Mississippian Research in Northwest Arkansas*

C. Liner[1], D. Zachry[1], and W. Manager[1]

Search and Discovery Article #41245 (2013)**
Posted November 25, 2013

*Adapted from presentation given at Tulsa Geological Society luncheon meeting, November 12, 2013, and at the AAPG Mid-Continent Section Meeting, Wichita, Kansas, October 12-15, 2013

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Abstract

Worldwide, about two thirds oil and gas reserves are estimated to be unconventional. These plays exploit reservoirs with low permeability and/or porosity making them difficult to characterize and produce. Difficult and expensive enhanced recovery methods such as precision horizontal drilling and multi-stage fracking make unconventional plays much more challenging than conventional hydrocarbon targets. Many unconventional plays are active in and around Arkansas, including the "Mississippi Lime" play in Northern Oklahoma and Kansas. The University of Arkansas can claim 70 years of investigation into the Mississippian section by faculty and students. We propose an ambitious, long-term plan to develop a digital 3D geomodel of the Mississippian over a 4000 square mile area of northern Arkansas and southwest Missouri. The goal is integration of information on all scales to build a regional model of the Mississippian, characterizing this unconventional reservoir at scales unavailable in typical exploration and production data. Our research will support expanding exploration and production activity in northern Oklahoma and Kansas.

We plan to characterize the unconventional Mississippian formation in outcrop and near surface occurrence on length scales from the very small (core analysis and well logs) to large features seen in remote sensing and commercial 3D seismic surveys. While this effort recognizes the many scales of data routinely used in hydrocarbon exploration, key aspects of our work are calibration and quantification through advanced outcrop technology and linkage of all scales of investigation. Our work will strive to subdivide the Mississippian section into meaningful intervals that can be mapped from outcrop and with typical petroleum exploration data (core, wireline and image logs, and 3D seismic).

Selected References

Blakey, R., 2013, North American Paleogeographic Maps: Early Mississippian (345 Ma): Website accessed November 15, 2013. (http://www2.nau.edu/rcb7/namM345.jpg)

Blakey, R., 2013, North American Paleogeographic Maps: Late Mississippian (325 Ma): Website accessed November 15, 2013. http://www2.nau.edu/rcb7/namM325.jpg

Blakey, R., 2013, North American Paleogeographic Maps: Early Pennsylvanian (315 Ma): Website accessed November 15, 2013. http://www2.nau.edu/rcb7/namPP315.jpg

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Mazzullo, S.J., B.W. Wilhite, and D.R. Boardman II, 2011, Lithostratigraphic architecture of the Mississippian Reeds Spring Formation (Middle Osagean) in Southwest Missouri, Northwest Arkansas, and Northeast Oklahoma: Outcrop analog of subsurface petroleum reservoirs: The Shale Shaker, Oklahoma City Geological Society (OCGS), v. 61/5, p. 254-269.

Selected Websites

Creek Minerals, Oil and Gas Investments: Website accessed November 15, 2013. http://www.creekminerals.com/wp-content/uploads/2011/12/Miss-Lime-Play.jpg

International Energy Agency (IEA), 2012, World Energy Outlook, 2012: Website accessed November 15, 2013. http://www.worldenergyoutlook.org/pressmedia/recentpresentations/PresentationWEO2012launch.pdf

World Oil Online, 2013,Website accessed November 15, 2013. http://www.worldoil.com/uploadedimages/Issues/Articles/Mar-2013/WO0313-Redden-ShaleTech-Miss-Fig-03.jpg

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12 November 2013

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Contents

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- Geophysics
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  - Species of chert
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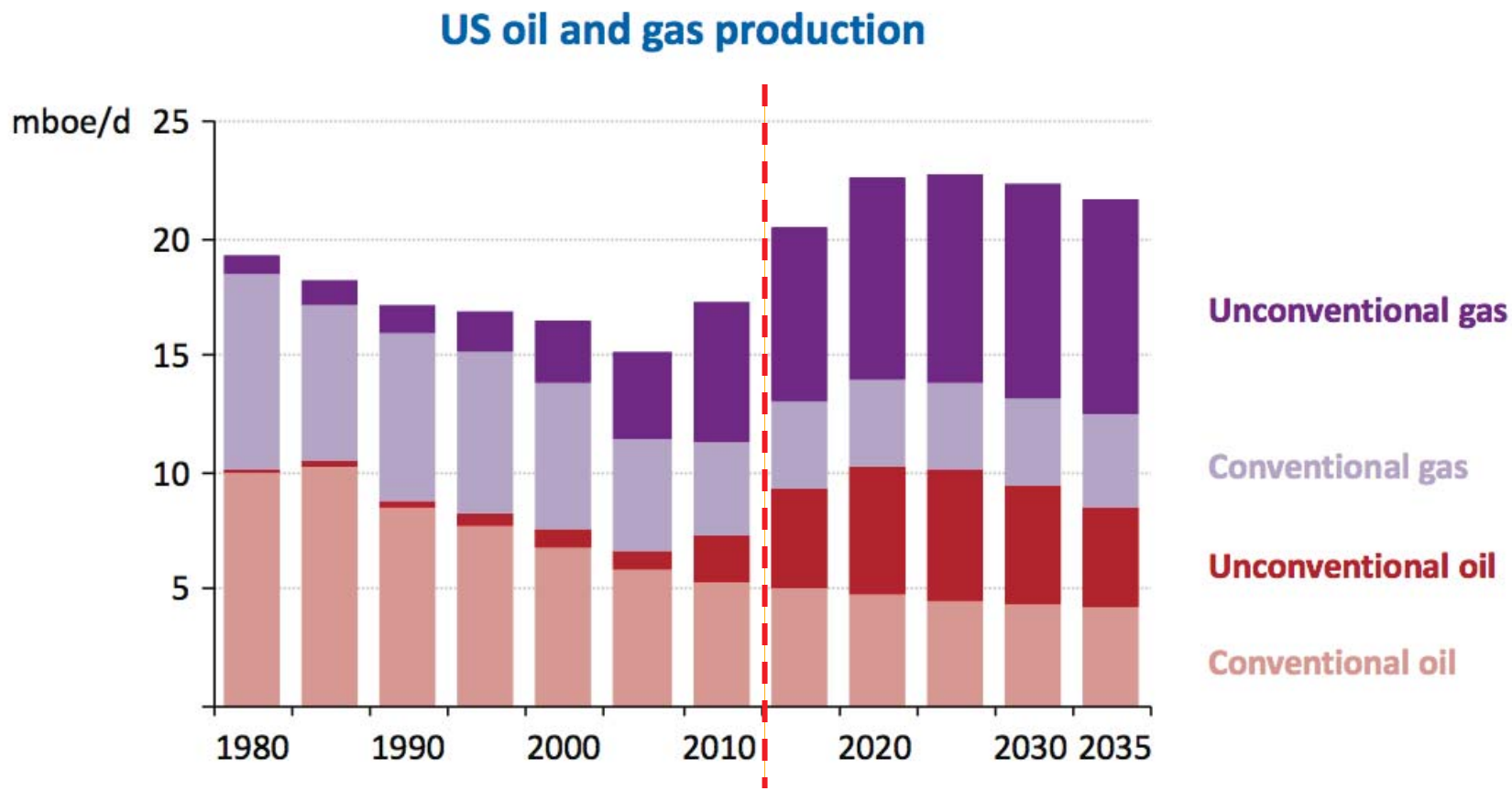
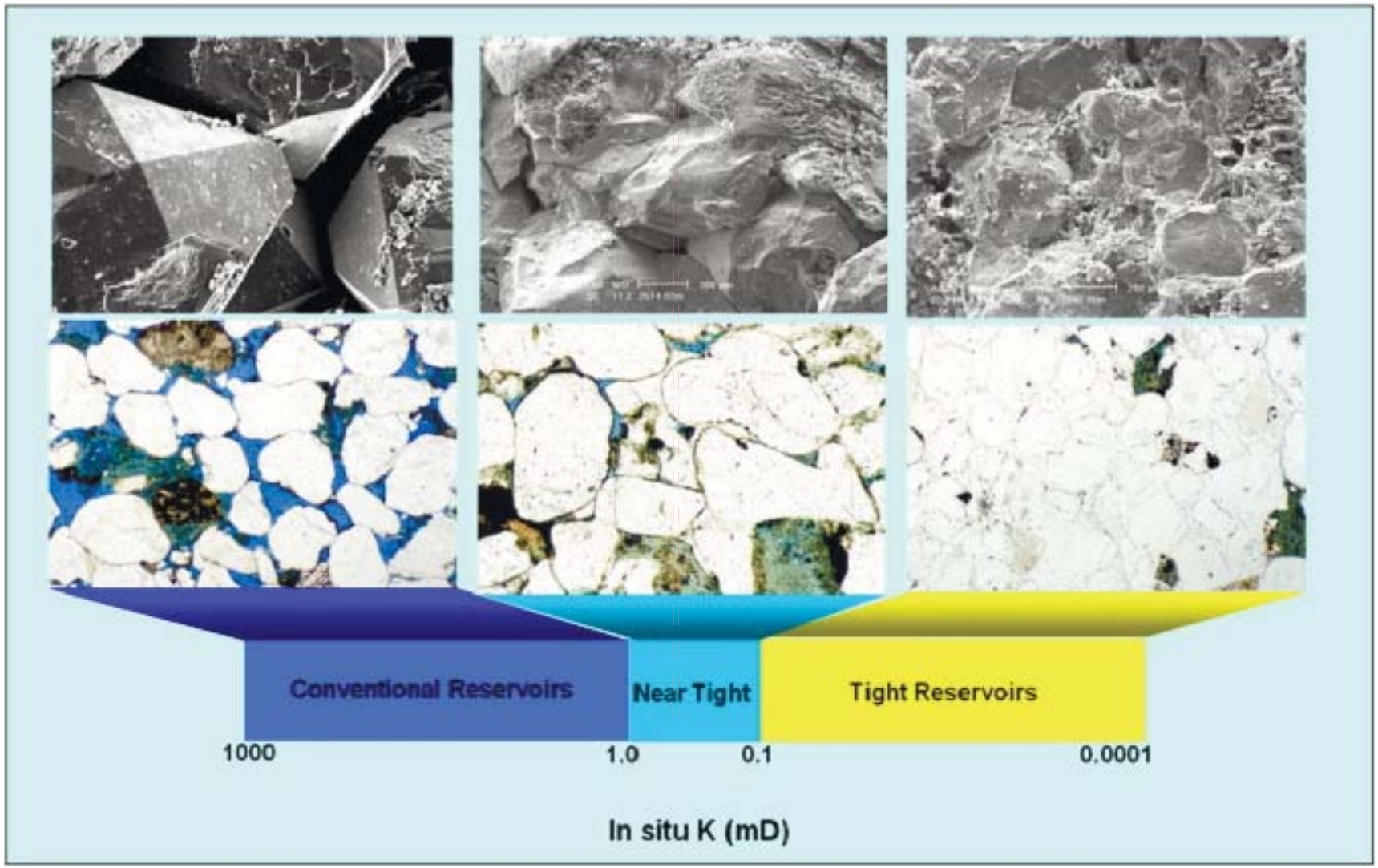
Intro: Unconventional Resources



The surge in unconventional oil & gas production has implications well beyond the United States

Unconventional Reservoirs



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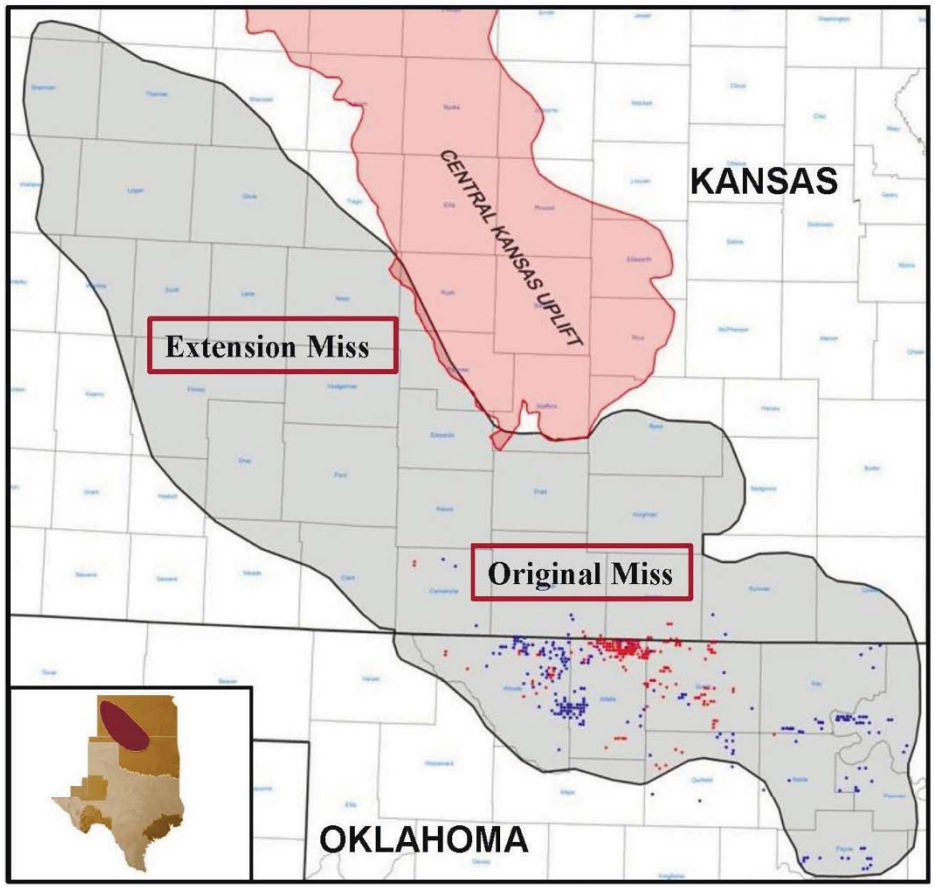

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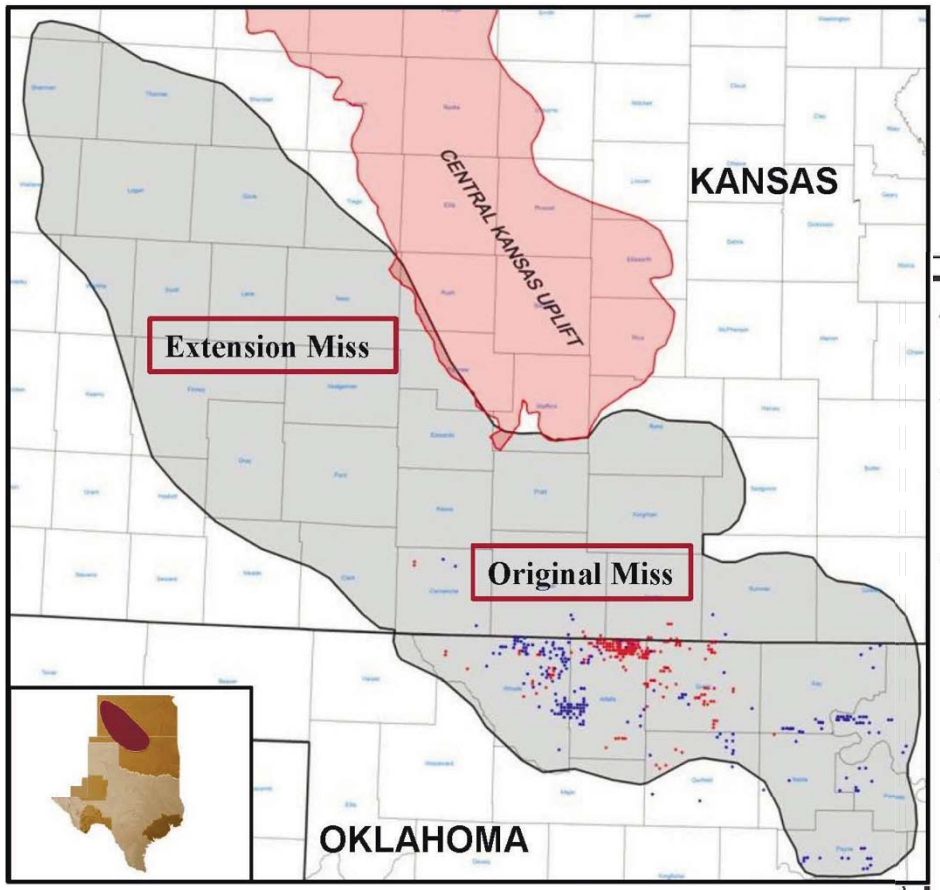
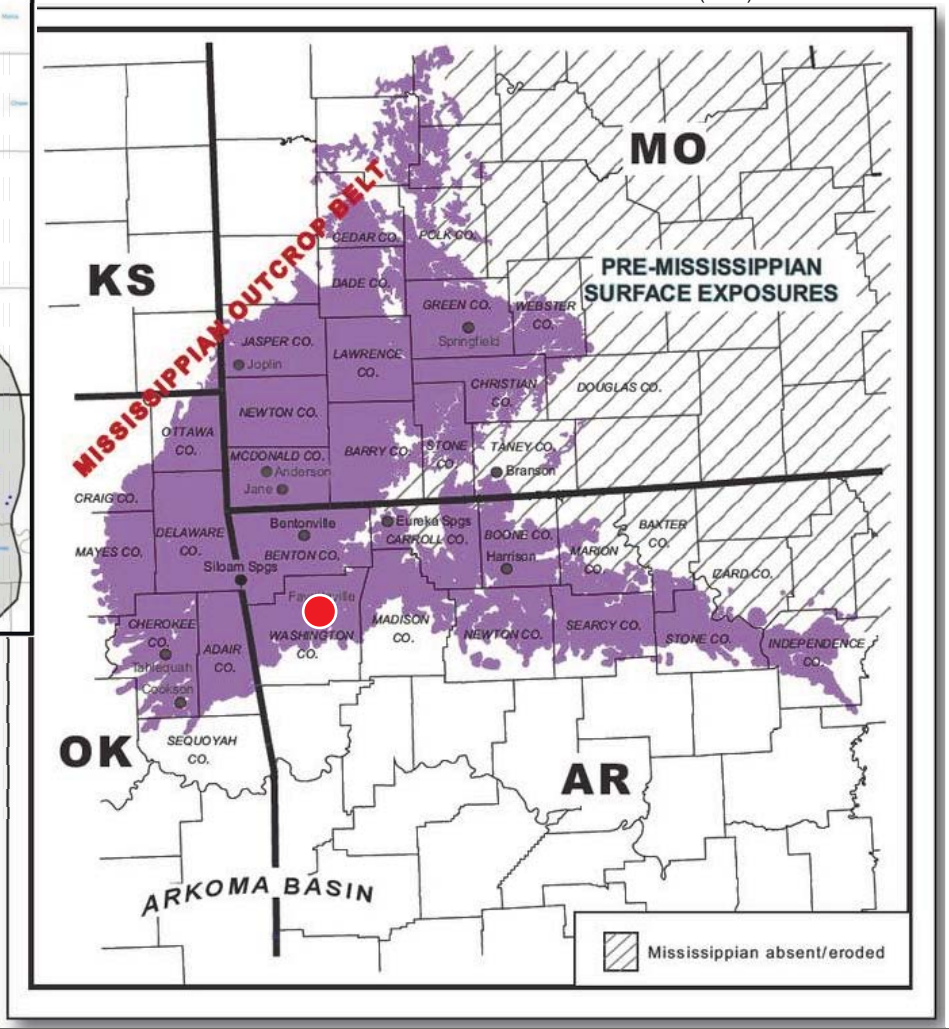


Mazzullo et al. (2011)



