Brooklyn College Lecture

# Megaconstruction Projects in New York City


## Charles Merguerian

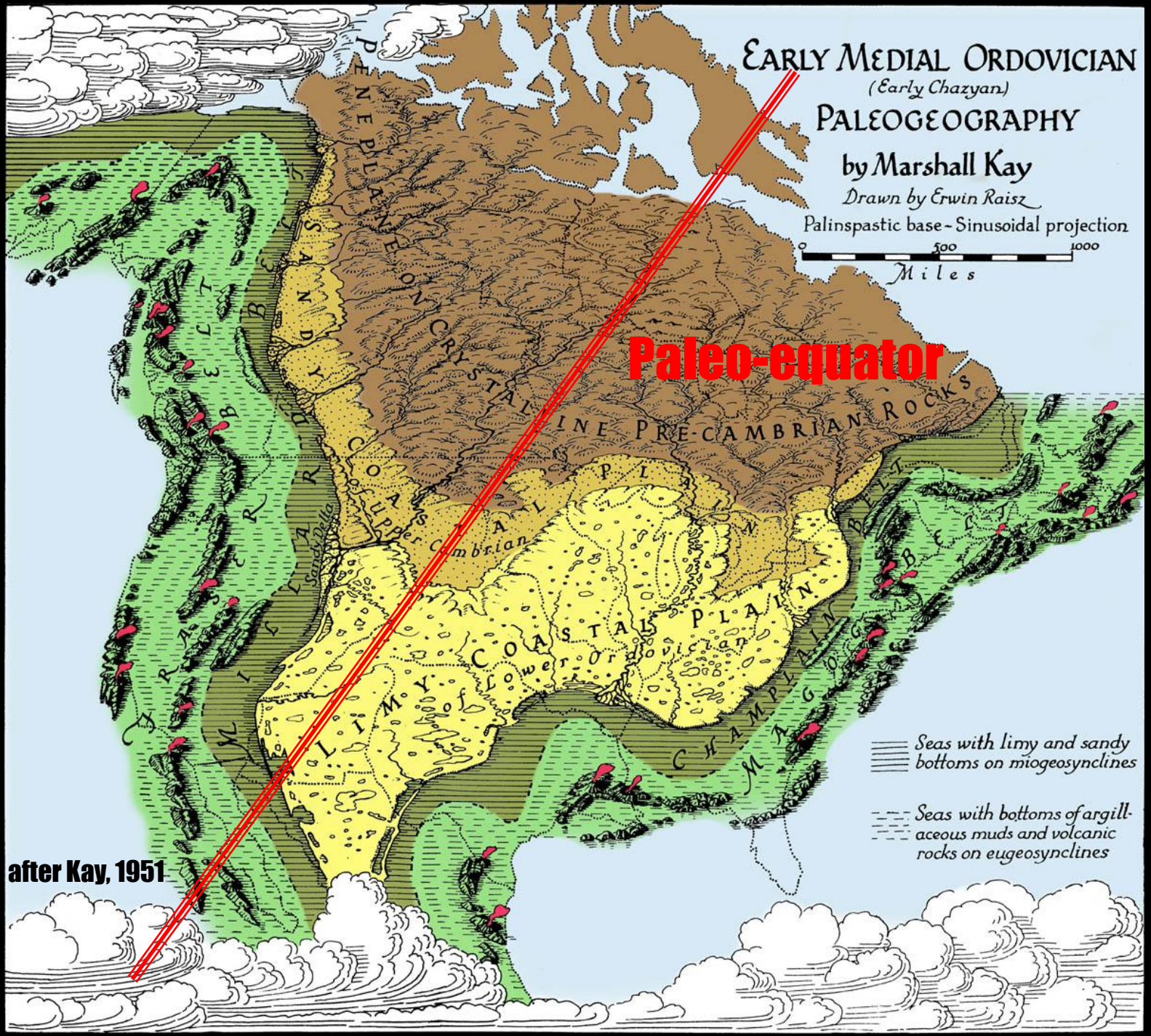
Hofstra Geology

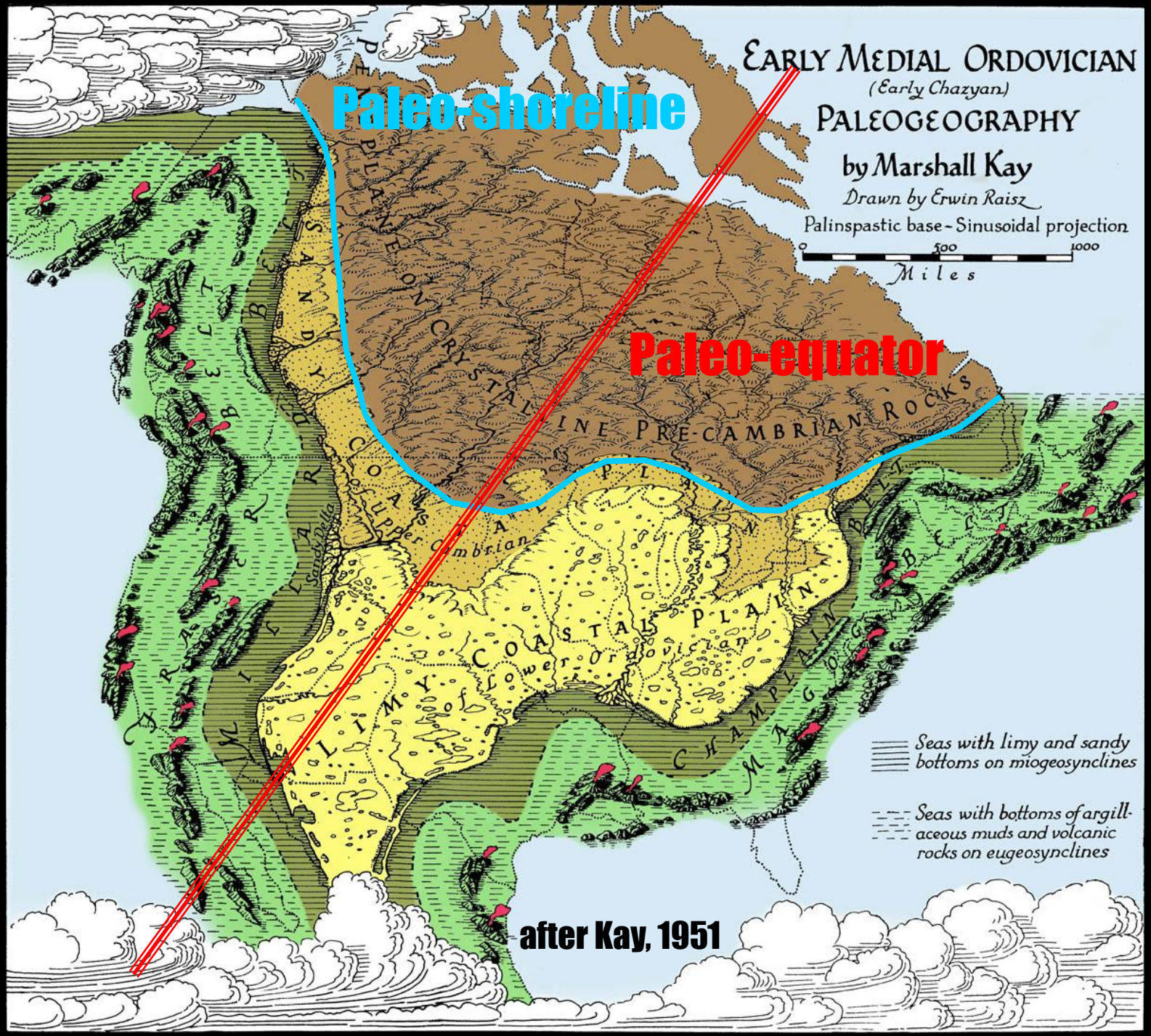

# Merguerian's Early Field Work on Manhattan Island

## In The Days When He Was Limber

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

**Proper Field Attire For NYC**


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


Paleo-shoreline
Paleo-equator
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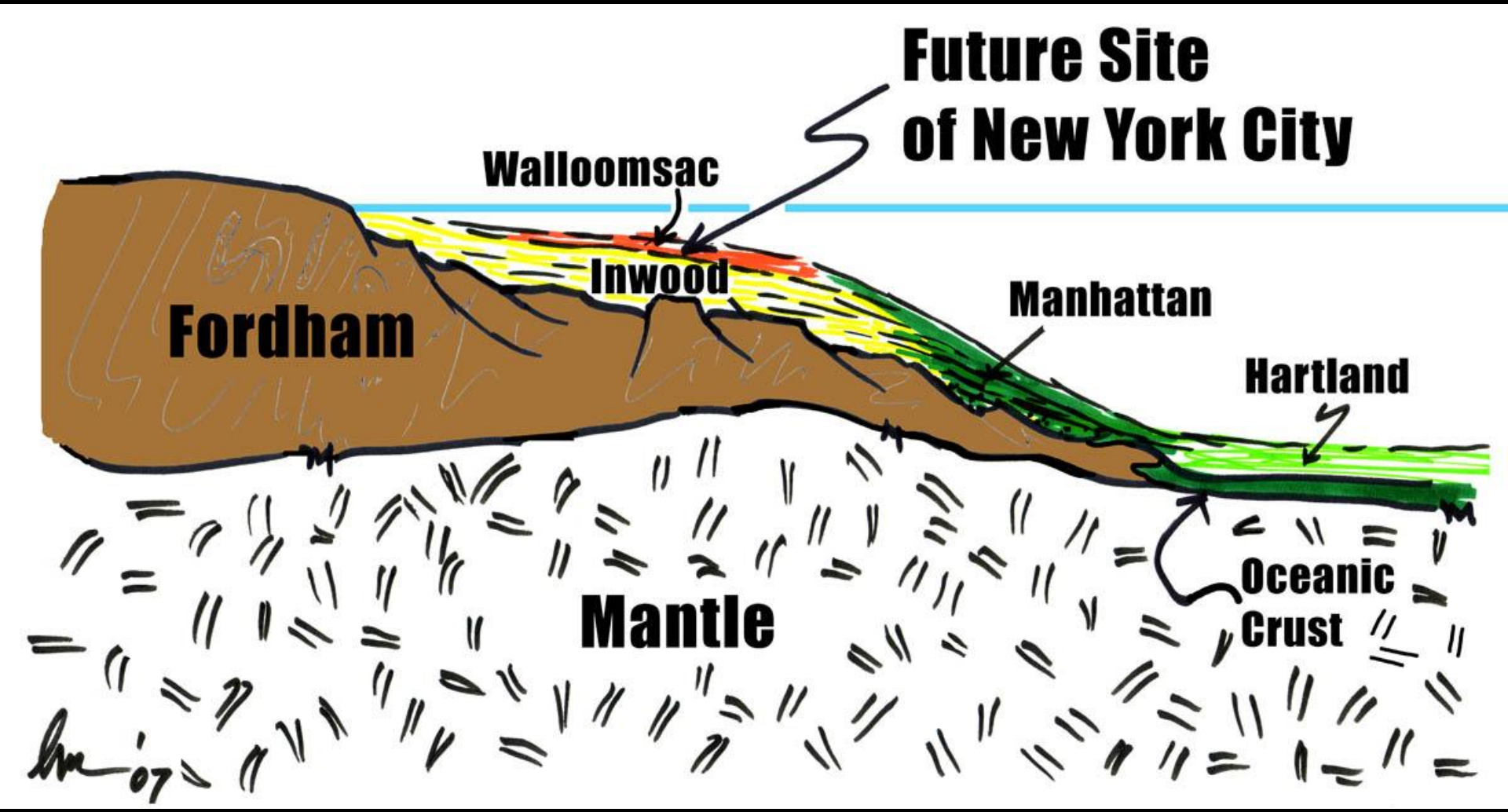
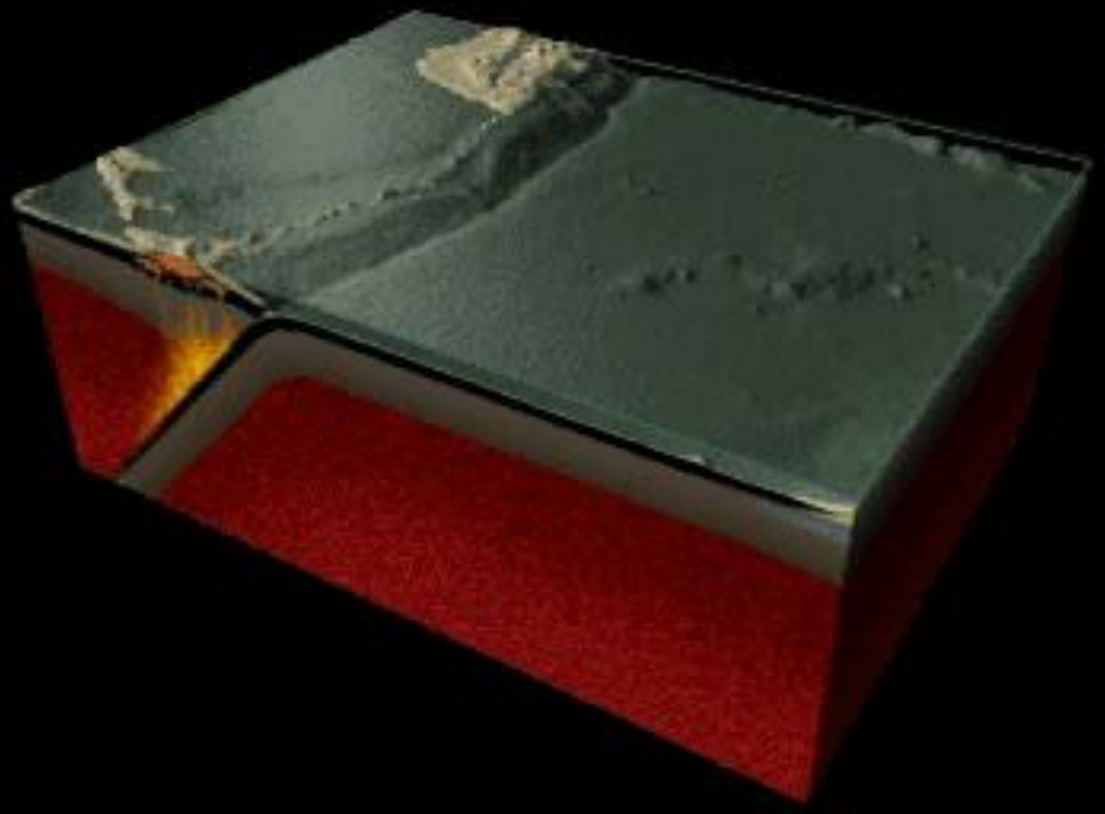
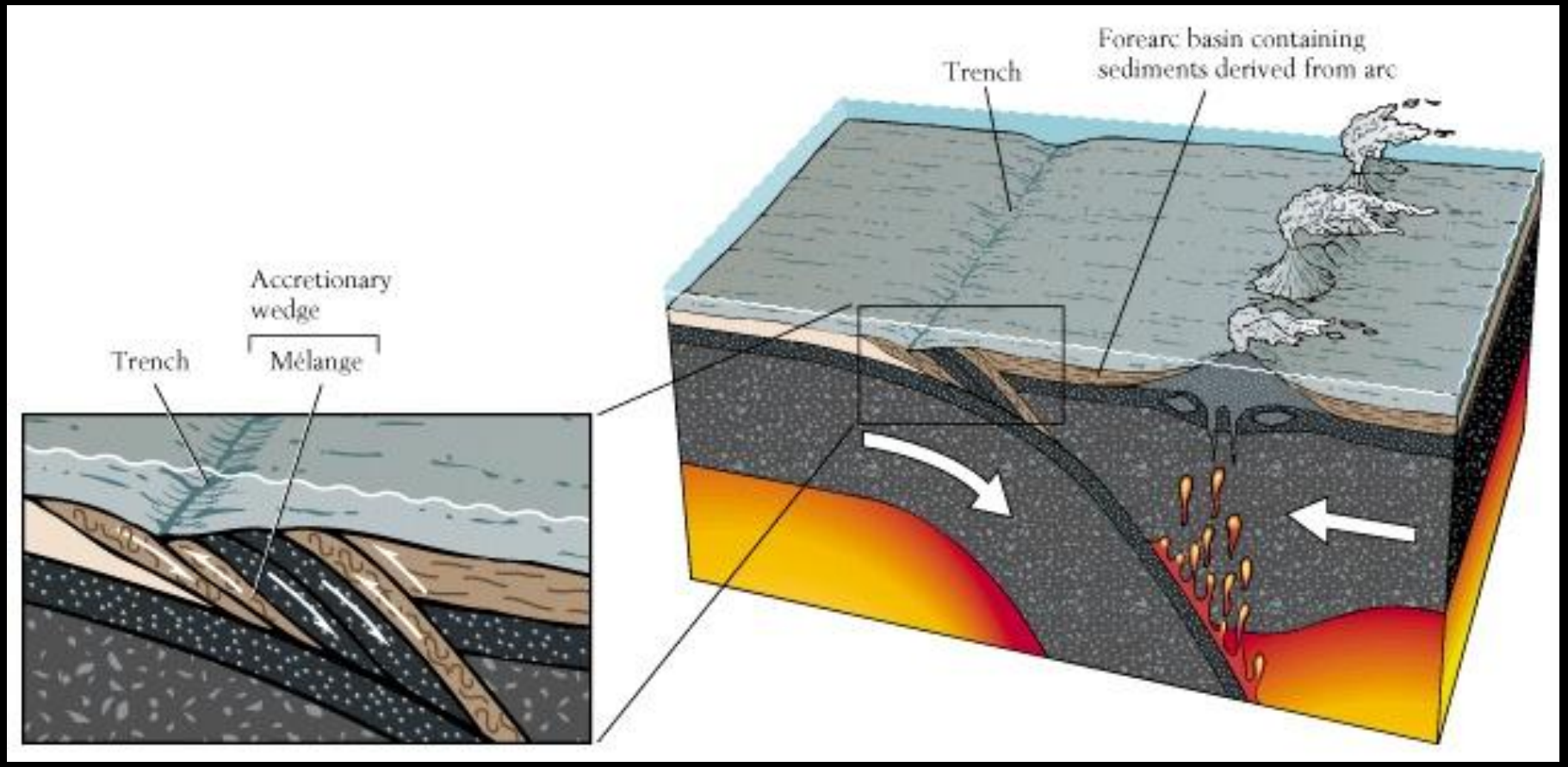
after Kay, 1951

