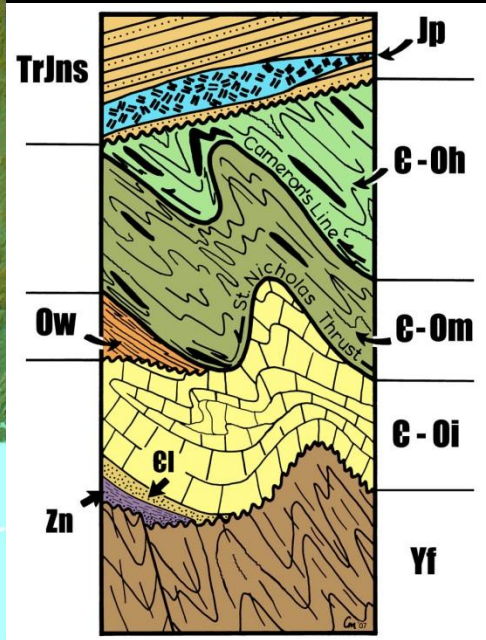
Stony Brook University

Geological Controls on Megaconstruction Projects, NYC

Charles Merguerian

25 April 2013

NYC Rocks



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

Penetration Destiny
TBM Tunnelling in NYC

First Robbins TBM [1952]

Factors: TBM Penetration Destiny

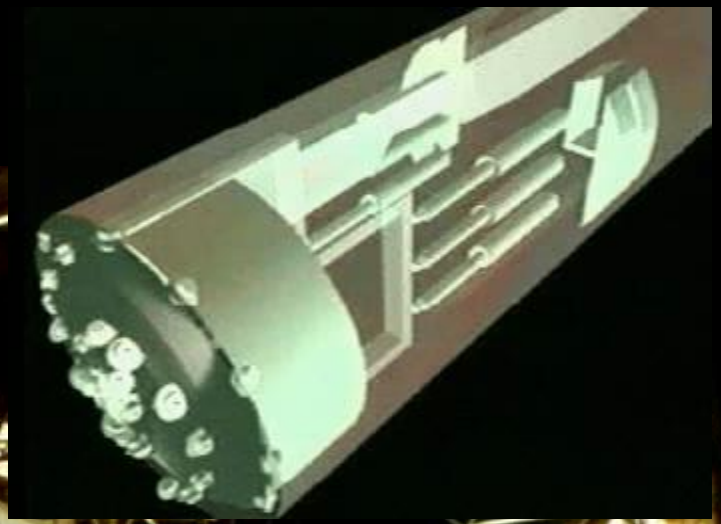
Intrinsic Factors (Penetration Rate)

- UCS
- Fracture Density – RQD/Recovery
- Faults/Joints
- Mineralogy
- Hardness/Density
- Rock Type
- Texture/Metamorphic Grade
- Fabric Orientation/Development

Episodic Factors (Utilization)

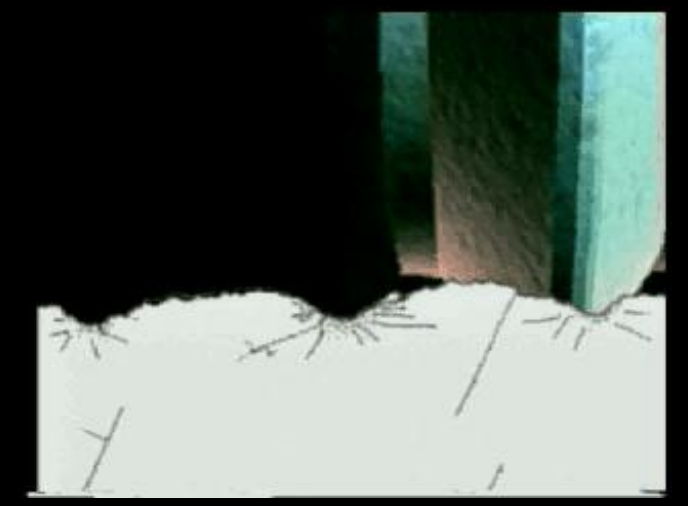
- Convergent Fault Zones
- Unusual Rock Types/Structures
- Stress Popping/Heave
- Water Inflows

