Outcrop Analog Lower Paleozoic Hydrothermal Dolomite Reservoirs, Mohawk Valley, New York

Reservoir Characterization Group
at the New York State Museum

Fortuna Energy Inc.

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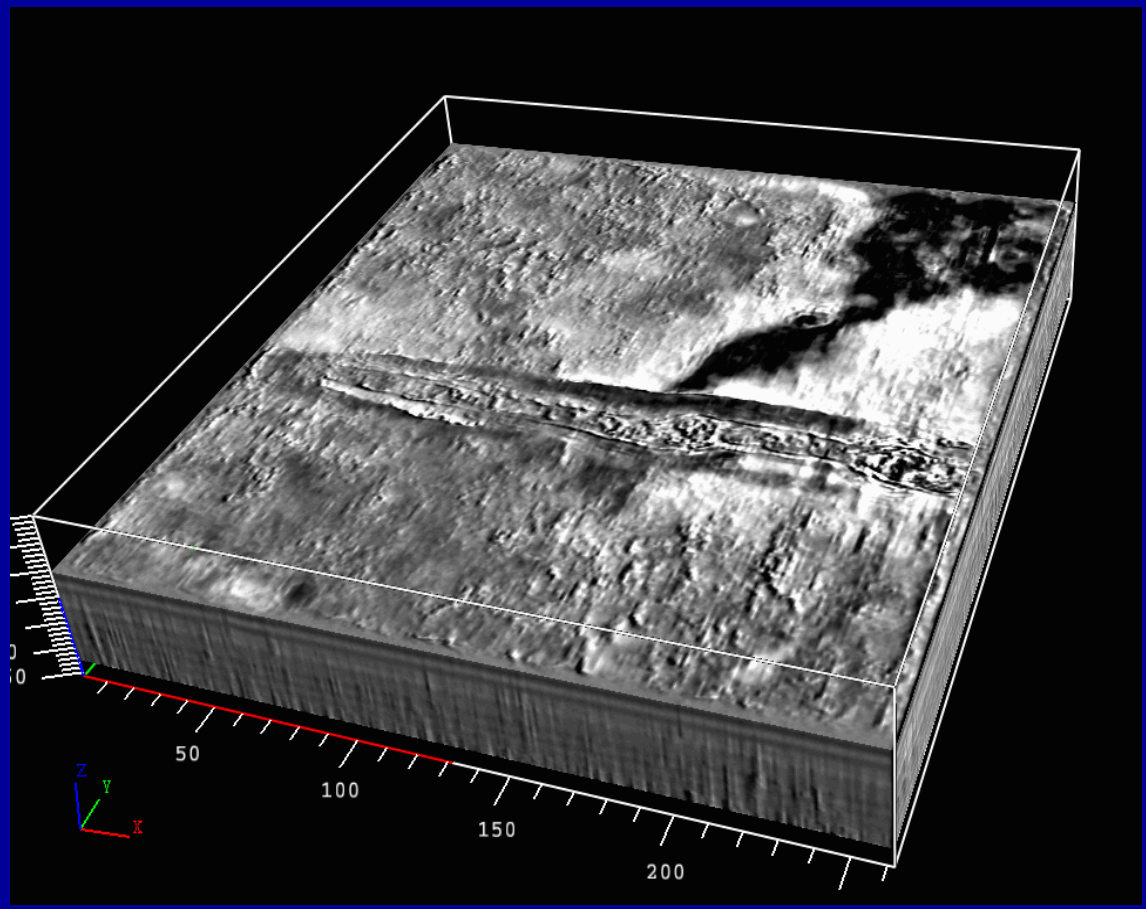
NYSERDA



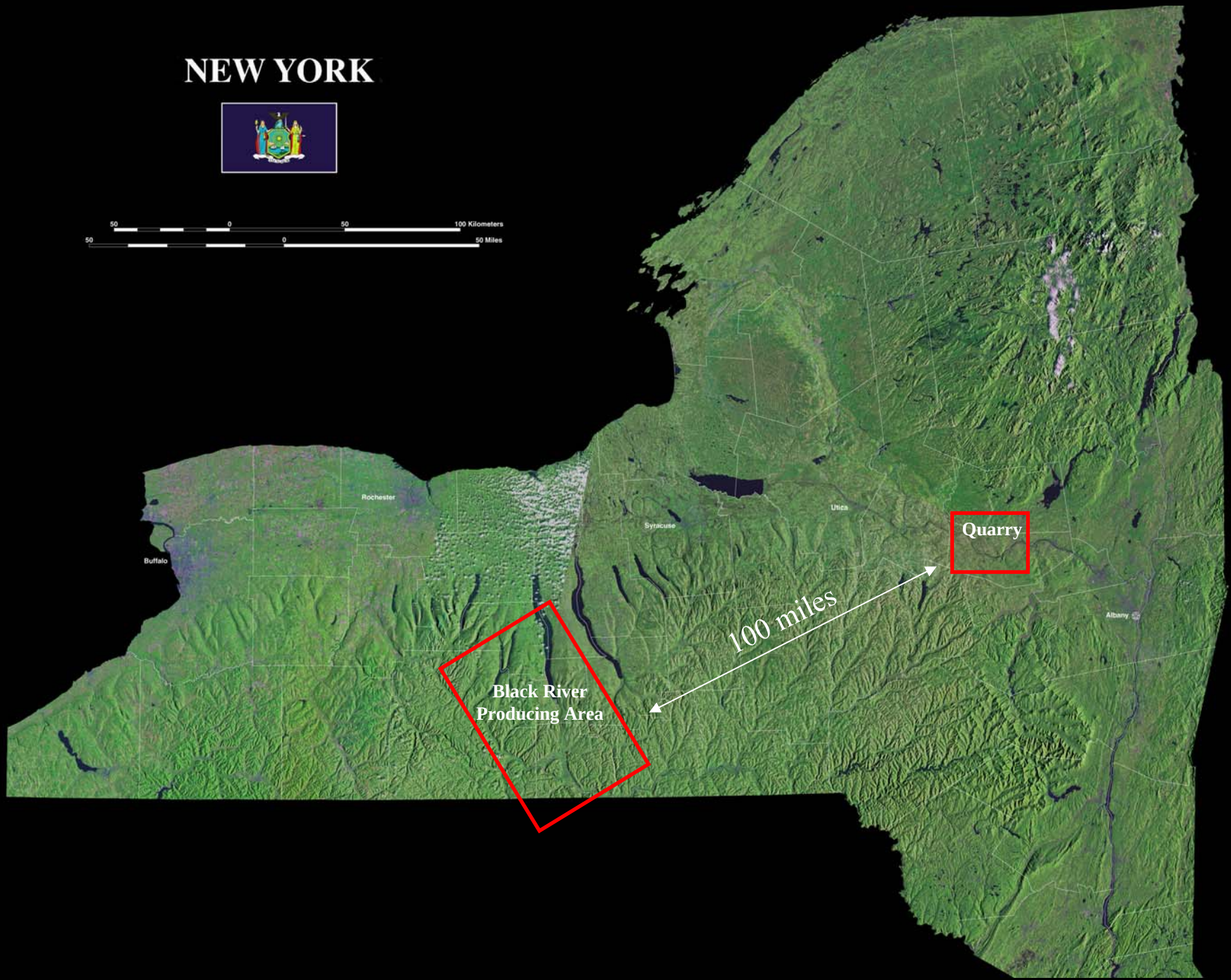
Richard Nyahay, Brian Slater, and Taury Smith
New York State Museum

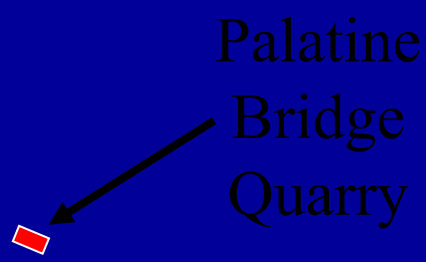
Introduction

- Trenton Black River hydrothermal dolomite reservoirs are complex and heterogeneous structural-stratigraphic-diagenetic plays
- A lot of the details are simply not resolvable with subsurface data
- Goal of this in-progress study is to use outcrop analog which can help better understand structural complexity, the links between faults, fractures, folds, rock types and diagenesis
- Will also provide excellent teaching opportunity for those interested in play

Outcrop Analog for Black River

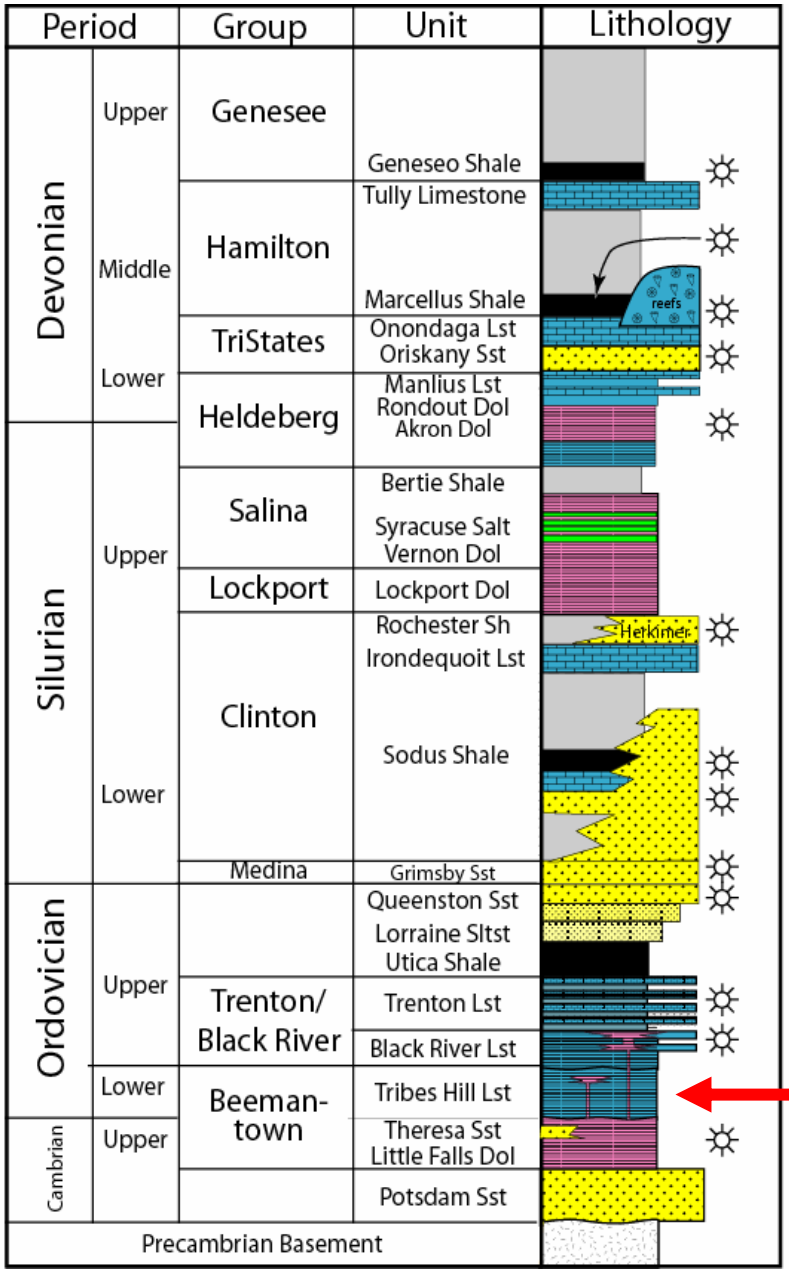
- Structural Analog
  - En echelon faults, folds, sags, scissor faults, strike-slip faulting
- Diagenetic Analog
  - Dolomite only occurs around faults
  - Saddle dolomite in vugs and fractures
  - Paragenetic sequence similar (matrix dolomite/saddle dolomite/quartz/bitumen/calcite)
  - Saddle dolomite-cemented breccias clearly fault-related (not karst)
  - Geochemistry of dolomites is similar


NEW YORK
50 0 50 100 Kilometers
50 0 50 Miles
Rochester
Buffalo
Syracuse
Utica
Albany
Quarry
100 miles
Black River
Producing Area



(Fisher, 1980)

Outcrop occurs near Mohawk River. Regional NE-SW trending normal faults with up to 500 feet of throw only affect Utica and older rocks.



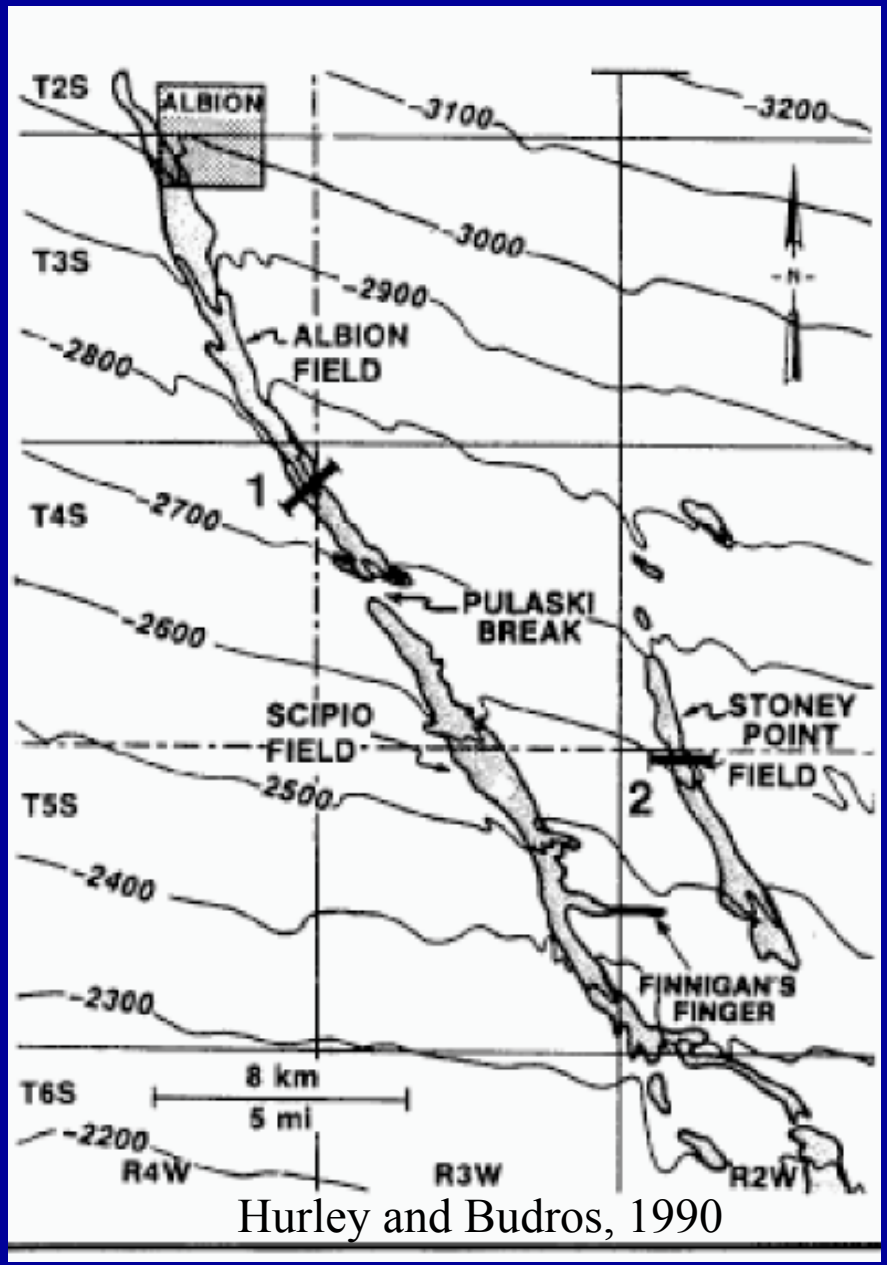
Tribes Hill Formation is Lower Ordovician and is the upper part of the Beekmantown

The Tribes Hill is mainly composed of limestone in the Mohawk Valley

The underlying Little Falls is all dolomite and sandstone with little or no limestone

