14th Annual Conference on Geology of Long Island and Metropolitan New York

State University of New York at Stony Brook

Long Island Geologists

Measuring Engineering Properties of NYC Rocks Using a Schmidt Rebound Hammer

Preliminary Results

Presented by:

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Why Measure the Engineering Properties of New York City Rocks?

C. Merguerian and C.J. Moss, 2005

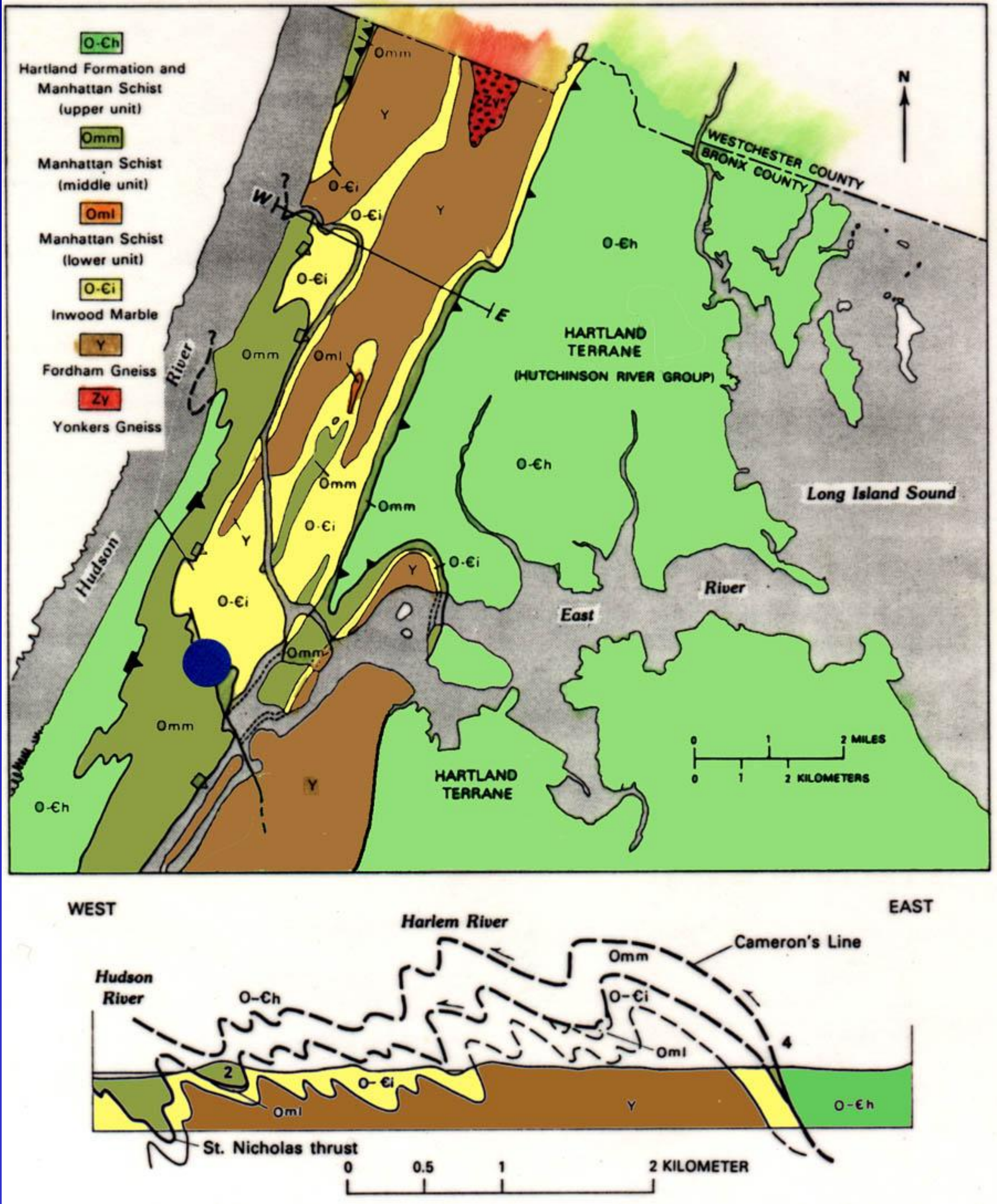
- *Complex geology*
- *Qualitative assessment based upon judgment*
- *No means of field assessment which is quantitative & economical*

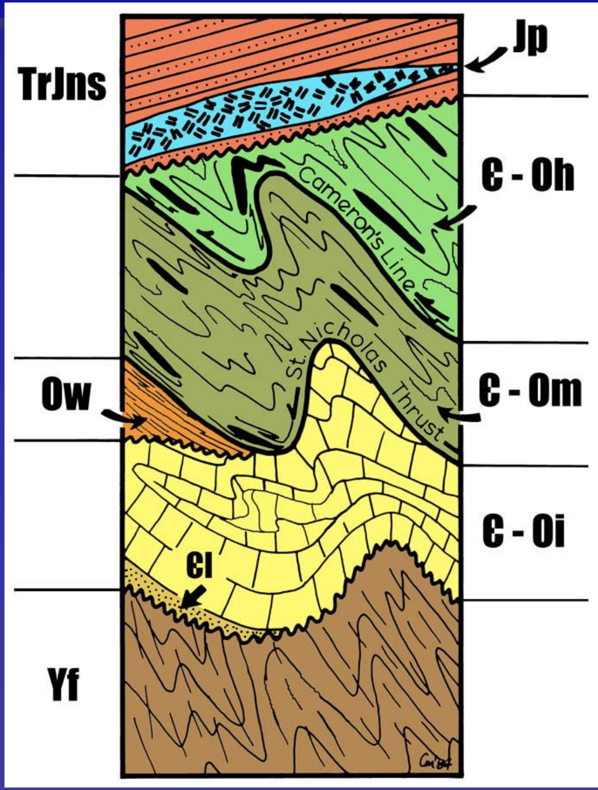
Basement excavations

Underground works

D.A. Vellone, 2005

Geology of New York City





Merguerian, 2001

Stratagraphic Chart of NYC Bedrock:

