Maximizing Use of Available Scientific Data in Oil and Gas Exploration in Tennessee

Bob Hatcher

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Department of Earth and Planetary Sciences
University of Tennessee–Knoxville

C

Lx

Lv

Jessamine dome

Illinois basin

Appalachian basin

P

Gulf Coastal Plain

N

Nashville dome

K

M

C

TOGA 48th Annual Mtg.
Gatlinburg, TN
May 14, 2019

PURPOSE:

Advocate (continued) use of available scientific data in oil exploration/field development/production

Data commonly used in oil exploration:

Well (geophysical) logs, cuttings, core, DSTs, seismic-reflection data (2D, 3D), aeromagnetic and gravity (potential field) data, surface & subsurface geologic data
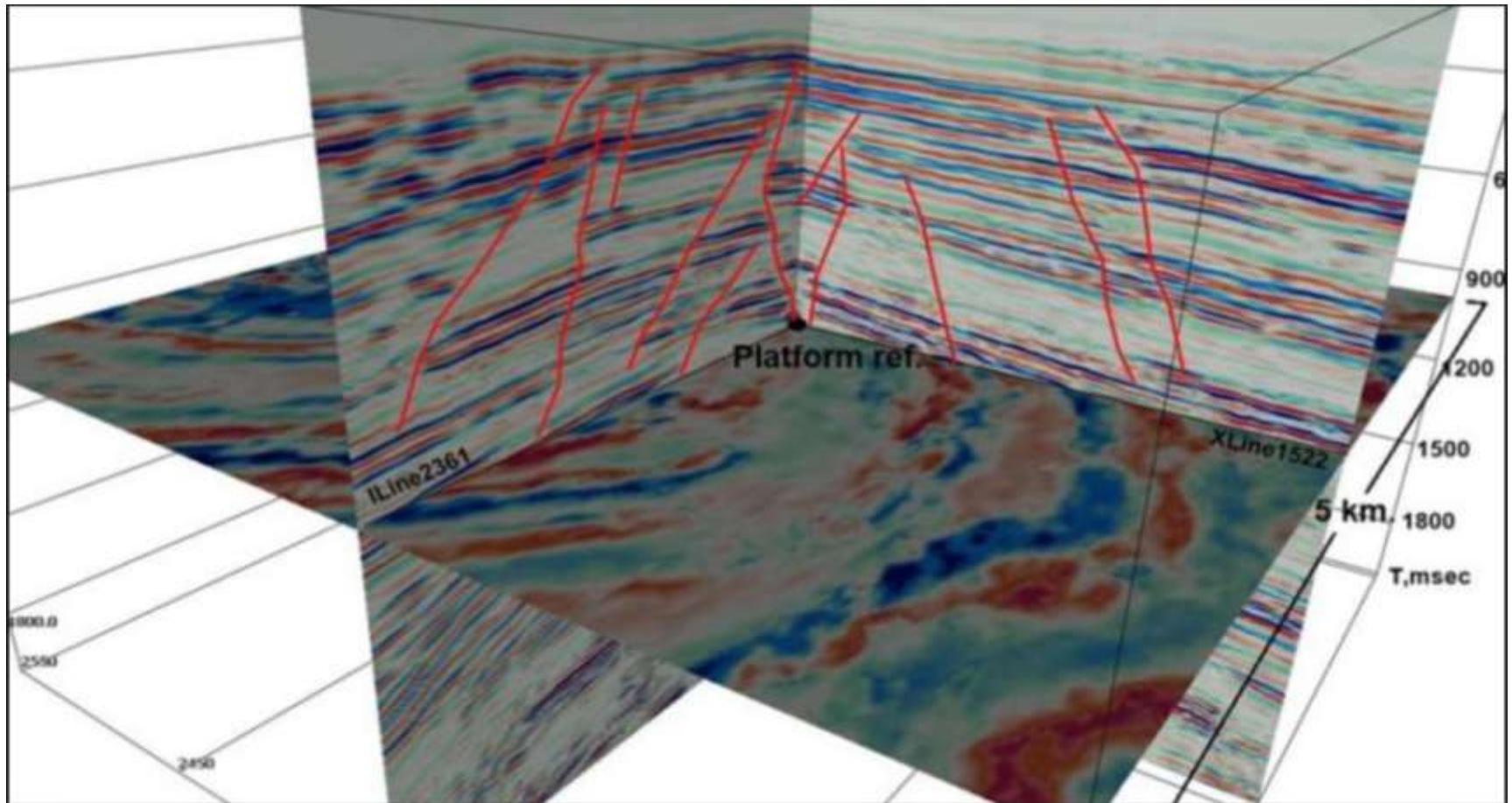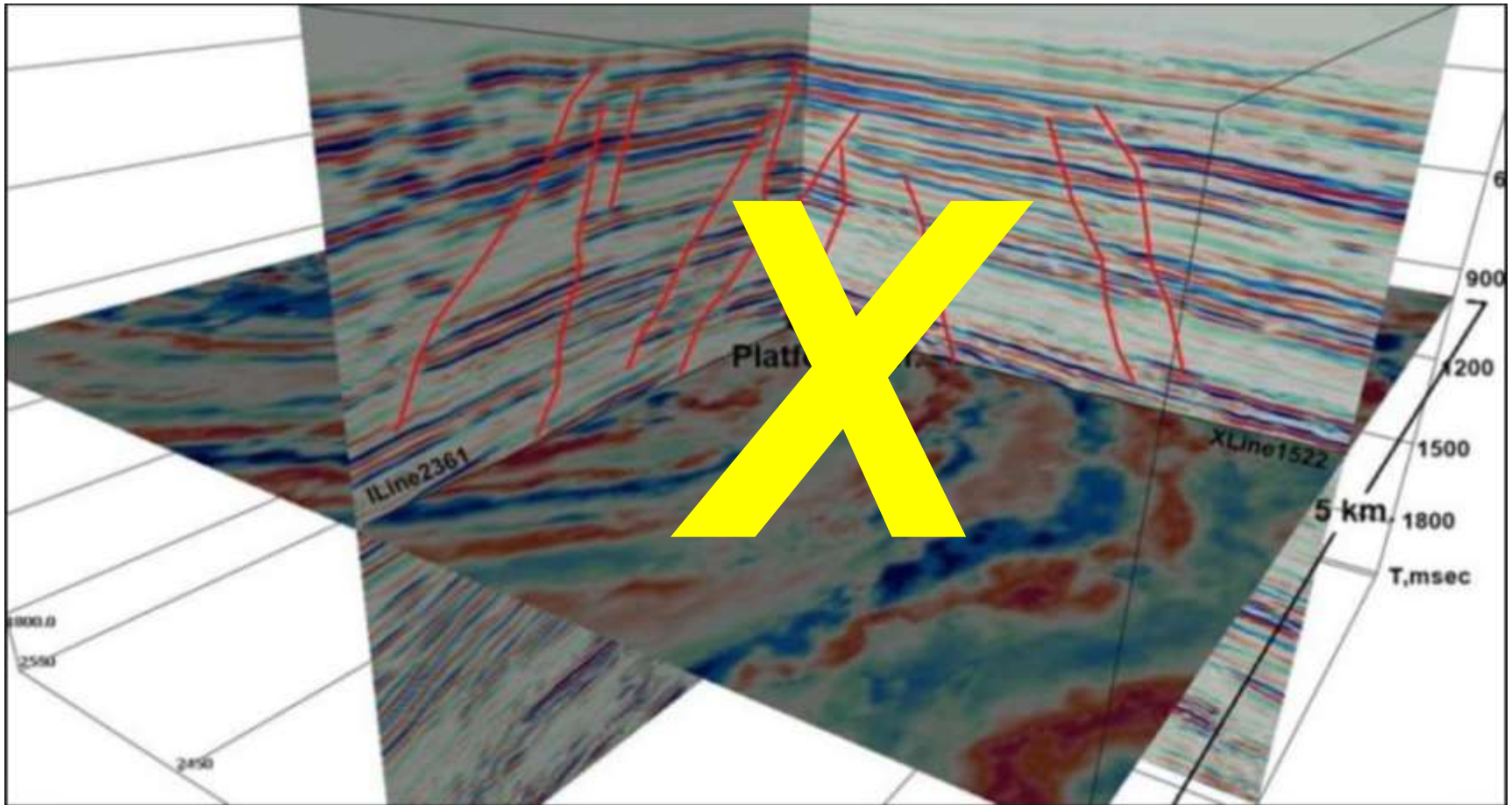
New data currently becoming available:

LiDar

Data mostly not available in Tennessee:

Seismic-reflection data (2D, 3D)

3D Seismic Reflection Data

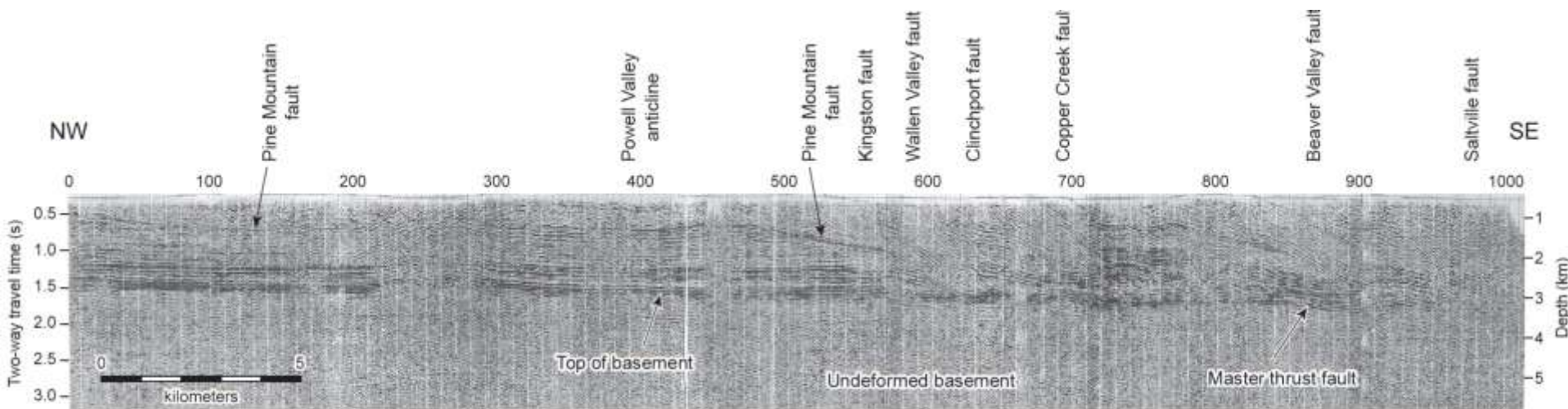# 3D Seismic Reflection Data
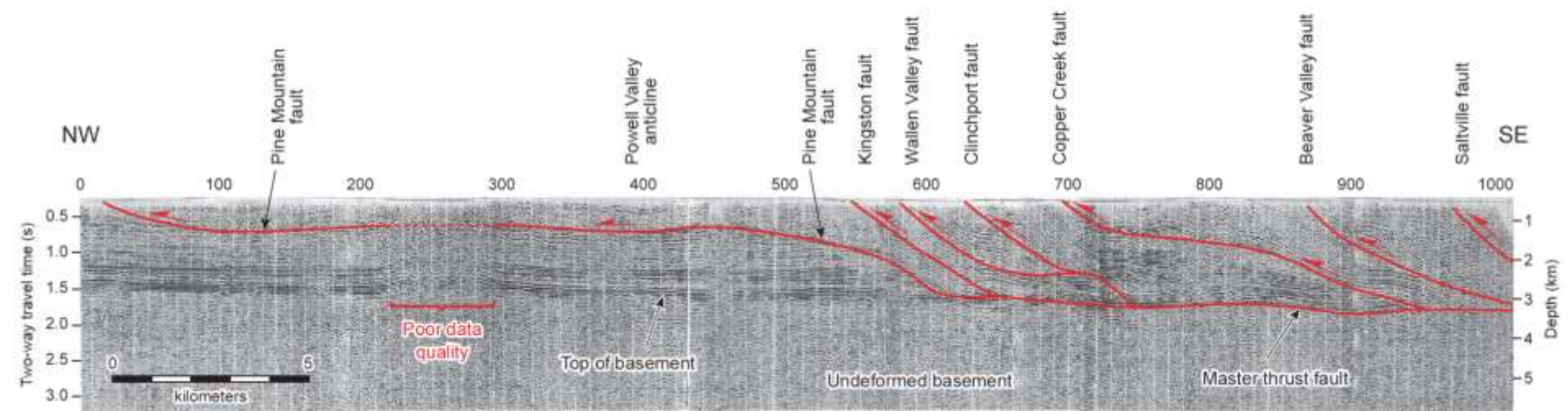
Vibroseis Survey Tandem Vibrating Trucks
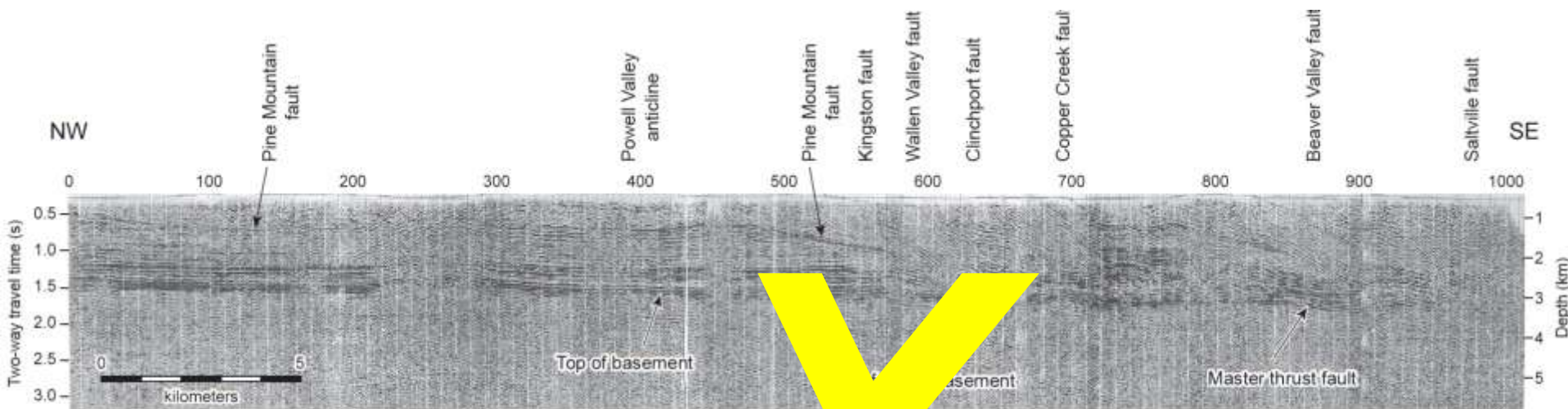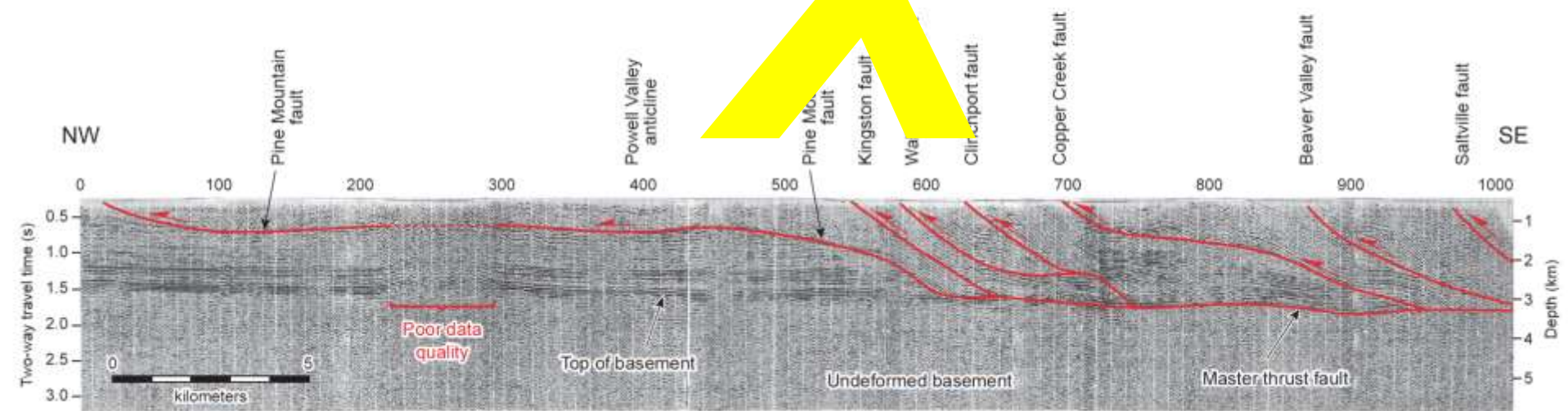
Vibroseis Survey Tandem Vibrating Trucks

