Arkansas Geological Survey
Bekki White, State Geologist and Director

Stratigraphy, Geochemistry, and Petrography of the Fayetteville Shale, North-Central Arkansas

Fayetteville Shale Poster
Miscellaneous Map Series
FF-MMS-OG-OZ-102
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Poster 1 of 2

ABSTRACT

Fayetteville Shale exposures along the Ozark Uplift of north-central Arkansas - Stratigraphy, Geochemistry, and Petrography

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The Mississippian Fayetteville Shale crops out across north-central Arkansas along the edge of the Arkoma Basin. Eight outcrops of the Fayetteville Shale were studied for their sedimentology, sequence stratigraphy, and GR log character (using a hand held scintillometer), and samples were obtained for petrographic (thin section) and geochemical (thermal maturation, organic content) attributes.

The basal part of the Fayetteville Shale overlies a ravinement surface at the top of the fossiliferous, quartzose, and very fine-grained Batesville Sandstone. Overlying the ravinement surface are interbedded organic-rich, silty to argillaceous and siliceous (locally phosphatic), petroliferous mudstones (transgressive deposits, condensed interval) that contain local concretions (calcareous and iron-rich). The section changes to primarily siliceous mudstones and chert approximately 40 miles to the east. Upsection, in the vicinity of Marshall, Arkansas, numerous stacked, graded beds (storm events), consisting of ooid/bivalve pack-stones/wackestones changing to micritic mudstones, calcareous cherts, and siliceous mudstones (distal highstand) are present. This sequence is cut by a ravinement surface having a bivalve-rich lag, and is overlain by dark-gray, siliceous mudstones that have a strong petroliferous odor (transgressive deposits, condensed interval). The remainder of the outcrop consists of light-gray, micritic and siliceous mudstones in bed-thickening parasequences (highstand) that are sharply overlain by a sequence boundary at the base of the Pitkin Limestone.

TOC values range from 0.28-8.3% (average 4.5%) and are generally higher in the organic-rich, siliceous and calcareous mudstones of the transgressive deposits/condensed interval associated with high GR values (over 200 API units). Vitrinite reflectance values (VRo) range from 0.82-1.55% (average 1.01%) and vary systematically with depth on the outcrop.

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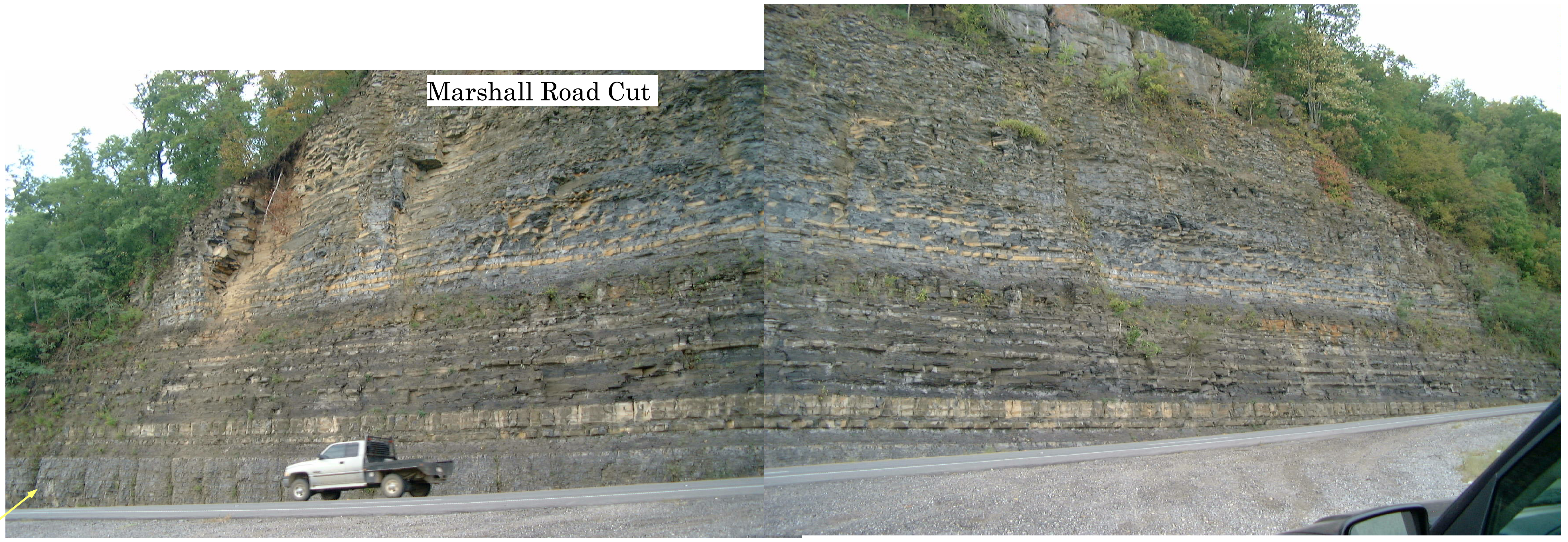
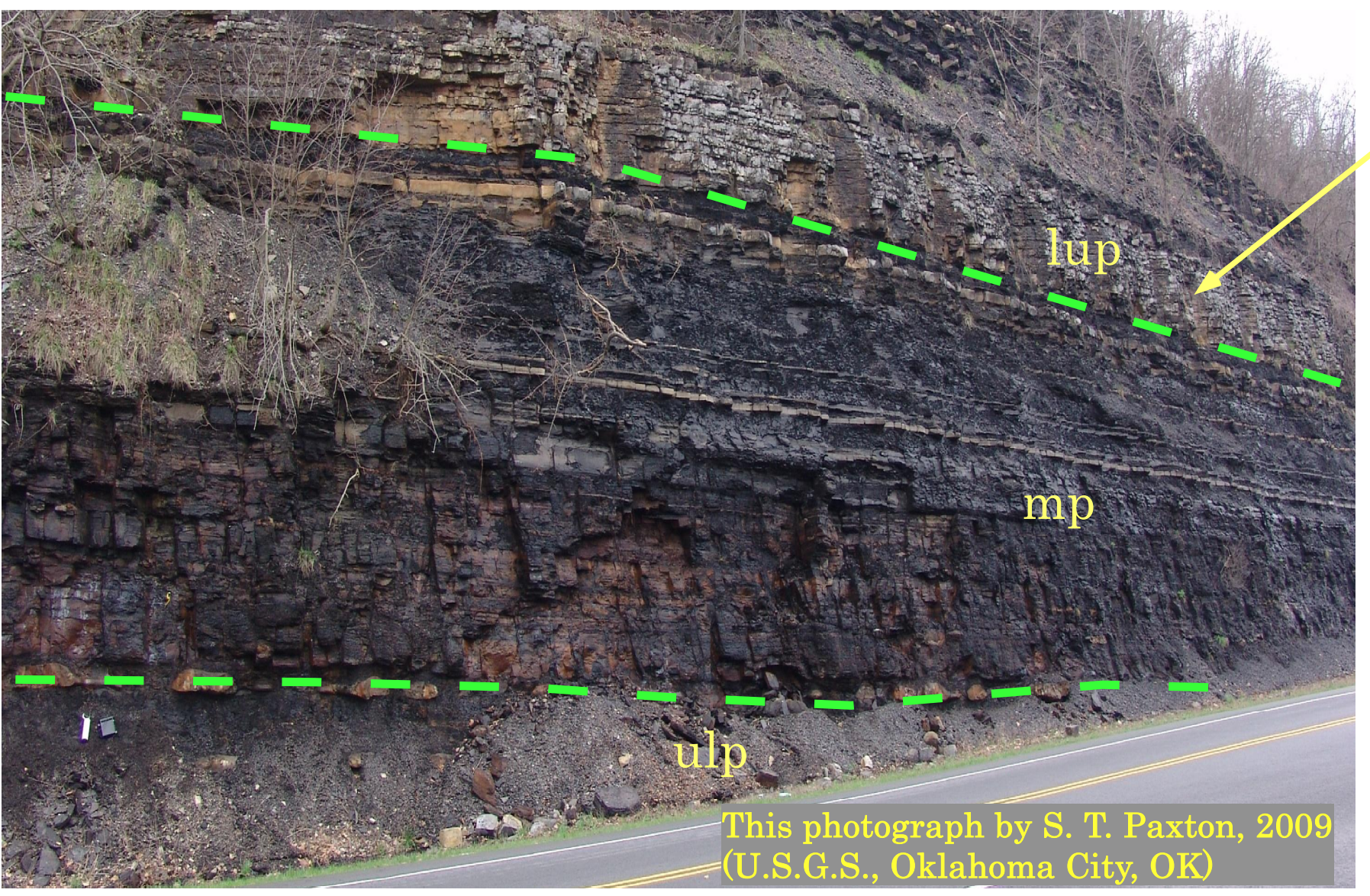
The authors extend their gratitude to EOG Resources in Oklahoma City, Oklahoma for providing data sets and permission to publish these posters


