Using Technology to Measure the Unreachable: Digital 3-D Outcrop Characterization using Close-Range Photogrammetry, Terrestrial Laser Scanning and Remote Sensing.

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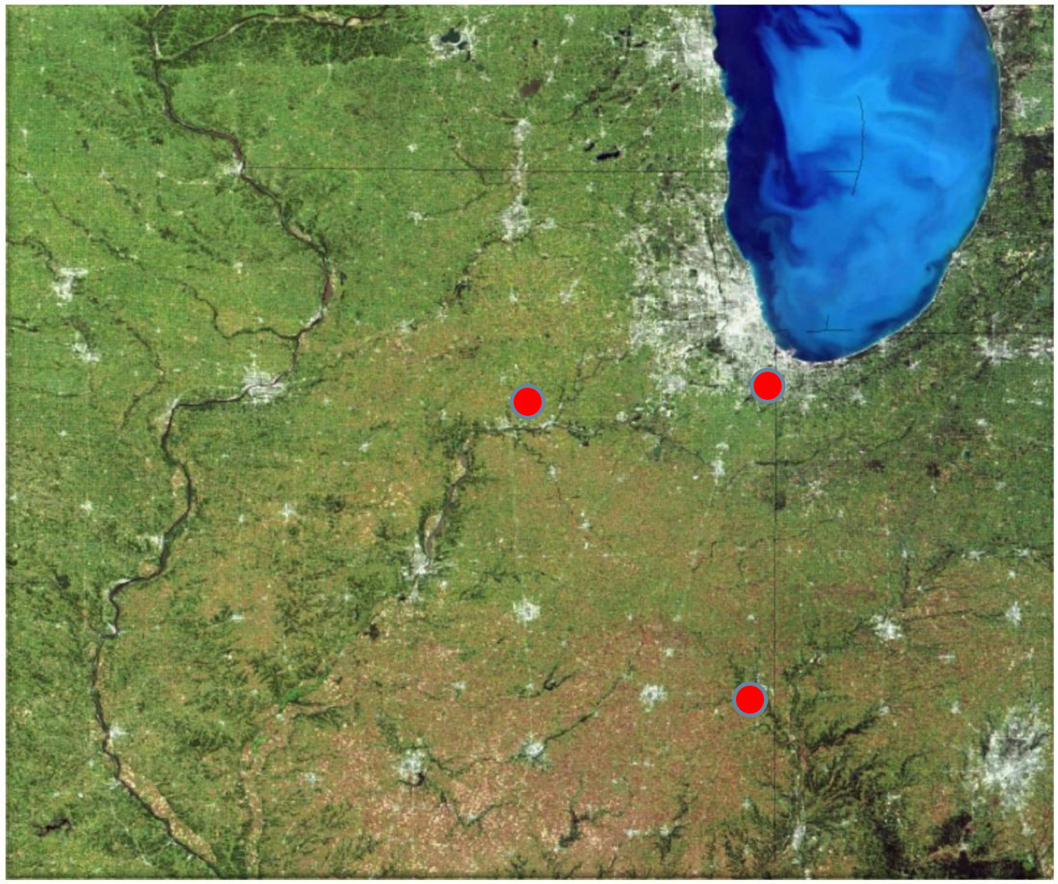

Funding for field work provided in part by the Metropolitan Water Reclamation District of Greater Chicago and MWH, Inc.

Surveying instruments provided courtesy of Prof. James Best, UIUC & IDOT.

Other support from Sirovision, Optech, Middle Fork F&W Area,

● Field study site

Gr. Lakes Geologic Mapping Coalition

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ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

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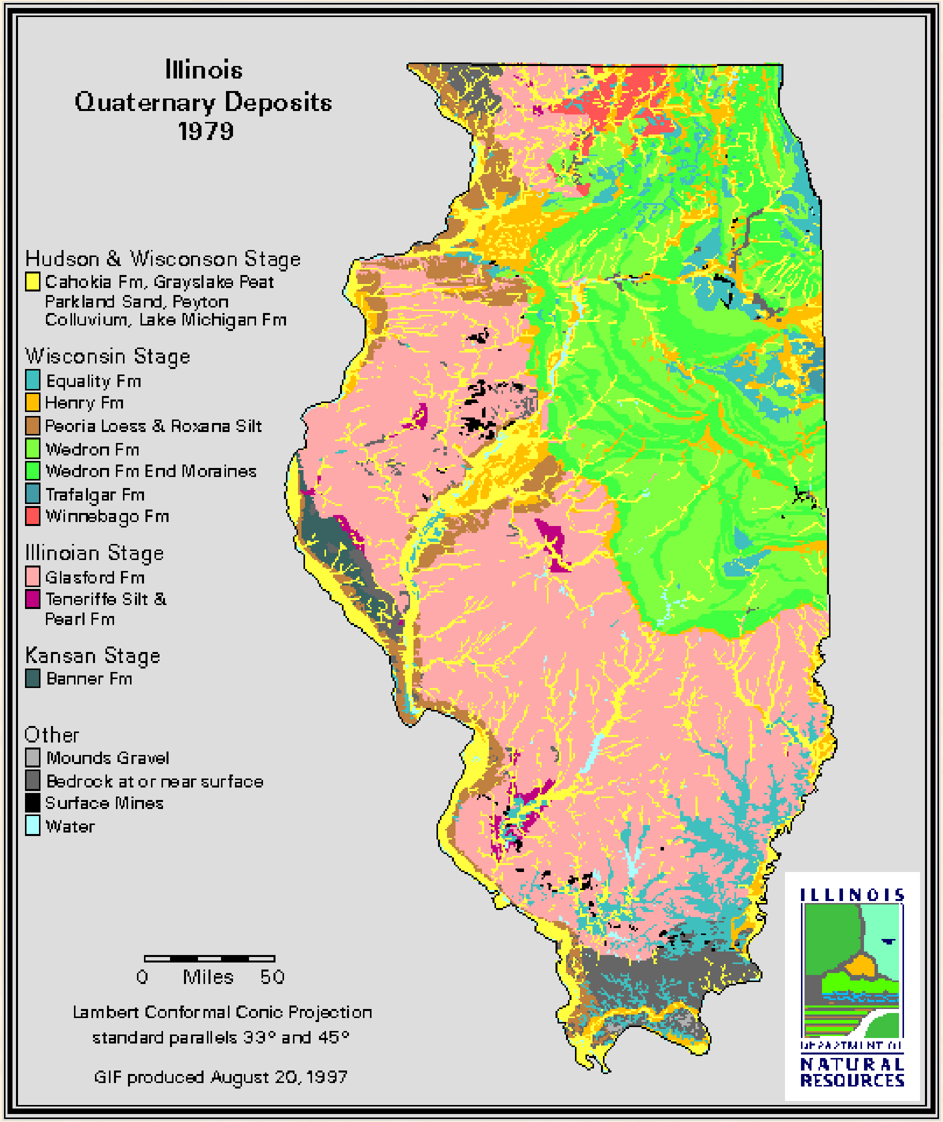
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Why new geologic maps?

- Previous surficial maps were made with data & technology available at the time.

- Society now wants detailed information for natural resources (aggregate, groundwater, energy, …), planning, and avoid environmental and natural hazards.

- 3D maps are needed for these purposes, but how to get 3D information for models?



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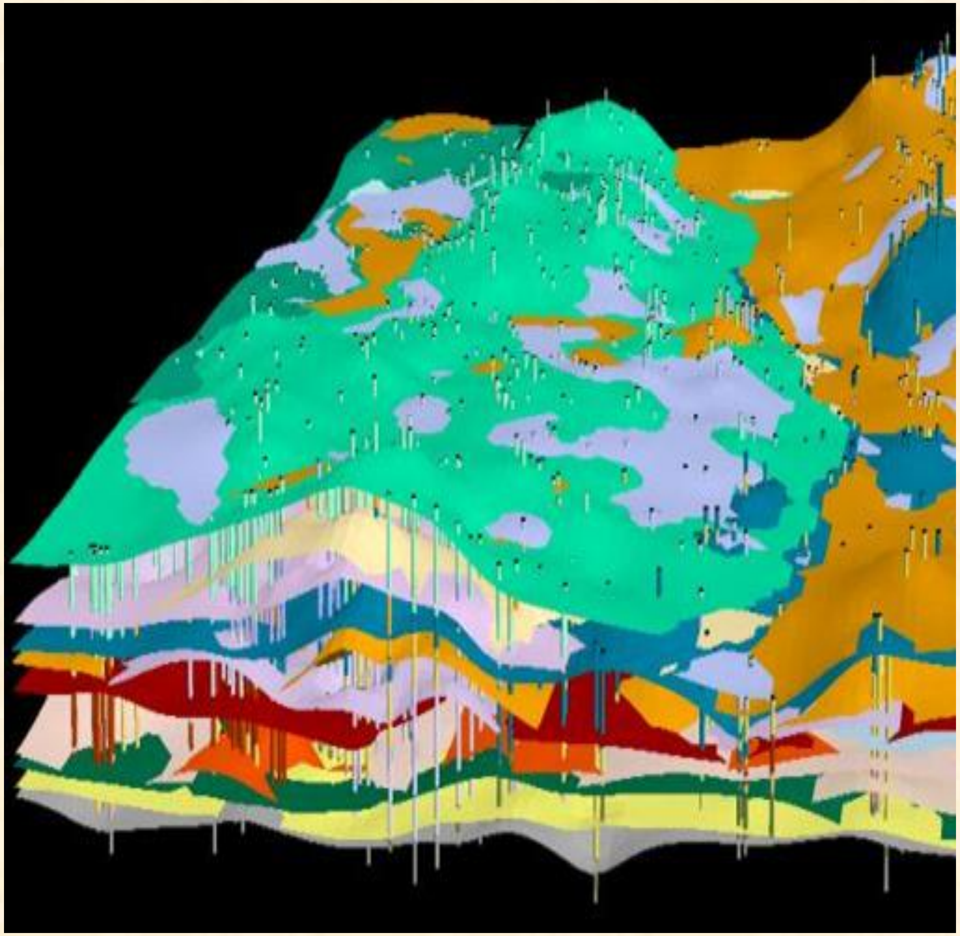
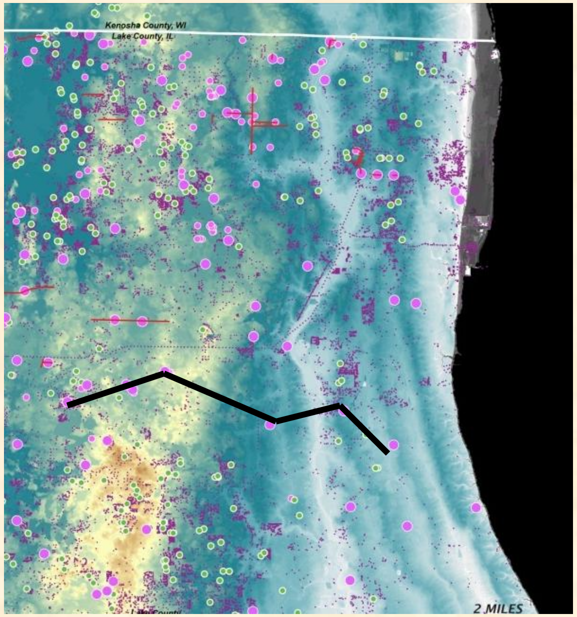
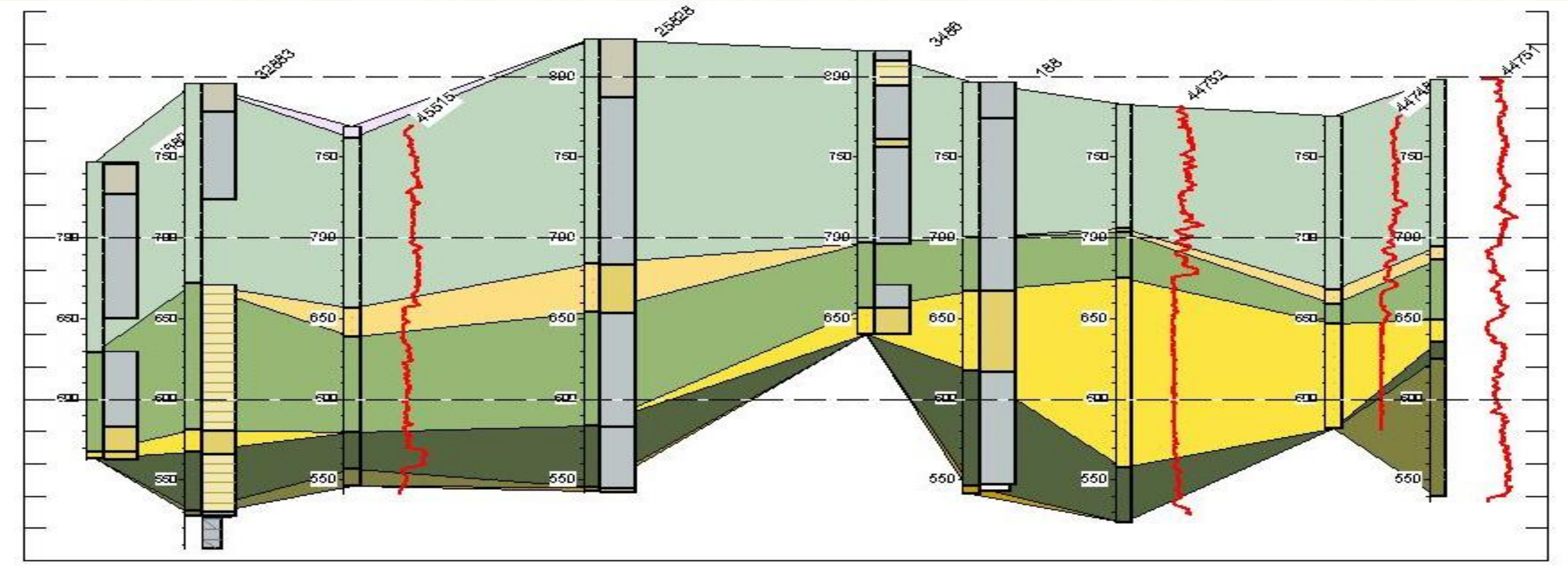




Obstacles to 3D modeling

- Connect dots or construct geology?
- Estimate occurrence or probability?
- Guess dimensions or measure?