(a)

(b)

(a)

NW — SE

Pine Mountain fault, Powell Valley anticline, Pine Mountain fault, Kingston fault, Wallen Valley fault, Clinchport fault, Copper Creek fault, Beaver Valley fault, Saltville fault

Two-way travel time (s) — Depth (km)

0 5 kilometers

Top of basement — basement — Master thrust fault

(b)

NW — SE

Pine Mountain fault, Powell Valley anticline, Pine Mo... fault, Kingston fault, Wa..., Clinchport fault, Copper Creek fault, Beaver Valley fault, Saltville fault

Two-way travel time (s) — Depth (km)

0 5 kilometers

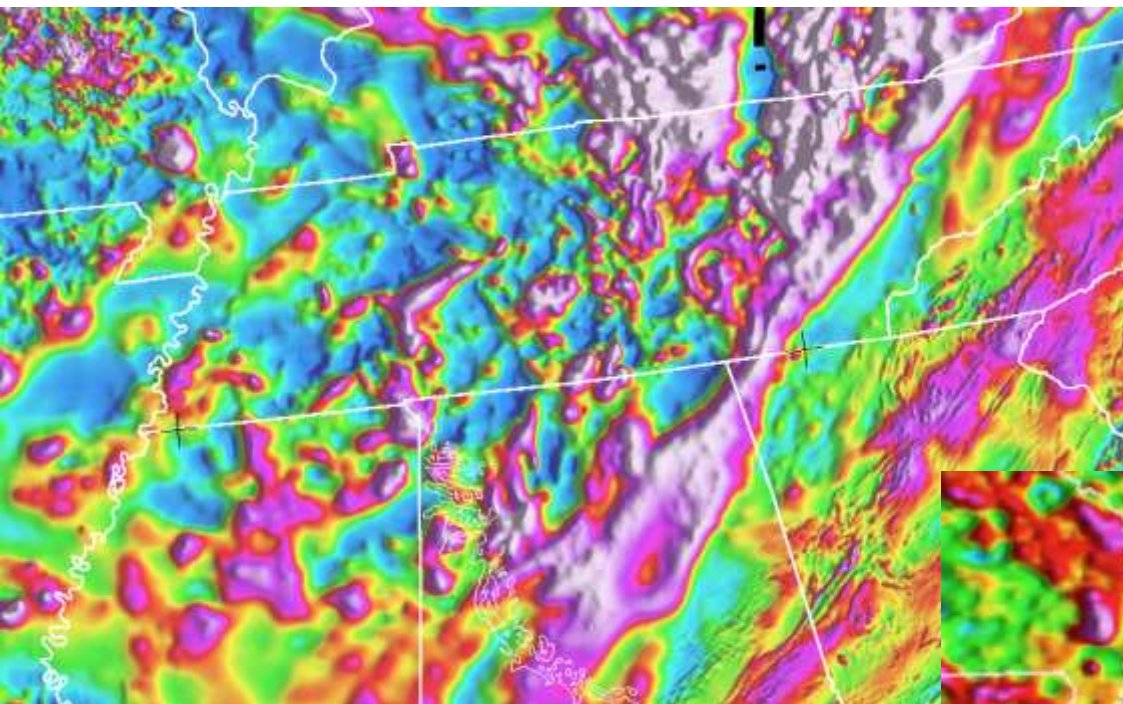Poor data quality, Top of basement, Undeformed basement, Master thrust fault

Data available in Tennessee, but commonly *not* used:
Why not?
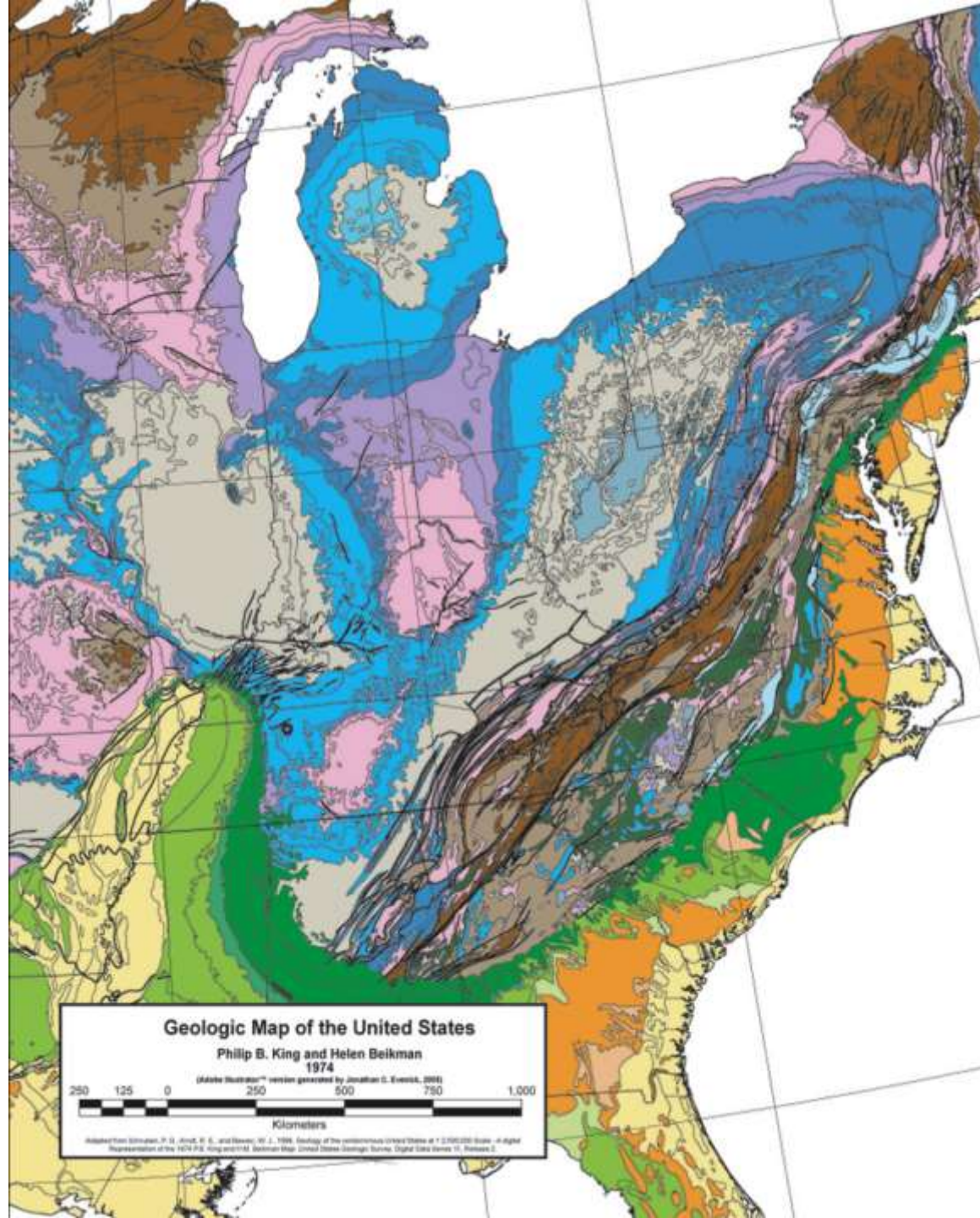### Aeromagnetic and gravity (potential field) data
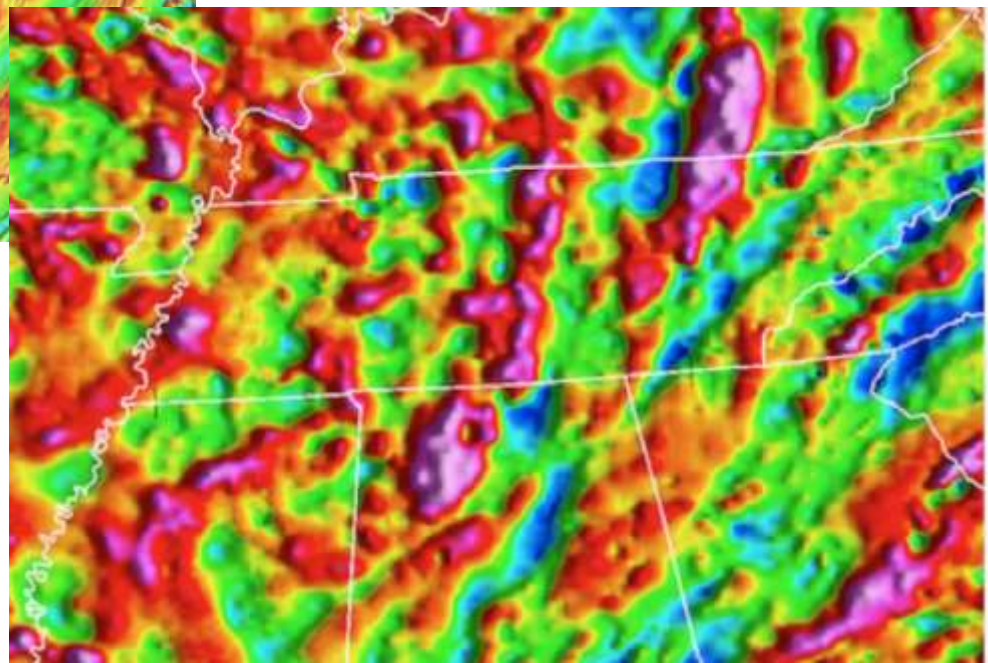
Left with:

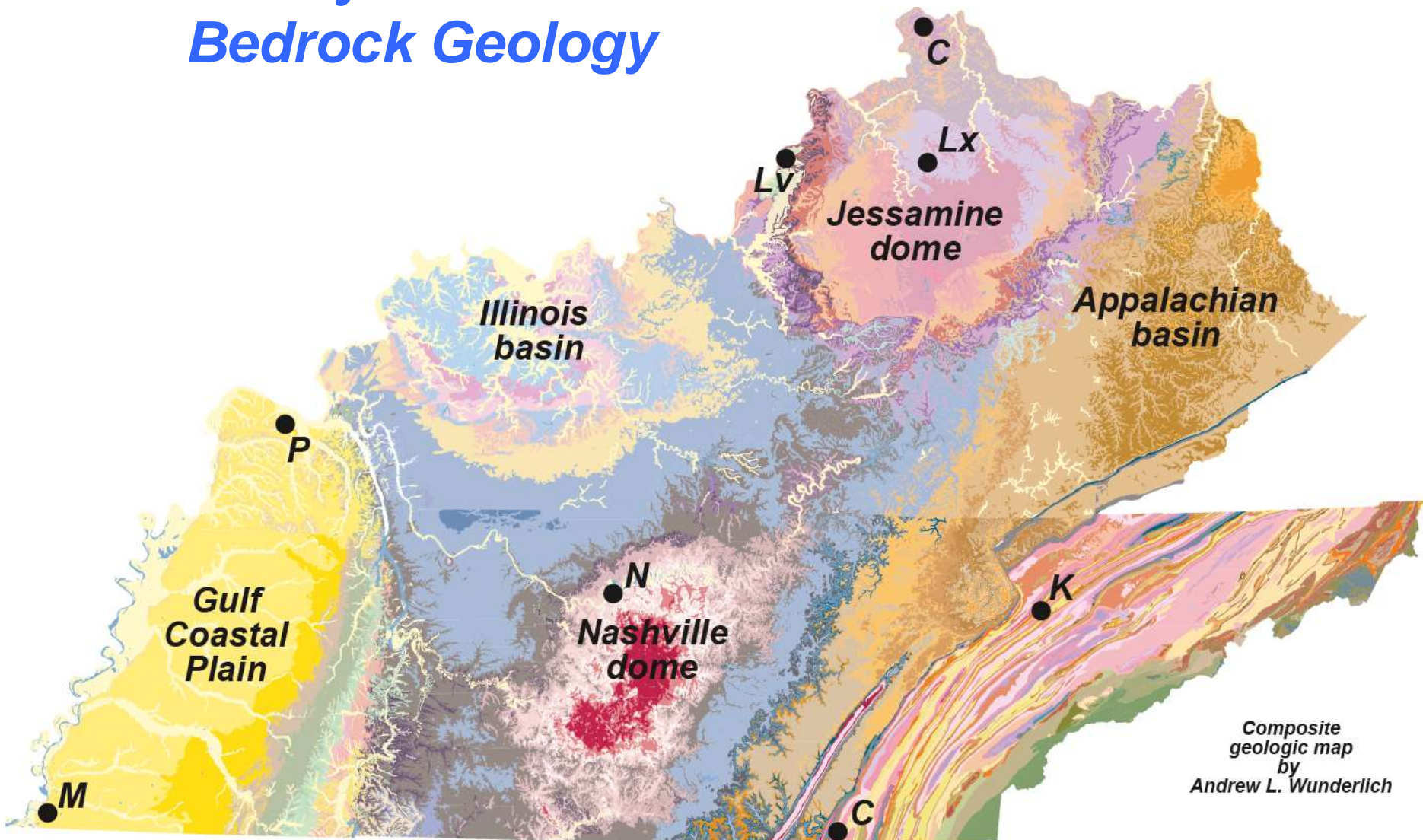## *Surface & Subsurface Geologic Data*
(not a bad option in TN & KY)