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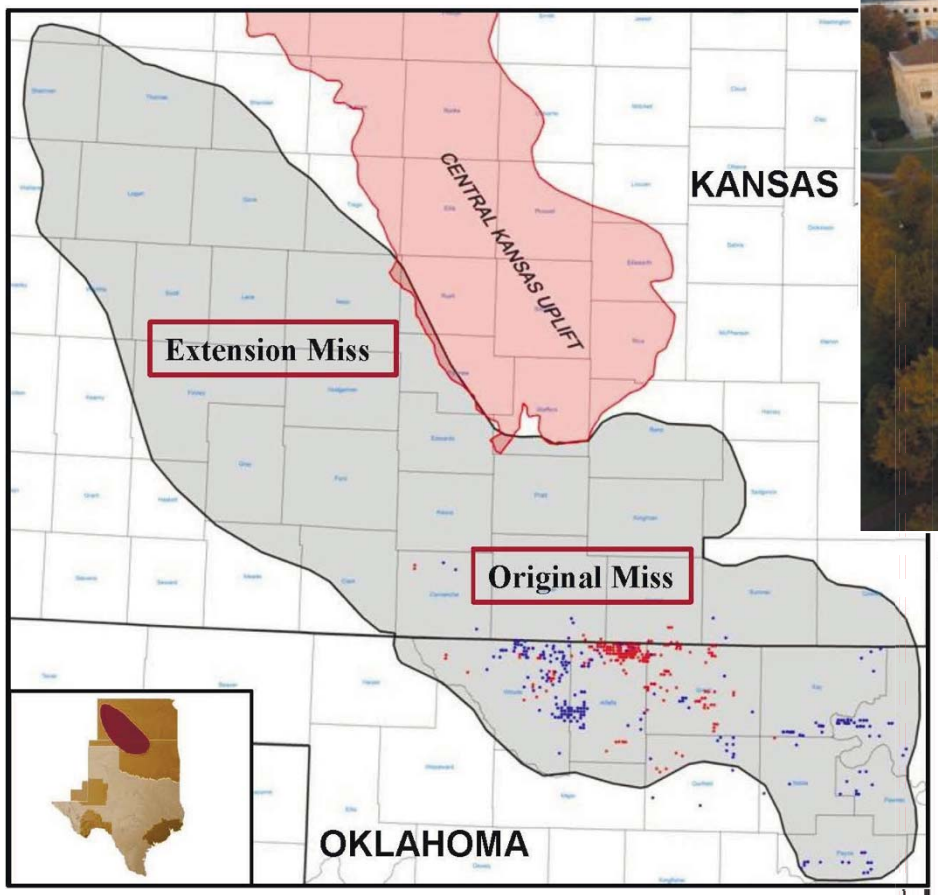
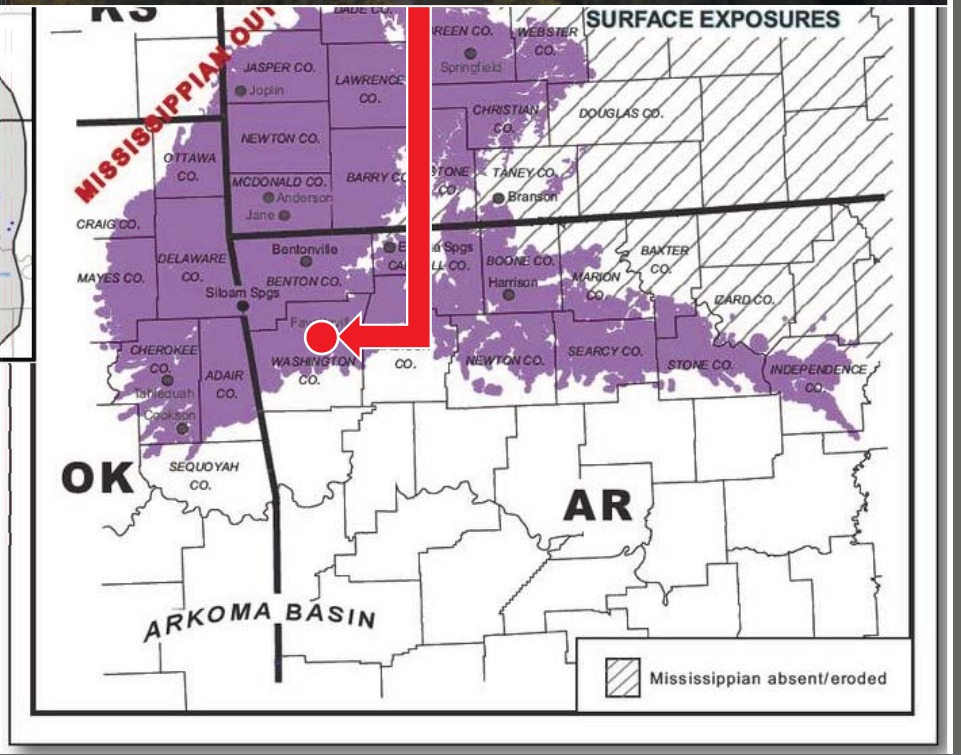
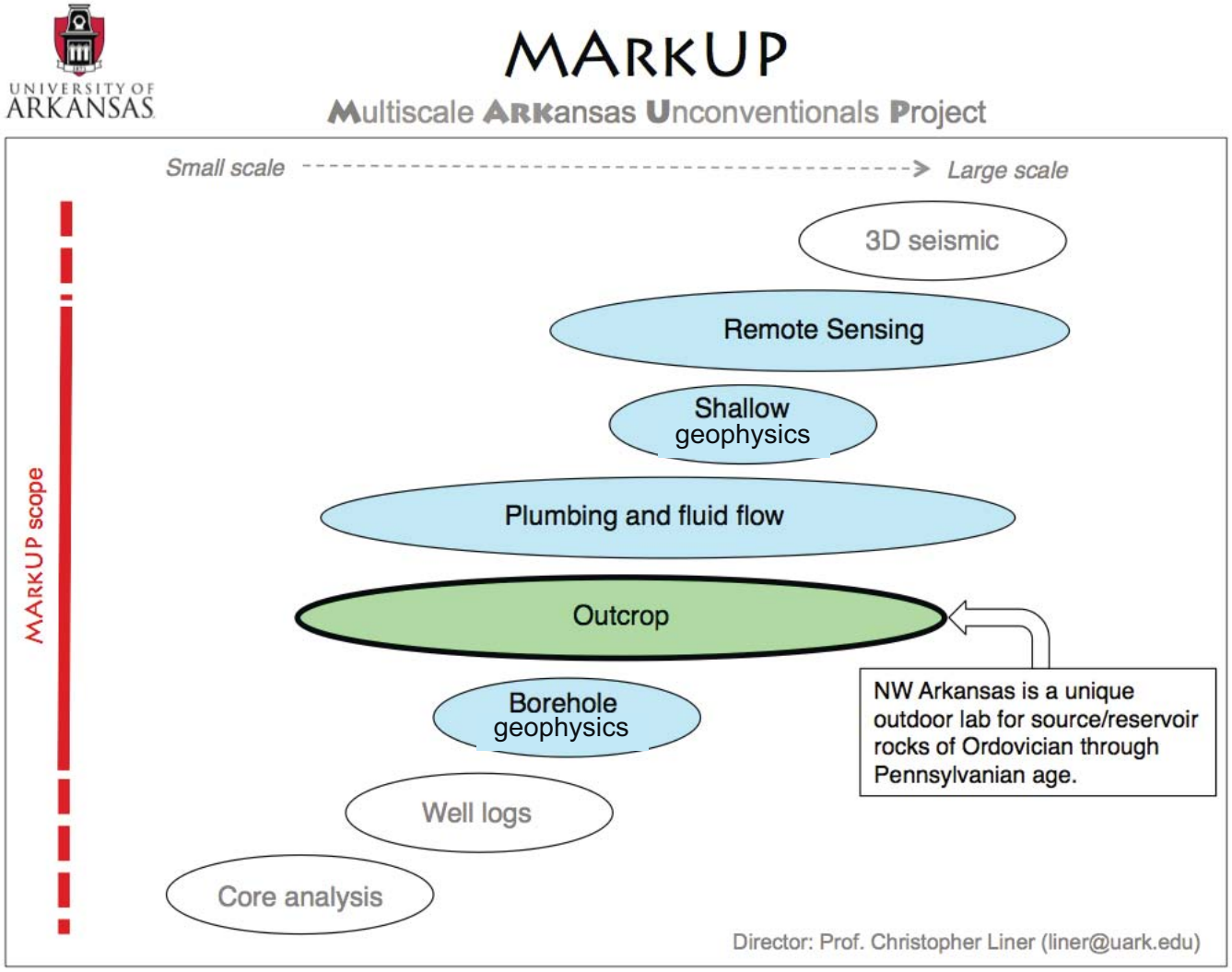


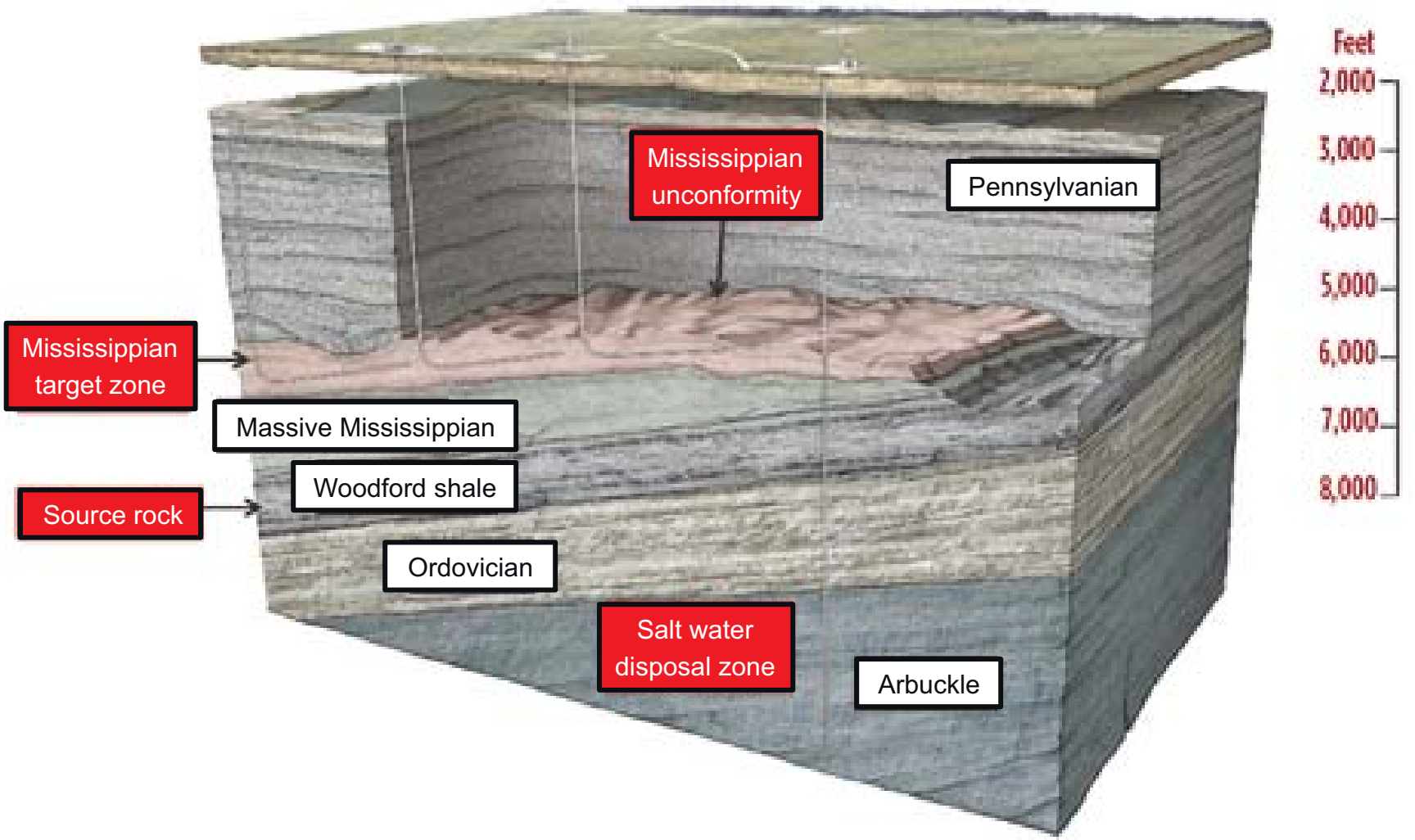


UNIVERSITY OF ARKANSAS

What is MArkUP?



Mississippian Lime



http://www.worldoil.com/uploadedimages/Issues/Articles/Mar-2013/WO0313-Redden-ShaleTech-Miss-Fig-03.jpg

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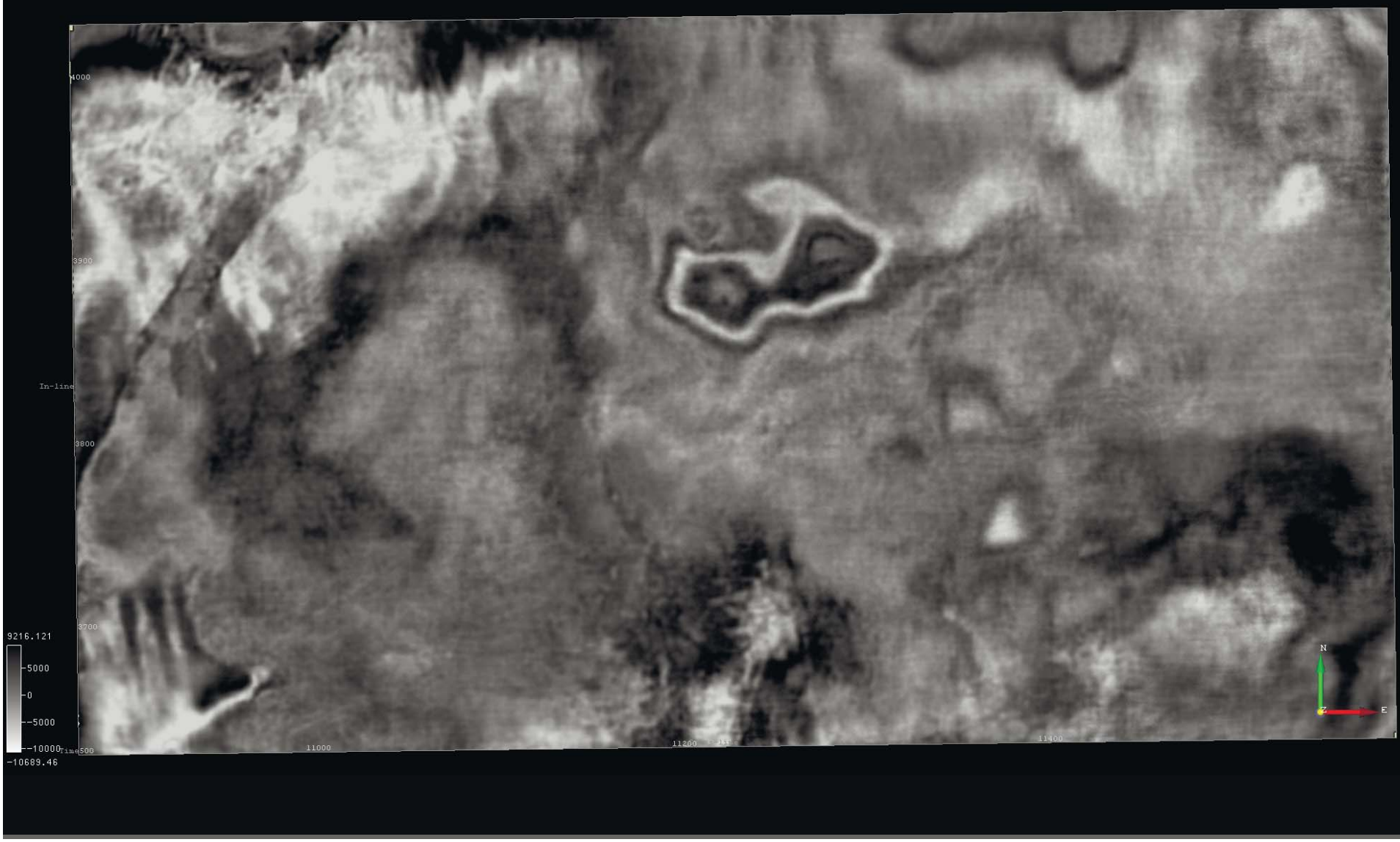
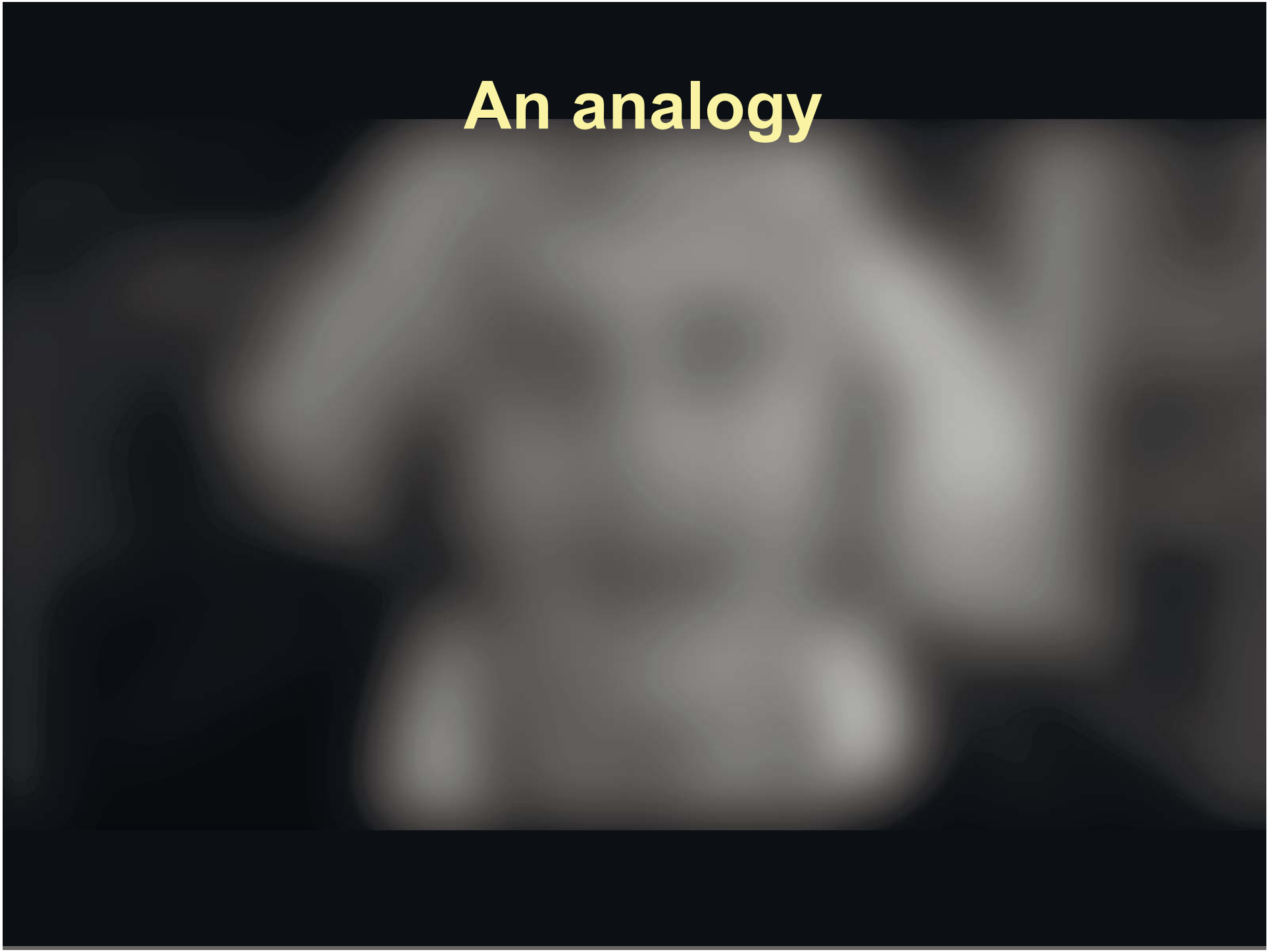


An analogy



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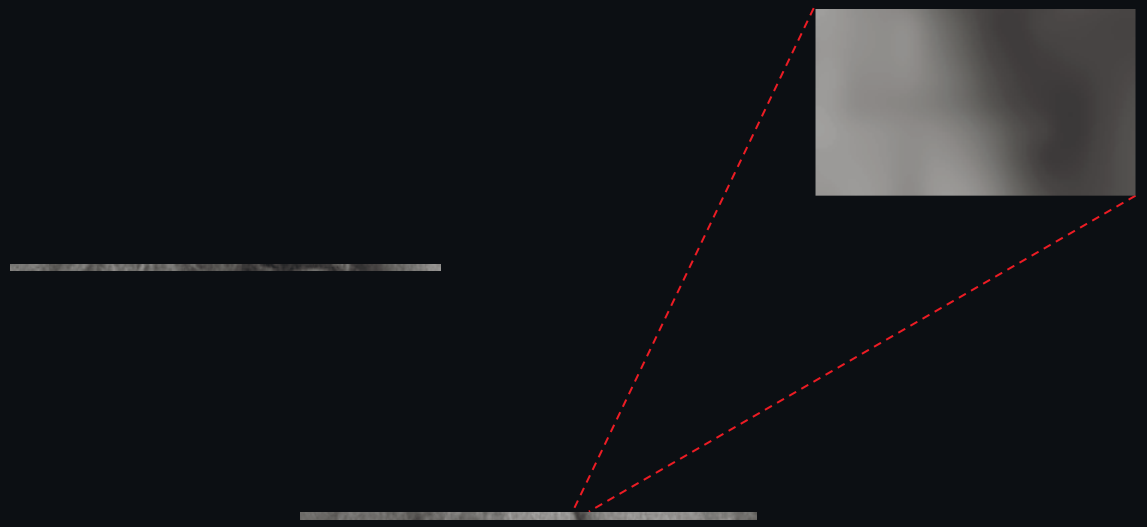
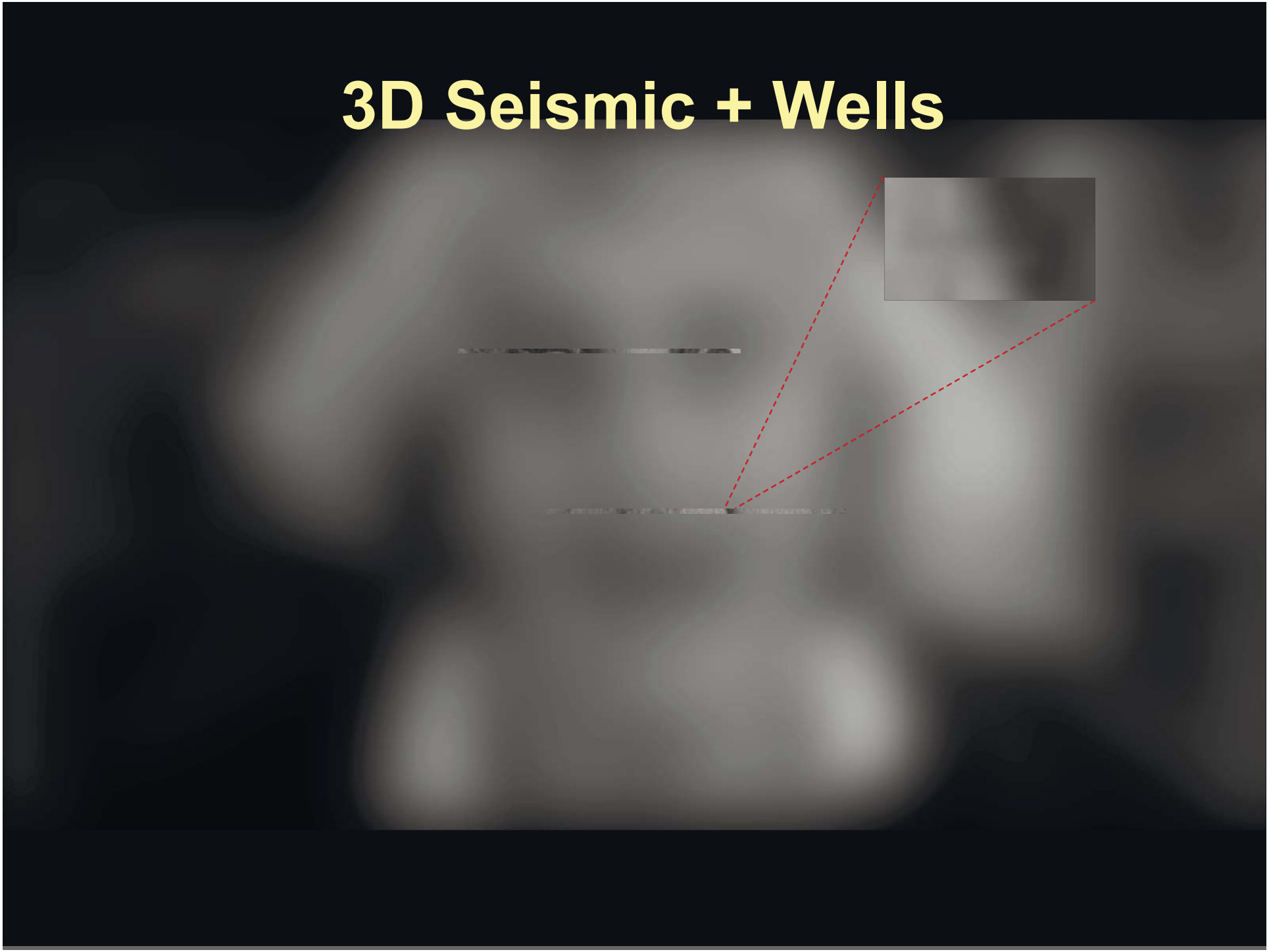
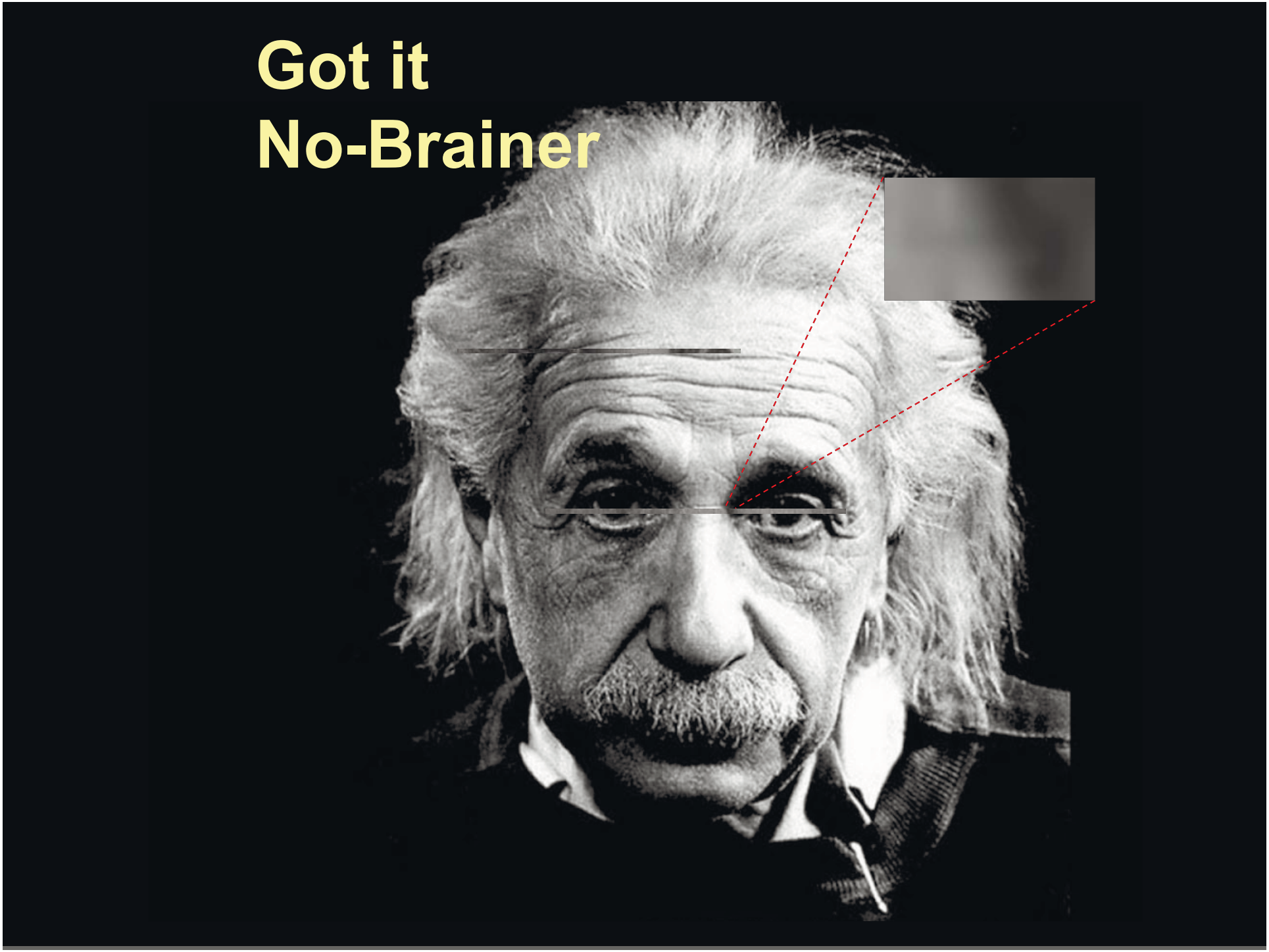