Marshall Road Cut

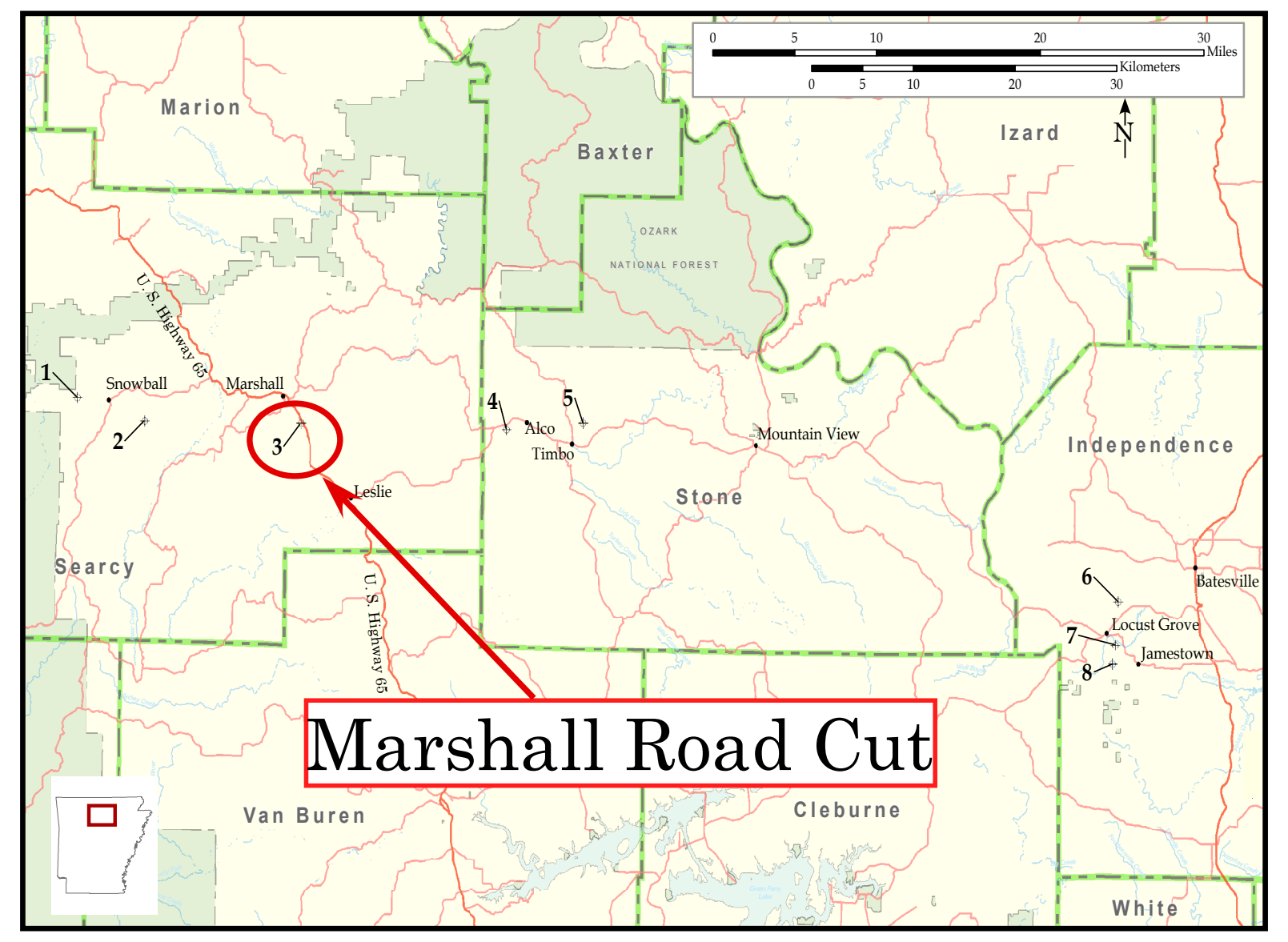
The upper part of the Fayetteville, and the lower part of the Pitkin Limestone are exposed. The roadcut is located south of Marshall, Arkansas, along U. S. Highway 65.

Informal unit boundaries shown in green


lup
mp
ulp
This photograph by S. T. Paxton, 2009 (U.S.G.S., Oklahoma City, OK)

The uppermost portion of the lower part (ulp), middle part (mp), and lower portion of the upper part (lup) of the Fayetteville Shale are exposed.

LOCATION


Marion
Baxter
Izard
N
Miles
Kilometers
OZARK NATIONAL FOREST
U.S. Highway 65
1
Snowball
Marshall
2
3
Leslie
4
Alco
Timbo
5
Mountain View
Independence
Stone
Searcy
Batesville
6
Locust Grove
7
Jamestown
8
Marshall Road Cut
Van Buren
Cleburne
White

Numbers refer to outcrop locations on POSTER 1 and POSTER 2

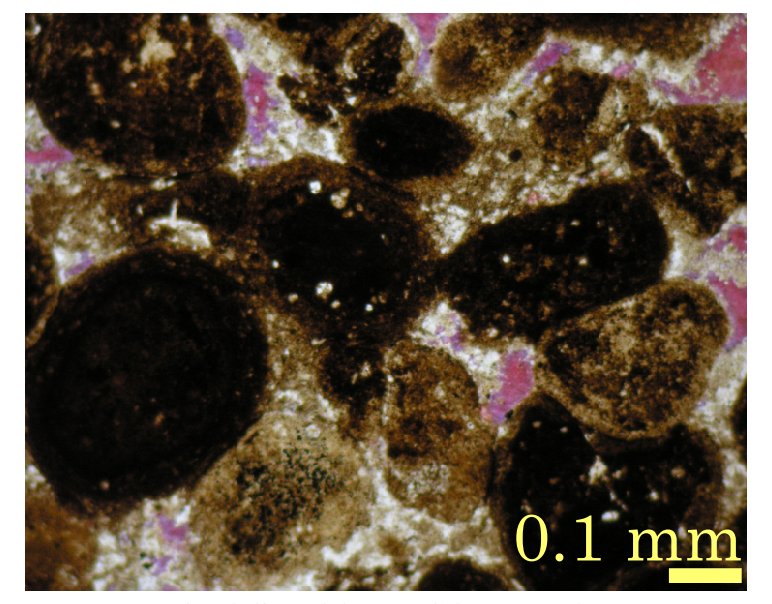
STRATIGRAPHIC SECTION

SYS.	SERIES	FORMATION
Miss.	Chesterian	Pitkin Ls
		Fayetteville Sh
		Batesville Ss
	Meramecian	Moorefield Sh
	Osagean	Boone Ls

PETROGRAPHIC SAMPLES

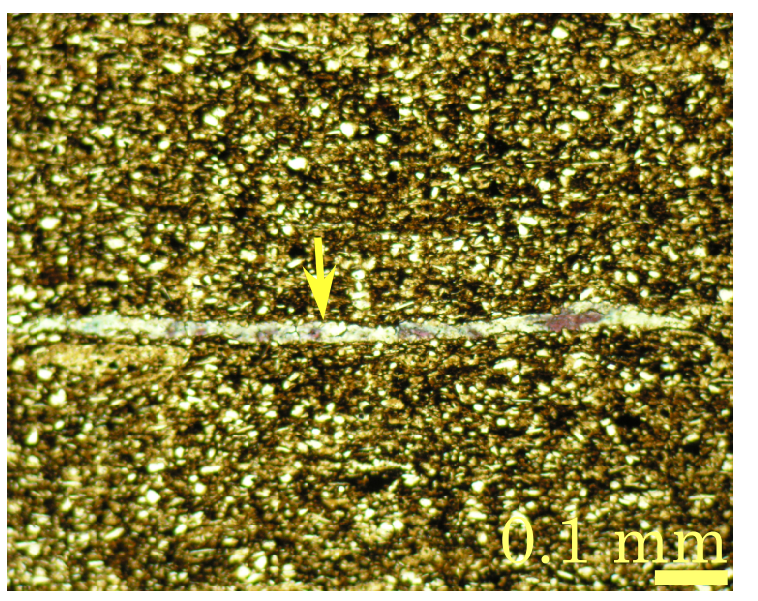
(Note: Numbers refer to outcrop sample location on photograph of Marshall Roadcut Interpreted and in XRD Data Table-Marshall Road Cut Samples)

②



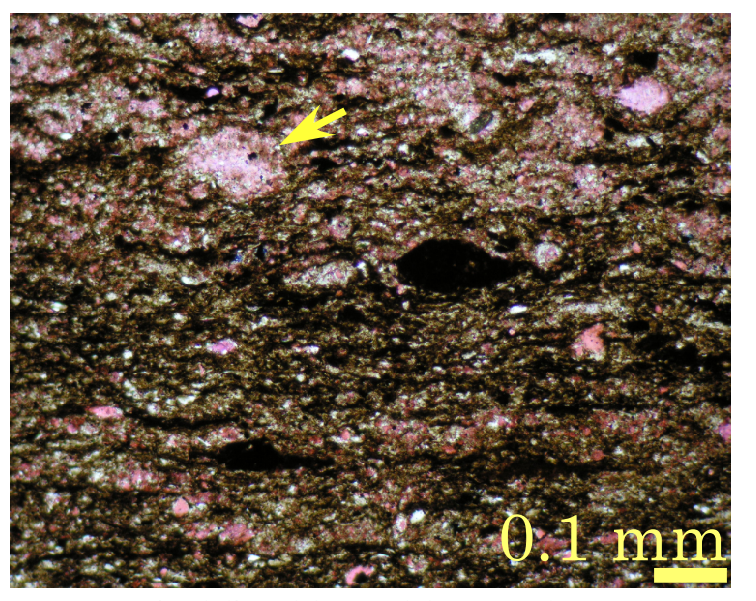
TRANSGRESSIVE/CONDENSED
Phosphatic nodule packstone/grainstone.
Packstone/grainstone with crude bedding, minor patches of compacted, detrital clay matrix and rare clay-rich laminations deformed by compaction. Consists of moderately-sorted phosphatic grains, some containing inclusions of silt-size quartz and mica.

