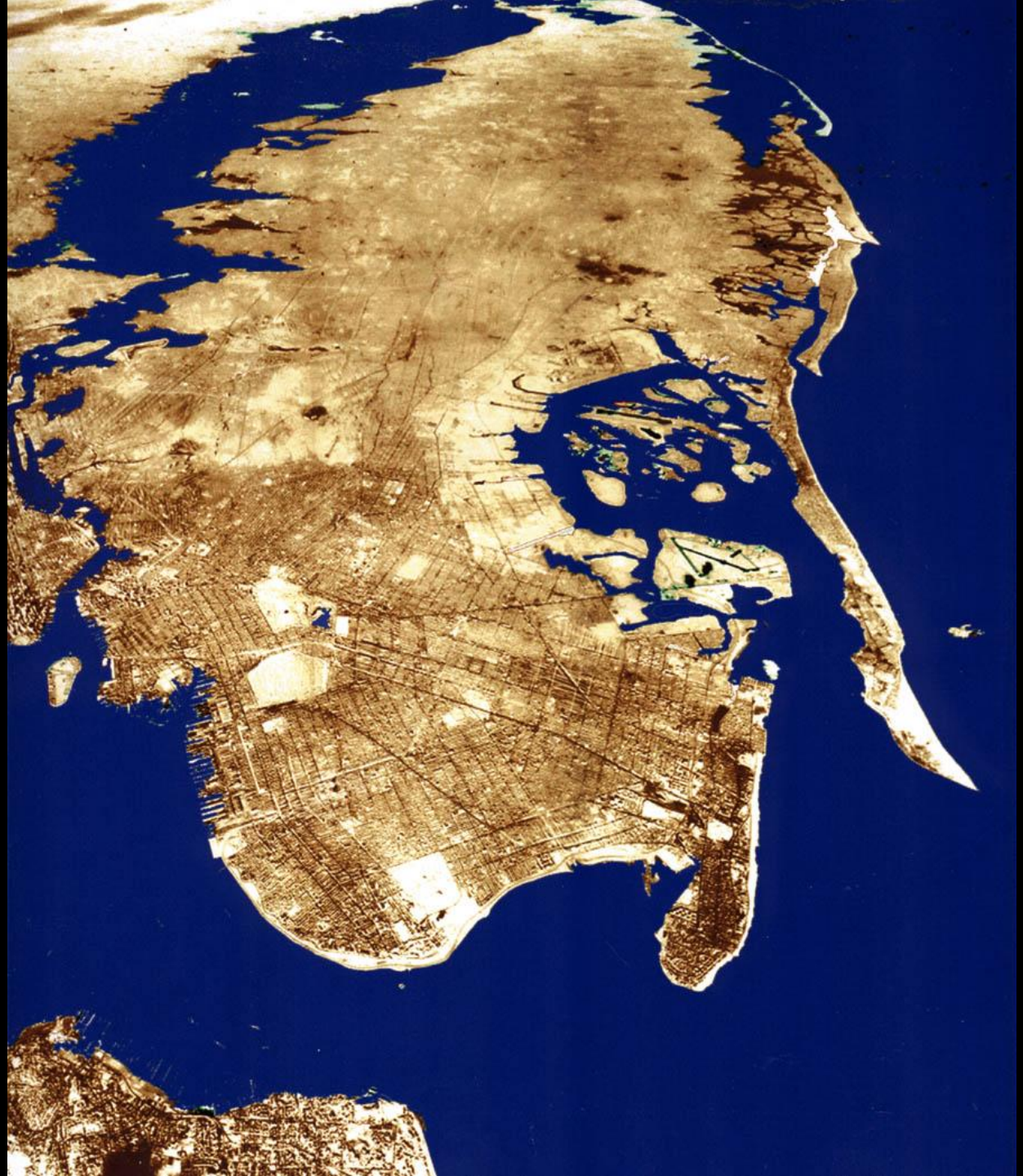
# Megaconstruction Projects in New York City


## Charles Merguerian

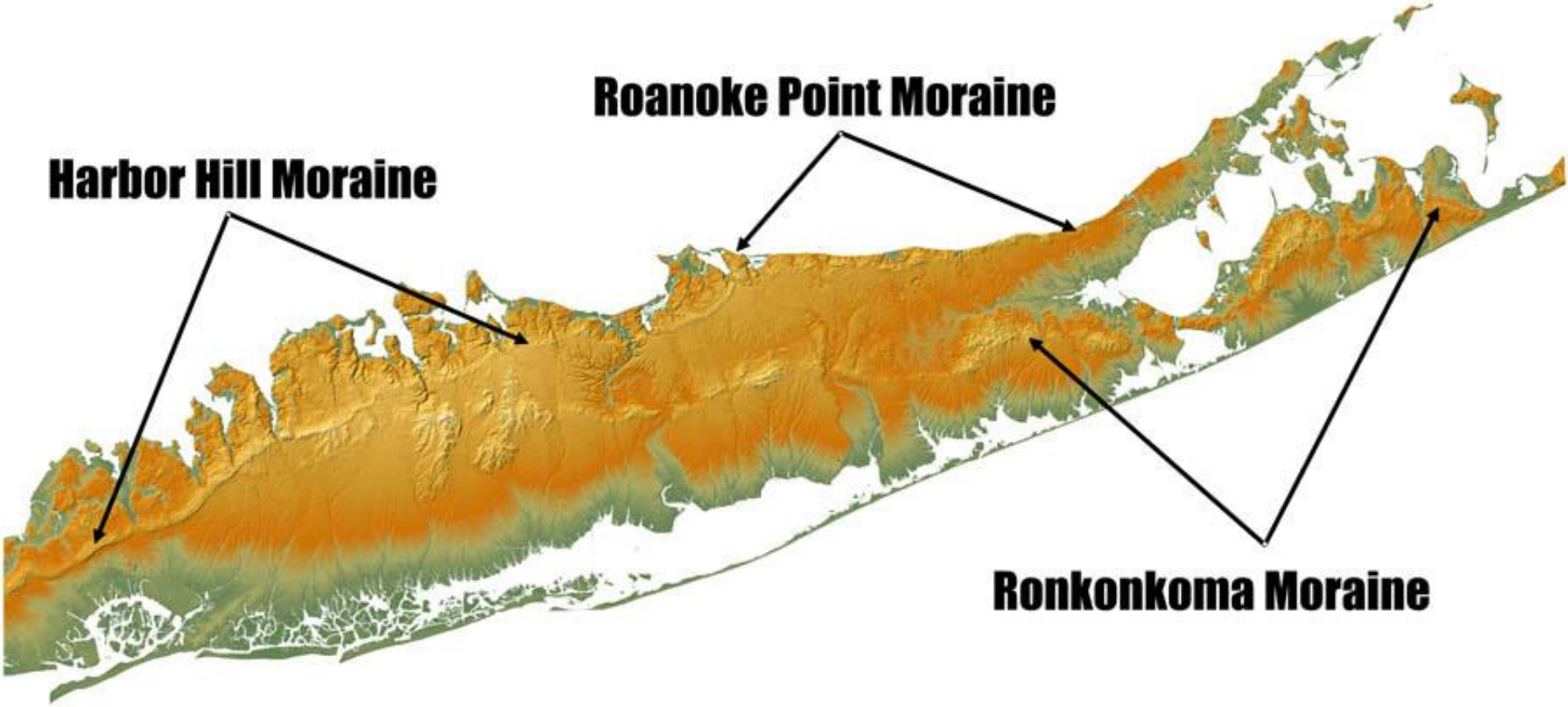
Hofstra Geology


# Lon Gisland

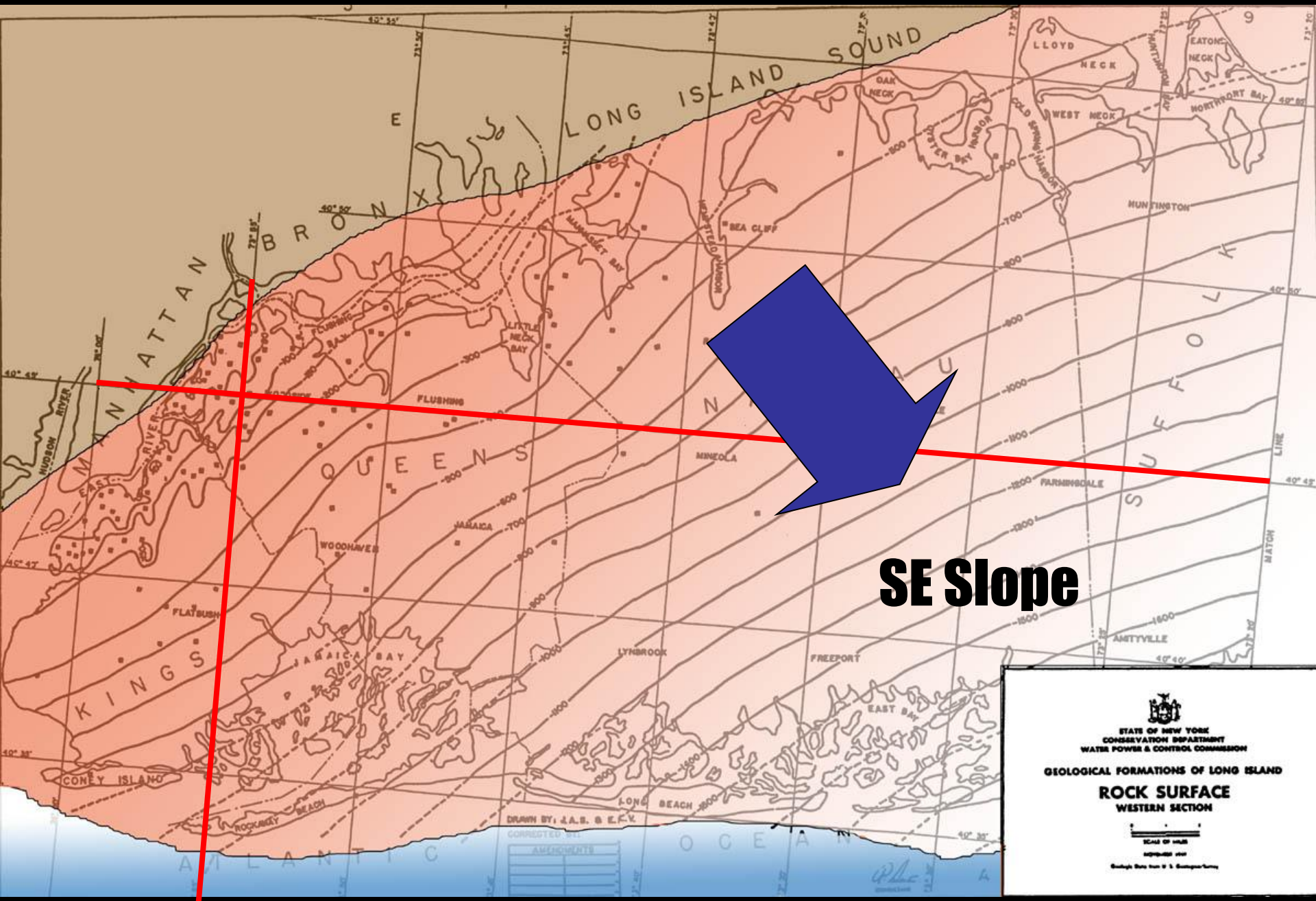
## Proper Spelling and Pronounciation

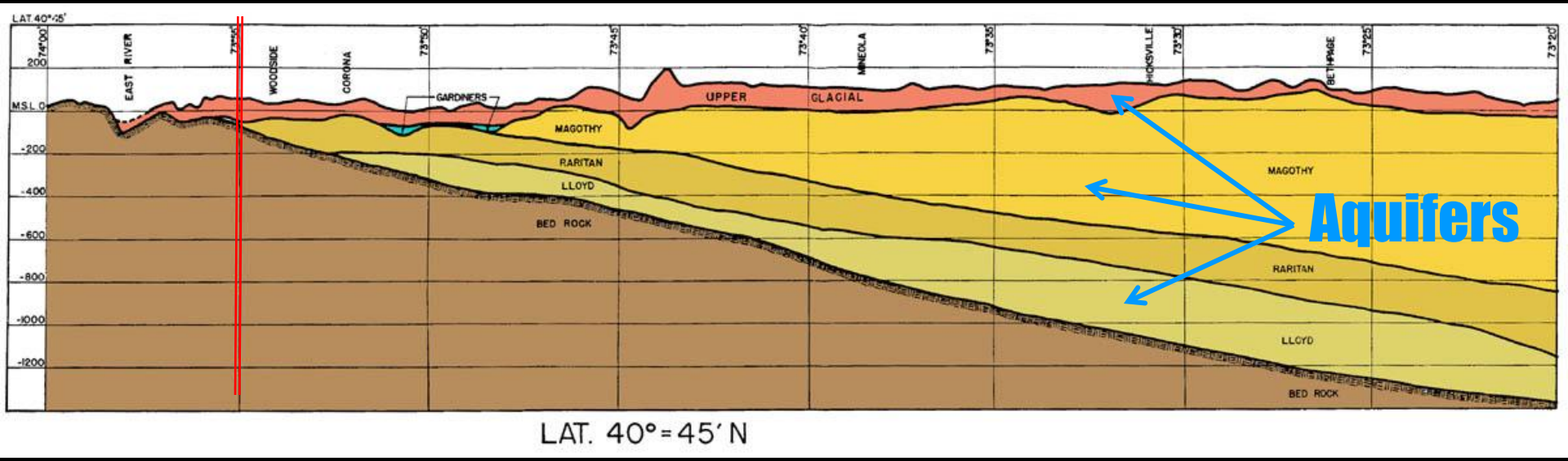


# Long Island's Glacial Moraines

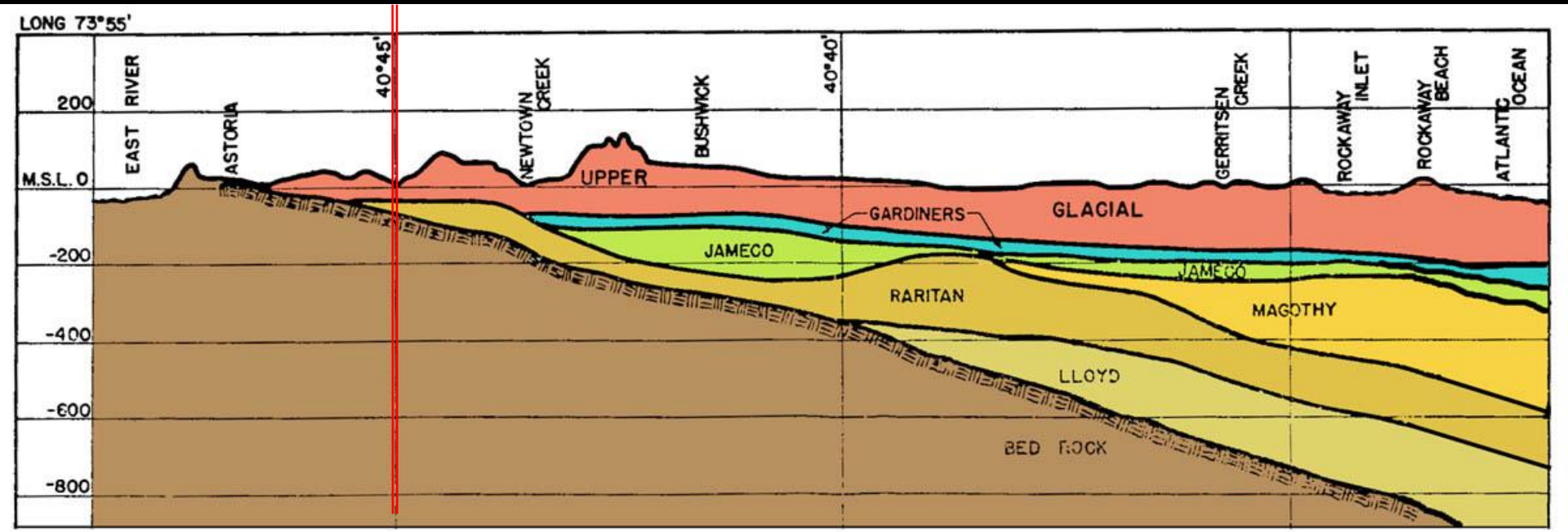



after Bennington, 2003


LONG ISLAND SOUND
MANHATTAN
BRONX
QUEENS
NASSAU
SUFFOLK
KINGS
LLOYD NECK
EATONS NECK
OAK NECK
WEST NECK
HUNTINGTON
BEA CLIFF
FLUSHING
MINEOLA
FARMINGDALE
WOODHAVEN
JAMAICA
FLATBUSH
JAMAICA BAY
LYNBROOK
FREEPORT
AMITYVILLE
EAST BAY
LONG BEACH
CONEY ISLAND
ROCKAWAY BEACH
HUDSON RIVER
EAST RIVER
LITTLE NECK BAY
MANHASSET BAY
HEMPSTEAD HARBOR
OYSTER BAY HARBOR
COLD SPRING HARBOR
NORTHPORT BAY
MATCH LINE
DRAWN BY: J.A.B. & E.F.V.
CORRECTED BY:
AMENDMENTS
ATLANTIC OCEAN
STATE OF NEW YORK
CONSERVATION DEPARTMENT
WATER POWER & CONTROL COMMISSION
GEOLOGICAL FORMATIONS OF LONG ISLAND
ROCK SURFACE
WESTERN SECTION
SCALE OF MILES
SE Slope



