Suffolk Gem and Mineral Club Lecture

Megaconstruction Projects in New York City

Charles Merguerian

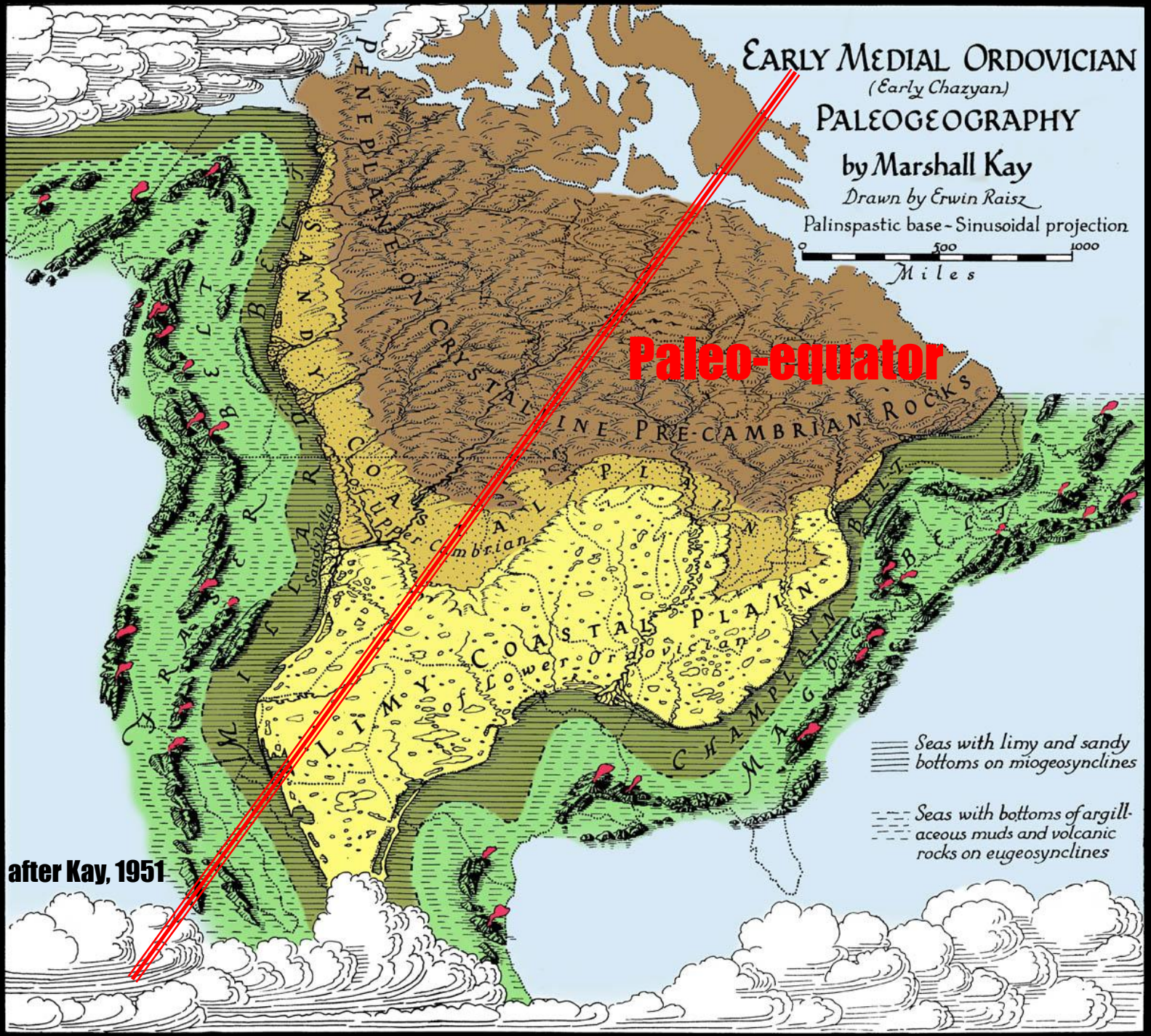
Hofstra Geology

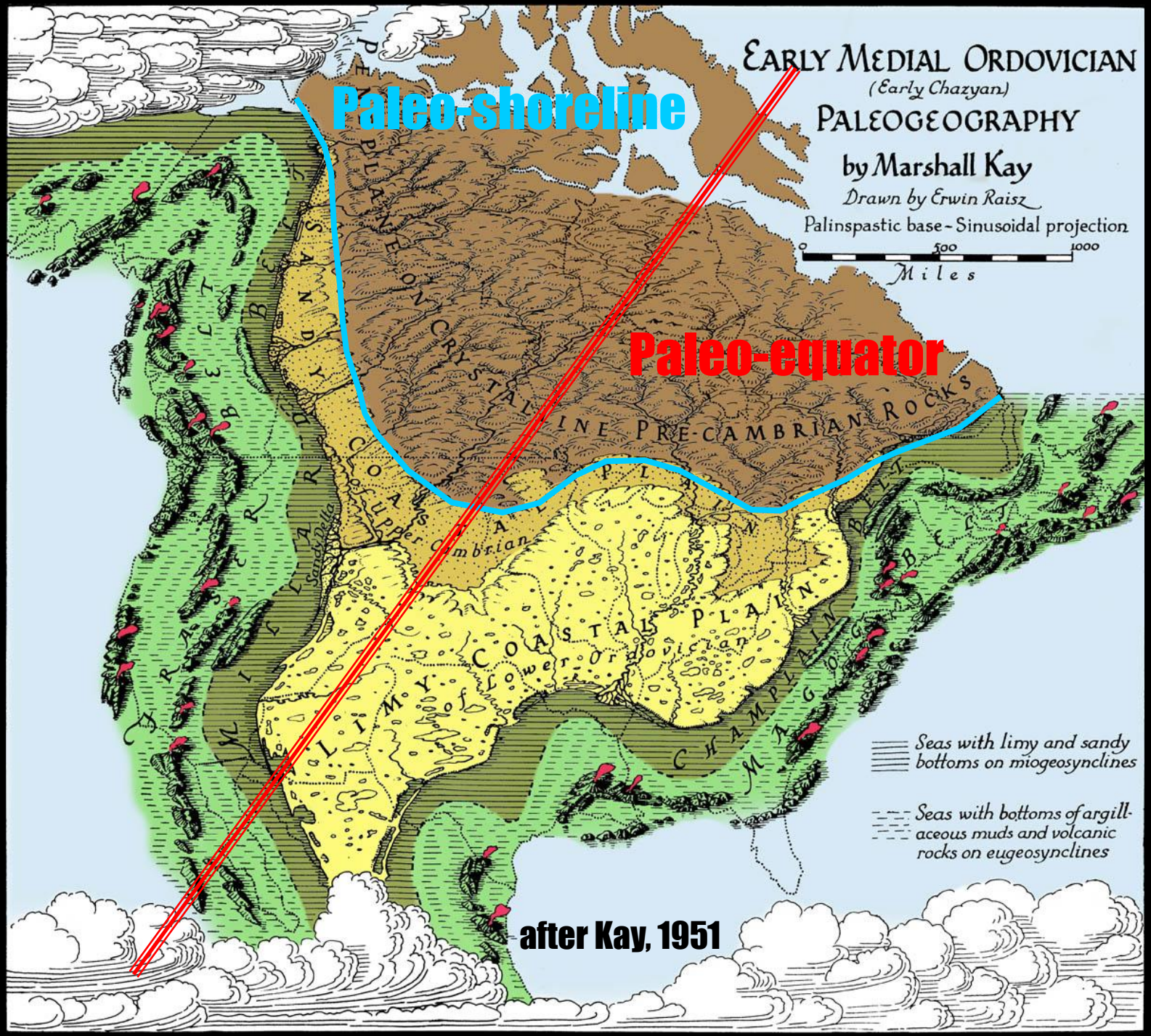
Merguerian's Early Field Work on Manhattan Island

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
EARLY MEDIAL ORDOVICIAN
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CHAMPLAIN MAGEOGEOSYNCLINE
ARAVAIPA BELT
APPALACHIAN BELT
Seas with limy and sandy bottoms on miogeosynclines
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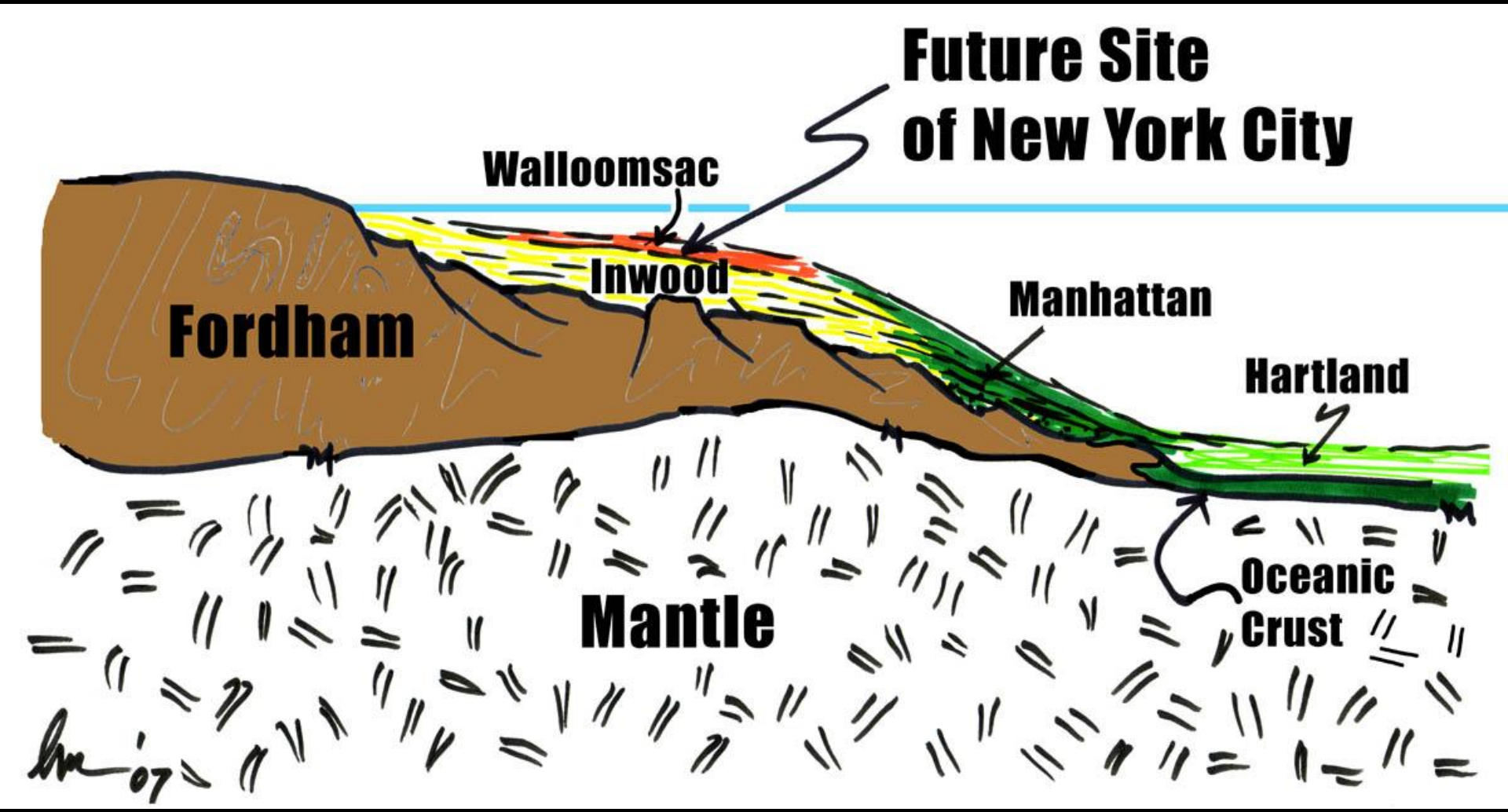
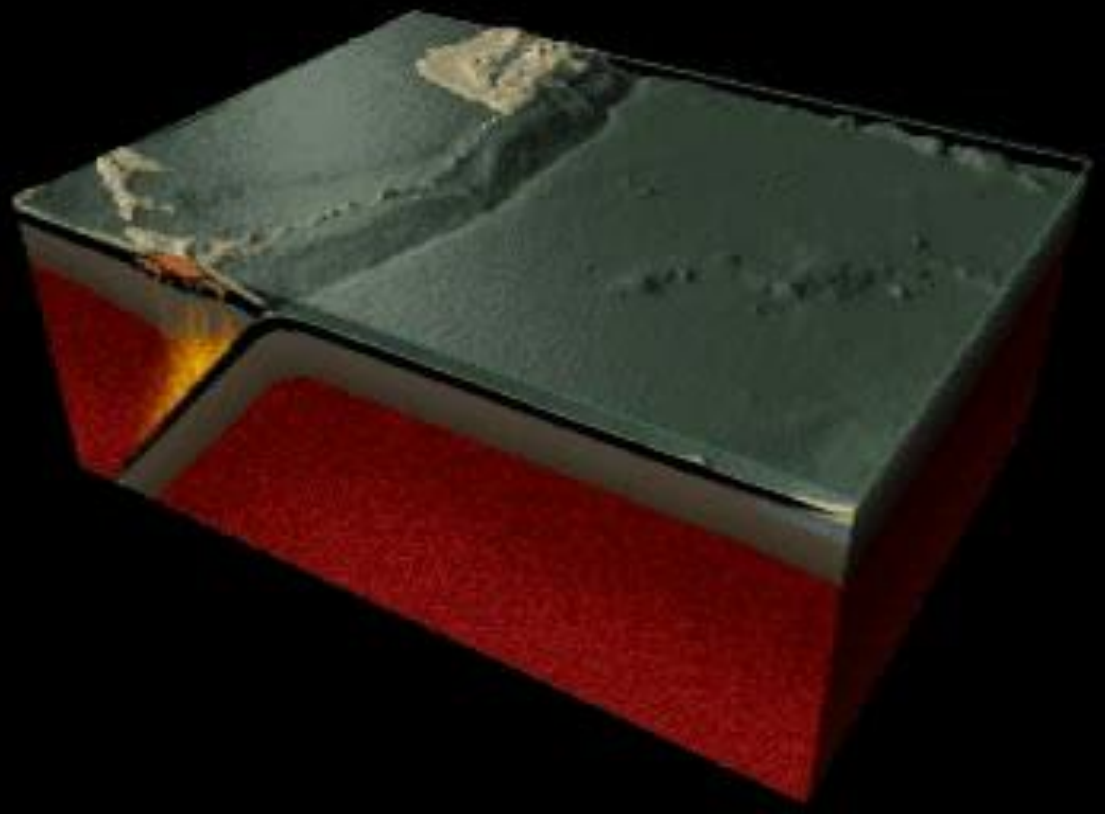
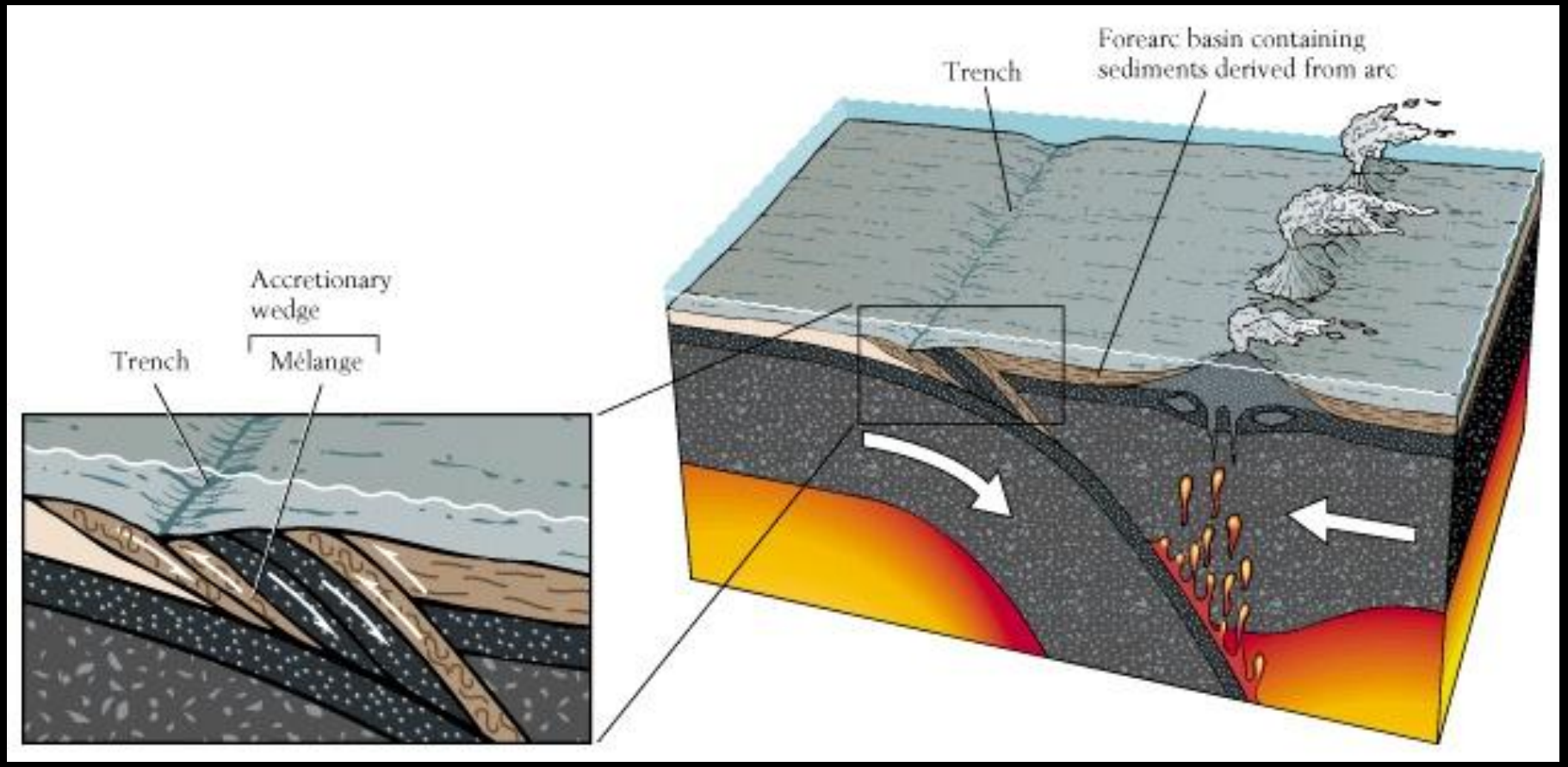
after Kay, 1951

