Outcrop Analog for Lower Paleozoic Hydrothermal Dolomite Reservoirs, Mohawk Valley, NY

A thesis presented to the Faculty
of the University at Albany
for the degree of
Master of Science
College of Arts & Sciences
Department of Geology

Brian E. Slater

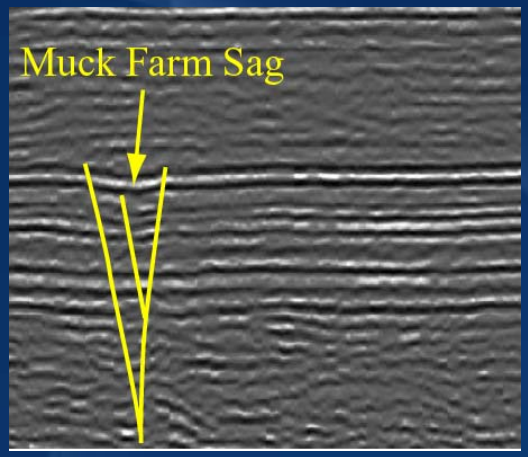
2007

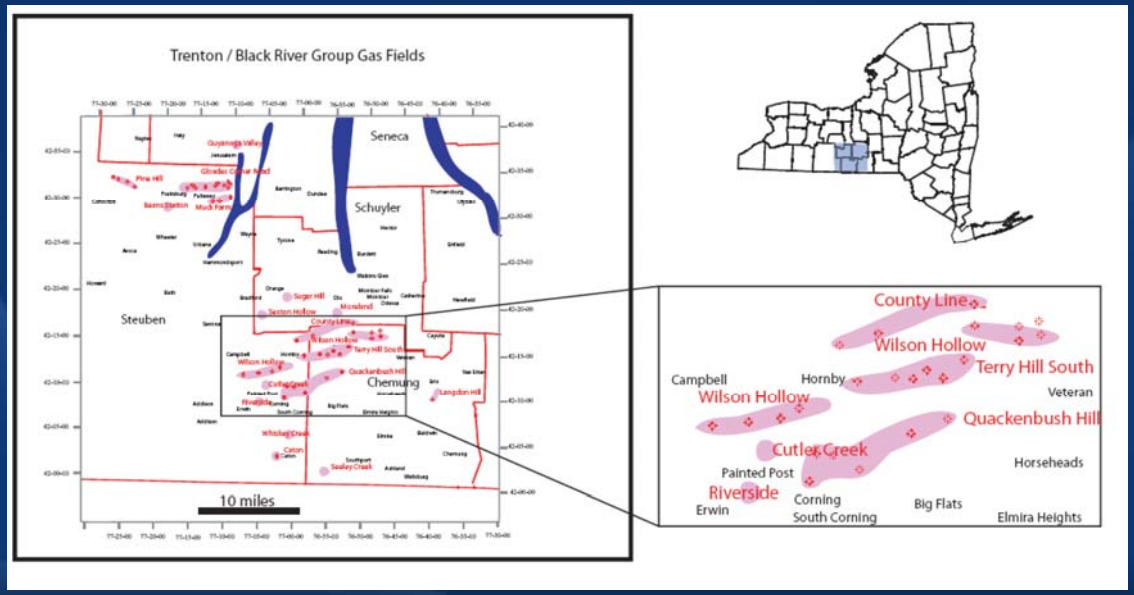
Introduction

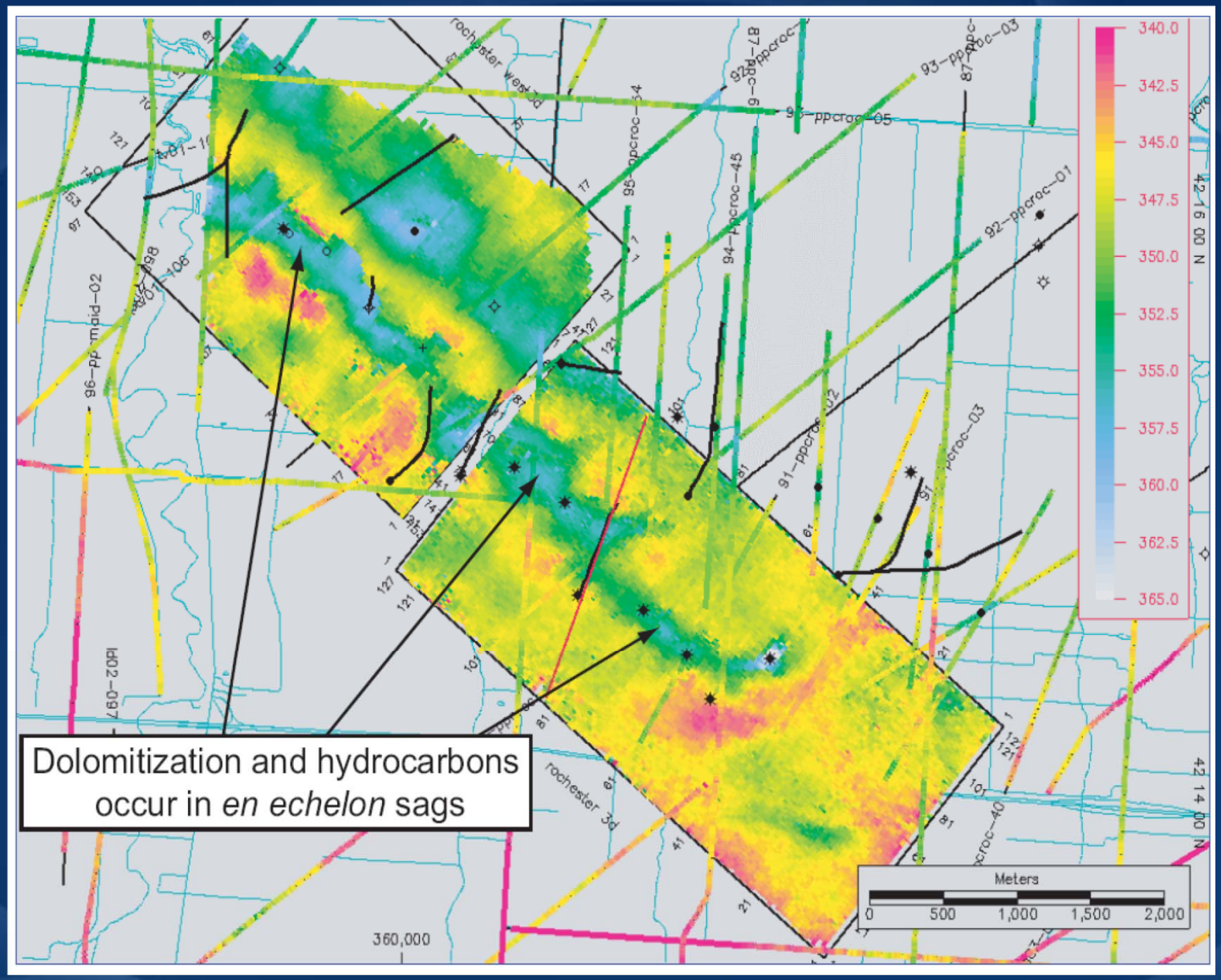
- The Hydrothermal Dolomite Play in NY
- Formation of Hydrothermal Dolomite
- Palatine Bridge Quarry Site
  - Location
  - Excavation
  - Geochemistry
  - Structure
  - Formation
- Comparison of Quarry to Producing Fields
- Conclusions

Production in New York

- In 2004 the Reed #1 Well was the largest on-shore gas well in the continental US
- Long, Linear, Highly Localized Dolomite Bodies
- Porosity occurs in vugs lined with saddle dolomite crystals
- In cross section these bodies appear as negative flower structures characterized by sags bound by anticlines






Dolomitization and hydrocarbons occur in *en echelon* sags
340.0
342.5
345.0
347.5
350.0
352.5
355.0
357.5
360.0
362.5
365.0
Meters
0
500
1,000
1,500
2,000
360,000
42 16 00 N
42 14 00 N
rochester west 3d
rochester 3d
96-pp maid-02
95-ppcroc-05
94-ppcroc-45
93-ppcroc-03
92-ppcroc-01
91-ppcroc-03
87-ppcroc-03

Model for Formation of Hydrothermal Dolomite

(Smith and Davies , 2006)

1. Deeply buried saline fluids become trapped in porous units overlain by impermeable cap rocks
2. Tectonic activity causes a breach in the cap rock allowing the pressurized fluids to escape upward along fault planes
3. These fluids rapidly rise to shallower depths where they are hotter than the ambient burial temperature or *hydrothermal*
4. These hot fluids commonly precipitate dolomite and as they cool they leach the surrounding limestone

The Palatine Bridge Study Site

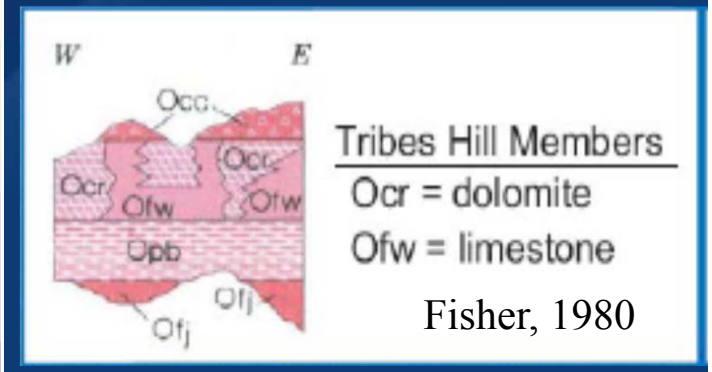
Location

- Central Mohawk Valley
- Town of Palatine Bridge
- Roughly 100 miles from NY's producing gas fields
- Outcrop of dolomite on the floor of the Frye Estate Quarry

Location (cont'd)

- Stratigraphically, the quarry is located in the Tribes Hill Fm.
- Thin to medium-bedded argillaceous limestone with patchy dolomitization throughout Mohawk Valley
- Overlies the Little Falls Dolostone, Potsdam Sandstone, and Precambrian Basement
- Overlain by the Black River Group, Trenton Group and Utica Shale

Period		Group	Unit	Lithology
Ordovician	Upper		Queenston Sst Lorraine Sltst Utica Shale	
		Trenton/ Black River	Trenton Lst	
			Black River Lst	
	Lower	Beekman-town	Tribes Hill Lst	Knox Unc.
Cambrian	Upper		Theresa Sst Little Falls Dol	
			Potsdam Sst	
Precambrian Basement				



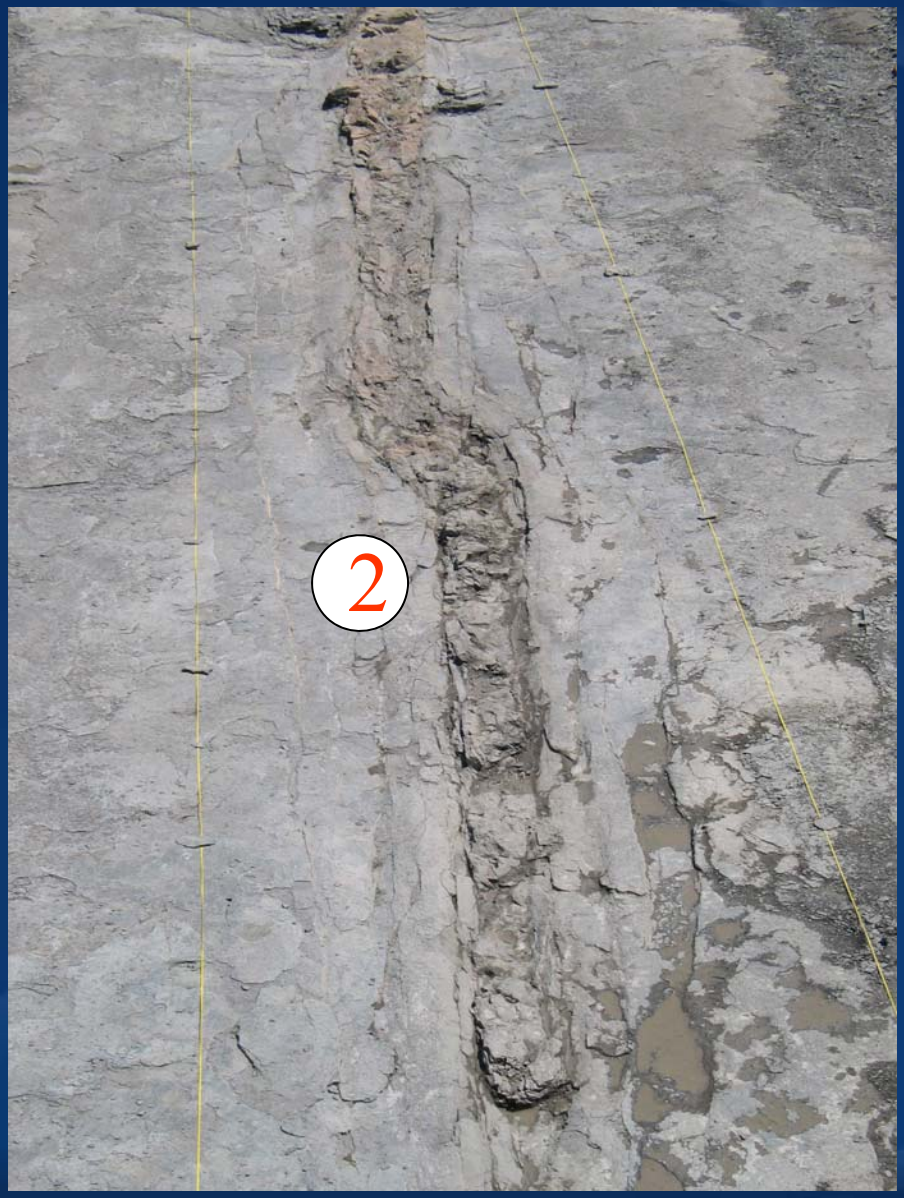
Excavation

Excavation

Excavation

Excavation

The Outcrop Revealed



Surficial Observations

Mineral Assemblage

- Matrix Dolomite
- Saddle Dolomite
- Calcite
- Pyrite
- Quartz

(Herkimer Diamond)

