Responding to New Discoveries: Workflow and Strategies for Conquering the "Data Gap" and Overcoming "Stuck-In-Rut Thinking"*

Susan Smith Nash[1]

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[1]Director, Education and Professional Development, AAPG, Tulsa OK (snash@aapg.org)

Abstract

How to gather and analyze relevant data quickly and effectively when a new discovery has been announced is the goal of this presentation. A company must work quickly to take advantage of opportunities with respect to acreage position decisions and drilling program modifications. At the same time, it is important to respond to the main challenges of "Data Gap" and "Stuck-In-Rut Thinking."

In doing so, it proposes a systematic approach to prioritizing information and also for challenging / interrogating the existing assumptions about the nature of the reservoir, especially when discoveries open up new zones, or extend the identified productive limits of existing ones. Often, decisions must be made quickly and it becomes very important to be able to evaluate the plays, either for acquiring or divesting acreage, or for developing or modifying drilling programs. Generally, there is a "triggering event" such as a discovery or the results of a seismic or geochemical study, which makes it important to reexamine the information and also to question the prevailing views and/or assumptions that have gone into the development of a model.

Developing a list of databases, core repositories, sample repositories, log libraries, journal articles, consortia white papers, and other sources of information is an important step. It is also important to revisit the information and reevaluate it, using new technologies (in the case of physical information) and to reprocess data sets (in the case of databases, etc.), using new techniques of data mining, including multivariate analysis.

Using the Springer Shale in the MidContinent as an example, the presentation develops a workflow for evaluating the resource. It starts with two different competing and complementary approaches. The first is the Petroleum System Approach, which looks at thermal history, depositional history, tectonic history, etc. The other is a Structural Intensity / Complexity Approach, which reviews the structural history, especially in very active and complex areas, to look at fracture networks, fracture types, faults, and "maximum crushing." The goals would be to identify super-sweet spots where there is a convergence of differently sourced hydrocarbons and to understand the migration and trapping pathways that result in preferential enrichment.

An information gathering stage is then developed, and a list of sources is developed. As the list is developed, the sources are evaluated. A list of tools, techniques, and analytical approaches for processing and evaluating the information is also developed.

- Commercial, Governmental, Societal Databases (production, pressure, location and history, etc.)
- Well logs (commercial and state / governmental)
- Core repositories
- Sample / cuttings repositories
- Strip logs / petrophysics repositories
- Master's theses / Ph.D. dissertations
- White papers by Consortia
- Professional association publications (refereed journals / monographs / maps)
- Government documents, maps, laboratory studies
- Private company and NOC information
- Seismic (group shoots, repositories, consortia, data rooms)
- A multi-disciplinary asset team is assembled in order to develop an approach to prioritizing the data, and then the team develops a list of "Key Questions" that they use to structure their approach.

Conclusions

- The Springer Shale is a great case study for how to systematically evaluate a new play or extension
- Develop workflow and keep it basin-centered
- Identify and evaluate sources of information
- Develop teams to evaluate the resource / asset
- Interrogate assumptions / "conventional wisdom"
- Reprocess old data where possible
- New tests of physical information

Selected References

Andrews, R.D., et al., 2001, Springer gas play in western Oklahoma: Oklahoma Geological Survey SP 2001, 123p.

Boyd, D.T., 2008, Stratigraphic guide to Oklahoma oil and gas reservoirs: Oklahoma Geological Survey SP 2008-1, 1 data sheet.

Higley, D.K., 2011, Undiscovered petroleum resources for the Woodford Shale and Thirteen Finger Limestone–Atoka Shale assessment units, Anadarko Basin: U.S. Geological Survey Open File Report 2011–1242, 3 sheets (website accessed December 7, 2014), (http://pubs.usgs.gov/of/2011/1242).