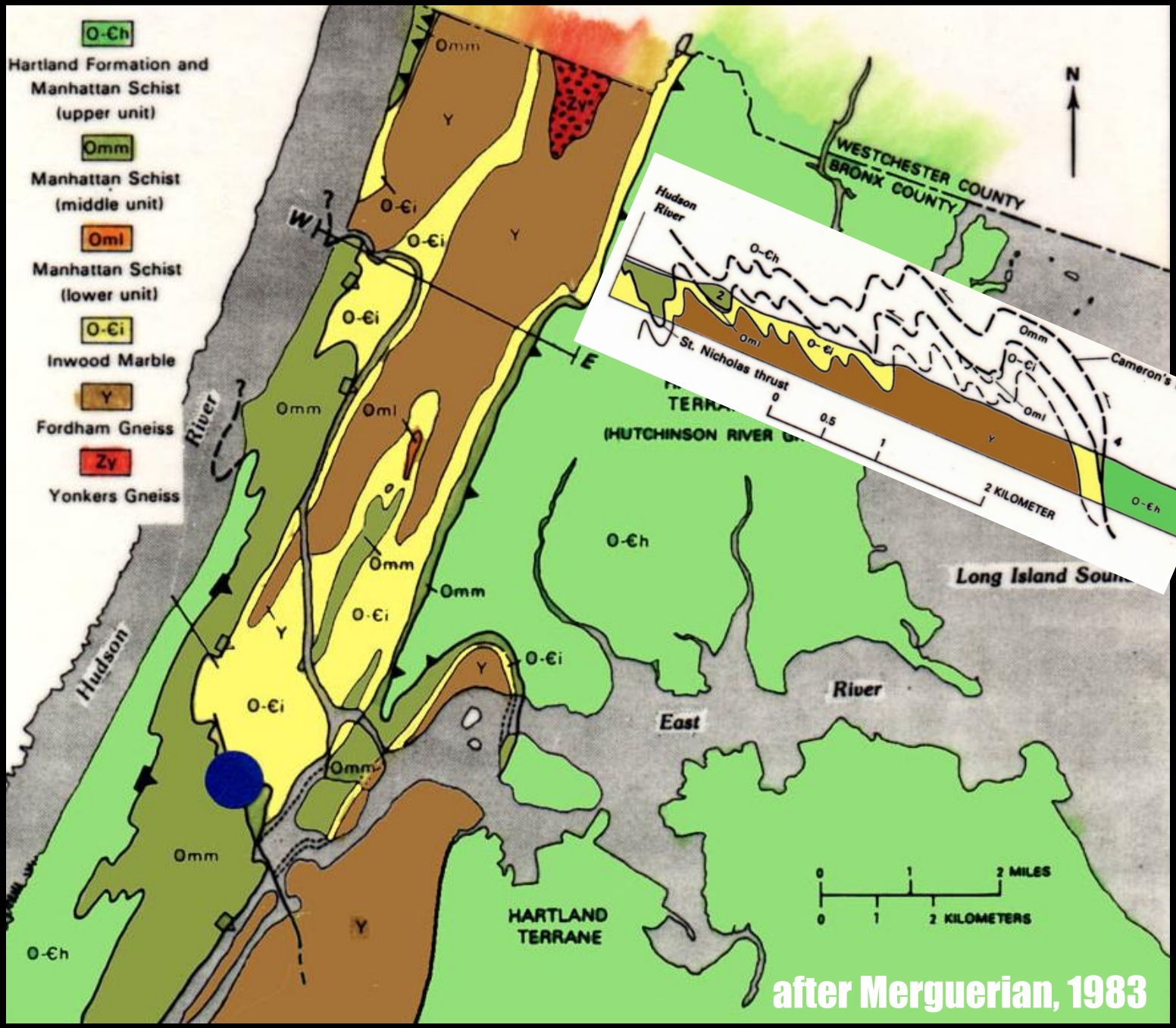

Future Site
of New York City
Walloomsac
Inwood
Fordham
Manhattan
Hartland
Oceanic
Crust
Mantle
'07

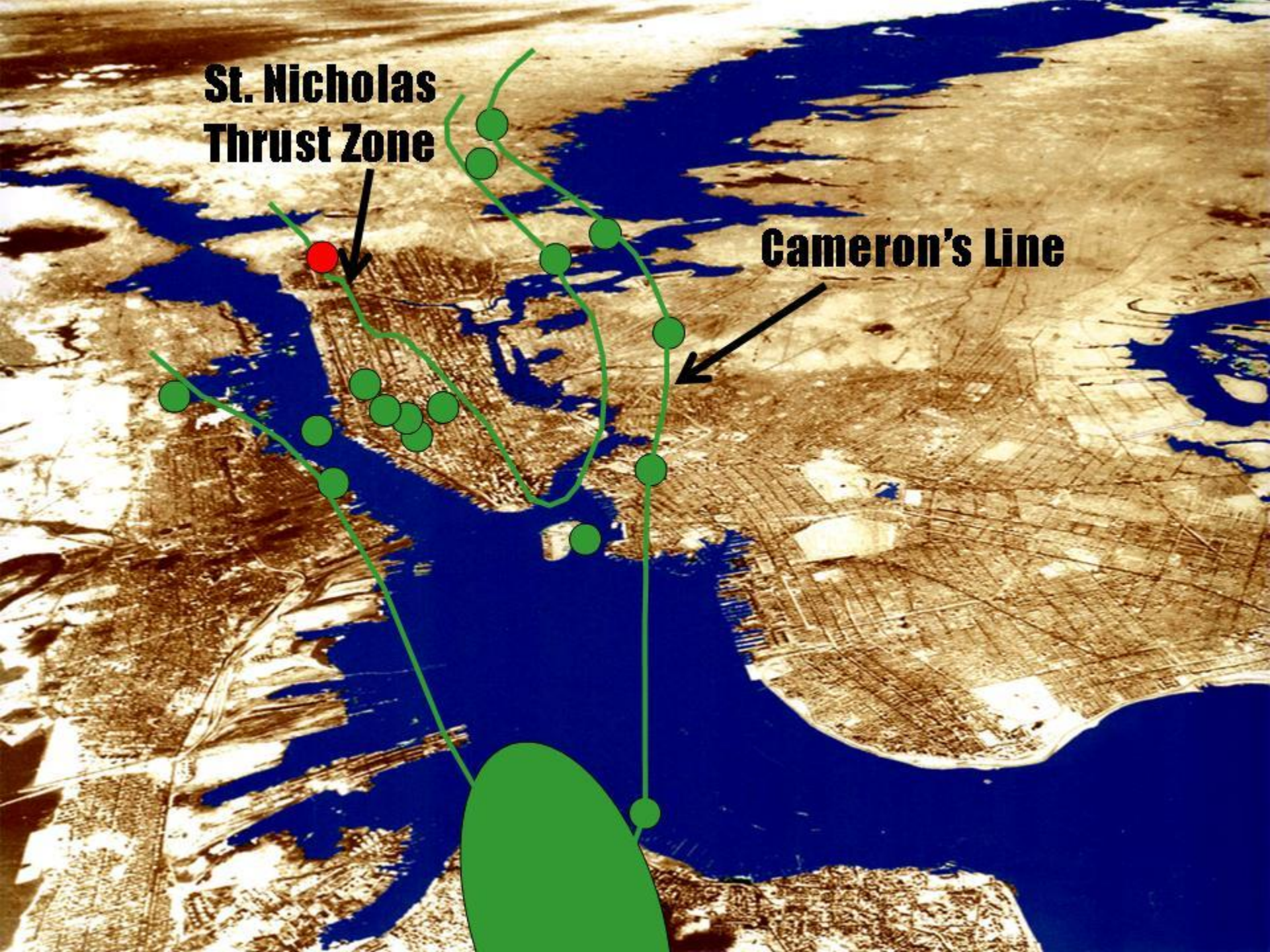
~ 450 Ma Taconic Arc – Passive Margin Collision

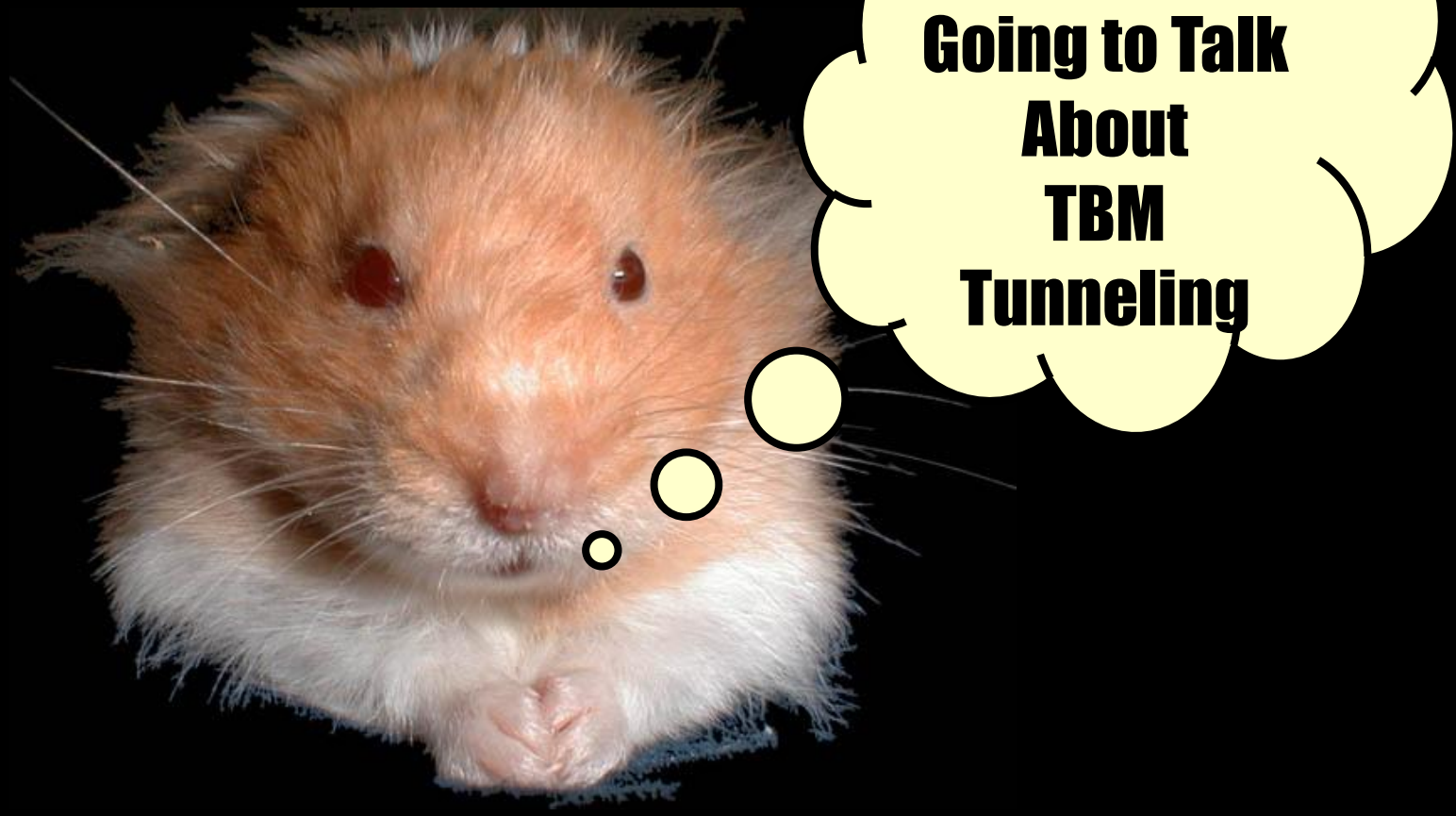


Taconian Accretionary Prism



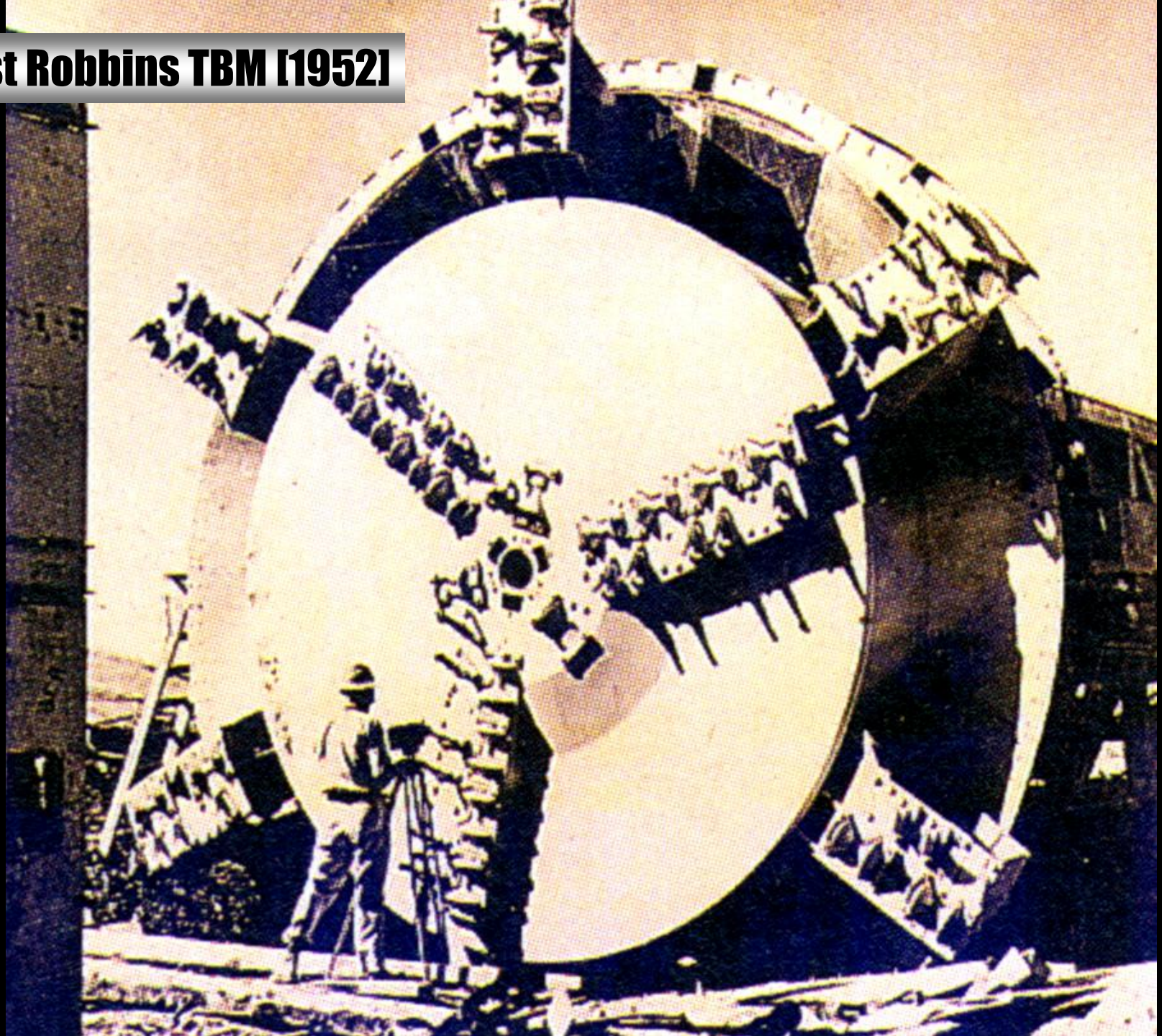

O-Ch
Hartland Formation and Manhattan Schist (upper unit)
Omm
Manhattan Schist (middle unit)
Oml
Manhattan Schist (lower unit)
O-Ci
Inwood Marble
Y
Fordham Gneiss
Zy
Yonkers Gneiss
N
WESTCHESTER COUNTY
BRONX COUNTY
Hudson River
O-Ch
Oml
O-Ci
Omm
Y
St. Nicholas thrust
Cameron's Line
0
0.5
1
2 KILOMETER
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]



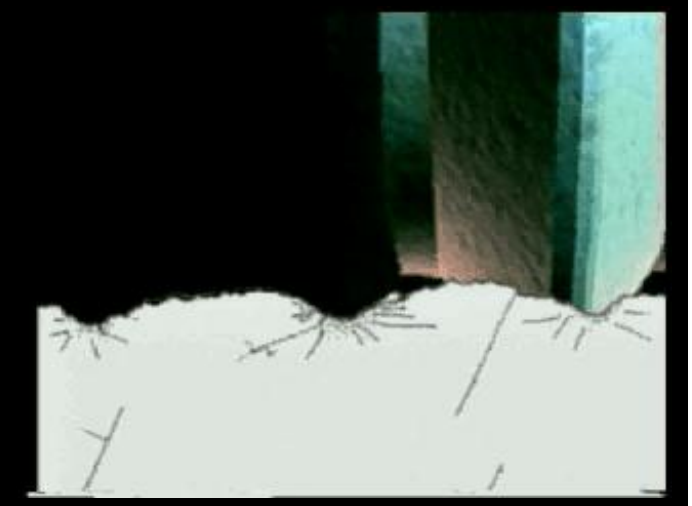
Holing Through North Tunnel, Hudson Tubes, French Line Dock (1904)