How to obtain numerical data?



Outcrop observations and measurements

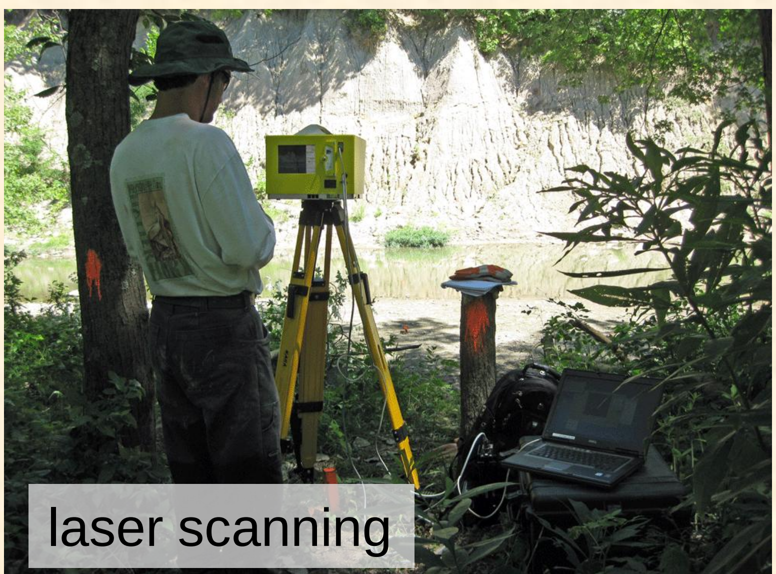
- 2-D outcrops = high detail and unit context where accessible.
- Better than 1-D borings because
  - *geometry + spatial dimensions*
  - *changes in properties/character of units (needed for groundwater and natural resource models)*

But! **2-D outcrop data not usually compiled into 3-D models.**

Three technologies for georeferenced outcrop measurements and 3D data

close range photogrammetry

- No technique is ‘perfect’
- None works everywhere
- None provides all data
- None simple to use
- All based upon satellite & transit surveying



laser scanning

GPS + transit instruments courtesy Jim Best

laser transit

Three technologies for georeferenced outcrop measurements and 3D data

close range photogrammetry

laser transit

laser scanning

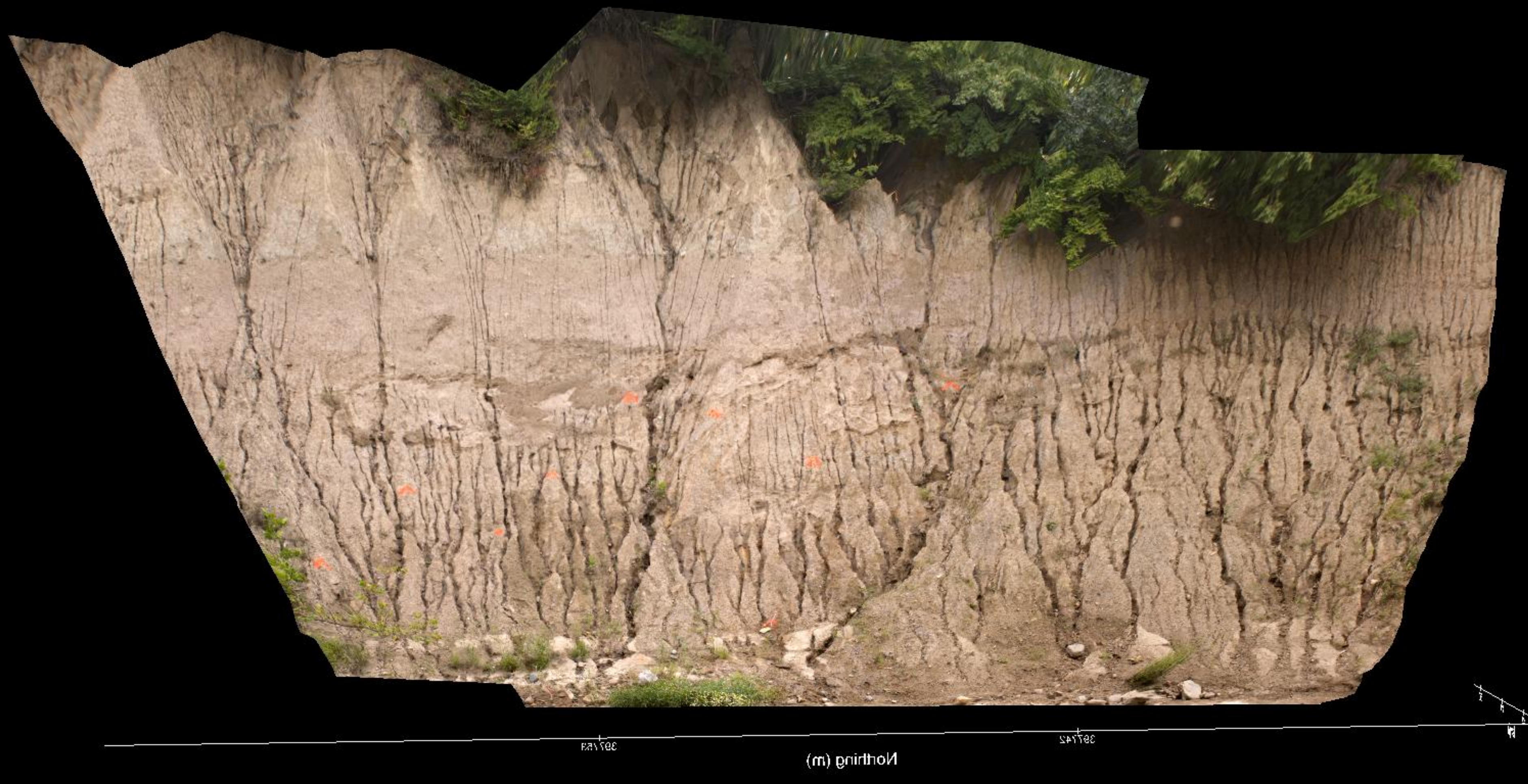
Outcrop close-range photogrammetry field setup