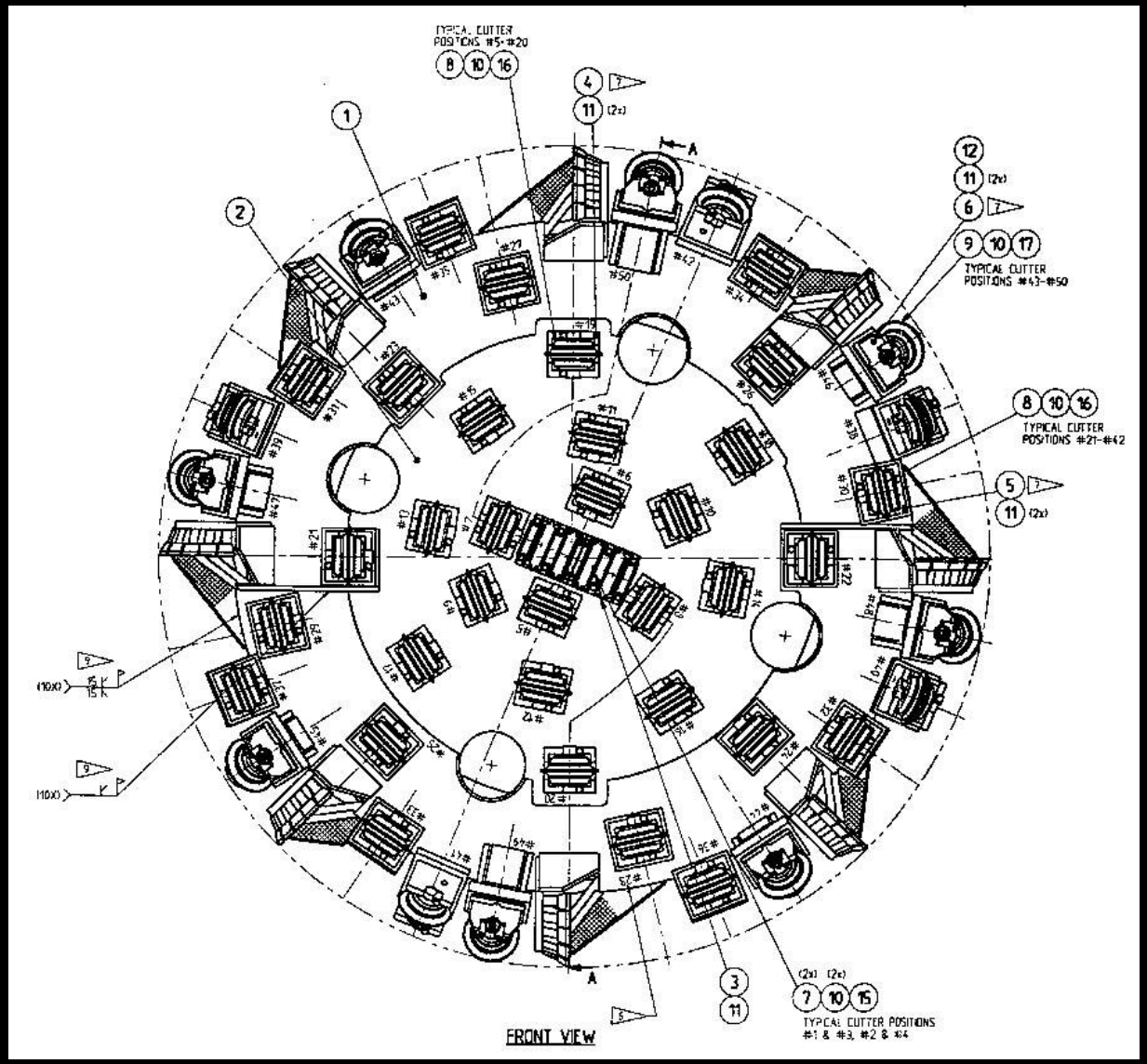
Robbins 235-282 HP Main Beam TBM



Chesterfield, England - 1996

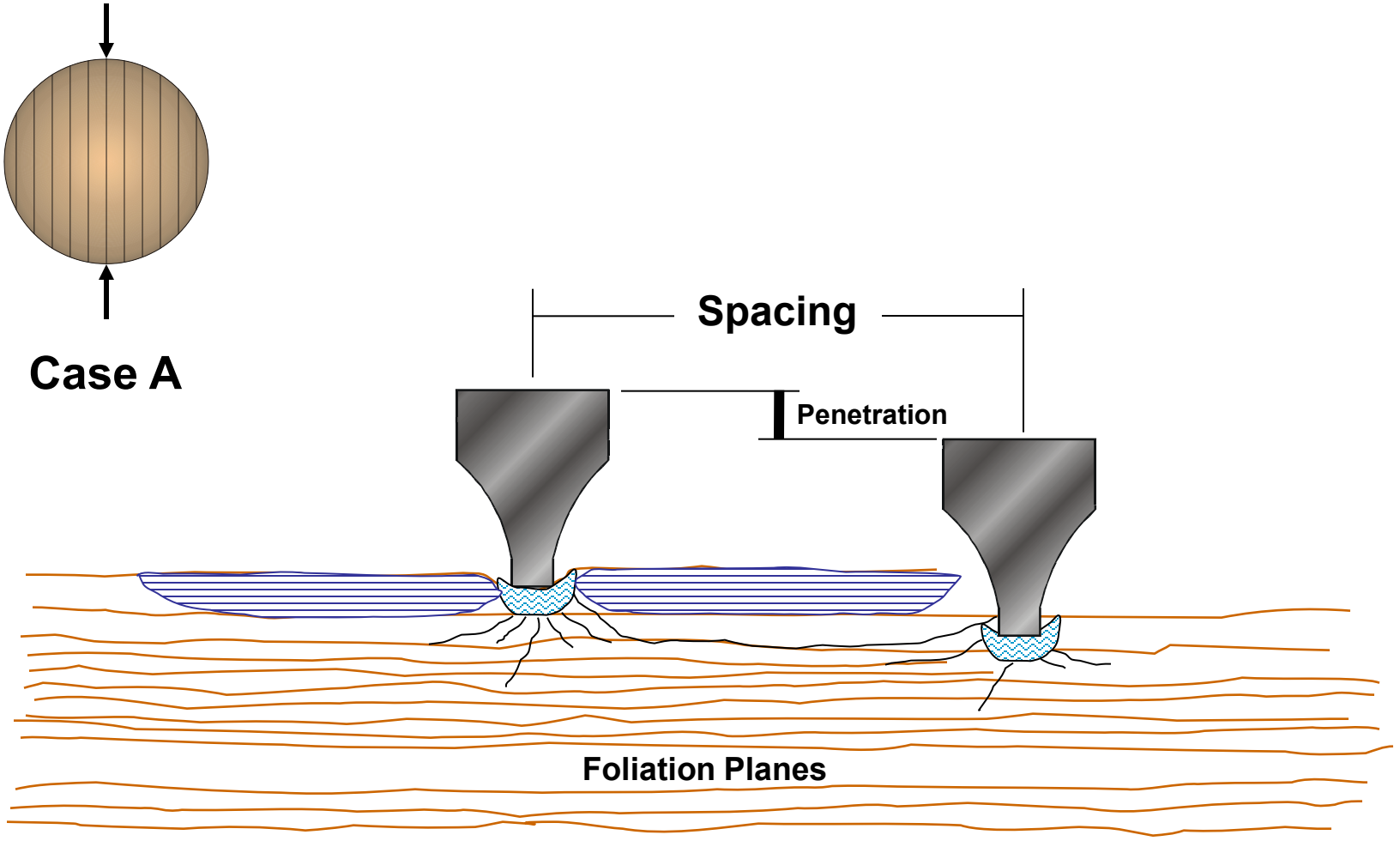
TBM Chip Production





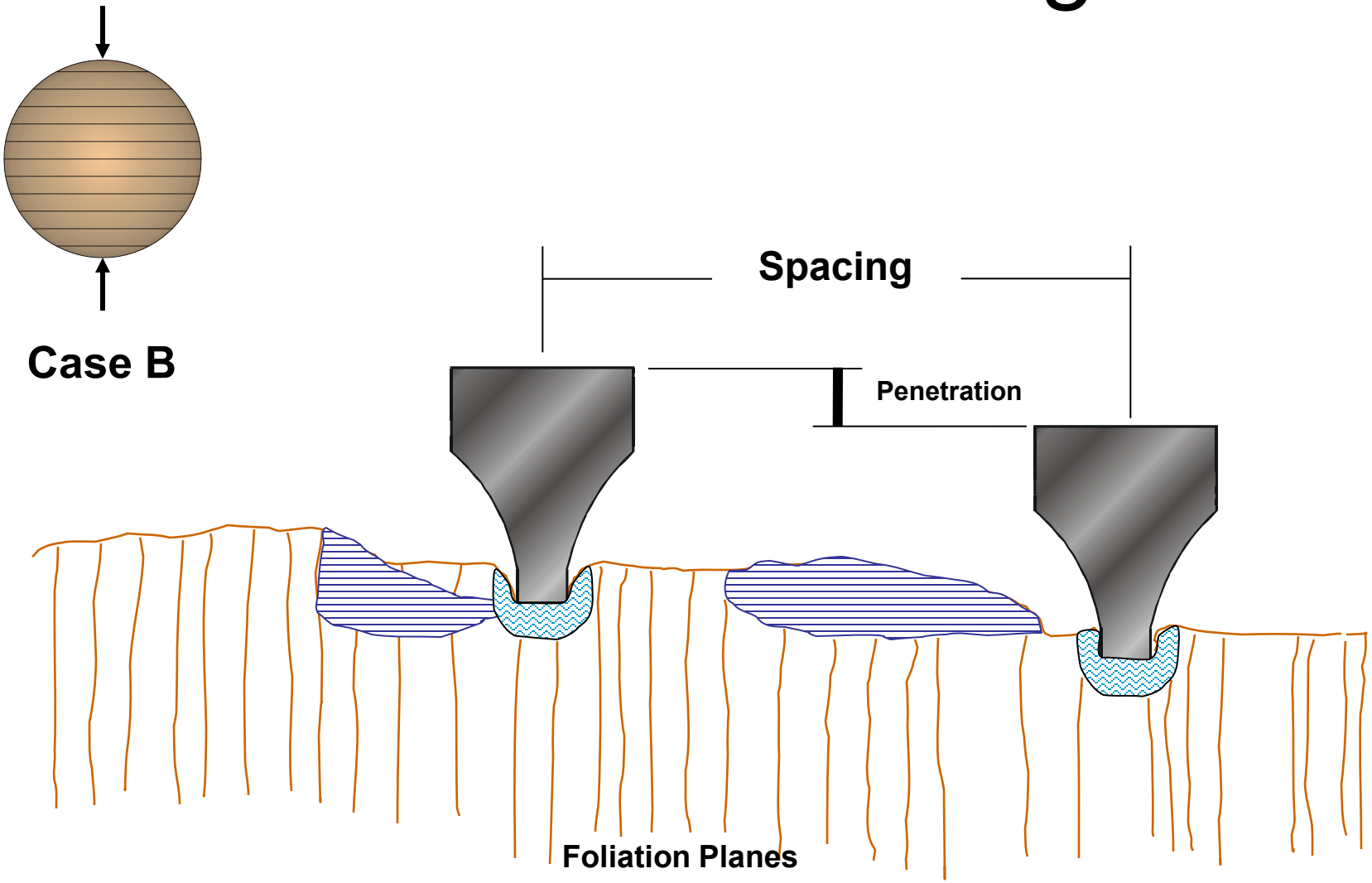
Desirable Kerf Pattern in Hard Rocks

Foliation Planes Parallel

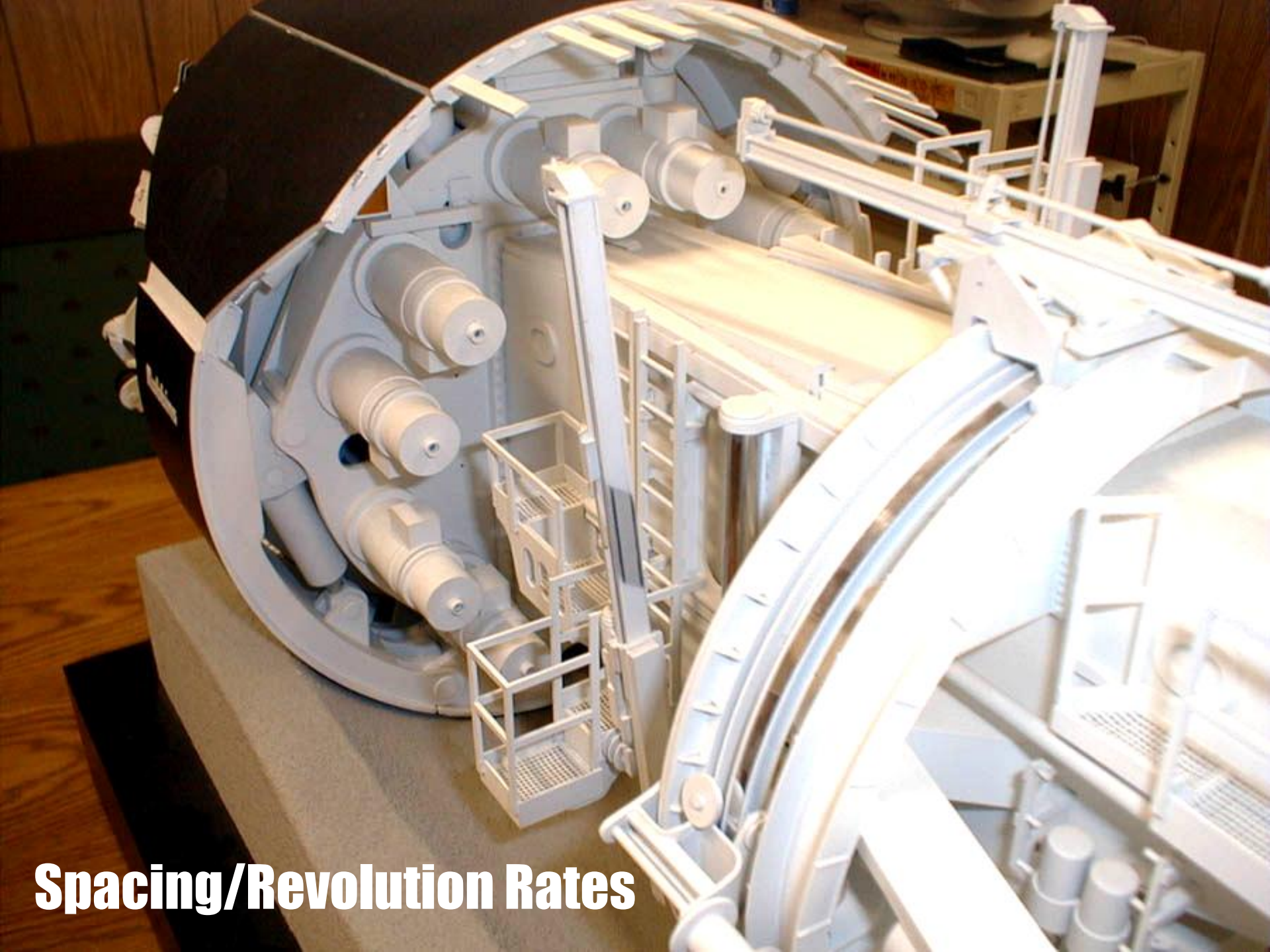


Chipping mechanism when TBM advancing perpendicular to foliation (Case A)