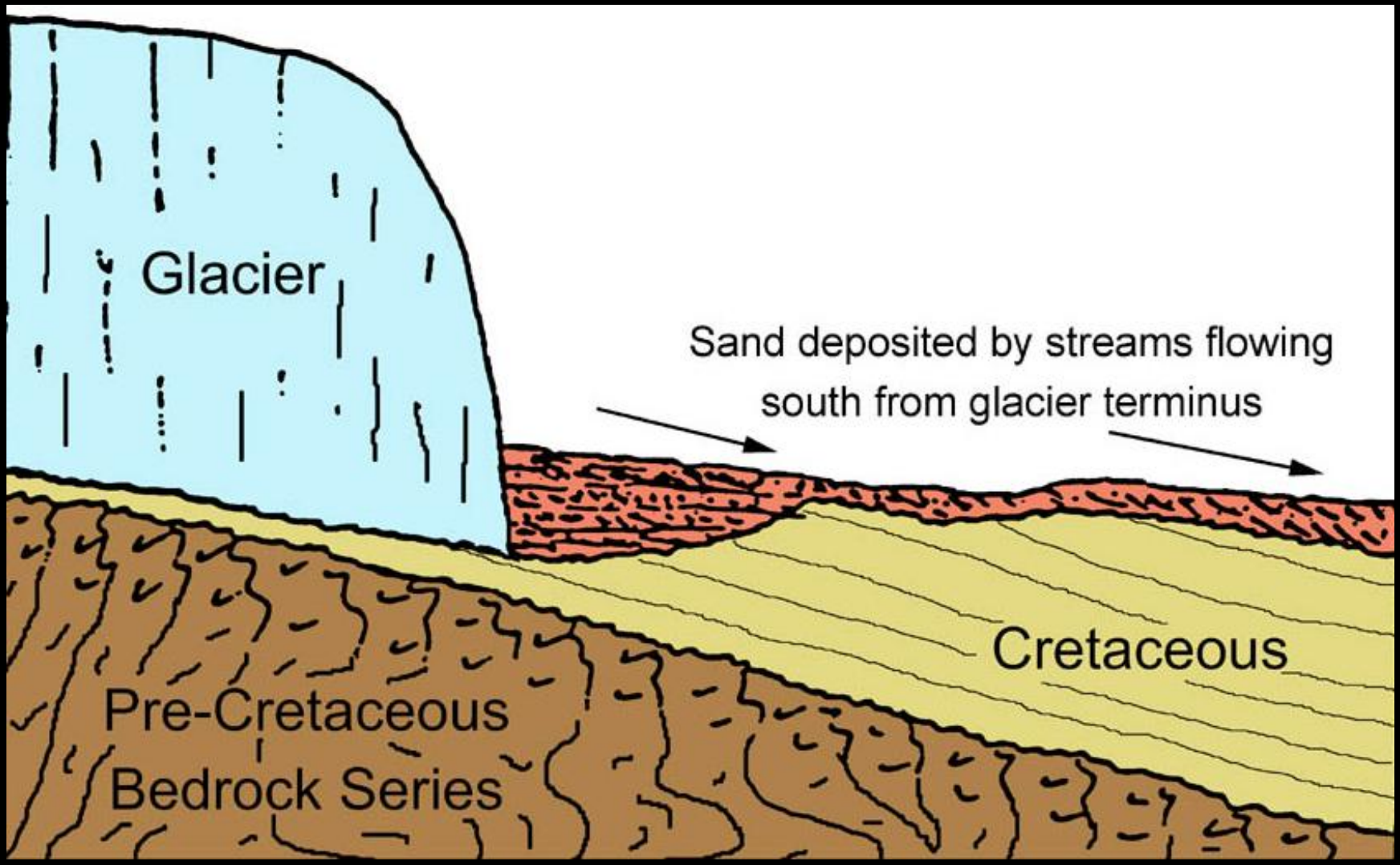

LAT. 40°=45' N



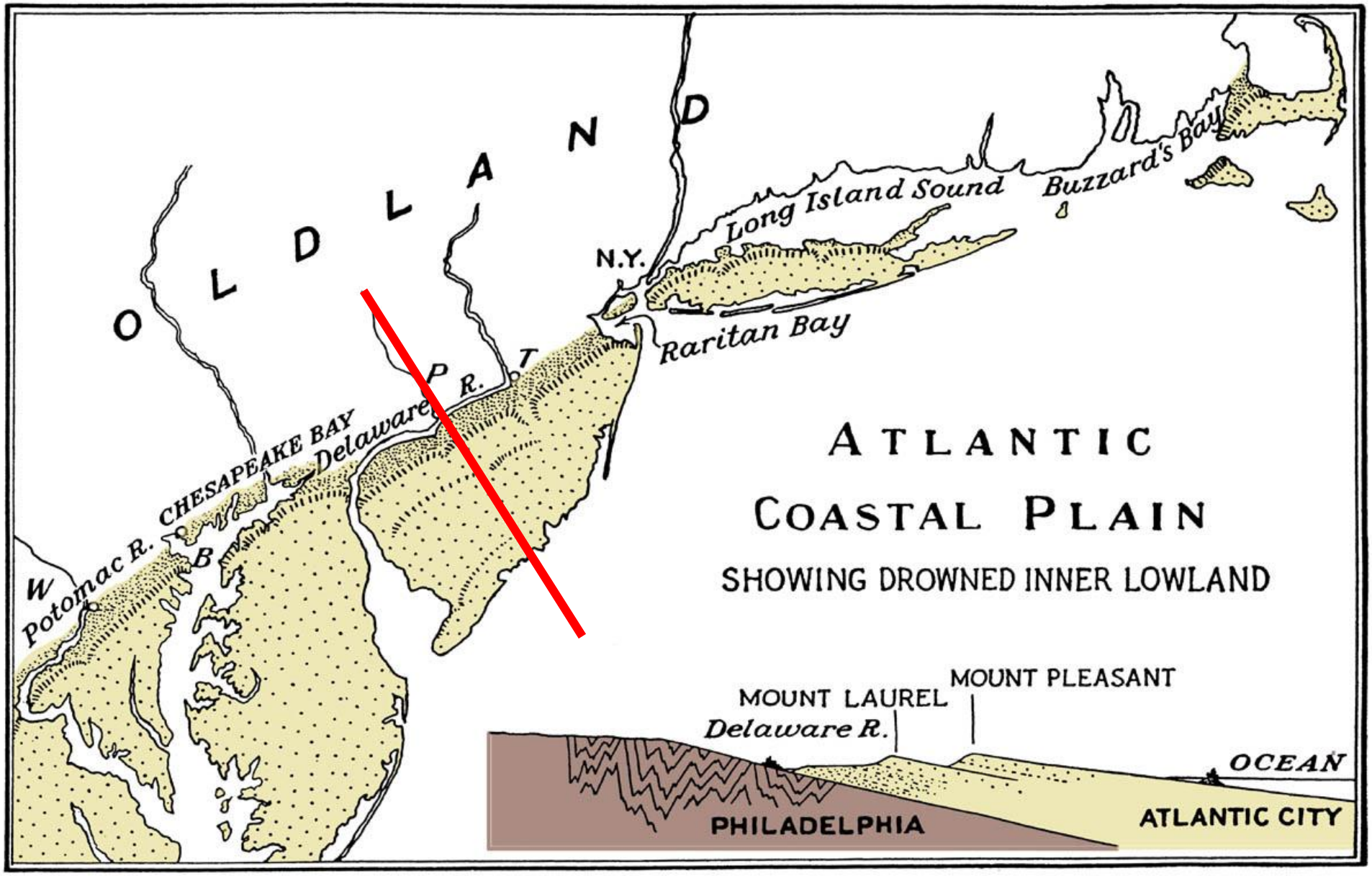

LONG. 73°=55' W

**Suter et al, 1949**

# Long Island Outwash Fans




after Merguerian and Sanders 1993

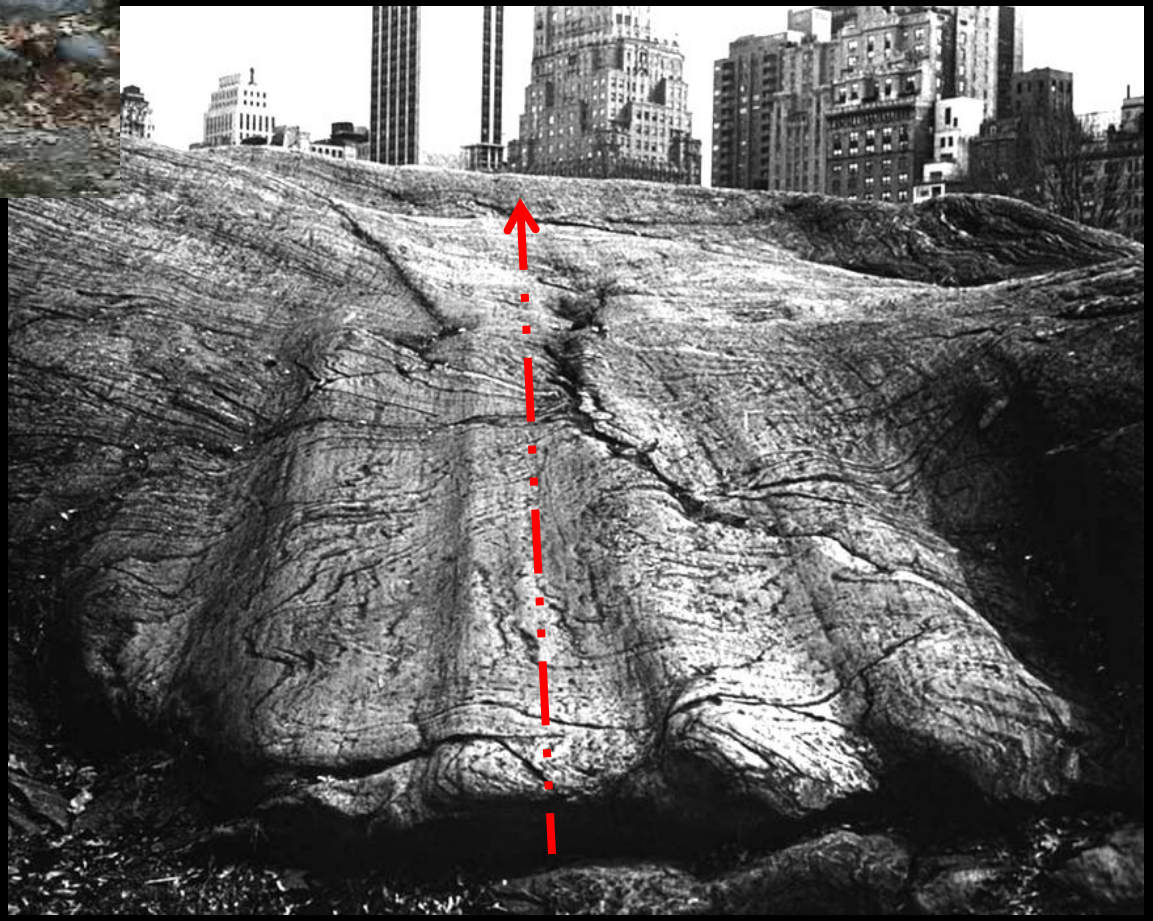


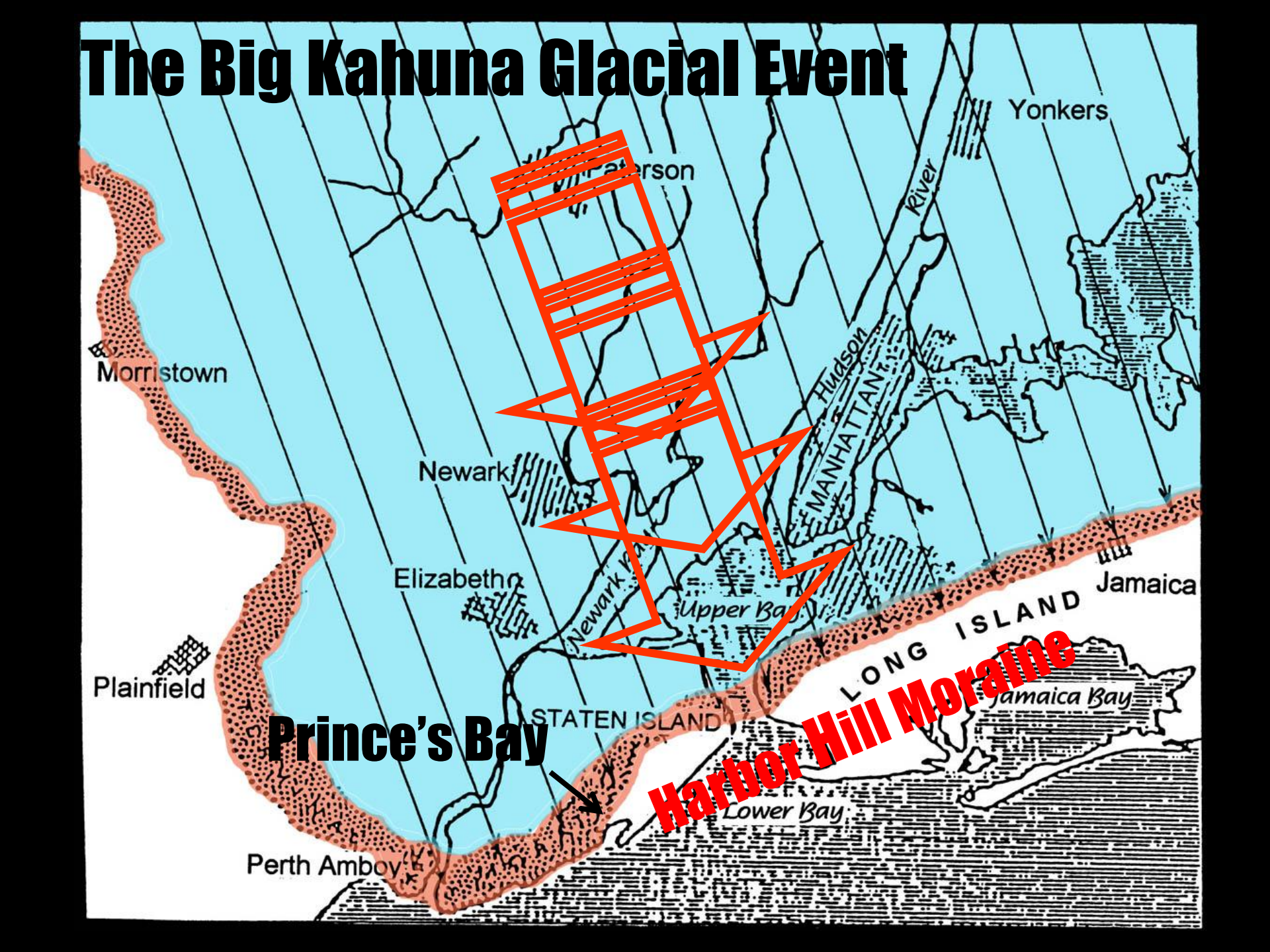

# Cretaceous Coastal Plain


# Pleistocene Glaciation

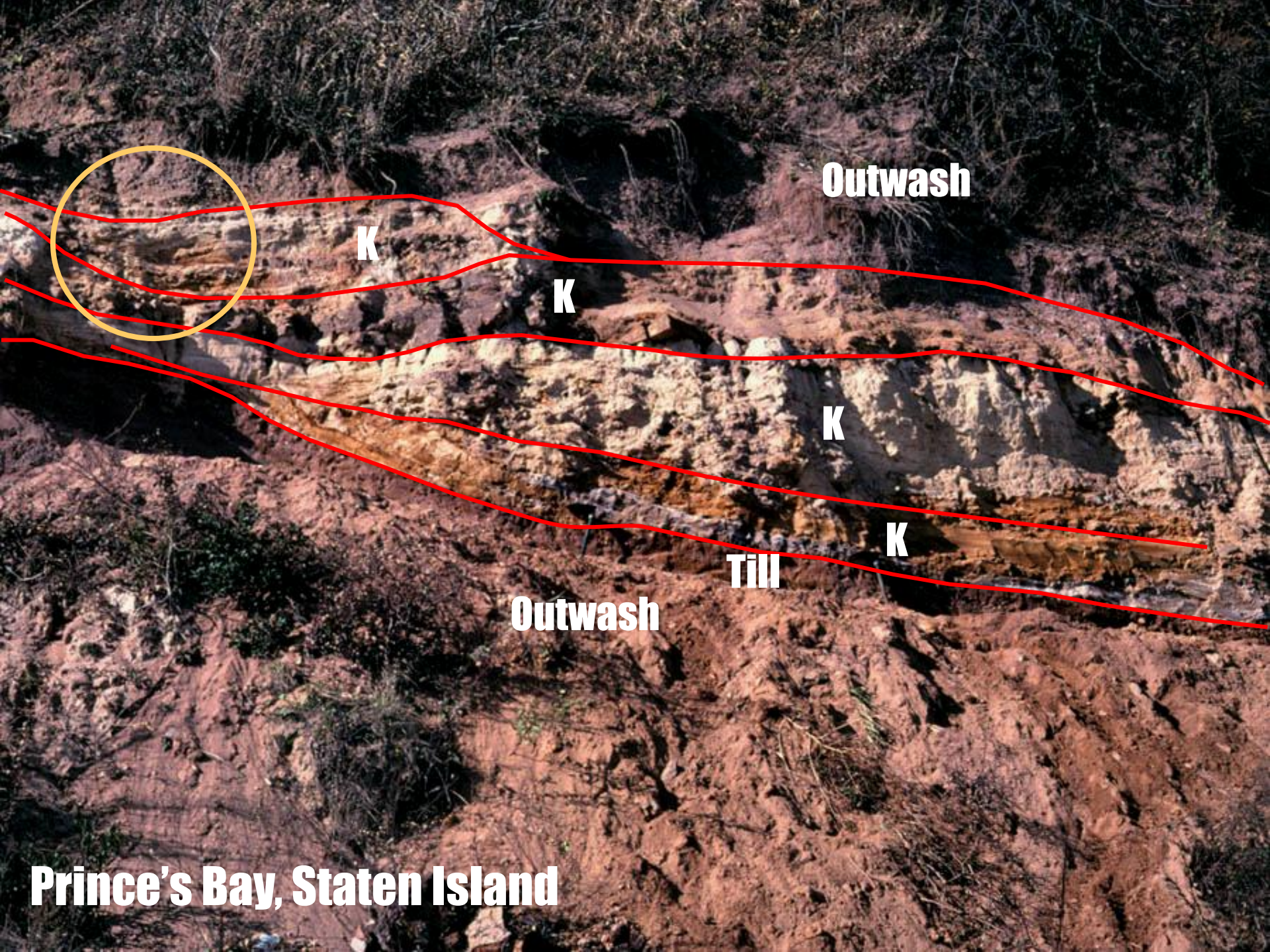
SE-Directed Glacial Striae, Central Park, NYC

# SE Glacial Grooves
# Central Park, NYC




The Big Kahuna Glacial Event
Yonkers
Hudson River
MANHATTAN
Morristown
Newark
Elizabeth
Jamaica
LONG ISLAND
Plainfield
STATEN ISLAND
Jamaica Bay
Prince's Bay
Harbor Hill Moraine
Lower Bay
Perth Amboy


Prince's Bay, Staten Island

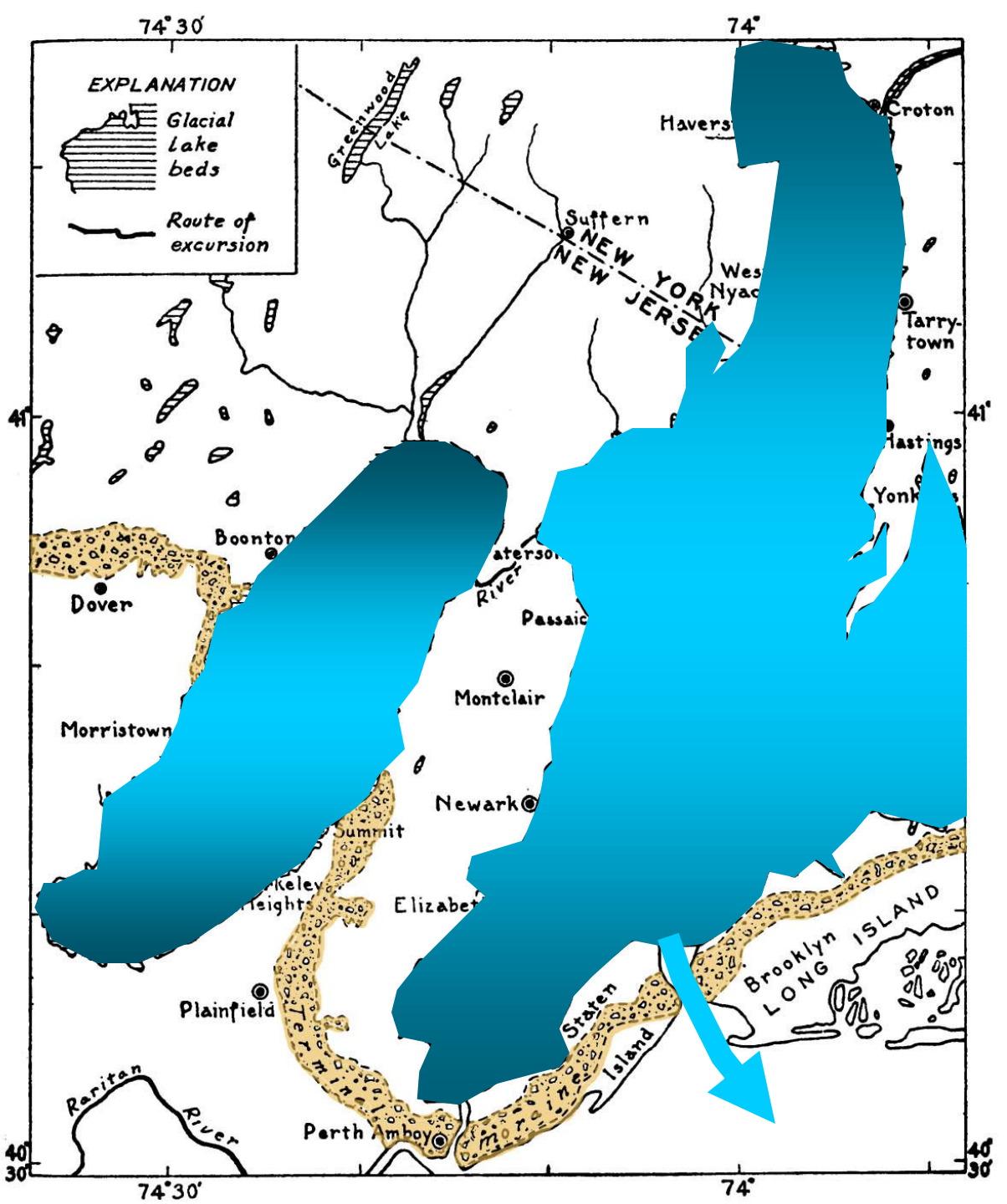

Outwash
K
K
K
K
Till
Outwash
Prince's Bay, Staten Island

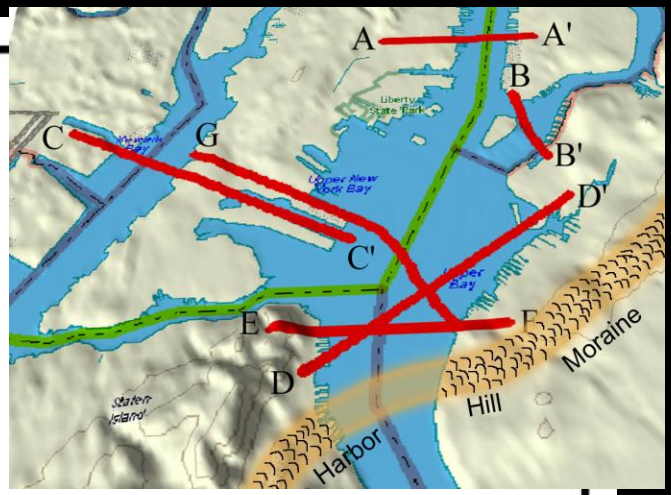

Plunge 17° into S60°W
AP = N4°E, 20°NW

# Glacial Lake Strata and the Harbor Hill Moraine

## Post-Woodfordian Drainage Through The Narrows

Berkey (1933)






G

o

tu

Stockton

v

o

tu

Walloomsac

o

Holocene silt

v

Hartland

# Two Tills and Varved Lake Strata Cut by Channels

E

o

tu

o

v

v

Holocene Silt

o

tu

tl

o

tl

o

?

?