Triassic and Younger Strata

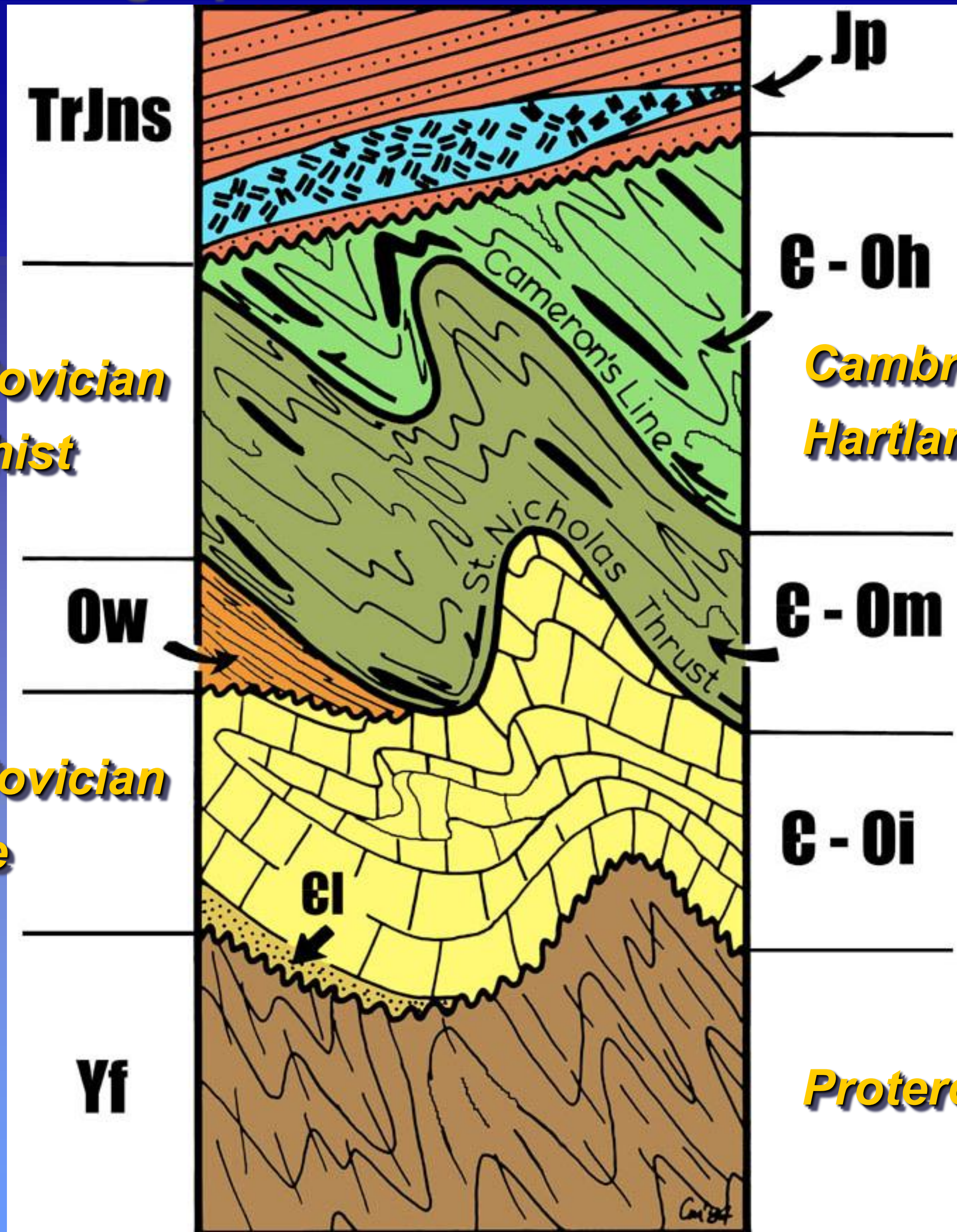
Palisades Diabase

Cambrian-Ordovician Manhattan Schist

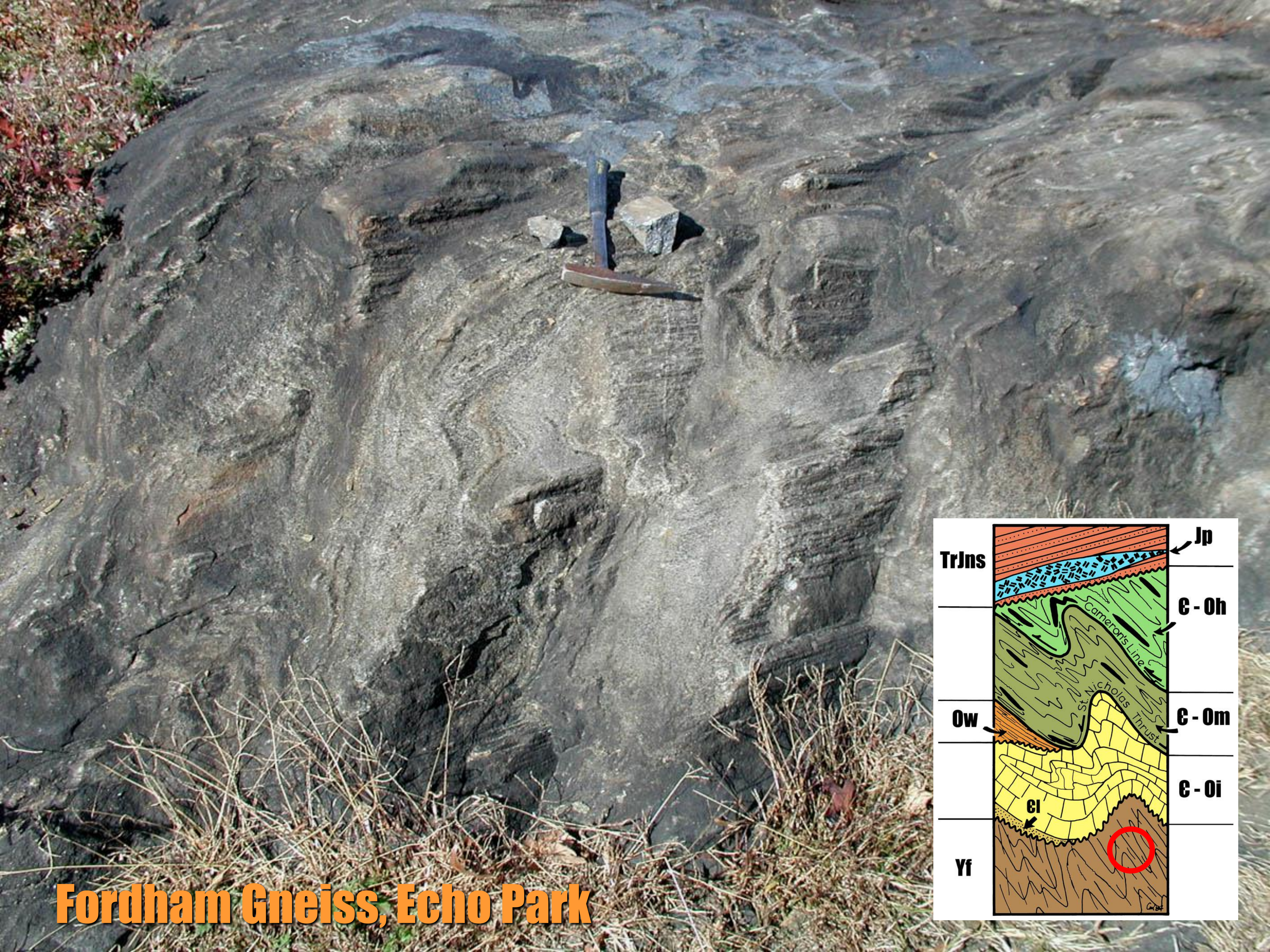