3D Seismic + Wells



Got it
No-Brainer



Oops

Knowledge of reservoir geology drives interpretation

System	Series	Formation thickness (ft)	Member thickness (ft)	Lithology more >>>>> less
Double line indicates unconformity			*Informal in italic*	
Pennsylvanian	Morrow	Bloyd Formation	Kessler	LS
			Dye	SH
			Caprock	SS/LS
			Woolsey/ Middle Bloyd	SH/SS
			Brentwood	LS
		Hale Formation	Prairie Grove	SS
			Cane Hill	SS
Mississippian	Chester	Pitkin Limestone		LS
		Fayetteville Shale	*Upper*	SH
			Wedington	SS
			Lower	SH
		Batesville Formation		SS/LS/SH
		Hindsville Limestone		LS
	Osage/ Meramec	Boone Formation	*Upper B*	LS/CH/TCH
			Upper A	LS/CH/TCH/SH
			Short Creek Oolite	LS
	Osage		*Lower C*	LS/CH
			Lower B	LS/CH/TCH
			Lower A	LS/CH
	may be 1 ft into Pierson	St. Joe Limestone	Pierson	LS
			Northview	LS/SH
	Kinderhook		Compton	LS
			Bachelor	SH
		Chattanooga Shale		SH
Devonian				
Ordovician		Everton Formation		LS/DOL/SS
		Cotter Dolomite		DOL/CH

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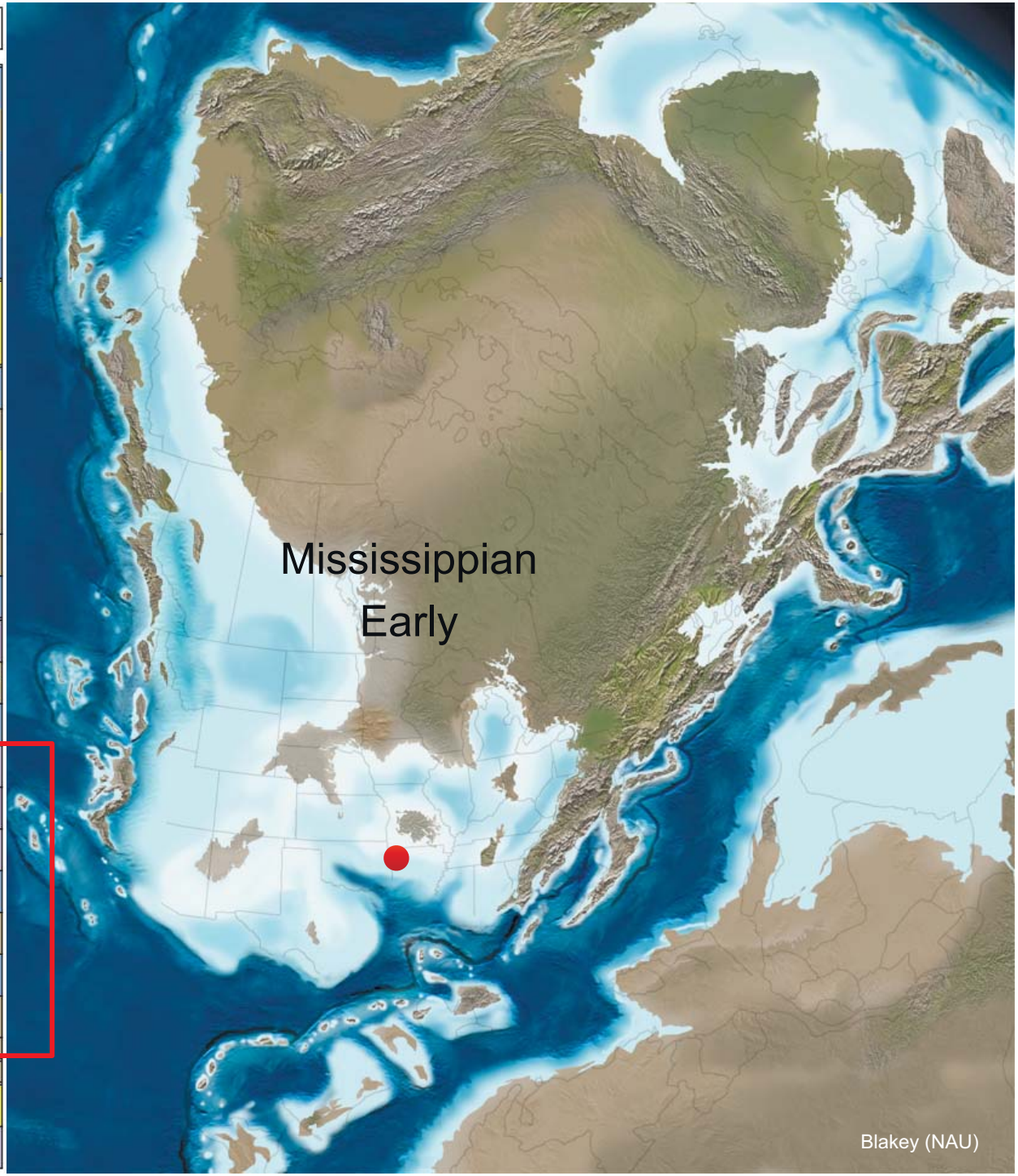

System	Series	Formation thickness (ft)	Member thickness (ft)	Lithology more >>>>> less
Double line indicates unconformity			*Informal in italic*	
Pennsylvanian	Morrow	Bloyd Formation	Kessler	LS
			Dye	SH
			Caprock	SS/LS
			Woolsey/ Middle Bloyd	SH/SS
			Brentwood	LS
		Hale Formation	Prairie Grove	SS
			Cane Hill	SS
Mississippian	Chester	Pitkin Limestone		LS
		Fayetteville Shale	*Upper*	SH
			Wedington	SS
			Lower	SH
		Batesville Formation		SS/LS/SH
		Hindsville Limestone		LS
	Osage/ Meramec	Boone Formation	*Upper B*	LS/CH/TCH
			Upper A	LS/CH/TCH/SH
			Short Creek Oolite	LS
	Osage		*Lower C*	LS/CH
			Lower B	LS/CH/TCH
			Lower A	LS/CH
	may be 1 ft into Pierson	St. Joe Limestone	Pierson	LS
	Kinderhook		Northview	LS/SH
			Compton	LS
			Bachelor	SH
		Chattanooga Shale		SH
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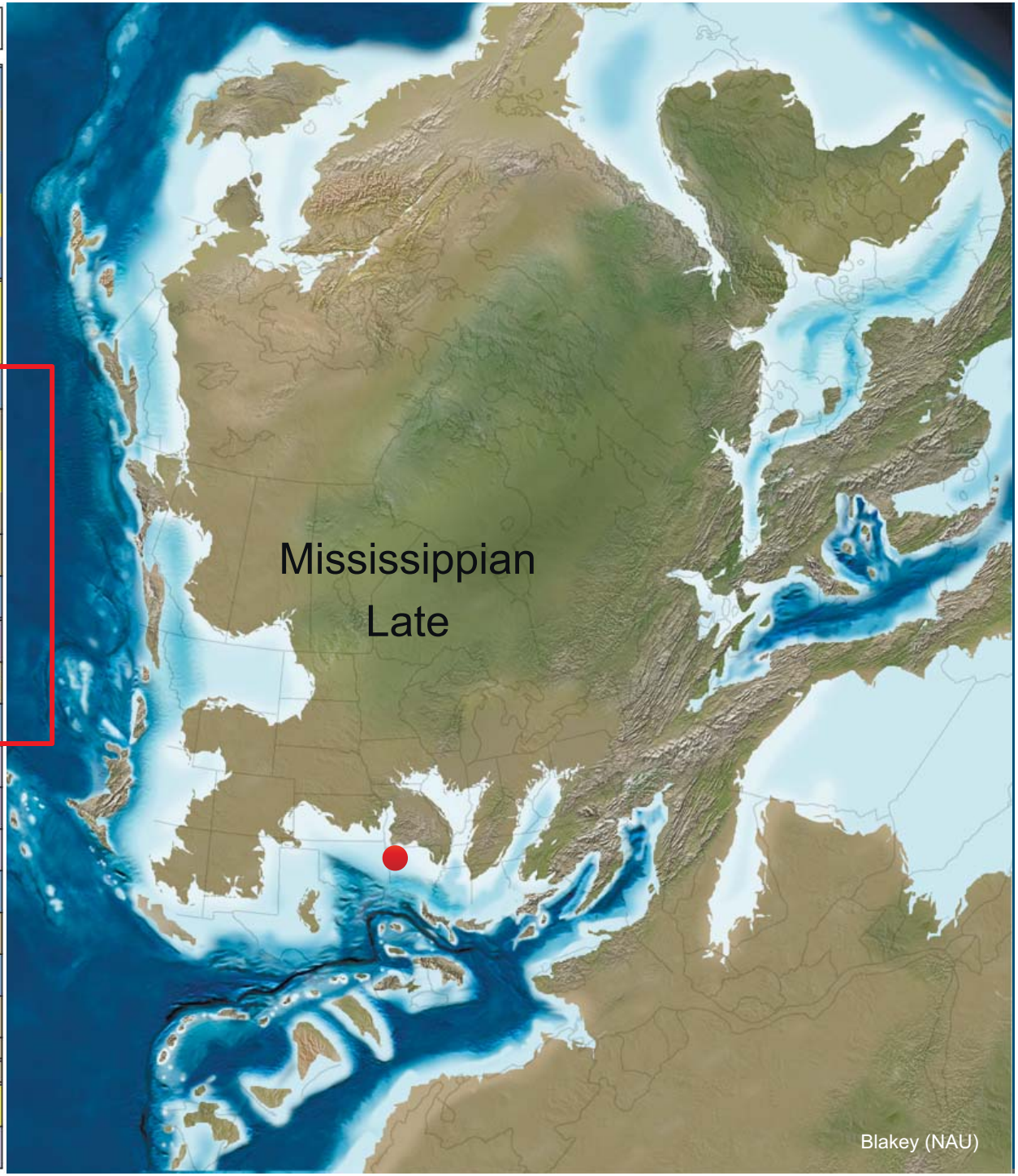

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Pennsylvanian	Morrow	Bloyd Formation	Kessler	LS
			Dye	SH
			Caprock	SS/LS
			Woolsey/ Middle Bloyd	SH/SS
			Brentwood	LS
		Hale Formation	Prairie Grove	SS
			Cane Hill	SS
Mississippian	Chester	Pitkin Limestone		LS
		Fayetteville Shale	*Upper*	SH
			Wedington	SS
			Lower	SH
		Batesville Formation		SS/LS/SH
		Hindsville Limestone		LS
	Osage/ Meramec	Boone Formation	*Upper B*	LS/CH/TCH
			Upper A	LS/CH/TCH/SH
			Short Creek Oolite	LS
	Osage		*Lower C*	LS/CH
			Lower B	LS/CH/TCH
			Lower A	LS/CH
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	Kinderhook		Northview	LS/SH
			Compton	LS
			Bachelor	SH
		Chattanooga Shale		SH
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Ordovician		Everton Formation		LS/DOL/SS
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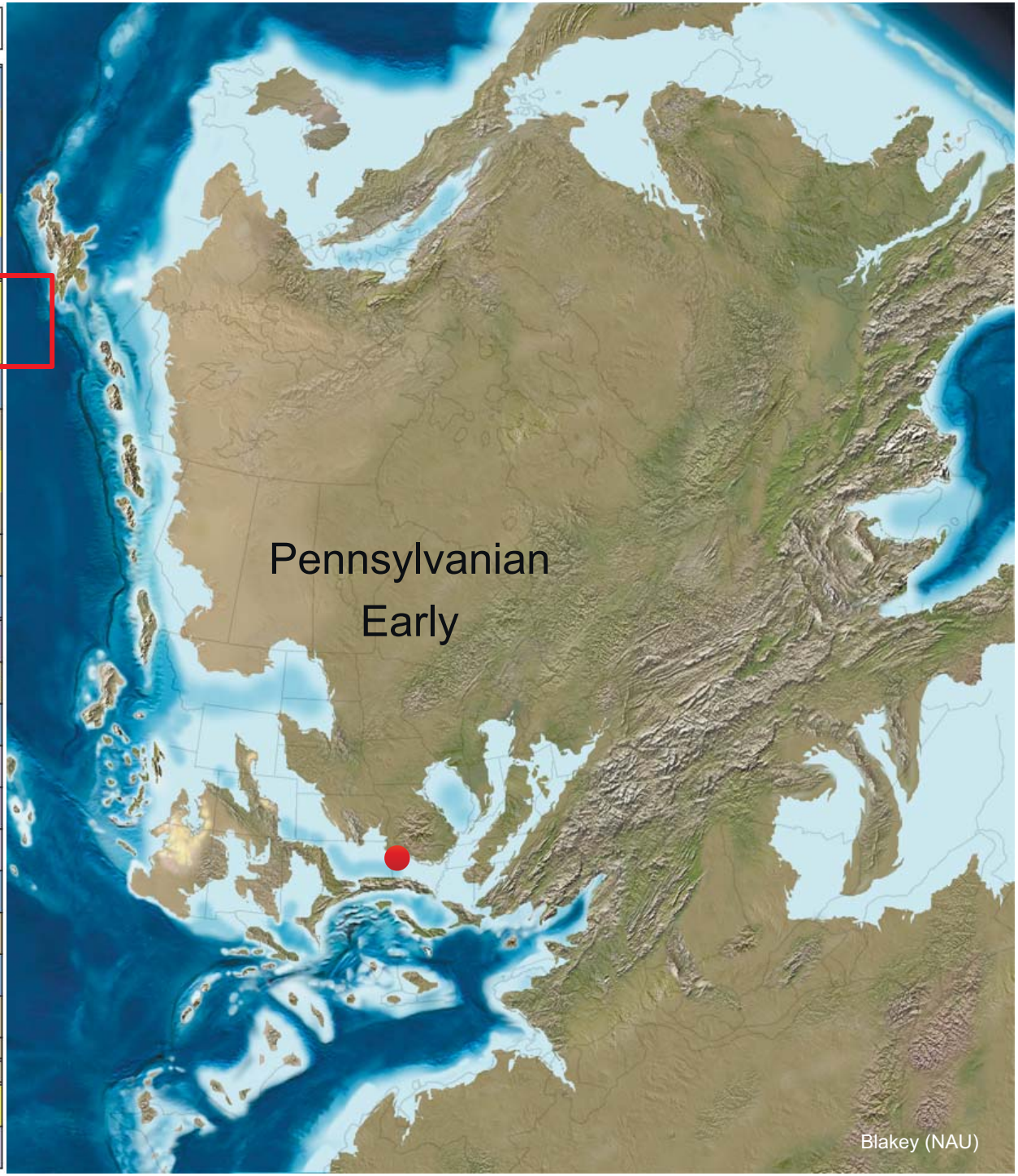

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			Dye	SH
			Caprock	SS/LS
			Woolsey/ Middle Bloyd	SH/SS
			Brentwood	LS
		Hale Formation	Prairie Grove	SS
			Cane Hill	SS
Mississippian	Chester	Pitkin Limestone		LS
		Fayetteville Shale	*Upper*	SH
			Wedington	SS
			Lower	SH
		Batesville Formation		SS/LS/SH
		Hindsville Limestone		LS
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			Upper A	LS/CH/TCH/SH
			Short Creek Oolite	LS
	Osage		*Lower C*	LS/CH
			Lower B	LS/CH/TCH
			Lower A	LS/CH
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			Compton	LS
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		Chattanooga Shale		SH
Devonian				
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		Cotter Dolomite		DOL/CH

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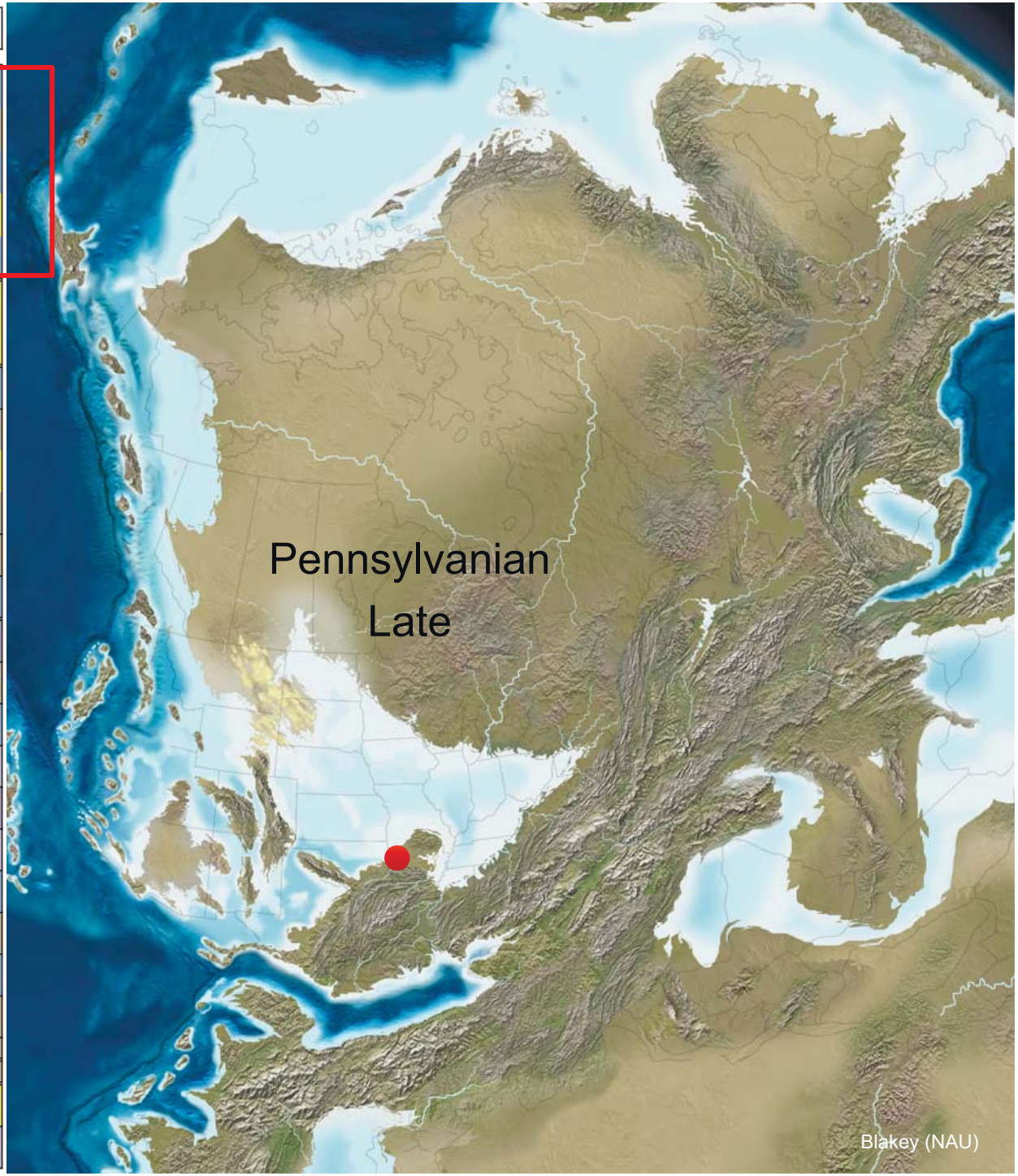
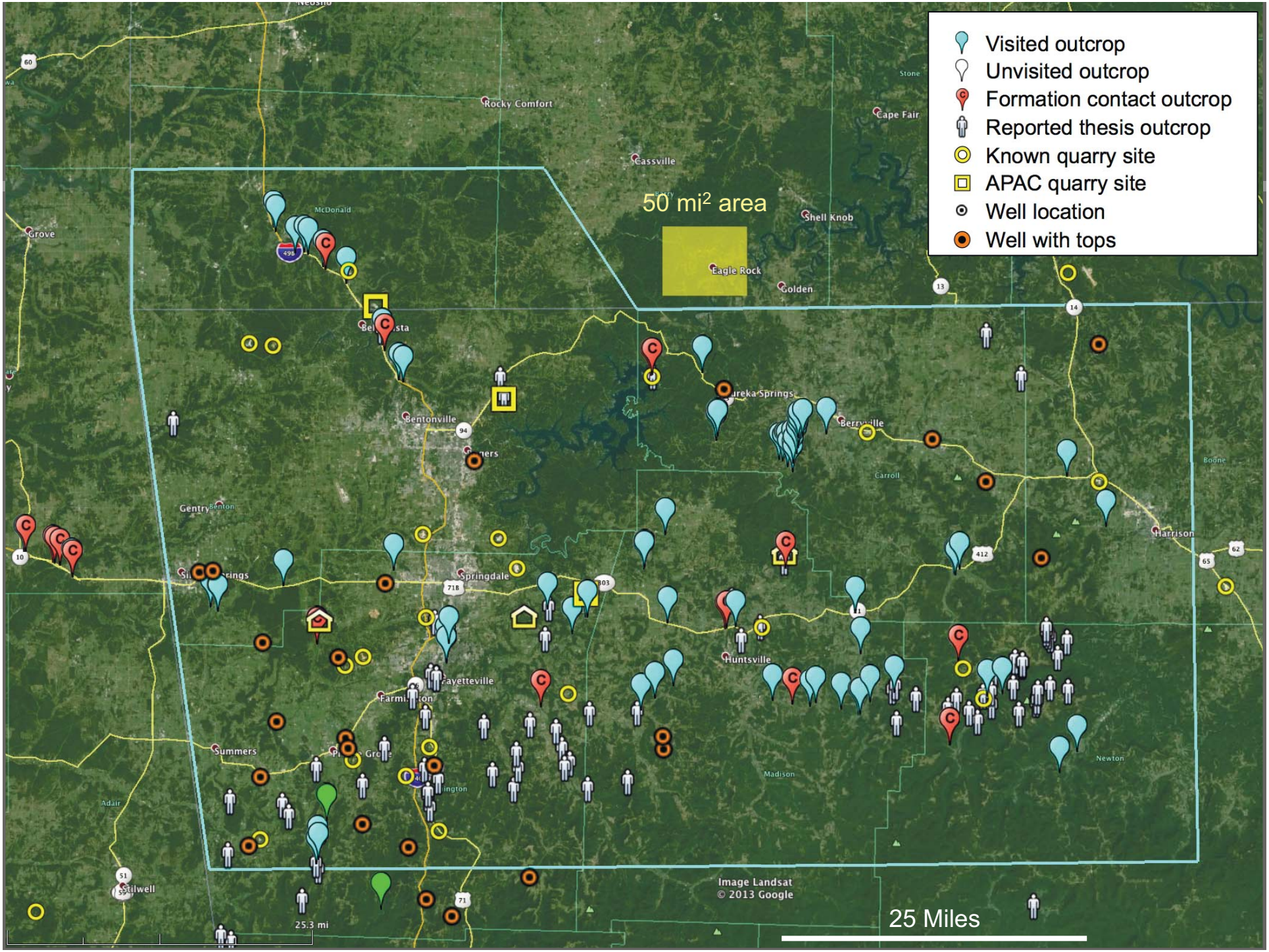