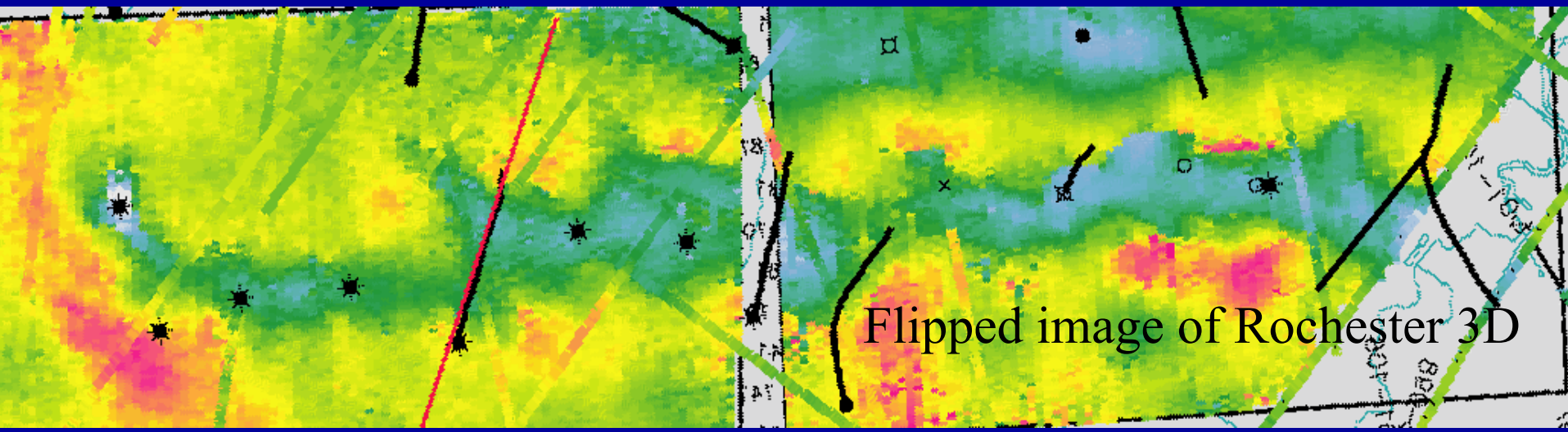
2004 Outcrop Analog Activity

- Partially uncovered dolomite structures
- Ran two 3D ground penetrating radar surveys
- Uncovered major structure in lower quarry delineated with 3D GPR
- Preliminary map of the structure
- Take initial aerial photographs
- Presented early results at AAPG Eastern Section meeting demonstrating value as an outcrop analog for TBR reservoirs



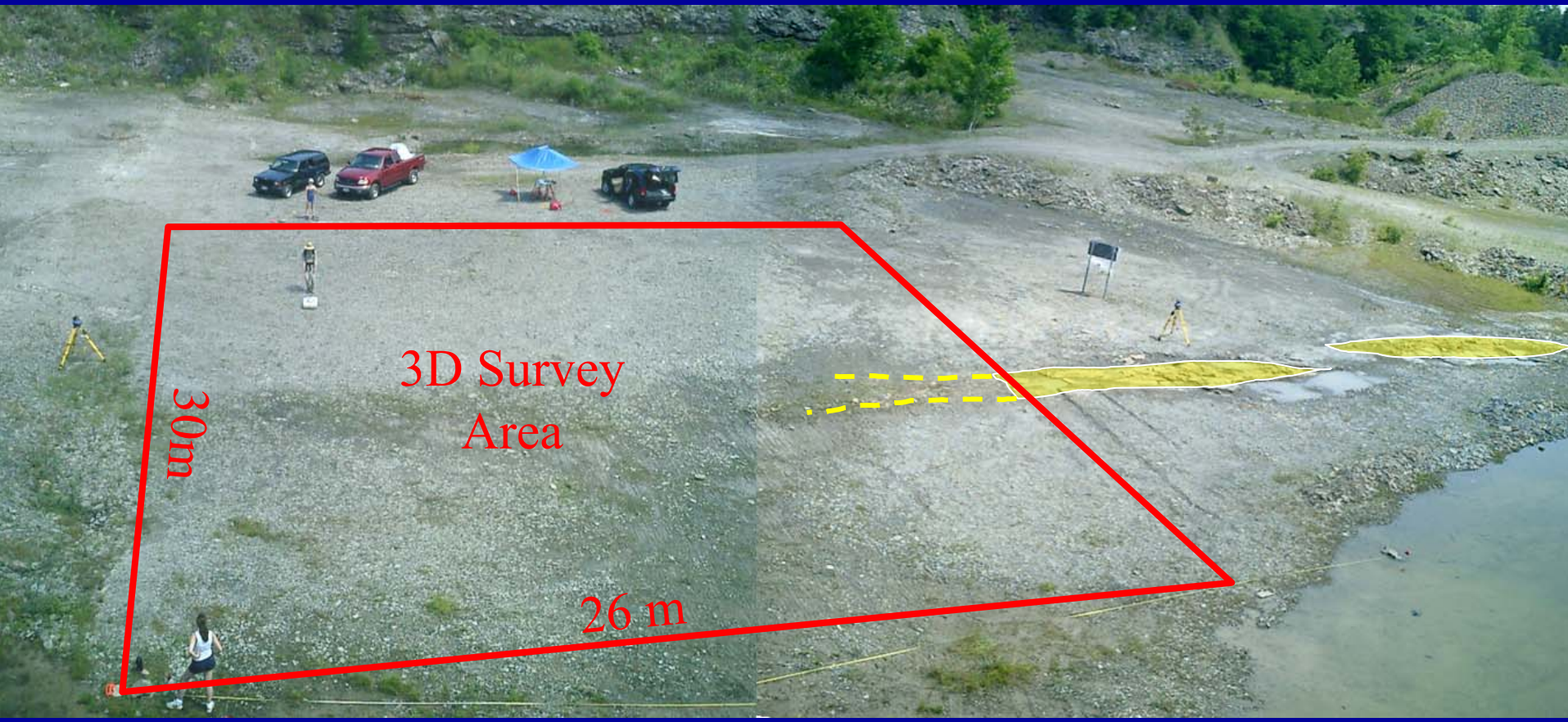
Hurley and Budros, 1990

Proportions and “break” remarkably similar to Albion Scipio



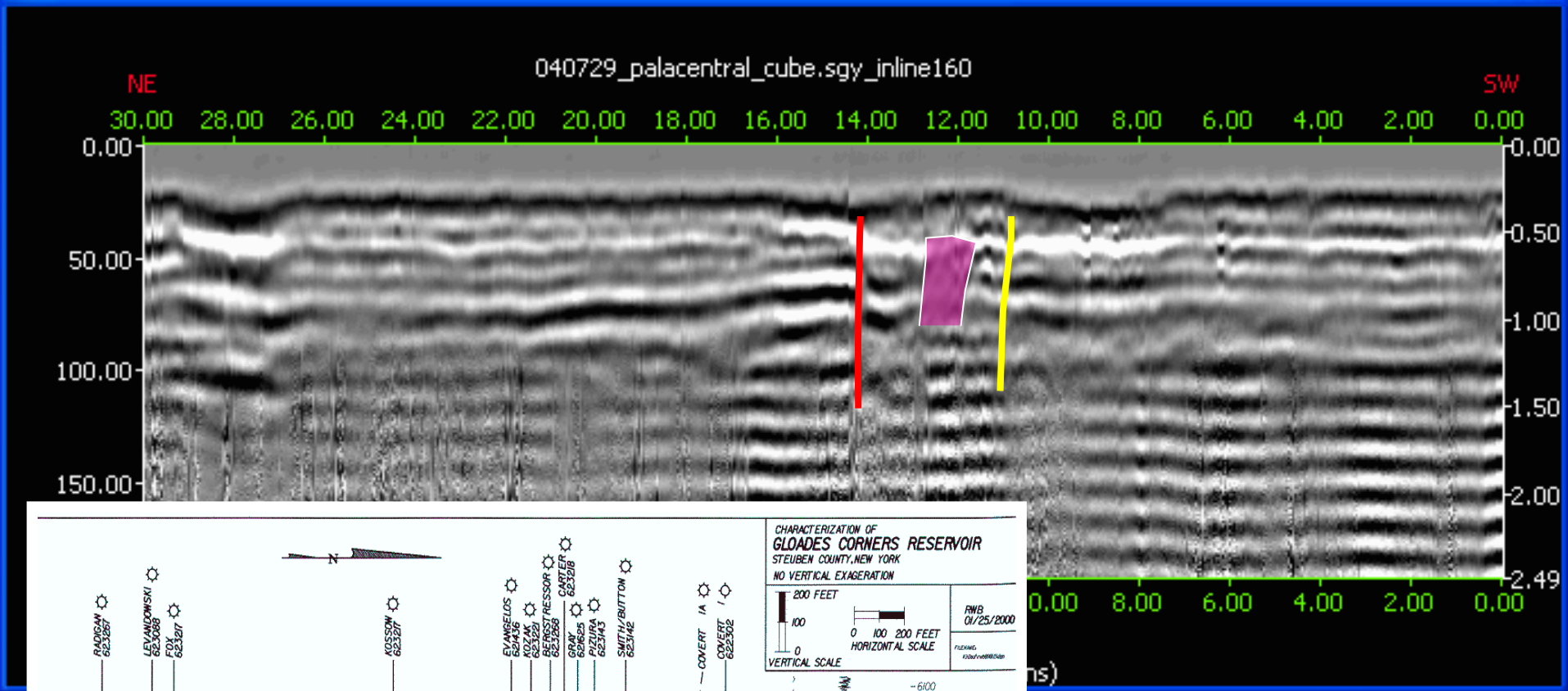
En echelon dolomitized bodies in quarry exposure very similar to en echelon bodies in Rochester 3D – Talisman and East Resources Geologists (who have seen the most 3D seismic) agreed that it looks like an excellent analog

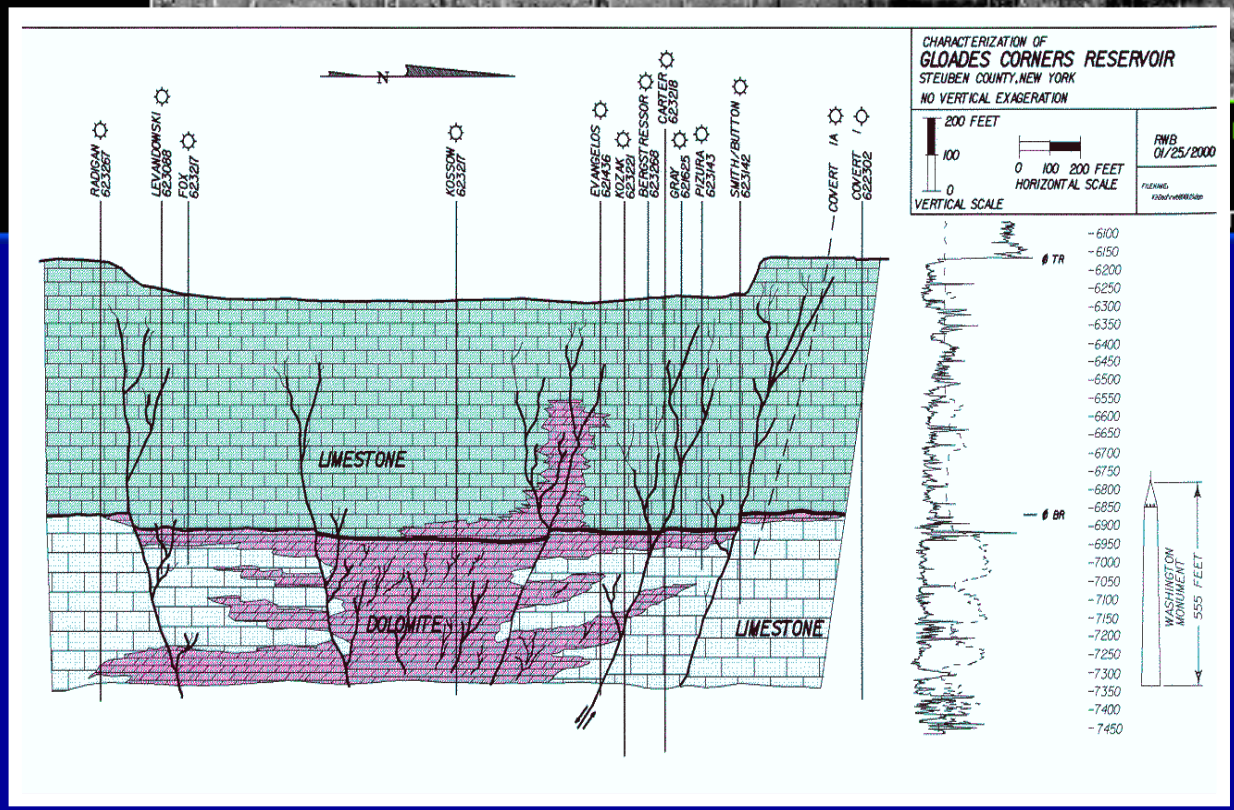
3-D Ground Penetrating Radar (GPR) Survey



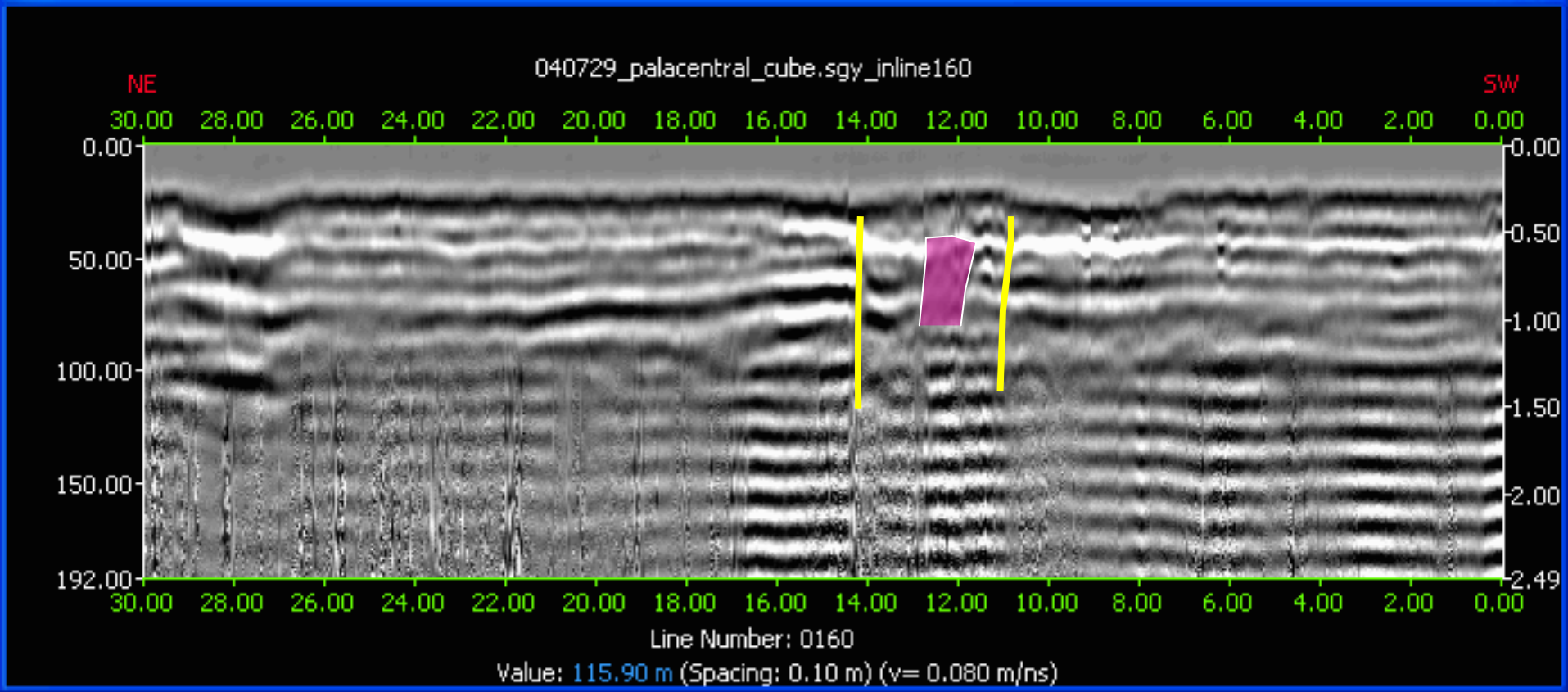
- 3D Survey processed in a few hours
- Shows incredible amount of detail
- Cheap and relatively easy

