Petroleum Resources of the Great American Carbonate Bank: Exercising Unconformity Thinking*

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Abstract

Cambrian Ordovician carbonates of Ellenburger, Arbuckle, and Knox reservoirs (GACB) are full of surprises and opportunities. Most of the 3,650 oil and gas fields (7.7 BBOE cumulative production) are closely associated with the Sauk Tippecanoe (S/T) Unconformity (470-460 MYBP). The S/T Unconformity (and other later unconformities) create traps, enhance reservoirs, and (along with faulting) provide petroleum system charge and migration pathways. Dolomite is the preferred reservoir rock. General environments of deposition affect reservoir quality and pay distribution. These include up dip, mid dip, aulacogen, and down dip settings. Field examples show key elements for prospecting. Horizontal drilling and 3D seismic provide valuable tools to explore for new production and to revisit productive areas and "condemned" areas with hydrocarbon shows. We plan to include a low flying helicopter high resolution overflight of the famous paleokarst exposures in the Franklin Mountains, El Paso, Texas (narrated by Dr. Jerome Bellian). The GACB system is offered as an analog for paleokarst carbonate systems. (This talk includes highlights from AAPG Memoir No. 98, 2012, and its petroleum resources Chapter 7).

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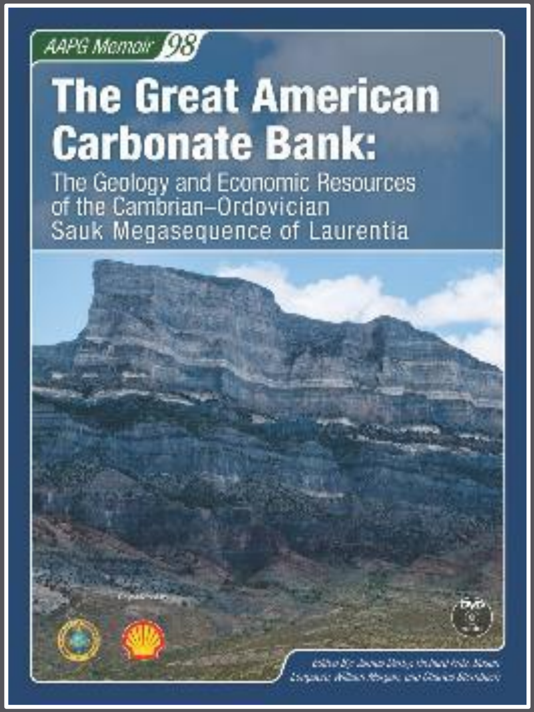
Petroleum Resources of the Great American Carbonate Bank

Exercising "Unconformity Thinking"

Charles A. Sternbach,
President Star Creek Energy and
President Elect AAPG

Origin of Talk

- "Great American Carbonate Bank" phrase coined by Ginsburg, Derby and Wilson for Upper Cambrian and Lower Ordovician intracratonic carbonates
- AAPG Memoir 98, 2012, Editors: Jim Derby, Rick Fritz, Susan Longacre, Bill Morgan, **Charles Sternbach**
- **Chapter 7, Oil and Gas production**
- Tribute To James Lee Wilson (on right)
- Lessons for other carbonate systems



Insights and Strategies

- Up-to-date production data (courtesy IHS)
- GACB reservoirs: Mid Continent, Canada, Greenland
- Fault juxtaposition of SR and seal key
- Diverse traps
- Most production comes from at or near the Sauk/Tippecanoe Unconformity
- Unconformity major karst imprint, highly variable reservoir
- Possible lessons for other carbonate systems

Importance of the Sauk/ Tippecanoe Unconformity (470-460 MYBP)

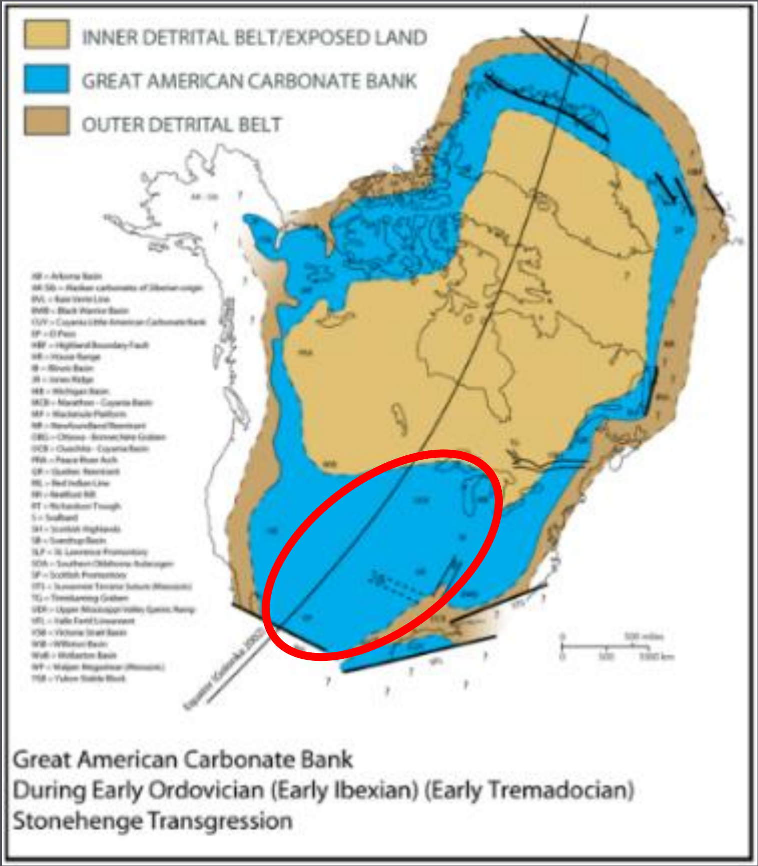
- Levorsen (1943) “Discovery Thinking”
- Sloss sequences
- Ewing 2002 “Unconformities make traps…find them and study them”
- Major production from GACB reservoir occurs close to Sauk/Tippecanoe unconformity

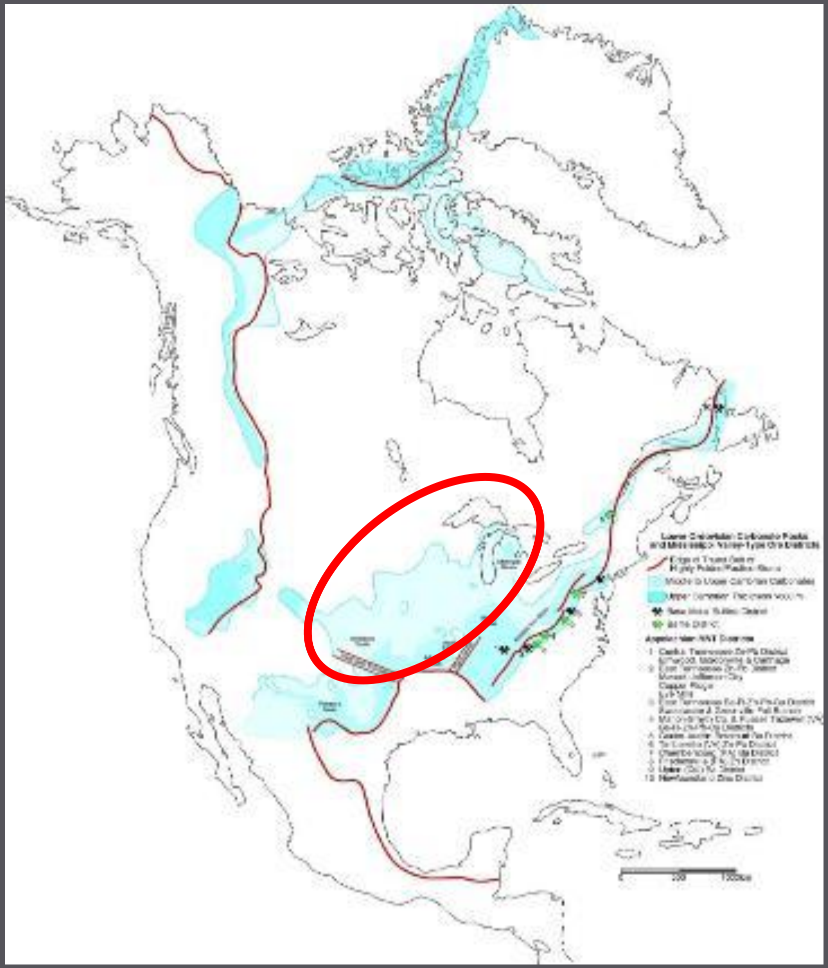
Reasons "Wedge belts" form prolific unconformity traps

1) Inherent porosity changes,
2) Pressure differential attracting HC
3) Migration paths, old traps
4) ***Karstified carbonates add interesting complexity***

Levorsen 1943

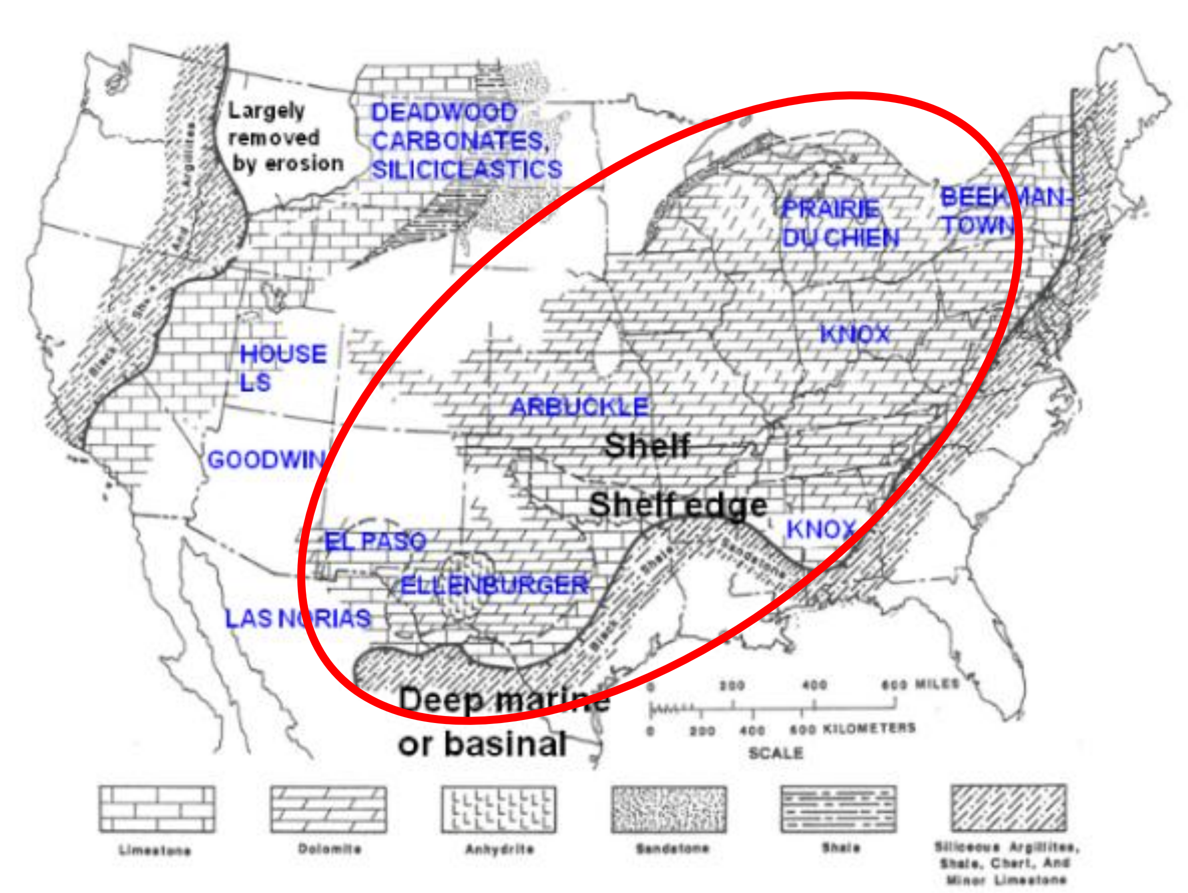
The "Big Picture"





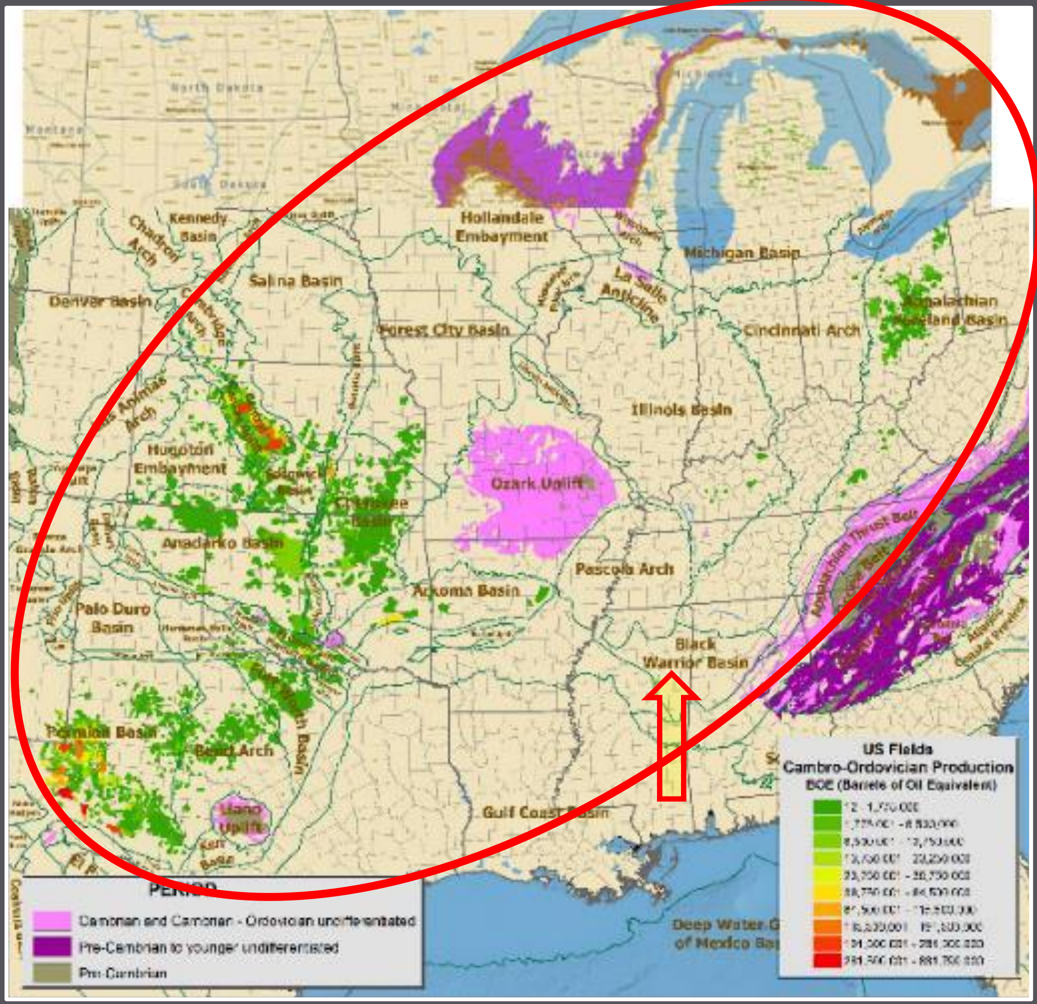
J.R. Derby (in press) Introduction Chapter, AAPG GACB Memoir