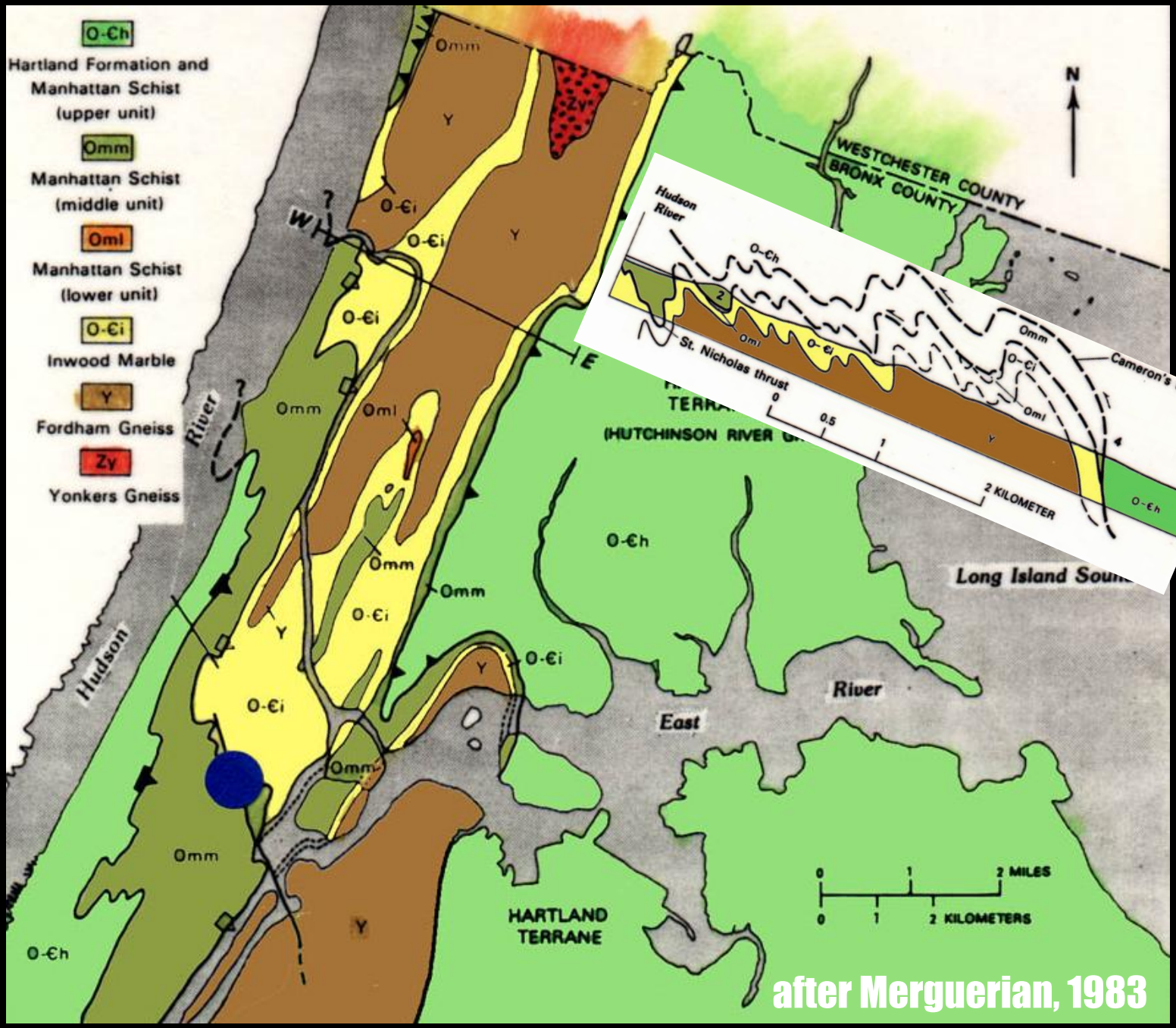

Future Site
of New York City
Walloomsac
Inwood
Fordham
Manhattan
Hartland
Oceanic
Crust
Mantle
'07

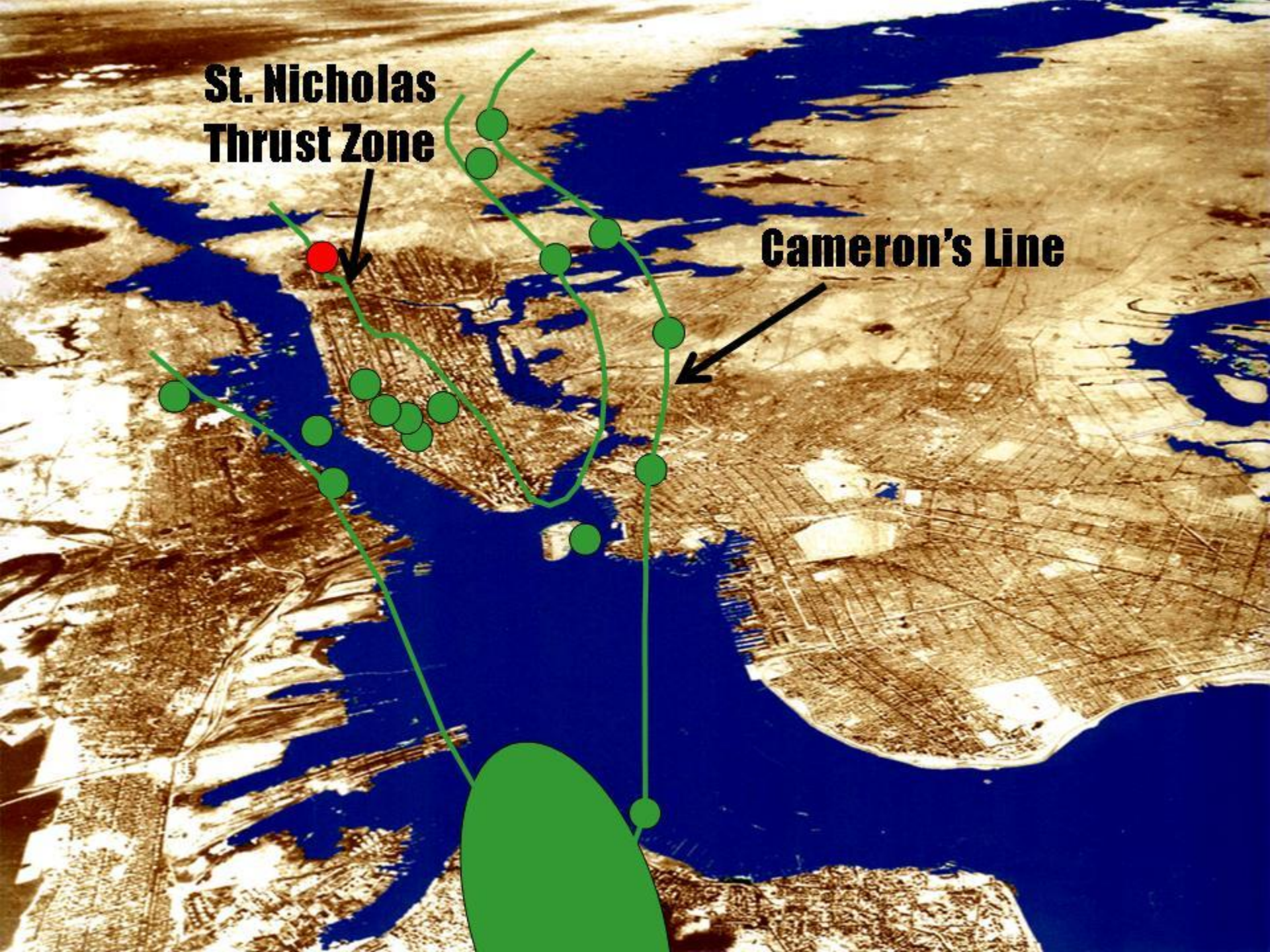
# ~ 450 Ma Taconic Arc – Passive Margin Collision

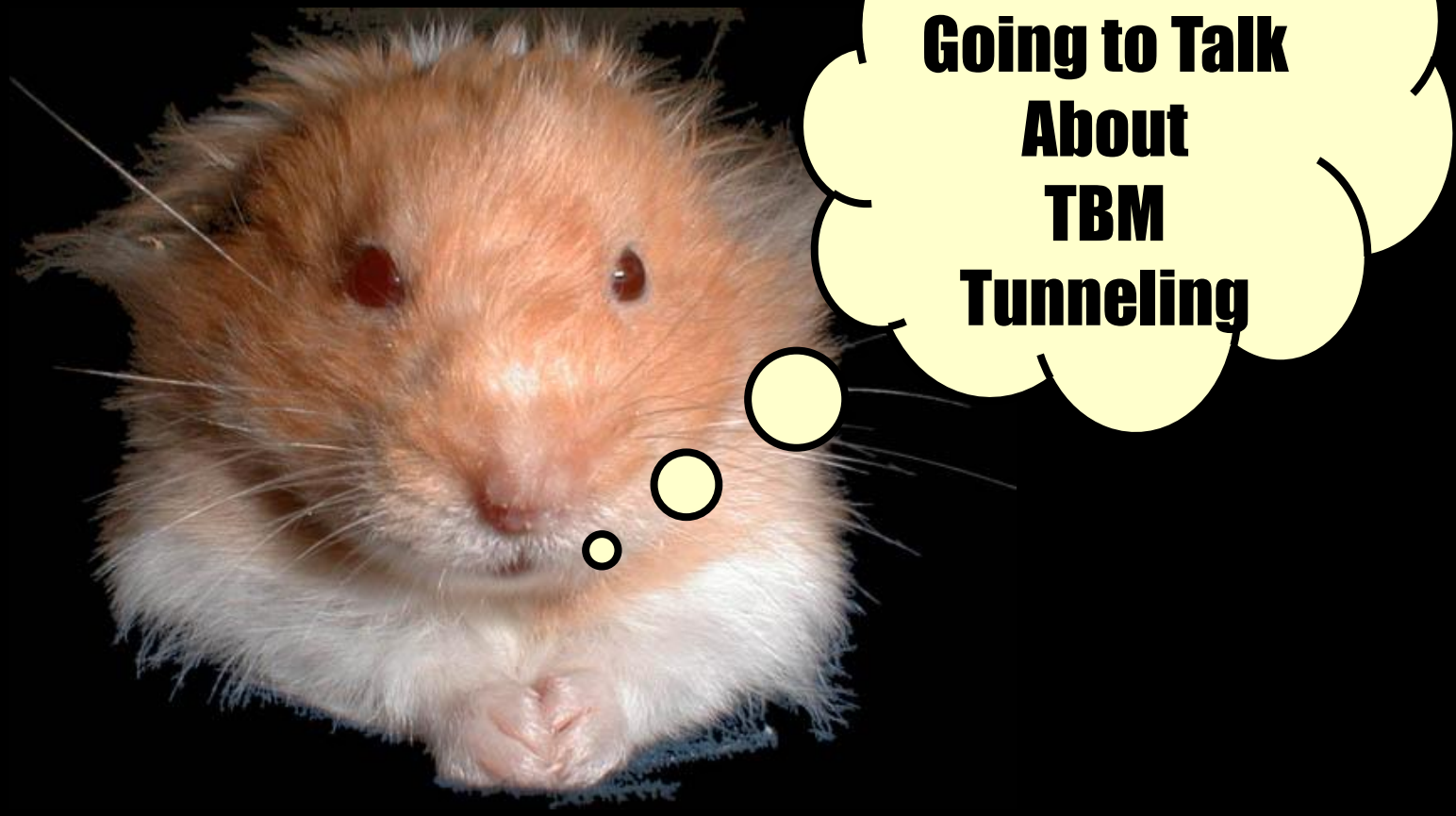


# Taconian Accretionary Prism



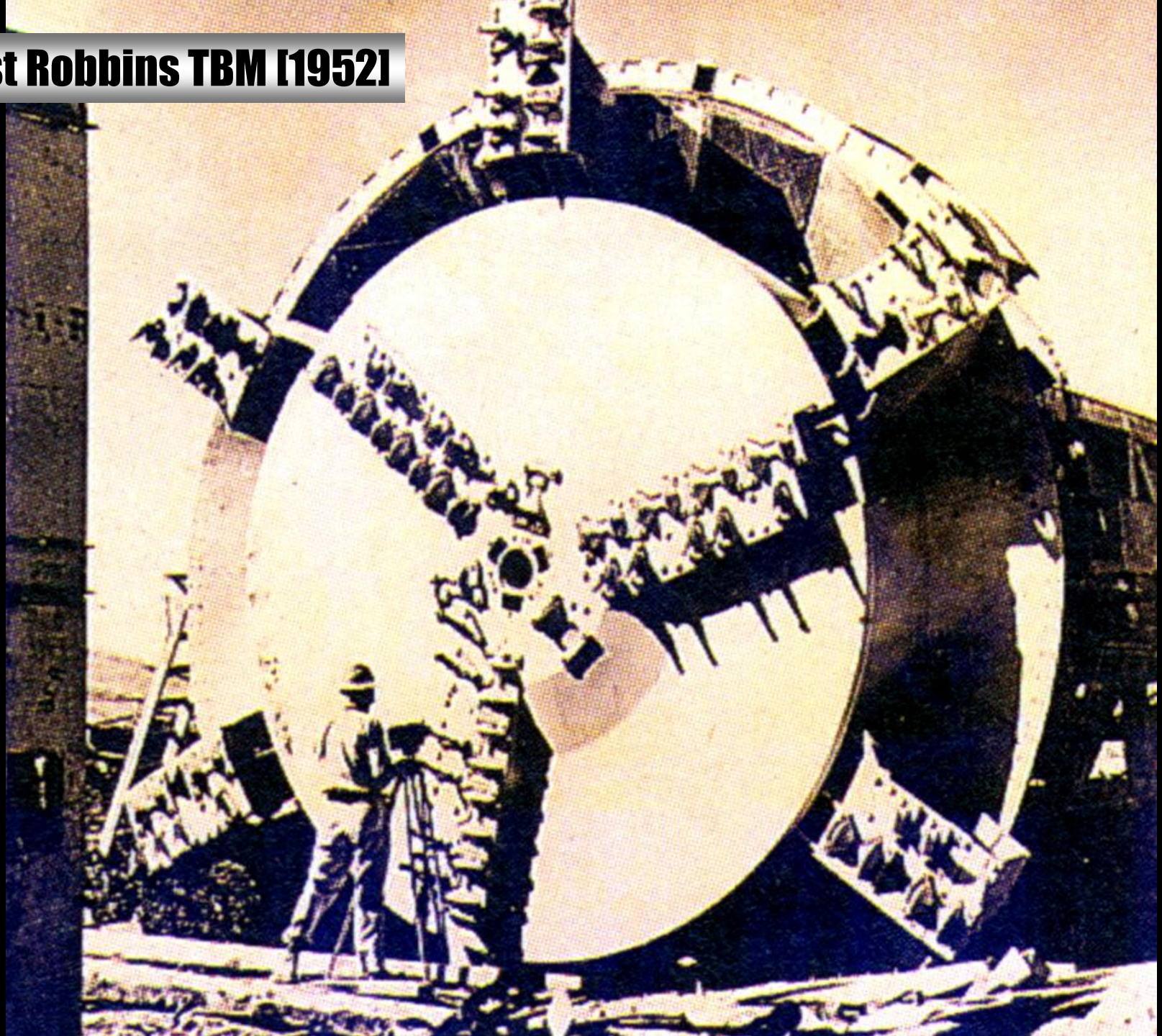

O-Ch
Hartland Formation and Manhattan Schist (upper unit)
Omm
Manhattan Schist (middle unit)
Oml
Manhattan Schist (lower unit)
O-Ci
Inwood Marble
Y
Fordham Gneiss
Zy
Yonkers Gneiss
N
WESTCHESTER COUNTY
BRONX COUNTY
Hudson River
O-Ch
Oml
O-Ci
Omm
Y
St. Nicholas thrust
Cameron's Line
0
0.5
1
2 KILOMETER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


St. Nicholas
Thrust Zone
Cameron's Line


Finally, He's
Going to Talk
About
TBM
Tunneling

# TBM Tunneling

# First Robbins TBM [1952]



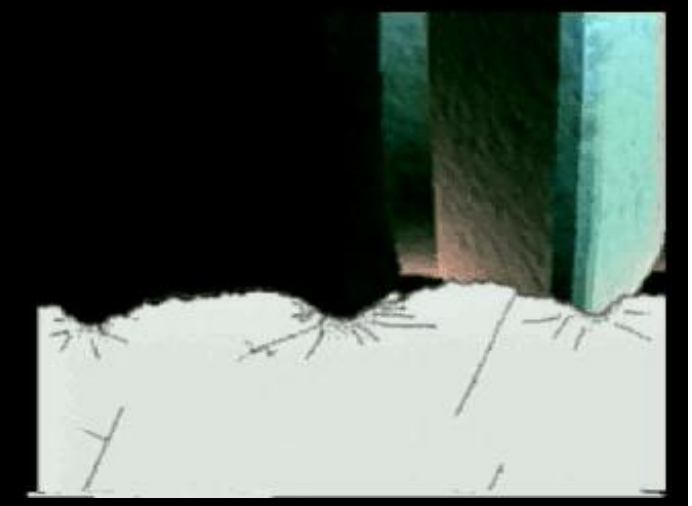
Holing Through North Tunnel, Hudson Tubes, French Line Dock (1904)