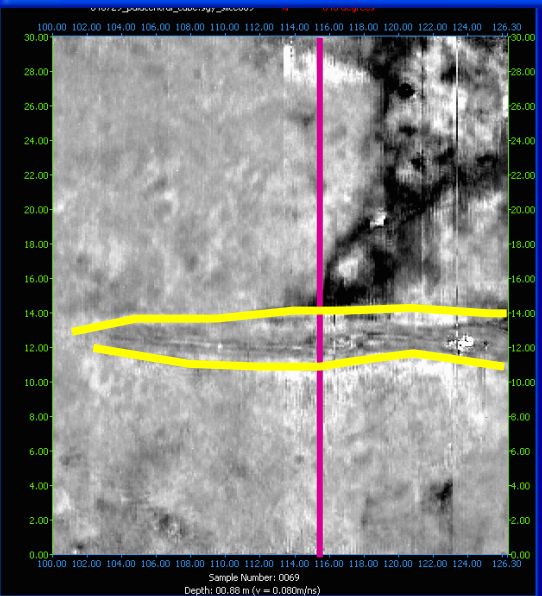
Survey Conducted by Mark Grasmueck, University of Miami with help from Dave Viggianao and NYSM

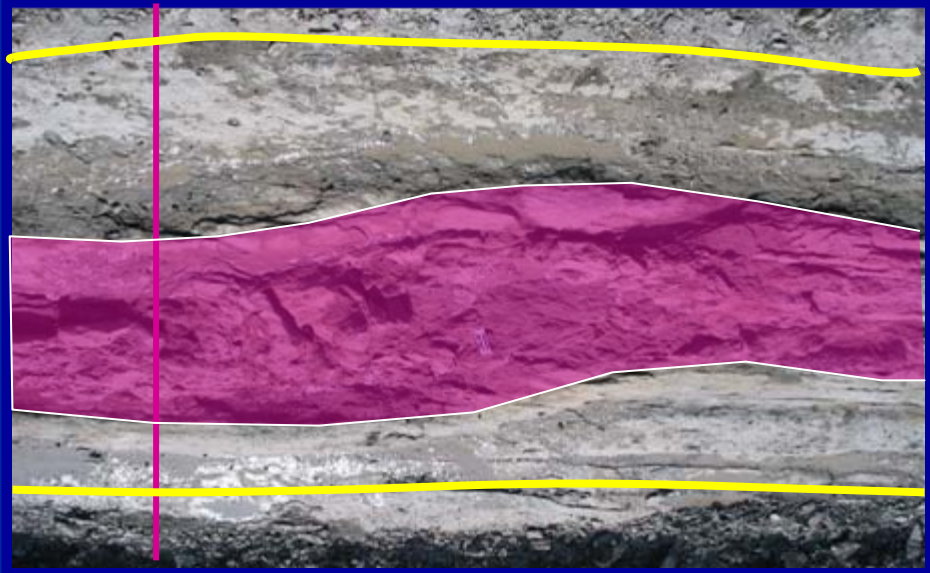




Dolomite distribution reminiscent of CNR cartoon with massive dolomite around faults in middle of feature

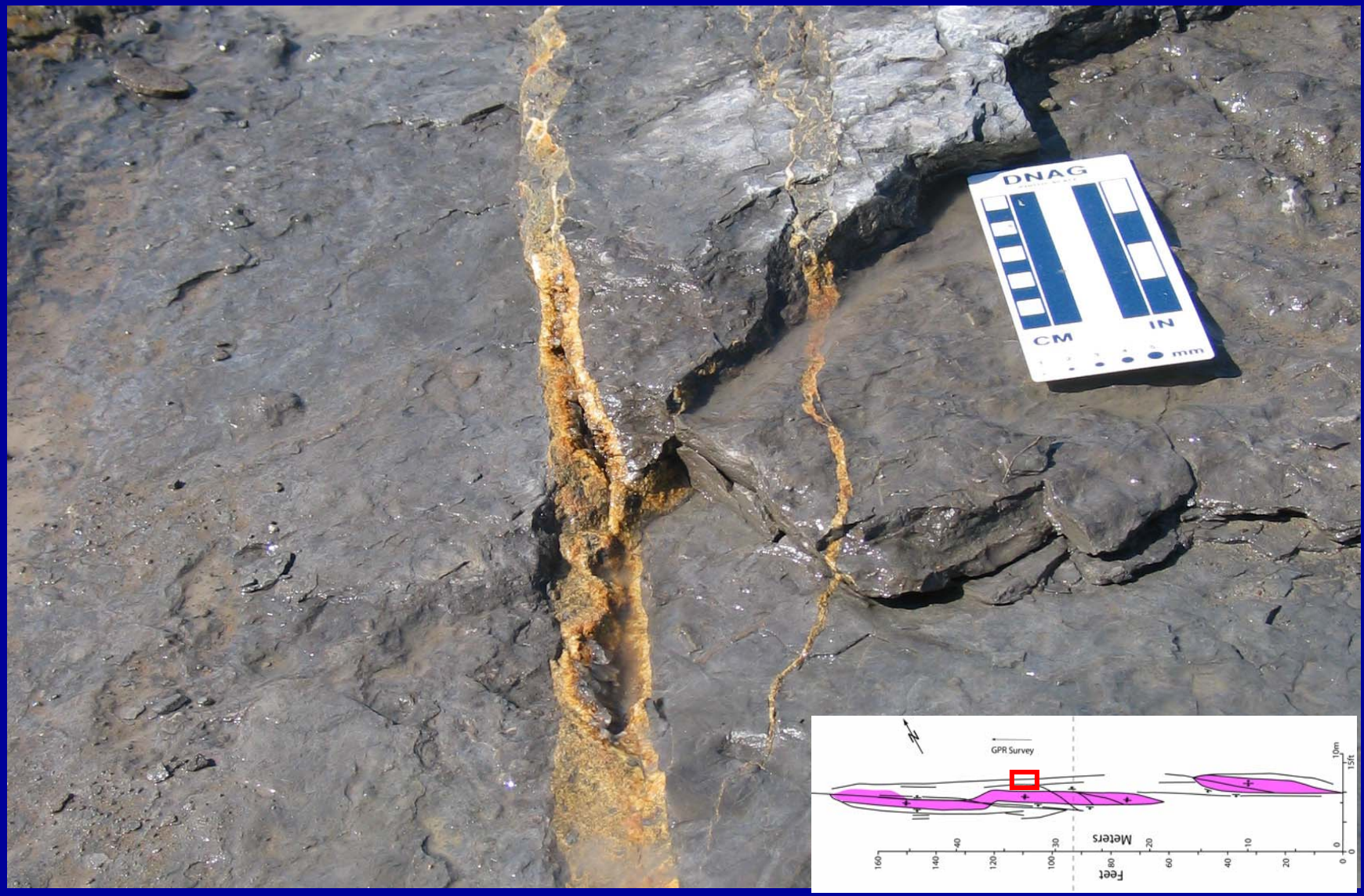






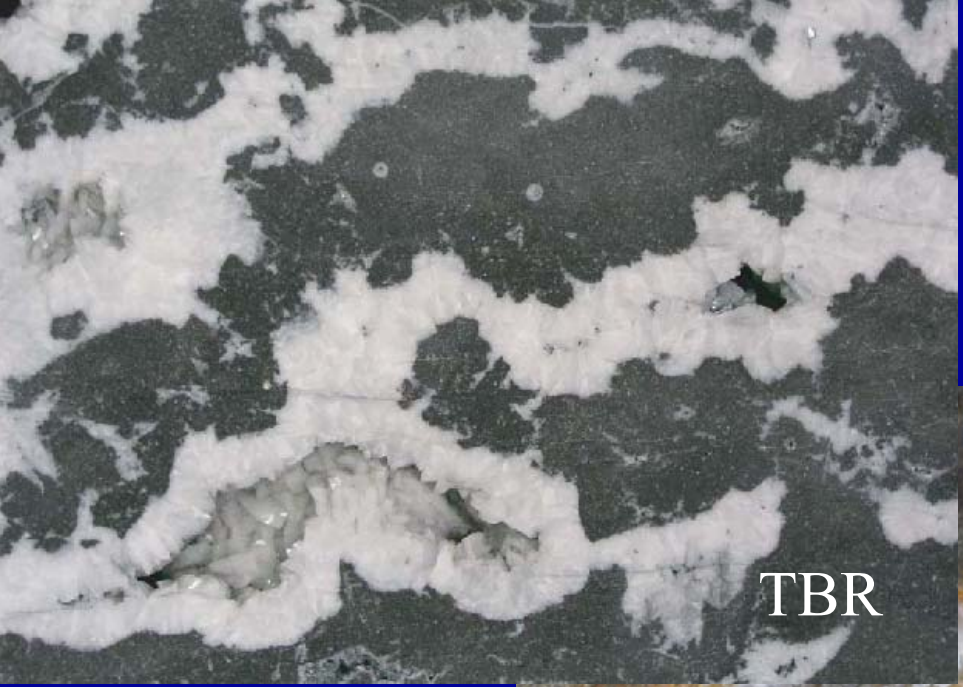
Dolomitized interval is dimmed out

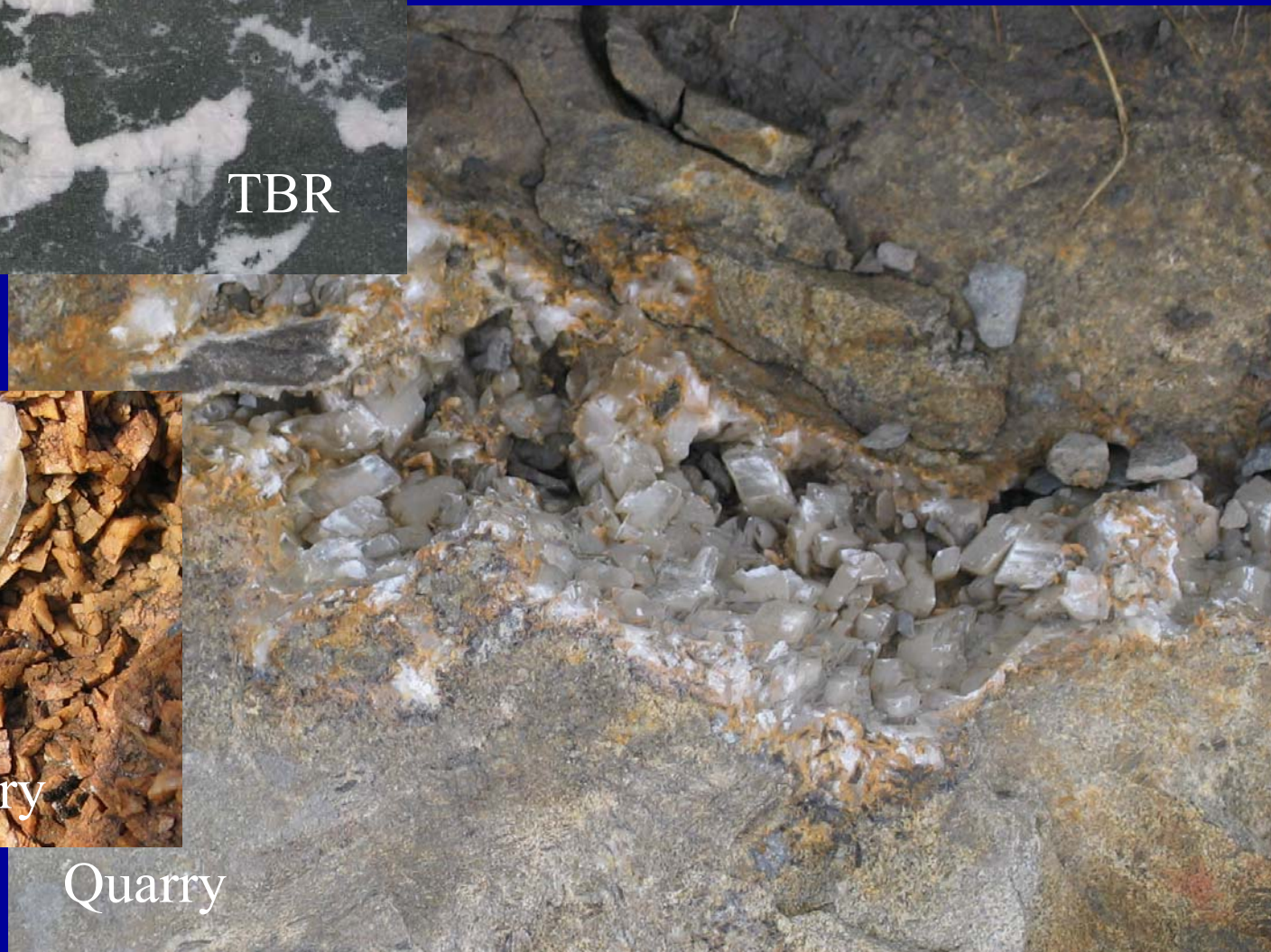
Not all of "sag" is dolomitized

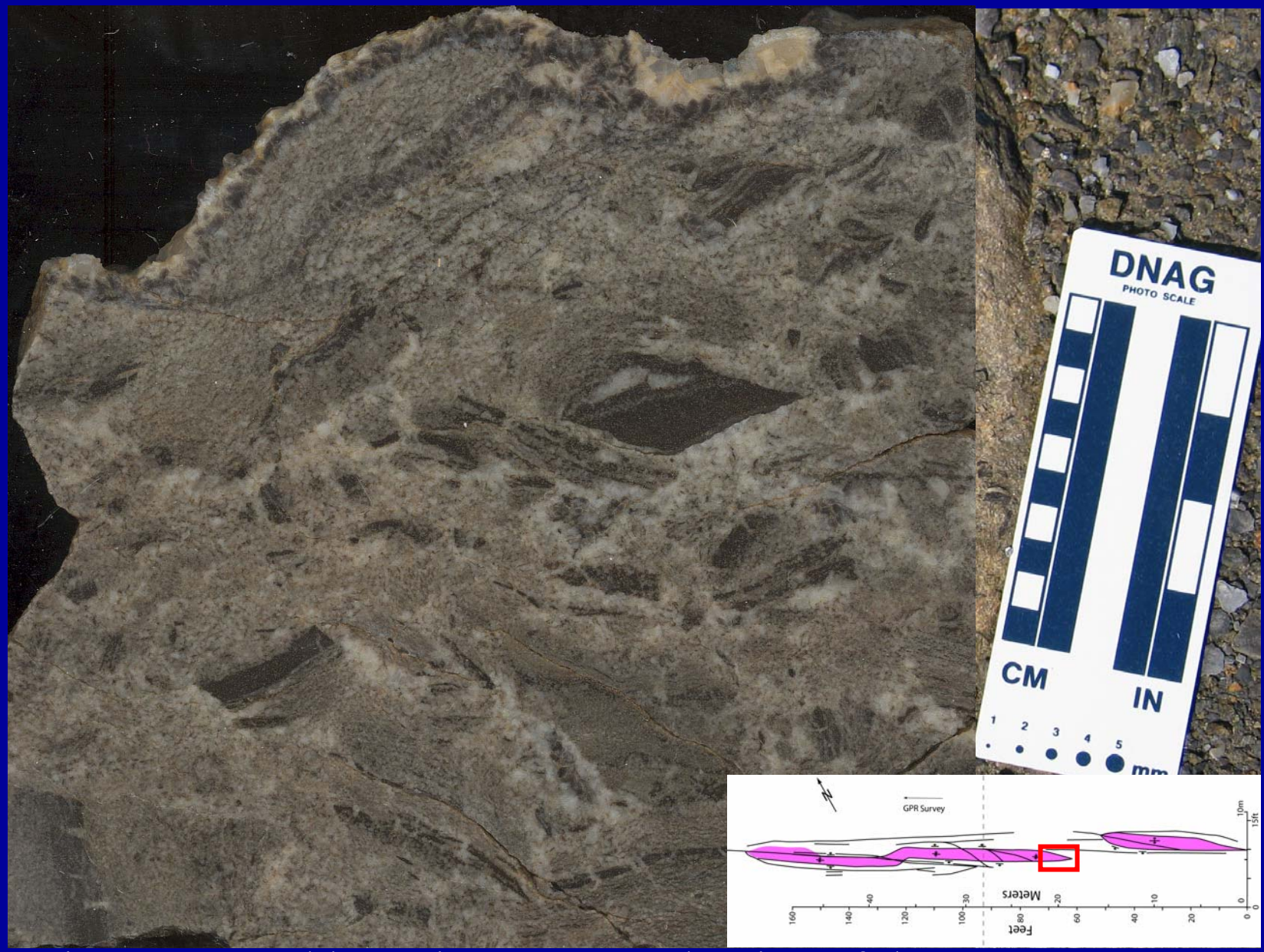


Most obvious open porosity is found in partially-cemented fractures on the northern flank of the structure and in vugs within the dolomite bodies – like many TBR reservoirs

