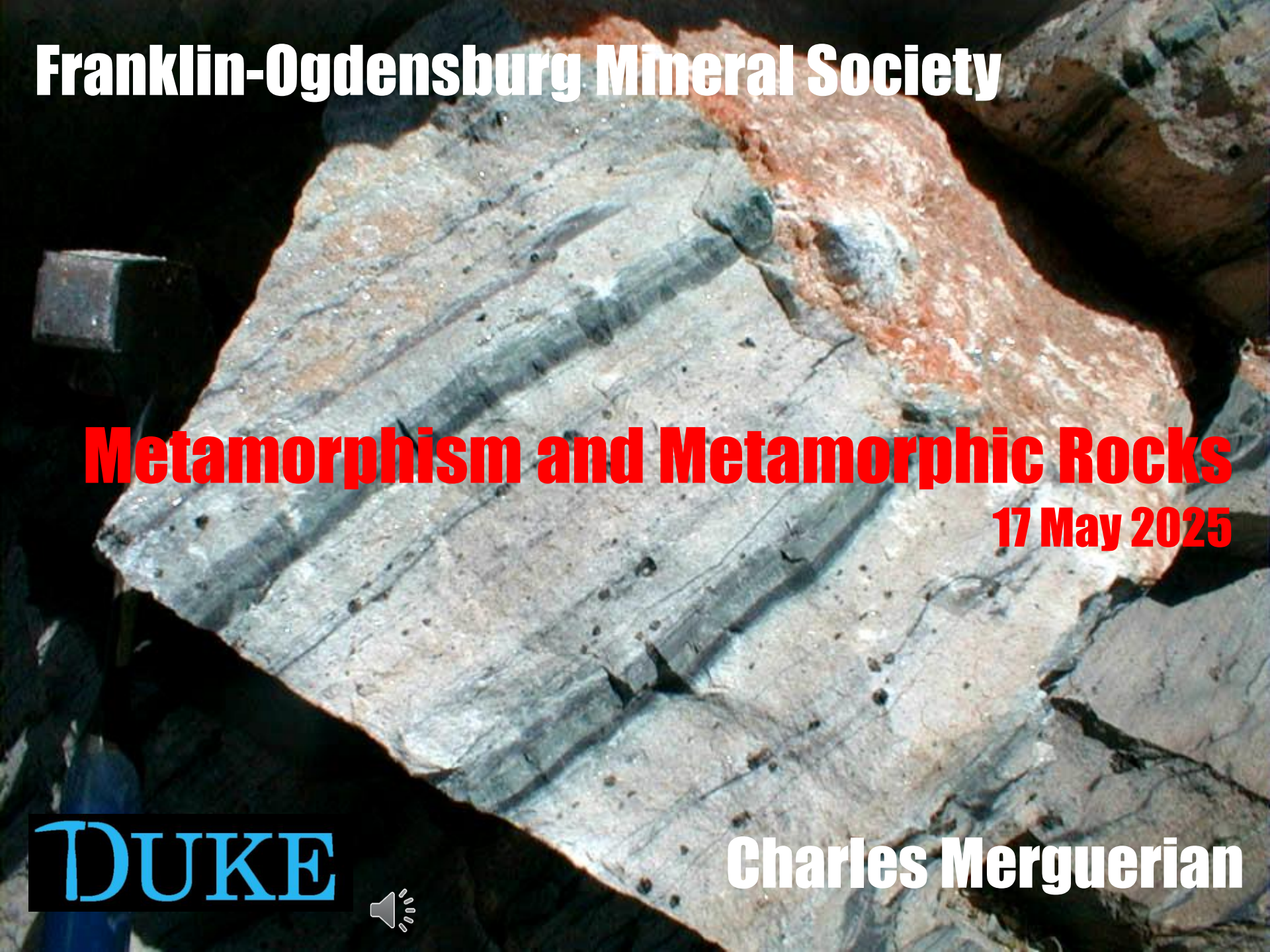
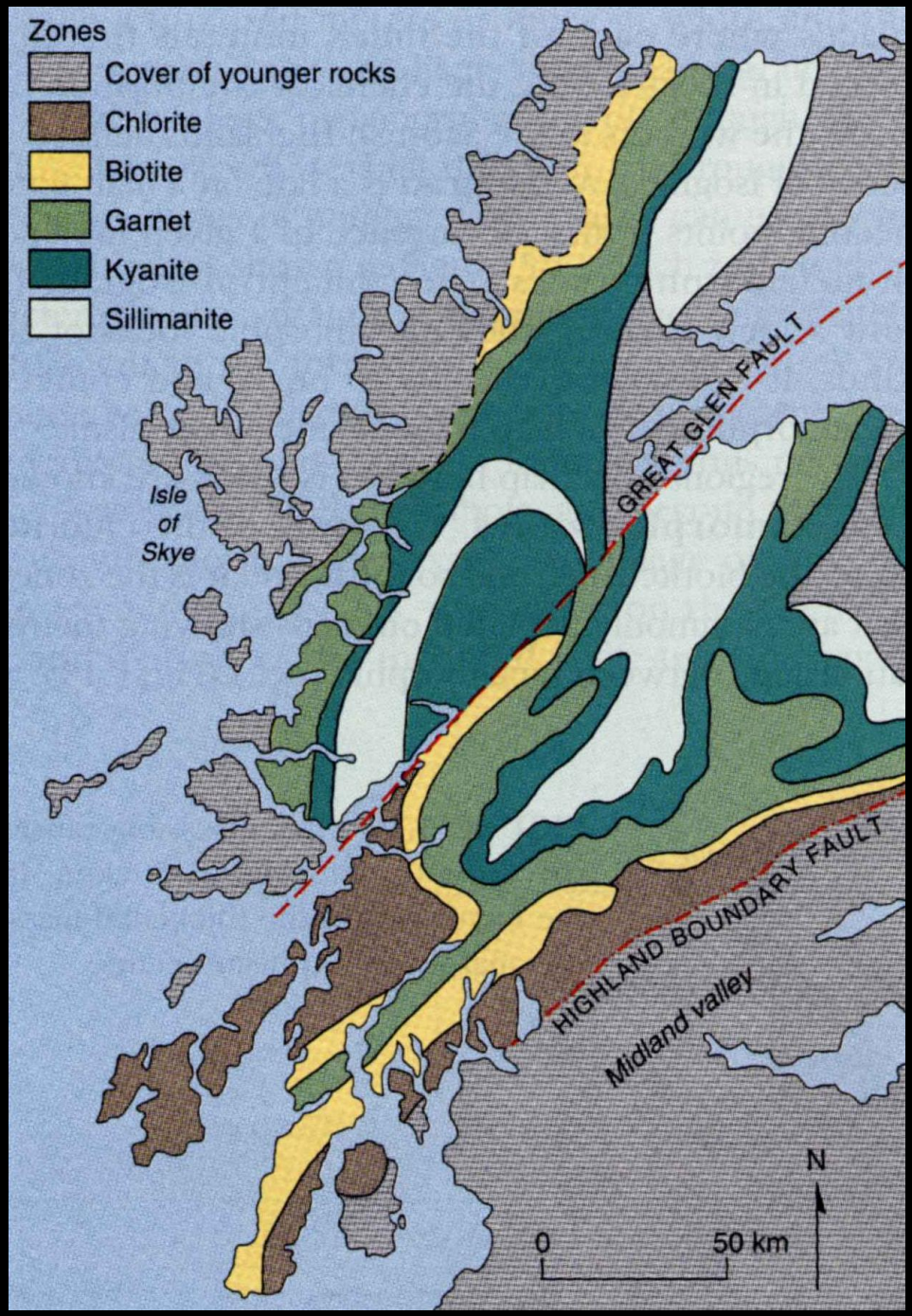
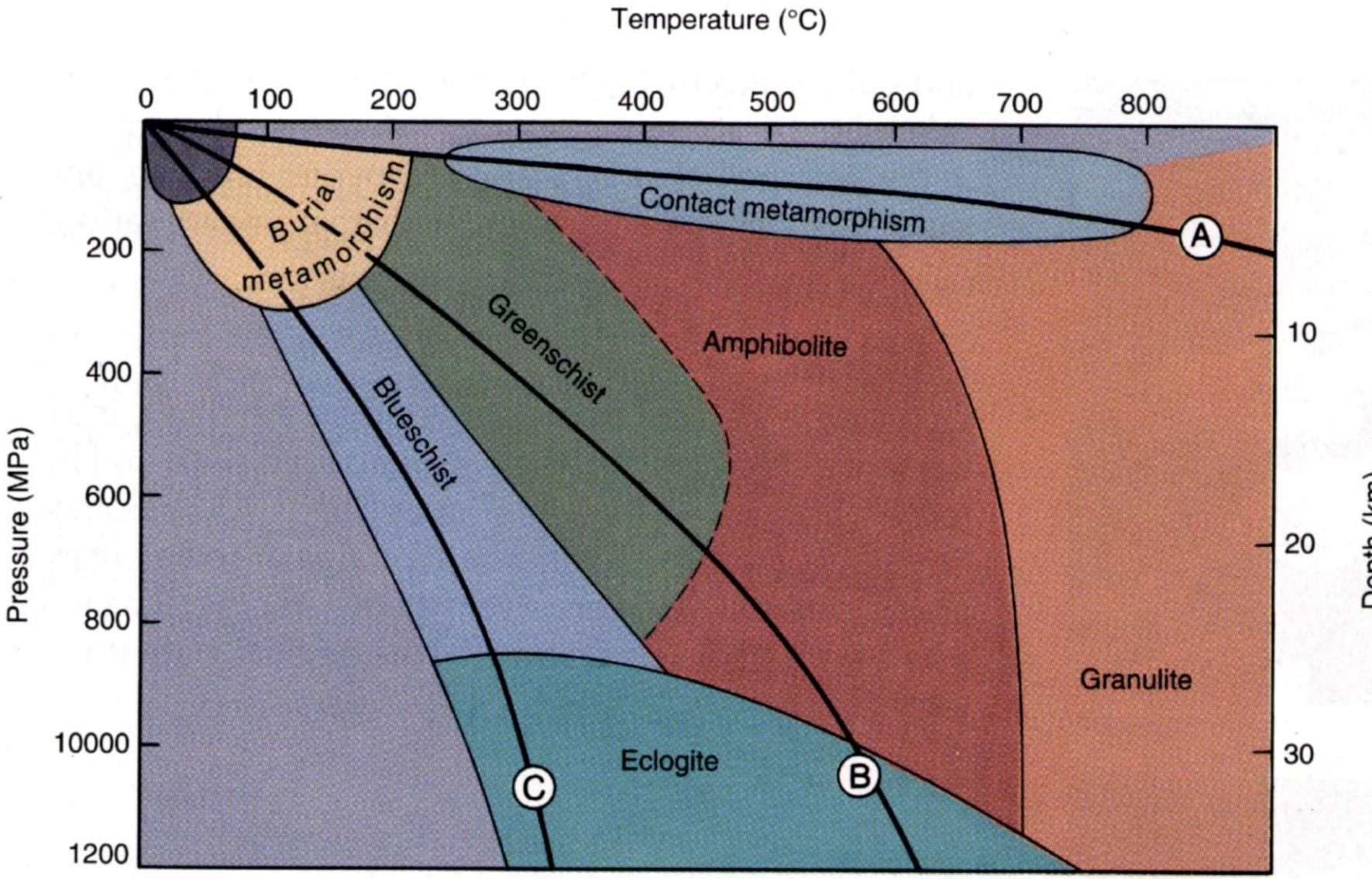

Franklin-Ogdensburg Mineral Society
Metamorphism and Metamorphic Rocks
17 May 2025
DUKE
Charles Merguerian

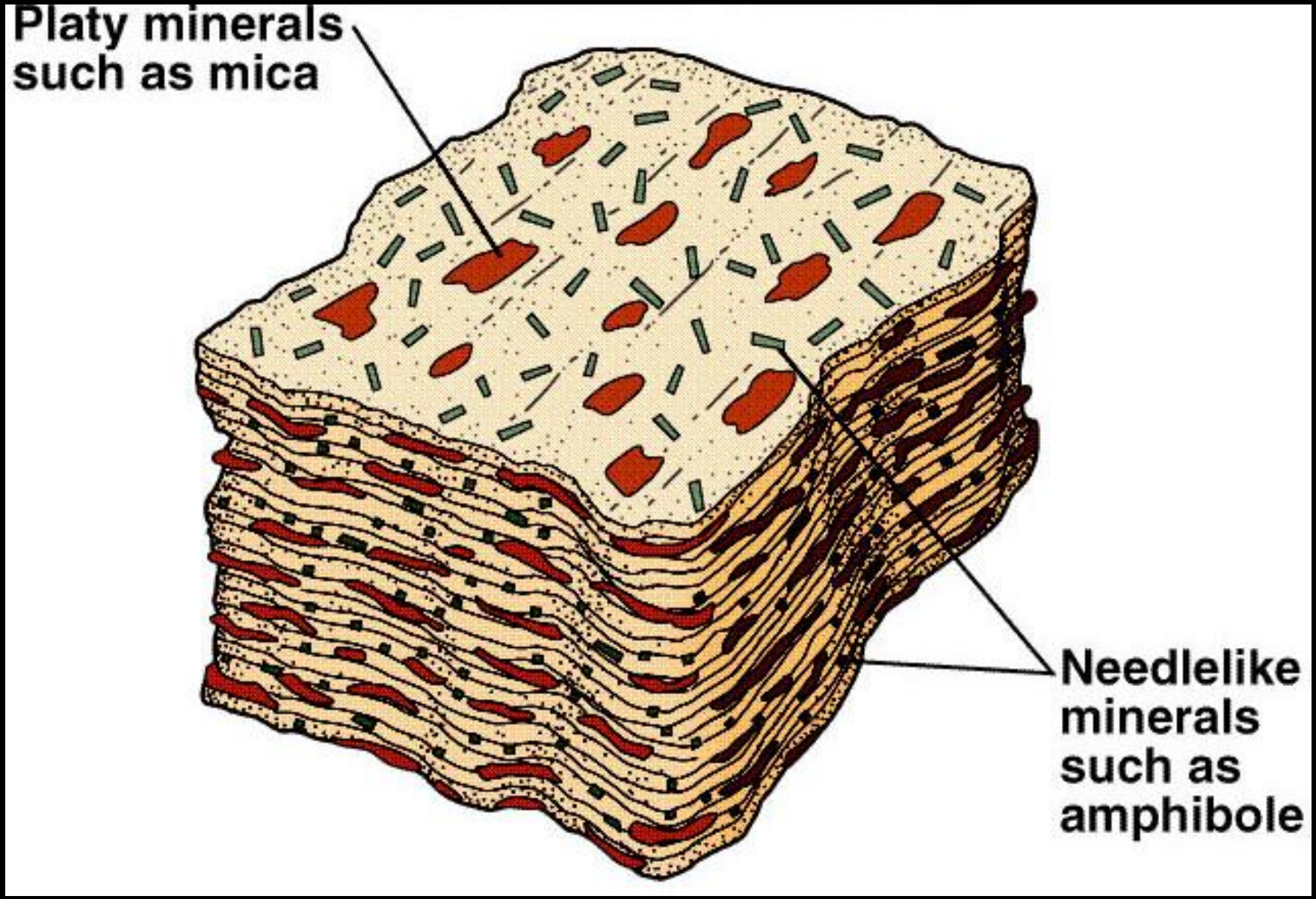

Regional
Foliates vs.
Non-Foliates
Contact
Volcanic vs.
Plutonic
Shock
Dynamic
Ductile vs.
Brittle