Foliation Planes Orthogonal



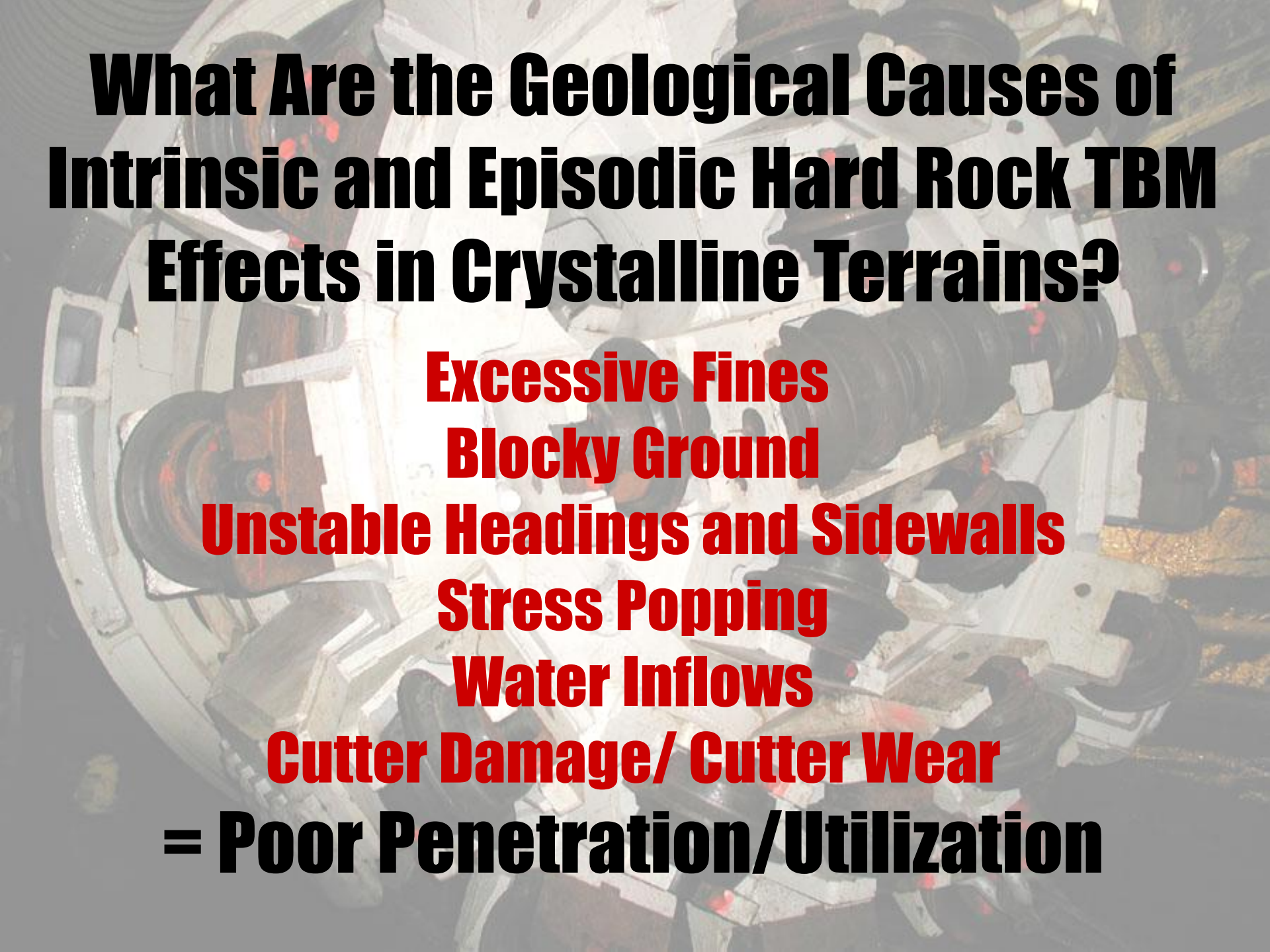
Chipping mechanism when TBM advancing parallel to foliation (Case B)


Spacing/Revolution Rates

Queens Tunnel TBM
422 HP Electric
Water Cooled,
Three Phase Motors

10 Motors Total
Usually 8 Online
Rotated Cutterhead
at 8.3 Rev/Min

New Research TBM Cutter Head Torque Dynamics



What Are the Geological Causes of Intrinsic and Episodic Hard Rock TBM Effects in Crystalline Terrains?

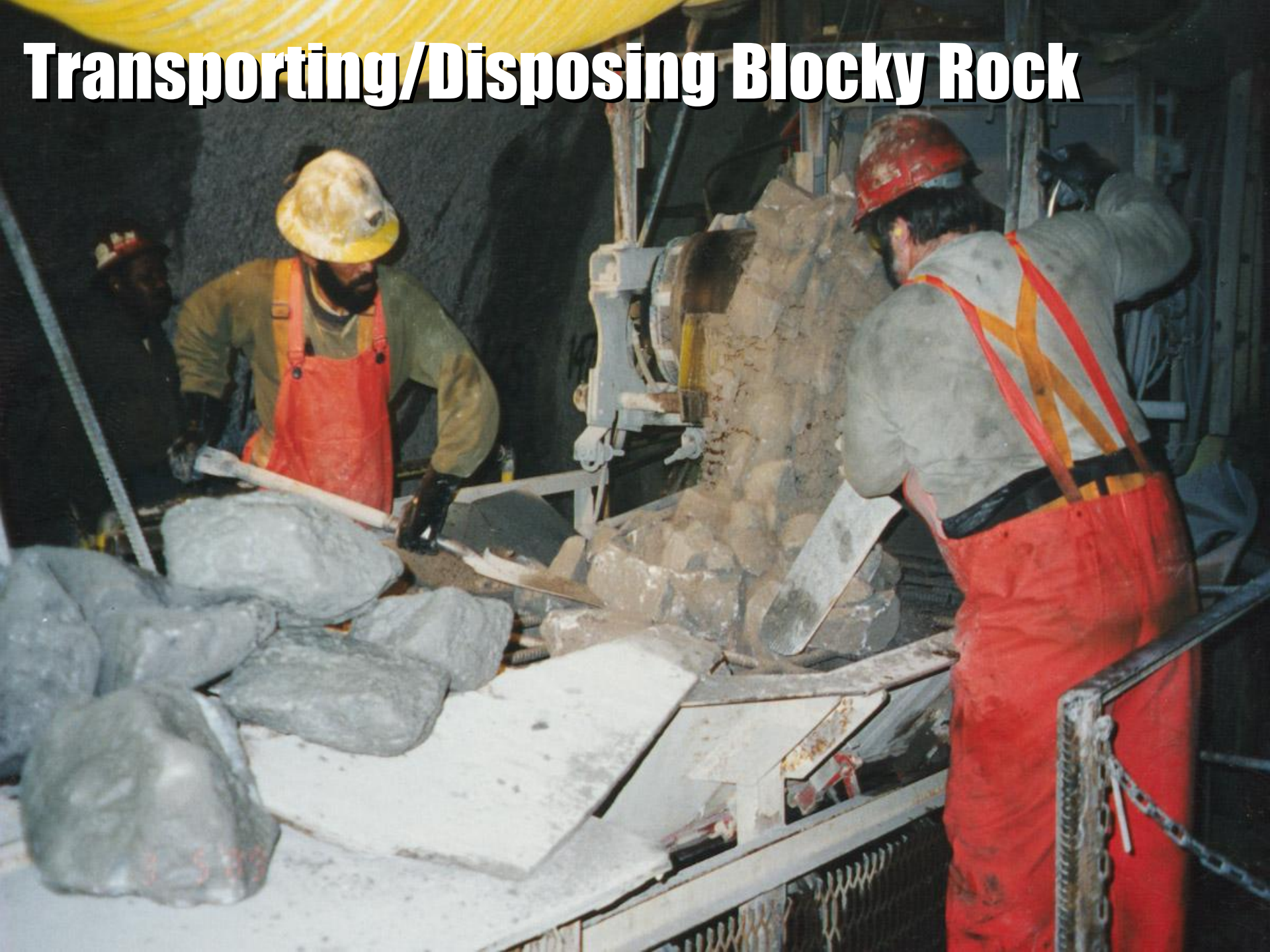
Excessive Fines
Blocky Ground
Unstable Headings and Sidewalls
Stress Popping
Water Inflows
Cutter Damage/ Cutter Wear