Cambrian-Ordovician Hartland Schist

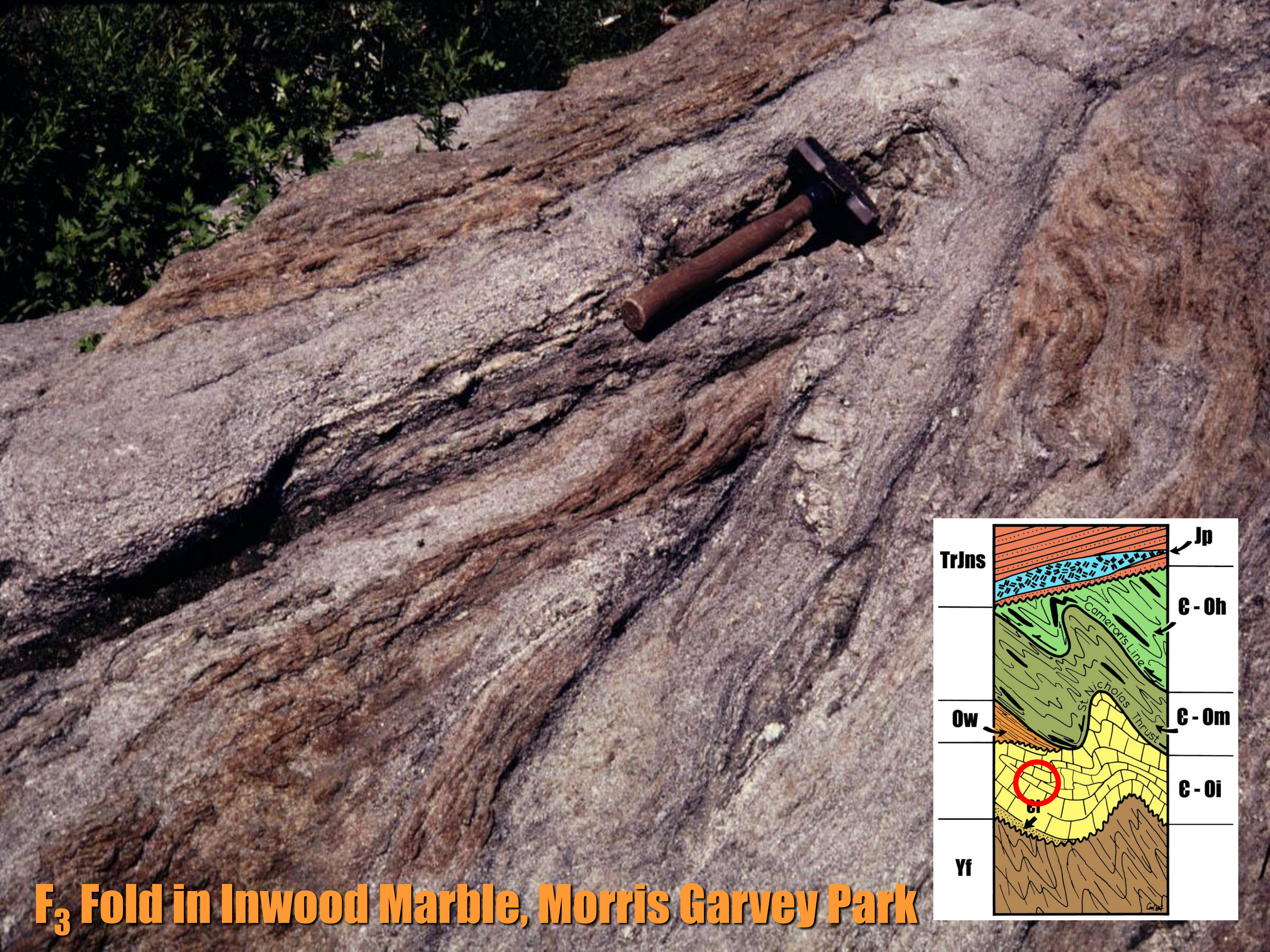
Walloomsac Schist

Cambrian-Ordovician Inwood Marble

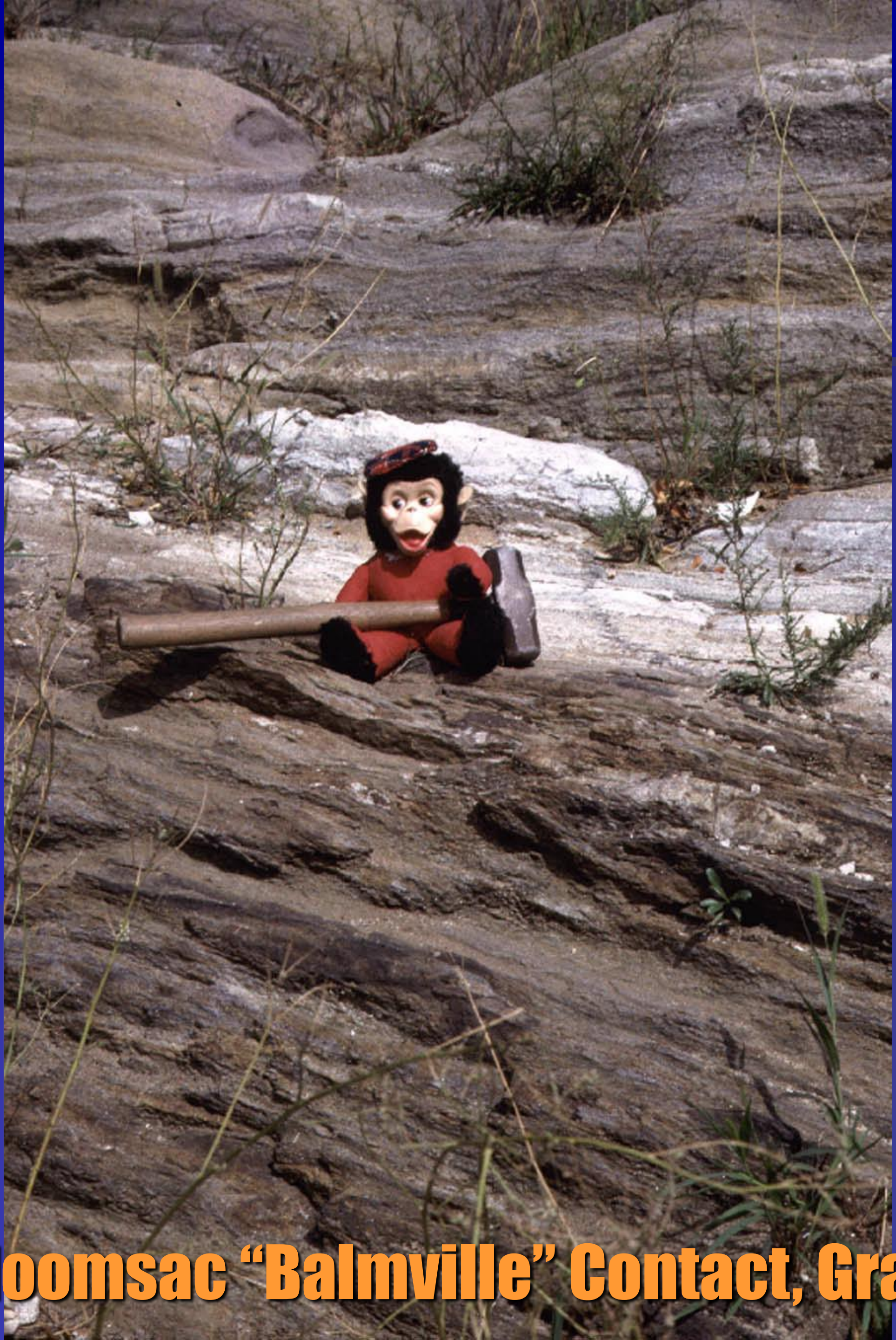