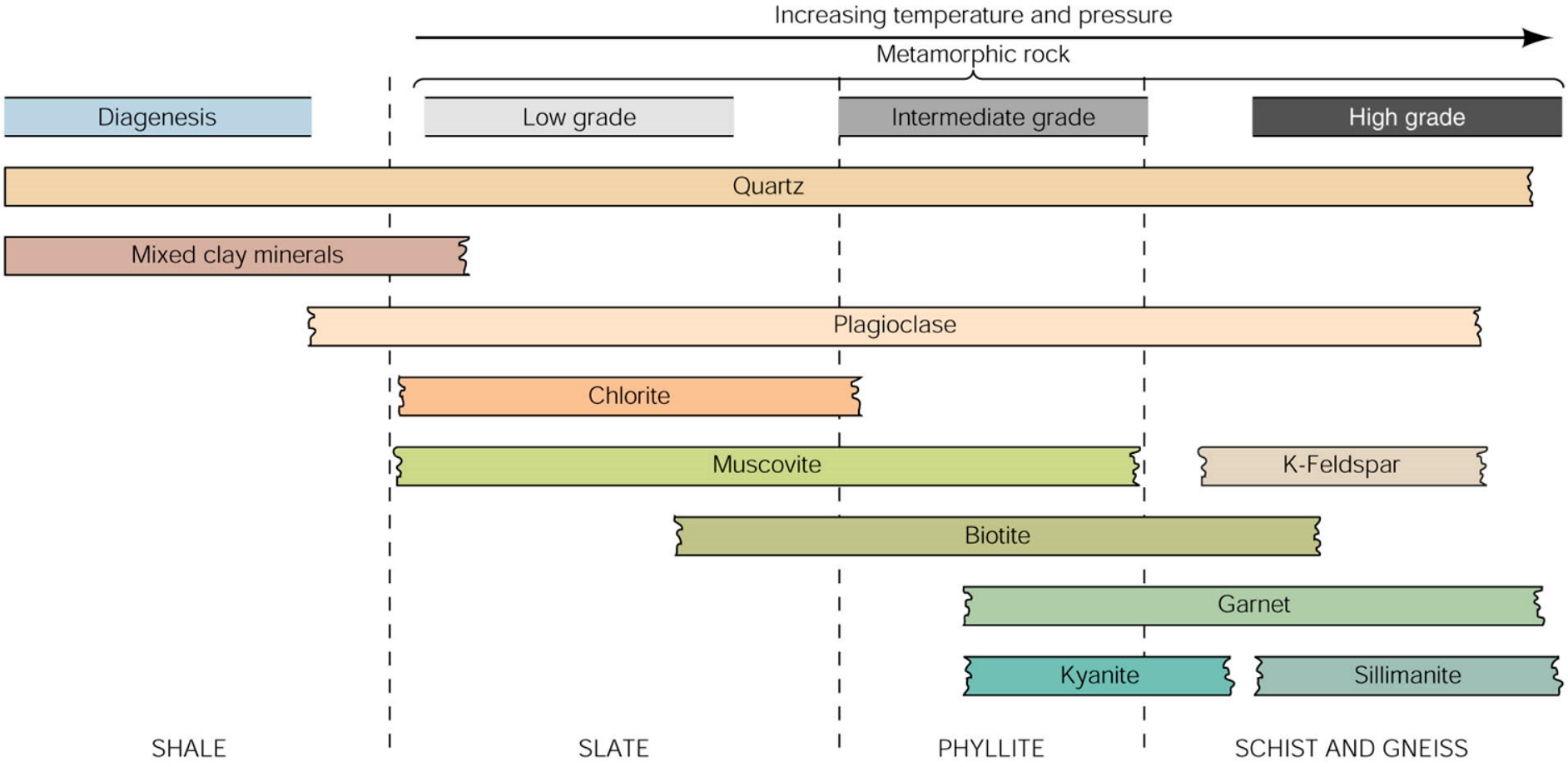


Barrovian Regional Metamorphic Zones

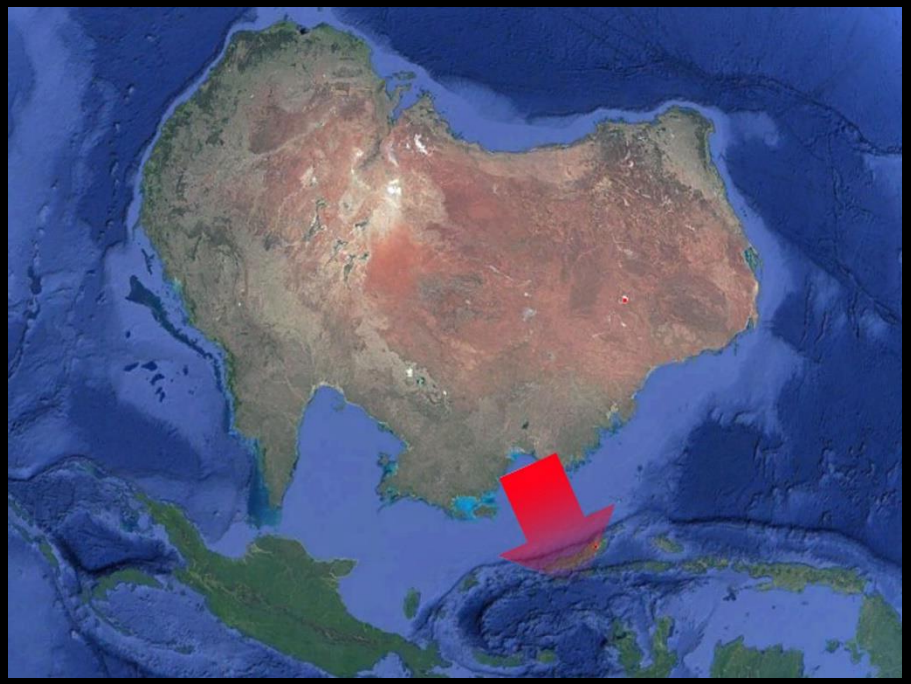

Temperature (°C)
0
100
200
300
400
500
600
700
800
Pressure (MPa)
200
400
600
800
10000
1200
Depth (km)
10
20
30
Burial metamorphism
Contact metamorphism
Greenschist
Amphibolite
Blueschist
Granulite
Eclogite
A
B
C

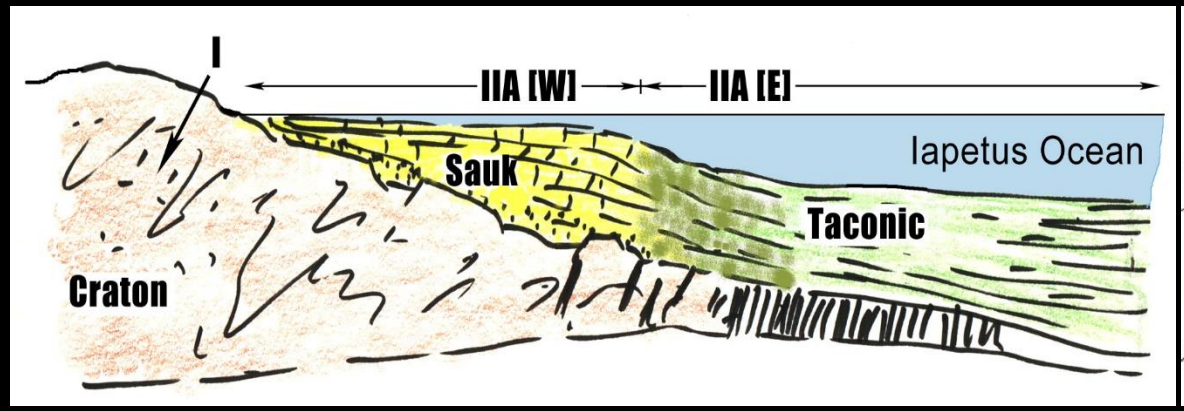
Regional Metamorphism = Foliated Rocks

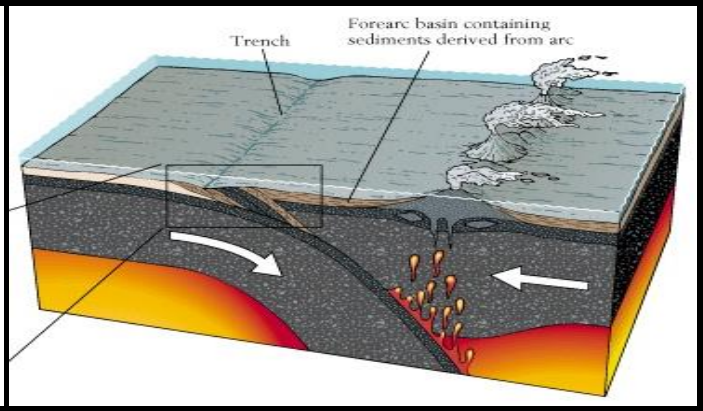


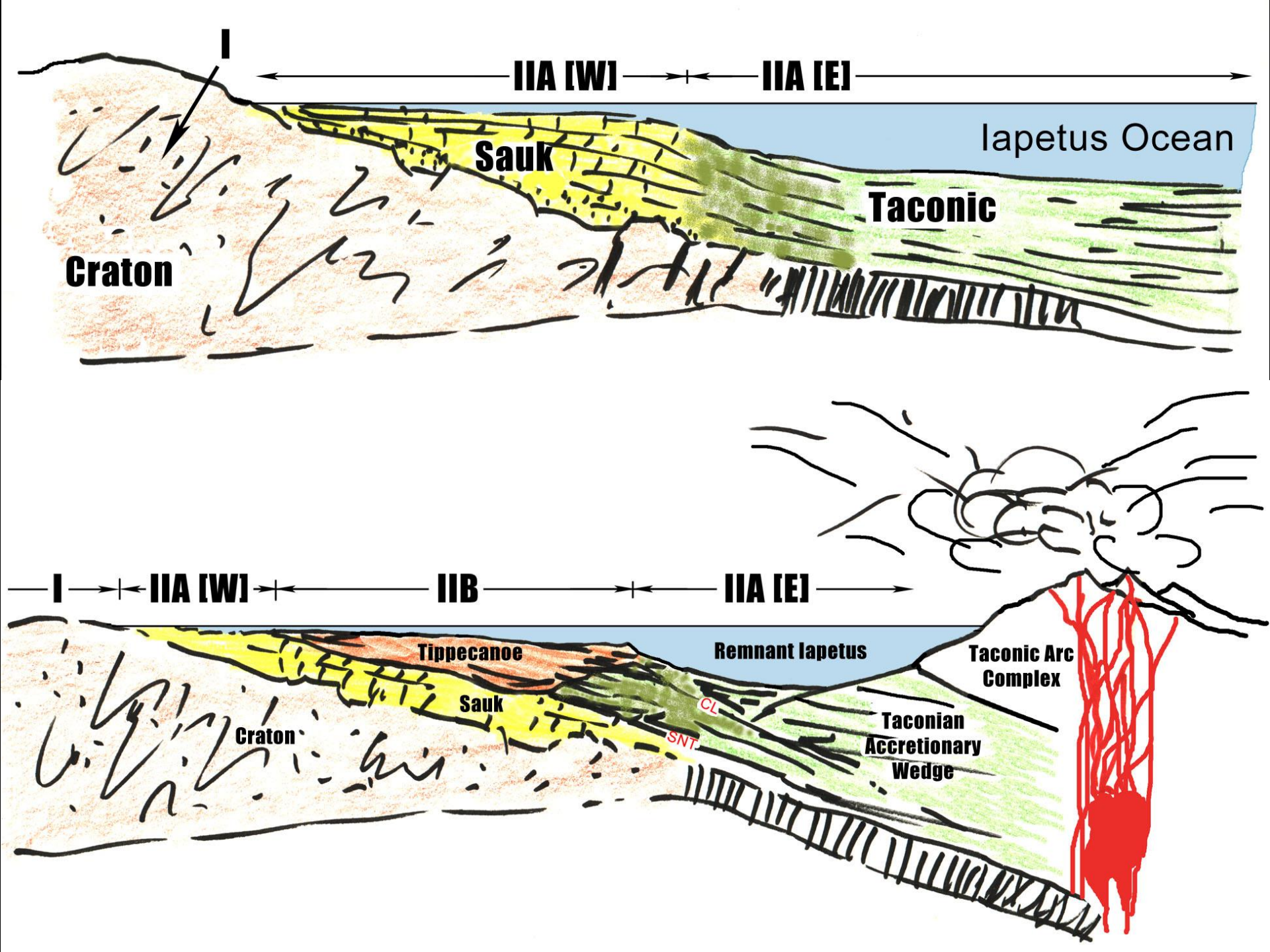

Increasing temperature and pressure
Metamorphic rock
Diagenesis
Low grade
Intermediate grade
High grade
Quartz
Mixed clay minerals
Plagioclase
Chlorite
Muscovite
K-Feldspar
Biotite
Garnet
Kyanite
Sillimanite
SHALE
SLATE
PHYLLITE
SCHIST AND GNEISS

~ 450 Ma Taconian Arc – Passive Margin Collision







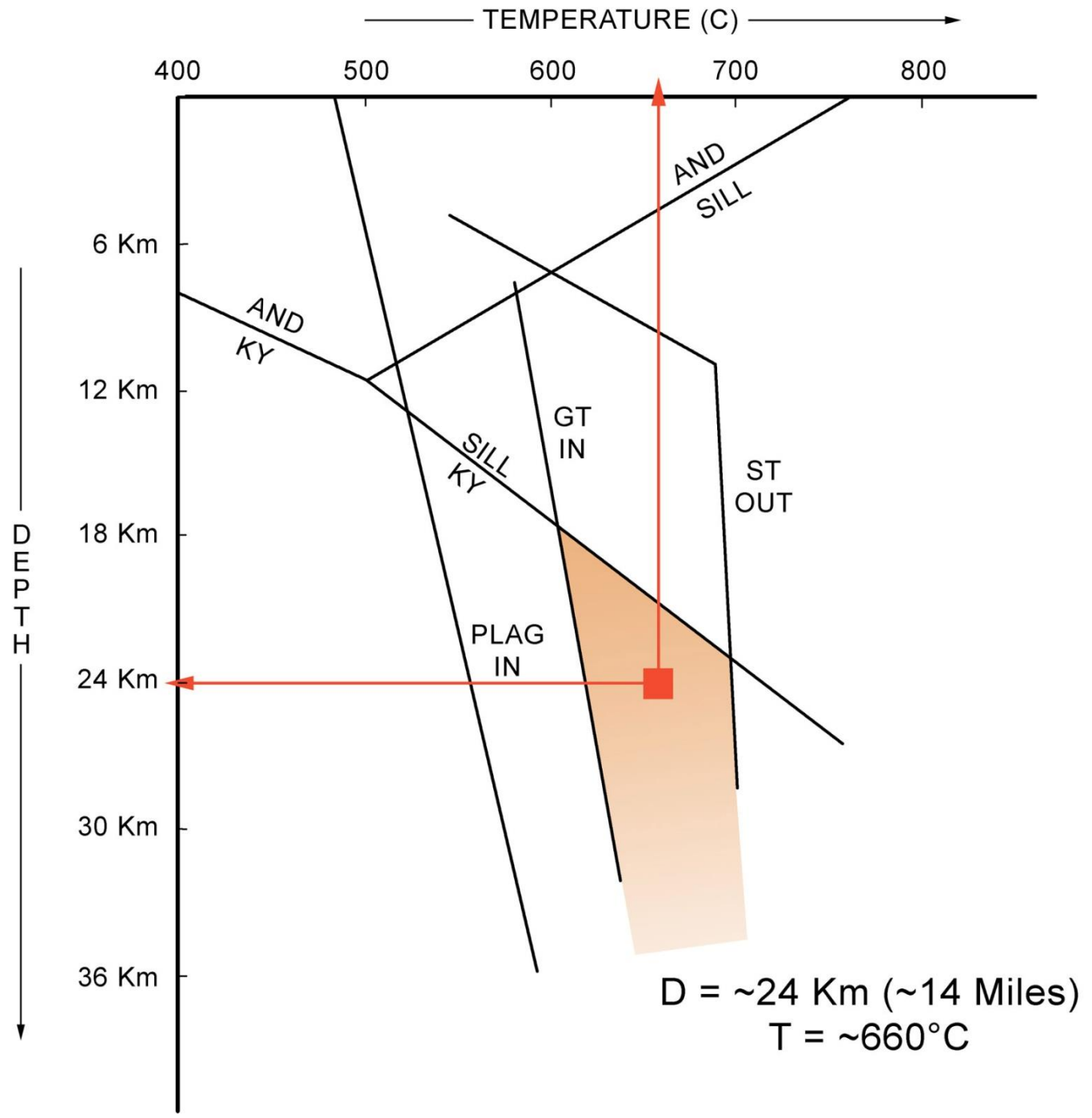

I
IIA [W]
IIA [E]
Iapetus Ocean
Sauk
Taconic
Craton
I
IIA [W]
IIB
IIA [E]
Tippecanoe
Remnant Iapetus
Taconic Arc
Complex
Sauk
CL
Taconian
Accretionary
Wedge
Craton
SNT

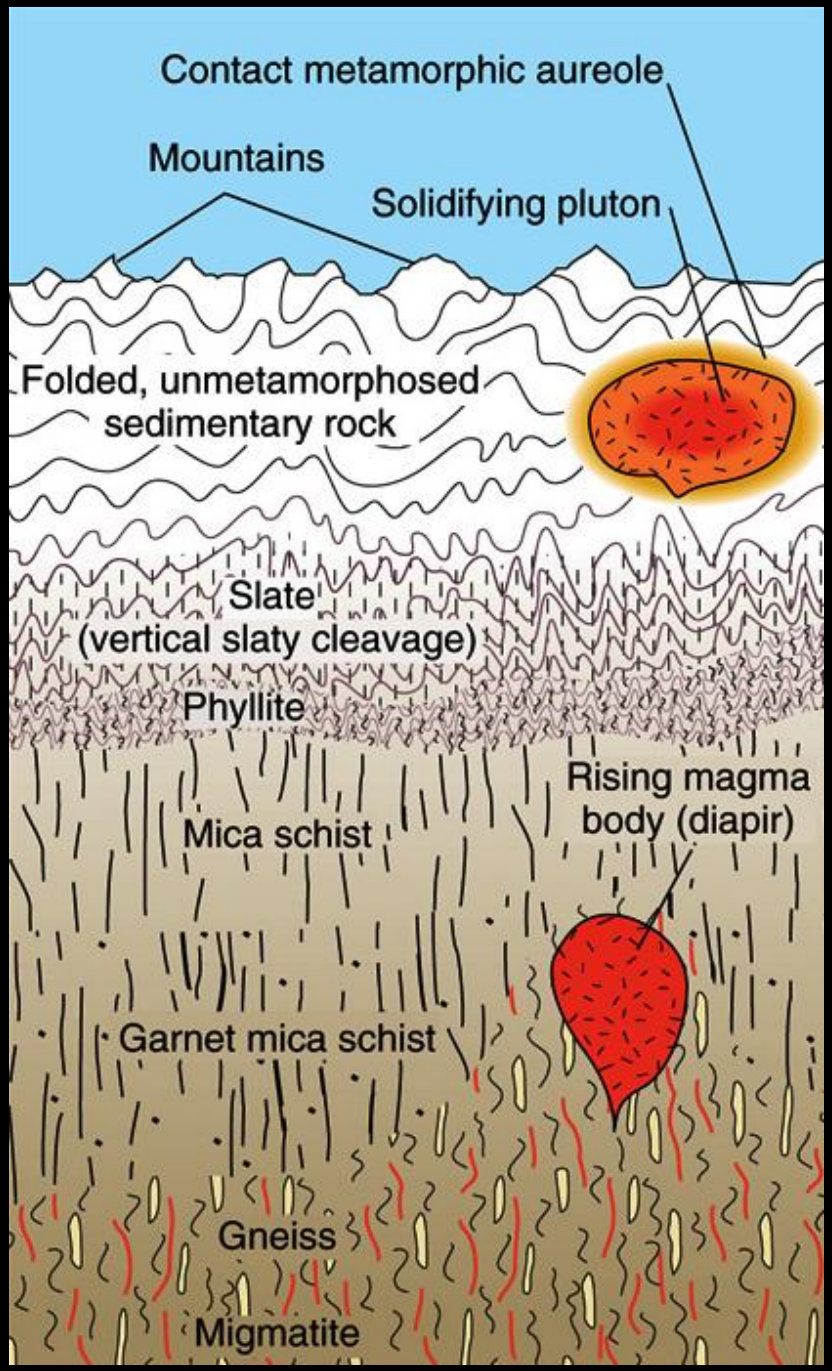
Minerals Are Your Pals, Your Friends!