= Poor Penetration/Utilization

Excessive Fines

Blocky Ground

Transporting/Disposing Blocky Rock



Damage to Horizontal Conveyor

Worn and Damaged Cutters


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

Additional Rock Support

High Water Inflows

Station 140+60

Unforseen Tunneling Problems

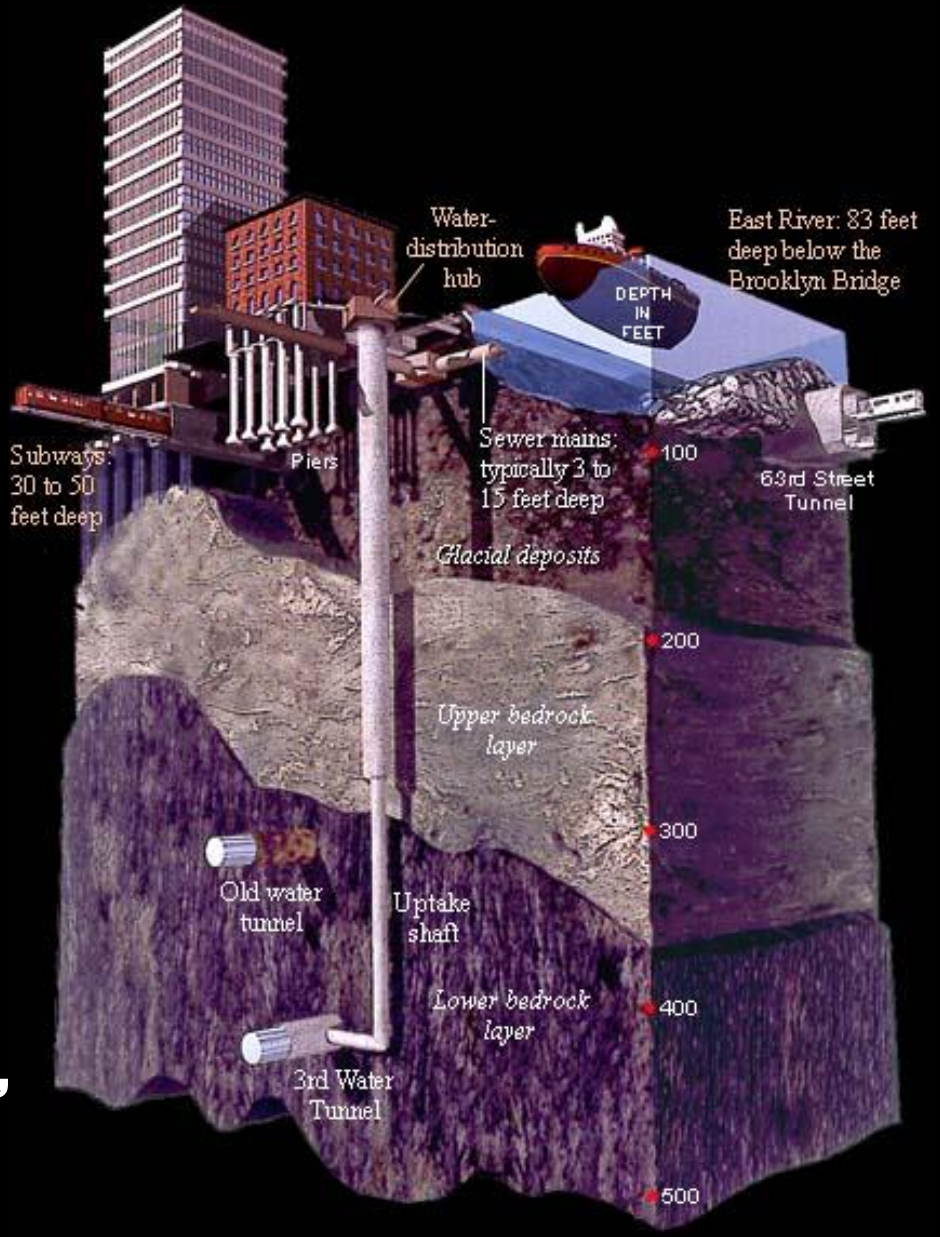
NYC TBM Projects (1971-2010)

West Side Interceptor
63rd Street Tunnel
Brooklyn Water Tunnel
Queens Water Tunnel
Con Edison Steam Tunnel
Manhattan Water Tunnel
East Side Access Project
Croton Water Tunnel/Plant
No. 7 Line IRT
Second Avenue Subway

NYC TBM Projects

West Side Interceptor

- First TBM Tunnel in NYC
- Two 9,000 Tunnels
- S=11' / N=8.5' Diameter
- ~Jul 1971 - Jul 1973
- Jarva Mark 12-1200
- Last 1,100' D&B Mined in Inwood Marble
- Hartland Formation (S) and Manhattan Schist (N)
- 488 Button Cutters in 8955'
- Penetration = 4.5'/Hr in 11'



NYC TBM Projects

63rd Street Tunnels

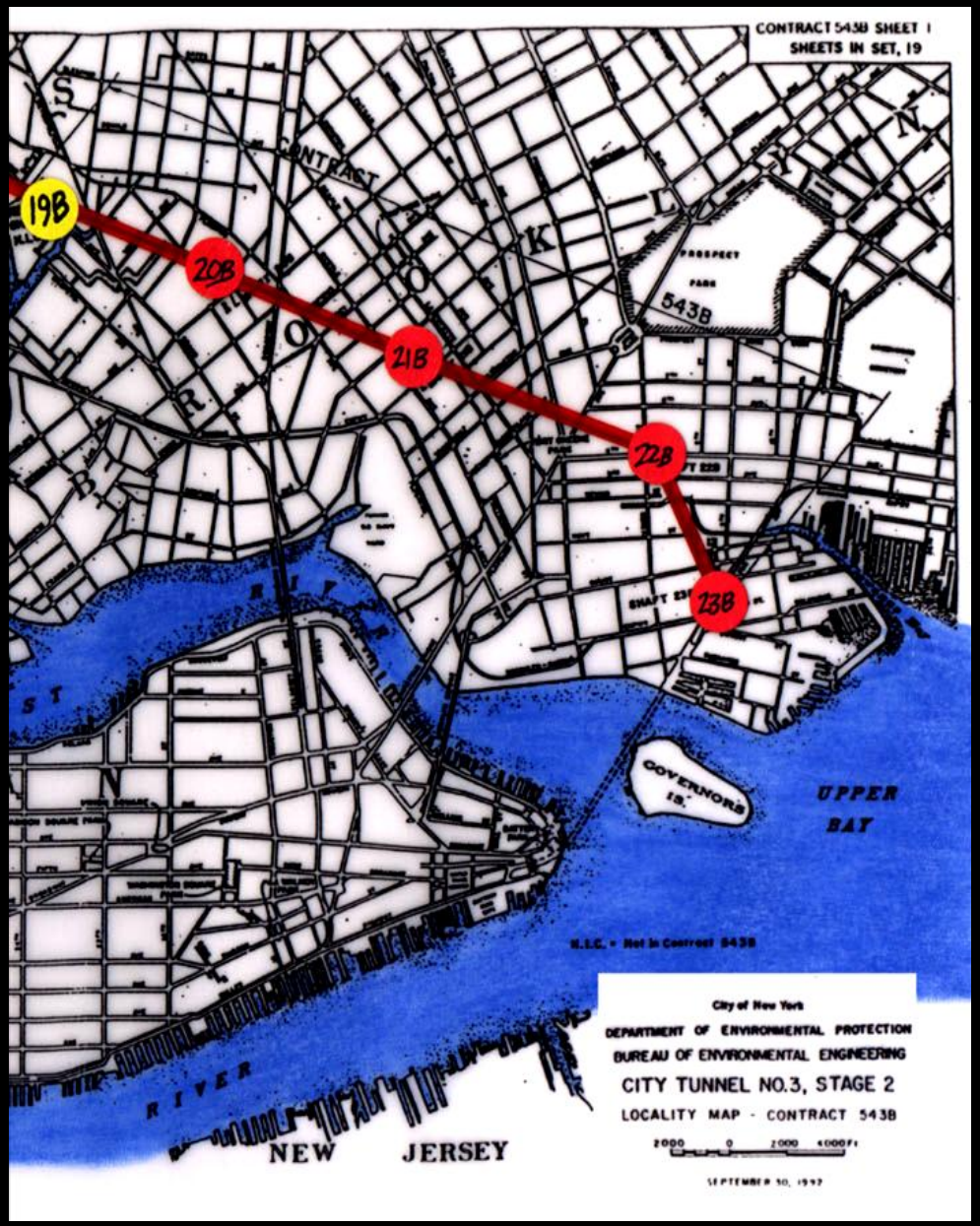
- Twin Tunnels - 4 Tracks
- Robbins 203-205 TBM
- Diameters 20.17'/22'
- Feb 1980 - May 1980
- Immersed Tube First
- Lower Level for LIRR
- Fordham Gneiss and Hartland Formation
- Penetration = 4.31'/Hr

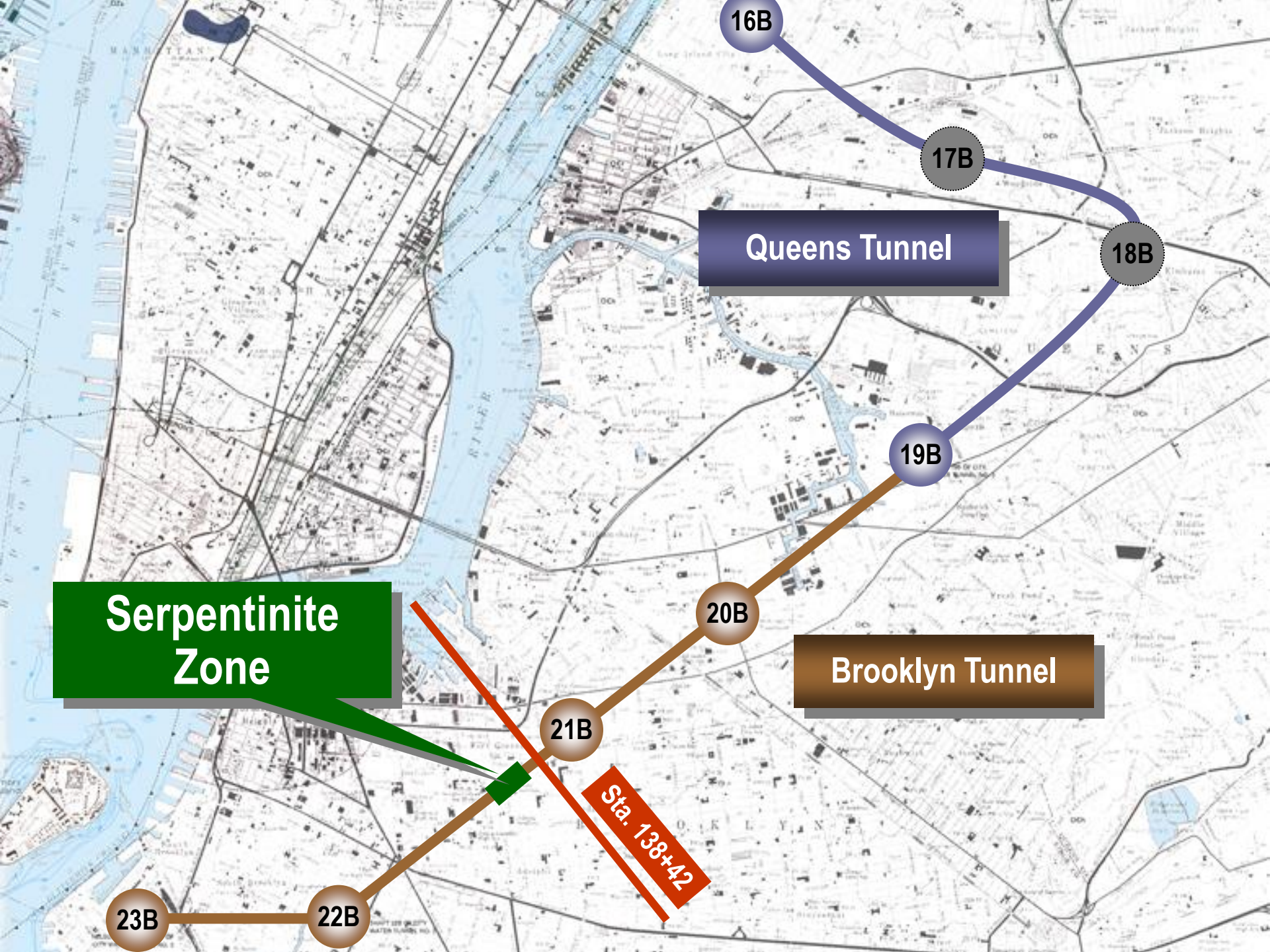
May 1980

NYC TBM Projects

Brooklyn Water Tunnel

- Open Beam TBM from 63rd Street Tunnel Job
- July 1994 – Jan 1997
- 19’ Diameter; 5.5 Mi
- Variable Penetration Through Zones A, B, C
- Fordham Gneiss and Walloomsac Schist
- Penetration = ~10’/Hour