Legacy Data

- Boone Formation (Hopkins, 1894)
- U Arkansas Geology 1913-2013
  - A century of Mississippian study

YEAR	AUTHOR	UNIVERSITY OF ARKANSAS MISS THESIS TITLES
1940	GOSNELL	Structure of the Osage Limestone
1951	OGLESBY	Correlation of the Pitkin Limestone of Northwest Arkansas
1956	AL-REFAI	A Heavy Mineral Analysis of Contemporary Sand Derived from the Boone Limestone Formation in Benton County, Northwest AR
1962	WALLER	A Comparative Study of the Pitkin and Hale Faunas of Northeastern OK
1963	WHITE	Geology of a Mississippian Reef Complex Near Huntsville, AR
1965	BENNETT	A Petrographic Study of a Pitkin Reef Complex located near Wesley, AR
1969	PINKLEY	A Paleoecological Investigation of Pitkin Lime and Mounds, Durham, AR
1971	HUGHES	Stratigraphic Analysis of the Pitkin, Hale and Bloyd Formations in the Grapevine Ridge-Liberty Hill Area, Washington and Crawford Counties, AR
1972	JACKSON	Petrography and Stratigraphy of Part A Pitkin Reef Complex
1975	COUGHLIN	Geologic and Environmental Factors Affecting Groundwater in the Boone Limestone of Northcentral Washington, County, Arkansas
1976	TEHAN	The Sedimentary Petrology of the Pitkin (Chesterian) Limestone, Washington and Crawford Counties, AR
1977	WARMATH	The Sedimentary Petrology and Lithofacies of the Pitkin Formation in Western Madison and Eastern Washington Counties, AR
1978	HALL	Devonian-Lowermost Mississippian Lithostratigraphy and Conodont Biostratigraphy, Northern AR
1979	LINER	Lithostratigraphy of the Boone Limestone (Lower Mississippian), Northwest Arkansas
1979	REZAIE	The Hydrogeology of the Boone-St.Joe Aquifer of Benton County, Arkansas
1979	VAN DEN HEUVAL	Petrography of the Boone Formation, Northwest Arkansas
1979	BROOKS	The Effect of Photo-Lineaments and Season on Water Chemistry of the Boone-St. Joe Aquifer of Benton County, AR
1979	LANGFORD	Petrology of the Hatton Tuff (Mississippian), Arkansas and Oklahoma
1980	CHITSAZAN	Hydrogeologic Evaluation of the Boone-St. Joe Carbonate Aquifer
1980	EDDY	A Tri-Potential Resistivity Study of Fractures, Caves, and Photo-Lineaments in the Boone-St. Joe Aquifer, Northwest AR
1980	TERRY	Devonian-Lowermost Mississippian Lithostratigraphy and Conodont Biostratigraphy of the Batesville District, Northeastern AR
1982	POST	Conodont Biostratigraphy of the St. Joe Formation (Lower Mississippian), North Central AR
1983	DOWNS	Lithostratigraphy of the Pitkin Formation: Mississippian, Madison, Newton, and Searcy Counties, AR (Manger)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Unvisited outcrop
Formation contact outcrop
Reported thesis outcrop
Known quarry site
APAC quarry site
Well location
Well with tops
50 mi² area
Rocky Comfort
Cassville
Cape Fair
Shell Knob
Eagle Rock
Golden
McDonald
Grove
Bentonville
Eureka Springs
Berryville
Carroll
Boone
Harrison
Gentry
Benton
Springdale
Huntsville
Fayetteville
Farmington
Summers
Madison
Newton
Adair
Stilwell
Image Landsat
© 2013 Google
25.3 mi
25 Miles

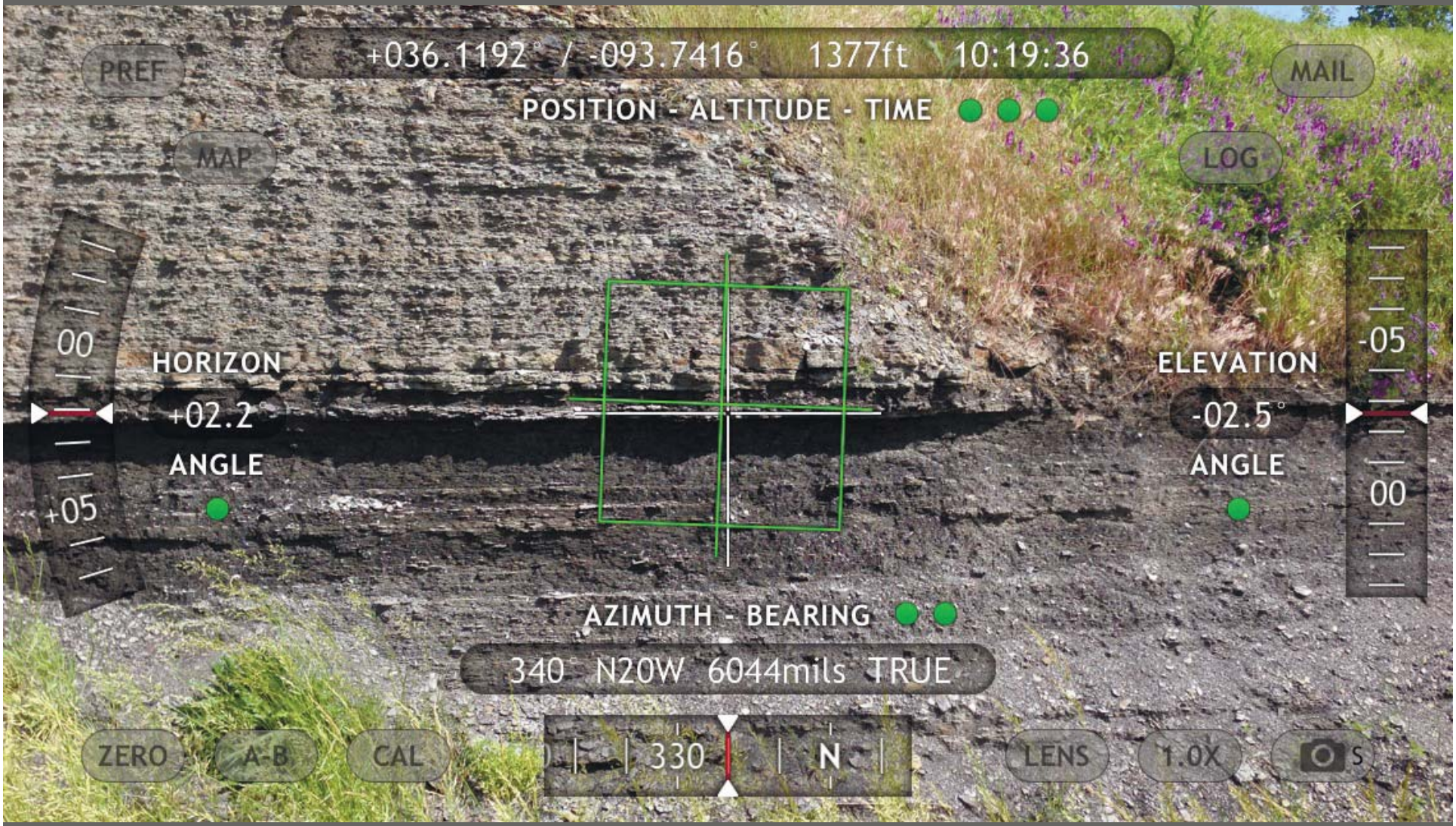
iPhone Geology

- Selected driving to fill coverage holes
- Geolocate App
  - Latitude and longitude (XY +/- 5-10 m)
  - Altitude (+/- 3-6 m)
- iPhone photos, key features and access
- Theodolite App
  - Strike and dip
- Post in Google Earth
- Classify outcrop features

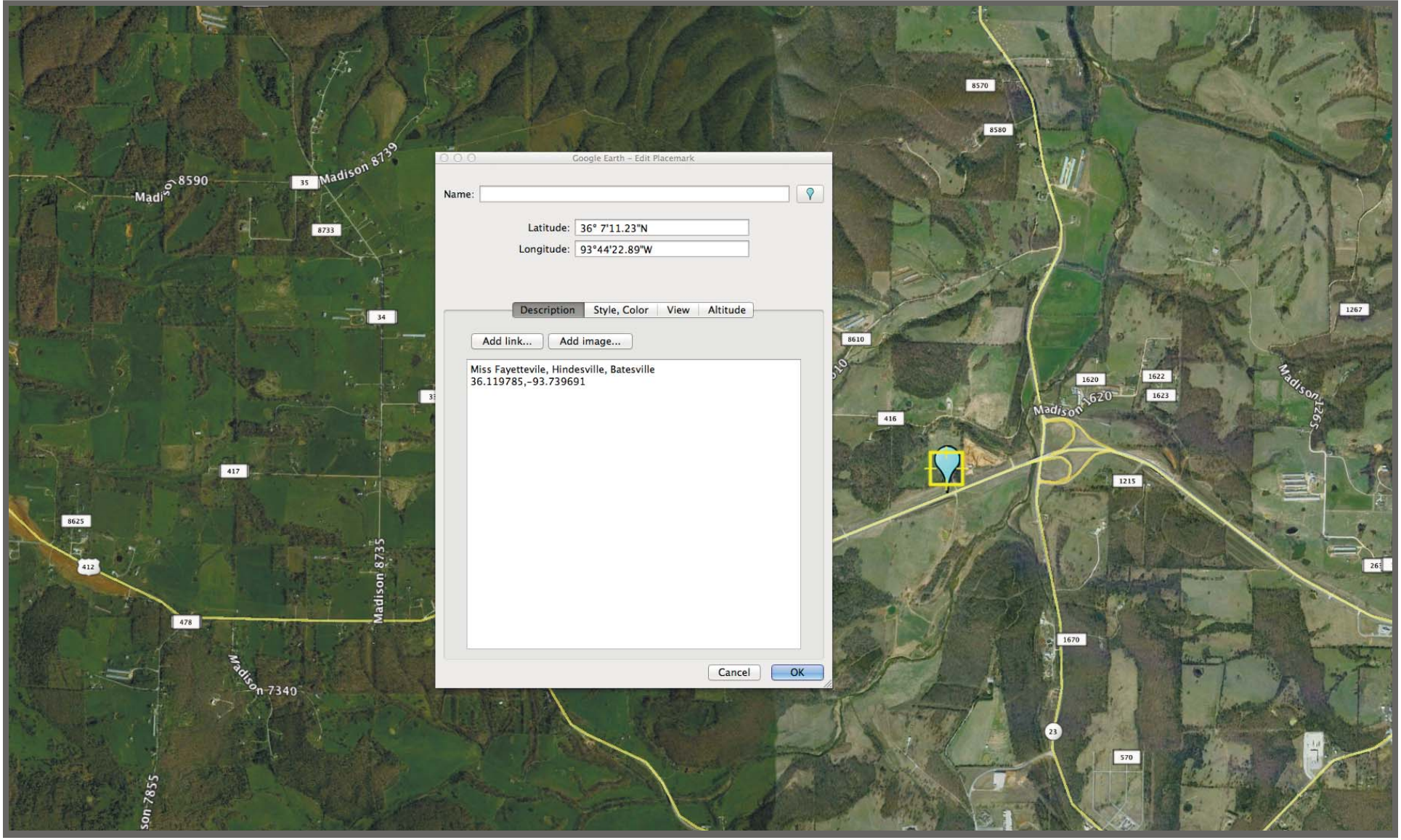
iPhone Geology: Geolocation App

iPhone Geology: Photos

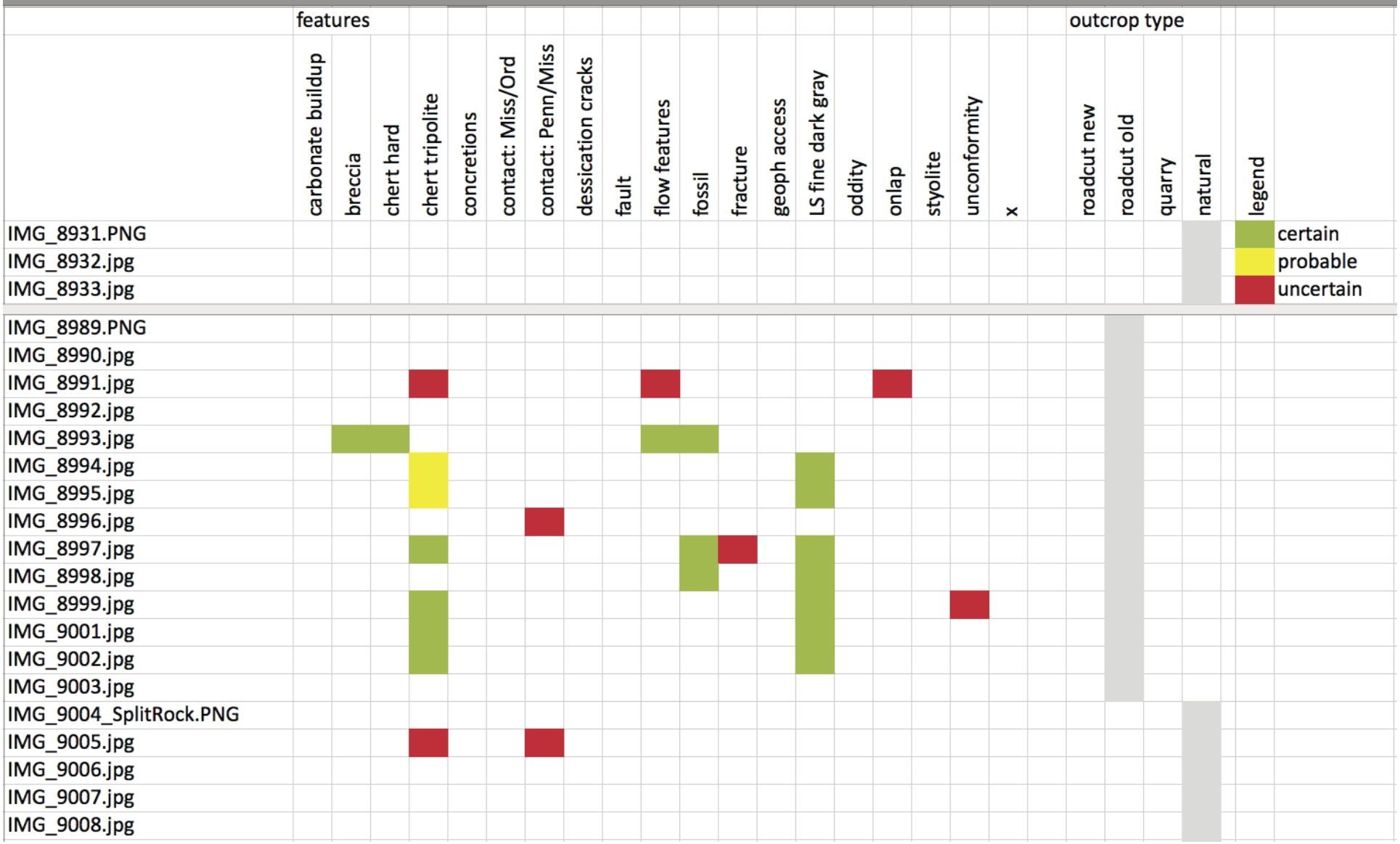
iPhone Geology: Theodolite App

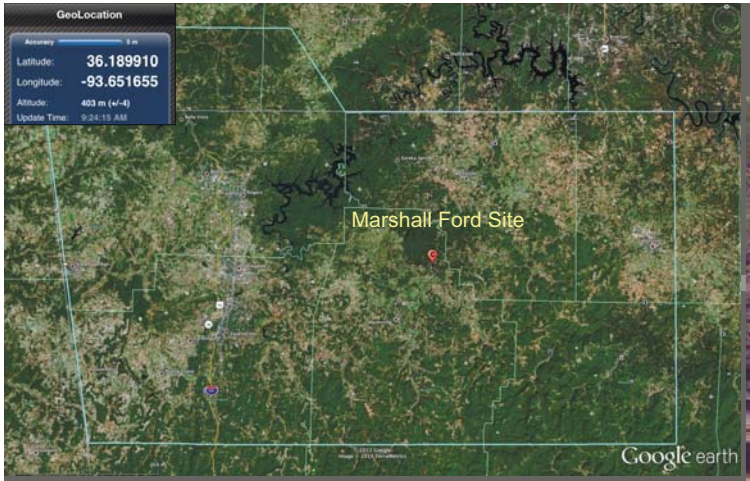


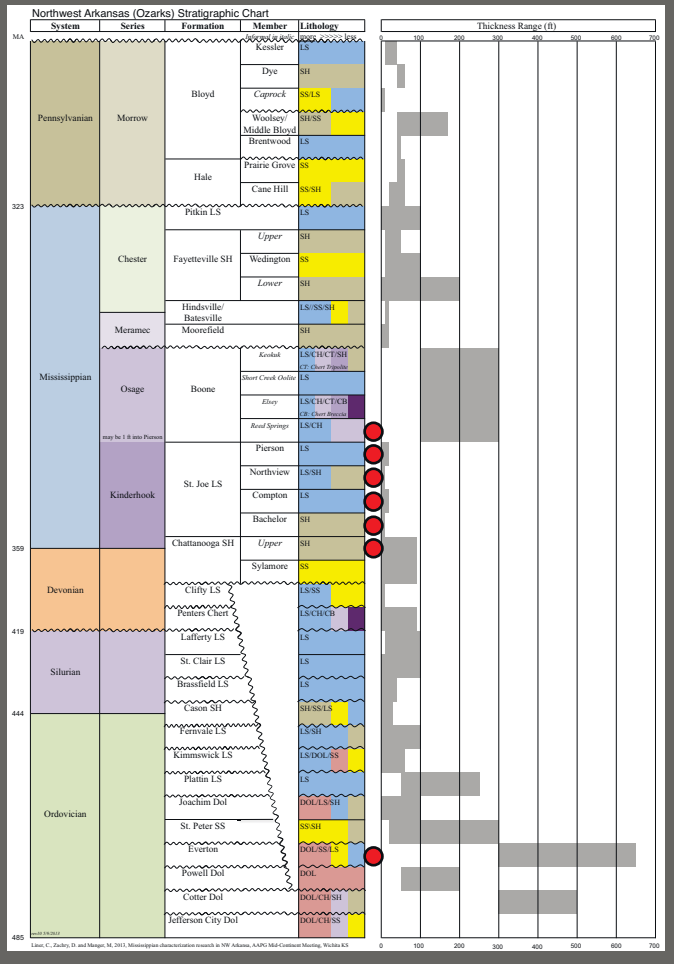
iPhone Geology: Google Earth



iPhone Geology: Classify Features







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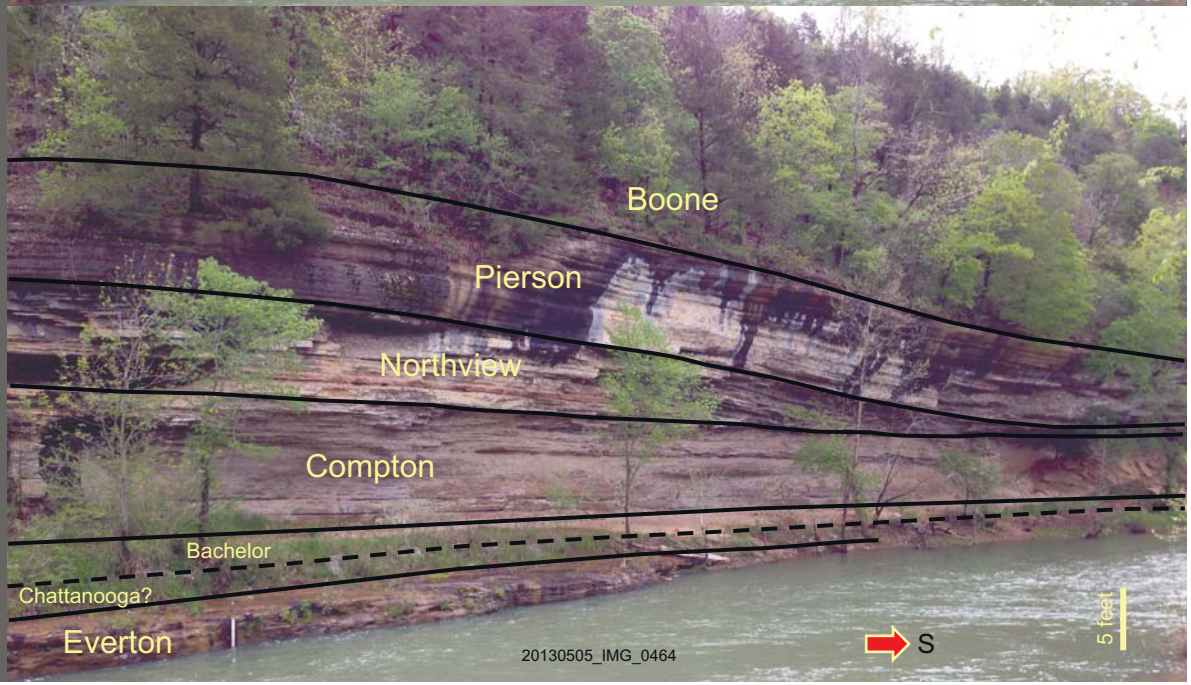
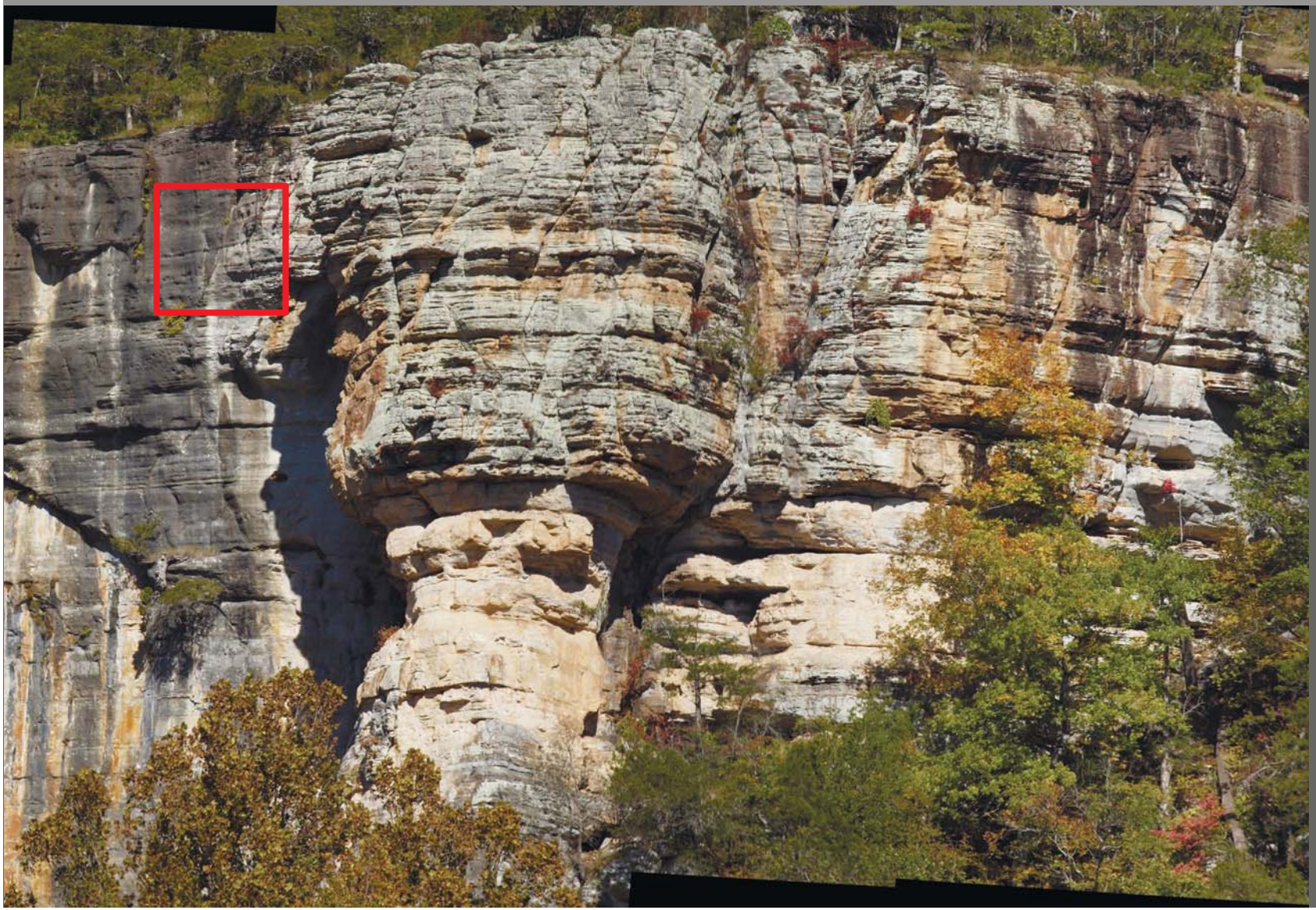