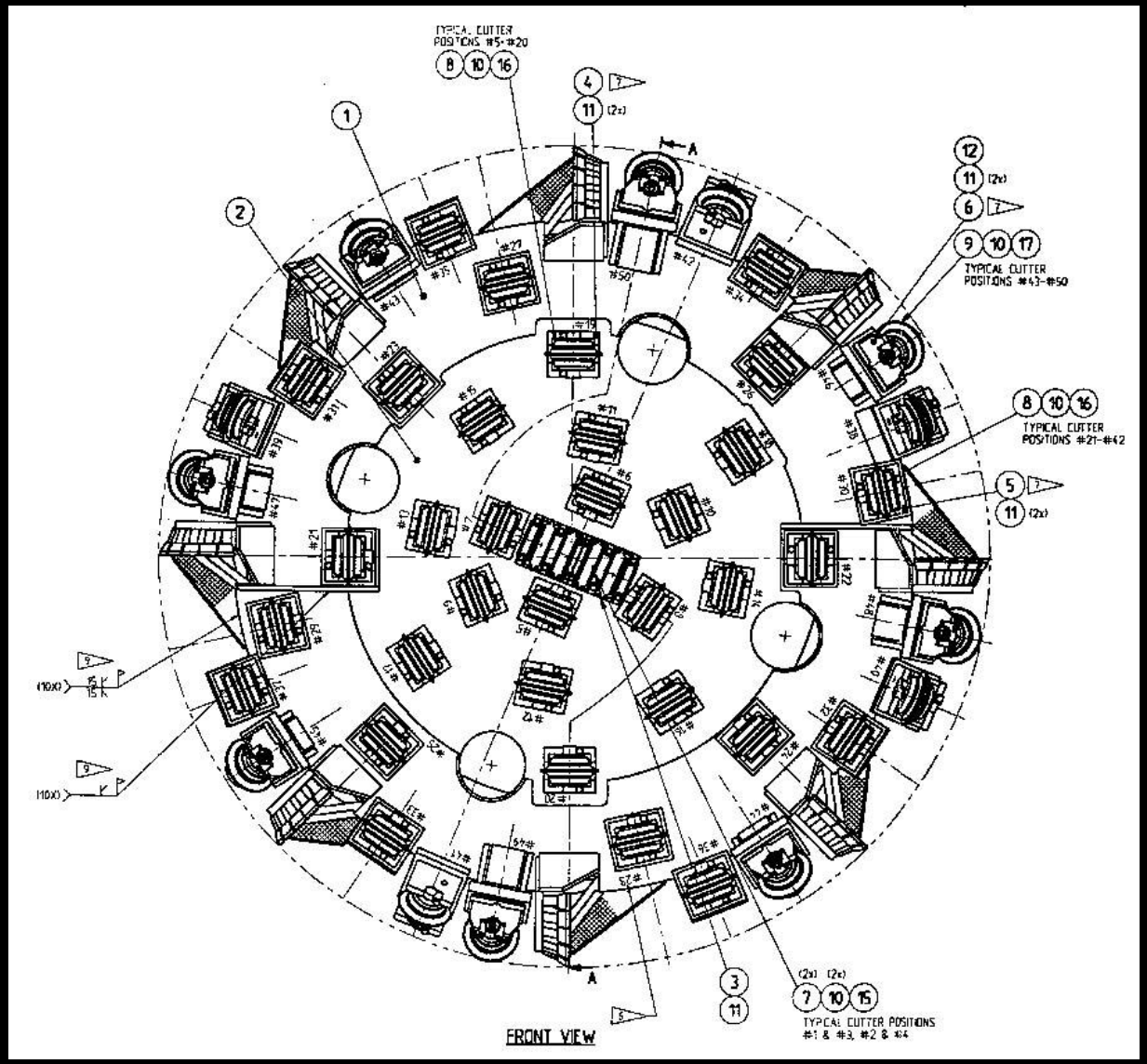
Sorenberg, Switzerland - Herrenknecht TBM

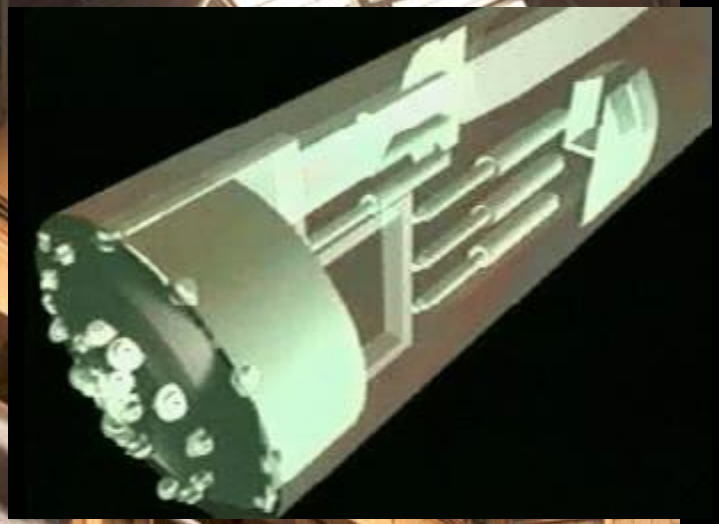
# Robbins 235-282 HP Hard Rock Main Beam TBM