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

Major Serpentinite Zone

Brooklyn Tunnel – Sta. 128+30

Schistose Rock

16B

17B

Queens Tunnel

18B

19B

Zone C

20B

21B

Zone B

Brooklyn Tunnel

Zone A

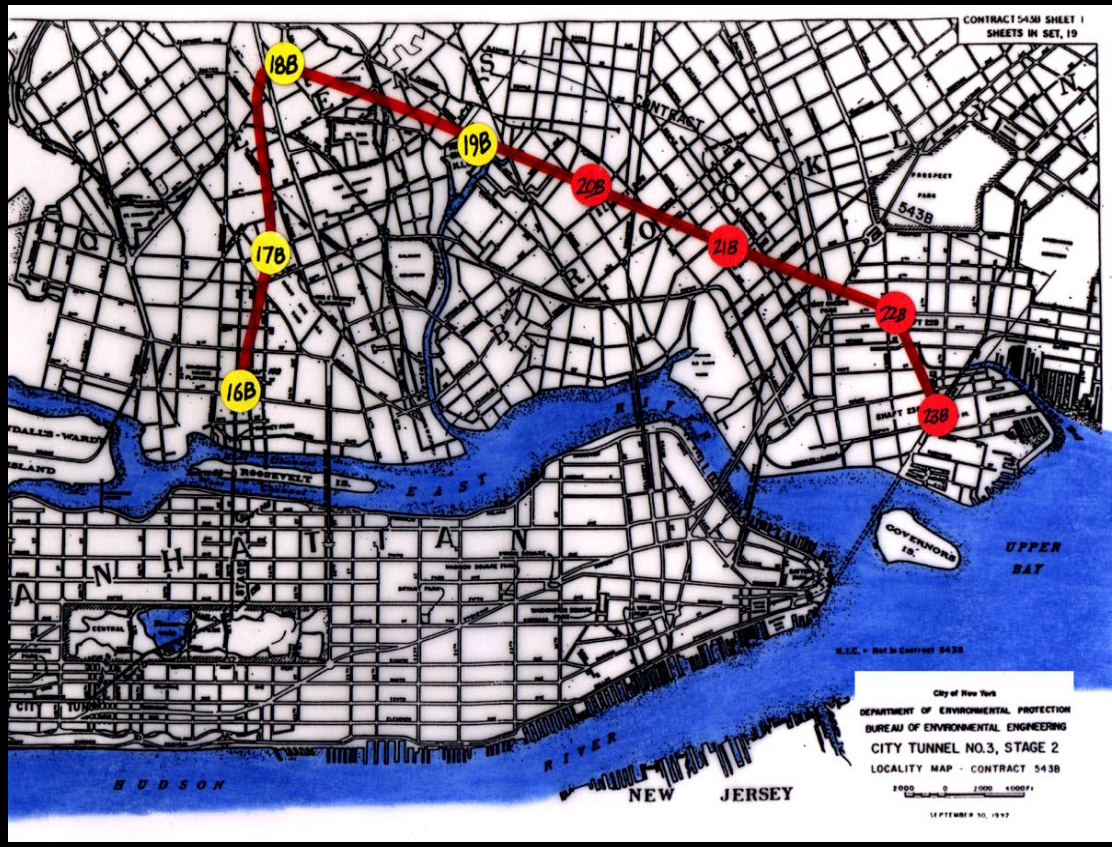
23B

22B

NYC TBM Projects

Queens Water Tunnel

- Open Beam HP TBM
- Oct 1996 - Oct 1999
- 19” Cutters; 4.76 Mi
- Garnet Zones (10%)
- Dike Swarm
- NNE Fault System
- Intersecting Faults
- Subhorizontal Fabrics
- QTC = Fordham Gneiss
- Penetration = 5.82’/Hr

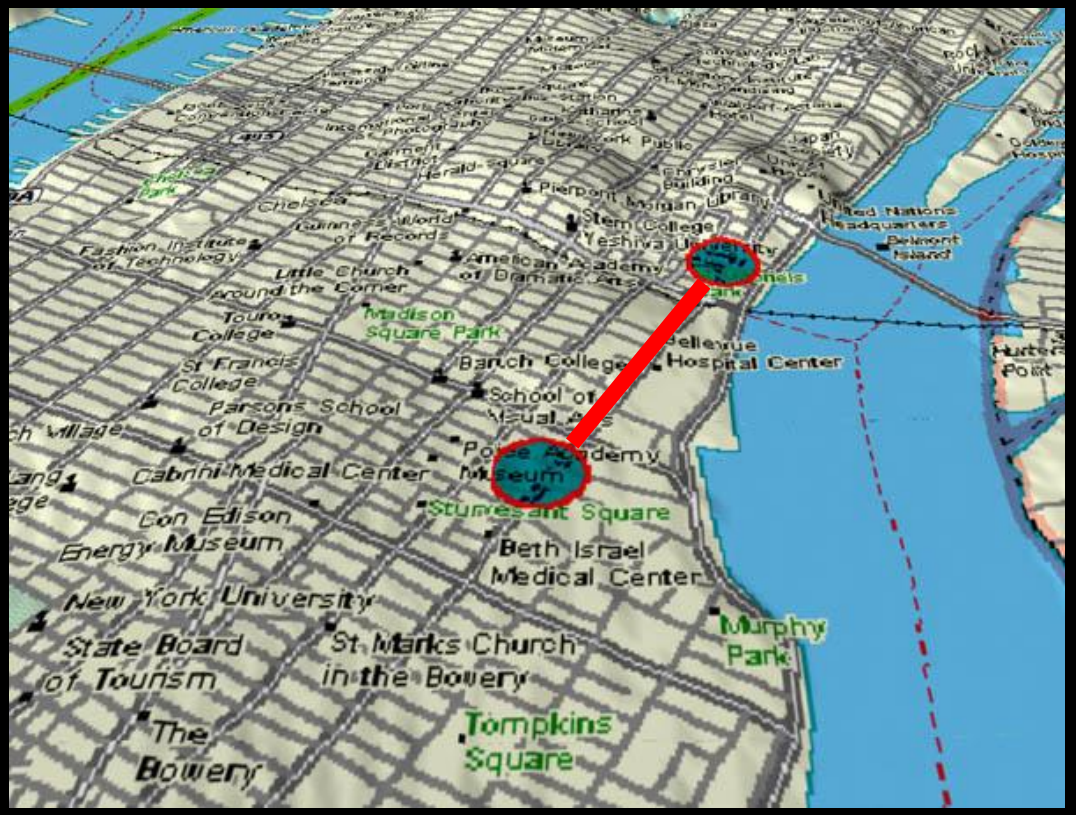


NYC TBM Projects

Con Edison Steam Tunnel

- 12.5’ Open Beam HP 215-257 TBM
- 17” Cutters; Length 0.76 Mi
- Oct 2002 - Feb 2003
- Hartland Formation
- Penetration = ~9’/Hr


Robbins HP 215-257




South Heading
Hartland Foliation NW Dip


Station 15+20

NYC TBM Projects

Manhattan Water Tunnel

- Retrofitted Con Ed Steam TBM
- Separate Drives (N, S, E-W)
- Length 9.04 Mi
- Diam 12.5’; 17” Cutters
- Hartland Formation
- Penetration = 13.6’/Hr

NYC TBM Projects

East Side Access Project

- Diam = 22’; 7.7 Mi; 19” Cutters
- Gently Inclined Hartland
- Seli Double Shield (7’/Hr)
  Robbins Open Beam (10’/Hr)
- Penetration Max = 15’/Hr