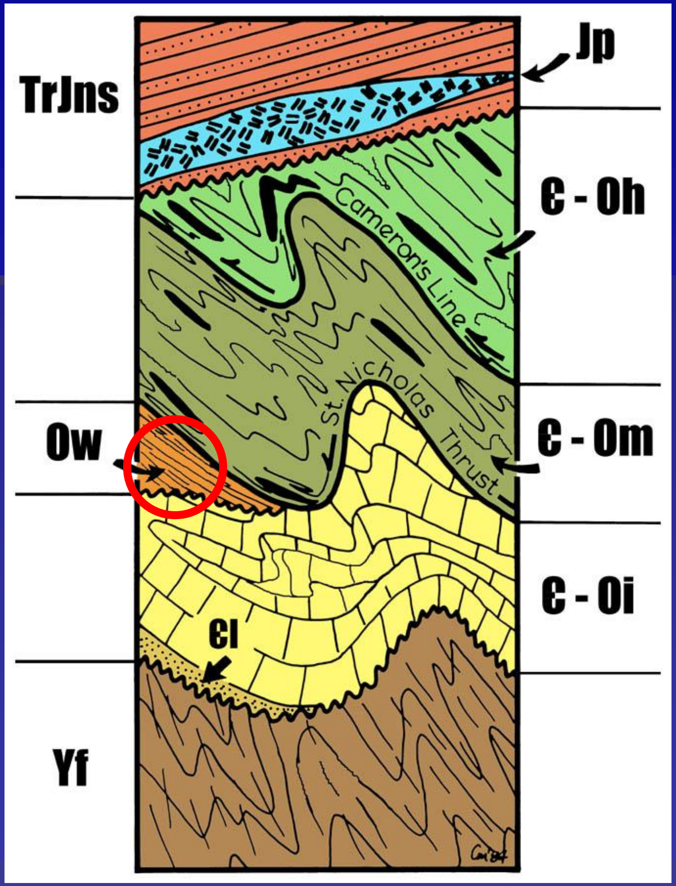
Proterozoic Fordham


Fordham Gneiss, Echo Park
TrJns
Jp
Є - Oh
Cameron's Line
St. Nicholas Thrust
Ow
Є - Om
Є - Oi
Єl
Yf