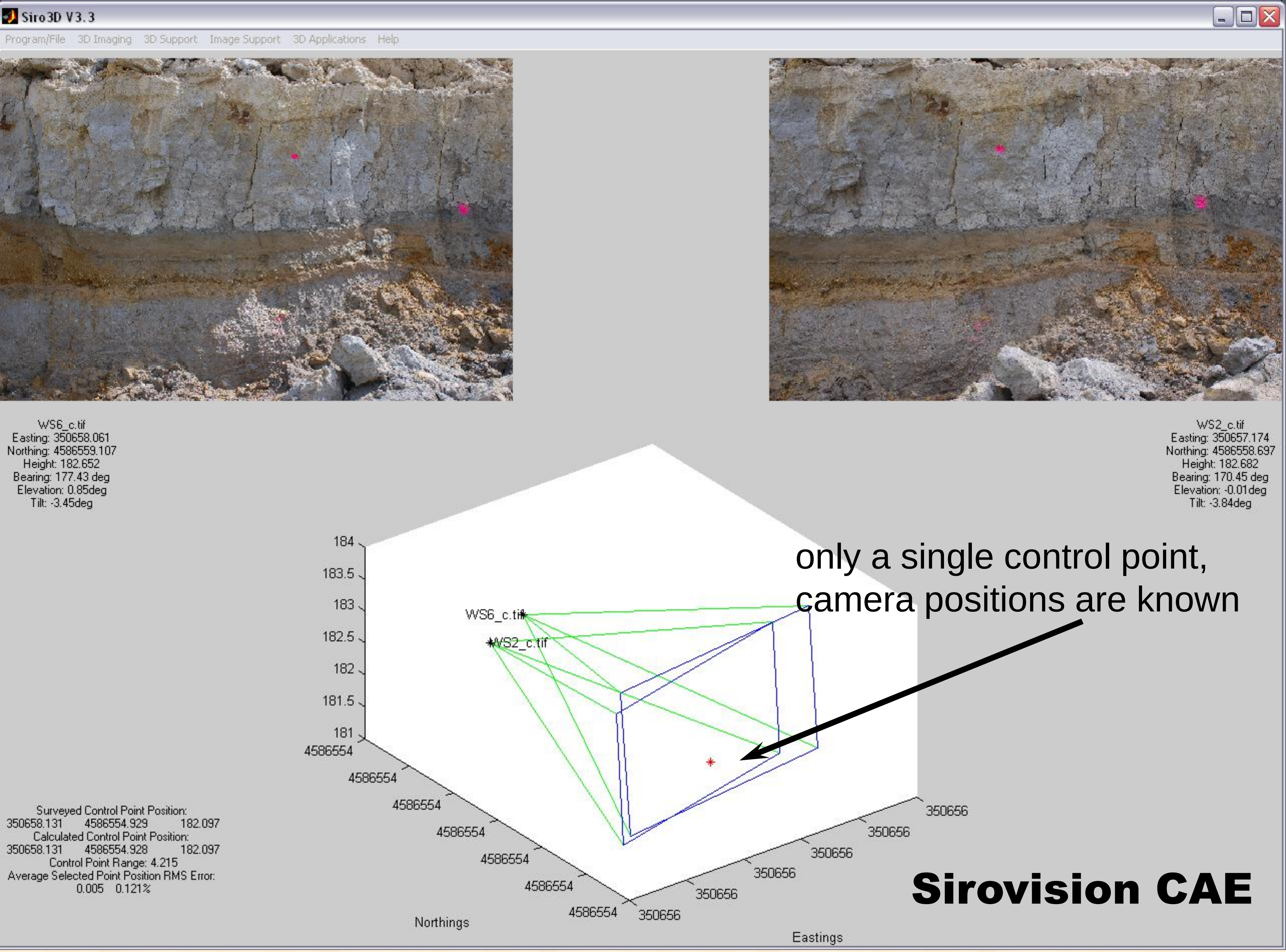
Unrectified photograph

- **Rectangular**
- **Square corners**

Orthorectified photograph

- Trapezoidal shape
- Corners are not square
- Geometrically correct




Siro3D V3.3
Program/File
3D Imaging
3D Support
Image Support
3D Applications
Help
WS6_c.tif
Easting: 350658.061
Northing: 4586559.107
Height: 182.652
Bearing: 177.43 deg
Elevation: 0.85deg
Tilt: -3.45deg
WS2_c.tif
Easting: 350657.174
Northing: 4586558.697
Height: 182.682
Bearing: 170.45 deg
Elevation: -0.01deg
Tilt: -3.84deg
184
183.5
183
182.5
182
181.5
181
WS6_c.tif
WS2_c.tif
4586554
4586554
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Northings
350656
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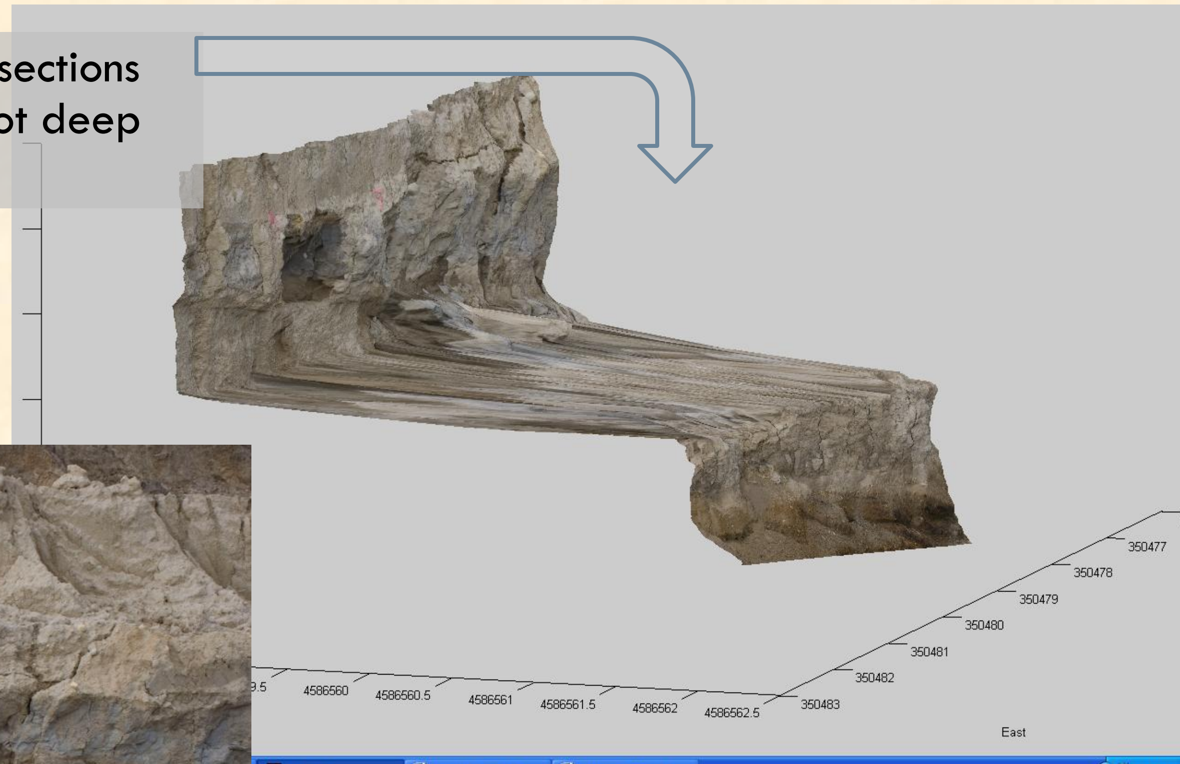
350656
Eastings
only a single control point,
camera positions are known
Surveyed Control Point Position:
350658.131 4586554.929 182.097
Calculated Control Point Position:
350658.131 4586554.928 182.097
Control Point Range: 4.215
Average Selected Point Position RMS Error:
0.005 0.121%
Sirovision CAE

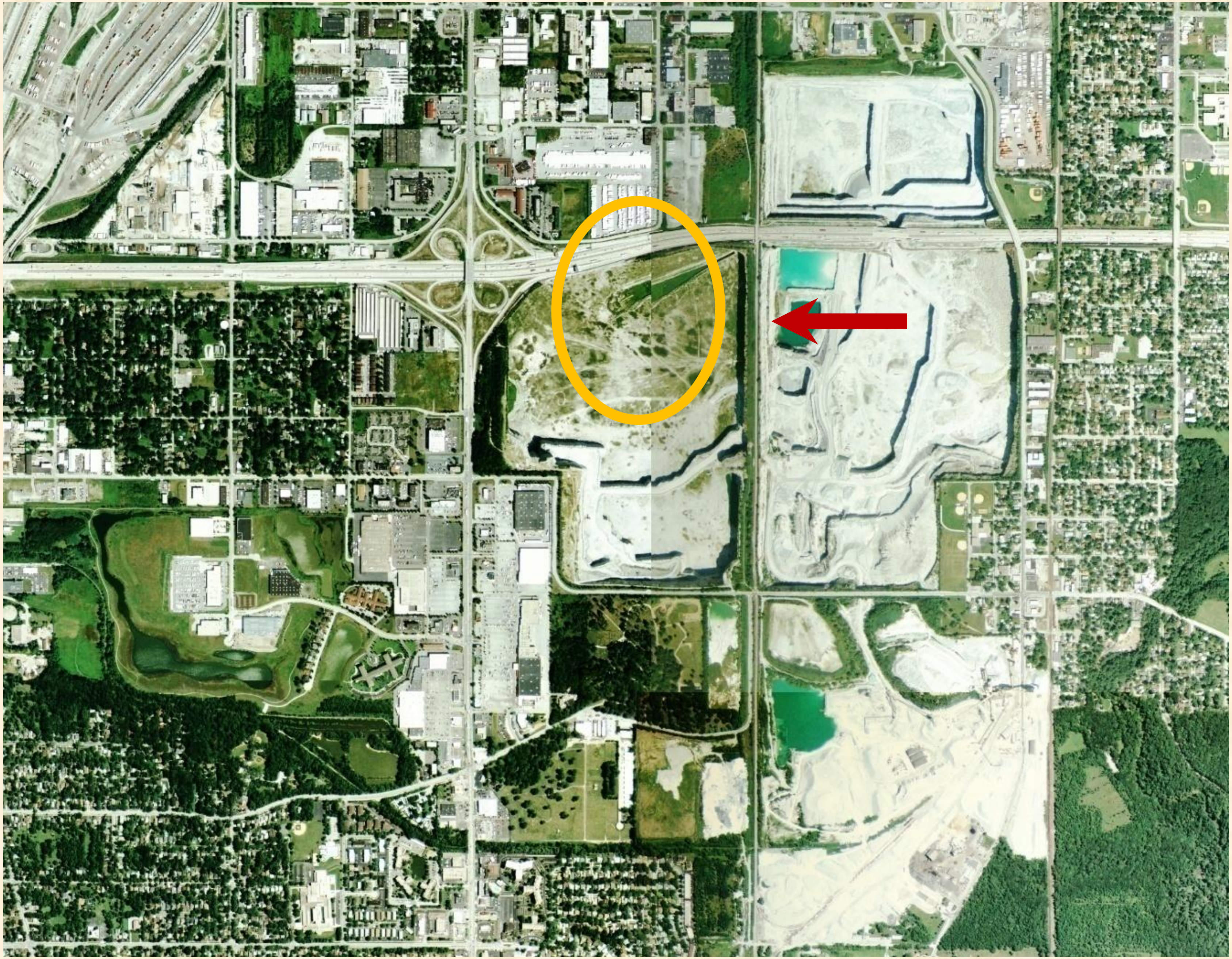
Stereophotography → georeferenced, orthorectified image

Note the offset of upper and lower sections of outcrop face offset by a 4-foot deep excavation.

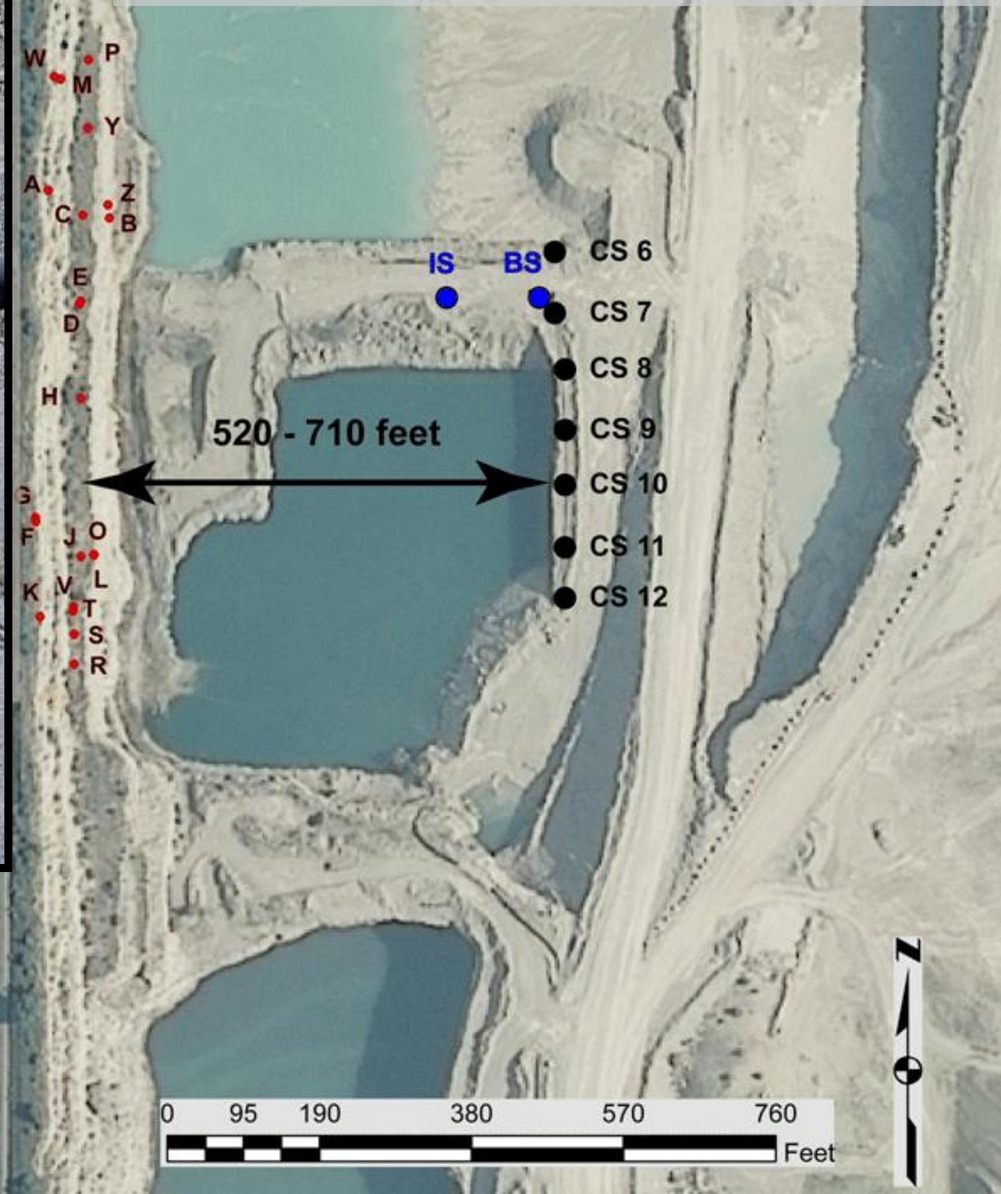


Orthorectified image has <u>no radial displacement</u> or optical errors.

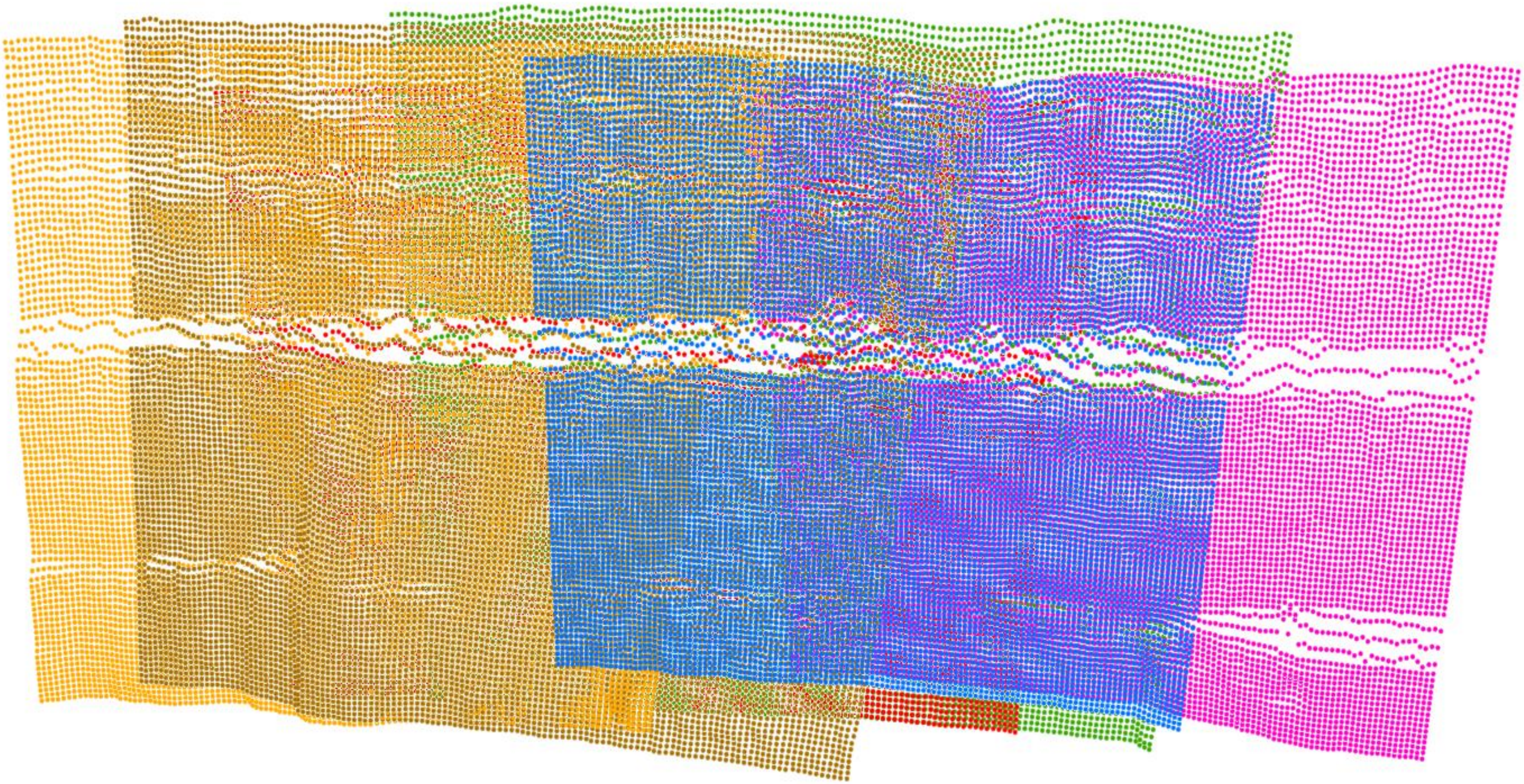
Thorn Creek stormwater storage



Surveying control and check points in field. Record on photomosiac.