Eastern US Geology

From King & Beikman, 1970, USGS

Geologic Map of the United States

Philip B. King and Helen Beikman
1974

(Adobe Illustrator™ version generated by Jonathan C. Everett, 2005)

| 250 | 125 | 0 | 250 | 500 | 750 | 1,000 |

Kilometers

Kentucky & Tennessee
Bedrock Geology

C

Lx

Lv

Jessamine dome

Appalachian basin

Illinois basin

P

N

Nashville dome

Gulf Coastal Plain

K

M

C

Composite geologic map by Andrew L. Wunderlich
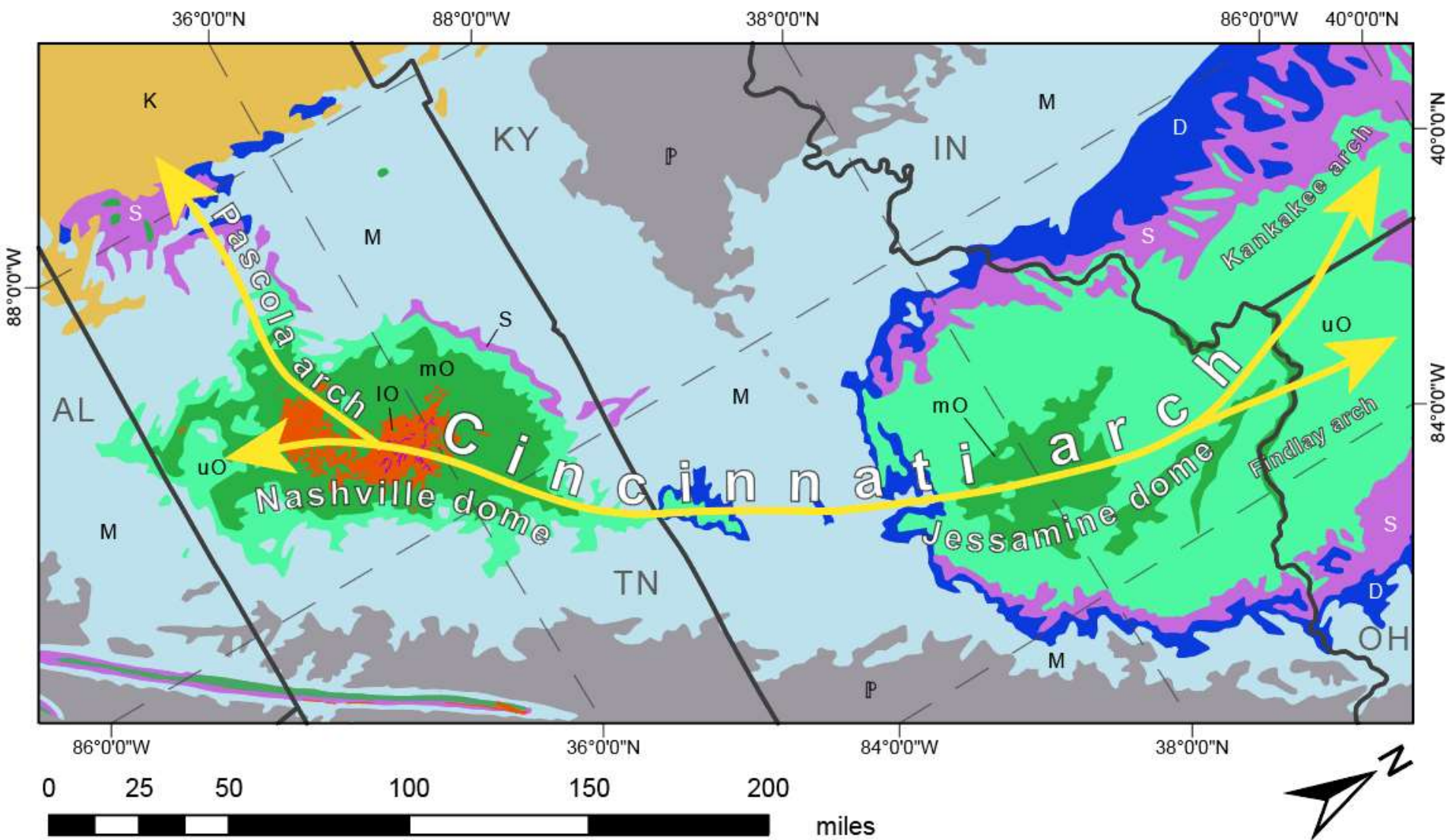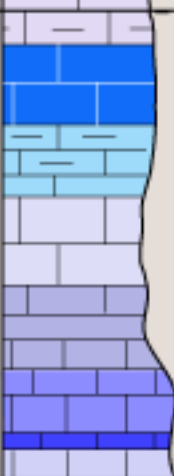
Image courtesy of Ken Boling

Ordovician–Silurian Stratigraphy in Sequatchie Valley

	LITHOLOGY	THICKNESS	FORMATION
MISSISSIPPIAN		100–150 ft	Fort Payne Chert
MISSISSIPPIAN ±DEVONIAN		10–15 ft	Chattanooga Shale
			Unconformity
SILURIAN		100 ft	Rockwood Formation
ORDOVICIAN — UPPER		170 ft	Sequatchie Formation
		200 ft	Reedsville Shale
			Leipers Fm.
ORDOVICIAN — MIDDLE (Stones R. Gr. Nashville Gr.)		1700 ft	Catheys Ls. Cannon Ls. Hermitage Fm. Carters Ls. Lebanon Ls. Ridley Ls. Pierce Ls. Murfreesboro Ls. Pond Spr. Fm.
ORDOVICIAN — LOWER (Knox Gr.)		250± ft	*Unconformity* Mascot Dolomite

From Wilson (1949) and Milici (1960)

Stratigraphy of the Oak Ridge Area

OAK RIDGE VALLEY
EAST FORK RIDGE±PILOT KNOB
PINE RIDGE
BEAR CREEK VALLEY
CHESTNUT RIDGE

LITHOLOGY	THICKNESS	FORMATION
MISSISSIPPIAN	100±150 ft	Fort Payne Chert
MISSISSIPPIAN ±DEVONIAN	20±30 ft	Chattanooga Shale
		Unconformity
SILURIAN	400 ft	Rockwood Formation
ORDOVICIAN — MIDDLE — Chickamauga Group	200 ft	Sequatchie Formation
	200 ft	Reedsville Shale
	1700 ft	Leipers Fm. / Nashville Group {Catheys Ls., Cannon Ls., Hermitage Fm.} / Stones River Group {Carters Ls., Lebanon Ls., Ridley Ls., Pierce Ls., Murfreesboro Ls.}
		Unconformity
ORDOVICIAN — LOWER — Knox Group	250±400 ft	Mascot Dolomite
	300±500 ft	Kingsport Formation
	130±200 ft	Longview Dolomite
	500±700 ft	Chepultepec Dolomite
CAMBRIAN — UPPER — Knox Group	800±1100 ft	Copper Ridge Dolomite
CAMBRIAN — Conasauga Group	340 ft	Maynardville Limestone
MIDDLE	490±590 ft	Nolichucky Shale
	320±410 ft	Dismal Gap Formation (shale/limestone formerly Maryville Ls.)
	80±110 ft	Rogersville Shale
	100±120 ft	Friendship Formation (limestone/shale formerly Rutledge Ls.)
LOWER	185±225 ft	Pumpkin Valley Shale
	1000+ ft	Rome Formation

Hatcher 6/3/03

Kentucky-Tennessee Producing Wells
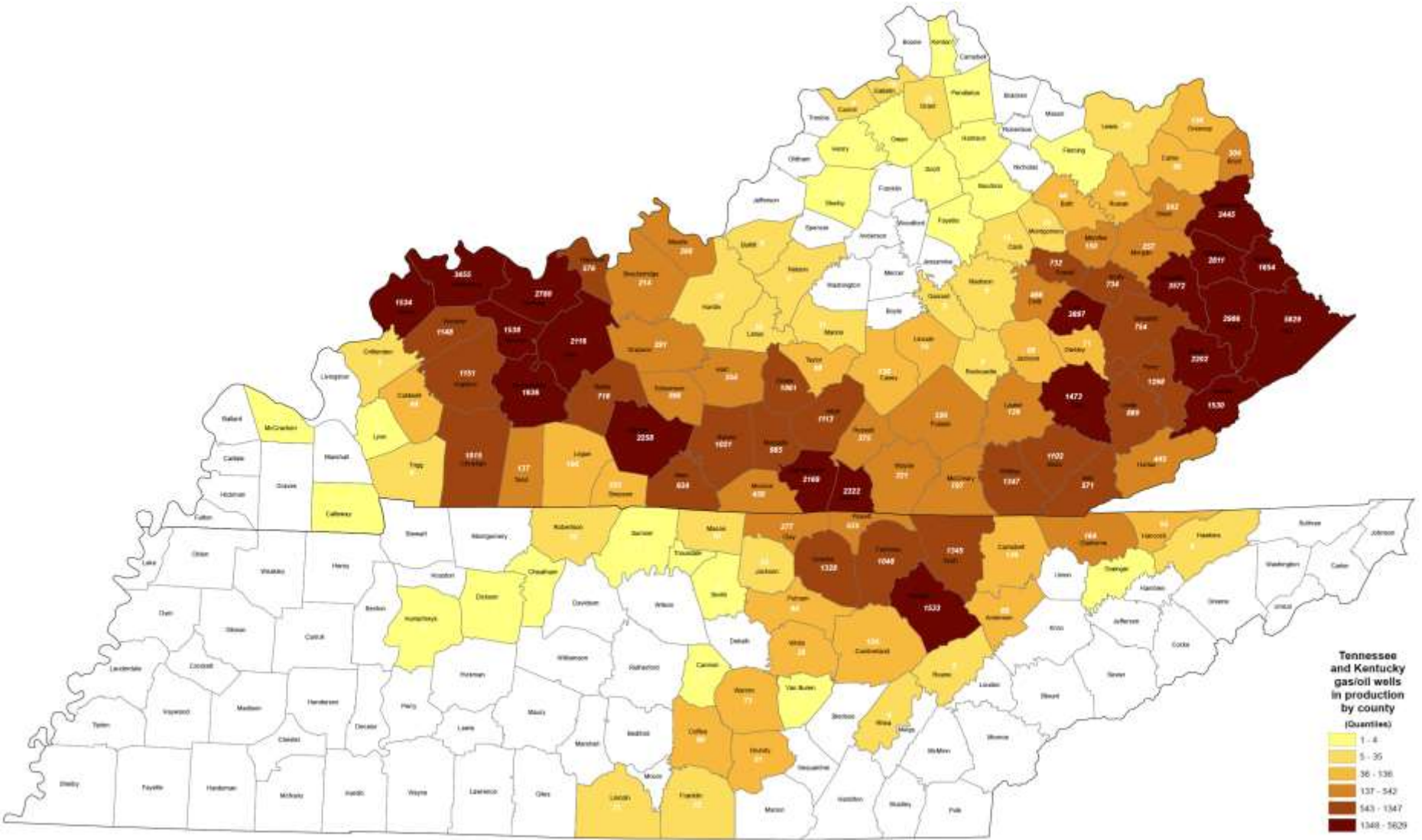
Could Tennessee increase production? How?

WELL LOCATION MAP, CUMBERLAND PLATEAU/
TENNESSEE
PREPARED BY COUGAR DOME, LLC
DR. GARY G BIBLE
423-215-1857
MAY 10, 2019

DISCLAIMER OF LIABILITY
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1 inch = 21,664 feet

0   29,000 58,000   116,000   174,000   232,000
Feet

Map courtesy of Dr. Gary G. Bible

At least 75 m.y. missing

TN 109 N of Gallatin, TN?

Ft. Payne Fm. (Miss.)