Chesterfield, England - 1996

# TBM Chip Production







Atlas Copco

Robbins TBM 160-284

MetroWest


Normal TBM Chips

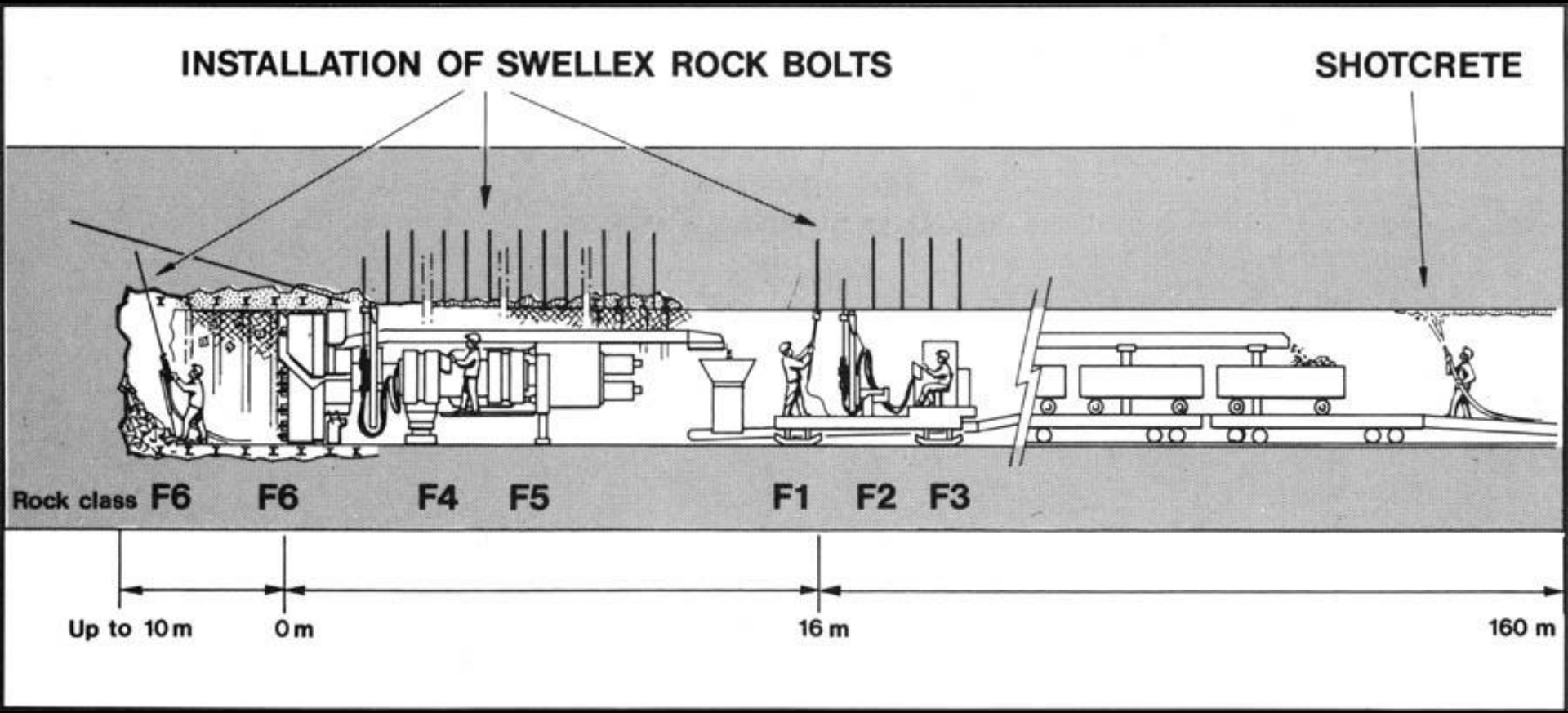

# In the Belly of the Beast

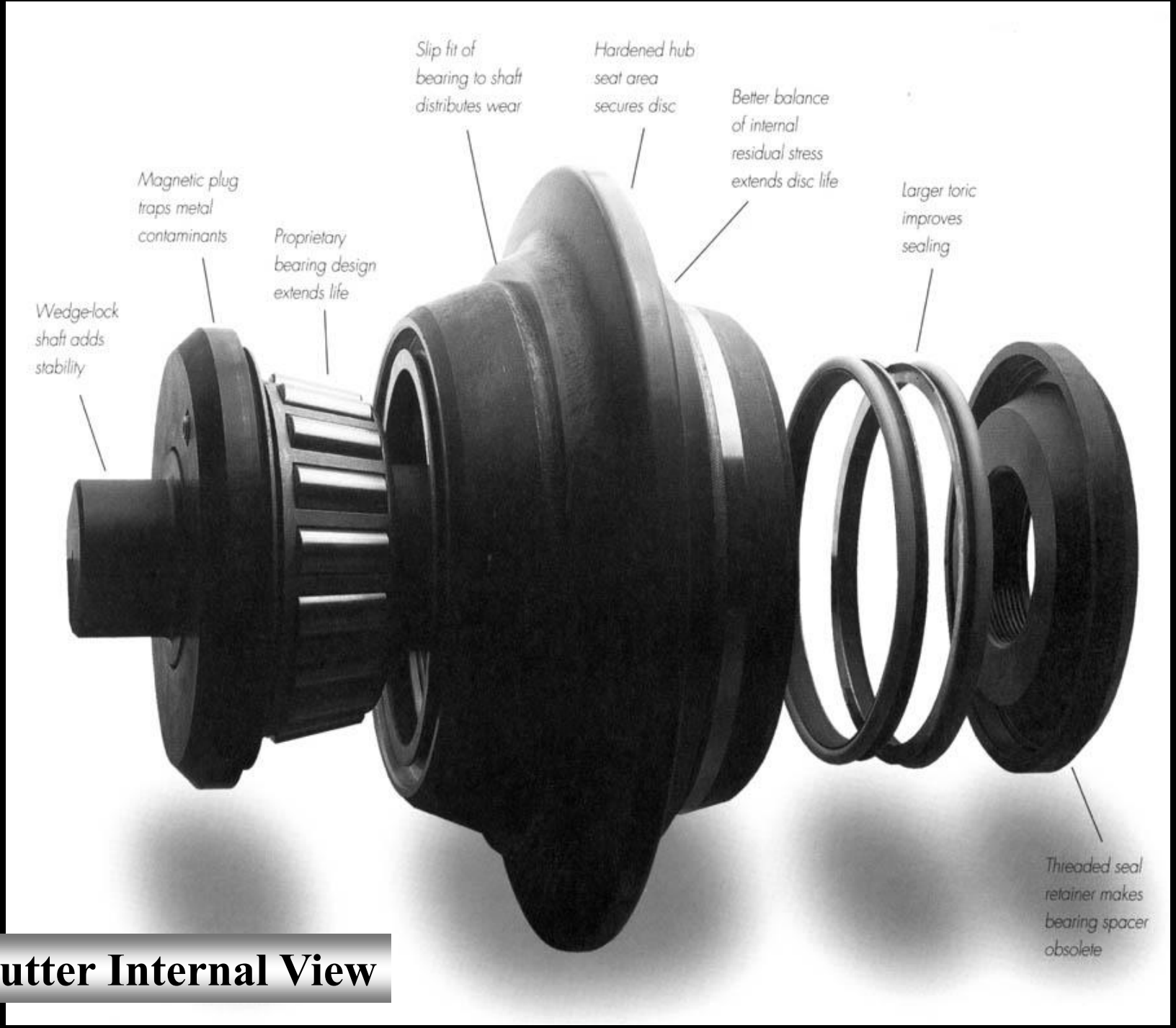
# Kerf Pattern in Hard Rock


TBM-Bored Tunnel


Swellex Bolts

# Swellex Rock Bolts

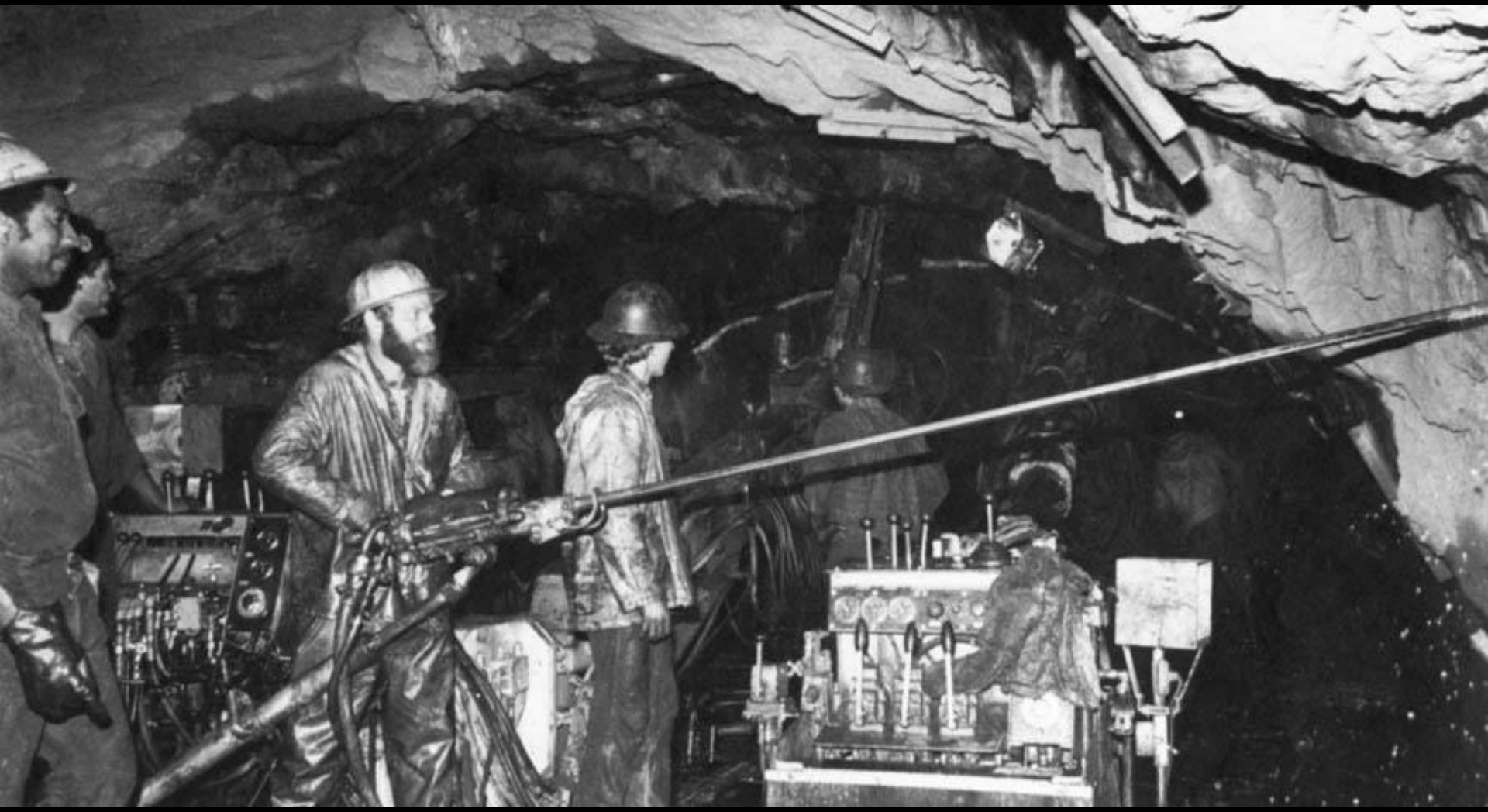





# Cutter Internal View

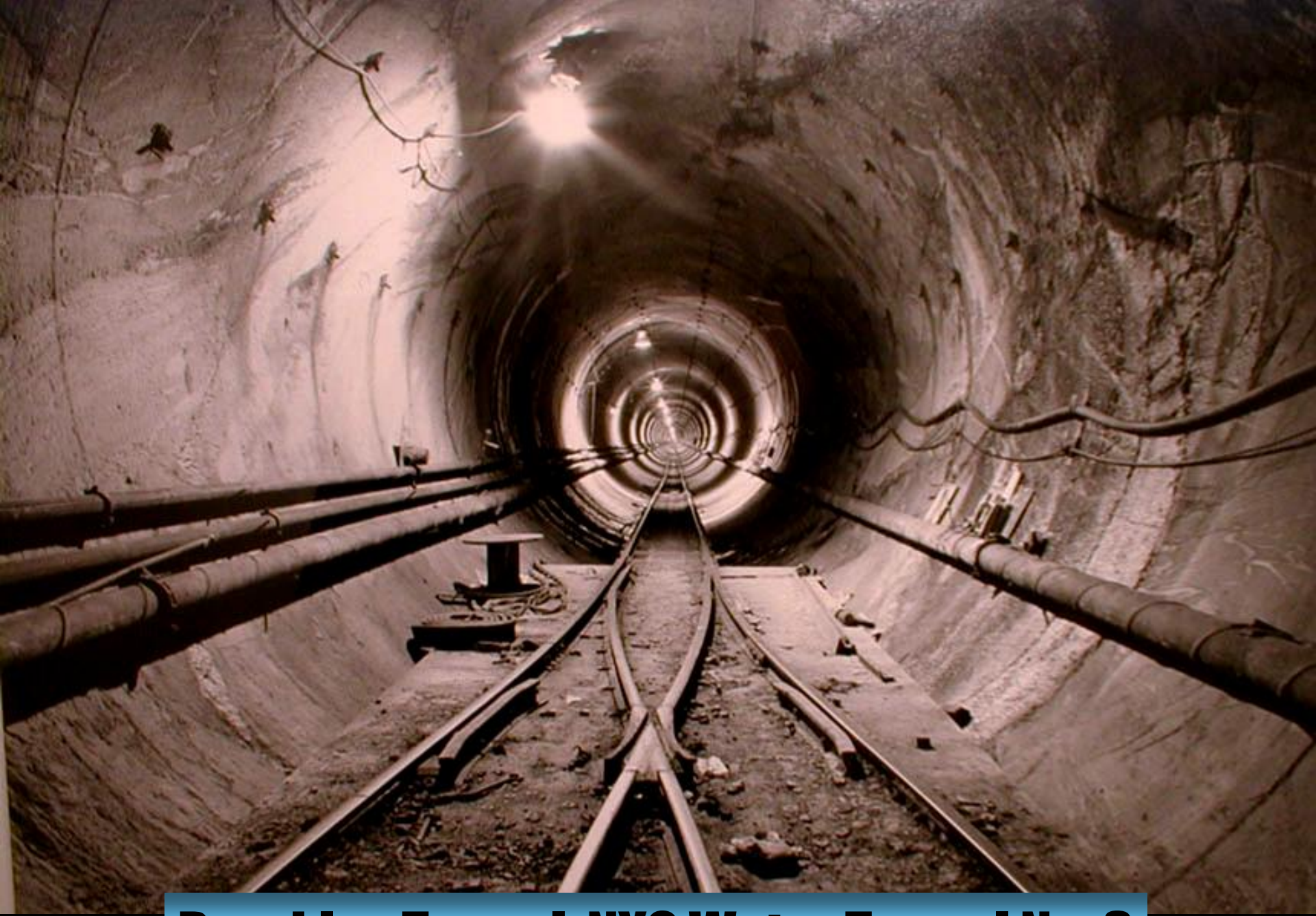
Before

After



CT3, Drill and Shoot Tunnel

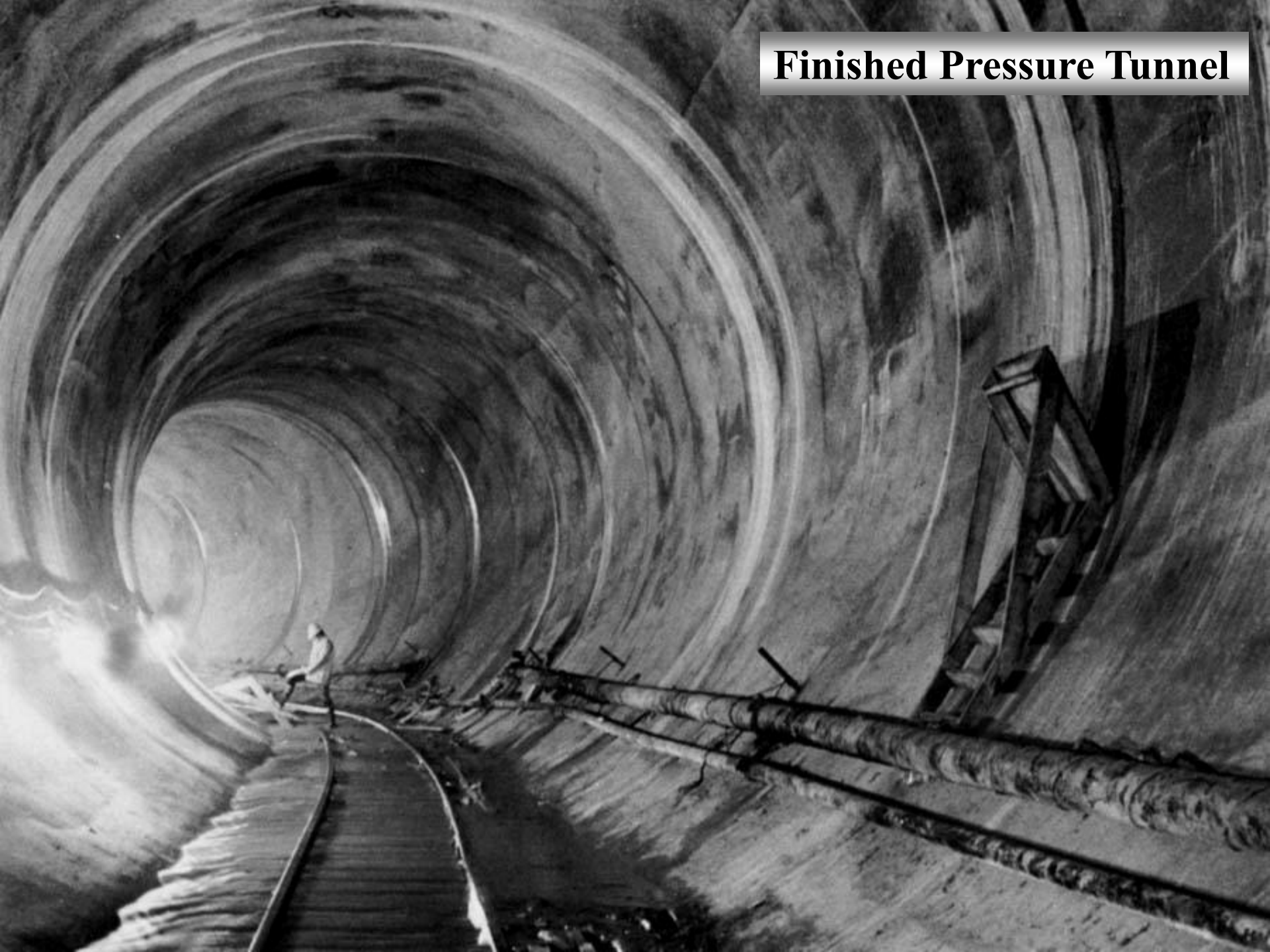
CT3, Scaling Drill and Shoot Tunnel



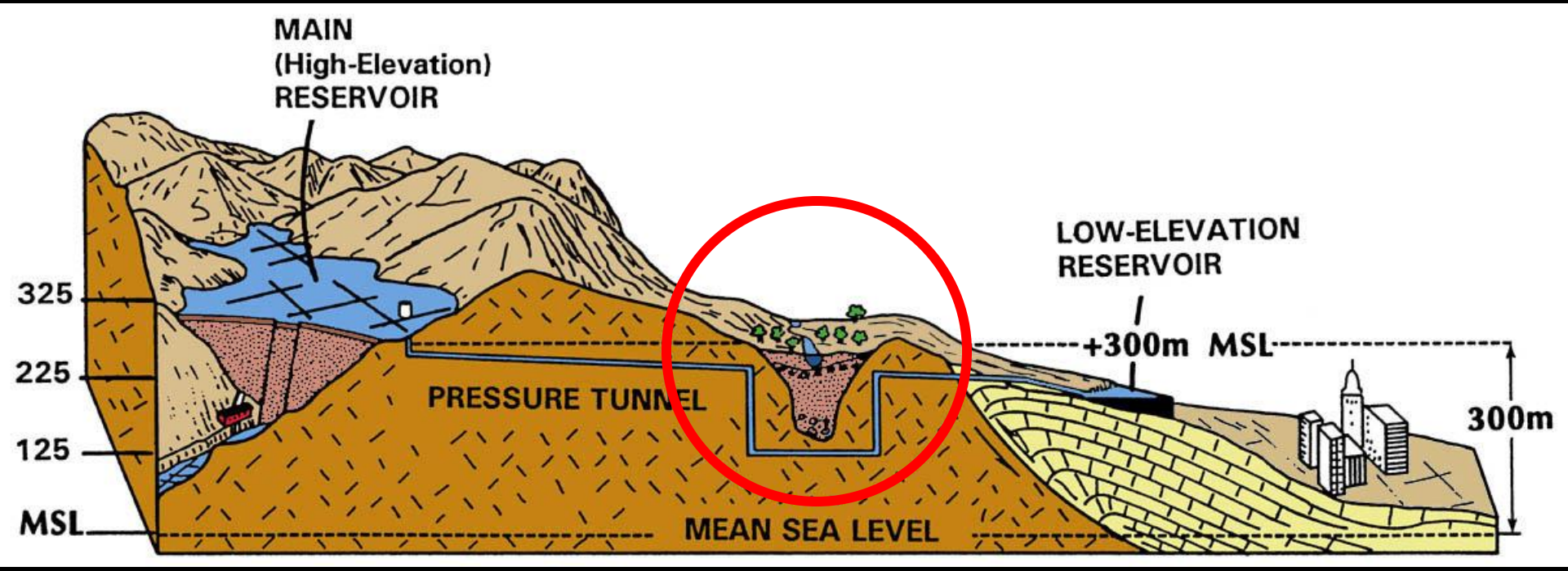
Brooklyn Tunnel, NYC Water Tunnel No. 3

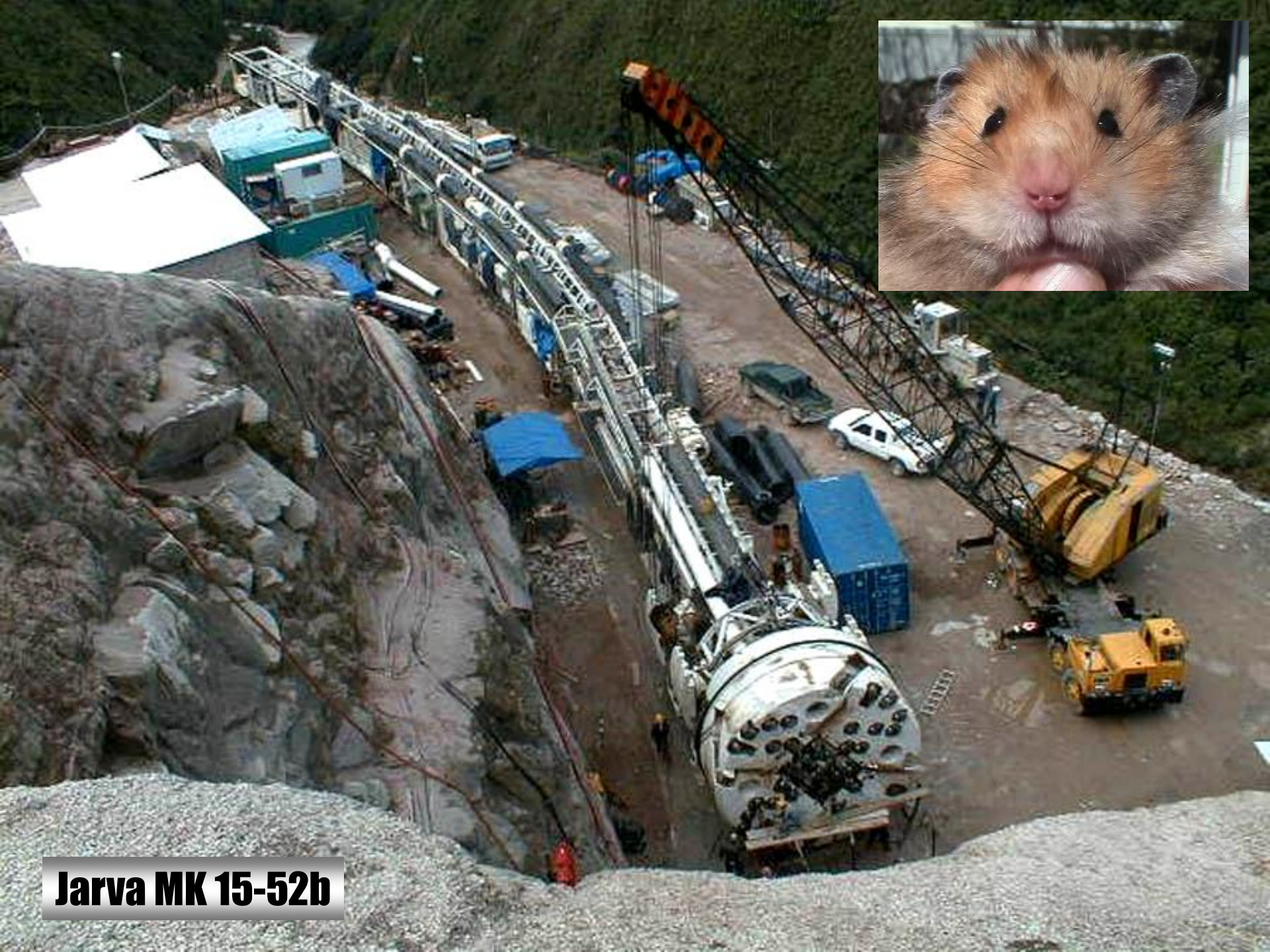

Ready to Pour Shaft 18B


Shaft 18B Forms


Finished Pressure Tunnel

# NYC Aqueduct
# Gravity Feed System – No Pumps

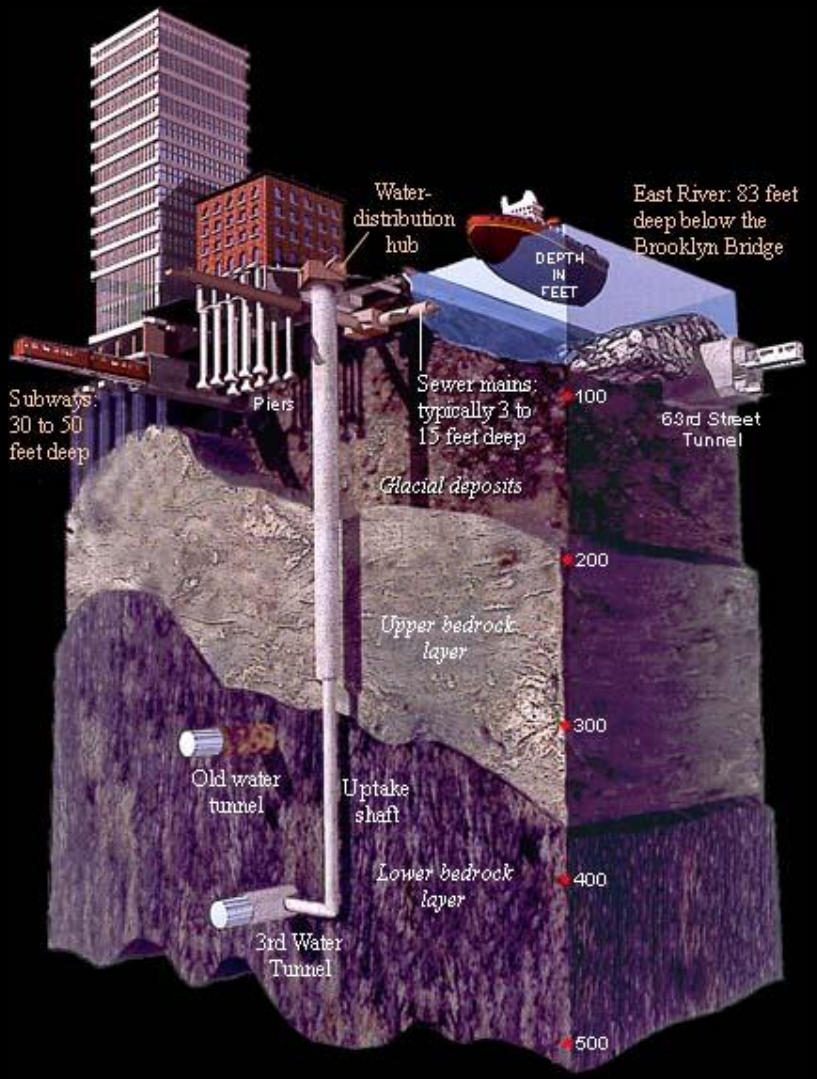



Jarva MK 15-52b

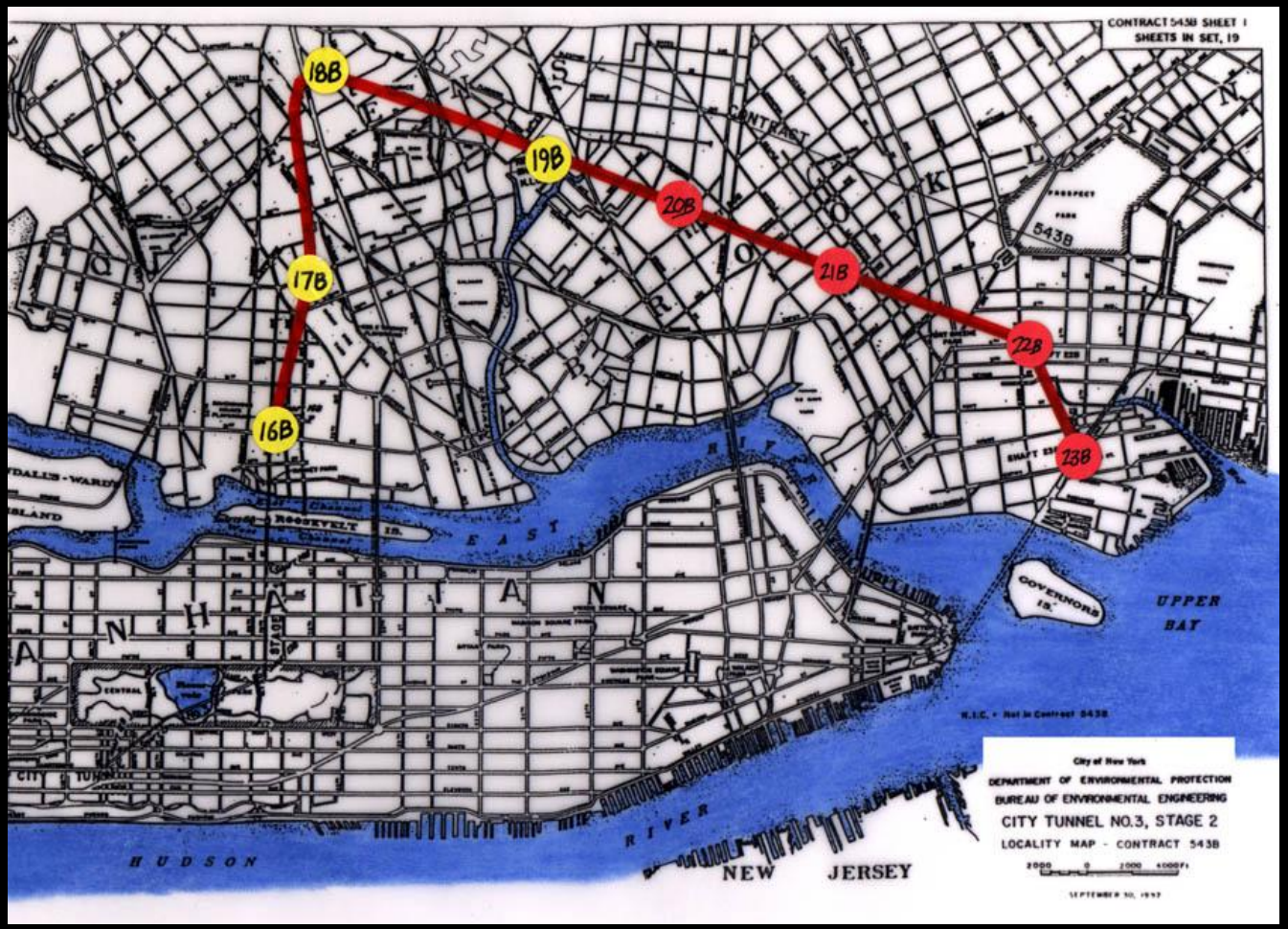

Remember Doc, You're Nothing Without Me!
Finally, He's Going to Talk About Mega-Construction Projects