Vuggy porosity and saddle dolomite



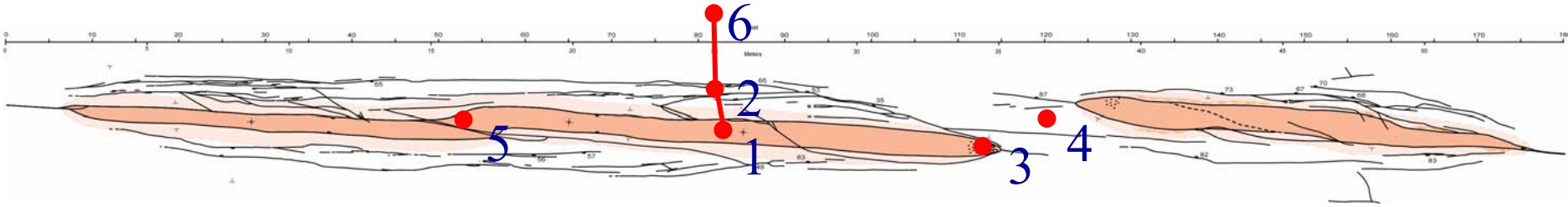


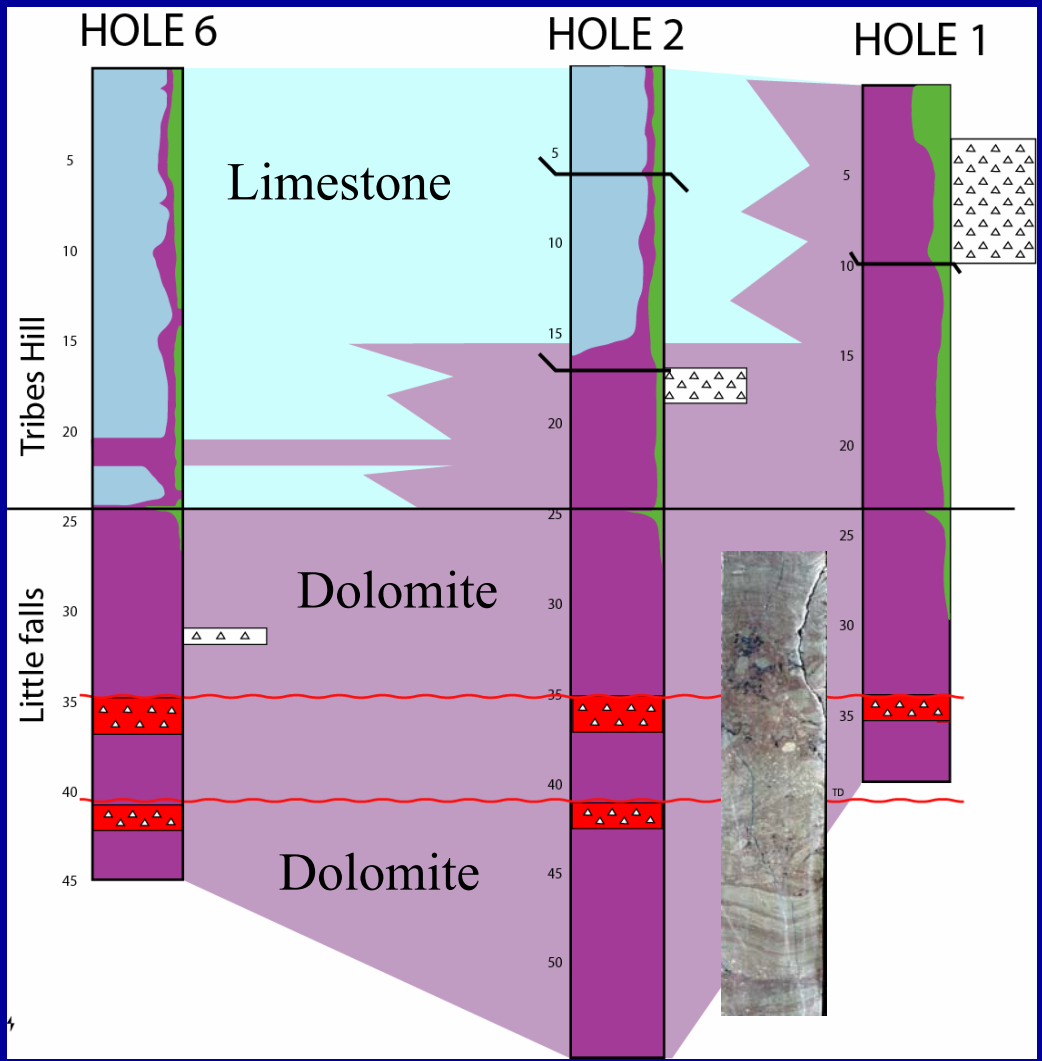


Dolomite-cemented breccia occurs at the tips of the structures, central portions of structures are dolomitized but mostly not brecciated

2005 Outcrop Analog Activity

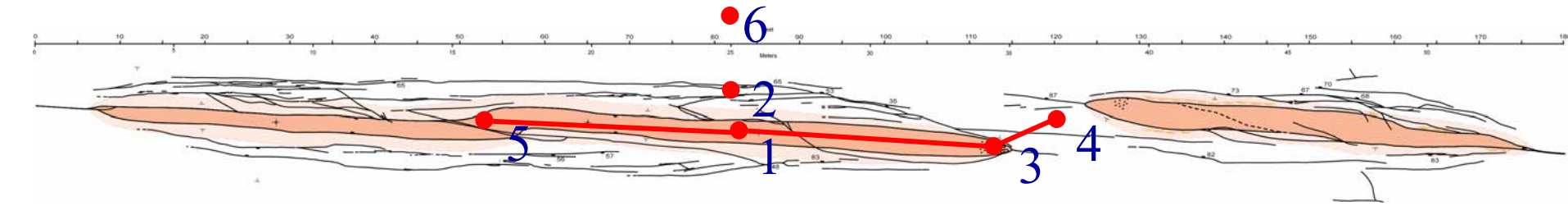
- Six cores taken
- Enhanced 3D GPR
- Better aerial photograph and refined map
- Geochemistry
- Workshop
- Begin trenching of bottom structure
- Begin clearing off the top quarry

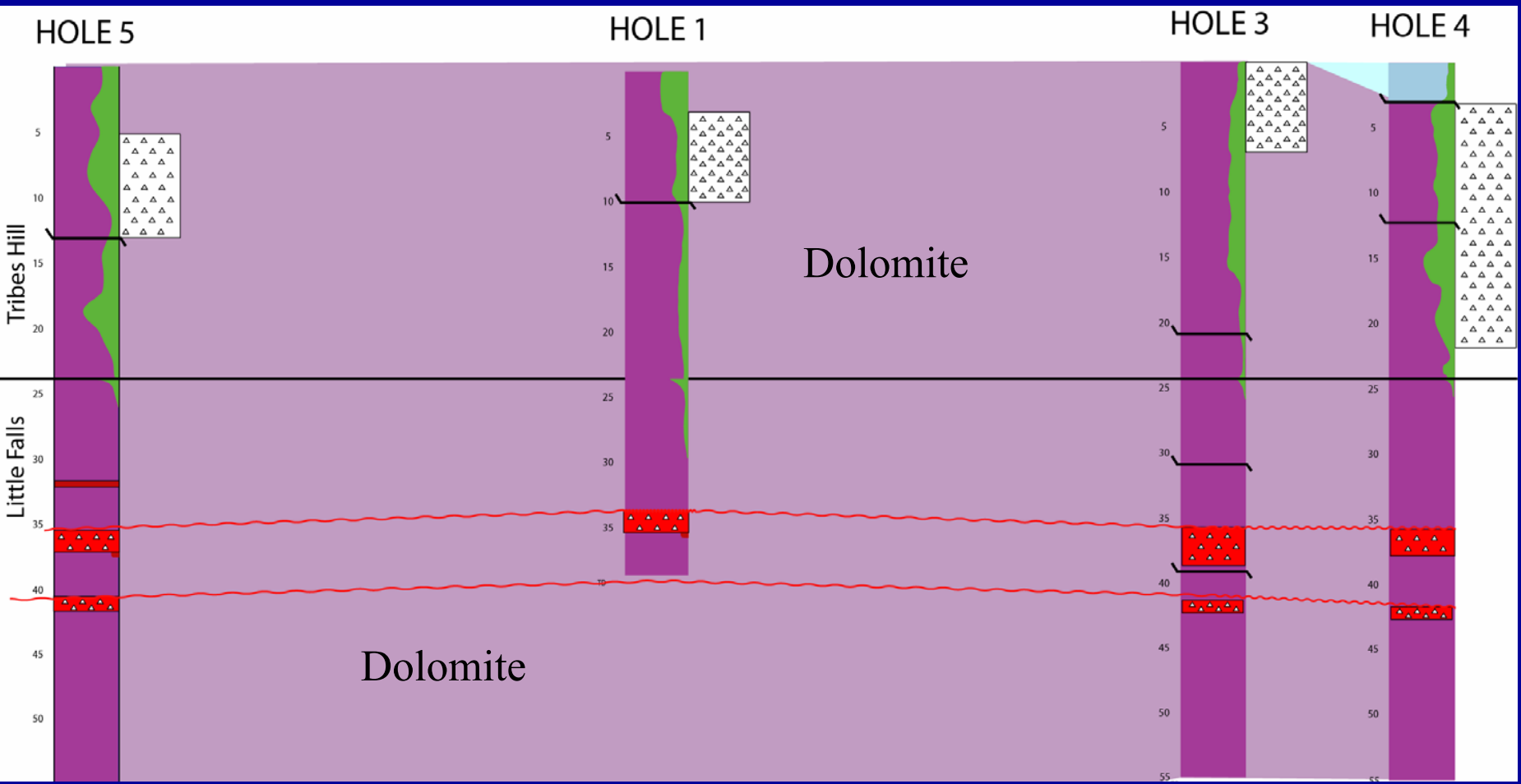




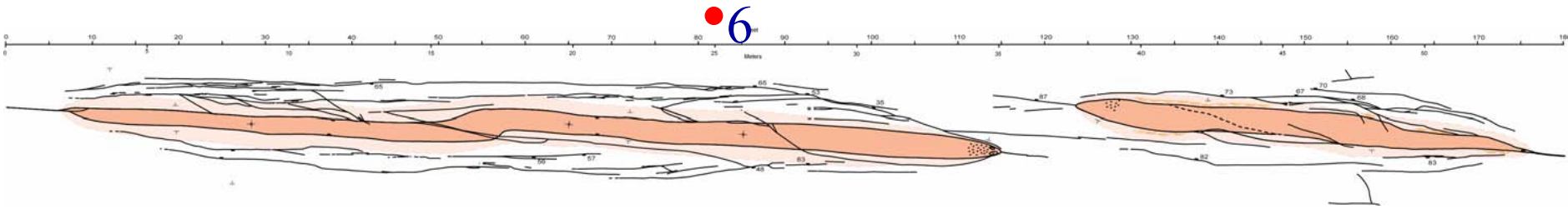
Coring Project – Thanks to NYDOT

Some permeability in cores especially at base of Tribes Hill in dolomite





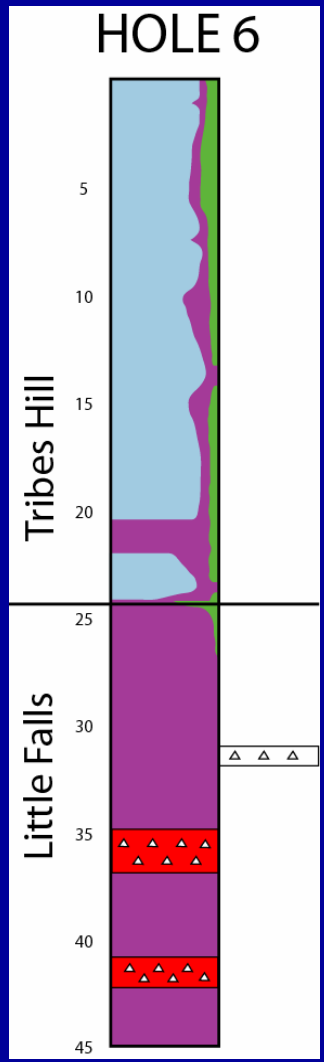
Hole 4 in “Break” is dolomitized starting about 3 feet down after it crosses fault



Hole 6 cuts no obvious faults and is about 18 feet away from the dolomitized trend. The Tribes Hill is 90% limestone

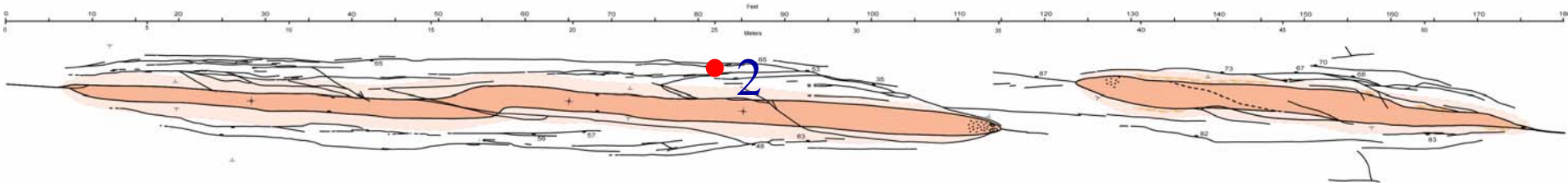
Limestones consist of mudstone, skeletal wackestone and skeletal packstone with abundant silty clay seams

This type of rock is generally not ideal for hydrothermal alteration



Hole 6 @10 ft

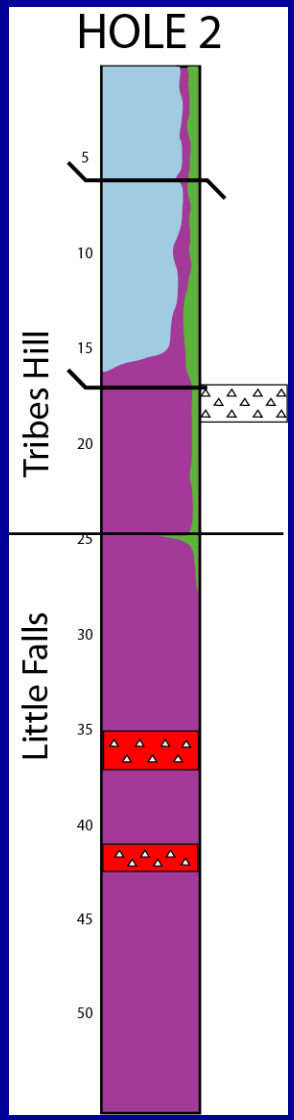
Hole 6 @ 43ft



Hole 2 was drilled inside outer fault zone into limestone at surface. The core cuts two faults.

