Clay Mineralogy, Provenance, and Sequence Stratigraphy of Upper Ordovician Shales in Eastern Ohio*

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Abstract

A combination of x-ray diffraction analyses of core data and spectral gamma ray logs were used to interpret the largely shale succession of the Late Ordovician between the top of the Trenton Limestone and the Queenston Shale in the subsurface of east-central Ohio. The four county study area is within the back-bulge region of the foreland basin associated with the Taconic Orogeny. The XRD data from the basal portion of the section reveal an increase upward in chlorite and quartz along with a decrease in carbonate, which is consistent with an increase in detrital rather than authigenic clays. Detrital chlorite is a common clay mineral in sediments shed from mountain belts and the appearance of the clay allows constraints to be placed on the transition from under to overfilled foreland basin. Isopach maps of six 4th-order sequences from 300 wells show that subsidence across the area was consistent and augmented by some combination of compaction over pre-existing structural and depositional features.

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Funding and Data:
Artex Oil Company

Outline

- Introduction to Research
- Geological Background
- Data
- Lithostratigraphy
- Clay Mineralogy
- TOC controls
- Isopach Maps
- Assign Sequence Stratigraphy Nomenclature
- Provenance Change

Working Hypothesis – the provenance of the Ordovician mudstones changed from a cratonic to an Appalachian source.

1) Changes in detrital clay mineralogy from core and/or well logs.

2) Dilution of siliciclastic material had a direct effect on the preservation of organics.

3) Use model to develop sequence stratigraphic nomenclature.

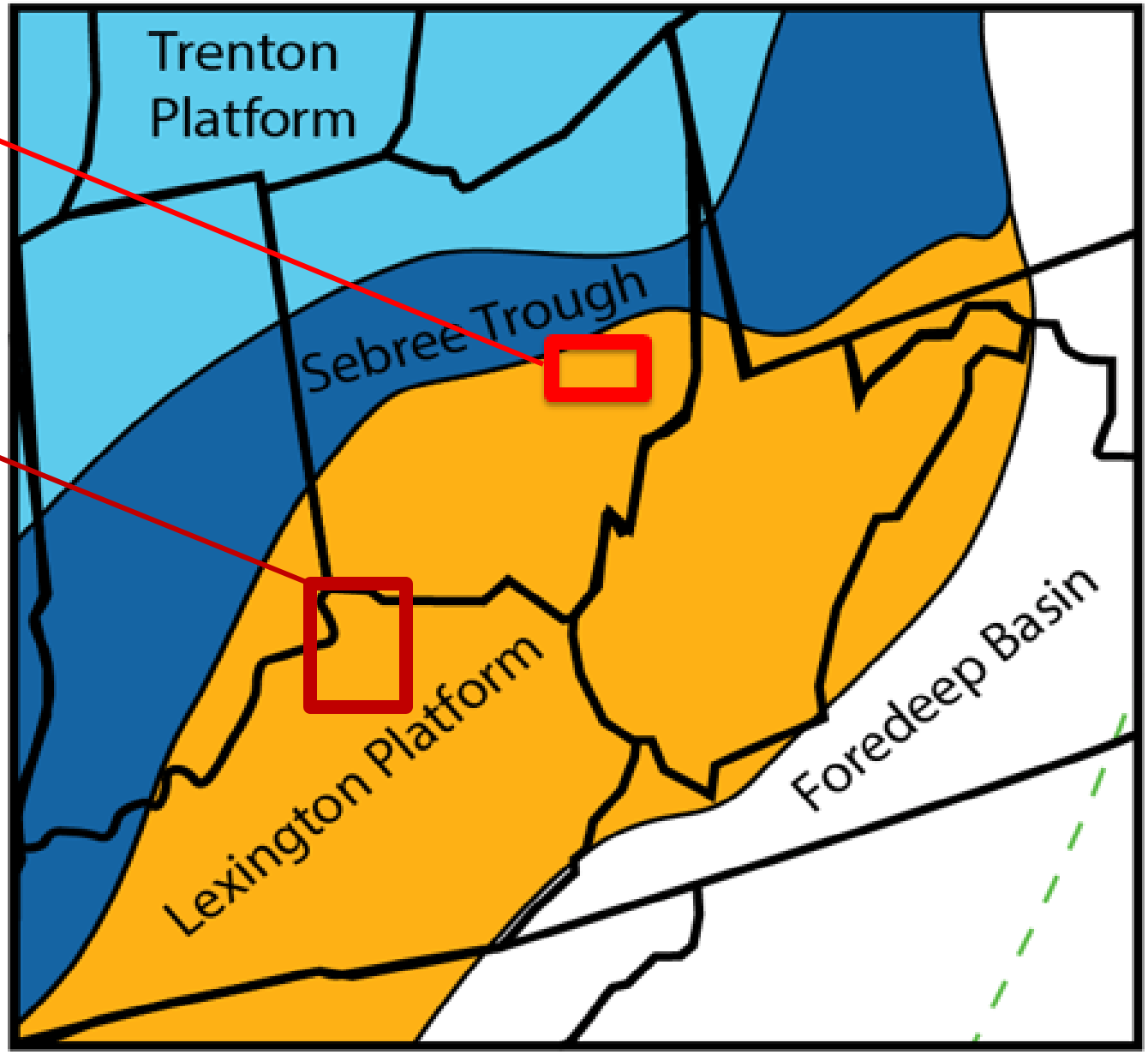
Middle Ordovician- 470 M.A.

Middle Ordovician- 470 M.A.

Study Area

Pope and Read (1997) & Holland and Patzkowsky (1996, 1997)