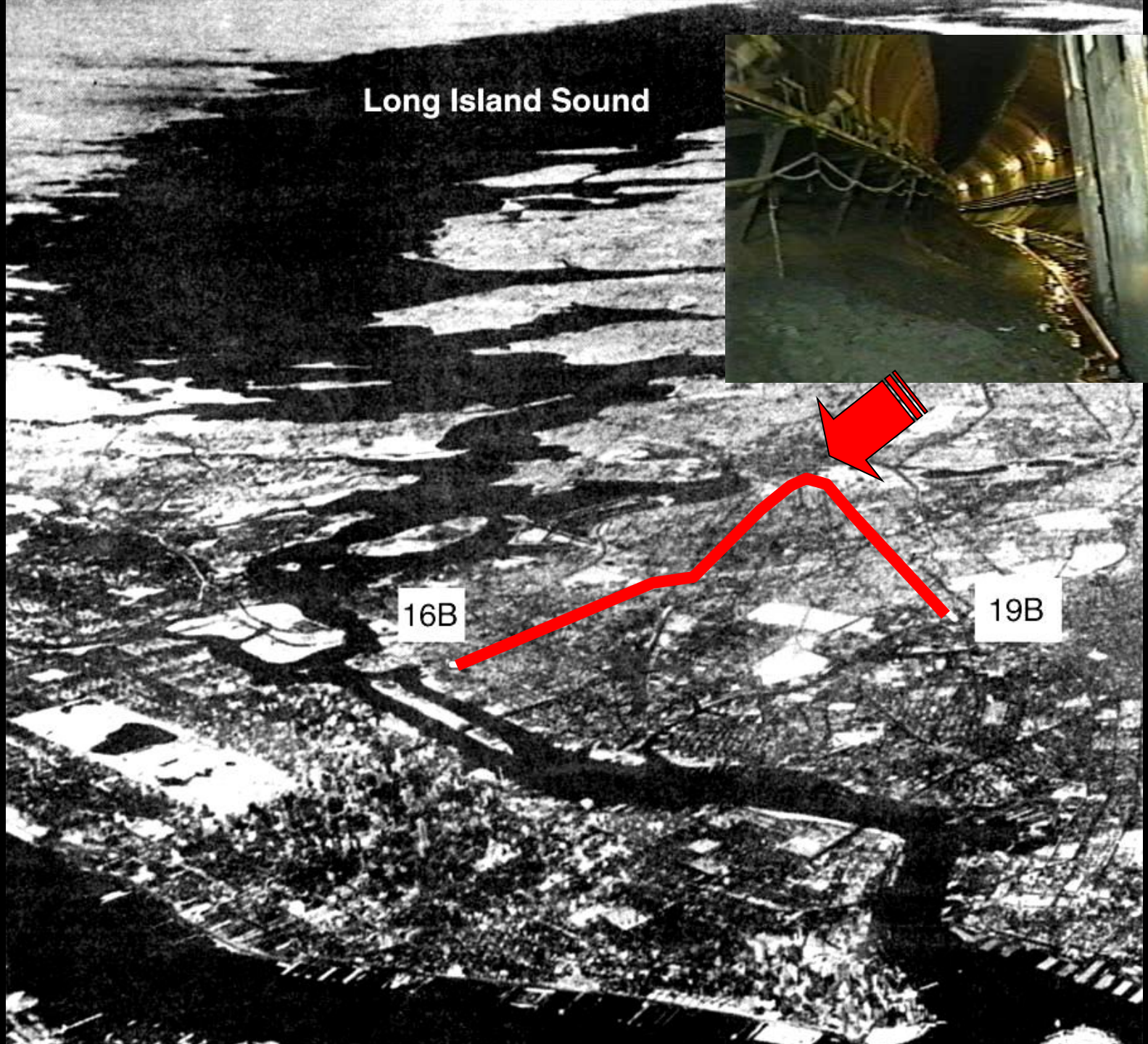
# Mega-Construction Projects

- Queens Water Tunnel
- Con Edison Steam Tunnel
- Manhattan Water Tunnel
- East Side Access Project
- Second Avenue Subway
- IRT #7 Line Extension
- LI Cross Sound Link Tunnel



# Construction of the Queens Tunnel
# NYC Water Tunnel #3
# Oct 1996 – Oct 1999




Long Island Sound
16B
19B


QUEENS TUNNEL


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
Madison Square Park
Touro College
St Francis College
Parsons School of Design
Baruch College
Bellevue Hospital Center
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

# Con Edison Steam Tunnel TBM

## Robbins HP 215-257 Hard Rock Machine
## Capable of 5’ stroke

# TBM at Con Ed Tunnel

## 30 Street and 1st Avenue

10 Oct 2002


Southern Heading
Shallow NW Dip

# TBM Starter Tunnel


Starter Tunnel to South Heading

# CT3, Stage2 Manhattan Water Tunnel

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## Shaft 26B


10 Oct 2002


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


26B South Heading

# Bottom of Shaft 26B

## 580’ Deep

# Manhattan Tunnel TBM

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

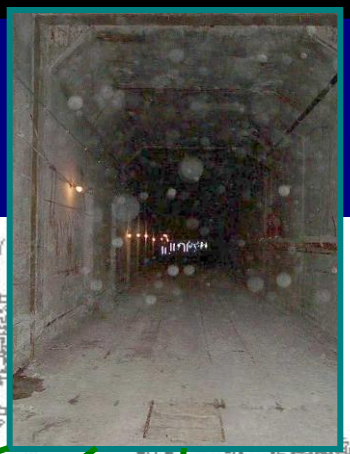
# East Side Access

# LIRR/MTA


Central Park
Metro-North Railroad
8,600ft
(17,200 Linear Ft.)
63rd Street Tunnel
63rd St
41st Ave
5,500ft
(11,200 Linear Ft.)
Sunnyside Yard
29th Ave
Northern Blvd
AMTRAK
LIRR Port Washington Branch
Queensborough Bridge
Mid-Day Storage Yard
Harold Interlocking
Queens Blvd
QUEENS
Roosevelt Island
Northern Blvd
Sunnyside Station
Arch Street Yard & Shop Facility
7,200ft
(24,000 Linear Ft.)
53rd St
Grand Central Terminal
42nd St
Long Island Expressway
Queens-Midtown Tunnel
LIRR Montauk Branch
EAST RIVER
MANHATTAN
BROOKLYN
Legend
Existing LIRR Tunnel Structure
Tunnel Structure to Be Built