WTC Minerals

Plagioclase
Garnet
Staurolite
Kyanite

Merguerian and Moss
2015

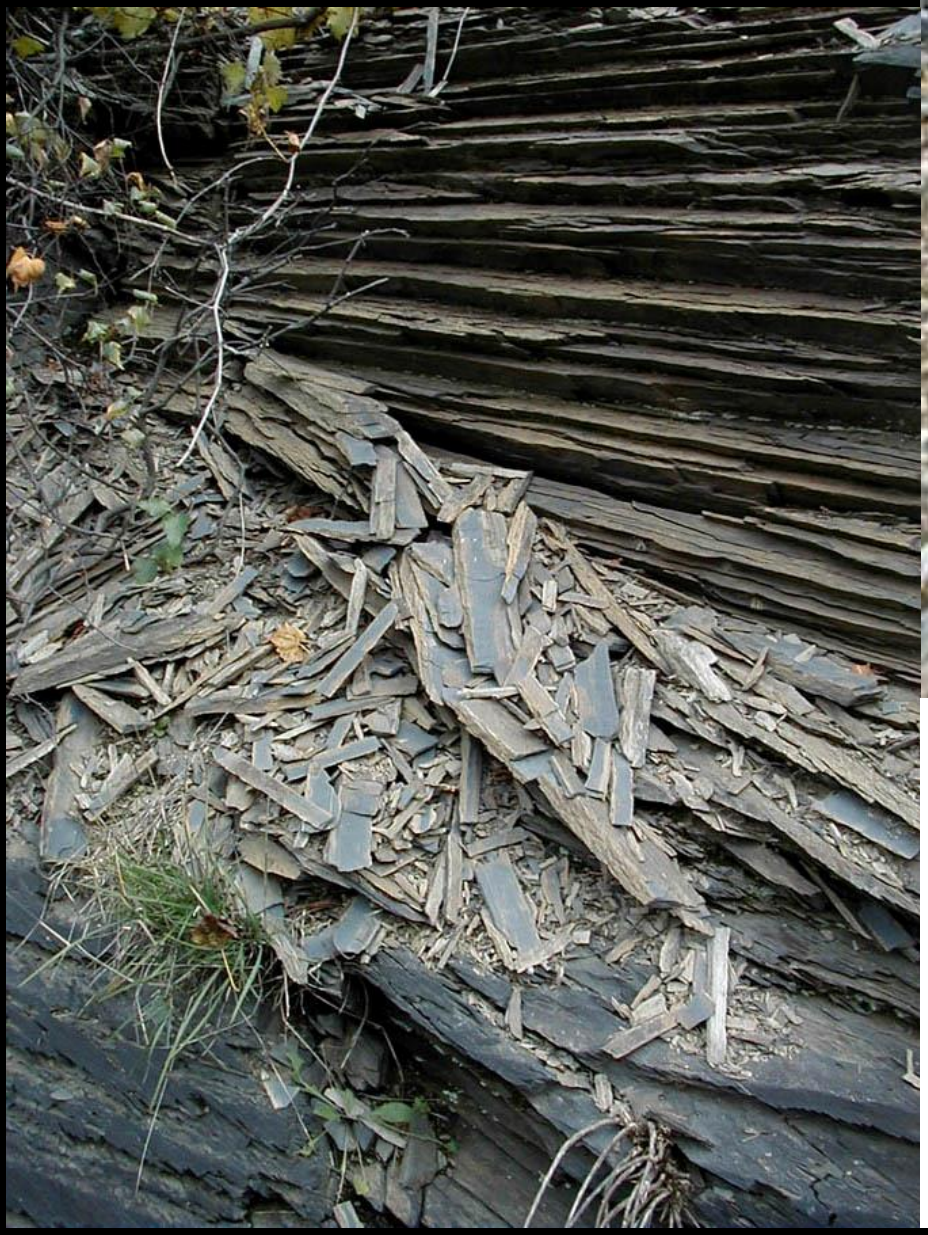


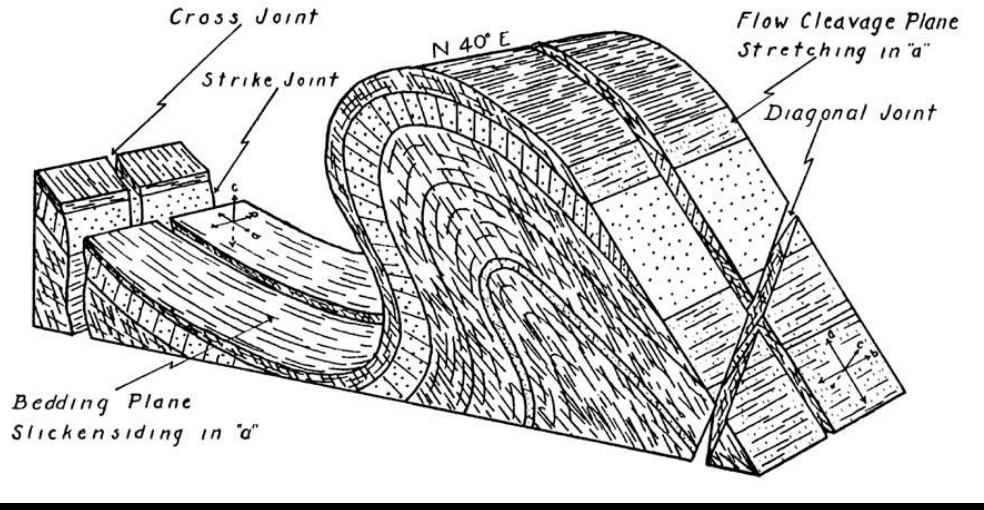


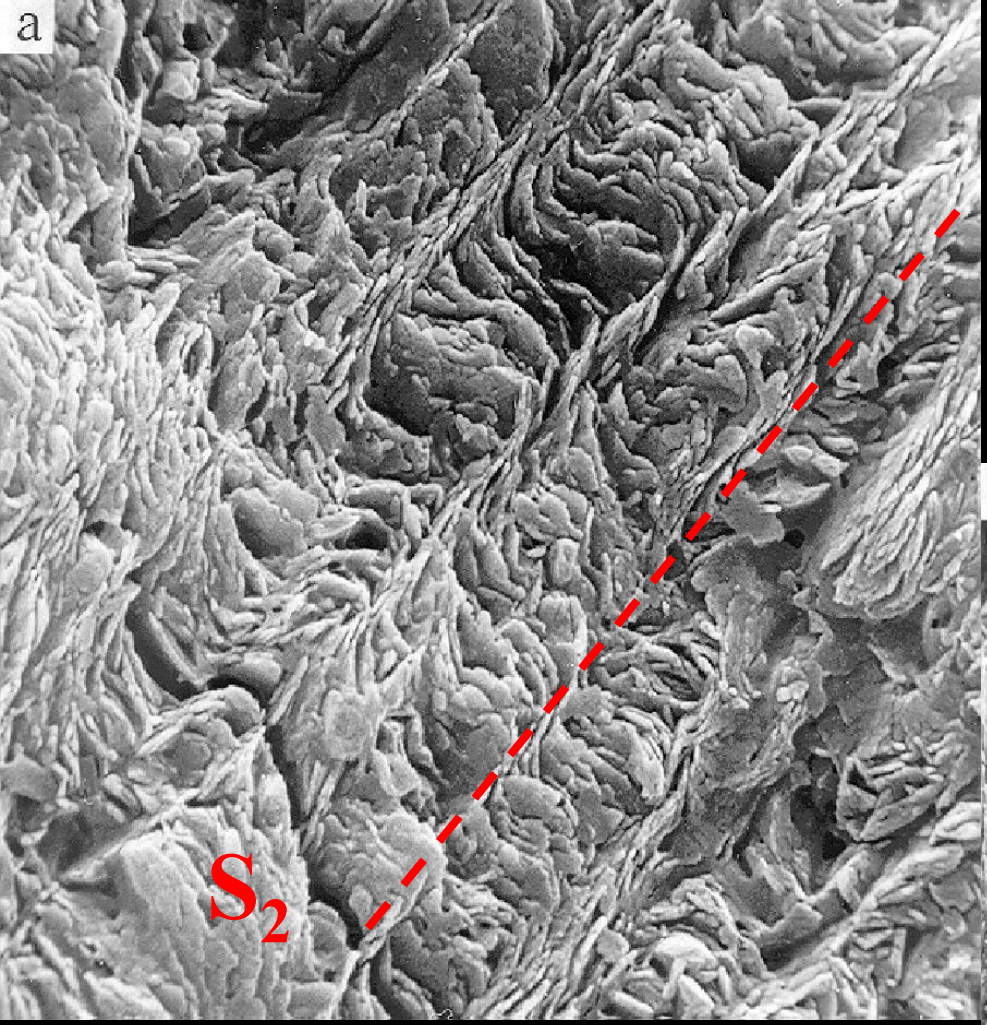
Shale (Sedim)
Slate
Phyllite
Schist
Gneiss
Migmatite
Orthogneiss

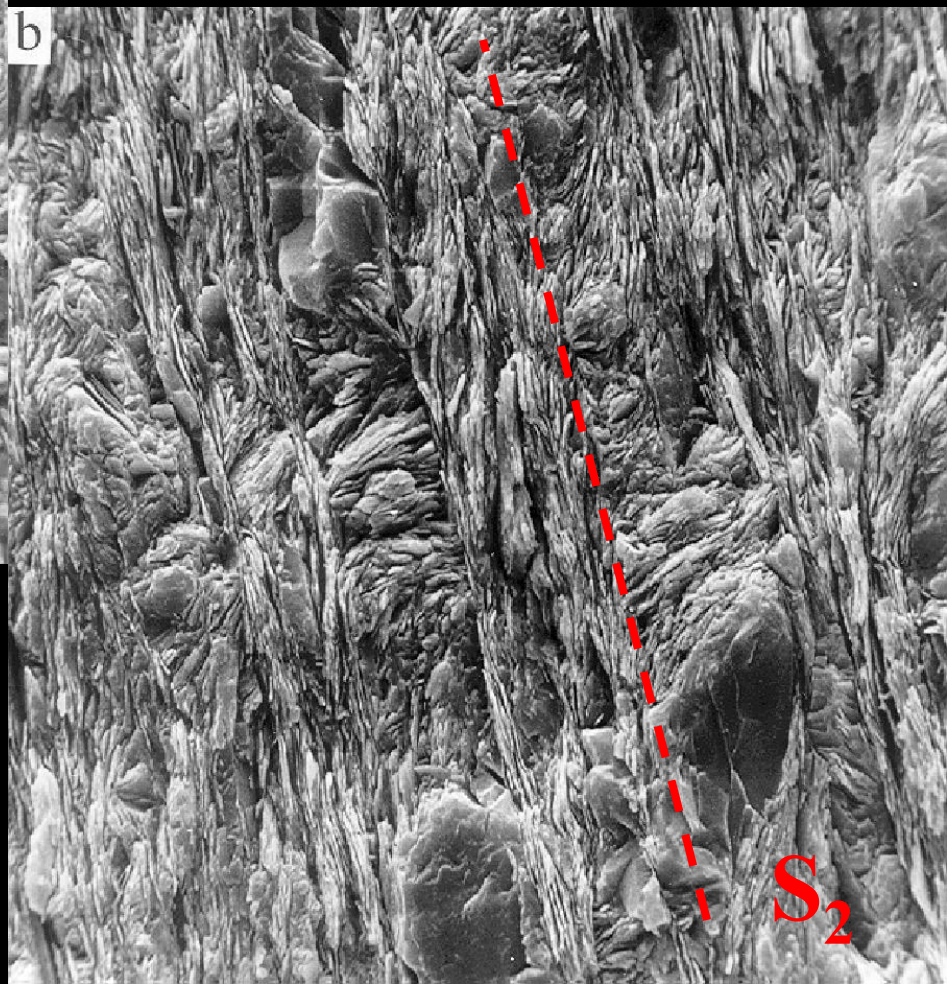
Taconic Slates, Newburgh, NY

Pencil Slates









SEM Images of Spaced Slaty Cleavage


Slaty Cleavage

Diffracted Slaty Cleavage

Normanskill Fm., J. Iorio Park, NY

Metacarbonate + Metasiltstone, Taconic Sequence, NY

Amphibolite Layer in Schist

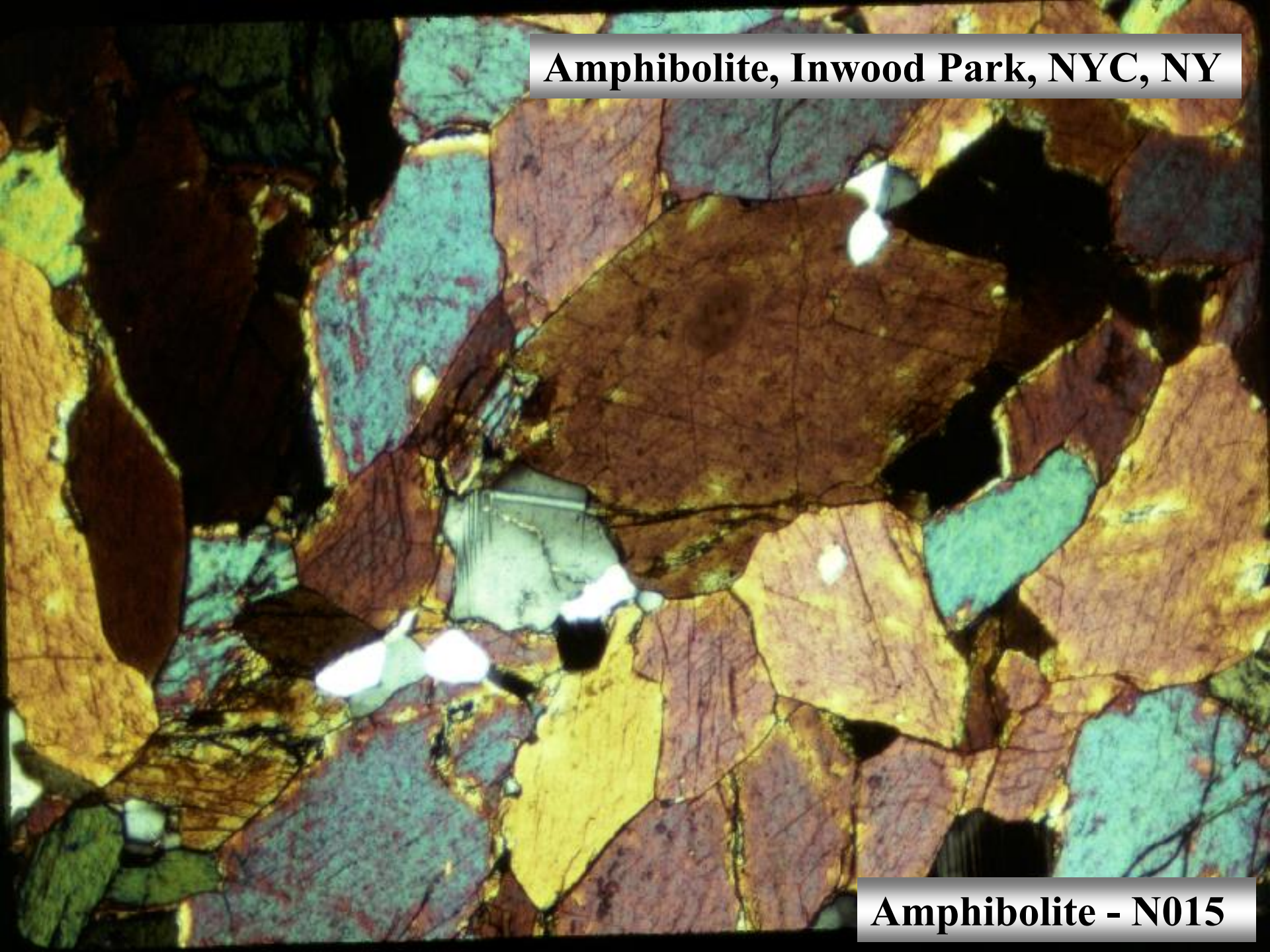
Hartland Fm., Central Park, NYC

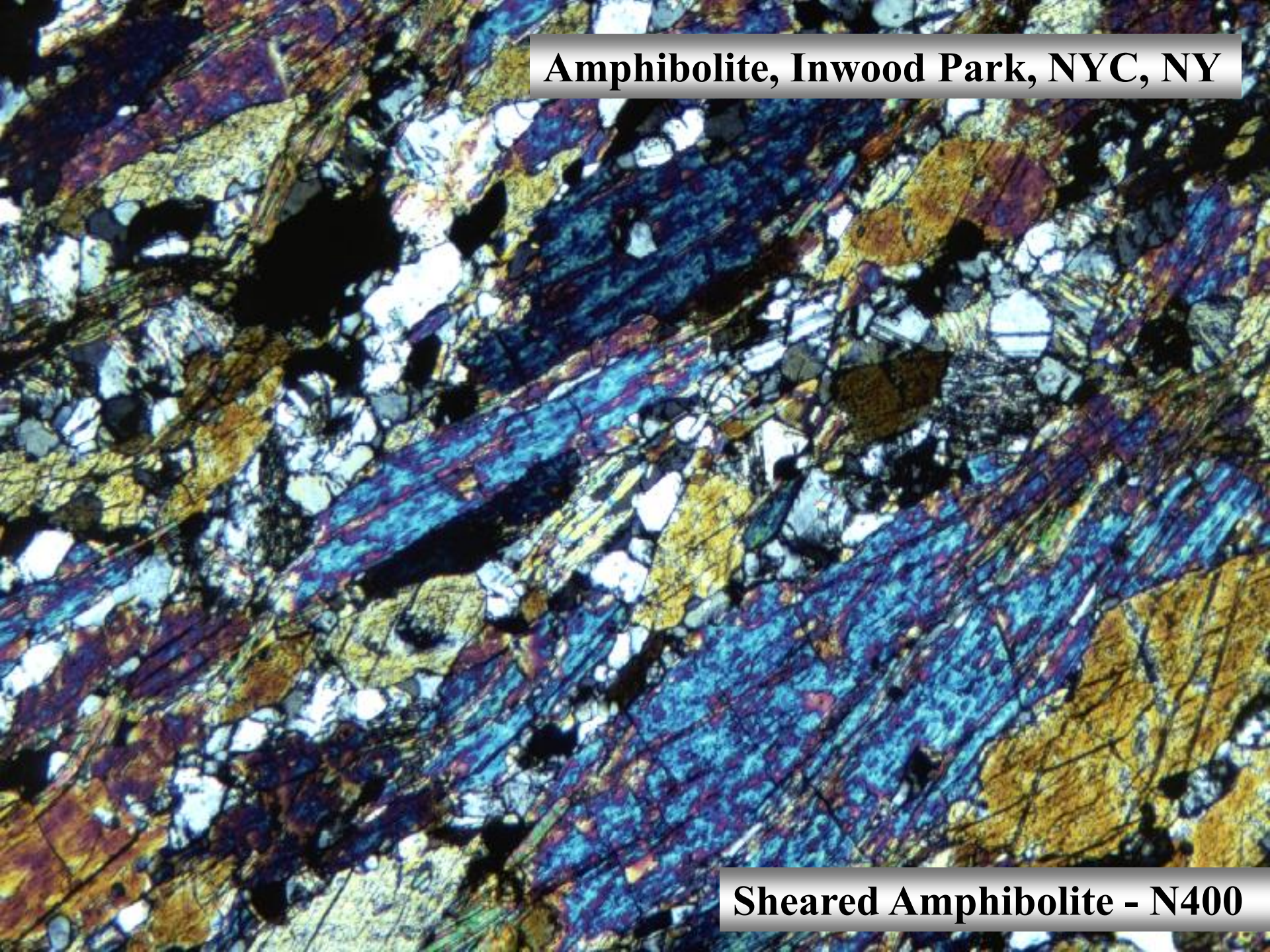

Disarticulated Amphibolite Fold
Mafic and Felsic Hartland Gneiss, So. Twin Island, NY