Virginia, Nashville Dome, and Cincinnati Arch

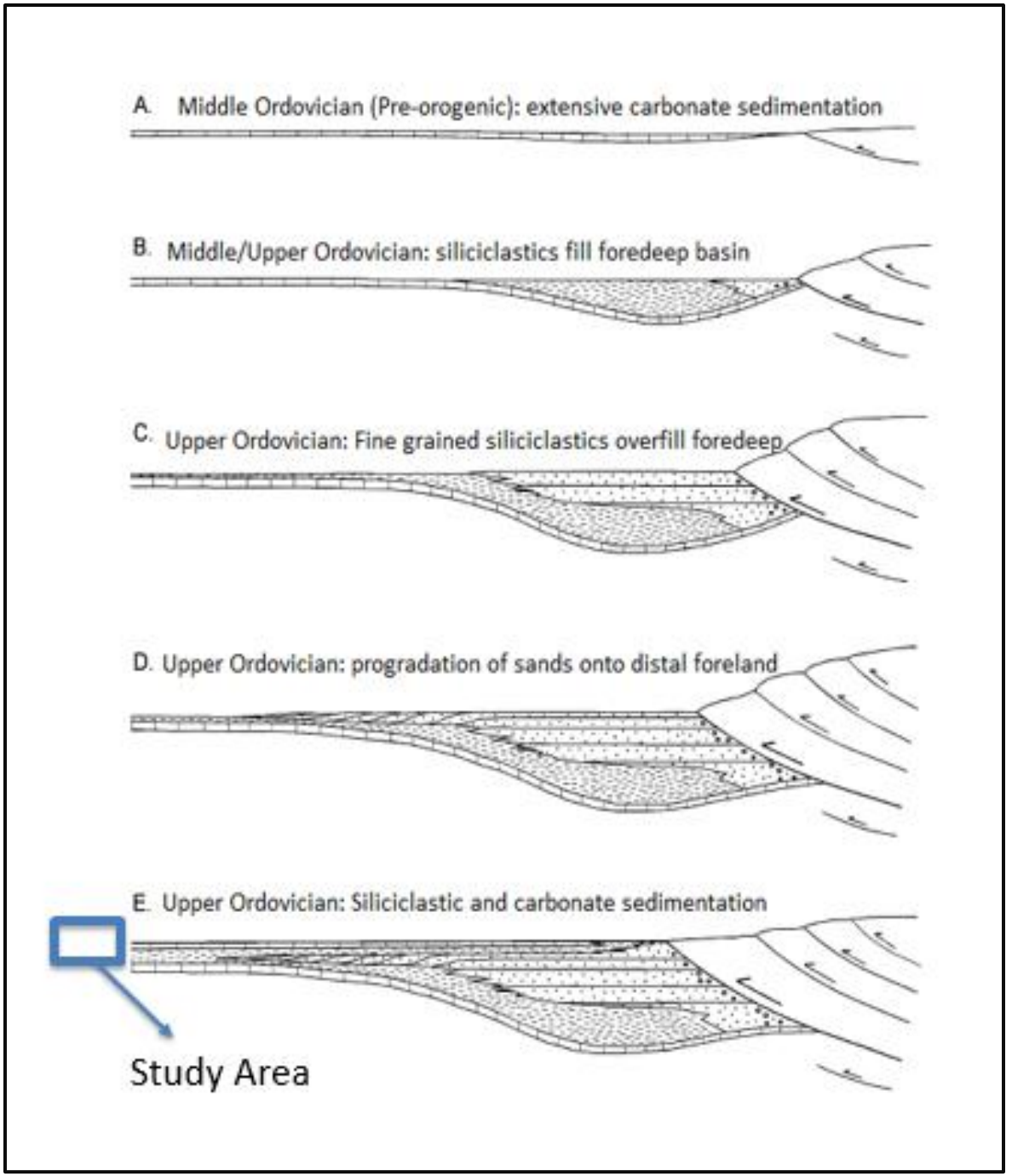


Modified after (Ettensohn, 2004)

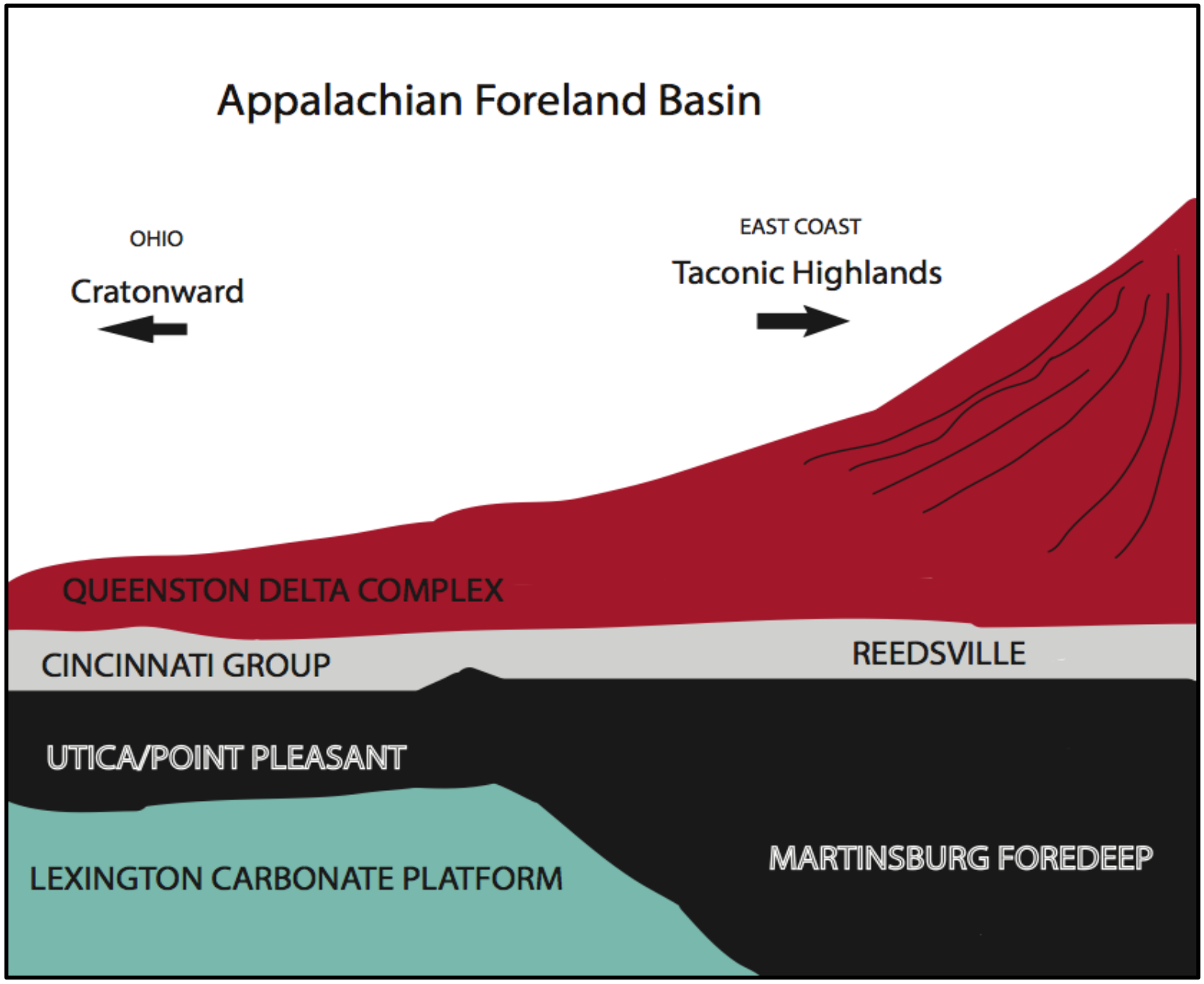

Williams
Fulton
Lucas
Ottawa
Lake
Ashtabula
Defiance
Henry
Wood
Sandusky
Erie
Cuyahoga
Geauga
Trumbull
Paulding
Putnam
Hancock
Seneca
Huron
Lorain
Medina
Summit
Portage
Mahoning
Van Wert
Allen
Wyandot
Crawford
Richland
Ashland
Wayne
Columbiana
Mercer
Auglaize
Hardin
Marion
Morrow
Knox
Holmes
Carroll
Tuscarawus
Jefferson
Shelby
Logan
Union
Delaware
Coshocton
Harrison
Darke
Champaign
Licking
Guernsey
Belmont
Miami
Clark
Madison
Franklin
Muskingum
Preble
Montgomery
Greene
Fayette
Pickaway
Fairfield
Perry
Noble
Monroe
Morgan
Butler
Warren
Clinton
Ross
Hocking
Washington
Athens
Hamilton
Clermont
Highland
Vinton
Meigs
Pike
Jackson
Brown
Adams
Scioto
Gallia
Lawrence
LOCAILIZED STUDY AREA

Foreland Basin

Short Wavelength Basin Formation due to thrust loading.