# Existing 63rd Street Tunnel





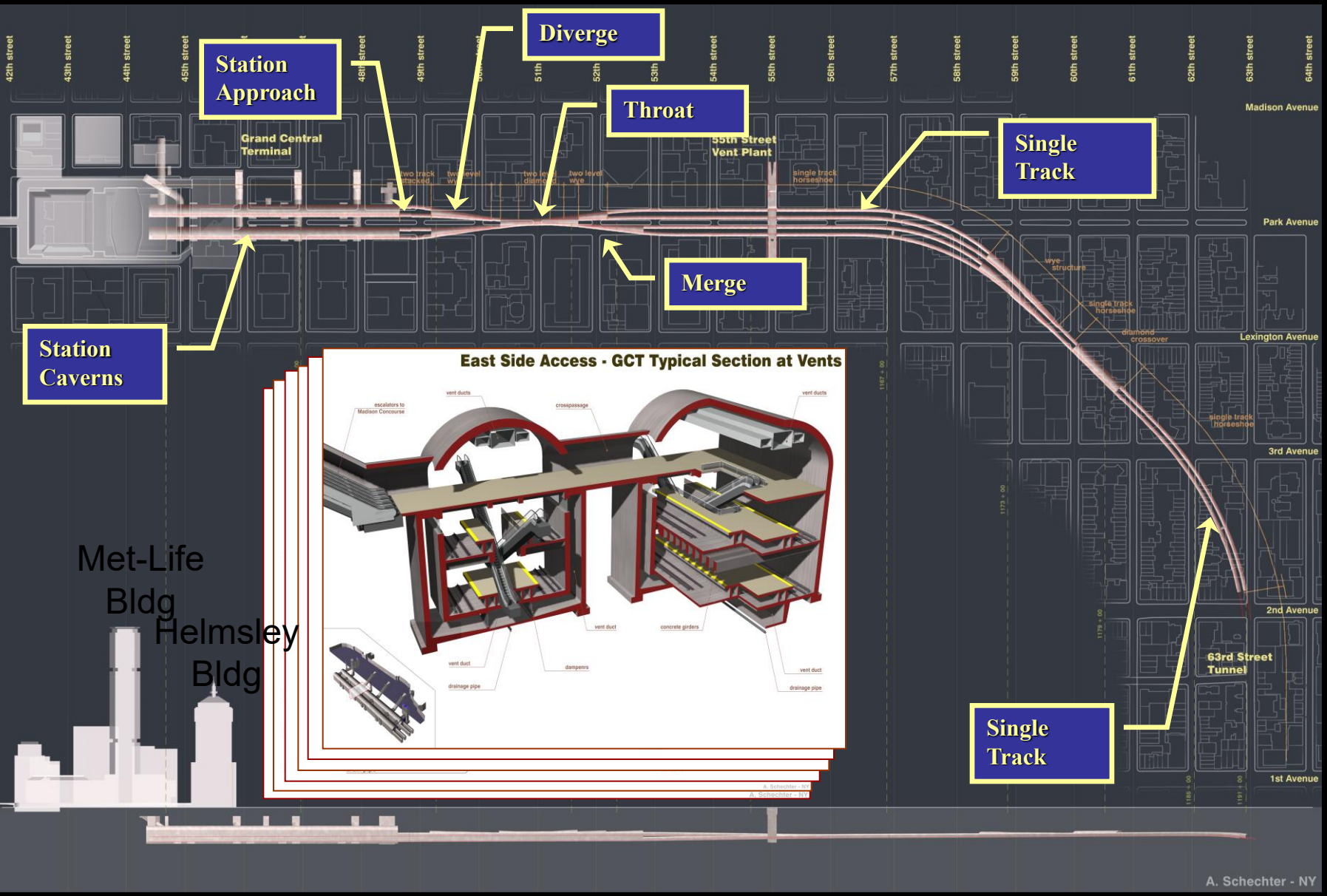




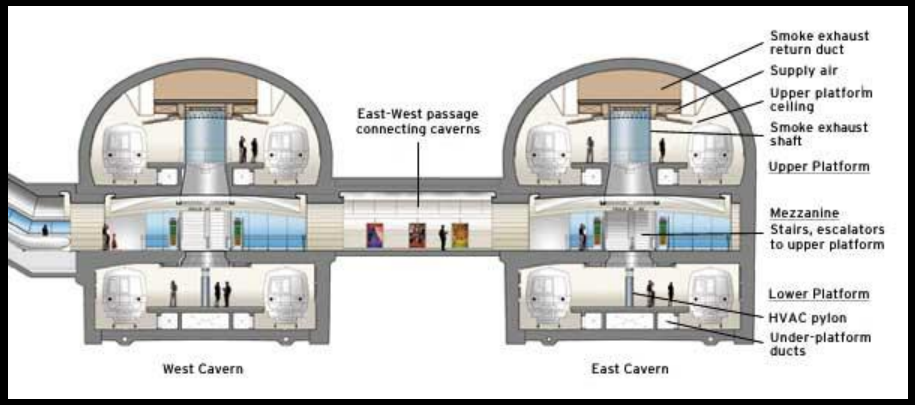
13 Aug 2007

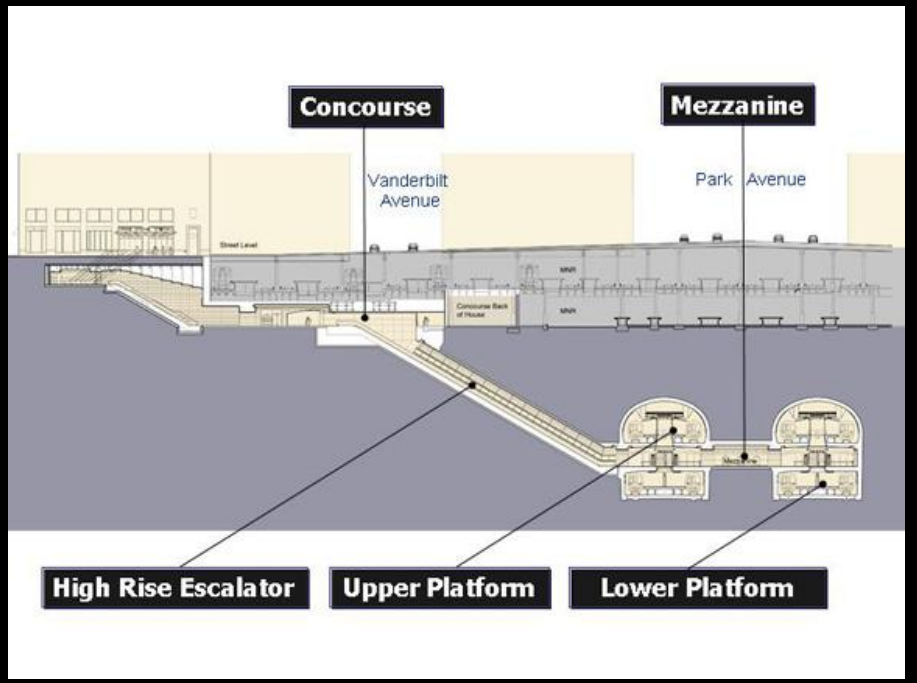

28 Nov 2007

# East Side Access Project Plans



# Construction Will Take Place Under Existing GCT



# Second Avenue El

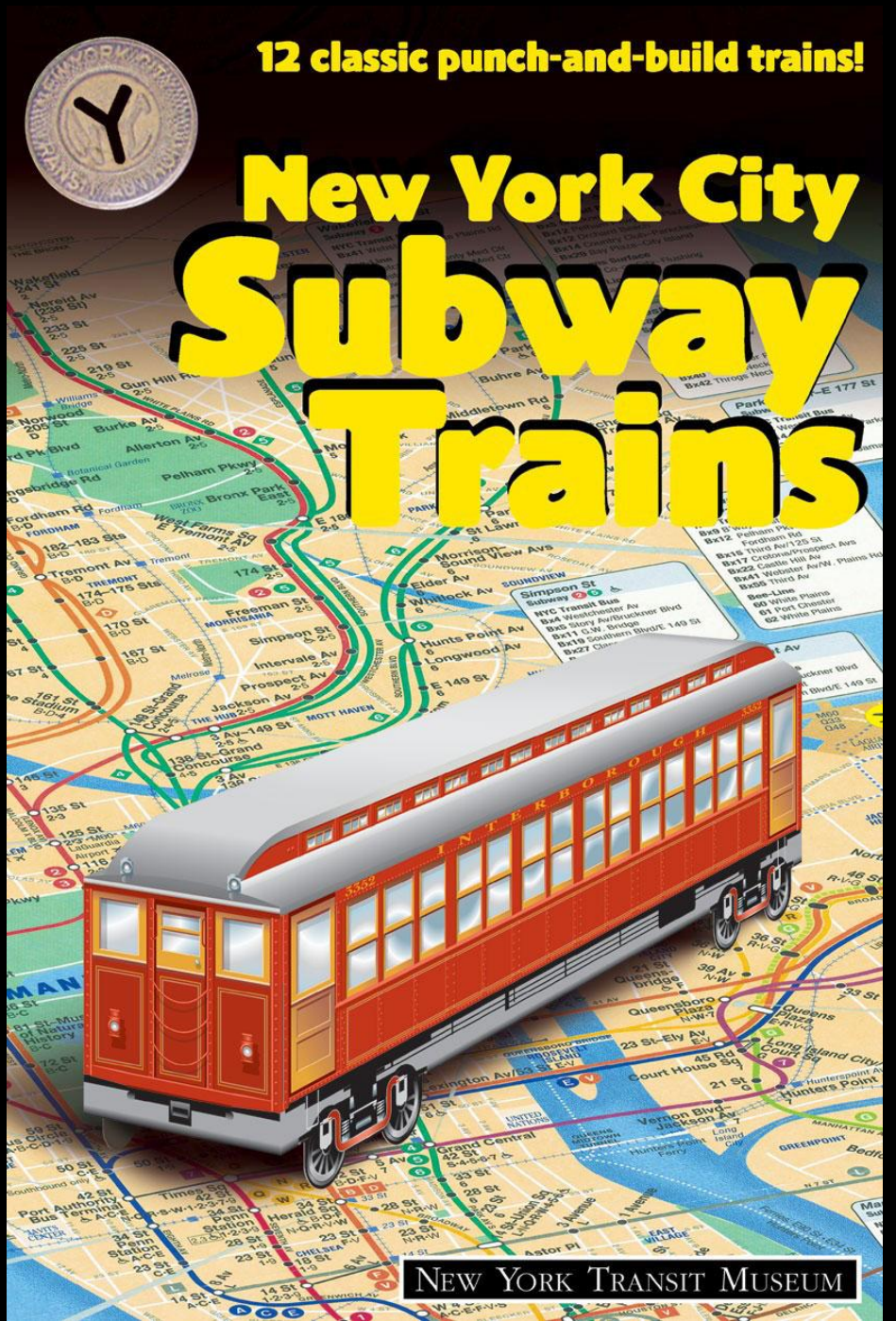

1929 – NYC BOT Proposes Second Avenue Subway

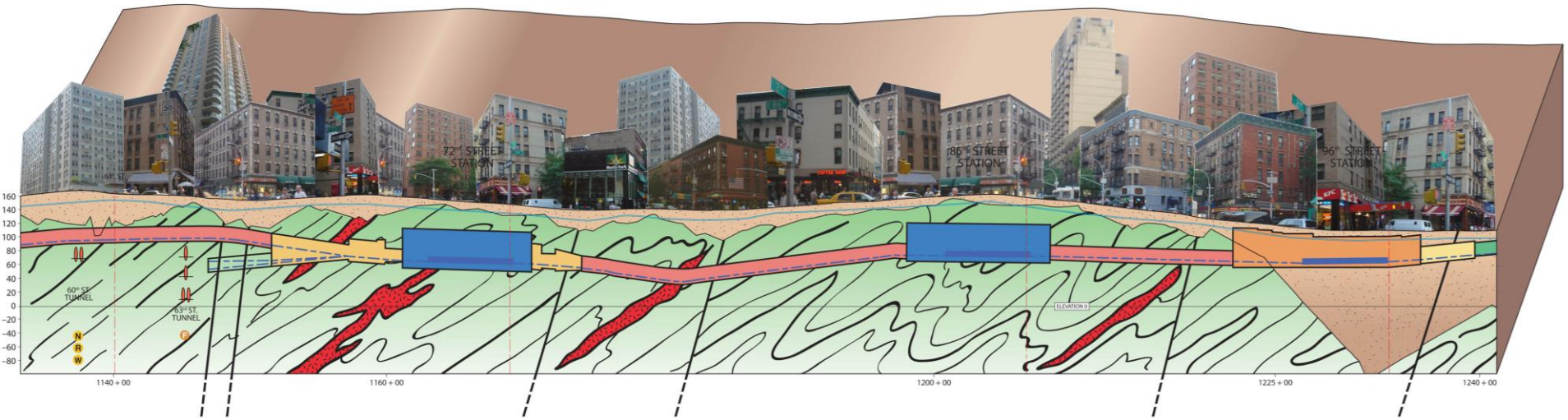
1931 – Plans Postponed Depression Era

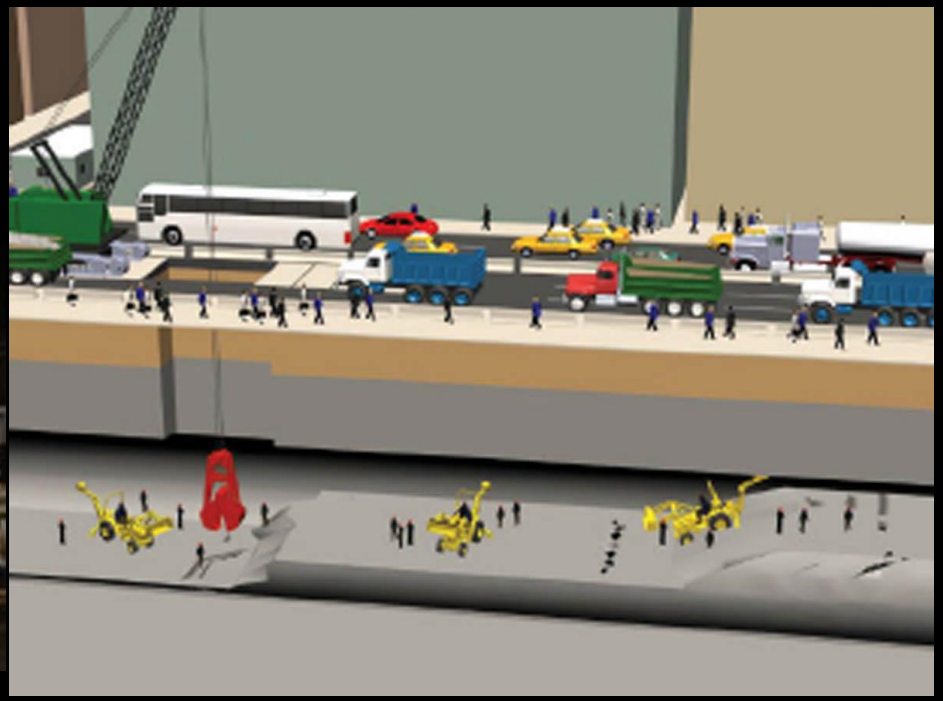
$86M → $249M → $500M

By 1948 – ( Abandonment]

# Second Avenue Subway

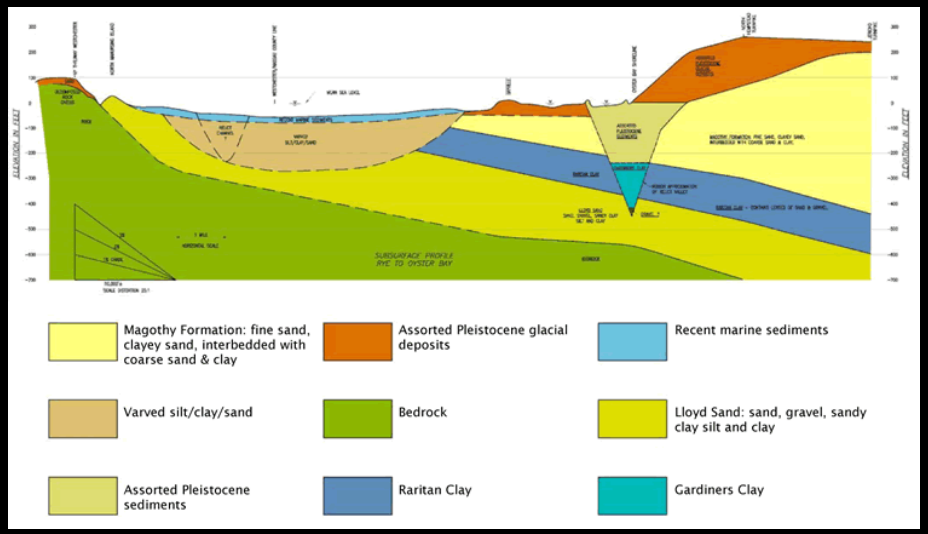



72nd STREET STATION
86th STREET STATION
96th STREET STATION
60th ST. TUNNEL
63rd ST. TUNNEL
N
R
W
ELEVATION 0
160
140
120
100
80
60
40
20
0
−20
−40
−60
−80
1140 + 00
1160 + 00
1200 + 00
1225 + 00
1240 + 00

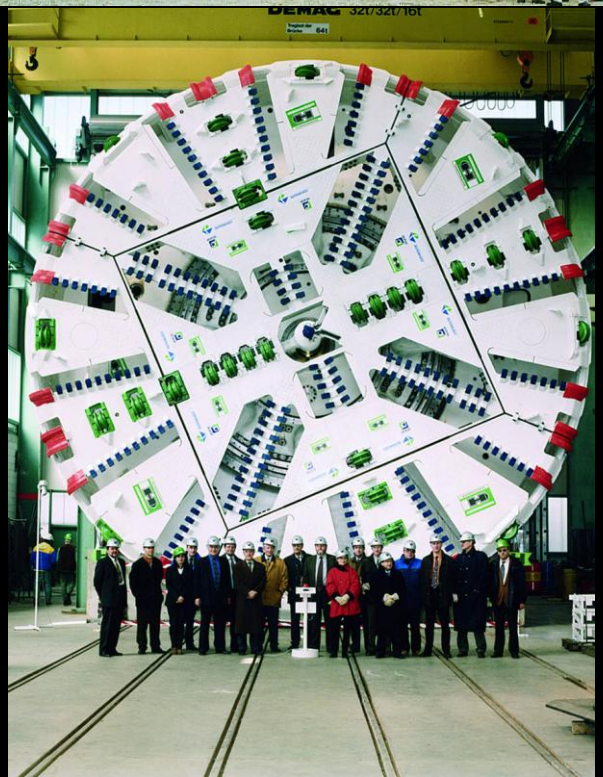


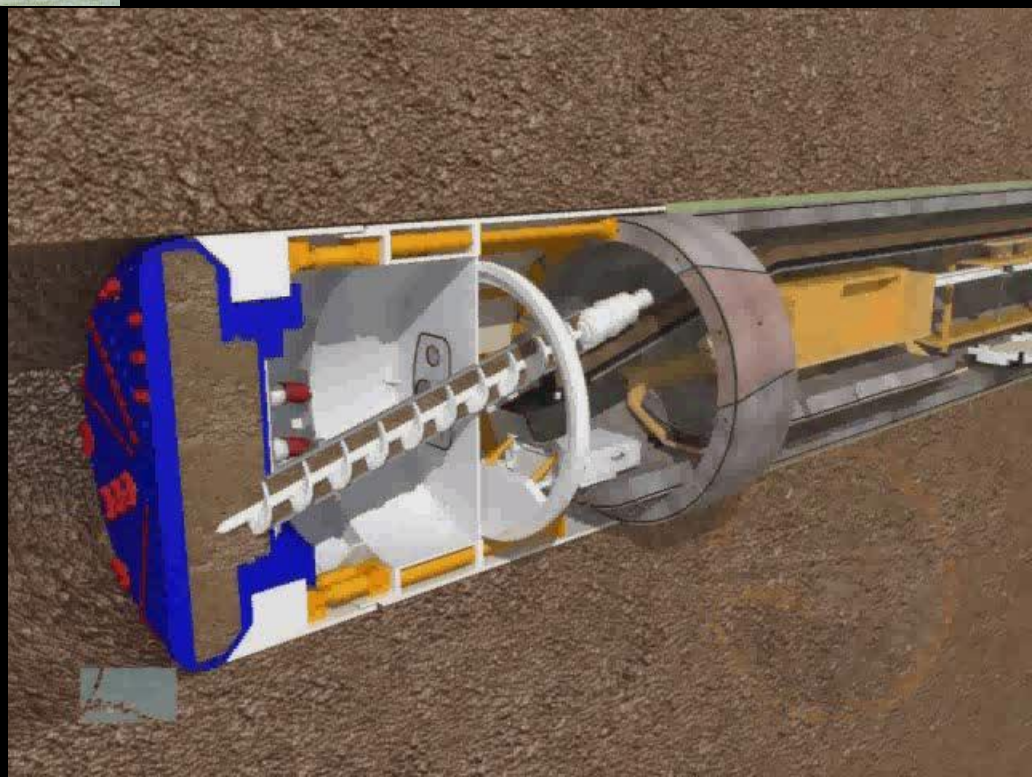
# IRT #7 Line Extension


# Cross Sound Link Project




# Soft Ground TBMs

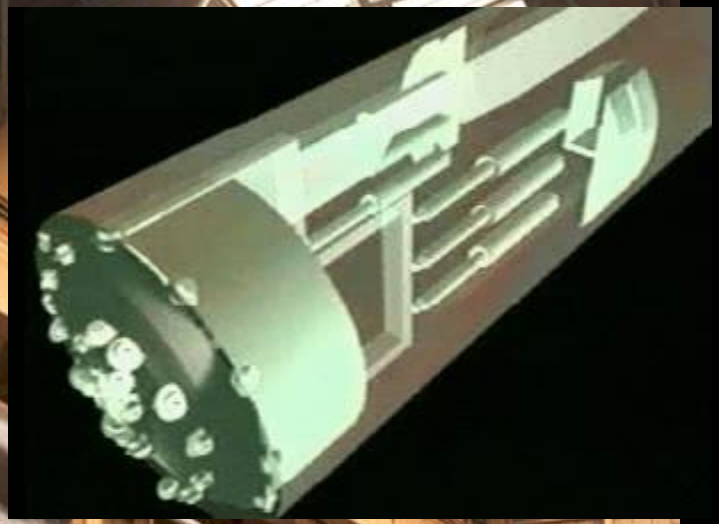



# Queens Tunnel Problems – A Case History

Robbins 235-282 HP TBM

# 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**



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

# Faults - Disturbed Ground Zone 59

Station 152+90

# Rainy Conditions

Station 140+60

# Unforseen Tunneling Problems

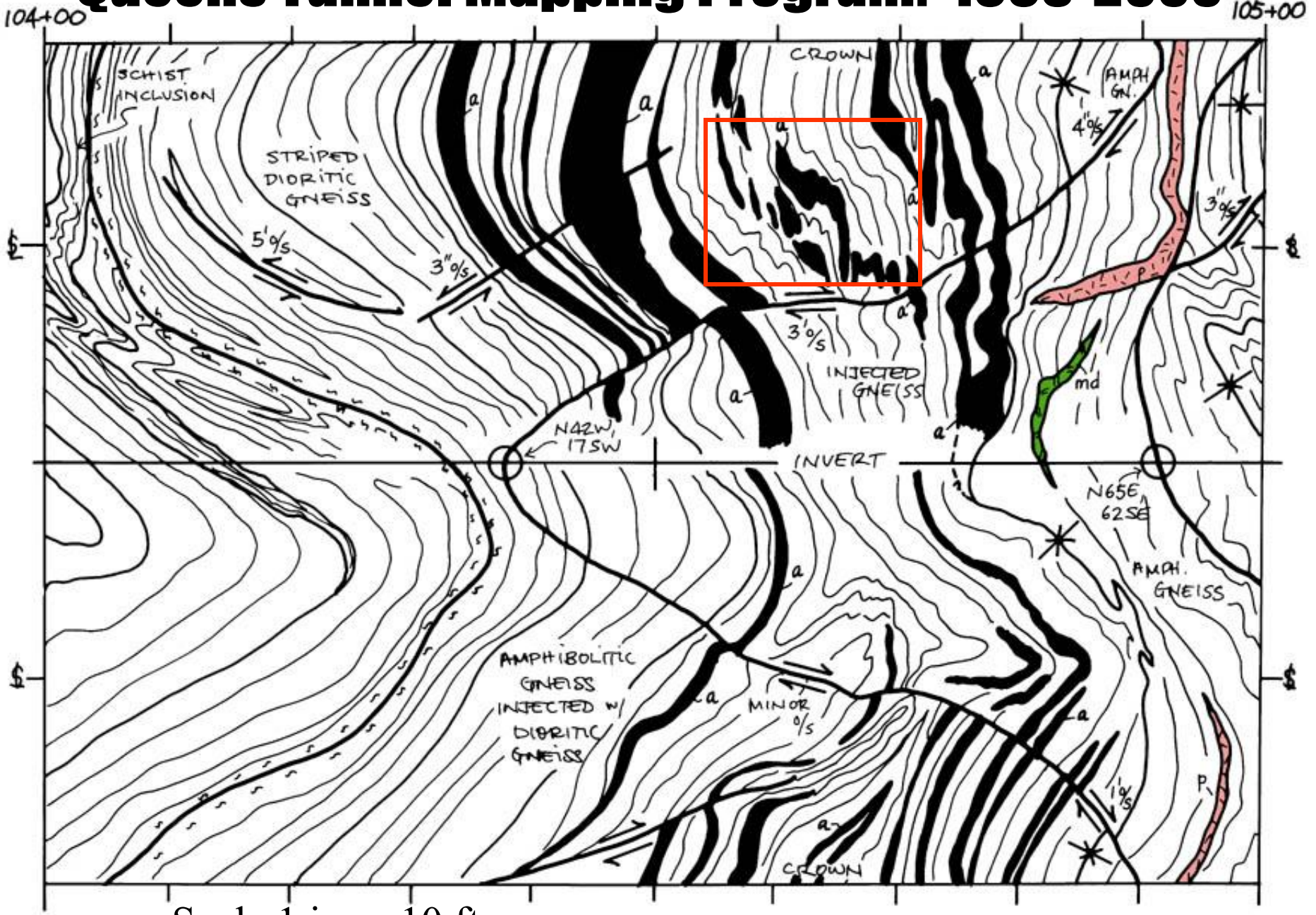
# Can Geologic Studies Help Predict TBM Penetration Destiny?

# 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

**Merguerian's Queens Tunnel Field Office**

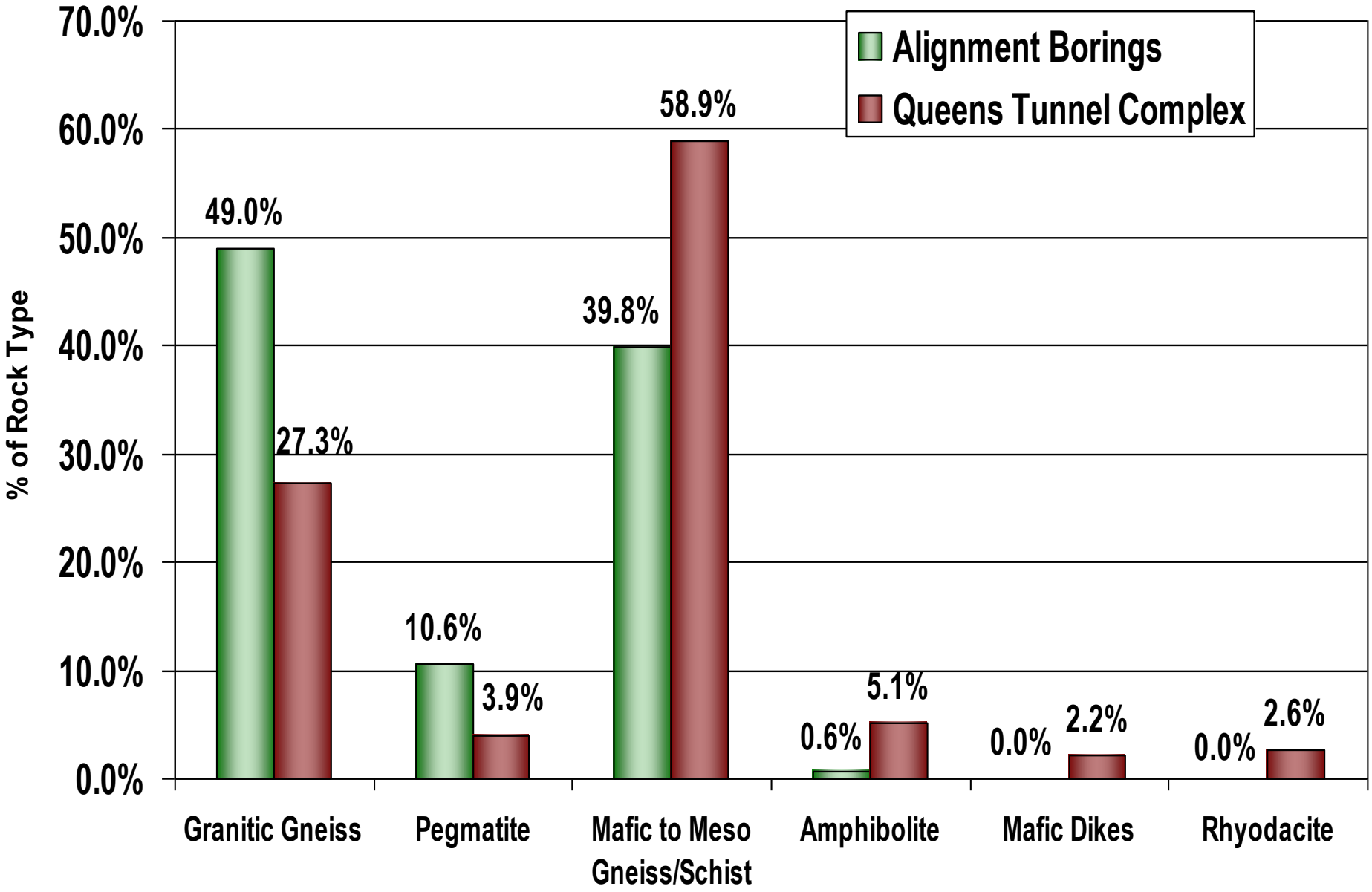
# Queens Tunnel Mapping Program: 1998-2000