N567 - Hartland Amphibolite
Central Park

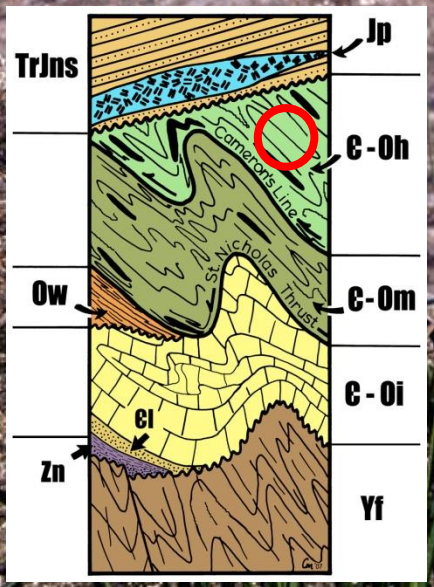

Garnet Amphibolite, So. Twin Island, NY

Depleted Garnet Rims, So. Twin Island, NY


Amphibolite, Inwood Park, NYC, NY
Amphibolite - N015

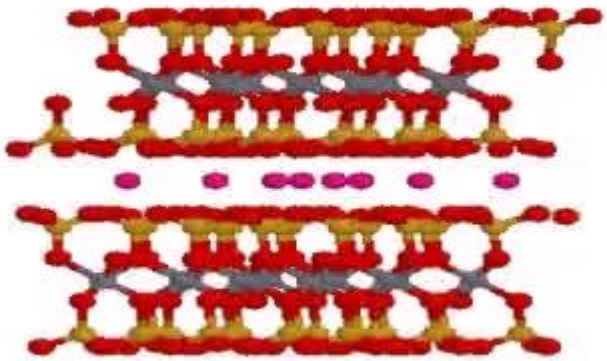

Amphibolite, Inwood Park, NYC, NY
Sheared Amphibolite - N400

Hartland Schist

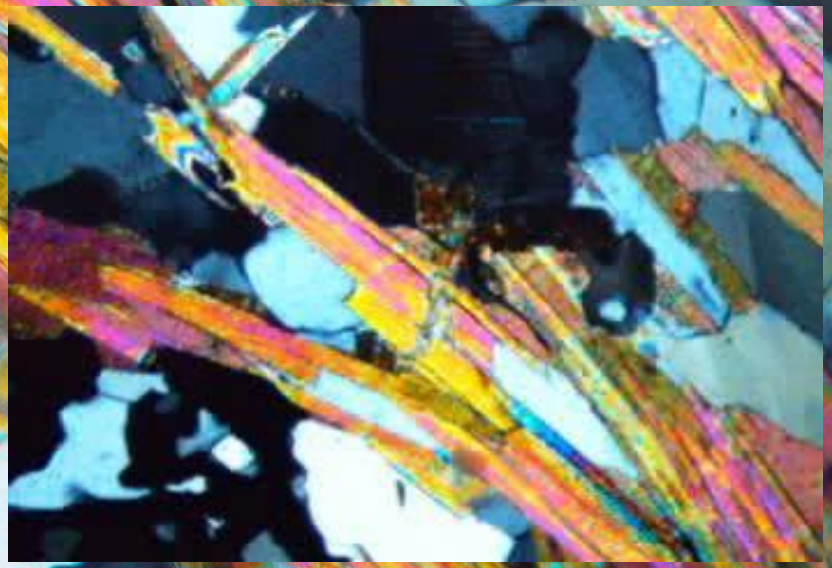


Riverside Park, NYC, NY

Hartland Schist

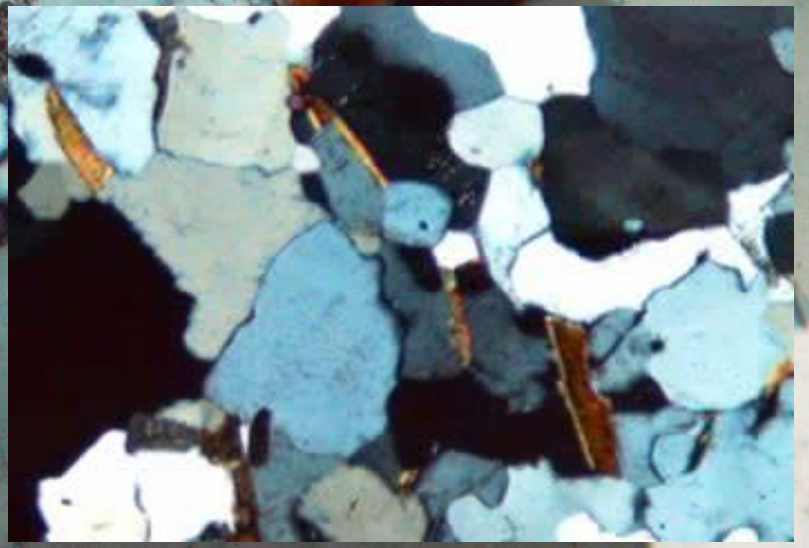


Hartland Schist



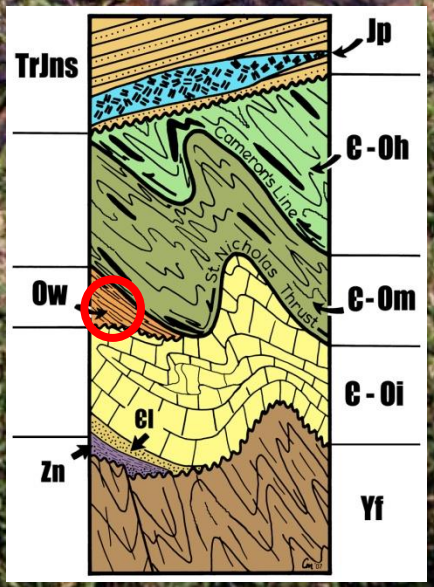
N629 – Warren Street (C-Oh)

Hartland Granofels



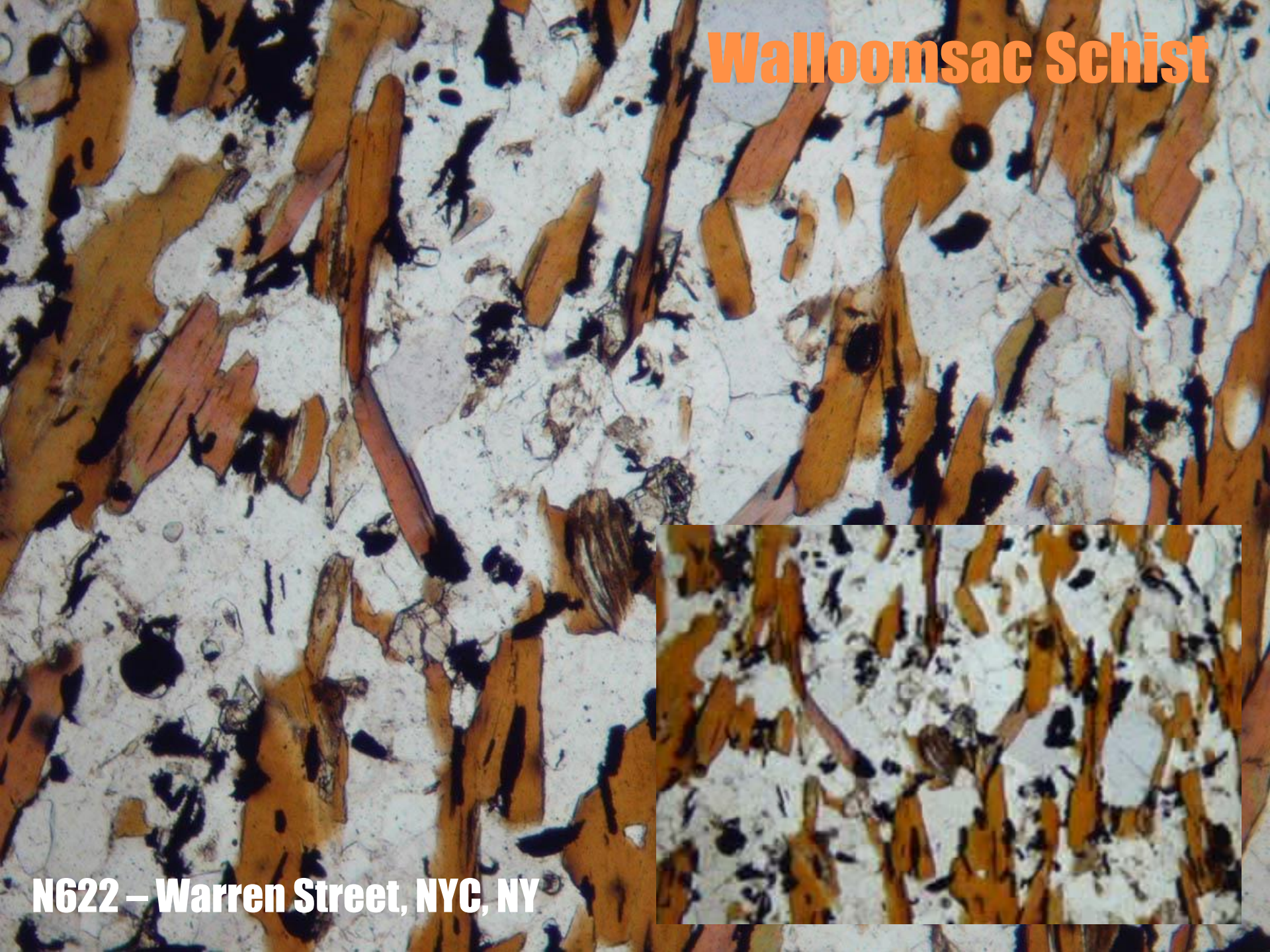
N624 – Warren Street (C-Oh)

Walloomsac Schist



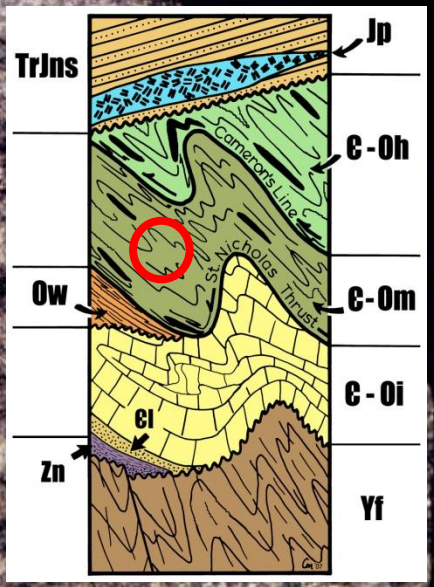
N289 Sulfidic Schist - Mt. Morris Park, NYC, NY

Walloomsac Schist

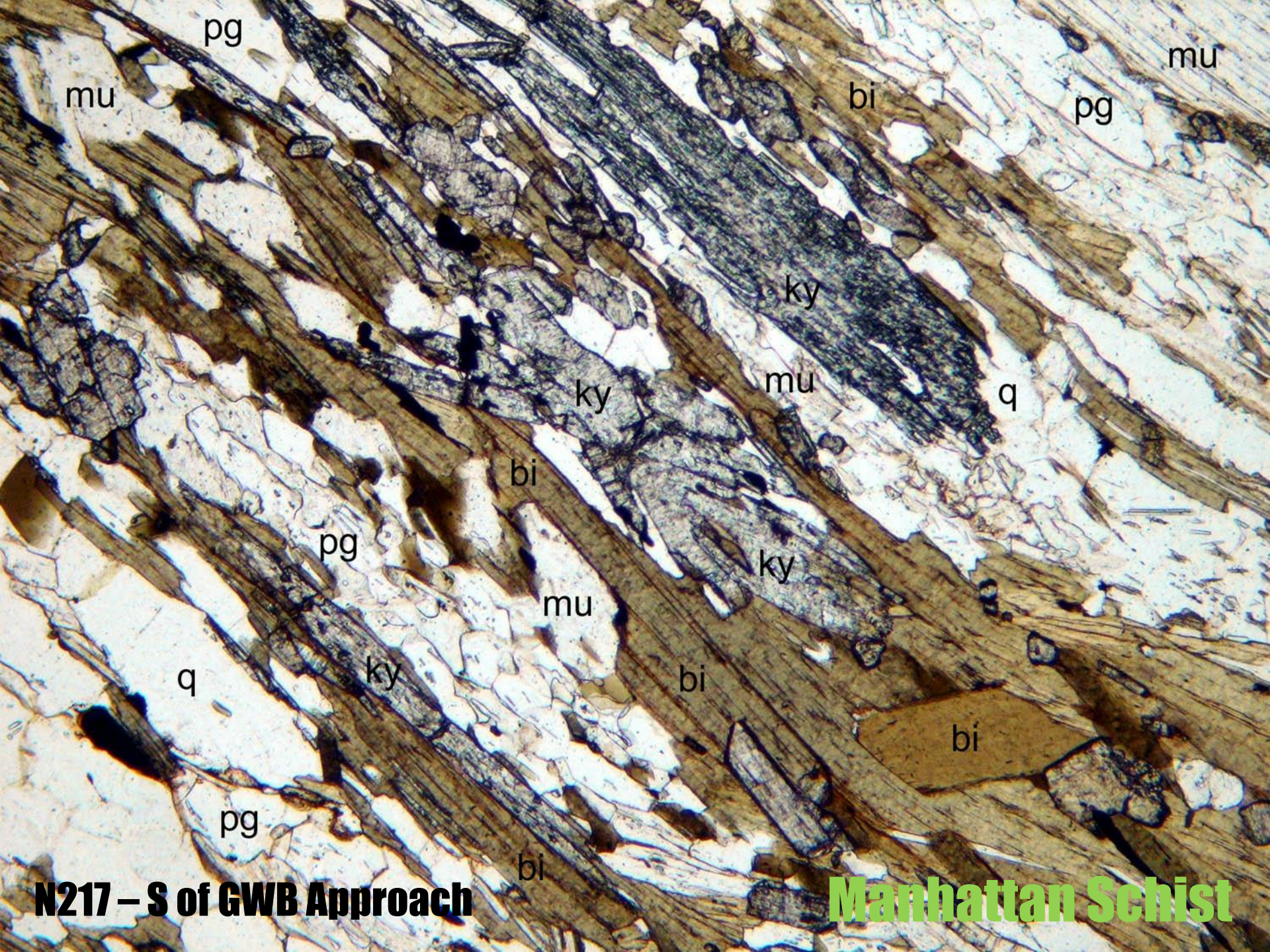


N622 – Warren Street, NYC, NY

Manhattan Schist



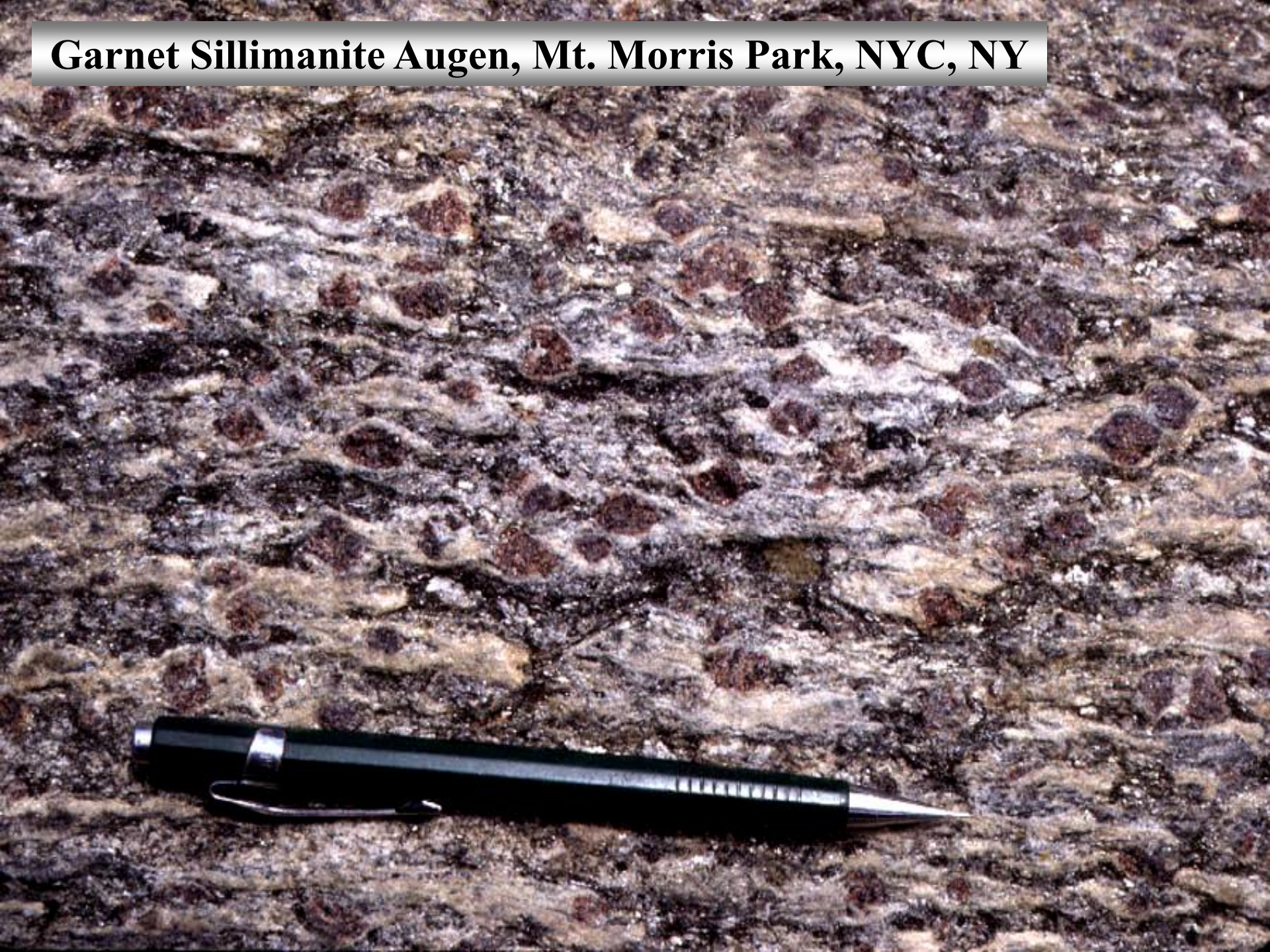
N283 - Kyanite Nodule - Mt Morris Park, NYC, NY