①



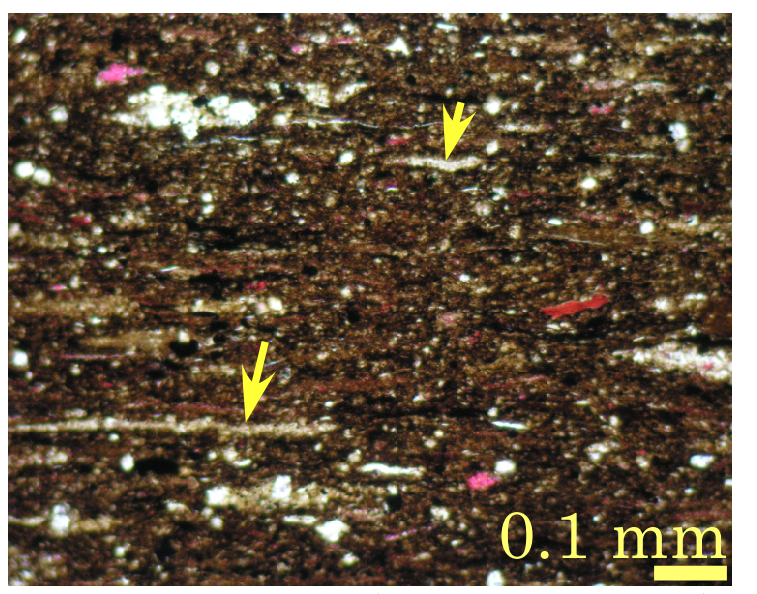
FLOODING SURFACE
Organic-rich, pyritic mudstone.
Dark gray, burrowed, with scattered silt-size grains, calcareous skeletal fragments, phosphatic grains, and pyritized organic fragments. Abundant clay matrix. Rare bivalve fragments (arrow).

③



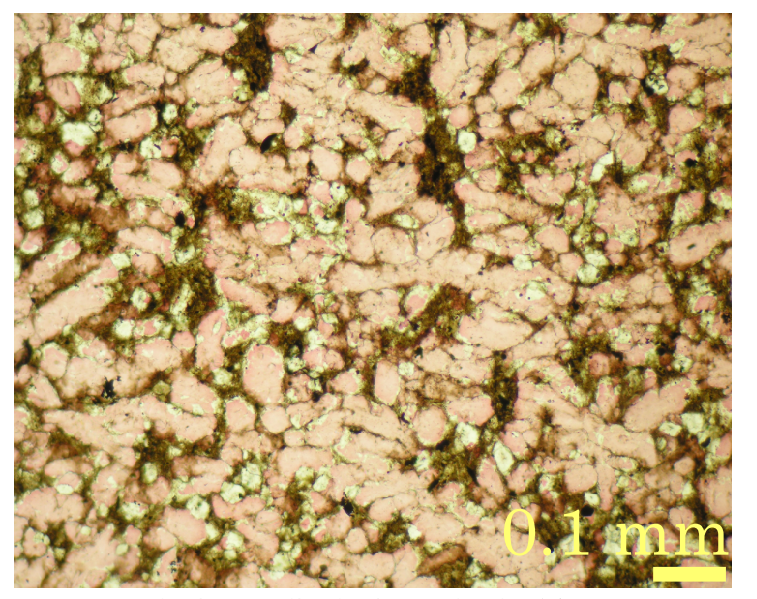
TRANSGRESSIVE/CONDENSED
Interlaminated siltstone, organic-rich skeletal wackestone/ mudstone, and organic pyritic siltstone.
Ripple- to thinly-laminated siltstone and limestone with wavy to lenticular bedding. Portions are burrowed. In the organic rich skeletal wackestone/mudstone, laminations are poorly defined. It contains rare thin-walled shell fragments that are partially replaced by ferroan calcite (arrow). Organic-rich pyritic siltstone is slightly calcareous.

④



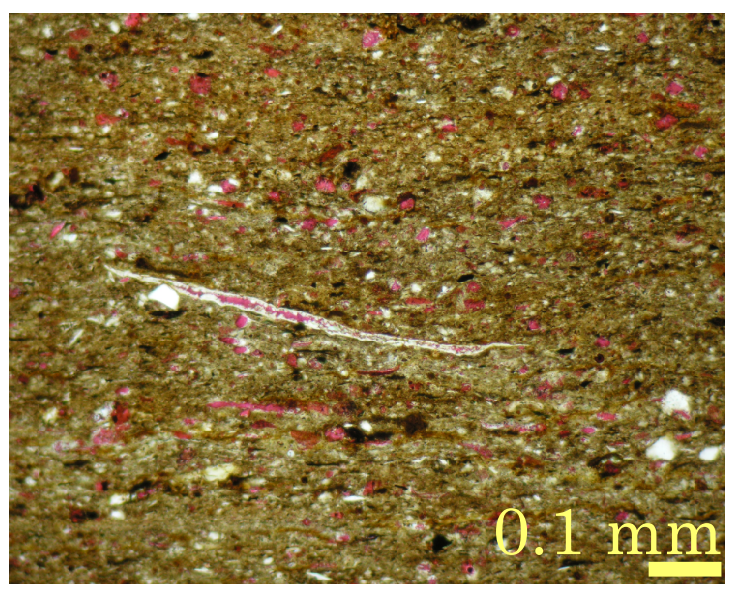
DISTAL HIGHSTAND (intervening mudstone)
Slightly silty, organic-rich, pyritic mudstone.
Dark gray to black, splintery and fissile mudstone with minor flattened shell fragments (arrows) subparallel to bedding. Pyritized organic matter, some medium silt-sized quartz. Minor amounts of thin-walled bivalve fragments. Rare Tasmanites spores.

⑤



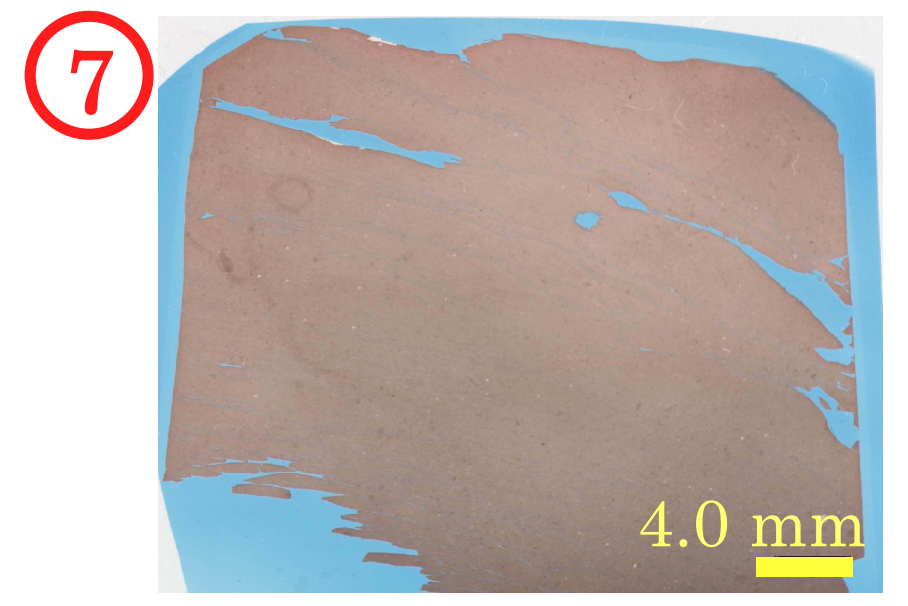
DISTAL HIGHSTAND STORM BED
Argillaceous, dolomitic skeletal packstone.
Slightly argillaceous and dolomitic fossiliferous limestone with crude bedding (fossils). Majority of sample is a shell hash with well-sorted bivalve fragments.