Familiar Formation names



C. A. Sternbach (in press) Petroleum Resources Chapter, AAPG GACB Memoir

Oil and Gas Production



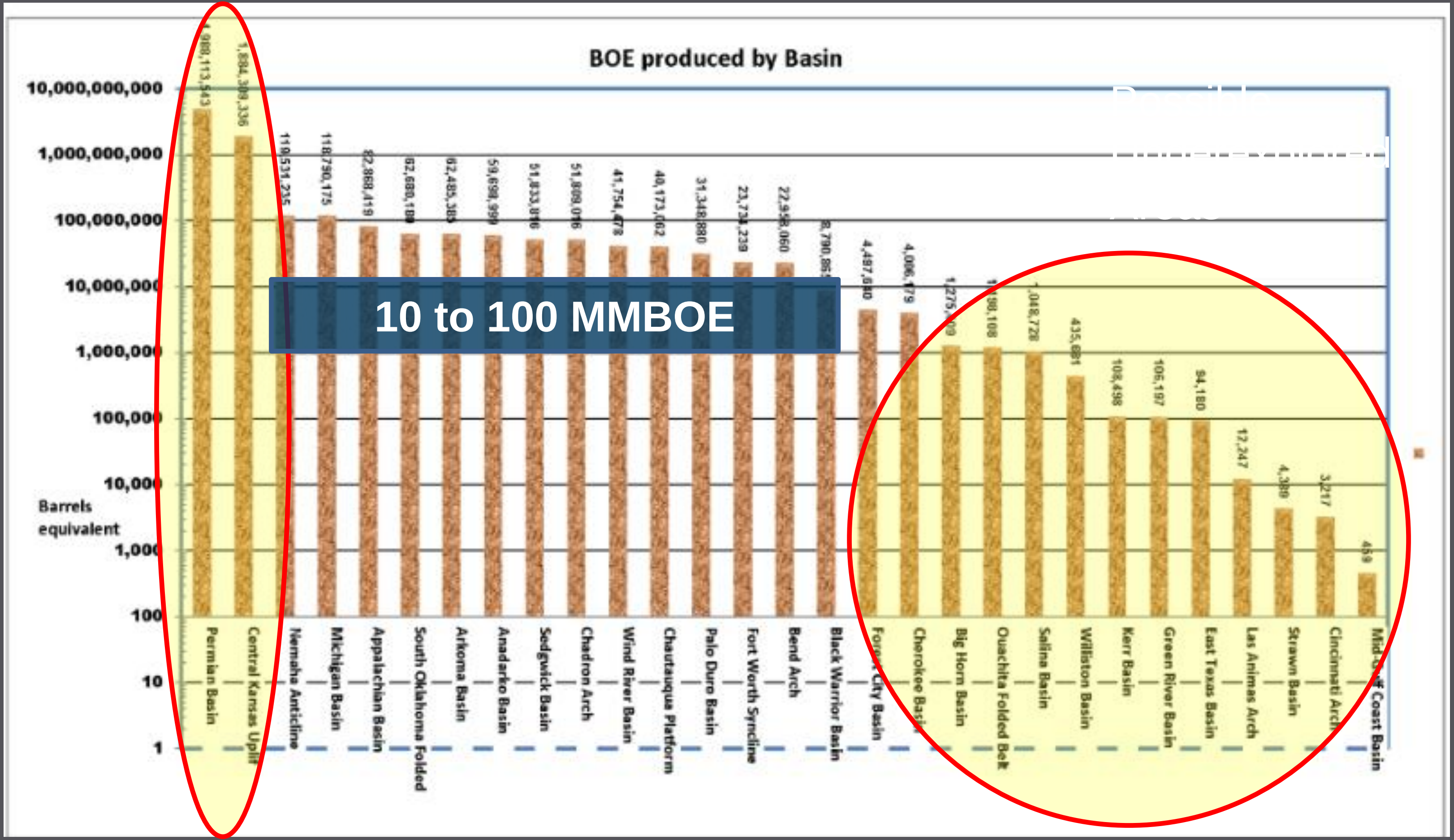
C.A. Sternbach, AAPG Memoir #98, Petroleum Resources Chapter 7, 2012

Data Courtesy IHS

Leading Basins

Two Basins Permian and CKU Dominate

Data Courtesy IHS

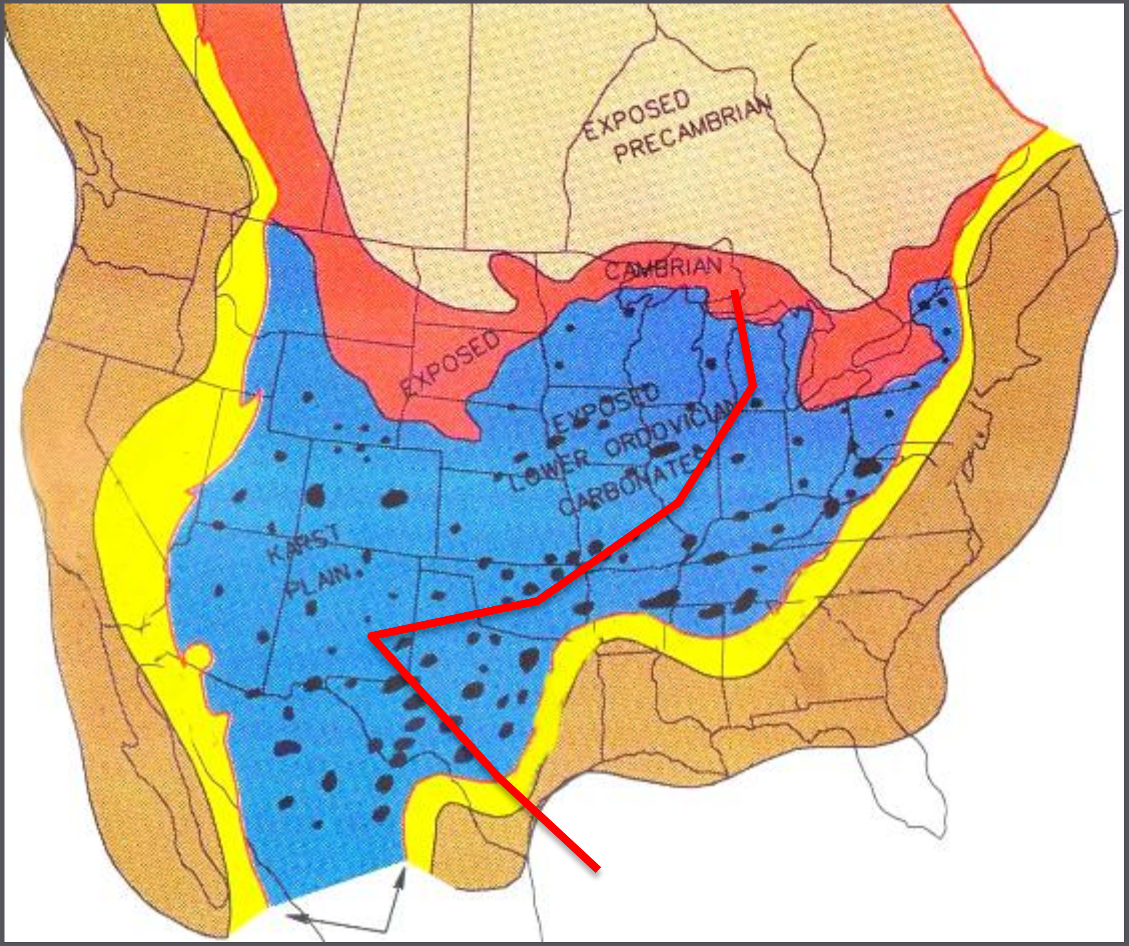


C.A. Sternbach, AAPG Memoir #98, Petroleum Resources Chapter 7, 2012,

Production Statistics

- Approximately 3,650 fields
- GACB reservoirs 4.13 billion BO 21TCF gas cum
- GACB reservoirs 7.7 billion BOE.
- More than half of this (57%) is oil
- Data provided courtesy of IHS
- Abundant Domestic US Oil; timely to revisit

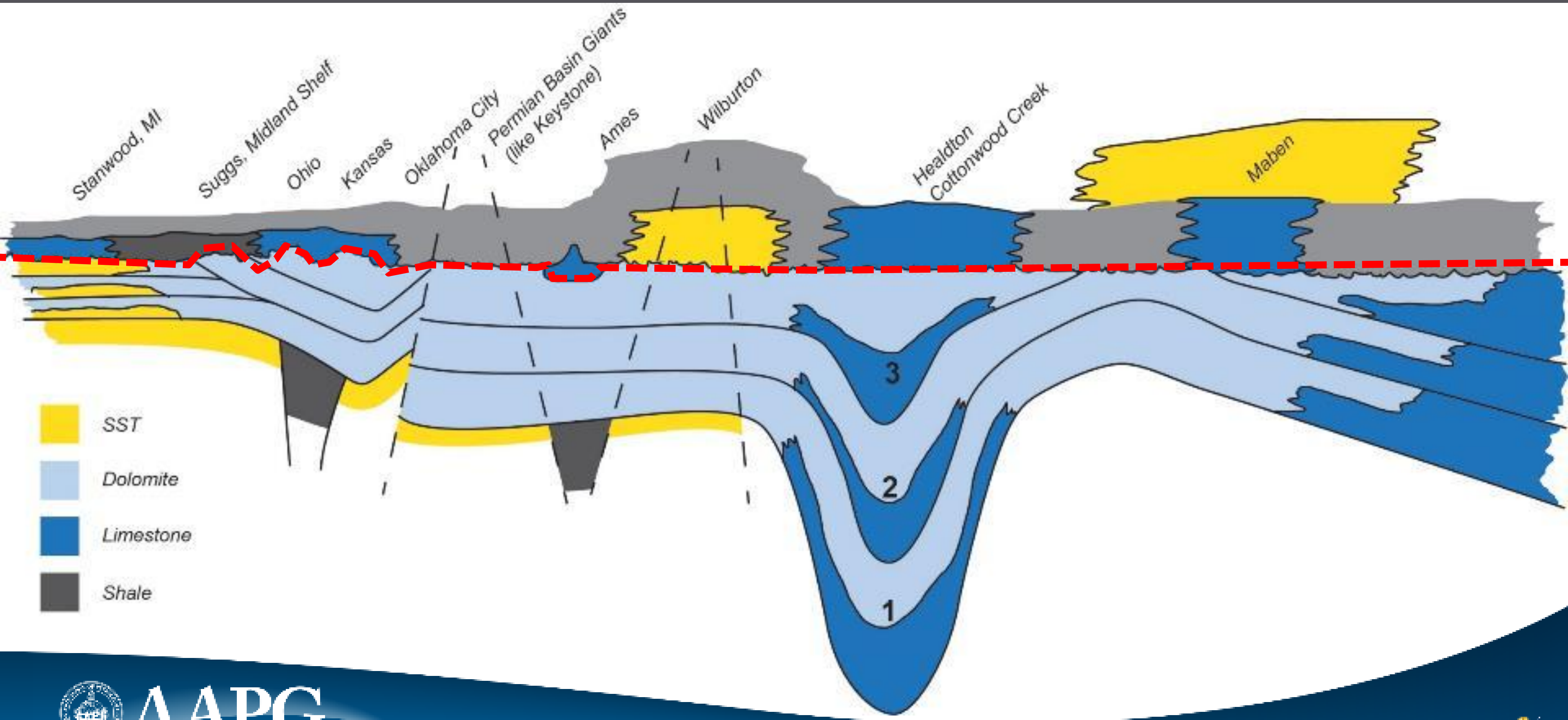
Karst plain of the exposure at the end of Sauk deposition prior to Tippecanoe submergence (470-460 MYBP)



Regional Composite Section

Datum: Sauk-Tippecanoe Unconformity 470-460 MYBP approx red line)

UPDIP	MIDDIP	AULACOGEN	DOWNDIP
Inner Detrital Belt Sandstones and Dolomite interbeds	Mid Dip Shelf Dolomite Main Productive Setting	Limestone increases	Outer Ramp Limestone Increases



AAPG Southwest Section

Regional Composite Section

Datum: Sauk-Tippecanoe Unconformity 470-460 MYBP approx red line)