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Responding to New Discoveries: Workflow and Strategies for Conquering the “Data Gap” and Overcoming “Stuck In Rut Thinking”

Susan Smith Nash, Ph.D.
AAPG

Prepared for the AAPG Unconventionals Update GTW, November 4-5, Austin, Texas

Premise

- Announcement – Springer shale discoveries!
- ***Happiness! I have acreage that has Springer shale…***
- New potential productive pay zone (shale) for my very own "stacked pay" pads
- Self-sourced plus migrated HCs (Woodford origin)
- Part of a great migration pathway from "kitchen"
- Fracture zones (and high fracability)

Opportunity & Challenge

Must work quickly to take advantage of opportunities

- Acreage position decisions
- Drilling program modifications
- Technical issues
- Capital requirements

Main challenges:

  - ***Data Gap***
  - ***"Stuck In Rut" Thinking***

Triggering Event : Springer Shale Press Releases

- *Continental's exploration team does it again – the Company is announcing a new oil discovery, the Springer Shale, located in the heart of the SCOOP.*
- The original discovery well and two subsequent confirmation wells have cumulative production of approximately 640 MBoe in the 20 months following the original discovery well. Continental currently has 11 producing wells in the oil fairway of the Springer Shale with an average 24-hour initial production (IP) rate of 1,140 Boe per day and an average 30-day IP of 700 Boe per day.
- Initial Springer Shale oil fairway production data suggests an EUR of 940 MBoe, with 67% oil and 17% natural gas liquids, for an average 4,500 foot lateral length.

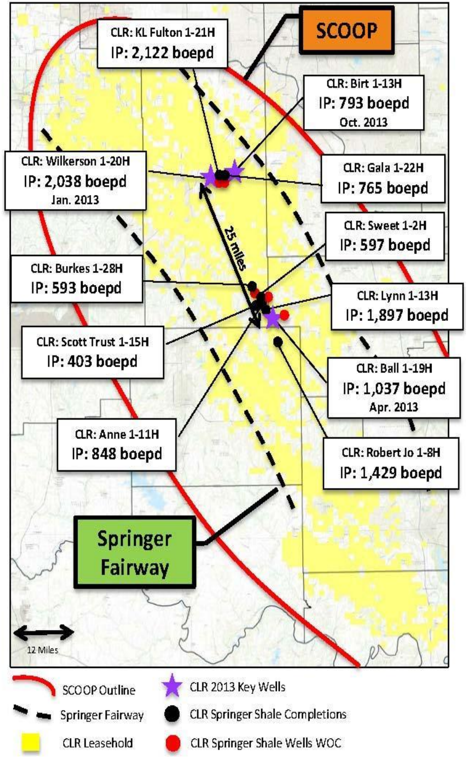
Now, what do I do?

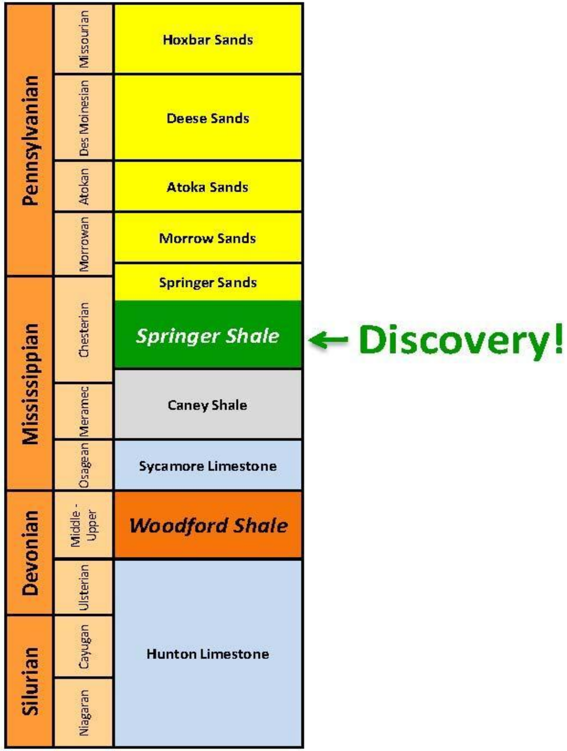
- Gather Data
- Formulate Key Questions
- Identify “Make or Break” Reservoir Quality Attributes / Criteria
- Determine Workflows for Implementation
- Team-Building: Who do I need?