⑥



DISTAL HIGHSTAND
Organic-rich, pyritic mudstone (slightly silty mudstone).
Dark brownish gray to black, slightly silty mudstone with mm-scale laminations defined by subtle changes in the concentrations of clay, organic matter, and pyrite. Matrix consists mostly of clay and pyritized, elongate organic material, with common fine calcareous skeletal debris. Bivalves, brachiopods, sponge spicules, and Tasmanites spores.

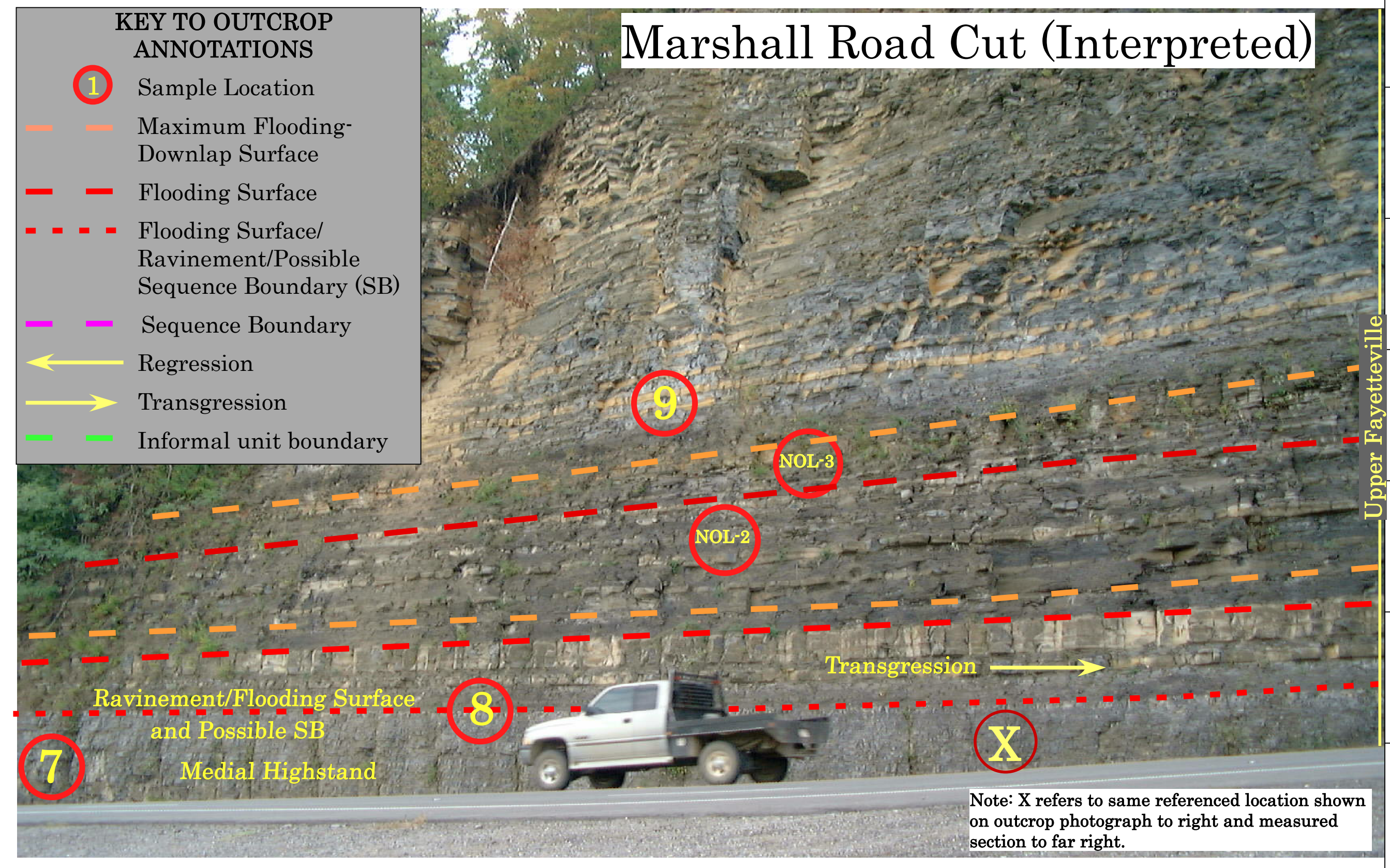
⑦

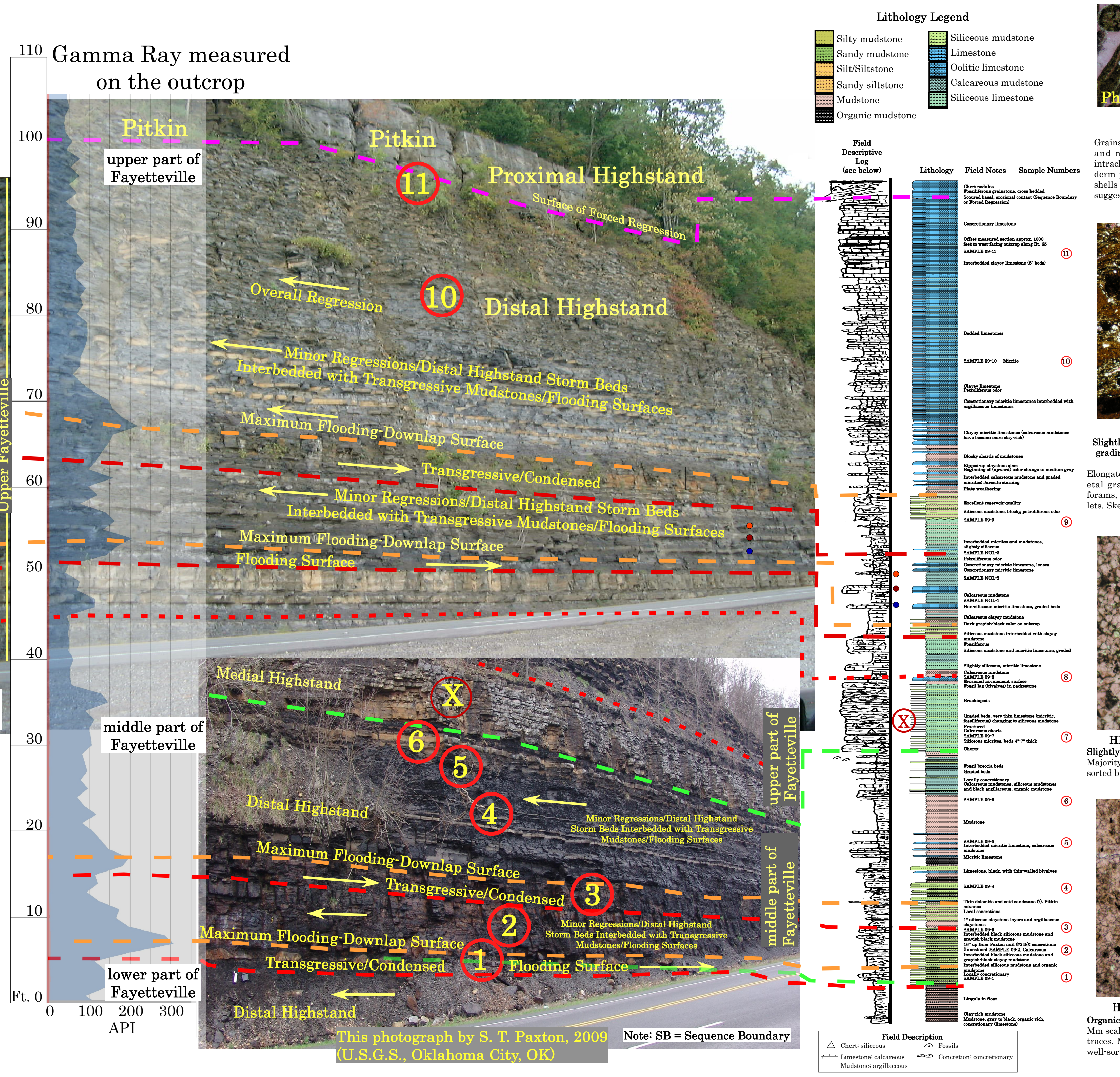


HIGHSTAND DEPOSITS (GRADED BEDS)
Peloidal packstone.
Light brownish gray, peloidal limestone. Massive to faintly bedded. Well packed, recrystallized peloids and minor scattered organic fragments; rare bivalves.