UPDIP

Inner Detrital Belt Sandstones and Dolomite interbeds

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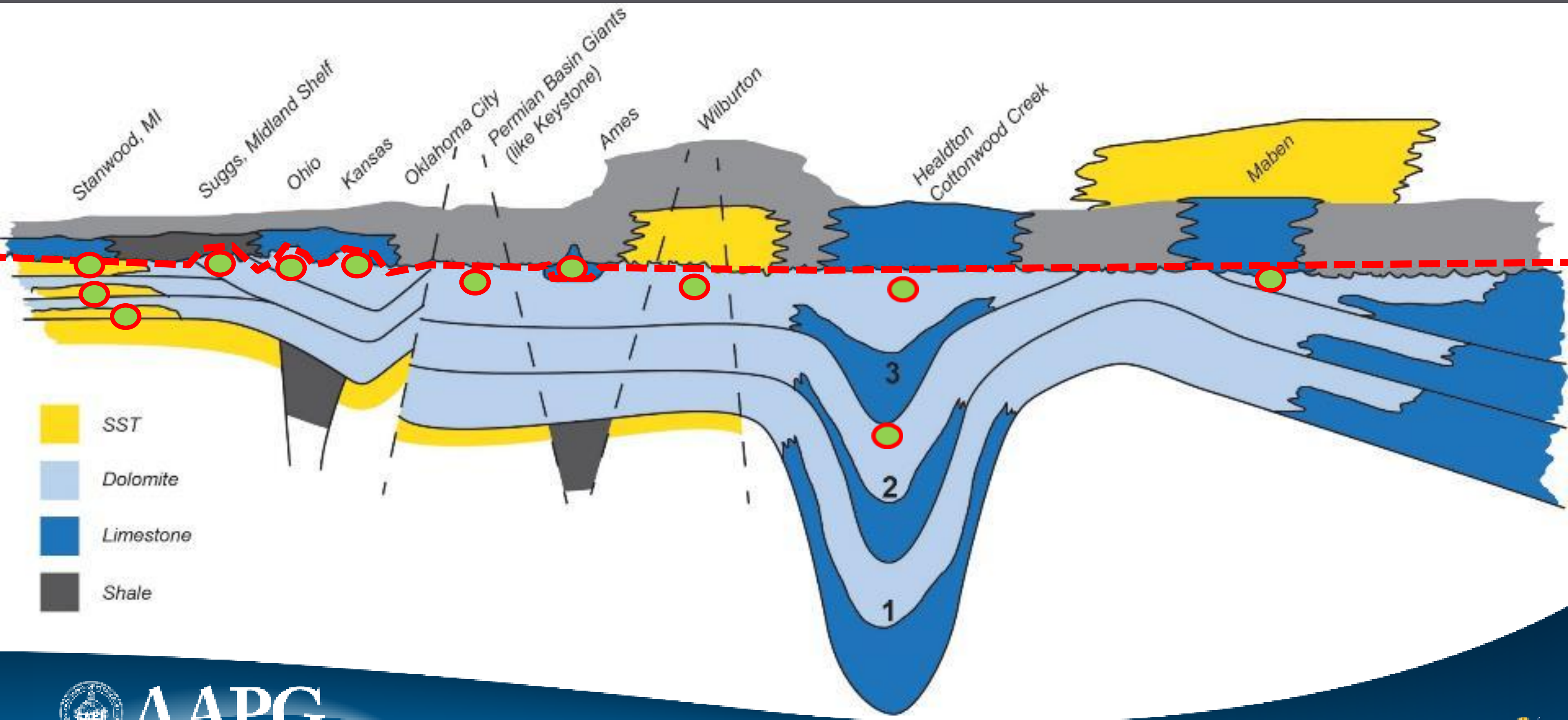
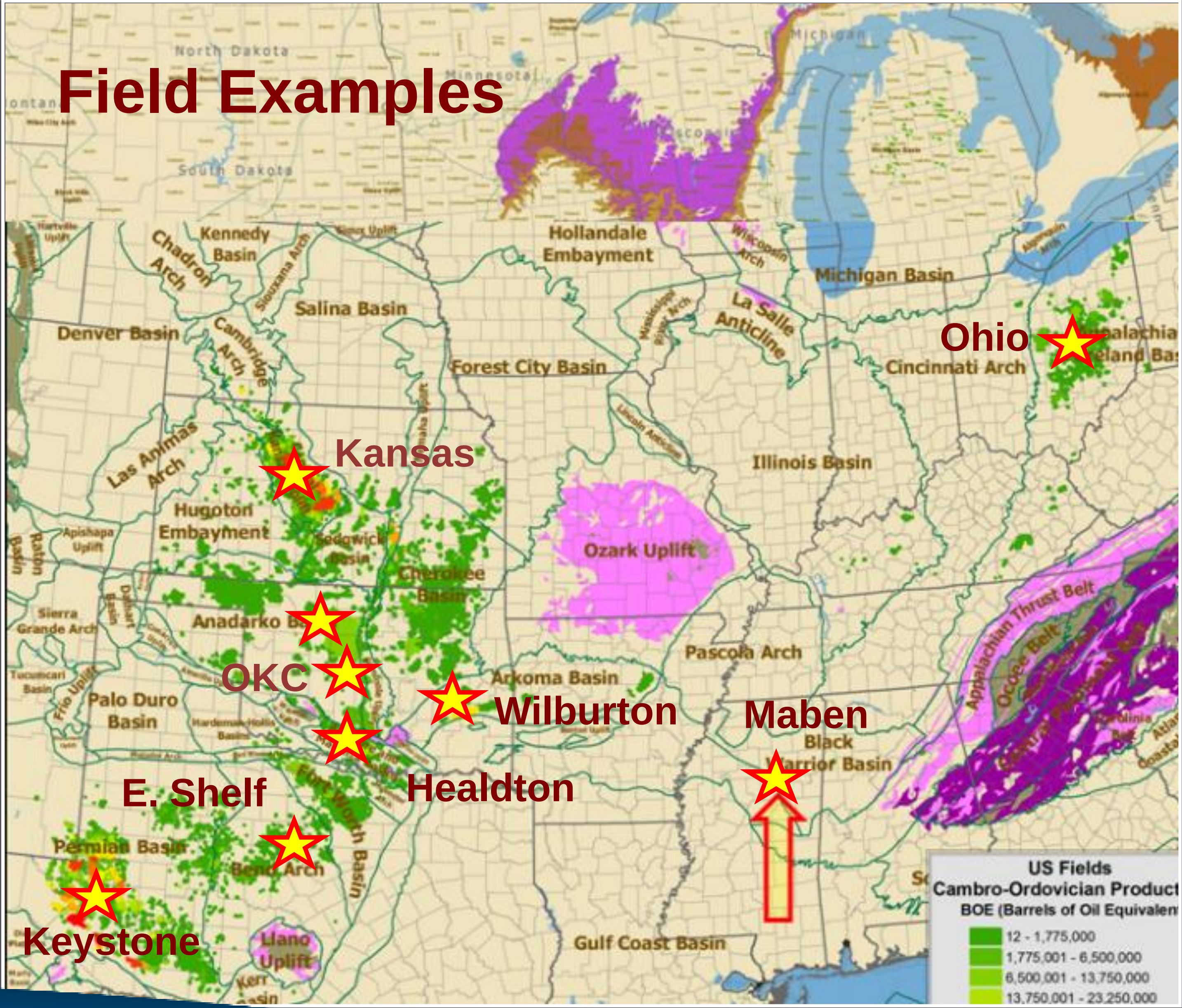
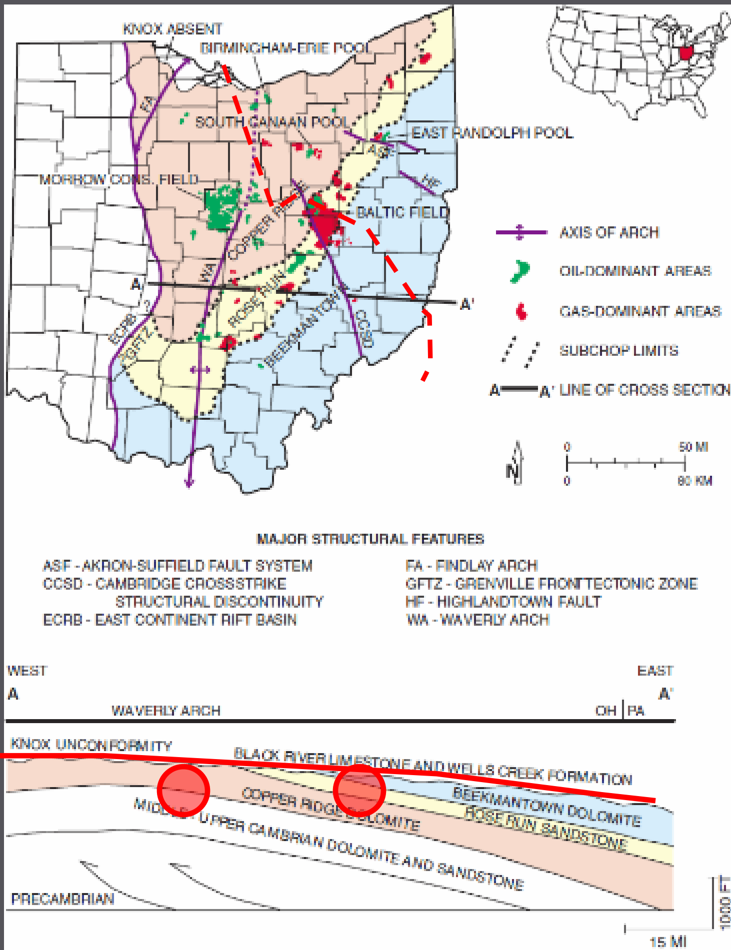


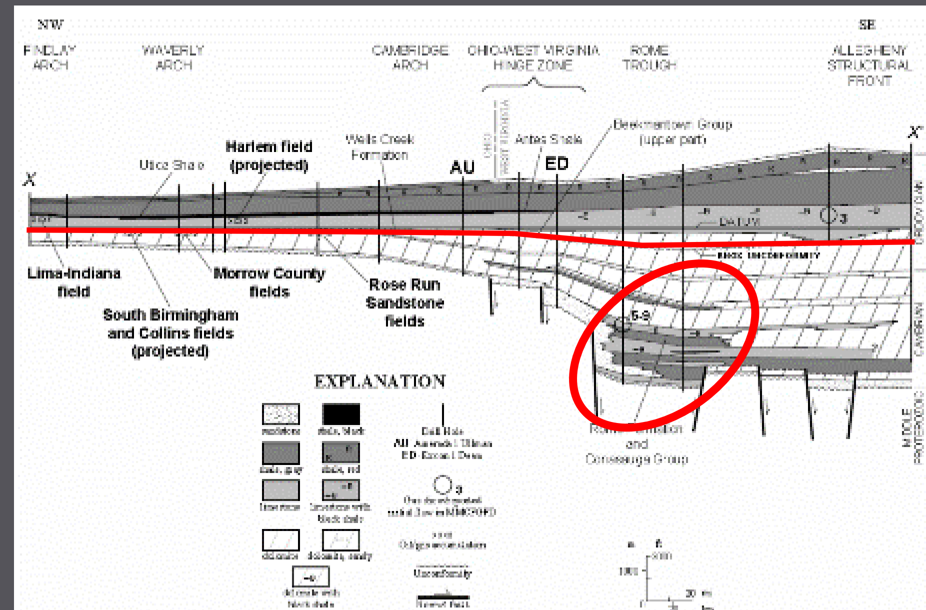
AAPG Southwest Section

Field Examples



Ohio Fields

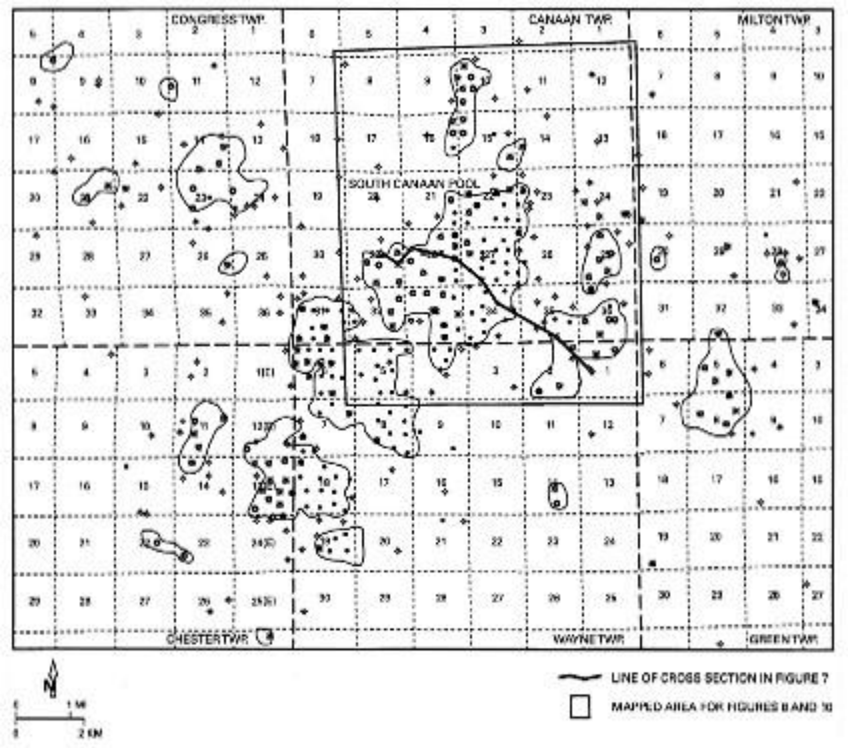




Note also that the Rome formation and Conasauga group contains an extra thick shale basin with source rock potential and 5-9 mmcf/d gas show (reprinted from Ryder, et.al, 1998, their Figure 2).

Figure 19. Map (on left) regional cross section across Ohio and the Appalachian fields (on right). The Sauk/Tippecanoe unconformity erodes the Beekmantown, Rose Run, and Conasauga formations producing erosion remnants and oil and gas traps, shown in detail below (reprinted from Riley, et al, 2002, their Figure 1).

South Canaan Pool, Ohio



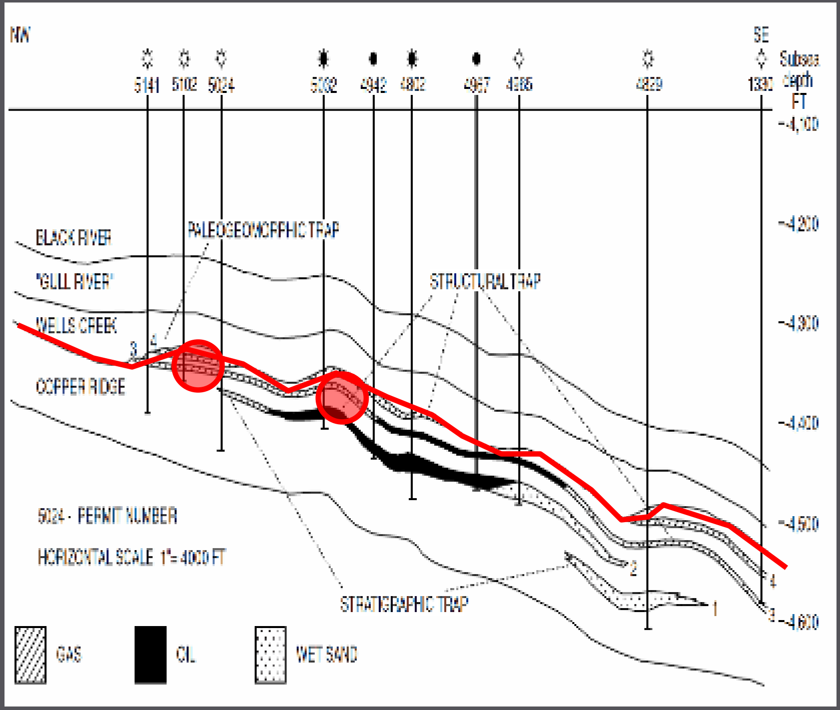


Figure 20 map (on left) and cross section (on right) over South Canaan pool showing angular erosion that creates stratigraphic truncation traps (reprinted from Riley, Wicks, and Thomas, 2002, their Figures 6 and 7, respectively).

Canaan Wayne Disc. 1989, Cum 3.4 MMBO, 20.1 BCF, 6.8 MMBOE, 132 oil wells

Kansas Differential Traps

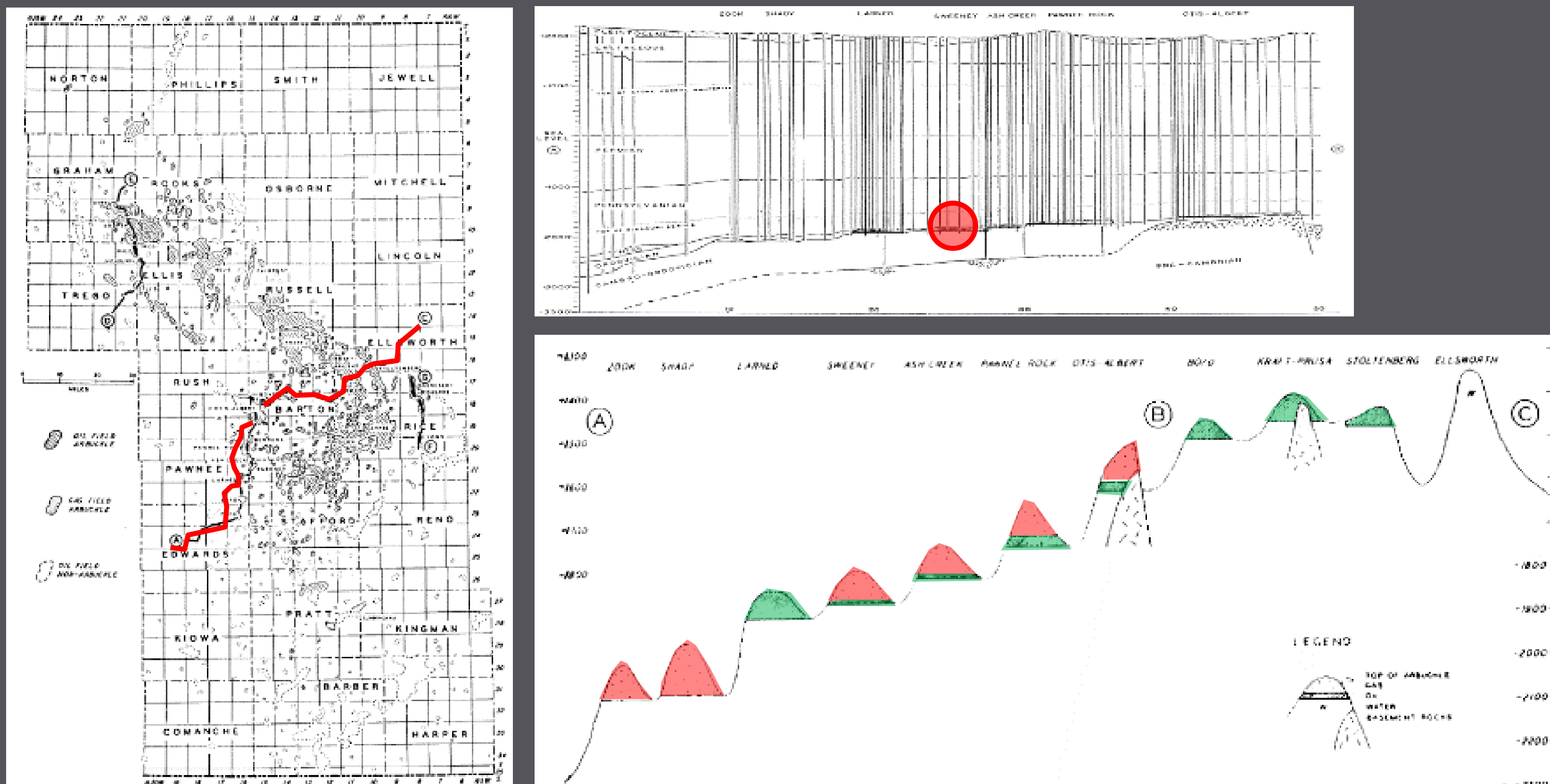
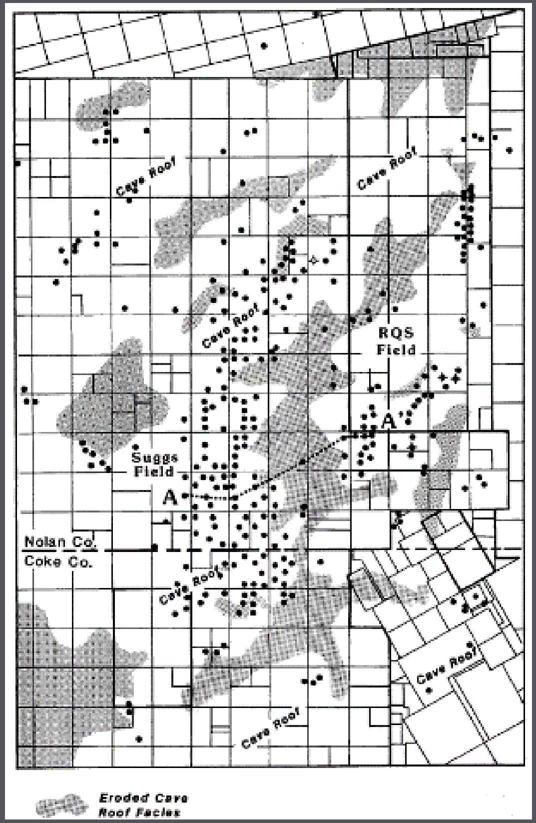


Figure 18. Map of Central Kansas (left) and cross section (right) showing lateral migration and differential entrapment of oil and gas from Edwards to Barton counties. Oil is up dip on right (northeast) and gas is down dip on left (southwest) (reprinted from Walters 1958, his Figures 1 and 3, respectively).