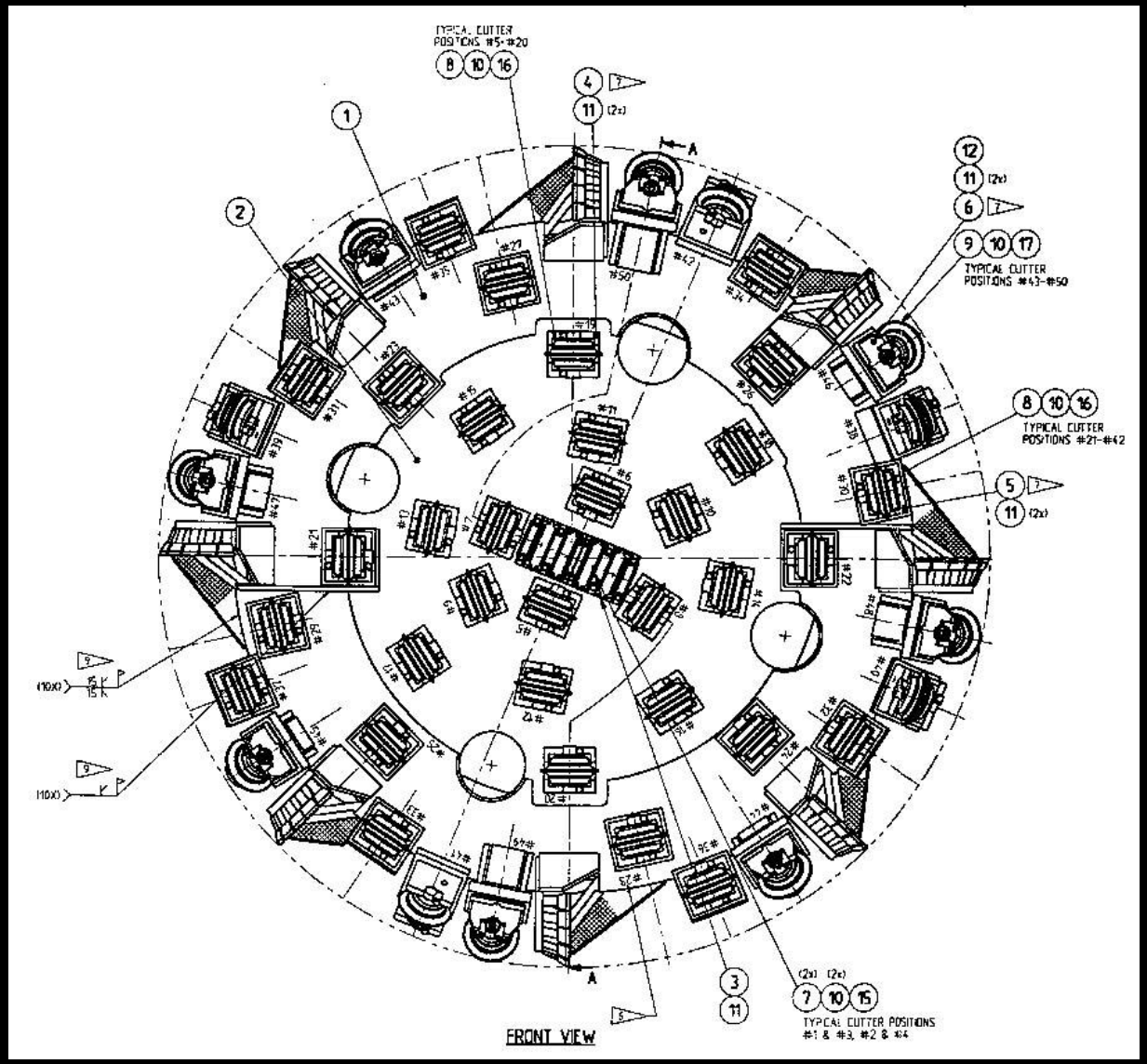
Sorenberg, Switzerland - Herrenknecht TBM

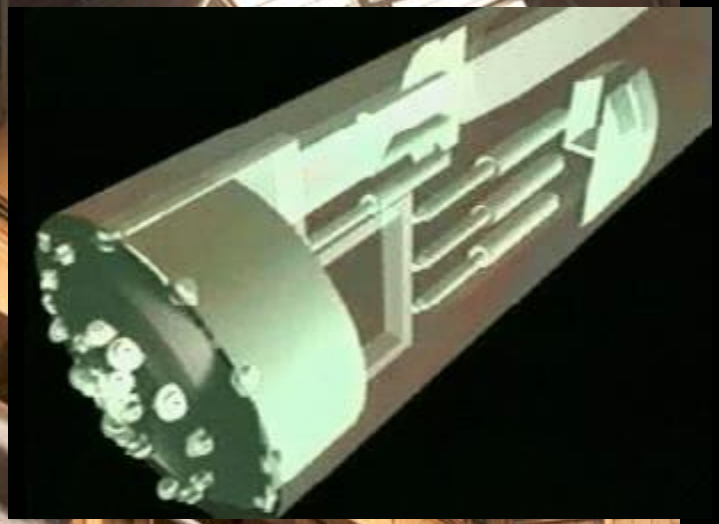
Robbins 235-282 HP Hard Rock Main Beam TBM