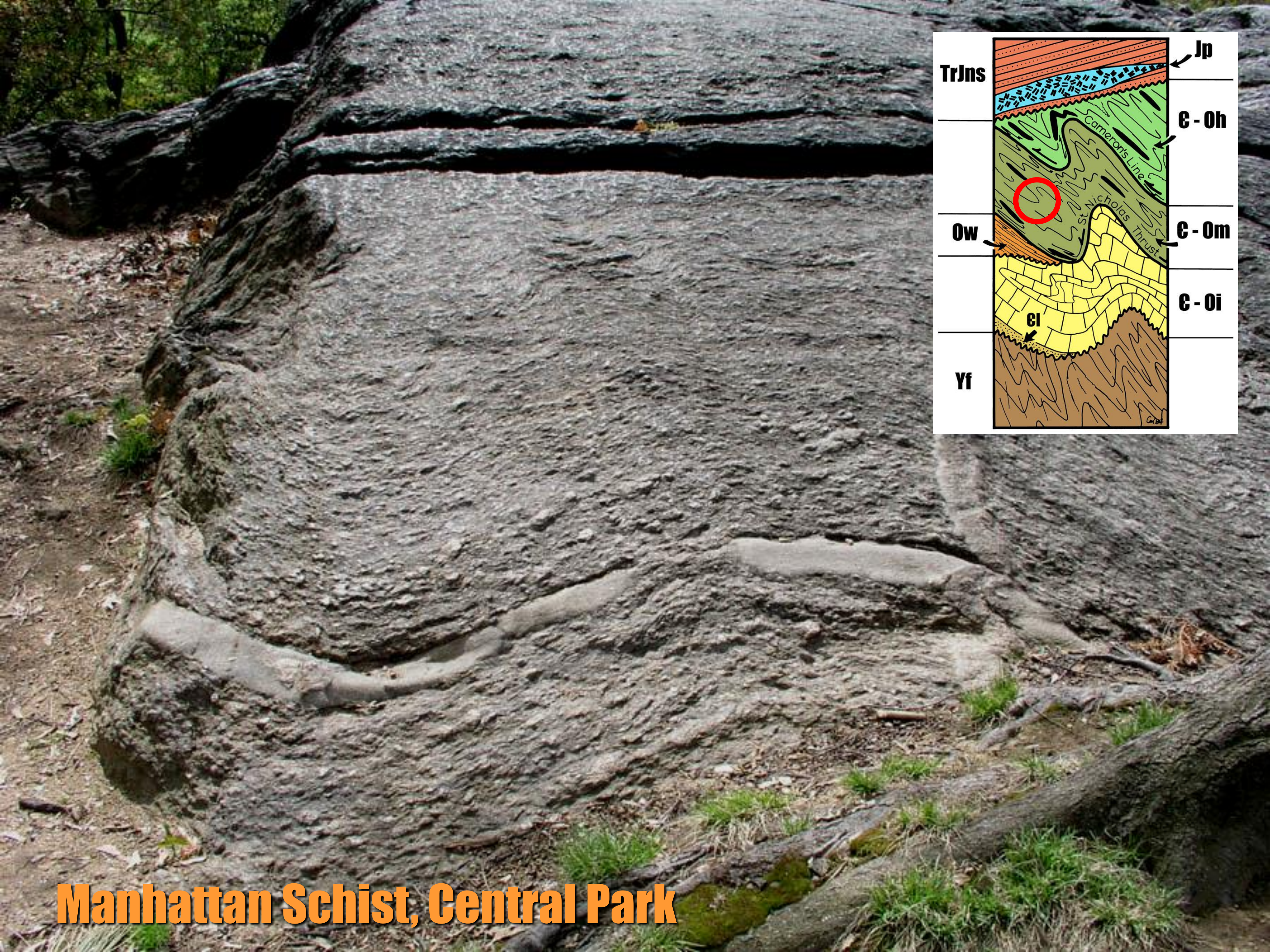


F_3 Fold in Inwood Marble, Morris Garvey Park





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



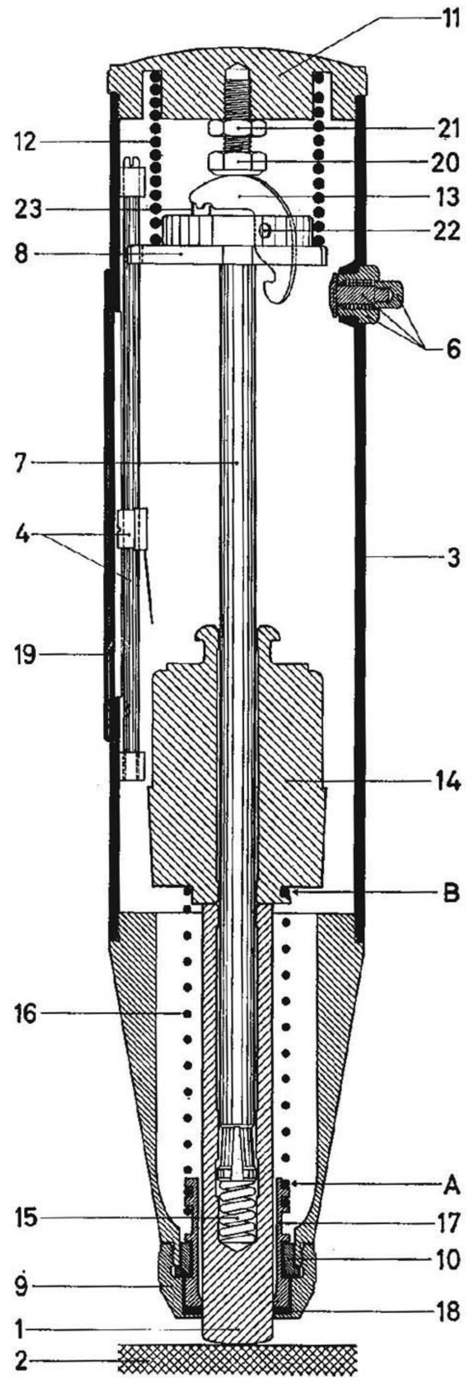
Manhattan Schist, Central Park


Retrograde Muscovite after Kyanite

Hartland Schist, Riverside Park


Hartland Amphibolite N567

Type L Schmidt hammer for field testing of rock strength



1 Impact Plunger
2 Test surface
3 Housing
4 Rider with guide rod
5 Not used
6 Push button, complete
7 Hammer guide bar
8 Guide disk
9 Cap
10 Two-part ring
11 Rear Cover
12 Compression spring
13 Pawl
14 Hammer mass
15 Retaining spring
16 Impact spring
17 Guide sleeve
18 Felt washer
19 Plexighlas window
20 Trip screw
21 Lock nut
22 Pin
23 Pawl spring
24 Screw
25 Conversion curves label

Longitudinal Section

Select Works of Prior Researchers

Baskerville (1987):