Eastern Shelf, Midland Basin



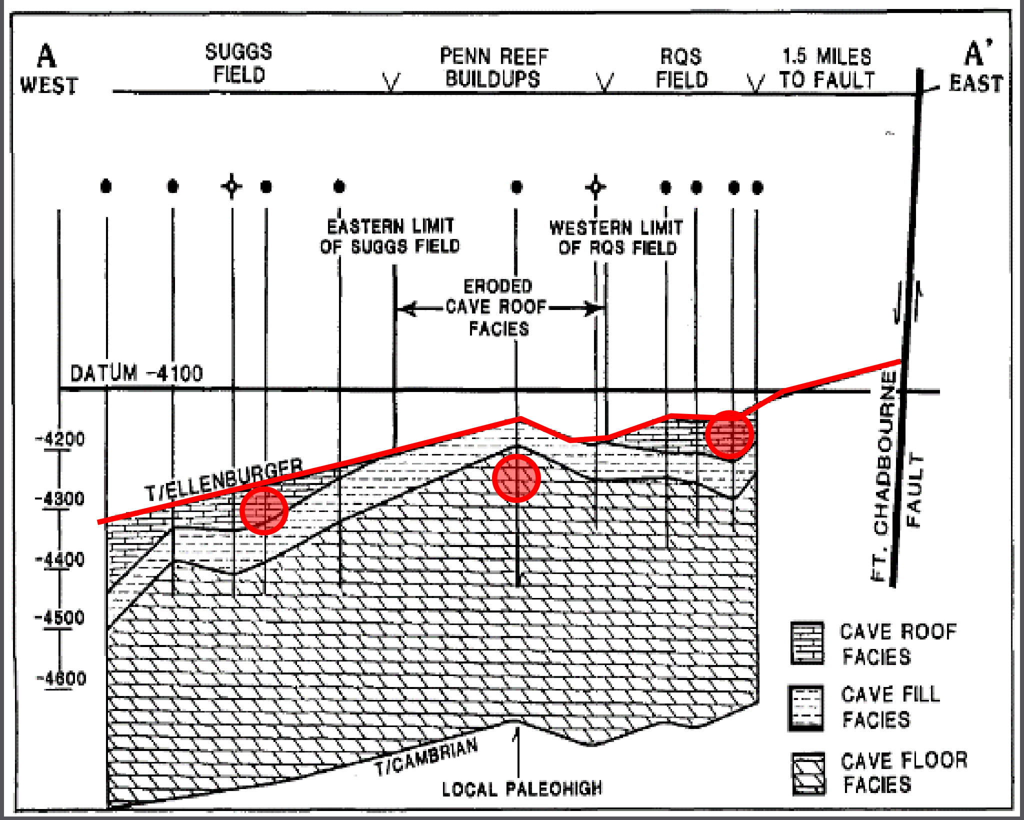
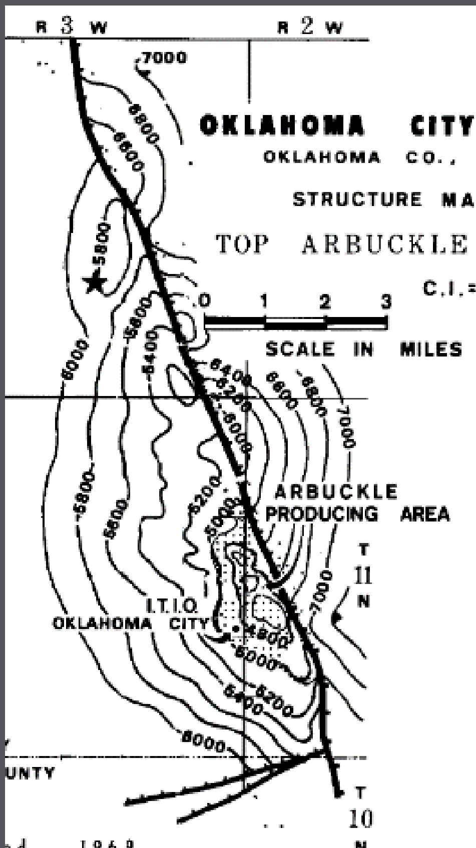


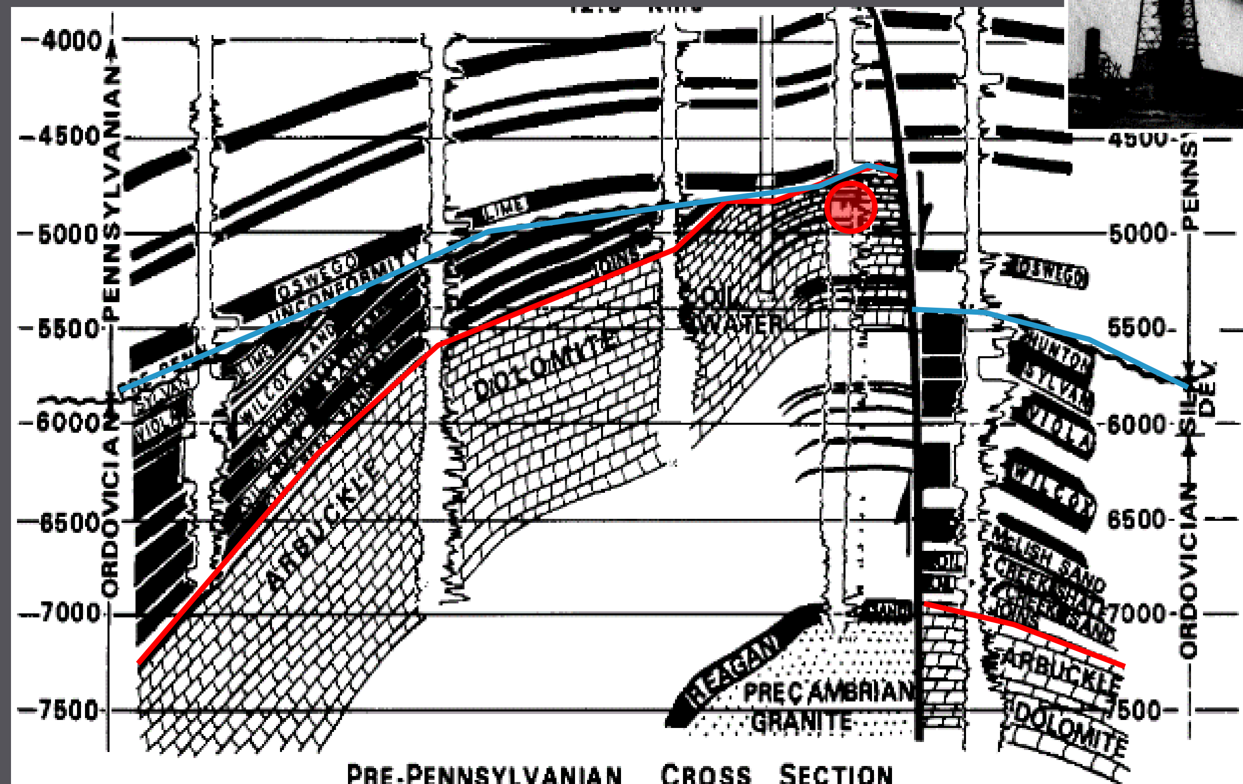
Figure 21. Map (left) and cross section (right) of eroded cave roof facies (shaded in gray) and underlying cave fill facies that provides seal and a trapping mechanism to fields in Nolan and Coke Counties, Texas on the Eastern Shelf of the Midland Basin (reprinted from Humphrey et al., 1994, their Figures 5 and 6, respectively).

Suggs Disc. 1982, Cum 10.1 MMBO, 9.2 BCF, 11.7 MMBOE, 144 oil wells

Oklahoma City Field



Max 6,564 BOPD From Arbuckle At 6,400' depth



Arbuckle structure map (left) and structural cross section (right) of Oklahoma City Field (reprinted from Gatewood, 1970, his Figures 14 and 6, respectively).

Disc. 1928, 18.2 MMBO, 68.3 BCF, 30 MMBOE from Arbuckle

Keystone Field, Central Basin

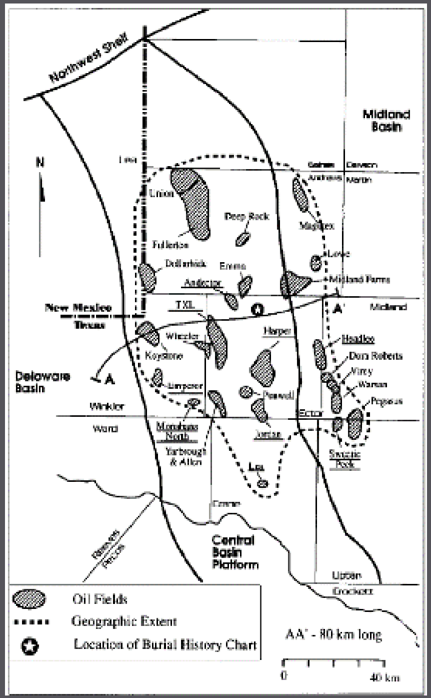
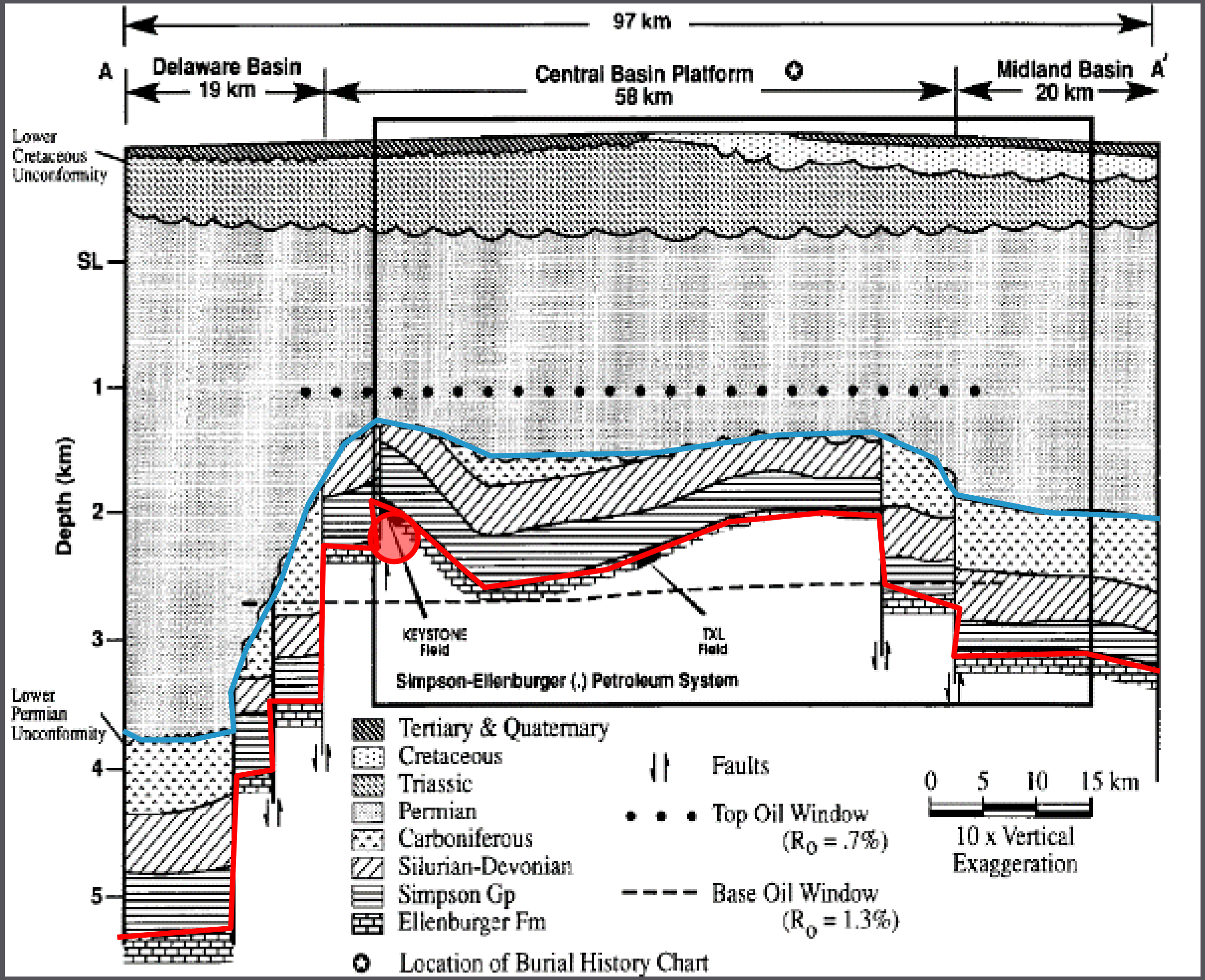
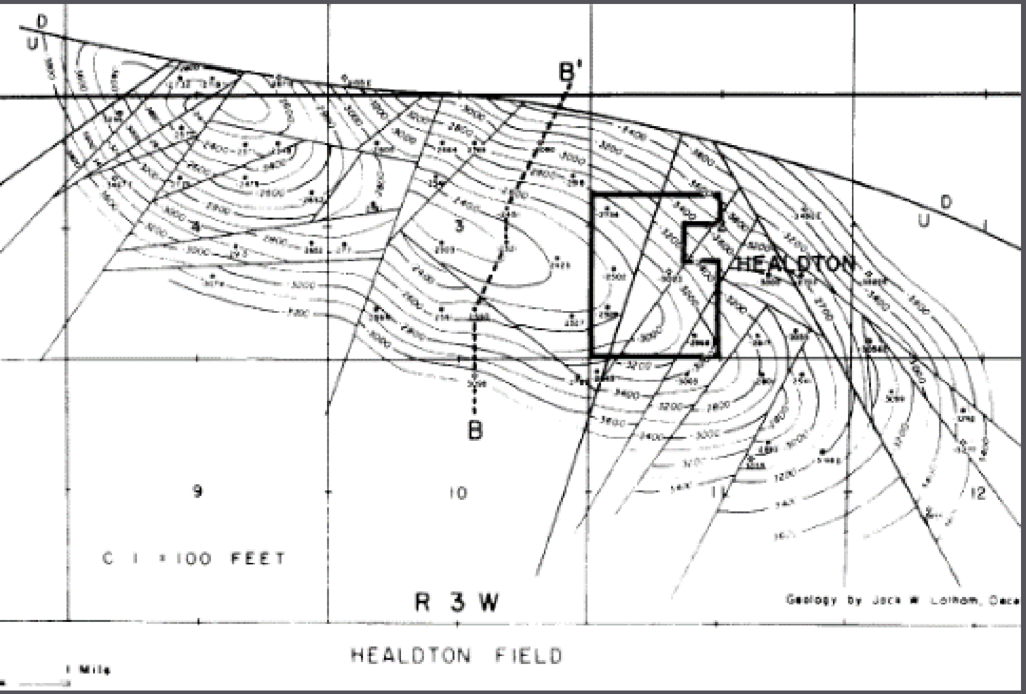


Figure 17. Map (left) and cross section (right) of the Central Basin Platform, Permian Basin Texas (reprinted from Katz et al., 1994, their Figures 28.2 and 28.3 respectively).