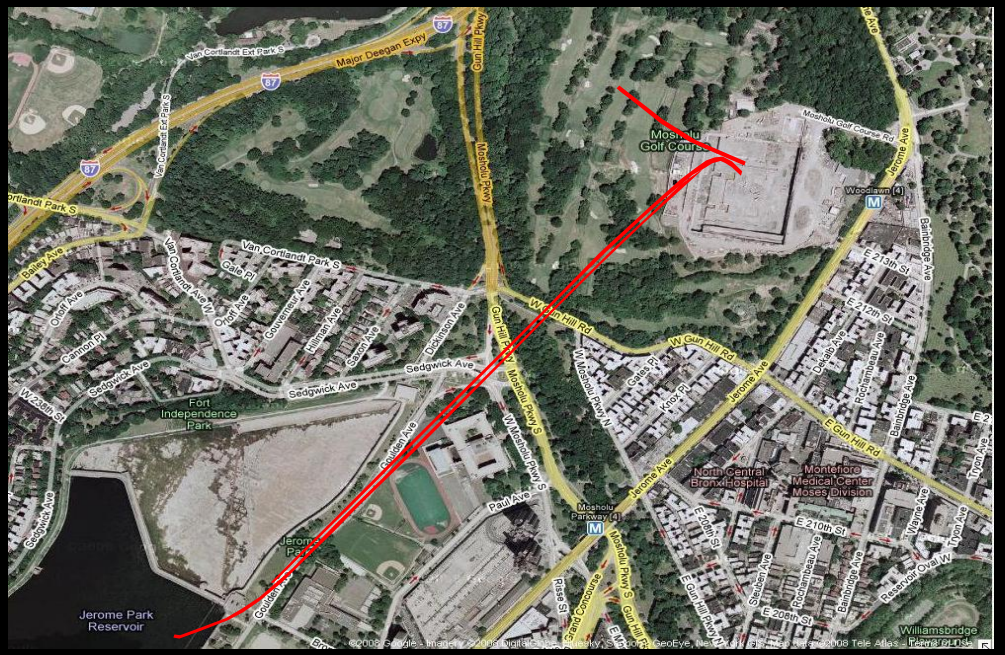

GCT


GCT

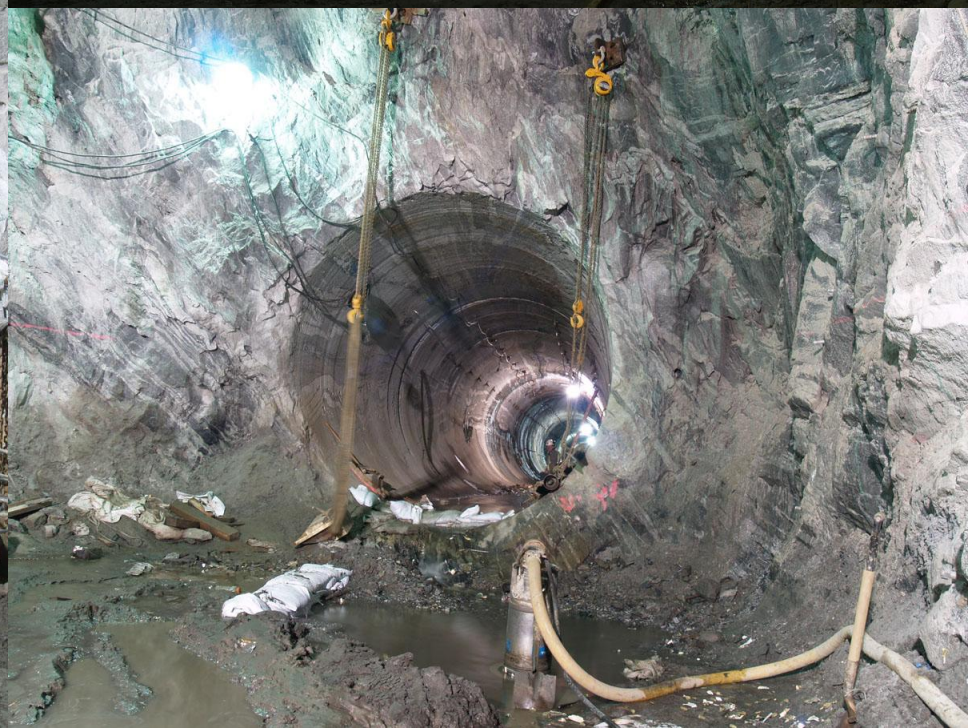
NYC TBM Projects

Croton Water Tunnel/Plant

- Retro-fit Manhattan TBM
- 17” Cutters (27 Total)
- Low 3,650’; Hi 3,150’; Raw 865’
- Diam = 13.5’; Length 1.29 Mi
- Bid as D&B; ~250 Mining Days Saved w/ TBM
- Fordham, Yonkers Gneiss
- Penetration = ~10’/Hr



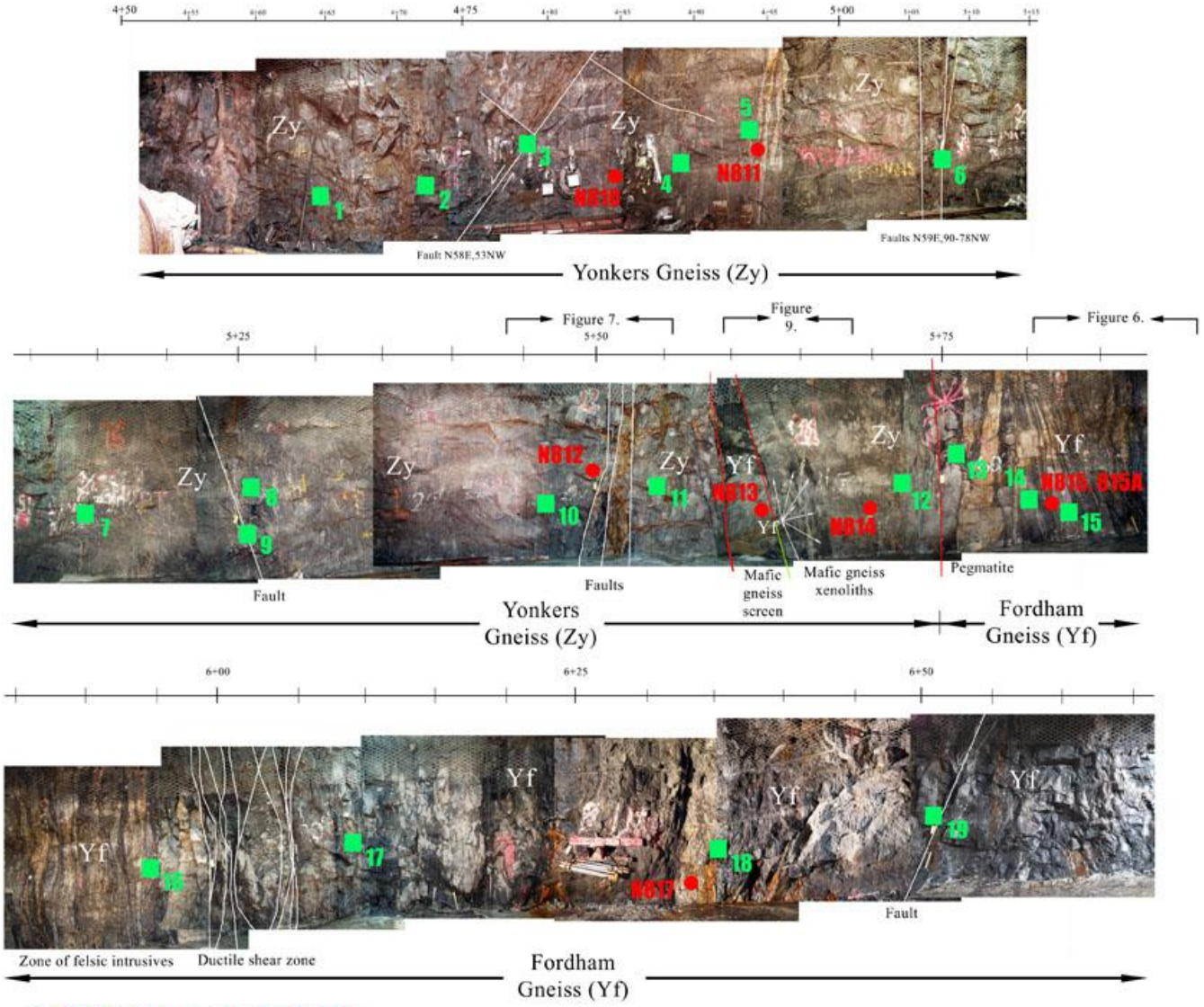



Yf
Low Water Tunnel (New Croton Aqueduct) – Jan 2009


Raw Water Tunnel – 865’

Croton Water Treatment Plant, Bronx New York - North Wall Raw Water Tunnel, Stations 4+50 to 6+65



● Rock Sample ■ Field Stations

Mapping by C. Merguerian 2009

NYC TBM Projects

No. 7 Line IRT Extension

- Double Shielded TBMs
- 34th Street Cavern - D&B
- Diam = 22.5'; Length 1.78 Mi
- Hartland Formation
- 4,700' One Year (~16'/Day) with Installed Segments