U.S.G.S. Open File Report: "Unconfined compressive strength on rock samples representative of the types found in Bronx County, NY"

Li, Rupert, Summers and Santi (2000):

"Analysis of impact hammer rebound to estimate rock drillability"

Katz, Reches and Roegiers (2000):

"Evaluation of mechanical rock properties using a Schmidt Hammer"

Bilgin, Dinçer and Copur (2002):

"The performance prediction of impact hammers from Schmidt hammer rebound values in Istanbul metro tunnel drivages"

Dinçer and Acar, Çobanoğlu and Uras (2004):

"Correlation between Schmidt hardness, uniaxial compressive strength and Young's modulus for andesites, basalts and tuffs"

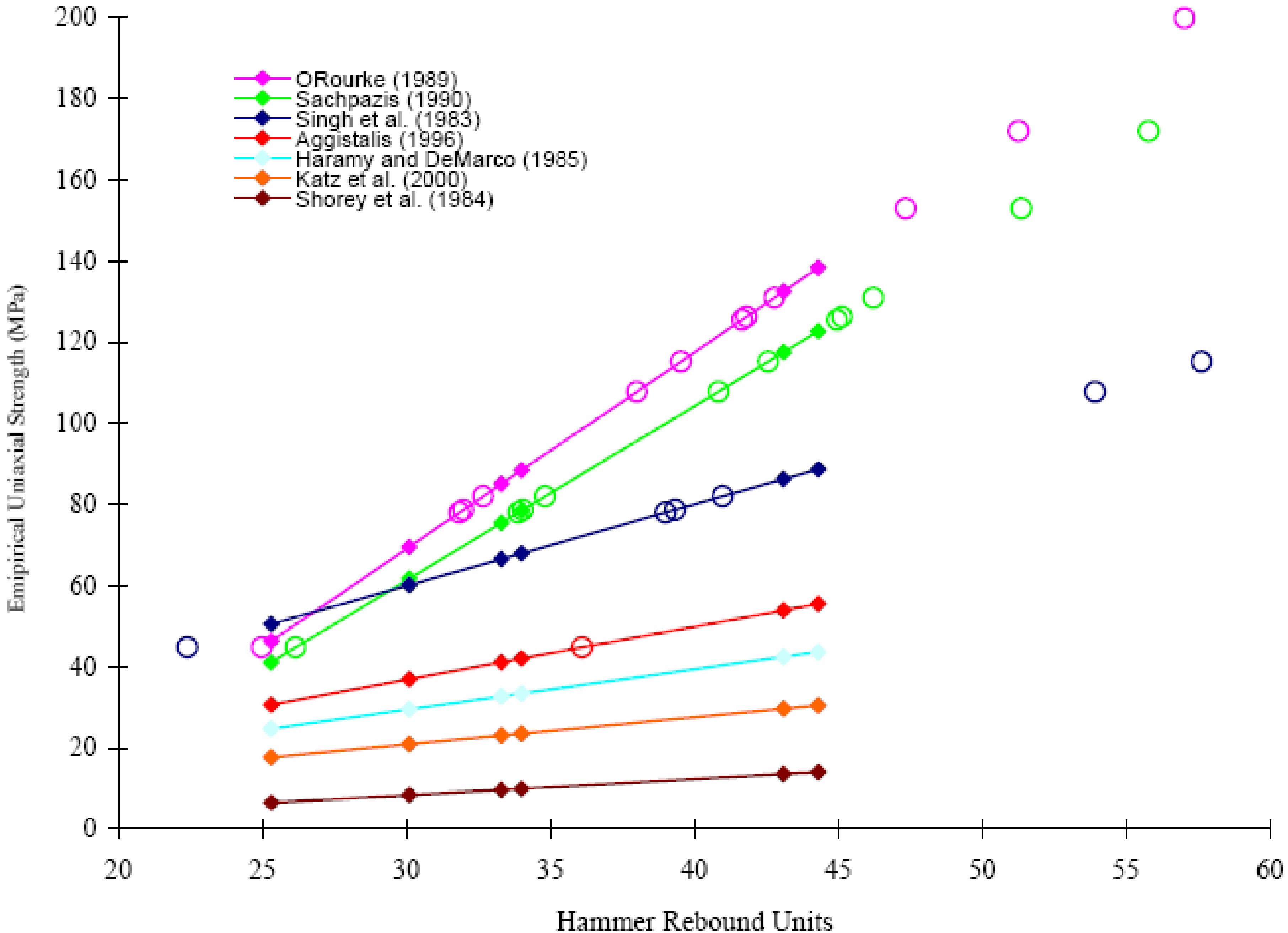
Table 1. Empirical relationship between UCS and the impact generated rebound hardness number (H_R) of tested rock material, a dimensionless measure reported by others.