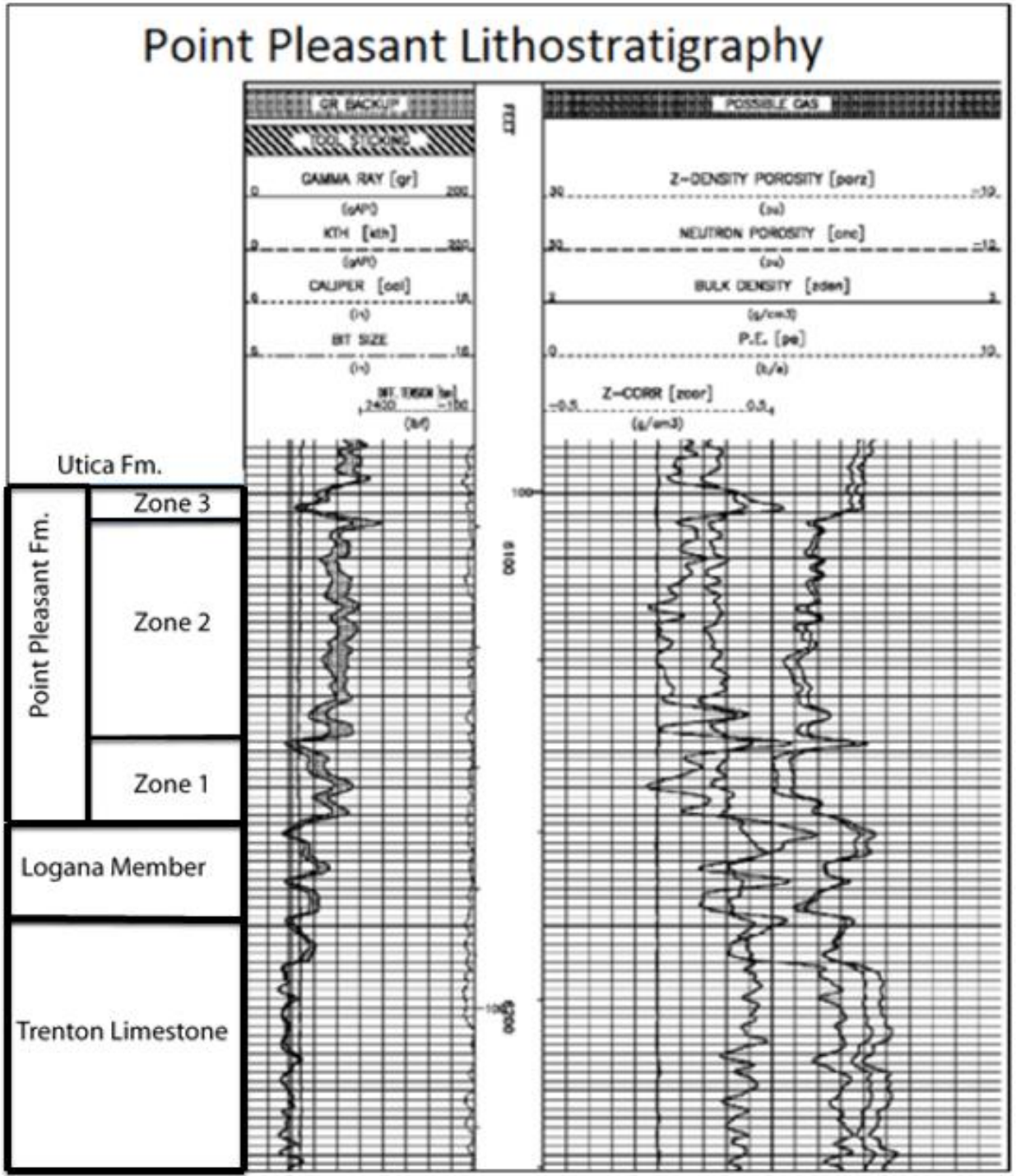
Castle (1978)


Appalachian Foreland Basin
OHIO
Cratonward
EAST COAST
Taconic Highlands
QUEENSTON DELTA COMPLEX
CINCINNATI GROUP
REEDSVILLE
UTICA/POINT PLEASANT
LEXINGTON CARBONATE PLATFORM
MARTINSBURG FOREDEEP

Data

- ~2000 deep wells with logs within study area.
- Barrel core and XRD on 11 wells.
- LePage and Wells-Crum bulk mineralogy was determined using XRD (5 foot) and SEM techniques (Quartz plus feldspar, carbonates, and clay minerals).
- Spectral gamma logs included on LePage and Wells-Crum.