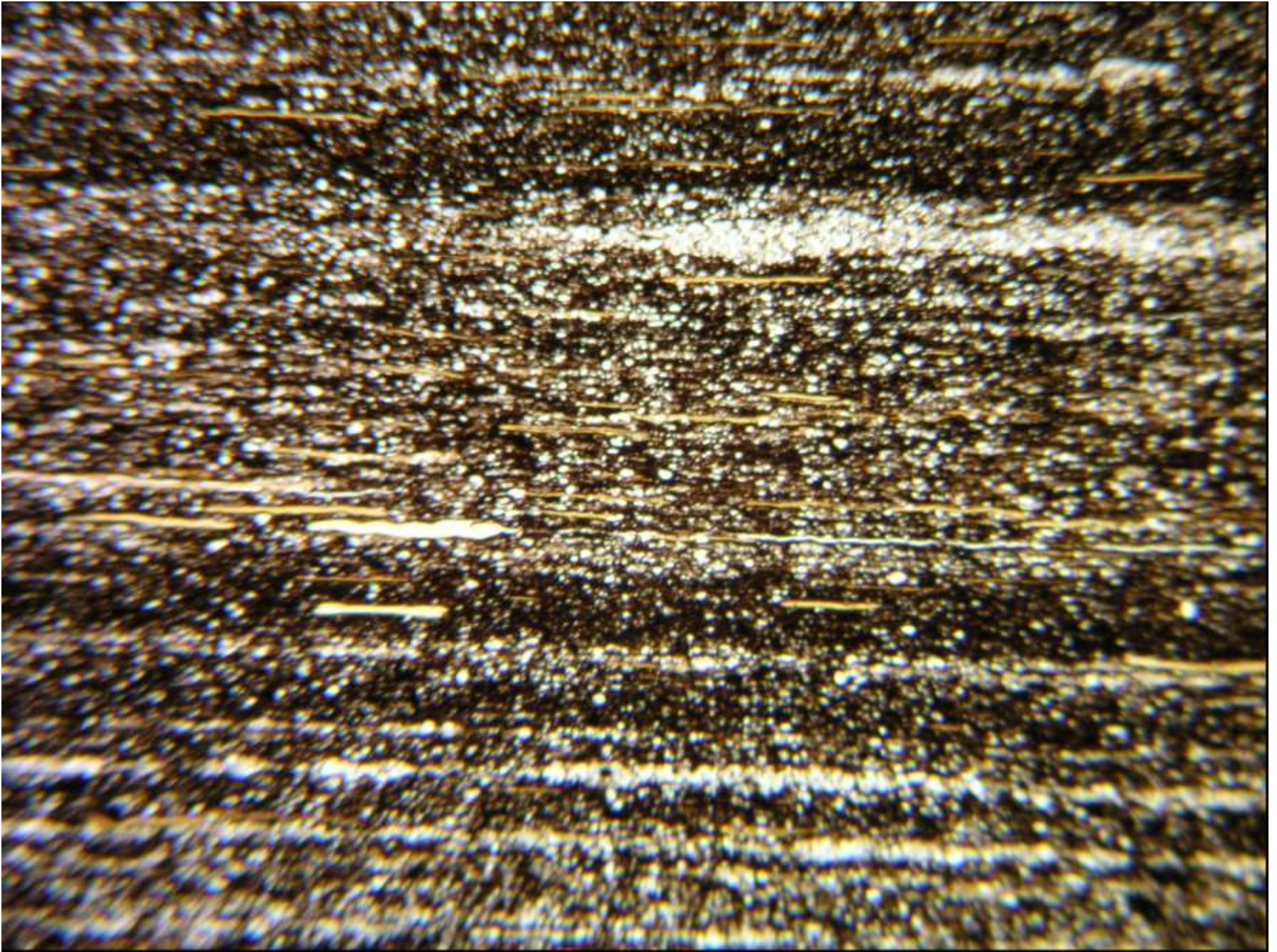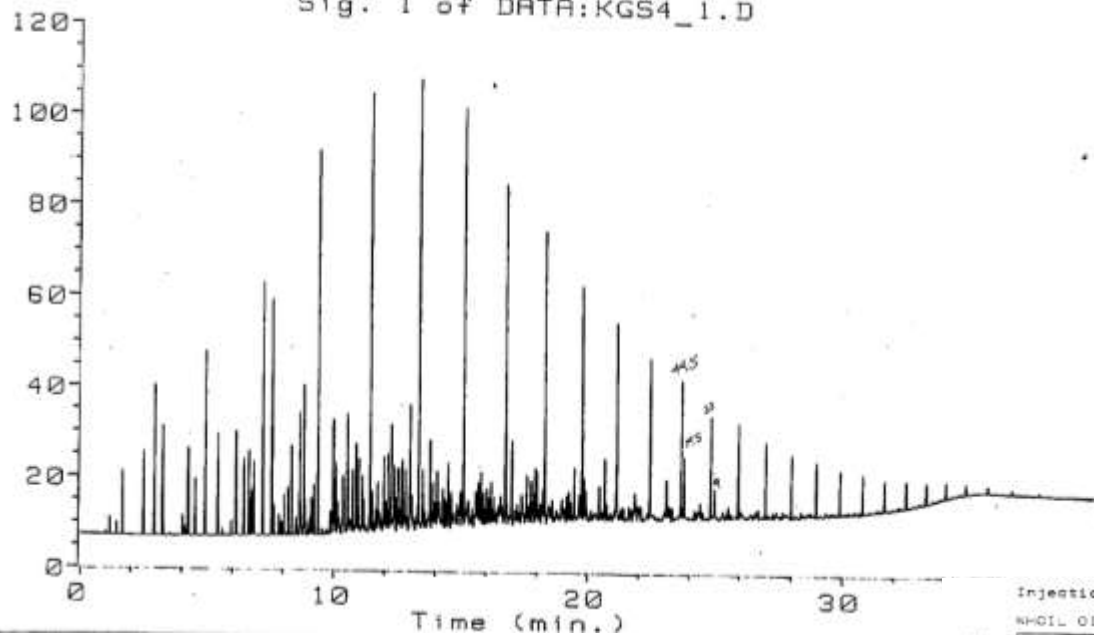**Chattanooga Sh. (Dev.-Miss.)**

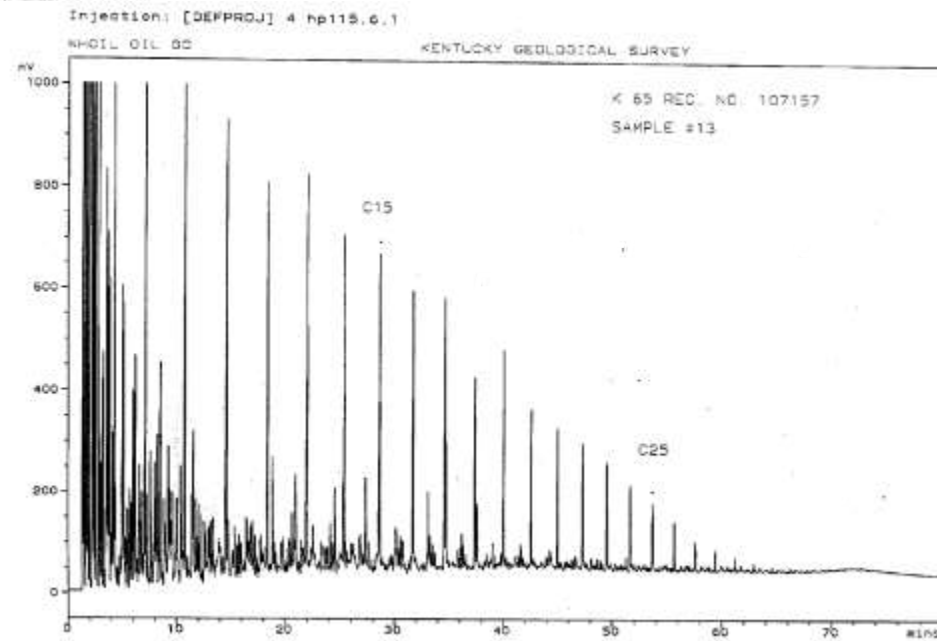**At least 83 m.y. missing**

Leipers Fm. (Ord.)
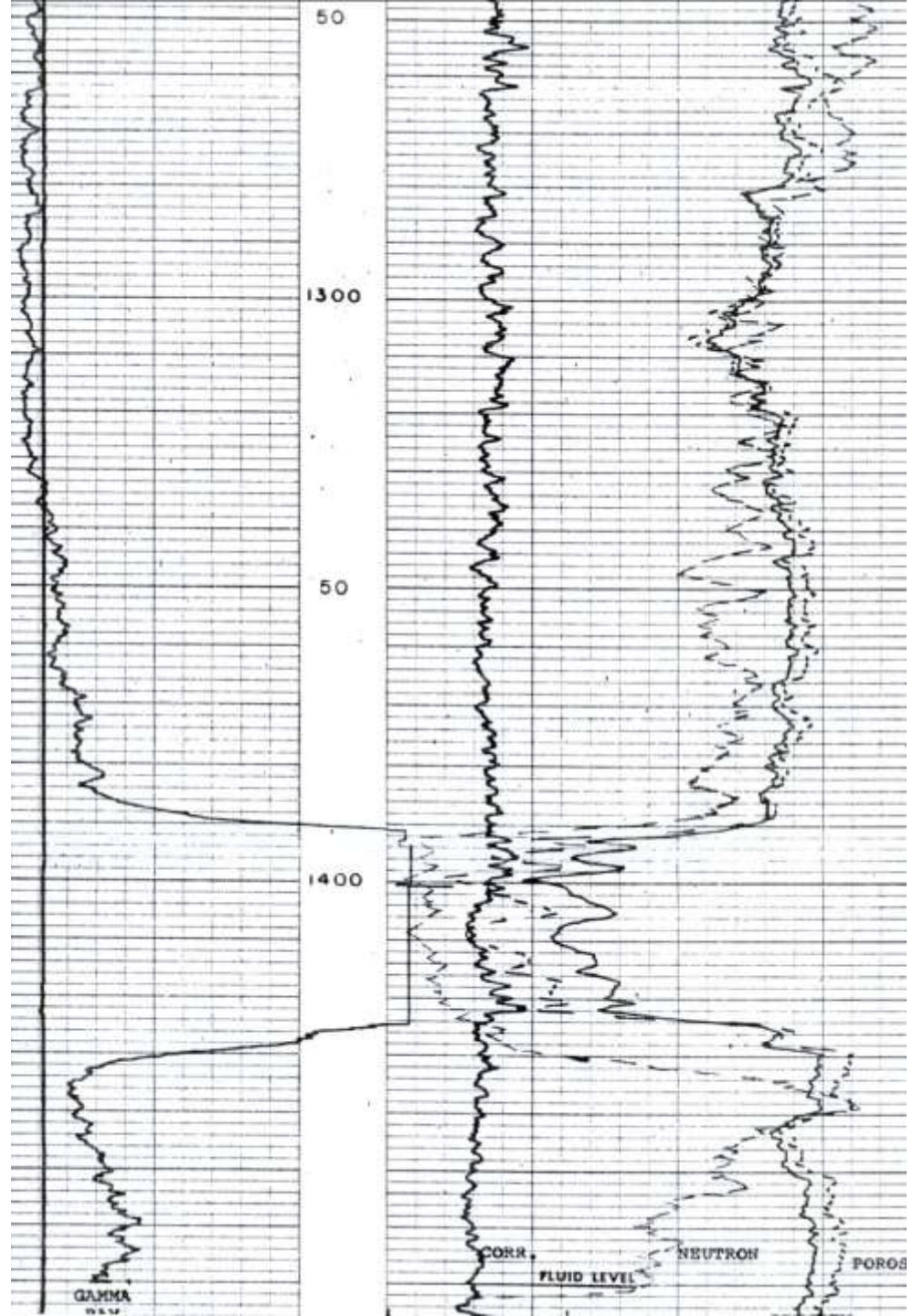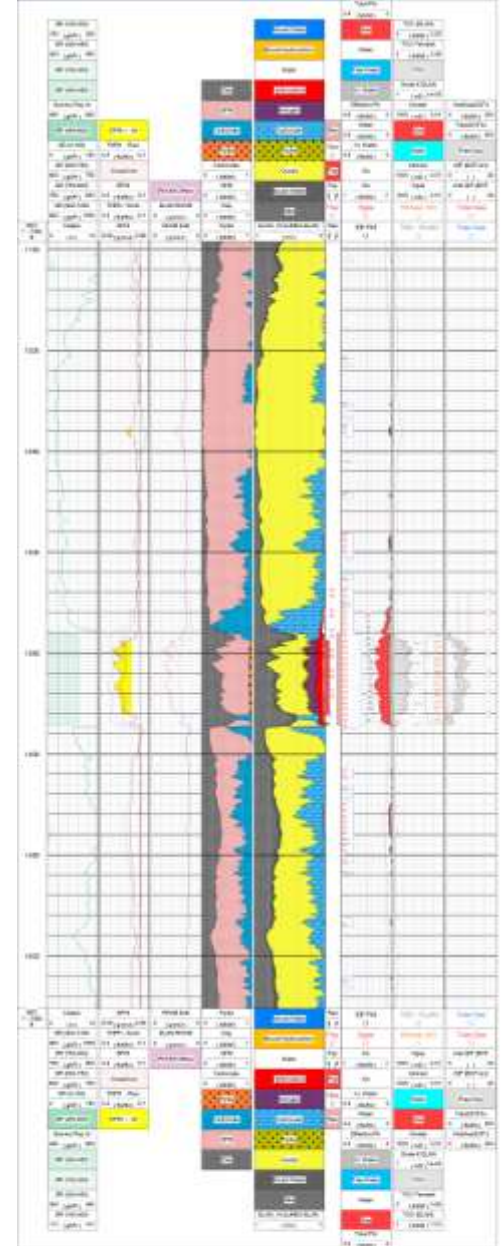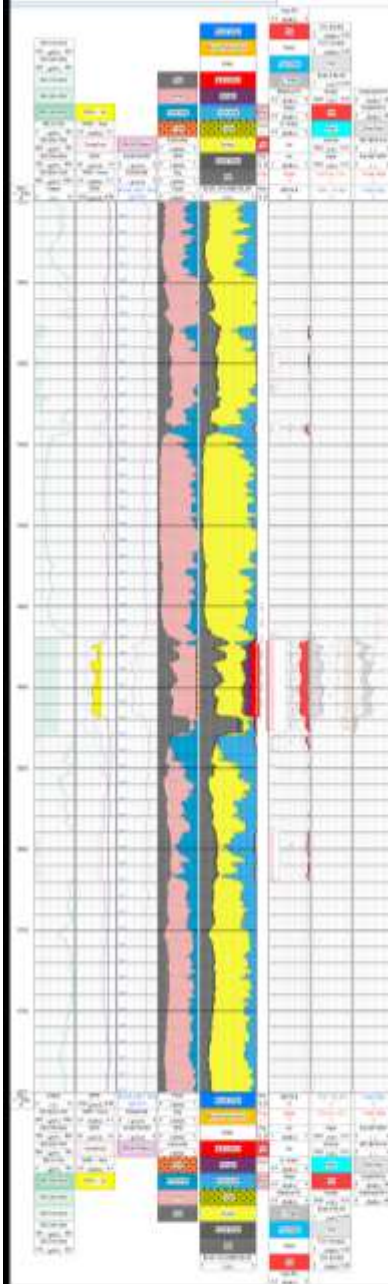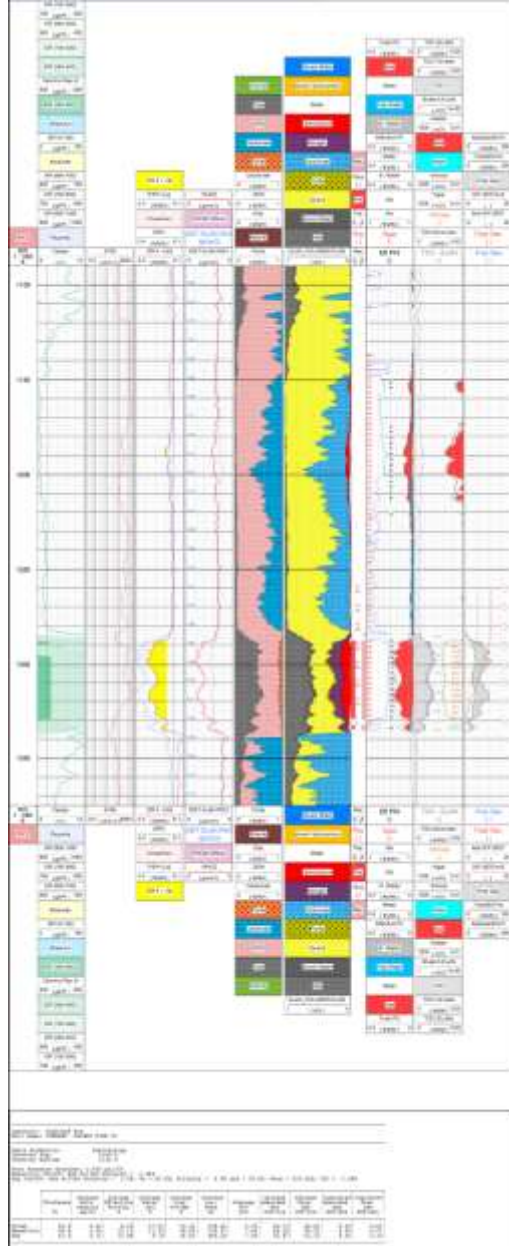
Where is the Oil?