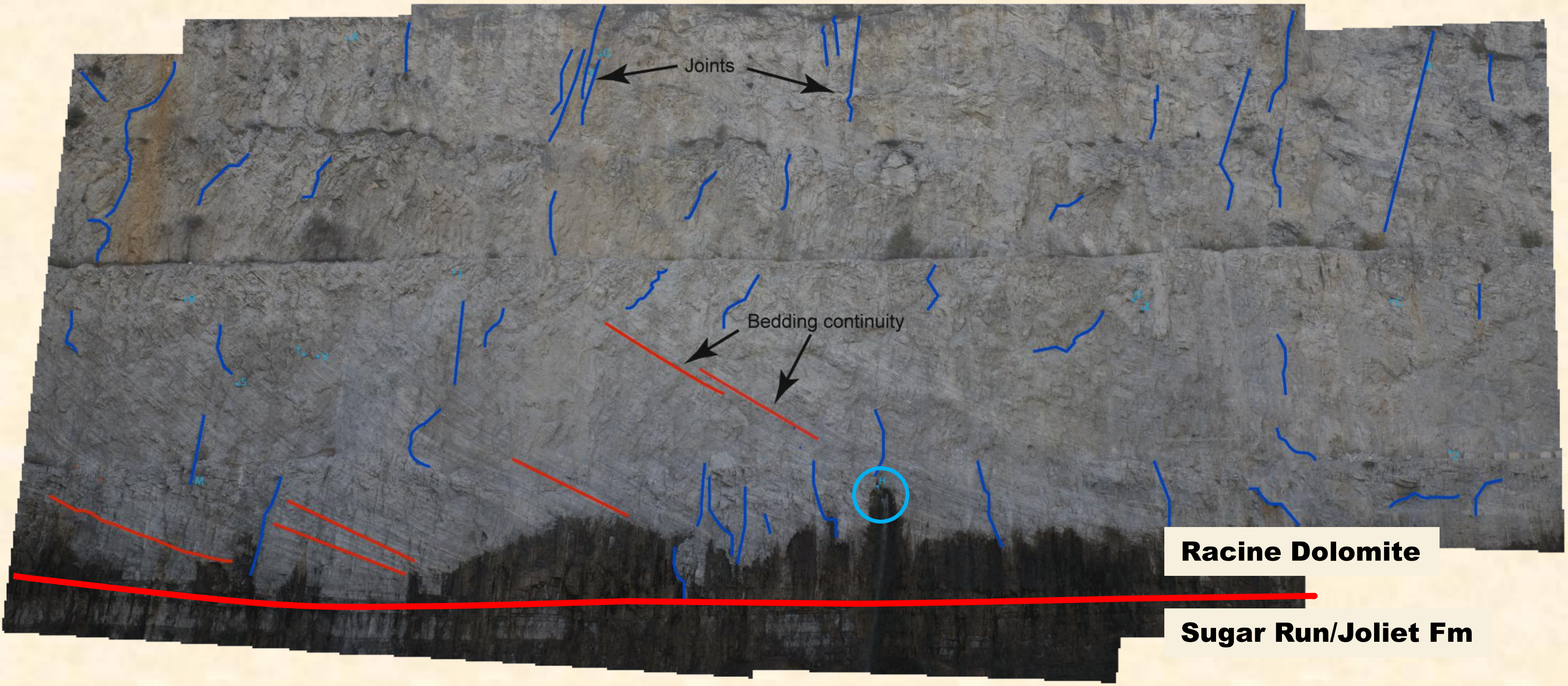
DEM extracted from the stereomodel by Sirovision
Multiple point clouds displayed in ArcScene



Good relative orientation

Measurements of Thornton Quarry N-S wall by Sirovision

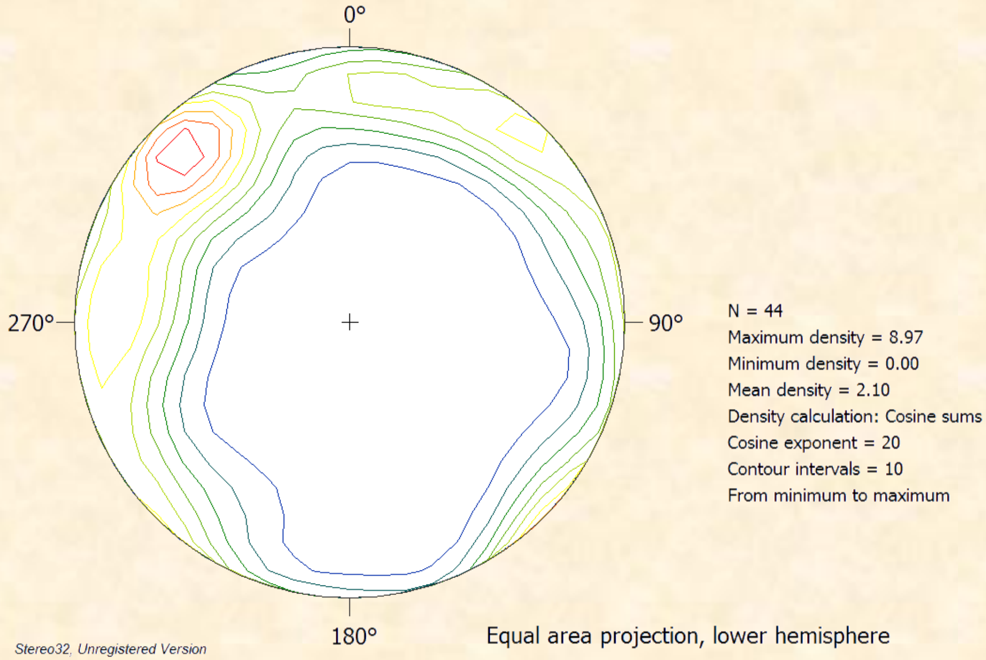
- Excellent geometry and results under difficult measurement conditions.
- <u>Joint orientation compares with previous results</u>



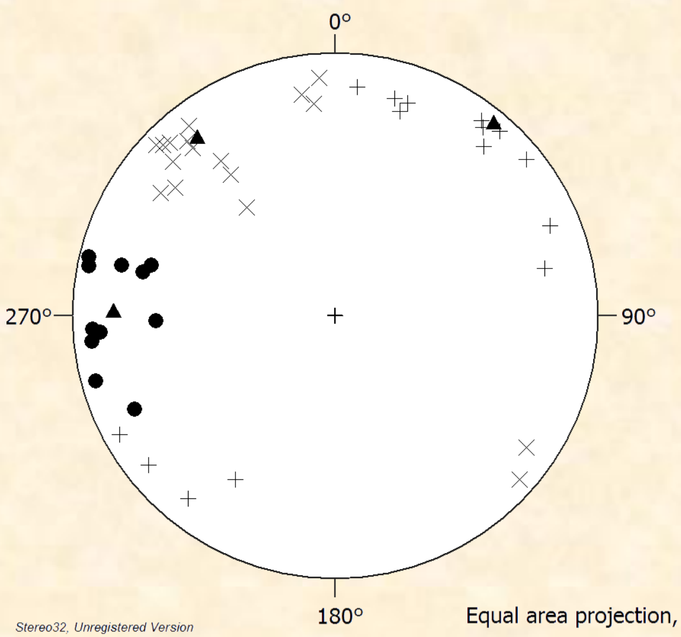
Thornton Quarry (Silurian reef) aggregate & hydrocarbon reservoir

- jointing
  - nearly all are closed
  - nearly all vertical
  - length = 20-40 feet
  - spacing 10-50; 100-200 feet
- 16 conduits
  - 2-foot avg opening, a 6 ft diameter
- change in bedding angle (apparent)
  - 2 to 41 degrees
- continuity of <u>bedding pairs</u>
  - ***not as continuous as you think****
  - avg <u>56 feet</u>, 20 to 115 feet in length
  - 0.4-1.2 feet thick pairs

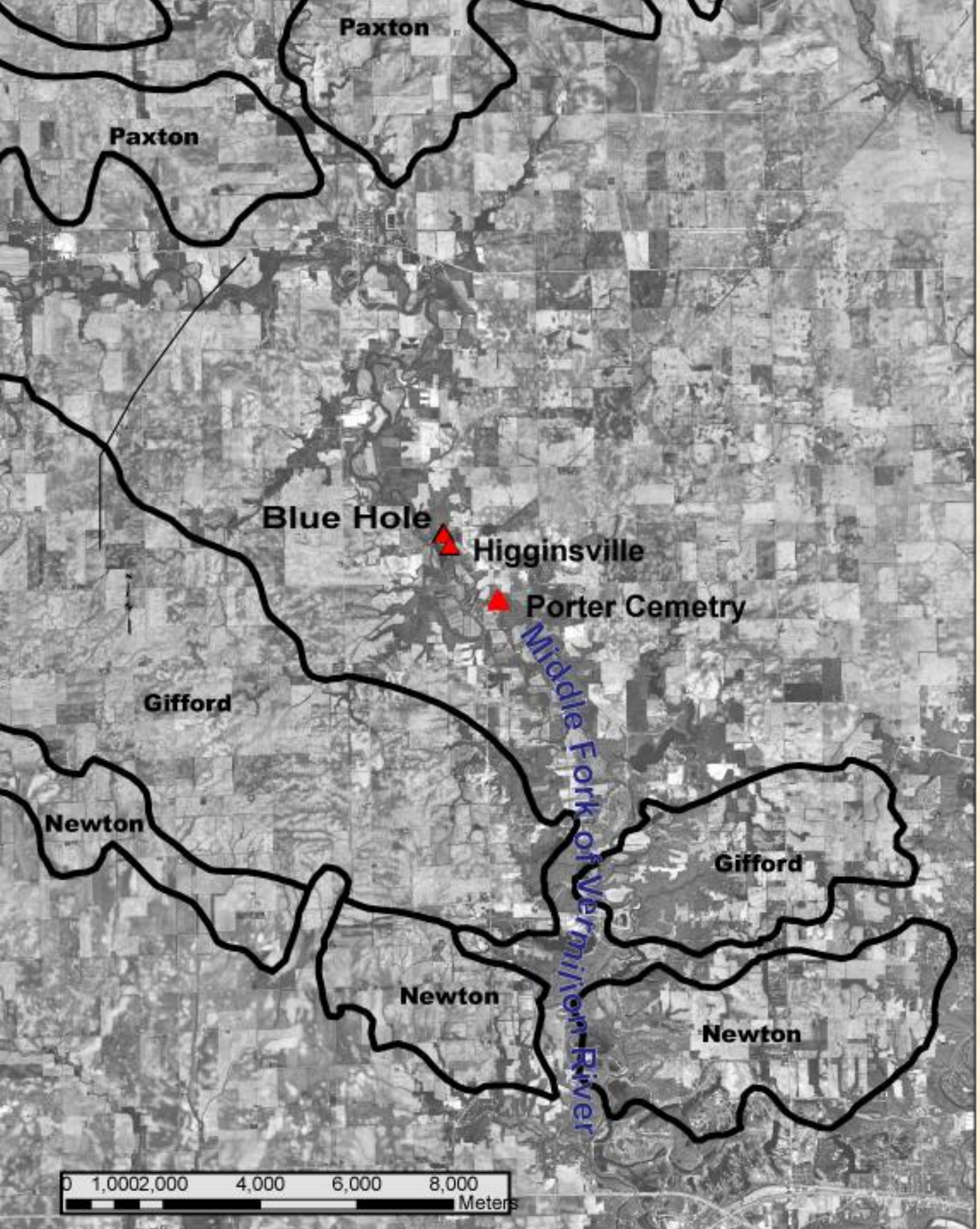
image resolution = 37 millimeters



Comparison of reduced data shows that D/DDN nearly same as conventional field methods.