Chesterfield, England - 1996

TBM Chip Production







Atlas Copco

Robbins TBM 160-284

MetroWest


Normal TBM Chips

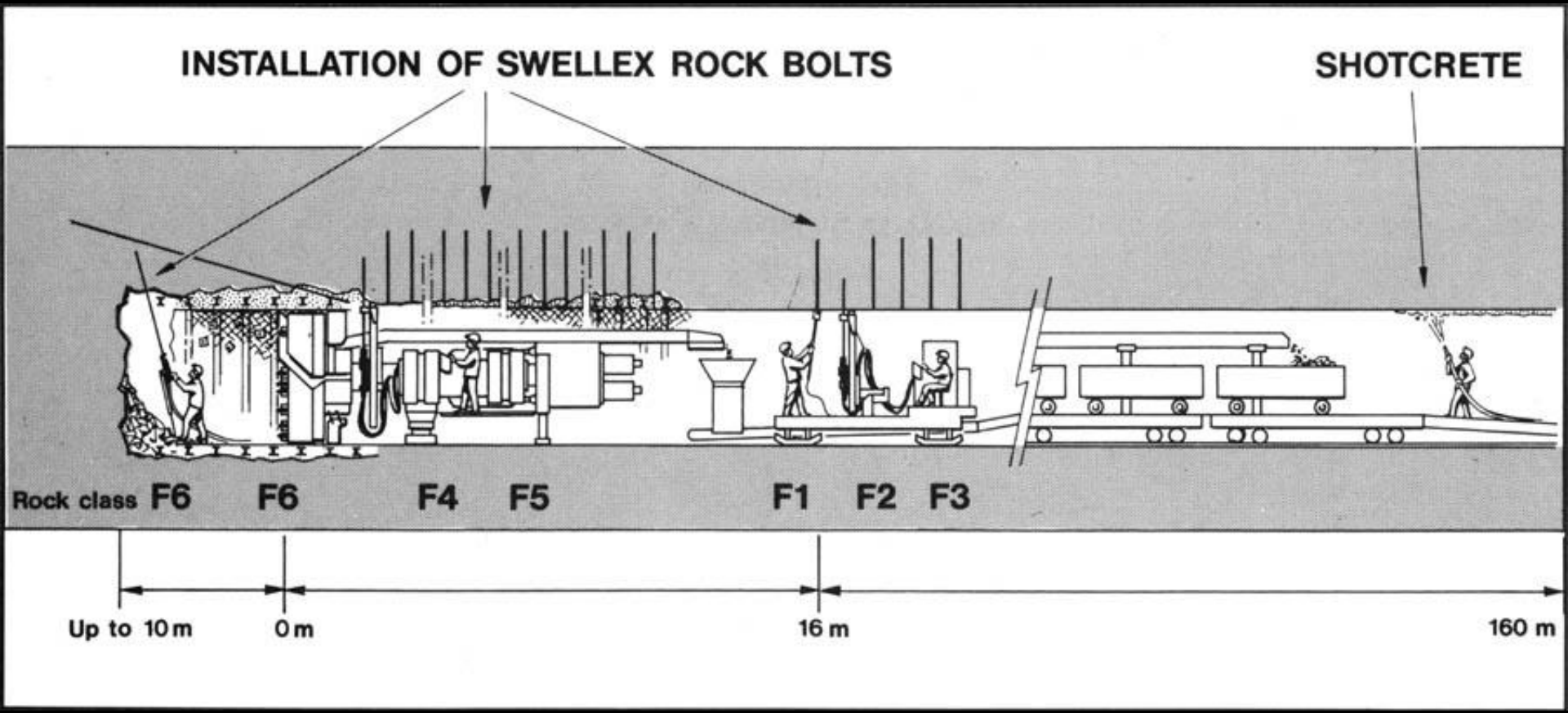
In the Belly of the Beast

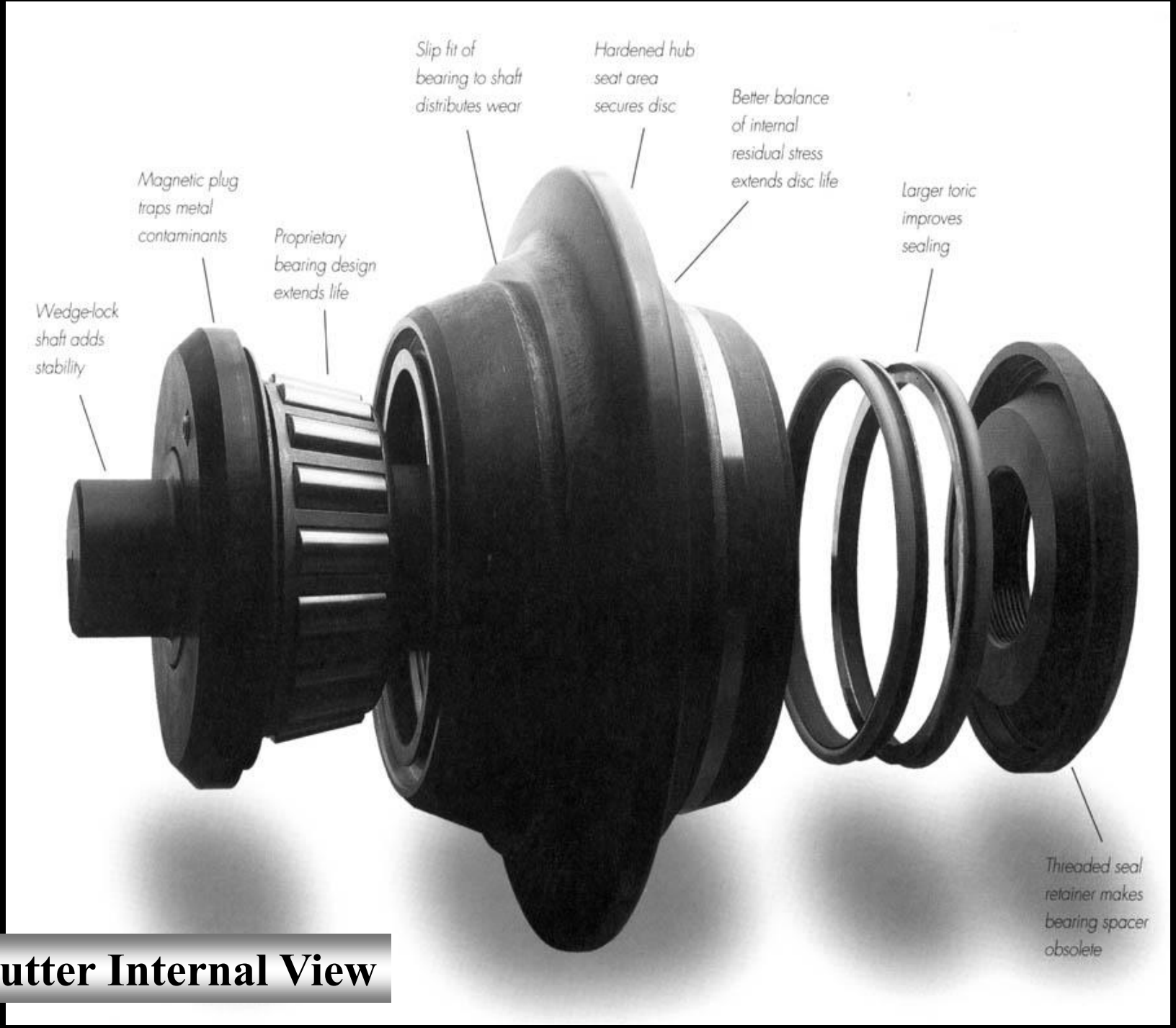
Kerf Pattern in Hard Rock


TBM-Bored Tunnel


Swellex Bolts

Swellex Rock Bolts

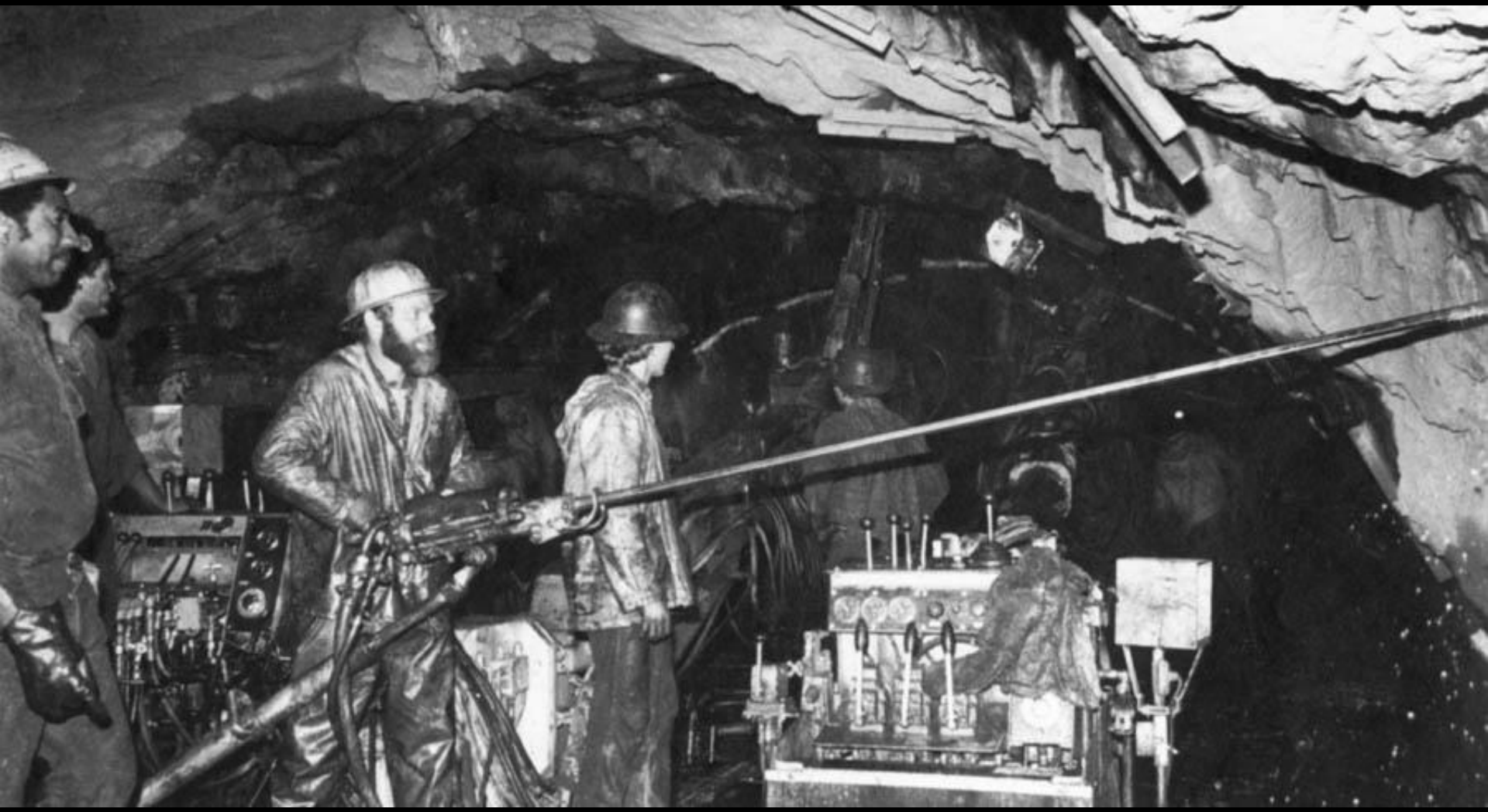




Cutter Internal View

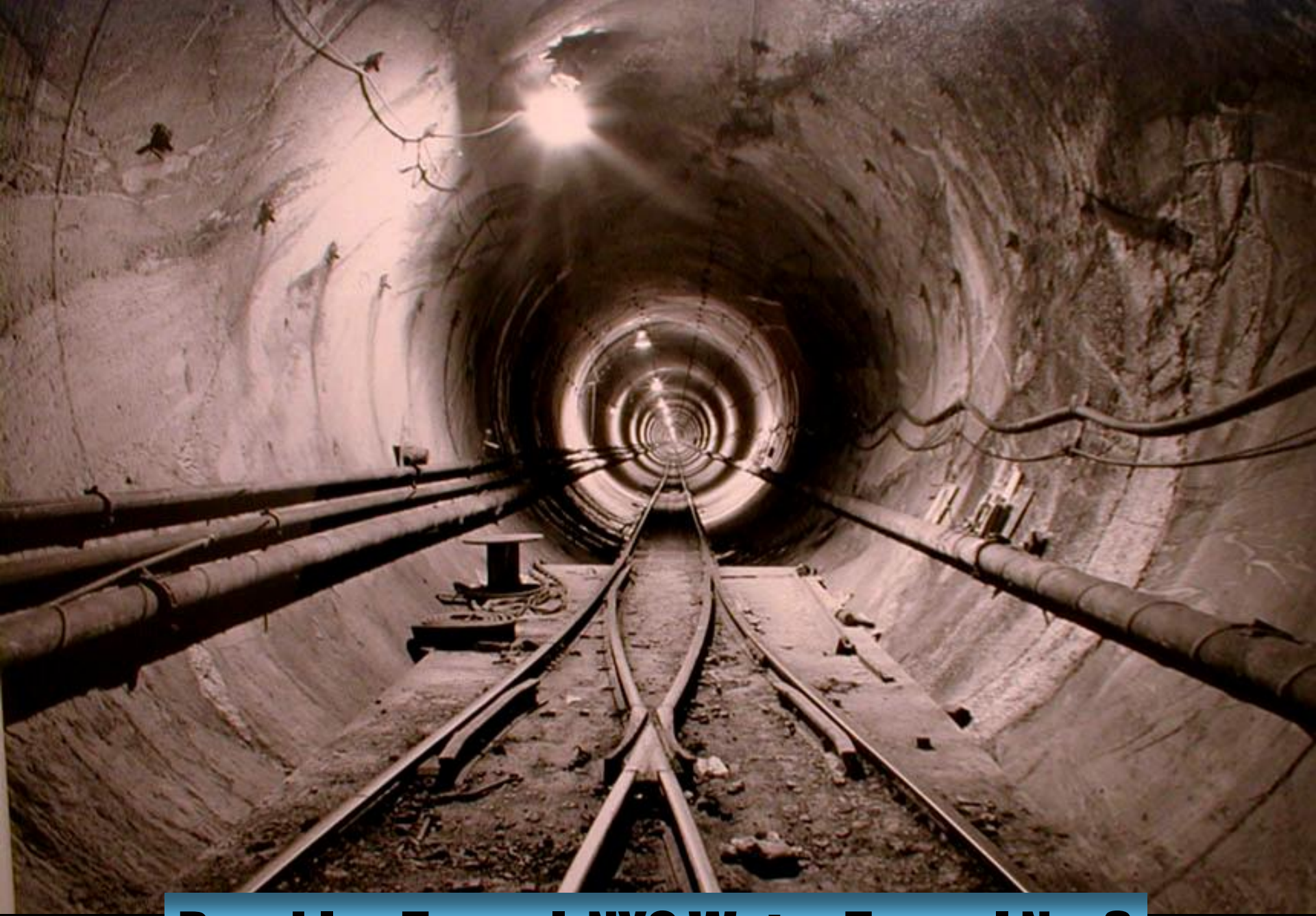
Before

After



CT3, Drill and Shoot Tunnel

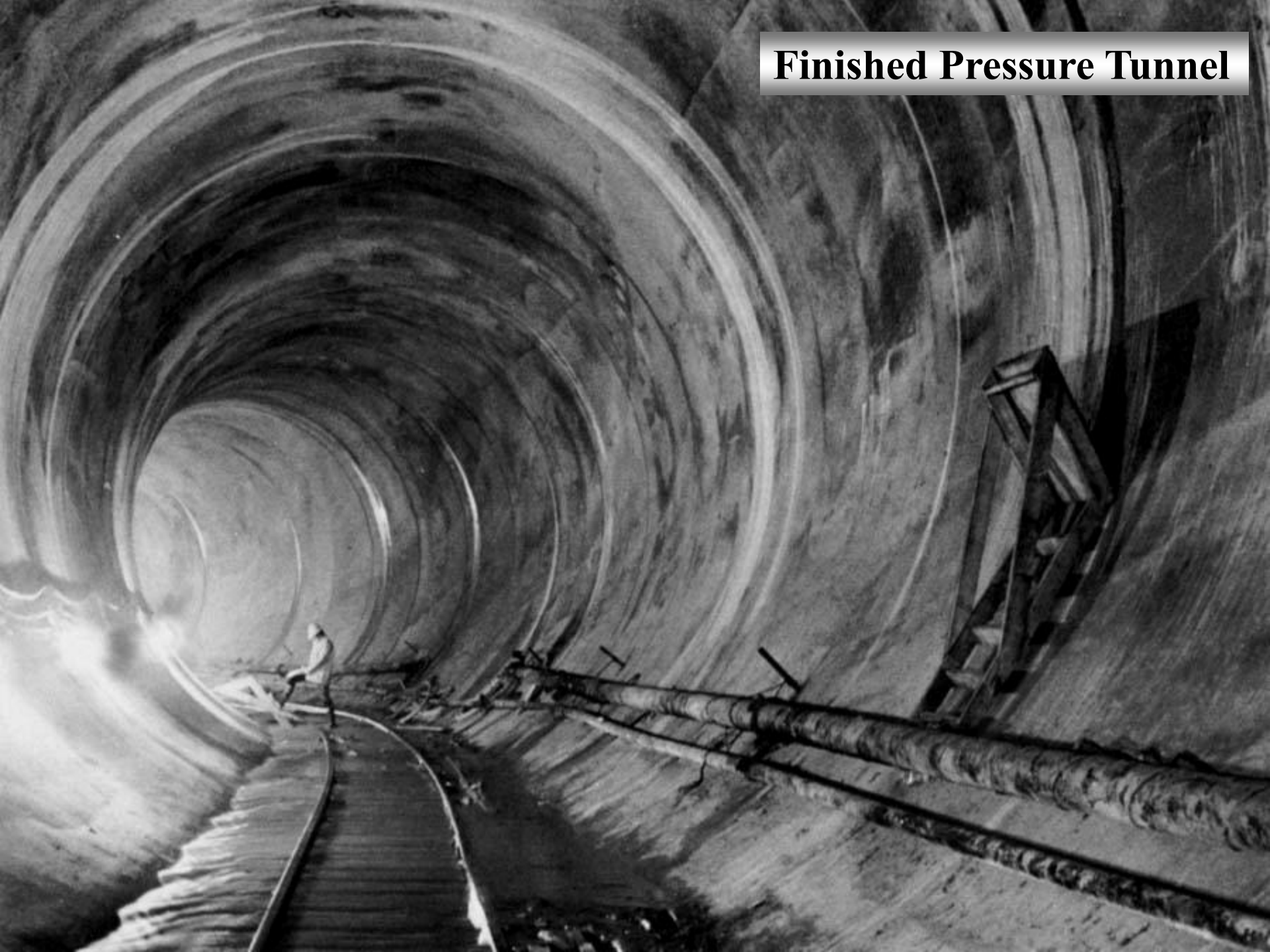
CT3, Scaling Drill and Shoot Tunnel



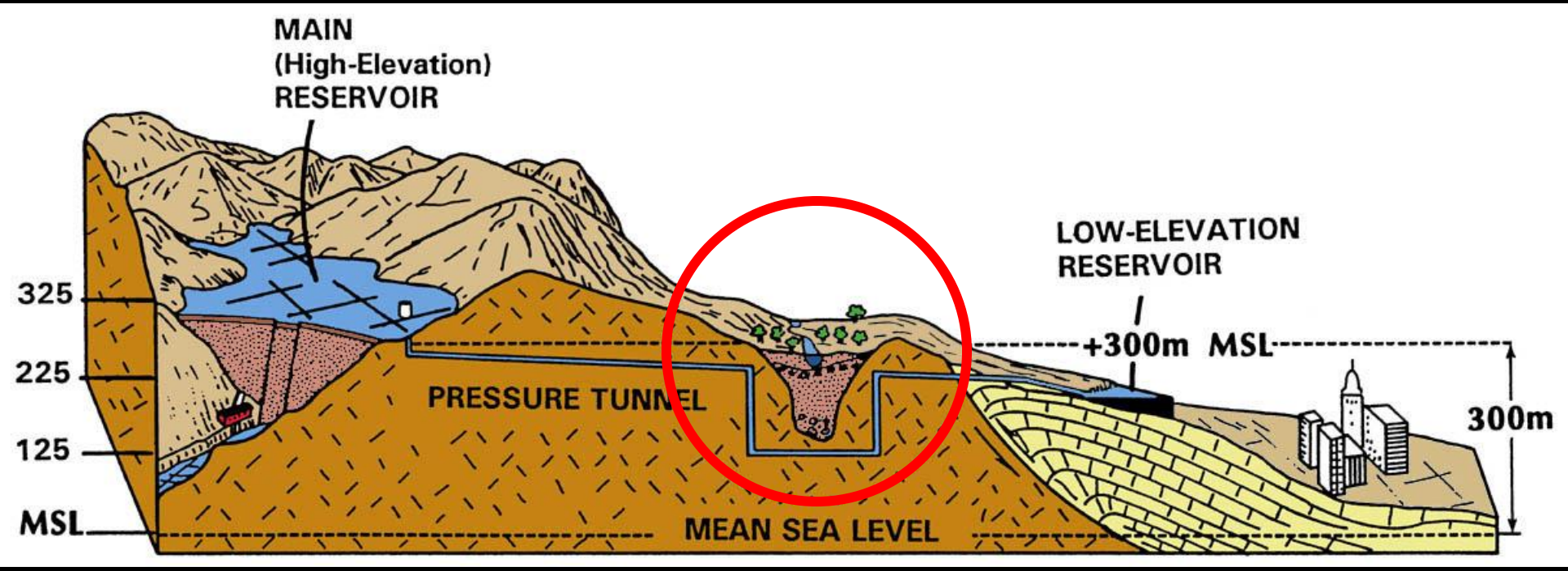
Brooklyn Tunnel, NYC Water Tunnel No. 3

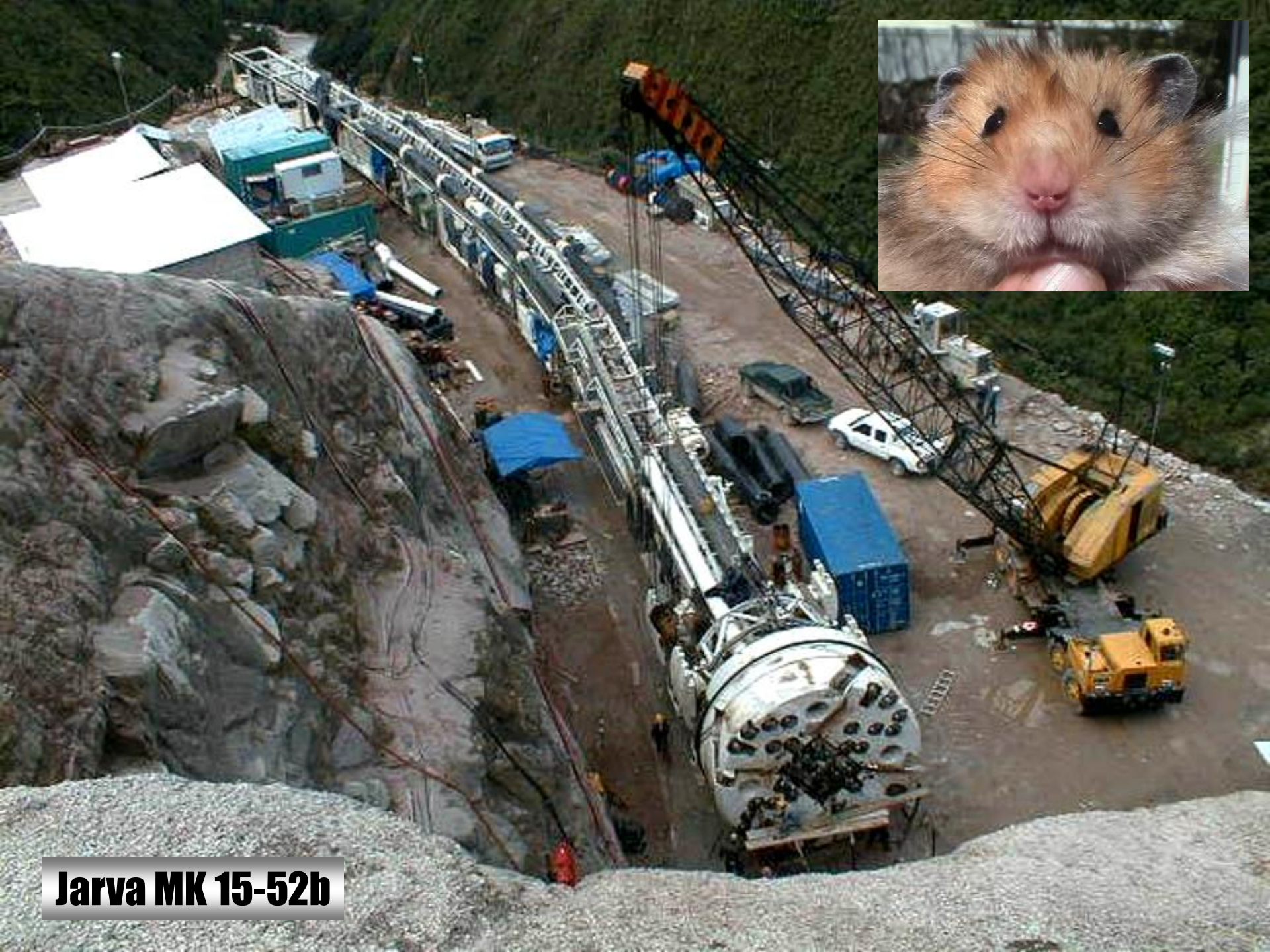

Ready to Pour Shaft 18B


Shaft 18B Forms


Finished Pressure Tunnel

NYC Aqueduct
Gravity Feed System – No Pumps

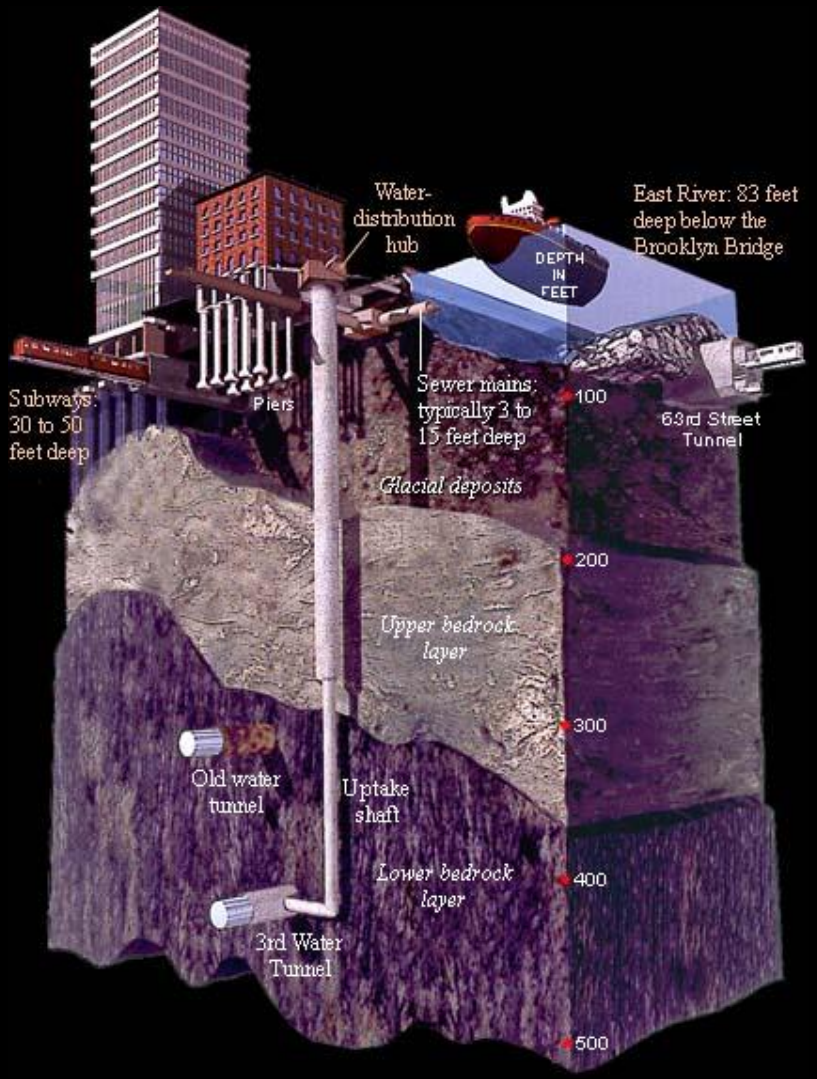



Jarva MK 15-52b

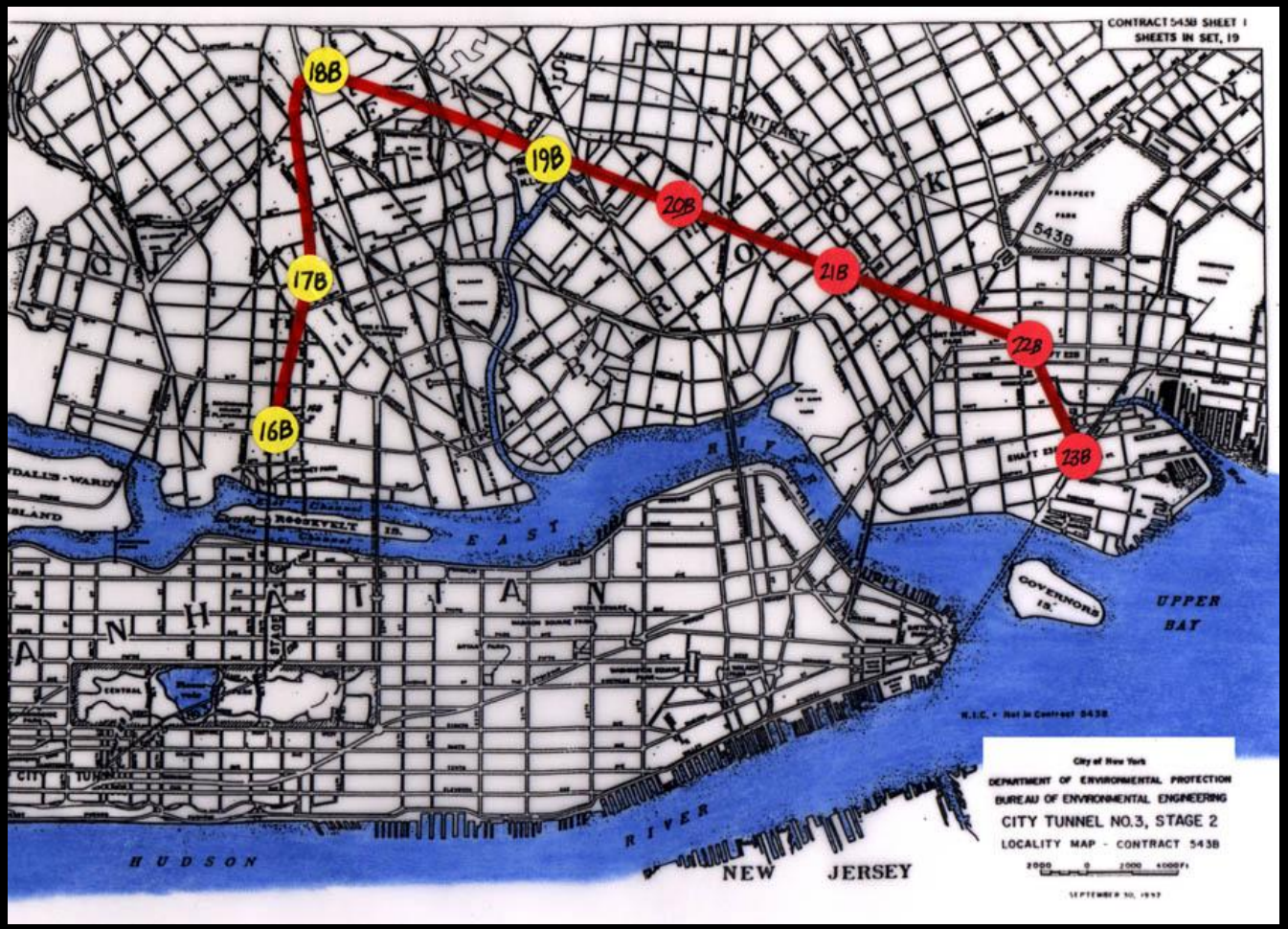

Remember Doc, You're Nothing Without Me!
Finally, He's Going to Talk About Mega-Construction Projects