Disc. 1943 147 MMBO, 485 BCF, 227 MMBOE

Healdton Field



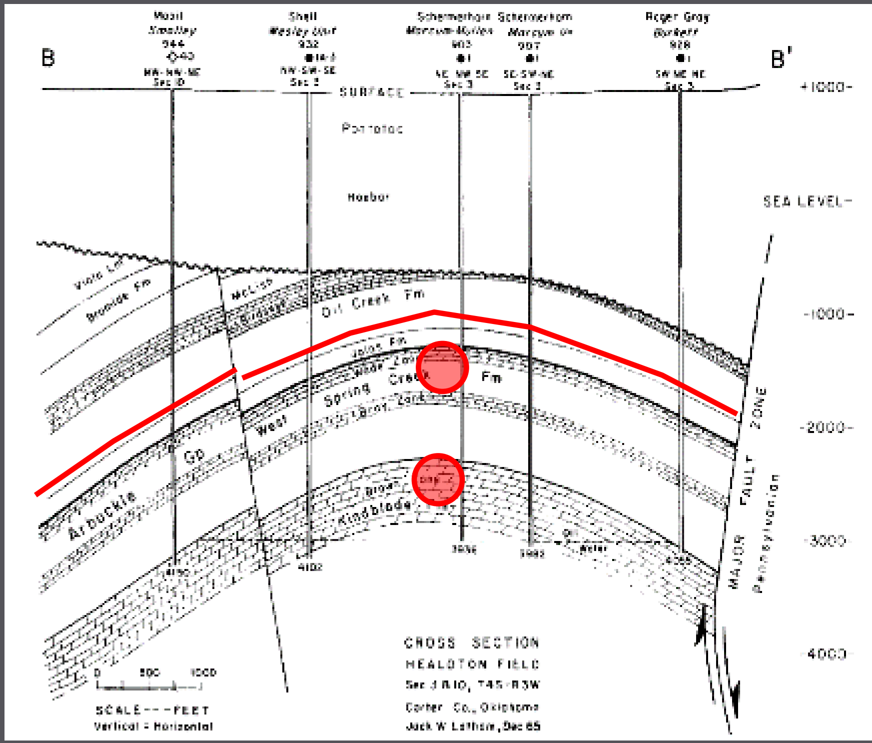


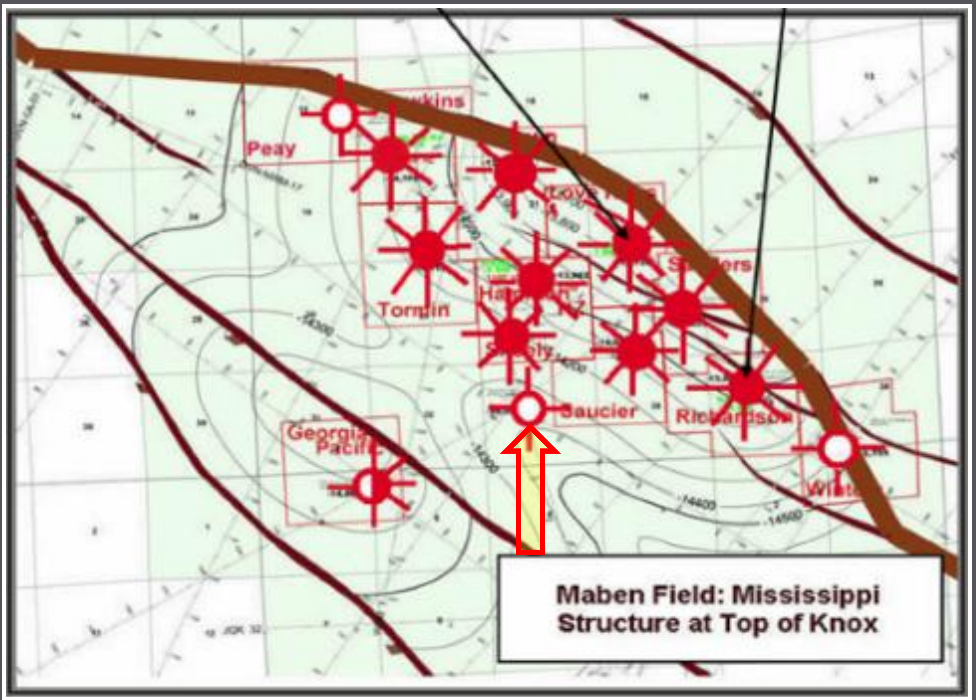
Figure 16. Arbuckle structure map (left) and structural cross section (right) of Healdton Field, southern Oklahoma (reprinted from Latham, 1962, his Figures 5 and 7, respectively). Note the “brown zone pay” is about 1,000’ beneath the top of the Arbuckle.

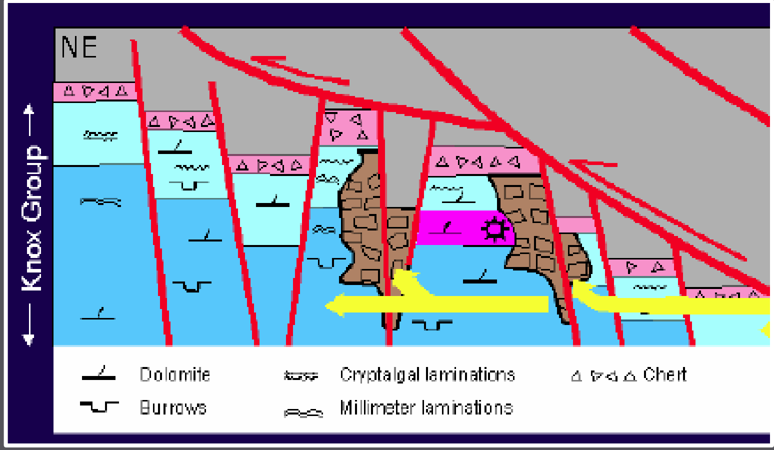
Disc. 1944 17.7 MMBO, 5.0 BCF, 18.5 MMBOE

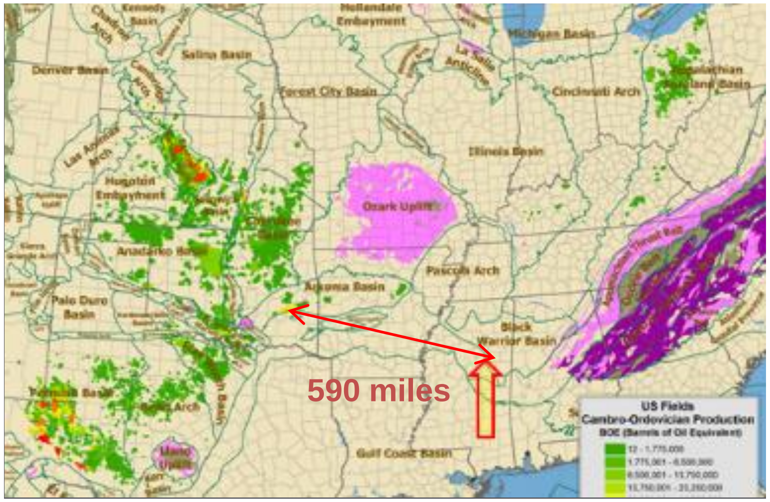
Getting off the “beaten path”

- Captain Cook did not like heavily traveled routes
- Instead, he ventured into uncharted lightly explored areas.
- As a result, Cook discovered more about the Pacific than all previous European explorers
- He probably would have liked lightly explored basins!

Maben Field







- Maben was far from significant GACB production
- (about 590 miles)
- Discovery in 1995 was a “rediscovery” of 1972 show well
- Texaco Sheely cum. 800 mmcfg; also Exxon Fulghum

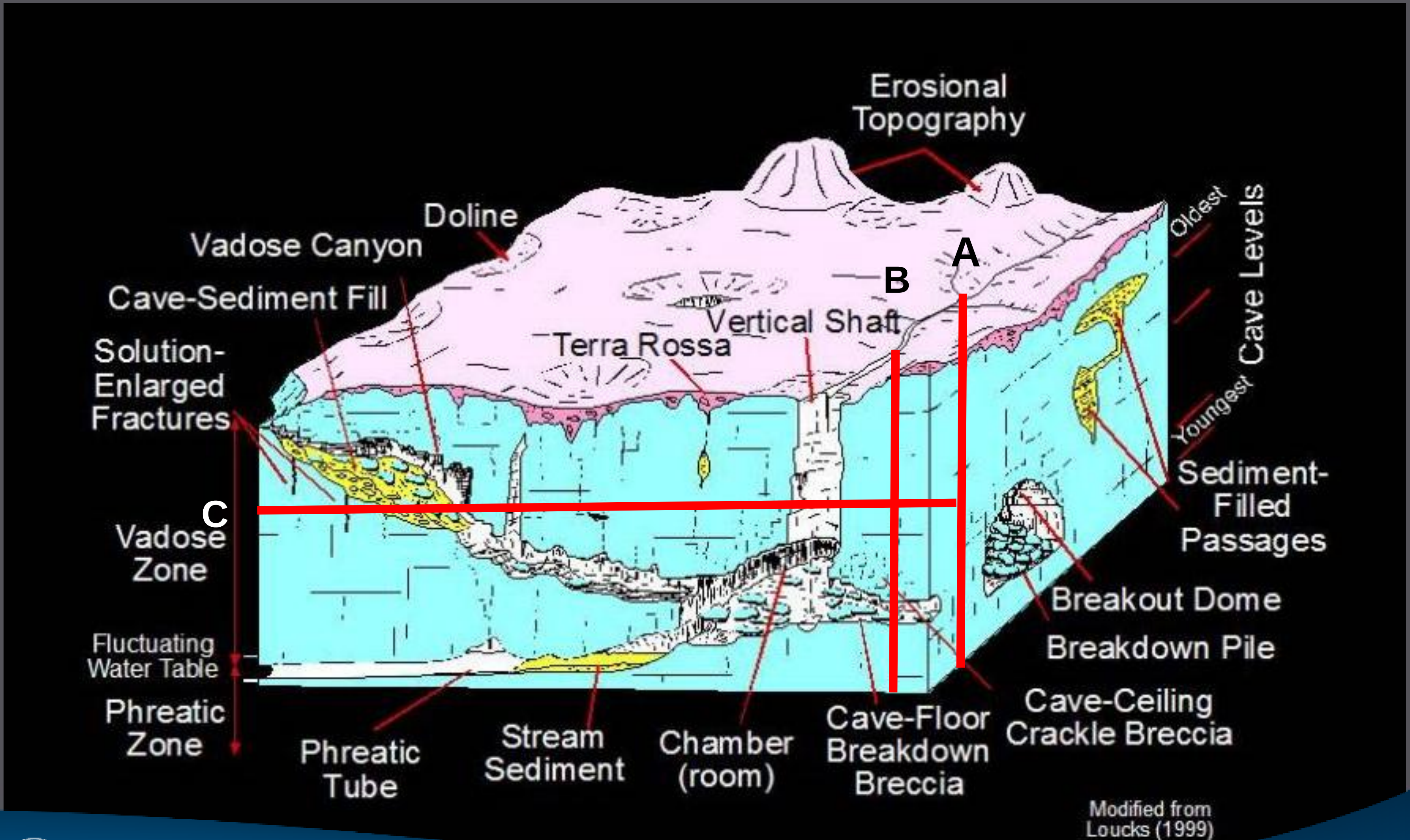
Disc. 1972/1995; Cum 51.7 BCF, 8.6 MMBOE
Julia Gale, et. al, 2008

GACB Reservoirs Can Be Full of Surprises

Gus Archie, friends with Bert Thomeer

- GACB reservoirs challenge classical petrophysics
- “You mean the well has already produced HOW MUCH??”

Schematic of cave processes



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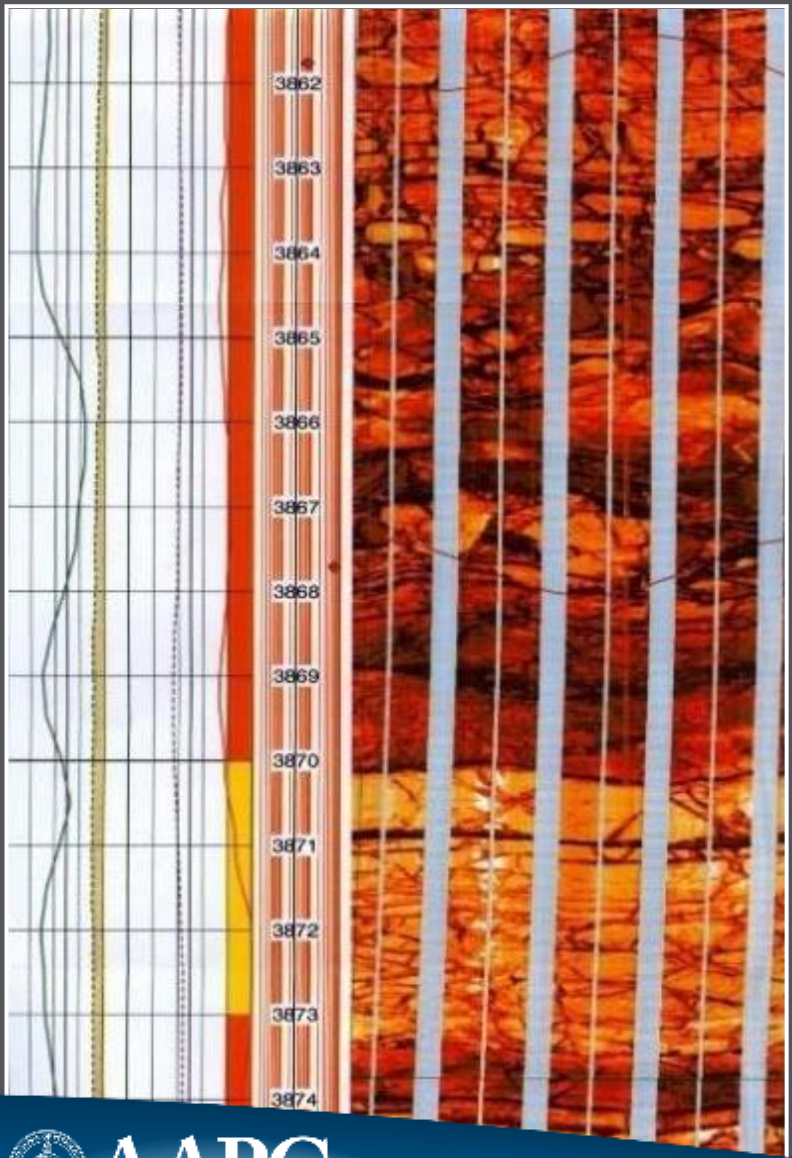


