Petroleum Resources of the Great American Carbonate Bank (Lower Ordovician – Upper Cambrian): Lessons from Heterogeneous Reservoirs, Diverse Traps, and Unconformity Thinking*

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Abstract

New maps, graphs, and charts of hydrocarbon trends enable insights at the field, basin, and regional scale of the prolific Lower Ordovician to Upper Cambrian GACB petroleum system. Approximately 3650 fields have produced oil and gas in about 30 producing regions concentrated mainly in the U.S. states of Texas, Oklahoma, Kansas, Nebraska, New Mexico, Michigan, Ohio, and Kentucky. More than 28,000 oil wells and 3000 gas wells have produced 4.13 billion BO and 21.18 TCF gas cumulative. Most (57%) of the combined 7.66 billion BOE hydrocarbons are oil. Under current market conditions it is timely to review GACB reservoirs. Of note, 50 oil and gas fields with reserves of > 1MMBOE have been found since 1987, indicating discoveries in these fabled reservoirs are still occurring.

There are two giant fields greater than 500 MMBOE: Gomez (5.3 TCF) and Puckett (3.8 TCF) gas fields in Pecos County, Texas; and seven oil fields greater than 100 MMBO in Texas and Kansas. One might ask how do significant outlier discoveries like Wilburton field (400 BCF) or Maben Field (51 BCF) occur? Maben was more than 100 miles away from age-equivalent production at the time of its discovery. Discussed here are discuss possible methodologies to assess frontier areas that may yield future surprises.

Depositional settings include: 1) mid-shelf, 2) deep shelf and 3) inner detrital belt. Most production comes from the mid-shelf setting from dolomite reservoirs with 3-15% matrix porosity; limestone reservoirs are relatively rare. The deep shelf and inner detrital belt also produce significant hydrocarbons. Paleokarst diagenesis overprints all depositional settings and can result in highly variable well performance. Field examples are discussed.

GACB fields produce from diverse trap types. Reservoirs juxtapose with source rock and seals in many configurations. Trap analysis can prioritize an exploration program in fault-bounded structures by comparing fault throws with thickness of sealing and non-sealing strata. Most oil-field pay occurs beneath the uppermost unconformity at or near the top of GACB reservoirs. Settings and conditions where notable exceptions occur are discussed.

The speaker shared insights from personal exploration experiences. It is hoped that insights from historical production, analog fields, and new tools will lead to more reserves in both old and new areas.

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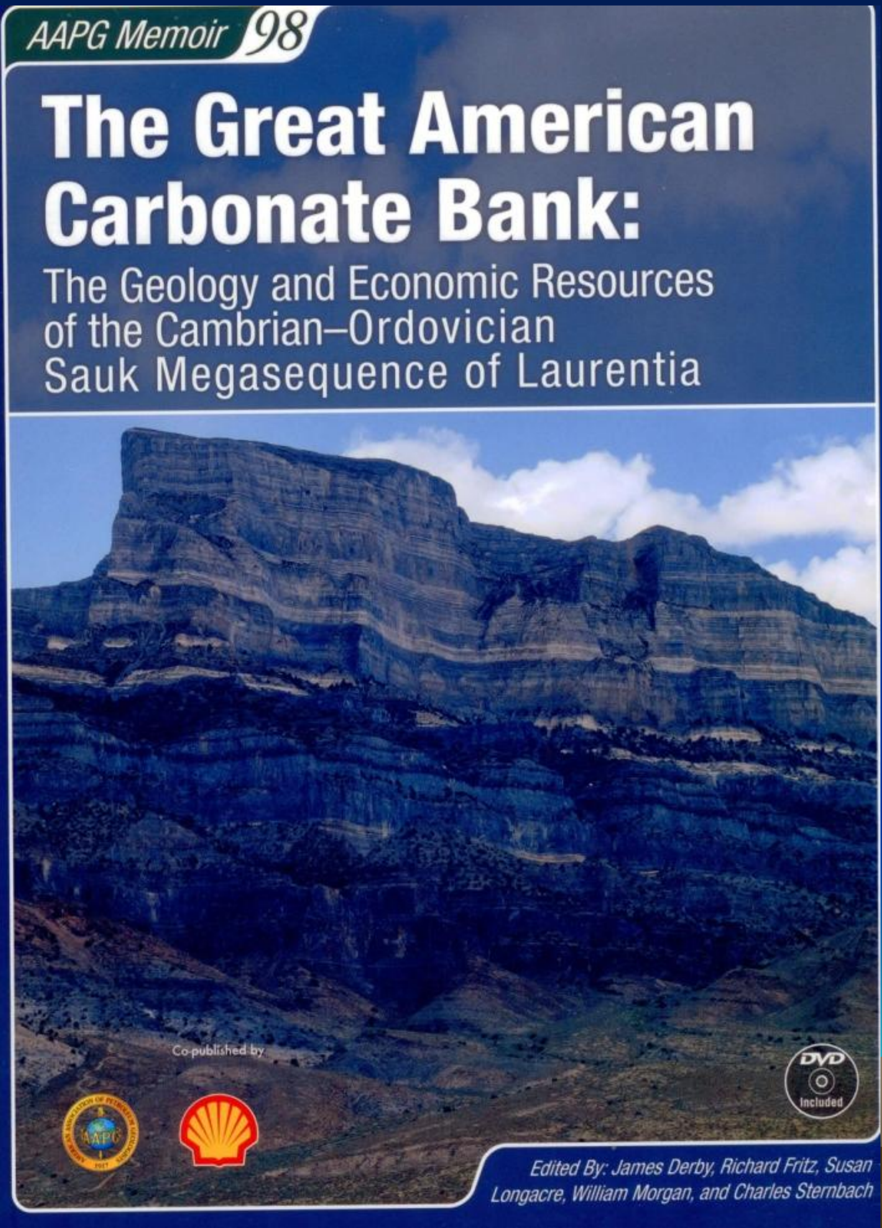
Petroleum Resources of the Great American Carbonate Bank (Lower Ordovician - Upper Cambrian)

Lessons from Heterogeneous Reservoirs, Diverse Traps, and Unconformity Thinking

Charles A. Sternbach,
President Star Creek Energy

Origin of Talk

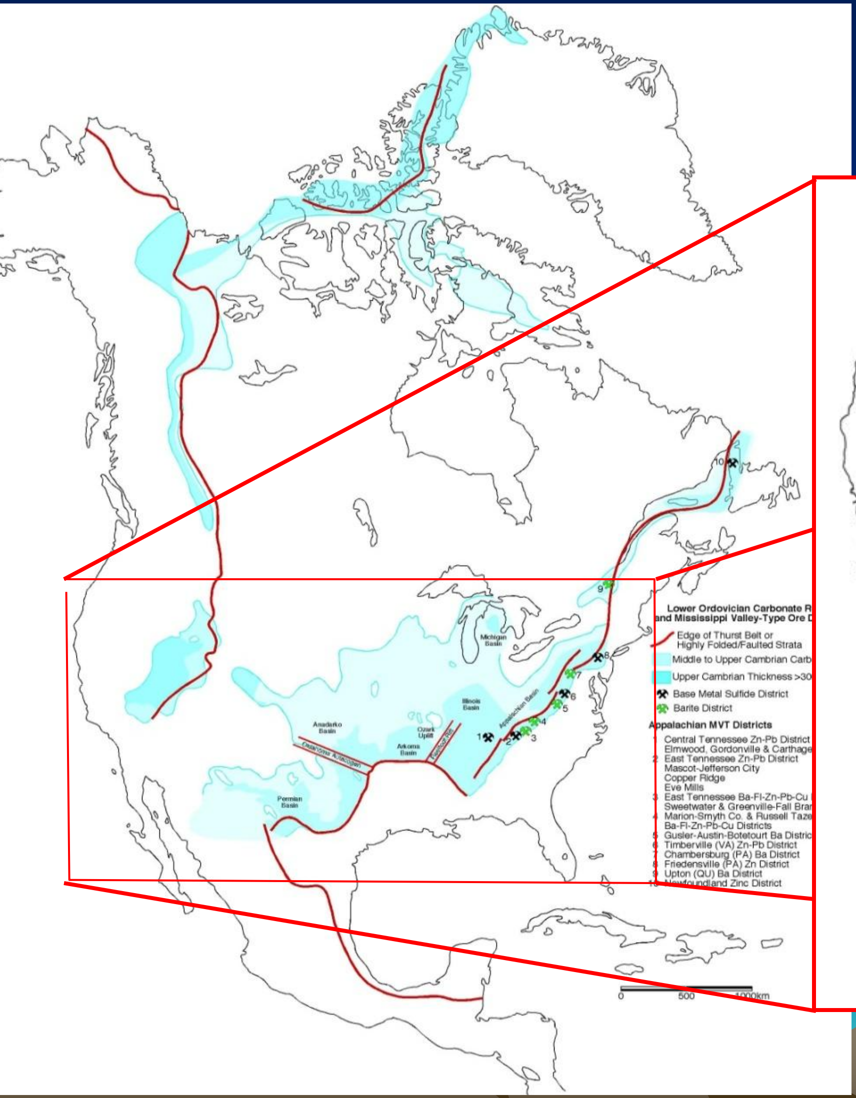


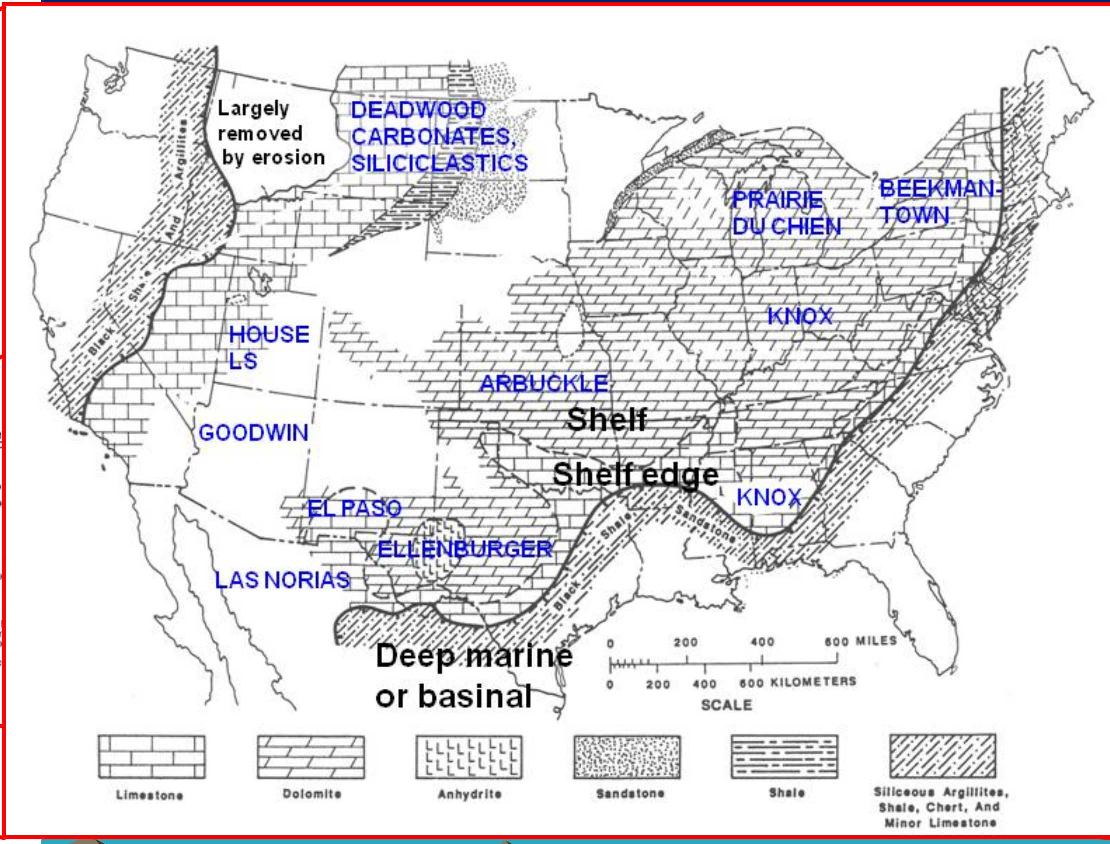
- Petroleum Production chapter of GACB ("Great American Carbonate Bank" so named by Ginsburg, Derby and Wilson)

Insights and Strategies

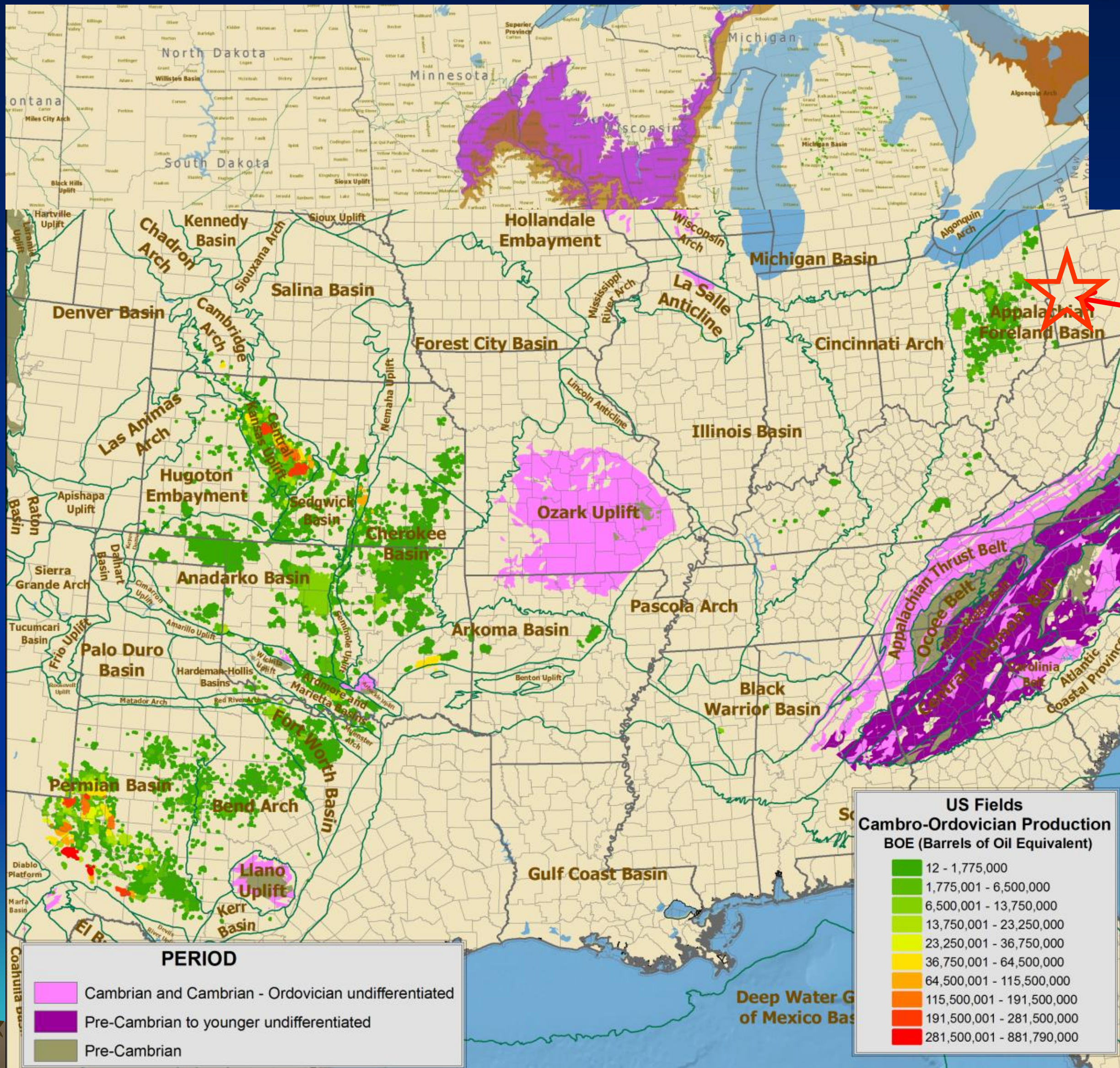
- Updated production data (courtesy IHS)
- Juxtaposition of SR and seal key
- Sauk/Tippecanoe Unconformity
  – major karst imprint
  – key role in hydrocarbon trap
  – migration pathway