LePage Well-
Muskingum Co, Ohio



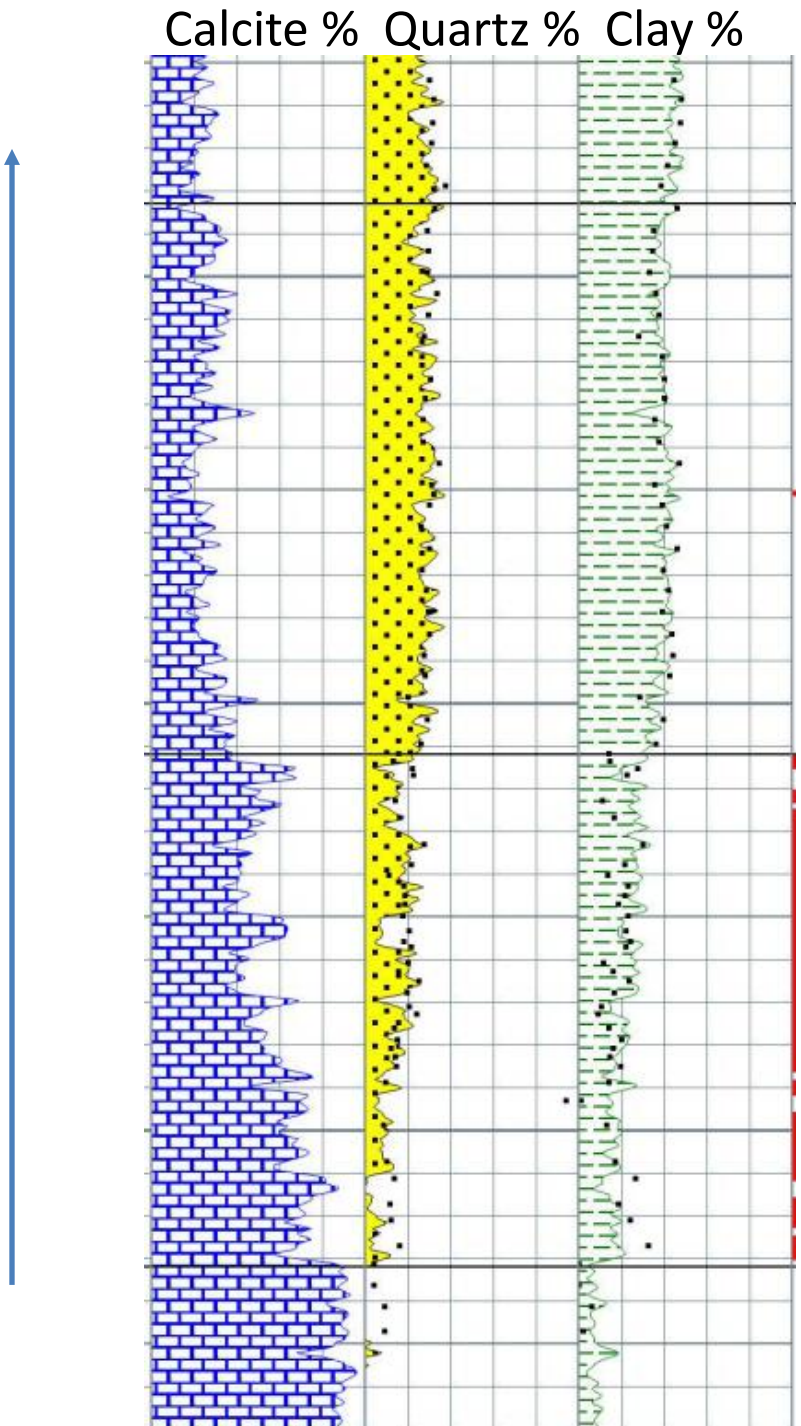
LAS DATA

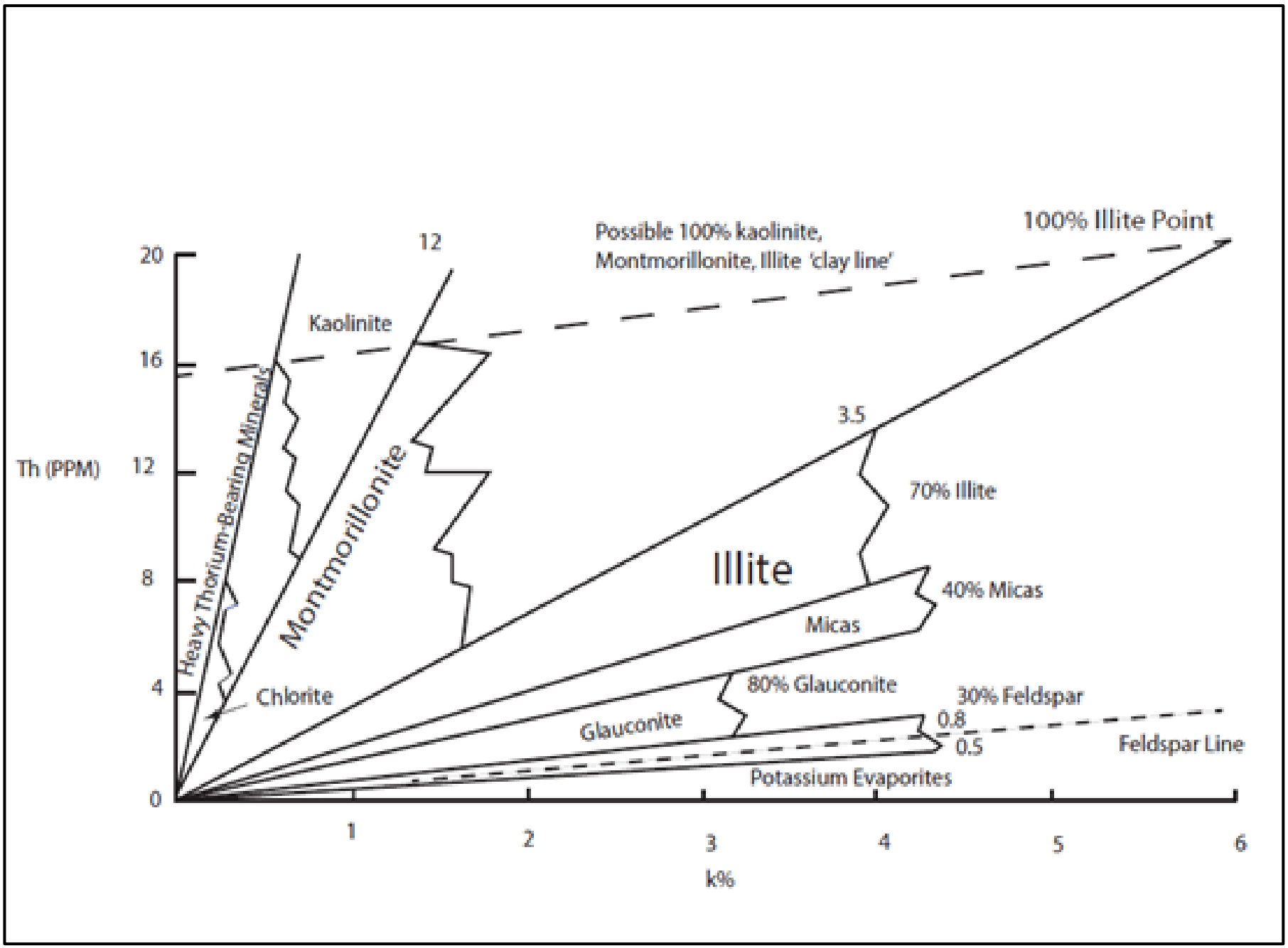
Log values adjusted for vertical resolution (2 ft)

Core Analysis

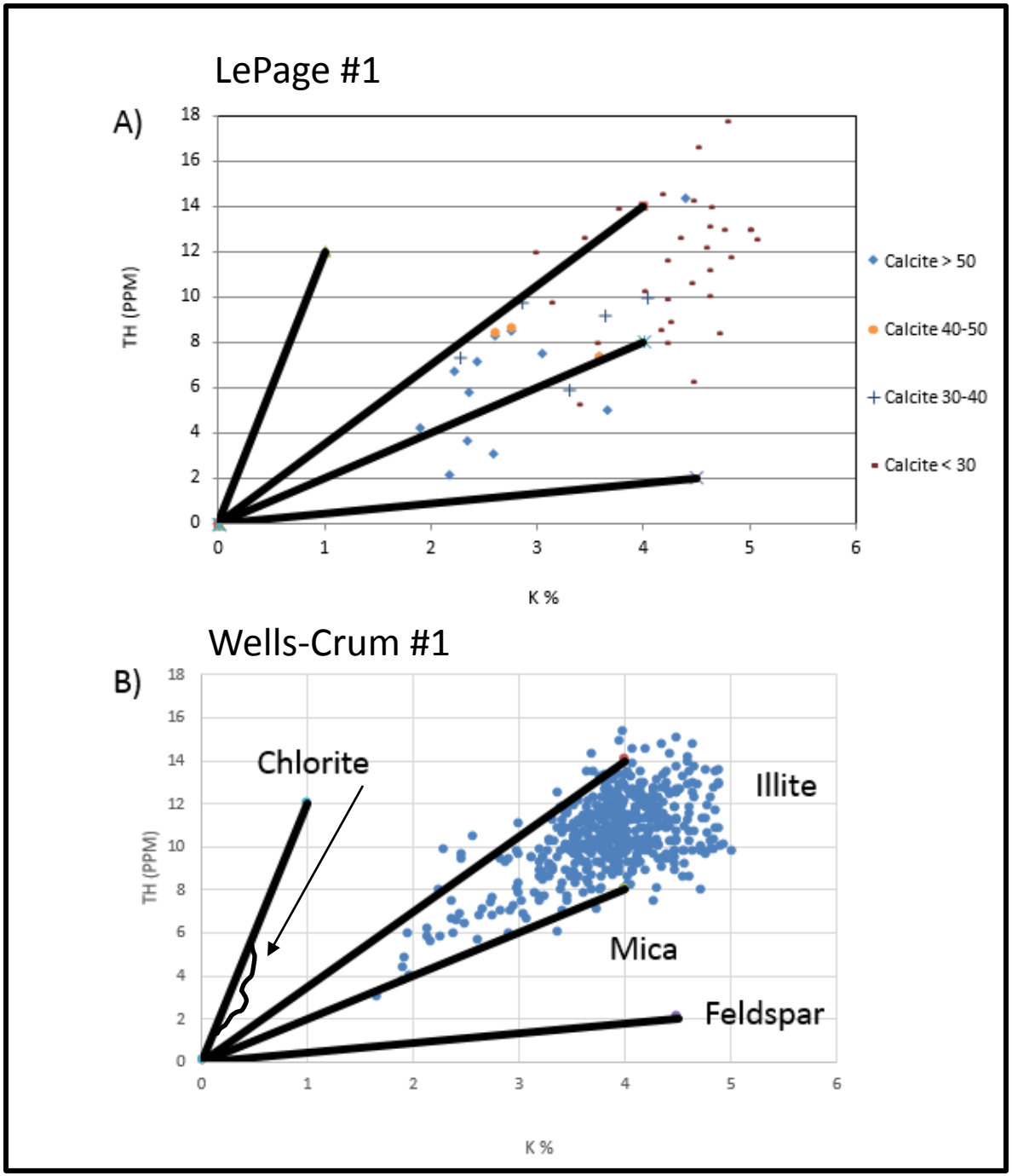
Depth	GR	K	Th	U	Samples	% Influence	GR Sum
5943	128.243	4.036	12.77	1.651			
5943.25	125.771	4.112	13.085	1.225			
5943.5	123.718	4.215	13.447	0.747			
5943.75	122.352	4.315	13.736	0.369			
5944	121.73	4.396	13.886	0.146			
5944.25	121.801	4.477	13.988	0.002			
5944.5	122.365	4.563	14.083	0.002			
5944.75	123.344	4.651	14.138	0.002			
5945	124.834	4.742	14.12	0.002	4	3.34375	4.17413688
5945.25	126.901	4.82	14.002	0.002	3	6.6875	8.48650438
5945.5	129.264	4.88	13.783	0.002	2	13.375	17.28906
5945.75	131.209	4.929	13.509	0.002	1		
5946	132.07	4.975	13.169	0.002	0	53.5	70.4218717
5946.25	131.61	5.028	12.73	0.002	1		
5946.5	130.095	5.082	12.261	0.002	2	13.375	17.4002063
5946.75	128.288	5.122	11.833	0.002	3	6.6875	8.57926
5947	127.064	5.144	11.502	0.002	4	3.34375	4.2487025
5947.25	126.699	5.148	11.306	0.002			
5947.5	126.702	5.145	11.144	0.002		SUM	130.599742
5947.75	126.09	5.148	10.928	0.002			
5948	124.257	5.138	10.717	0.002			
5948.25	121.524	5.096	10.555	0.002			
5948.5	119.03	5.043	10.458	0.002			
5948.75	117.795	4.988	10.425	0.002			