The upper 16 feet is limestone

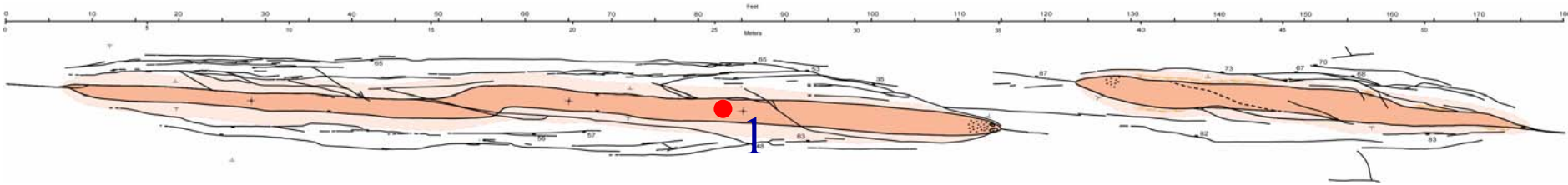
All of the Tribes Hill is dolomitized below the second fault which is filled with coarse, porous saddle dolomite



Hole 2 @ 7ft

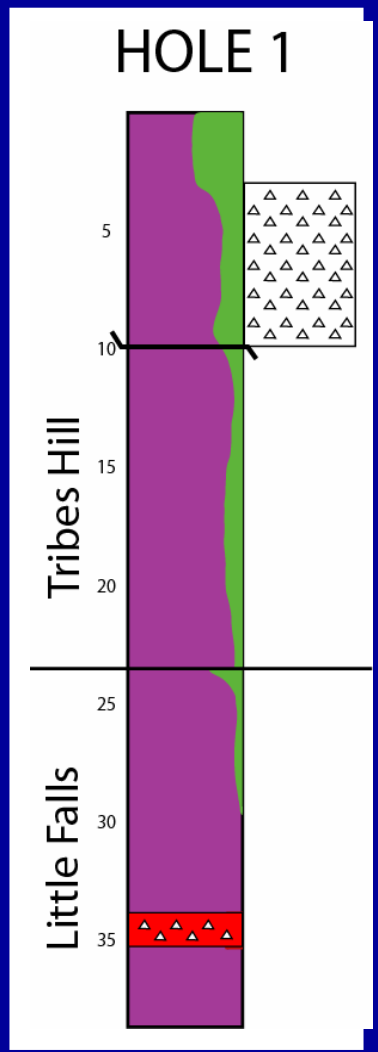
Hole 2 @16.

Fractures and vugs from TBR compose most of the porosity



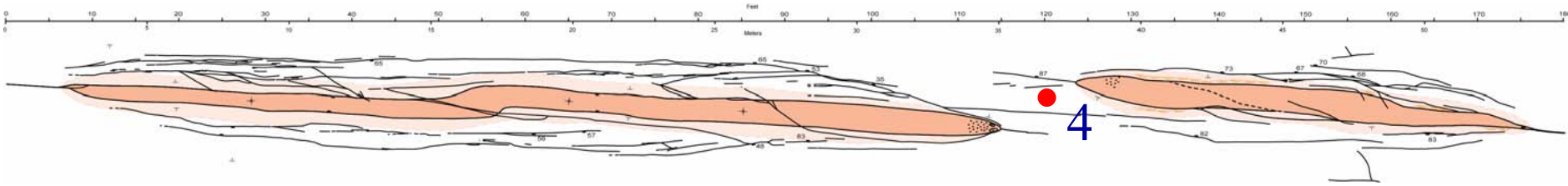
Hole 1 is cut by at one obvious fault. The Tribes Hill Formation is completely dolomitized. Chaotic bedding with small faults especially in upper 10 feet.

Pyrite fills small fault in Lower Tribes Hill near contact with Little Falls



Hole 1 @ 9.5ft

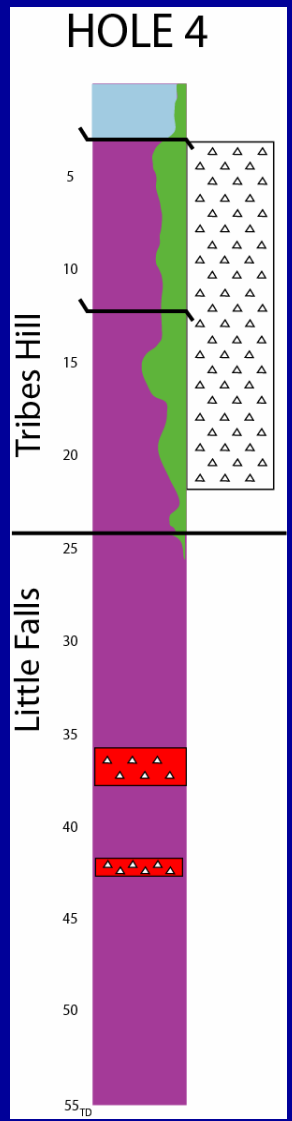
Hole 1 @ 23ft



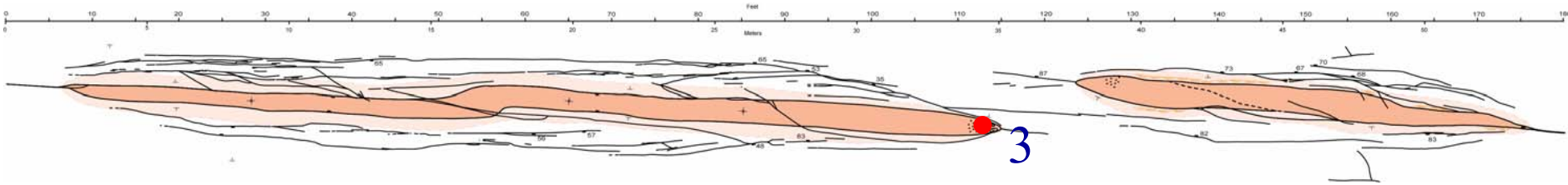
Hole 4 is cut by a fault @ 3ft.

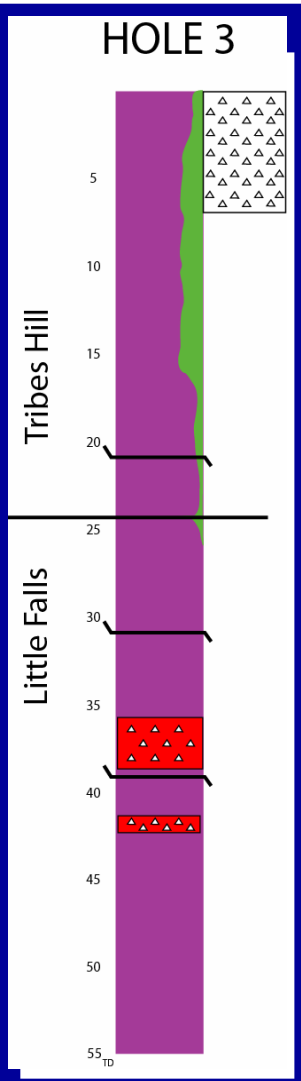
Tribes Hill Formation is limestone above the fault and dolomitized beneath the fault and the dolomite is heavily brecciated.

This suggests that the two dolomite bodies are connected at depth



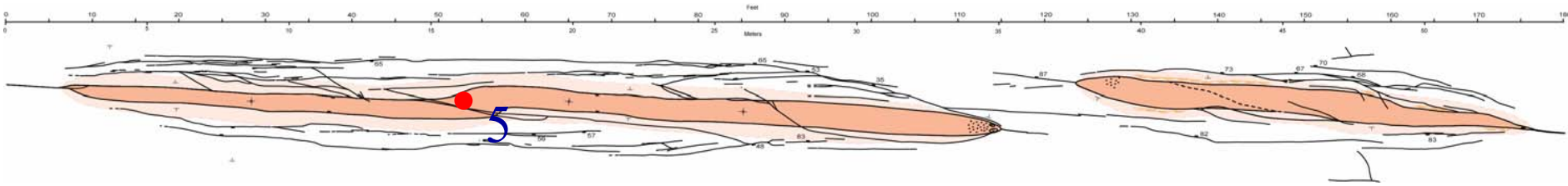
Hole 4 @ 14 ft





Hole 3 was drilled into the tip which is obviously brecciated on the surface. Breccia extends down for several feet. Tribes Hill totally dolomitized.

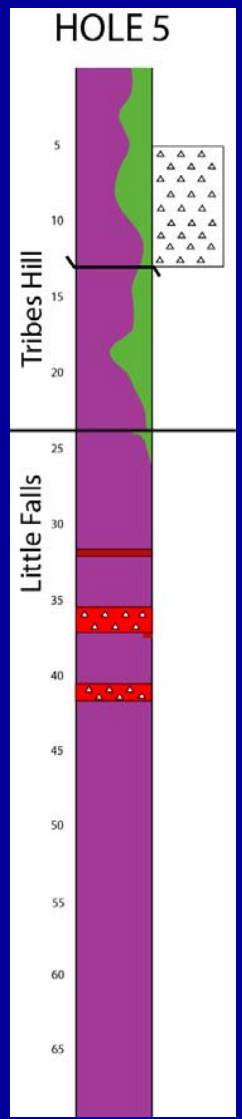
Hole 3 @1ft



Hole 5

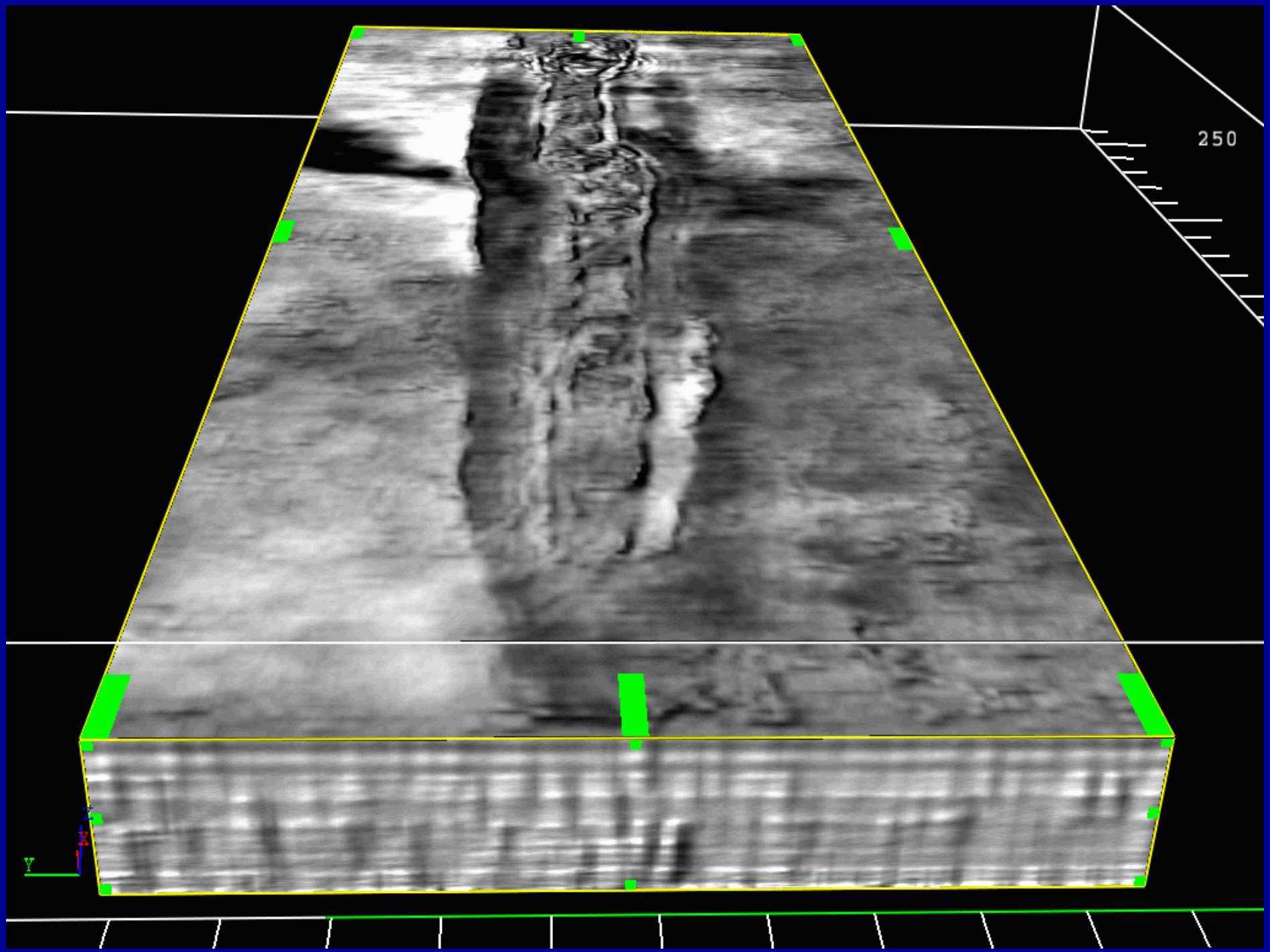
Tribes Hill is completely dolomitized with common chaotic bedding in Hole 5 which is located in jog.

The Tribes Hill dolomite is commonly brecciated and highly pyritized.



Hole 5 @ 14ft

Hole 5 @40.5f


250
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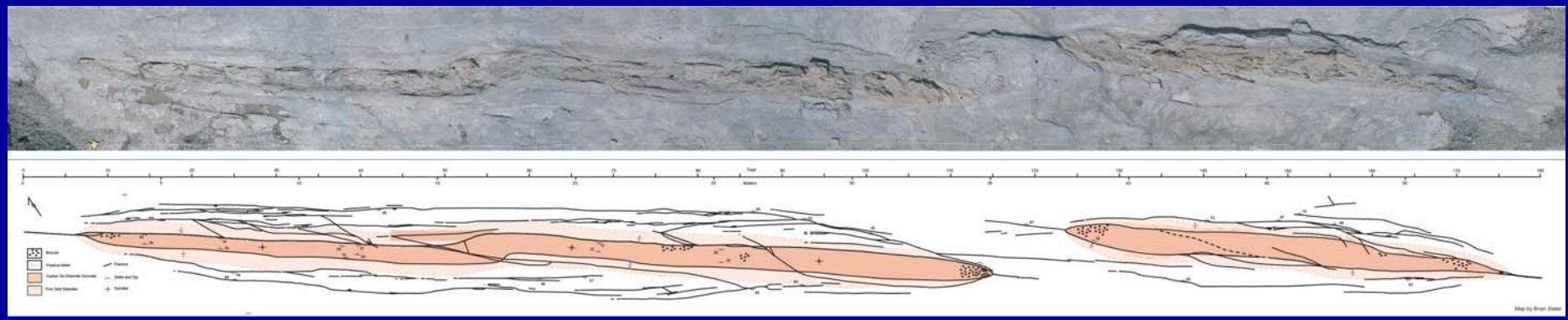
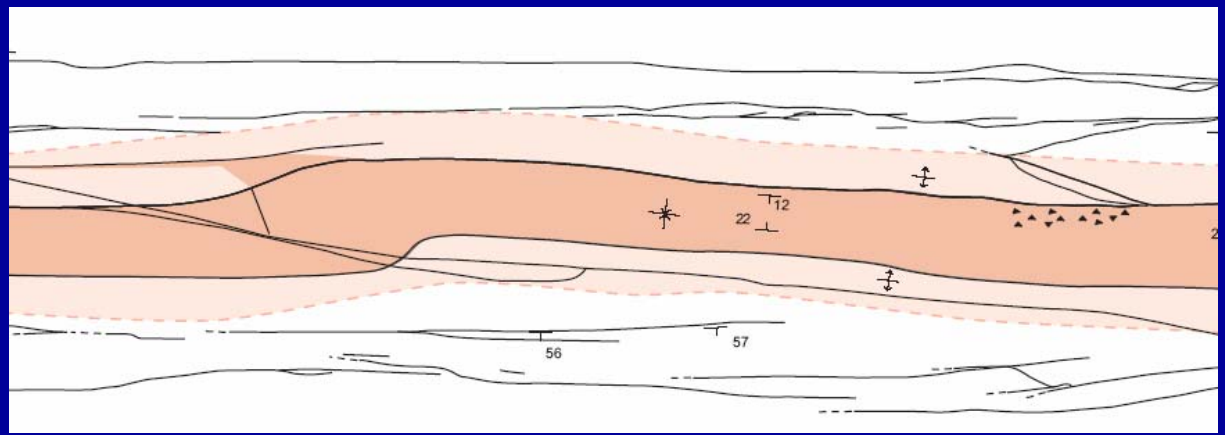
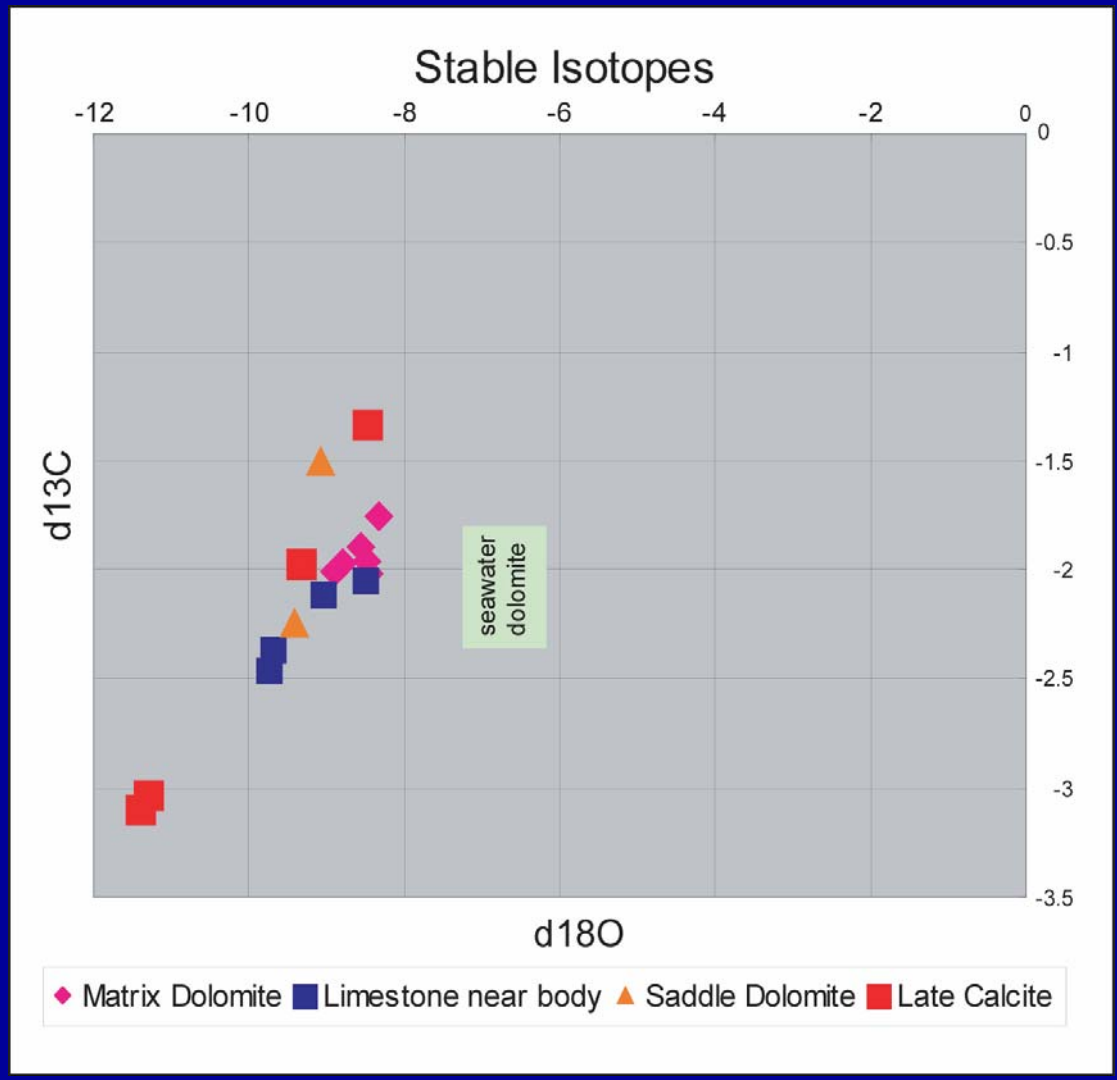
New Map and Enhanced Aerial Photographs