KEY TO OUTCROP ANNOTATIONS

- ① Sample Location
- Maximum Flooding-Downlap Surface
- Flooding Surface
- Flooding Surface/ Ravinement/Possible Sequence Boundary (SB)
- Sequence Boundary
- ← Regression
- → Transgression
- Informal unit boundary




Marshall Road Cut (Interpreted)
9
NOL-3
NOL-2
Transgression
8
Ravinement/Flooding Surface and Possible SB
7
Medial Highstand
X
Upper Fayetteville
Gamma Ray measured on the outcrop
110
100
90
80
70
60
50
40
30
20
10
Ft. 0
0
100
200
300
API
Pitkin
upper part of Fayetteville
middle part of Fayetteville
lower part of Fayetteville
Pitkin
11
Proximal Highstand
Surface of Forced Regression
Overall Regression
10
Distal Highstand
Minor Regressions/Distal Highstand Storm Beds Interbedded with Transgressive Mudstones/Flooding Surfaces
Maximum Flooding-Downlap Surface
Transgressive/Condensed
Minor Regressions/Distal Highstand Storm Beds Interbedded with Transgressive Mudstones/Flooding Surfaces
Maximum Flooding-Downlap Surface
Flooding Surface
Medial Highstand
X
6
5
4
Distal Highstand
Minor Regressions/Distal Highstand Storm Beds Interbedded with Transgressive Mudstones/Flooding Surfaces
Maximum Flooding-Downlap Surface
Transgressive/Condensed
3
2
Minor Regressions/Distal Highstand Storm Beds Interbedded with Transgressive Mudstones/Flooding Surfaces
Maximum Flooding-Downlap Surface
Transgressive/Condensed
1
Flooding Surface
Distal Highstand
upper part of Fayetteville
middle part of Fayetteville
This photograph by S. T. Paxton, 2009 (U.S.G.S., Oklahoma City, OK)
Field Descriptive Log (see below)
Lithology
Field Notes
Sample Numbers
Field Description
Chert; siliceous
Fossils
Limestone; calcareous
Concretion; concretionary
Mudstone; argillaceous

Note: X refers to same referenced location shown on outcrop photograph to right and measured section to far right.

Note: SB = Sequence Boundary

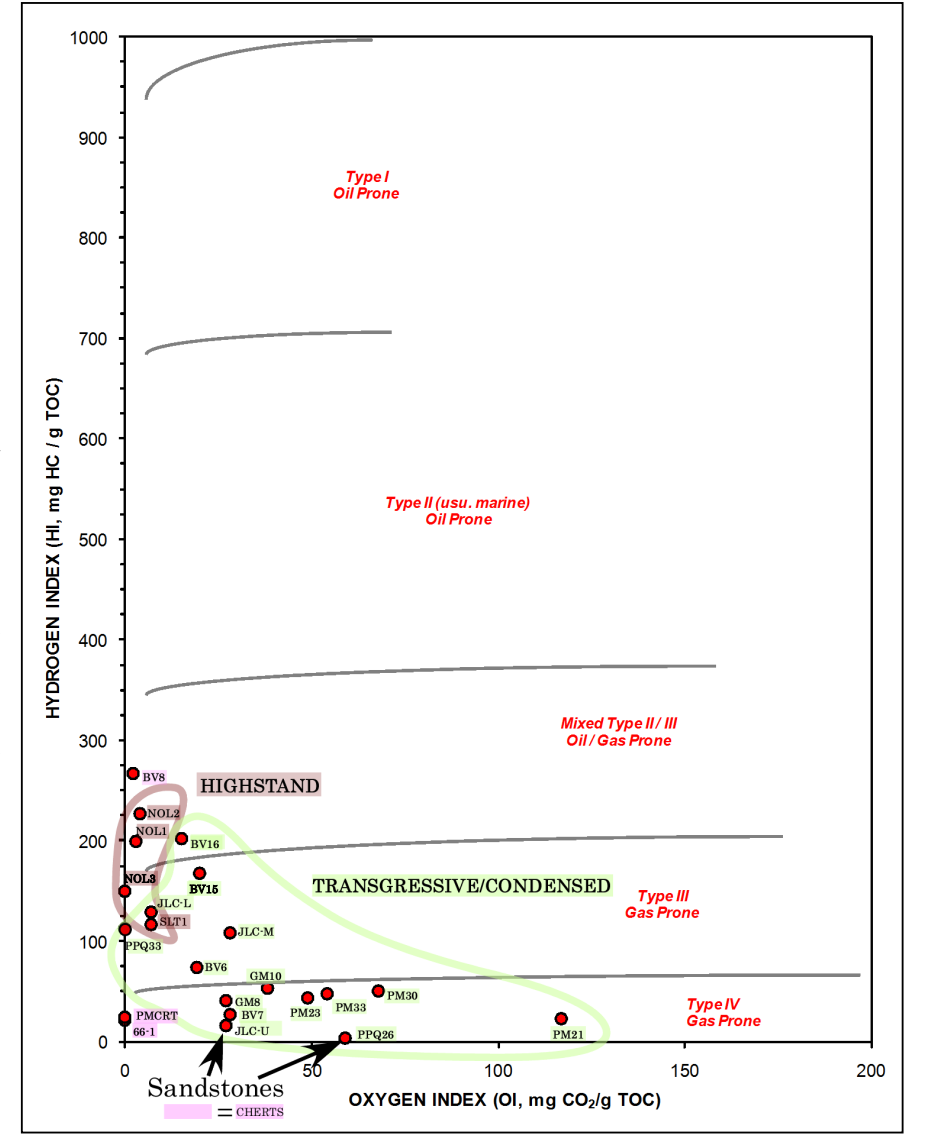
Lithology Legend

Silty mudstone	Siliceous mudstone
Sandy mudstone	Limestone
Silt/Siltstone	Oolitic limestone
Sandy siltstone	Calcareous mudstone
Mudstone	Siliceous limestone
Organic mudstone	

GEOCHEMISTRY

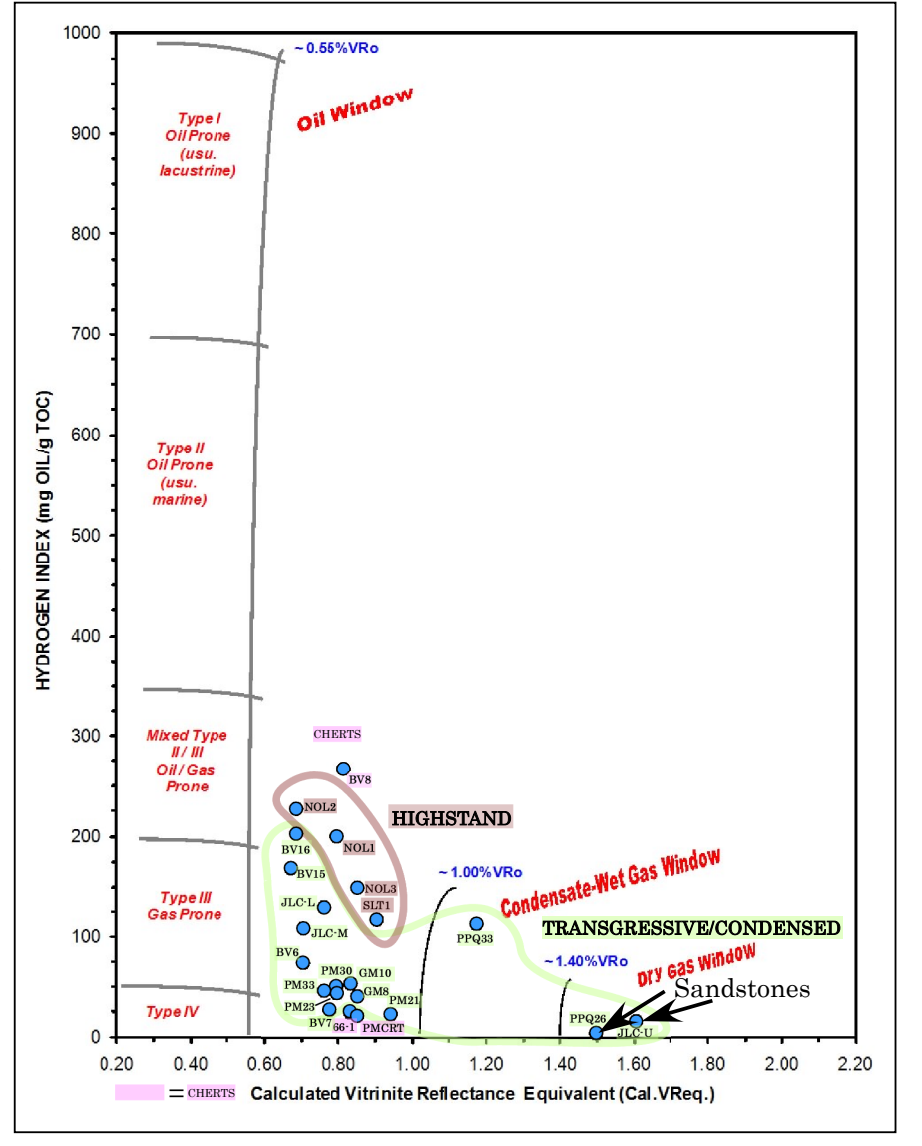
Kerogen Type

All outcrop samples fall in the range of Type II-IV with Hydrogen Indices less than 300 and Oxygen Indices generally less than 75. Highstand shales tend to be Type II/III; shales of the Transgressive/Condensed interval tend to be Types III and IV.