Gas Chromatograph Patterns & Biomarkers— Oil (or gas) sources
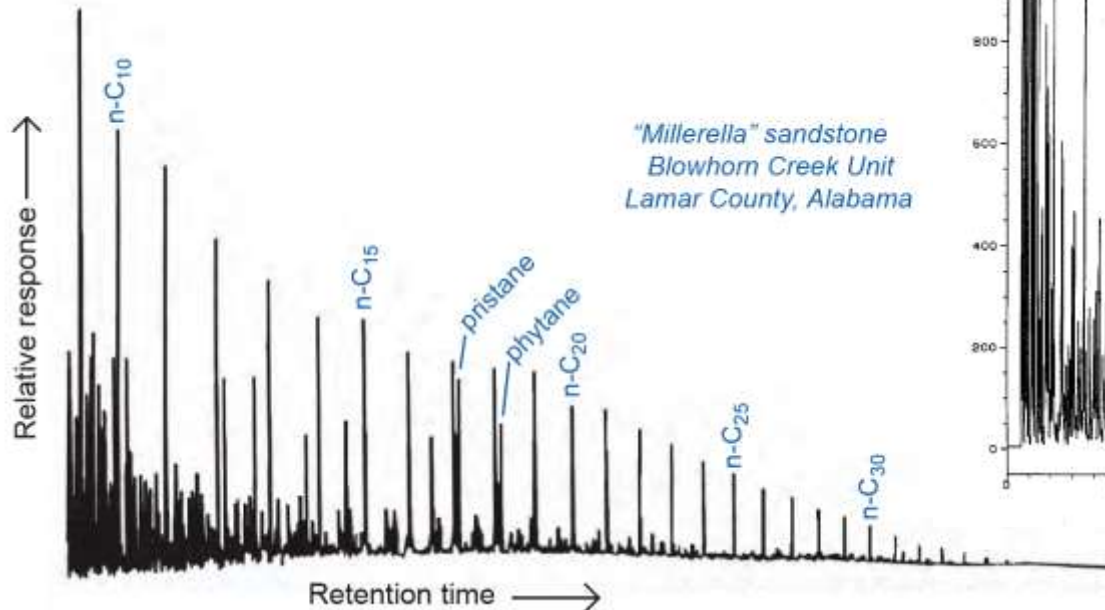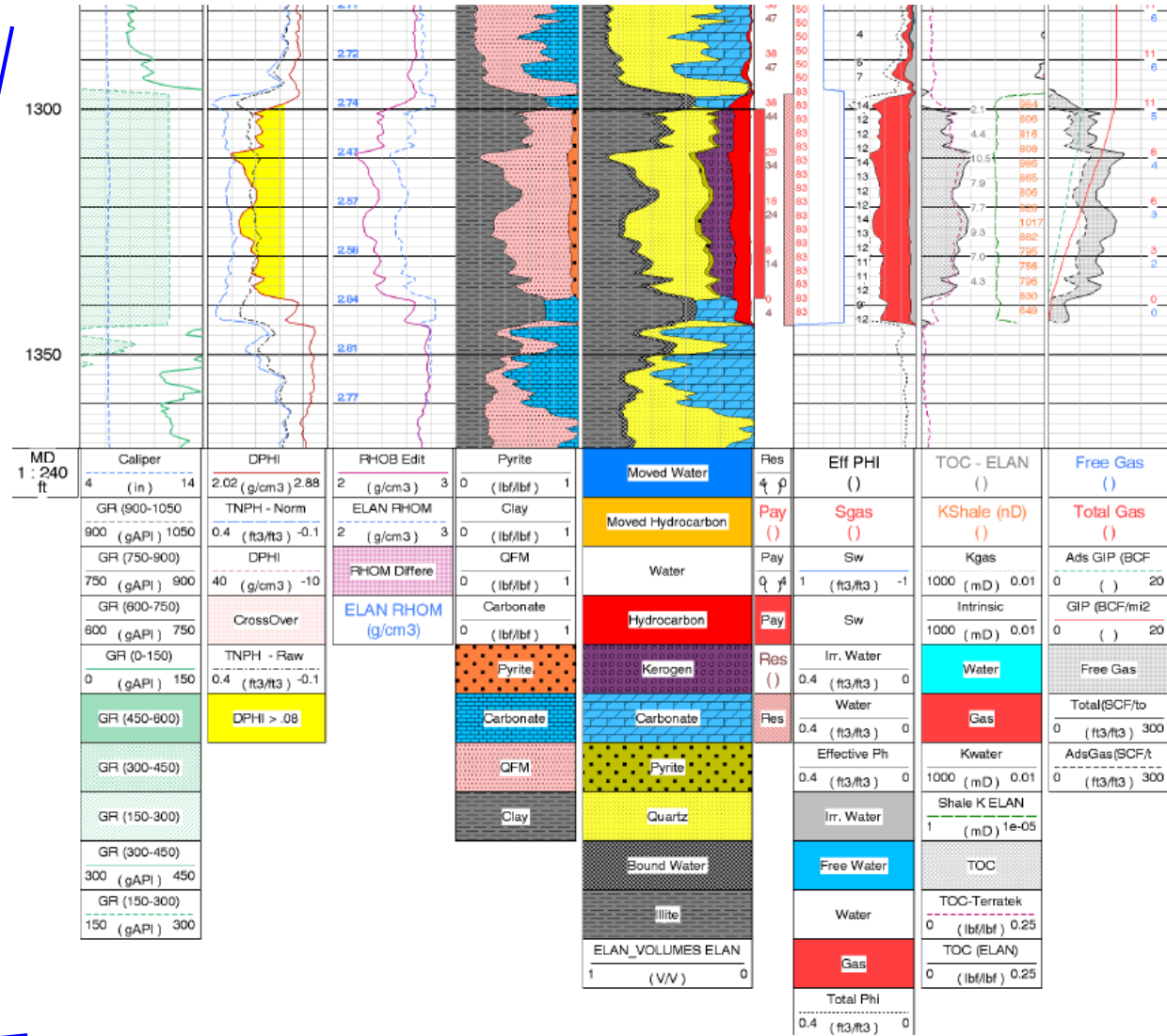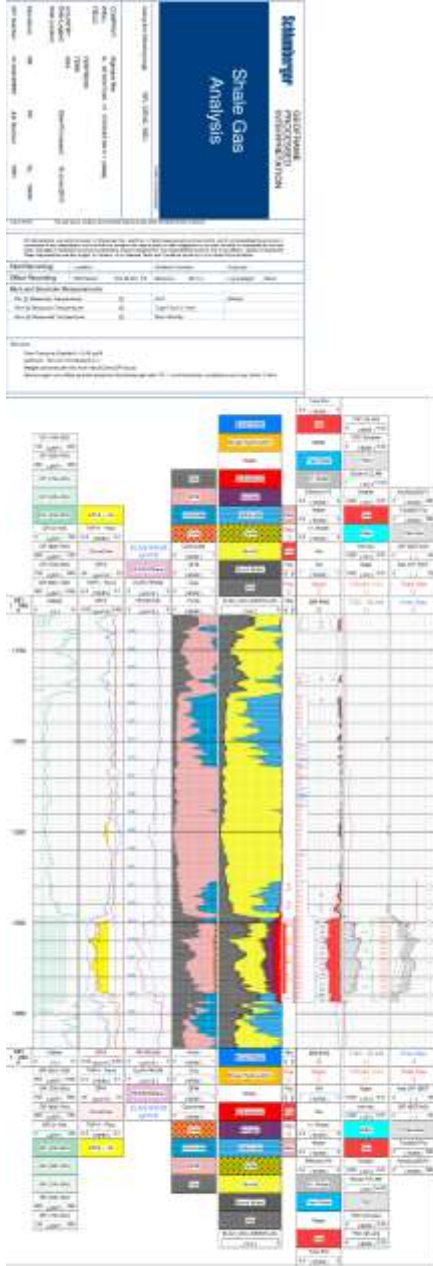
1970s or Older Geophysical Log

Chattanooga Shale

Modern Schlumberger Technology

Modern Schlumberger Technology

	Thickness ft	Average Bulk Density gm/cc	Average Effective Porsity %	Average Water Sat. %	Average Clay Volume %	Average Log. Perm nD	Average TOC wt%	Average Adsorbed Gas SCF/ton	Average Free Gas SCF/ton	Cumulated Adsorbed Gas BCF/sec	Cumulated Free Gas BCF/sec
Gross	48.0	2.40	11.68	17.01	37.51	645.54	5.82	57.27	56.20	5.57	5.57
Reservoir	47.0	2.39	11.89	16.67	37.50	778.01	5.93	58.34	57.30	5.55	5.56
Pay	38.5	2.34	12.29	16.67	33.12	845.21	7.19	70.75	60.15	5.51	4.71

Ladd Kemmer #1

Collar elev. 2366 ft.

1,000

Top Chattanooga 1,580 ft
Base Chattanooga 1,620 ft

2,000

Possible fault ~2,520 ft.

3,000

Possible fault ~3,640 ft.

Thrust fault ~3,900 ft.

Nashville Gr.

4,000

Stones River Gr.

Top Stones River 4,140 ft

Top Knox (Mascot) 4,810 ft

5000

chert-matrix ss.

Top Kingsport 5,760 ft (est)

6000

Top Longview 6,260 ft (est)

Top Chepultepec 6,510 ft (est)

dol. cem. ss.

7,000

Top Copper Ridge 7,010 ft (est)

Depth in feet

Top Maynardville 7,940 ft

8,000

Top Nolichucky 8,210 ft

9,000

Top Rome 9,140 ft

Top dolomitee 9,760 ft
Top ss/sltst/sh/arkose 9,910 ft

10,000

Top basement 10,080 ft

T.D. 10,141 ft

Thrust fault ~3,900 ft.

4,000

Cannon Ls.

Top Hermitage 4,090 ft

4,100

Top Carters 4,140 ft

M

D

4,200

Top Lebanon 4,240 ft

4,300

Top Ridley 4,340 ft

4,400

Top Pierce 4,480 ft

4,500

Top Murphreesboro 4,530 ft

4,600

4,700

Top Wells Ck. 4,780 ft

4,800

Top Knox (Mascot) 4,810 ft

4,900

RDH 6/4/03

Sanford Heirs #1

Collar elev. 913 ft.

Thrust fault 3,790 ft.

Top Reedsville 4,010 ft

Top Stones River 4,182 ft

Nashville Gr.

Top Stones River 4,720 ft

Stones River Gr.

Top Knox (Mascot) 5,948 ft

chert-matrix ss.

Top Kingsport 6,413 ft (est)

Top Longview 6,915 ft (est)

Top Chepultepec 7,148 ft (est)

dol. cem. ss.

Top Copper Ridge 7,648 ft (est)

Top Maynardville 8,500 ft

Top Nolichucky 8,870 ft

Top Rome 10,000 ft

Top ss/sltst/sh/arkose 11,028 ft

Top basement 11,442 ft

T.D. 11,534 ft

Depth in feet

RDH '03

Top of Stones River Group & Important Marker Beds
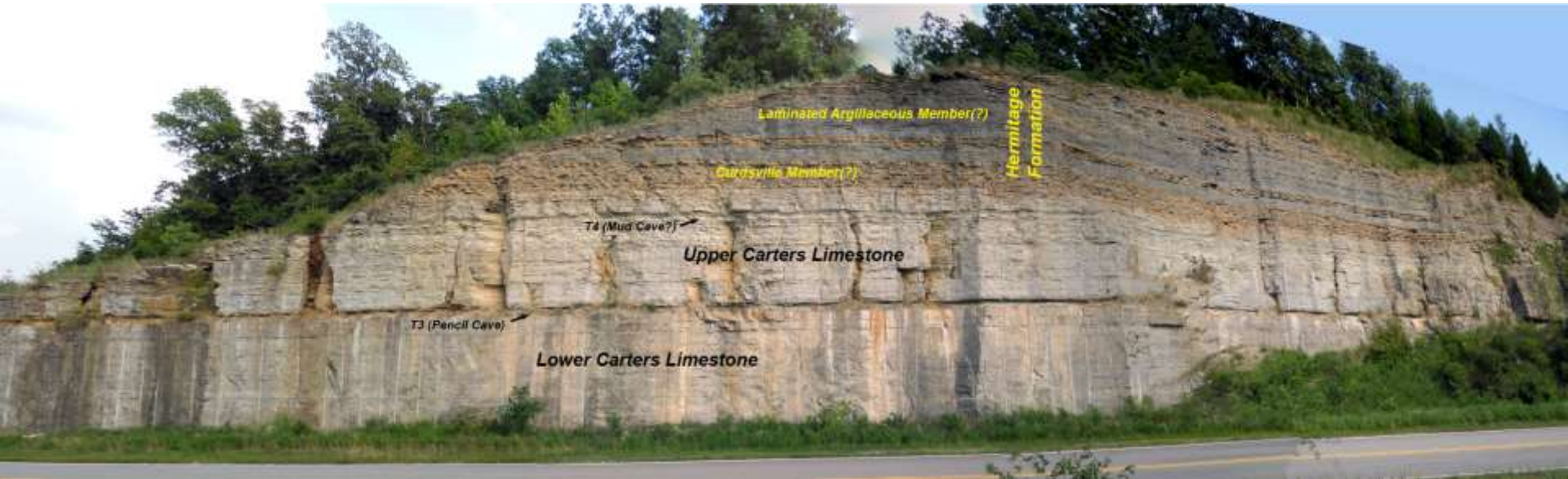
TN 109 (Gallatin) Exit on I-40
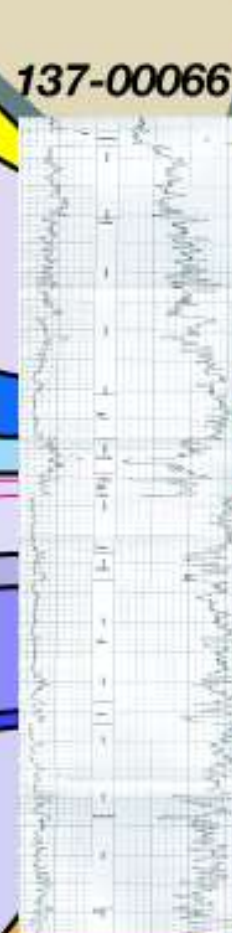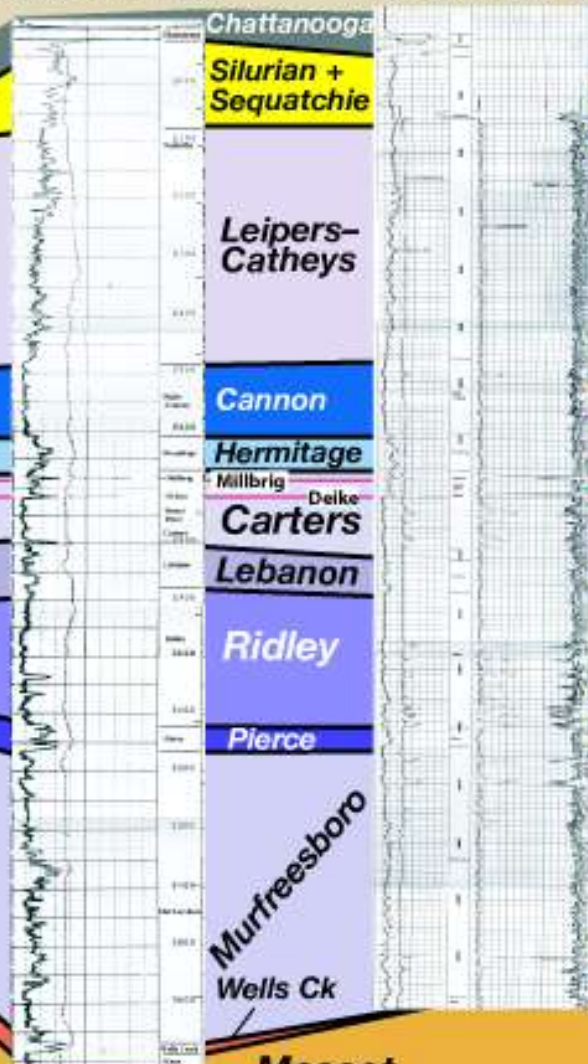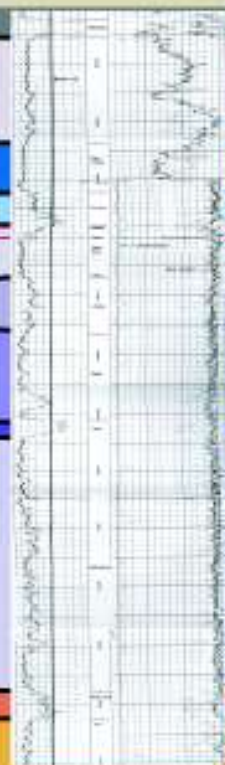E of Nashville