Deep Resolution Photography



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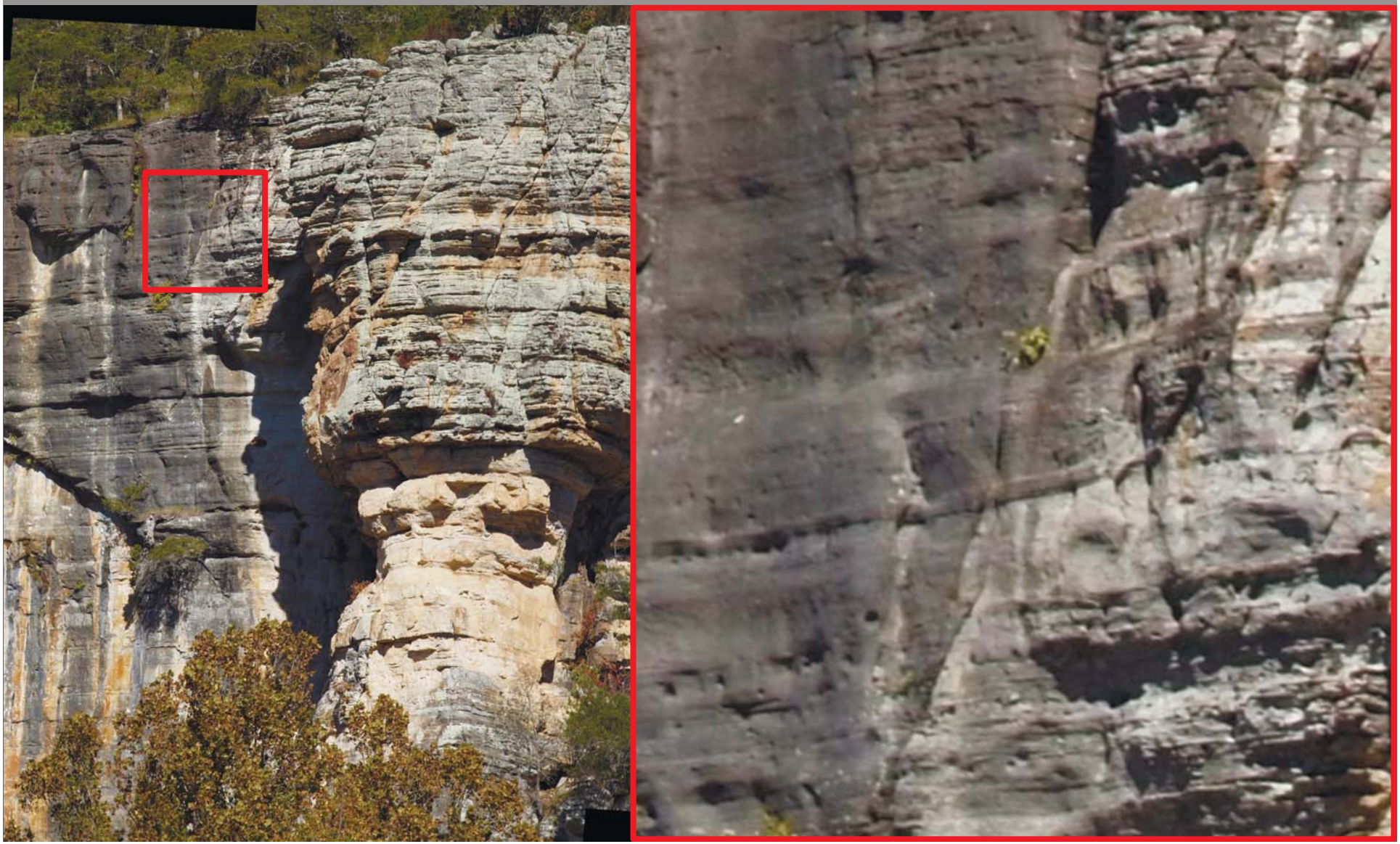
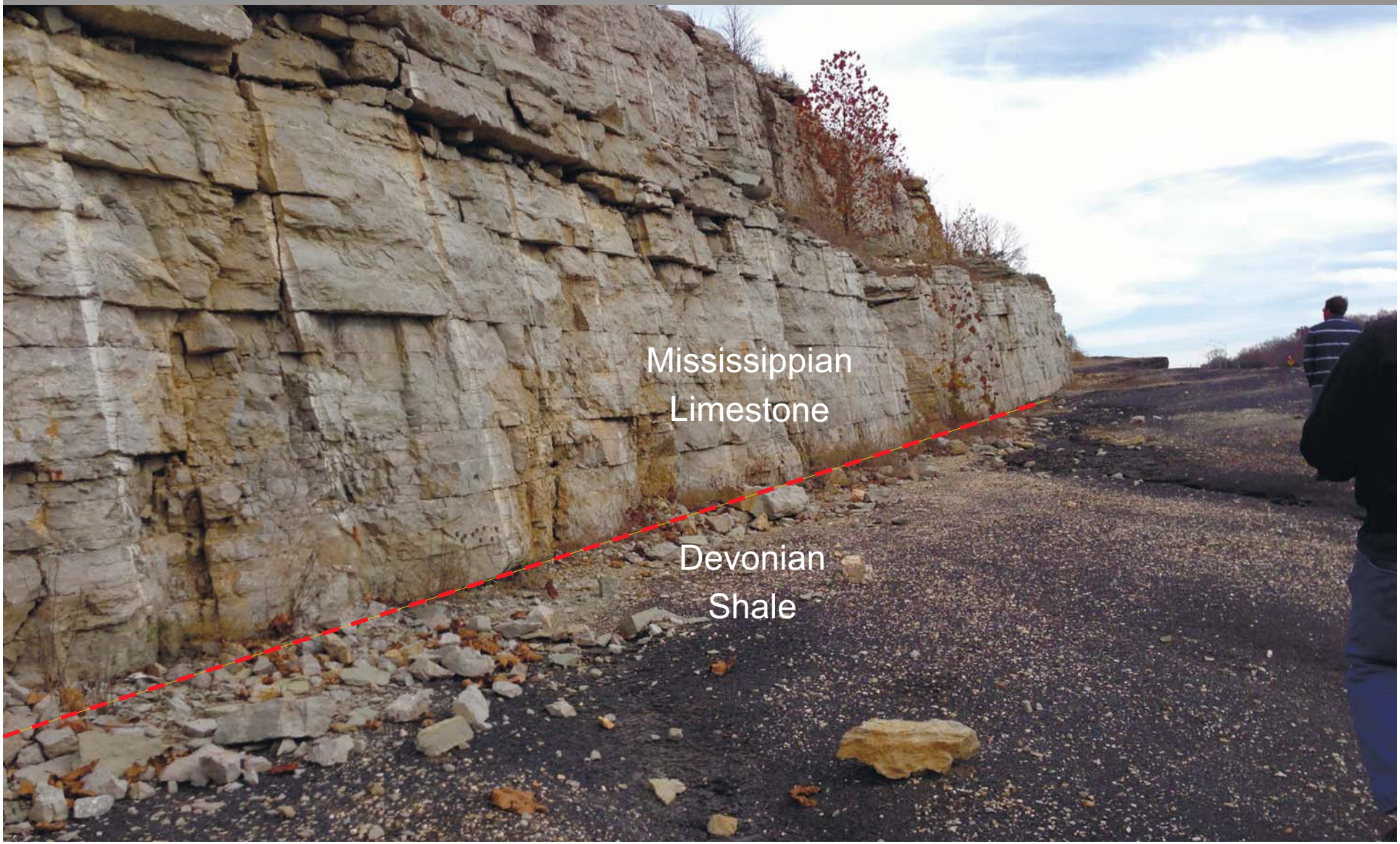
Deep Resolution Photography



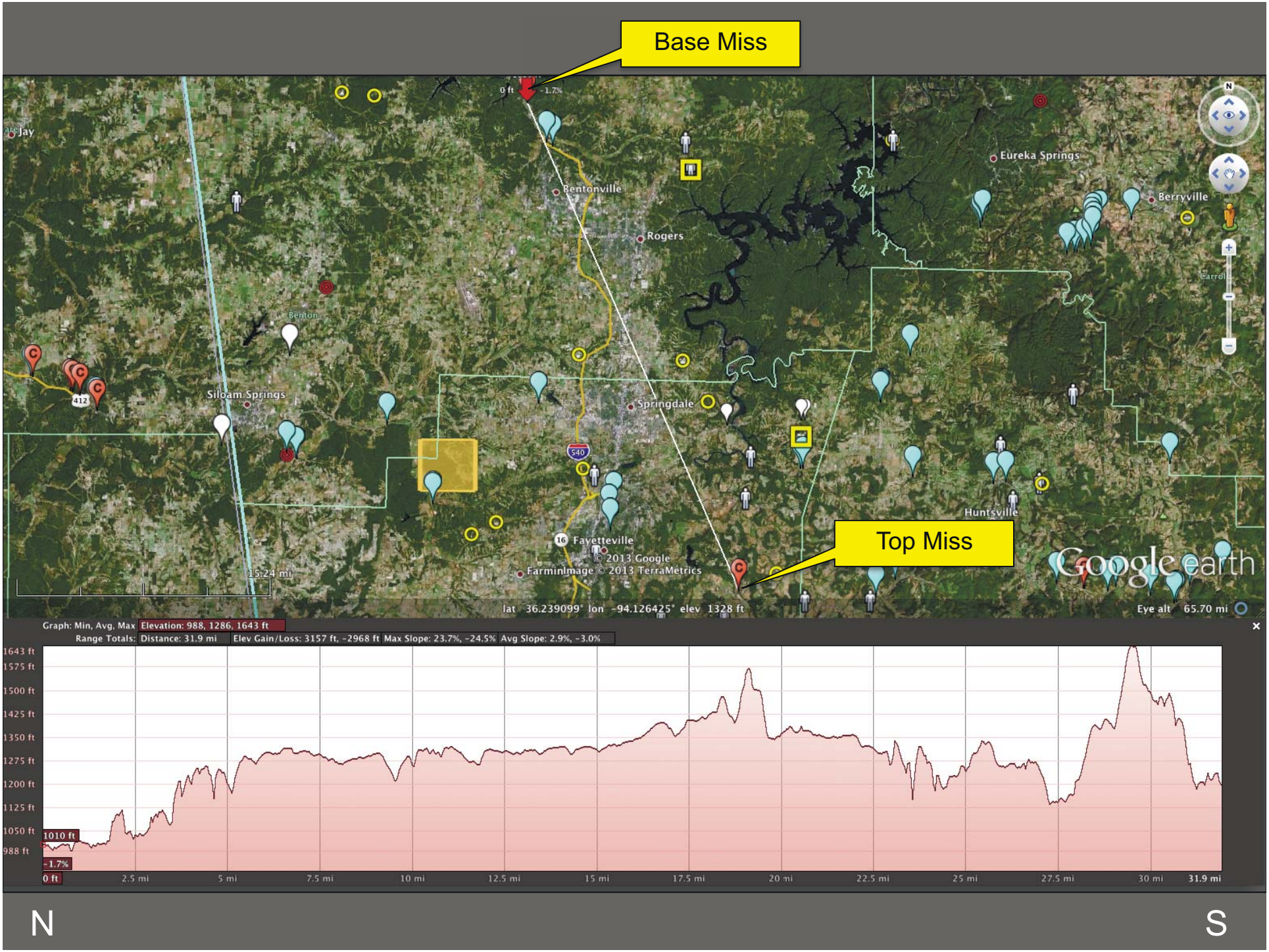
Formation Contacts and Fragments

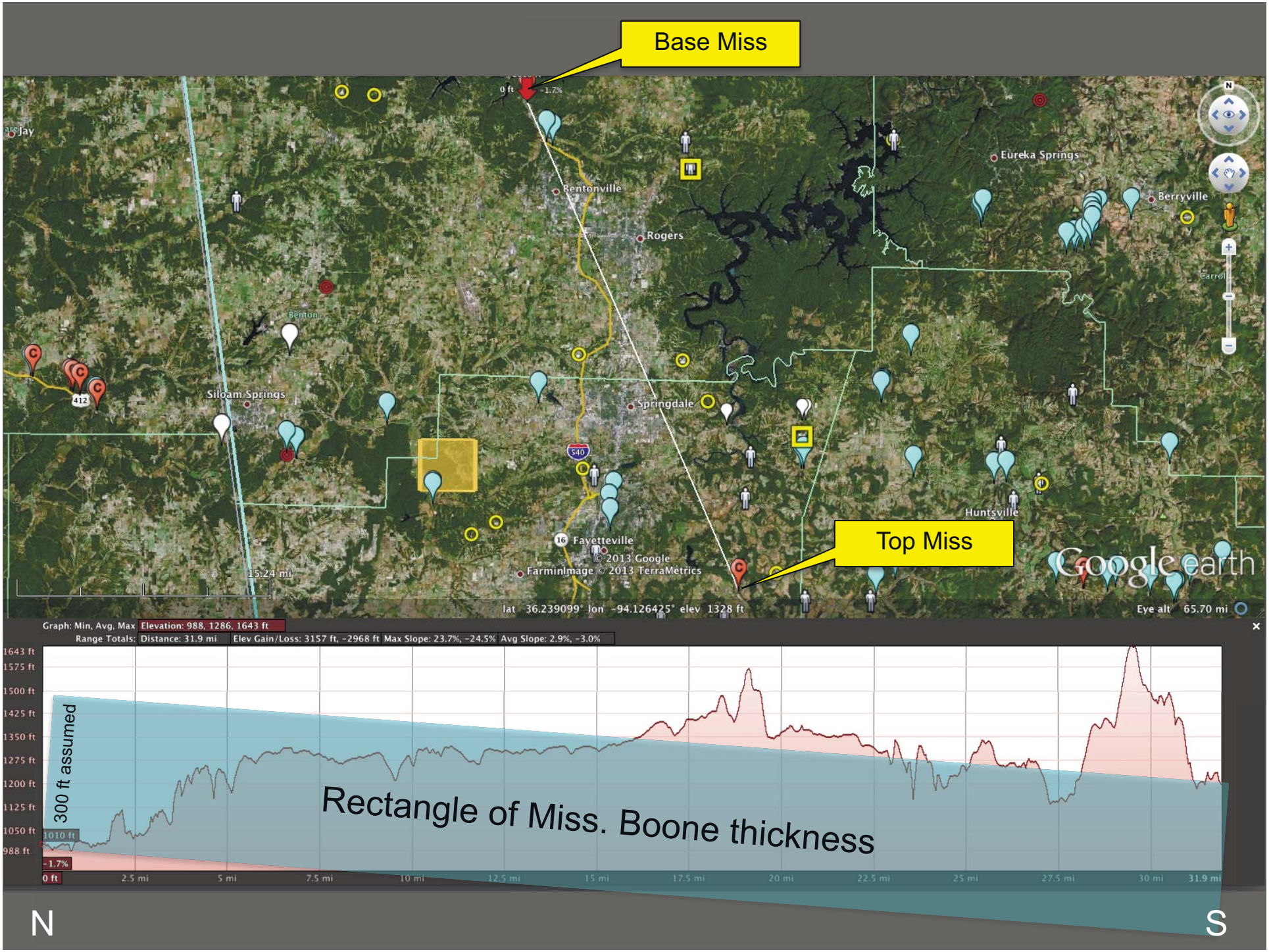


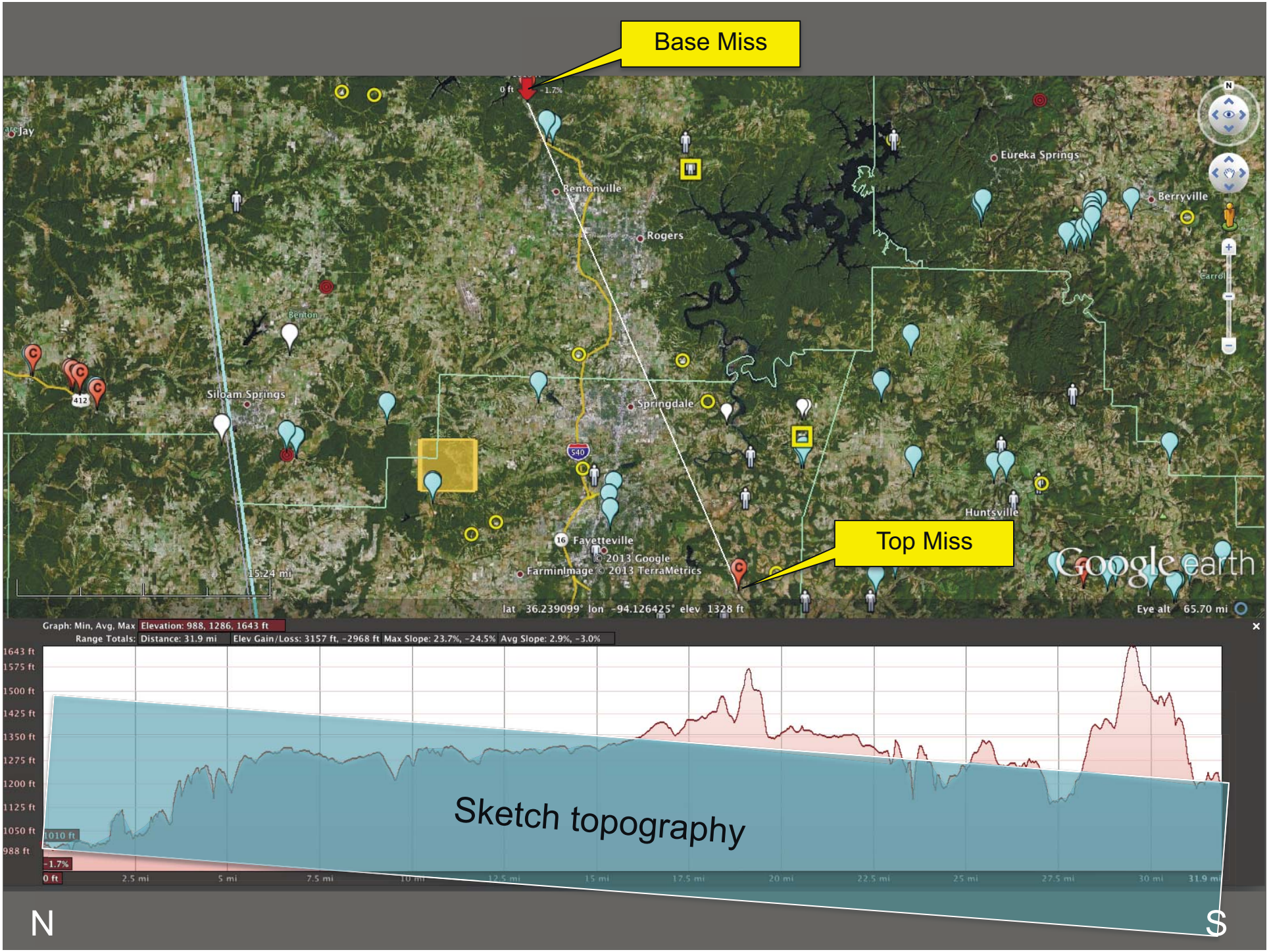
Formation Contacts and Fragments

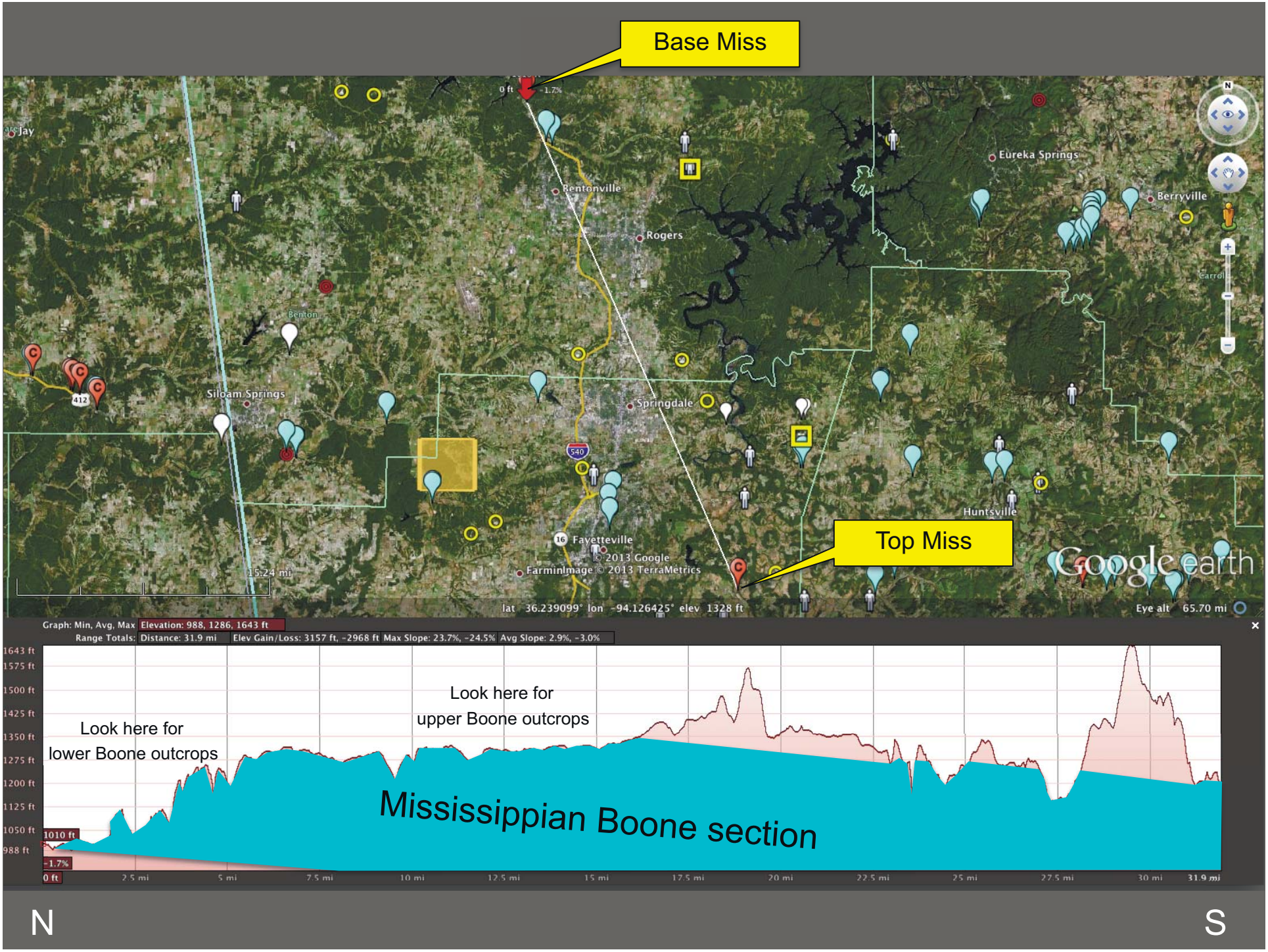
- Top/base of Boone are key features
  - Google Earth profile topography
    - Constraint on outcrop fragments