Formations producing in GACB Heartland





Oil and Gas Production



Pittsburgh

Data Courtesy IHS

C.A. Sternbach (2012), Petroleum Resources Chapter, AAPG GACB Memoir

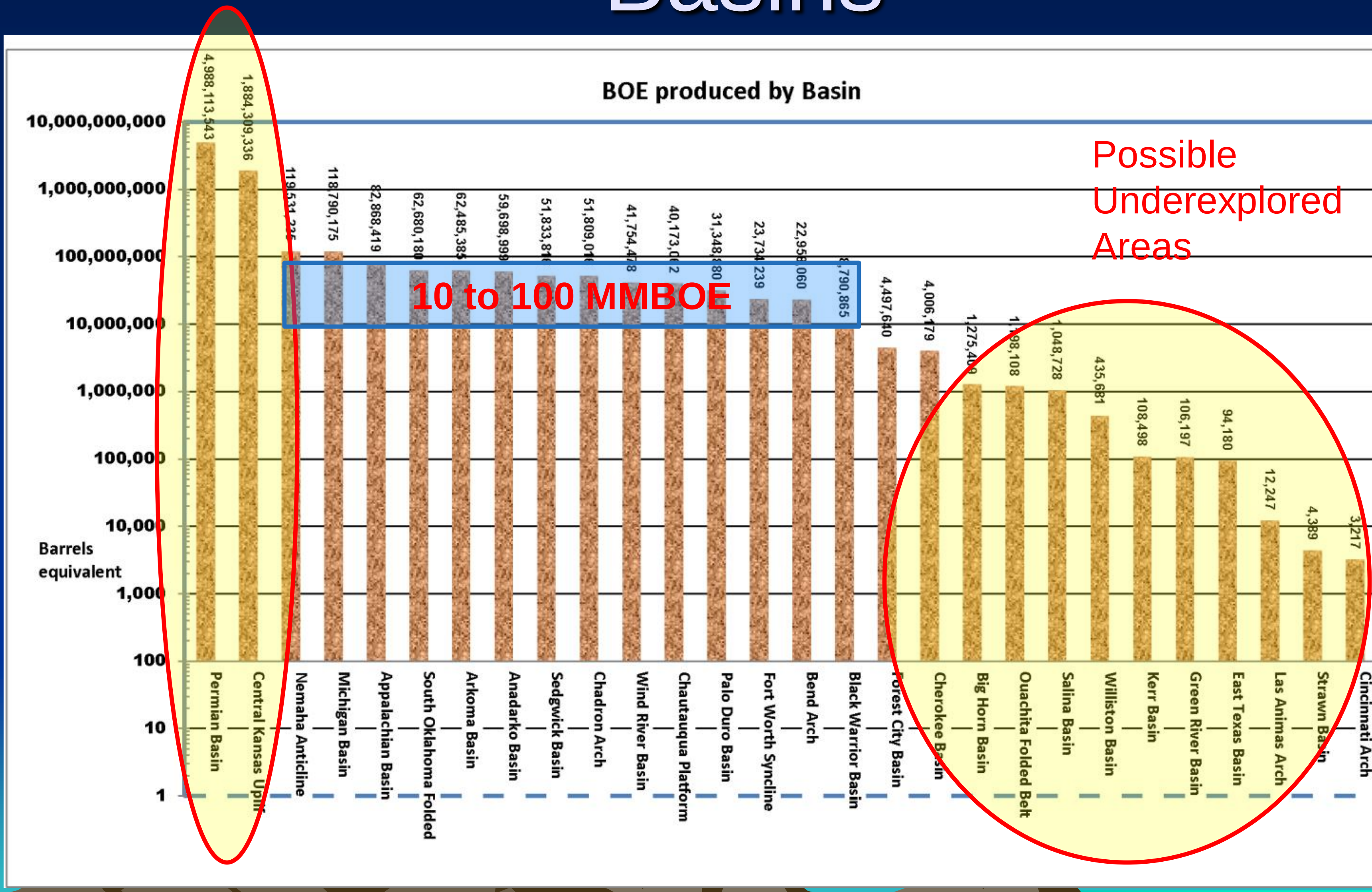
Statistics

- 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, **timely to revisit**

Data provided courtesy of IHS

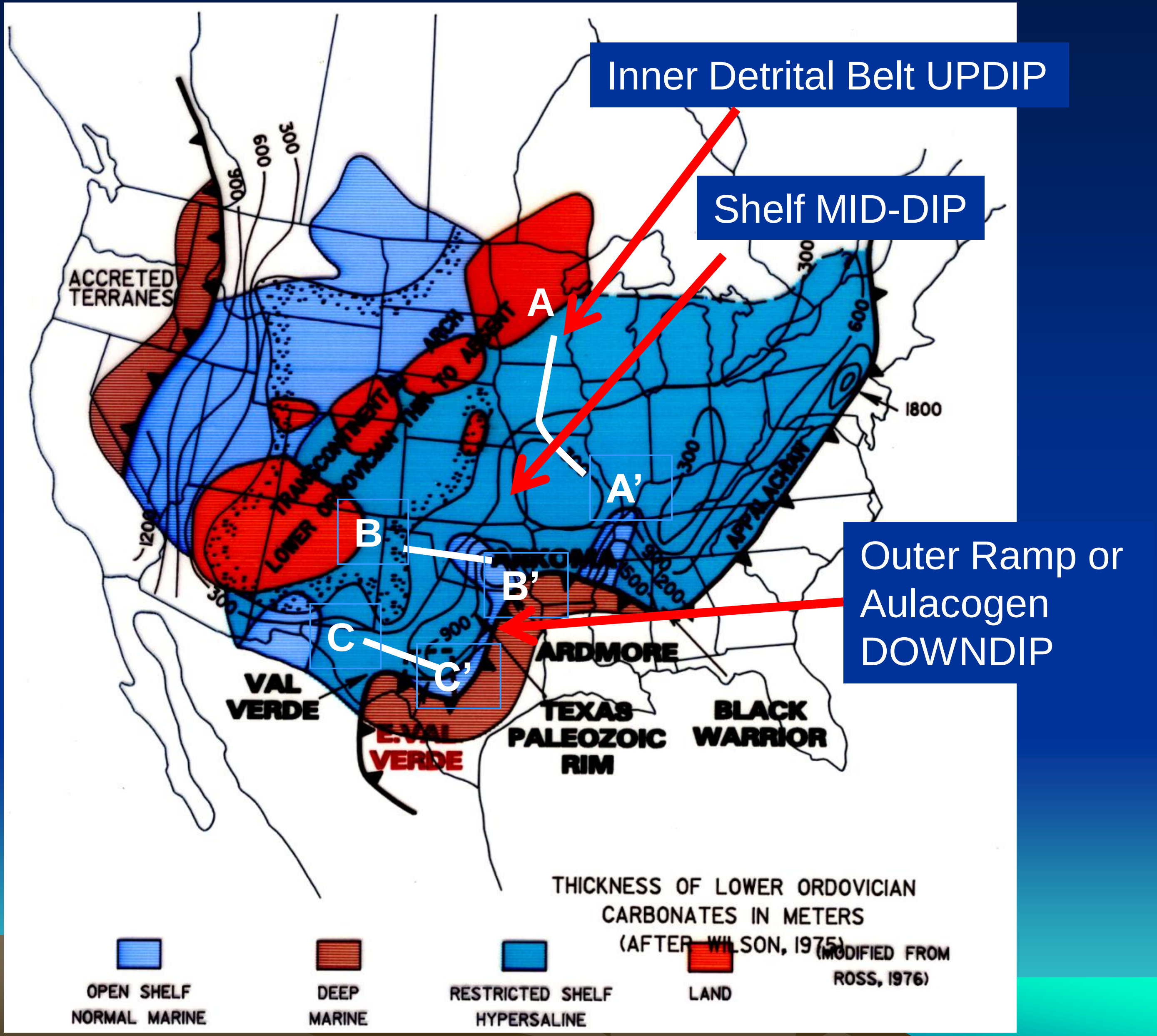
Two Basins
Dominate:
Permian and CKU

Basins



C.A. Sternbach (2012), Petroleum Resources Chapter, AAPG GACB Memoir

GACB depositional facies and isopach



A

Regional Composite Section

C'

Updip

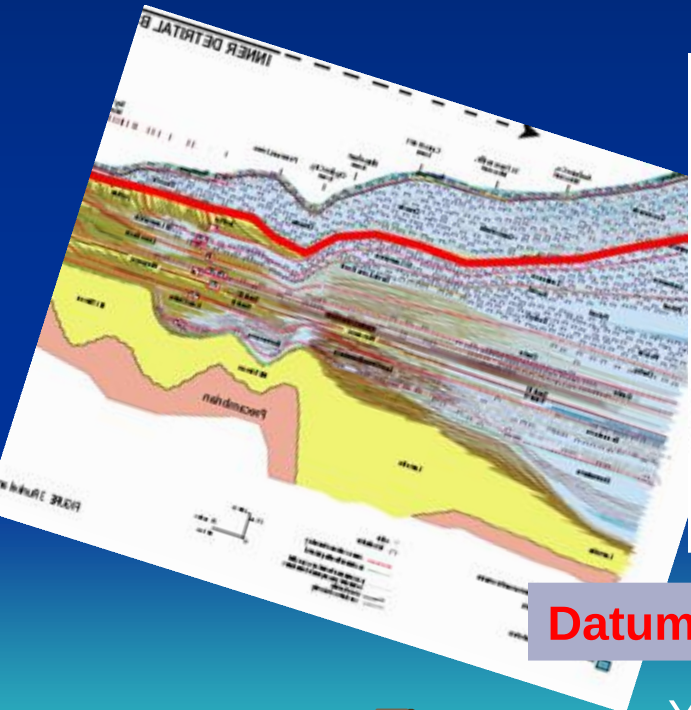
Downdip

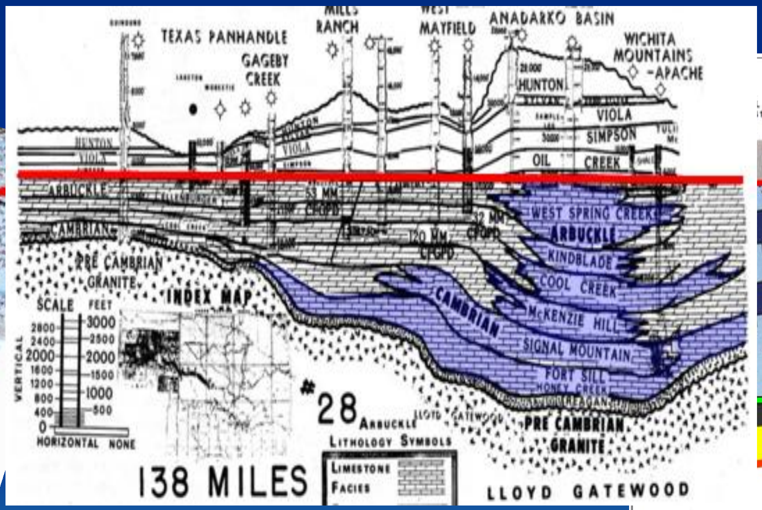
Inner Detrital Belt Sandstones and Dolomites

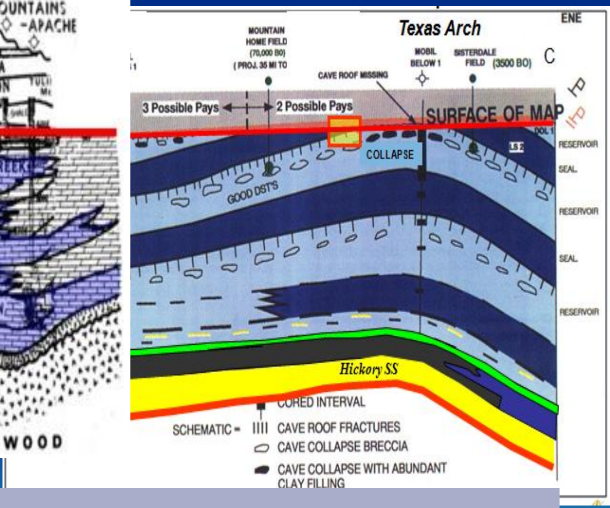
Mid-Dip Shelf Dolomite Main Productive Setting

Downdip Aulacogen Limestone increases

Outer Ramp Limestone Increases





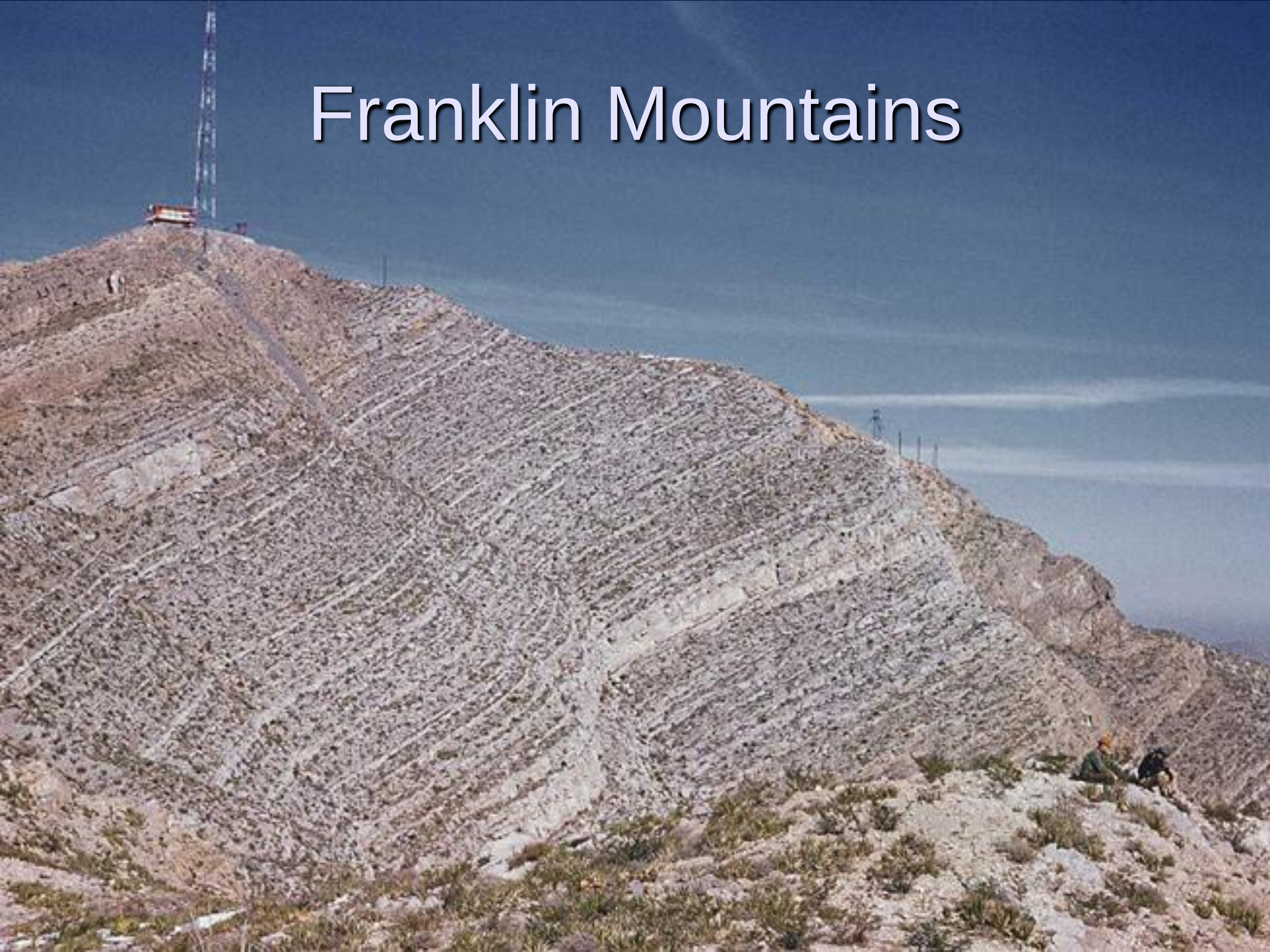


Datum: Sauk-Tippecanoe Unconformity (approx red line)