1 cm

Geochemistry

- STRONTIUM ISOTOPE

Mihai Ducea (U Arizona)

- STABLE ISOTOPES

Steve Howe (U Albany)

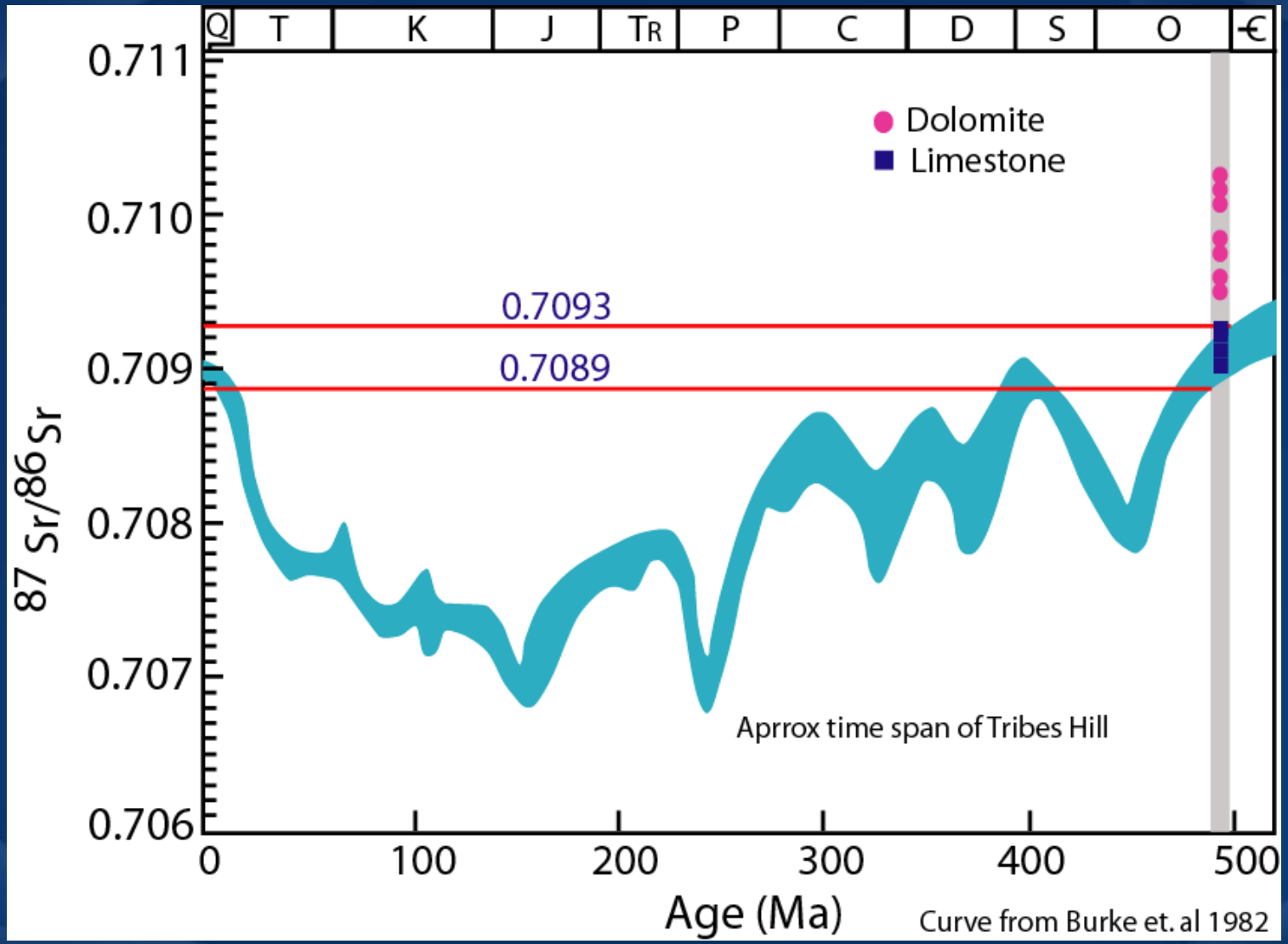
Peter Swart (U Miami)

- FLUID INCLUSIONS

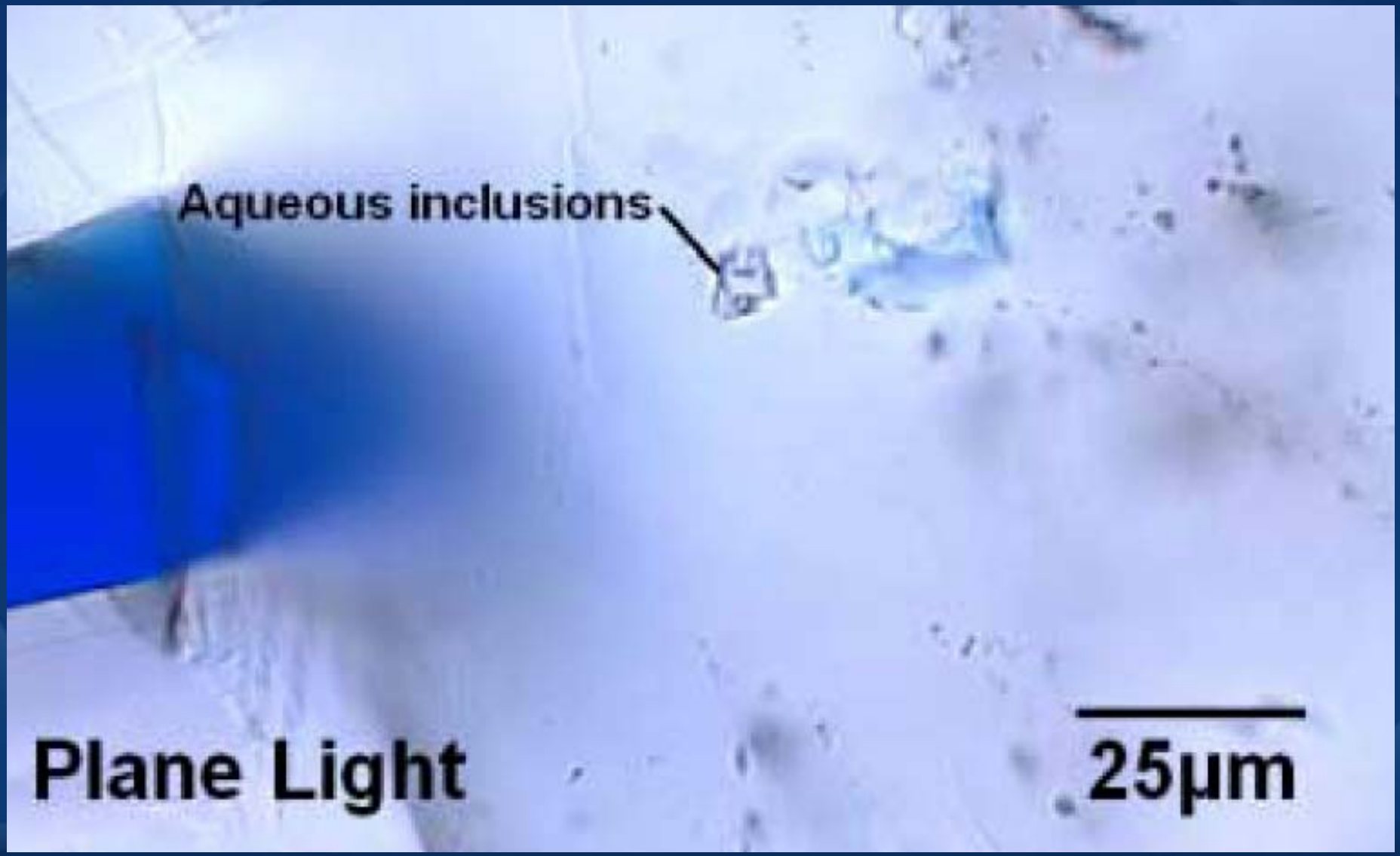
Fluid Inclusion Tech. (OK)

Brian Slater (U Albany)

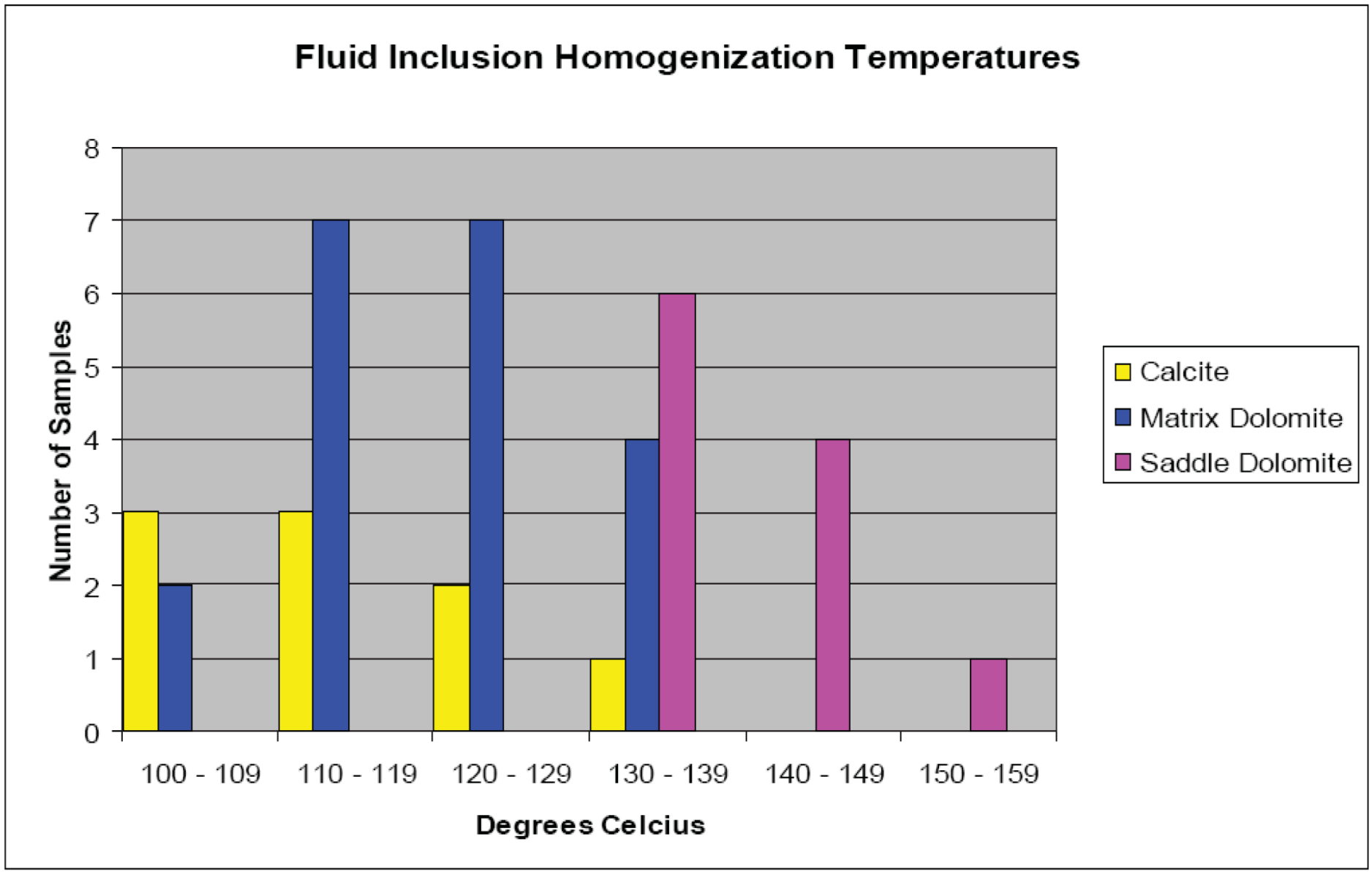
Strontium Isotope Composition of Seawater Through Time