Example:
Continental Resources and the Springer Shale

- “Fairway” ideal depth, pressure, stacked pay with Woodford (and others)
- 2,000 bopd
- 12,500 ft depth
- 447 MMBoe unrisked
- 127 net MMBoe fairway
- 320 net MMBoe, 1.9 Tcfe in gas / condensate fairways

Graphics: Continental Resources





Petroleum Systems Approach

Basin Model

What are the existing opinions / models that explain the geological history and petroleum generation?

Heat flow maps / Pressure regimes

Depositional Environment

Key work in the field

Underlying assumptions

Diagenetic Alteration

Fracture Network Formation

Springer Shale Play

- Fingerprint the hydrocarbons (oil, gas, condensate)
- Extreme depositional environment modeling
- Migration pathways (deposition, tilting, geomechanics – need tectonic activity + heat flow)
- Physical & chemical accelerants to migration
- Sweet spots – transcending the stratigraphic trap concepts (reprocess 3D seismic)
- Whipstocked laterals (post-decline) – particularly important with Springer – go in and offset / whipstock to drain discrete lenticular units

Springer Shale Play Workflow

Petroleum System Approach:

- Thermal history (self sourcing?)
- Depositional history
- Tectonics

Structural Intensity / Complexity Approach:

- Fracture networks / fracture typing
- Faulting
- Stress regimes & "Maximum Crushing"
- Pore pressure (macro and nano)

Goals:

- Identify super sweet spots (convergence of Woodford & Springer oil?)
- Migration and trapping pathways / preferential enrichment
- Fracture networks and types
- Pressure regime / stresses
- Maximum tectonic activity (faults / folds / "maximum crushing" in situ

Springer Shale Information Gathering

Data

Data:

Well Data:

DrillingInfo

I H S

Core and Sample Data:

Location of Data // Libraries of the “texts” everyone has read

USGS / Denver

OU / Core – Sample library

Springer Shale Information Gathering

Tools, Techniques, Technologies

Tools / Techniques / Approaches needed (from basic to more complex)

- Geochemistry (gas / oil fingerprinting; kerogen typing)
- 3D seismic
- XRD / XRF
- Cores (from pilots, etc.)
- Pressure information (geomechanics)
- Pressure history (production?)
- Thermal history (USGS studies?)

Developing a List of Sources of Data

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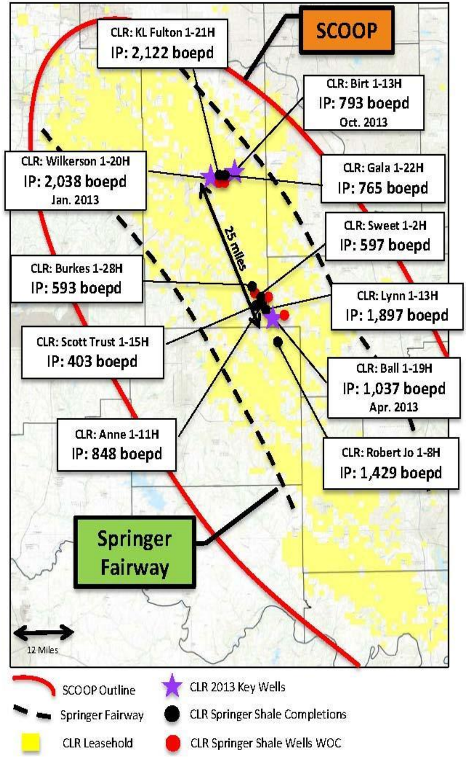
Continental Resources: Springer Shale

- Discovery well: Wilkerson 1-20H (Jan 2013)
- Delineation well: Ball 1-19H (April 2013)
- Confirmation well: Birt 1-13H (October 2013)
- 2014: continued confirmations

- Questions:
  - Where are confirmations?
  - Continuity / conductivity of resources?
  - Pressure Regime – what are the reservoir pressures?