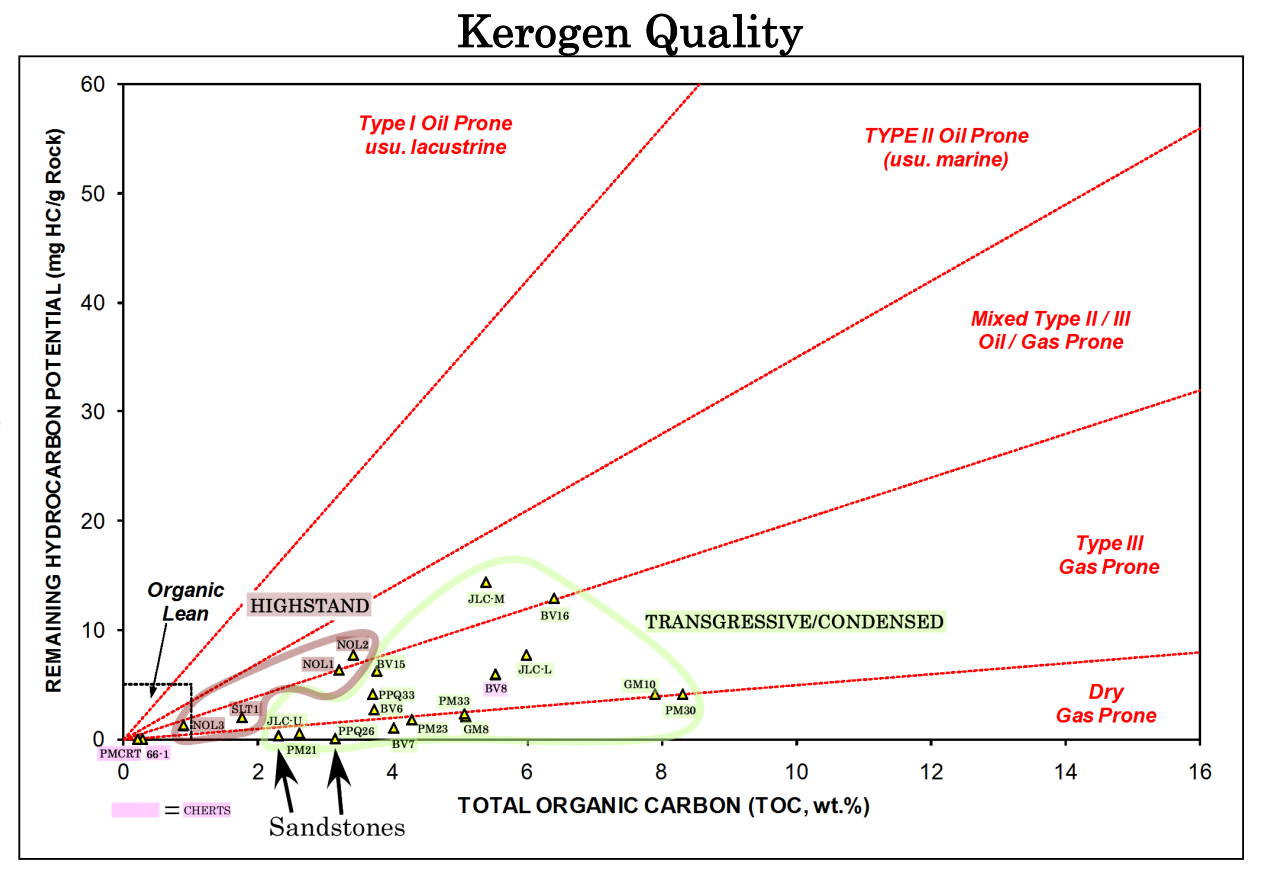
Kerogen Type and Maturity

Most outcrop samples (18/21) have calculated VRo values less than 1.00 (mixed oil & gas prone).



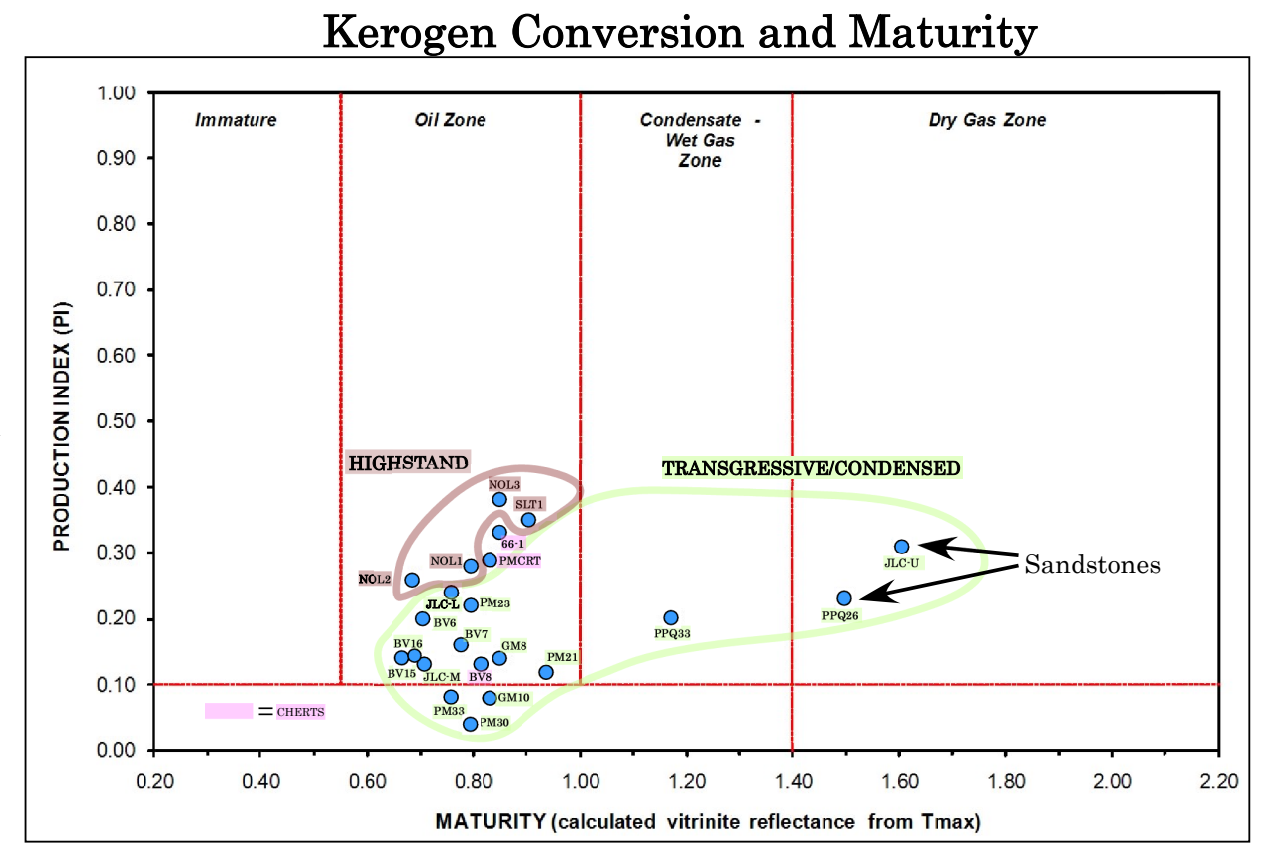
Kerogen Quality

Highstand shales tend to have lower TOC's (<4%) than shales of the Transgressive/Condensed interval (2-8.3%).



Kerogen Conversion and Maturity

Highstand shales tend to have slightly higher Productivity Indices.



⑧

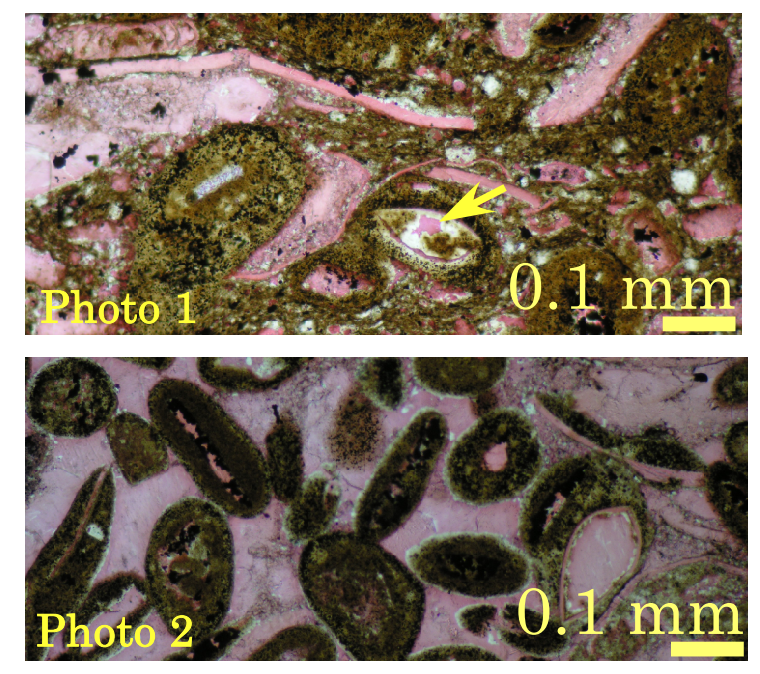
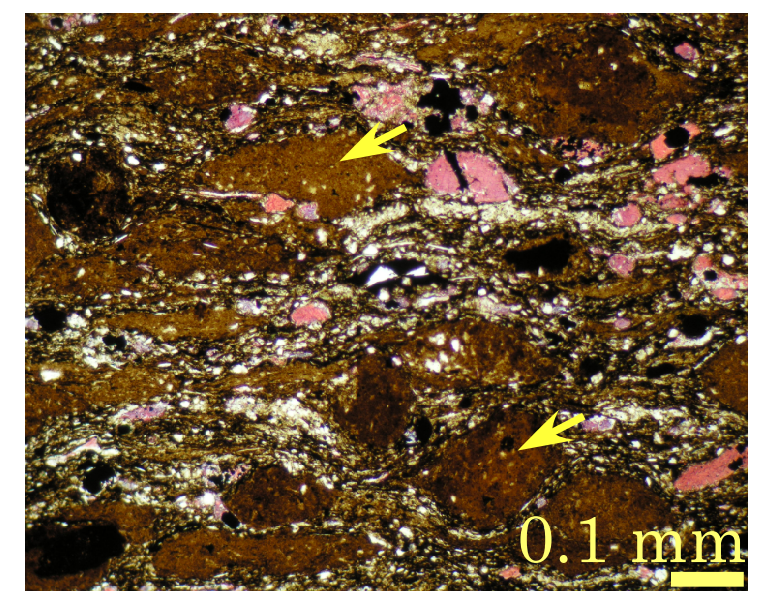