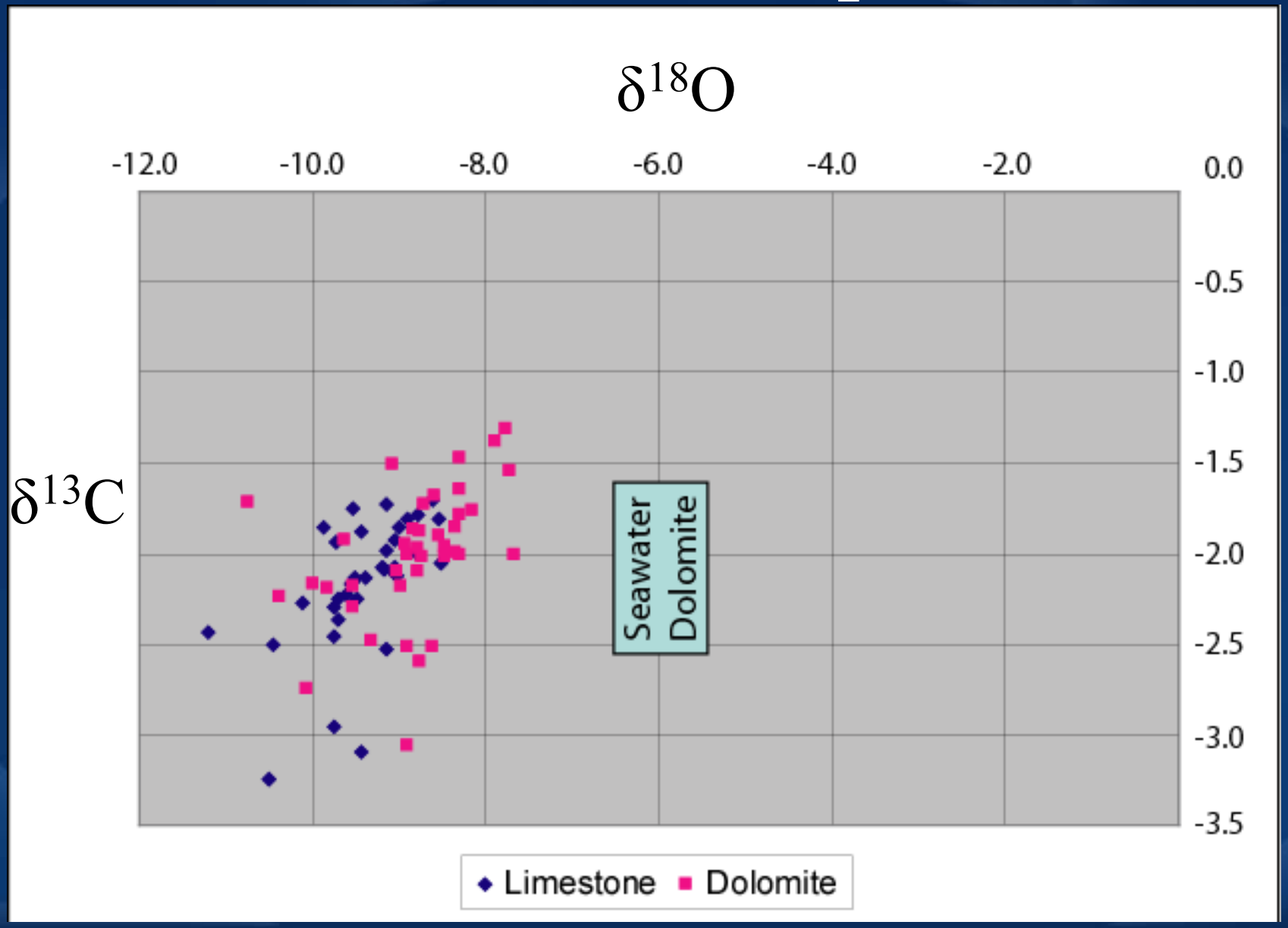
Fluid Inclusions



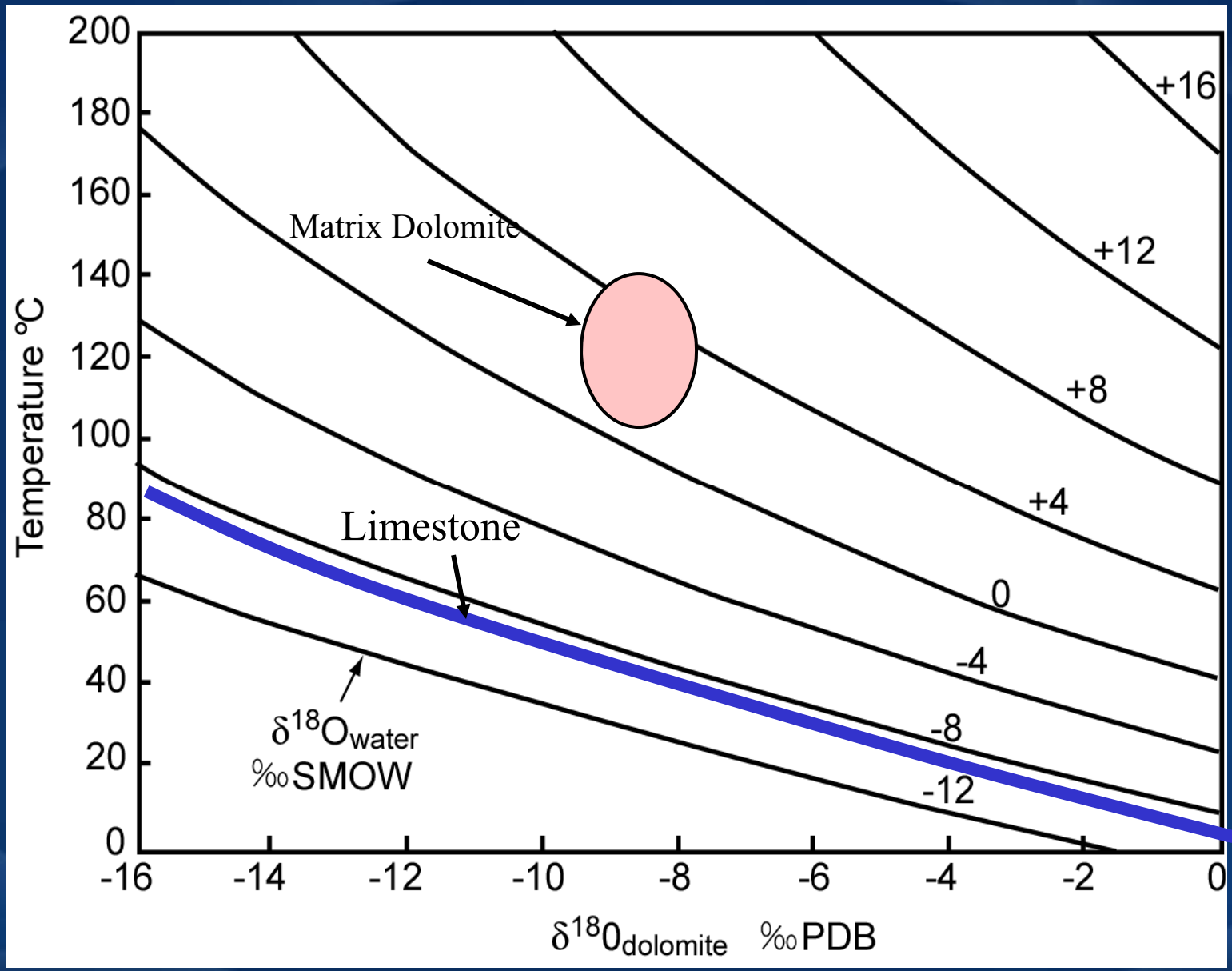
Fluid Inclusions



Stable Isotopes

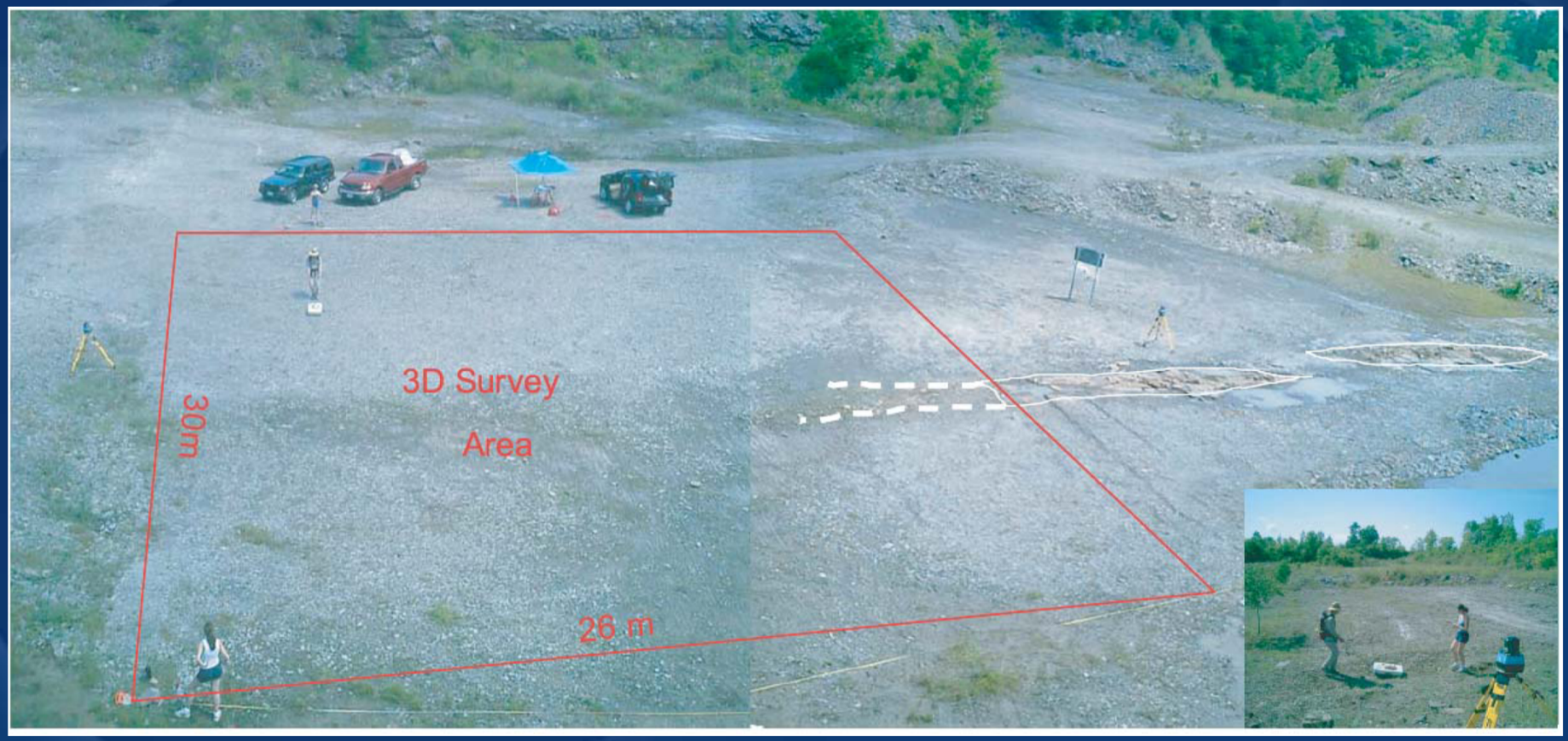


Fluid Inclusions vs. Oxygen Isotopes

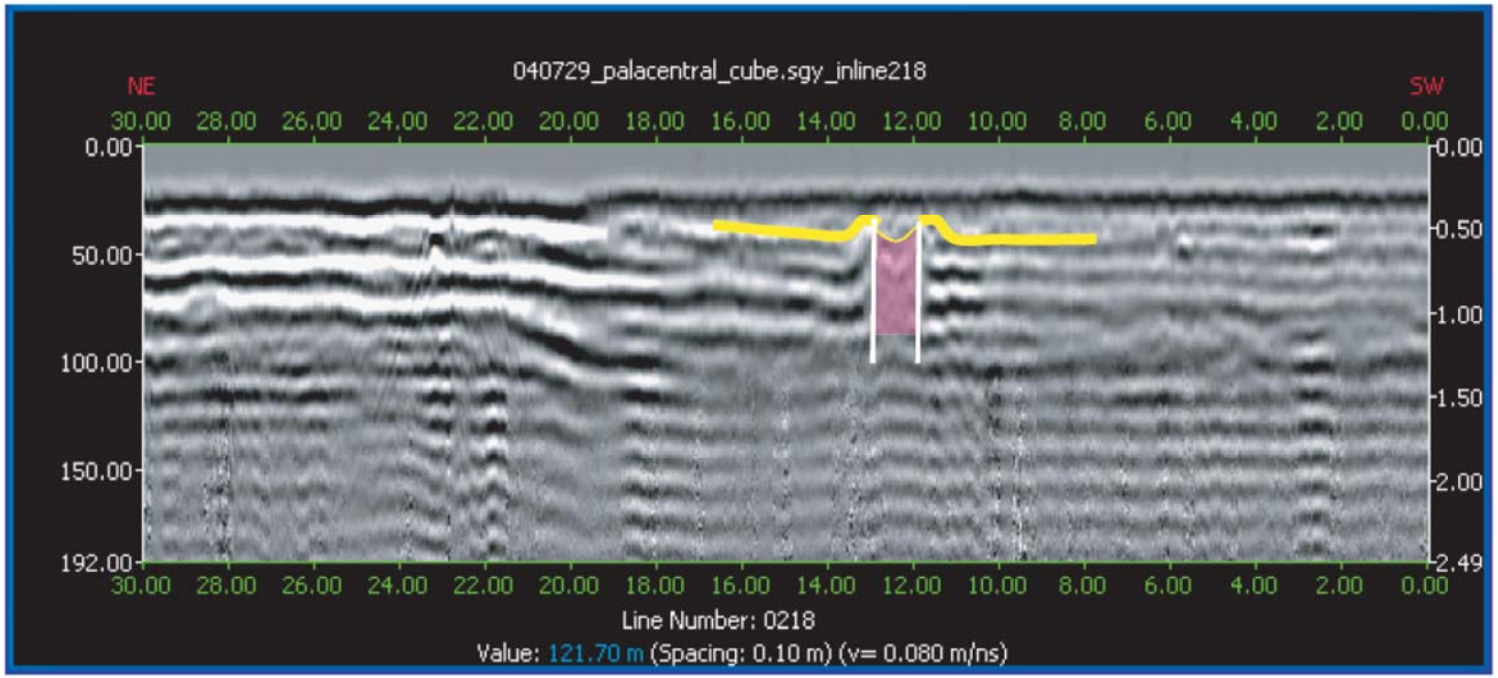


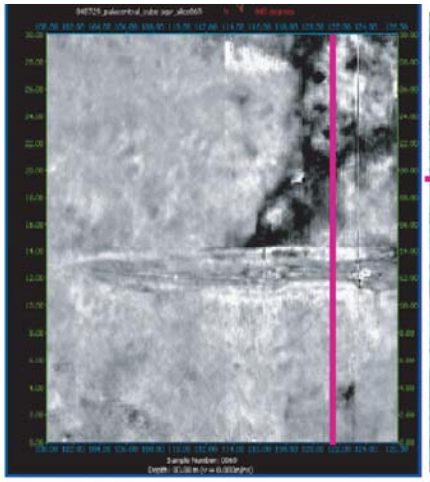
Allan and Wiggins, 1993

Ground Penetrating Radar

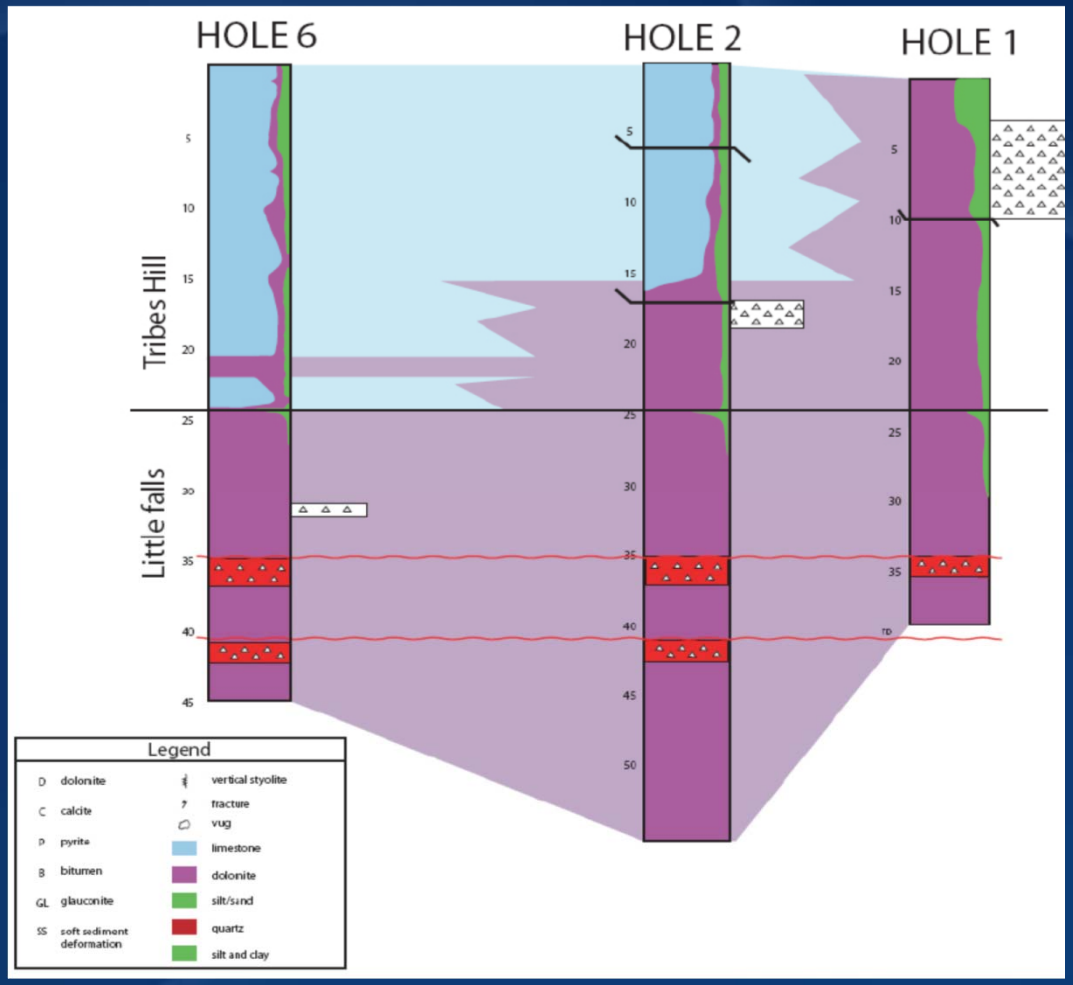


GPR Results


040729_palacentral_cube.sgy_inline218
NE
SW
30.00 28.00 26.00 24.00 22.00 20.00 18.00 16.00 14.00 12.00 10.00 8.00 6.00 4.00 2.00 0.00