N217 – S of GWB Approach

Manhattan Schist


Manhattan Schist
Central Park, NYC, NY

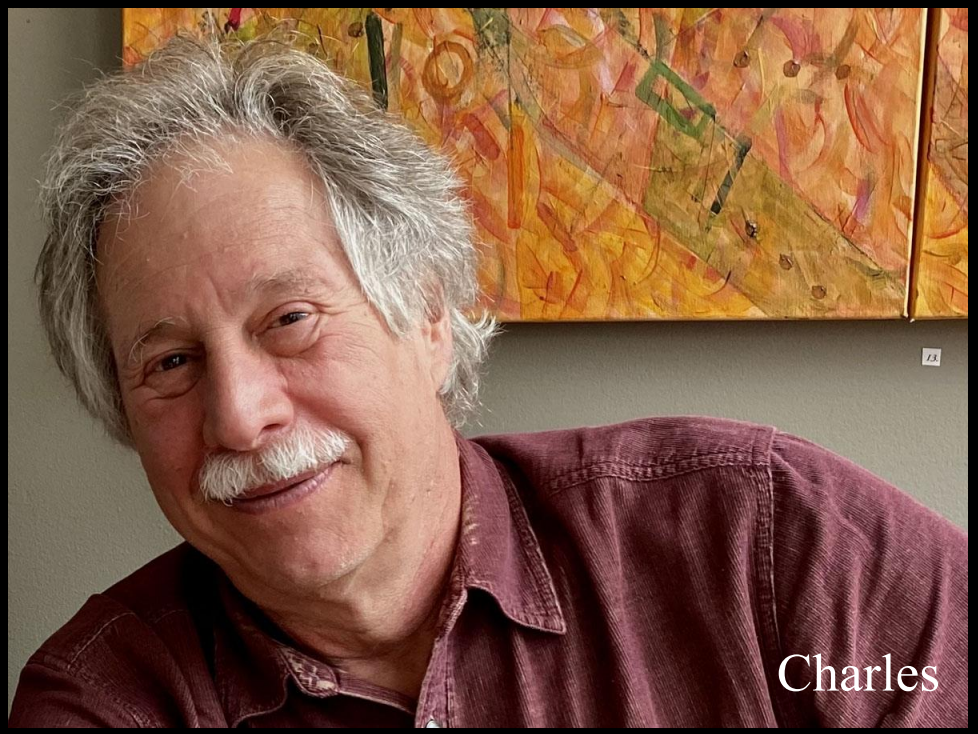

Garnet Sillimanite Augen, Mt. Morris Park, NYC, NY

Queens Water Tunnel – CT3

Duke Geological Lab

Full Service Geotechnical and Tunneling Analysis

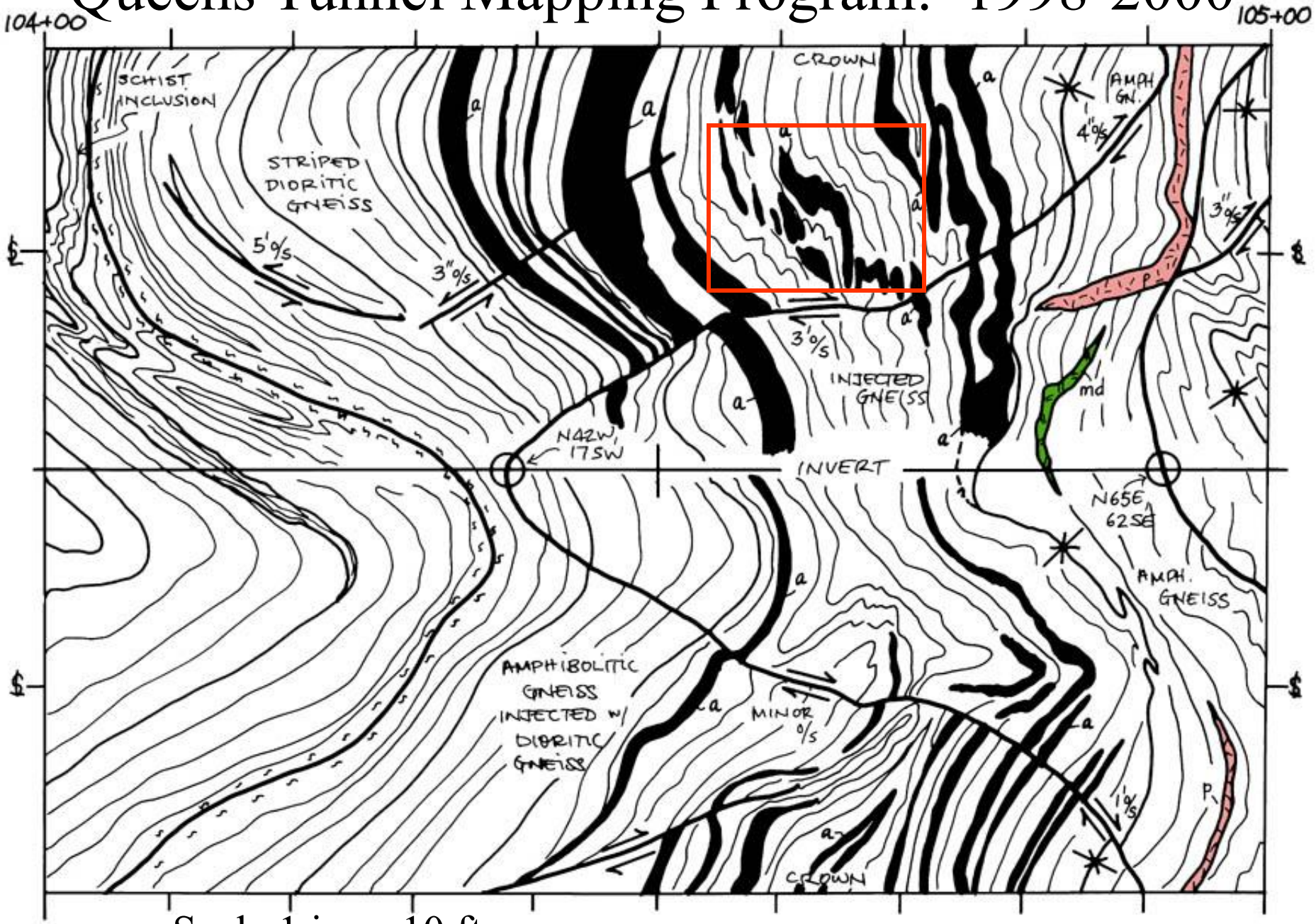
www.dukelabs.com



Office Help

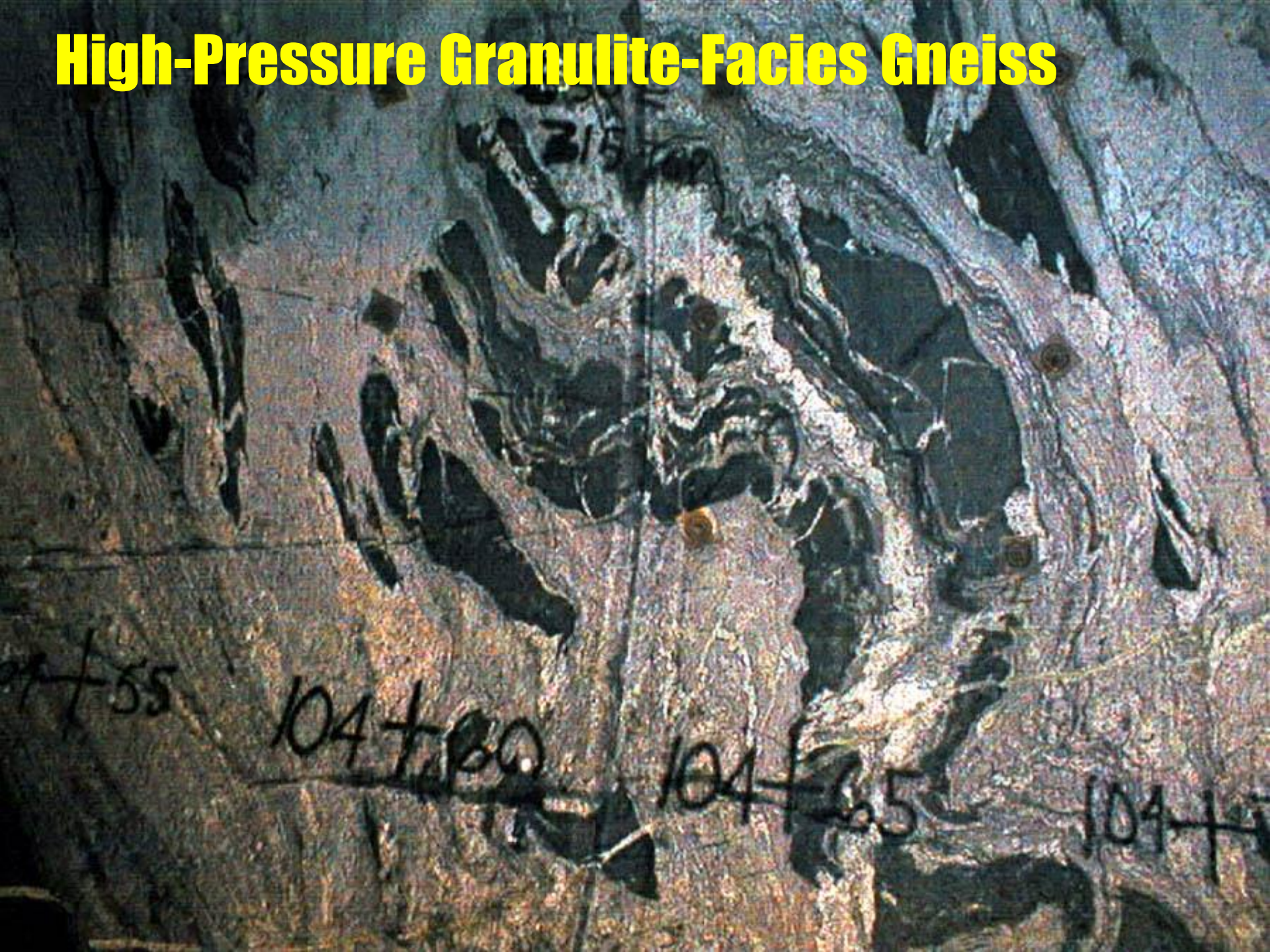
Dukelabs' CT3 Tunnel Field Office

Queens Tunnel Mapping Program: 1998-2000

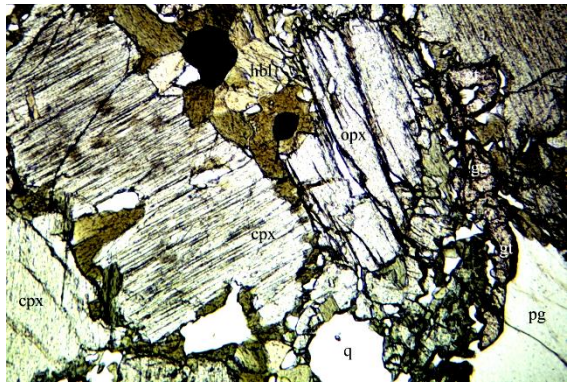


- Scale 1 in. = 10 ft

High-Pressure Granulite-Facies Gneiss



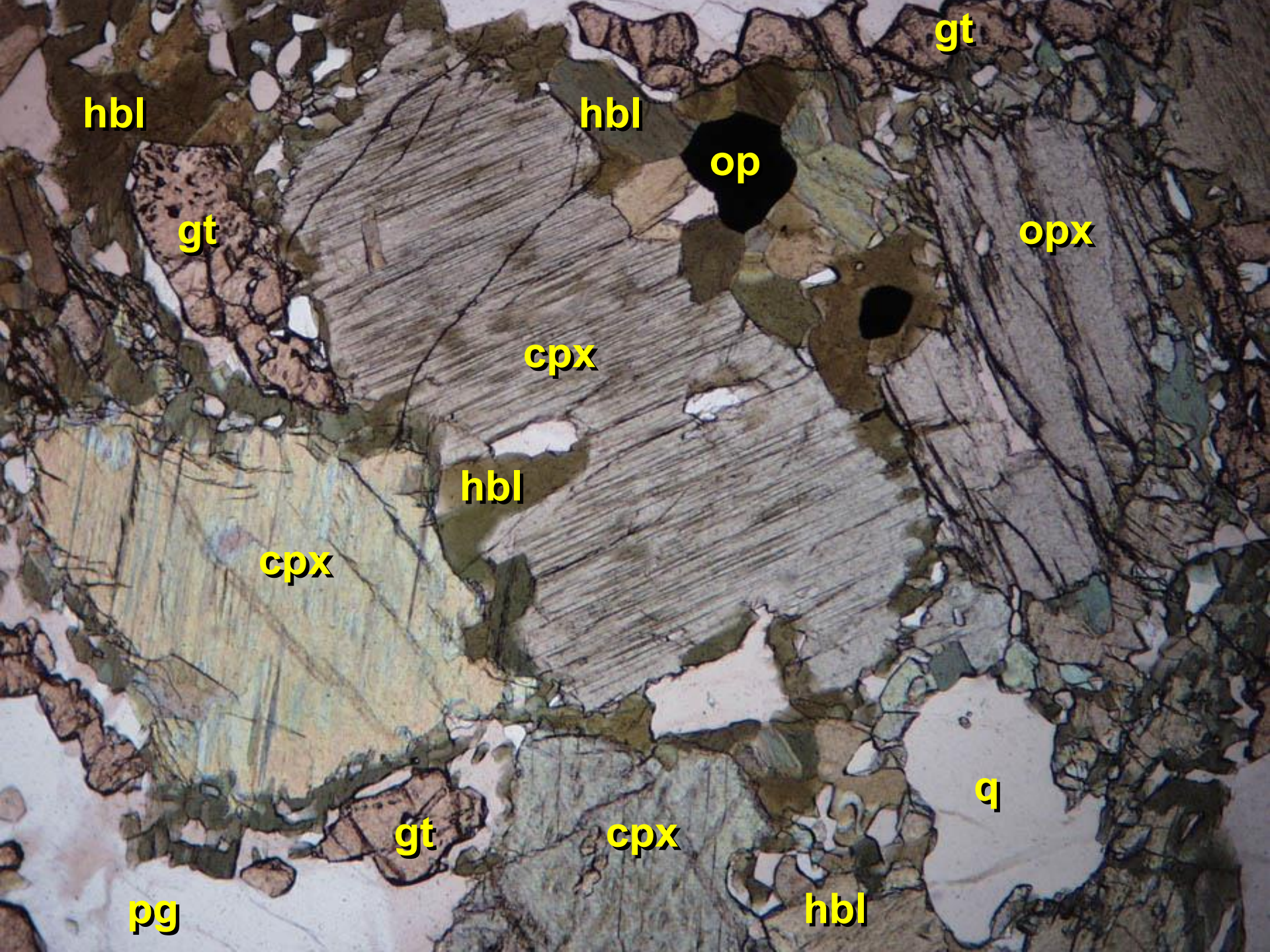
- **Petrographic Analysis (92 Samples)**
  - **Texture**
  - **Mineralogy**
  - **Internal Structure**
  - **Metamorphism**