F

o

tu

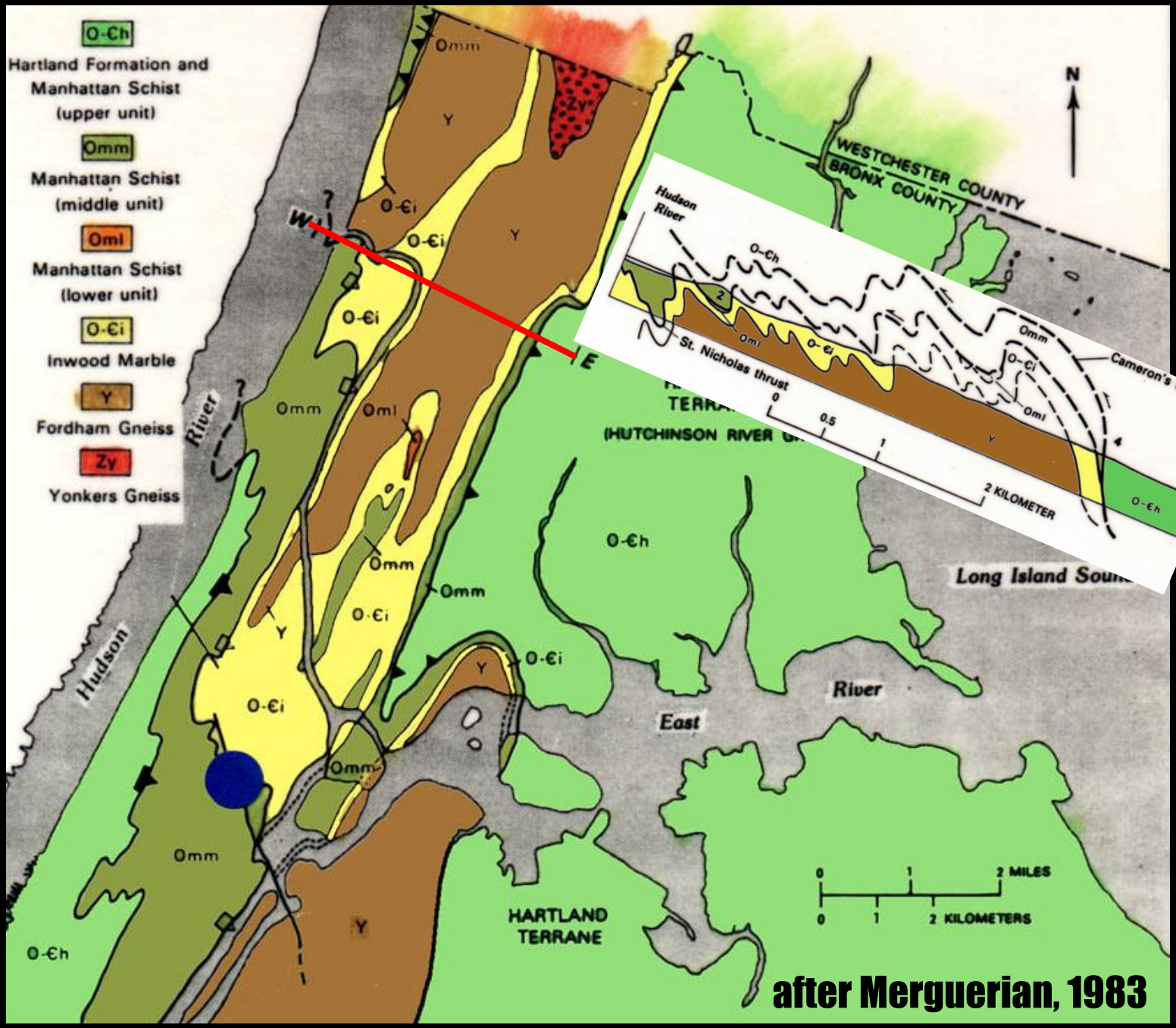
tl

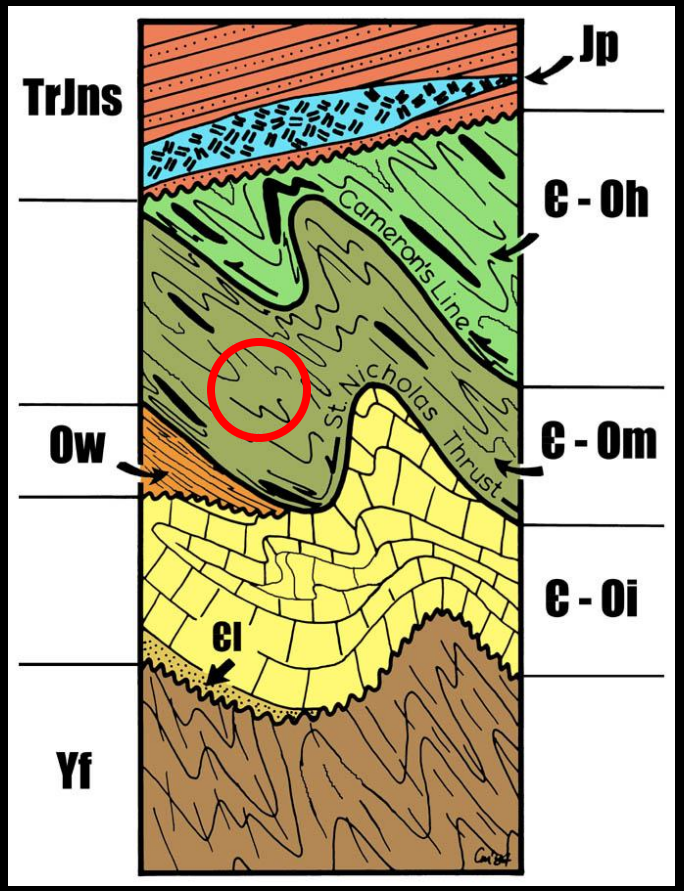
Serpentinite

Hartland

QT Complex

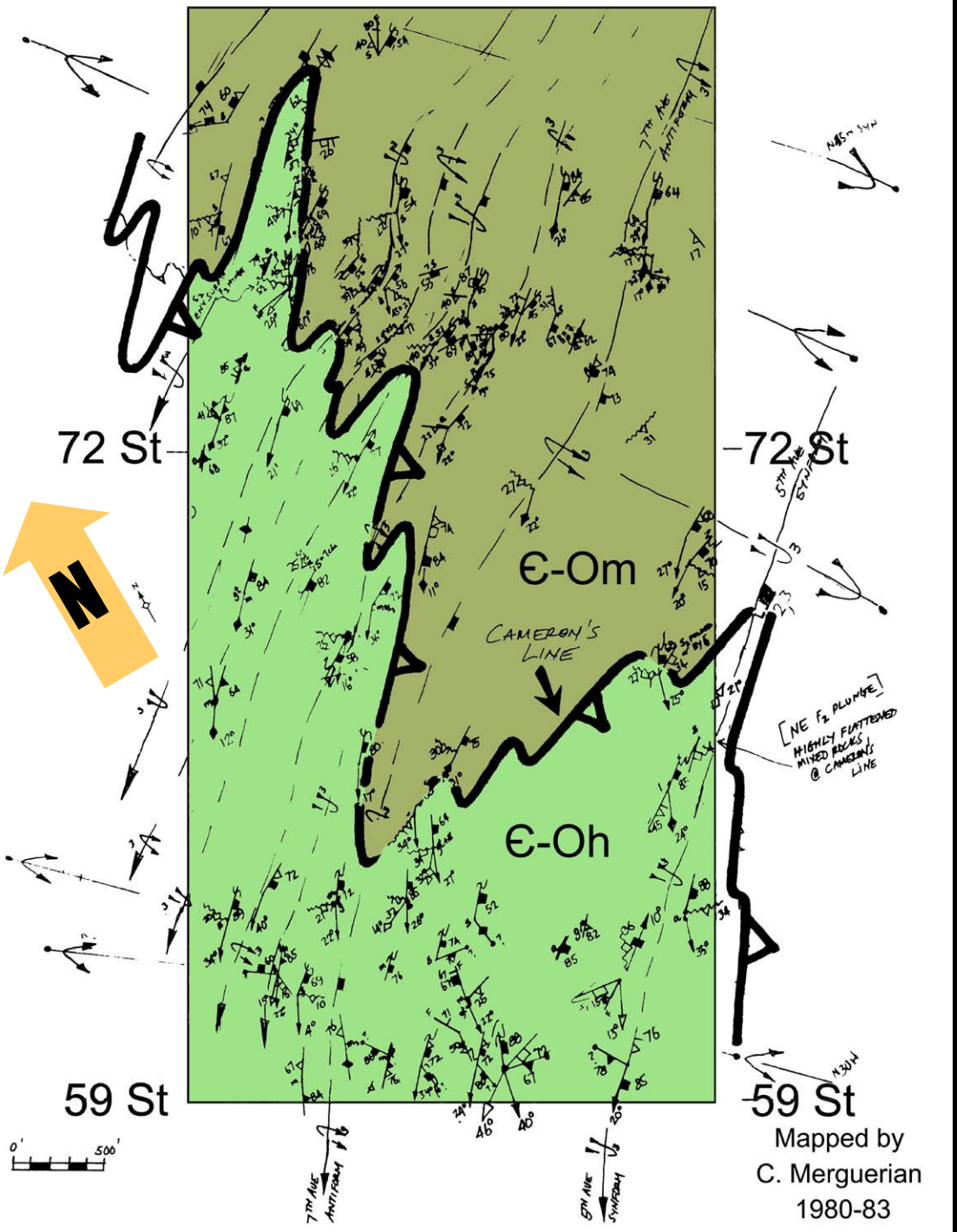
# Hudson Abandons Former Channels – Floods Through Narrows


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
N
WESTCHESTER COUNTY
BRONX COUNTY
Hudson River
O-Ch
Oml
O-Ei
Omm
St. Nicholas thrust
Cameron's Line
0
0.5
1
2 KILOMETER
W
E
Hudson River
East River
Long Island Sound
HARTLAND TERRANE
0 1 2 MILES
0 1 2 KILOMETERS
after Merguerian, 1983