N S


Base Miss
Top Miss
Bentonville
Rogers
Eureka Springs
Berryville
Benton
Siloam Springs
Springdale
Fayetteville
Huntsville
Jay
15.24 mi
© 2013 Google
FarmInImage © 2013 TerraMetrics
Google earth
lat 36.239099° lon -94.126425° elev 1328 ft
Eye alt 65.70 mi
Graph: Min, Avg, Max Elevation: 988, 1286, 1643 ft
Range Totals: Distance: 31.9 mi Elev Gain/Loss: 3157 ft, -2968 ft Max Slope: 23.7%, -24.5% Avg Slope: 2.9%, -3.0%
1643 ft
1575 ft
1500 ft
1425 ft
1350 ft
1275 ft
1200 ft
1125 ft
1050 ft
988 ft
1010 ft
-1.7%
0 ft
2.5 mi
5 mi
7.5 mi
10 mi
12.5 mi
15 mi
17.5 mi
20 mi
22.5 mi
25 mi
27.5 mi
30 mi
31.9 mi
N
S

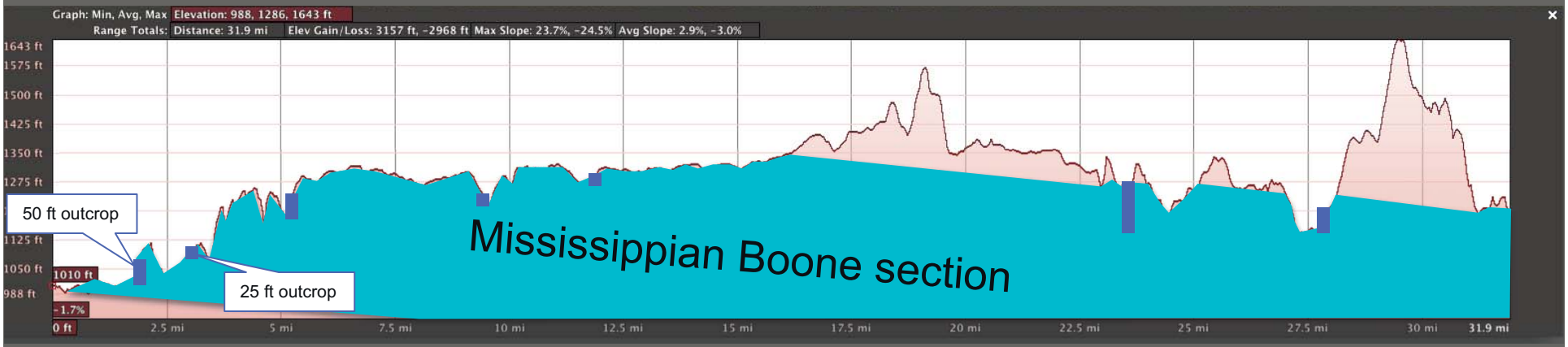

Base Miss
Top Miss
Eureka Springs
Berryville
Bentonville
Rogers
Benton
Siloam Springs
Springdale
Fayetteville
Huntsville
Jay
15.24 mi
© 2013 Google
FarminImage © 2013 TerraMetrics
lat 36.239099° lon -94.126425° elev 1328 ft
Eye alt 65.70 mi
Graph: Min, Avg, Max Elevation: 988, 1286, 1643 ft
Range Totals: Distance: 31.9 mi Elev Gain/Loss: 3157 ft, -2968 ft Max Slope: 23.7%, -24.5% Avg Slope: 2.9%, -3.0%
1643 ft
1575 ft
1500 ft
1425 ft
1350 ft
1275 ft
1200 ft
1125 ft
1050 ft
988 ft
1010 ft
-1.7%
0 ft
2.5 mi
5 mi
7.5 mi
10 mi
12.5 mi
15 mi
17.5 mi
20 mi
22.5 mi
25 mi
27.5 mi
30 mi
31.9 mi
300 ft assumed
Rectangle of Miss. Boone thickness
N
S


Base Miss
Top Miss
Sketch topography
N
S
Eureka Springs
Berryville
Bentonville
Rogers
Benton
Siloam Springs
Springdale
Fayetteville
Huntsville
Google earth
Graph: Min, Avg, Max Elevation: 988, 1286, 1643 ft
Range Totals: Distance: 31.9 mi Elev Gain/Loss: 3157 ft, -2968 ft Max Slope: 23.7%, -24.5% Avg Slope: 2.9%, -3.0%


Base Miss
Top Miss
Look here for
lower Boone outcrops
Look here for
upper Boone outcrops
Mississippian Boone section
N
S