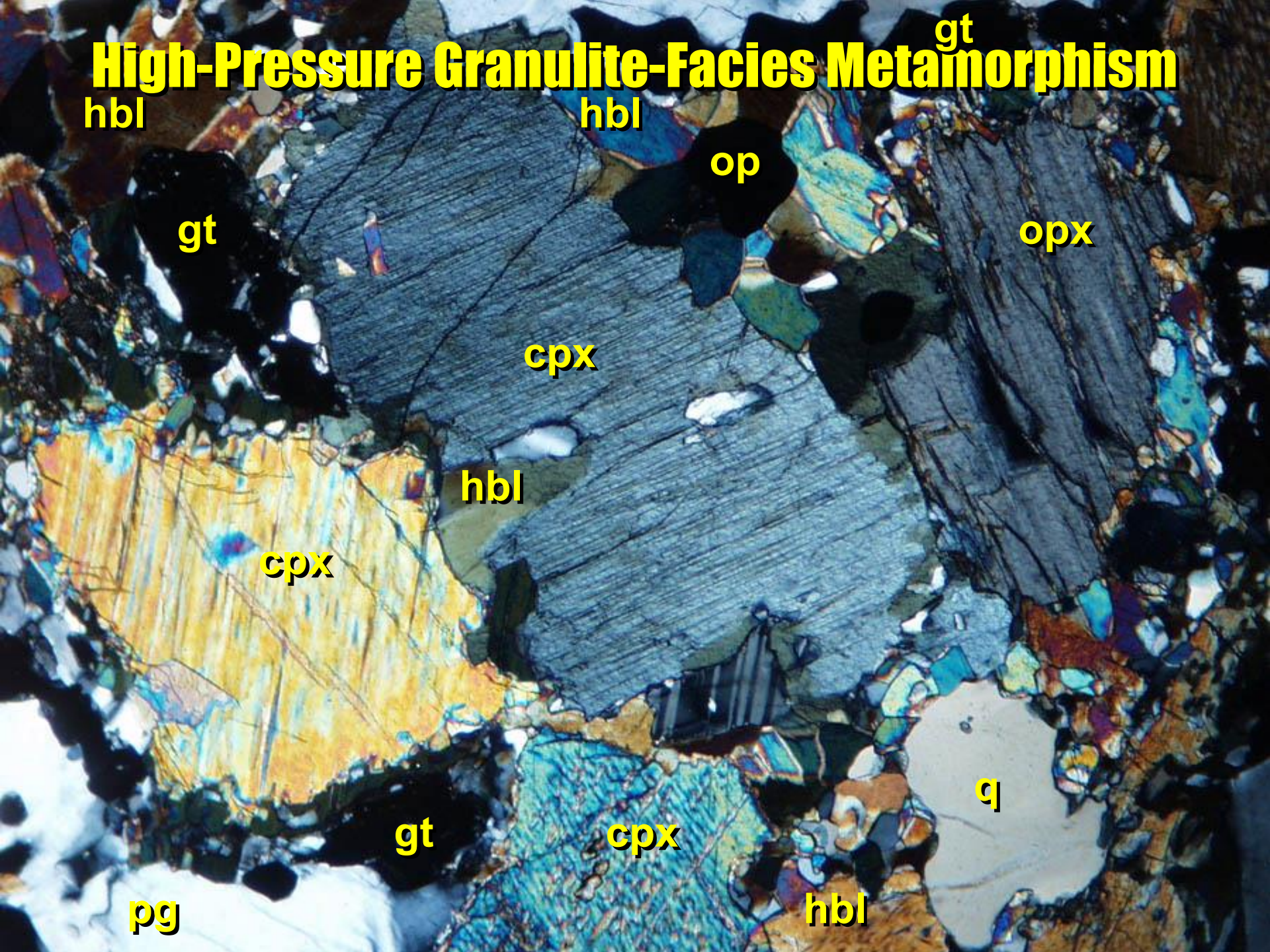


Thin section photomicrograph

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

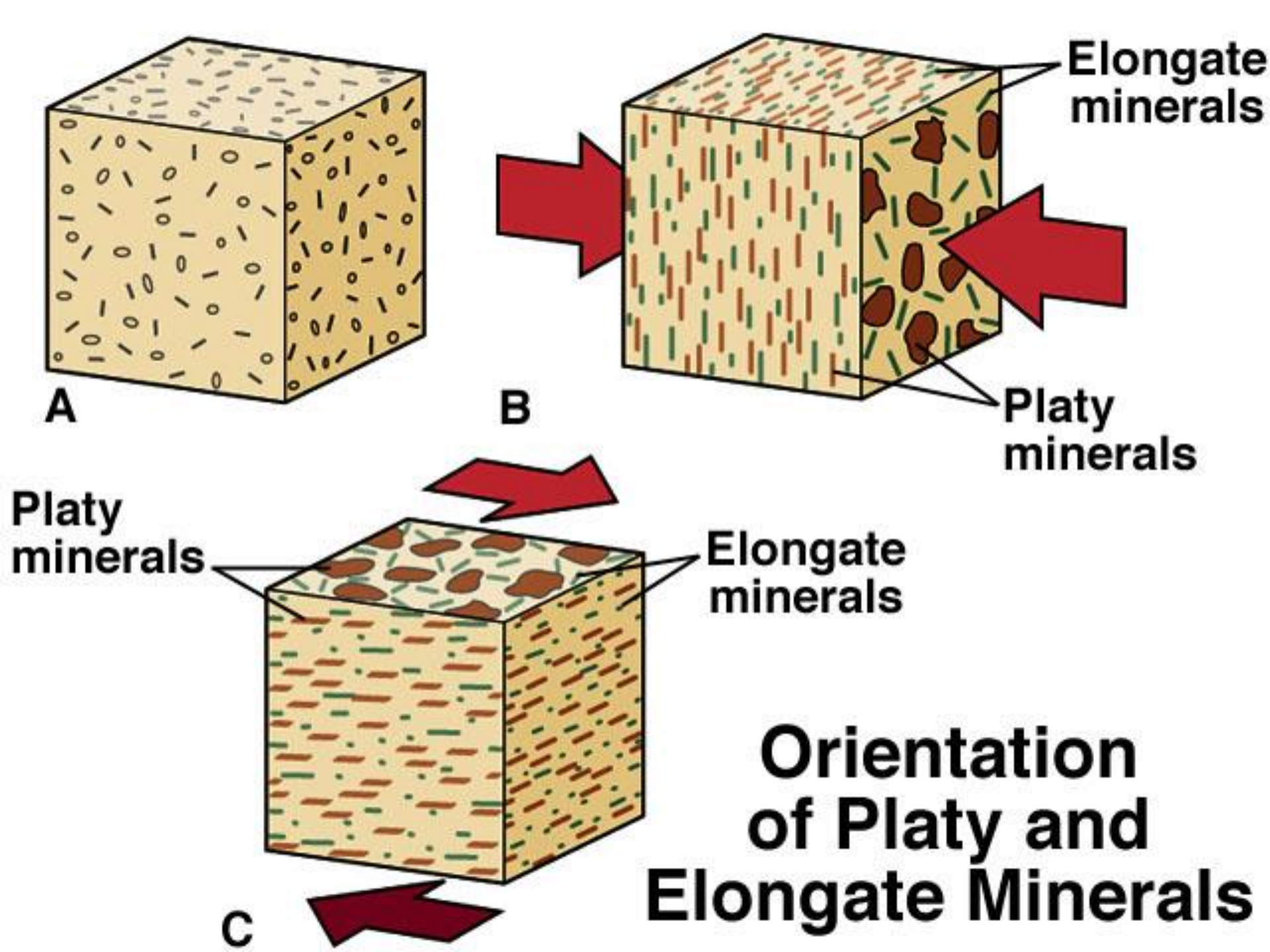
Petrographic Data Sheet


gt
hbl
hbl
op
gt
opx
cpx
hbl
cpx
q
gt
cpx
pg
hbl


High-Pressure Granulite-Facies Metamorphism
gt
hbl
hbl
op
gt
opx
cpx
hbl
cpx
q
gt
cpx
pg
hbl

Migmatite Gneiss

Sheared Migmatite Gneiss, So. Twin Island, NY


A
B
Elongate minerals
Platy minerals
Platy minerals
Elongate minerals
C
Orientation of Platy and Elongate Minerals

Metaconglomerate


Metaconglomerate

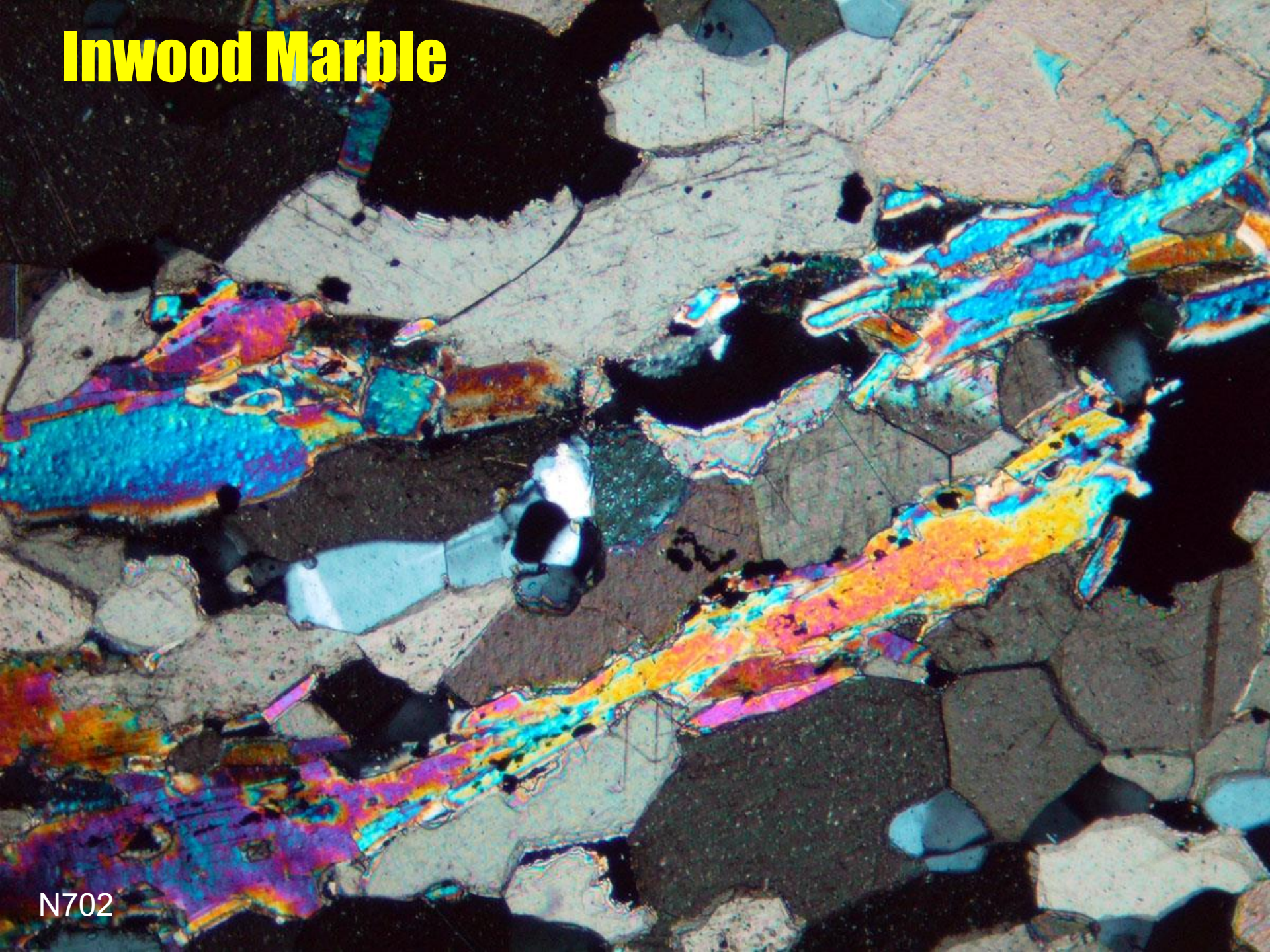
Non-Foliates: Sandstone to Quartzite

Inwood Marble

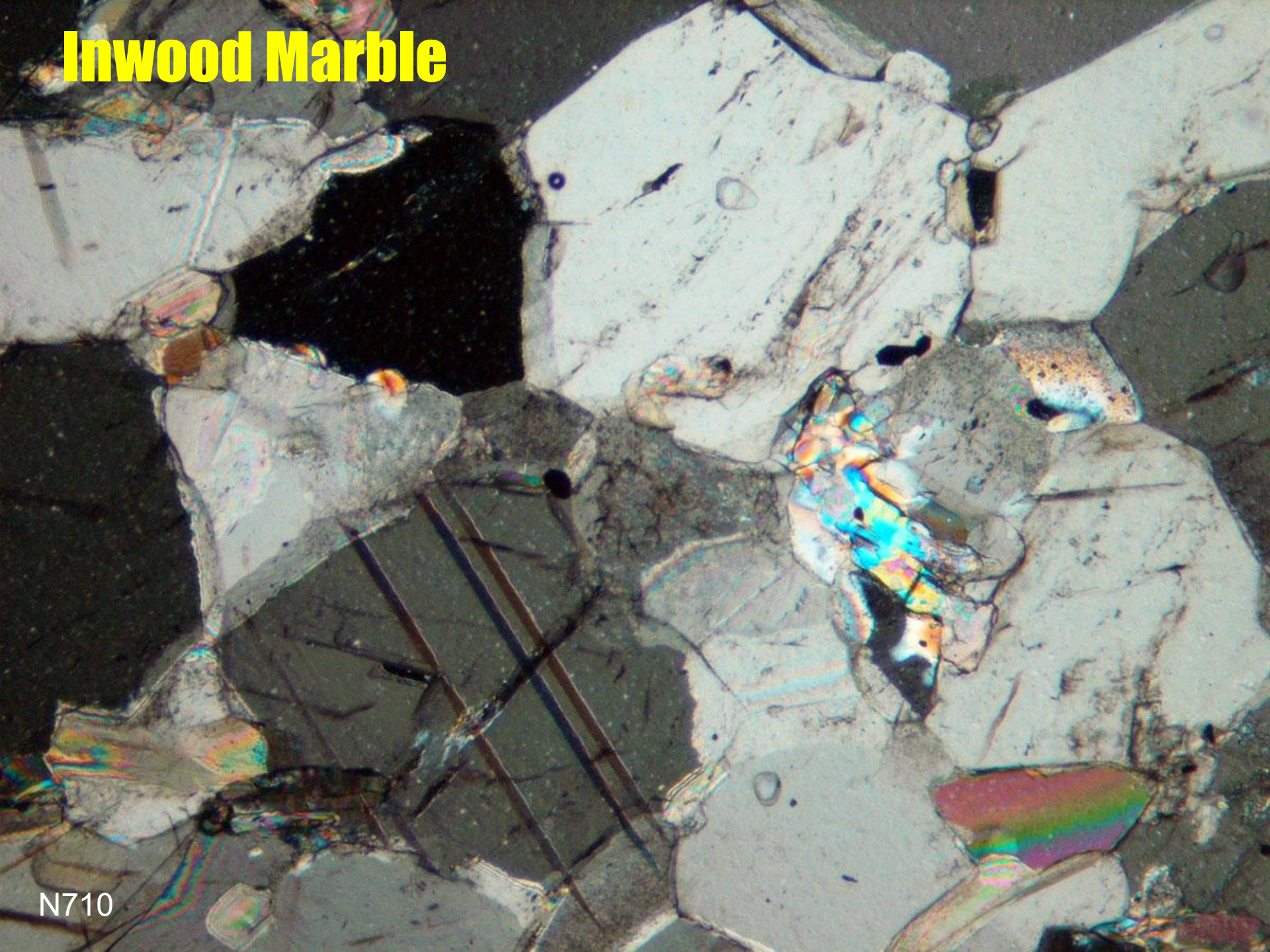
Inwood Marble


Inwood Marble

Inwood Marble

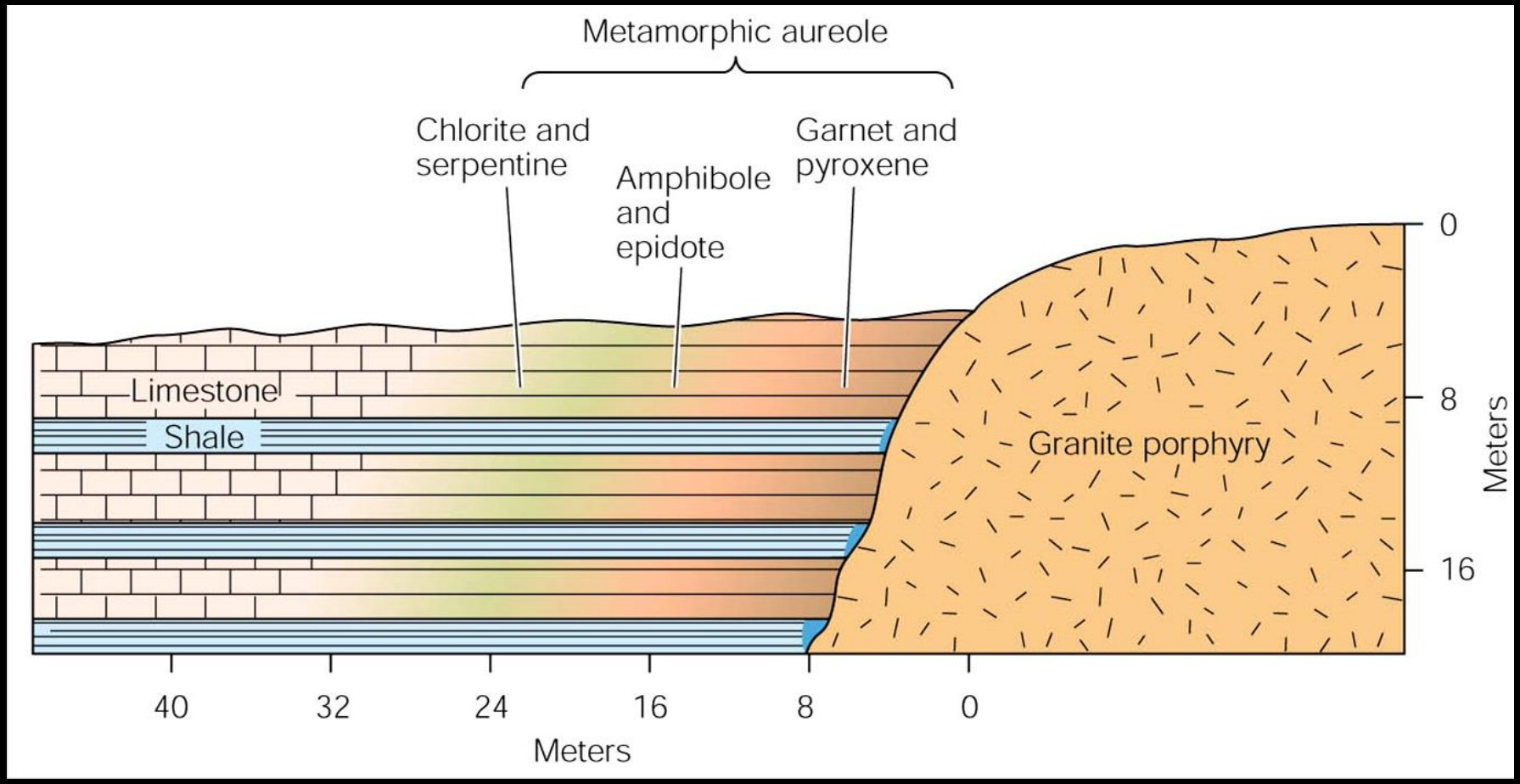


N702


Inwood Marble
N710

Inwood Marble

Contact Metamorphism



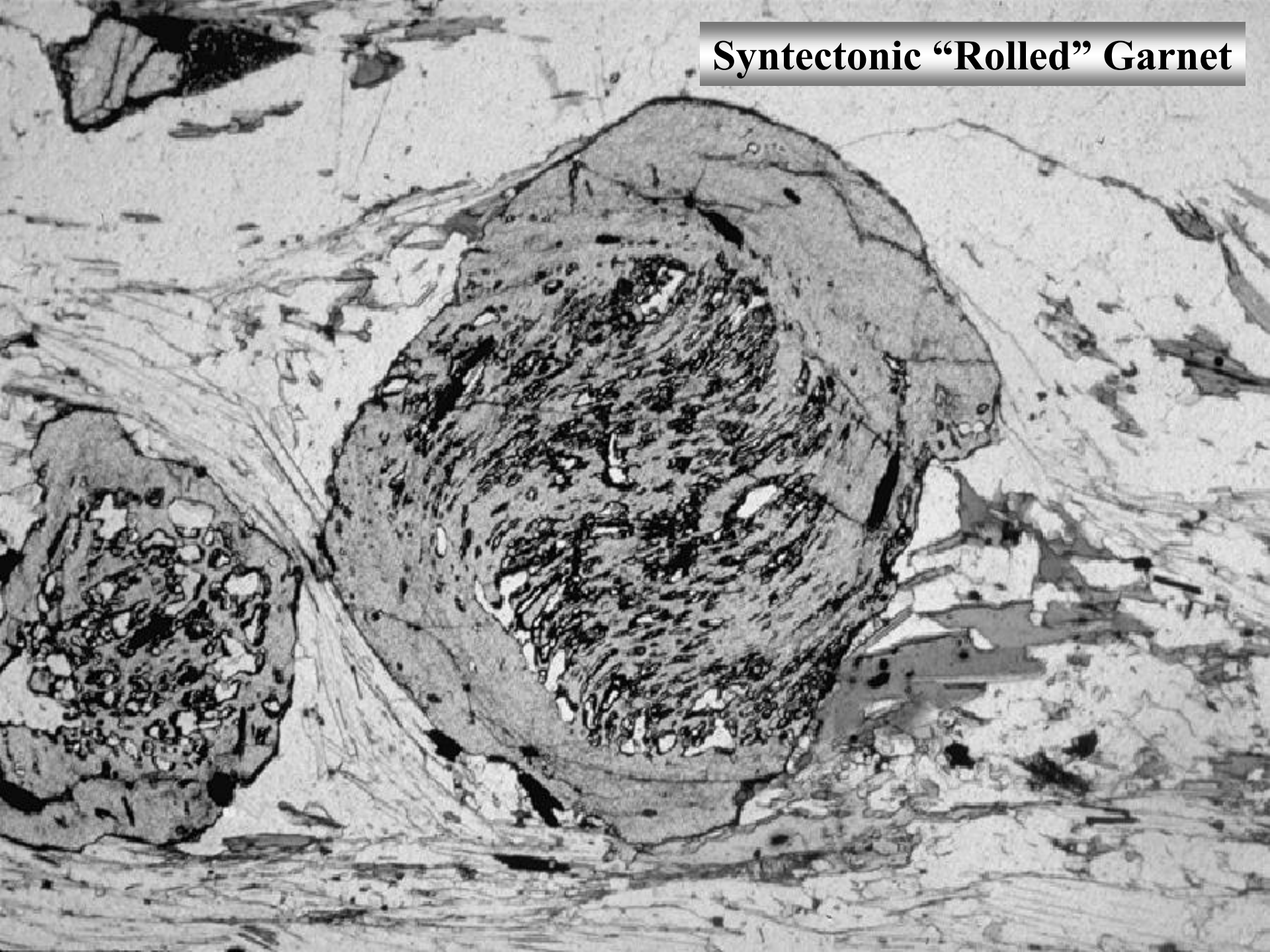
Contact Garnet Porphyroblasts, Castner Fm., TX