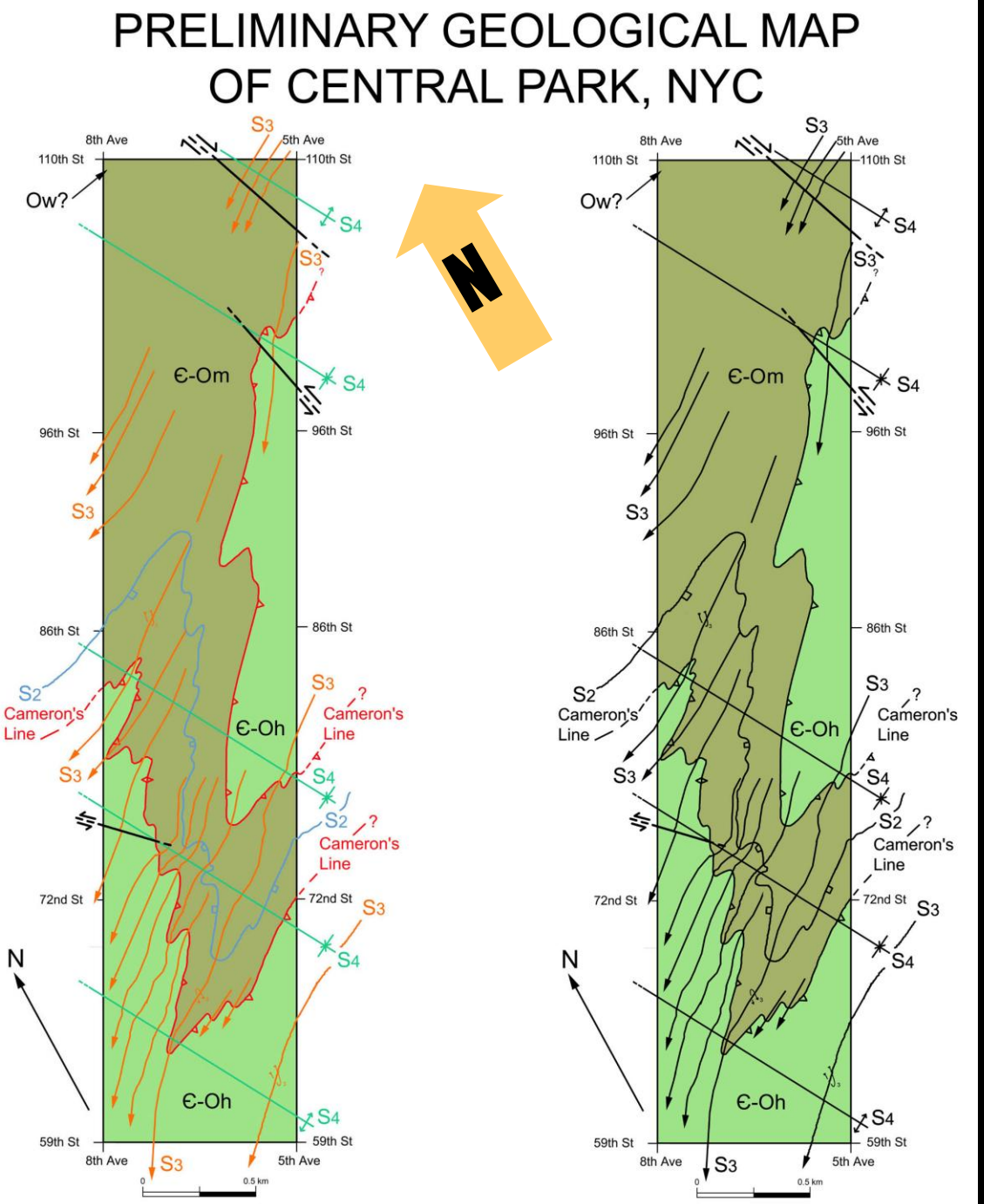

# $F_3$ Folds of $S_2$ Manhattan Schist Central Park, NYC

# Cameron's Line in Central Park

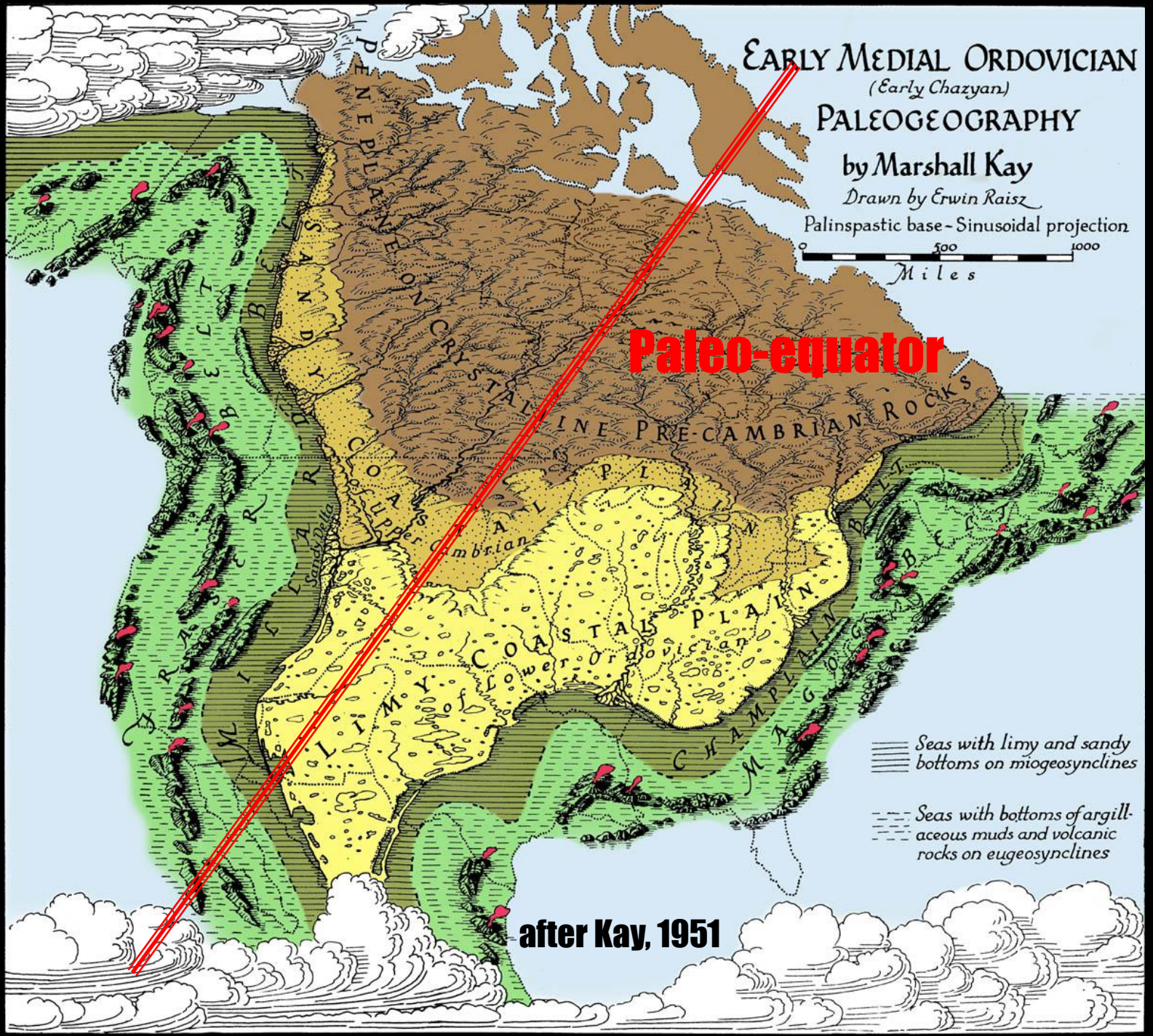



Merguerian 1980-83

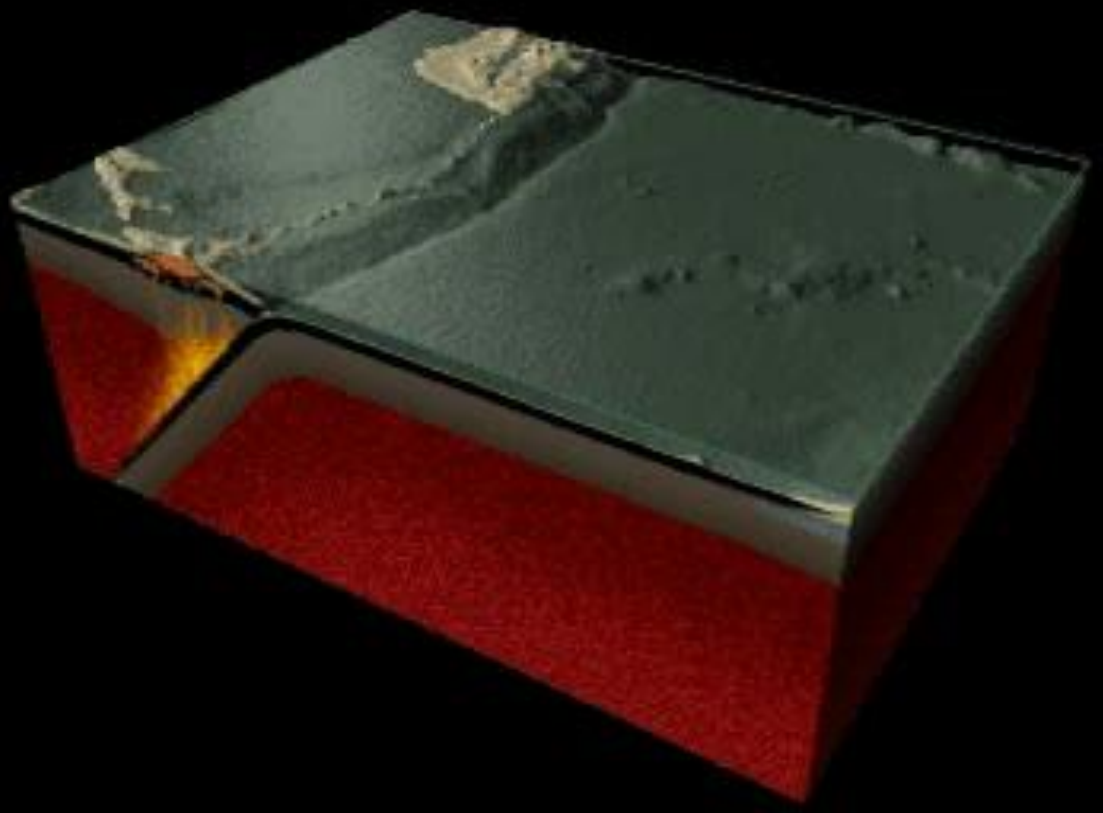
# Cameron's Line in Central Park



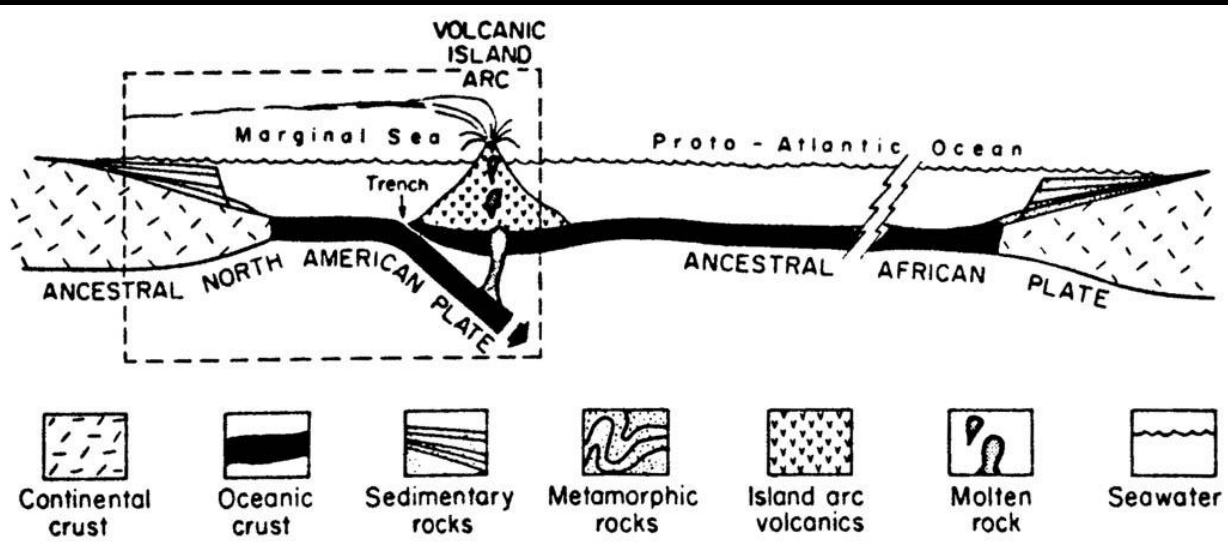

Merguerian and Merguerian, 2004

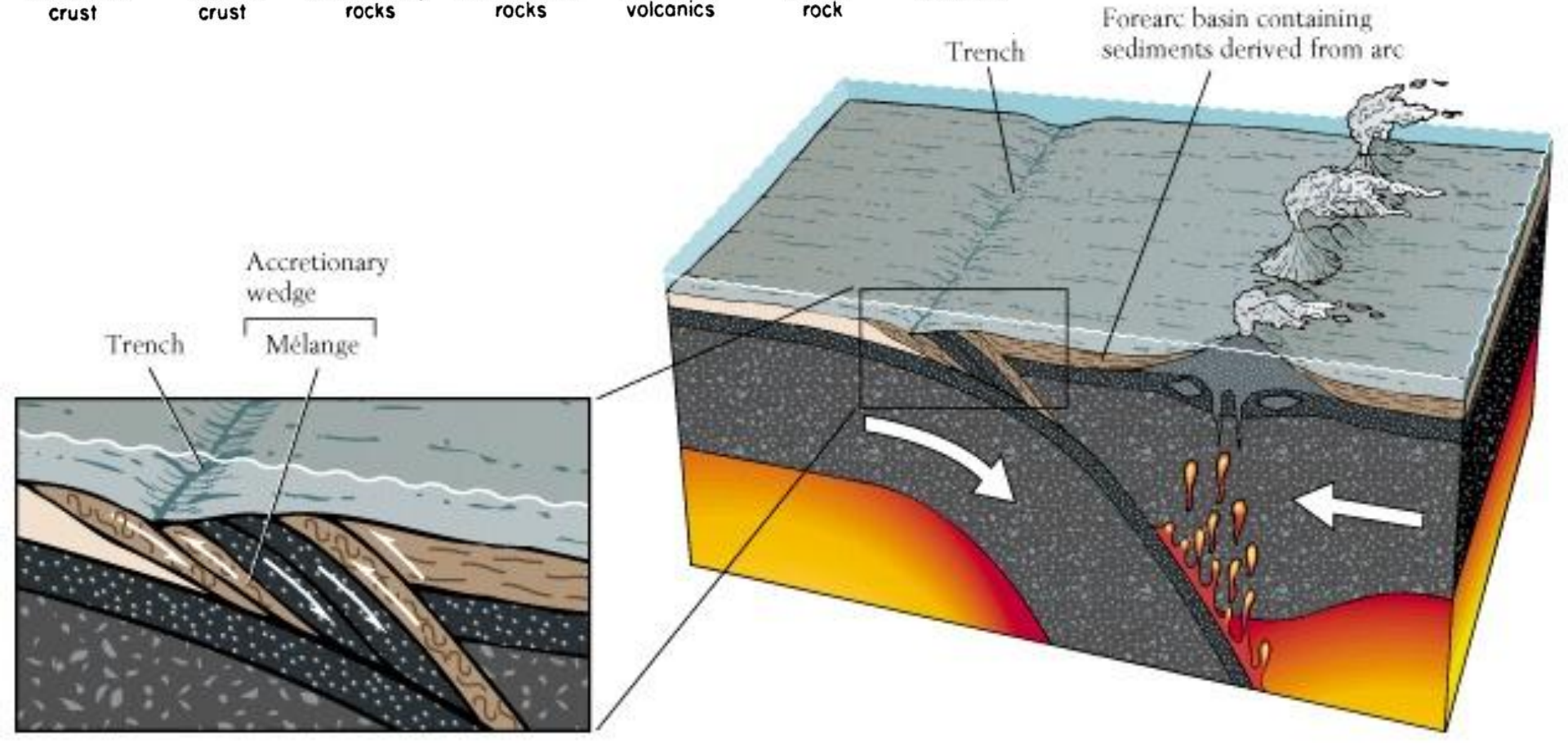

EARLY MEDIAL ORDOVICIAN
(Early Chazyan)
PALEOGEOGRAPHY
by Marshall Kay
Drawn by Erwin Raisz
Palinspastic base - Sinusoidal projection
0
500
1000
Miles
Paleo-equator
after Kay, 1951
PENEPLANED CRYSTALLINE PRE-CAMBRIAN ROCKS
SANDY BELT
COASTAL PLAIN of Upper Cambrian
LIMY COASTAL PLAIN of Lower Ordovician
CHAMPLAIN MAGOG BELT
Seas with limy and sandy bottoms on miogeosynclines
Seas with bottoms of argillaceous muds and volcanic rocks on eugeosynclines

# Taconic Arc – Passive Margin Collision



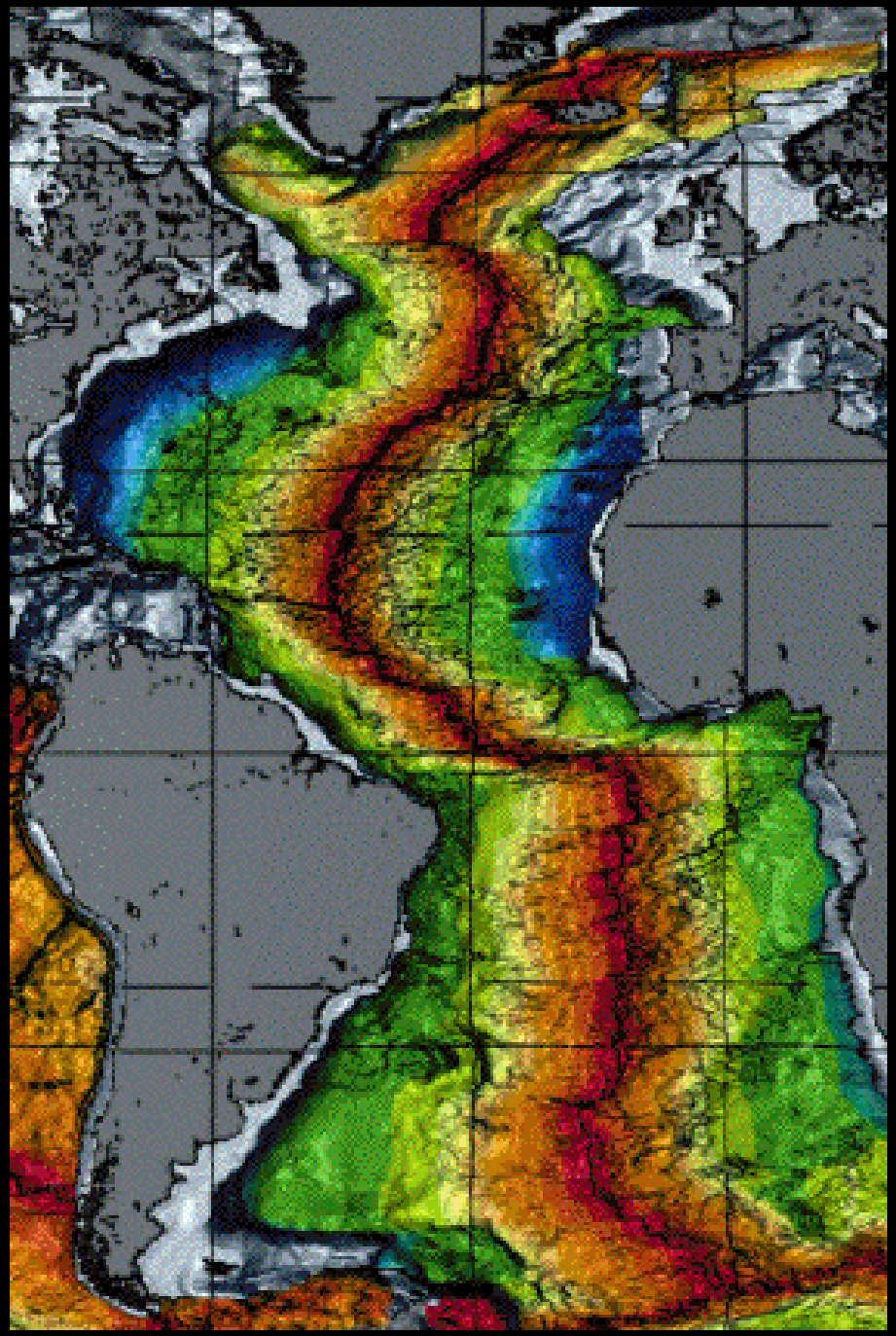
# Plate Boundary Accretionary Tectonics



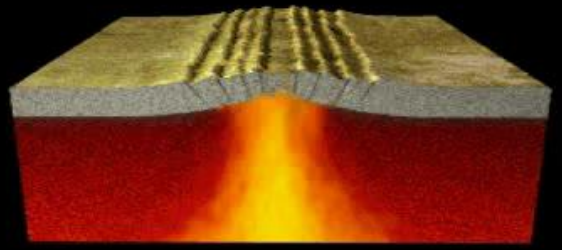




December 2004


[4]
[3]
[2]
[1]

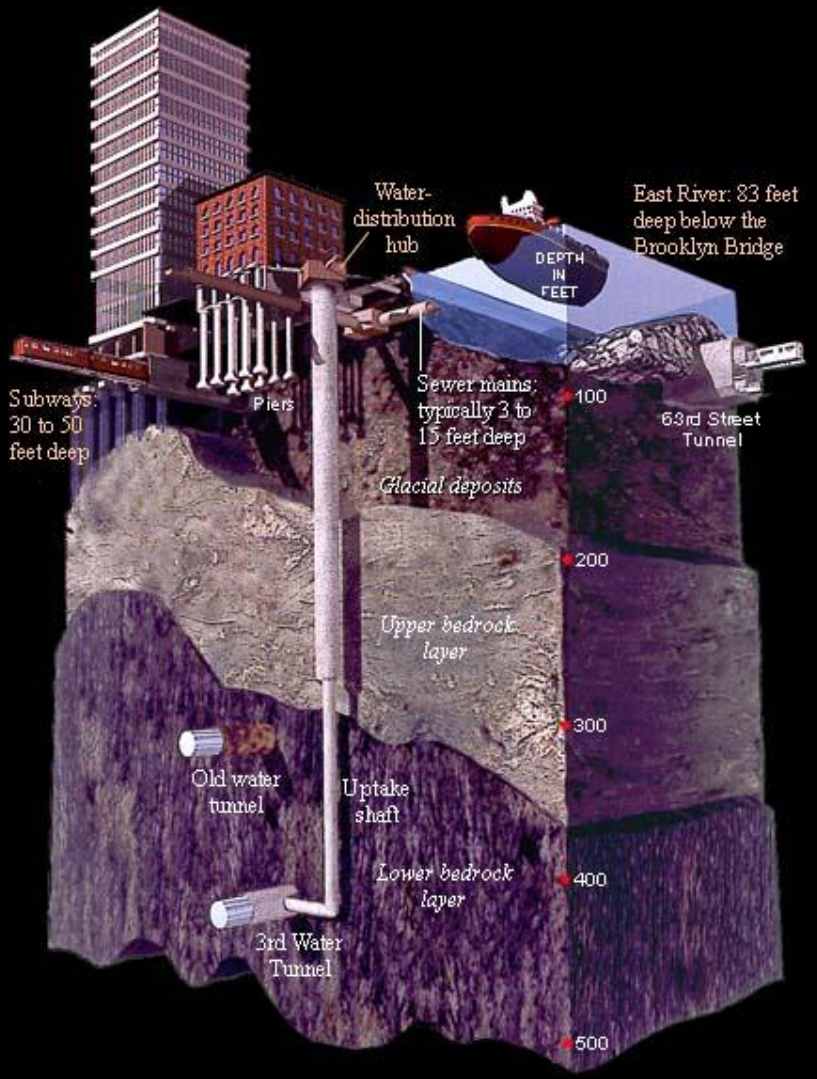


# Oceanic Crust



# Mega-Construction Projects

- Con Edison Steam Tunnel
- IRT #7 Line Extension
- Second Avenue Subway
- East Side Access
- NYC Water Tunnel #3




Jarva MK 15-52b


Con Edison
Utility Tunnel
Pierpont Morgan Library
Stern College
Yeshiva University
United Nations Headquarters
Belmont Island
Fashion Institute of Technology
Little Church around the Corner
American Academy of Dramatic Arts
Touro College
Madison Square Park
Bellevue Hospital Center
Baruch College
St Francis College
Parsons School of Design
School of Visual Arts
Police Academy Museum
Cabrini Medical Center
Stuyvesant Square
Con Edison Energy Museum
Beth Israel Medical Center
New York University
State Board of Tourism
St Marks Church in the Bowery
Murphy Park
The Bowery
Tompkins Square
Dukelabs © 2003

# TBM at Con Ed Tunnel

## 30 Street and 1st Avenue

# TBM Starter Tunnel

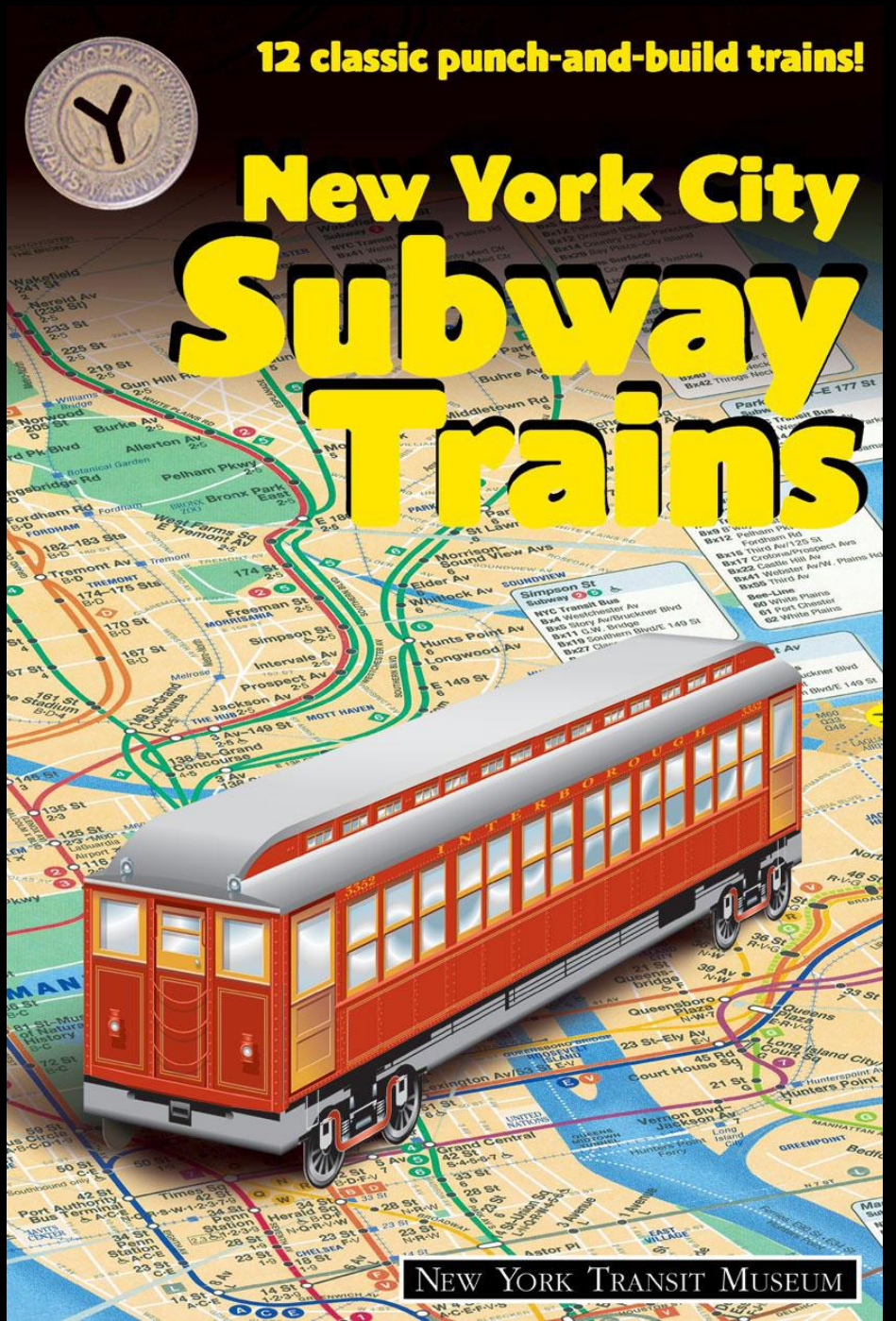

Southern Heading
Shallow NW Dip

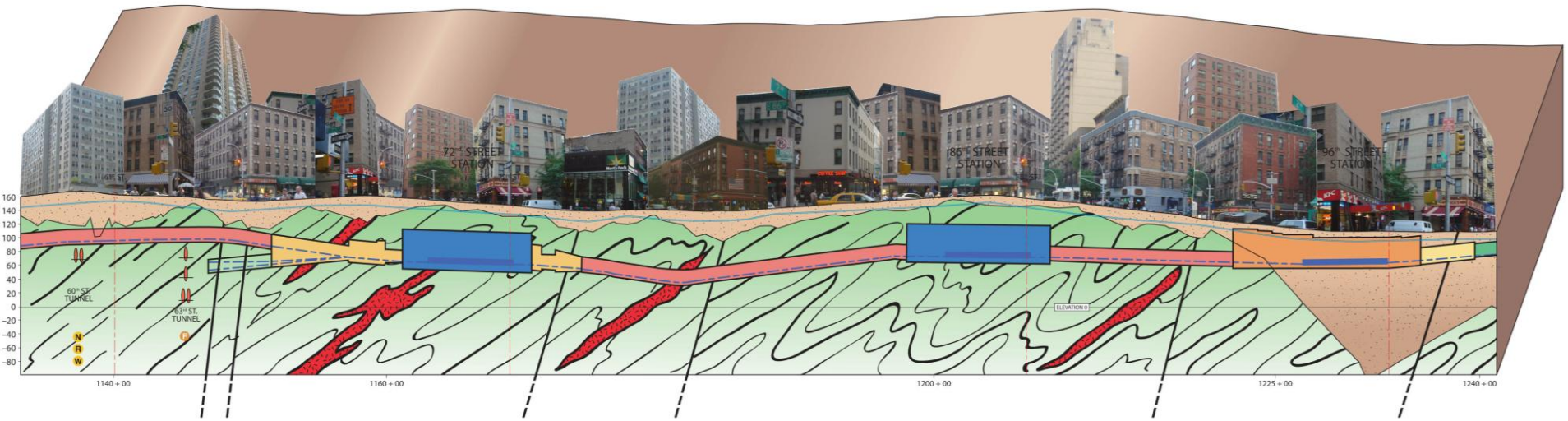
# IRT #7 Line Extension

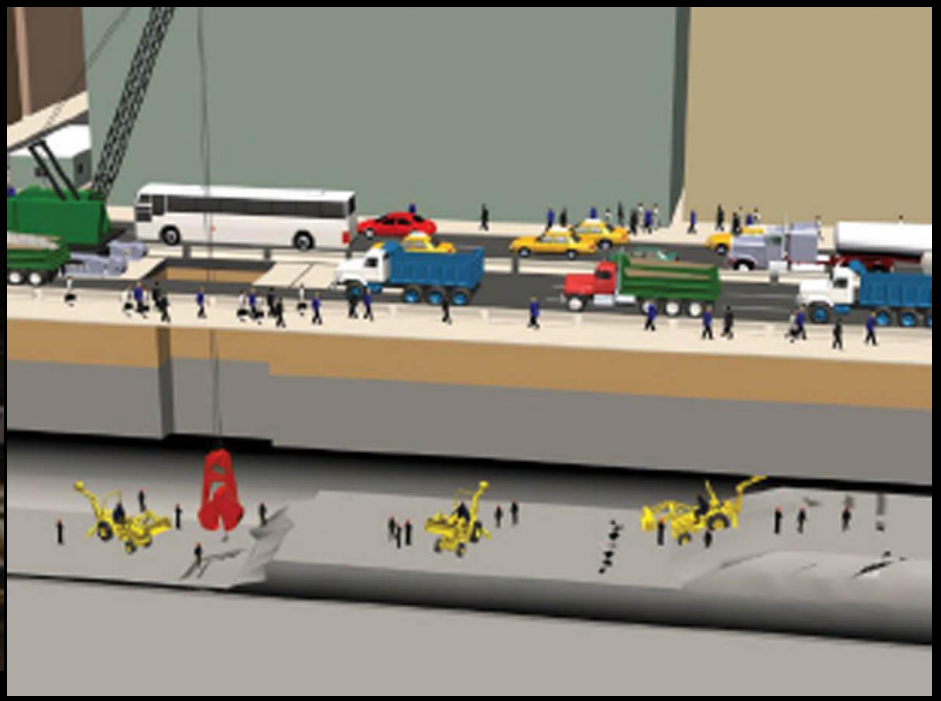

# Second Avenue El


1929 – NYC BOT Proposes Second Avenue Subway
1931 – Plans Postponed Depression Era
$86M → $249M → $500M
By 1948 – ( Abandonment]