Possible Subsurface Stratigraphy

151-00057

137-00066

049-20079

035-20163

041-20001

031-20001

031-20001

Pickett
137-00066
151-00057
Fentress
Scott
049-20079
041-20001
De Kalb
Cumberland
035-20163
Coffee
031-20001

25 0   50
kilometers

N

Chattanooga
Silurian + Sequatchie
Leipers–Catheys
Cannon
Hermitage
Millbrig
Deike
Carters
Lebanon
Ridley
Pierce
Murfreesboro
Wells Ck
Mascot

Black shale

Shale with minor sandstone

Shaly limestone

Limestone with minor shale

Shale and sandy limestone

Massive limestone

Limestone with shale

Massive limestone

Limestone with shale

Shale with limestone

Massive dolostone

(a)

① BISHOP HOFFMAN 2 KY 62035

② COFFEY HEIRS 2 KY 87114

③ BRYANT KY 37601

④ LUM CREEKMORE 1 KY 93179

⑤ ANNA MARY CREEKMORE 1 KY 48667

⑥ HARMON 1 KY 94533

⑦ PEIRER TROXELL 1 KY 89228

⑧ LOIS REYNOLDS 1 KY 84495

⑨ PHILLIP PERKINS 1 KY 93030

⑩ J. L. WHITE 7–B KY 102243

Chattanooga

Silurian

Catheys-Leipers

Cannon

Hermitage

Carters

Lebanon

Ridley

Murfreesboro

Pond Spring

Knox

From Hatcher & Bailey, 2020, Structural Geology

Bentonites in Upper Carters, Lower Hermitage

Behind car wash at intersection of TN 62 & TN 95 in Oak Ridge, TN

Defining petroleum systems: surface & subsurface data

Petroleum Systems in Tennessee


AAPG Memoir 60

THE PETROLEUM SYSTEM– FROM SOURCE TO TRAP

Edited by Leslie B. Magoon and Wallace G. Dow

Approximately 4,000 ft

Sandstone, shale, and coal (coal-bed methane) — Pennsylvanian Petrol. System

Pennington Fm. — Shale and limestone

"Big Lime" (oil & gas)

Silty dolomite and shale

Limestone reefs (oil)

Ft. Payne Fm.

Devonian-Mississippian Petrol. System

Chattanooga black shale (source & gas reservoir)

Shaly limestone

Limestone (oil & gas)

Sandy-shaly limestone   Volcanic ash beds

Limestone

Shaly limestone

Limestone

Shaly limestone

Limestone (oil & gas)

Shaly limestone

Ordovician Petrol. System

Knox Dolomite (source & oil & gas reservoir)

RDH 2/28/13

Not to scale

Source for Ordovician Hydrocarbons

Copper Ridge Dolomite
U.S. 25E

Oil Residues in Vug in Knox Dolomite

Pasminco Elmwood Mine near Carthage, TN

Fluorite

Oil residue

Quartz

Upper Knox dolomite
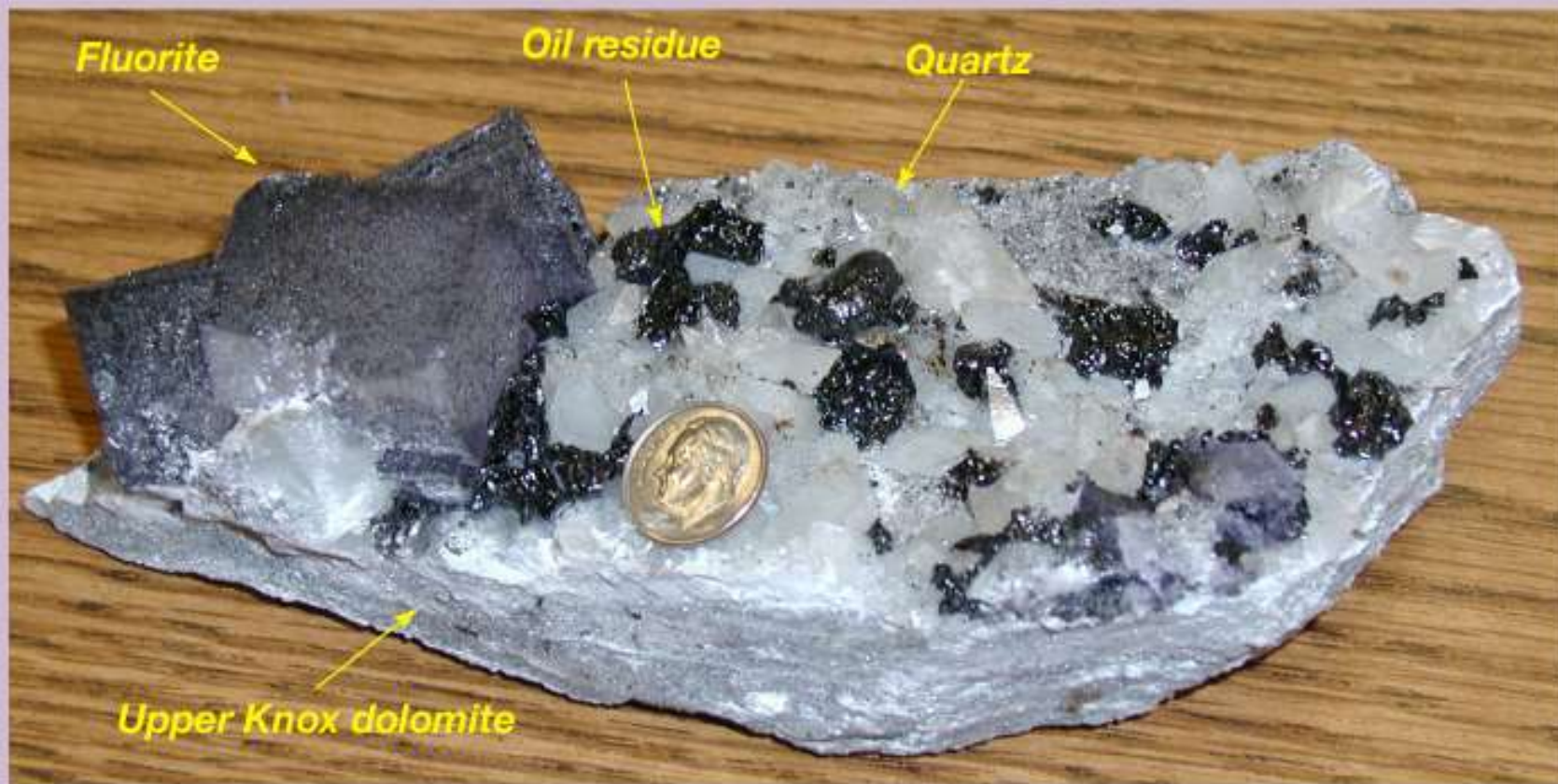
Specimen donated to UT by Pasminco and geologist Fred Smith

RDH '03

Ft. Payne Fm. (Miss.)

Chattanooga Sh. (Dev.-Miss.)
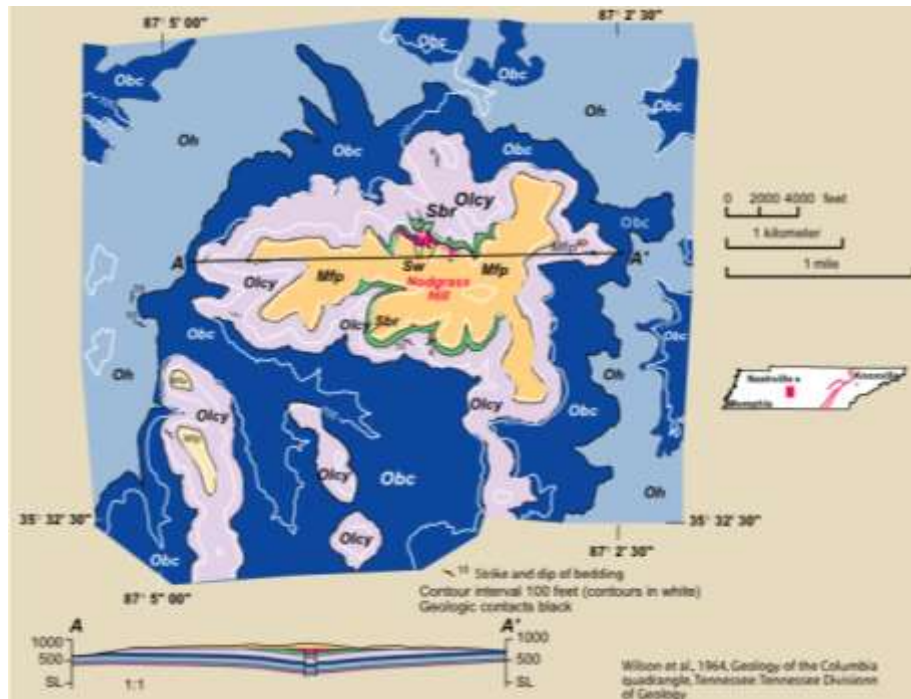
At least 83 m.y. missing

Leipers Fm. (Ord.)
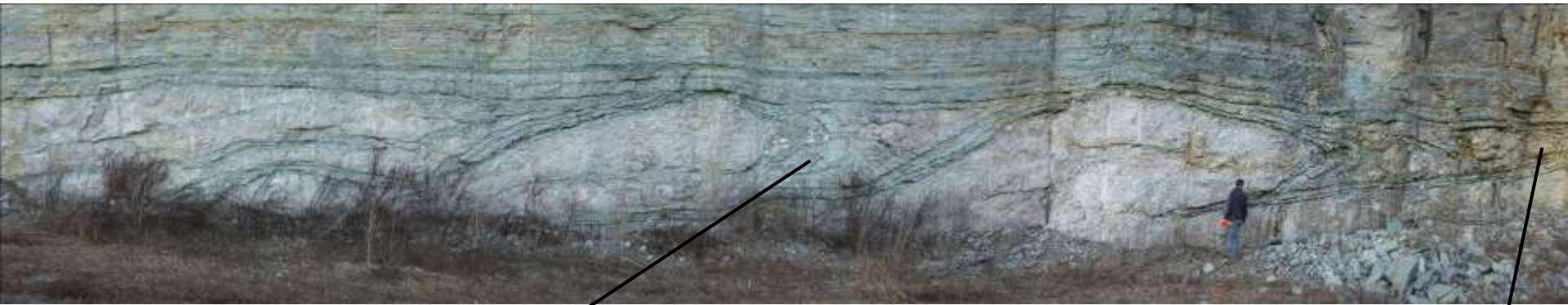
At least 75 m.y. missing
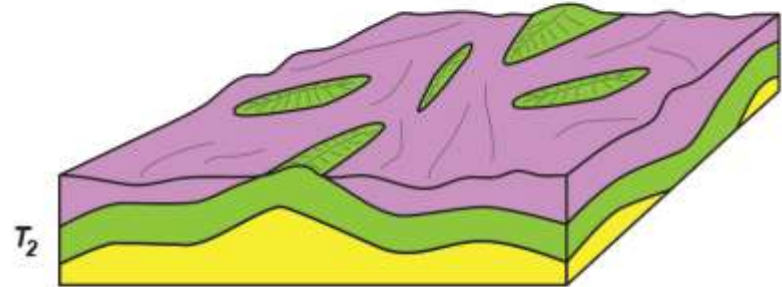
TN 109 N of Gallatin, TN?