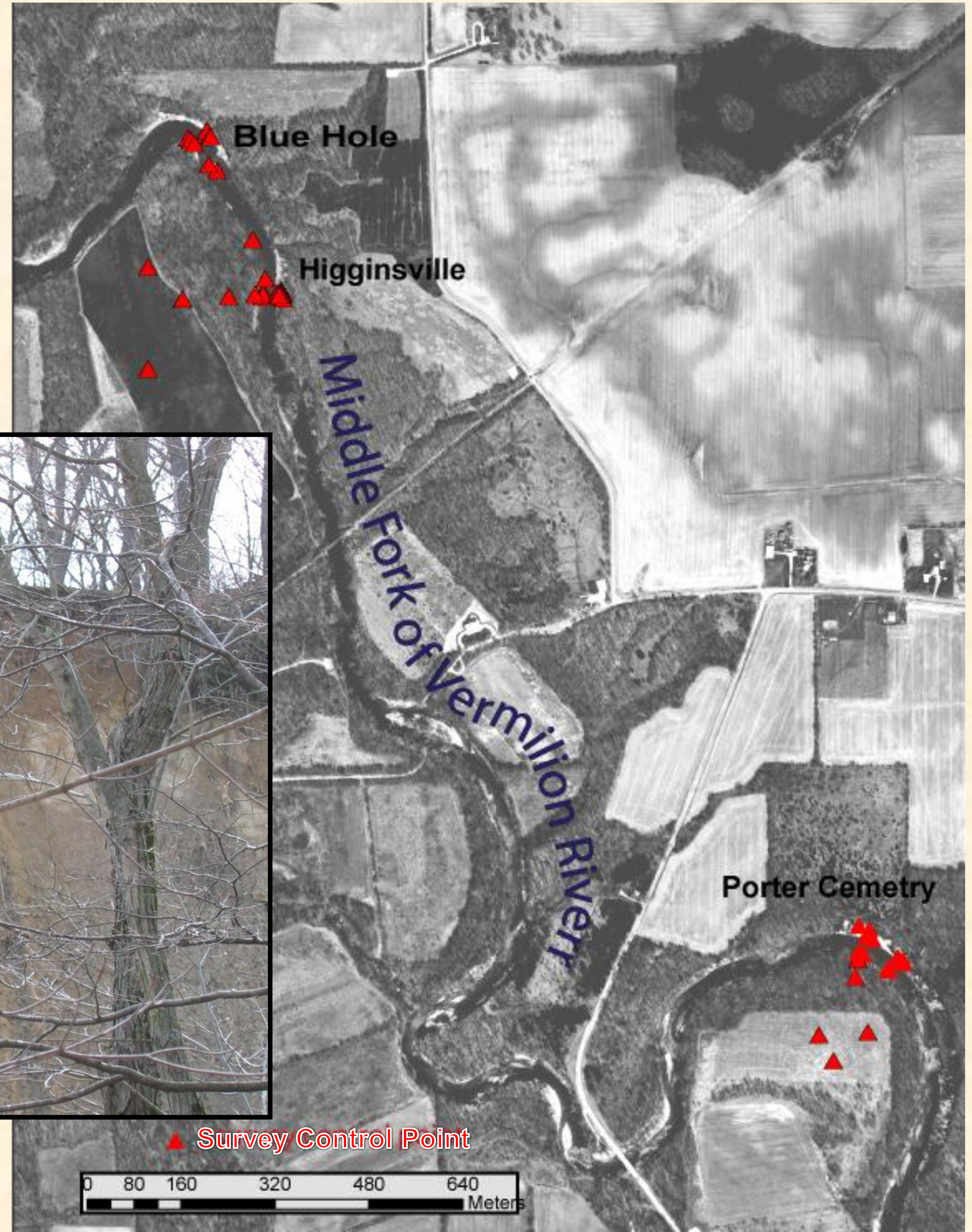
	Average strike of normal joints		
Study	Set I	Set II	Angle between joints
Foote 1982, east site	N49° E	N36° W	75-87
Djavid and Fitzpatrick 2008	N48° E	N46° W	92
Shuri and Kelsay 1984	N45° E	N45° W	90
Harza Engineering Company 1986	N42° E	N34° W	76
STS Consultants, Ltd.	N41.1° E	S44.5° E	85.6
	Eigenvector	Eigenvector	
This study, joint sets	N52.1° E	N50.4°W	102.5
This study, fracture	N0.30° E		



Middle Fork Vermilion River

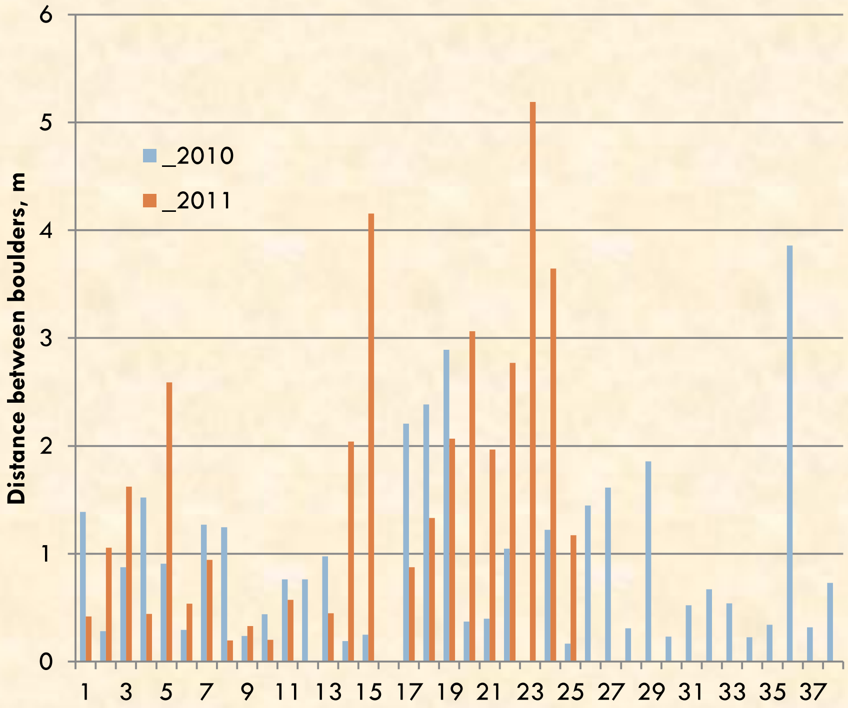
- 3D modeling for Mahomet Aquifer project
- New instrument
  - Compare techniques
- No nearby survey control
- Site inaccessible in high water (spring)
- Lots of riparian vegetation
  - Mostly poison ivy

Vegetation obscured outcrop. Not suited to stereophotography for photogrammetry or lidar without extensive preparation.



Boulder pavement in Tiskilwa, Blue Hole site

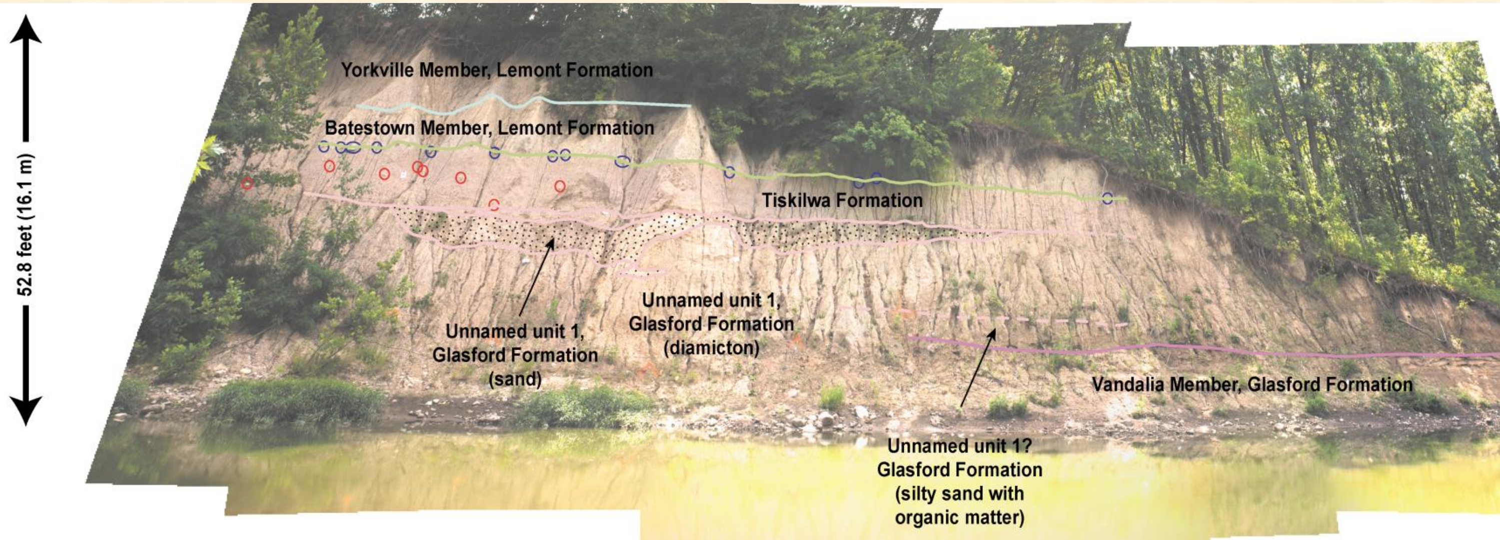
Distance Between Boulders w/in Cluster

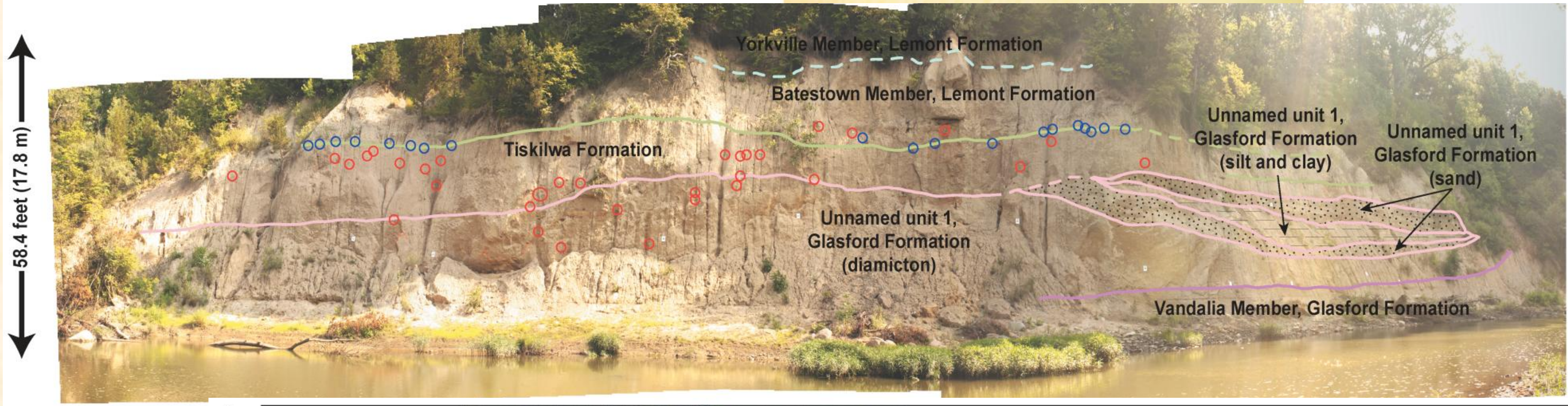


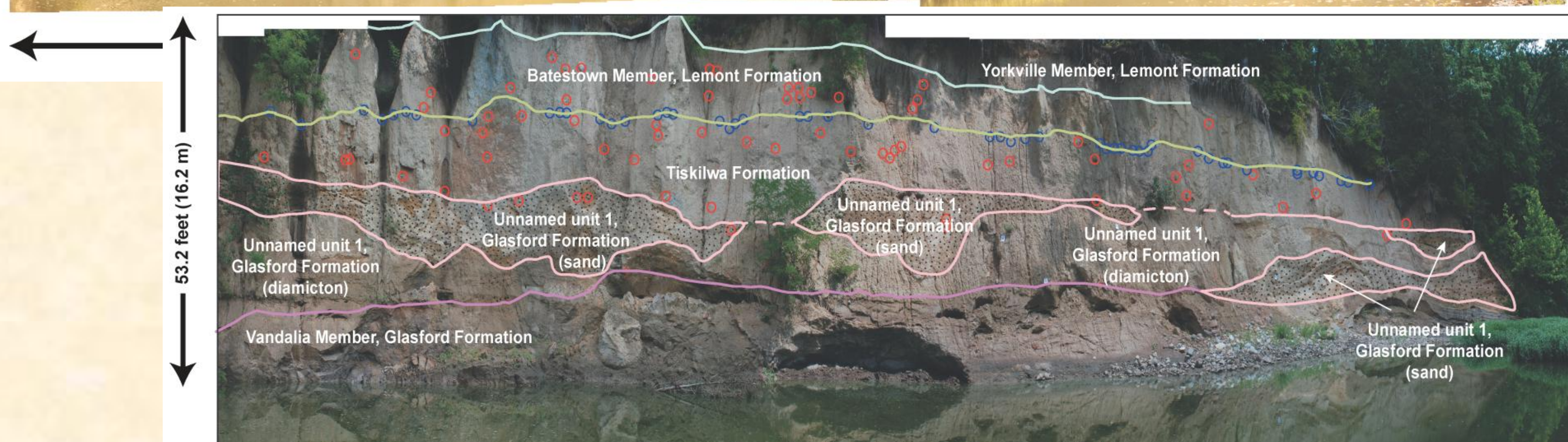
- 4 of 59 boulders > 3m apart
- X = 1.2m ; s = 0.1m
- each boulder cluster deposited same time.