# Second Avenue Subway

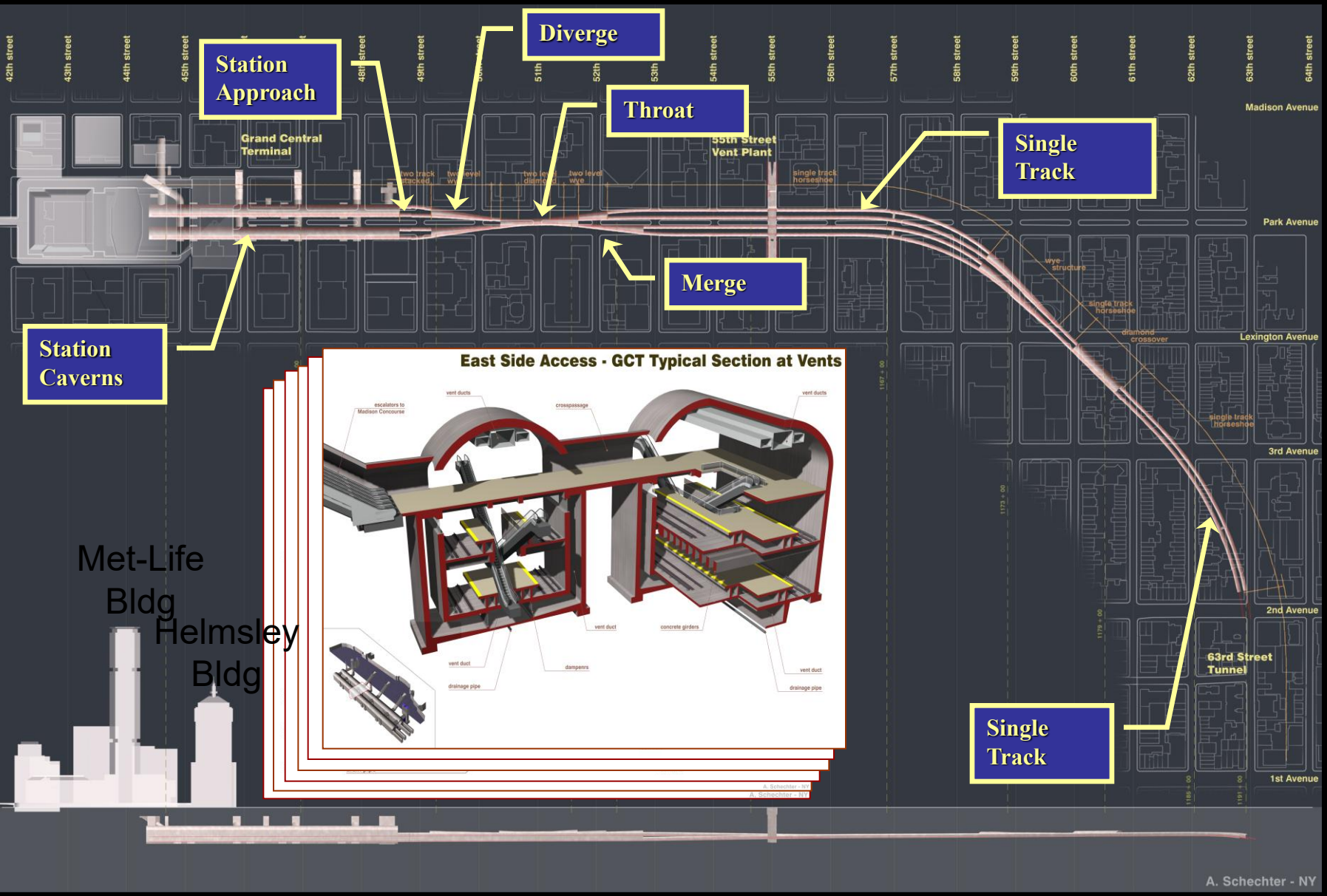



72nd STREET STATION
86th STREET STATION
96th STREET STATION
60th ST. TUNNEL
63rd ST. TUNNEL
N
R
W
ELEVATION 0
160
140
120
100
80
60
40
20
0
−20
−40
−60
−80
1140 + 00
1160 + 00
1200 + 00
1225 + 00
1240 + 00

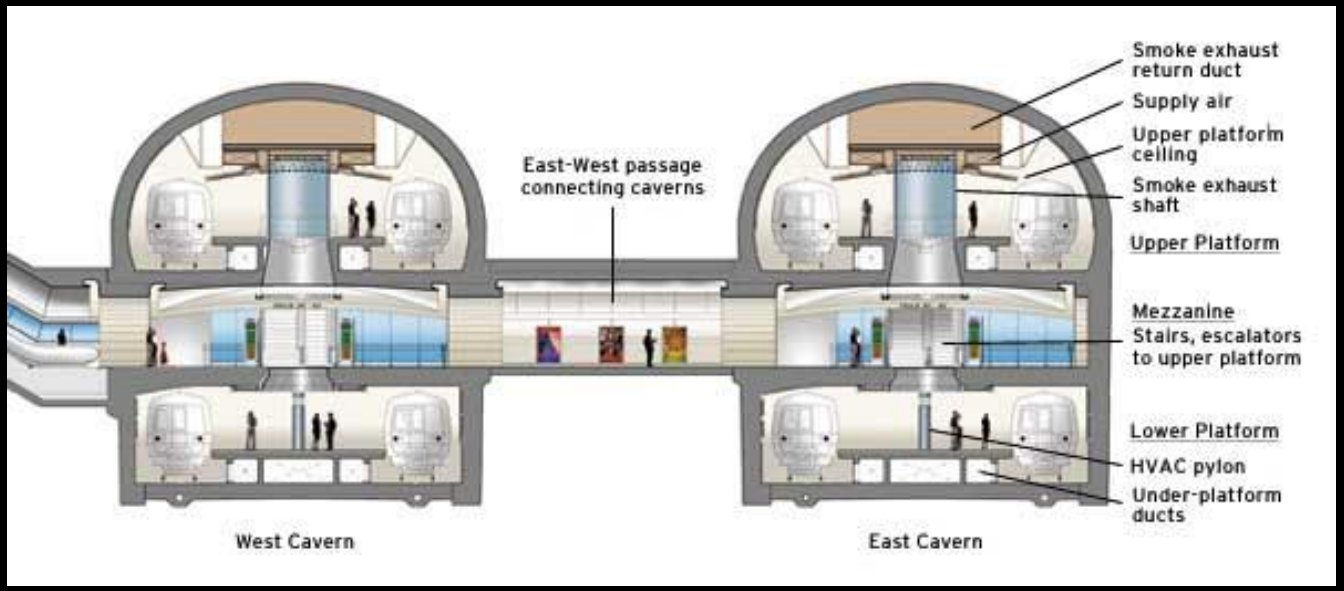


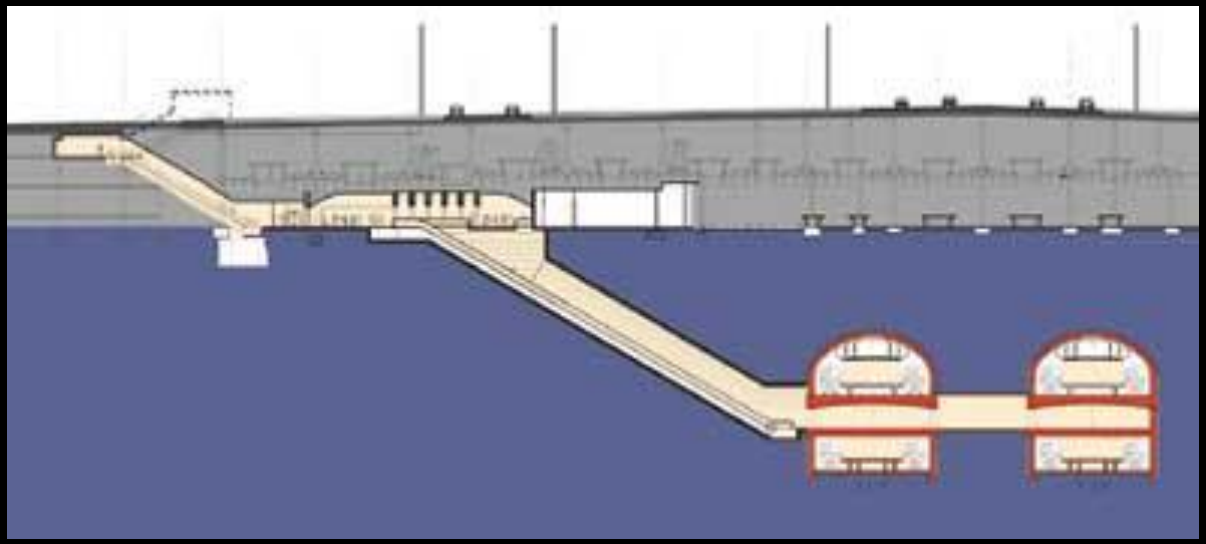
# East Side Access

# East Side Access Project Plans



# Construction Will Take Place Under Existing GCT



# CT3, Stage2 Manhattan Water Tunnel

## Shaft 26B


10 Oct 2002


South Heading

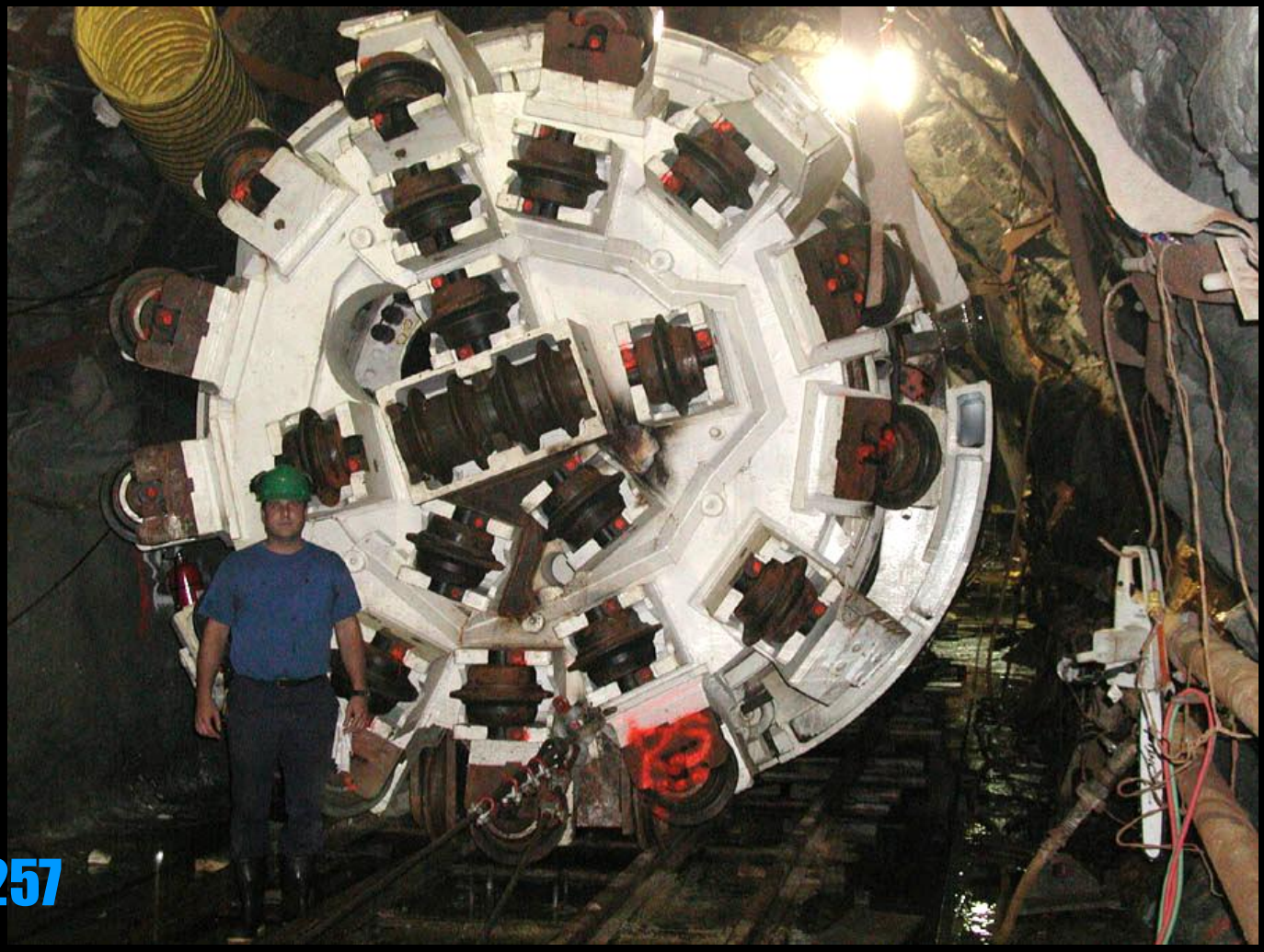
# Bottom of Shaft 26B

## 580’ Deep


NEW JERSEY
13B
MAIN TUNNEL (Central Park)
24B
MAIN TUNNEL (West Side)
25B
33B
CROSSTOWN TUNNEL (Mid-town)
26B
32B
MAIN TUNNEL (West Side)
27B
MANHATTAN
28B
31B
29B
30B
MAIN TUNNEL (South Loop)
Excavated
To be Excavated
Shafts

# Manhattan Tunnel TBM

## Rebuilt Robbins HP 215-257 hard rock machine (used first on Con Ed Utility Tunnel on 1st Avenue)

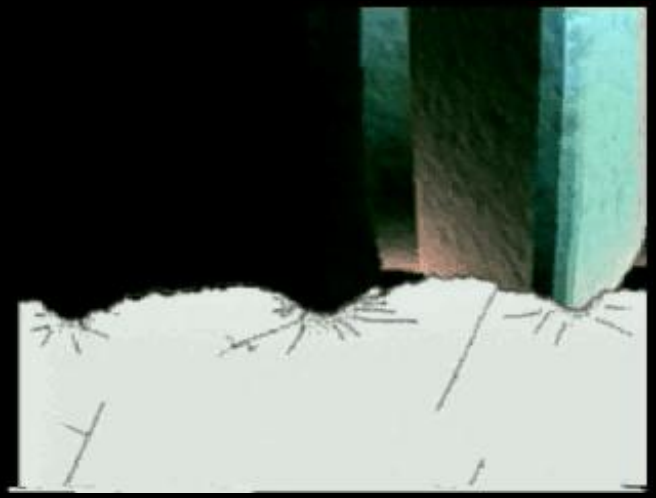


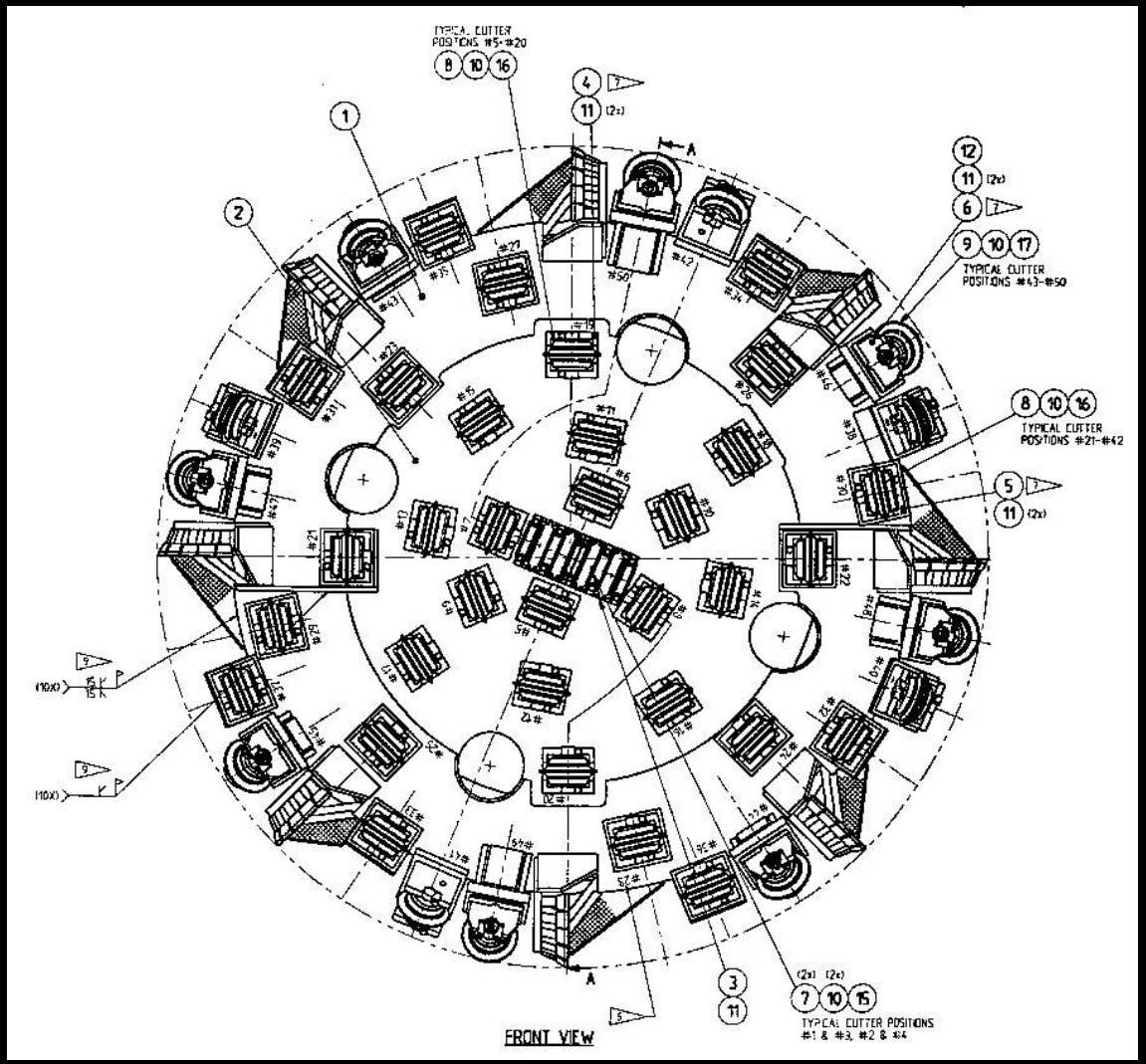
Robbins HP 215-257

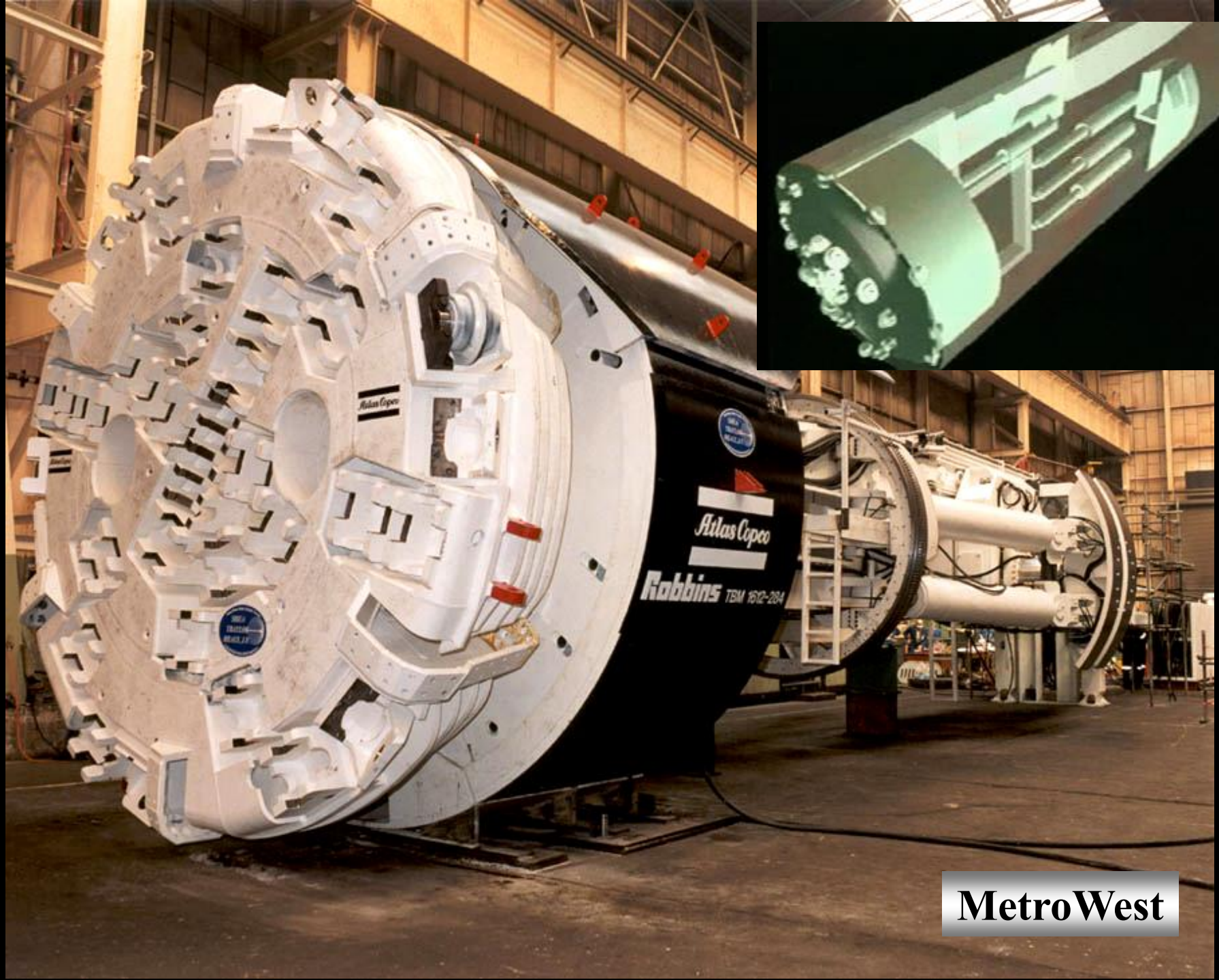
# What Are the Geological Controls on Effective Hard Rock TBM Tunneling in Crystalline Terrains?