Formation Fragments

- Outcrop fragments in context
  - Progress in stratigraphic zonation



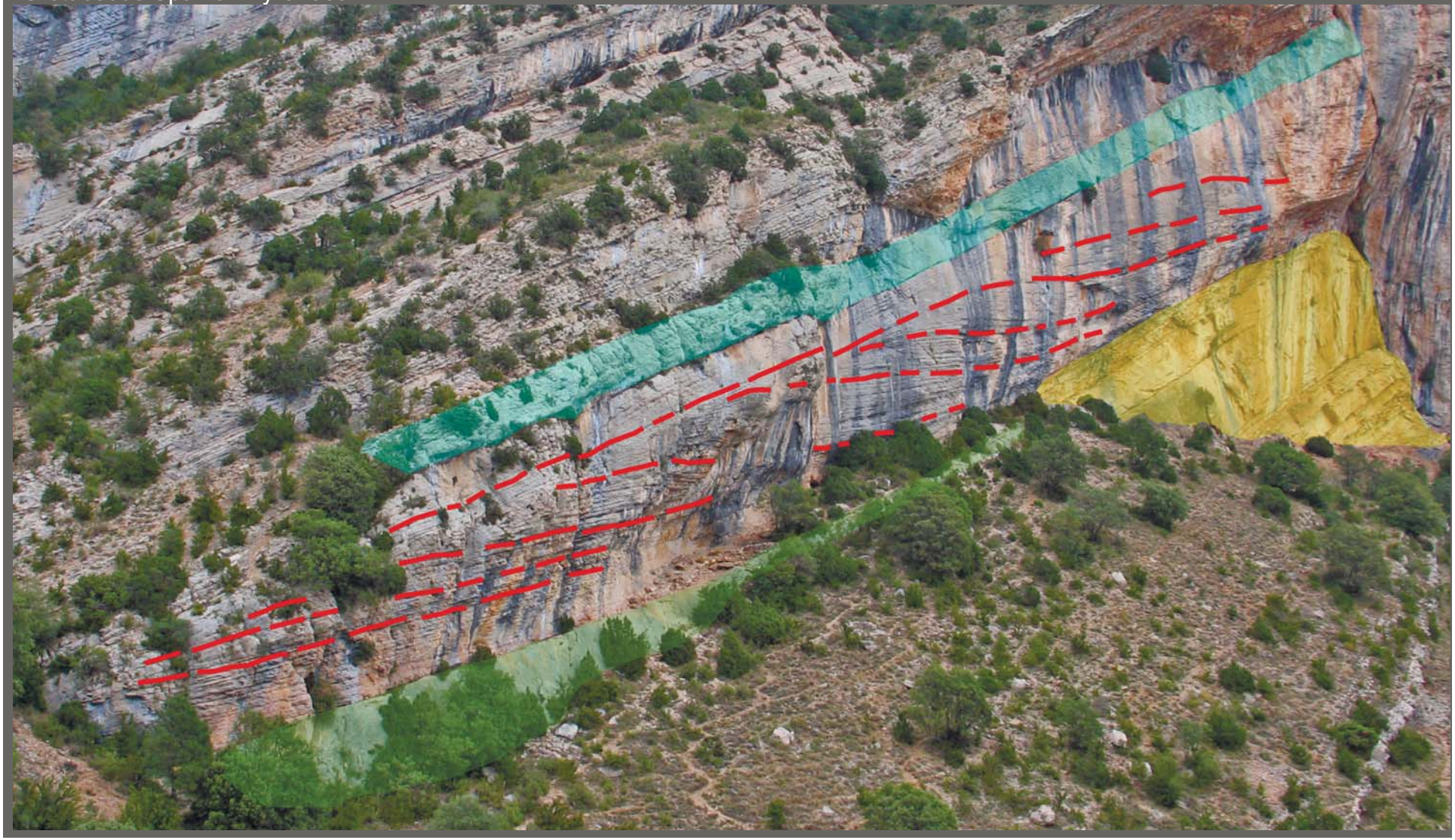
N S

Sequence Stratigraphy

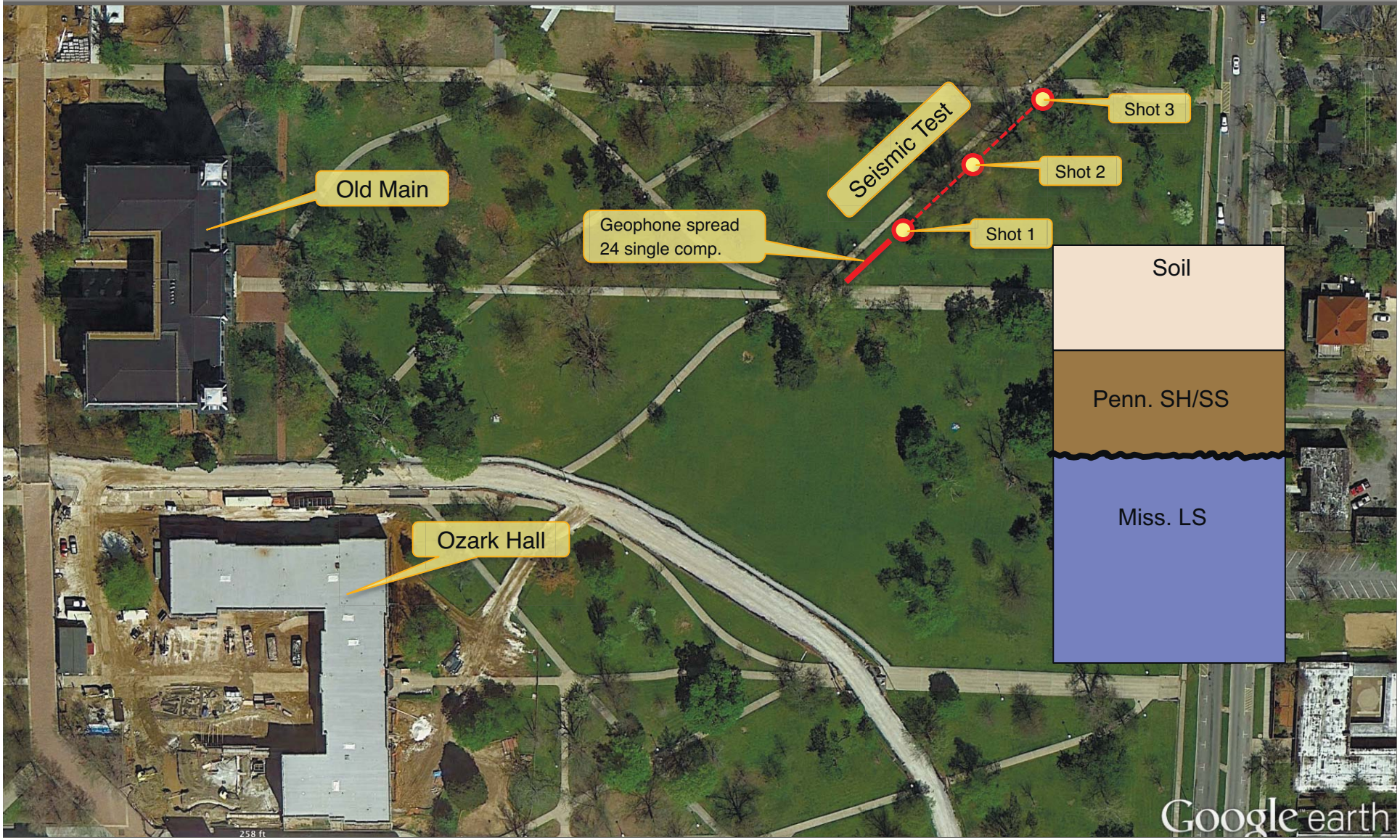
Cretaceous Spanish Pyrenees

Sequence Stratigraphy

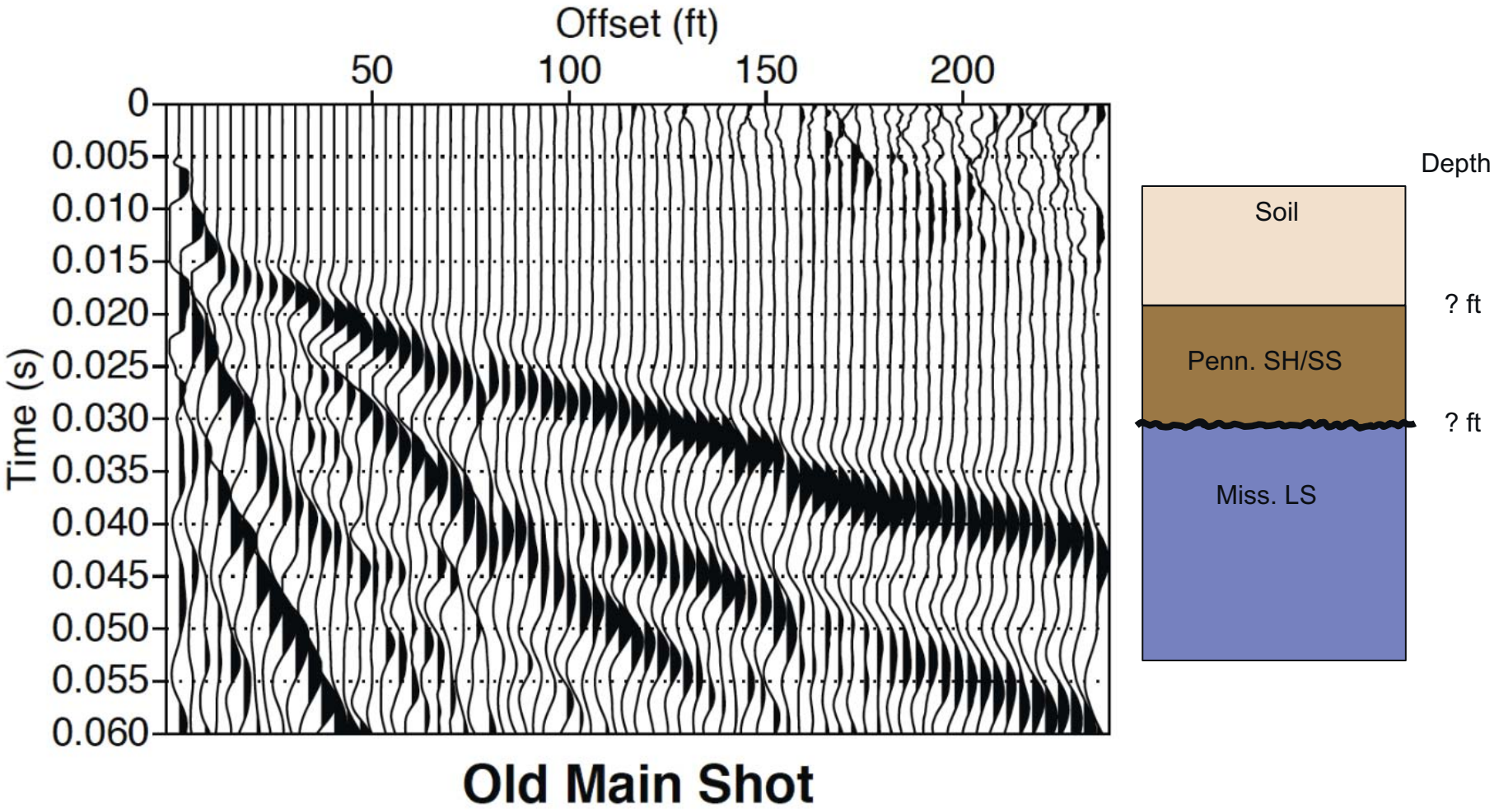
Cretaceous Spanish Pyrenees



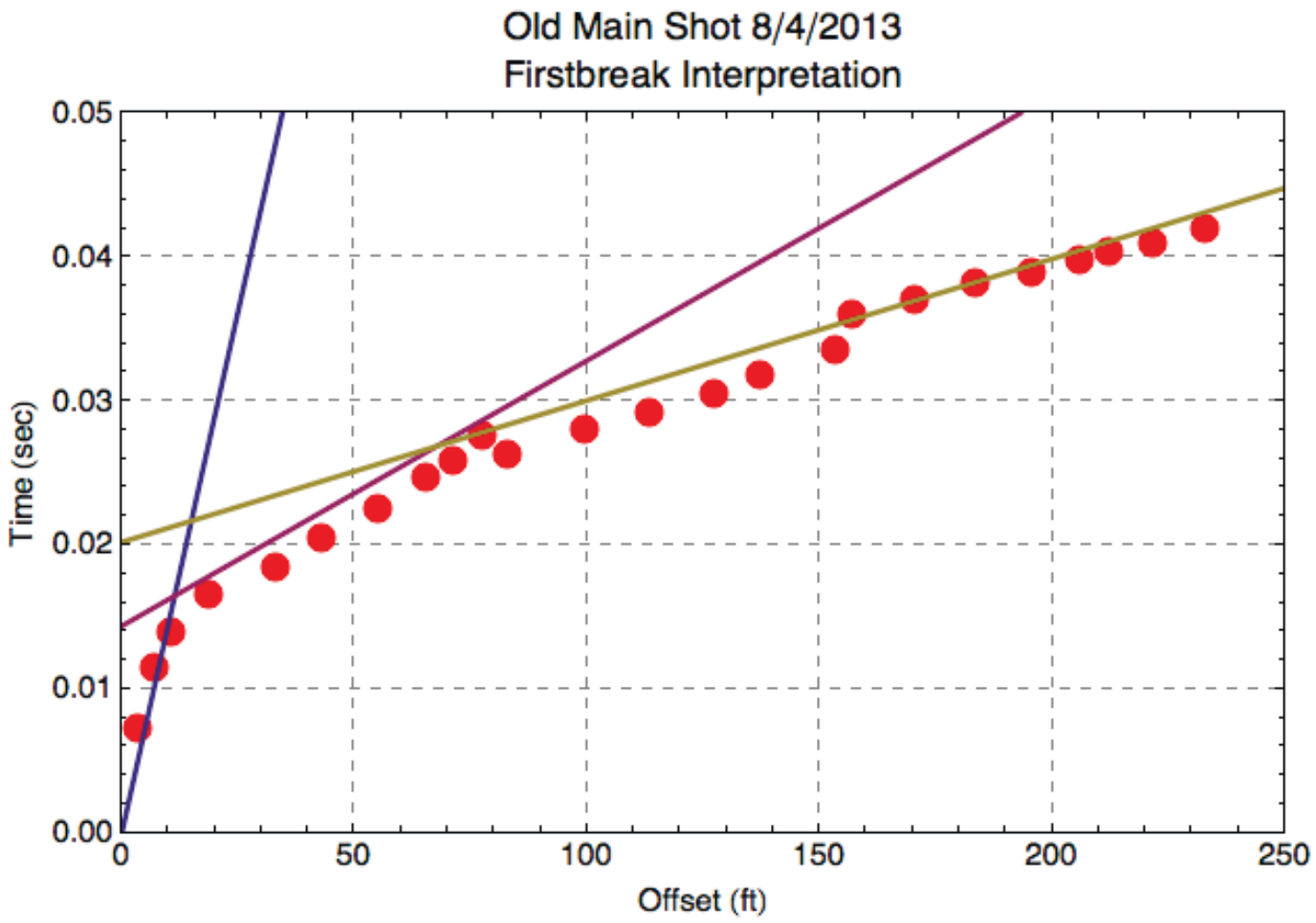
Geophysics: Buried Contacts

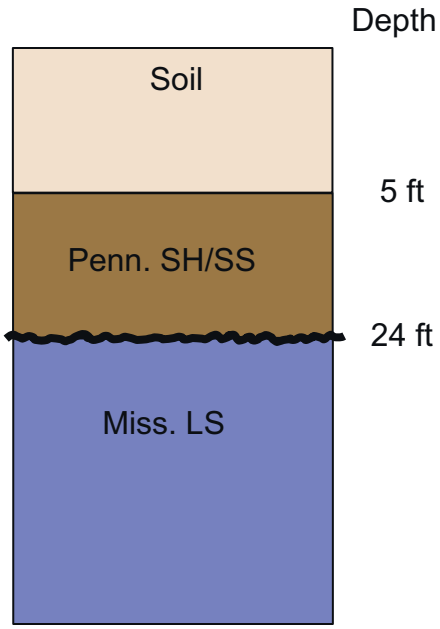


Geophysics: Buried Contacts

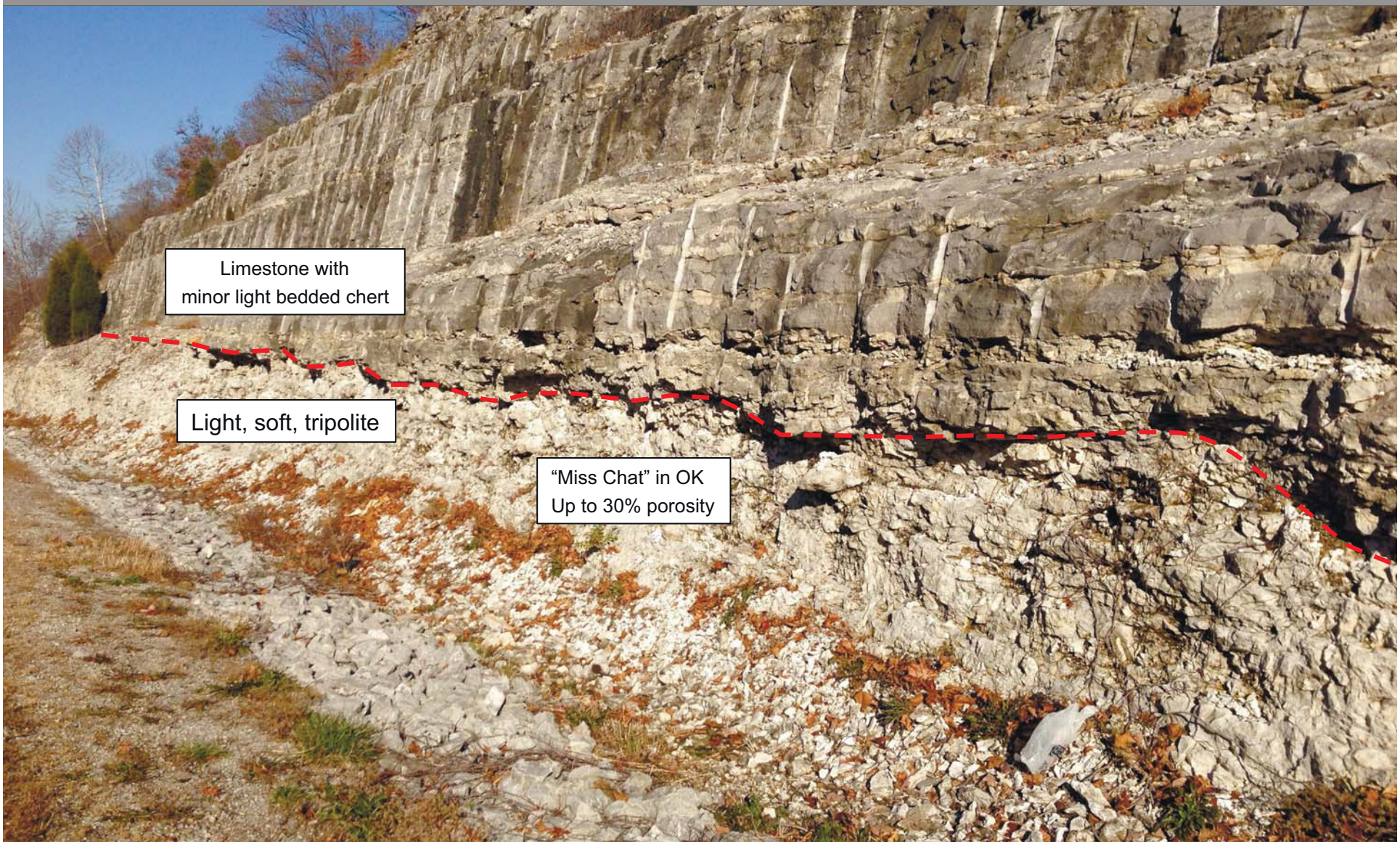


Geophysics: Buried Contacts



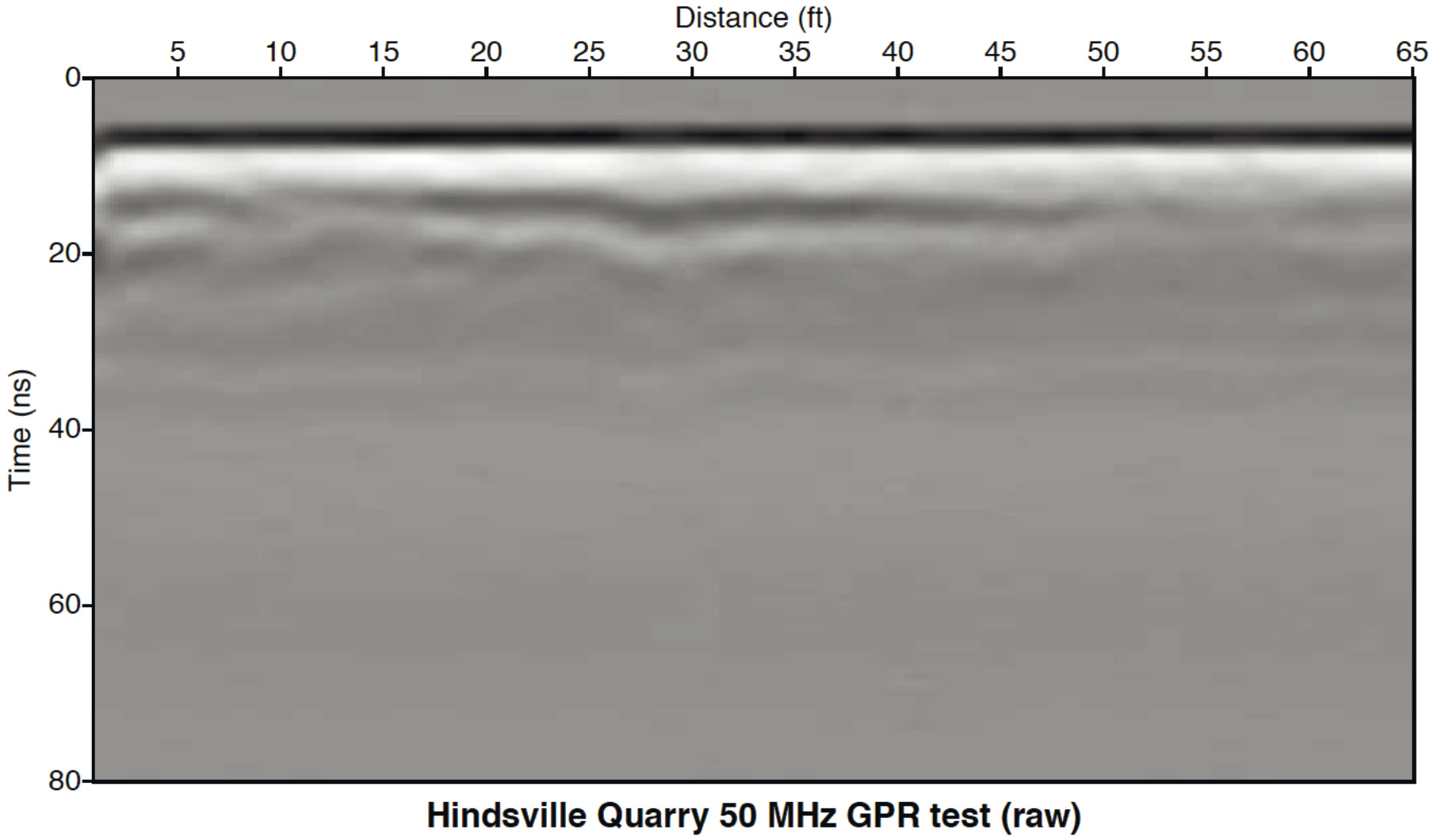


Geophysics: Species of Chert



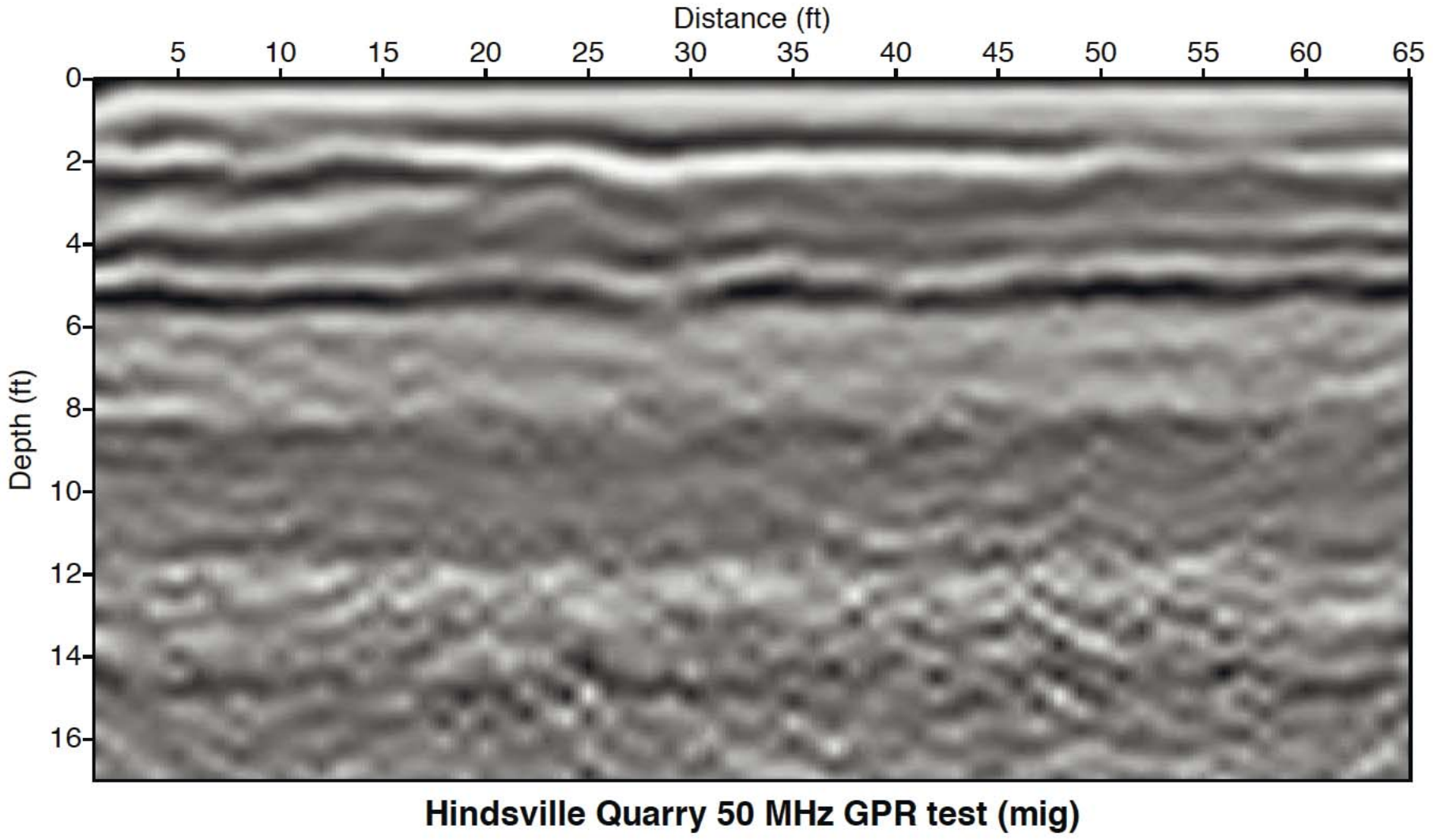

apac
TM

GPR Profile



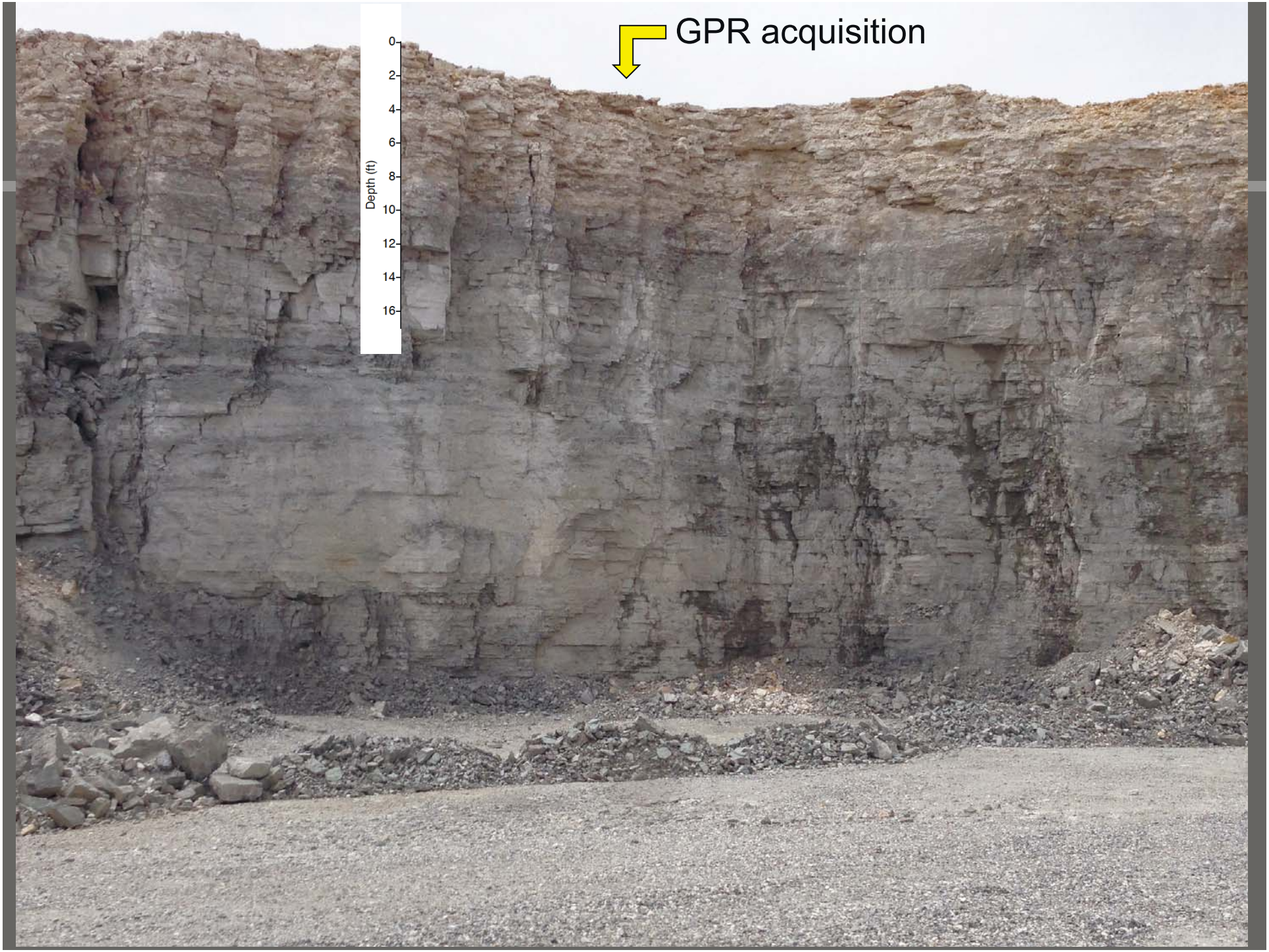
Hindsville Quarry 50 MHz GPR test (raw)

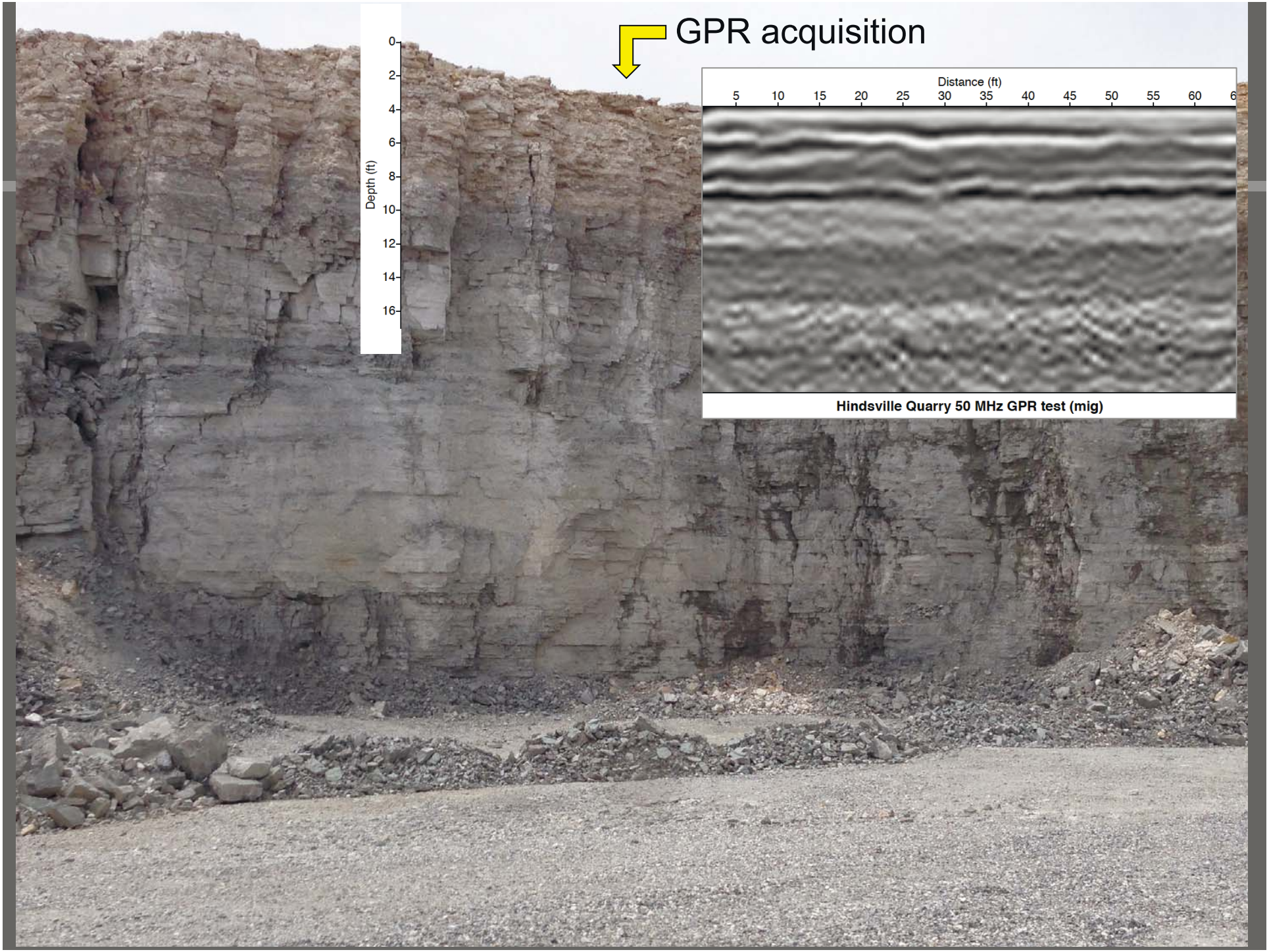
GPR Profile

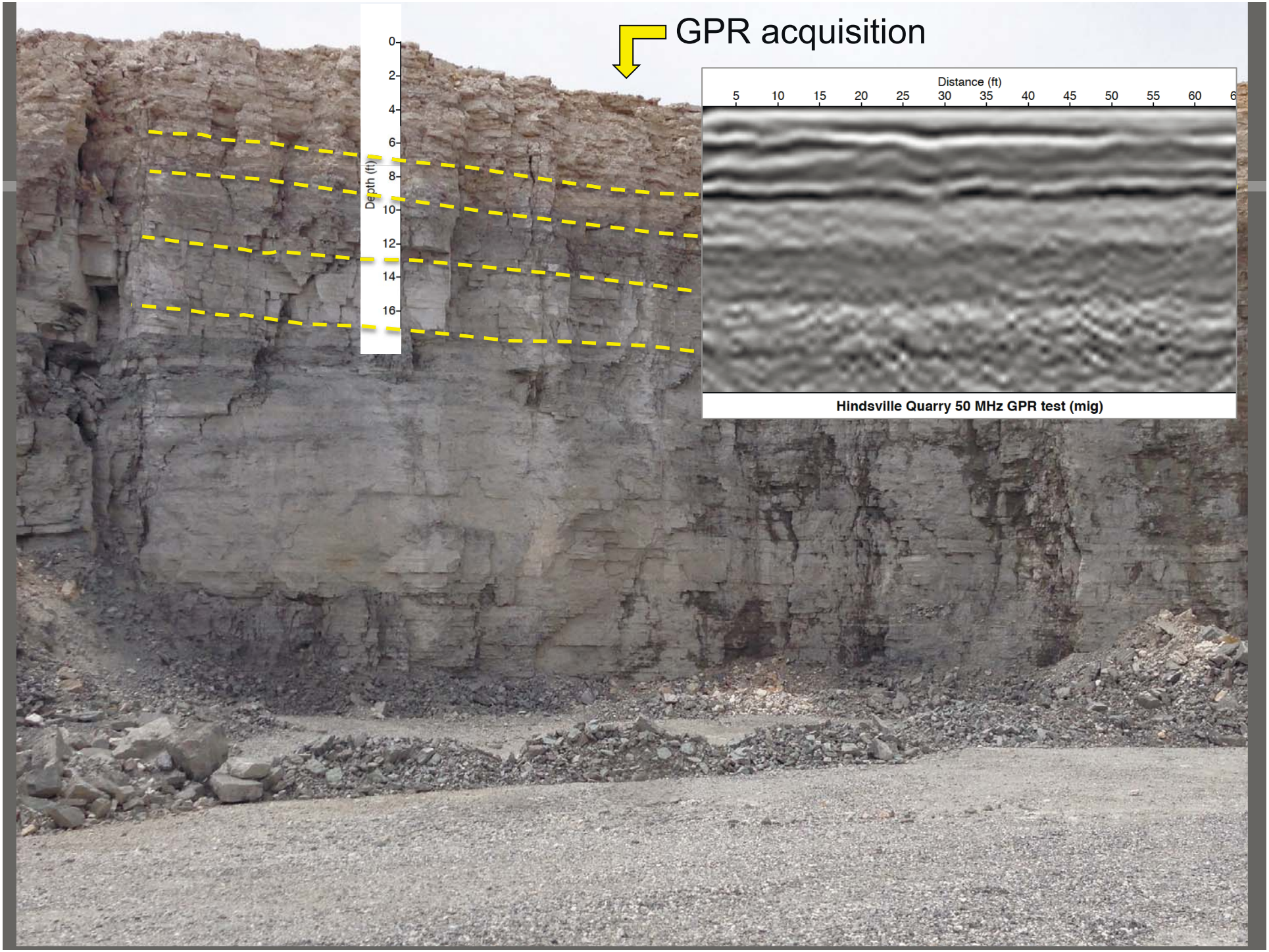


Hindsville Quarry 50 MHz GPR test (mig)