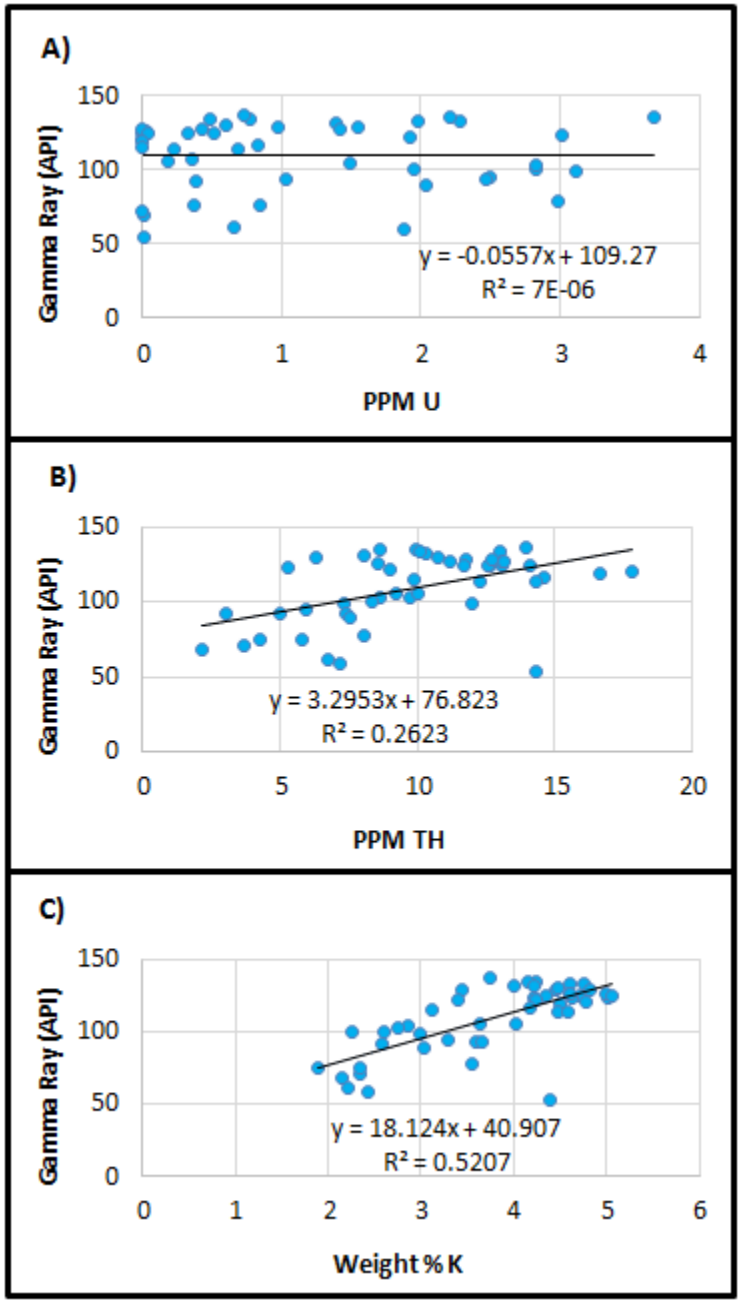
Increasing Gamma values



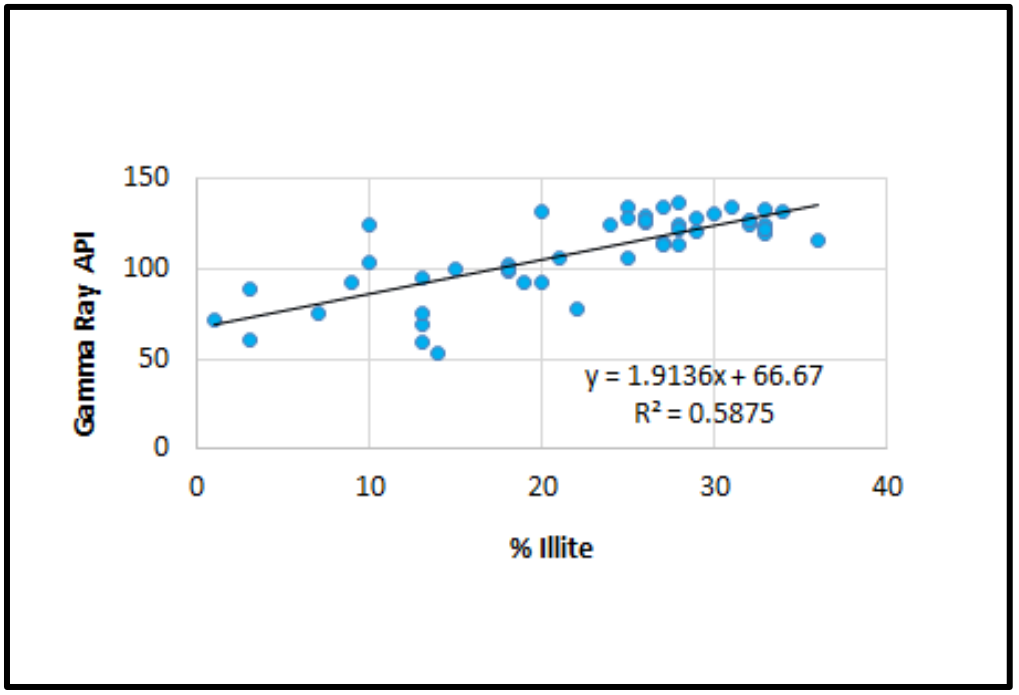

Possible 100% kaolinite,
Montmorillonite, Illite 'clay line'
100% Illite Point
12
20
16
12
8
4
0
Th (PPM)
Kaolinite
Heavy Thorium-Bearing Minerals
Montmorillonite
3.5
70% Illite
Illite
40% Micas
Micas
Chlorite
80% Glauconite
30% Feldspar
Glauconite
0.8
0.5
Feldspar Line
Potassium Evaporites
1
2
3
4
5
6
k%

Quirein (1982) Spectral gamma-ray data.