Clusters are not close.
6 of 15 clusters < 9m apart
clusters are separated, perhaps as events.

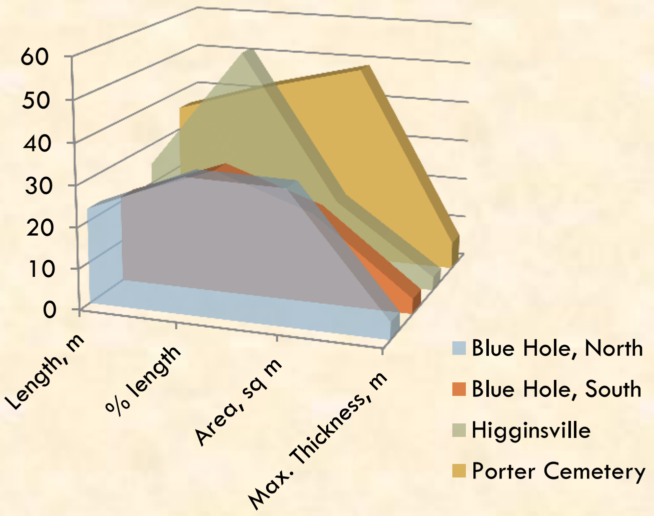
Stream channels cut into Glasford Fm at three (3) outcrops Middle Fork Vermilion River







Measurements of channels developed in Glasford Fm. along the Middle Fork Vermilion R.



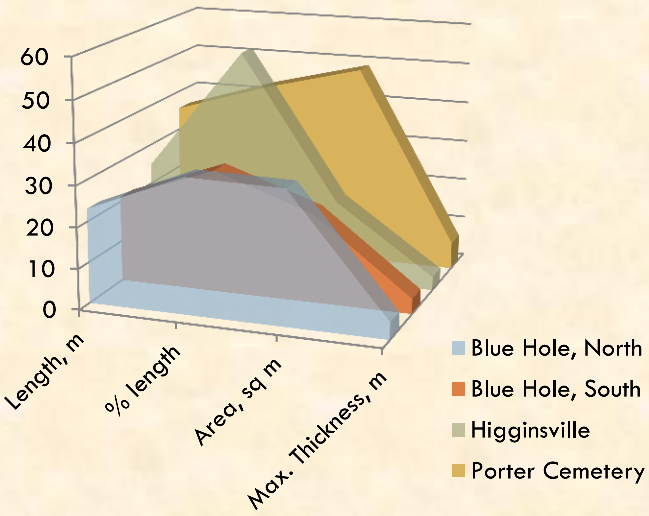
Location	Width, m	% length	Area, sq m	Thickness, m
Blue Hole, North	23.1	32	32.6	4.2
Blue Hole, South	21.2	30	21.9	3.7
Higginsville	24.9	55	19.8	3.3
Porter Cemetery	35.6	43	49	6.6
BH Combined	44.3	63		
Mean	26.2	40.25	30.825	4.45
Standard Error	3.22	5.65	6.68	0.74
Median	24	38	27.25	3.95
Standard Deviation	6.45	11.30	13.35	1.48
Sample Variance	41.55	127.58	178.23	2.19
Range	14.4	25	29.2	3.3
Minimum	21.2	30	19.8	3.3
Maximum	35.6	55	49	6.6

Maximum channel thicknesses ranges between ~3.3 – 6.6 meters.

Channel lengths range 43-62% of outcrop length so, likelihood of encountering sand in Glasford Fm. is ~50%.

So, lateral borings could improve well capacity or yield.

Measurements of channels developed in Glasford Fm. along the Middle Fork Vermilion R.



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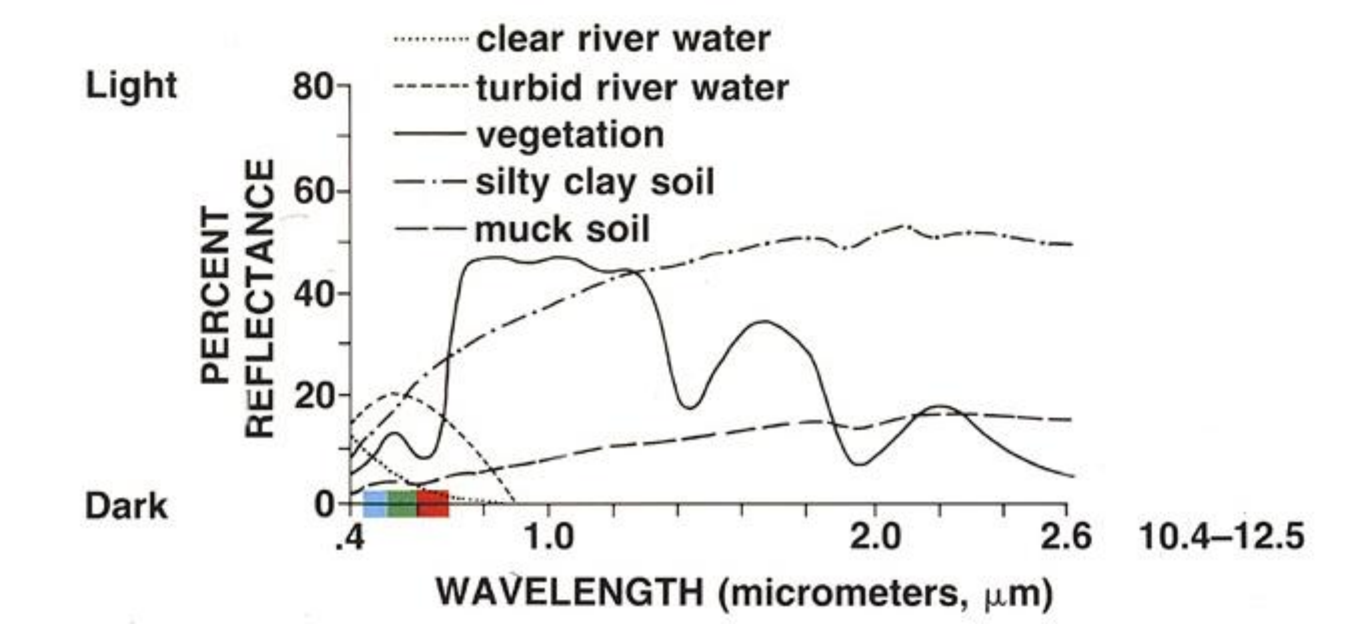
- Probability of channel occurrence in an outcrop is ~50%
- Lithologic, conductivity variability in several tills.
- Variability of hydraulic conductivity, k does not appear large
- Well capacity or yield likely depends upon length of buried channels & interconnectivity. So, are shapes or areas of channel cuts important?

Challenges the notion that "sand lenses" in glacial sediments are hit or miss.

- ✓ Challenges the "unpredictable" character of glacial sediments.
- ✓ Converts observations (what we 'knew') to measurable phenomena.

New challenge is that this places a burden on earth scientists to reliably predict occurrence, areas, and dimensions of sediments.

Image Processing and Remote Sensing of Visible and Infrared Imagery



- Enhancement – e.g., histogram stretch
- Band ratios – enhance Fe oxidation and mineralogy
- Statistical Analysis – e.g., unsupervised classification
- Direct Detection or Indication – hyperspectral, thermal