GPR acquisition

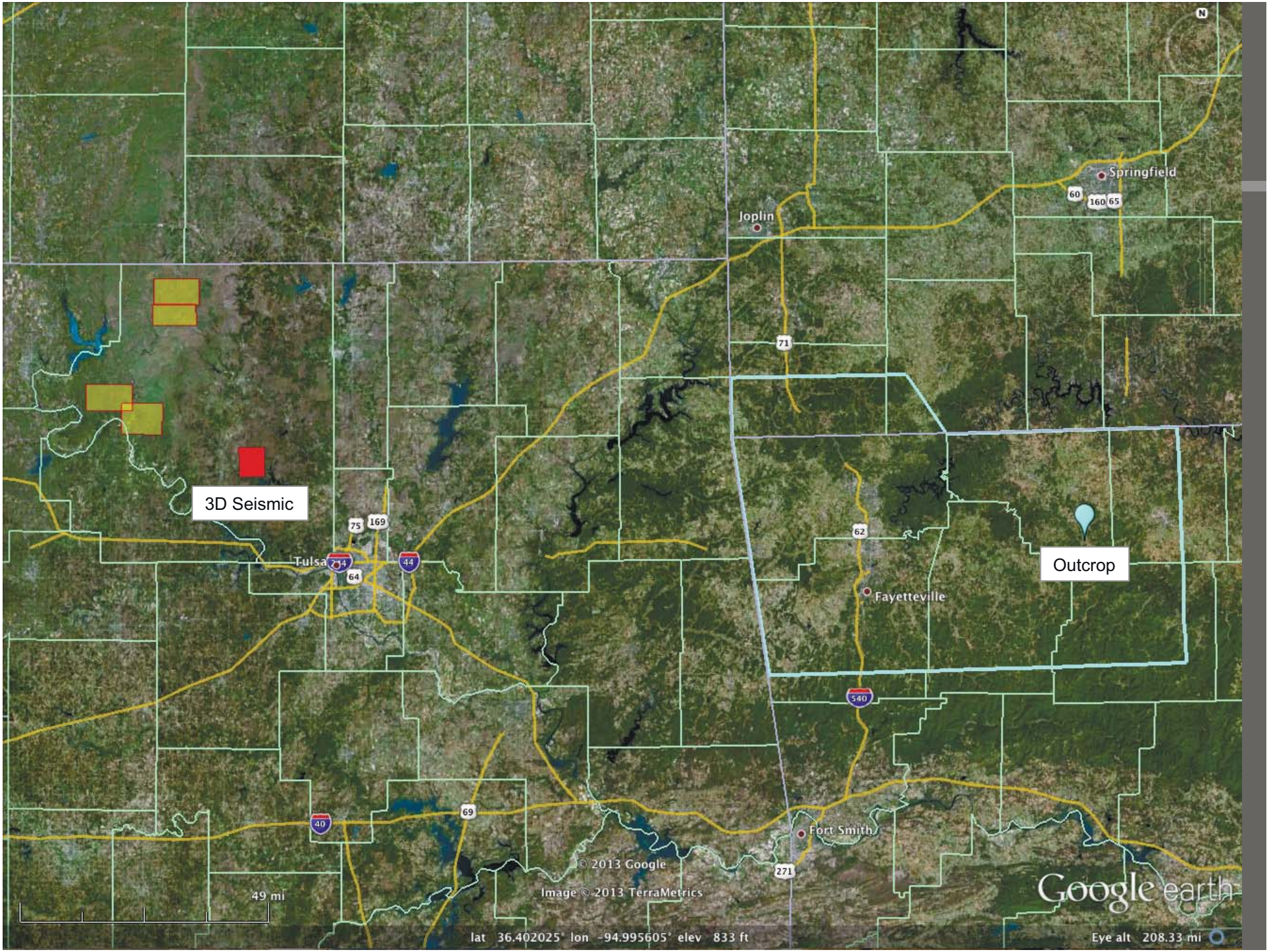

GPR acquisition
Depth (ft)
0
2
4
6
8
10
12
14
16


GPR acquisition
Depth (ft)
0
2
4
6
8
10
12
14
16
Distance (ft)
5
10
15
20
25
30
35
40
45
50
55
60
Hindsville Quarry 50 MHz GPR test (mig)

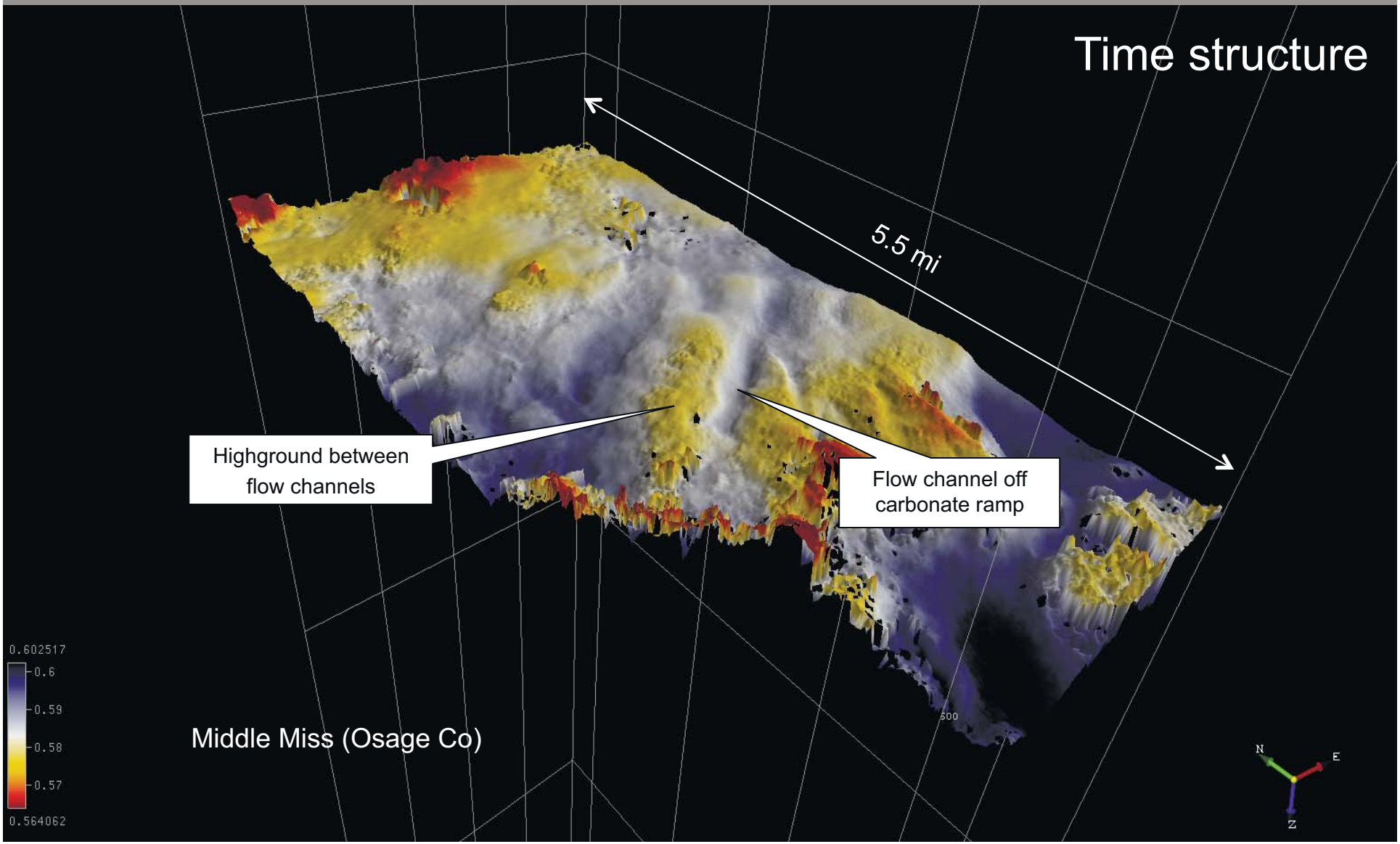

GPR acquisition
Depth (ft)
0
2
4
6
8
10
12
14
16
Distance (ft)
5
10
15
20
25
30
35
40
45
50
55
60
Hindsville Quarry 50 MHz GPR test (mig)

Geophysics: Transported Carbonate Sediment

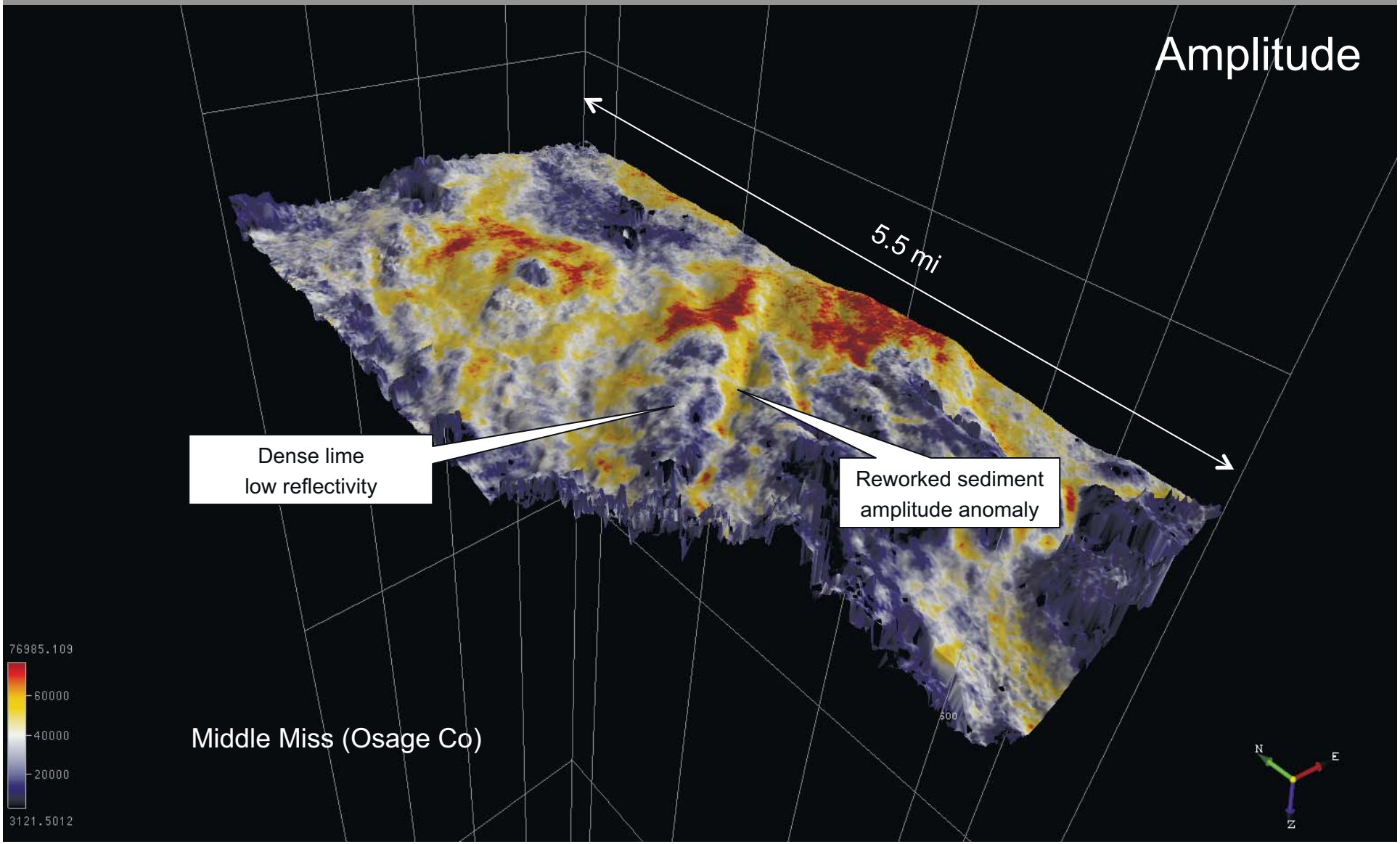
Geophysics: Transported Carbonate Sediment


3D Seismic
Outcrop
Springfield
Joplin
Tulsa
Fayetteville
Fort Smith
60
160
65
71
75
169
44
64
62
540
40
69
271
49 mi
© 2013 Google
Image © 2013 TerraMetrics
Google earth
lat 36.402025° lon -94.995605° elev 833 ft
Eye alt 208.33 mi

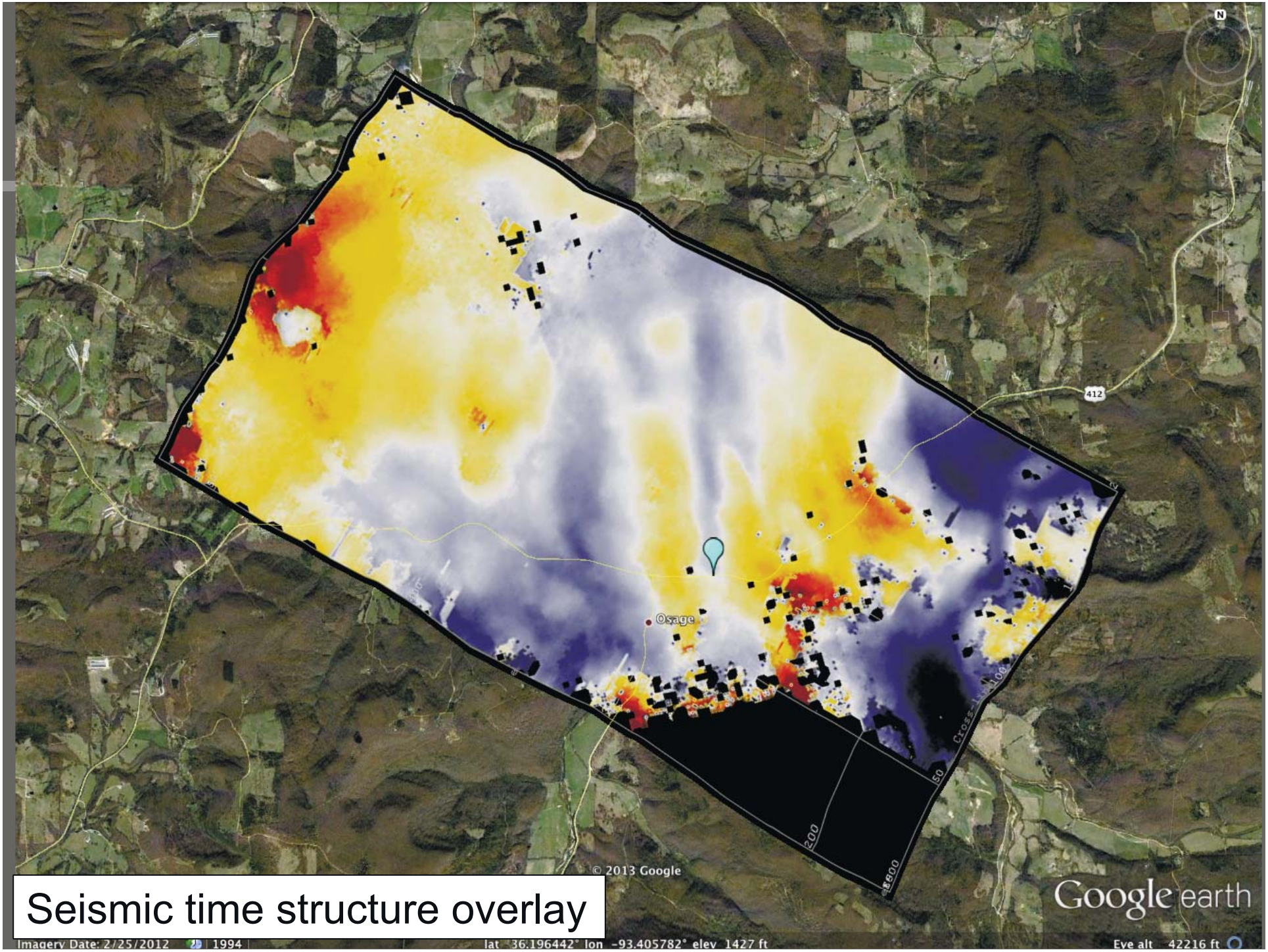
Geophysics: Transported Carbonate Sediment

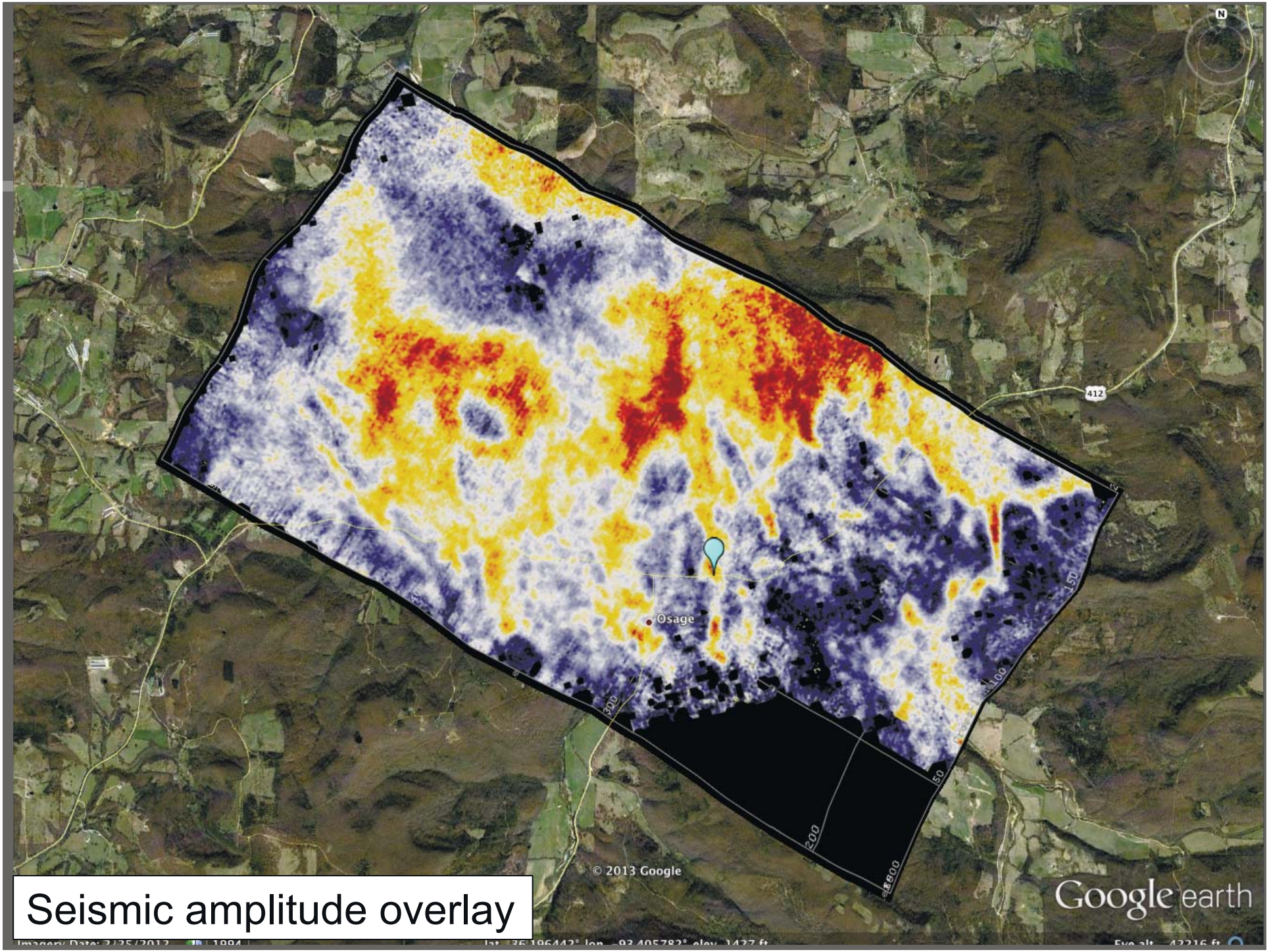


Geophysics: Transported Carbonate Sediment




N
412
Osage
© 2013 Google
9073 ft
103
Google earth
Imagery Date: 2/25/2012
1994
lat 36.196442° lon -93.405782° elev 1427 ft
Eye alt 42216 ft


Seismic time structure overlay
412
Osage
© 2013 Google
Google earth
Imagery Date: 2/25/2012
1994
lat 36.196442° lon -93.405782° elev 1427 ft
Eye alt 42216 ft



Seismic amplitude overlay

Ongoing Projects

Basement Faults and Sedimentary Structures

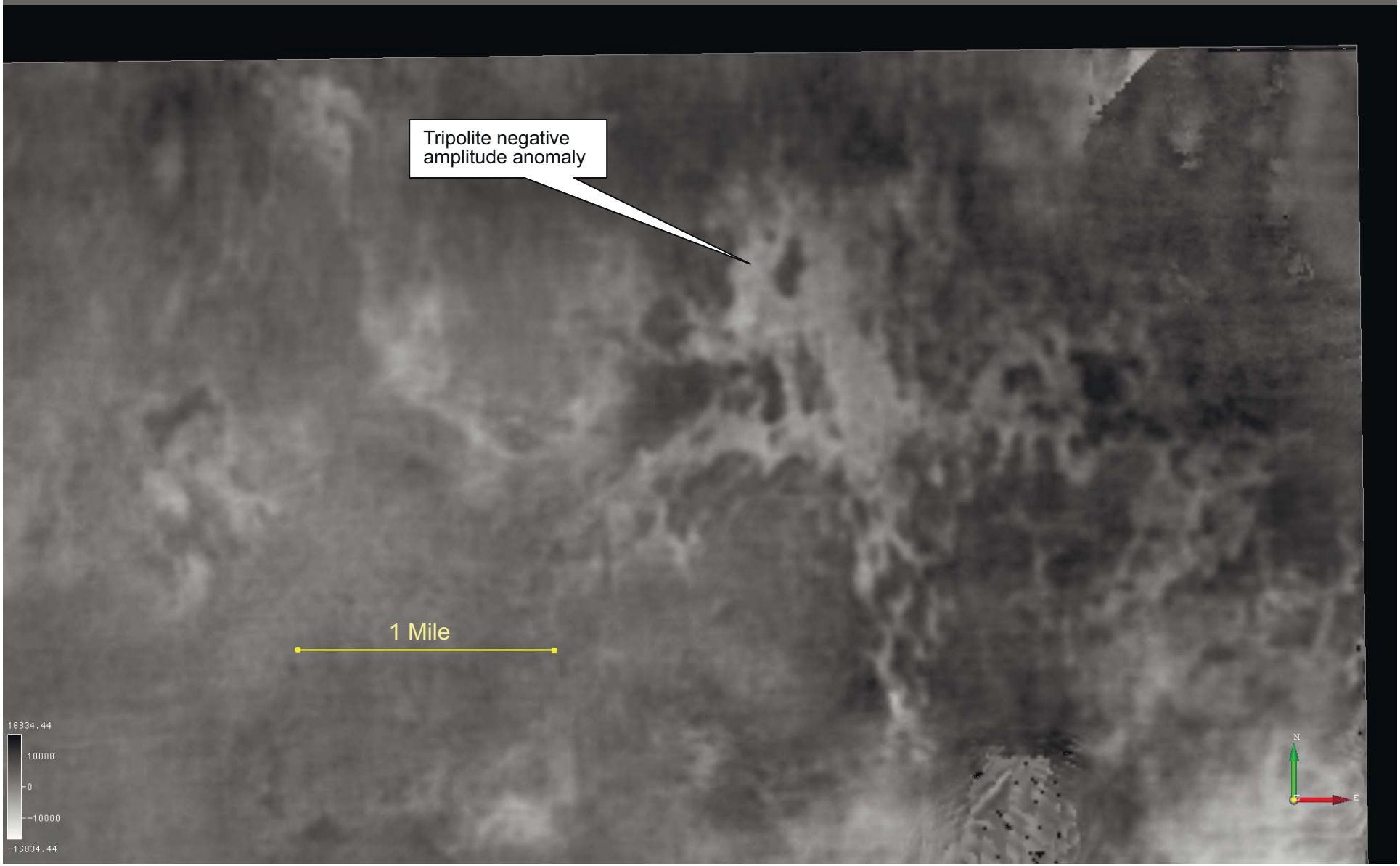
Mechanical Stratigraphy of Miss. Carbonates

Field Mapping of Basal Boone Chert Mounds

Penn Sequence Stratigraphy in NE Oklahoma

3D Seismic Mapping of Tripolite/Chat

Rethink the Tripolite



Conclusions

- Mississippian carbonate
  - Unconventional target in OK and KS
    - Complex reservoir
  - Near surface geophysics in AR can help
    - Formation contacts and fragments
    - Chert occurance and type
    - Transported sediment

liner@uark.edu

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