**Low Penetration Rates**
**Excessive Fines**
**Blocky Ground**
**Unstable Headings and Sidewalls**

# Low Penetration Rates






Atlas Copco
Robbins TBM 160-284
MetroWest

# Excessive Fines

# Desirable Kerf Pattern in Hard Rocks

# Blocky Ground

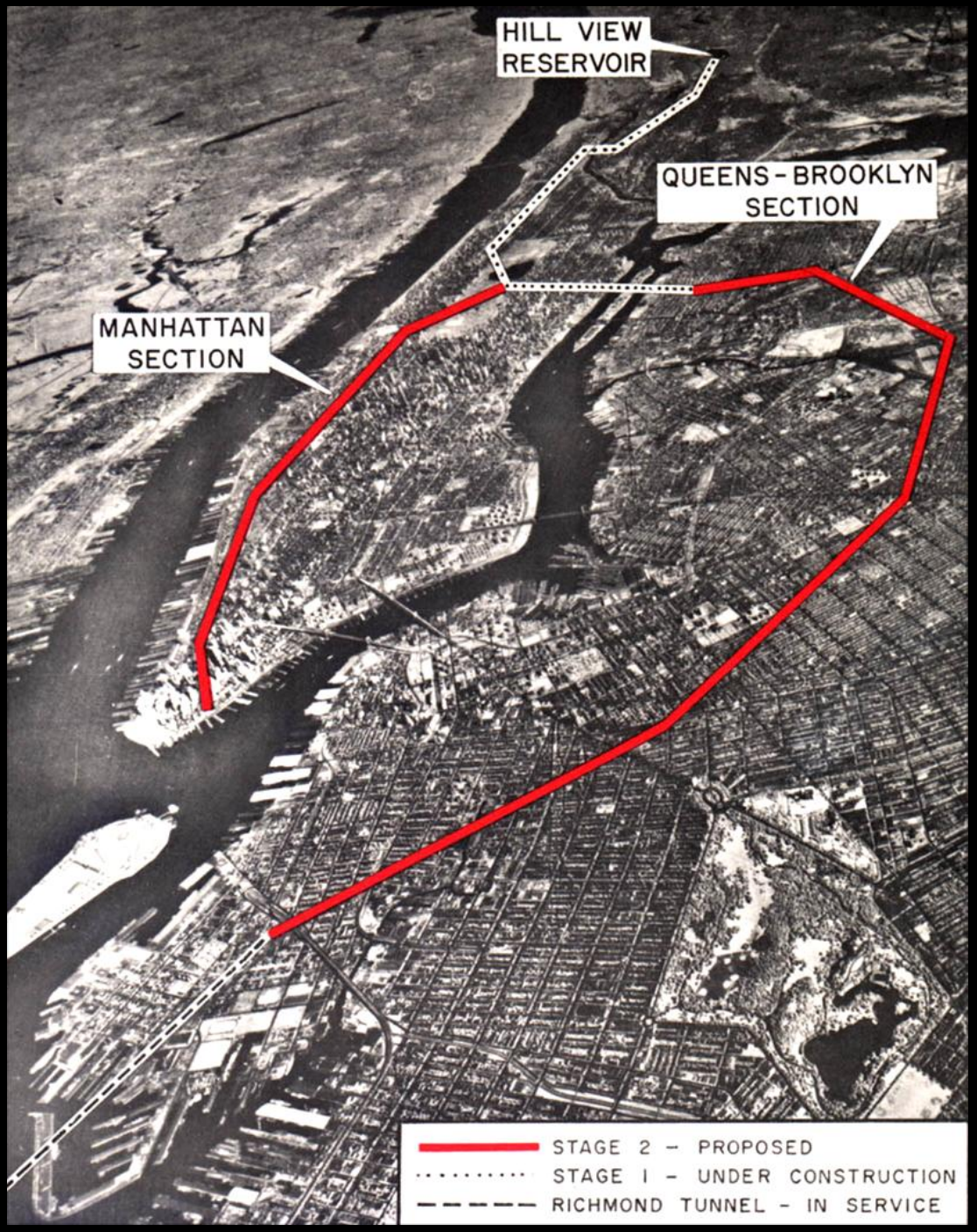

Collapsed Crown and Sidewalls
Short Stand-up Times
Station 153+30

# Unforseen Tunneling Problems

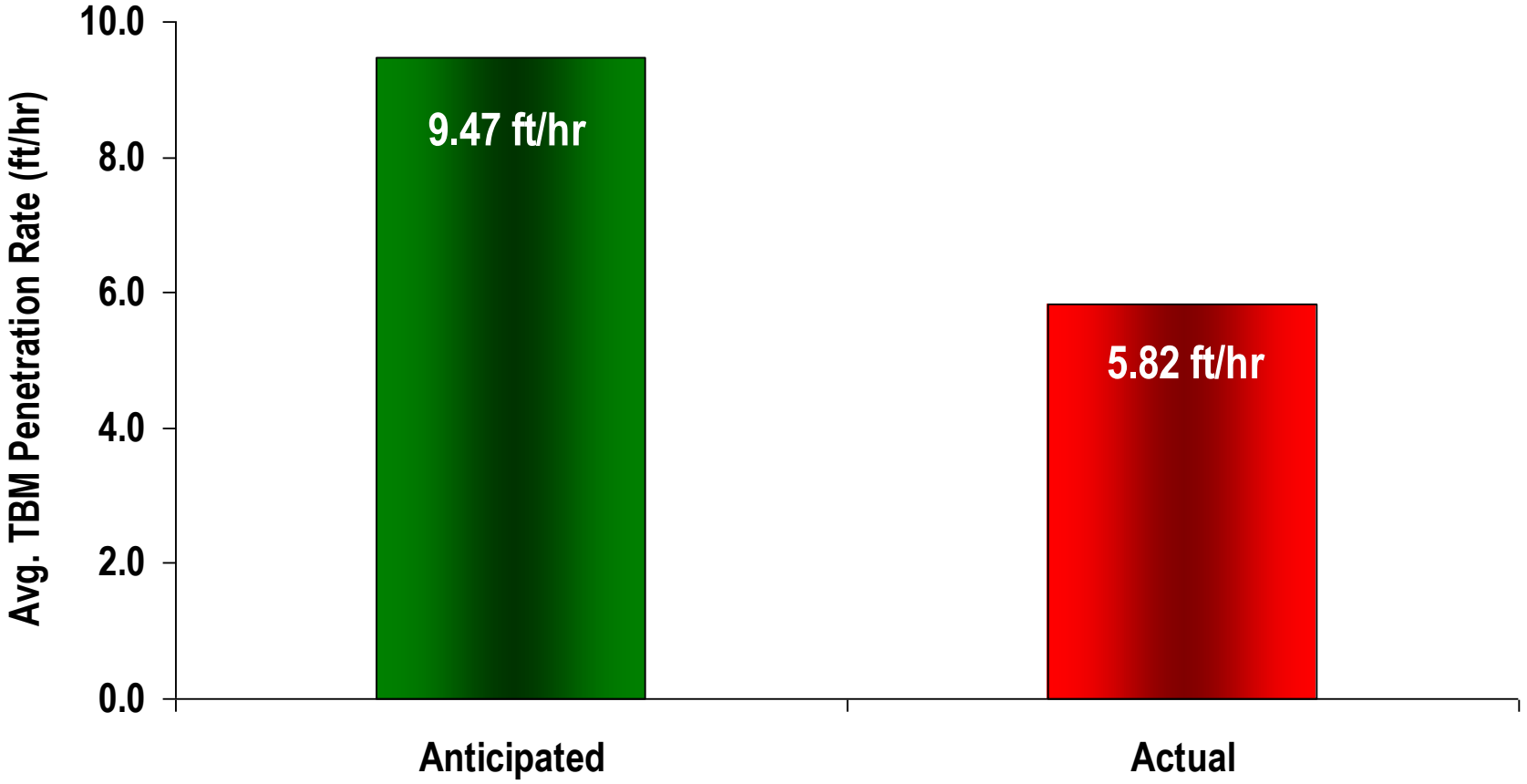
# Queens Tunnel Problems – A Case History

Robbins 235-282 HP TBM

# City Tunnel #3
# Stages 1 and 2



# QT Anticipated vs. Actual Penetration Rates



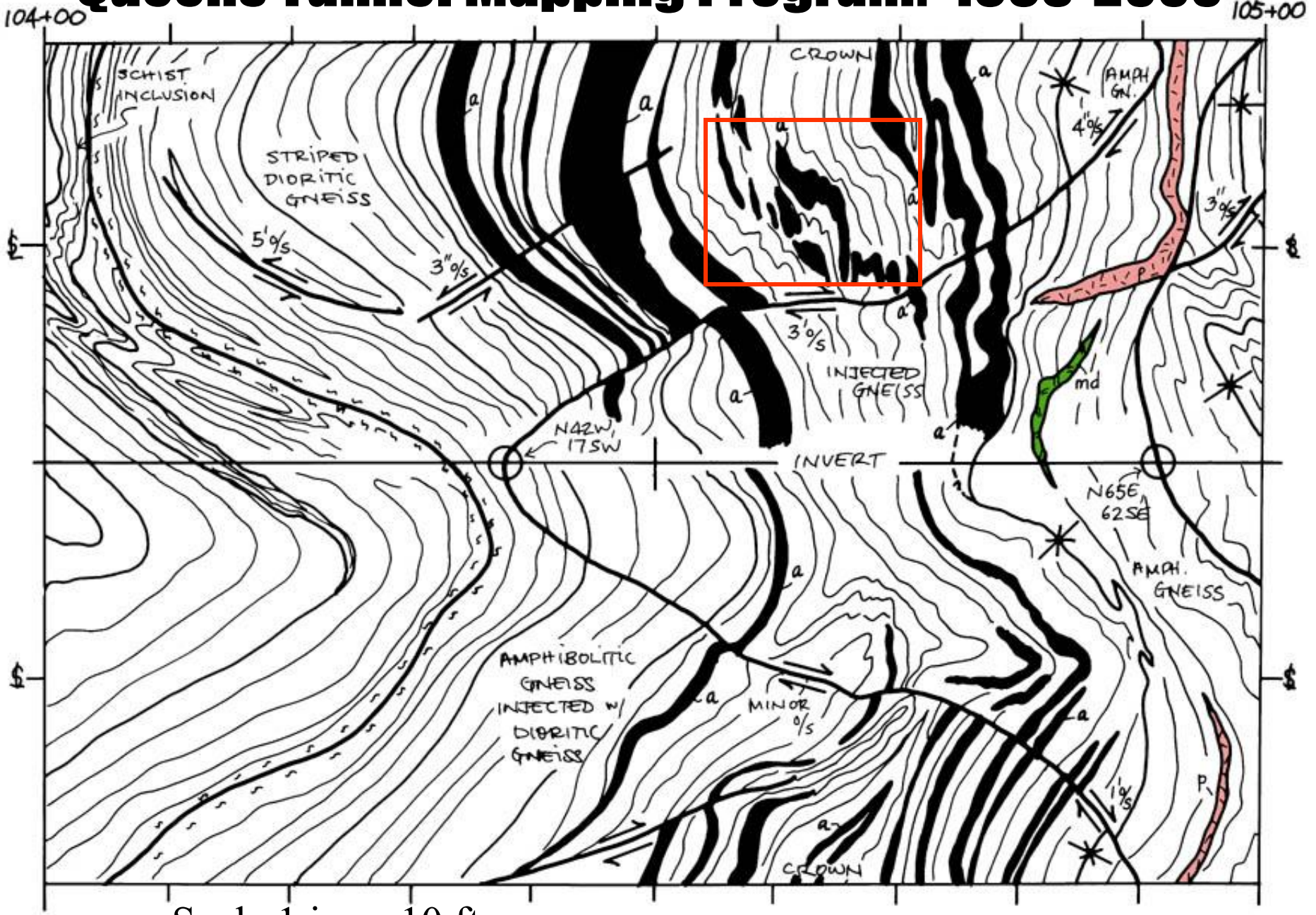
# Pre-Bid Analysis Should Include:


• Published Maps and Reports
• Boring Analysis
Fractures
Rock Types
Rock Fabrics
Density Studies
Petrographic Studies
• Rock Fabric Studies
Mineralogy
Texture
Orientation

# Can Geologic Studies Help Predict TBM Penetration Destiny?

# Merguerian's Field Office

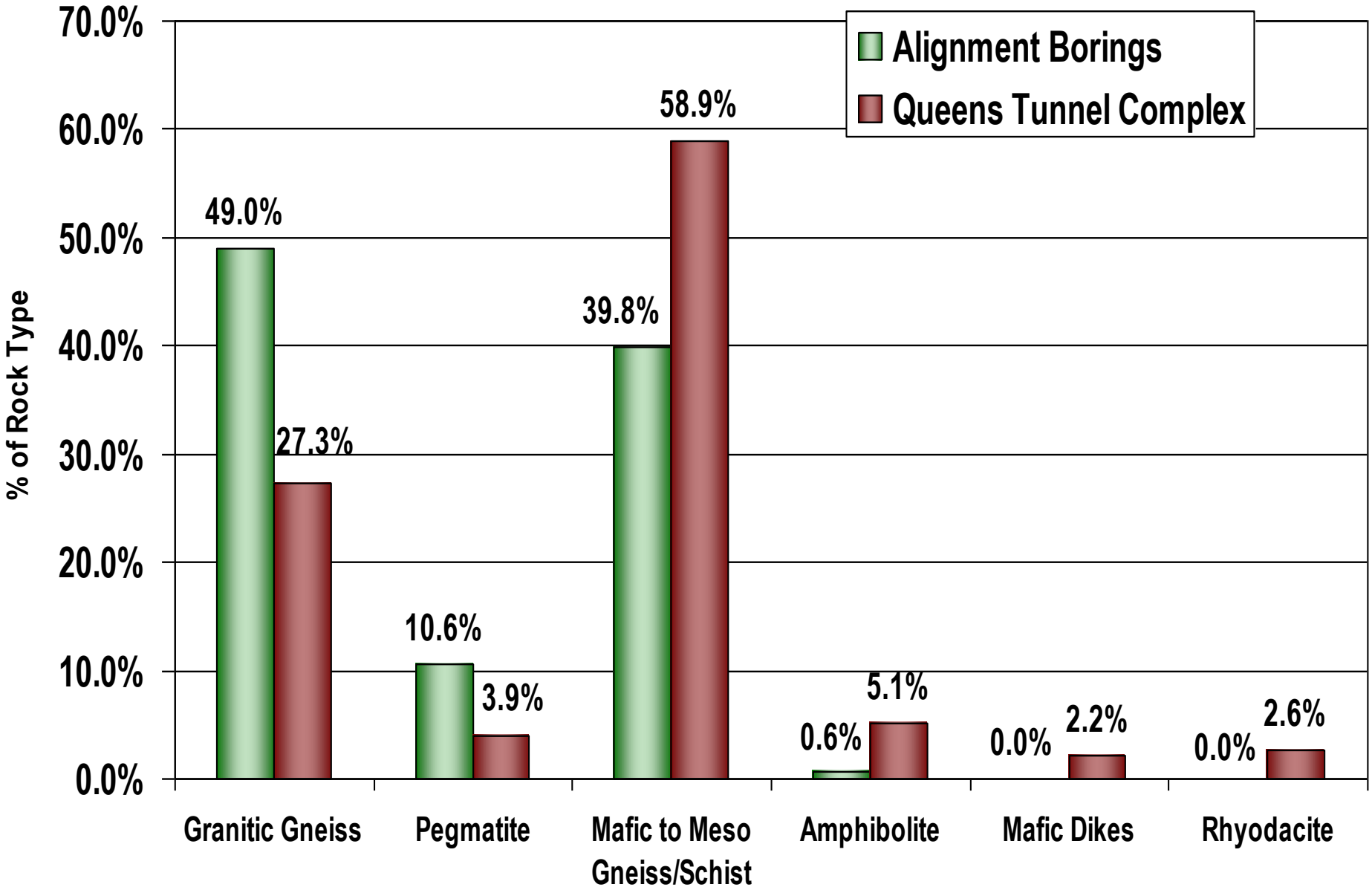
# Queens Tunnel Mapping Program: 1998-2000