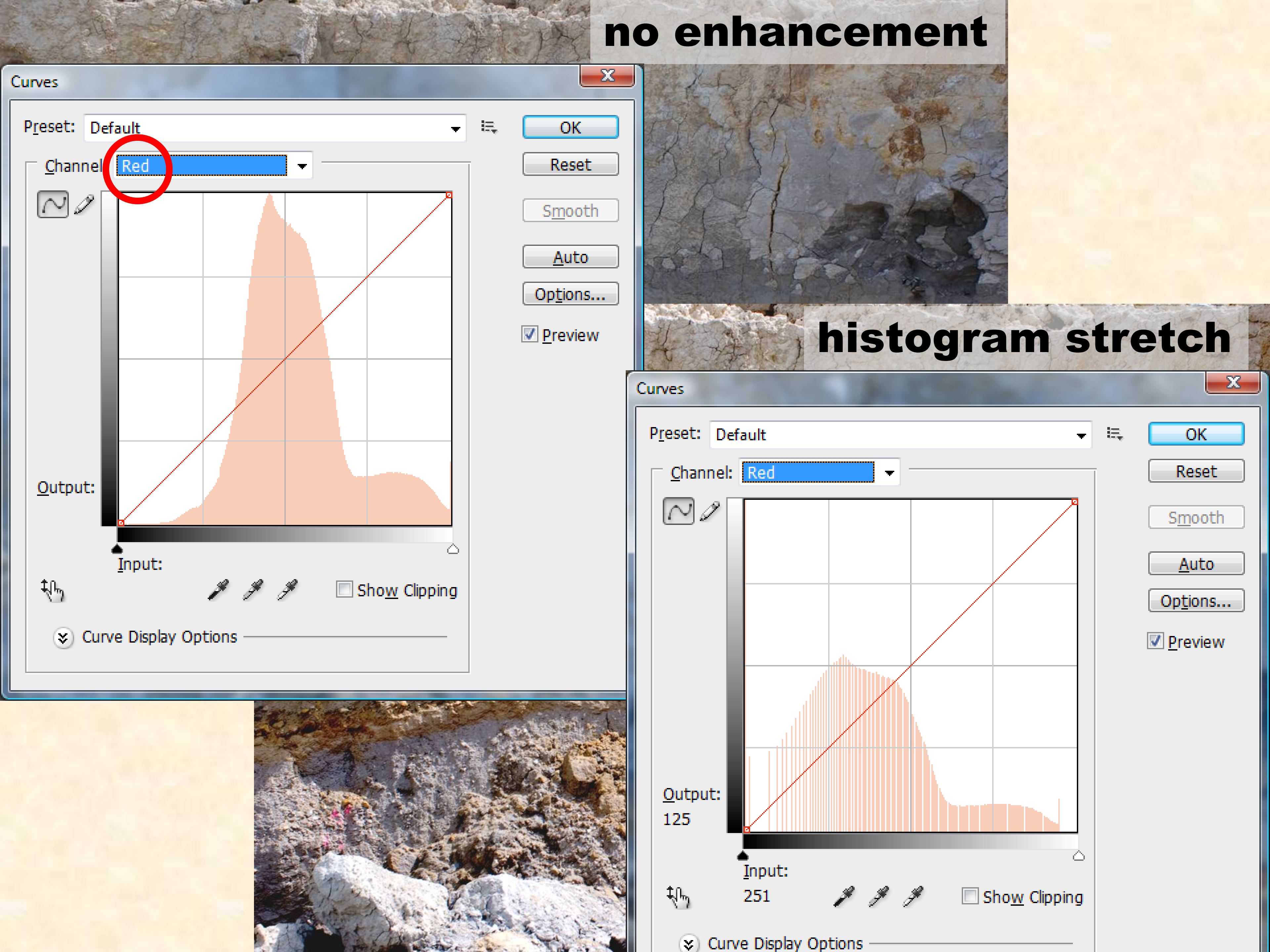
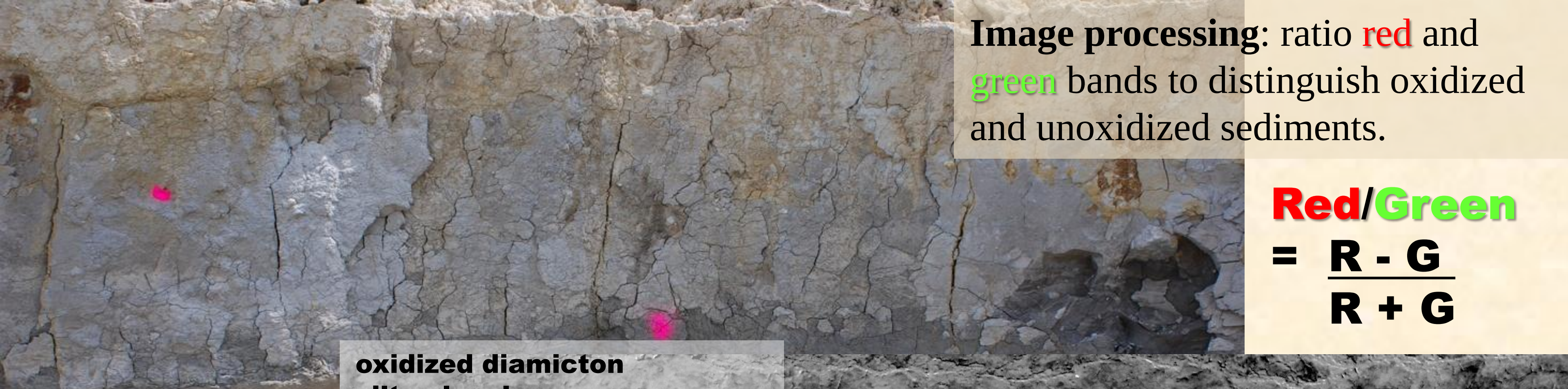
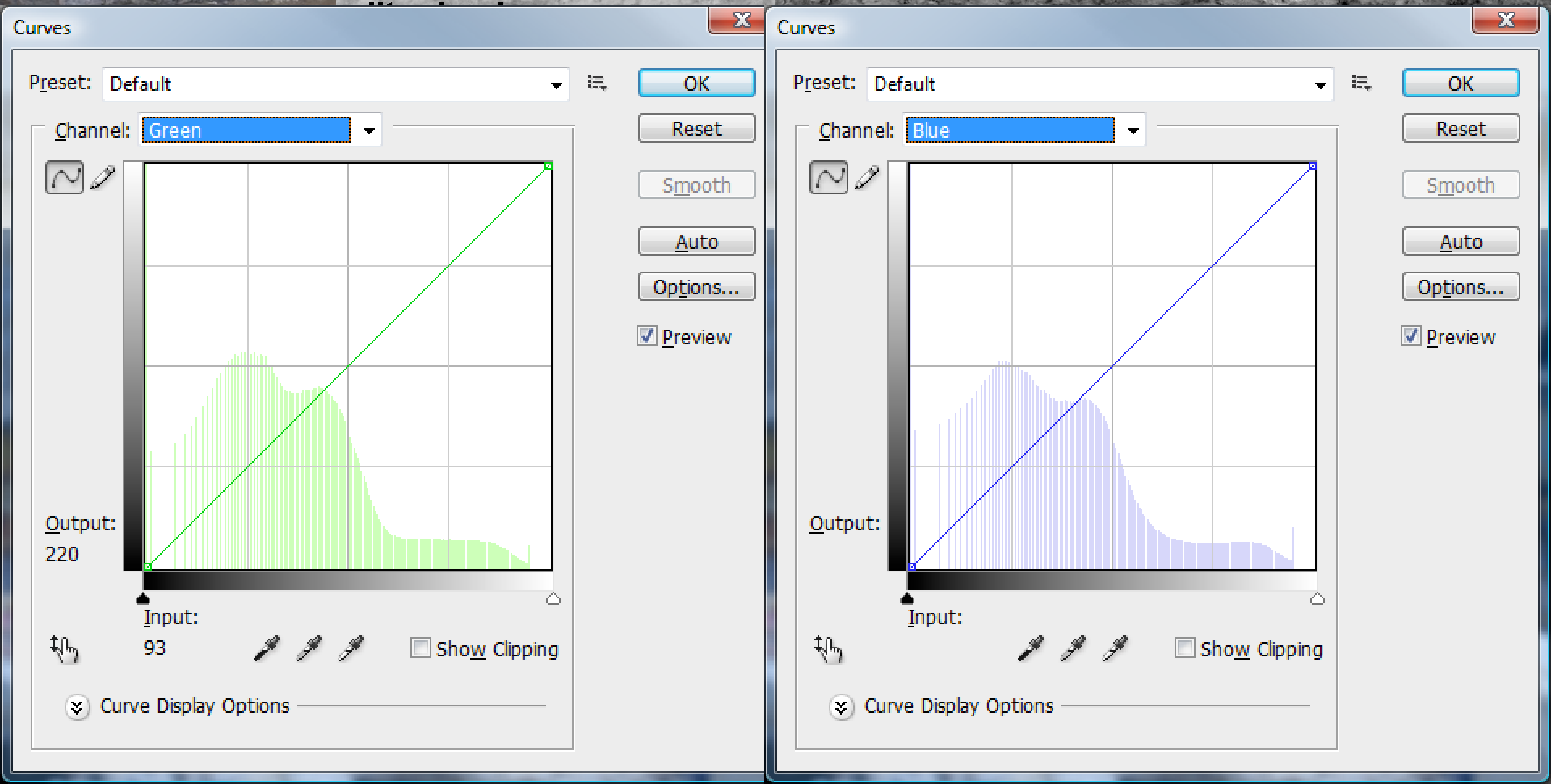

no enhancement
Curves
Preset: Default
Channel: Red
OK
Reset
Smooth
Auto
Options...
Preview
Output:
Input:
Show Clipping
Curve Display Options
histogram stretch
Curves
Preset: Default
Channel: Red
OK
Reset
Smooth
Auto
Options...
Preview
Output:
125
Input:
251
Show Clipping
Curve Display Options

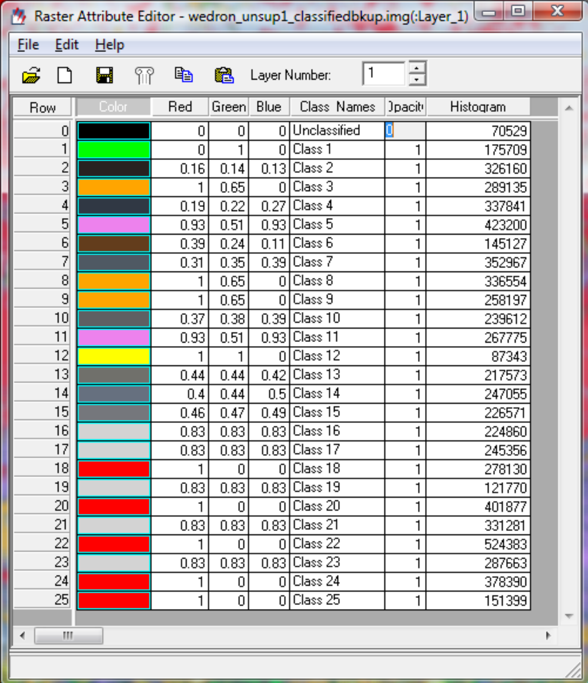
Image processing: ratio red and green bands to distinguish oxidized and unoxidized sediments.

Red/Green

$$= \frac{R - G}{R + G}$$







Row	Color	Red	Green	Blue	Class Names	Opacity	Histogram
0		0	0	0	Unclassified	0	70529
1		0	1	0	Class 1	1	175709
2		0.16	0.14	0.13	Class 2	1	326160
3		1	0.65	0	Class 3	1	289135
4		0.19	0.22	0.27	Class 4	1	337841
5		0.93	0.51	0.93	Class 5	1	423200
6		0.39	0.24	0.11	Class 6	1	145127
7		0.31	0.35	0.39	Class 7	1	352967
8		1	0.65	0	Class 8	1	336554
9		1	0.65	0	Class 9	1	258197
10		0.37	0.38	0.39	Class 10	1	239612
11		0.93	0.51	0.93	Class 11	1	267775
12		1	1	0	Class 12	1	87343
13		0.44	0.44	0.42	Class 13	1	217573
14		0.4	0.44	0.5	Class 14	1	247055
15		0.46	0.47	0.49	Class 15	1	226571
16		0.83	0.83	0.83	Class 16	1	224860
17		0.83	0.83	0.83	Class 17	1	245356
18		1	0	0	Class 18	1	278130
19		0.83	0.83	0.83	Class 19	1	121770
20		1	0	0	Class 20	1	401877
21		0.83	0.83	0.83	Class 21	1	331281
22		1	0	0	Class 22	1	524383
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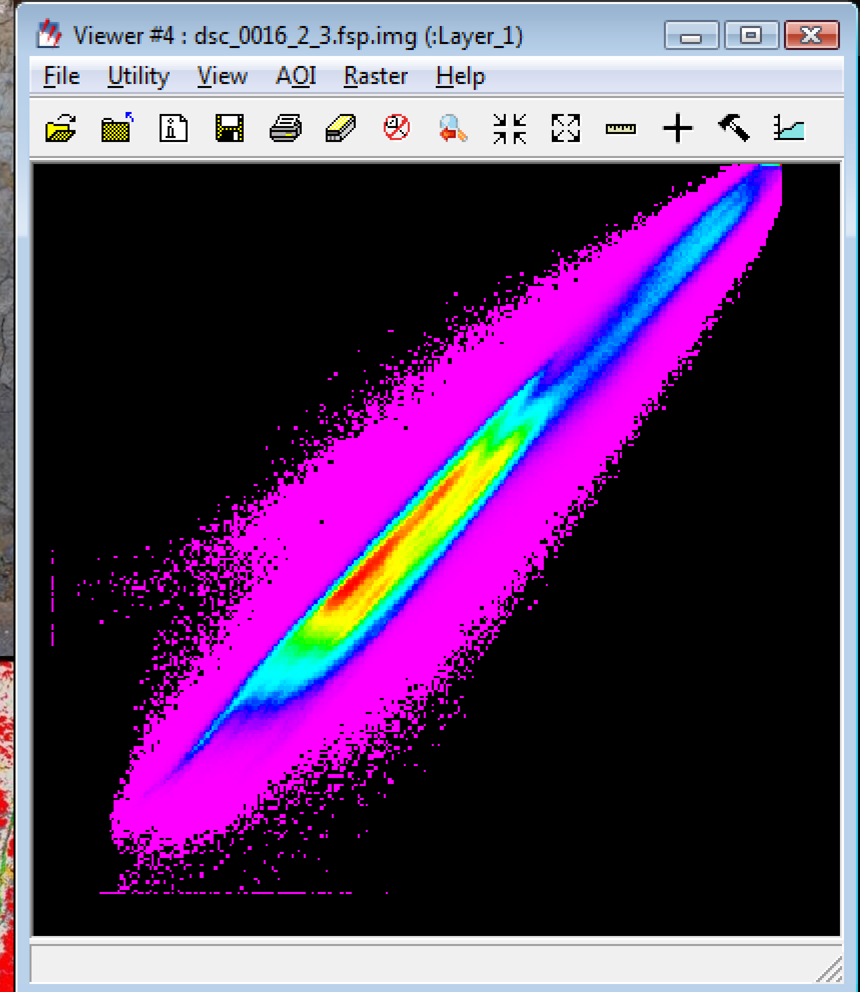
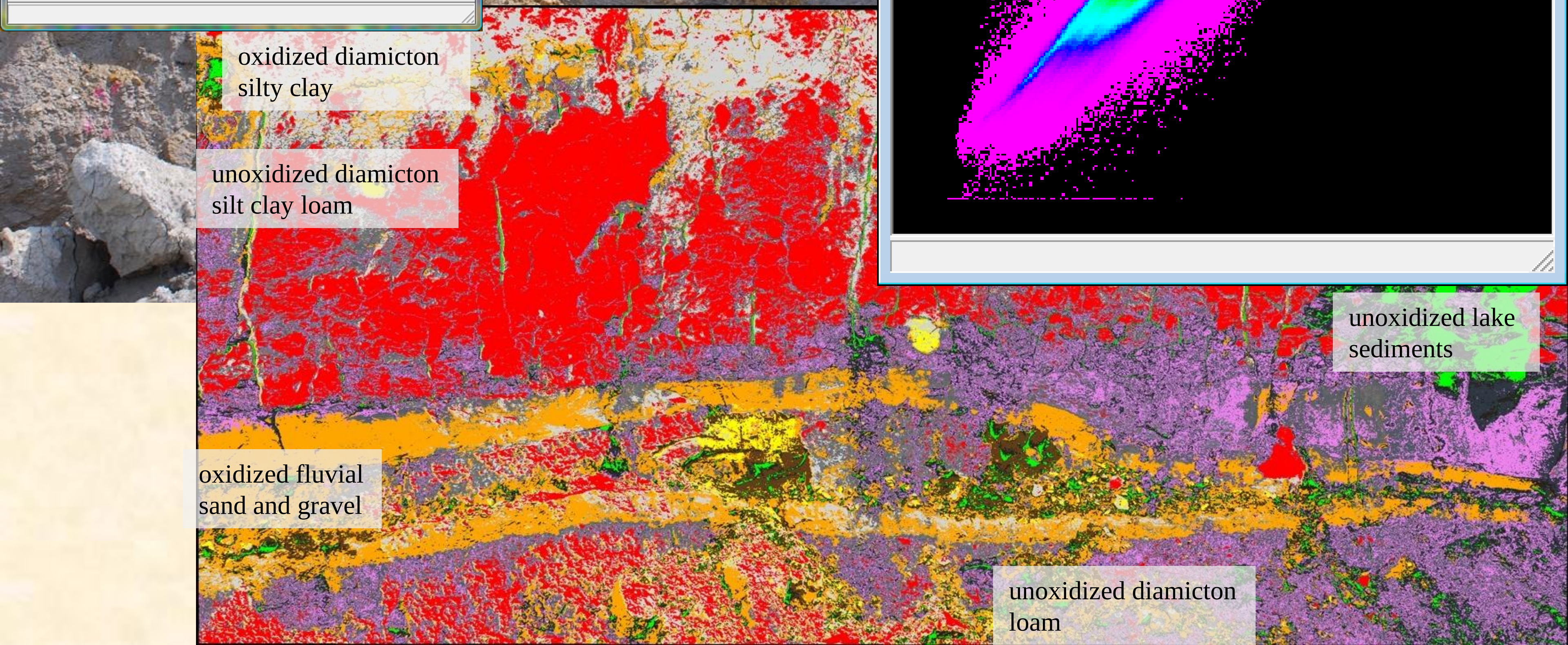
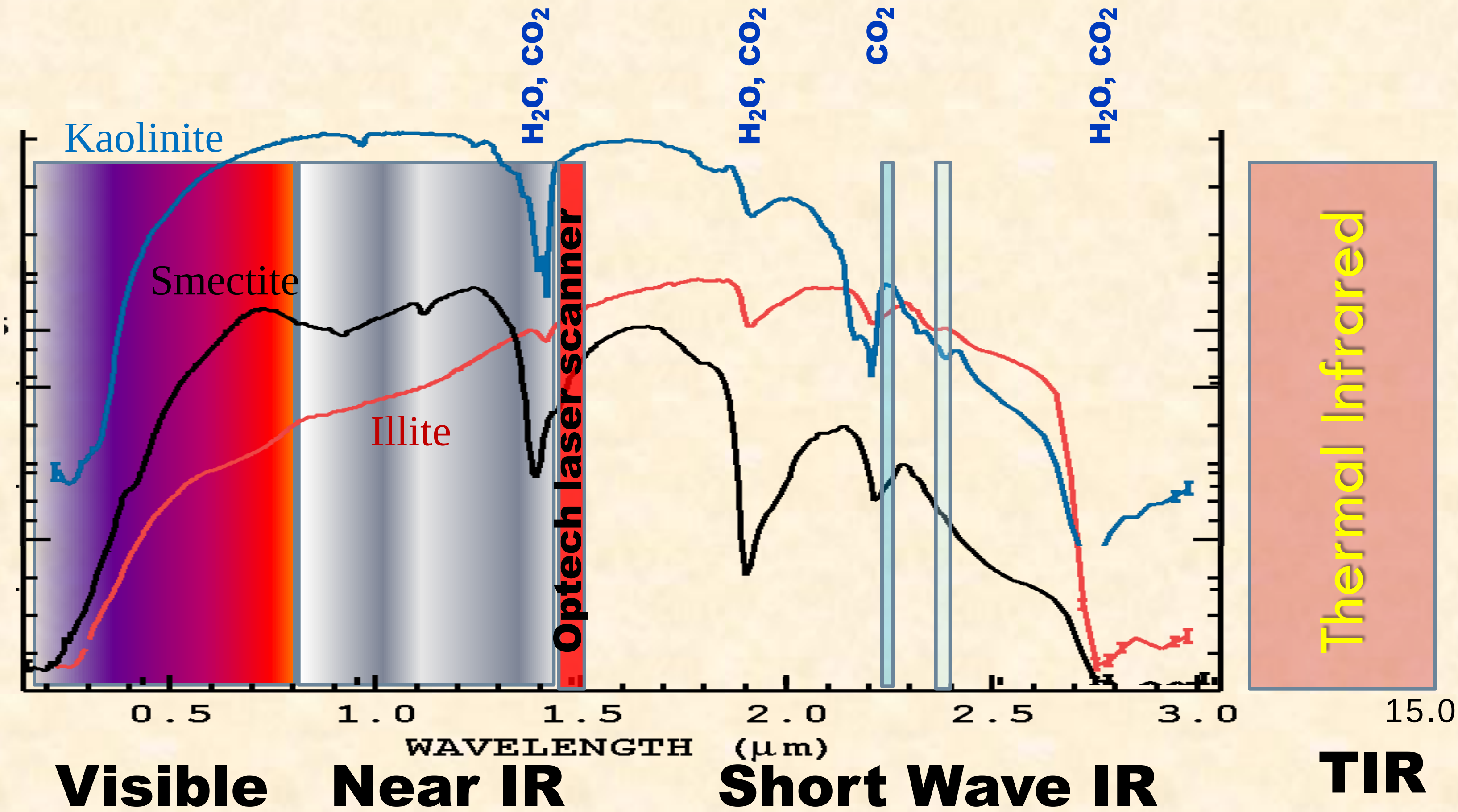
24		1	0	0	Class 24	1	378390
25		1	0	0	Class 25	1	151399