Porphyroblasts

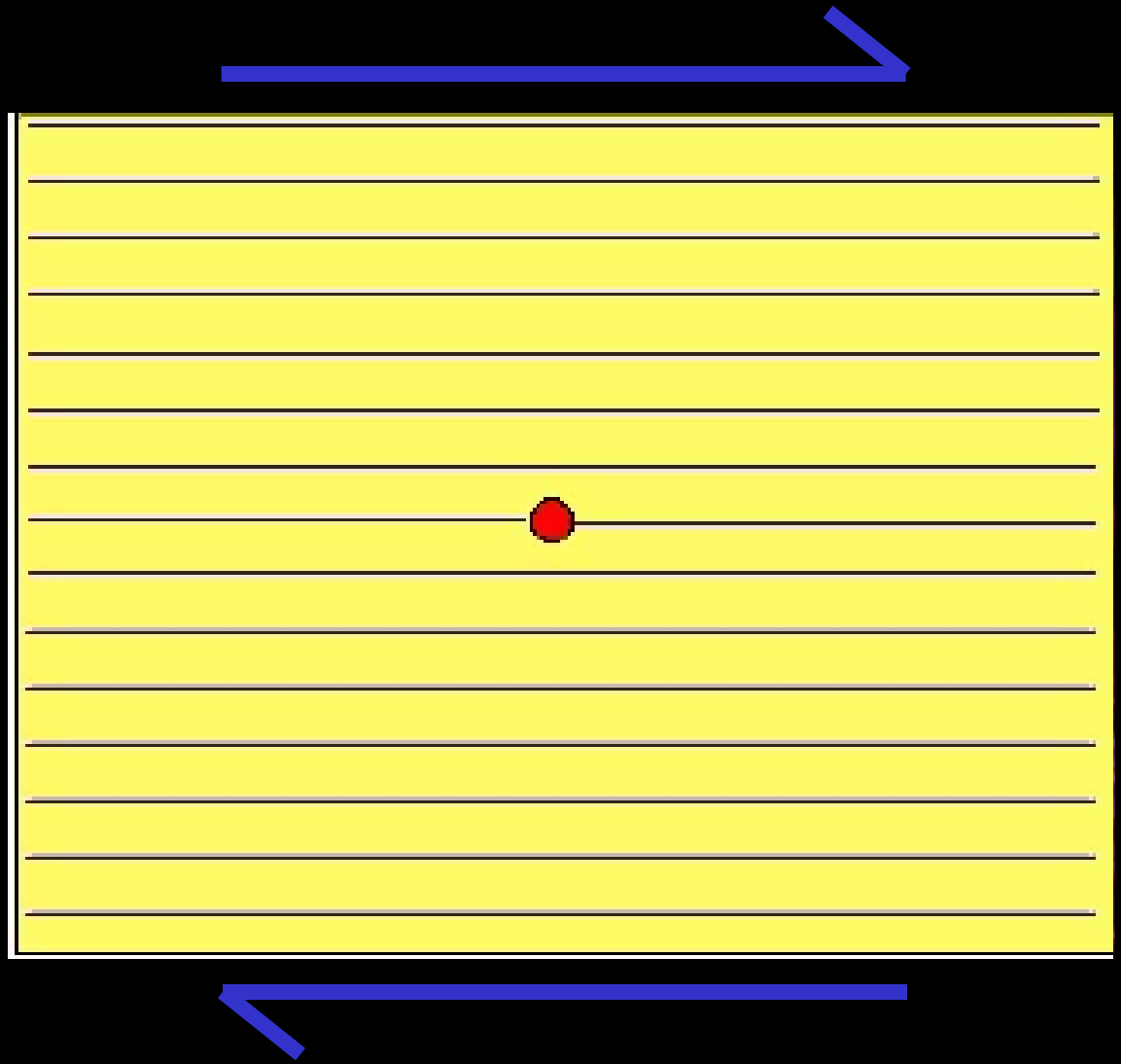
Garnet Staurolite Schist, Roxbury Falls, CT

Porphyroblastic Texture

Syntectonic “Rolled” Garnet



Rotated Garnet Porphyroblast

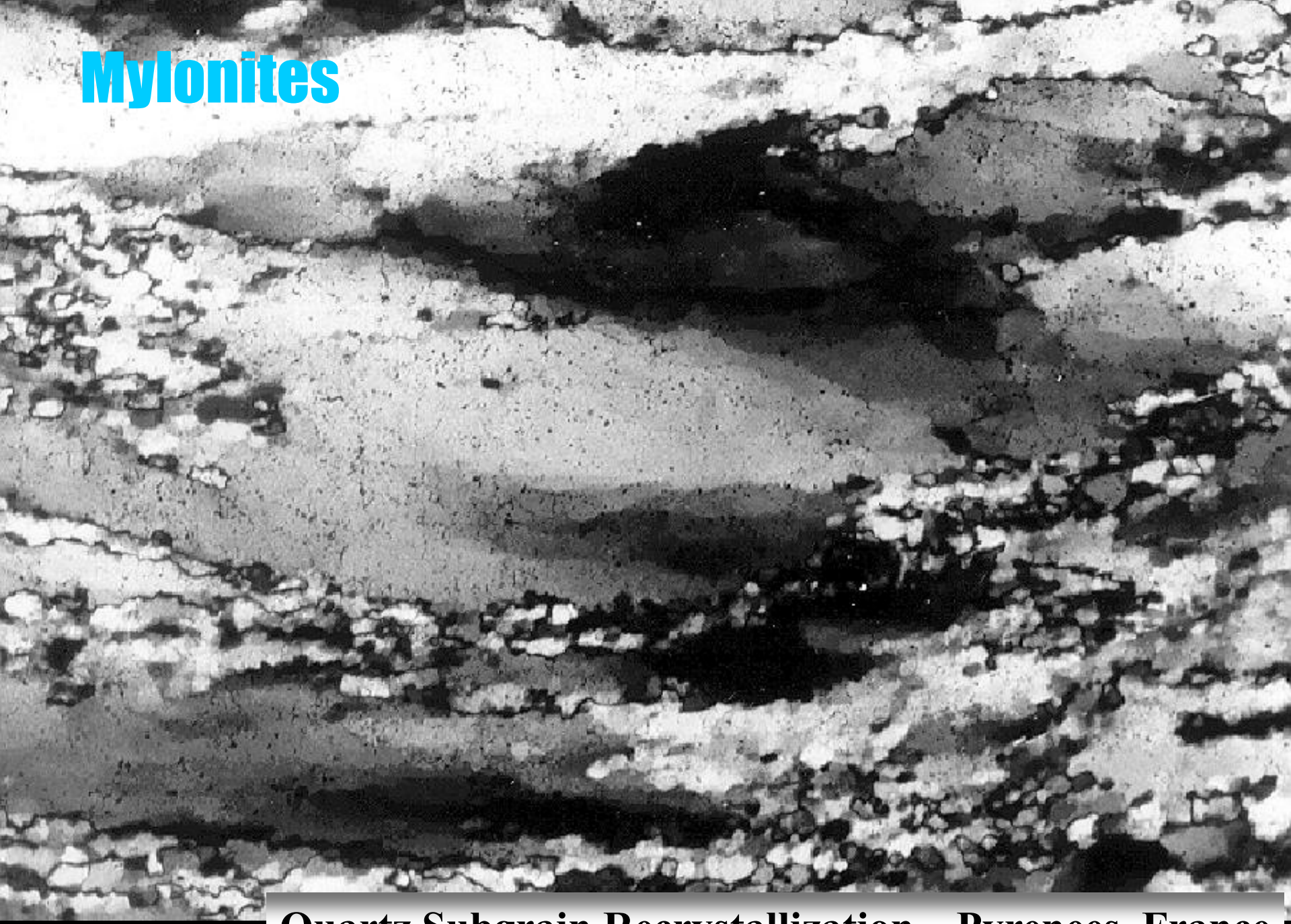


Dynamic Metamorphism - Mylonitic Rocks

Recrystallization with Shear

Mylonitization

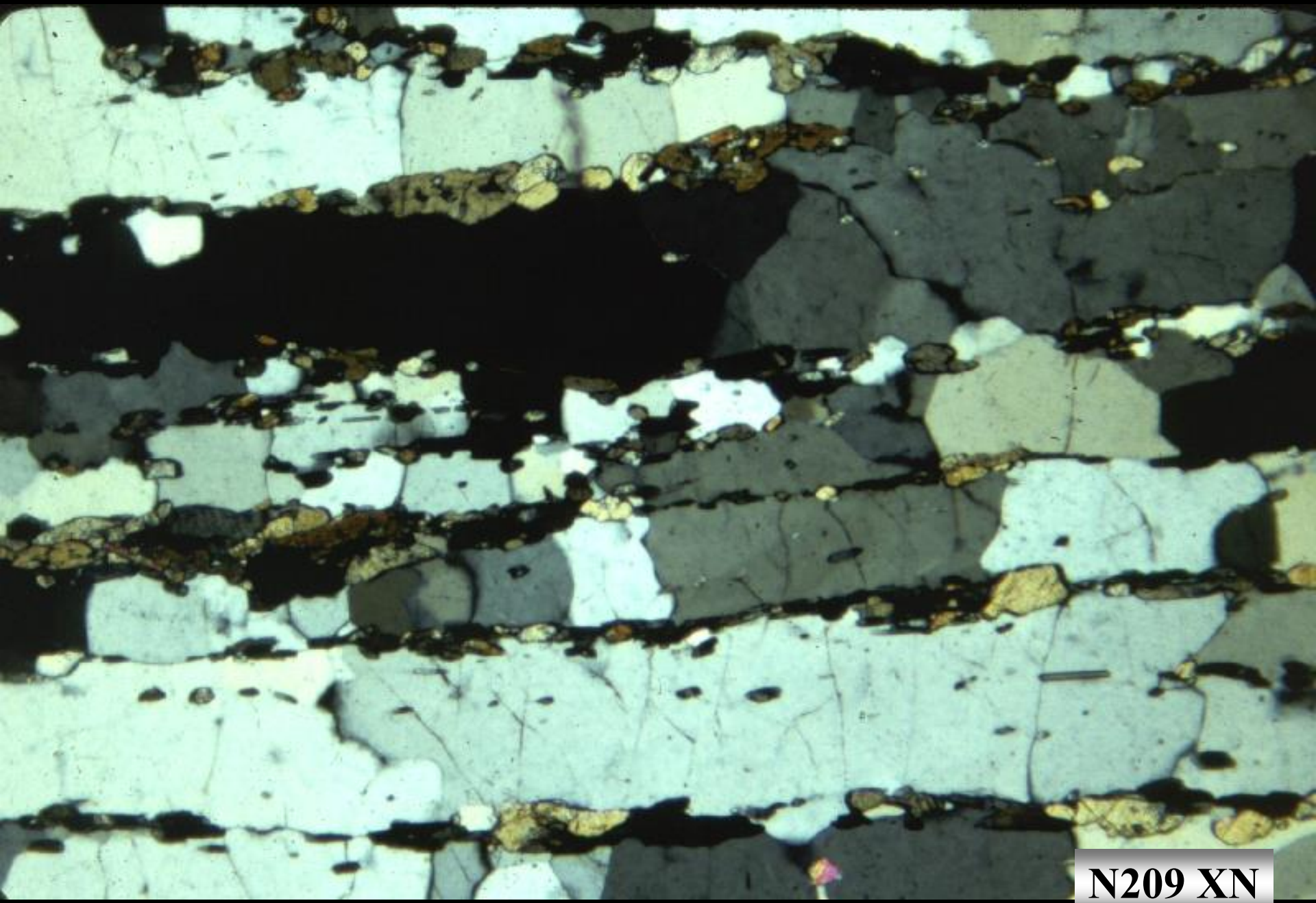
Mylonites

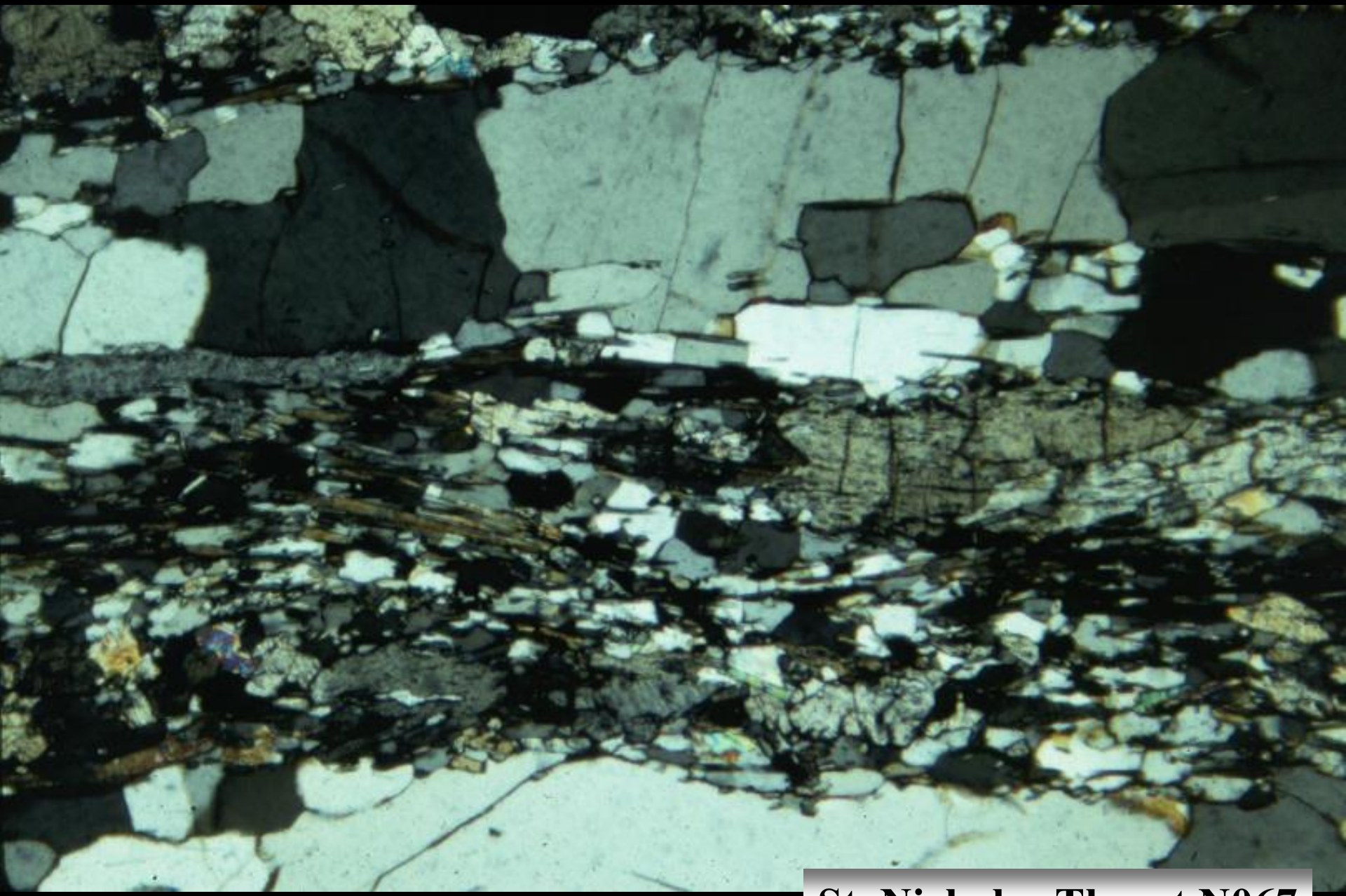


Quartz Subgrain Recrystallization – Pyrenees, France

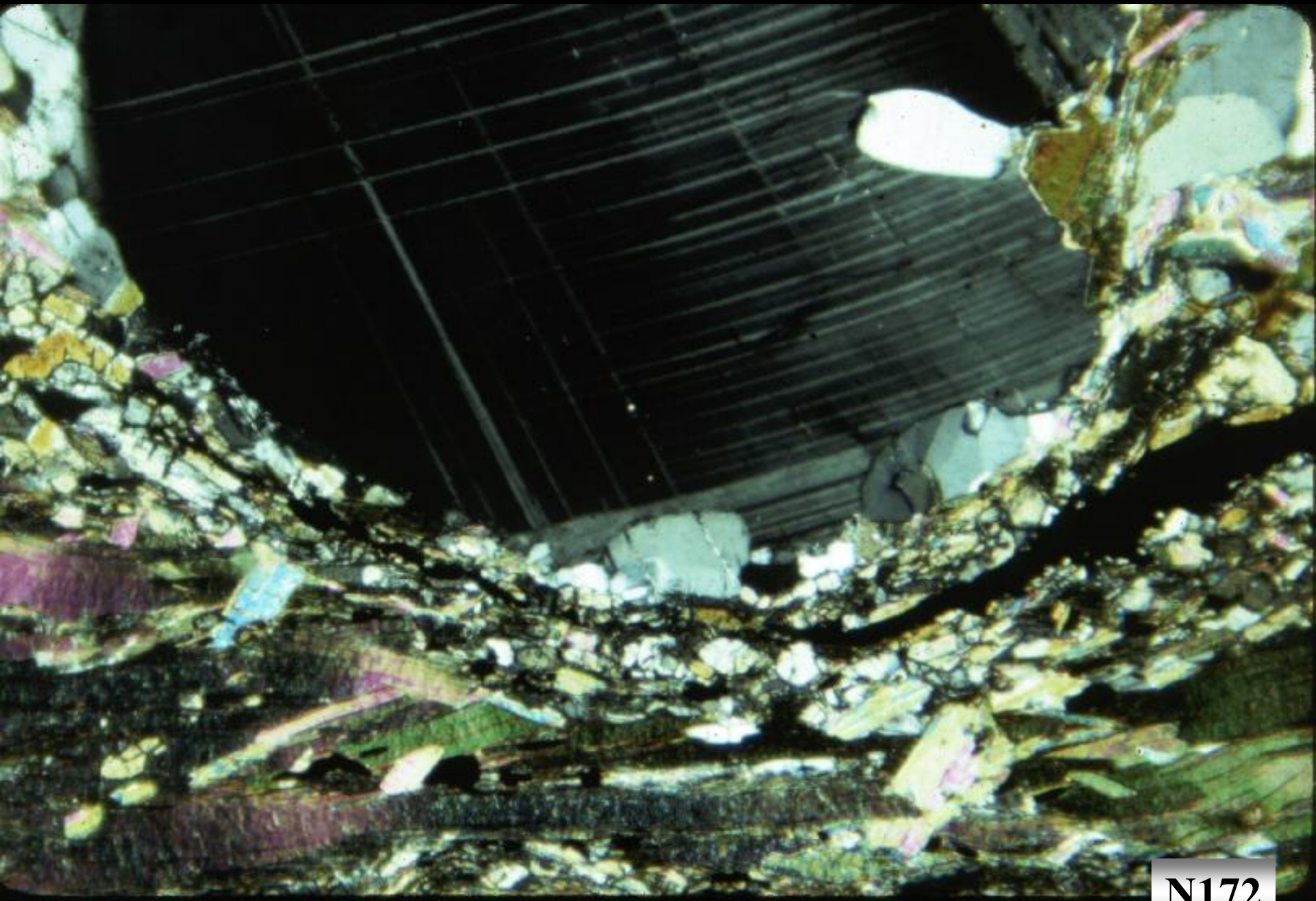
Shredded Mica “Fish” in Quartzite Mylonite – Minas Gerais, Brazil