Part of Columbia, TN, Quad
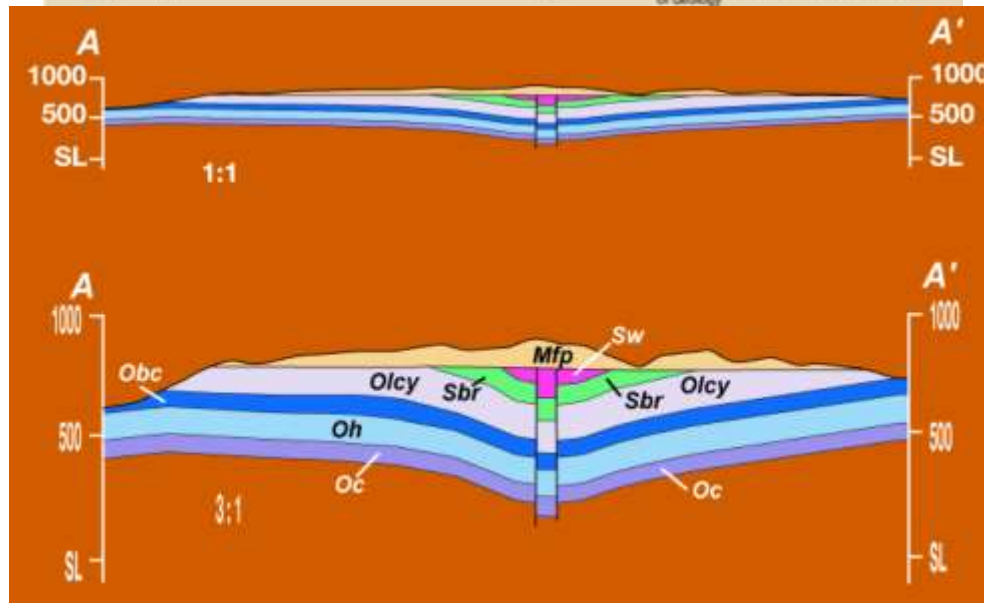
Pre- and Post- Chattanooga Relationships
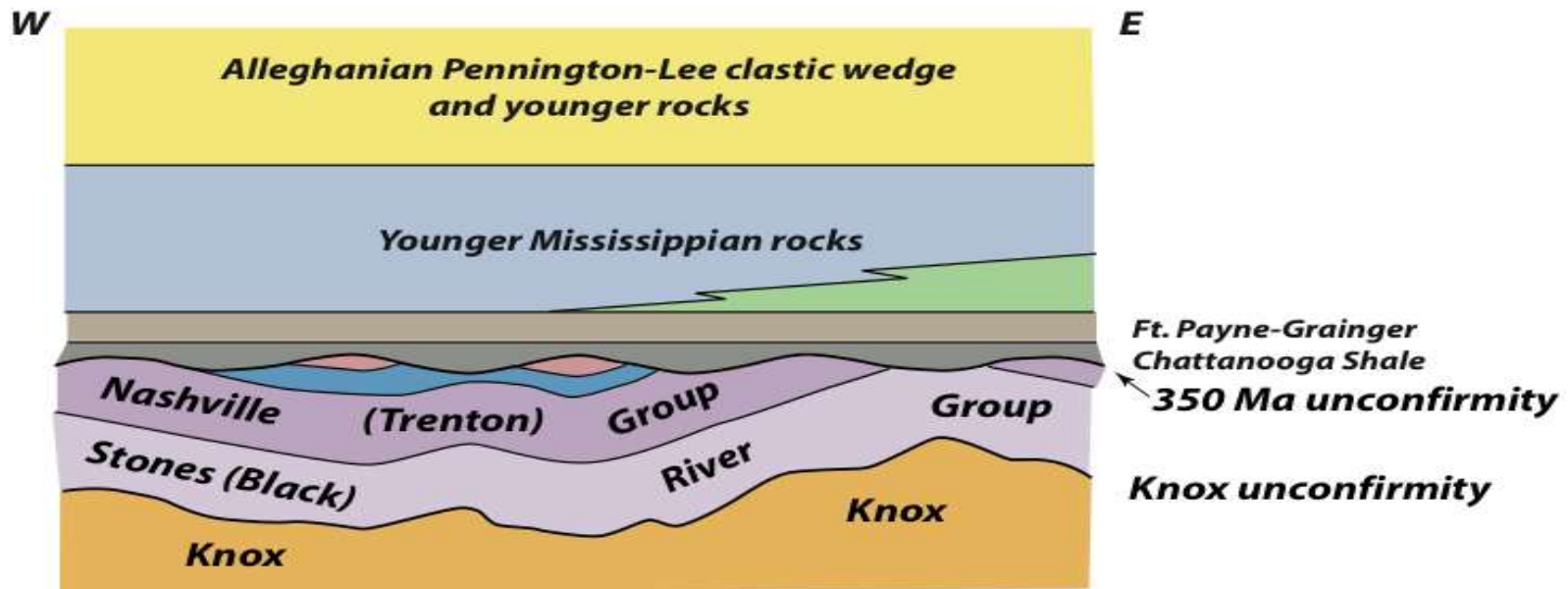
Sequential Geologic History
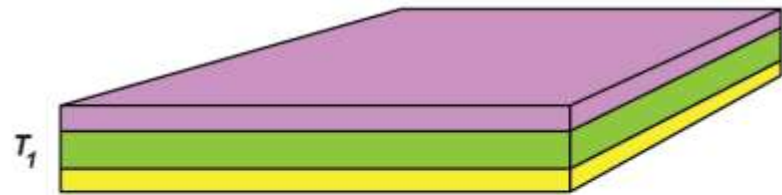
T_1 — Pre-Mid-Silurian deposition

T_2 — Post-Mid-Silurian-pre-Late Devonian deformation (Acadian-NeoAcadian orogeny?) & nascent doming, erosion
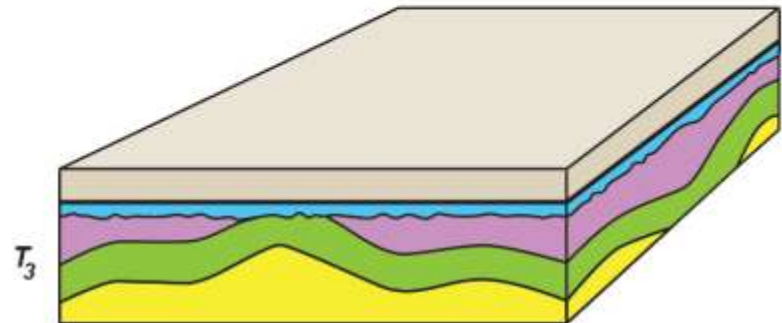
T_3 — Late Devonian-Pennsylvanian deposition

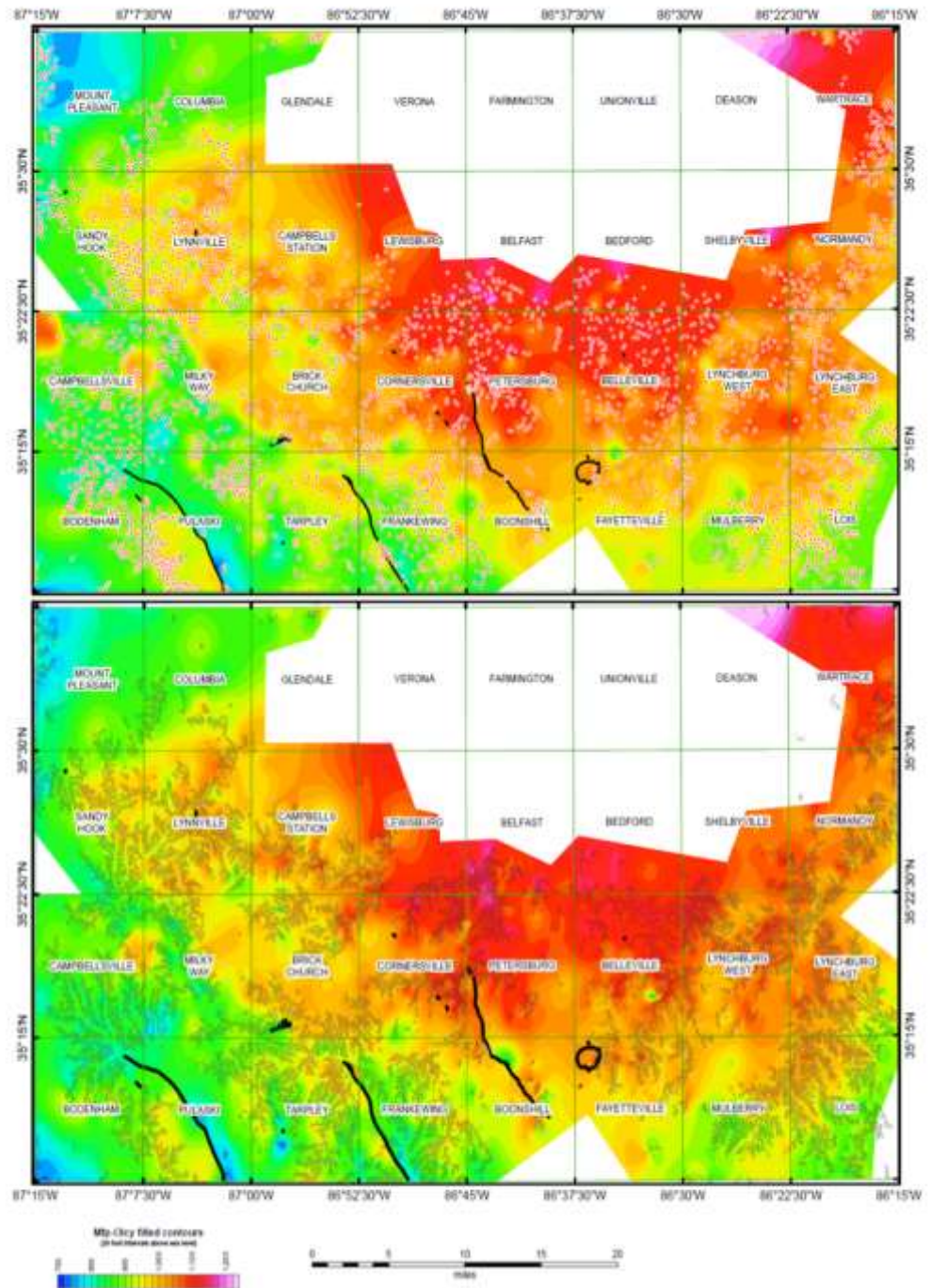T_4 — Late Pennsylvanian-Early Permian Alleghanian orogeny & renewed doming

ALW-RDH 2017
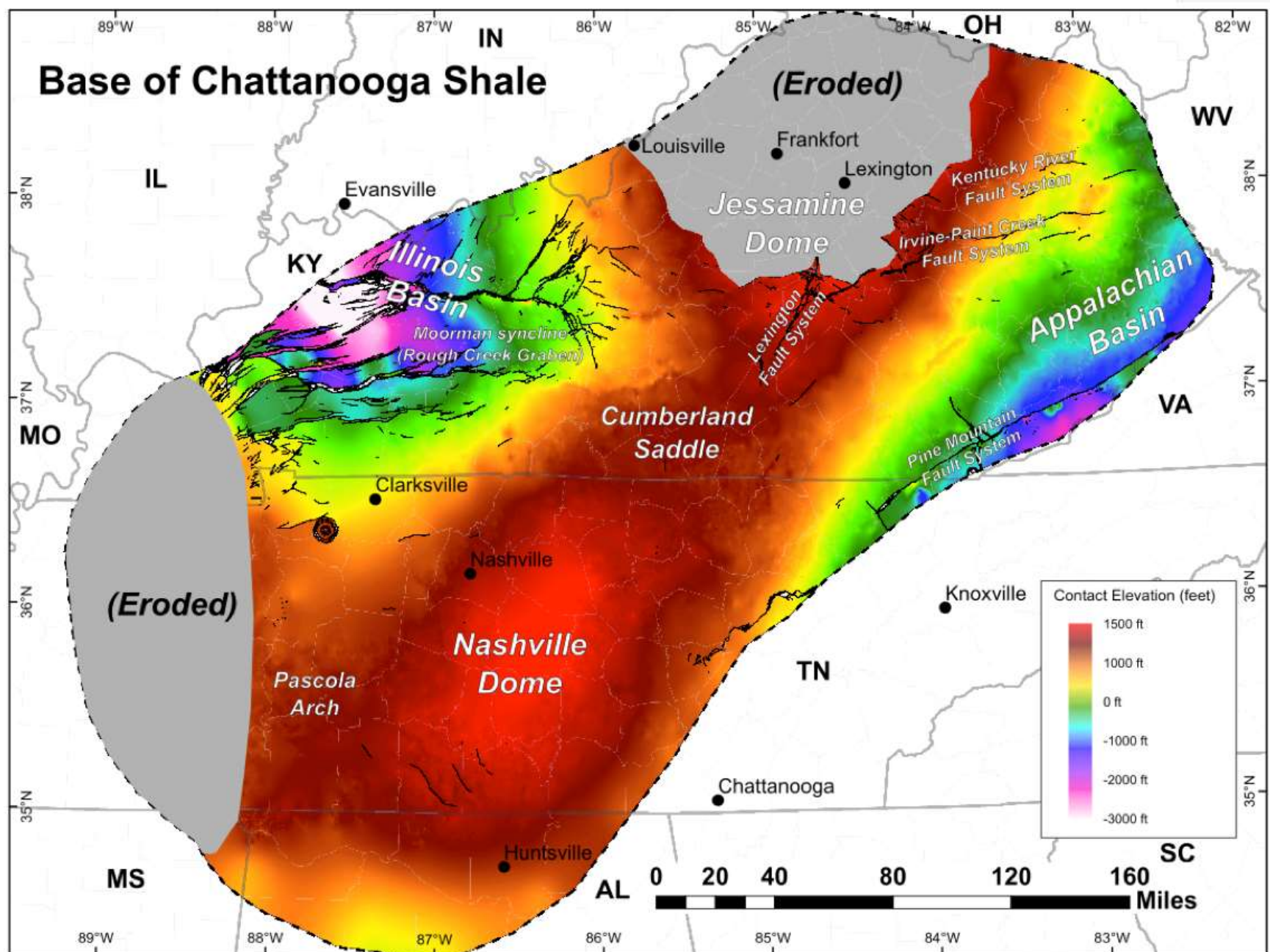
Image courtesy of Ken Boling

Using Modern Technology

4,000 points hand picked, contoured in ArcMap by Andrew Wunderlich and Morgan Strissel

Base Chattanooga Shale (southern Nashville dome)