0.00
50.00
100.00
150.00
192.00
0.00
0.50
1.00
1.50
2.00
2.49
Line Number: 0218
Value: 121.70 m (Spacing: 0.10 m) (v= 0.080 m/ns)

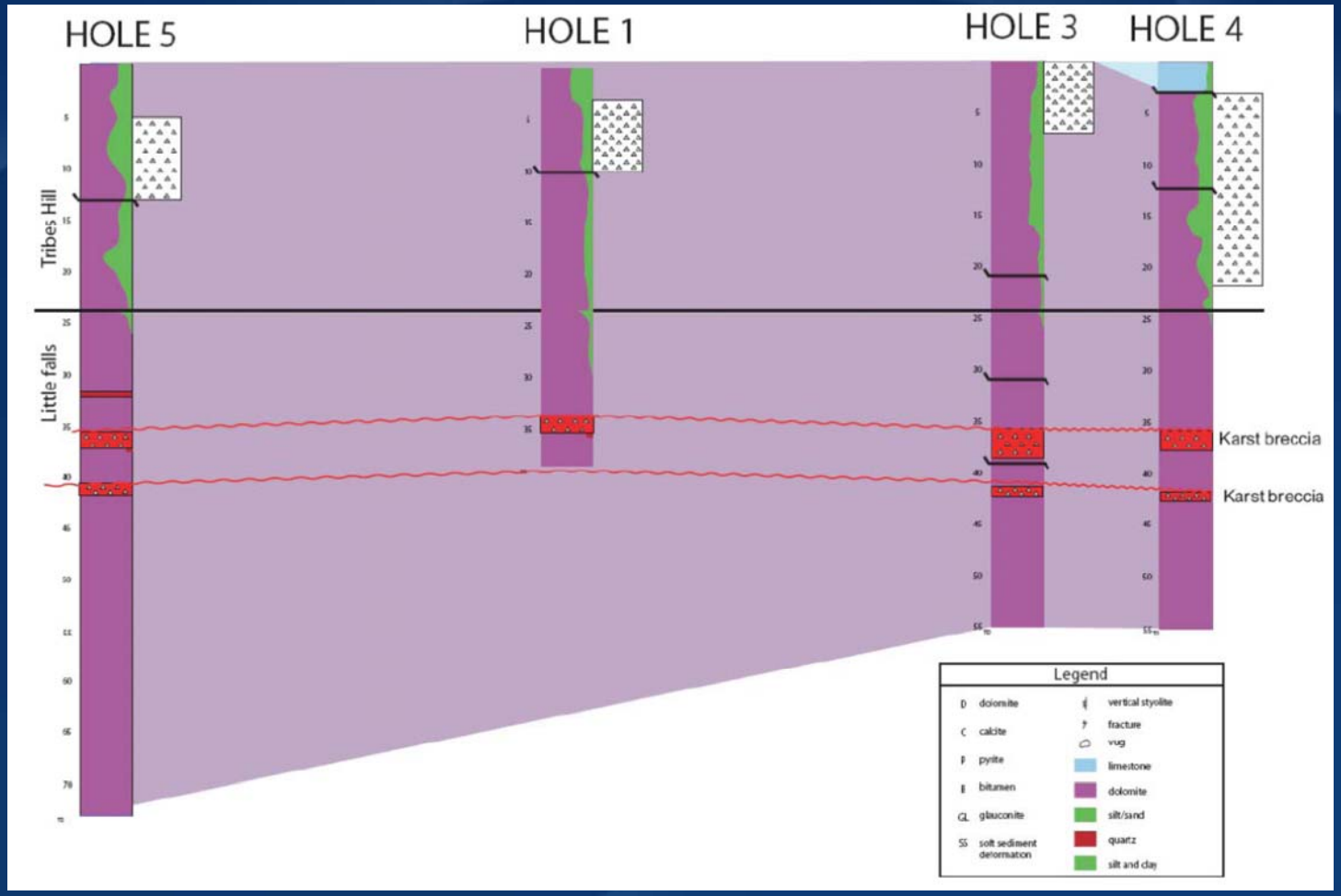


Drill Cores

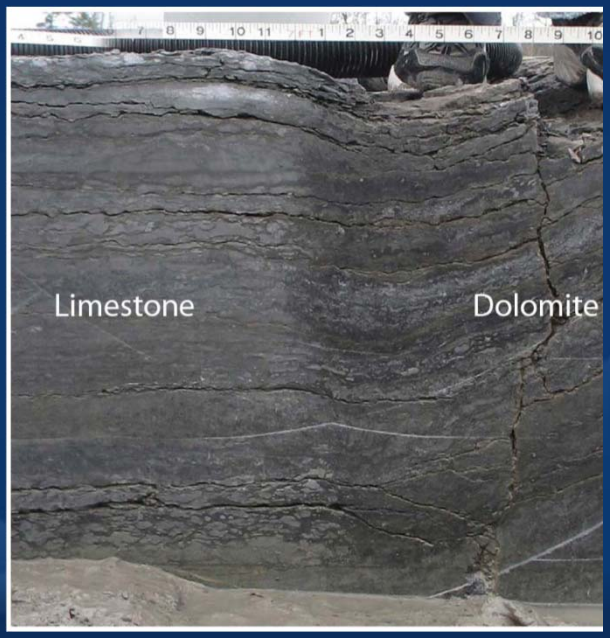

HOLE 6
HOLE 2
HOLE 1
Tribes Hill
Little falls
Legend
D dolonite
C calcite
P pyrite
B bitumen
GL glauconite
SS soft sediment deformation
vertical styolite
fracture
vug
limestone
dolonite
silt/sand
quartz
silt and clay


6
2
1
5
3
4

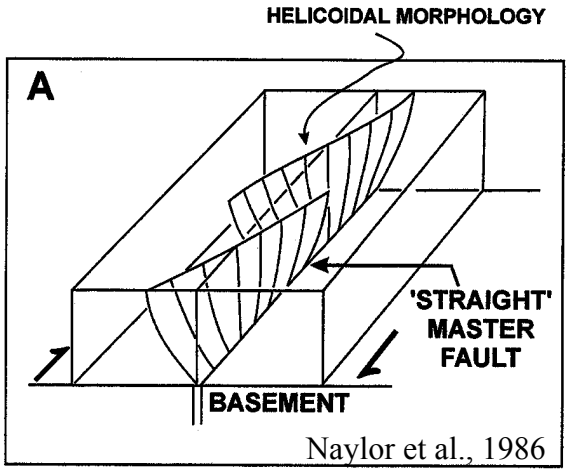
Drill Cores (cont'd)