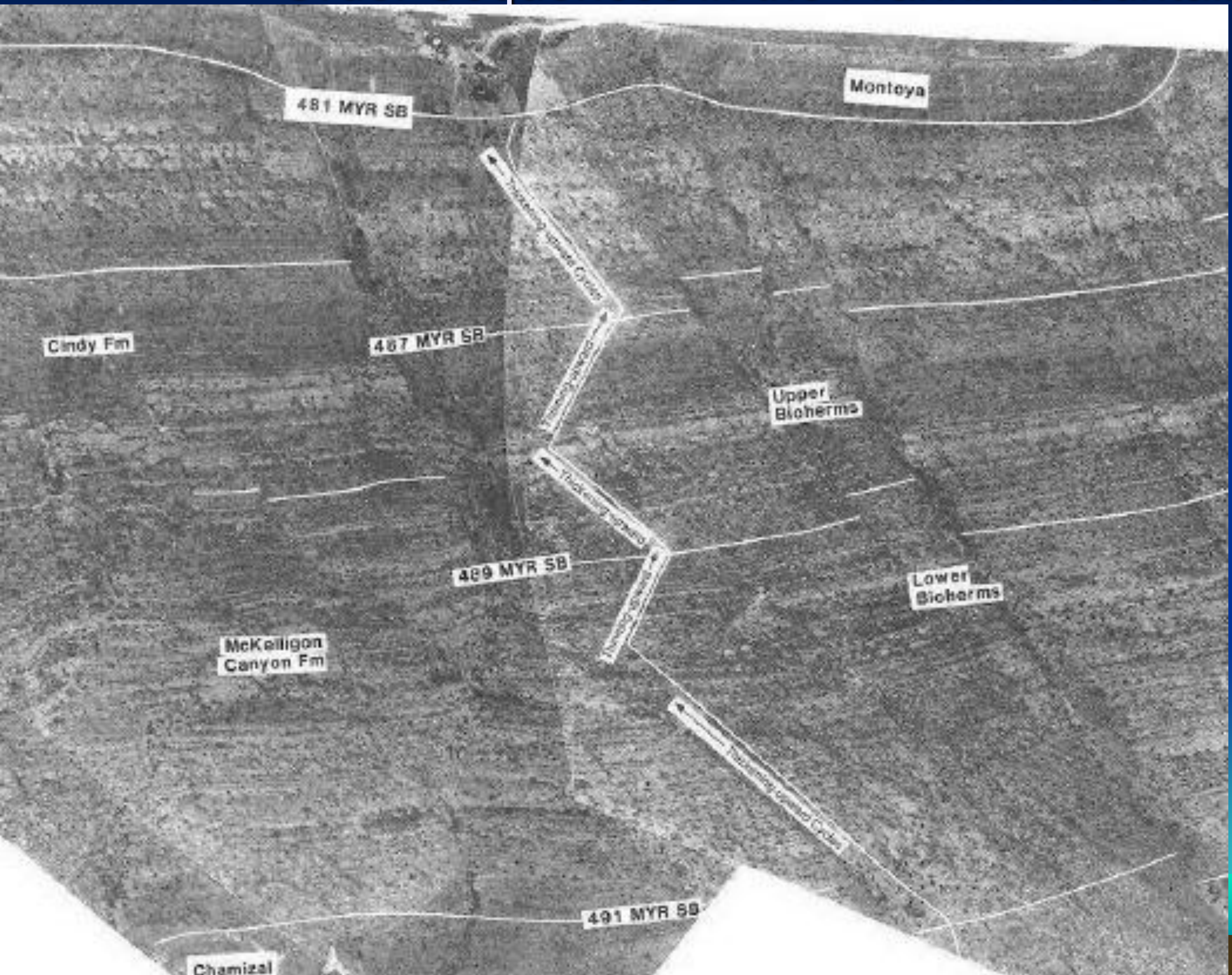
Yellow= sandstone; cyan= dolomite; dark blue= limestone

Figures left to right: Runkel et al. (2012), Gatewood (1979) and Sternbach (1993)

Franklin Mountains

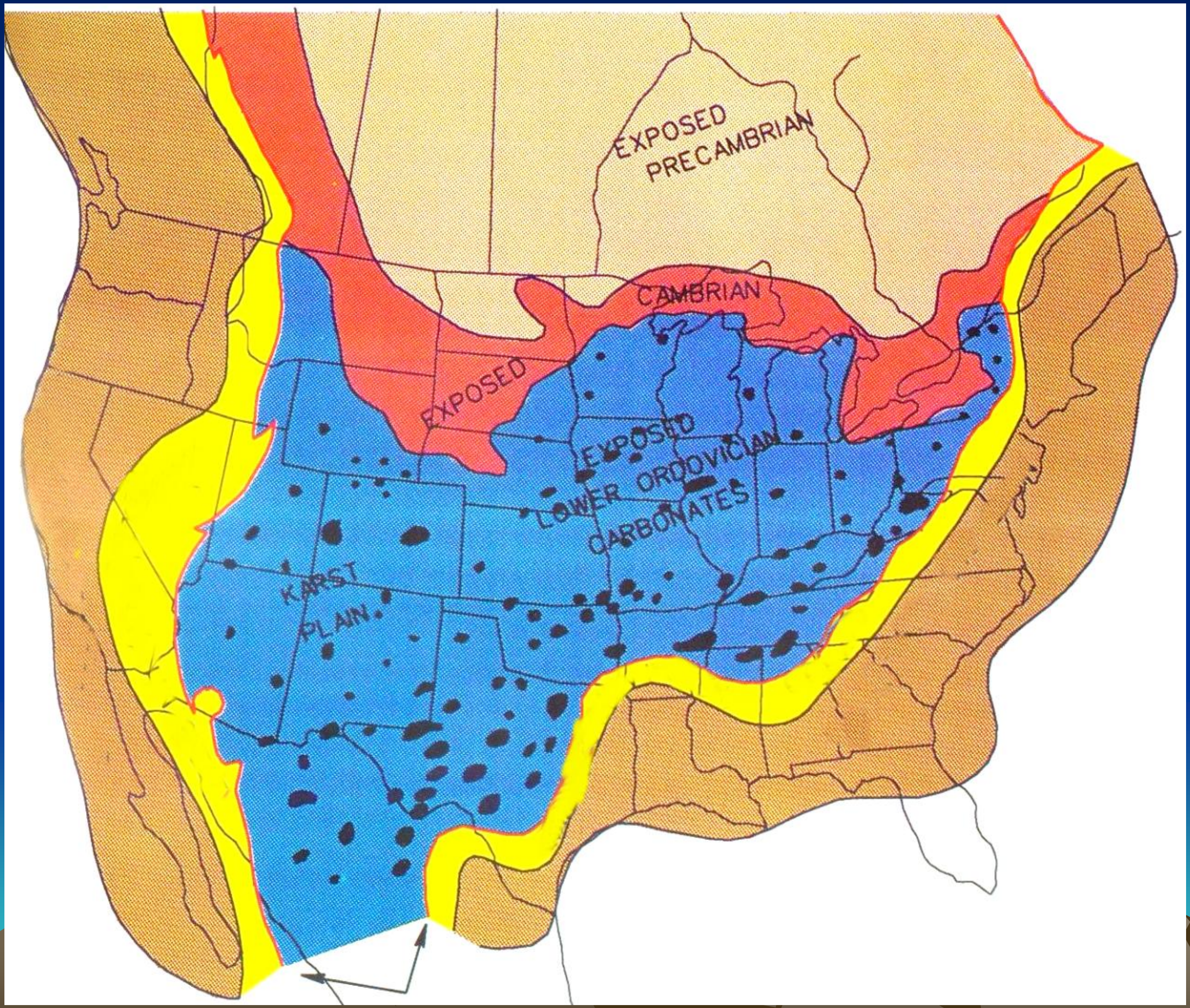


High-Frequency Platform Carbonate Cycles and Third-Order Sequences in the Franklin Mountains



Goldhammer et al. (1993)

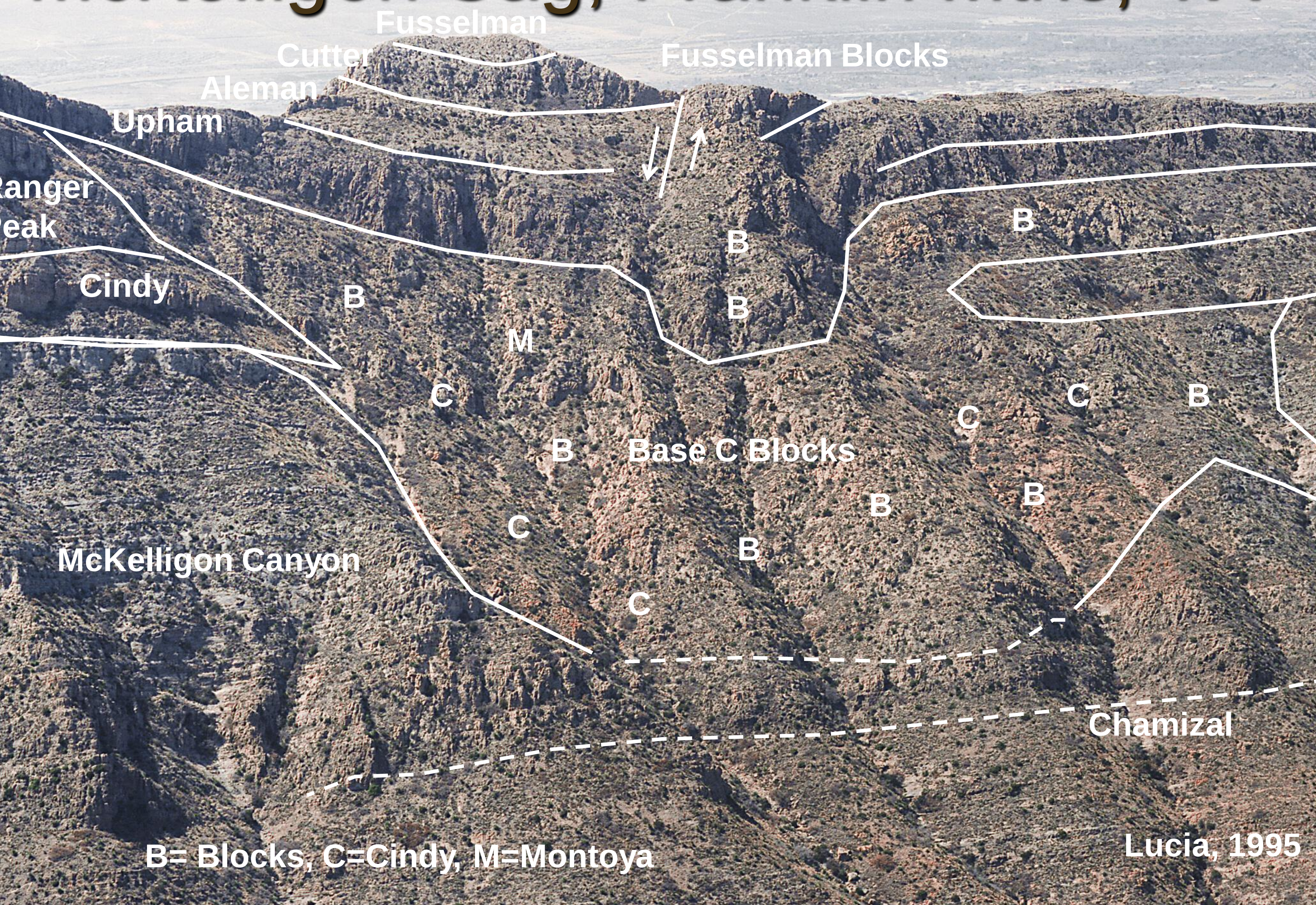
GACB Karst plain: end of Sauk deposition prior to Tippecanoe submergence



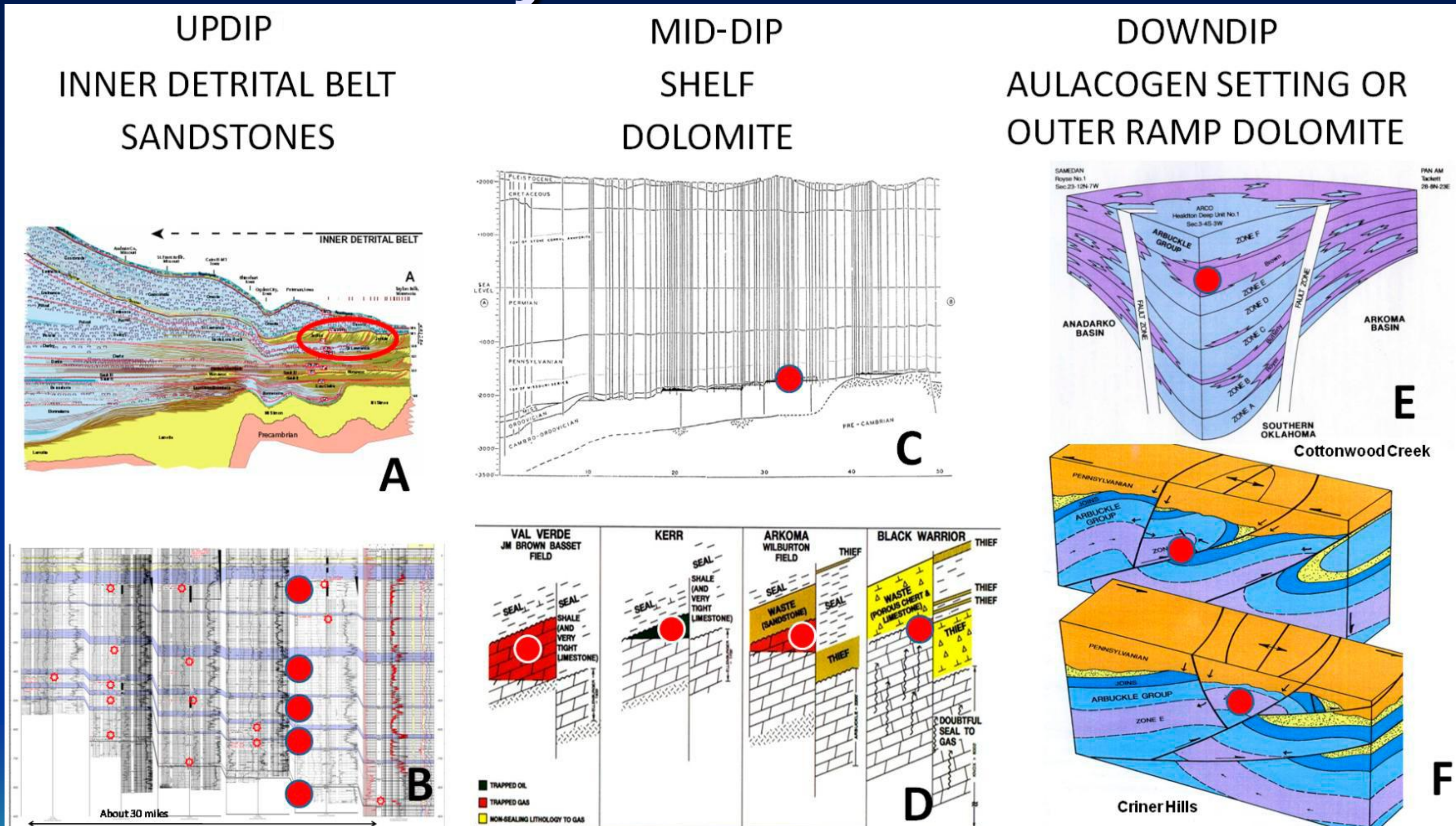
- Exposure
- Dissolution
- Cave Collapse
- Diagenesis
- Fractures

McKelligon Sag, Franklin Mtns, TX

McKelligon Sag, Franklin Mtns, TX

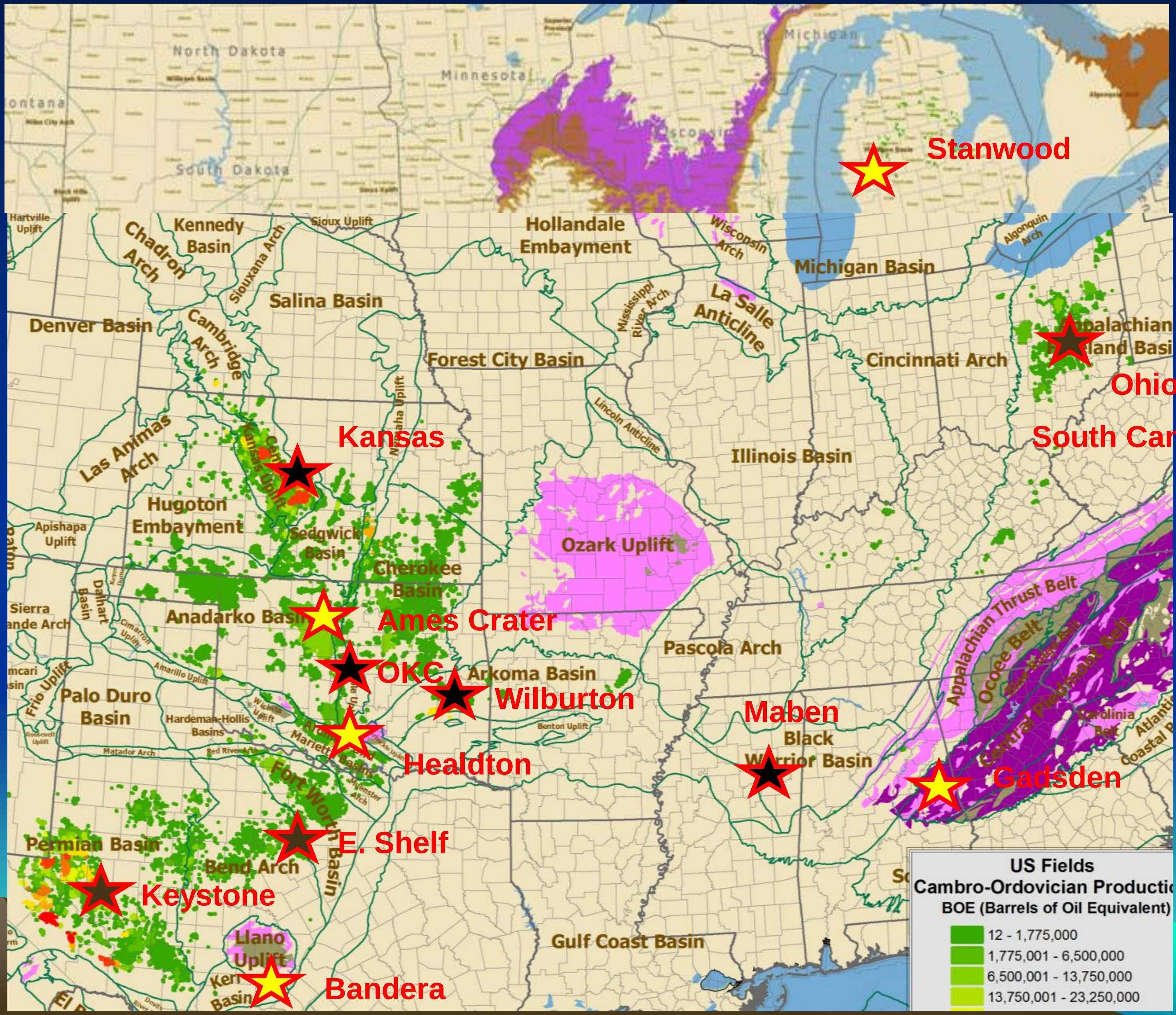


Pay occurrence



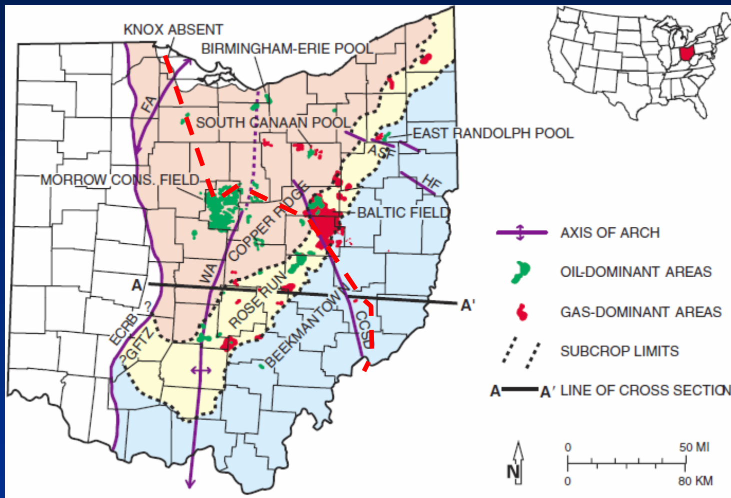
Schematic profile representations of where hydrocarbons are generally produced in GACB shelf reservoirs (red circles). (GACB papers by: 1) Runkel et al., 2) Sternbach, and 3) Fritz et al.).