Same area: 73,000 points machine picked, contoured in ArcMap by Ken Boling
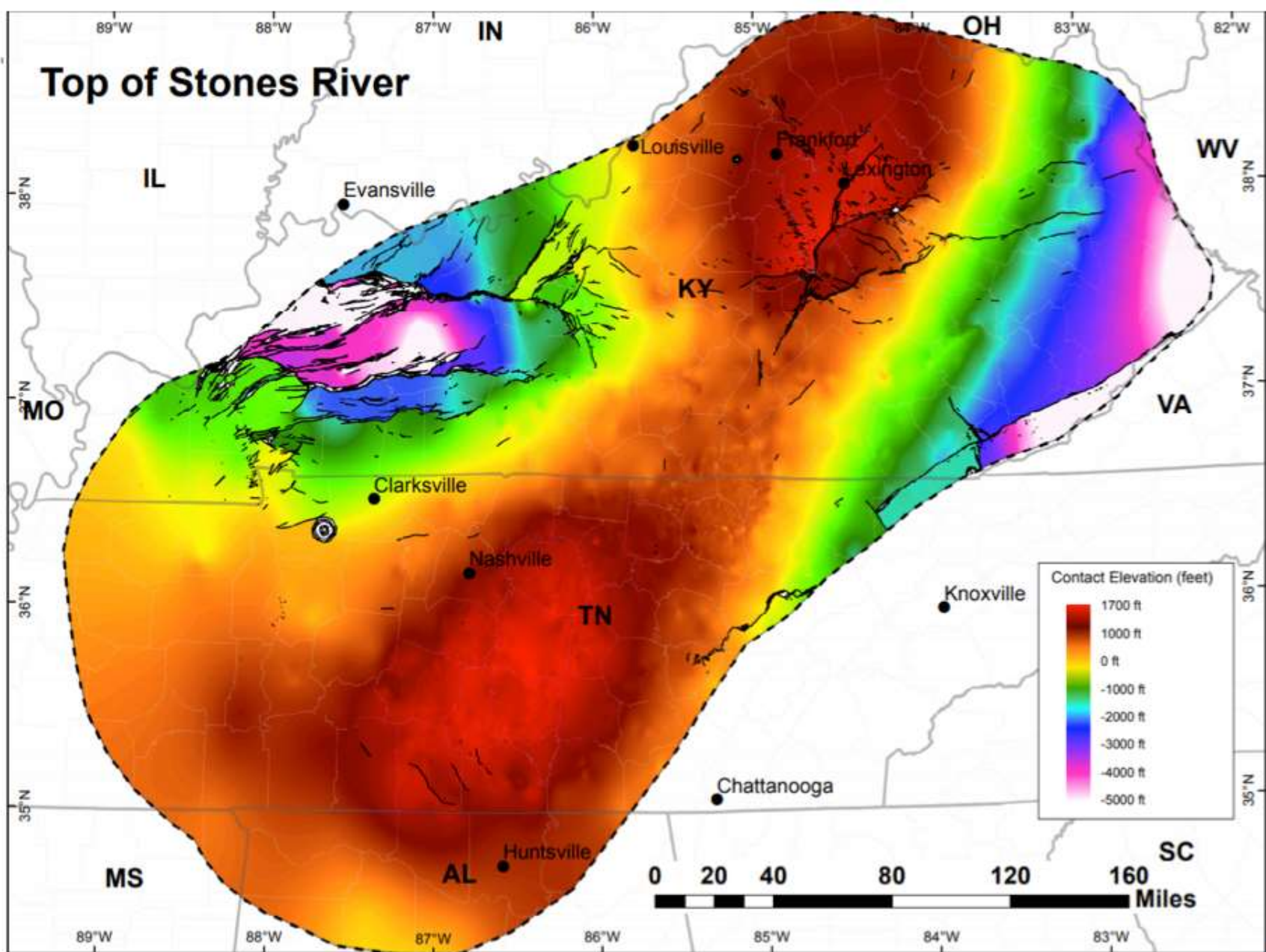
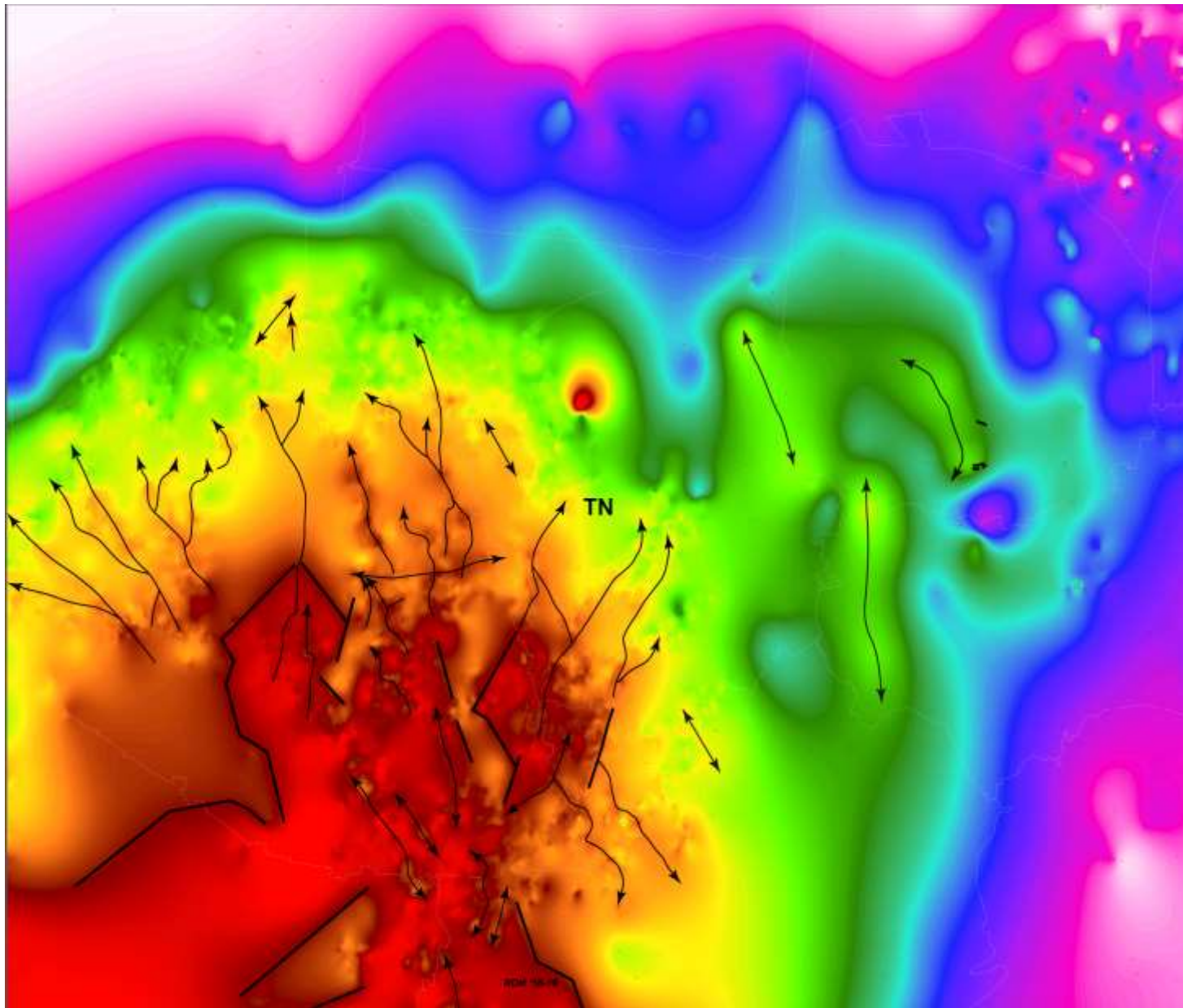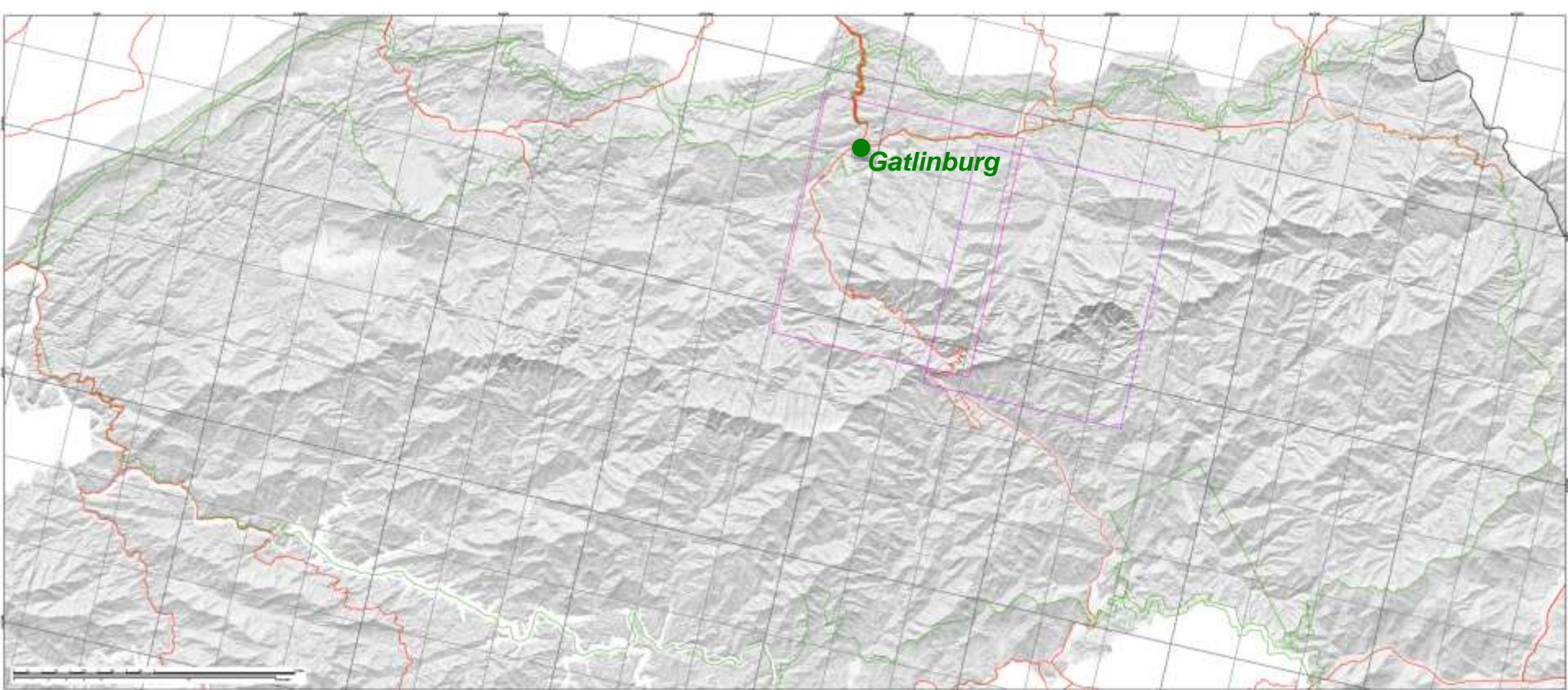**Images courtesy of Ken Boling**

Top of Stones River

Image courtesy of Ken Boling

Top Stones River Group, NE Nashville dome: Hi-Tech, Lo Tech

*Top Stones R surface courtesy of Ken Boling,
structural interpretation by RDH*

LiDar Image GSMNP

Gatlinburg

Useful information from LiDar data

- *Bedrock fractures, some contacts*

- *More precise well locations (recall Gary Bible TOGA presentation a couple of yrs. ago).*

Conclusions: Take-Home Points

- *Limited kinds of data should not hinder good O & G exploration/development, as long as there are enough.*

- *Numerous opportunities exist to employ new technologies for reprocessing and utilizing existing data, or to assemble and analyze large data sets.*

Dinosaurs' Almanac
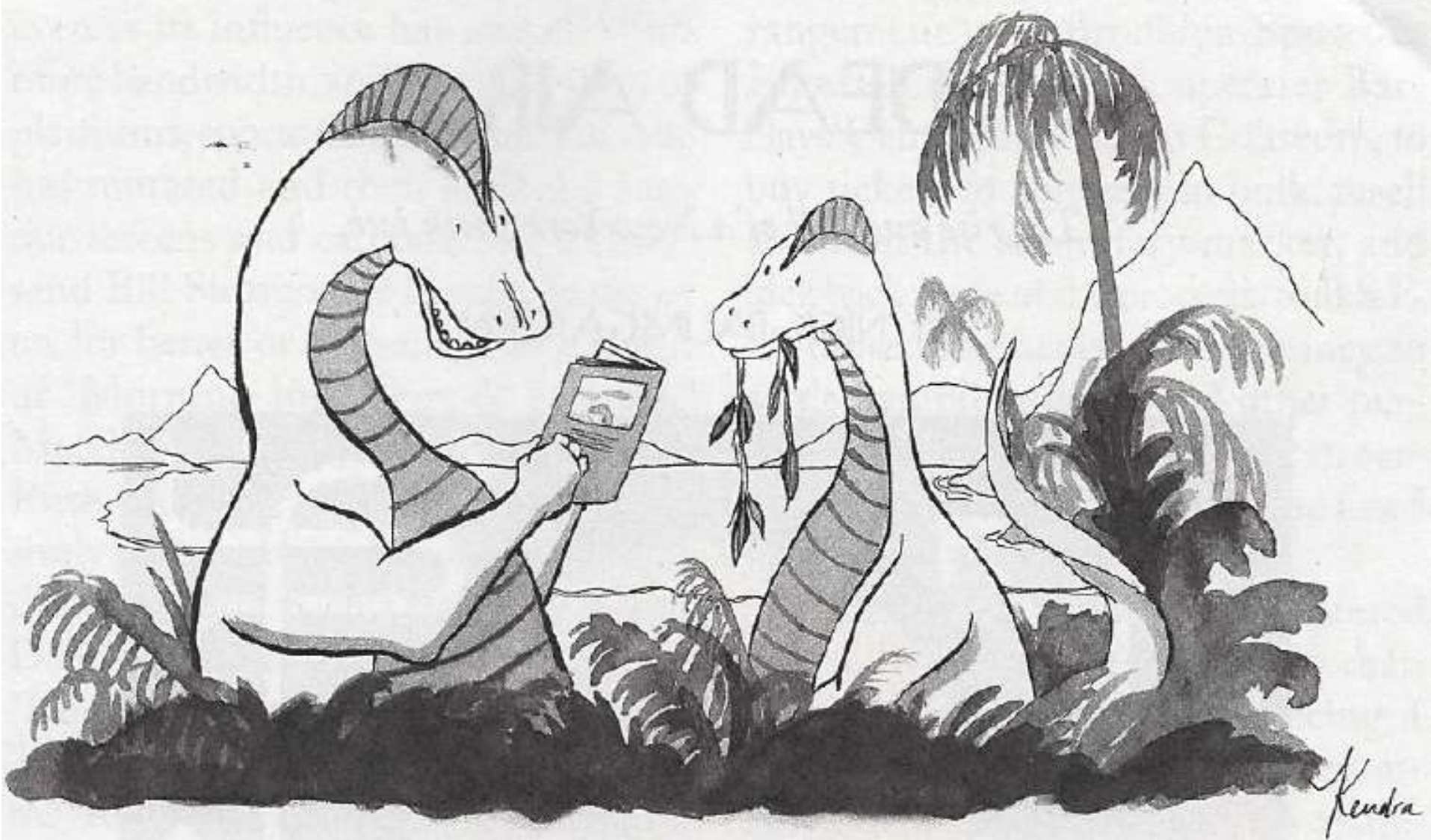
"Weird. It says we'll all die this year."