Karst Reservoir in Magnolia Below core west of Bandera Structures

Todd Field Cumulative Oil/well

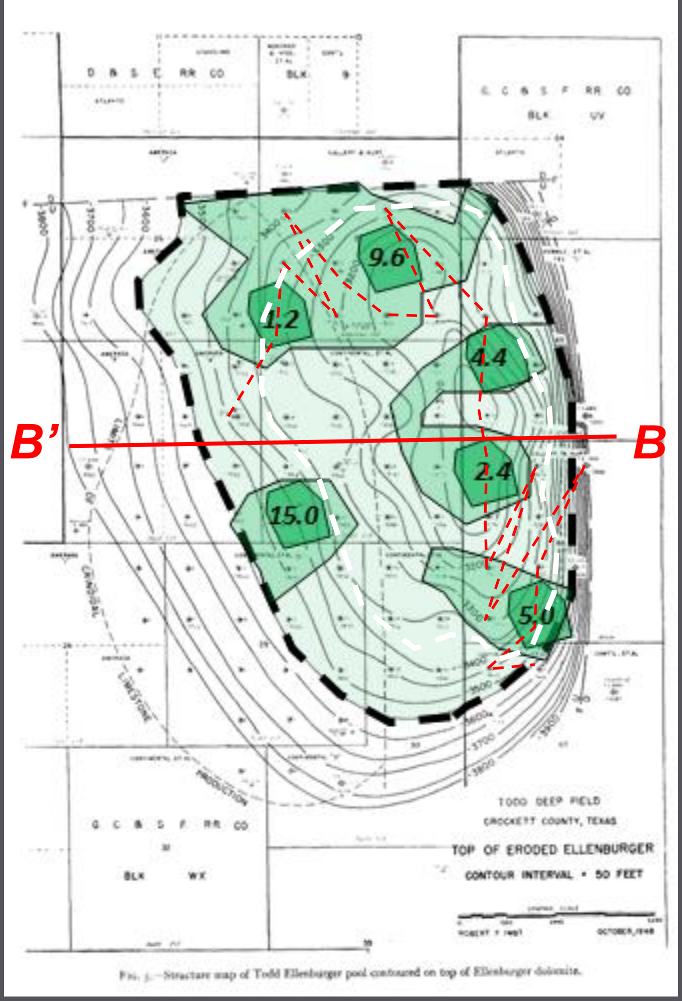
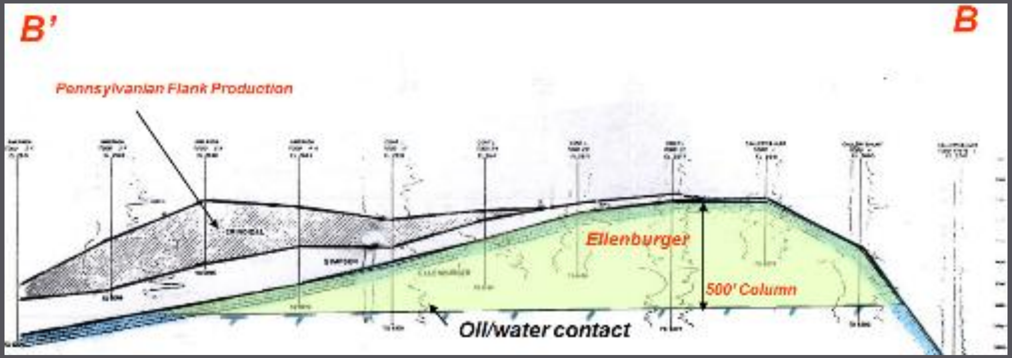


Fig. 3.—Structure map of Todd Ellenburger pool contoured on top of Ellenburger dolomite.



- 40 wells produce 50 MMBOE (avg1.25 MMBOE/WELL)
- Median p50 140,000 BOE
- Crestal wells 9.6 MMBO to 1,597 BO
- Flank well 15.0 MMBO, best well in field drilled late

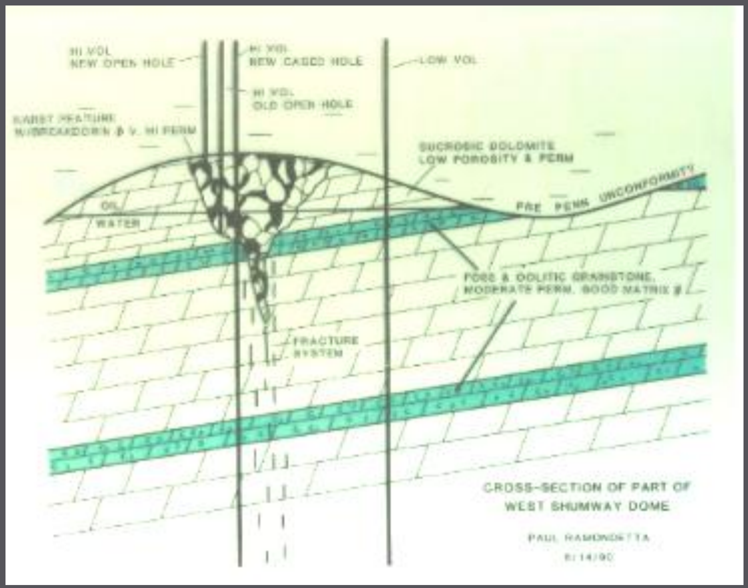
		Percentile	
1	1,597	4%	96%
2	2,929	7%	93%
3	4,281	11%	89%
4	35,753	14%	86%
5	52,632	18%	82%
6	58,207	21%	79%
7	65,505	25%	75%
8	70,204	29%	71%
9	70,878	32%	68%
10	74,511	36%	64%
11	84,305	39%	61%
12	92,428	43%	57%
13	120,701	46%	54%
14	140,312	50%	50%
15	142,113	54%	46%
16	216,440	57%	43%
17	245,972	61%	39%
18	250,029	64%	36%
19	275,673	68%	32%
20	280,374	71%	29%
21	420,264	75%	25%
22	436,718	79%	21%
23	547,869	82%	18%
24	1,264,403	86%	14%
25	2,403,866	89%	11%
26	4,412,866	93%	7%
27	4,968,099	96%	4%
28	9,637,145	100%	0%
Crest	26,376,074		
Total	47,554,860		
%	55%		

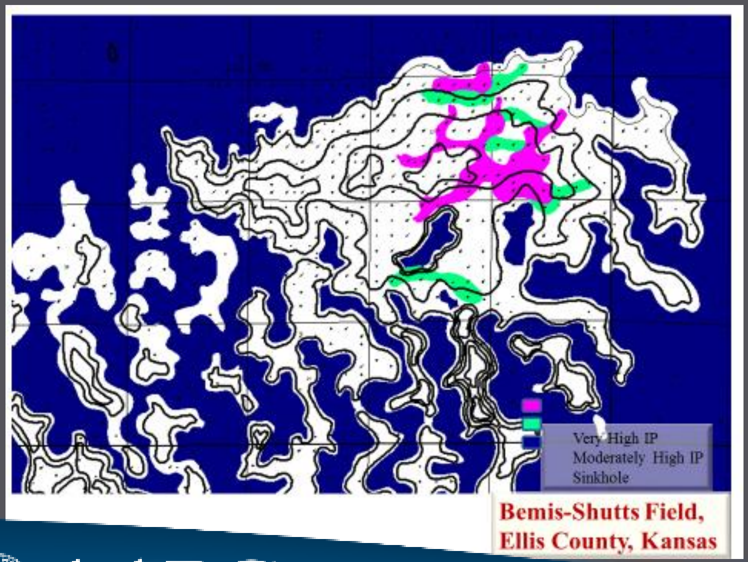
Todd Field, Crockett County Texas, Ozona Arch (reprinted from Imbt and McCollum, 1950

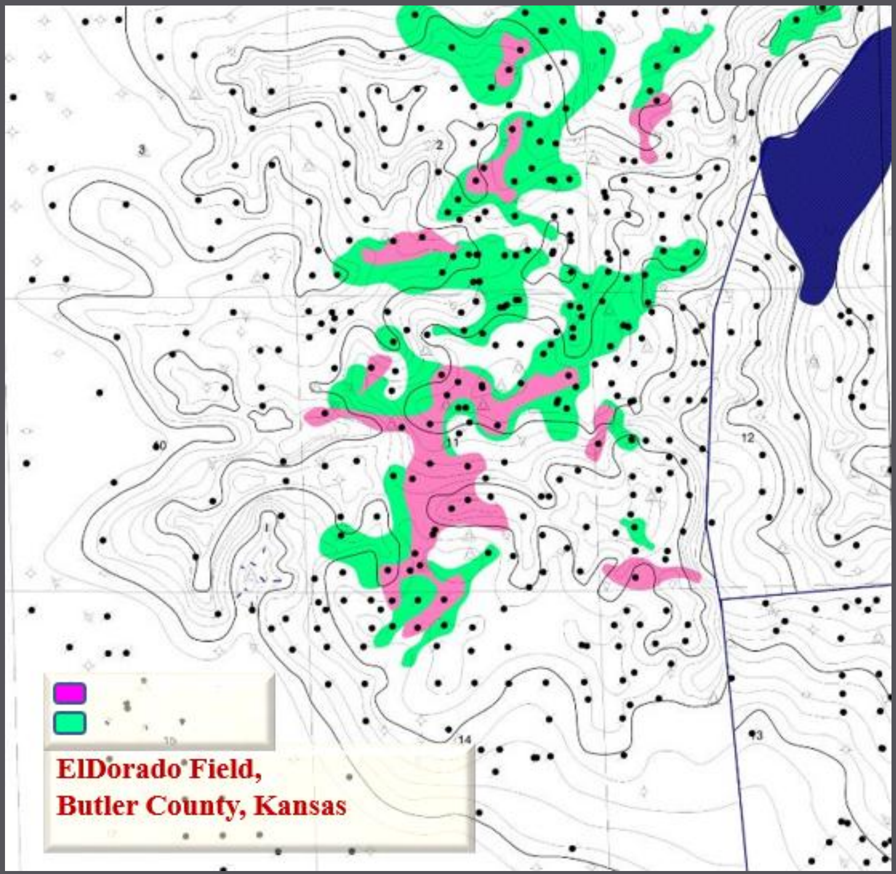
Disc. 1945, Cum 48.4 MMBO, 7.9 BCF, 50.0 MMBOE

AAPG Southwest Section

UNCONFORMITY THINKING

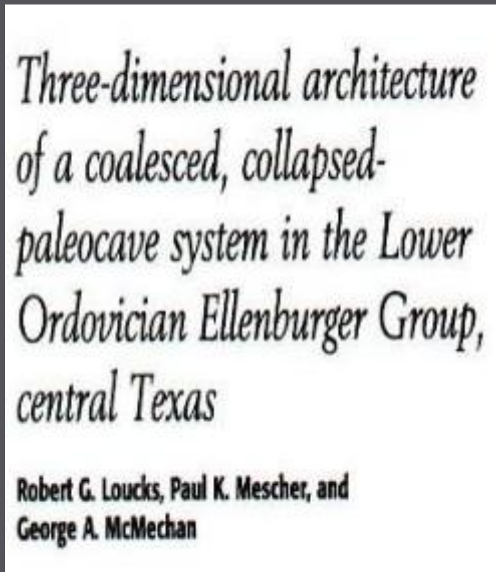




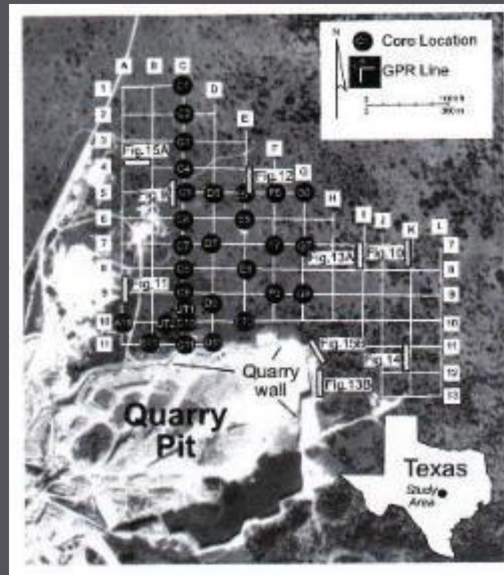


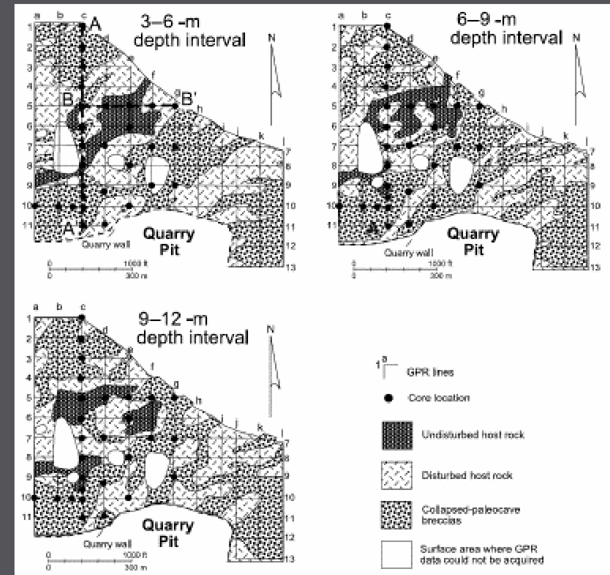
Kansas Examples from
Paul J. Ramondetta, 2012

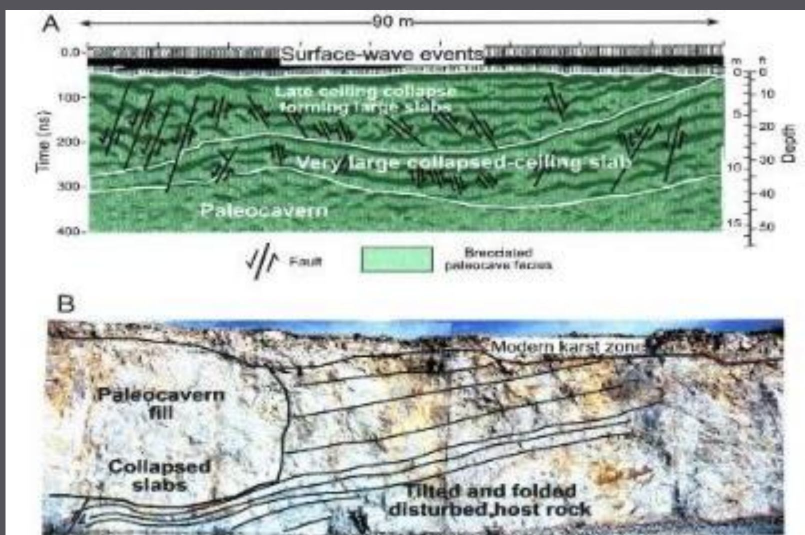
UNCONFORMITY THINKING

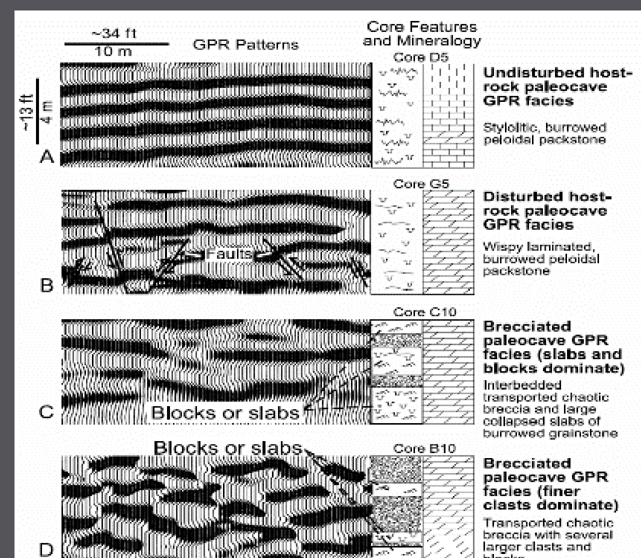

Three-dimensional architecture of a coalesced, collapsed-paleocave system in the Lower Ordovician Ellenburger Group, central Texas