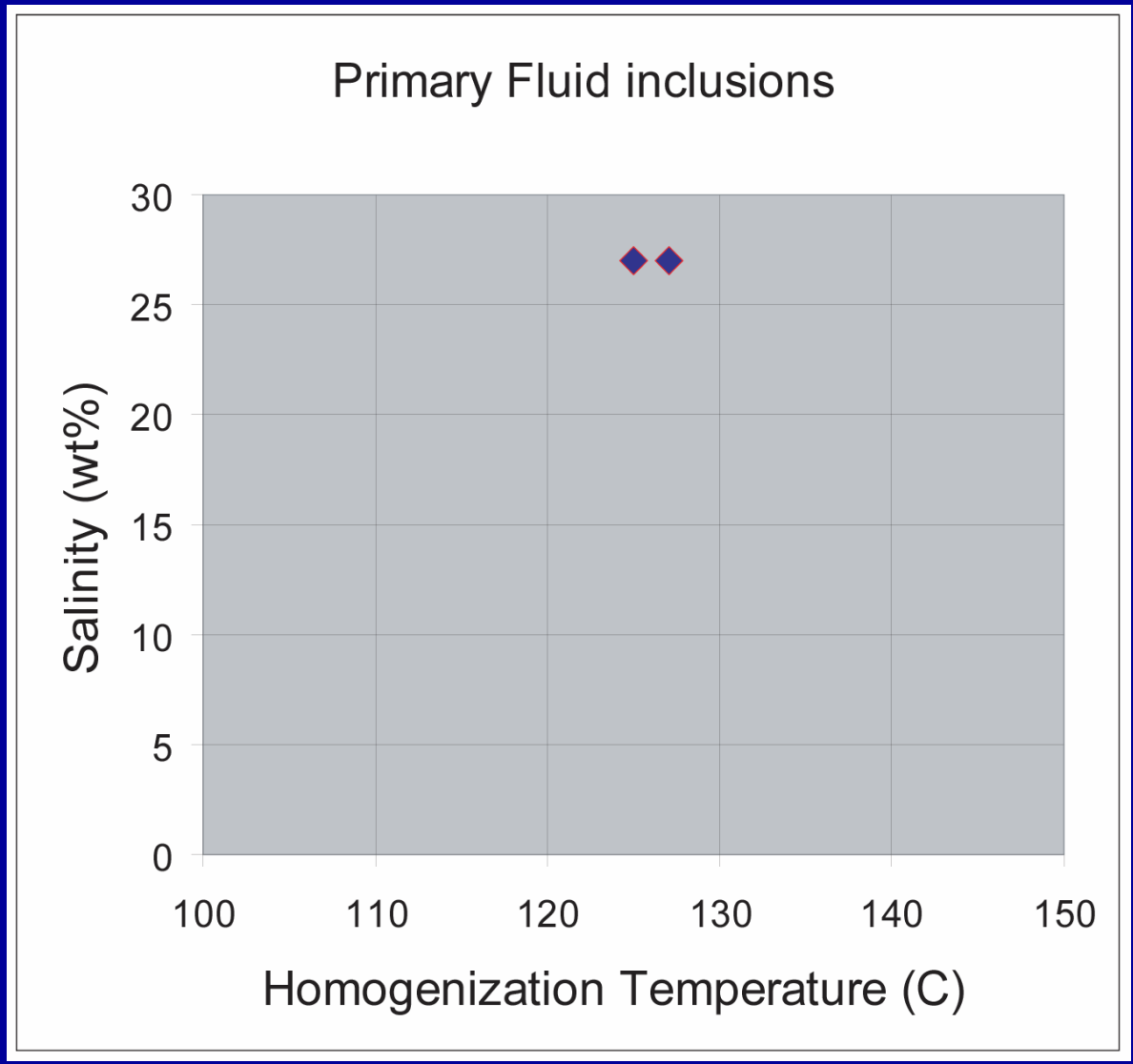




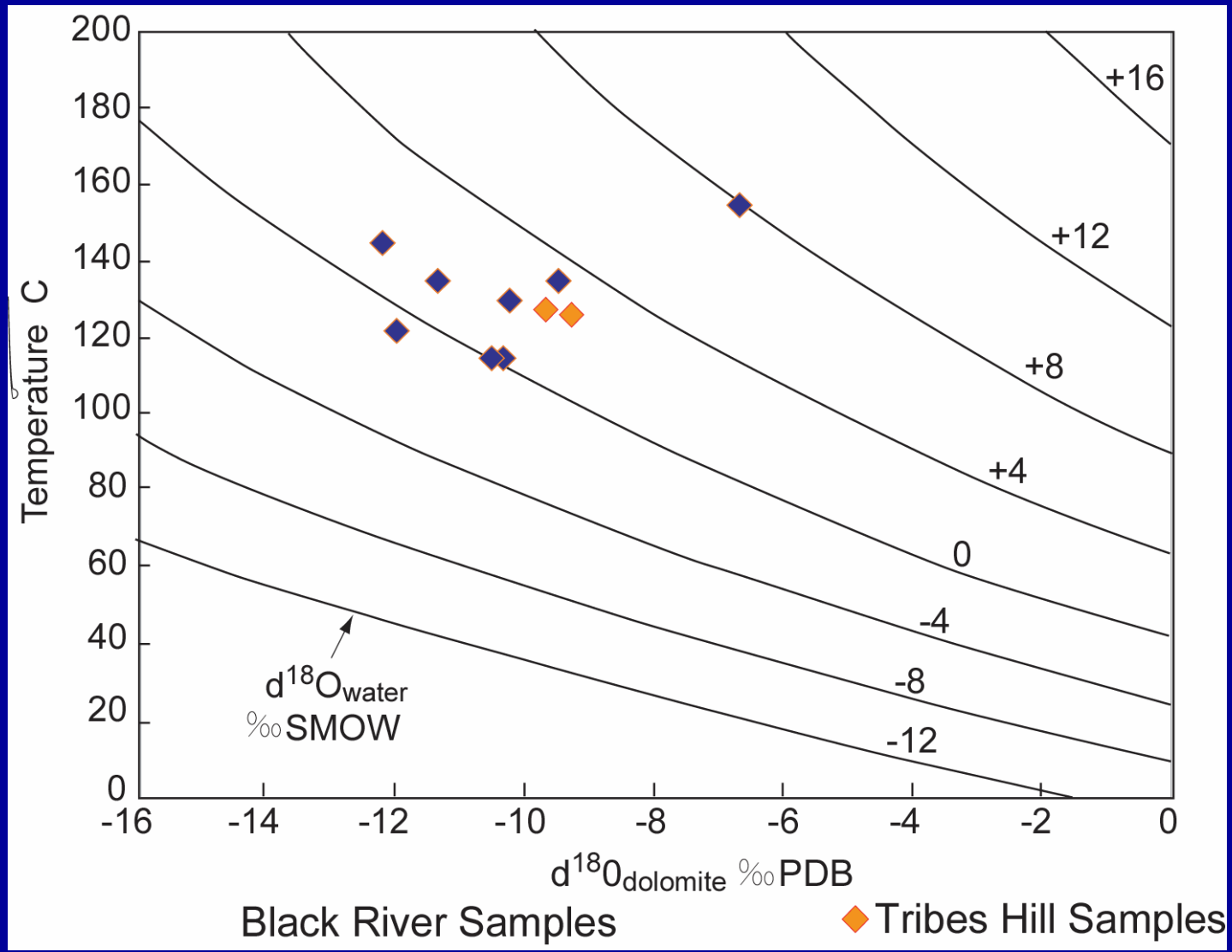
Geochemistry



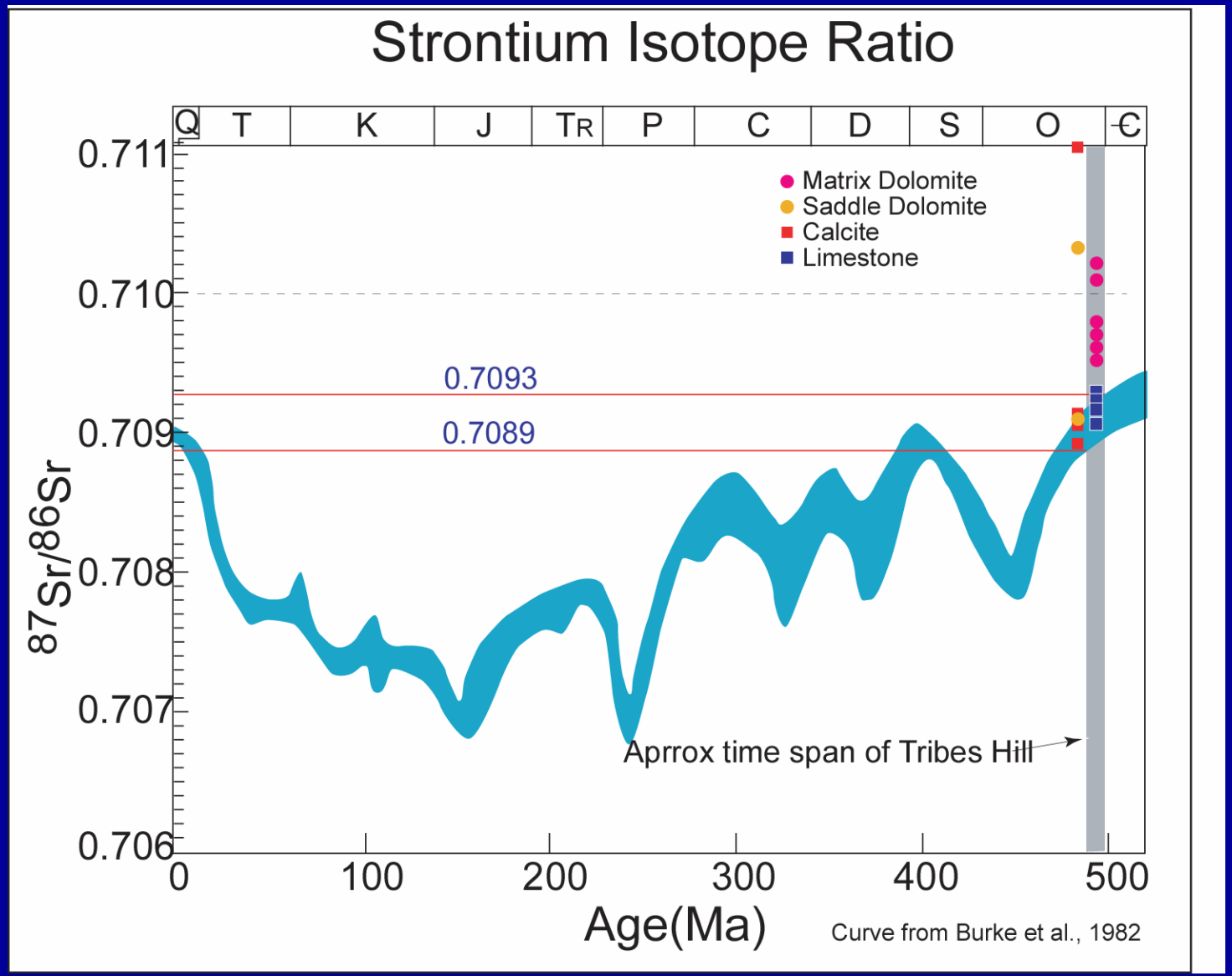
$\delta^{18}O$ values for matrix dolomite and saddle dolomite are lighter than seawater dolomites would be.



Primary fluid inclusion homogenization temperatures range from 120-130° with average around 125C. Salinities are a very high 26-28 wt%.



This plot suggests that Tribes Hill and Black River samples formed from fluids that were about +2 per mil - much heavier than seawater in the Ordovician which was around –6 to –9 per mil .