- Scale 1 in. = 10 ft


104+55
104+60
104+65

# Comparative Lithologic Analysis



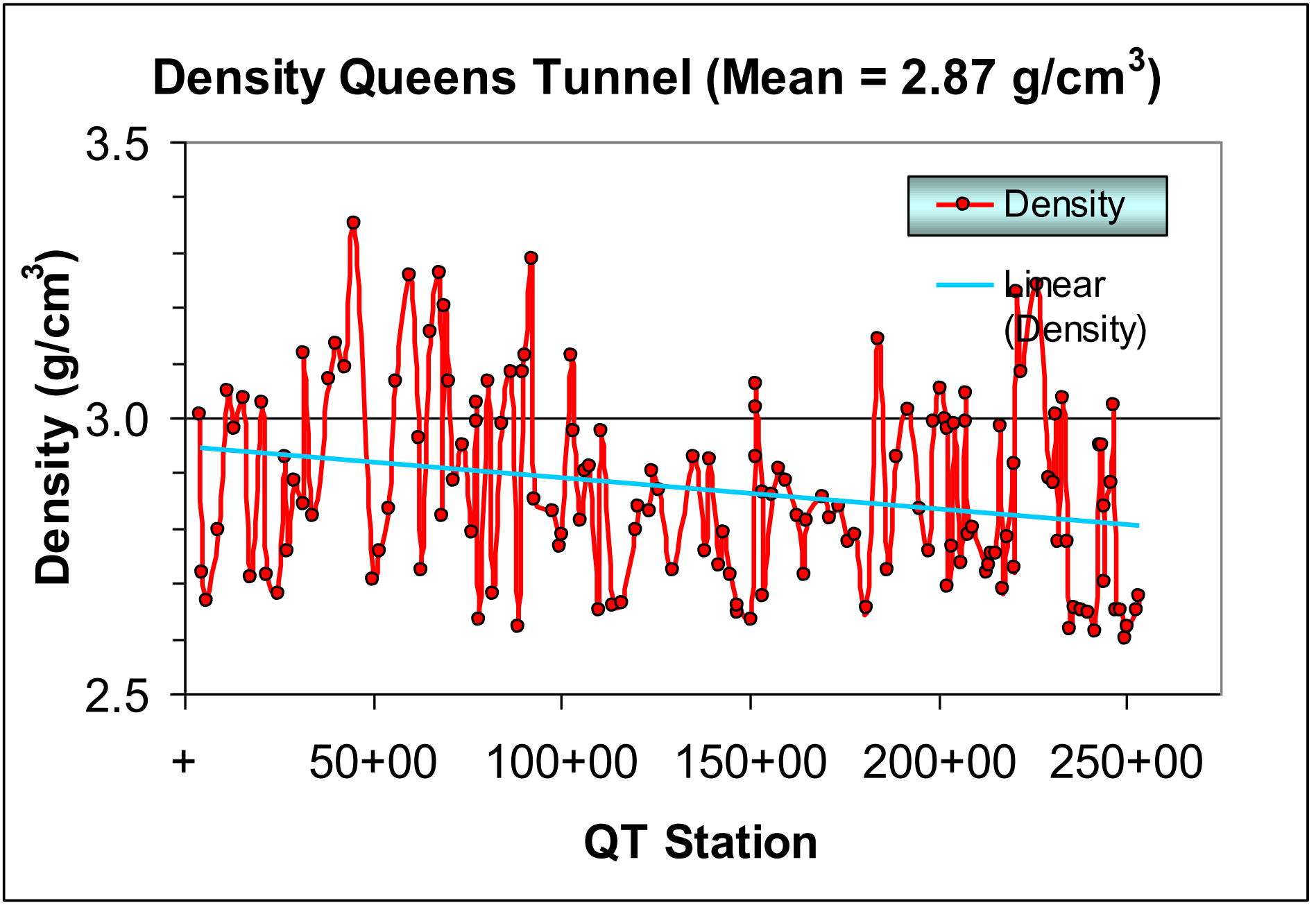
# The Queens Tunnel Complex

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

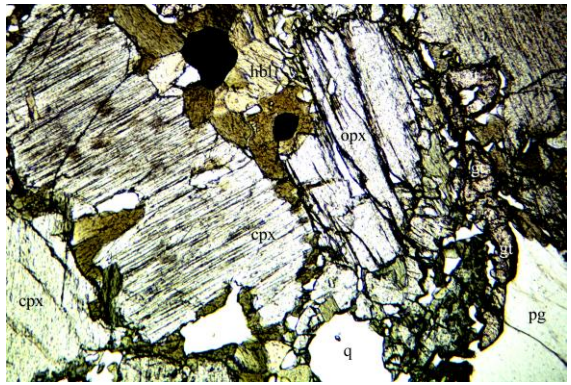
II. Leuco- to Mesocratic Gneiss

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

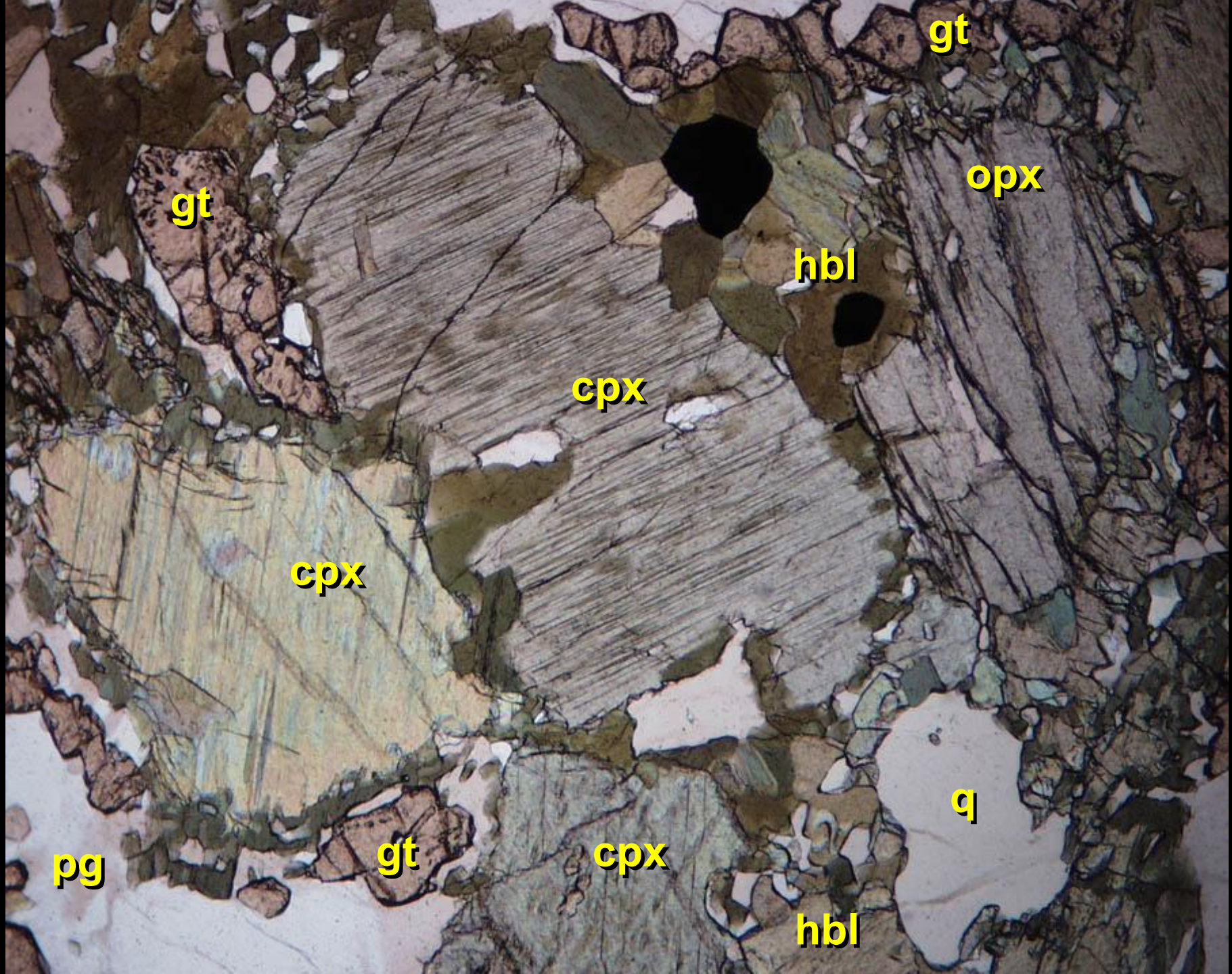
- **Petrographic Analysis (92 Samples)**
  - **Texture**
  - **Mineralogy**
  - **Internal Structure**
  - **Metamorphism**




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 | Mn some Ex | M Ex sol | 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 | tr ms |
| 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 | Rev Zoning | M | M **bugn** some | vermic wi Qtz | M fine sieve/verm | 10 c vermi |
| 068+10 | 068+10 | 5:50 | | M | | M | 55 | m | M | m gn | | *m vermic with pla* | ag |
| 070+60 | 070+60 | 45 | | M | | M | 45+ | ? | core? | m. Gn | m | M | m |
| Q141 | 071+80 | 30 | 2.9 | 5 | | M sieve | | M sieve | | tr gn | M okh | M sieve | 2 |

Petrographic Data Sheet


gt
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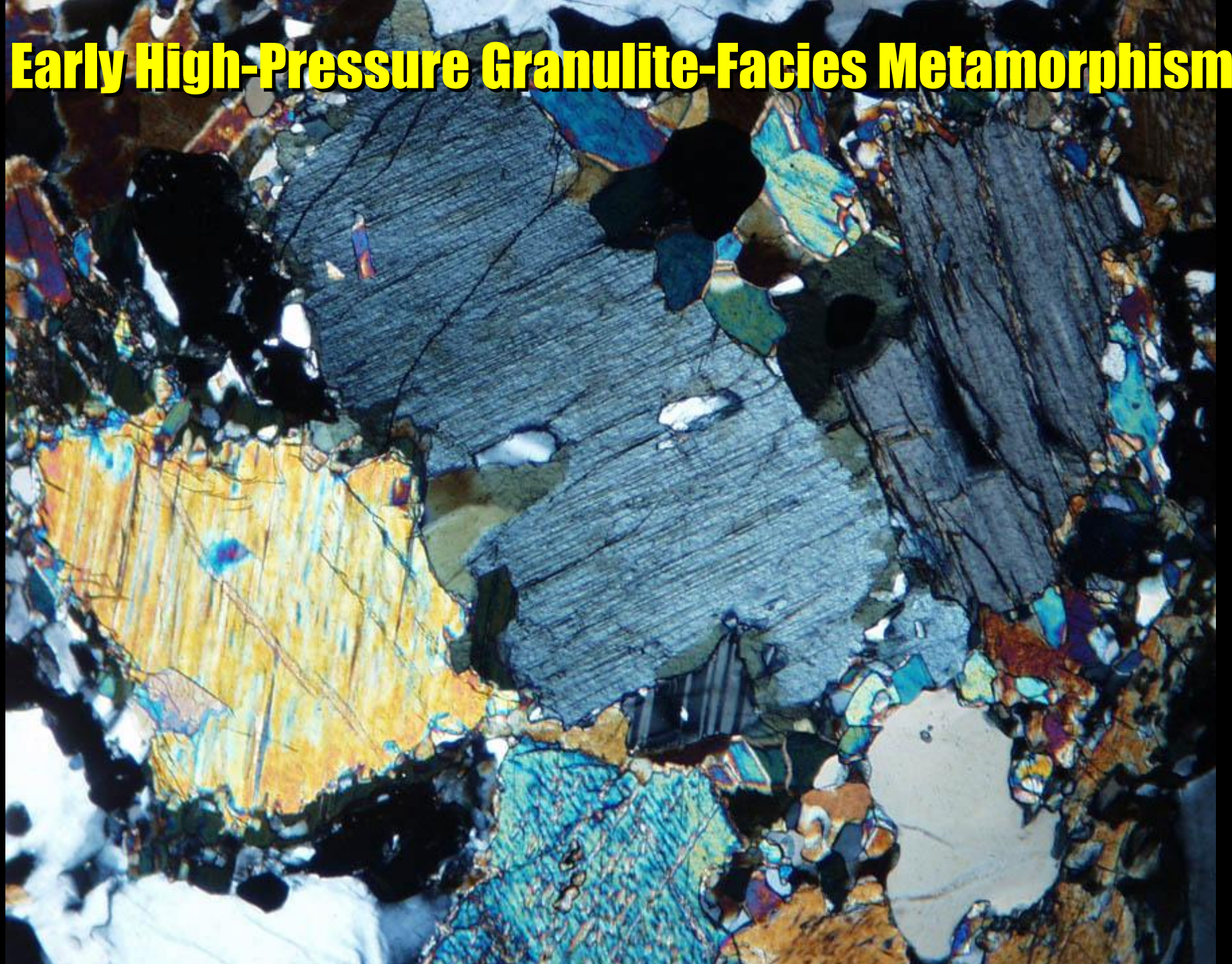
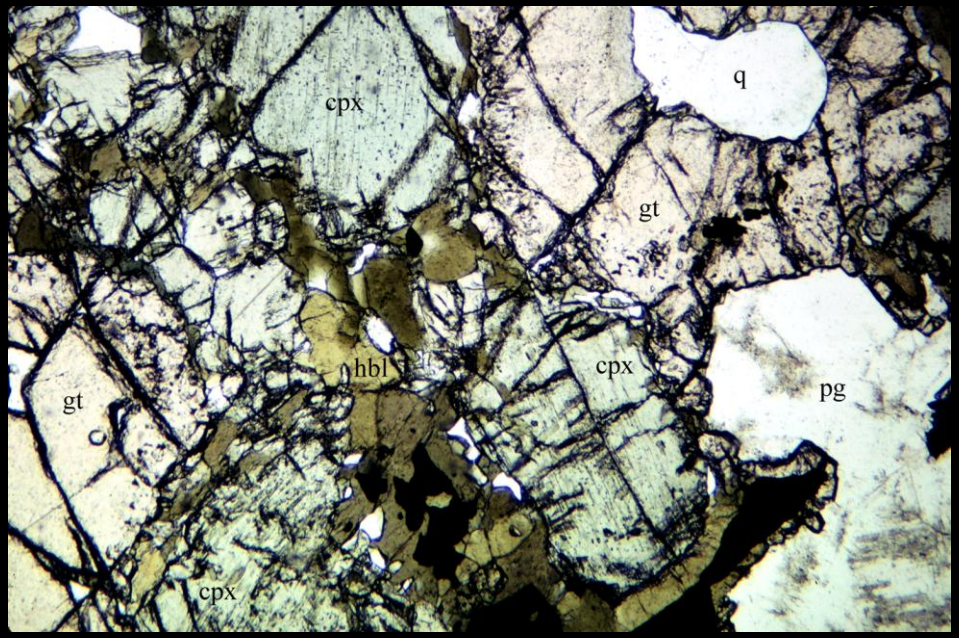
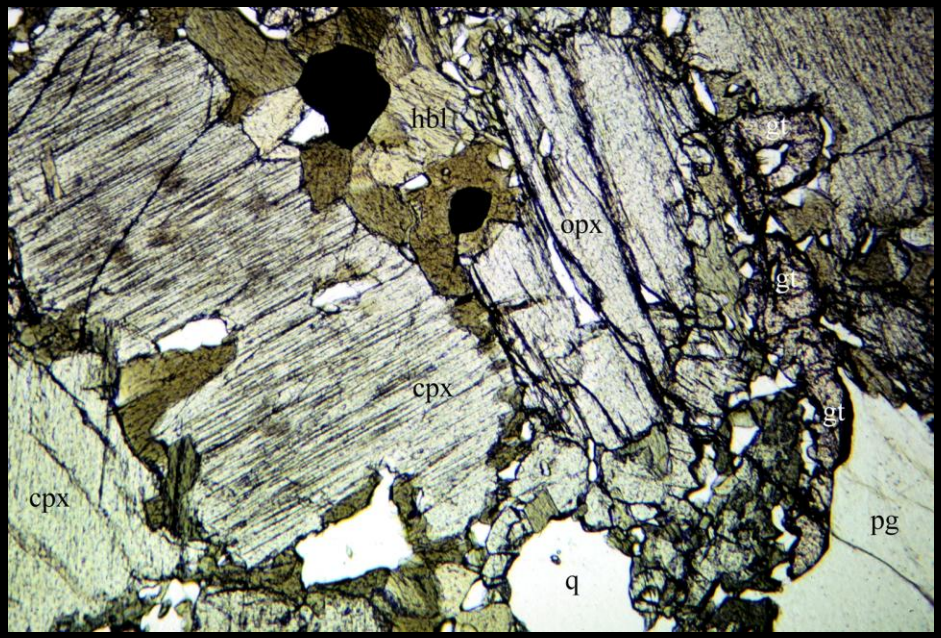
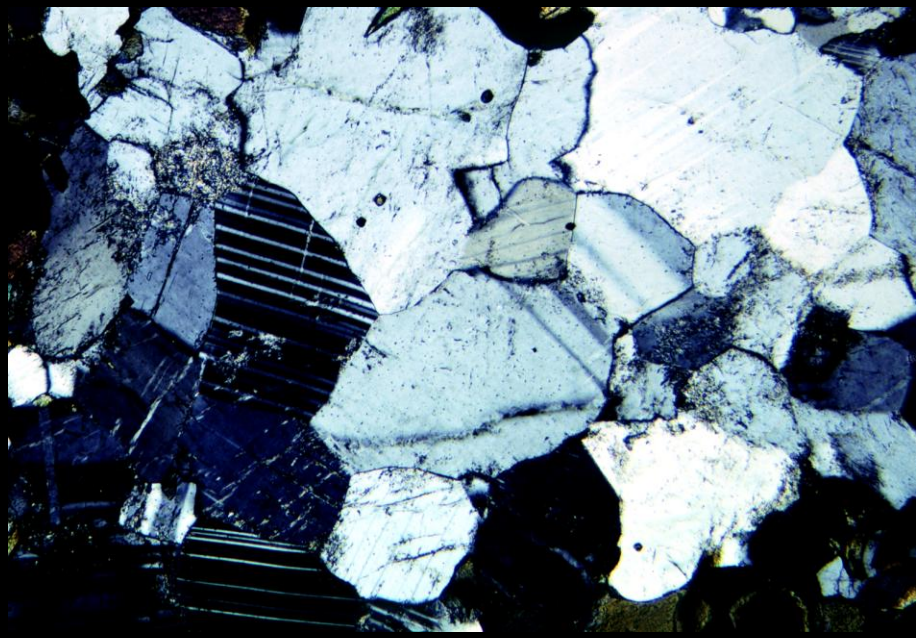
# Early High-Pressure Granulite-Facies Metamorphism



