stops
32
33
31
37
21
18
17
34
20
16
15
19
14
22
13
8
12
11
7
9
30
10
35
28
29
27
6
5
26
4
25
23
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

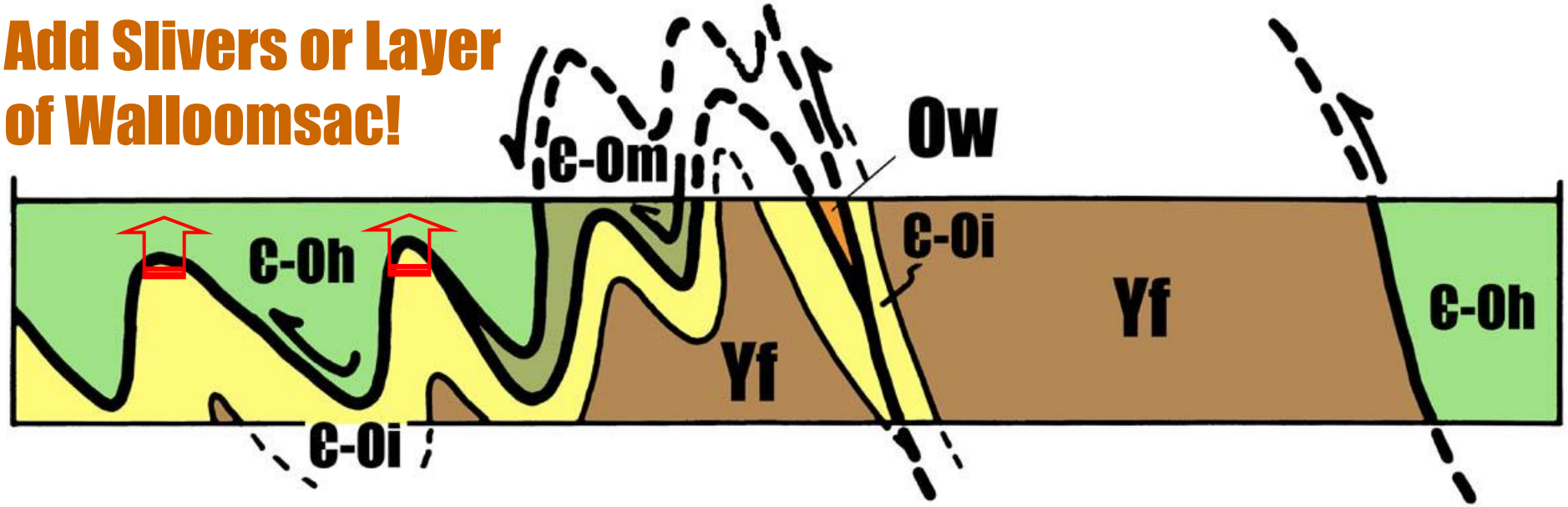

World Trade Center
Field Stops
C-Oh
Ow
Ow
C-Oh
Merguerian 2009

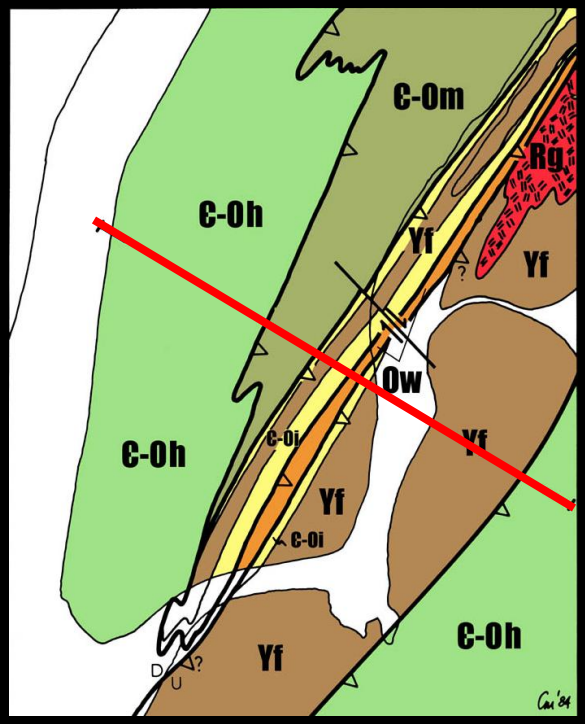


Interpretive Geologic Map of SE Manhattan, Brooklyn, and Queens Based on Borings of Berkey (1910)