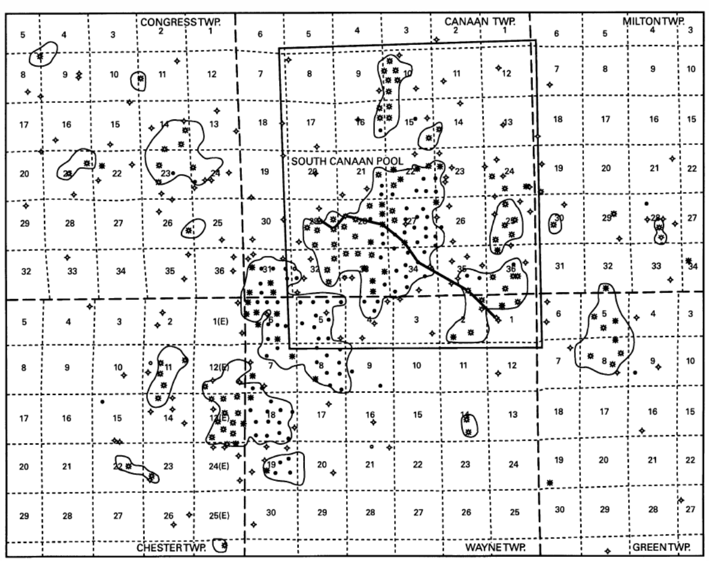
Field Examples

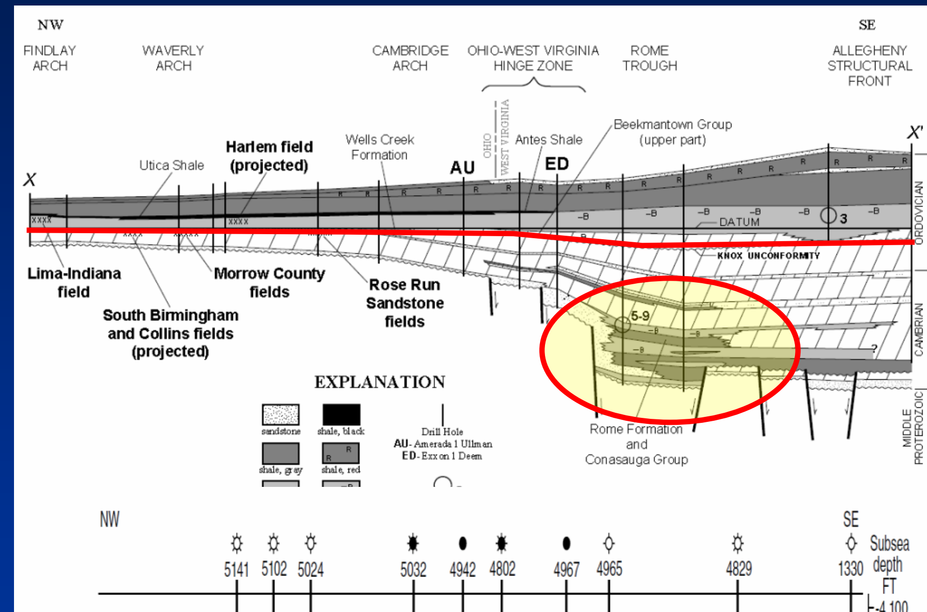


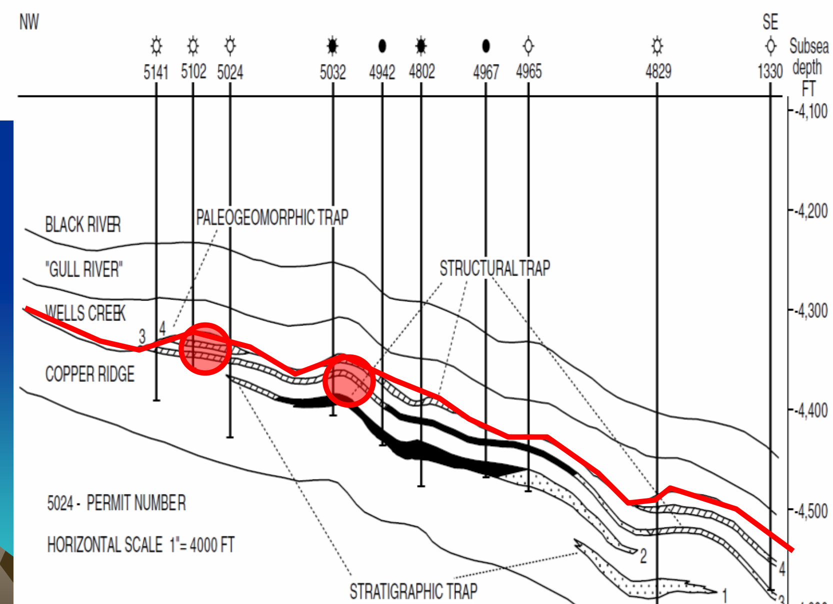
Ohio Fields

Rome Formation and Conasauga Group contain an extra thick shale basin with source rock potential and 5-9 mmcfgd gas show (Ryder et al., 1998)





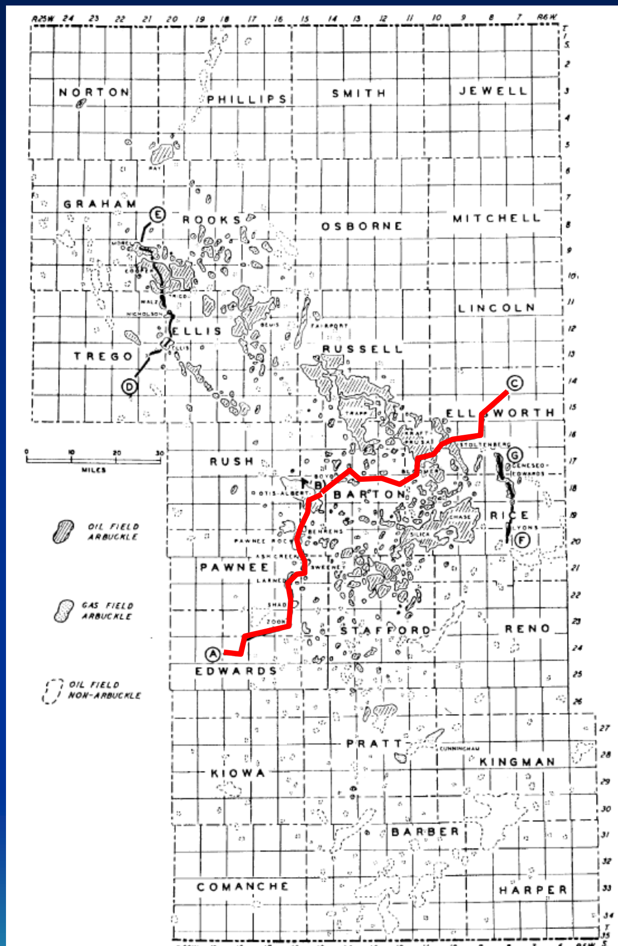


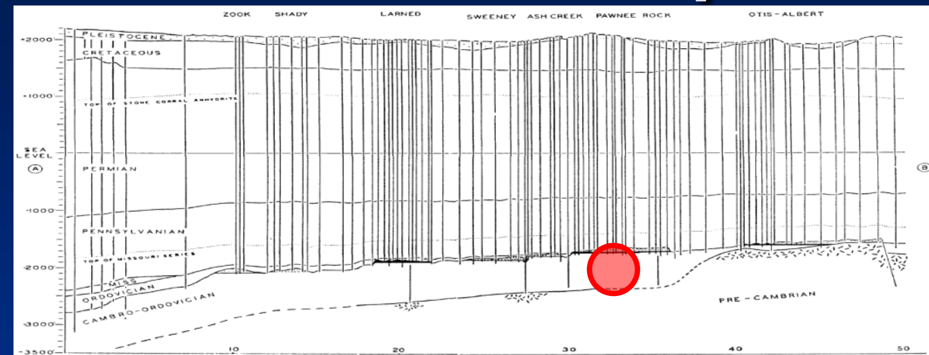


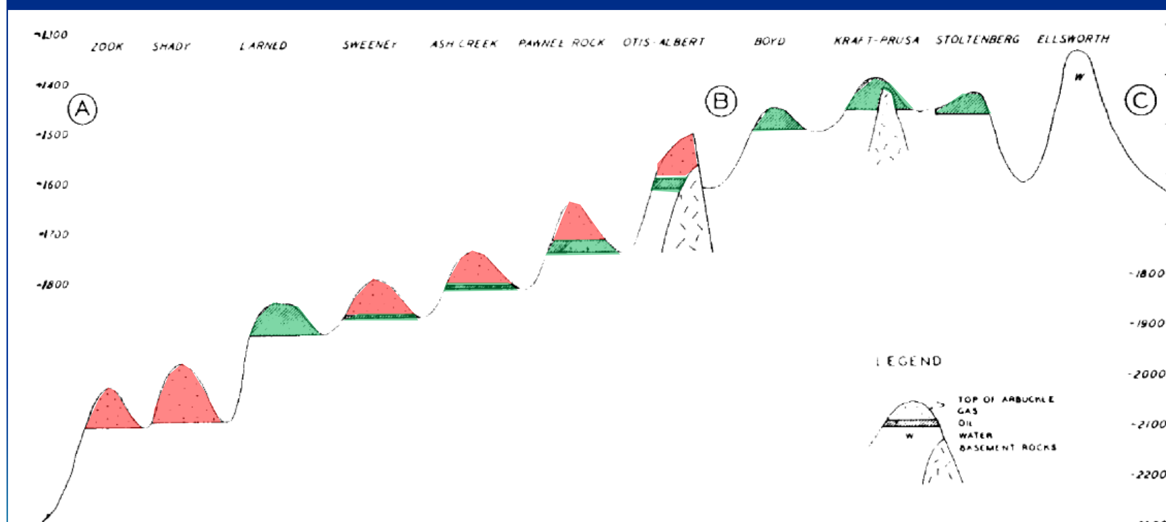
Riley et al., 2002

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

Kansas Differential traps

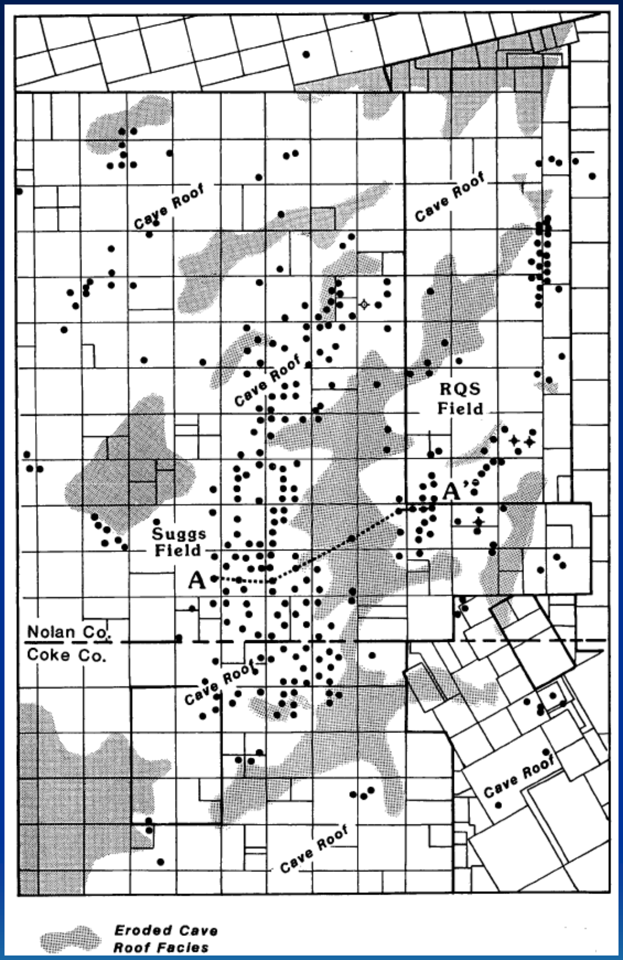


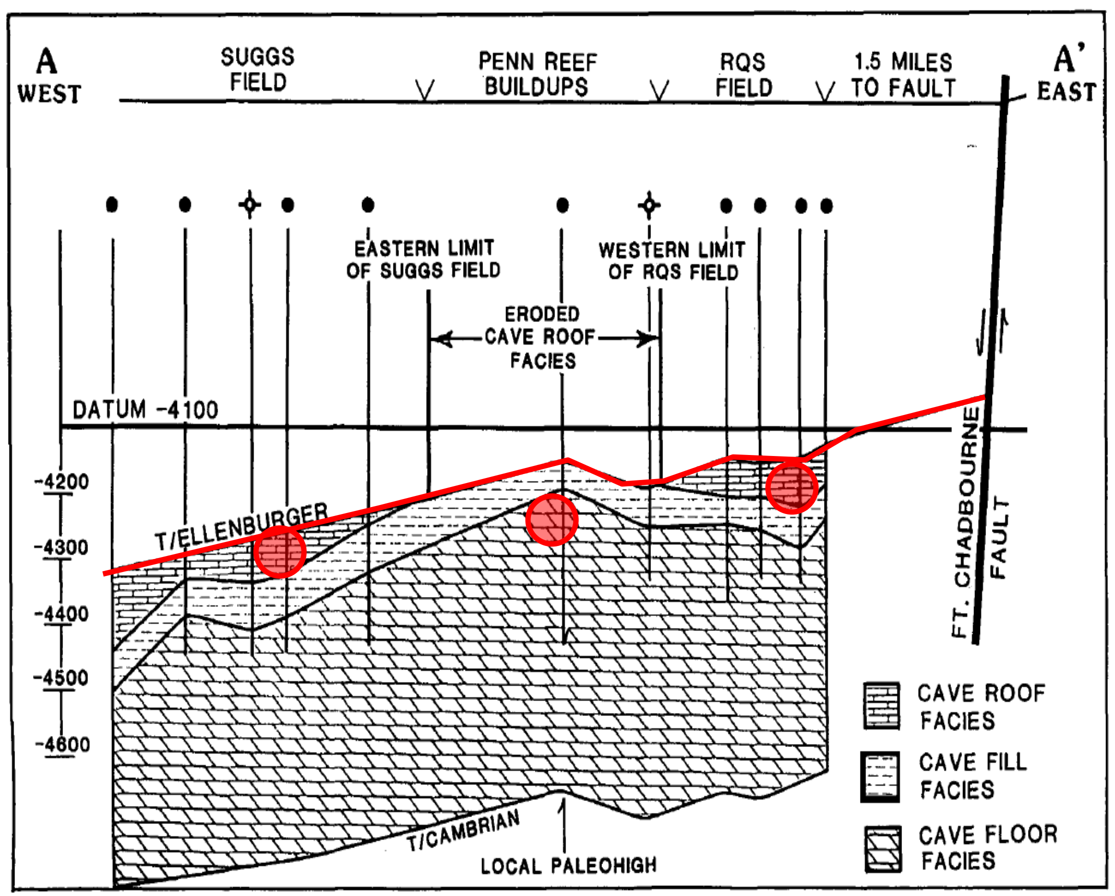




Map of Central Kansas (left) and cross section (right) showing lateral migration and differential entrapment of oil and gas from Edwards to Barton counties (Walters, 1958).