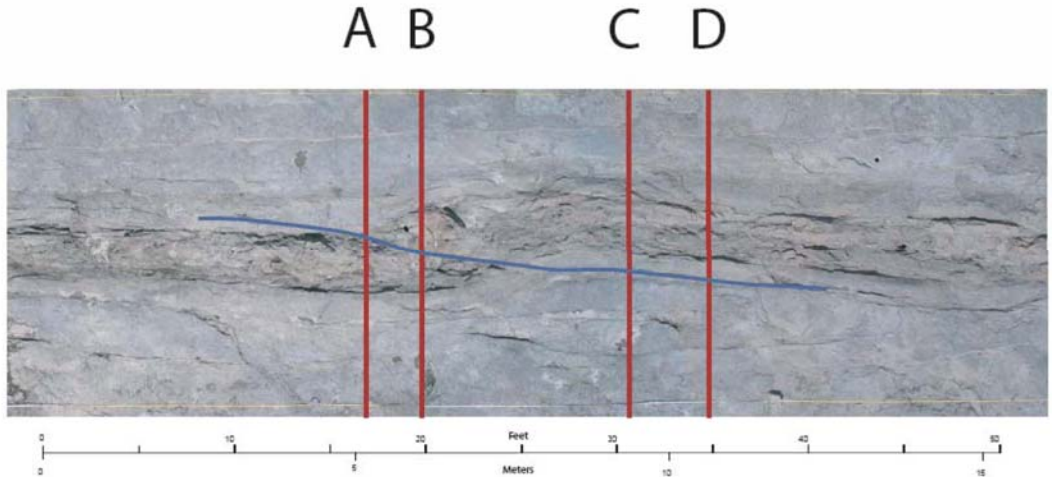
Trenches

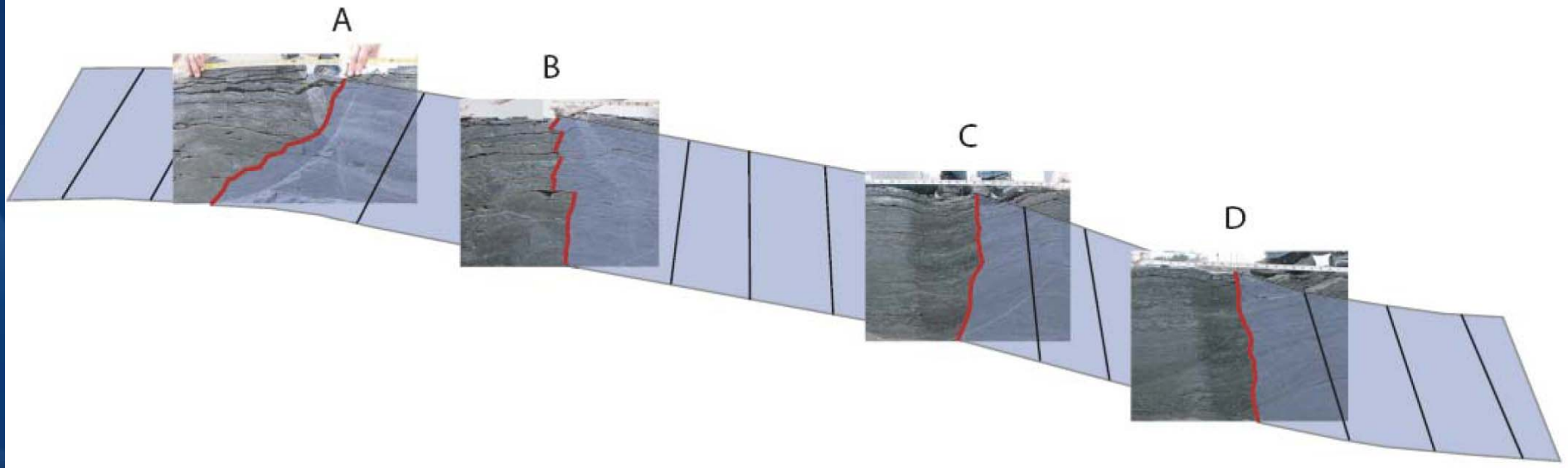


Scissor Fault



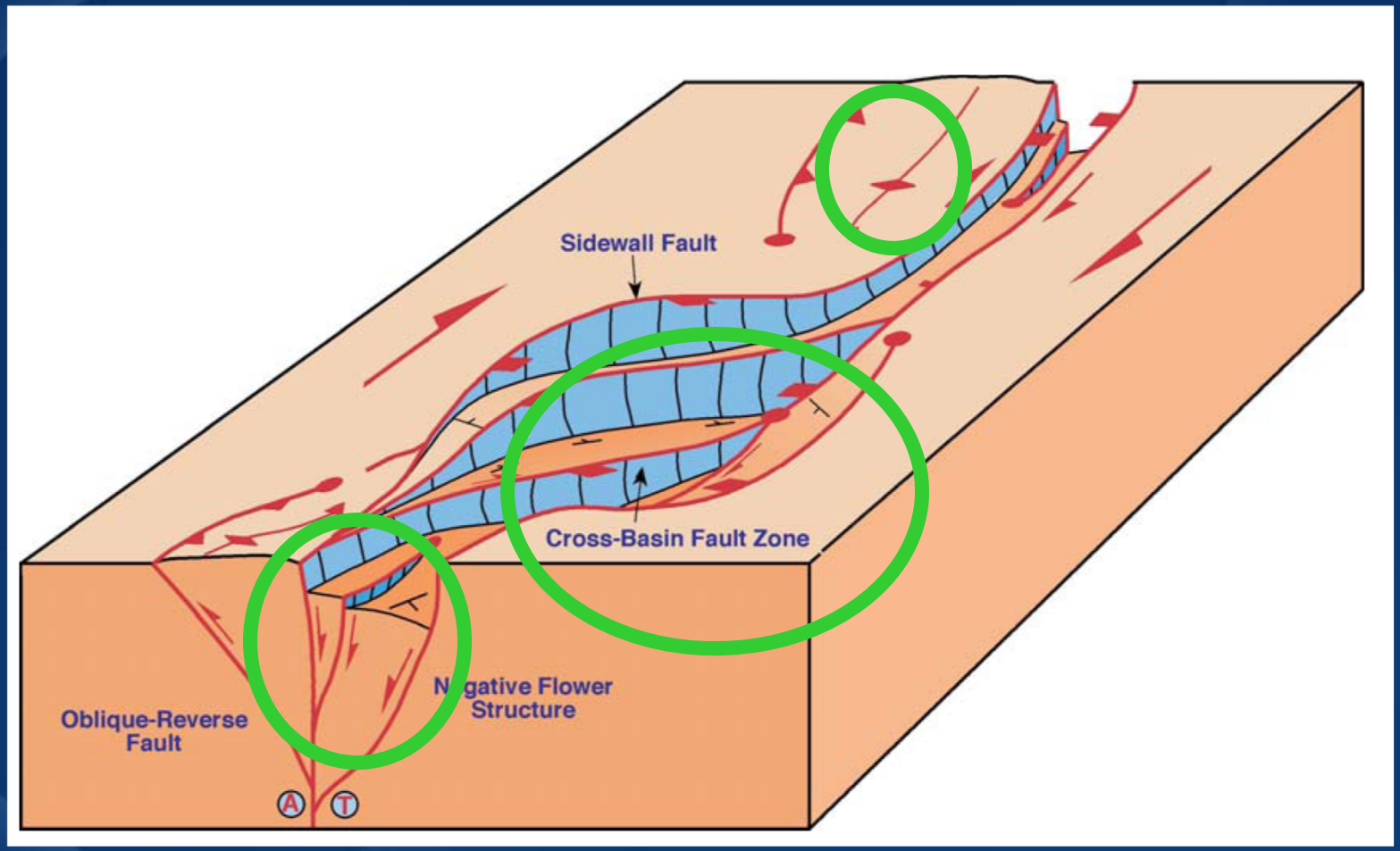
Naylor et al., 1986



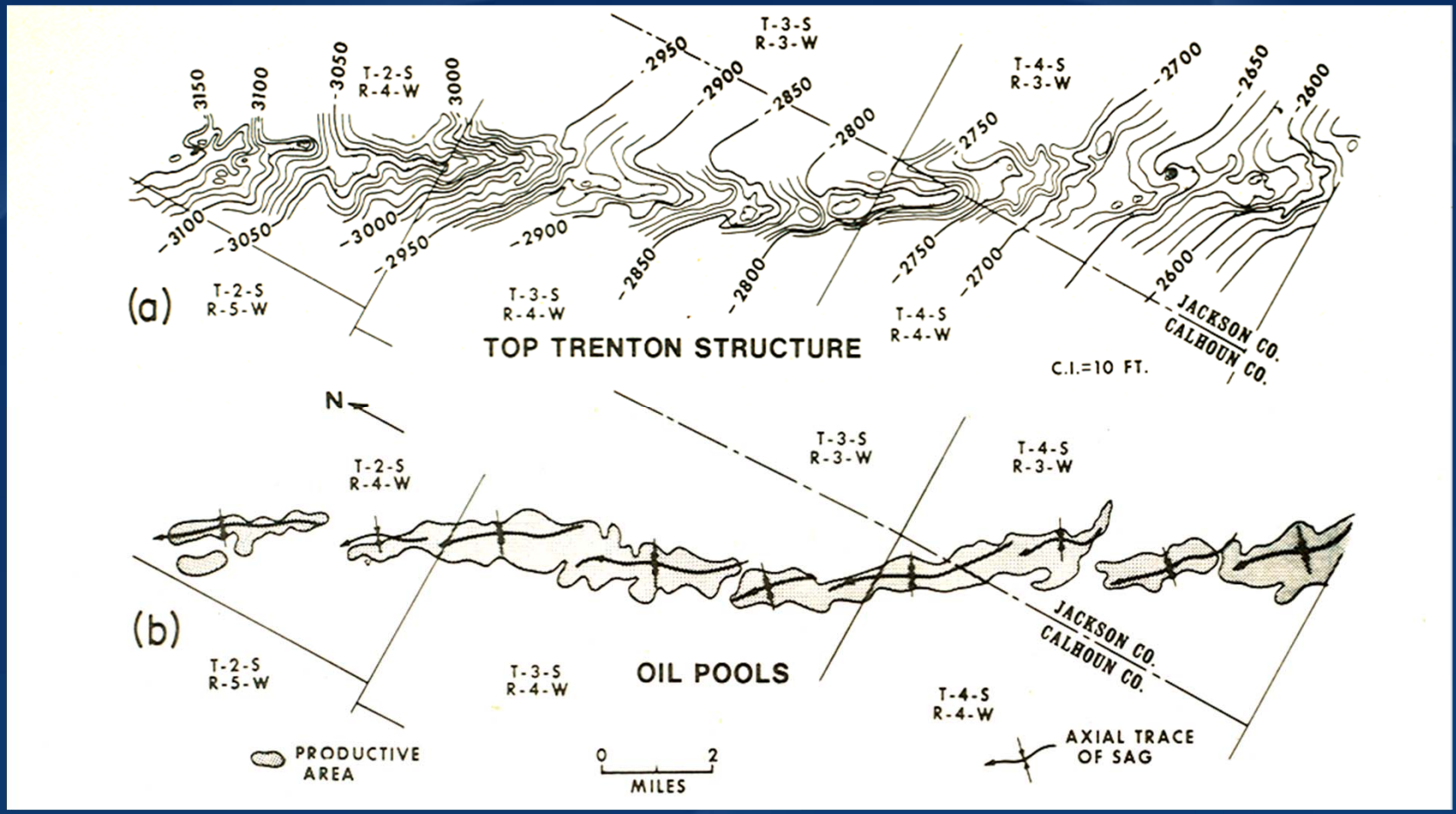


Dooley & McClay

Strike-slip Pull-apart Model



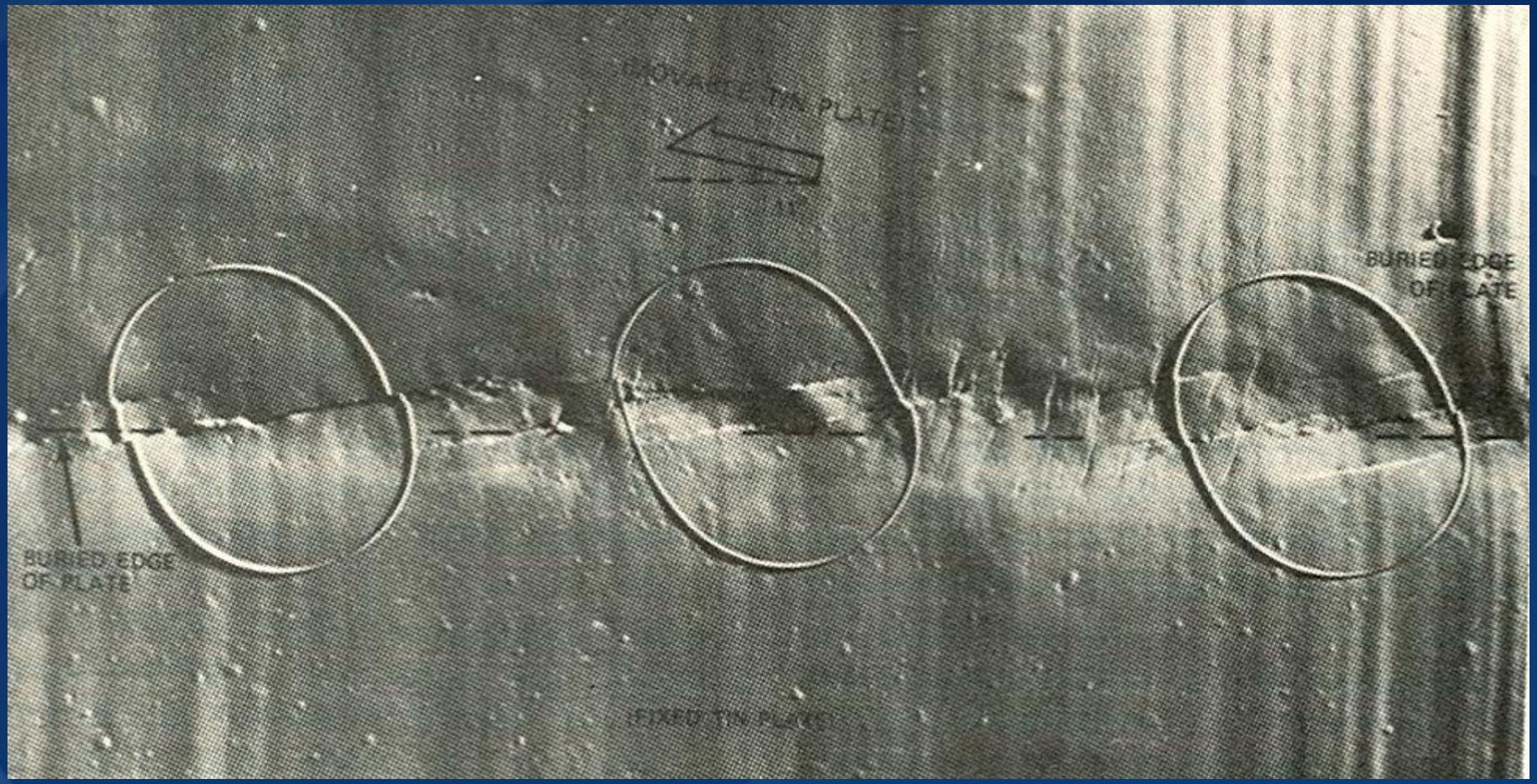
Harding, 1974



In order to produce the sags found at Albion Scipio, Harding added a component of extension to the fault movement or "oblique divergent slip" at 11° to the trend of fault

"An oblique divergent component would have emphasized the extensional effects of the mild deformation and would have tended to open the synthetic fractures, facilitating dolomitization"