Robert G. Loucks, Paul K. Mescher, and George A. McMechan

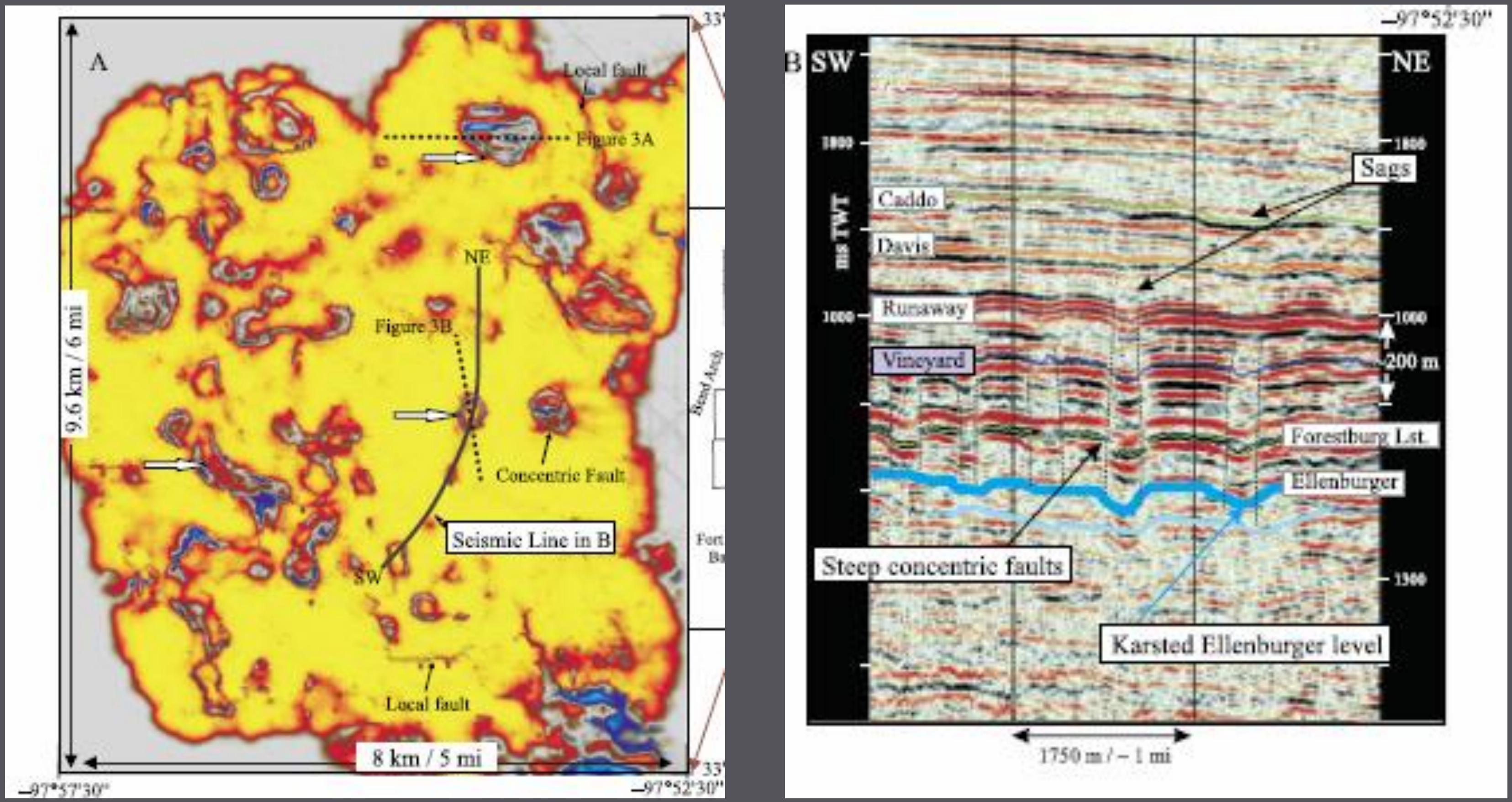






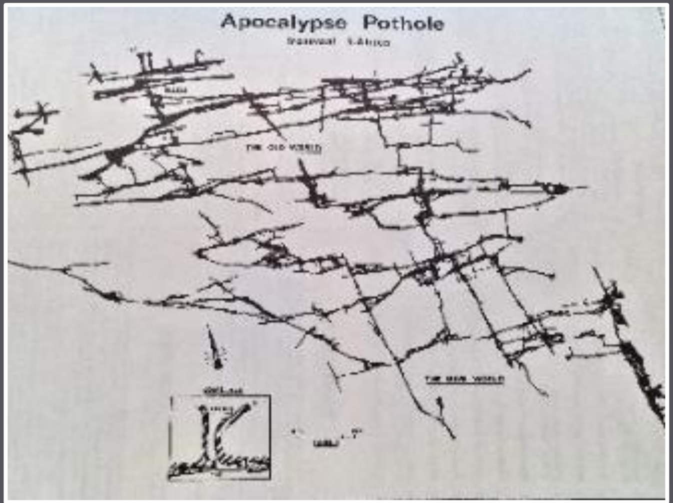


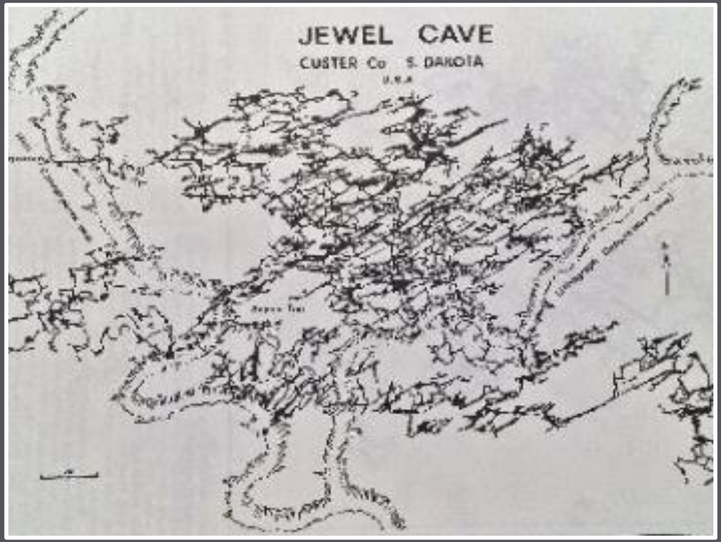
Examples of Seismic Detection Karst in the Fort Worth Basin

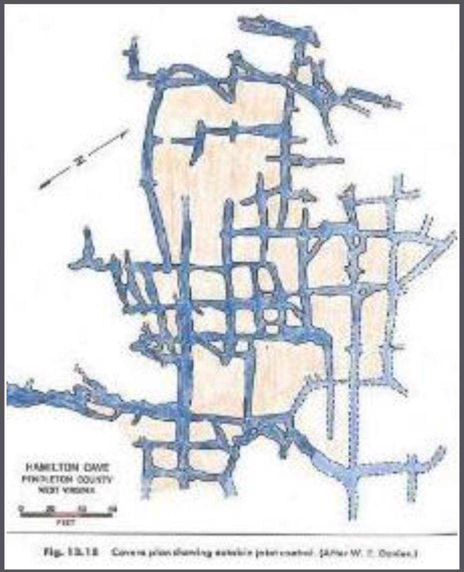


From McDonnell 2007 (AAPG Bulletin)

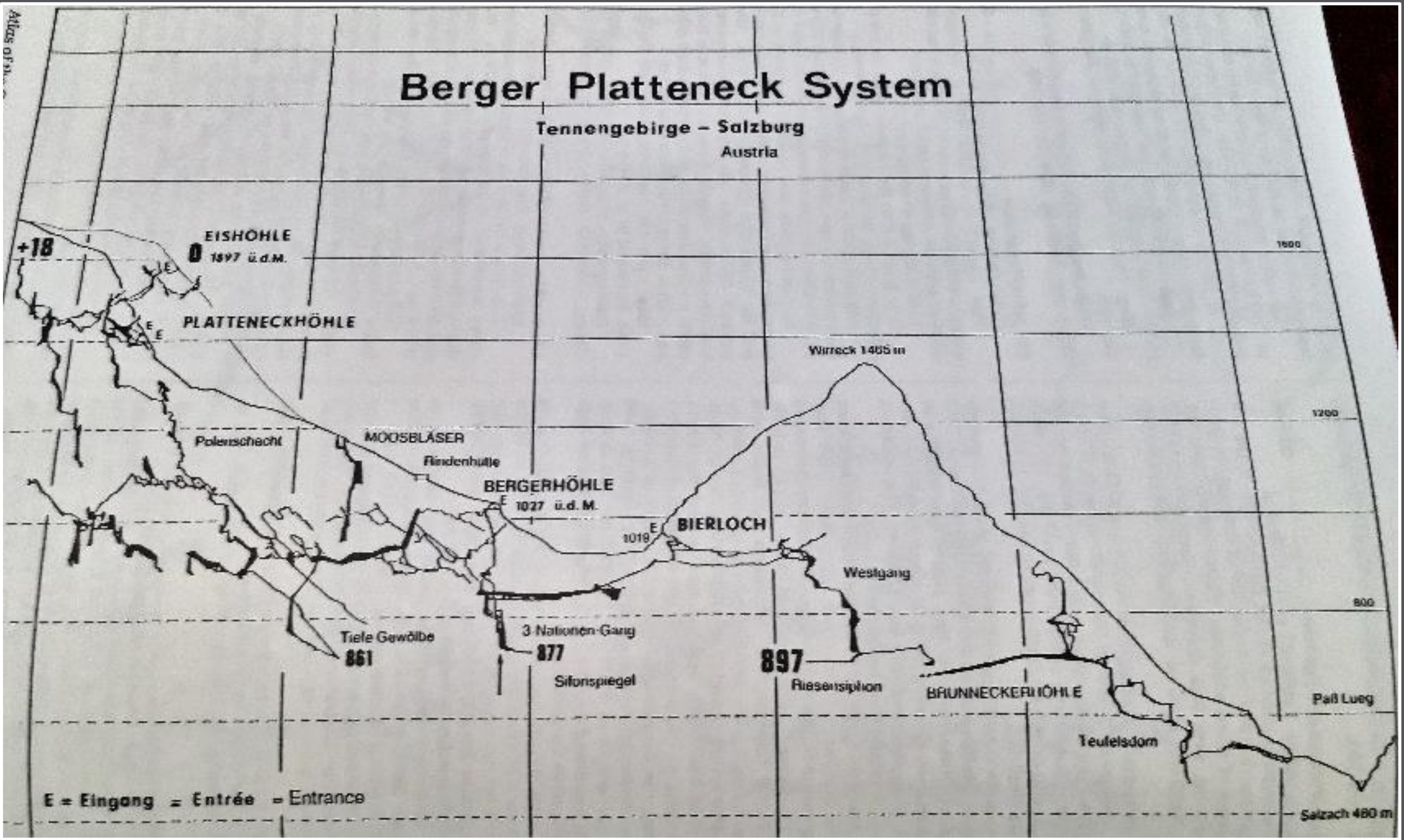
Let's Go Caving!







Maps from:
"Altas of Great Caves of the World", Courbon, 1989



Vertical Profiles from: “Altas of Great Caves of the World”, Courbon, 1989

Karst Plateau

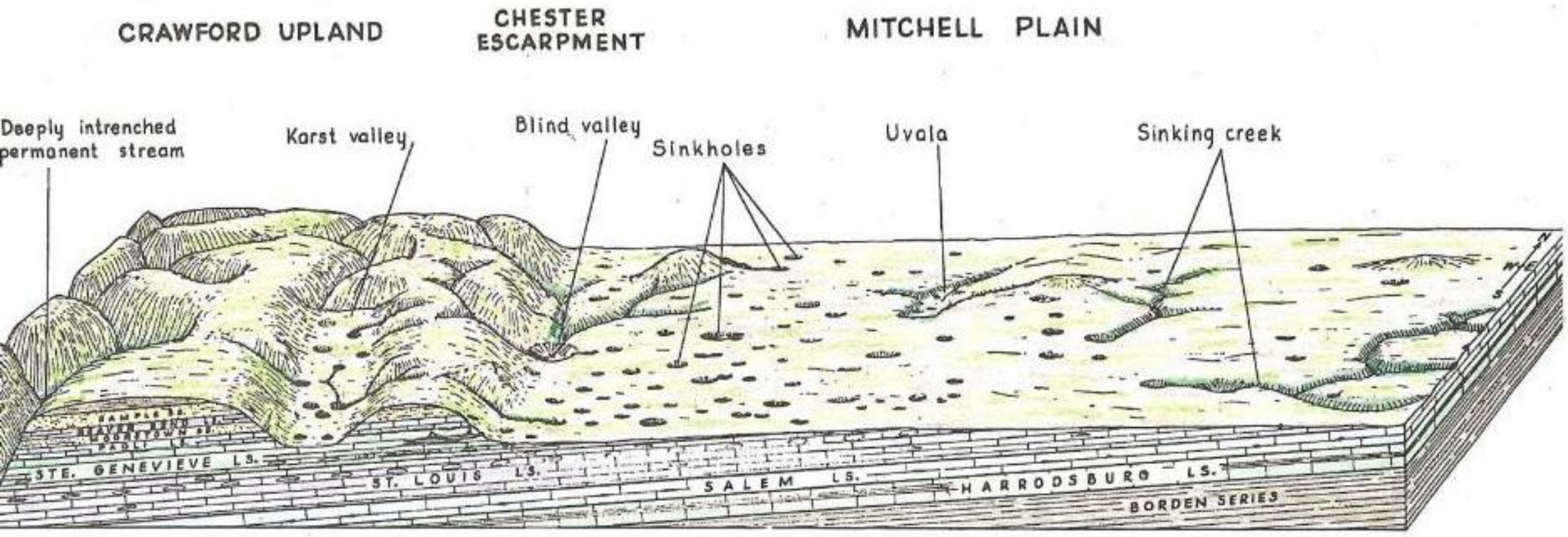
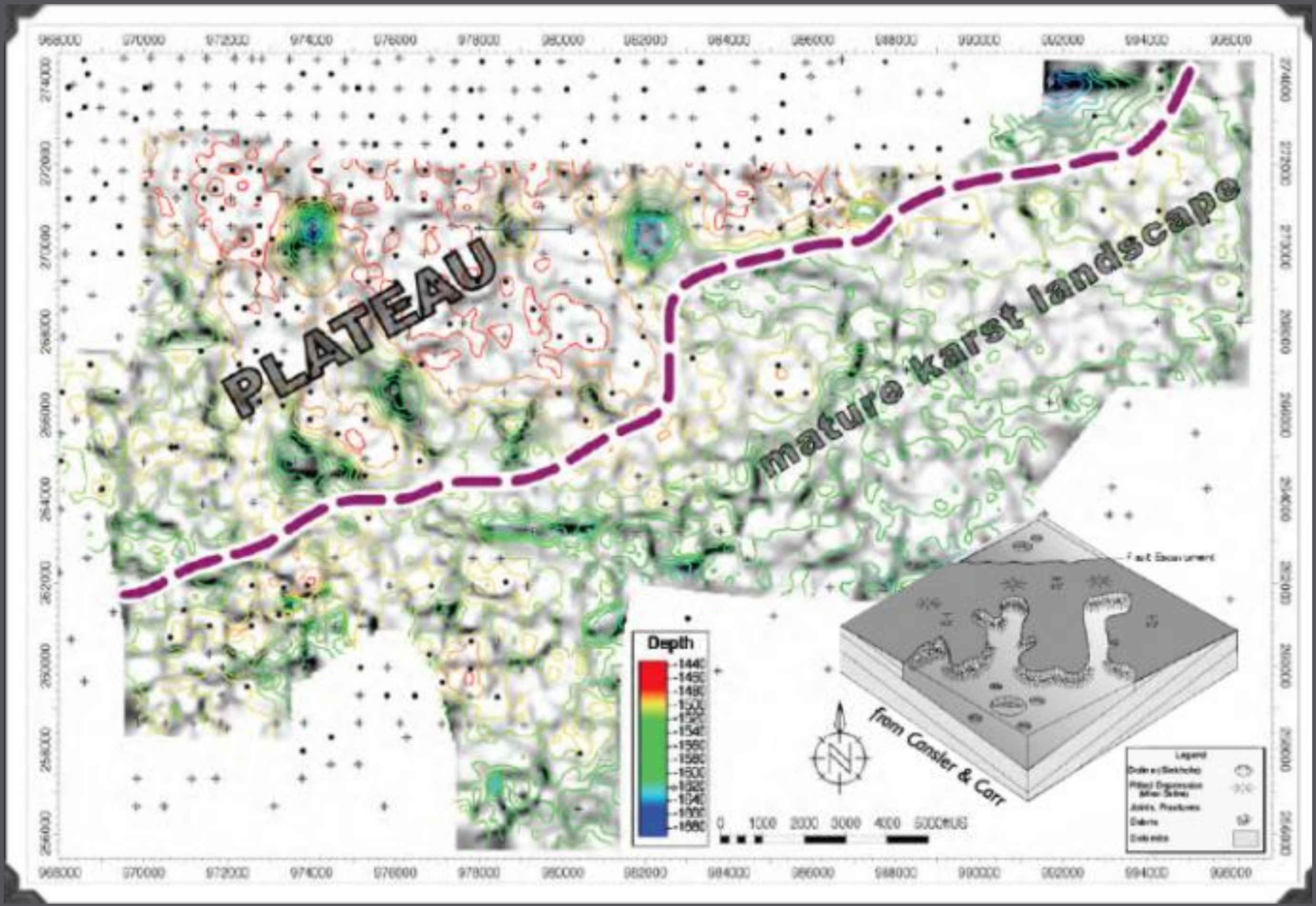


Fig. 13.5 Idealized diagram of a portion of the karst area in southern Indiana. (Drawing by William J. Wayne.)