Eastern Shelf, Midland Basin



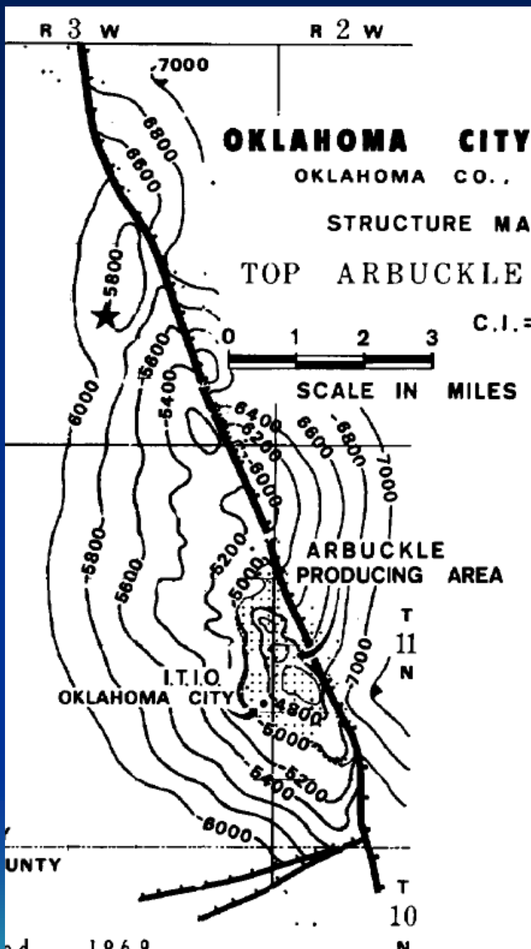


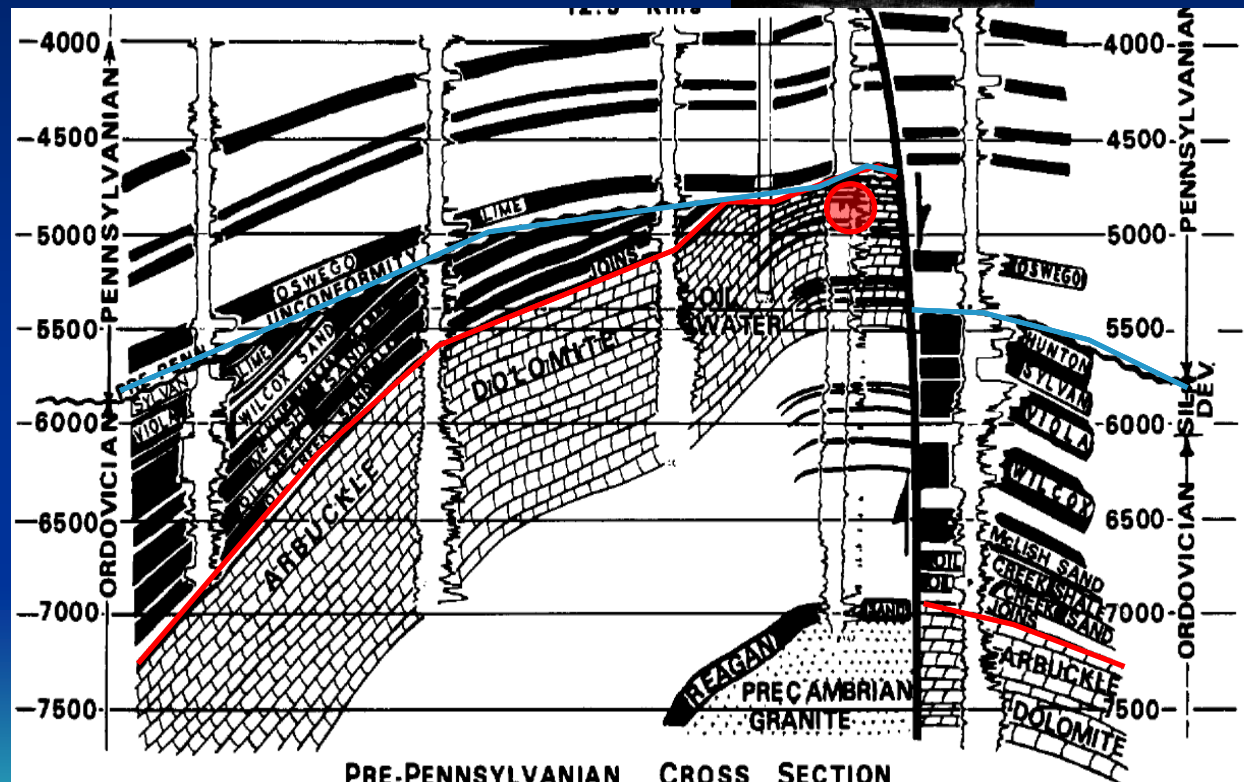
Humphrey et al., 1994

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

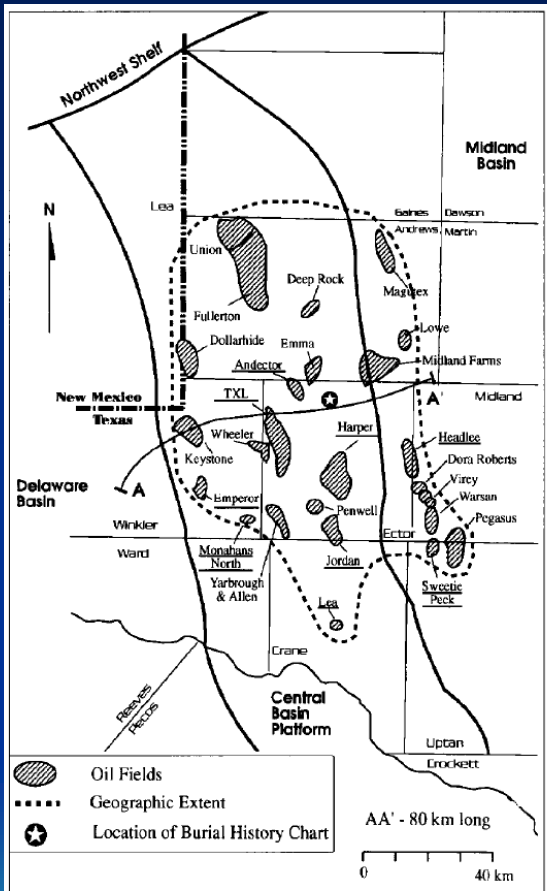




Arbuckle structure map (left) and structural cross section (right) of Oklahoma City Field (reprinted from Gatewood, 1970)

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

Keystone Field, Central Basin



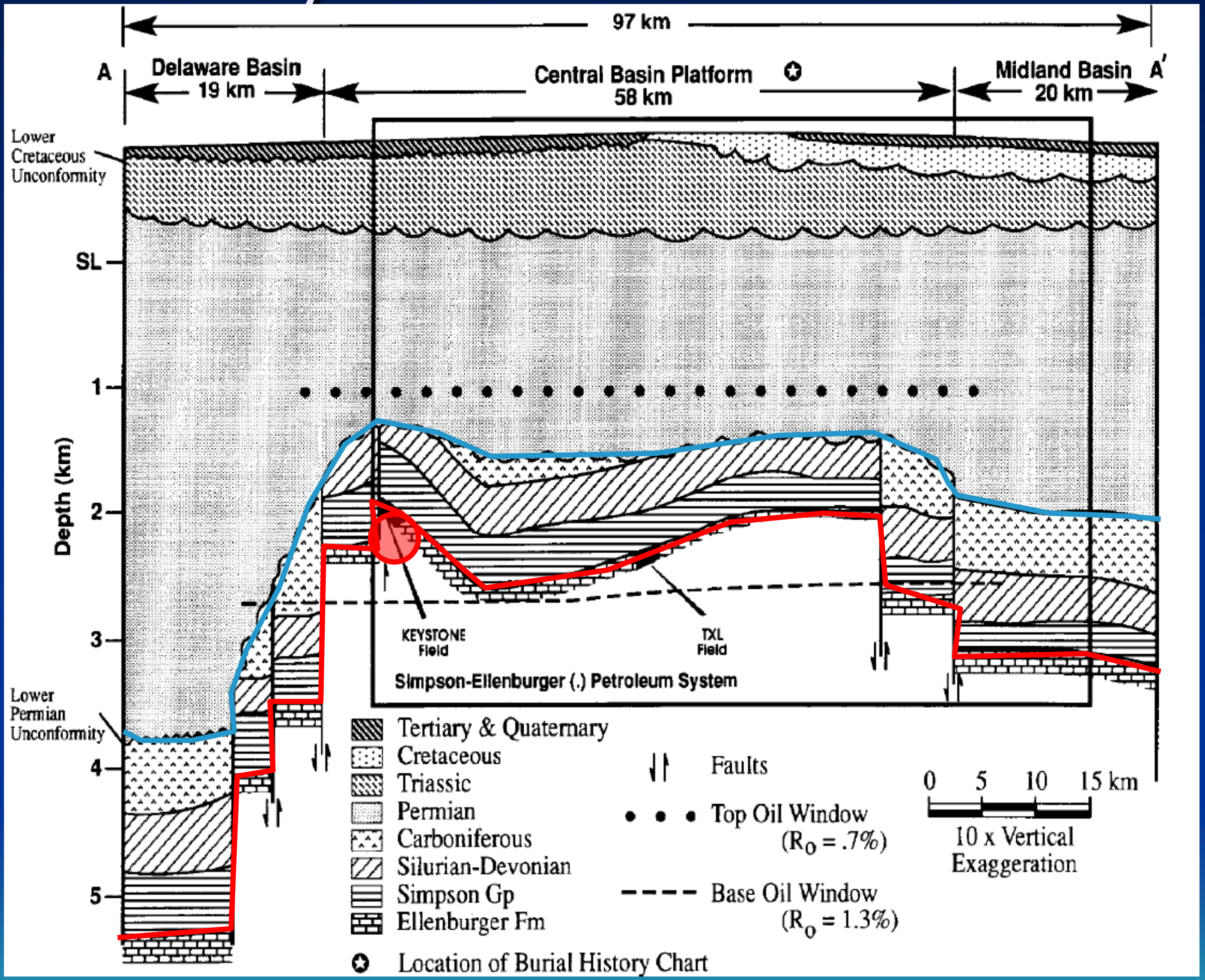
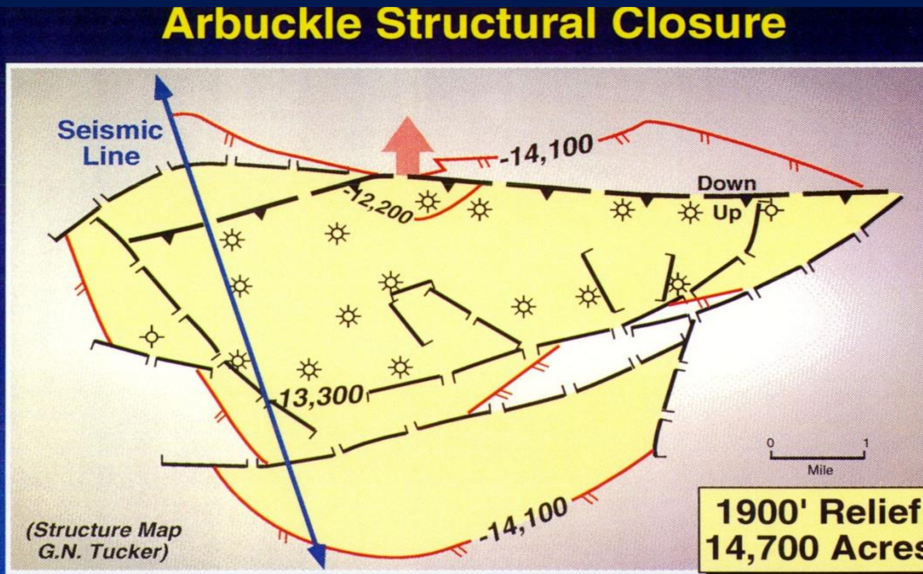
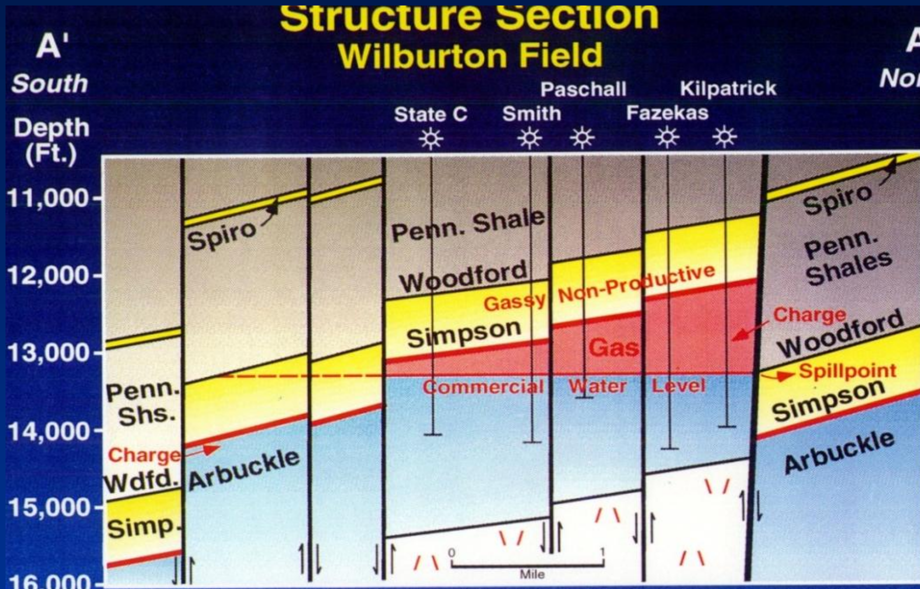


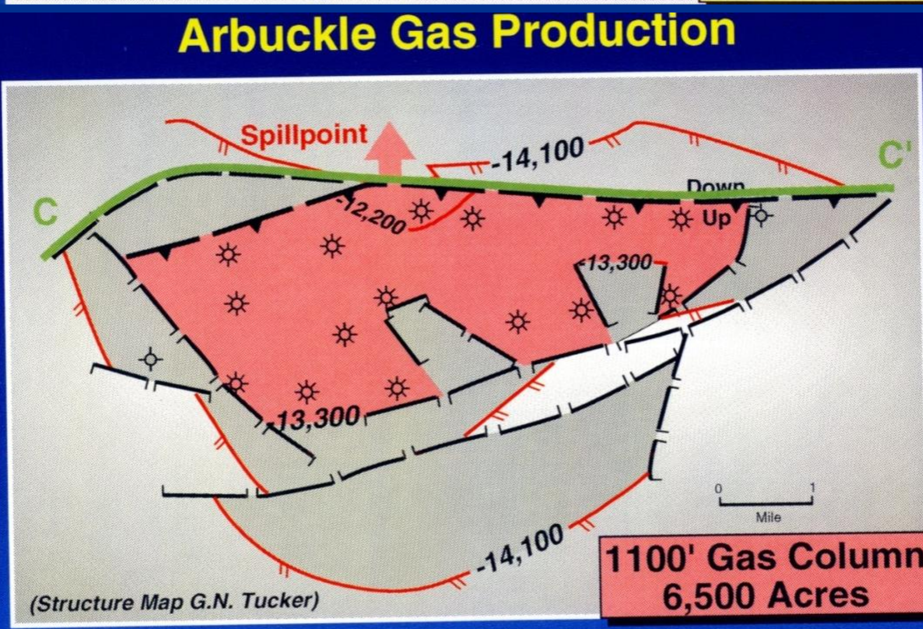
Figure 17. Map (left) and cross section (right) of the Central Basin Platform, Permian Basin Texas (Katz et al., 1994).