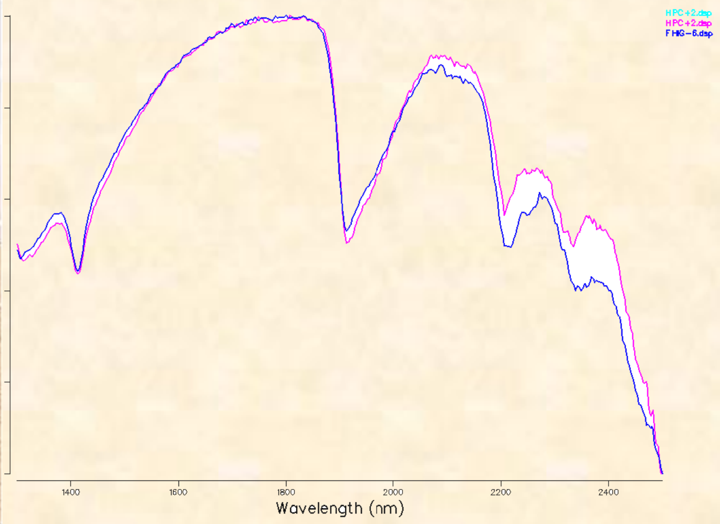


Imaging Spectroscopy (hyperspectral)



Dealing with imperfect conditions – band ratio **Band1/Band2**


1CTI 634
Specim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HPC+2.dsp
FHIG-6.dsp
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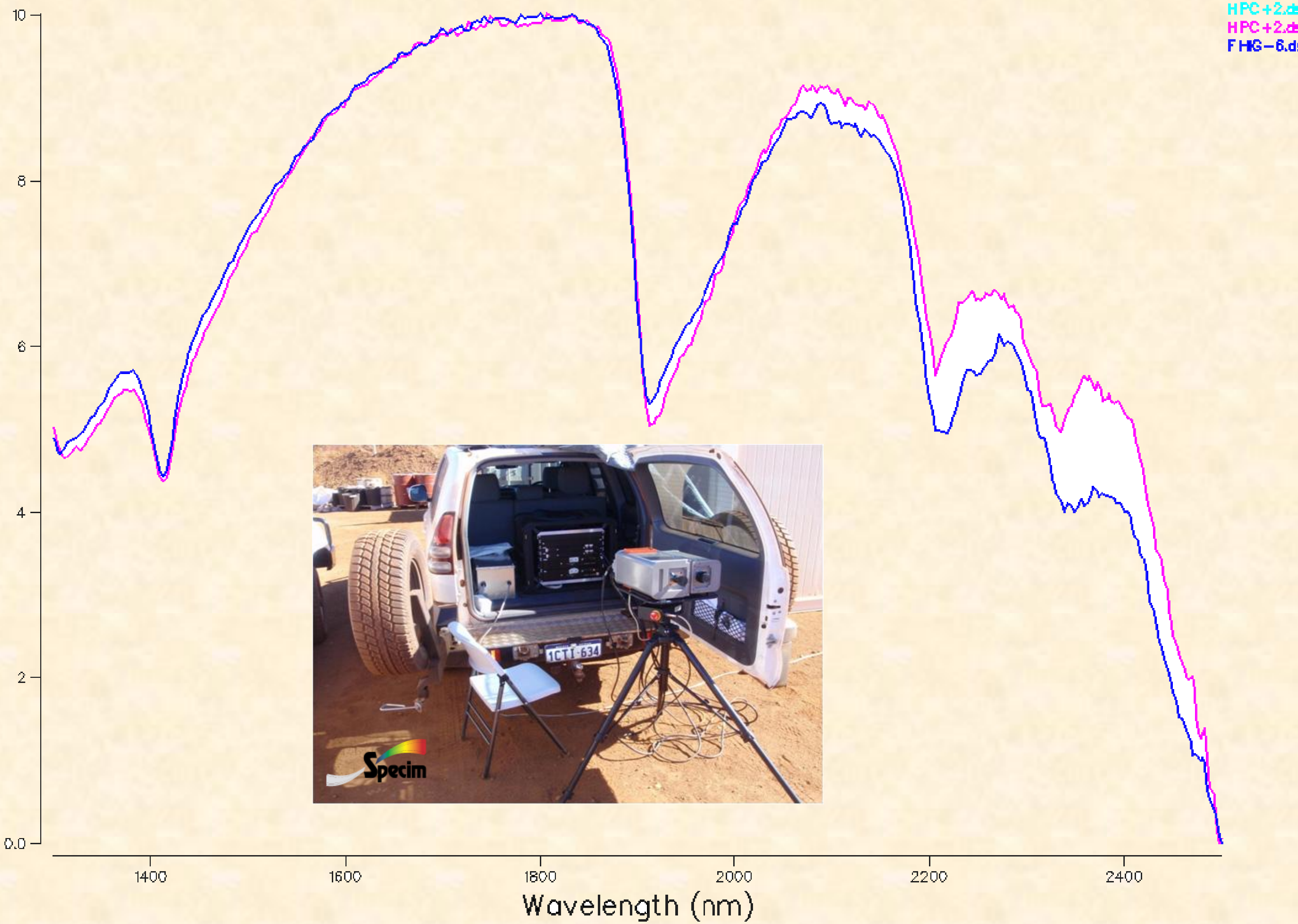
1600
1800
2000
2200
2400
Wavelength (nm)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HPC+2.d
FHIG-6.d
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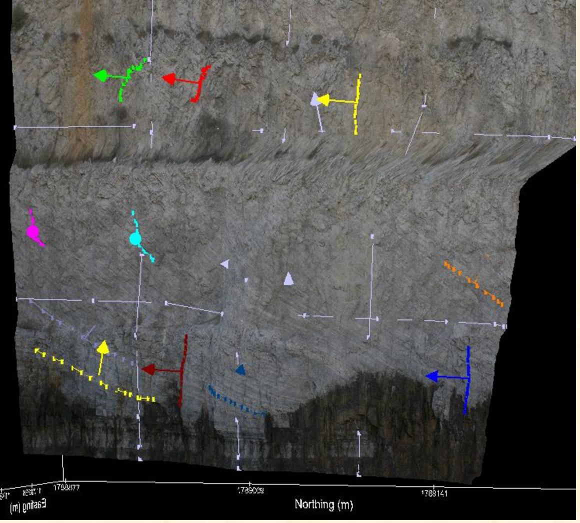
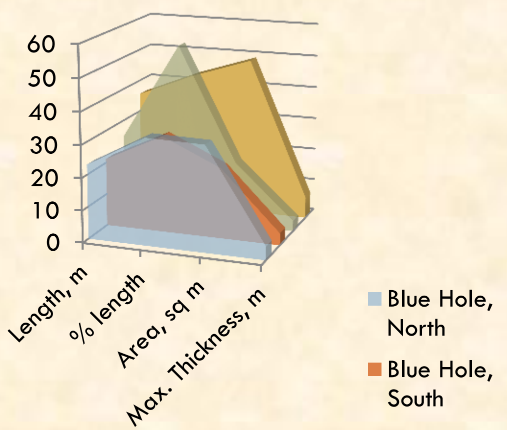
8
6
4
2
0.0
1400
1600
1800
2000
2200
2400
Wavelength (nm)
Specim





Remotely! Expediently! Virtually, and Cheaply!

• *<u>Georeference & measure</u>* [modeling] subtle changes in lithology and texture;

•*Differentiate* zones & facies [sedimentology] within ‘homogenous’ units based on mineralogy;

• *Identify* moisture-density/texture [engineering] using nonvisible imagery;

• *Better utilize* expensive laboratory analyses [cost] extrapolate and target sampling and lab test data;

• *Virtual preservation* [conservation, travel costs] of ephemeral outcrops and type sections.

Spring Lake Sand Pit in McHenry Co.