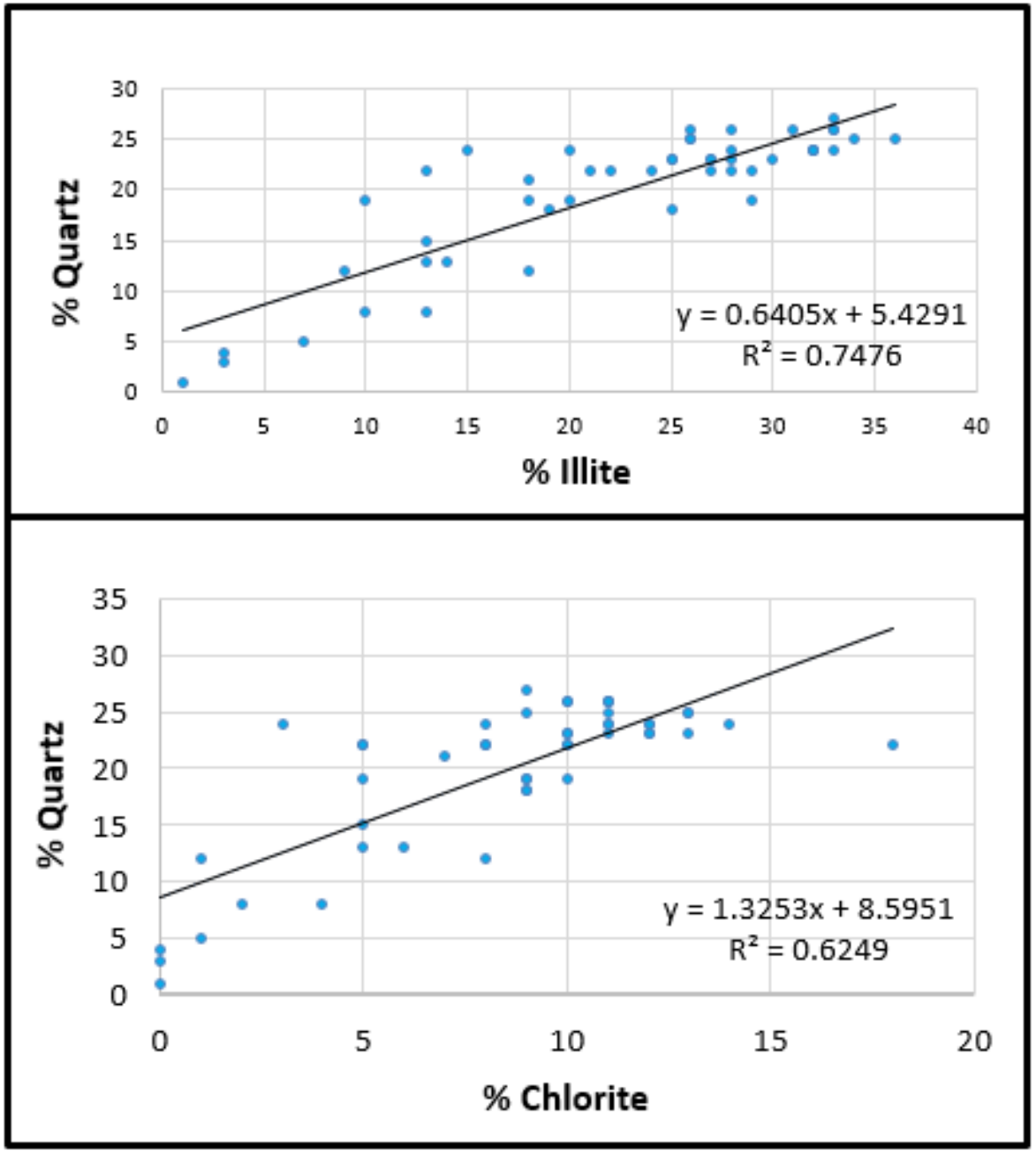
The amount of illite is the main control on gamma-ray response.



Are the clays detrital?

Quartz assumed to be largely detrital in mudstone (Weaver, 1989).

The dominant type of clays correlate with quartz (Illite and Chlorite).



Summary

- Correlations
  - Quartz vs Gamma= Yes
  - Illite vs Gamma= Yes
  - Illite vs Quartz= Yes
  - Illite + Chlorite vs Quartz= Yes

The only way to explain the above correlations is the increase in detrital muds has a greater influence on gamma than the quartz present.

XRD	Chlorite	Illite	Mixed Layer	Kaolinite	Calcite	Quartz	TOC
Utica	13%	29%	5%	1%	18%	24%	1%
Zone 3	10%	20%	4%	1%	39%	18%	1%
Zone 2	9%	20%	3%	2%	36%	22%	2%
Zone 1	3%	8%	1%	0%	34%	10%	4%
Logana	2%	7%	1%	0%	75%	6%	2%

Averages from 11 cores: A change in provenance is recorded by changes in detrital clays and quartz from zone 1 to zone 2.

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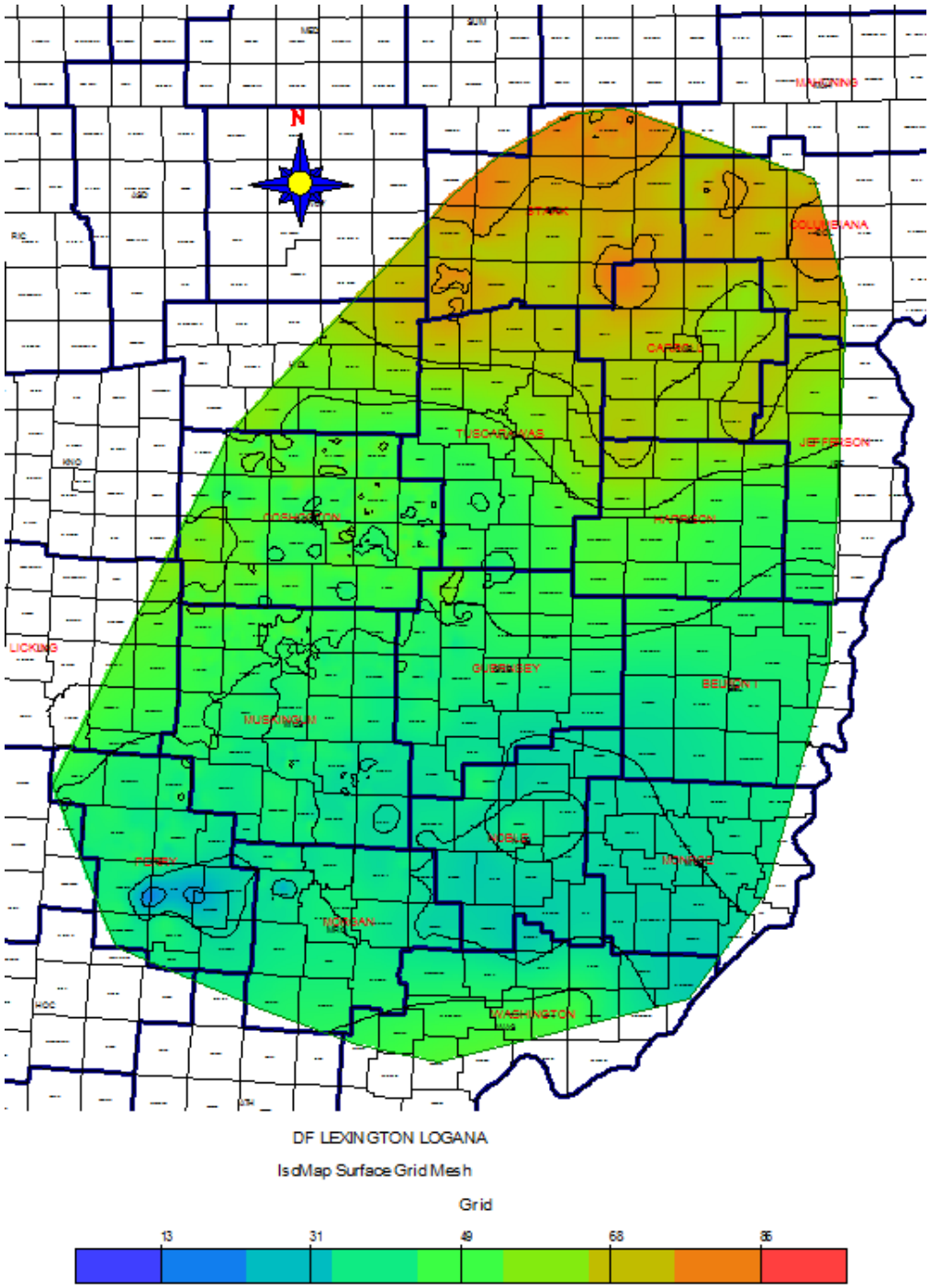
Logana	2%	7%	1%	0%	75%	6%	2%

Above a critical threshold, dilution by siliciclastic mineral matter decreases the concentration of organic matter in the sediment (Bohacs, 1998).