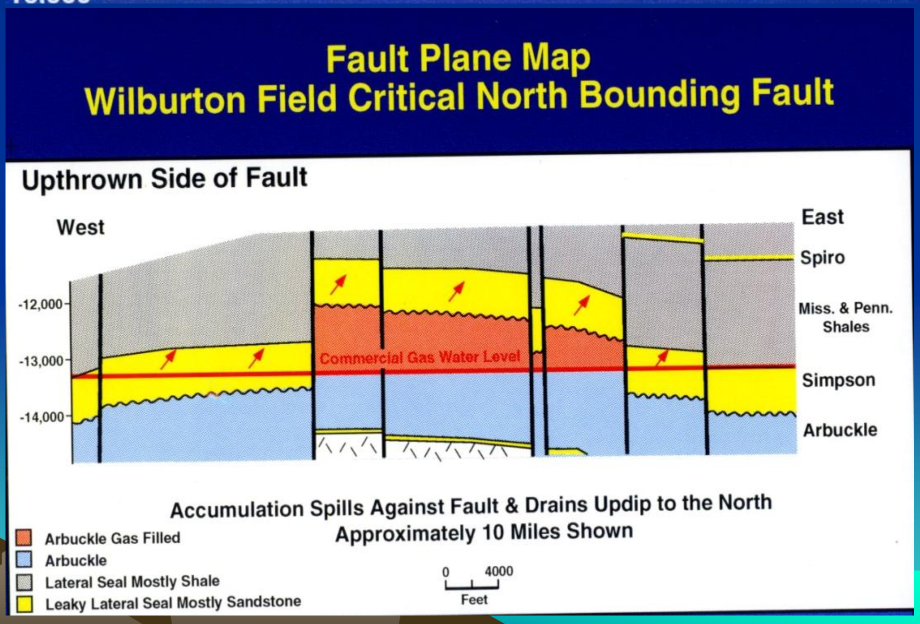
Disc. 1943 147 MMBO, 485 BCF, 227 MMBOE

Wilburton Field, Arkoma Basin





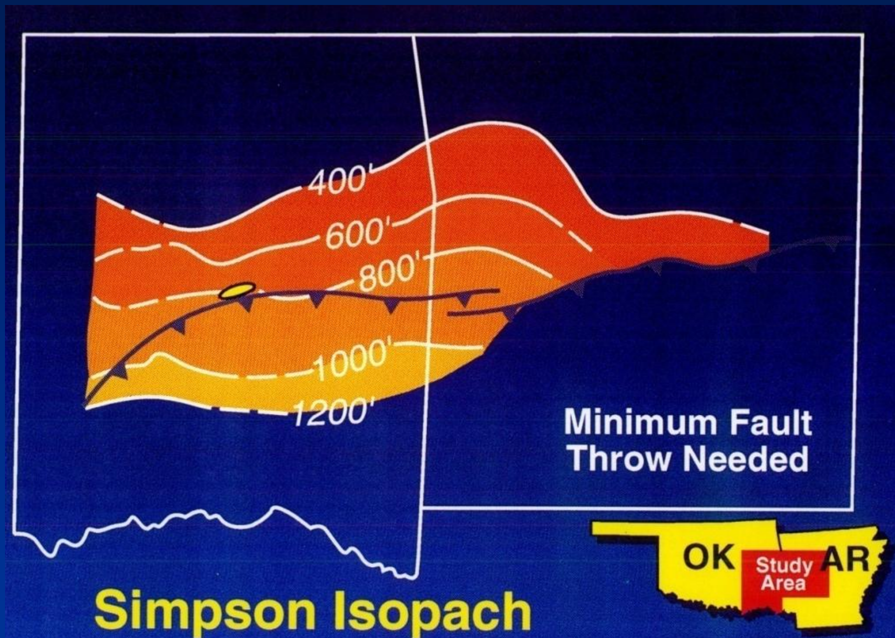


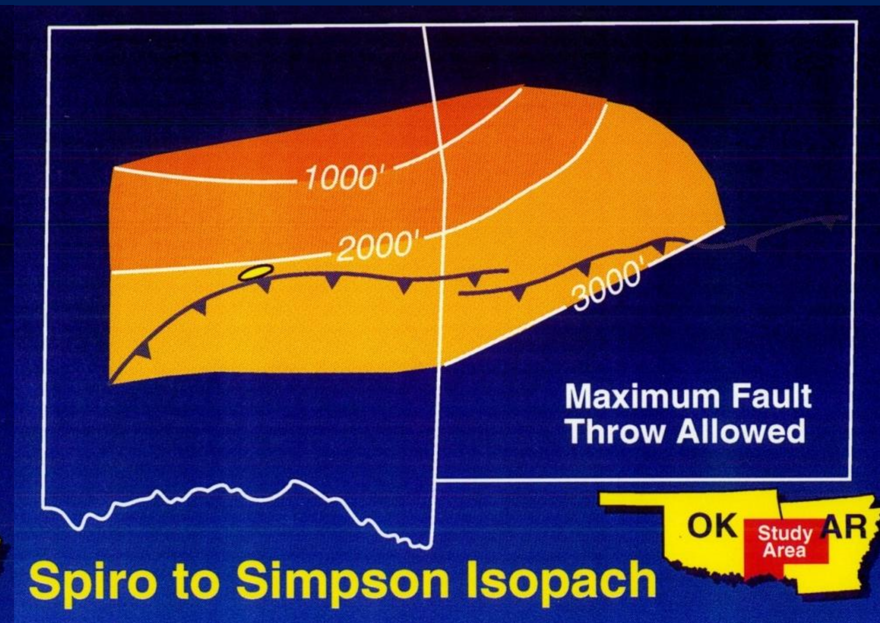


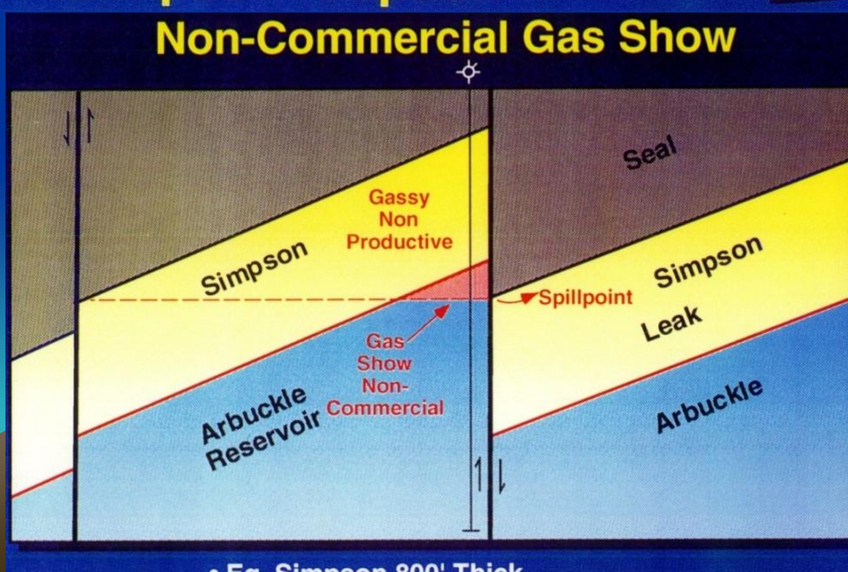
Disc. 1987 365 BCF, 61 MMBOE

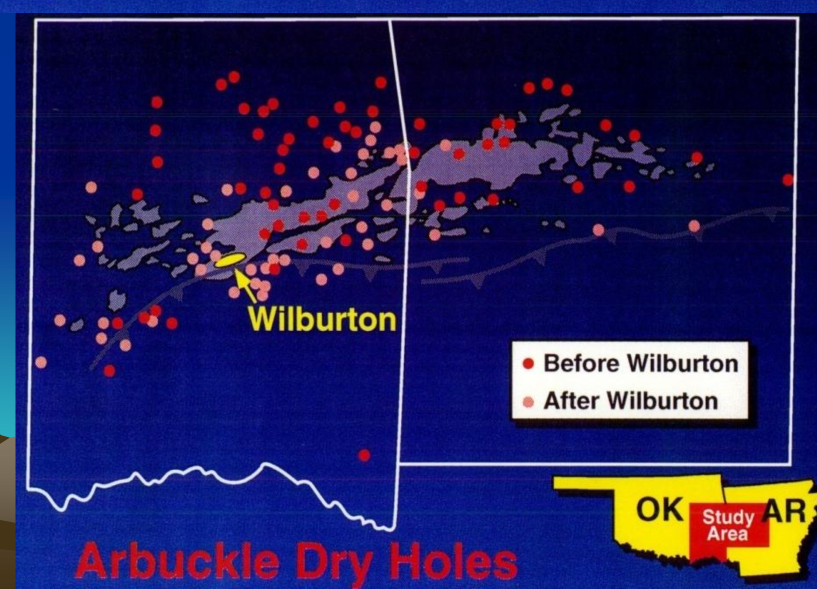
C.A. Sternbach, 1993

The "Goldilocks" Fault throws

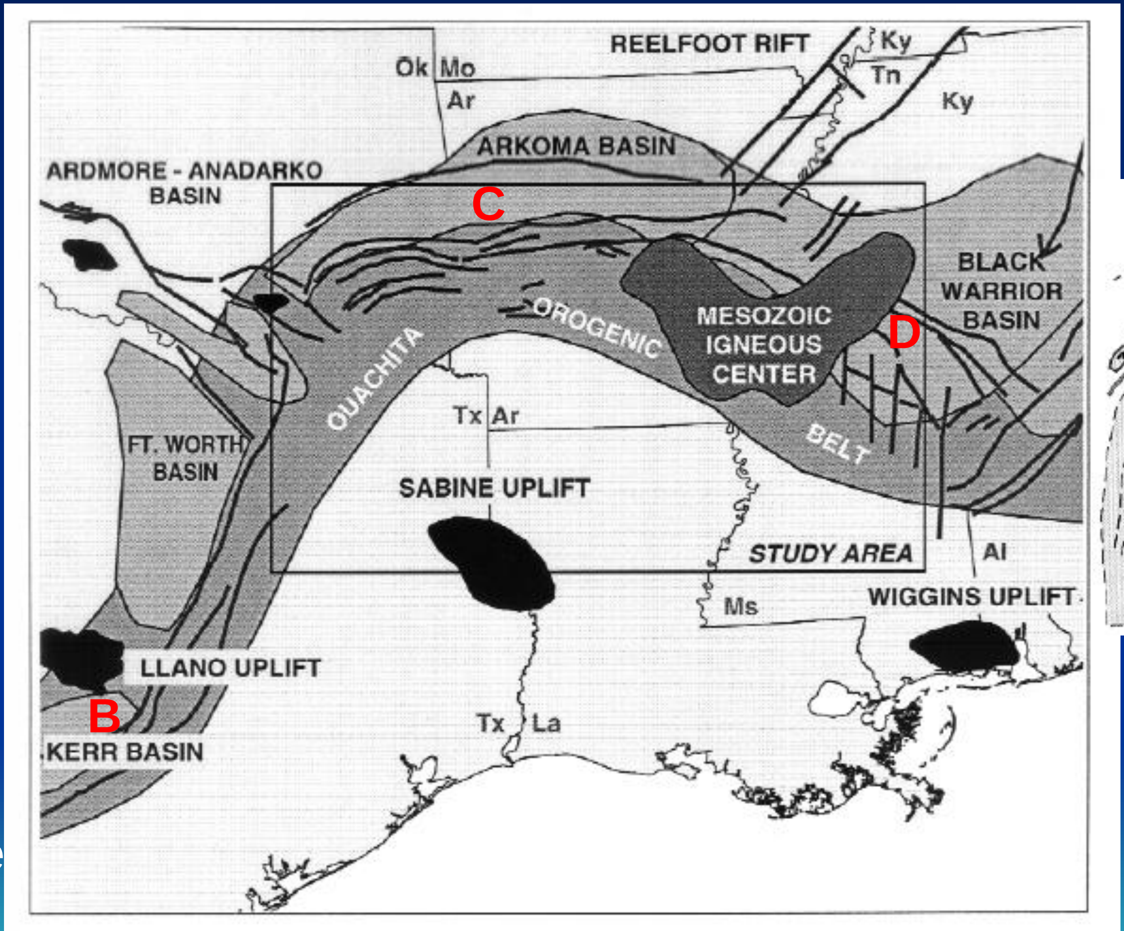






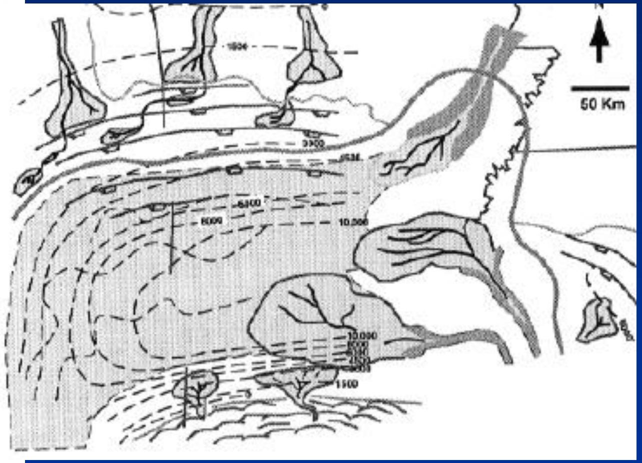


Basins along the Ouachita Thrust Belt



A

Val Verde Basin



Note: Carboniferous sandstone sourced from north and east

Reference: Coleman, 2000

Evaluating Oil/Gas water contacts on large structural blocks can require:

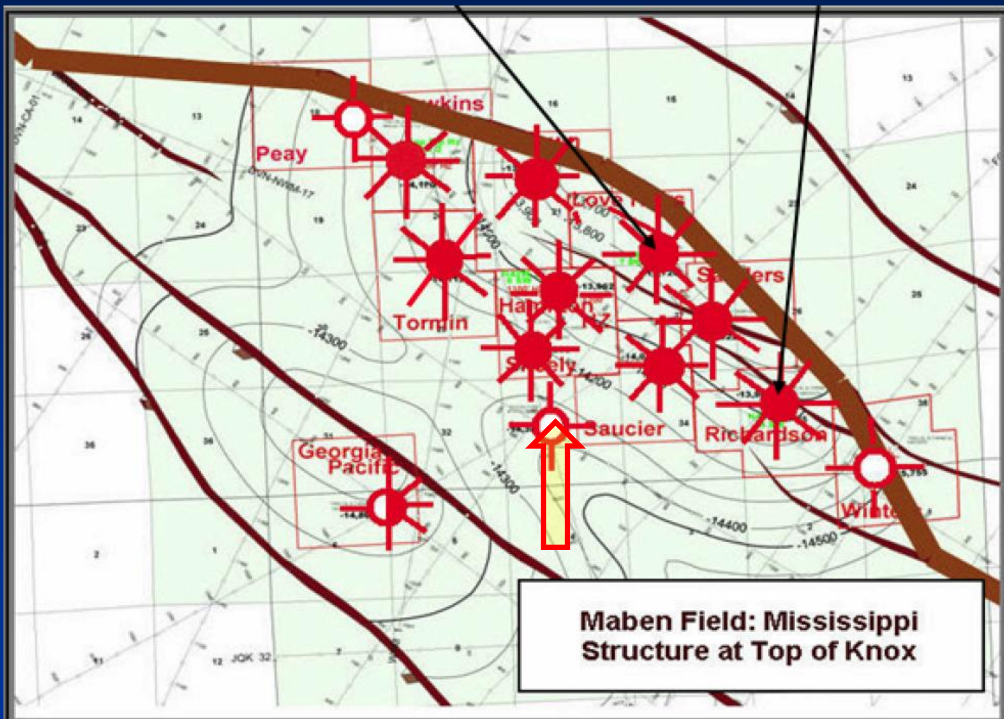
- Structure map (upthrown and downthrown)
- Cross Section (showing fluid levels)
- Fault plane map to define reservoir to reservoir leak point
- Insights scalable on field, basin, and multi-basin orogenic trend

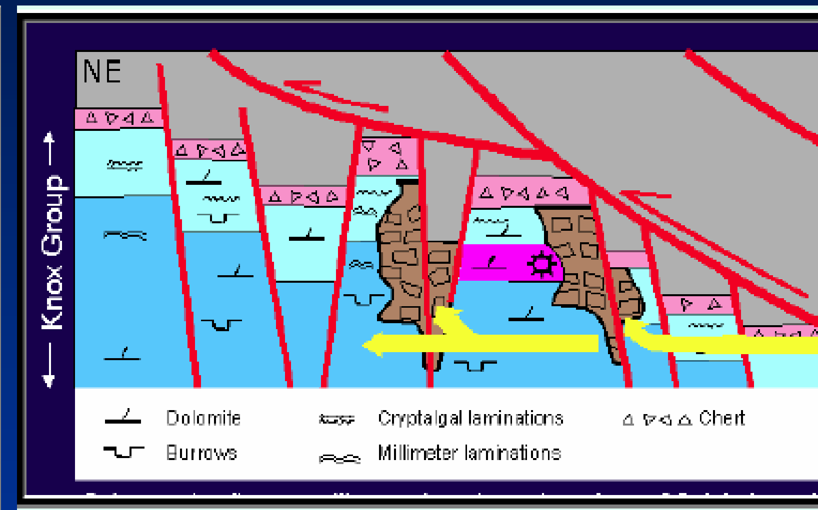
Sometimes it pays to get off the "beaten path"

- Captain Cook avoided heavily traveled routes
- Cook ventured into lightly explored areas
- Cook discovered more about the Pacific Ocean than all previous European explorers

Captain Cook (portrait by Nathaniel Dance, 1776).

