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.

References Cited


Website

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

Data Courtesy IHS

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

- Approximately 3,650 fields
- GACB reservoirs 4.13 billion BO 21 TCF 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

Possible Underexplored Areas

10 to 100 MMBOE

C.A. Sternbach (2012), Petroleum Resources Chapter, AAPG GACB Memoir
GACB depositional facies and isopach

- Inner Detrital Belt UPDIP
- Shelf MID-DIP
- Outer Ramp or Aulacogen DOWNDIP
Regional Composite Section

Updip
Inner Detrital Belt Sandstones and Dolomites

Mid-Dip Shelf Dolomite Main Productive Setting

Downdip Aulacogen Limestone increases

Downdip
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
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
- Kansas
- South Canaan

Ohio Fields

Rome Formation and Conasauga Group contain an extra thick shale basin with source rock potential and 5-9 mmcf/gd 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

Arbuckle Structural Closure

Arbuckle Gas Production

Structure Section Wilburton Field

Fault Plane Map Wilburton Field Critical North Bounding Fault

Disc. 1987 365 BCF, 61 MMBOE

C.A. Sternbach, 1993
The “Goldilocks” Fault throws

Simpson Isopach

Non-Commercial Gas Show

Spiro to Simpson Isopach

Arbuckle Dry Holes

- Before Wilburton
- After Wilburton
Basins along the Ouachita Thrust Belt

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 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
Maben Field - A Comeback Story

• 1970: Texaco Sheeley #1 well completed as a low-volume "Knox-Ordovician" dry gas well 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

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

Gus Archie
Schematic of cave processes

From Loucks, 1999
• CARTER FMI

Karst Reservoir in Magnolia Below 1 core west of Bandera Structures
40 wells produce 50 MMBOE (avg 1.25 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
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

A
Surface-wave events
Late ceiling collapse forming large slabs
Very large collapsed-ceiling slab
Paleocavern

\[ \sqrt[\sqrt] \text{Fault} \]
Brecciated paleocave facies

B
Modern karst zone
Collapsed slabs
Tilted and folded disturbed host rock
Paleocavern fill

C
Blocks or slabs

D
Brecciated paleocave facies (slabs and blocks dominate)
Interbedded transported chaotic breccia and large collapsed slabs of burrowed grainstone

GPR Patterns
Core D5
Undisturbed host-rock paleocave GPR facies
Stylolitic, burrowed peloidal packstone

Disturbed host-rock paleocave GPR facies
Wisy laminated, burrowed peloidal packstone

Bracciated paleocave GPR facies (finer clasts dominate)
Transported chaotic breccia with several larger clasts and blocks
Examples of seismic Detection Karst in the Fort Worth Basin

From McDonnell 2007 (AAPG Bulletin)
3D Seismic Map View

Note: representative Sinkholes In red circles
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

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