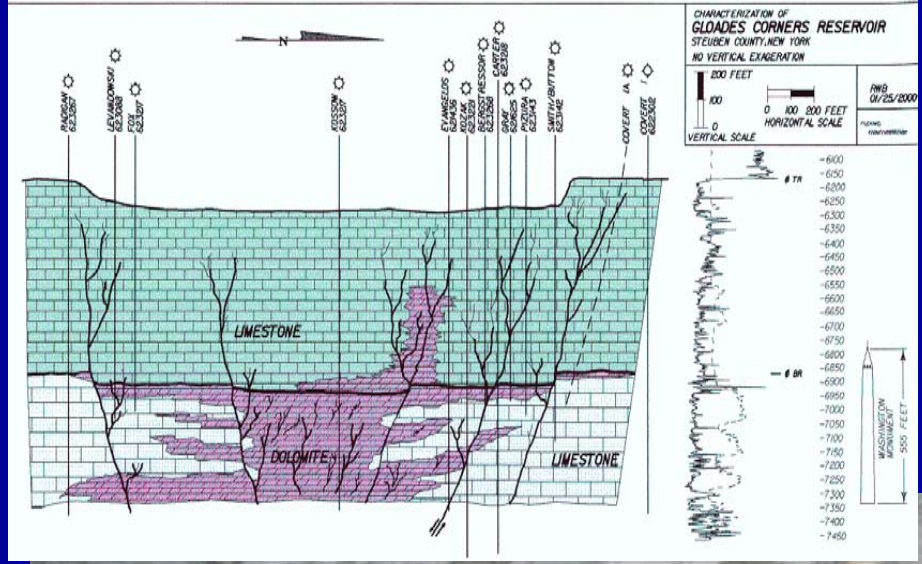
Matrix and saddle dolomites are radiogenic compared to Lower Ordovician seawater which suggests interaction with underlying basement or feldspathic sandstones

Geochemistry

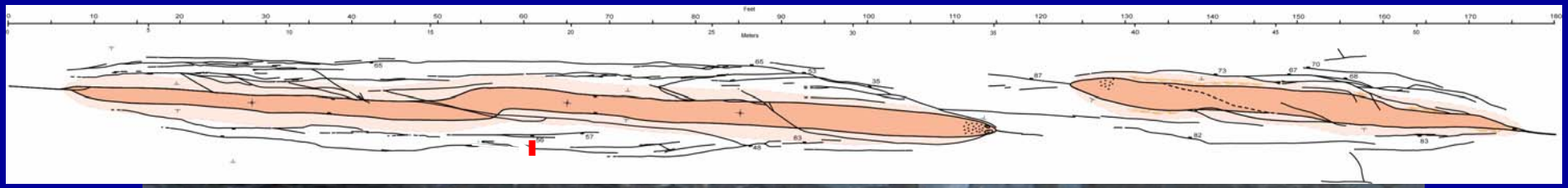
- All of these analyses suggest that the dolomite formed from a hot (125°C), saline (26 wt%) brine that passed through underlying basement or feldspathic sandstones prior to making the dolomite
- These values are very similar to those found in the Black River reservoirs

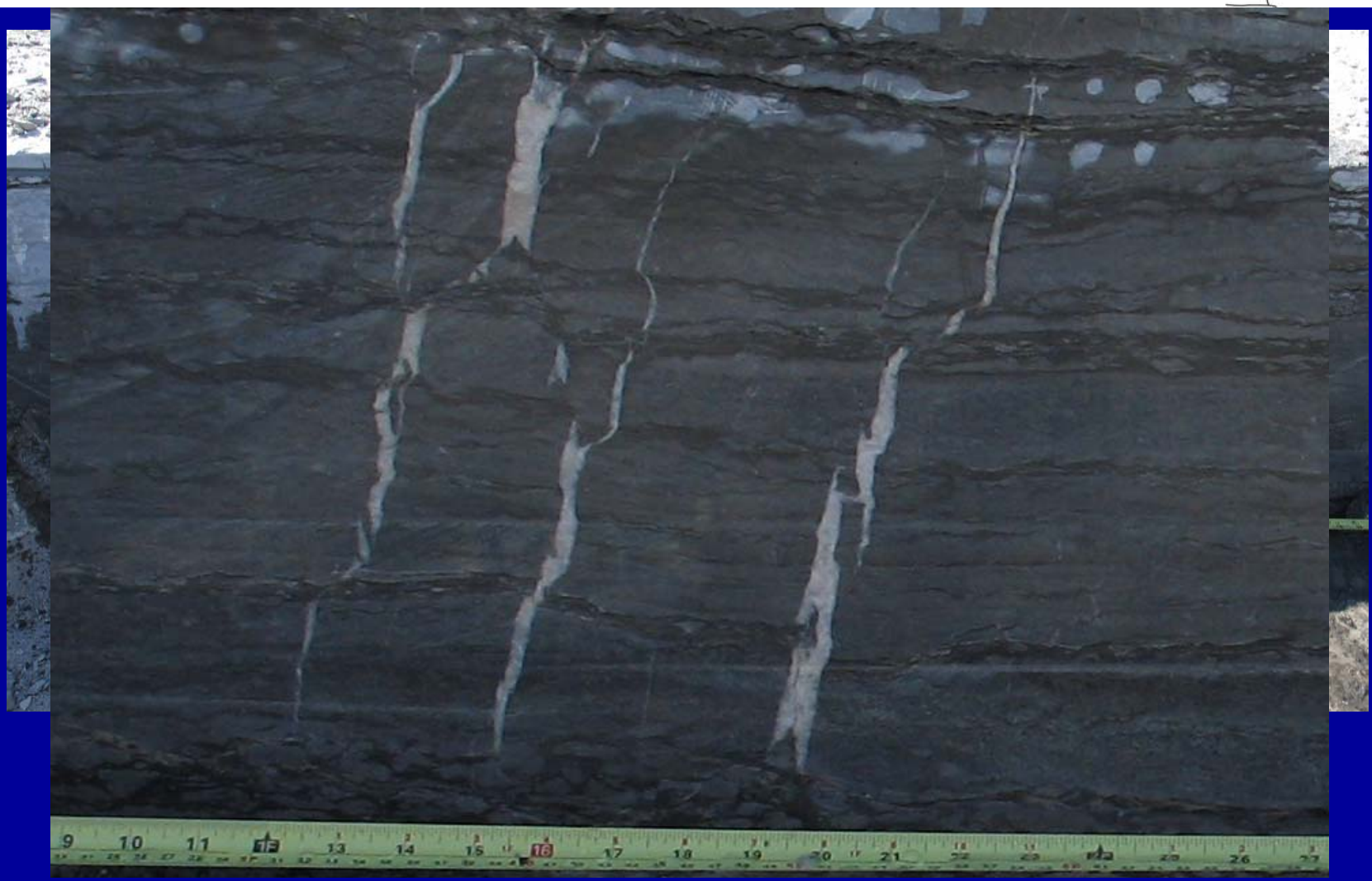
Core workshop and quarry fieldtrip June 7, 2005


Feet
Meters
65
57
48
83
87
73
67
70
68
82
83

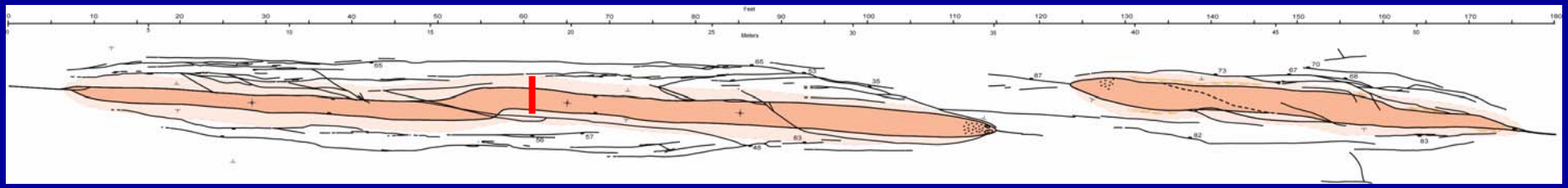


Dolomite core of the structure stays wet longer than limestone

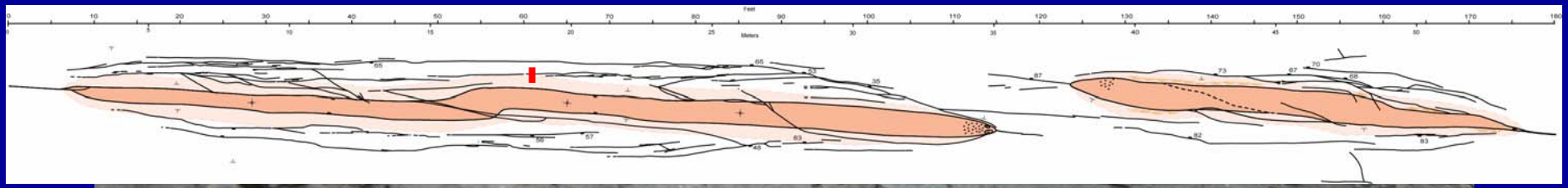




Fractures dip away from the dolomite body and are plugged with calcite on the south side

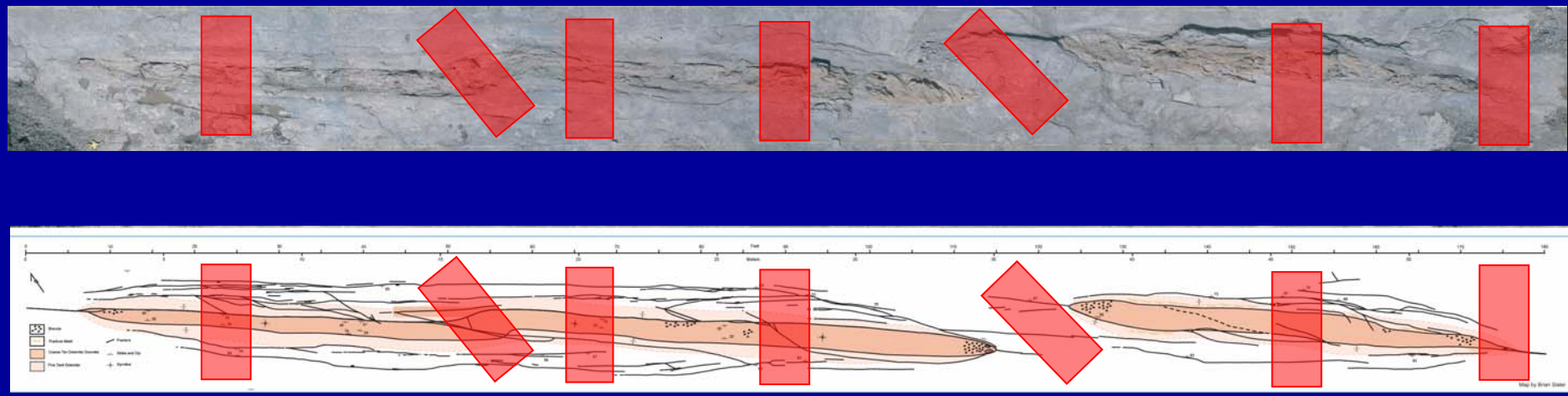


The dolomitized core is folded and has some open fractures – the sag here is more of a syncline than a graben



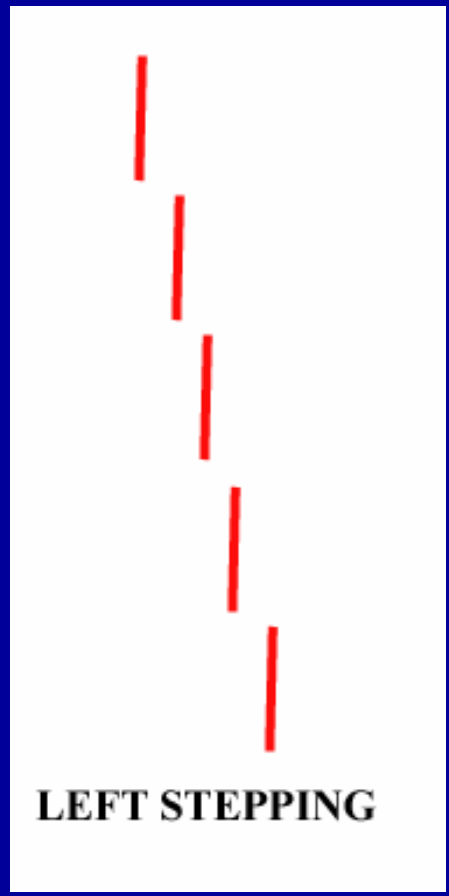
Faults are partially cemented with dolomite, have porosity and have reverse sense of motion on near north side

Future Trench Sites

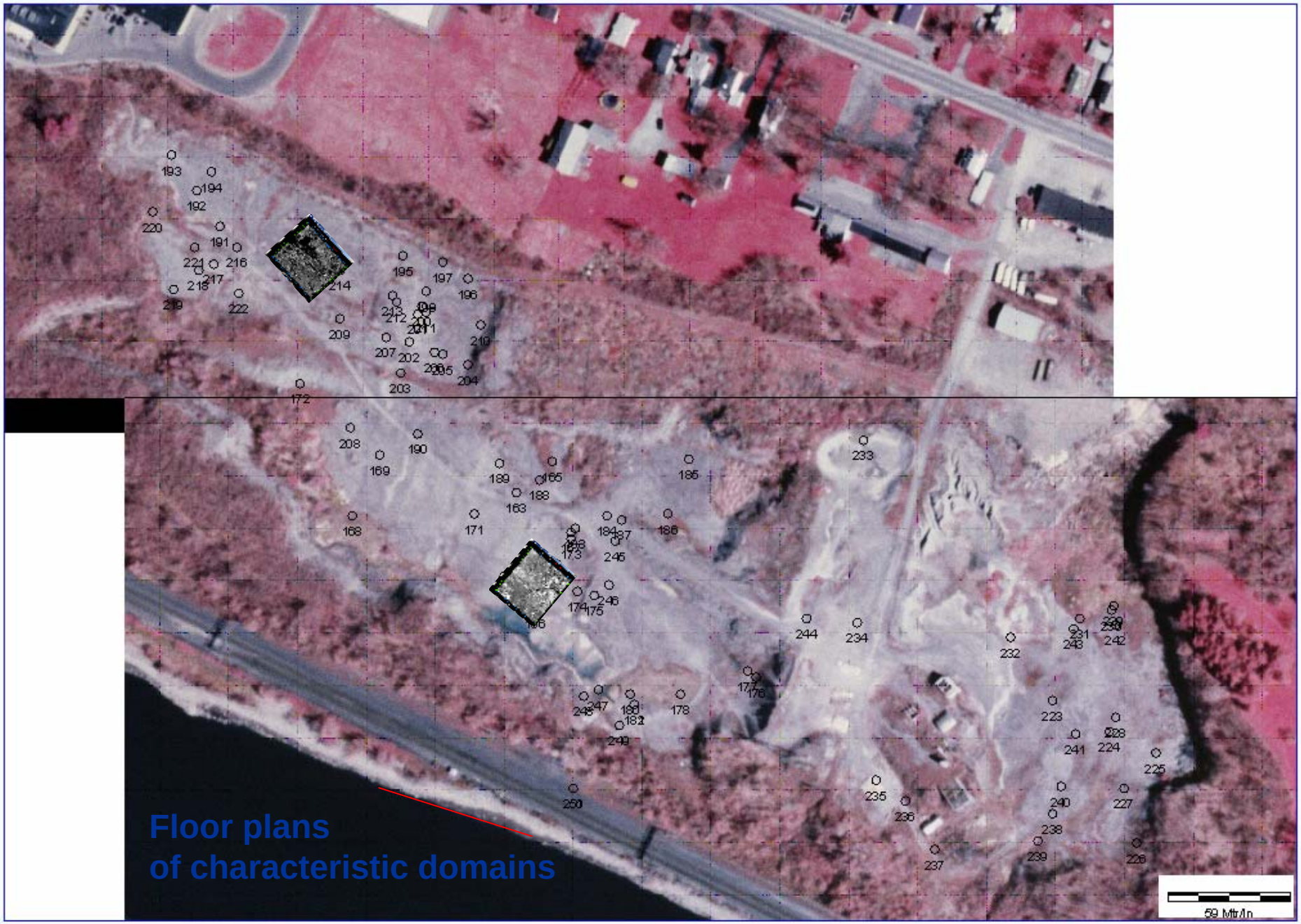


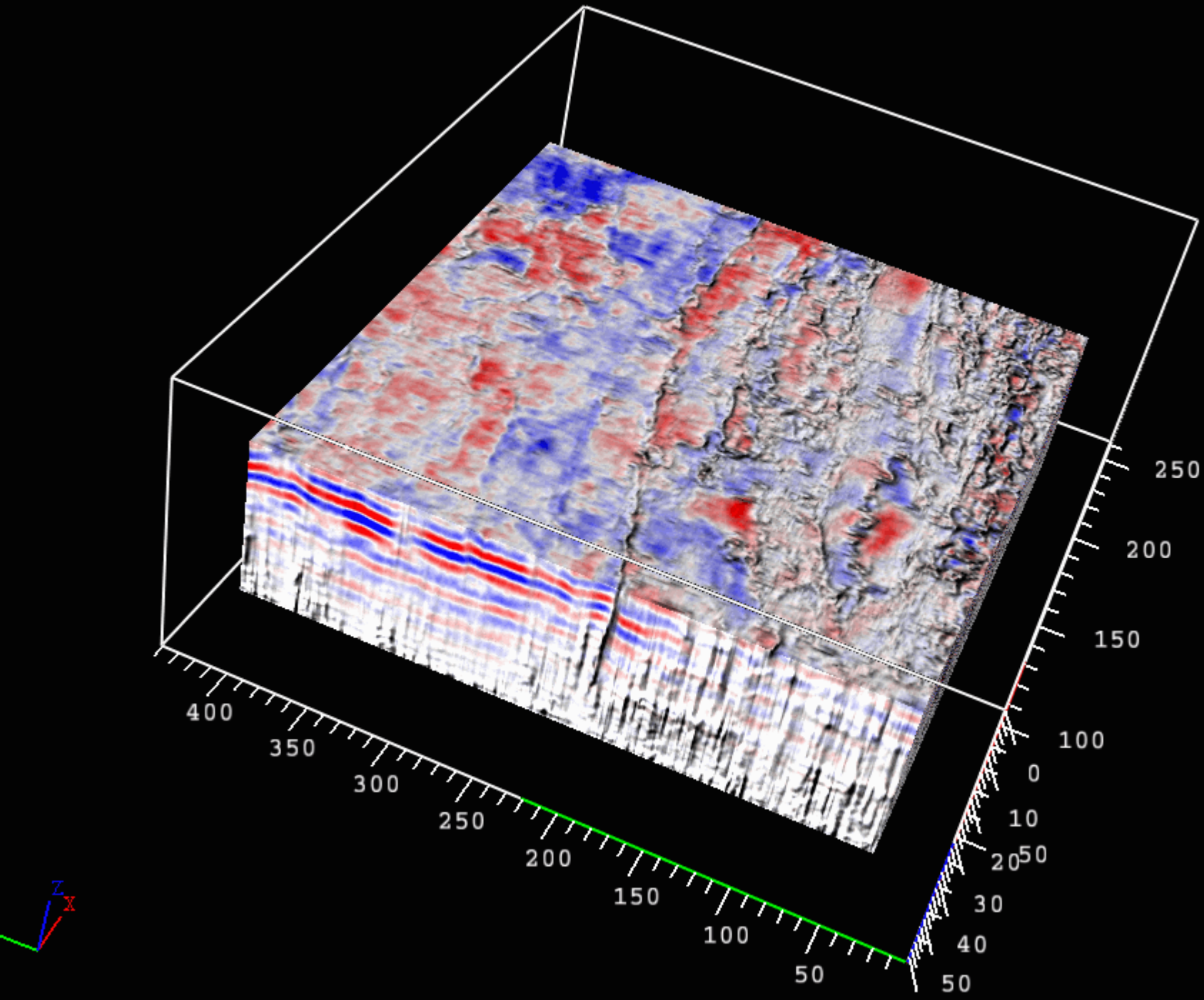
We plan to trench key parts of structure including tips, jog, break and middle parts of features in order to better understand fault dip, type, and where dolomite and open fracture and vuggy porosity occur.