Merguerian, 1984

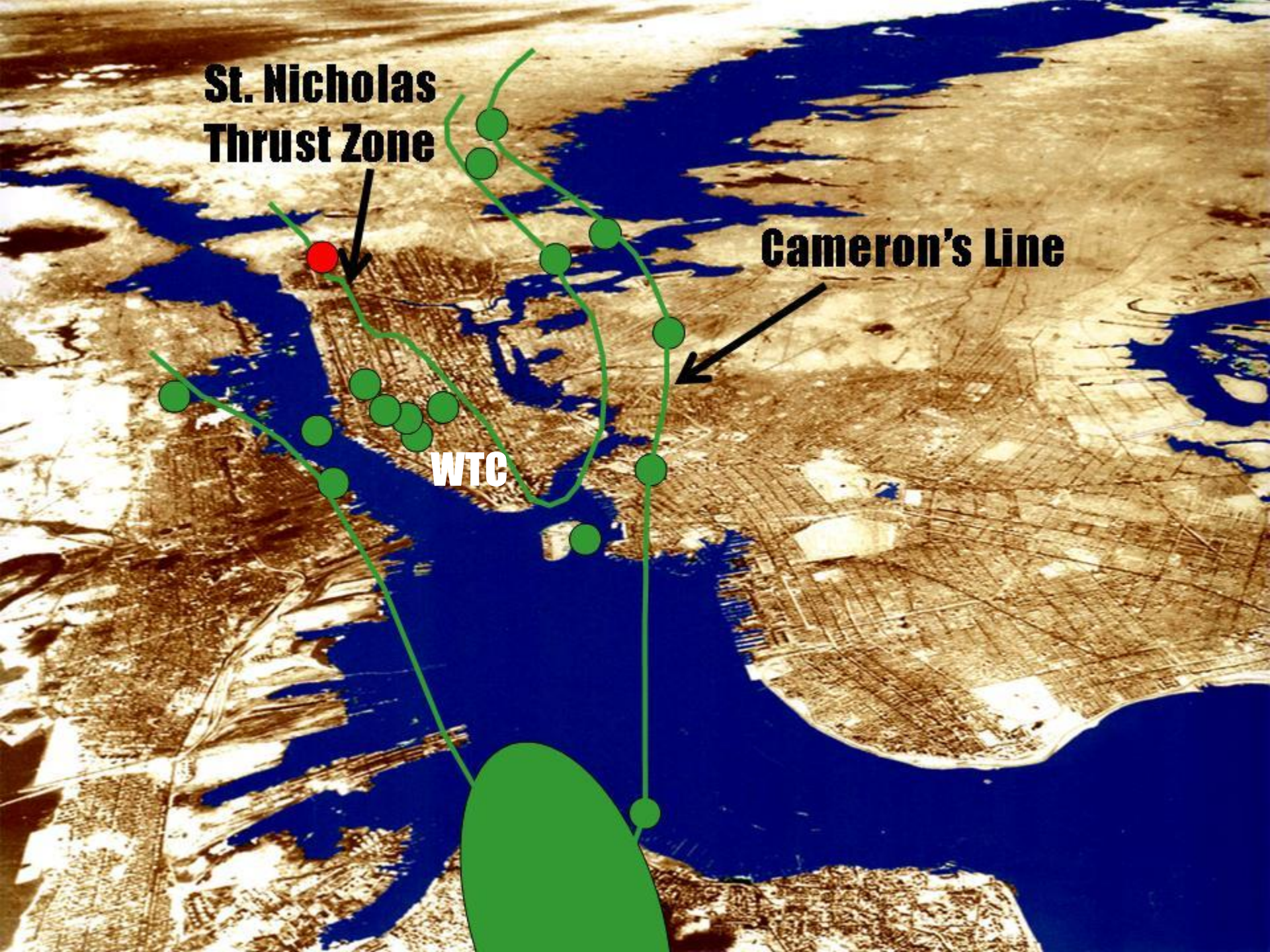
Add Slivers or Layer of Walloomsac!





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

Merguerian, ~~1984~~ (2010)


St. Nicholas
Thrust Zone
Cameron's Line
WTC


Biting? There's No Biting in the Hamster Industry!
Thanks For Attending Questions Please ??
Visit www.dukelabs.com for recent NYC geology articles

Future WTC Research at Hofstra Geology :

Refine Map
Mineralogy
Petrography
X-Ray Microprobe
XRF