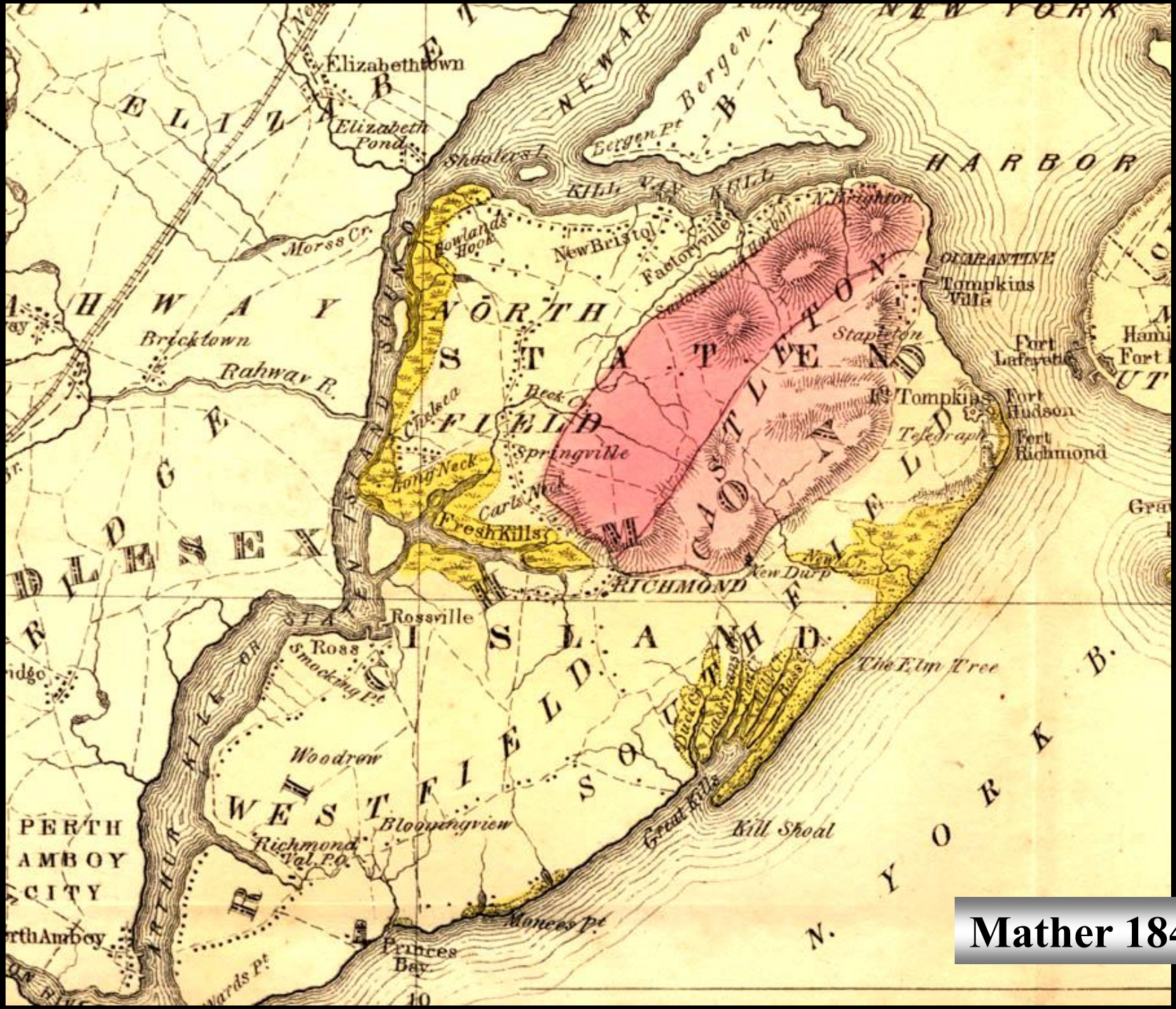

Mylonitic Manhattan Schist, St. Nicholas Thrust, NYC


N209 XN



St. Nicholas Thrust N067


N172

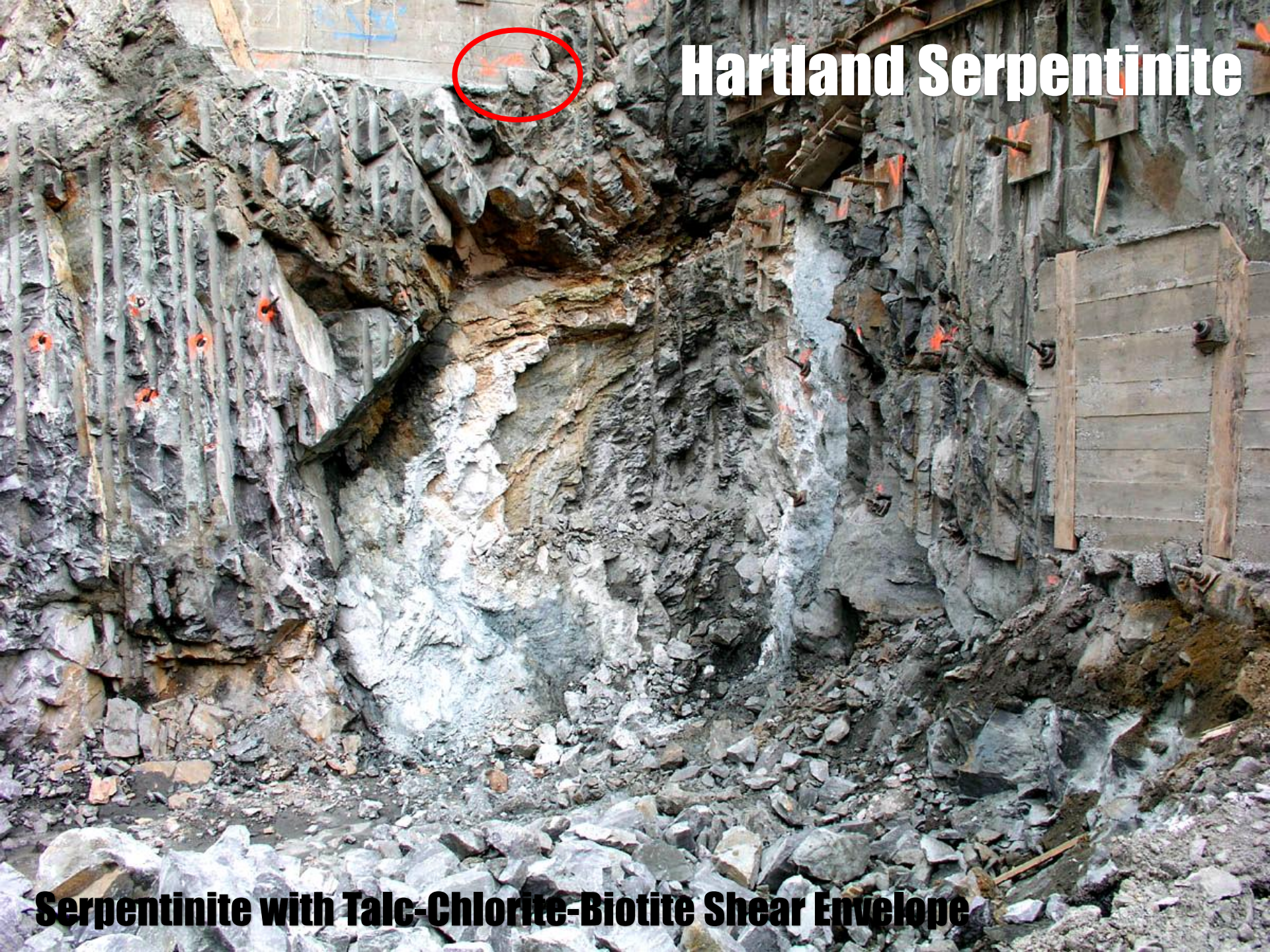

Elizabethtown
Elizabeth Pond
Shooters I.
Bergen Pt
Bergen
KILL VAN KULL
N. Brighton
Morse Cr.
Howlands Hook
New Bristol
Factoryville
Sailors Snug Harbor
QUARANTINE
Tompkins Ville
Stapleton
Fort Lafayette
Bricktown
Rahway R.
Chelsea
Beck Cr.
Springville
Fort Tompkins
Fort Hudson
Telegraph
Fort Richmond
Long Neck
Carls Neck
Fresh Kills
New Dorp
RICHMOND
Rossville
Ross
Smocking Pt
The Elm Tree
Woodrow
Bloomingview
Richmond Val. P.O.
Great Kills
Kill Shoal
PERTH AMBOY CITY
Princes Bay
Monces pt
Wards Pt
10

Mather 1843


Staten Island Serpentinite

Franciscan Complex, Coast Ranges, South Bay, CA

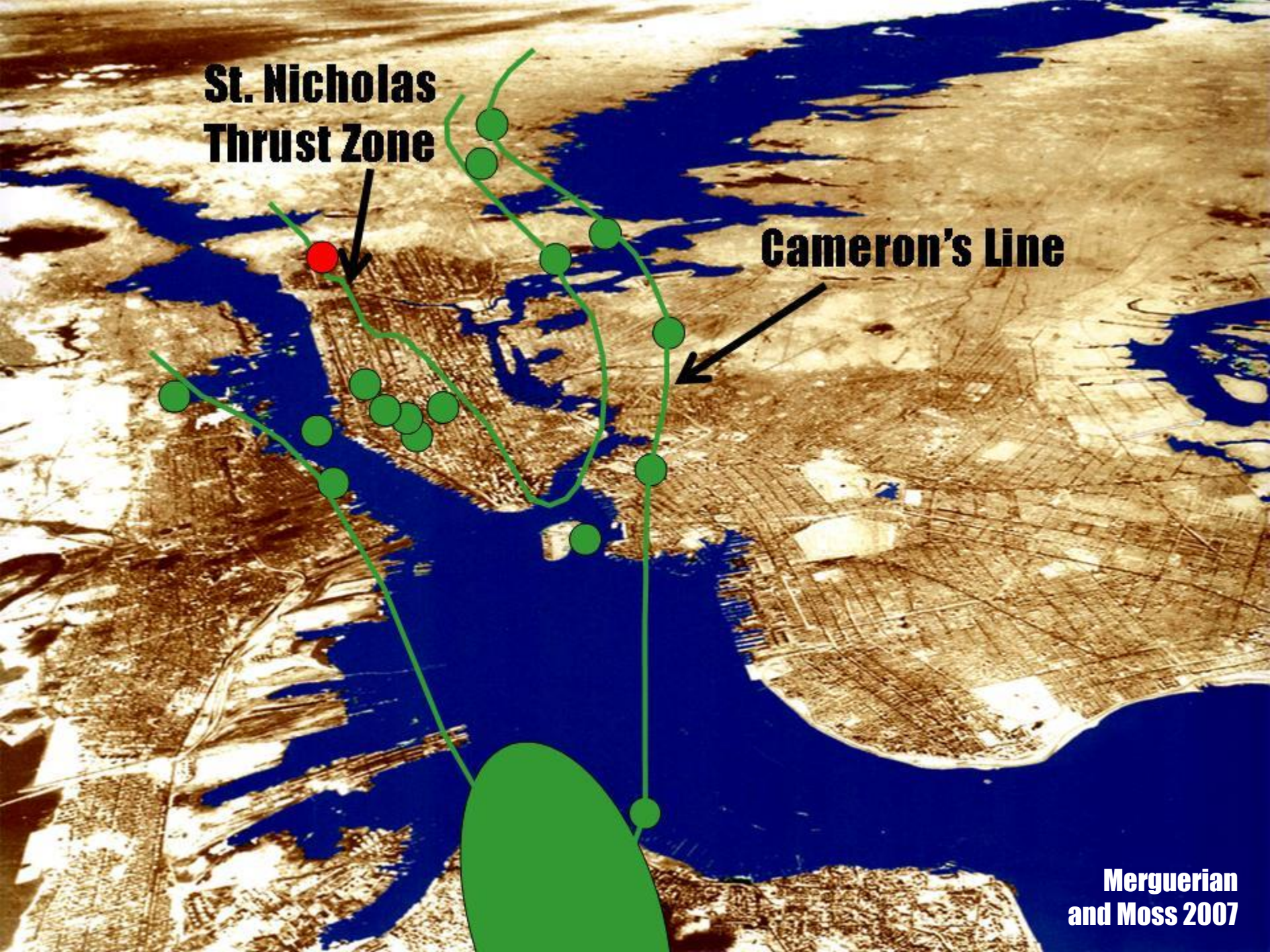

Serpentinite, Foothills Belt, CA

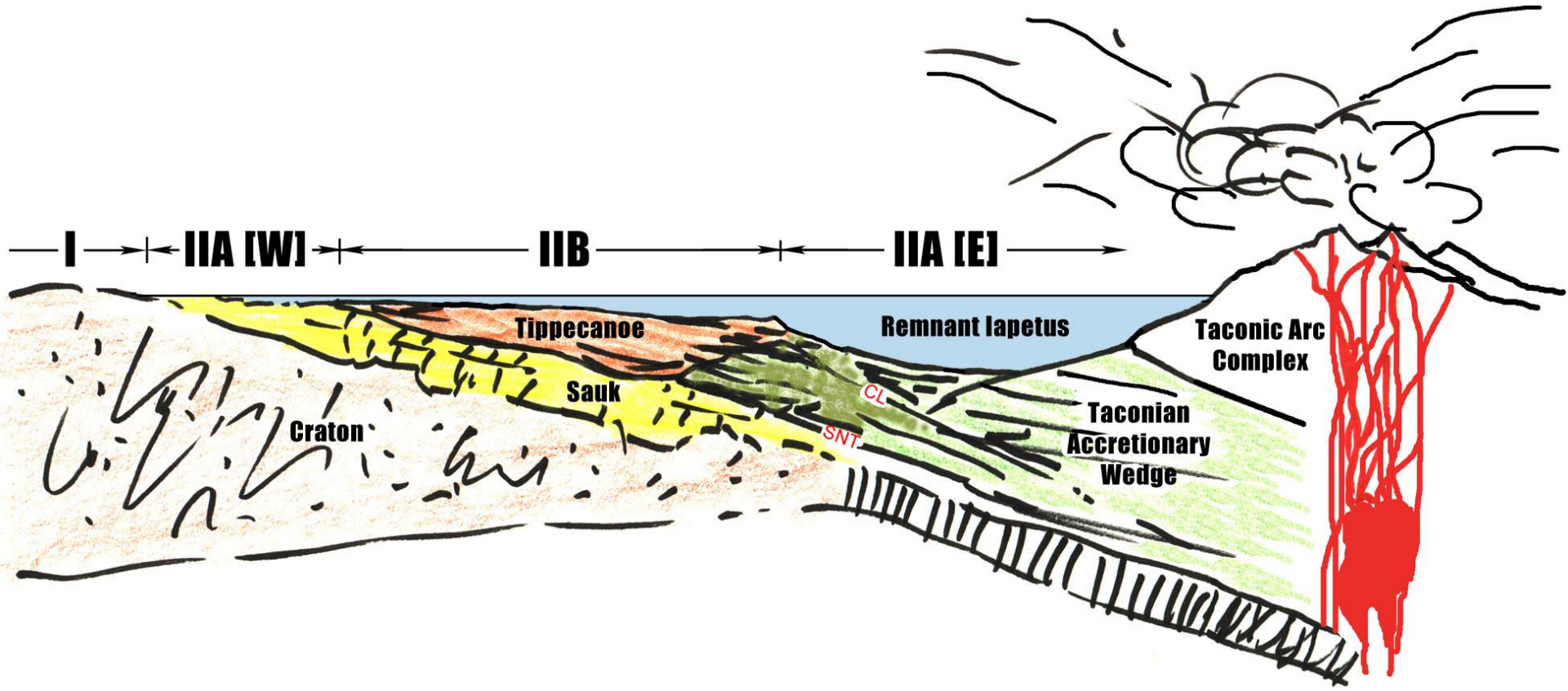

Hartland Serpentinite
Serpentinite with Talc-Chlorite-Biotite Shear Envelope


Cigar-Shaped Mass with Steep Plunge Southward
Base Not Exposed
>10 m Long Dimension
70°
Merguerian and Moss 2005

Sheared Western Margin

Merguerian and Moss 2005


St. Nicholas
Thrust Zone
Cameron's Line
Merguerian
and Moss 2007


I
IIA [W]
IIB
IIA [E]
Tippecanoe
Remnant Iapetus
Taconic Arc Complex
Sauk
CL
Craton
SNT
Taconian Accretionary Wedge


DUKE
OK, That's It!
I've Heard Enough!
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Erases