We will use this data to build a 3D structural and diagenetic model



Working on structural analysis – after trenching we may do sandbox modeling


Floor plans
of characteristic domains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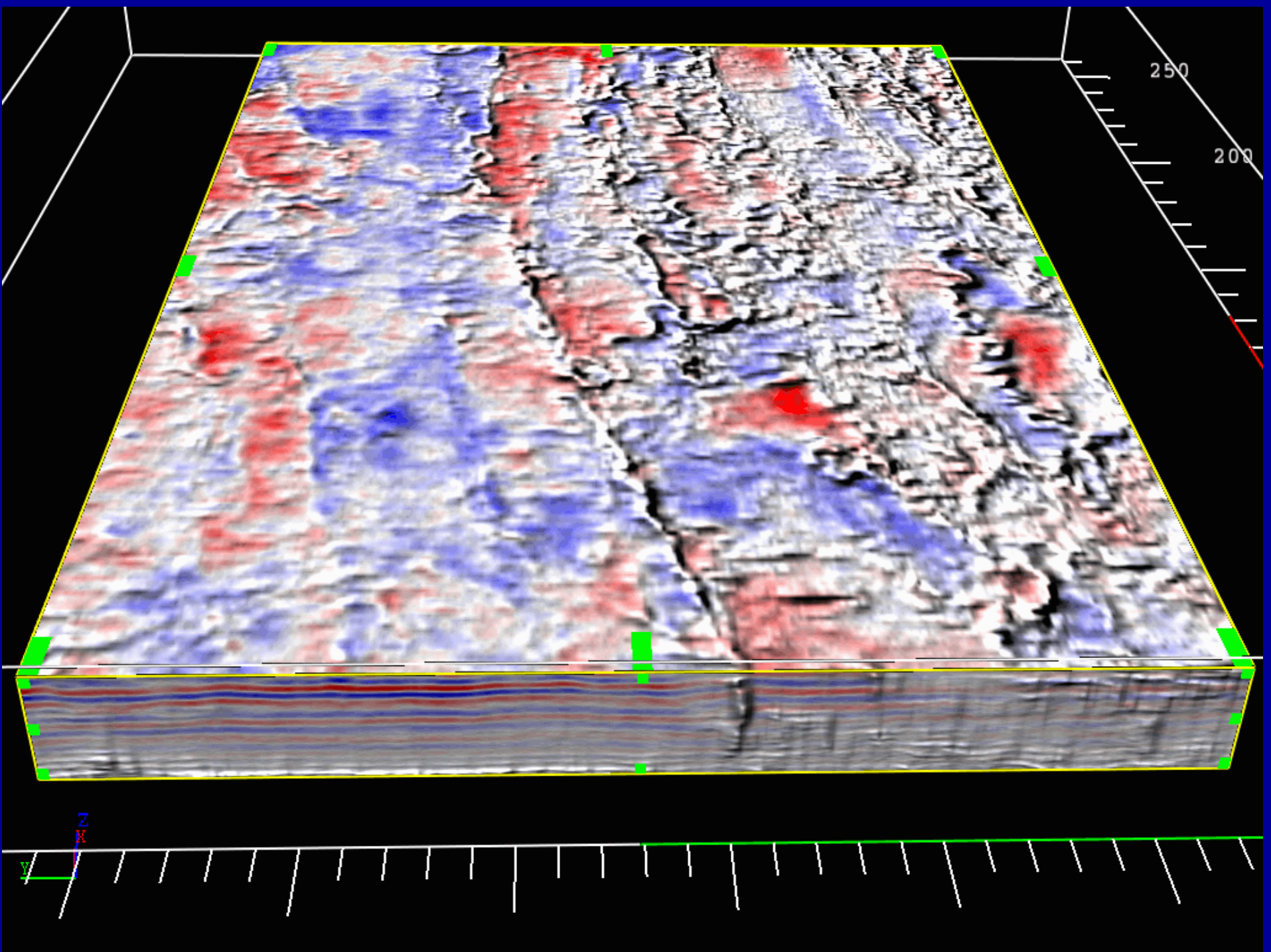
Z
X


250
200
Z
X
Y

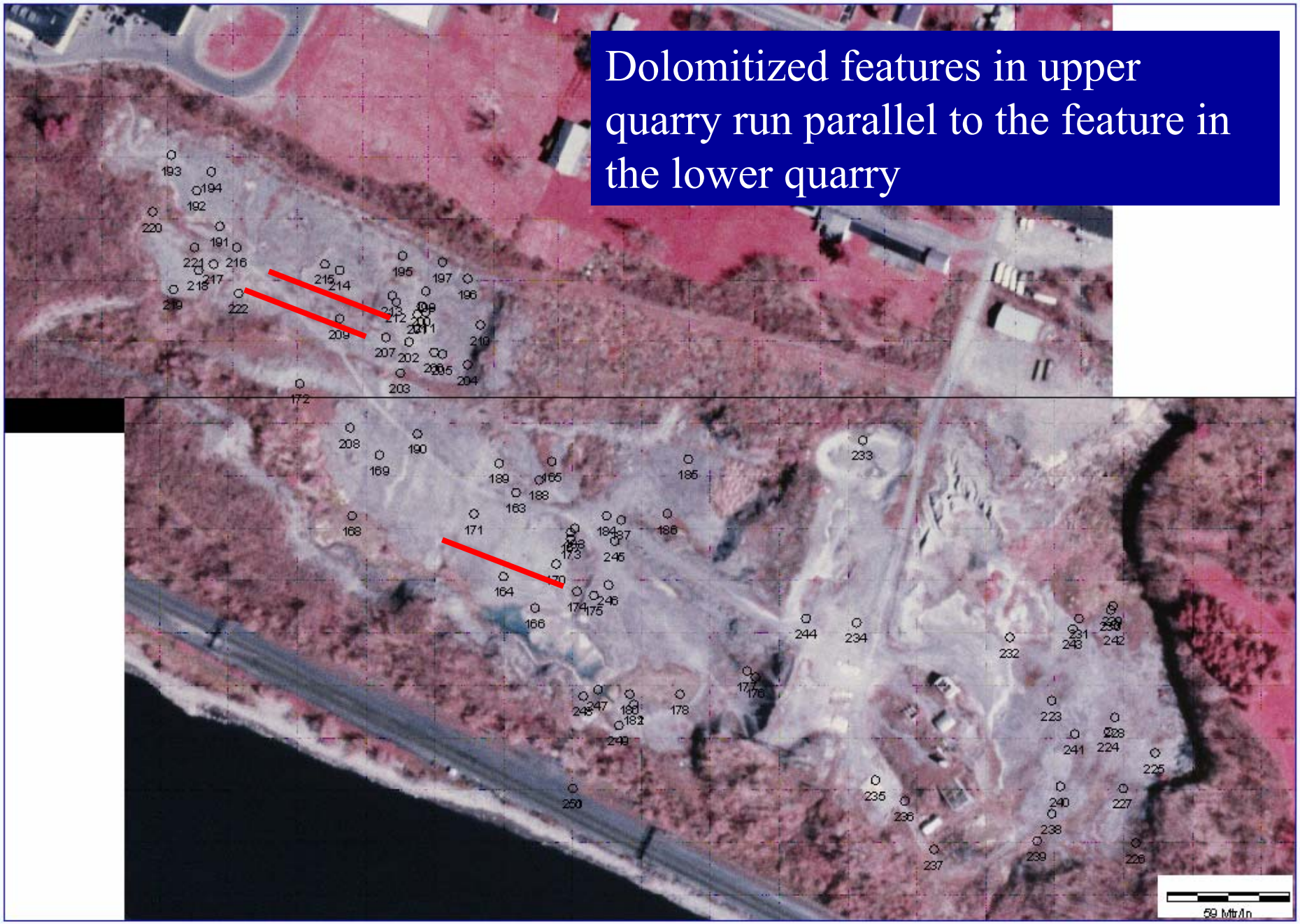
Upper quarry before and after partial cleaning

Upper Quarry Structures

Sag with beds dipping at 30° on both sides into structure

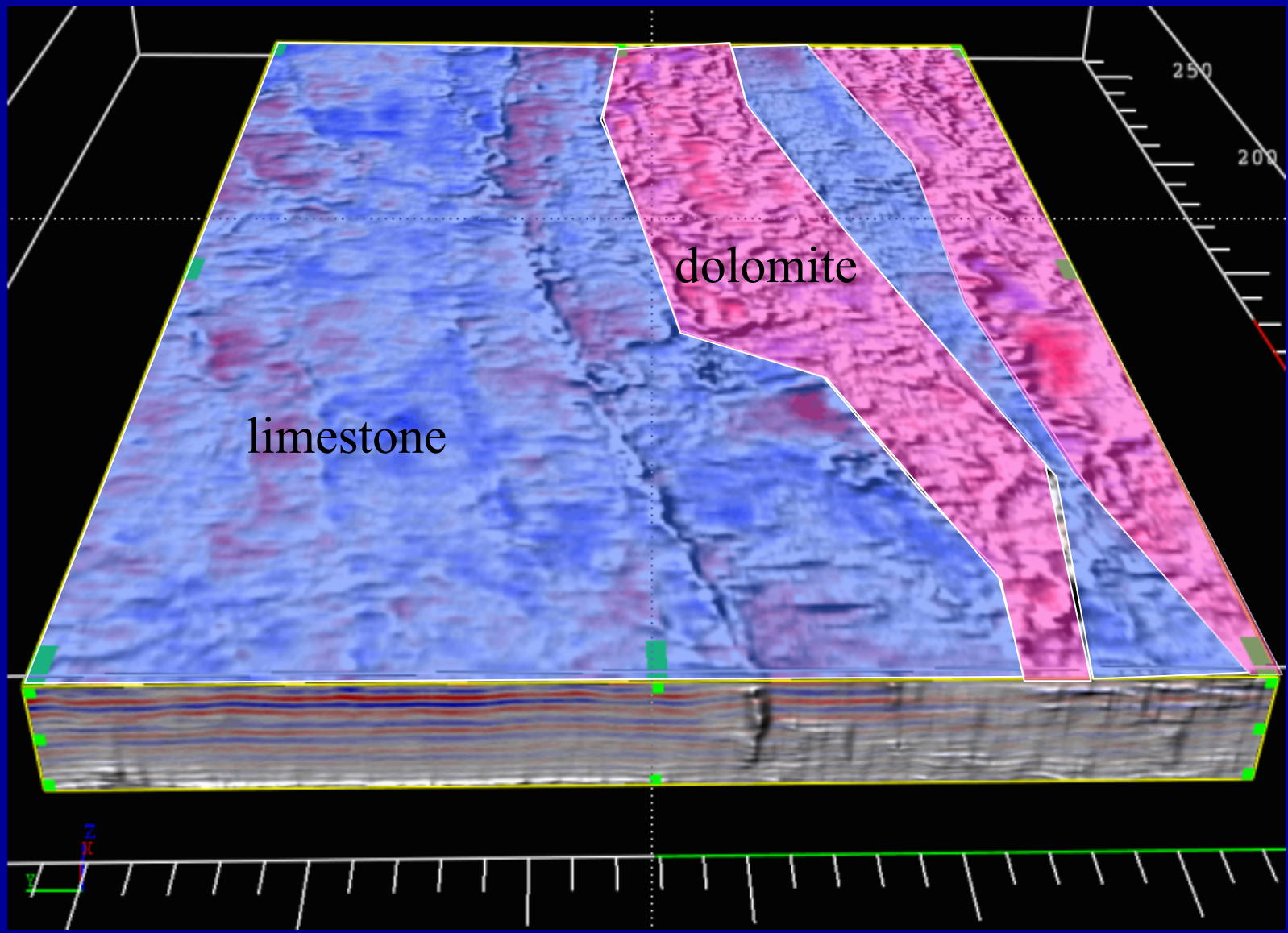
Sliver of limestone preserved in middle of dolomite body

What if a vertical well was drilled right here in a TBR Field?


Dolomitized features in upper quarry run parallel to the feature in the lower quarry

Like lower quarry, there is porosity in vugs and fractures

It looks like there is also matrix porosity in some of the coarser rock types like this flat pebble conglomerate

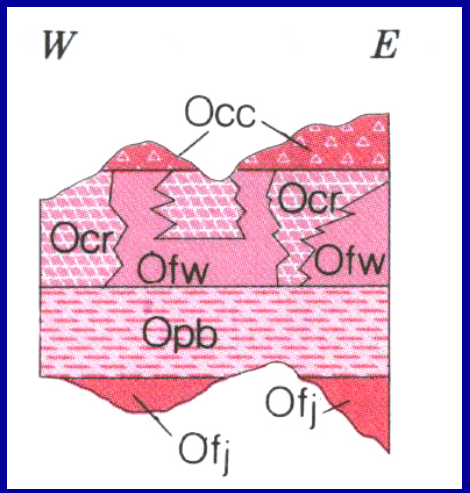


After first pass, it looks like there are at least two dolomite bodies, but it is bigger and more complex than lower quarry –planning to clean it, trench it and map it in detail

Upper Quarry

- Lot of faulting, not all faults have associated dolomite (just like TBR play)
- Matrix, vuggy and fracture porosity
- Bigger than lower quarry exposure
- Will compare to lower quarry to see similarities
- Needs to be cleaned
- Plan to expand GPR survey and make detailed map and take aerial photos
- Also plan to cut trenches here

Tribes Hill



Ocr =dolomite
Ofw=limestone

The Tribes Hill is variably dolomitized in throughout the area- some dolomite bodies big enough to be reservoirs

dolomite

TH all limestone here (Fisher, 1980)

Horizontal slickensides support strike-slip faulting in the area

Future Work

- Will continue to trench structures in the lower and upper quarry
- Will try to get shallow seismic refraction line that can image structures down to basement (probably about 400 ft)
- Will finish geochemistry and petrography on dolomites
- Will work to uncover other fault-controlled dolomites in the upper quarry
- Will expand 3D GPR coverage
- Will make a detailed map of known existing dolomite bodies in the quarry

Conclusions

- The quarry feature is a great analog for the Black River Play
- The upper quarry shows similar features that formed higher in the section suggesting similar process of formation.
- Porosity so far is limited to the northern flanks.
- More work and study need to be done
- This is just Chapter 2 – more chapters to be written

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