Harding, 1974



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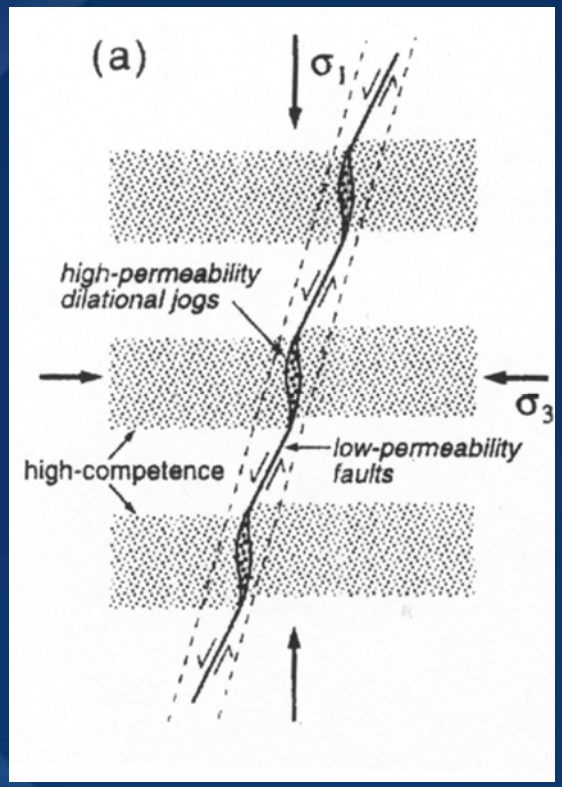
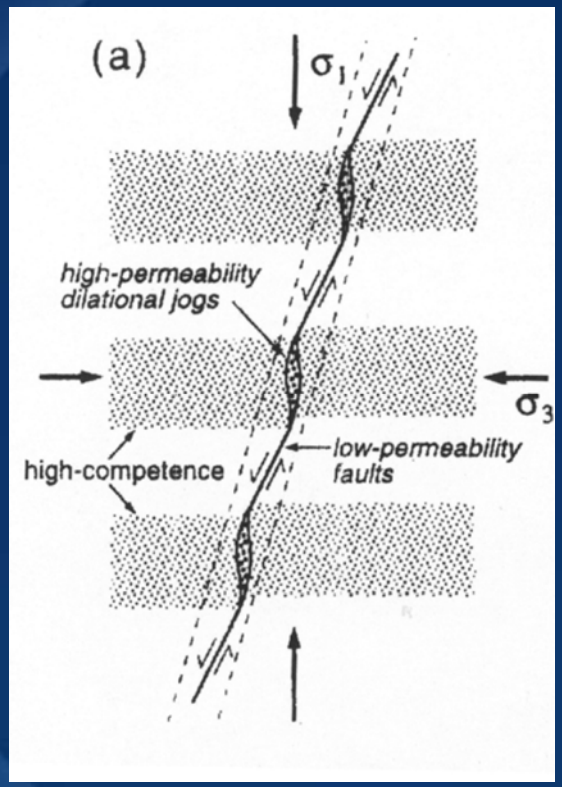
Sibson

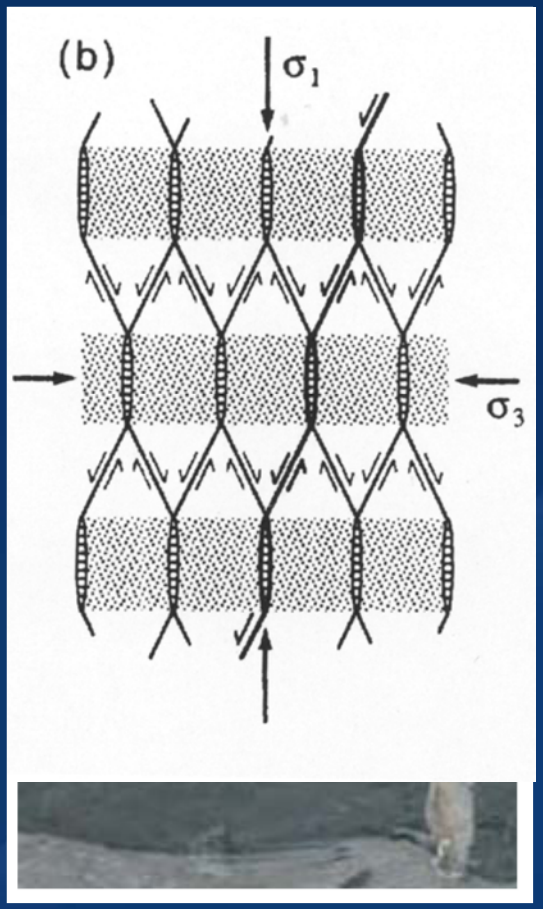
The Nature of Faults and Fractures



Sibson

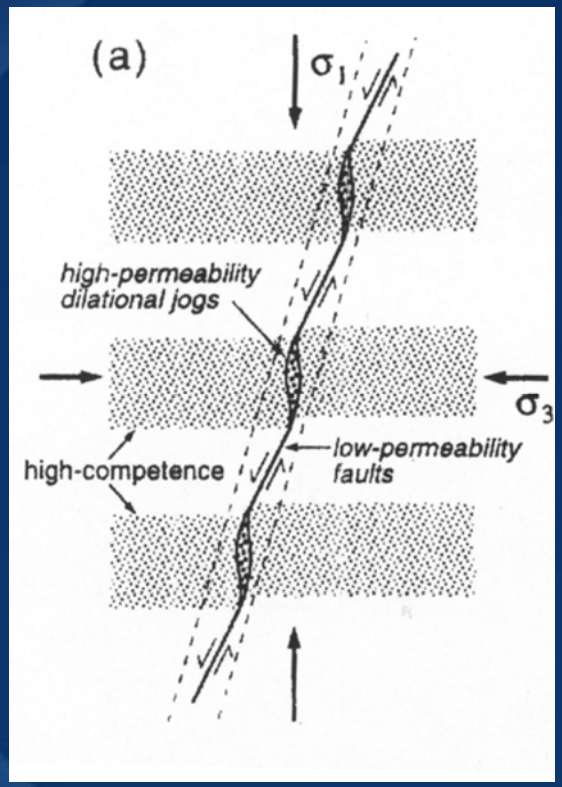
The Nature of Faults and Fractures

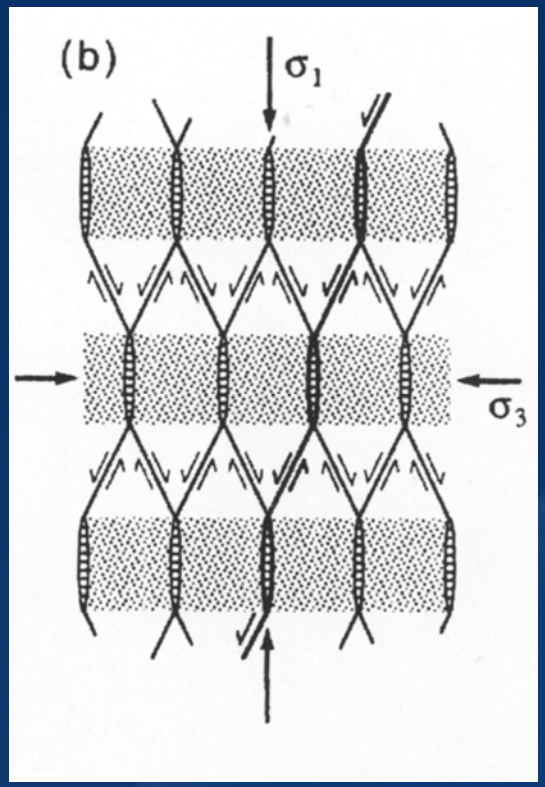


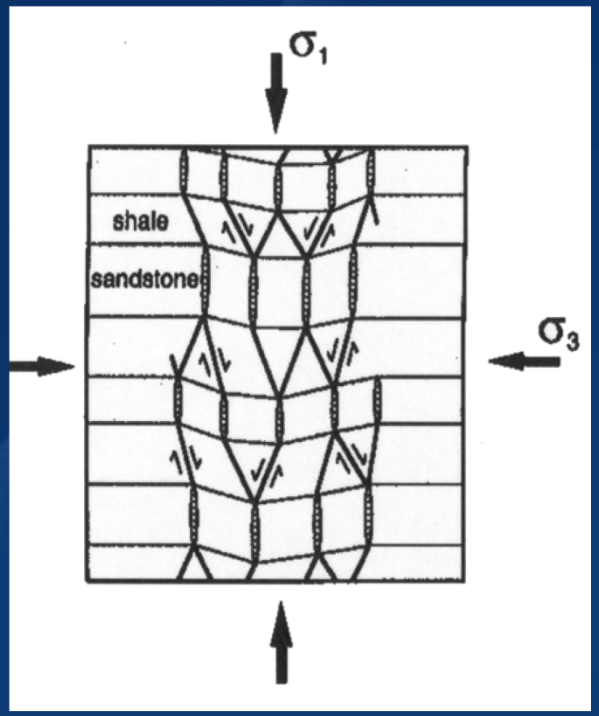


Sibson

The Nature of Faults and Fractures





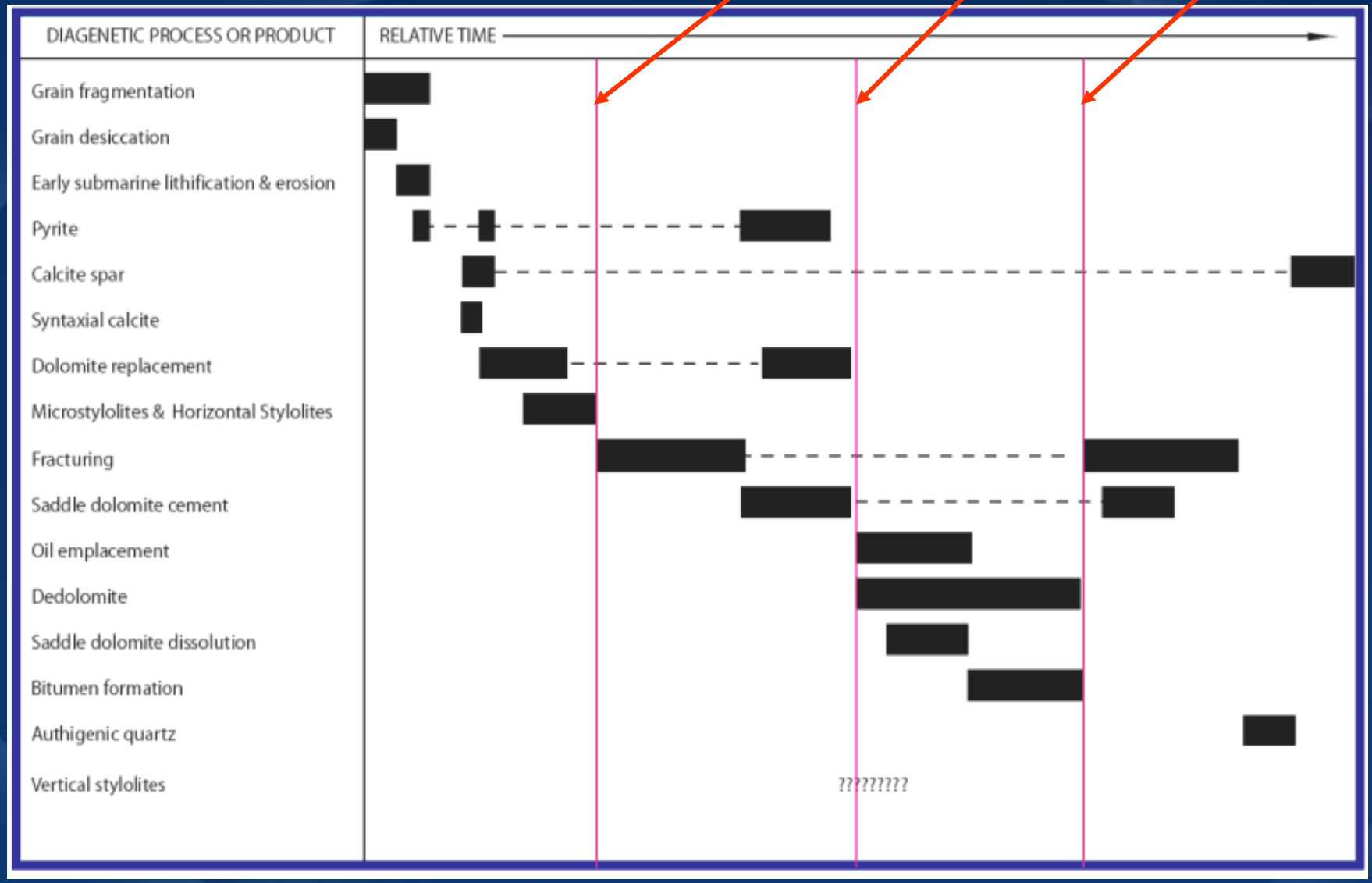


Sibson

The Nature of Faults and Fractures

Timing

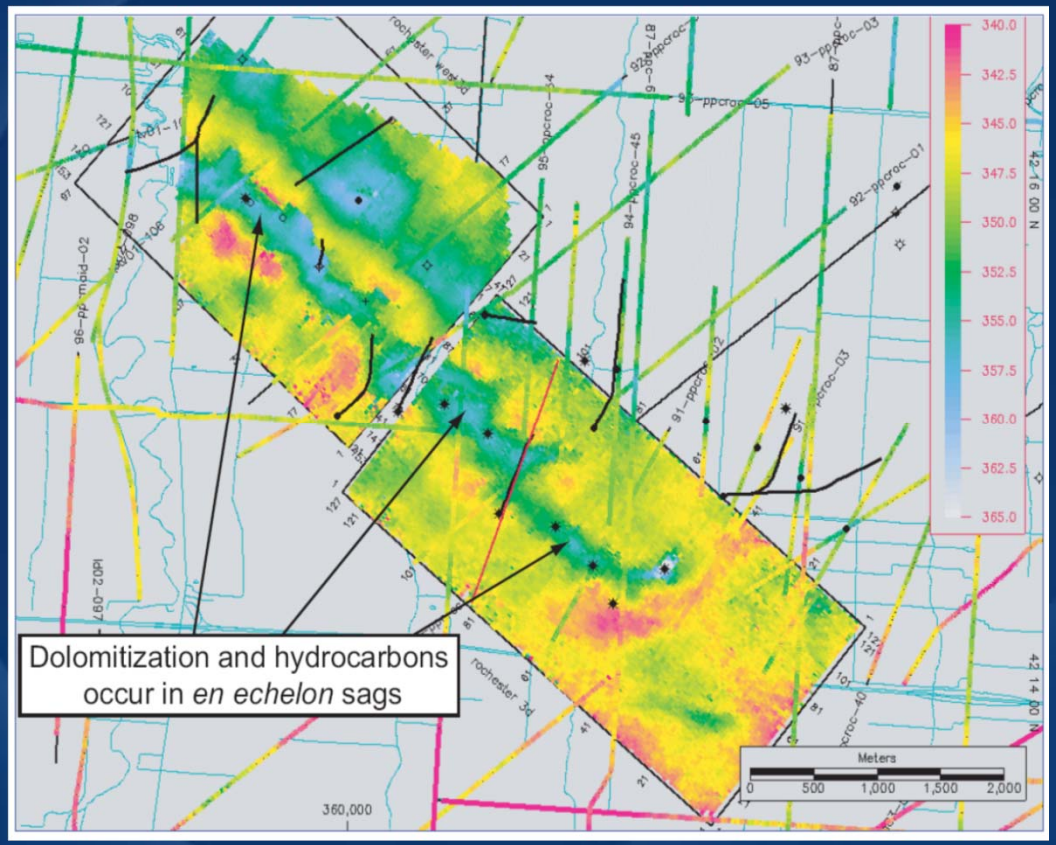
Taconic? Acadian? Alleghanian?