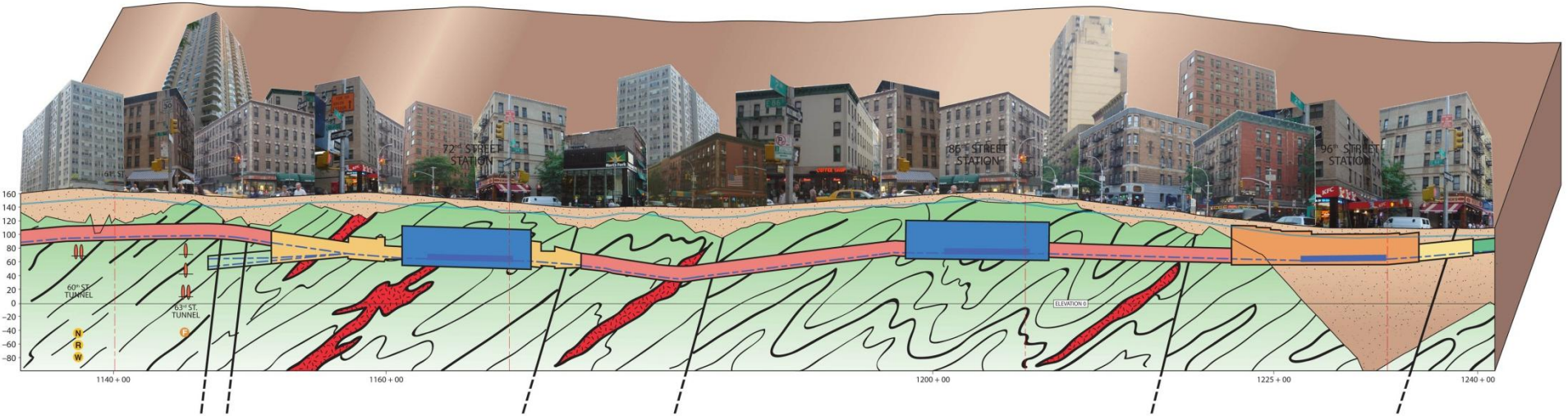
July 2010

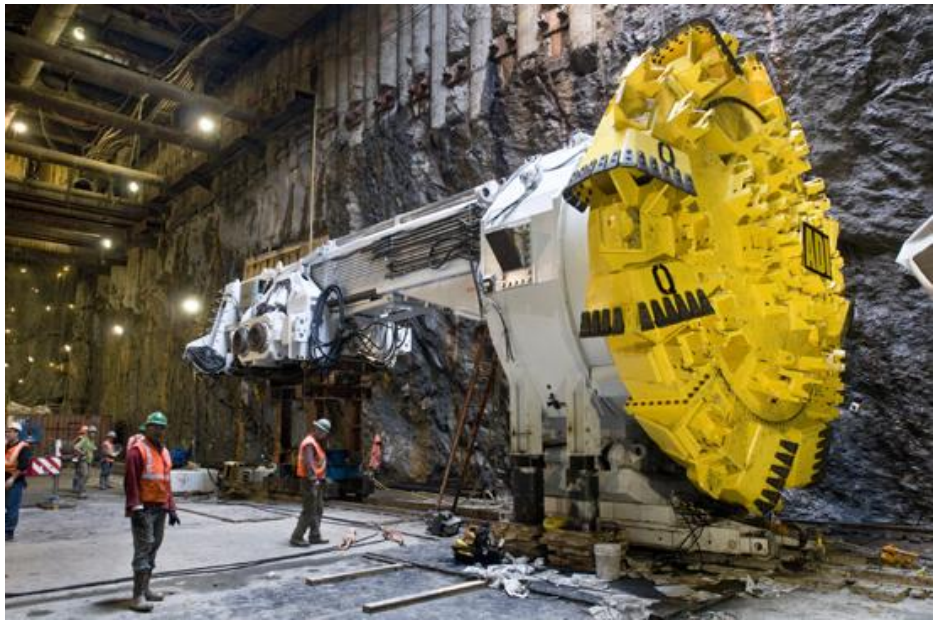
NYC TBM Projects

Second Avenue Subway

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

Threading The Needle





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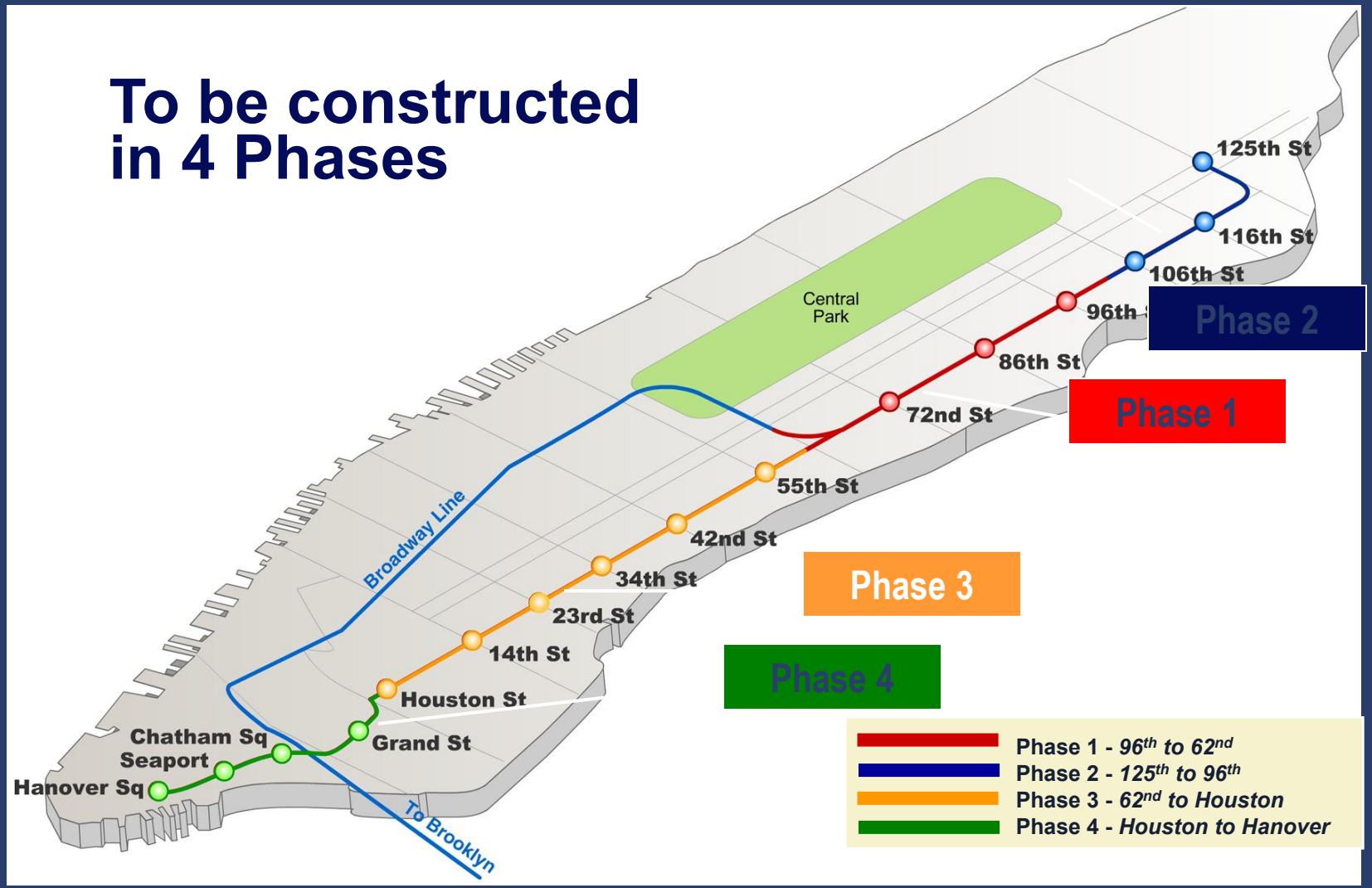
Project Phases

To be constructed in 4 Phases



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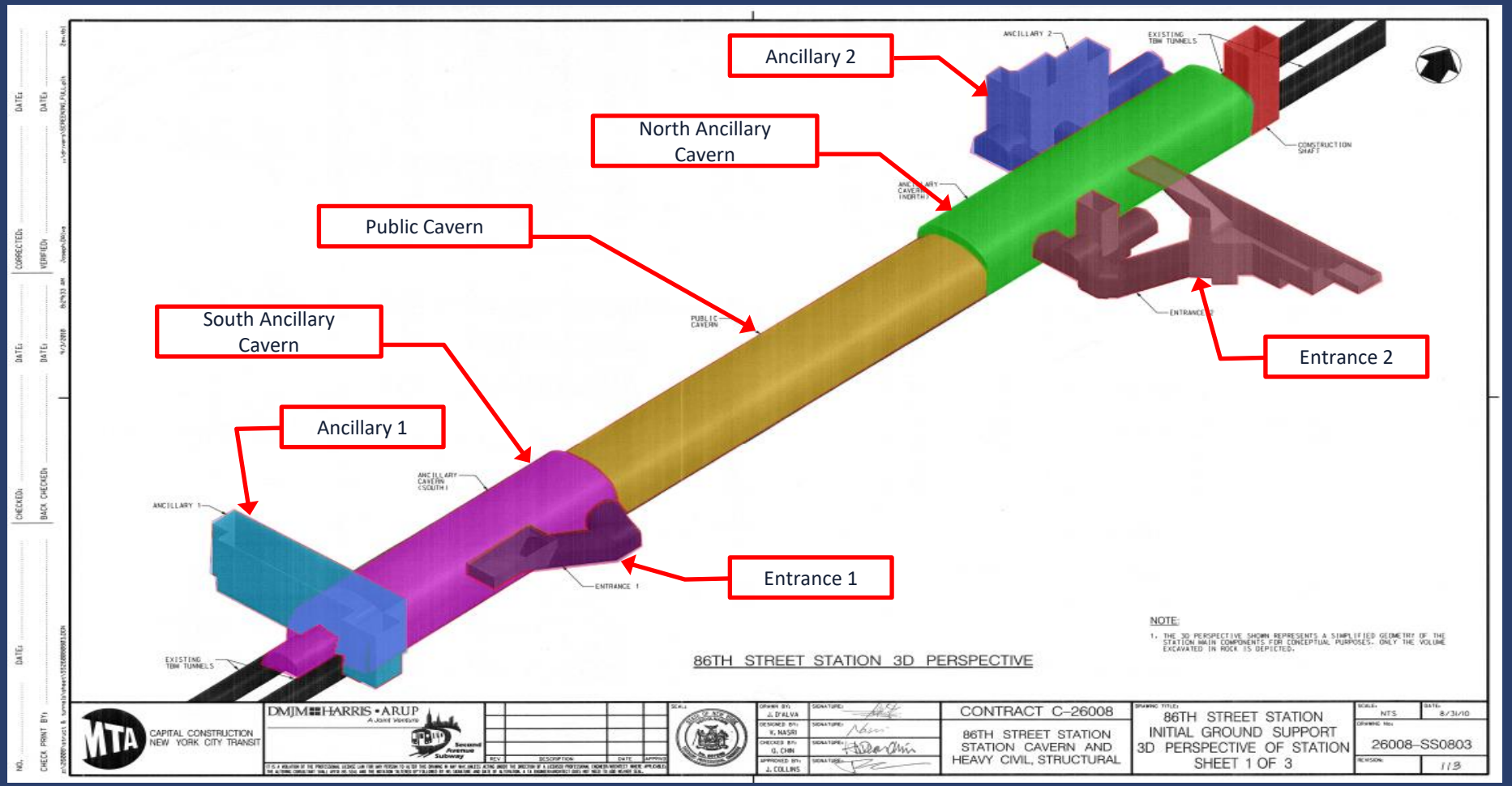
Project Overview