Source	Equation*	R	Rock Type(s)
Singh et al. (1983)	UCS = 2 H_R	0.72	30 Sedimentary units
Shorey et al. (1984)	UCS = 0.4 H_R-3.6	0.94	20 Lithological units
Haramy and DeMarco (1985)	UCS = 0.994 H_R-0.383	0.70	10 Lithological units
O'Rourke (1989)	UCS = 702 H_R-11040 (psi)	0.77	Sandstone, Siltstone, Limestone and Anhydrite
Sachpazis (1990)	UCS = (H_R-15.7244) / 0.2329	0.91	33 Lithological units
Aggistalis (1996)	UCS = 1.31H_R-2.52	0.55	Gabbro and basalt
Katz et al. (2000)	UCS = 0.792+0.067 H_R±0.231	0.96	7 Different rock types

R regression coefficient, the notation of H_R was used in lieu of *N* to represent Schmidt values
*Equations as presented in Dinçer et al. 2004.

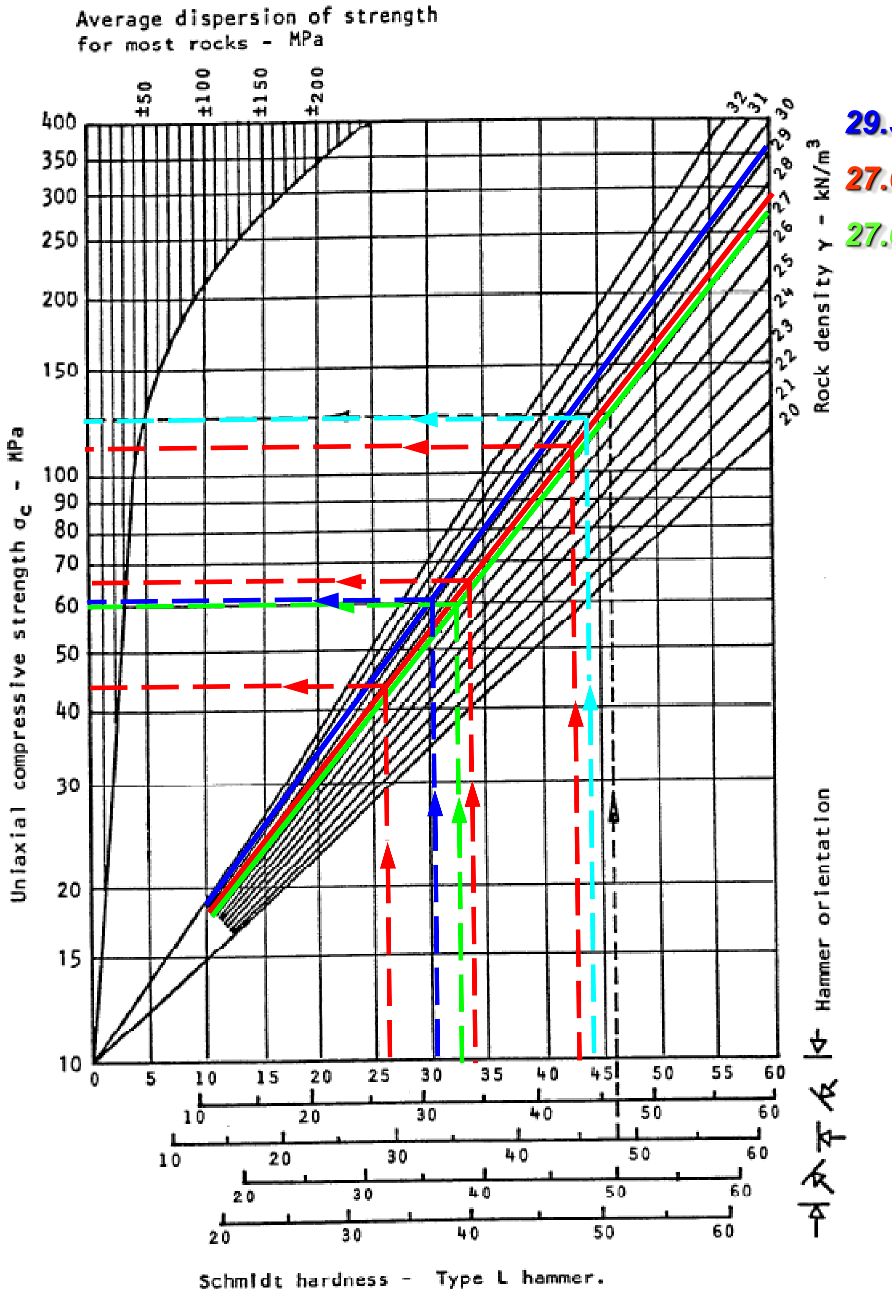
Table 2. Test results by major lithologic categories for all samples as part of this study.