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;

Disc. 1972/1995; Cum 51.7 BCF, 8.6 MMBOE

Julia Gale et al., 2008

Maben Field- A Comeback Story

- **1970: Texaco Sheeley #1 well completed as a low-volume "Knox-Ordovician" dry gas well in in Maben Field, Mississippi.**

- **1970-1995: well produced at marginal rates of 100-200 MCFGPD,**
  - **largely forgotten by industry.**

- **Late 1990's Fina geologist noticed well had zero decline;**
  - **pressure data indicate potentially large gas accumulation.**

- **1997: Fina Sanders #1, a 15,000-foot offset to the Sheely well**
  - **completed for sustained production at 5-6 MMCFG/D**

- **Today: “re-discovered” field has produced about 60 BCF dry gas, 9 wells.**

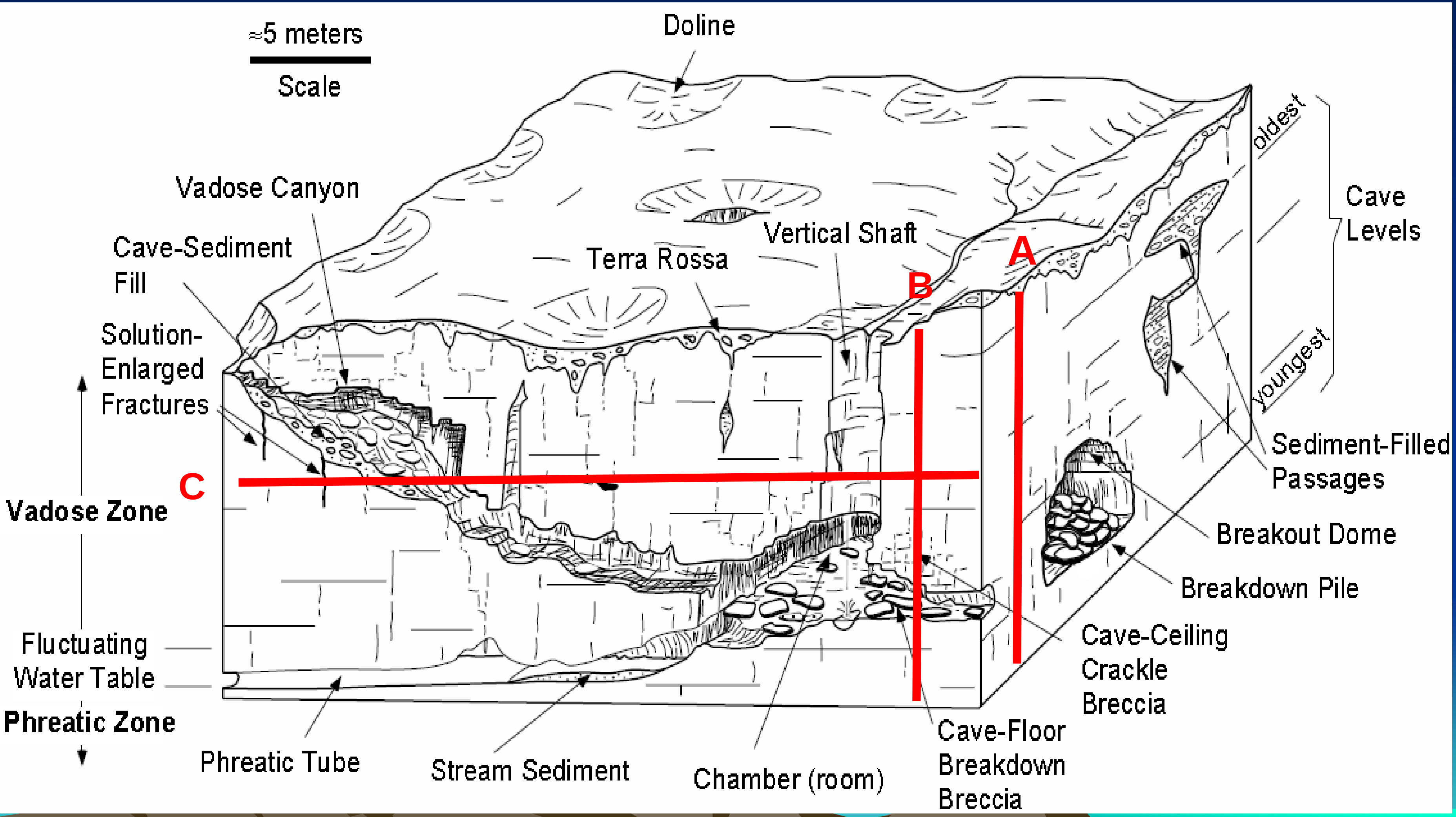
- Source: Vision Exploration webpage http://www.visionexploration.com/ordovician.htm

Karst-Modified Carbonate Reservoirs can be full of surprises

Gus Archie

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

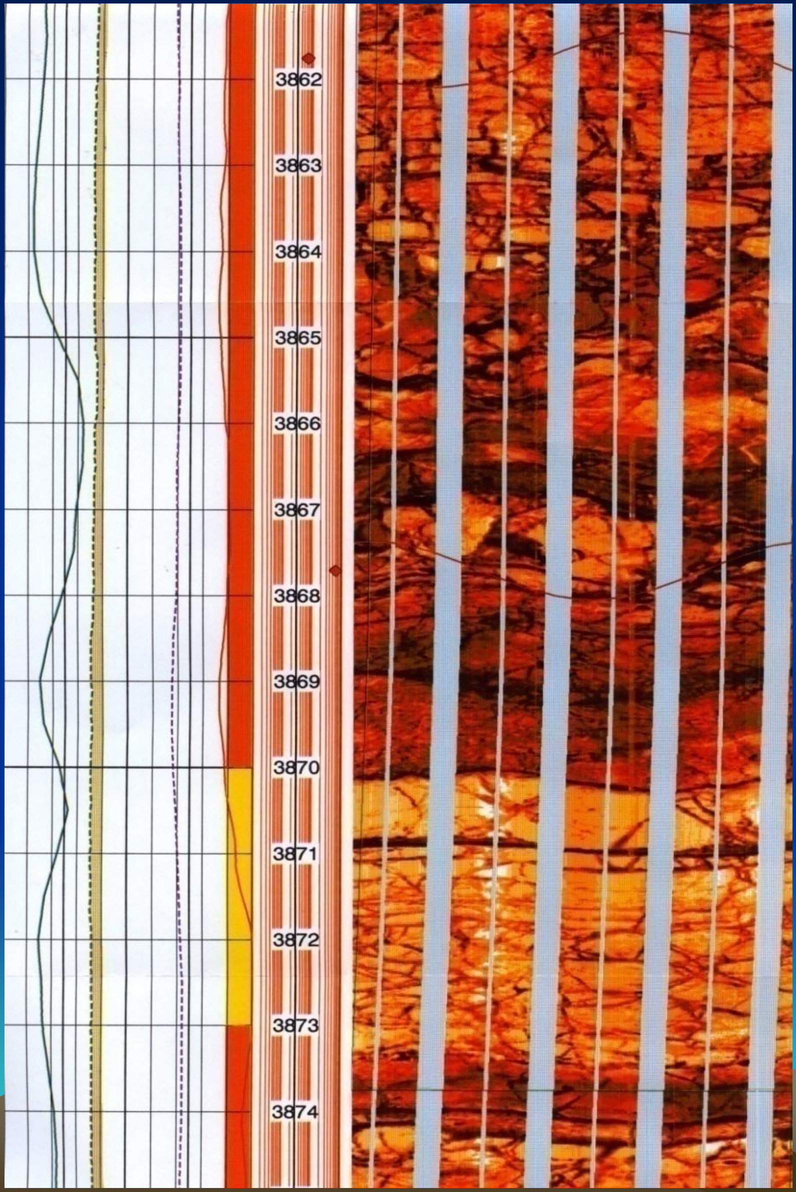
Schematic of cave processes



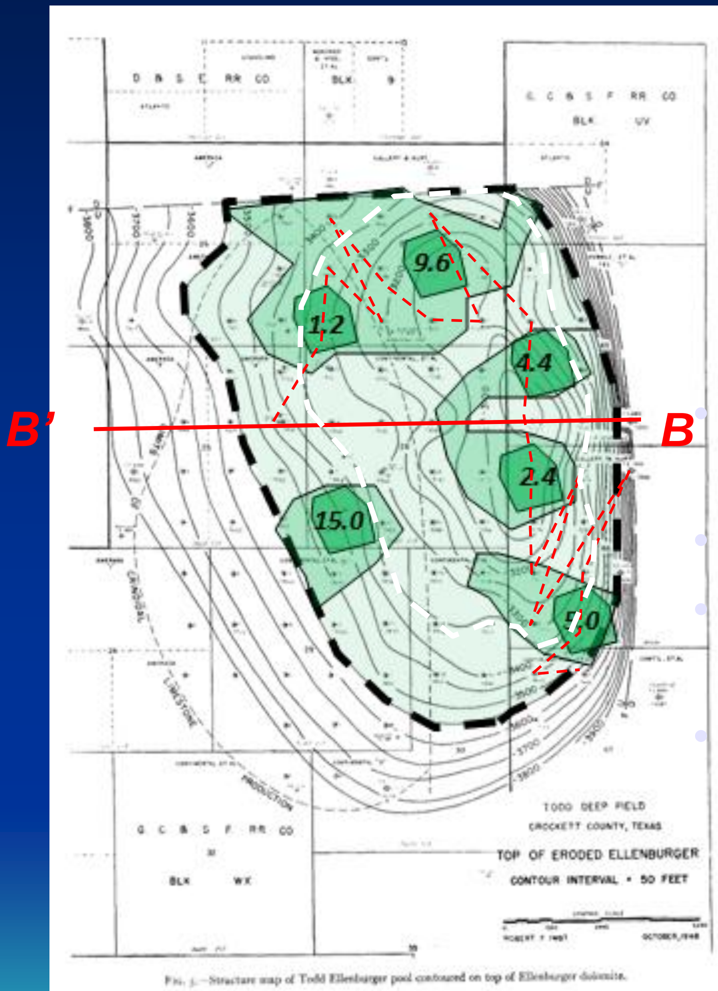
From Loucks, 1999

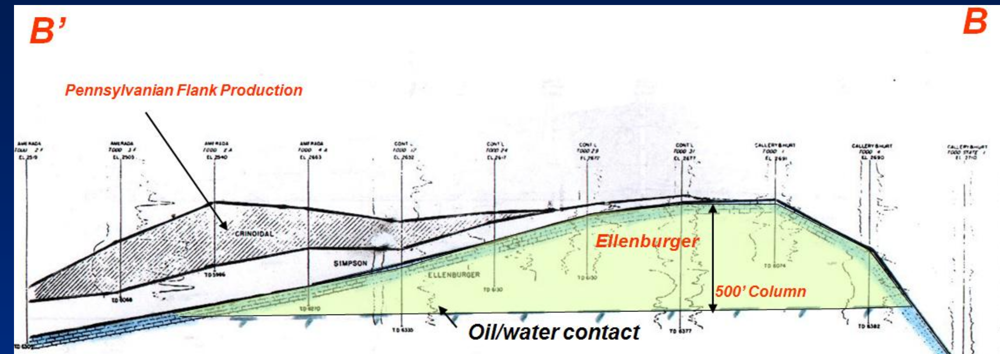
- CARTER FMI

Karst Reservoir in Magnolia Below 1 core west of Bandera Structures



Todd Field Cumulative Oil/well





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

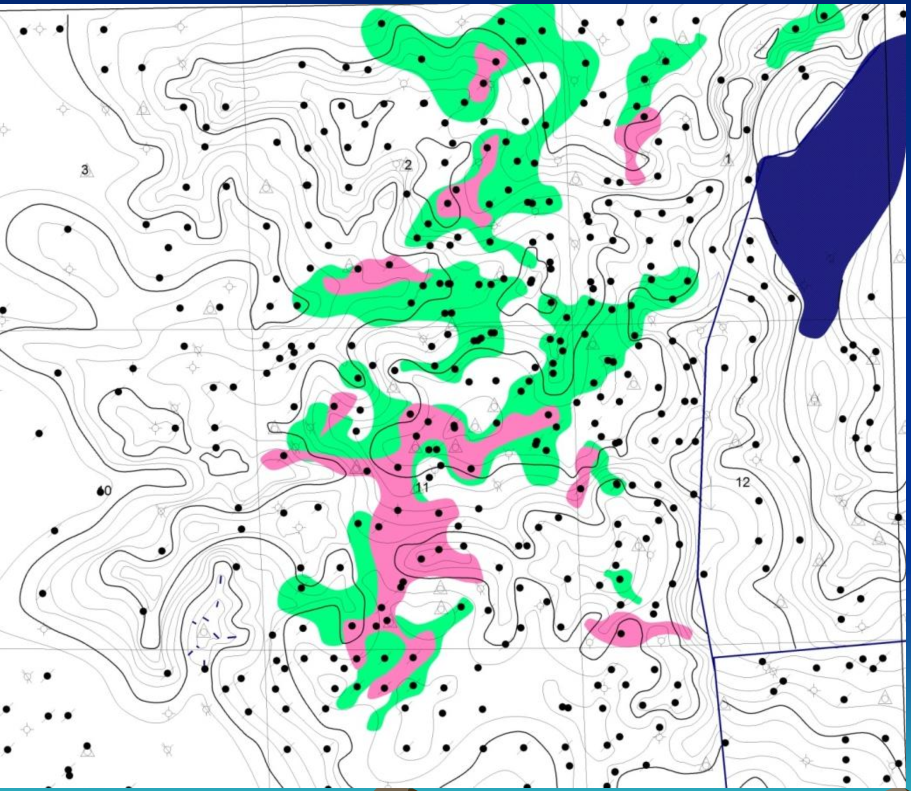
		Percentile	
1	1,597	4%	96%
2	2,929	7%	93%
3	4,281	11%	89%
4	35,753	14%	86%
5	52,632	18%	82%
6	58,207	21%	79%
7	65,505	25%	75%
8	70,204	29%	71%
9	70,878	32%	68%
10	74,511	36%	64%
11	84,305	39%	61%
12	92,428	43%	57%
13	120,701	46%	54%
14	140,312	50%	50%
15	142,113	54%	46%
16	216,440	57%	43%
17	245,972	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 (Imbt and McCollum, 1950)

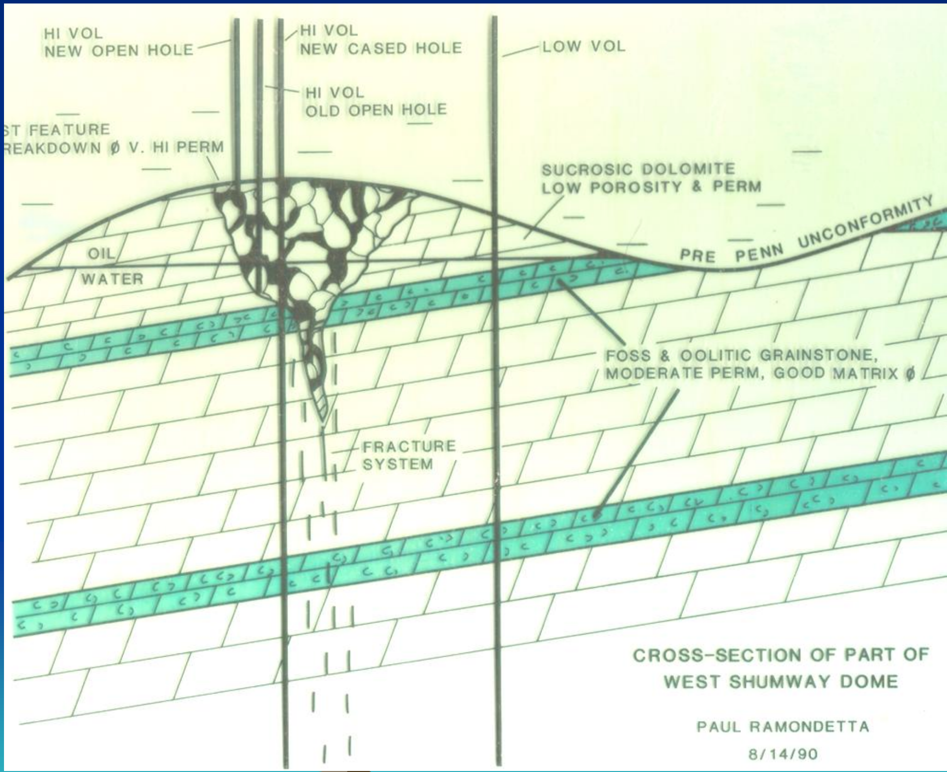
Disc. 1945, Cum 48.4 MMBO, 7.9 BCF, 50.0 MMBOE