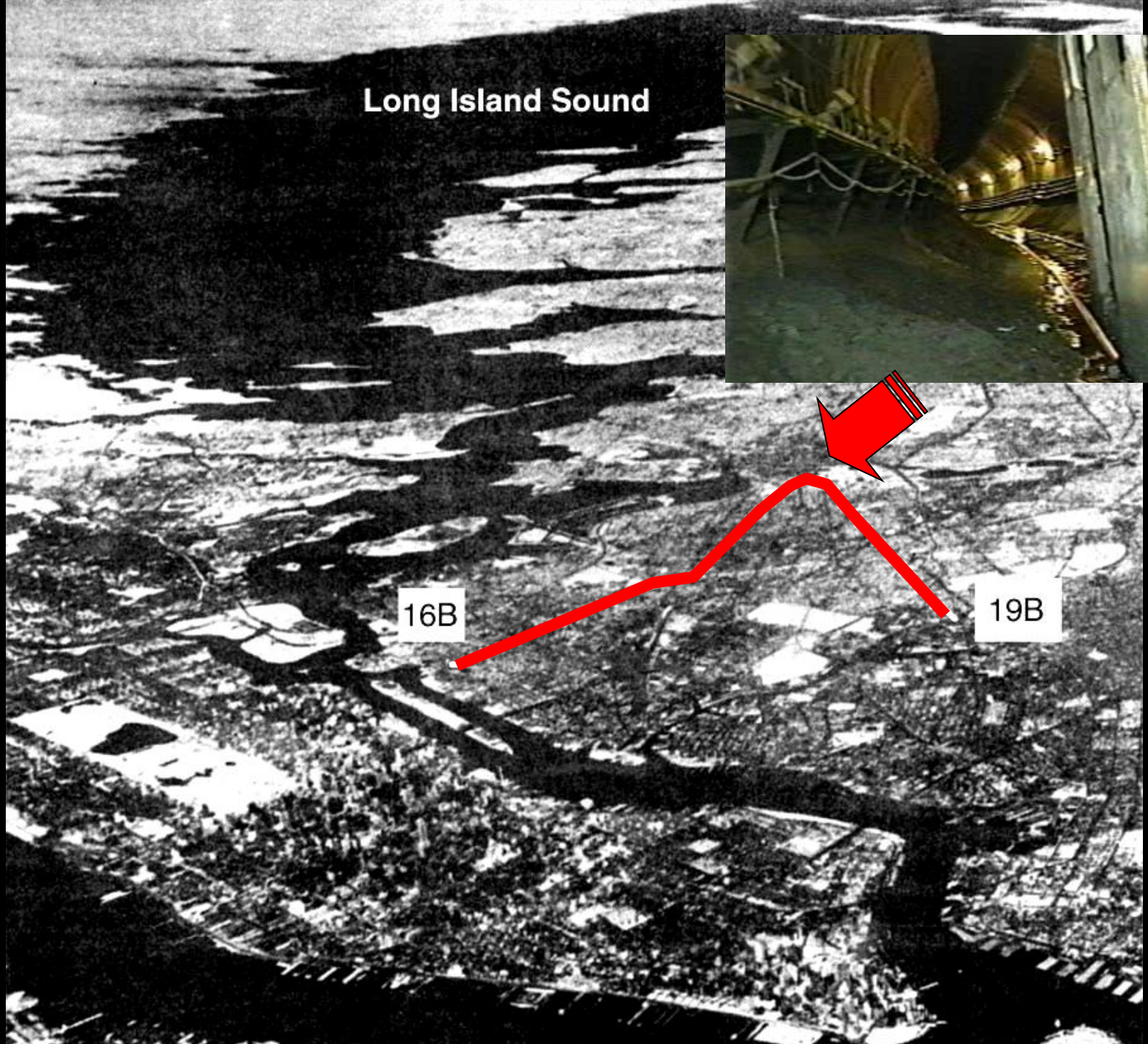
Mega-Construction Projects

- 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
Chrysler Building
United Nations Headquarters
Stern College
Yeshiva University
American Academy of Dramatic Arts
Little Church around the Corner
Touro College
Madison Square Park
Bellevue Hospital Center
Baruch College
St Francis College
Parsons School of Design
Cabrini Medical Center
Police Academy Museum
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
Tompkins Square
The Bowery
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

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

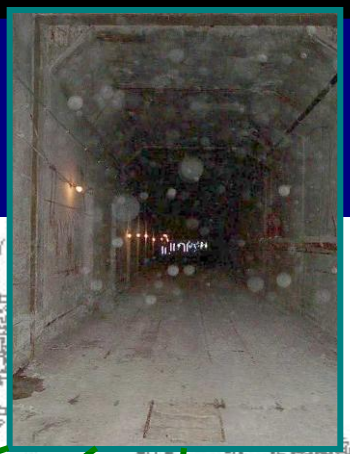
Rebuilt Robbins HP 215-257 hard rock machine (first used at Con Ed Utility Tunnel on 1st Avenue)

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

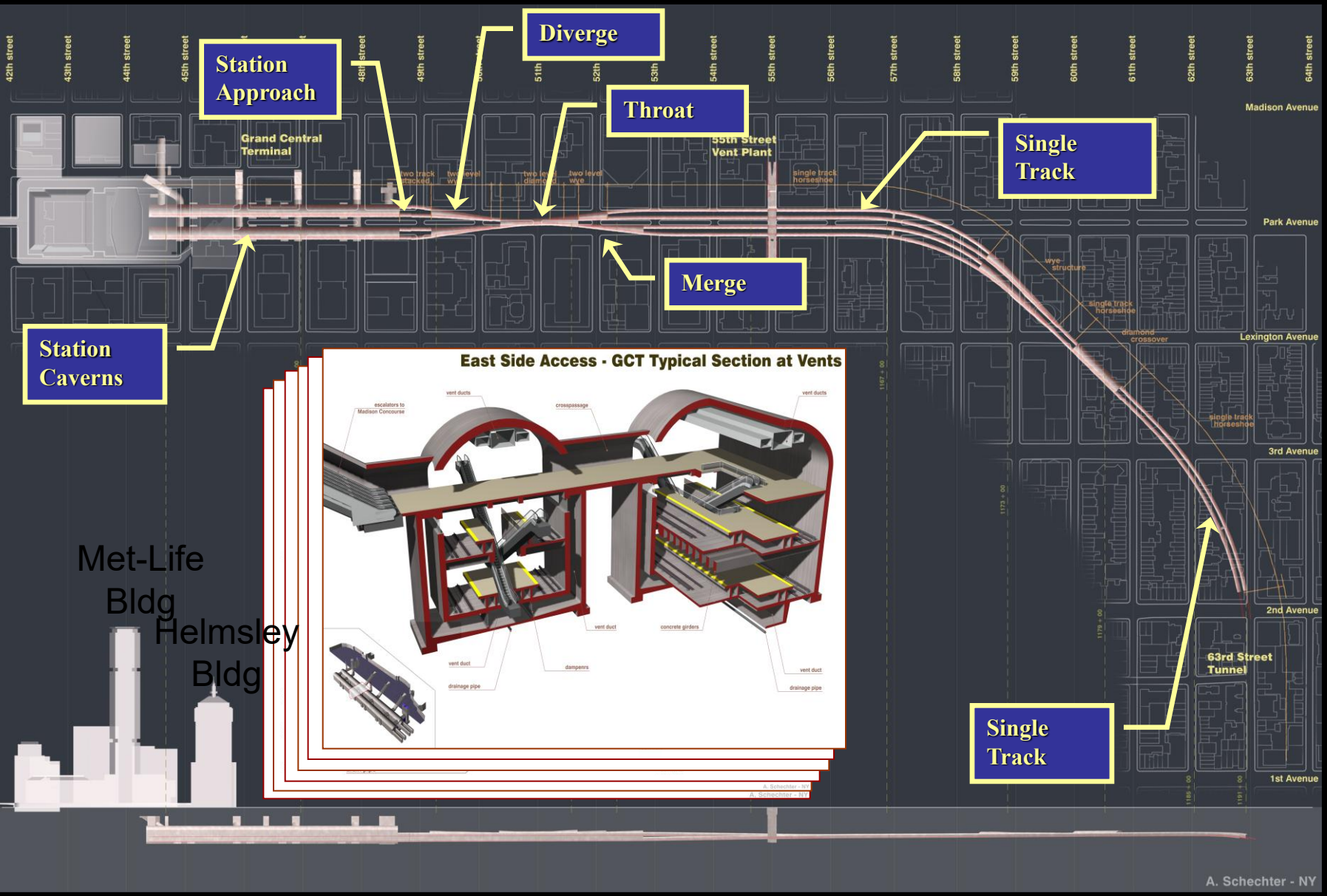
Existing 63rd Street Tunnel



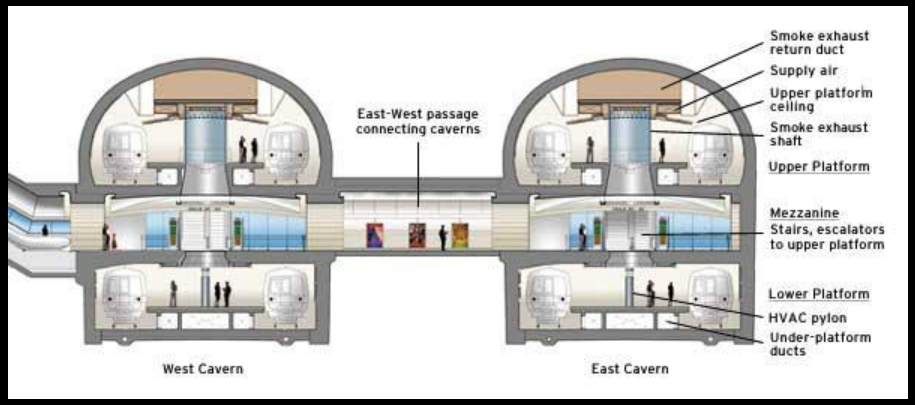

13 Aug 2007

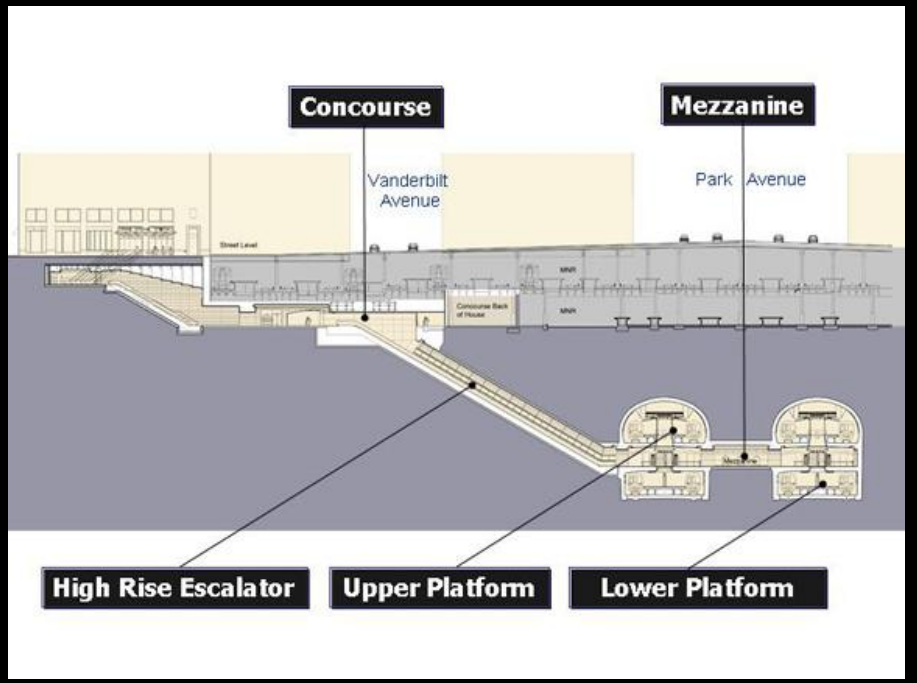

28 Nov 2007

East Side Access Project Plans



Construction Will Take Place Under Existing GCT





Second Avenue El

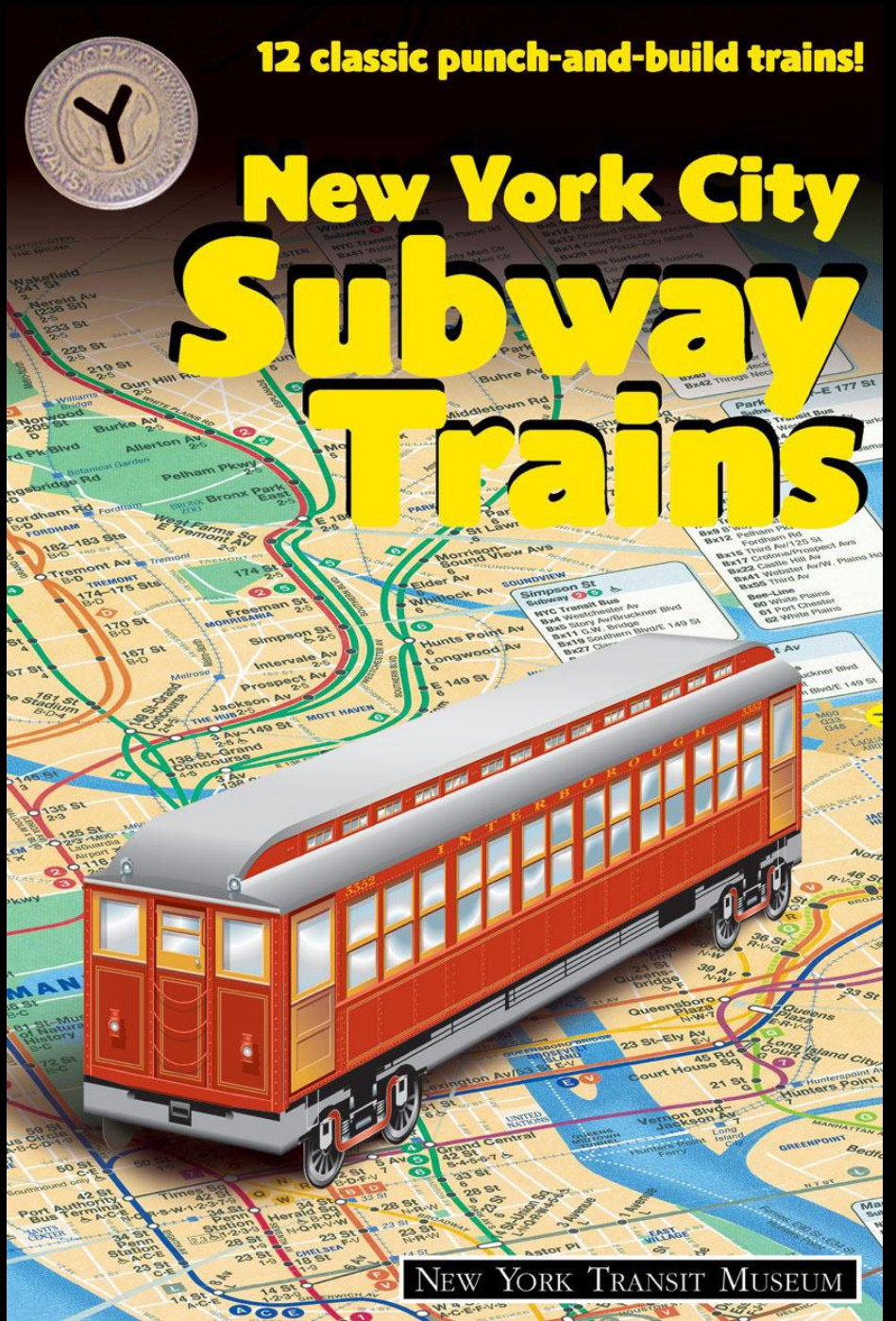
1929 – NYC BOT Proposes Second Avenue Subway