Rock Type	Measurement	Average Measurement	Maximum	Minimum	Standard deviation
Hartland schistose rocks	Schmidt hammer rebound values (H_R)	25.3	35.0	12.0	5.5
Hartland Amphibolites	Schmidt hammer rebound values (H_R)	30.1	39.0	23.0	3.8
Inwood Marble	Schmidt hammer rebound values (H_R)	33.3	42.0	23.0	4.5
Manhattan Schist	Schmidt hammer rebound values (H_R)	34.0	45.0	21.5	4.1
Walloomsac Interlayered schist and calc-silicate	Schmidt hammer rebound values (H_R)	43.1	54.5	29.0	4.6
Fordham Gneiss	Schmidt hammer rebound values (H_R)	44.3	56.5	28.5	3.2


ORourke (1989)
Sachpazis (1990)
Singh et al. (1983)
Aggistalis (1996)
Haramy and DeMarco (1985)
Katz et al. (2000)
Shorey et al. (1984)
Empirical Uniaxial Strength (MPa)
Hammer Rebound Units
0
20
40
60
80
100
120
140
160
180
200
20
25
30
35
40
45
50
55
60

Schmidt Hammer Nomograph

(From: Hoek & Bray, 1977, *Rock Slope Engineering*, p. 98)

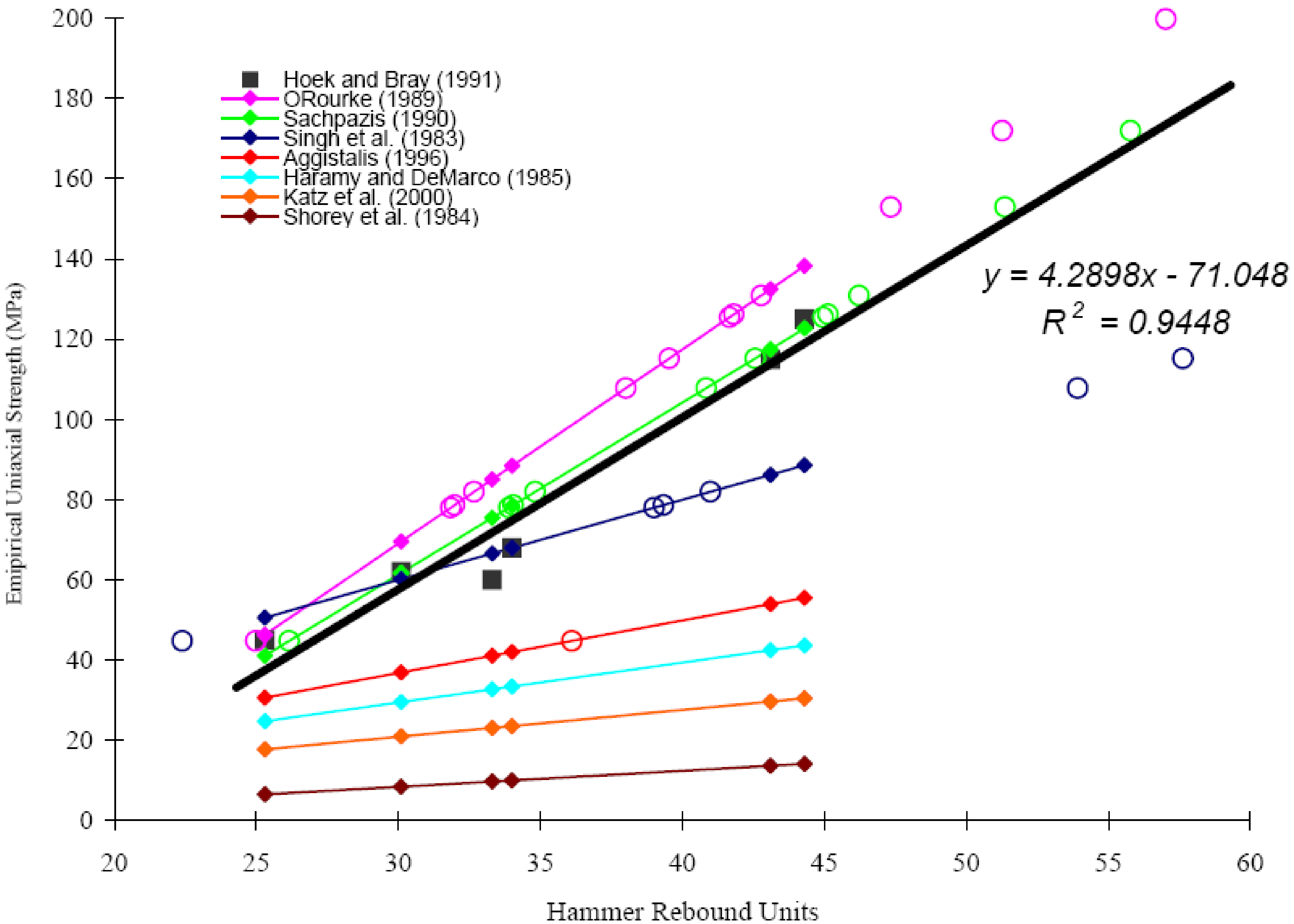


Relationship between Schmidt hardness and the uniaxial compressive strength of rock, after Deere and Miller[100].

Rock Type	Average Rebound Number	UCS (MPa)
Hartland schistose rocks	25.3	45
Hartland Amphibolite	30.1	60
Inwood marble	33.3	62
Manhattan schist	34.0	68
Walloomsac schist	43.1	115
Fordham gneiss	44.3	125

Schmidt hammer nomograph from Hoek & Bray, *Rock Slope Engineering, 3rd ed., 1991, p.92.*

Rock densities from R.E. Goodman, *Rock Mechanics, 2nd ed., 1989, p.33.*



Hoek and Bray (1991)
ORourke (1989)
Sachpazis (1990)
Singh et al. (1983)
Aggistalis (1996)
Haramy and DeMarco (1985)
Katz et al. (2000)
Shorey et al. (1984)
y = 4.2898x - 71.048
R^2 = 0.9448
Empirical Uniaxial Strength (MPa)
Hammer Rebound Units
0
20
40
60
80
100
120
140
160
180
200
20
25
30
35
40
45
50
55
60

Concluding Thoughts…

- *Presently there is no economical means of field assessment of rock strength which is quantitative.*

- *Prior researchers have attempted to develop correlations to various rock types and lithologies, however…*

- *Present correlations do not accurately represent the complex geology which is represented by the rocks of New York City.*

- *Preliminary results are encouraging and support further research to develop equations specific to New York City geology.*

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Q/A

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