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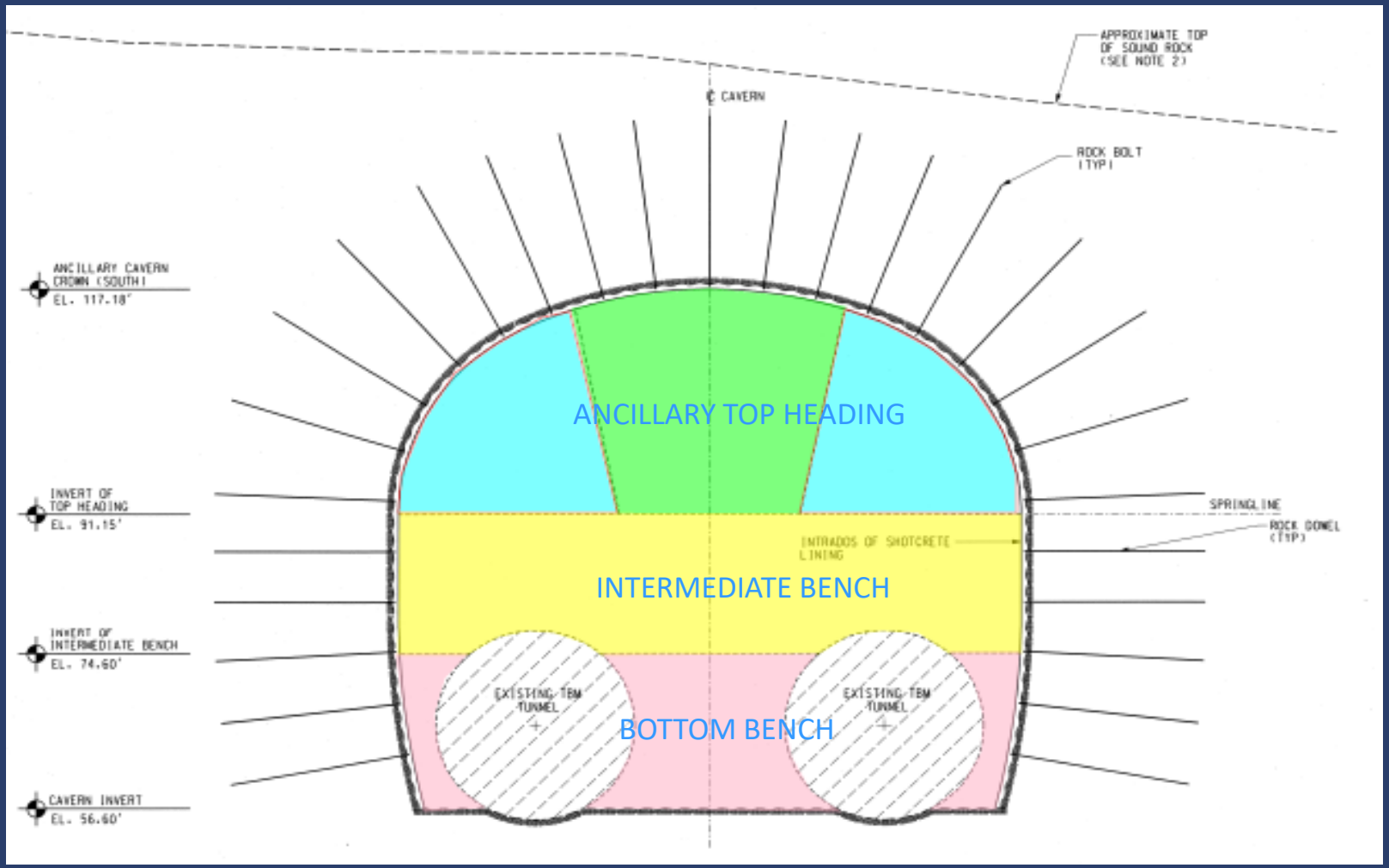
Ancillary Cavern Excavation

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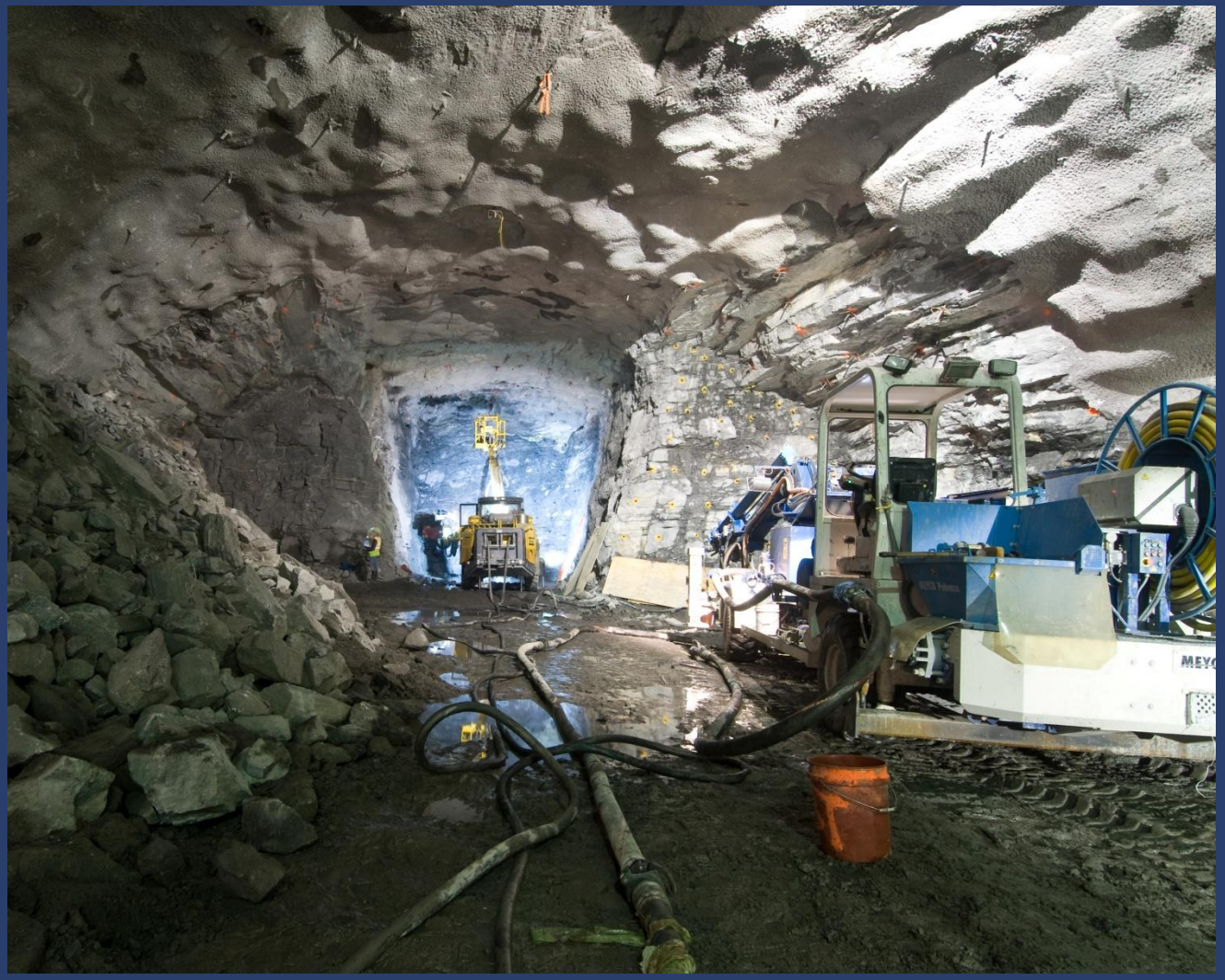

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Can Geologic Studies Help Predict TBM Penetration Destiny?

Pre-Bid Analysis Should Include:

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

Factors: TBM Penetration Destiny

Intrinsic Factors (Penetration Rate)

- UCS
- Fracture Density – RQD/Recovery
- Faults/Joints
- Mineralogy
- Hardness/Density
- Rock Type
- Texture/Metamorphic Grade
- Fabric Orientation/Development

Episodic Factors (Utilization)

- Convergent Fault Zones
- Unusual Rock Types/Structures
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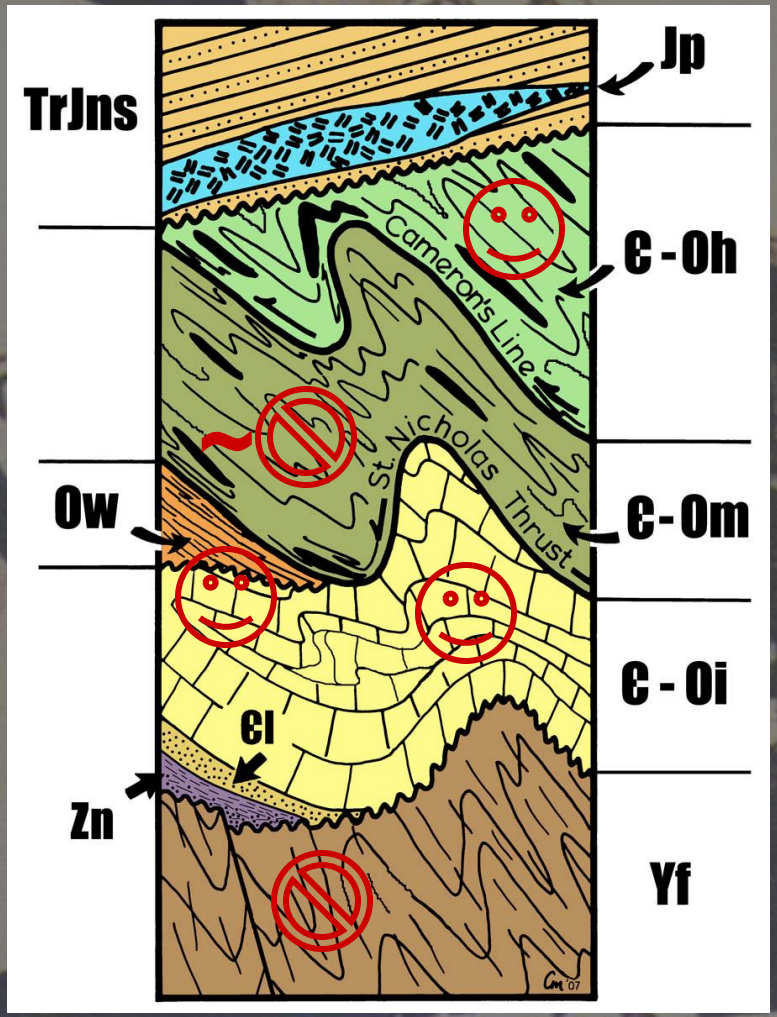
- Water Inflows




OK, That's It! I've Heard Enough!
H. Manne

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