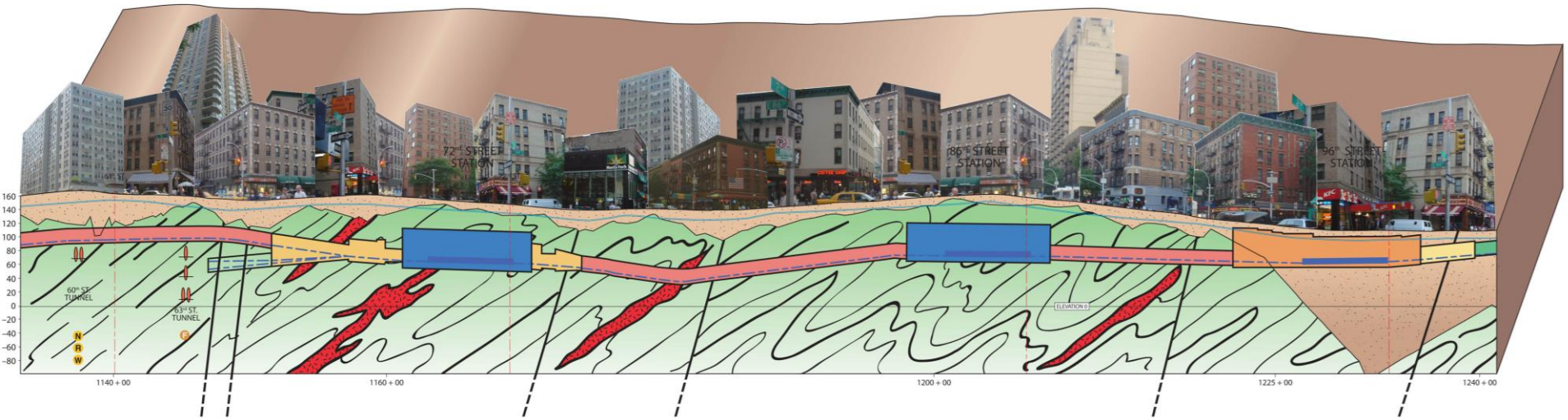
1931 – Plans Postponed Depression Era

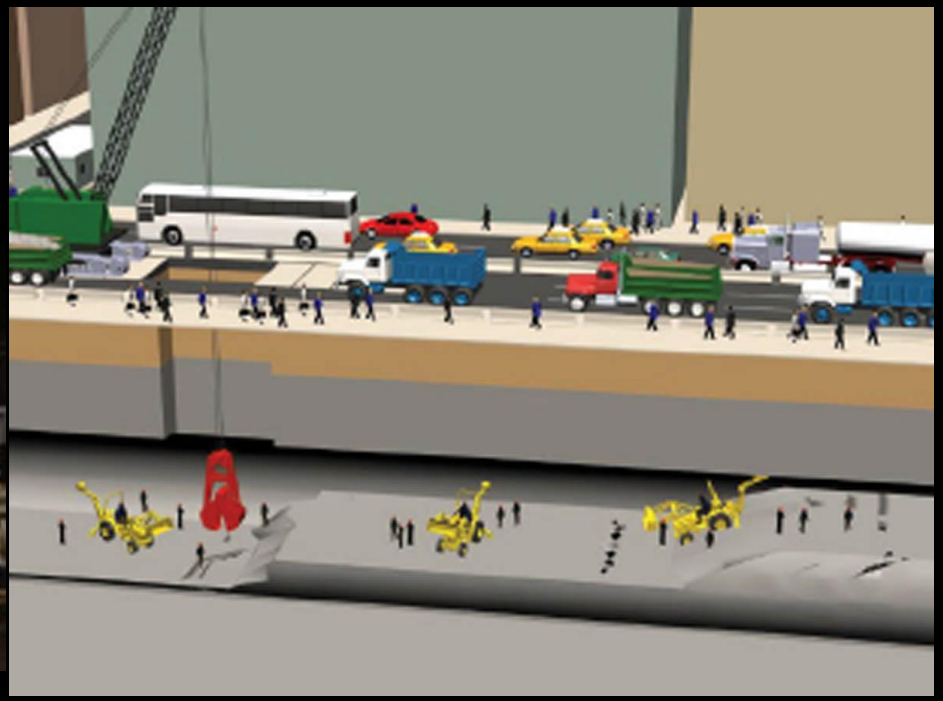
$86M → $249M → $500M

By 1948 – (Abandonment]

Second Avenue Subway

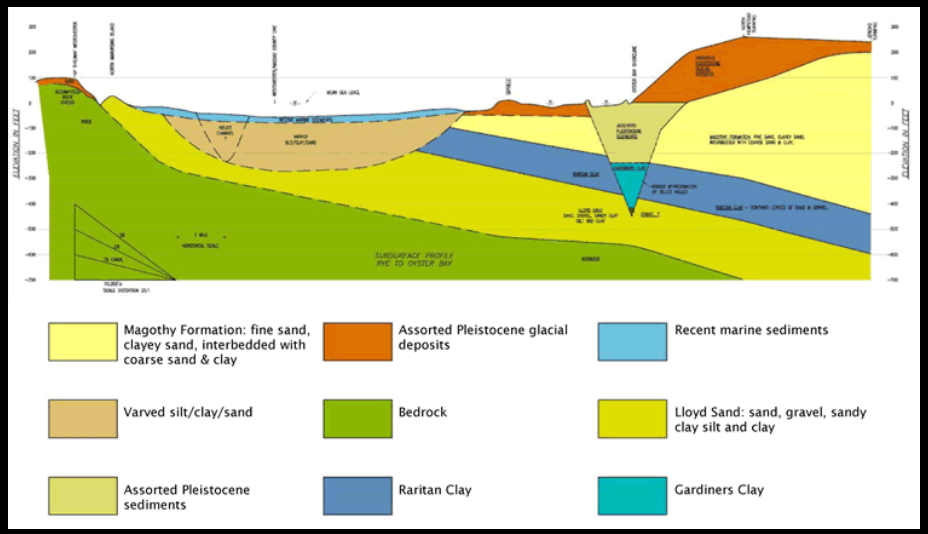



72nd STREET STATION
86th STREET STATION
96th STREET STATION
60th ST. TUNNEL
63rd ST. TUNNEL
N
R
W
ELEVATION 0
160
140
120
100
80
60
40
20
0
−20
−40
−60
−80
1140 + 00
1160 + 00
1200 + 00
1225 + 00
1240 + 00

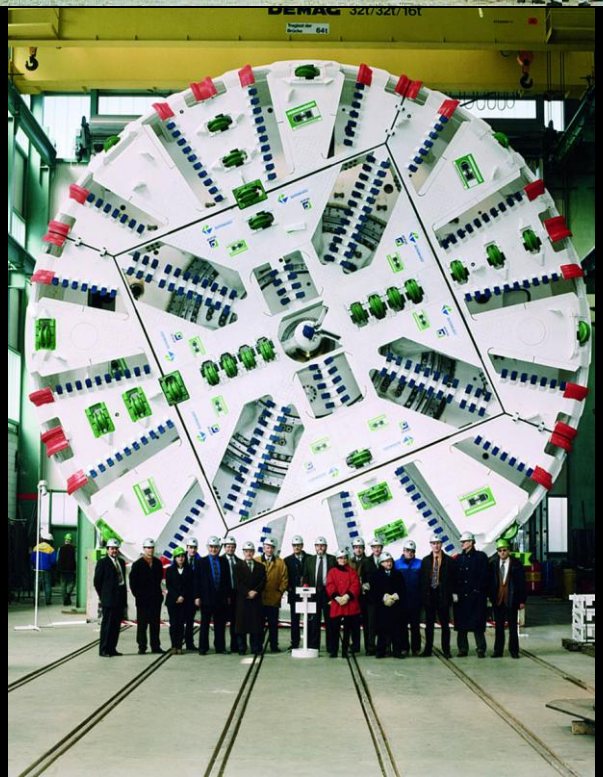


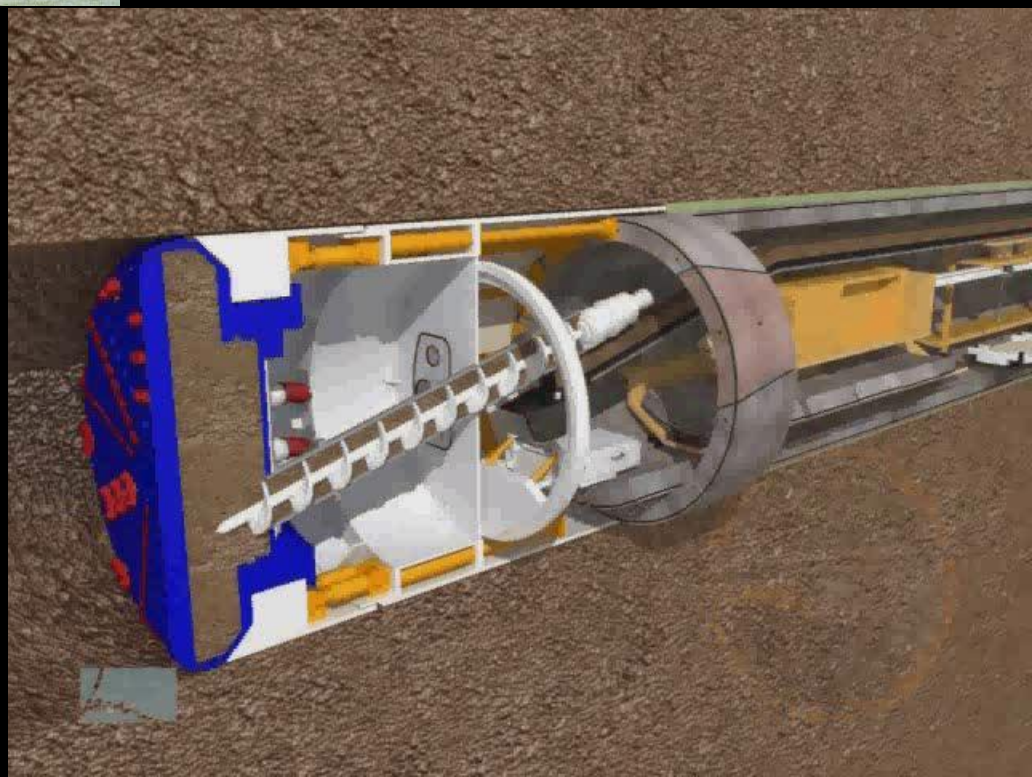
IRT #7 Line Extension

Cross Sound Link Project



Soft Ground TBMs



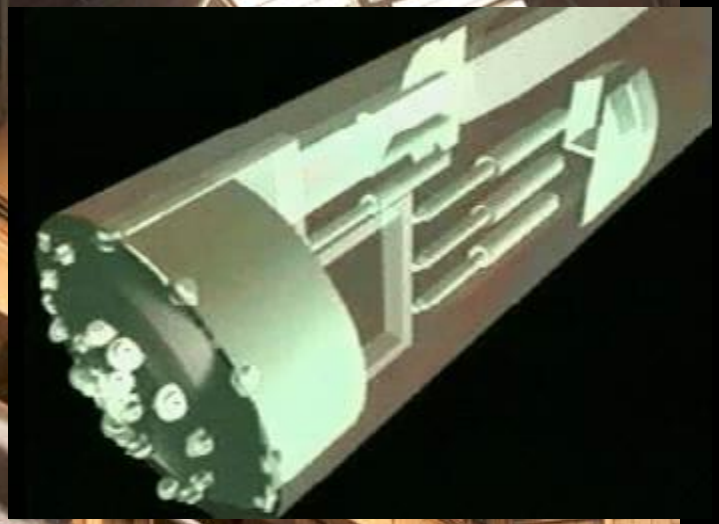


Queens Tunnel Problems – A Case History

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

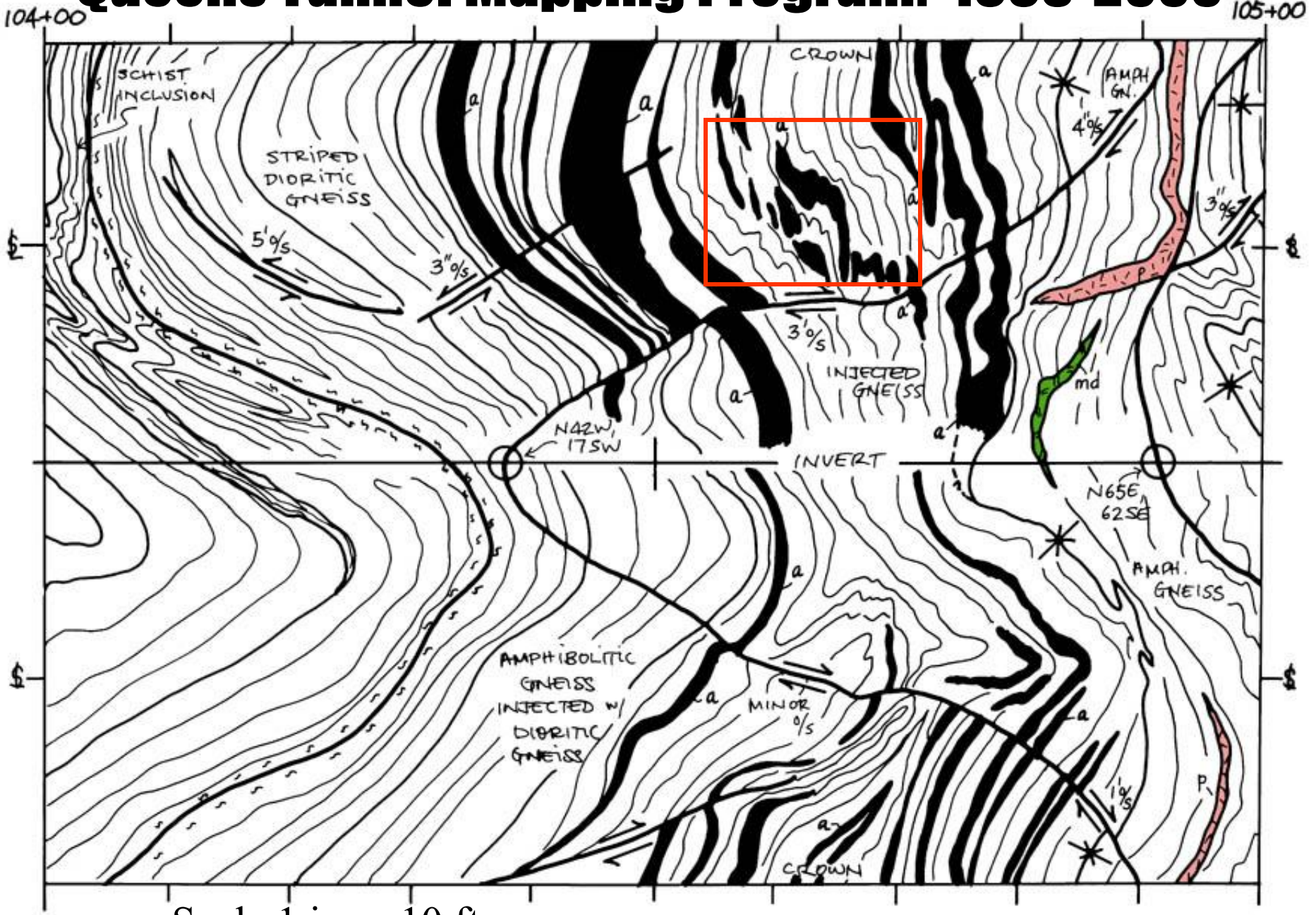
Can Geologic Studies Help Predict TBM Penetration Destiny?

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

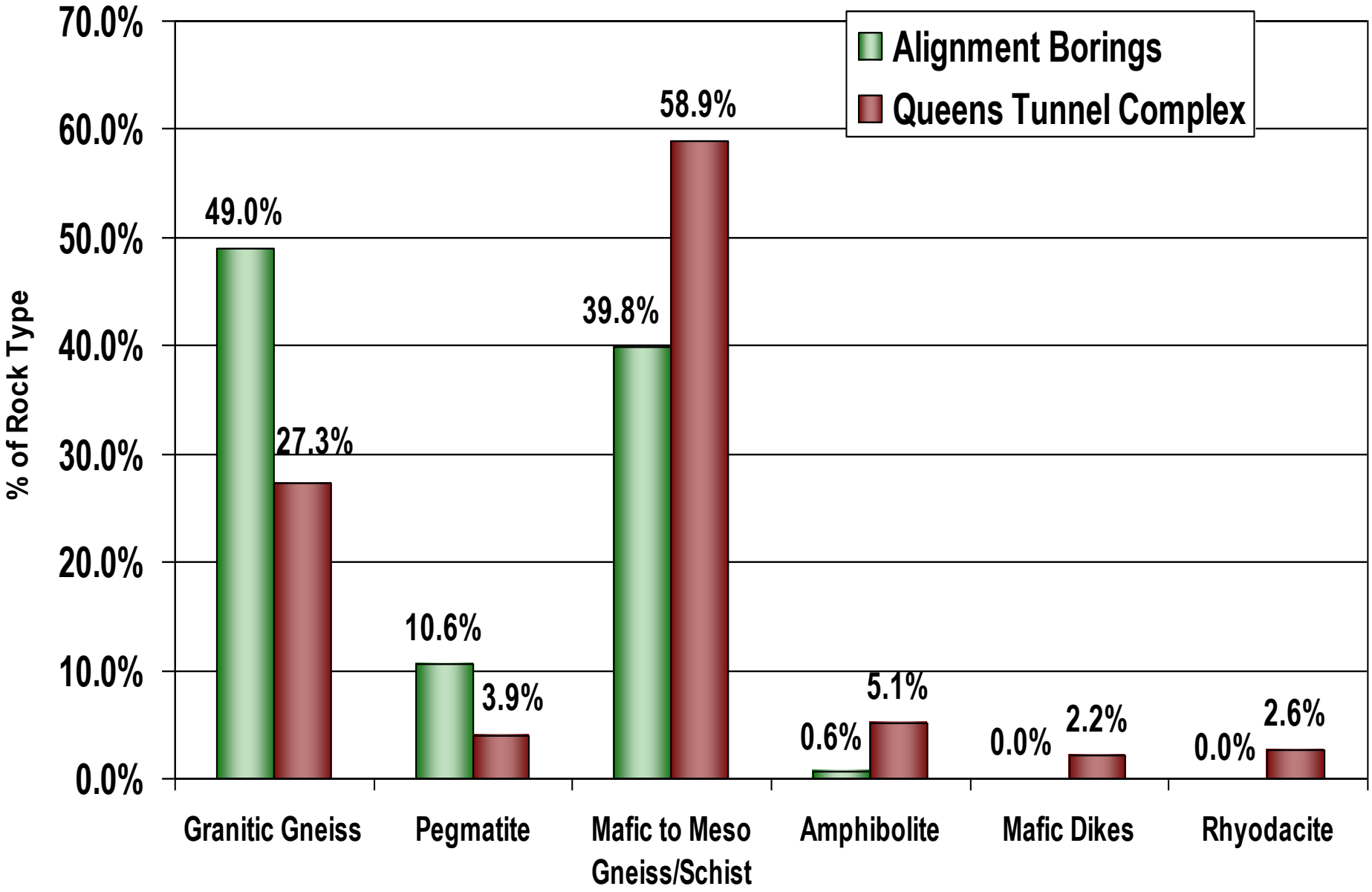
Queens Tunnel Mapping Program: 1998-2000