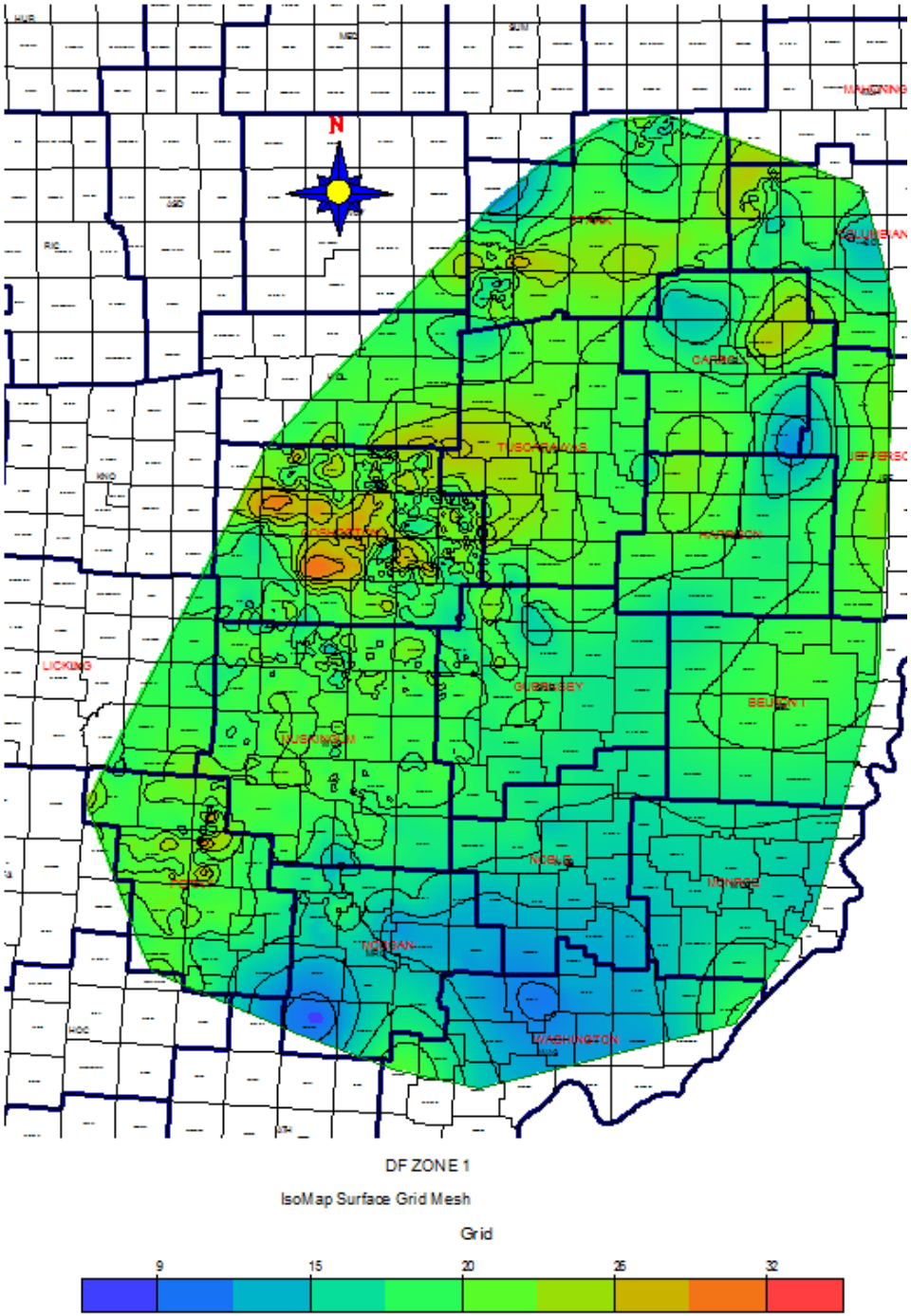
LEXINGTON LOGANA ISOPACH

-Shows the Sebree Trough development



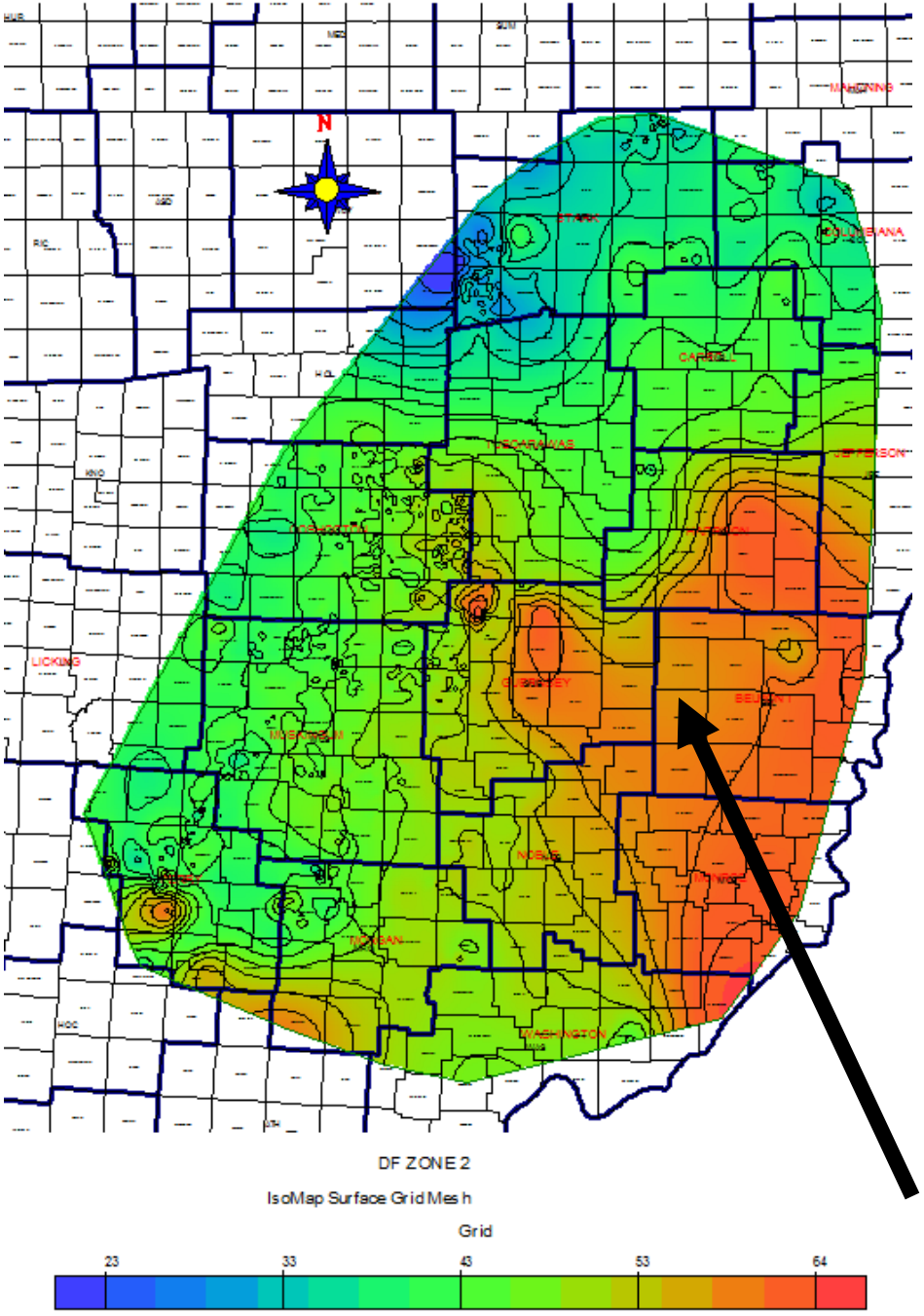
ZONE 1 ISOPACH

-This zone seems to be thicker in the oil window



ZONE 2 ISOPACH

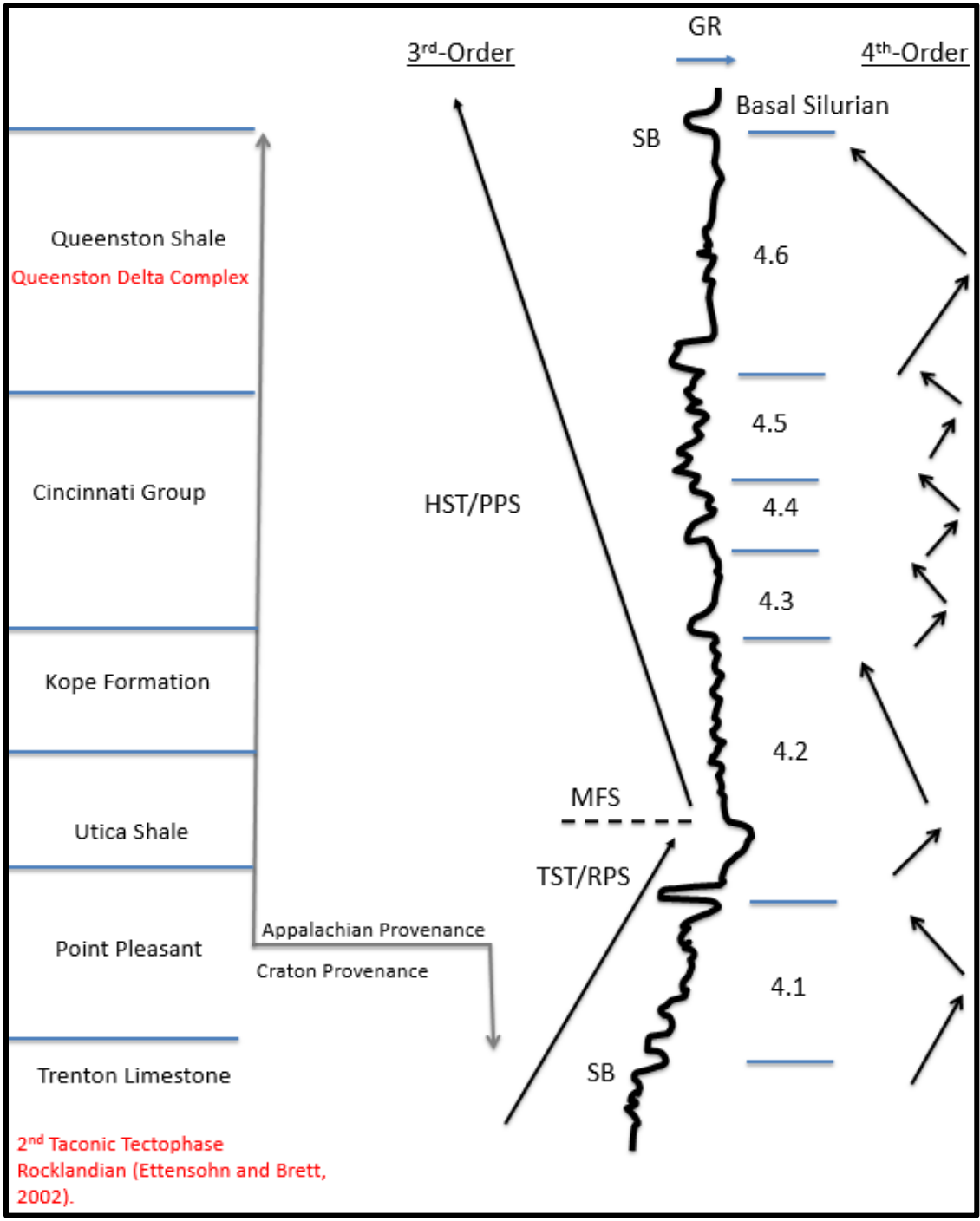
-Showing the prograding siliciclastics onto the craton.



Provenance change predates 3rd-order MFS.

Implies overfilled foredeep during marine transgression.

Implies high sedimentation rates.



Conclusions

- Conclusion 1- the mineralogy of the Ordovician mudstones can be predicted using well log data.

- Dominant clay minerals (illite) can be predicted from well log data.

Conclusions