Photo 1
0.1 mm
Photo 2
0.1 mm

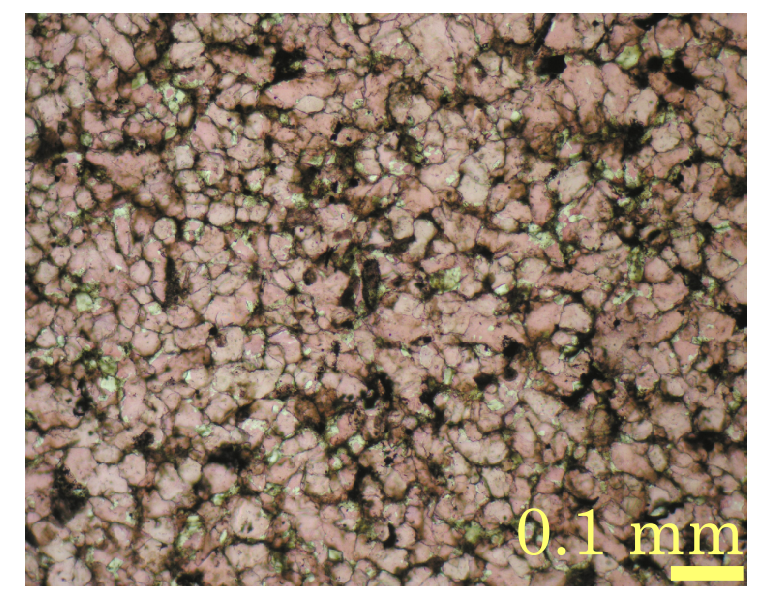
TRANSGRESSIVE LAG
Skeletal-rich phosphatic nodular packstone.
Grains consist predominantly of well sorted phosphatic grains, and minor phosphate-coated skeletal clasts, siliceous intraclasts, and fecal pellets. Abraded bivalves, minor echinoderm plates, forams, ostracods (arrow). Many of the curved shells are filled with depositional mud on their concave side, suggesting they were eroded and re-deposited.

⑨



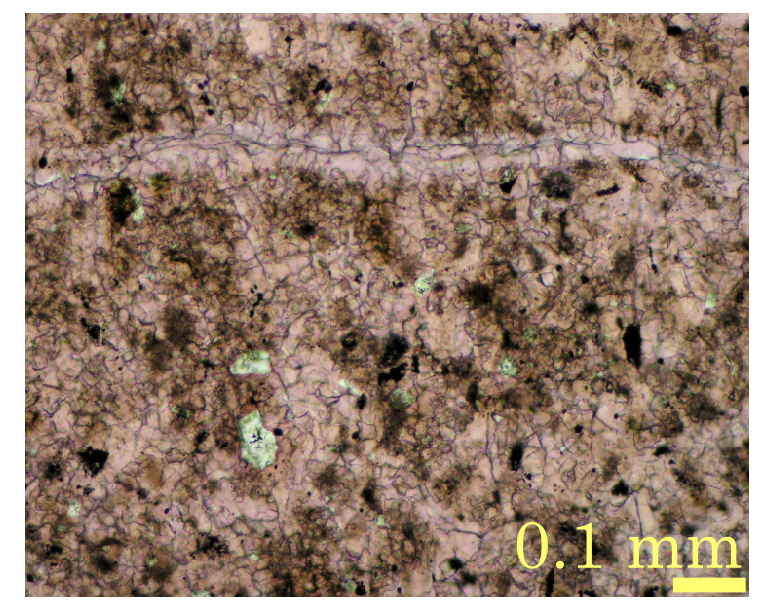
DISTAL HIGHSTAND STORM BED
Slightly fossiliferous, muddy phosphatic nodule packstone, grading to slightly silty, fossiliferous phosphatic nodular packstone.
Elongated, compacted phosphatic grains (arrows); minor skeletal grains (thin-walled bivalves), rare spines, ostracods, forams, phosphatic tooth and bone fragments, and fecal pellets. Skeletal fragments abraded.

⑩



HIGHSTAND DEPOSITS (STORM BEDS)
Slightly argillaceous, dolomitic skeletal packstone/grainstone.
Majority of sample appears to be a shell hash with very well-sorted bivalve fragments. Offshore or lower shoreface.

⑪



HIGHSTAND DEPOSITS (STORM BEDS)
Organic-rich, slightly dolomitic, skeletal packstone/grainstone.
Mm scale laminations and possible ripple laminations or burrow traces. Majority of sample appears to be a shell hash with very well-sorted bivalve fragments. Offshore or lower shoreface?

X-Ray Diffraction Analysis (Weight %)*

Marshall Road Cut Samples Only

Sample	CLAYS				CARBONATES			OTHER MINERALS						TOTALS		
Identity	Chlorite	Kaolinite	Illite	Mx I/S*	Calcite	Fe-Dol	Siderite	Quartz	K-spar	Plag.	Pyrite	Apatite	Barite	Clays	Carb.	Other
01	2	1	3	2	34	1	Tr	16	Tr	2	13	26	0	8	35	57
02	Tr	Tr	2	Tr	91	0	Tr	3	Tr	1	1	2	0	2	91	7
03	4	1	33	4	24	0	Tr	28	1	2	1	2	0	42	24	34
04	2	1	19	2	12	1	Tr	30	1	4	12	16	0	24	13	63
05	12	2	37	5	Tr	0	Tr	31	1	6	4	2	0	56	Tr	44
06	Tr	Tr	3	1	84	0	Tr	8	Tr	2	1	1	0	4	84	12
07	3	1	8	1	60	4	Tr	17	1	2	2	1	0	13	64	23
08	4	1	13	2	9	0	Tr	56	1	3	3	8	0	20	9	71
09	2	1	7	2	67	6	Tr	12	Tr	1	1	1	0	12	73	15
10	2	1	4	2	5	0	Tr	27	Tr	1	1	57	0	9	5	86
11	8	2	23	3	26	2	Tr	24	1	4	4	3	0	36	28	36
AVERAGE	4	1	14	2	37	1	Tr	23	1	2	4	11	0	21	38	41

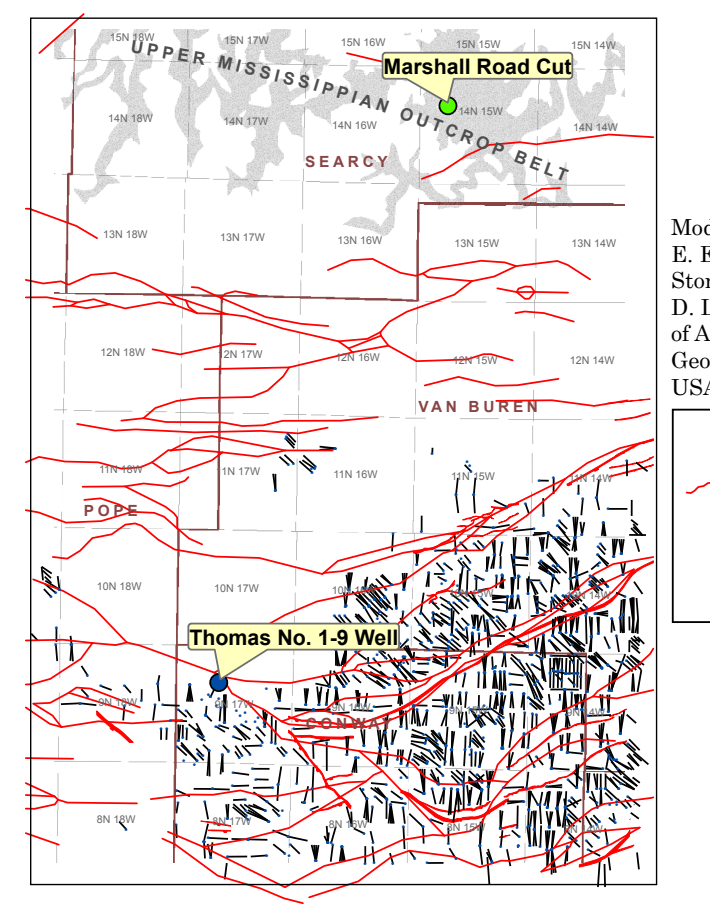
* Randomly interstratified mixed-layer illite/smectite; Approximately 85-90% expandable layers