- Scale 1 in. = 10 ft


104+55
104+60
104+65

Comparative Lithologic Analysis



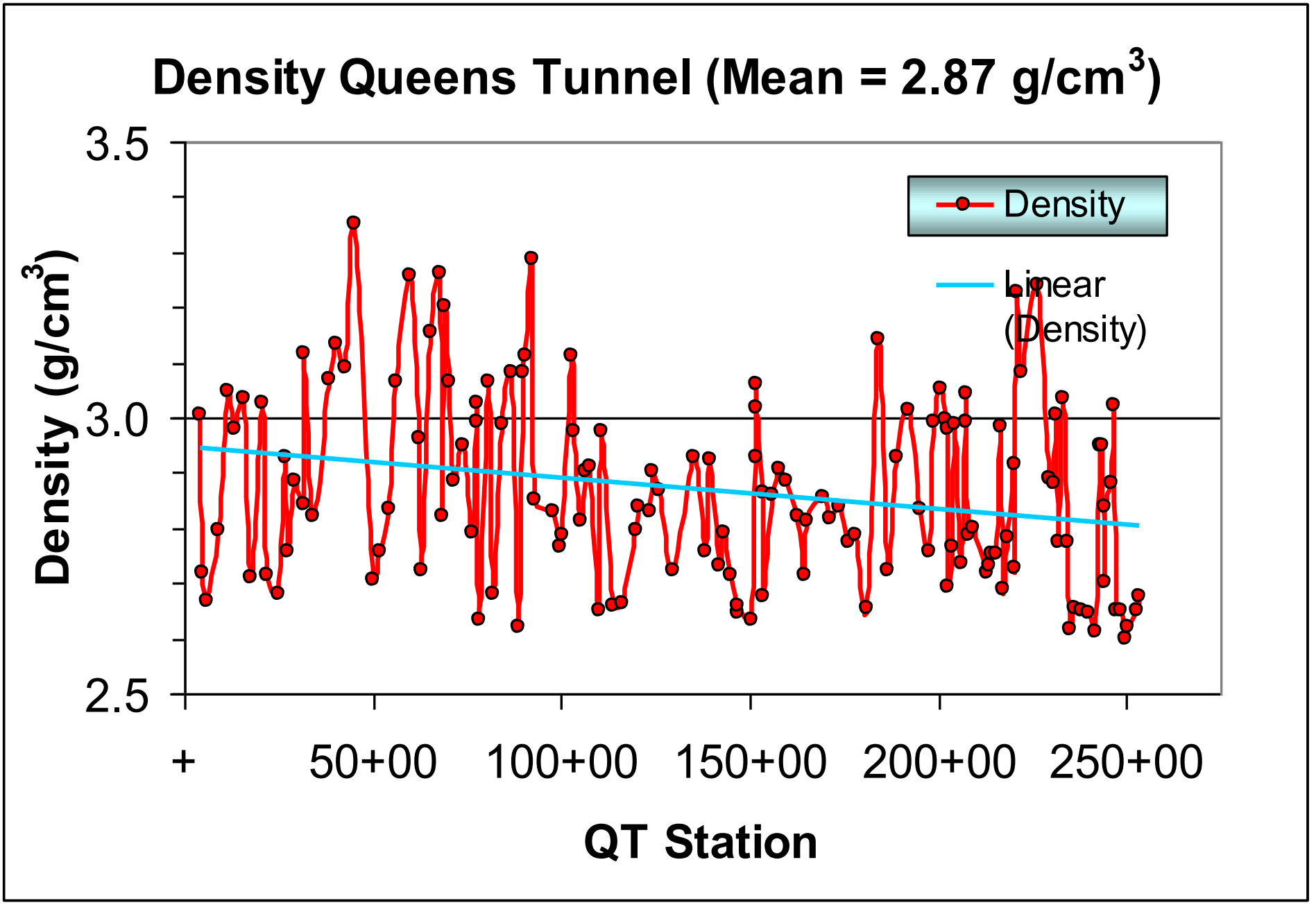
The Queens Tunnel Complex

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

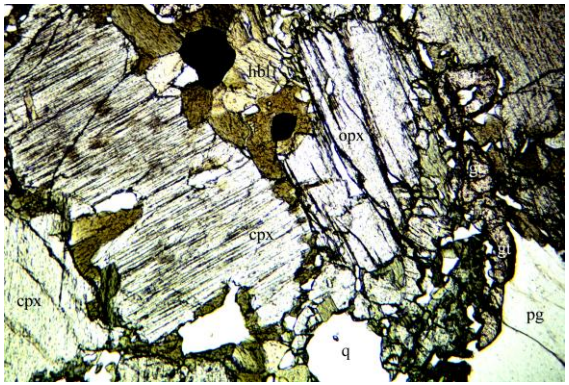
II. Leuco- to Mesocratic Gneiss

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

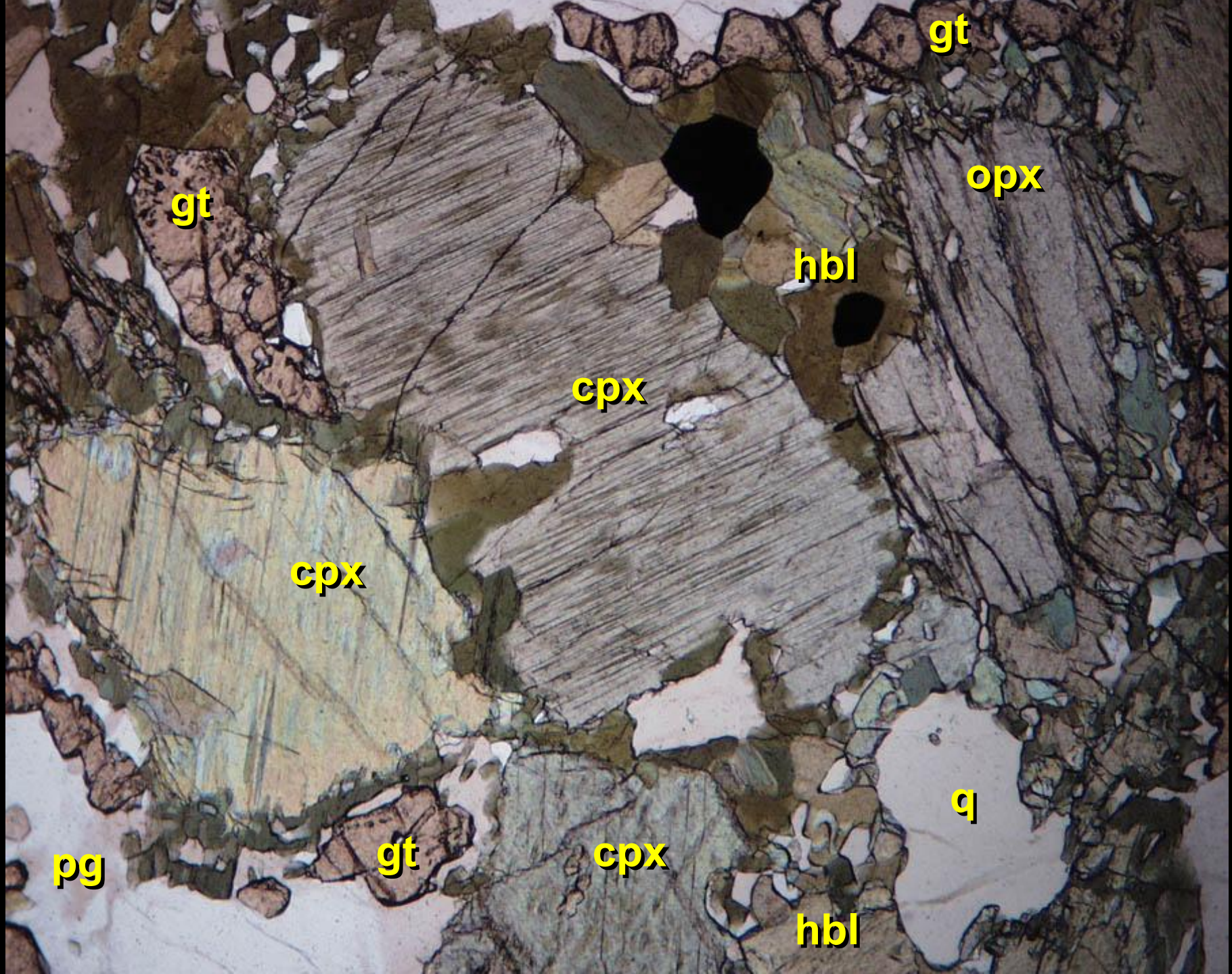
- **Petrographic Analysis (92 Samples)**
  - **Texture**
  - **Mineralogy**
  - **Internal Structure**
  - **Metamorphism**



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
opx
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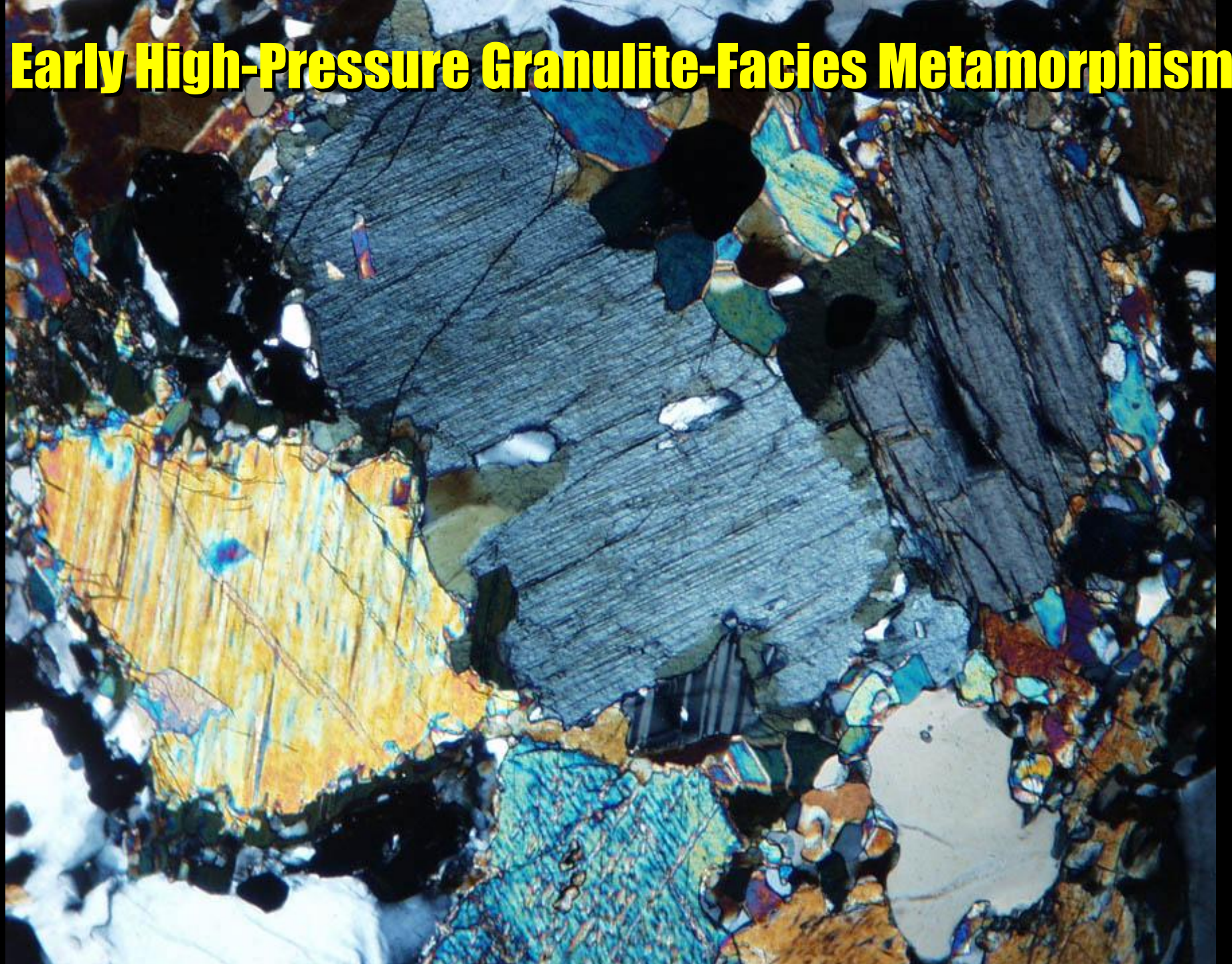
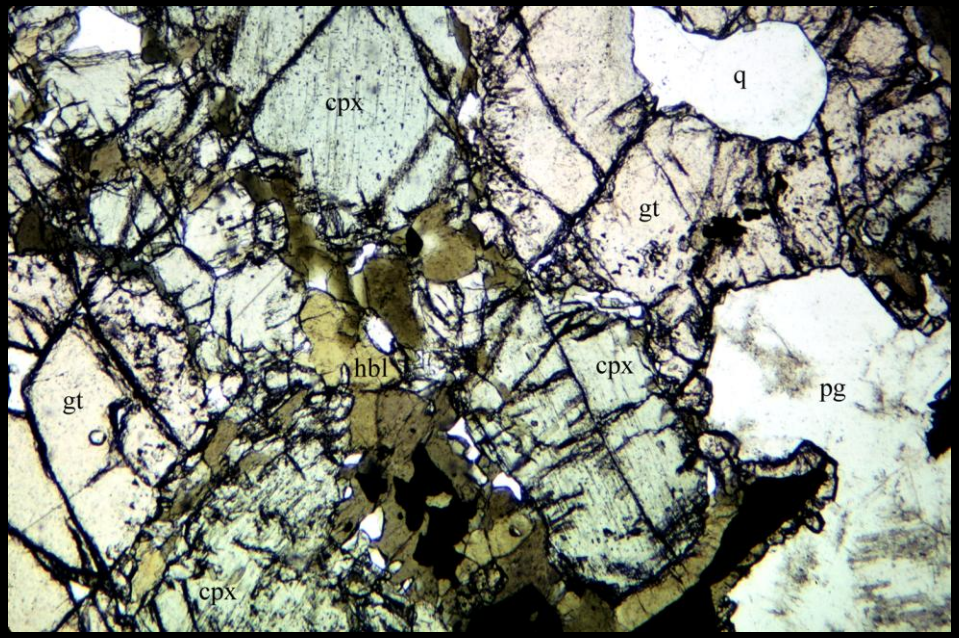
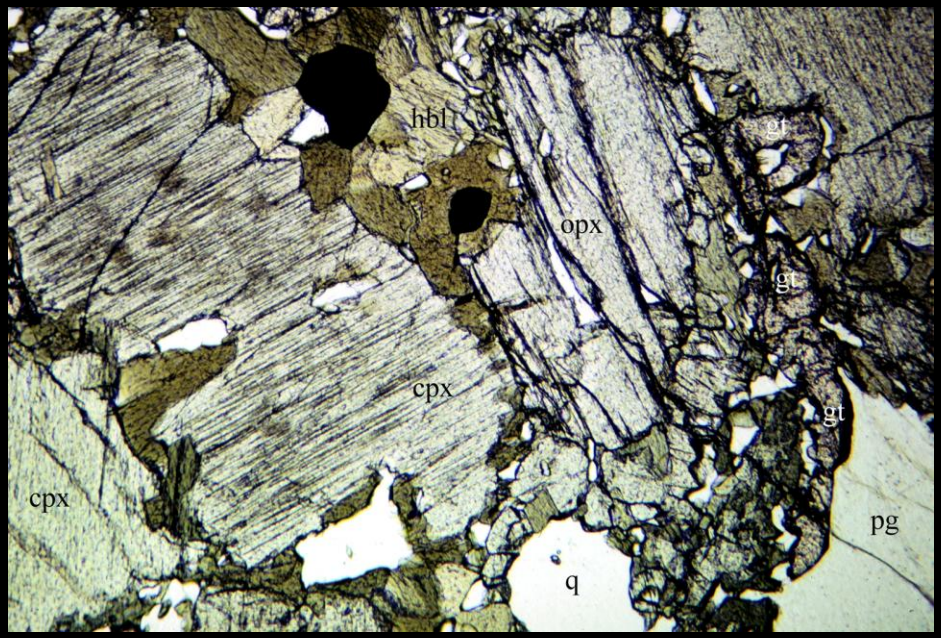
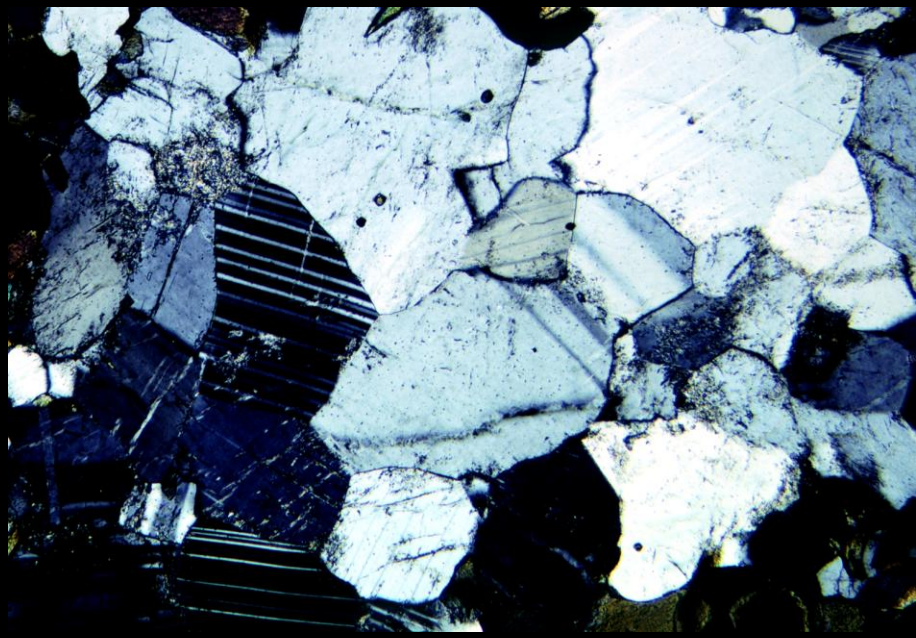
Early High-Pressure Granulite-Facies Metamorphism