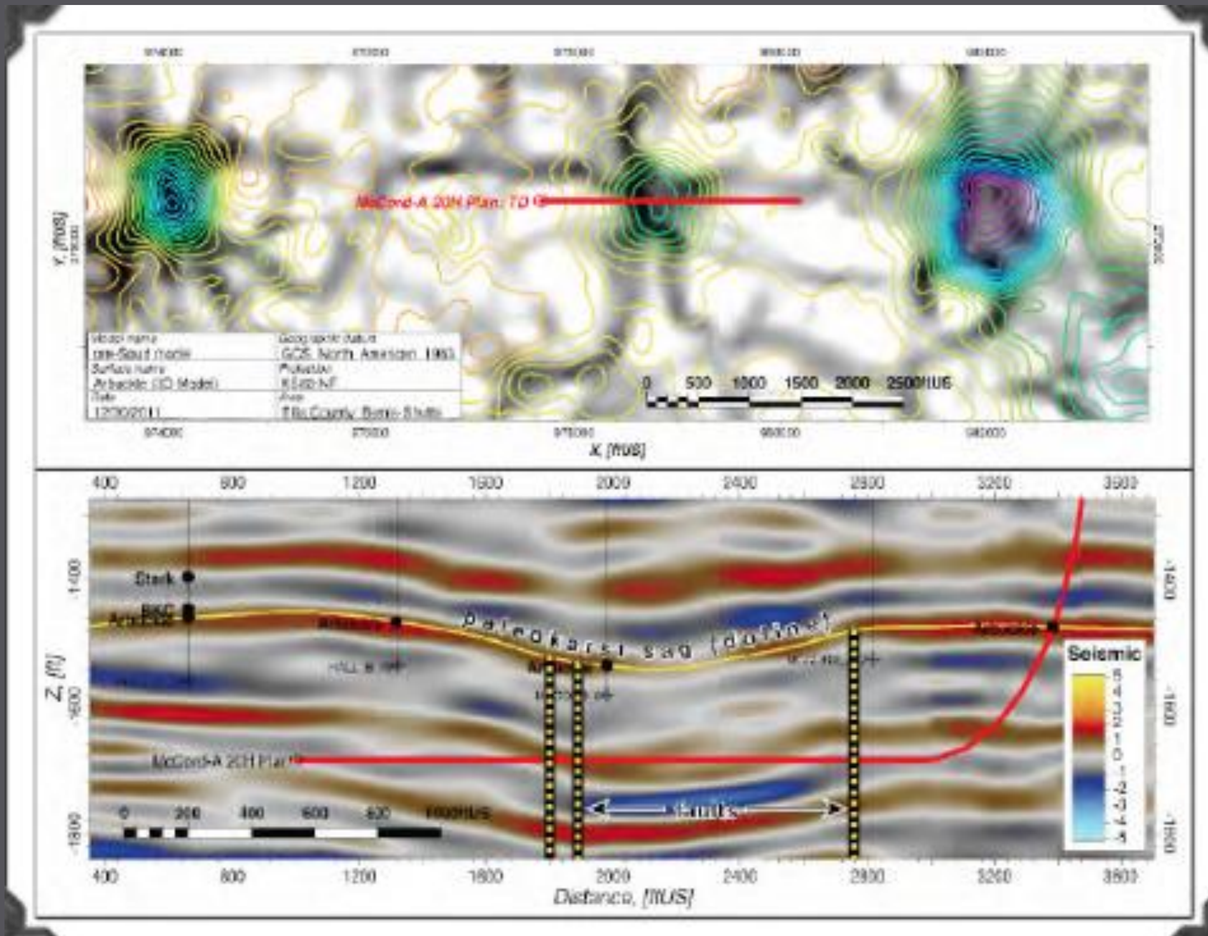
Kansas Examples from Paul J. Ramondetta, 2012

Paleokarst–Sapped Plateau



Kansas Examples from Paul J. Ramondetta, 2012

Key Findings



Kansas Examples from Paul J. Ramondetta, 2012

- Seismic volumetric-curvature (VC) attributes are important for characterizing paleokarst architecture and geomorphic evolution
- 2,000-ft lateral directly confirms presence of a VC-identified, fault-bound doline
- Dolines are coincident with VC-identified radial lineaments
- Dolines developed across a sapped plateau

Lessons From Fistorical GACB Exploration; Possible Strategies

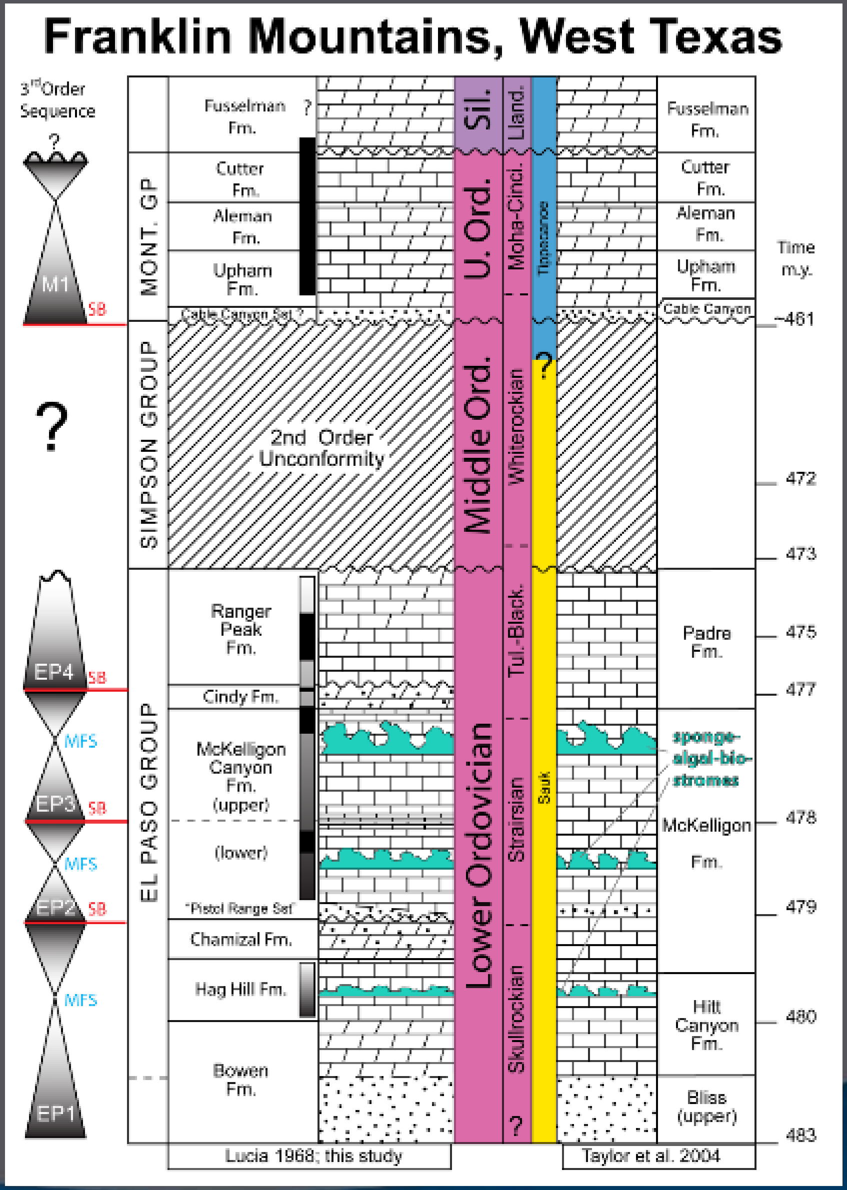
GACB reservoirs have a long successful history of oil and gas production. Future **success** seems likely to involve:

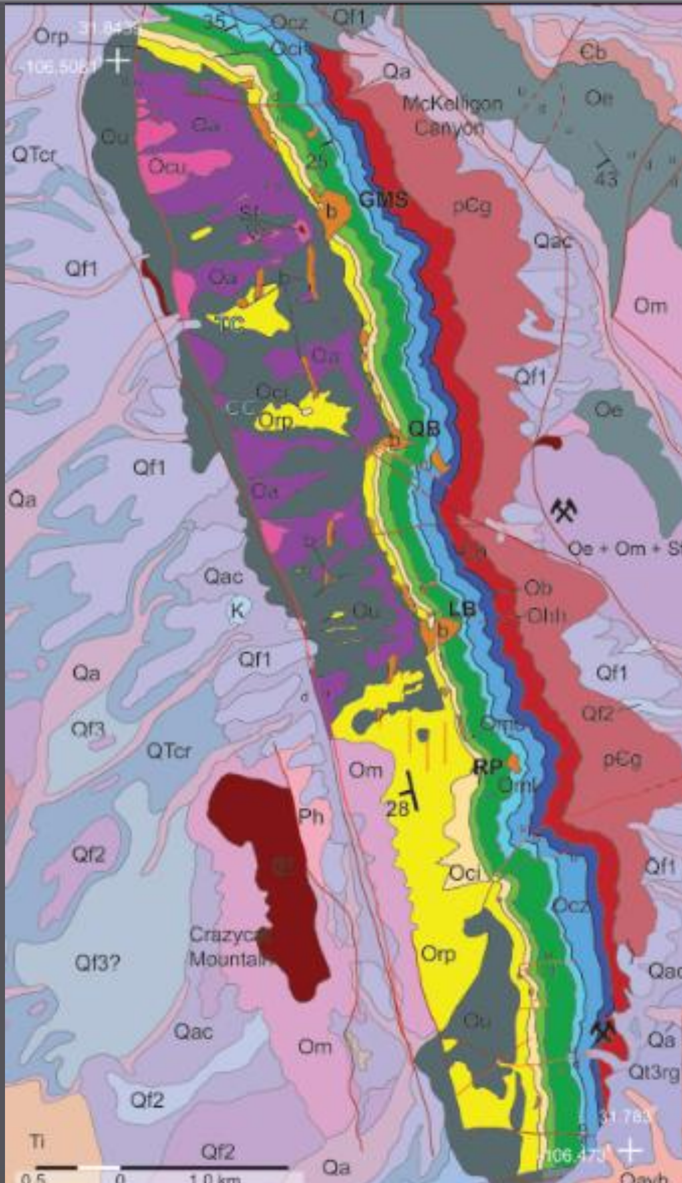
- Continued focus on reservoirs and traps below the Sauk\Tippecanoe unconformity
- Trap analysis of fault closures and horst blocks
- Look for fundamentals and hydrocarbon shows even if in outlier basins
- Persistently explore around wells that made some oil or gas but that may have failed to intersect permeable rock that may still be connected to unproduced oil and gas
- May need to rethink hydrocarbon shows with high water cuts
- Stacked pays possible in the inner detrital belt or shelf edge depositional settings
- Use of seismic and other techniques to assess variable reservoir
- Directional drilling that intersects more fractures and karst related fabrics
- Identification of thermally cooked source rock rich sub basins that may provide hydrocarbons to overlying GACB reservoirs in conventional traps

UNCONFORMITY THINKING

<u>The El Paso and Montoya Groups</u>

- Richardson, G.B., 1904 and 1909
- Nelson, L.A., 1940
- Cloud, P.E. and Barnes, V.E. 1948
- Lucia, F.J., 1968
- LeMone, D.V., 1968
- Lucia, F.J., 1971*
- Harbour, R.L., 1972
- Kerans and Lucia, 1989
- Goldhammer et al. 1993
- Lucia, F.J., 1995*
- Bellian, J.A. 2009*

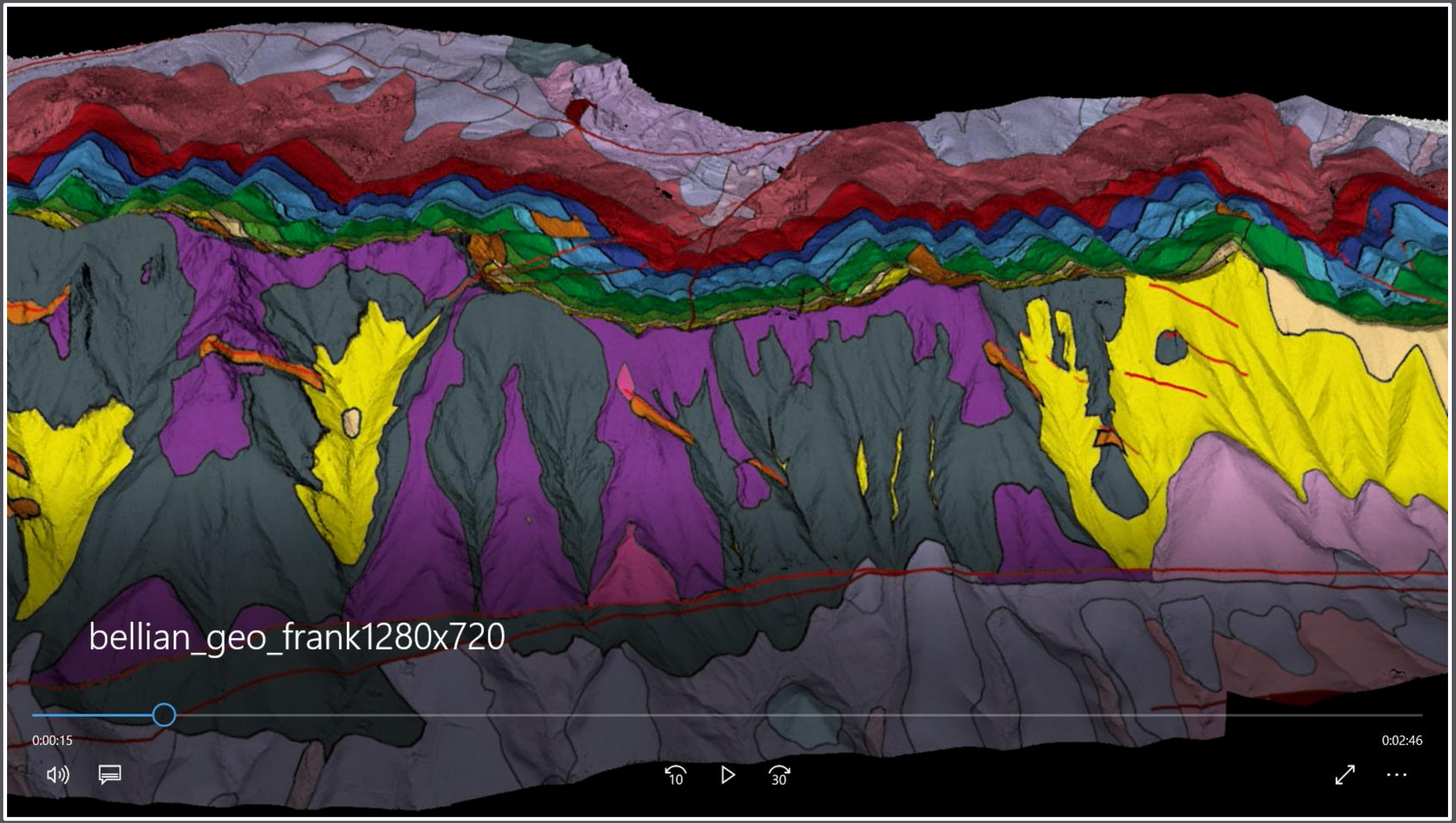




- What was stress regime during GACB time?
- Western Boundary Fault (WBF) is Tertiary Laramide Uplift ~K/T
- Topography makes fault tracking extremely difficult.
- Breccias appear to cluster.

AAPG Southwest Section

Franklin Mountains



Dr. Jerome Bellian

THANK YOU