CHERTS
HIGHSTAND
TRANSGRESSIVE/CONDENSED
TRANSGRESSIVE LAG
FLOODING SURFACE

Samples From All Outcrops (POSTERS 1 and 2)

Sample	CARBONATES			OTHER MINERALS							TOTALS		
ID	Calcite¹	Dolomite	Siderite	Quartz	K-spar	Plag.	Pyrite	Apatite	Hydroxide*	Hematite	Clays	Carb.	Other
JLC-U	0	0	Tr	92	0	1	Tr	0	0	0	7	Tr	93
JLC-M	0	0	Tr	90	0	1	0	0	0	0	9	Tr	91
JLC-L	Tr	0	1	60	Tr	2	7	0	0	0	30	1	69
NOL-2★	10	16	10	22	0	7	13	0	0	0	22	36	42
NOL-3★	72	4	Tr	13	1	2	2	0	0	0	6	76	18
BV-6	Tr	0	Tr	94	0	0	1	0	0	0	5	Tr	95
BV-7	Tr	0	1	74	Tr	1	1	0	0	0	23	1	76
BV-8	2	2	0	86	Tr	1	2	0	0	0	7	4	89
BV-15	8	Tr	Tr	64	0	3	4	0	0	0	21	8	71
BV-16	Tr	0	0	76	0	2	1	0	0	0	21	Tr	79
PPQ-16	0	0	Tr	77	1	1	Tr	0	1	Tr	20	Tr	80
PPQ-26	Tr	0	0	52	1	1	Tr	0	0	0	46	Tr	54
PPQ-33	11	1	0	36	2	1	7	0	0	0	42	12	46
PM-21	Tr	0	2	66	Tr	3	4	Tr	0	0	25	2	73
PM-23	1	1	3	33	1	2	3	0	0	0	56	5	39
PM-30	1	0	1	40	Tr	5	1	0	0	0	52	2	46
PM-33	1	0	3	44	1	5	2	0	0	0	44	4	52
PM-Chert	1	0	0	98	0	0	Tr	0	0	0	1	1	98
GM-8	2	0	1	44	1	3	1	0	0	0	48	3	49
GM-10	Tr	0	1	49	Tr	5	Tr	0	0	0	45	1	54
66-1	1	2	Tr	94	0	0	1	0	0	0	2	3	95
Slate-1	47	1	1	31	0	7	2	0	0	0	11	49	40
AVERAGE	7	1	1	62	Tr	2	2	Tr	Tr	Tr	25	9	66

¹May include the Fe-rich variety. *Includes 1% gibbsite [Al(OH)3] & Tr goethite [FeO(OH)]
★ These 2 samples are from Marshall Road Cut (POSTER 1); remaining samples are shown on POSTER 2


UPPER MISSISSIPPIAN OUTCROP BELT
Marshall Road Cut
SEARCY
VAN BUREN
POPE
Thomas No. 1-9 Well

Well location of downhole log

Modified after Haley, B. R., Glick, E. E., Bush, W. V., Clardy, B. F., Stone, C. G., Woodward, M. B., and D. L. Zachary, 1993, Geologic Map of Arkansas, scale 1:500,000 U. S. Geological Survey, Reston, Virginia, USA.

LEGEND

- Surface fault
- Plan view projections of horizontal well laterals

KEY

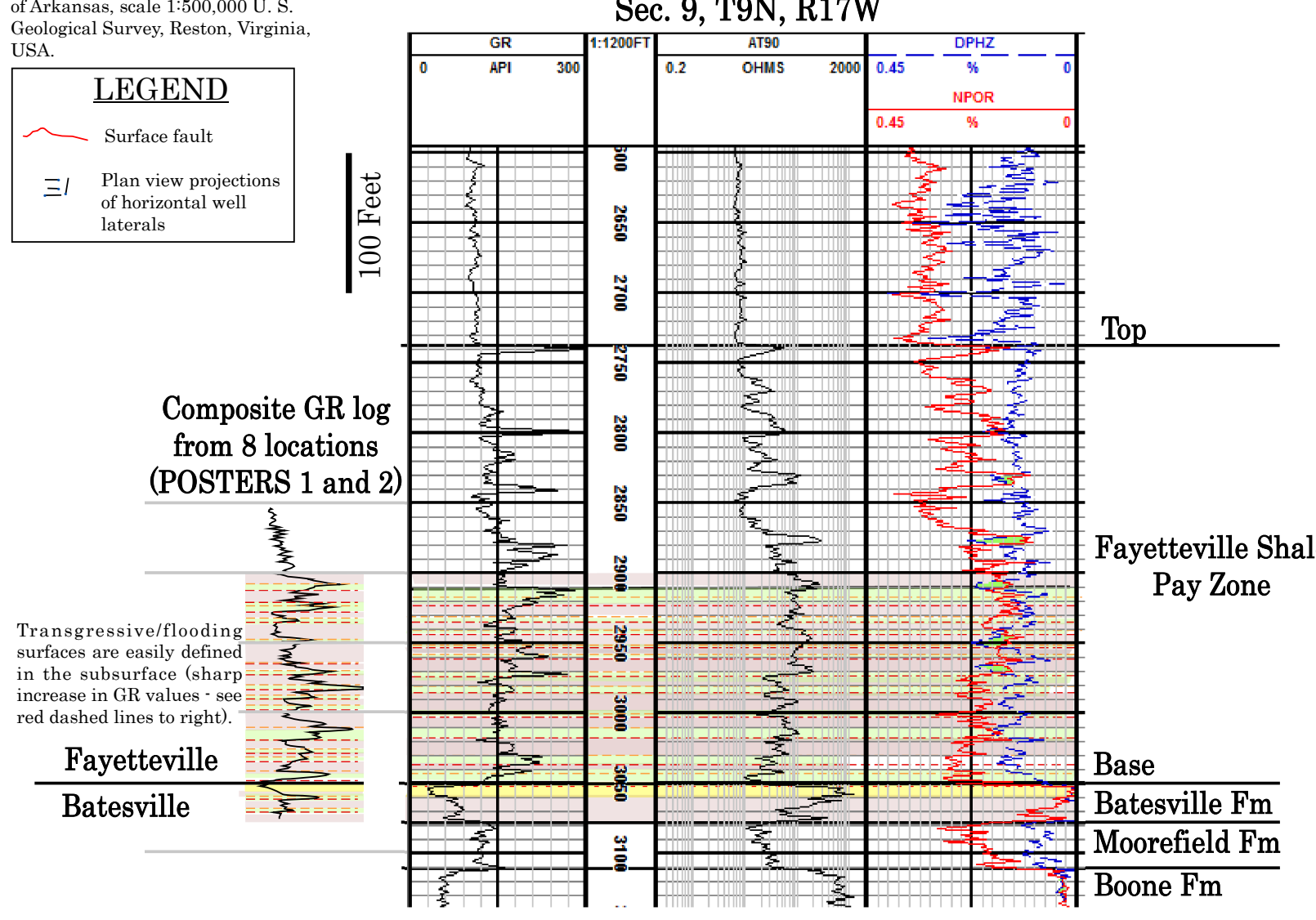
HIGHSTAND
TRANSGRESSIVE/ CONDENSED
SANDSTONE

- Sequence Boundary
- Maximum Flooding-Downlap Surface
- Flooding Surface
- Flooding Surface/ Ravinement/Possible Sequence Boundary (SB)

Log Calibration

Outcrop composite gamma ray log calibrated to downhole log with stratigraphic correlation

Thomas No. 1-9
Sec. 9, T9N, R17W



Transgressive/flooding surfaces are easily defined in the subsurface (sharp increase in GR values - see red dashed lines to right).

Typical well log response in the Fayetteville Shale, Thomas 1-9. The discovery well is located in the B-43* Production Area.

Modified from Ratchford, M. E., Bridges, L.C., Jordan, D., Dow, W. G., Colbert, A., and D. M. Jarvie, 2006, Organic Geochemistry and Thermal Maturation Analysis within the Fayetteville Shale Study Area - Eastern Arkoma Basin and Mississippi Embayment Regions, Arkansas: Information Circular 37, Arkansas Geological Commission.

*Production Area is defined by the Arkansas Oil and Gas Commission