- Scale 1 in. = 10 ft


104 +60
104 +65

# Comparative Lithologic Analysis



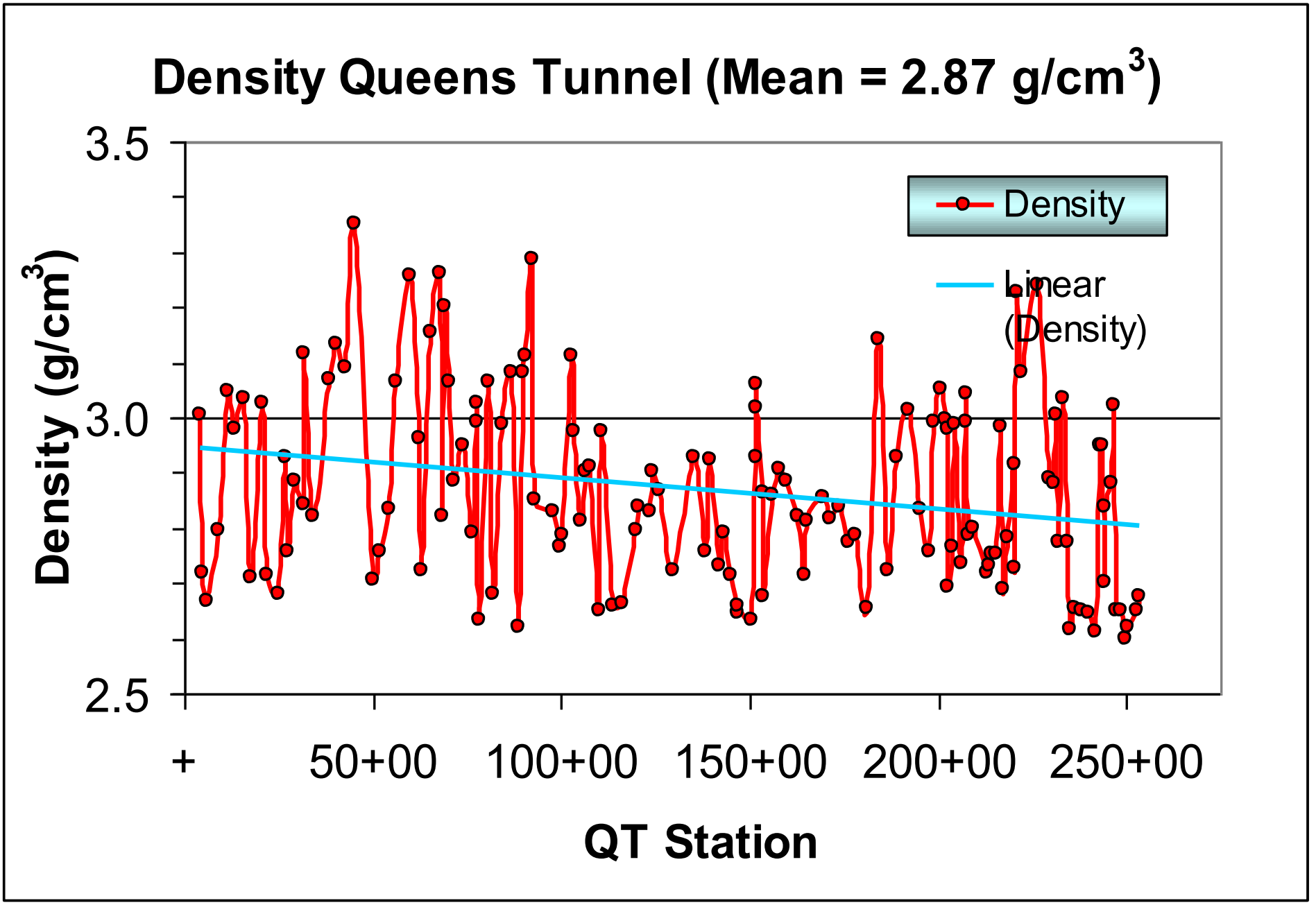
# The Queens Tunnel Complex

I. Garnet-Clinopyroxene-Plagioclase Rocks
+/- Hornblende, Quartz, K-feldspar

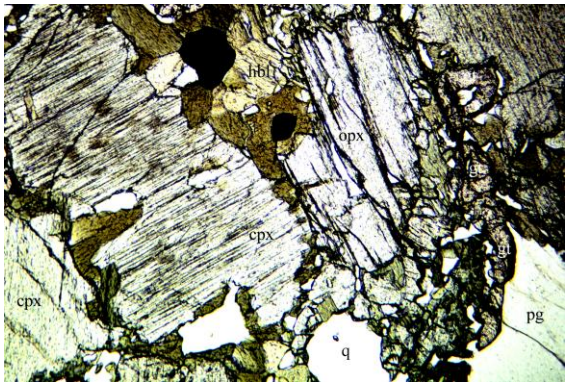
II. Leuco- to Mesocratic Gneiss

III. Mafic to Mesocratic Rocks

Leucocratic (0%-35% mafic mineral content), Mesocratic (35%-65% mafic mineral content), and Melanocratic (65%-90% mafic mineral content) gneiss form the bulk of the Queens Tunnel Complex


Density Queens Tunnel (Mean = 2.87 g/cm3)
Density (g/cm3)
3.5
3.0
2.5
Density
Linear (Density)
+
50+00
100+00
150+00
200+00
250+00
QT Station

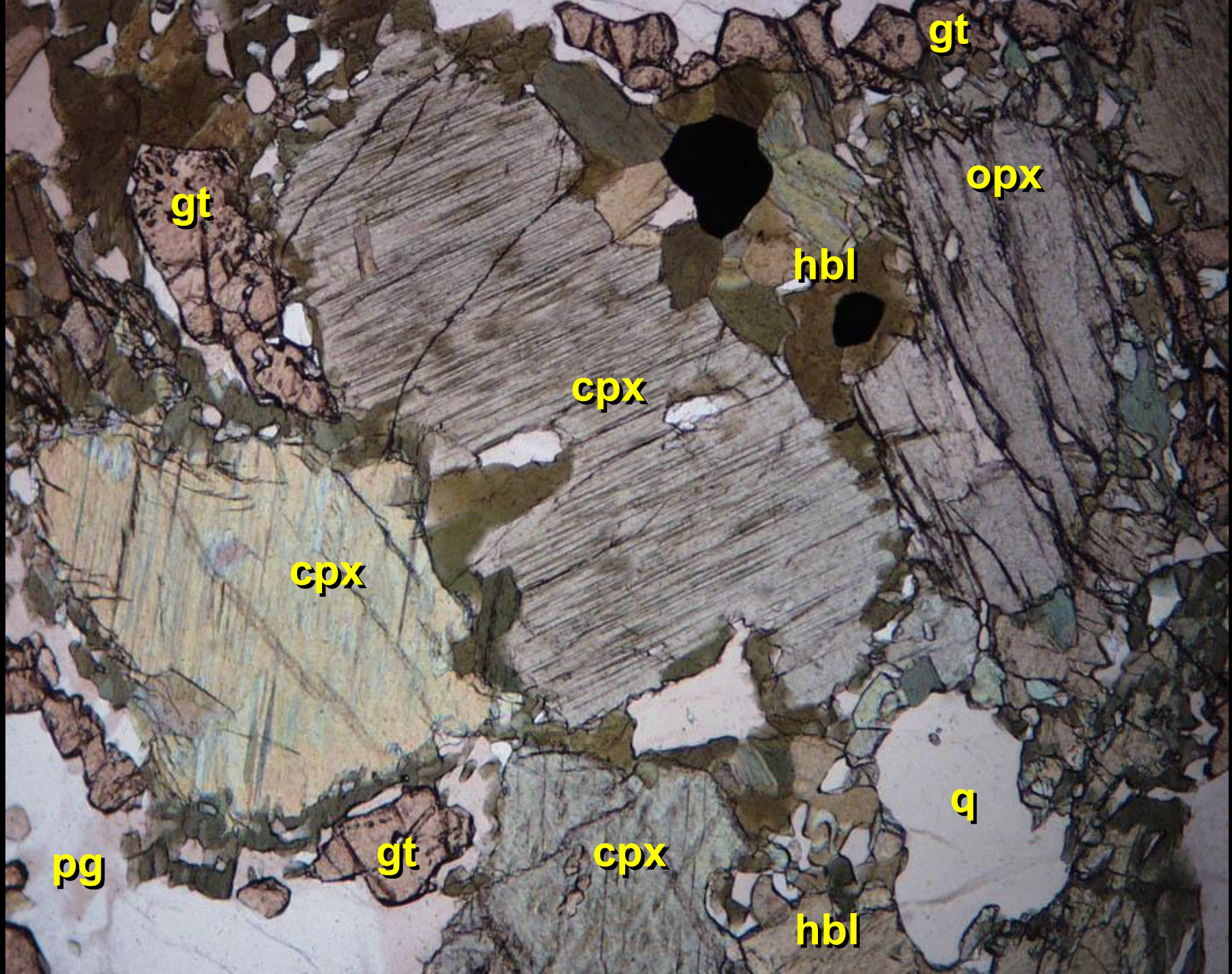
- **Petrographic Analysis (92 Samples)**
  - **Texture**
  - **Mineralogy**
  - **Internal Structure**
  - **Metamorphism**




Thin section photomicrograph

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

Petrographic Data Sheet


gt
opx
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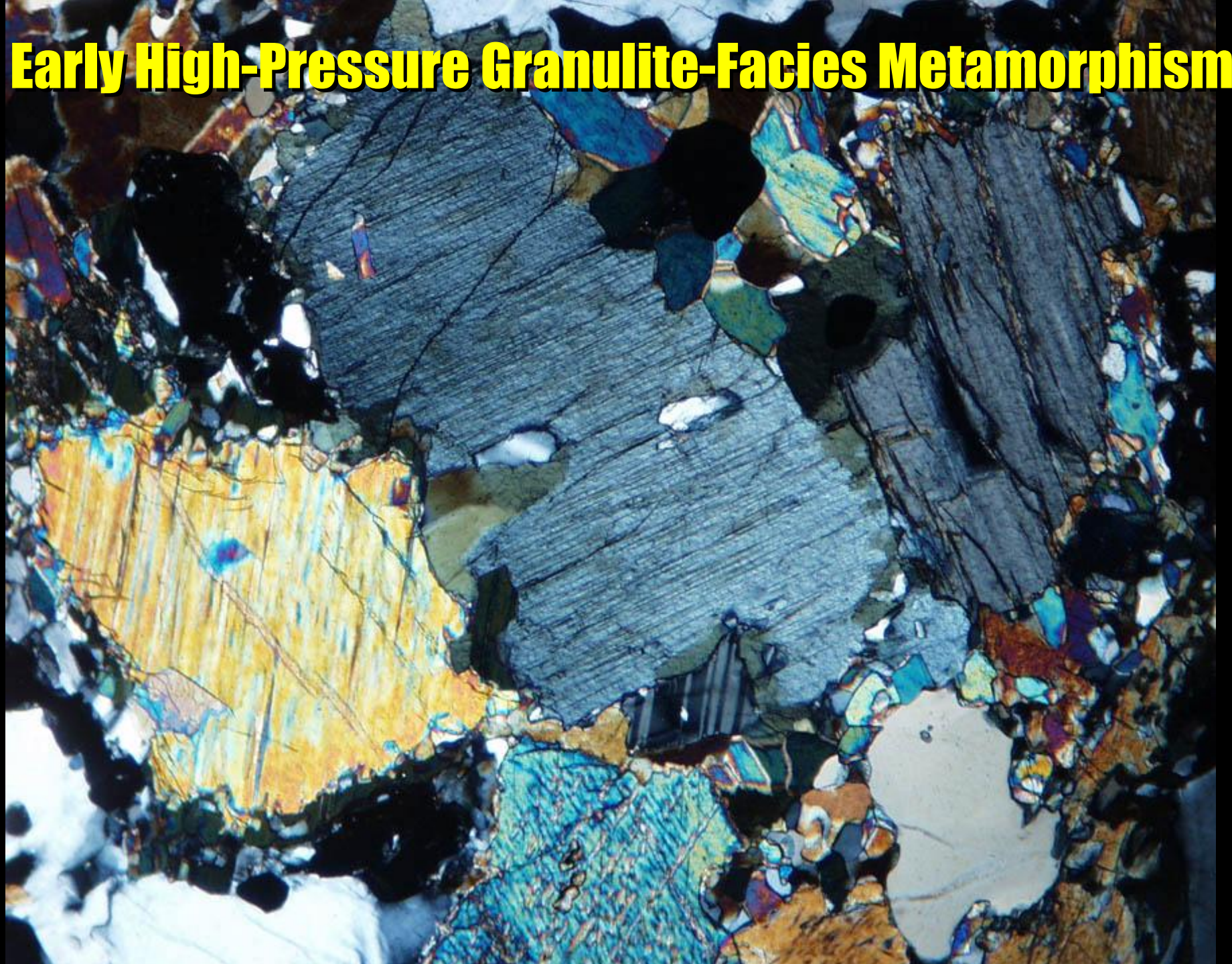
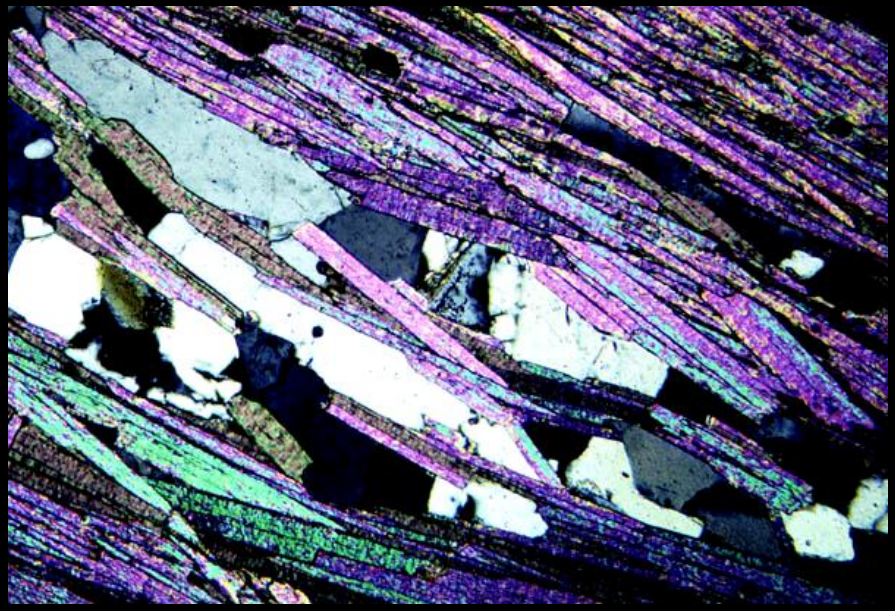
# Early High-Pressure Granulite-Facies Metamorphism



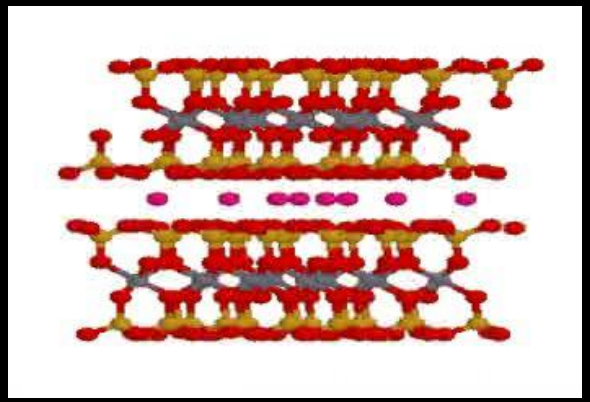
# Mica Content of Rock Fabric

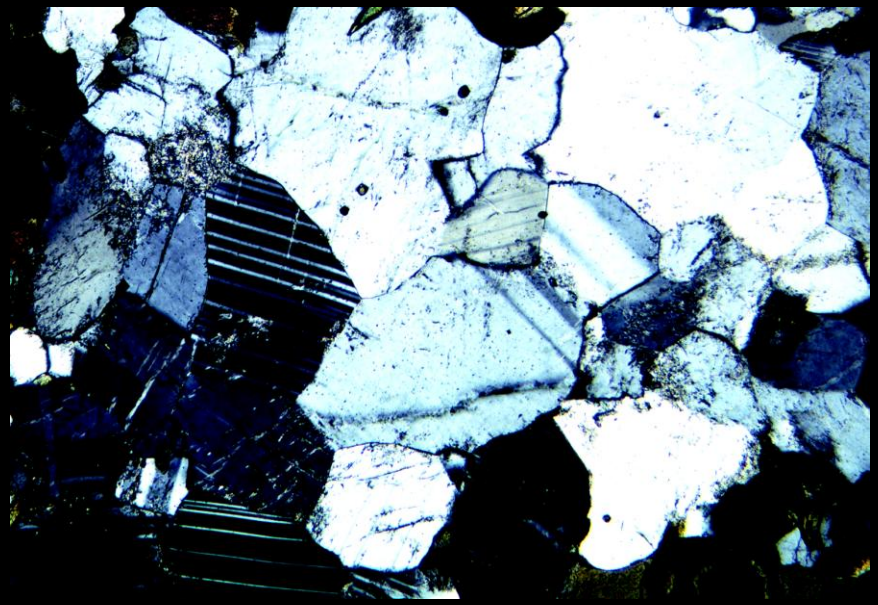
**Micaceous (+/- hornblende) penetrative foliation**