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



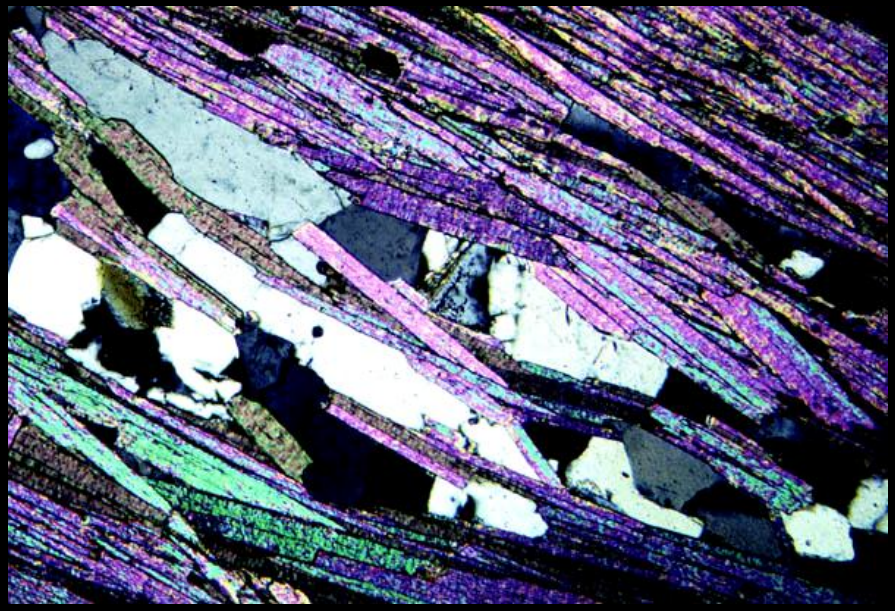



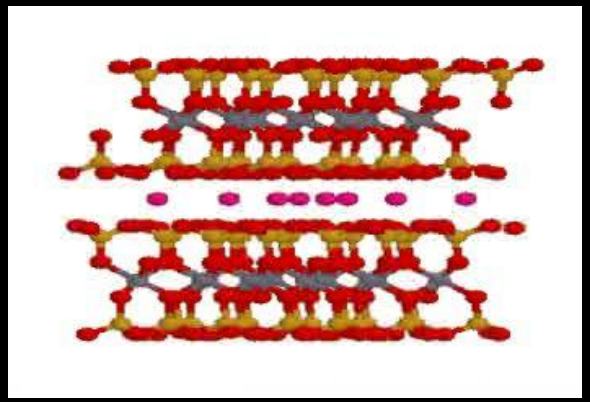
# Mica Content of Rock Fabric

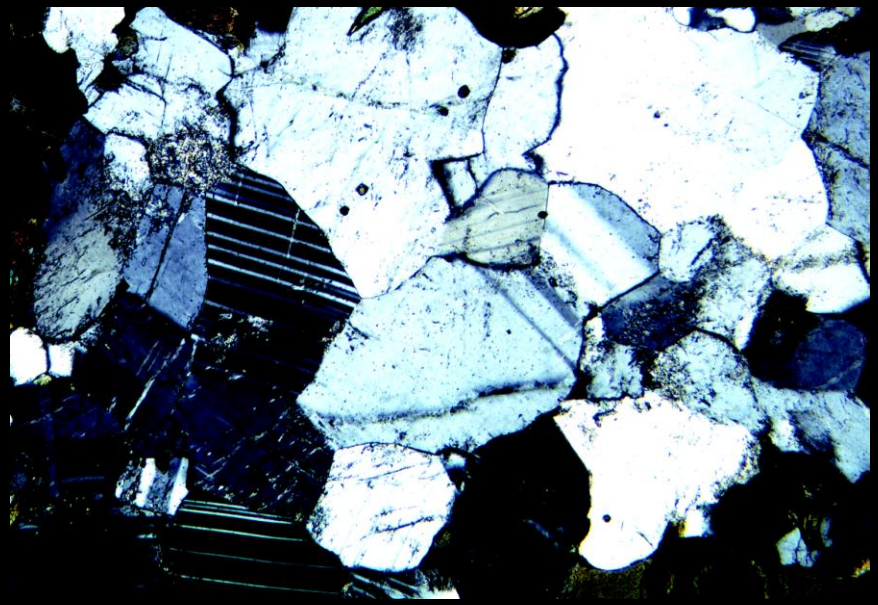
**Micaceous (+/- hornblende) penetrative foliation**

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

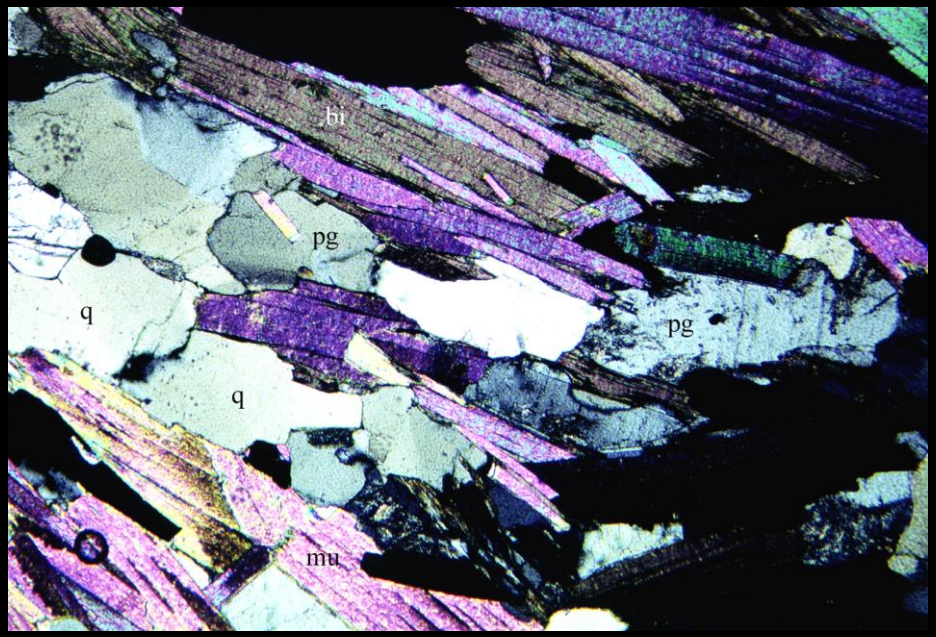


Foliated

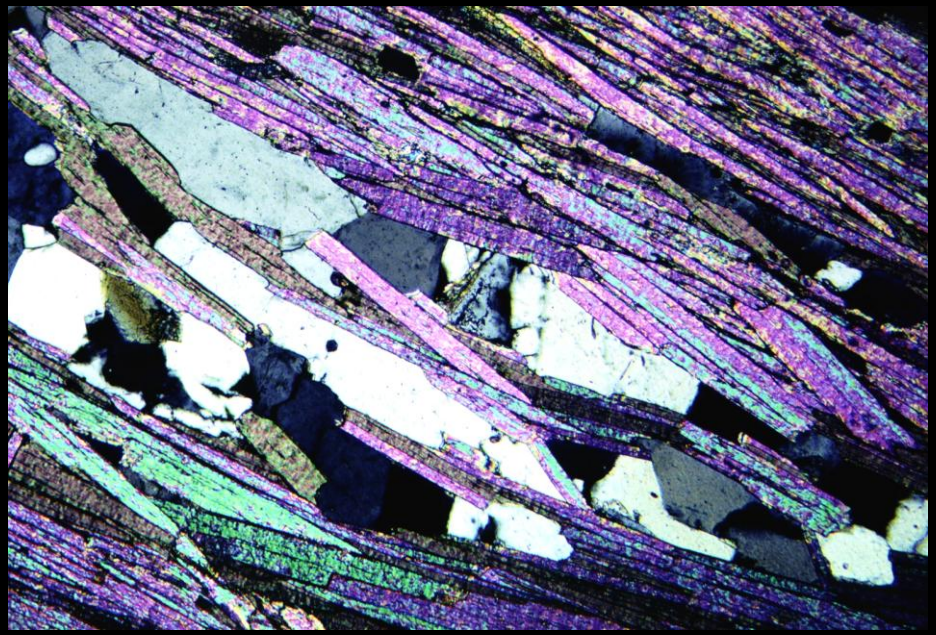




Non-Foliated



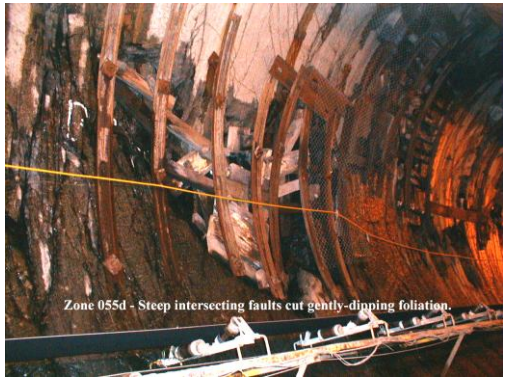

# In Western Manhattan:
# Amphibolite Facies Schists
# Well-layered Hartland Fm.
# Foliated Textures
# Great Rocks for Tunneling and Excavation!



# Orientation of Rock Layering

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

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

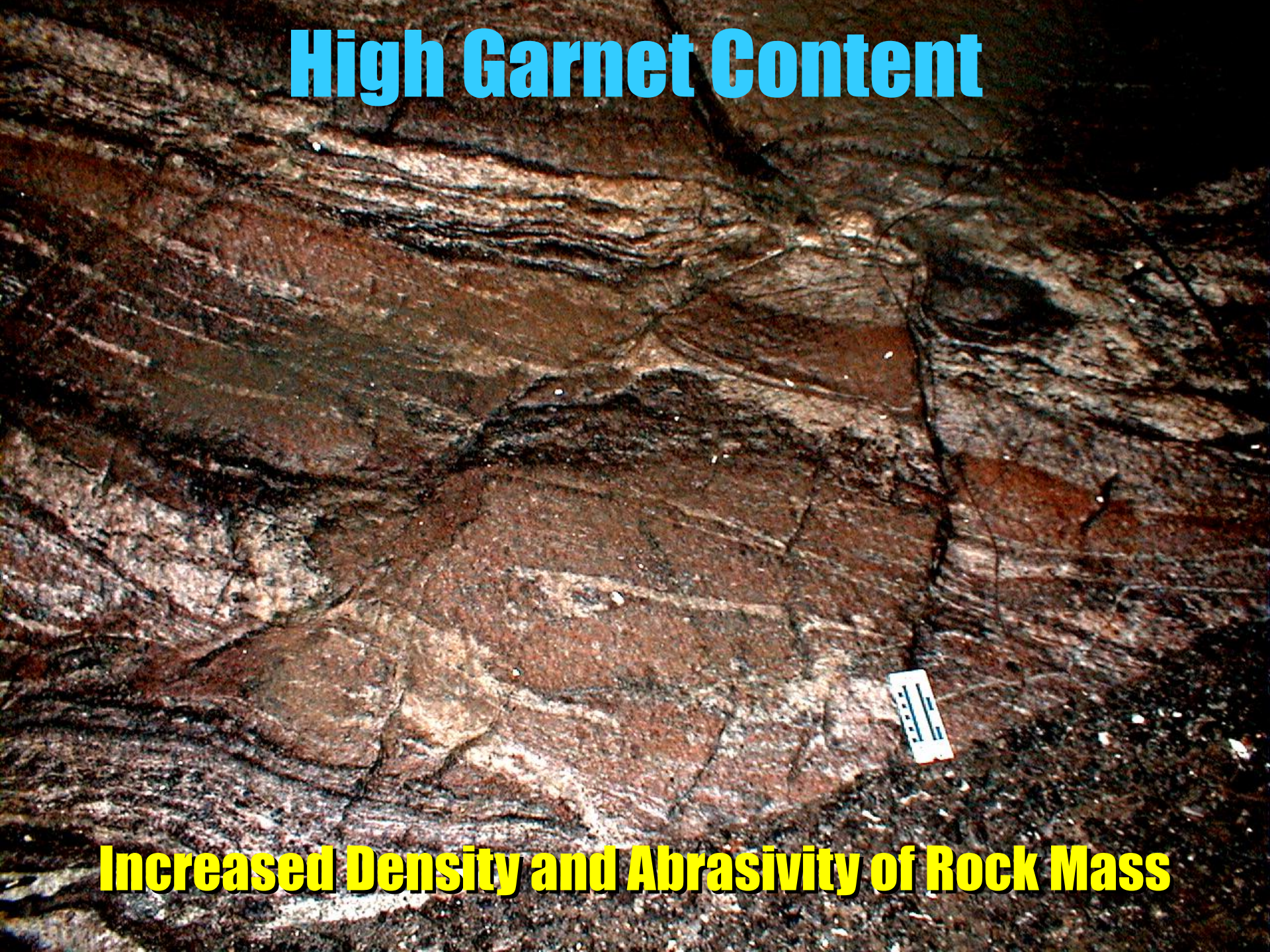



**Highly variable trends found**

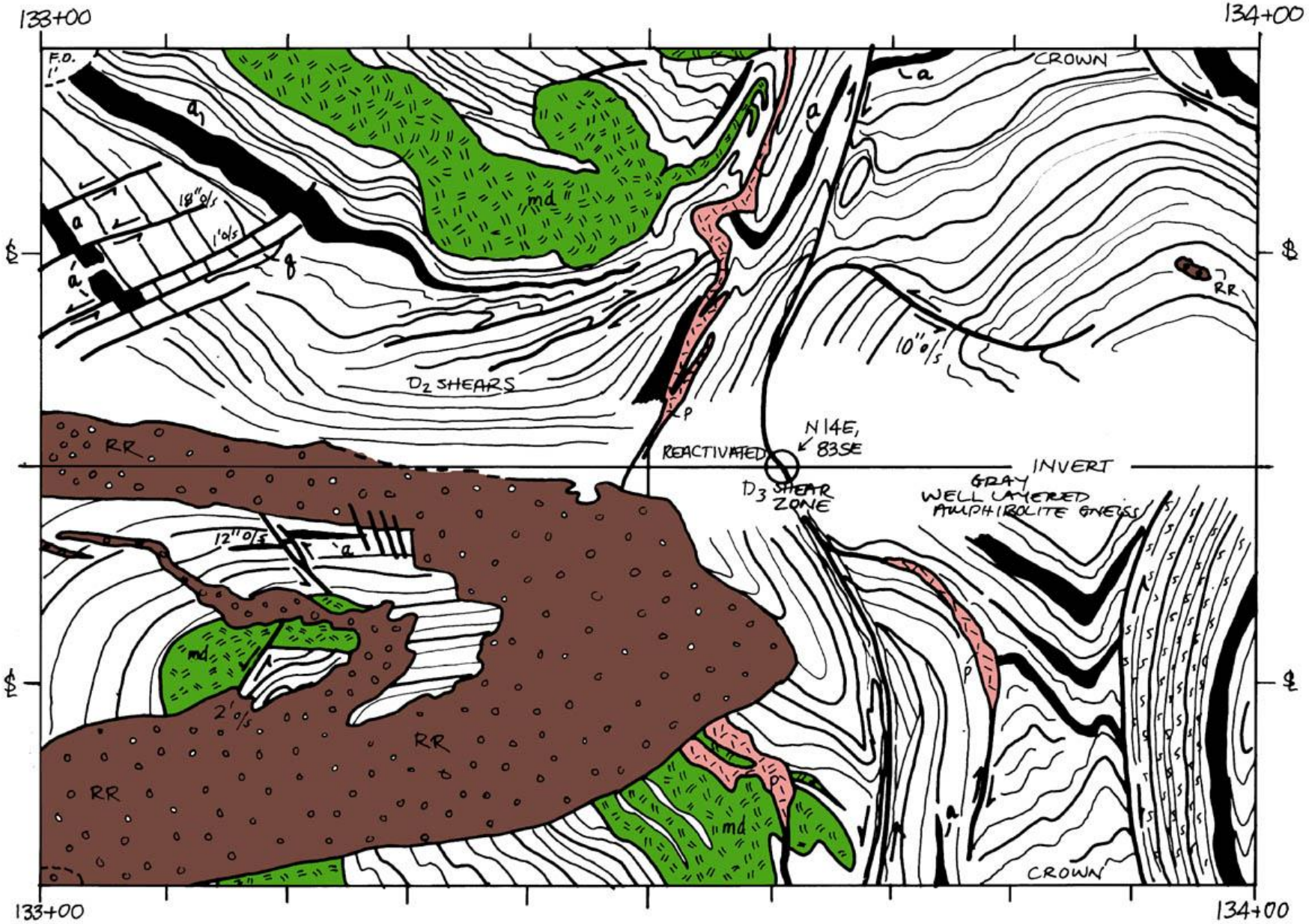
- **Extended reaches of tunnel exhibited gentle dips**

**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

# 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?

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