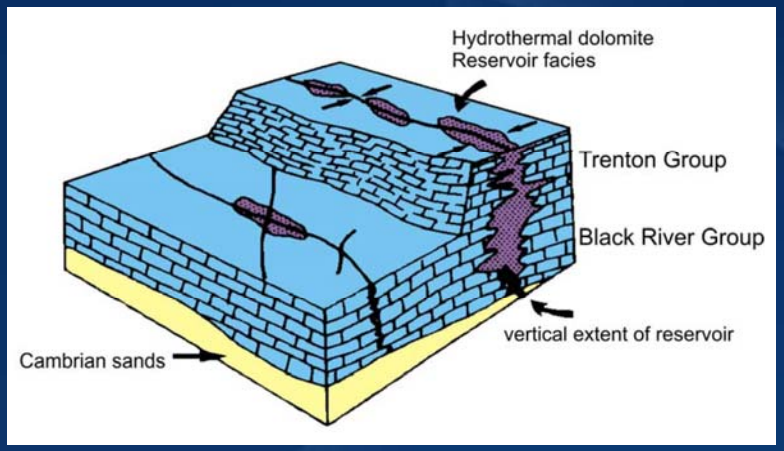


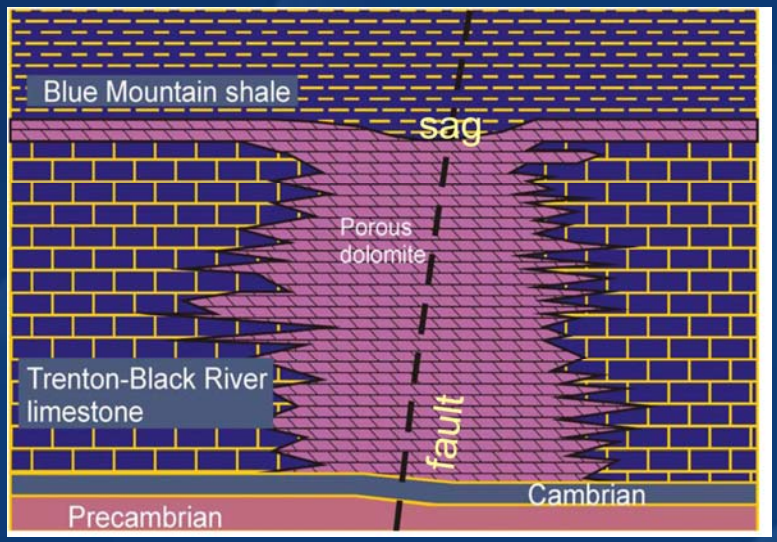
Bray, 2006

Comparison to Producing Fields

Rochester Field (ONT, Canada)