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



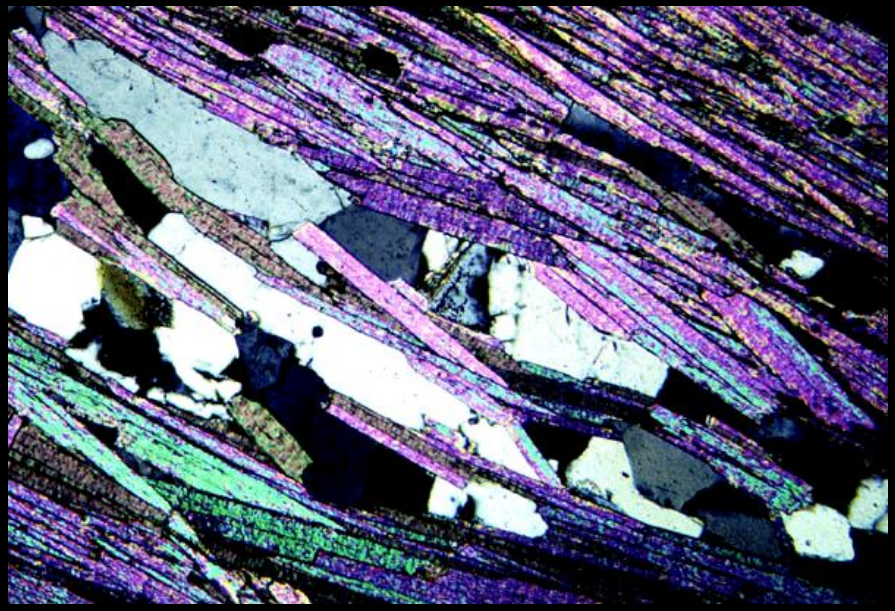




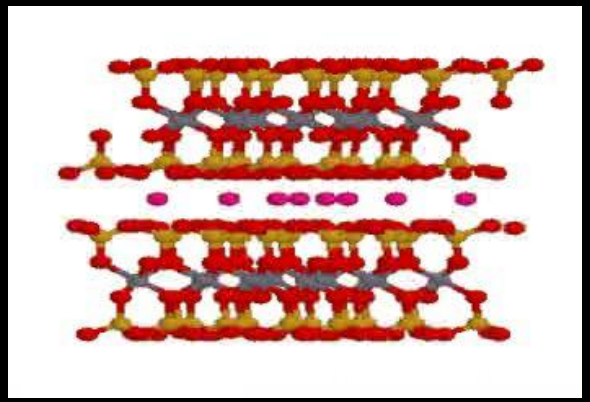
Mica Content of Rock Fabric

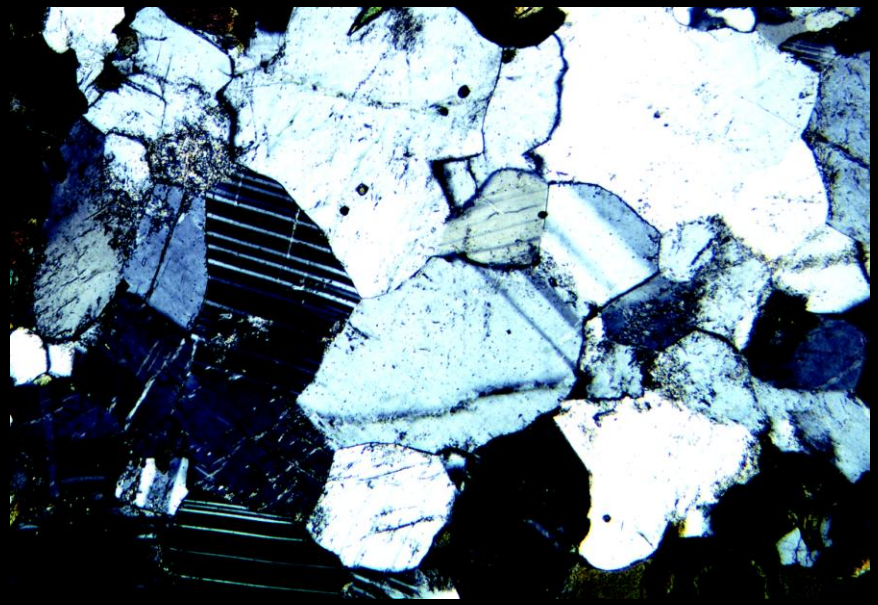
Micaceous (+/- hornblende) penetrative foliation

vs. non-foliated "granoblastic" rock mass

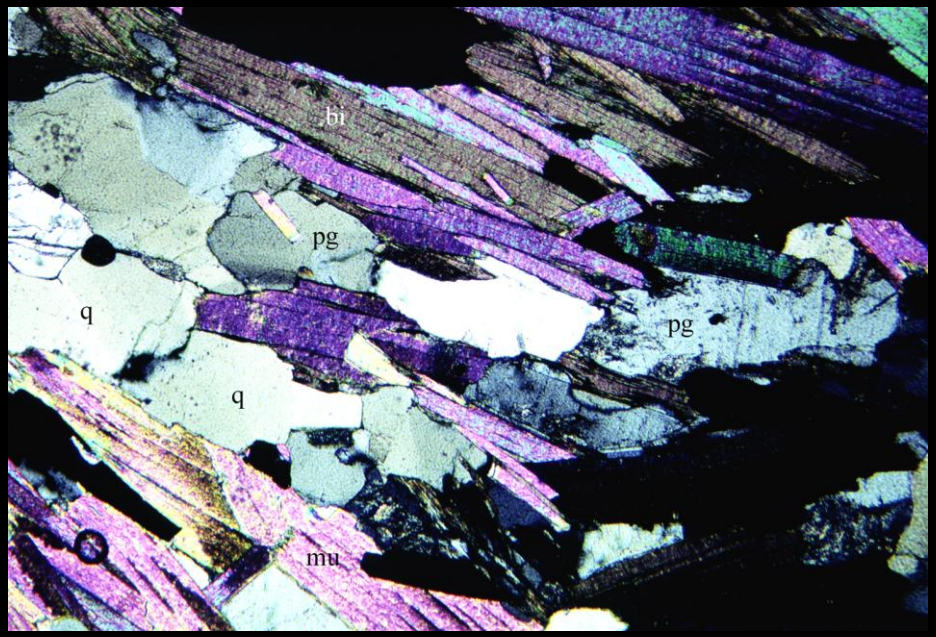


Foliated

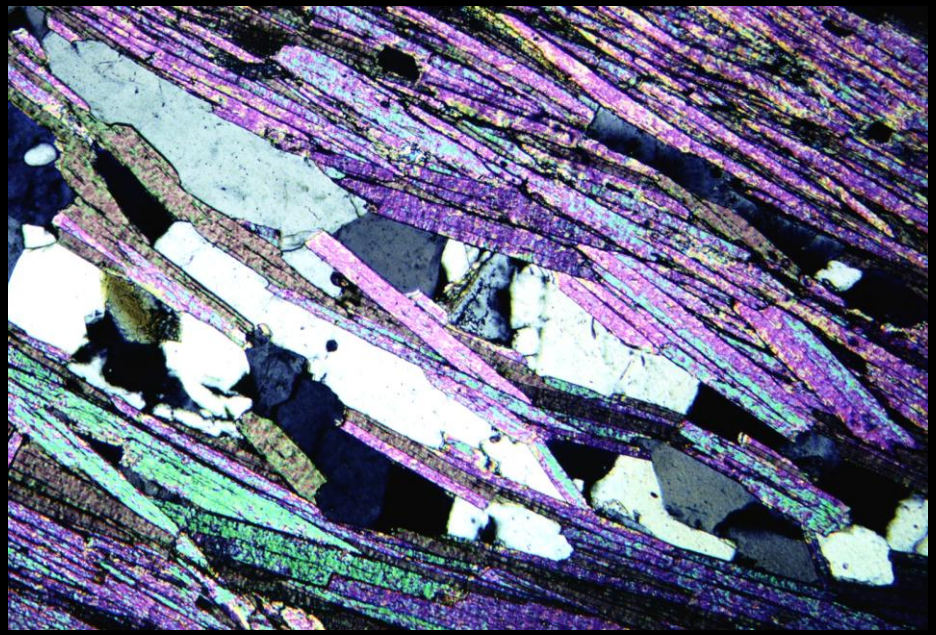




Non-Foliated



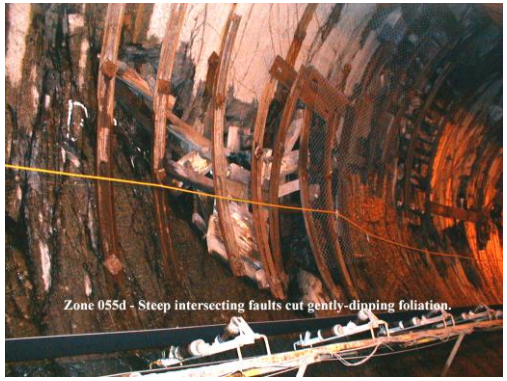
In Western Manhattan:
Amphibolite Facies Schists
Well-layered Hartland Fm.
Foliated Textures
Great Rocks for Tunneling and Excavation!



Orientation of Rock Layering

NE strike and moderate 57° dip anticipated

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

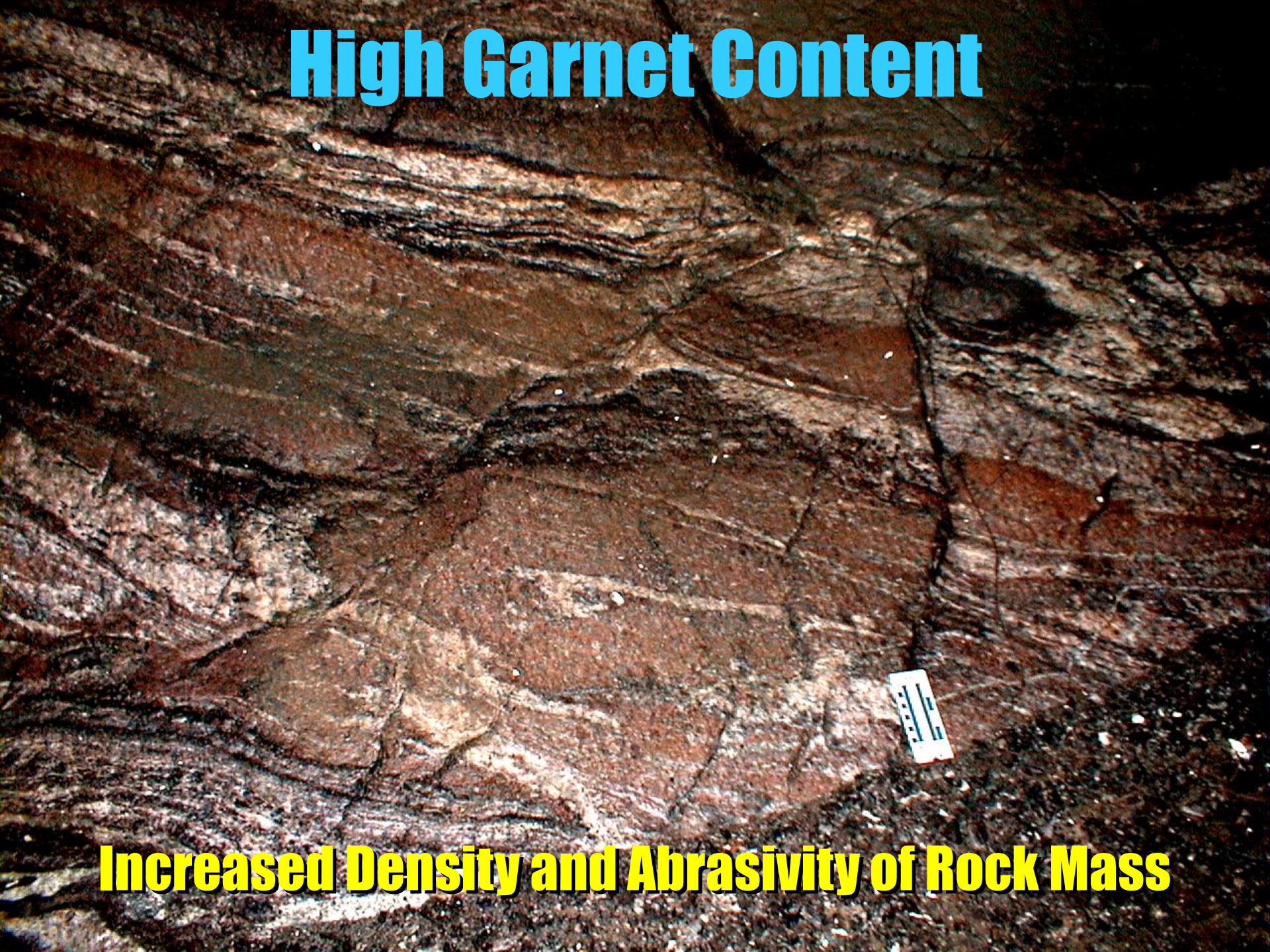


Highly variable trends found

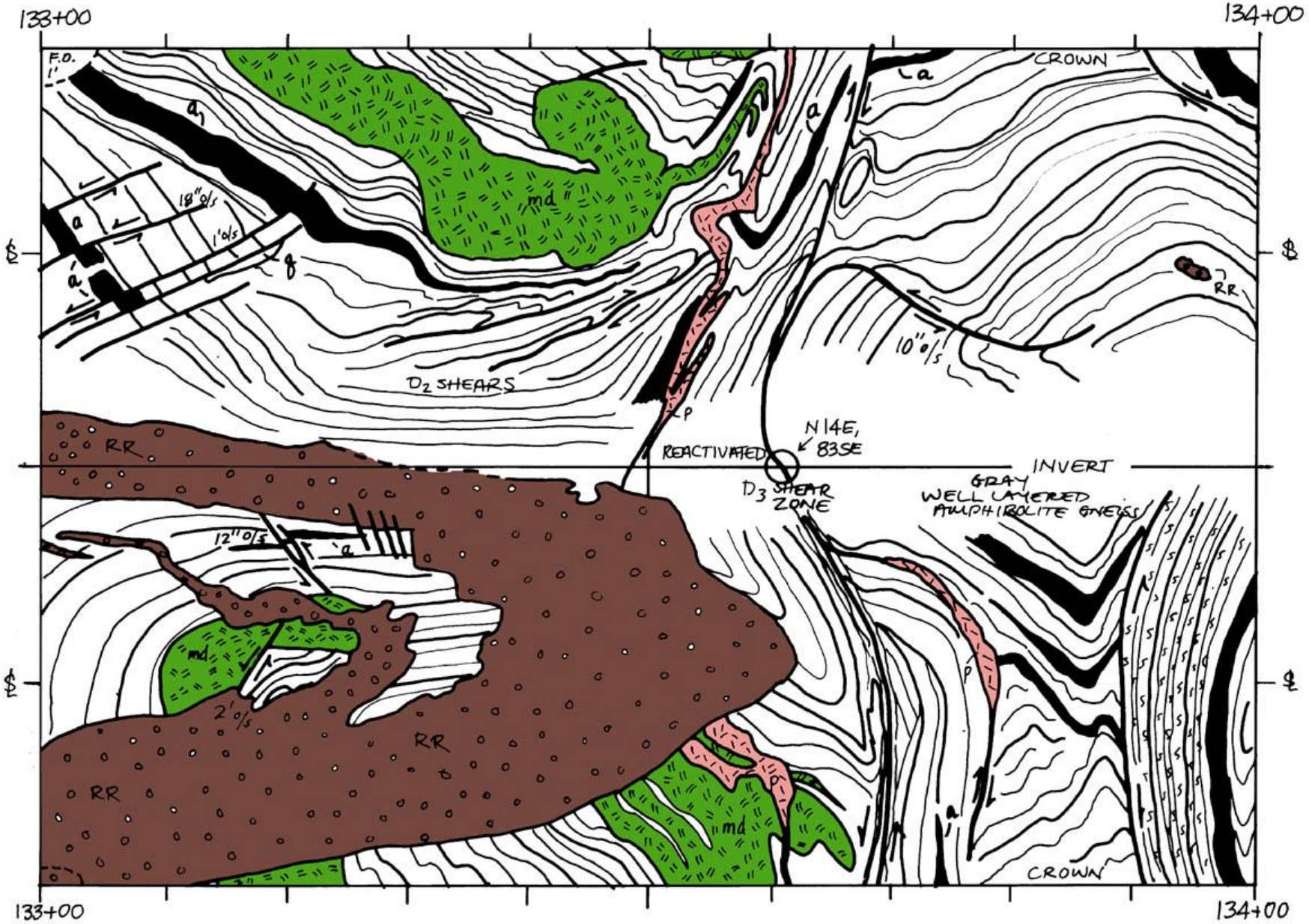
- **Extended reaches of tunnel exhibited gentle dips**

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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