- Conclusion 2- the provenance of the Ordovician mudstones changed from a cratonic to an Appalachian source.

- The transition from zone 1 to zone 2 within the Point Pleasant Formation represents the change from the craton to the Taconic Mountains.

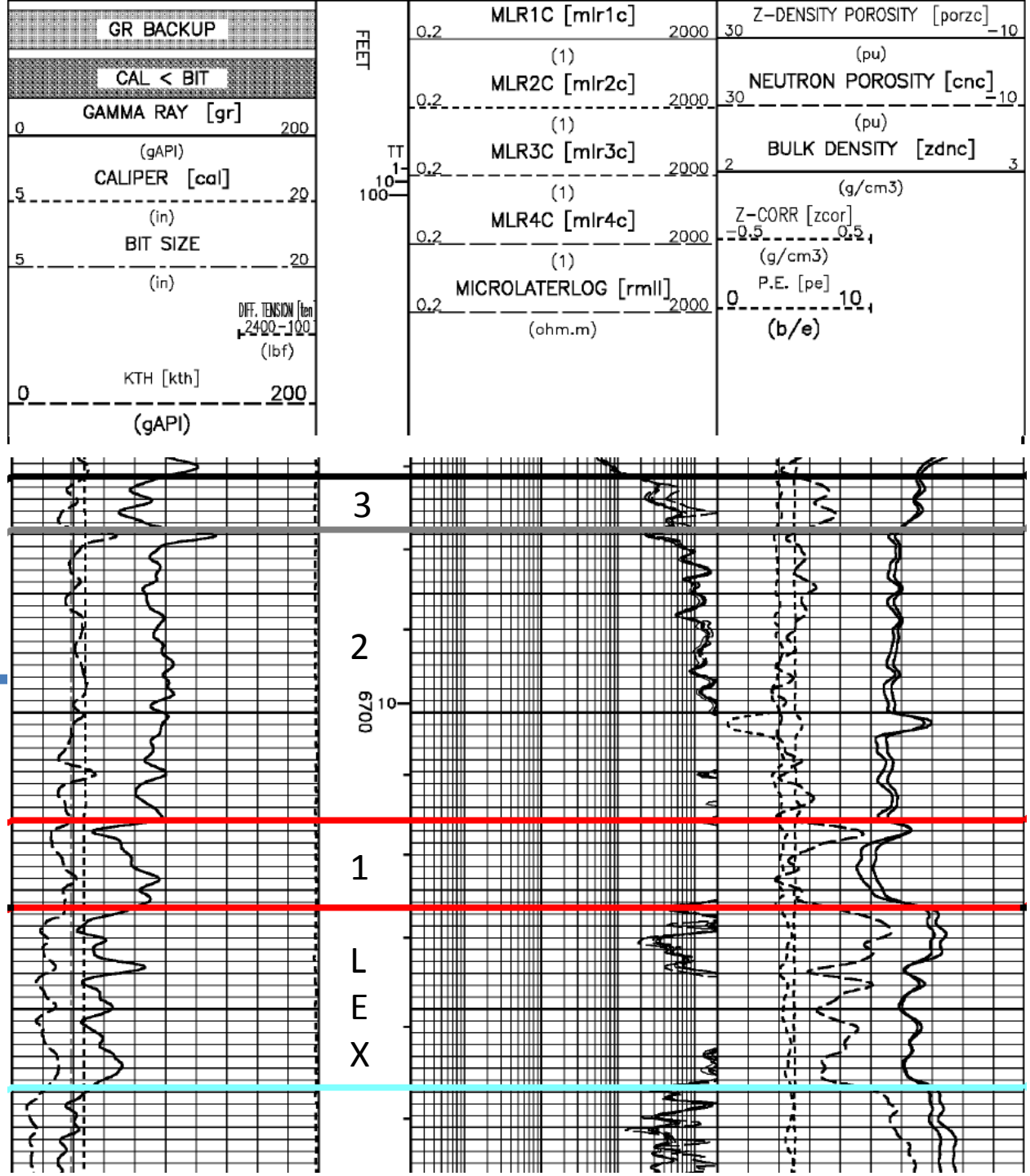
Conclusions

- Conclusion 3- Detrital clays and quartz diluted the productivity and the preservation of organics. Resulting in lower TOC in the upper part of the Point Pleasant Formation.

Source Change:
TOC Preservation
Decreased Permeability
Decreased Porosity

Geomechanics:
Ductile vs Brittle

Provenance Change



Thank You!

Questions?

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