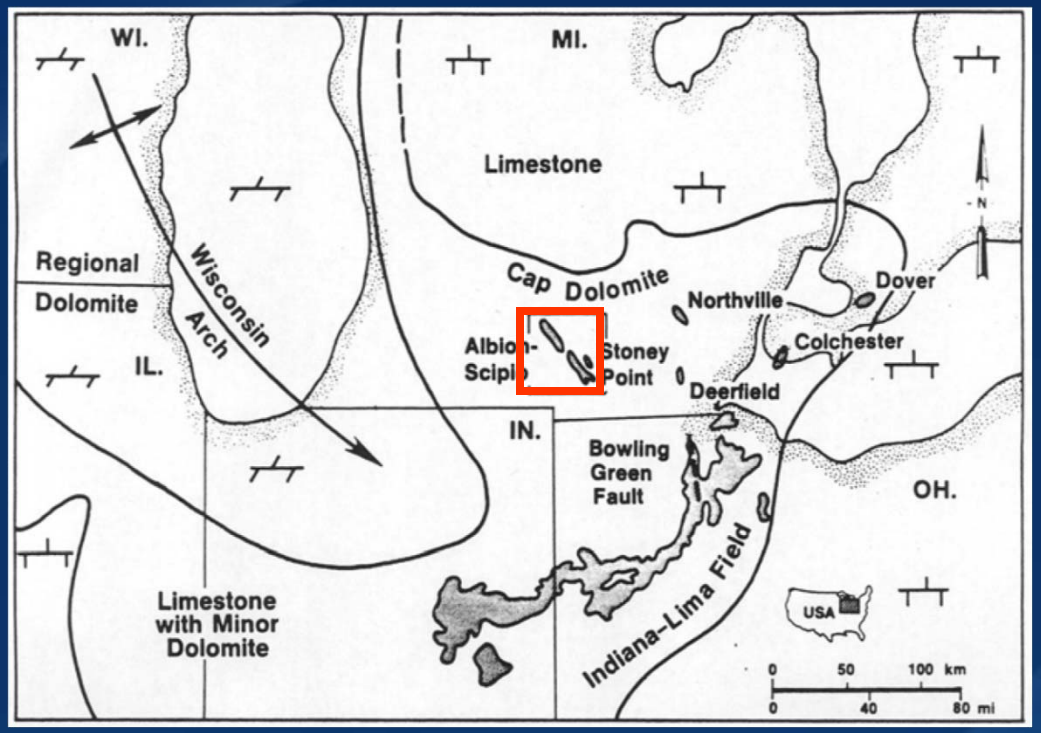


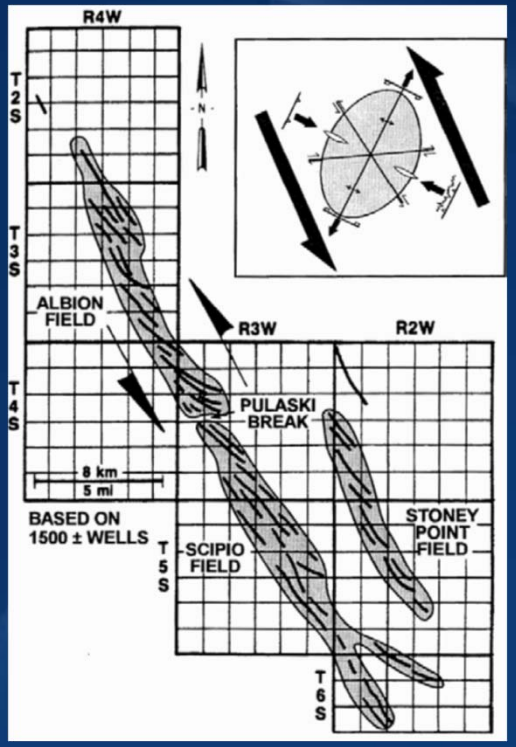


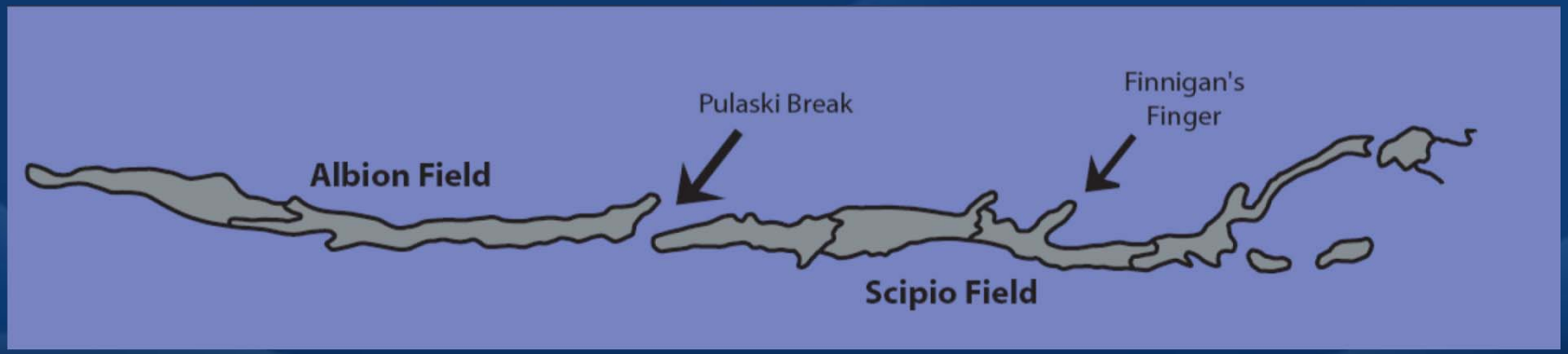


From Carter, 1996

Albion – Scipio Fields

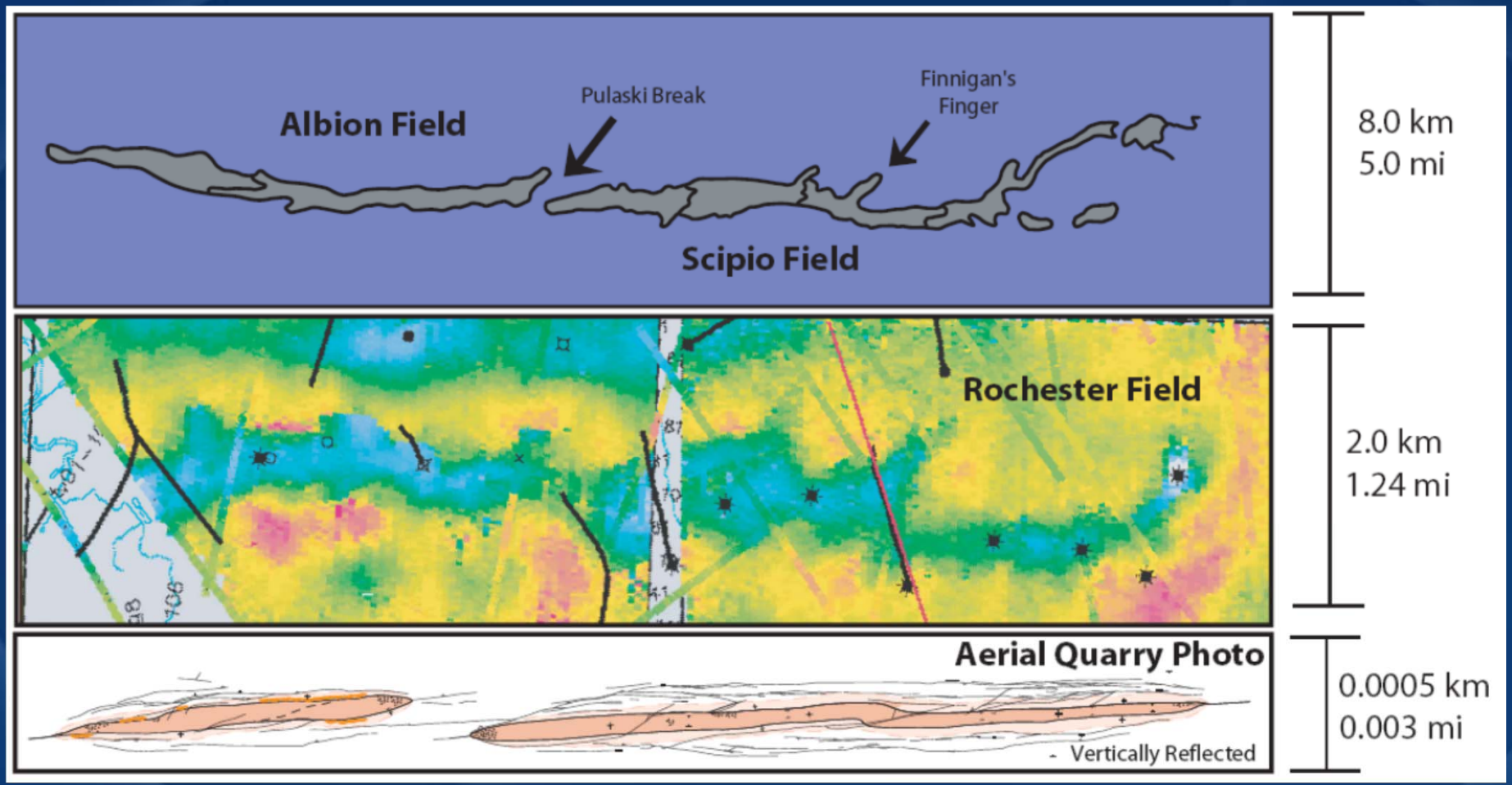




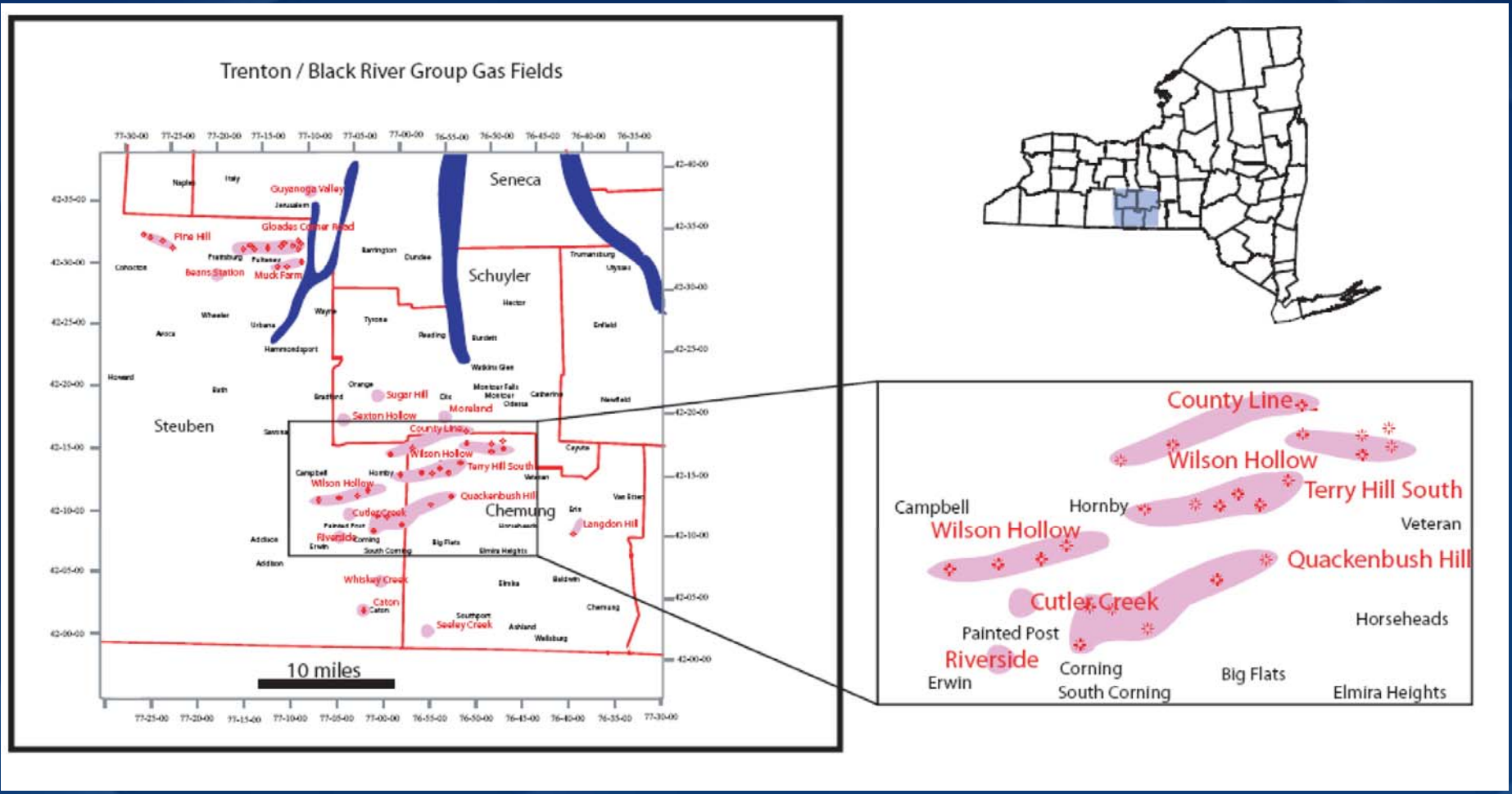


From Hurley & Budros, 1990

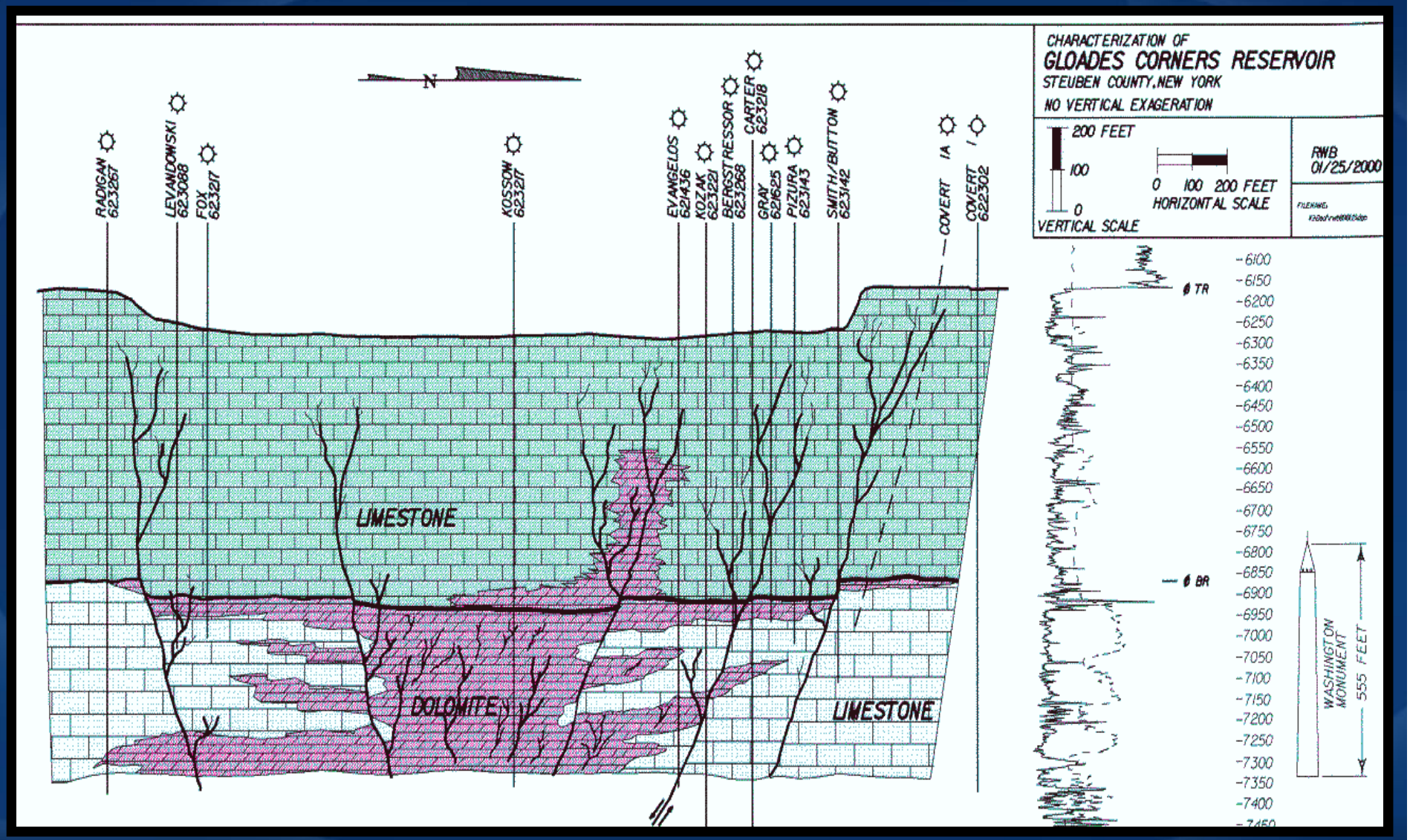
Geometric Comparison



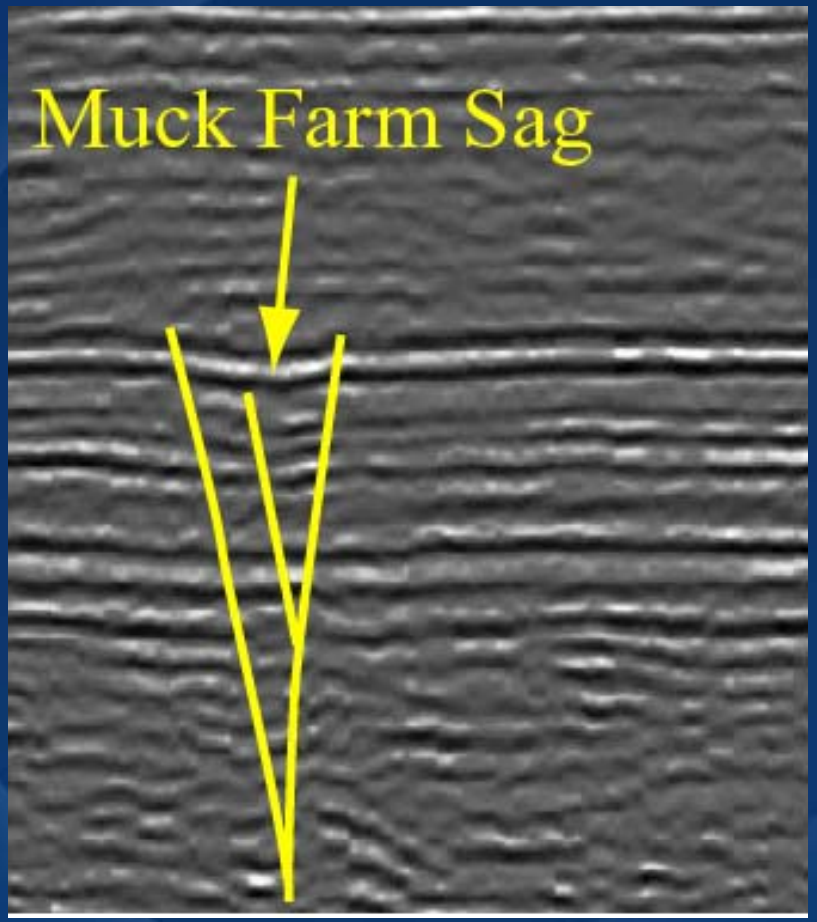
New York – Southern Tier



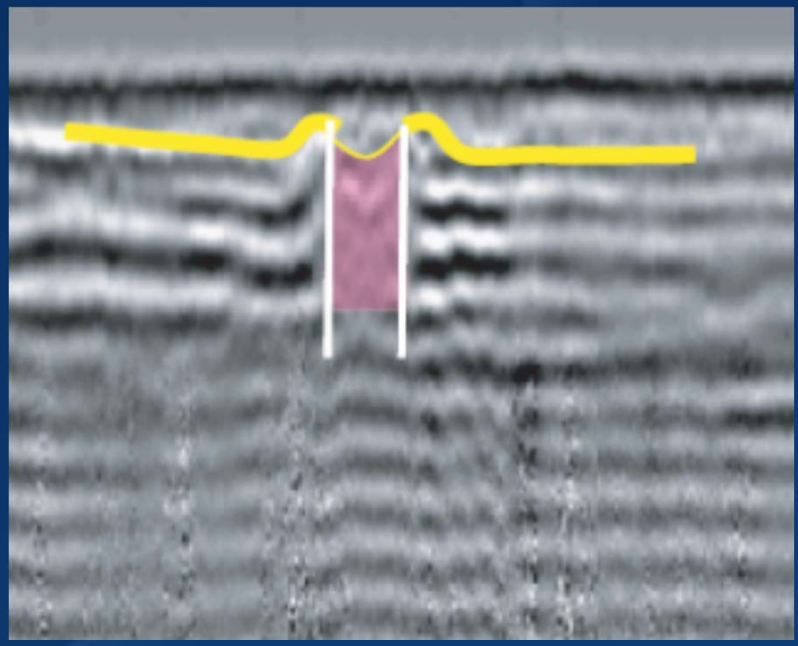
New York – Southern Tier



Sag Comparison



Quarry Sag



Geochemical Comparison

NY Fields

- Fluid Inclusions range from (100 - 160ºC)
- Elevated or radiogenic $^{87}Sr/^{86}Sr$ (0.7085 – 0.709)
- "Light" or negative $\delta^{18}O$ values (-8 to –12‰)
- High salinities (13 - 17% NaCl)
- Mineral Assemblage: Matrix Dolomite, Saddle Dolomite, Calcite, Quartz, Bitumen, Pyrite

From Smith, 2006

Quarry

- Fluid Inclusions range from (100 - 160ºC)
- Elevated or radiogenic $^{87}Sr/^{86}Sr$ (0.7089 – 0.710)
- "Light" or negative $\delta^{18}O$ values (-7.7 to -10.4‰)
- High salinities (26 - 30% NaCl)
- Mineral Assemblage: Saddle Dolomite, Calcite, Quartz, Bitumen, Pyrite, Sphalerite

Conclusions

- Although the Palatine Bridge dolomite outcrop can not be said to be unequivocally hydrothermal in origin, all characteristics of the site point to fault related fluid flow and precipitation of crystals at temperatures greater than surrounding rock at that time.
- Faulting an fluid flow is believed to have been episodic, with major events occurring during the Taconic Orogeny (~470 Ma) and the Alleghanian Orogeny (~350 Ma).
- Although their scales differ greatly, the geometric and geochemical similarities between the Palatine Bridge study site and producing hydrothermal dolomite fields make it an excellent outcrop analog for use in the characterization of and exploration for future oil and gas prospects.

Acknowledgements

UNIVERSITY AT ALBANY
State University of New York

EIT

THE UNIVERSITY OF ARIZONA

Fortuna Energy Inc.

Triana Energy
Twenty-First Century Explorers

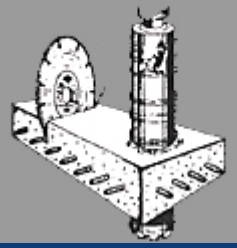
Shaker RENTALS

UNIVERSITY OF Miami

Reservoir Characterization Group
at the New York State Museum

NYSERDA
New York State Energy Research and Development Authority

EAGLE ASSOCIATES



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PETROLEUM COMPANY

Thank You!