Eldorado Field, Butler County Kansas

Map highlighting very high IP wells in red, high IP wells green



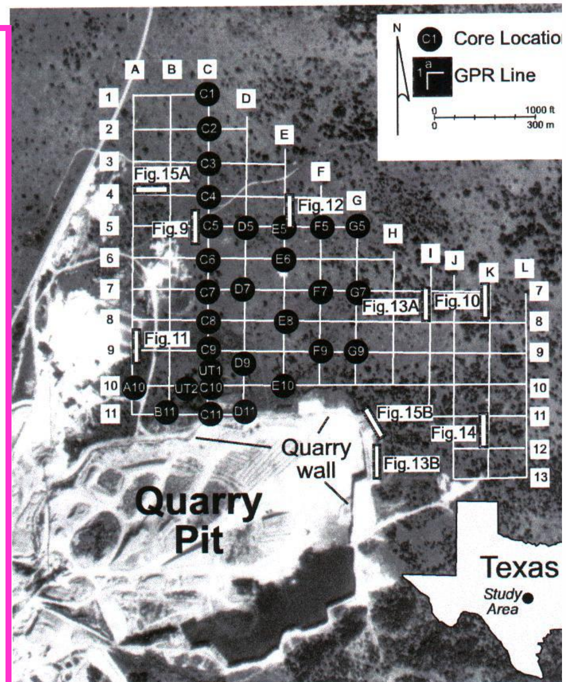
Profile showing enhanced Karstification along fracture zones

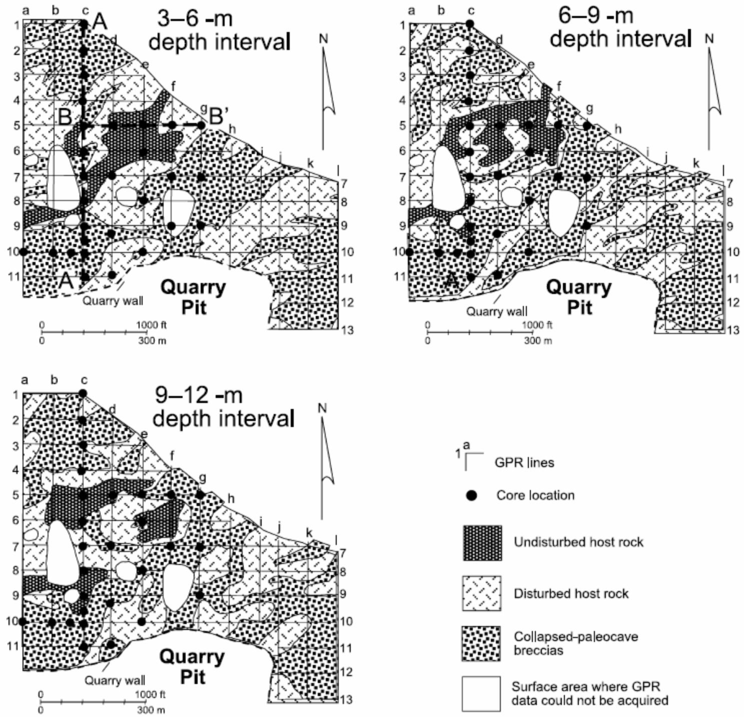


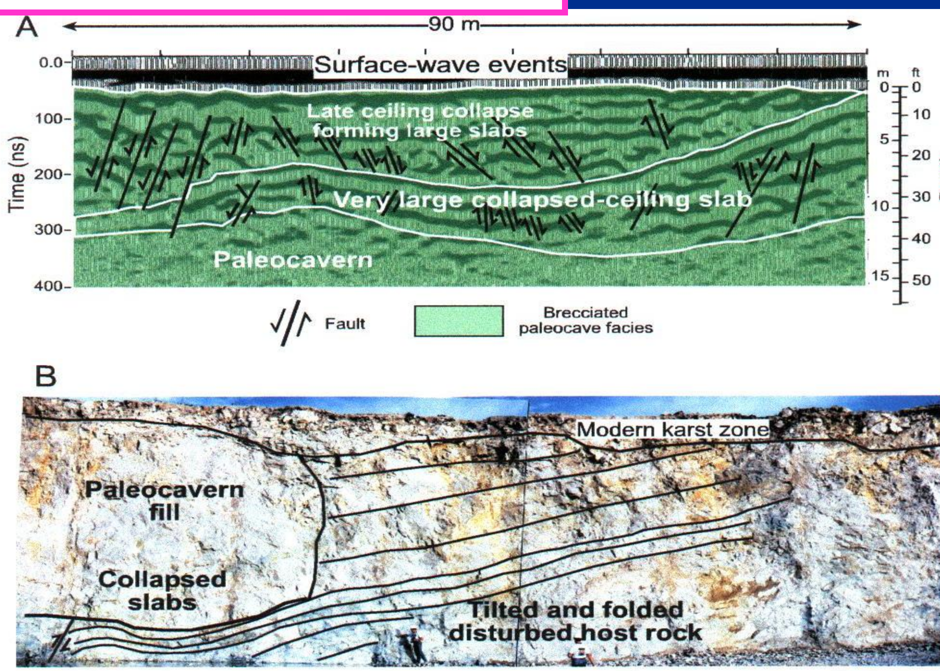
P.J. Ramondetta, 2012

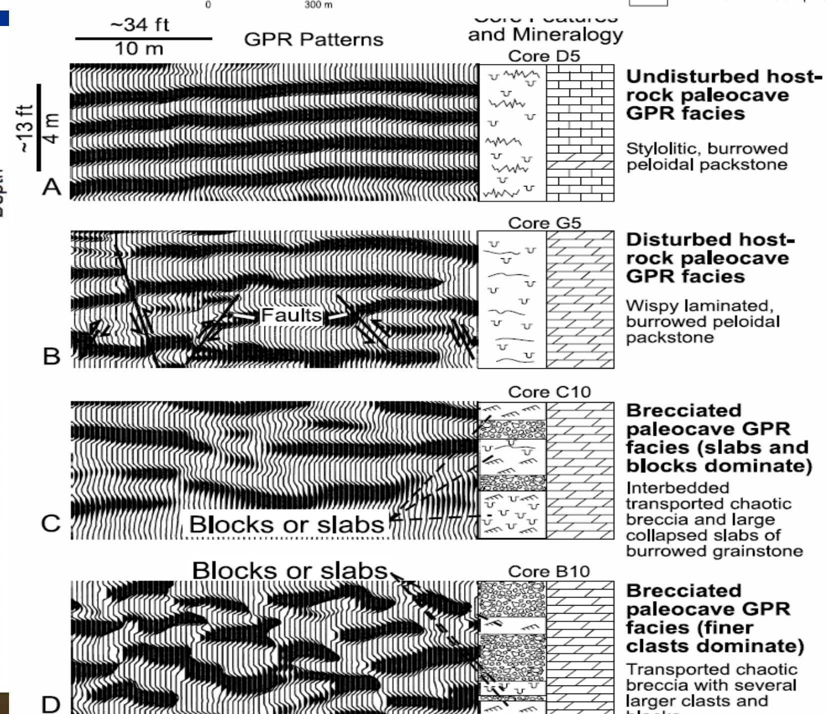
Three-dimensional architecture of a coalesced, collapsed-paleocave system in the Lower Ordovician Ellenburger Group, central Texas

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

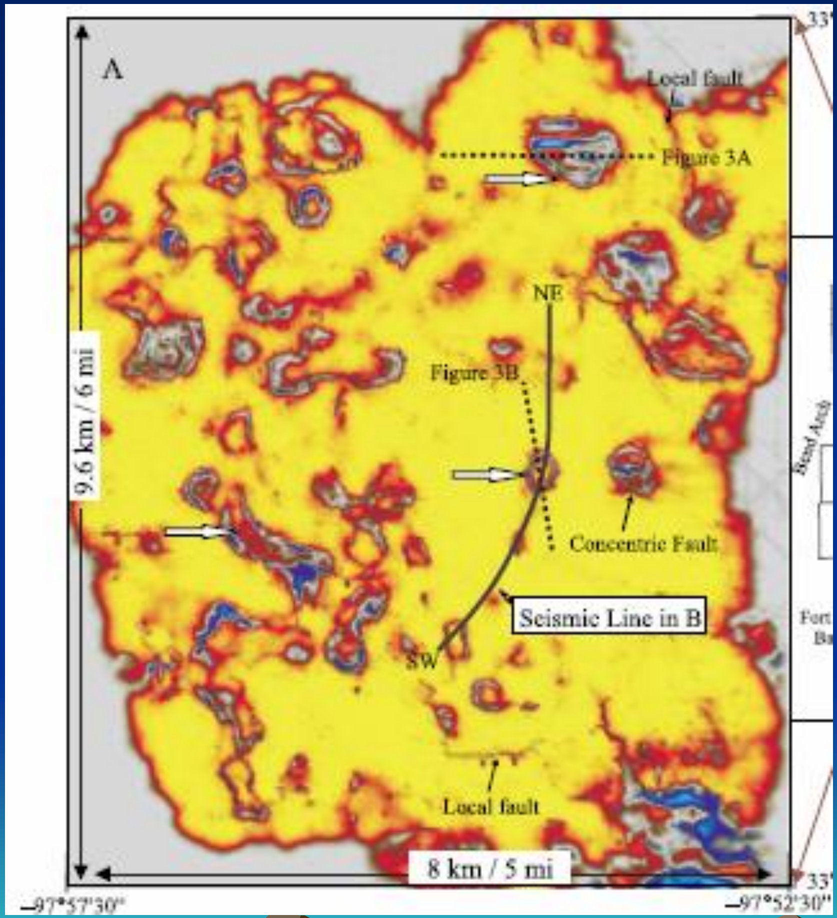


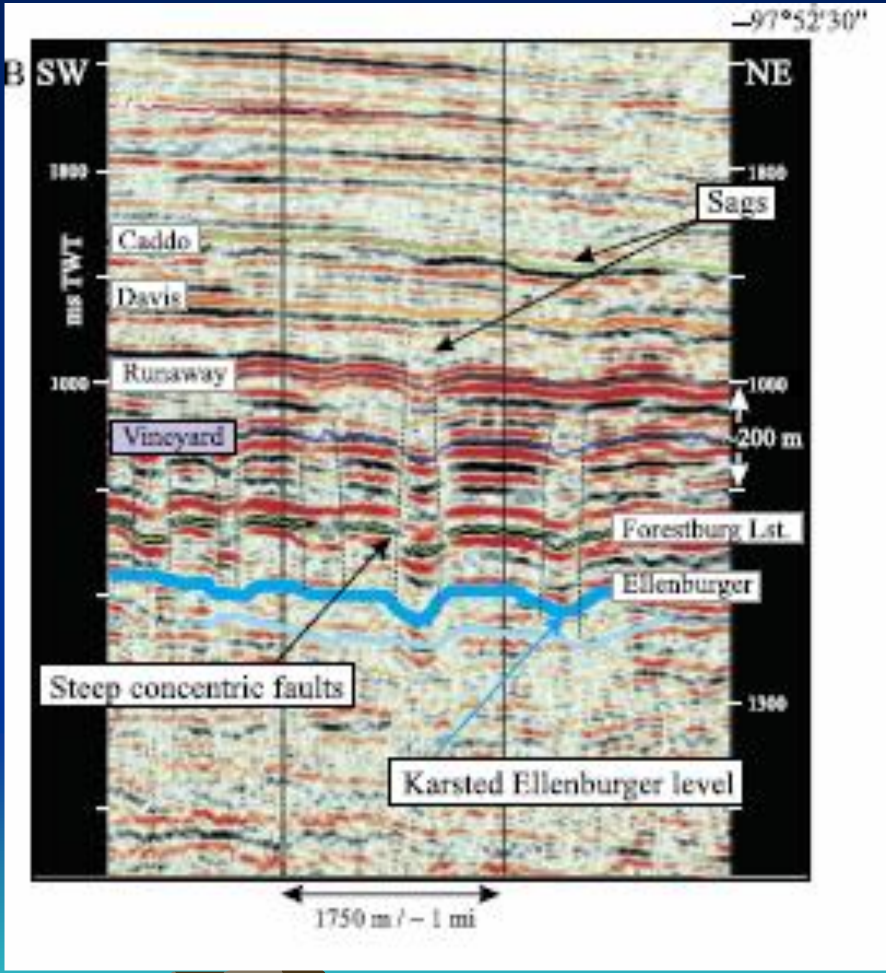






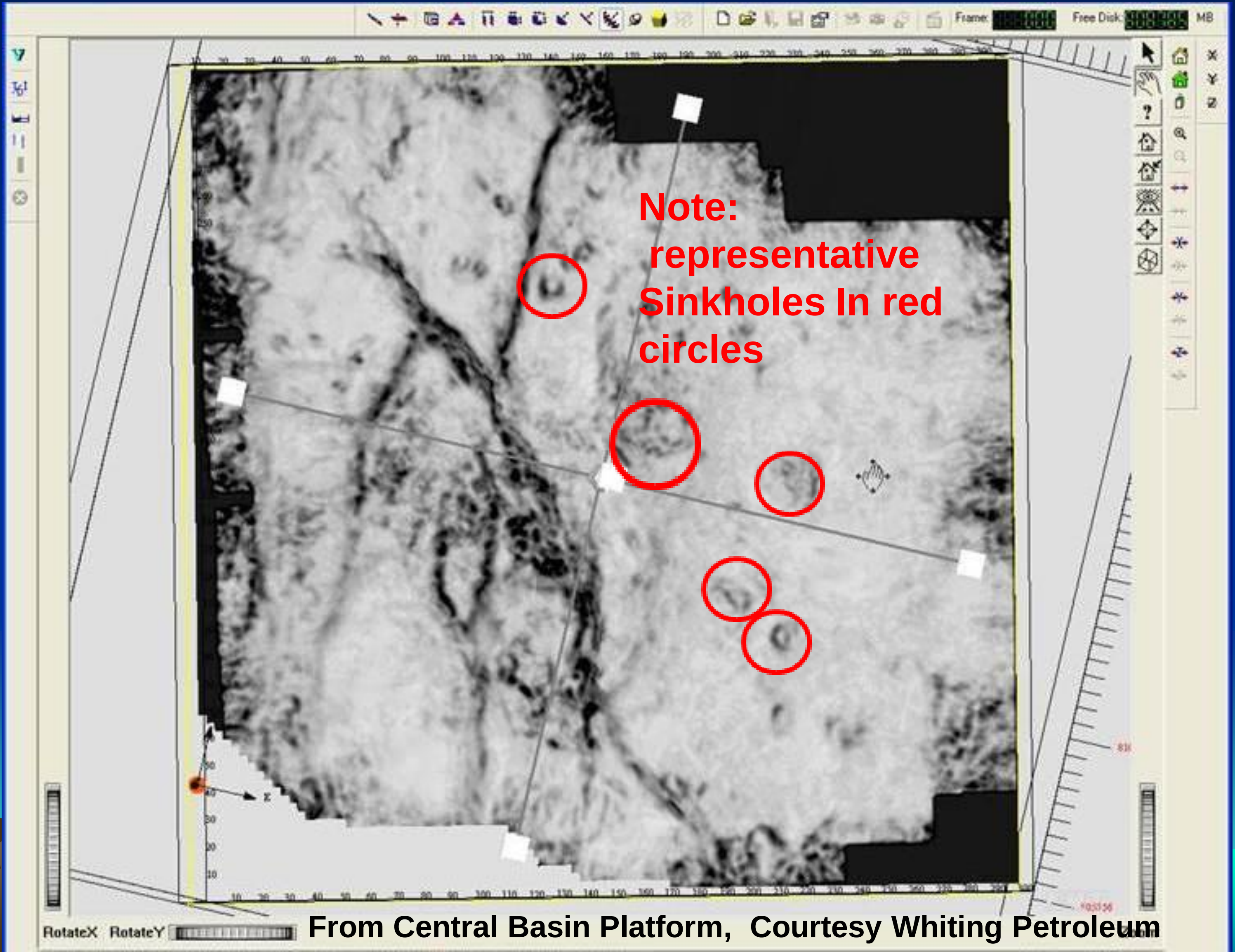
Examples of seismic Detection Karst in the Fort Worth Basin





From McDonnell 2007 (AAPG Bulletin)

3D Seismic Map View



From Central Basin Platform, Courtesy Whiting Petroleum

Exploration lessons, future strategies

- Focus on reservoirs and traps below the Sauk/Tippecanoe unconformity.

- Trap analysis of fault closures and horst blocks can help predict viable traps and hydrocarbon fluid levels.

- “Re-explore” around wells that made some oil or gas. They may have failed to intersect permeable rock while still connected to unproduced oil and gas.

- Identify areas with favorable fundamentals and hydrocarbon shows even if found within outlier basins (remember Captain Cook!).

- Directionally drill to intersect more fractures and karst-related fabrics.

- Use seismic and other techniques to assess variable reservoir.

Oil (in GACB) will continue to be found in unexpected places

Thanks to AAPG, GACB colleagues, Friends of the C/O, exploration partners, and inspirations like:
- James Lee Wilson
- Gerry Friedman
- Jed Clampett