**vs. non-foliated "granoblastic" rock mass**



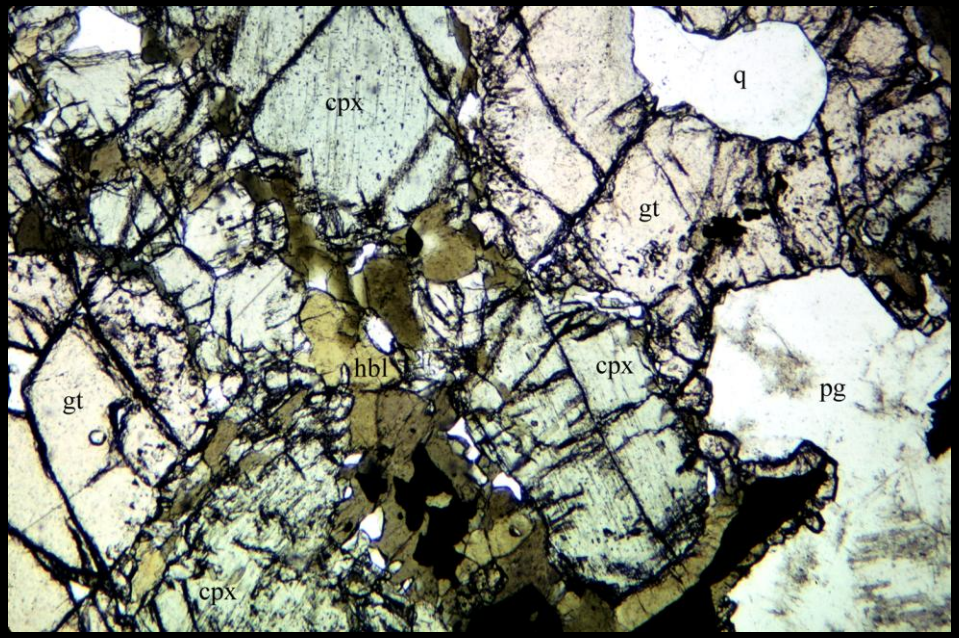
Foliated

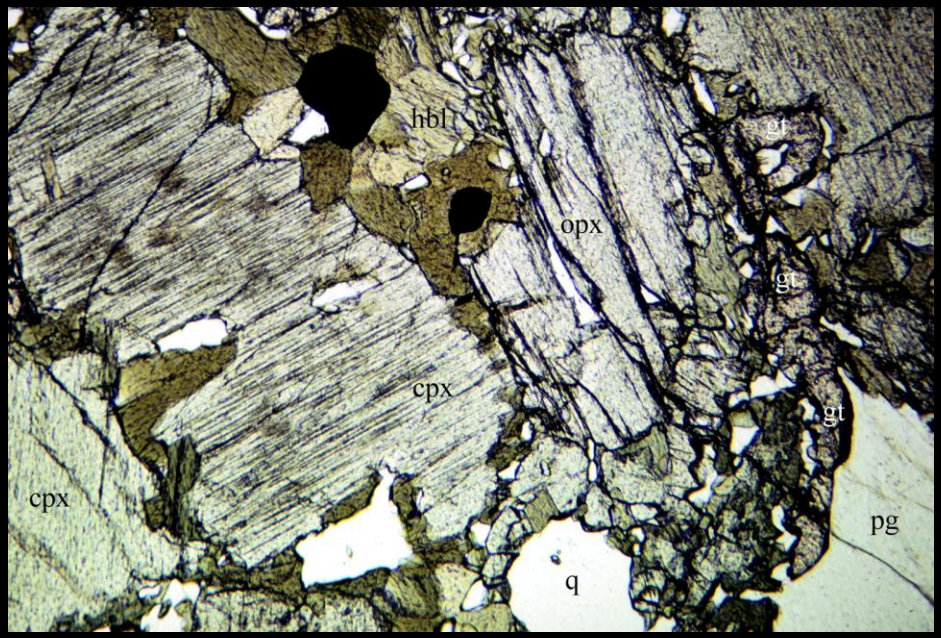


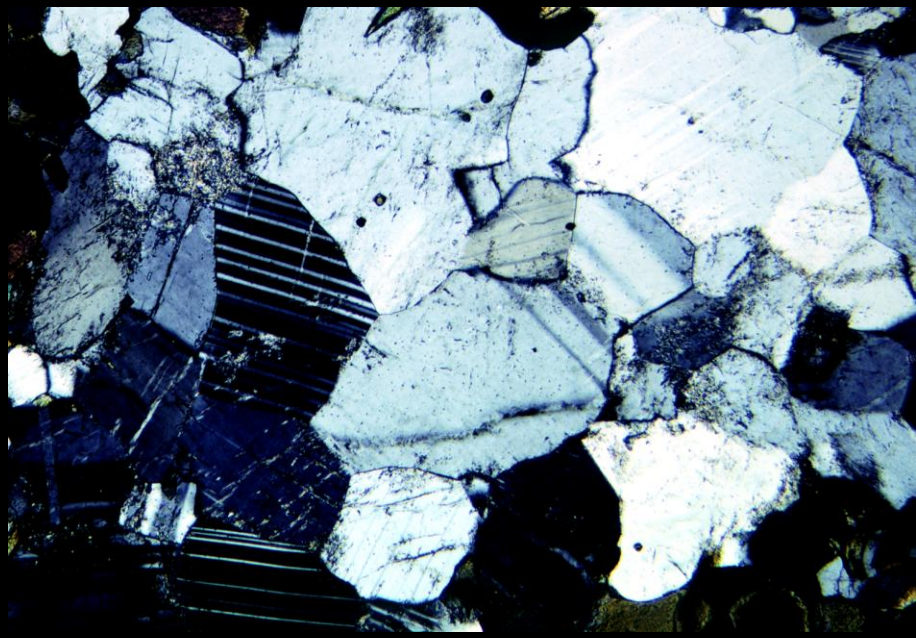


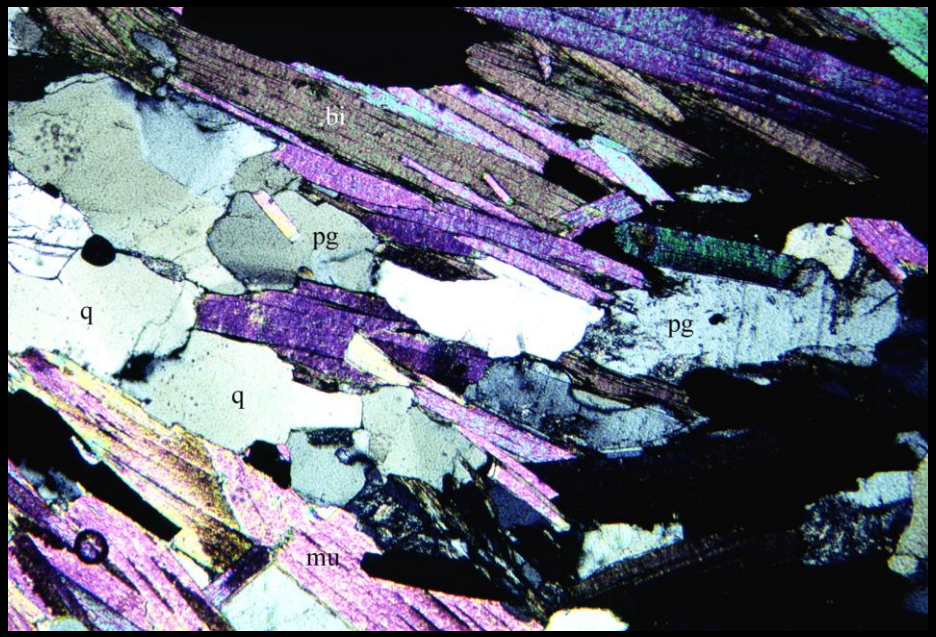
Non-Foliated

# Granulite Facies Gneisses Found in the Queens Tunnel Granoblastic Textures Tough Rocks for Tunneling

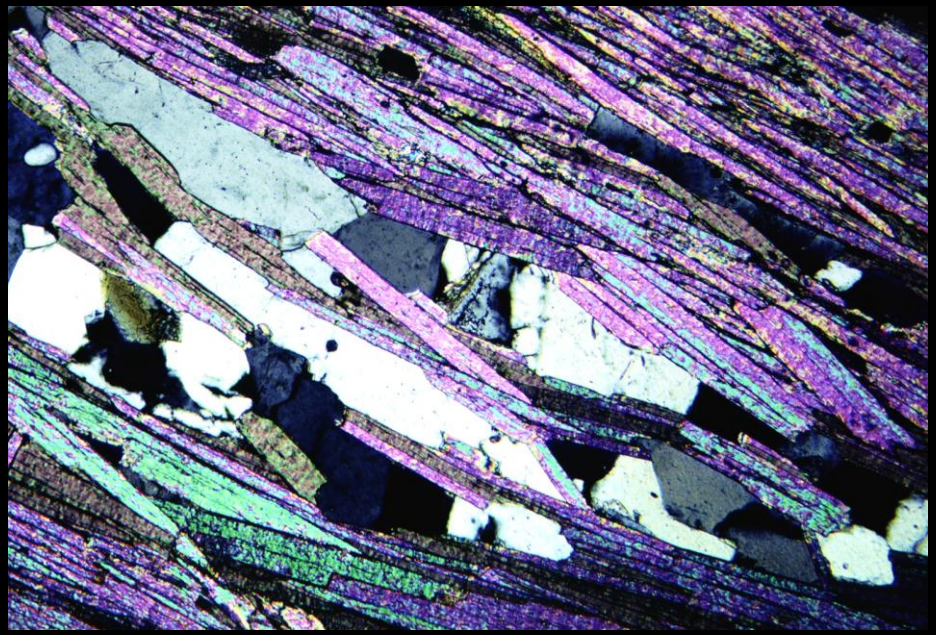




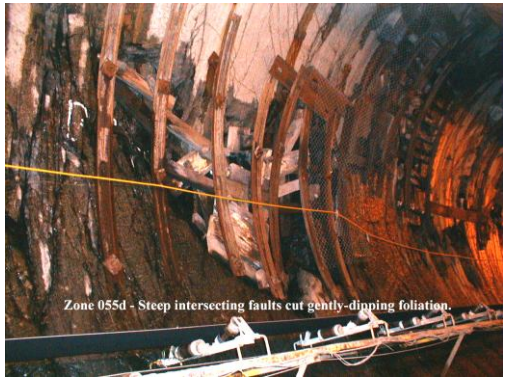

# In Western Manhattan:
# Amphibolite Facies Schists
# Well-layered Hartland Fm.
# Foliated Textures
# Great Rocks for Tunneling and Excavation!



# Orientation of Rock Layering

**NE strike and moderate 57° dip anticipated**

- **[Based on borings, Chesman, Tarkoy]**

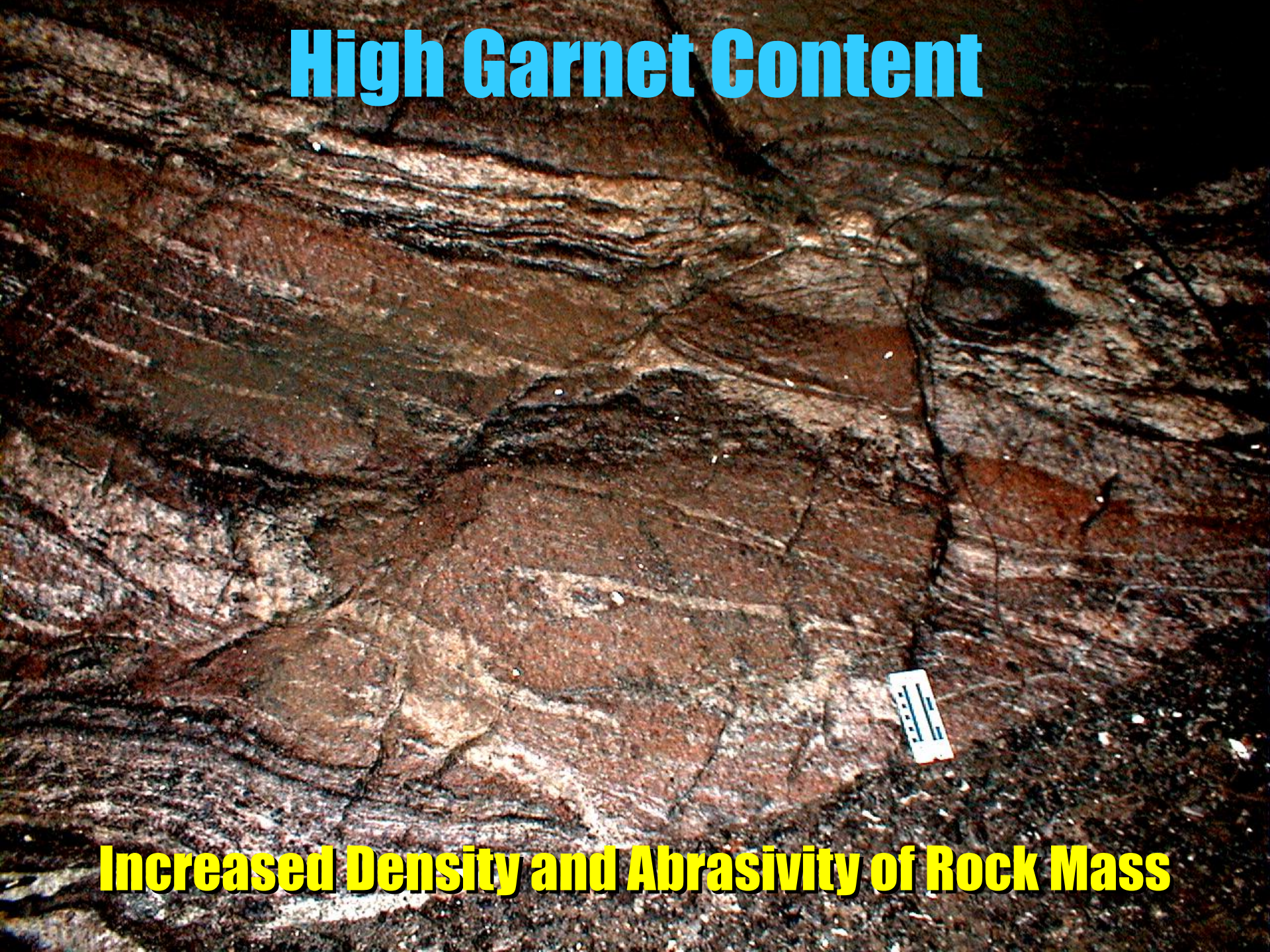



**Highly variable trends found**

- **Extended reaches of tunnel exhibited gentle dips**

**Only one boring (QTL-12) exhibited gentle dips at tunnel horizon**

| | | NE Leg | | NW Leg | |
|---|---|---|---|---|---|
| Gentle Dips | | 17/93 | 18% | 44/139 | 32% |
| Moderate Dips | | 34/93 | 37% | 28/139 | 20% |
| Steep Dips | | 42/93 | 45% | 67/139 | 48% |

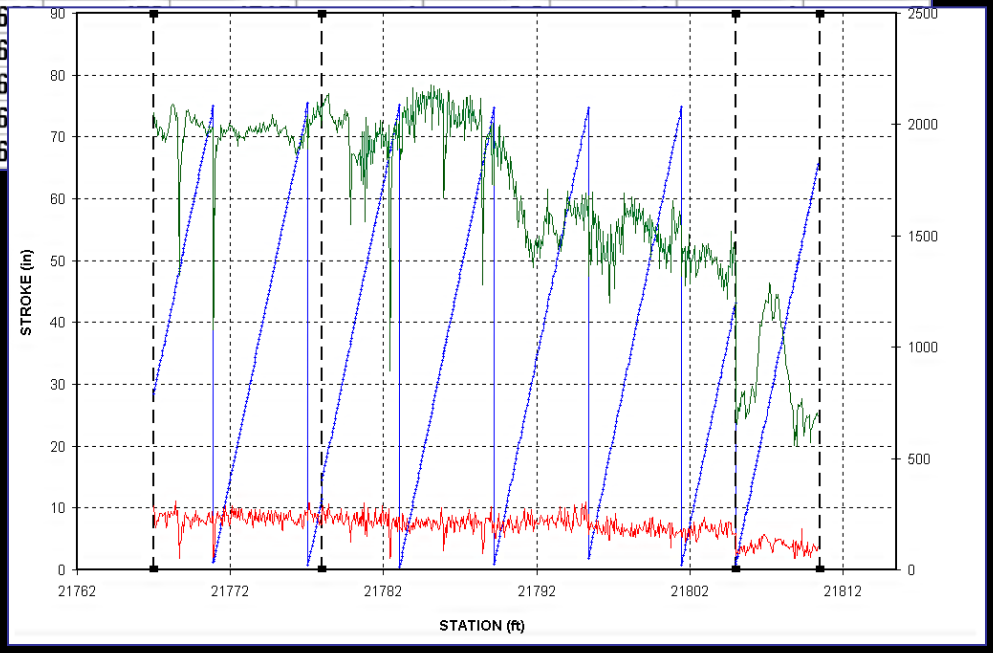

High Garnet Content
Increased Density and Abrasivity of Rock Mass

# Reduced TBM Penetration Rate Investigation

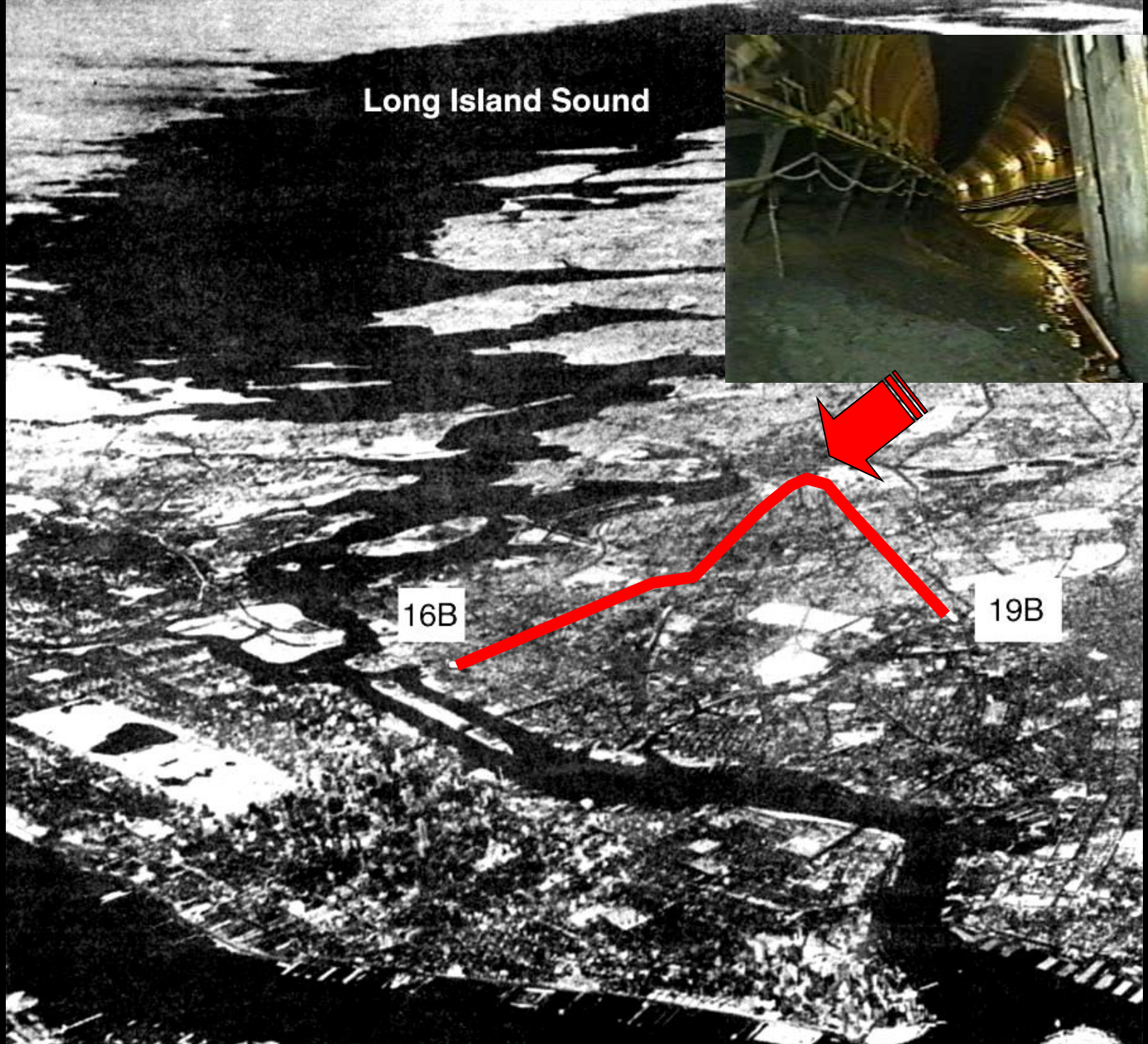
*(TBM Data Logger)*

**The Queens Tunnel TBM utilized a CIC-200 Data Recorder capable of continuous data gathering.**

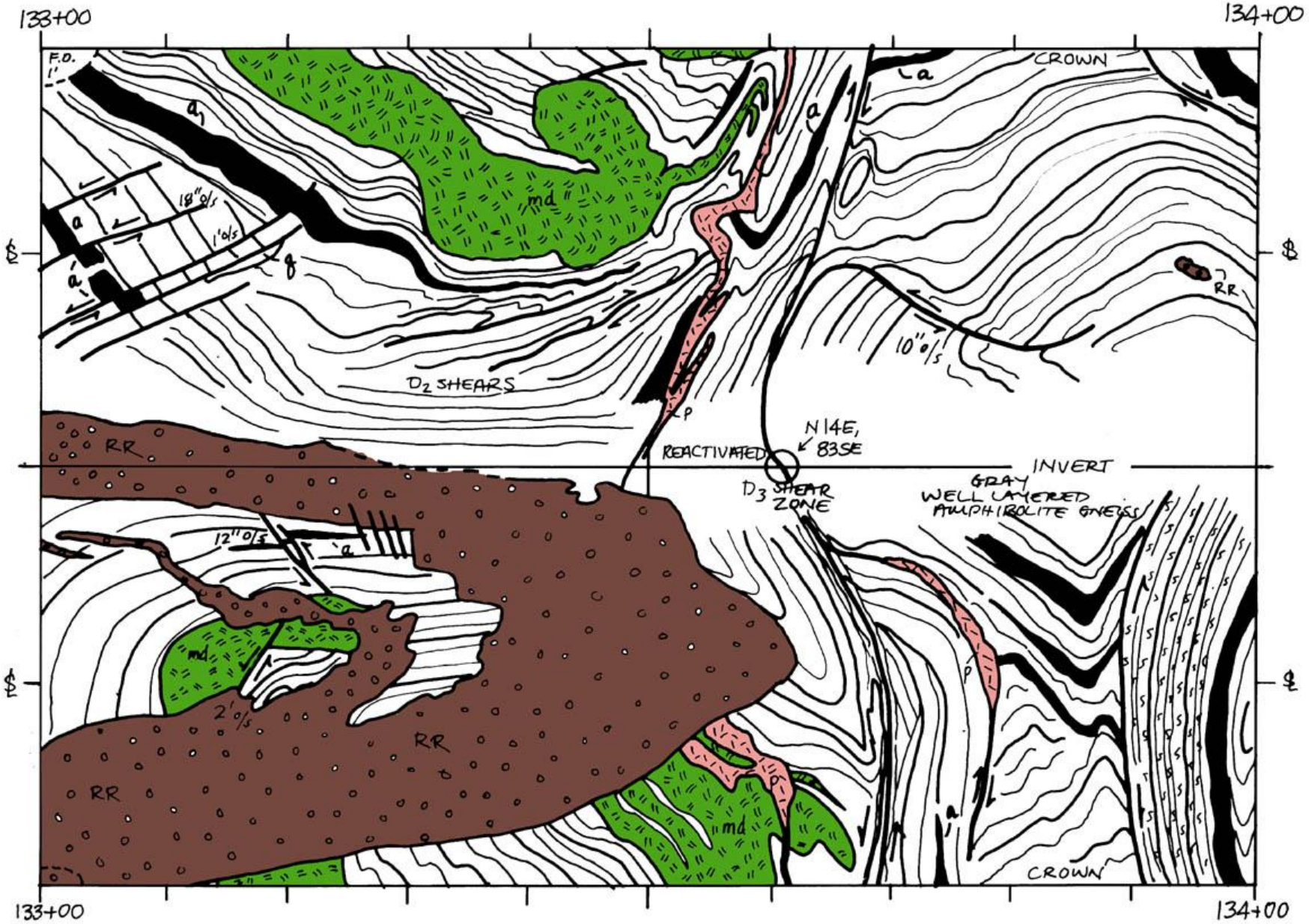
| Robbins | TBM | 235-282 | Queens | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| File | opened | on | Thu | 4/1/1999 | 0:00:04 | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| DATE | TIME | SPARE | STROK | FT/HR | VOLTS | SPARE | AMPS | TONS | BORNG | L.SID | R.SID | PGRIP | M1_M10SI |
| 4/1/1999 | 2:09:10 | 0 | 36.2 | 0 | 488 | 701 | 36 | 643 | 1 | -3.8 | -1.4 | 1 | 7 |
| 4/1/1999 | 2:09:40 | 0 | 36.4 | 1.3 | 490 | 701 | 54 | 1026 | 1 | -3.8 | -1.4 | 1 | 7 |
| 4/1/1999 | 2:10:10 | 0 | 36.5 | 1.3 | 488 | 698 | 85 | 1419 | 1 | -3.8 | -1.4 | 1 | 7 |
| 4/1/1999 | 2:10:40 | 0 | 37 | 3.6 | 485 | 695 | 151 | 1511 | 1 | -3.8 | -1.4 | 1 | 7 |
| 4/1/1999 | 2:11:10 | 0 | 37.4 | 5.2 | 483 | 6 | | | | | | | |
| 4/1/1999 | 2:11:40 | 0 | 38.1 | 5.9 | 480 | 6 | | | | | | | |
| 4/1/1999 | 2:12:10 | 0 | 38.8 | 8.2 | 481 | 6 | | | | | | | |
| 4/1/1999 | 2:12:40 | 0 | 39.7 | 7.5 | 478 | 6 | | | | | | | |
| 4/1/1999 | 2:13:10 | 0 | 40.5 | 8.2 | 480 | 6 | | | | | | | |




**Data logger recorded the TBM data every 30 seconds**


Long Island Sound
16B
19B

# Dike 4


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


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

# Short Stand-up Times

# Major Lithologic Contrast

# Lava Flows in Woodside?

# Download NYC Geology Publications @ www.hofstra.edu