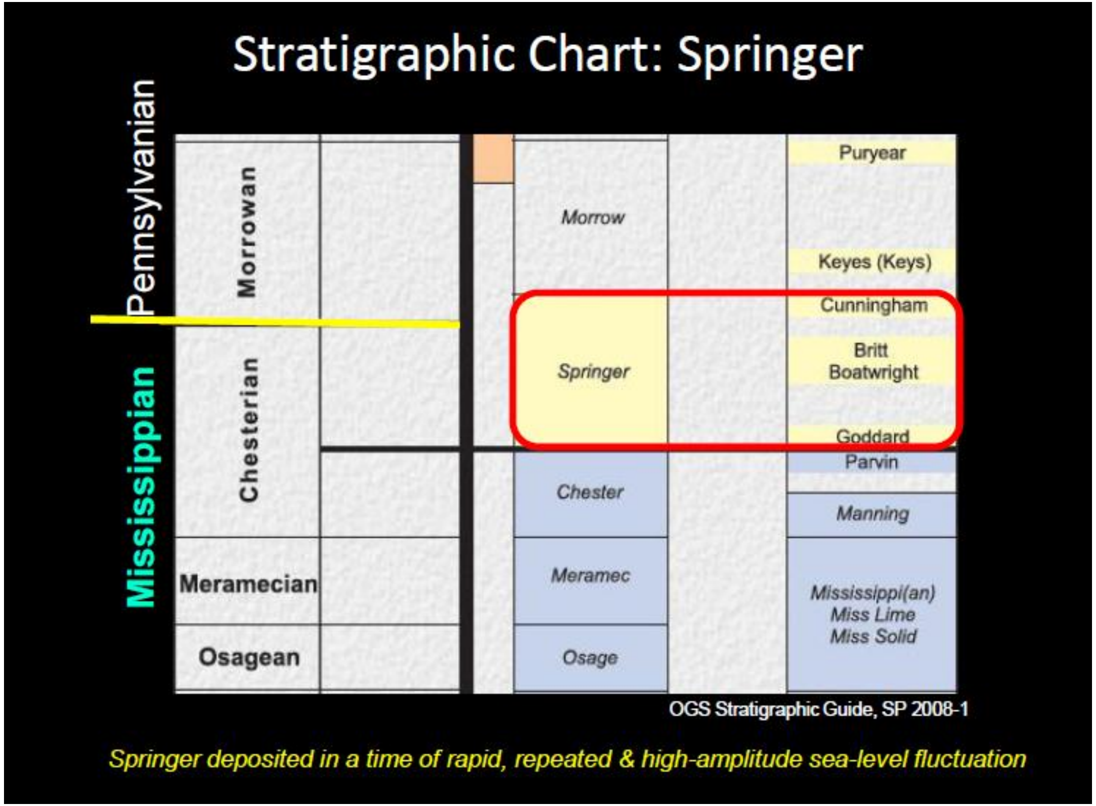


Graphics: Continental Resources

Springer Formation

- Mississippian-Pennsylvanian boundary
- Highly heterogeneous
- Pressure variations

Graphics: Continental Resources



Key Questions - 1

- Source & Migration
  – Truly self-sourced? Or, combined with Woodford?
    - TOC for Springer tends to be somewhat low (according to early work)
  – ID / fingerprint the oil and gas?
    - Where the Woodford & the Springer HC's are trapped together (areas of relative accessible porosity & permeability) = super sweet spots
  – Provenance Matters (migration along faults, fracture networks, along unconformable surfaces)
    - How are the migration pathways mapped by the USGS relevant to the Springer?
    - Can we propose something completely different?

Historical Springer Production

Springer sand:

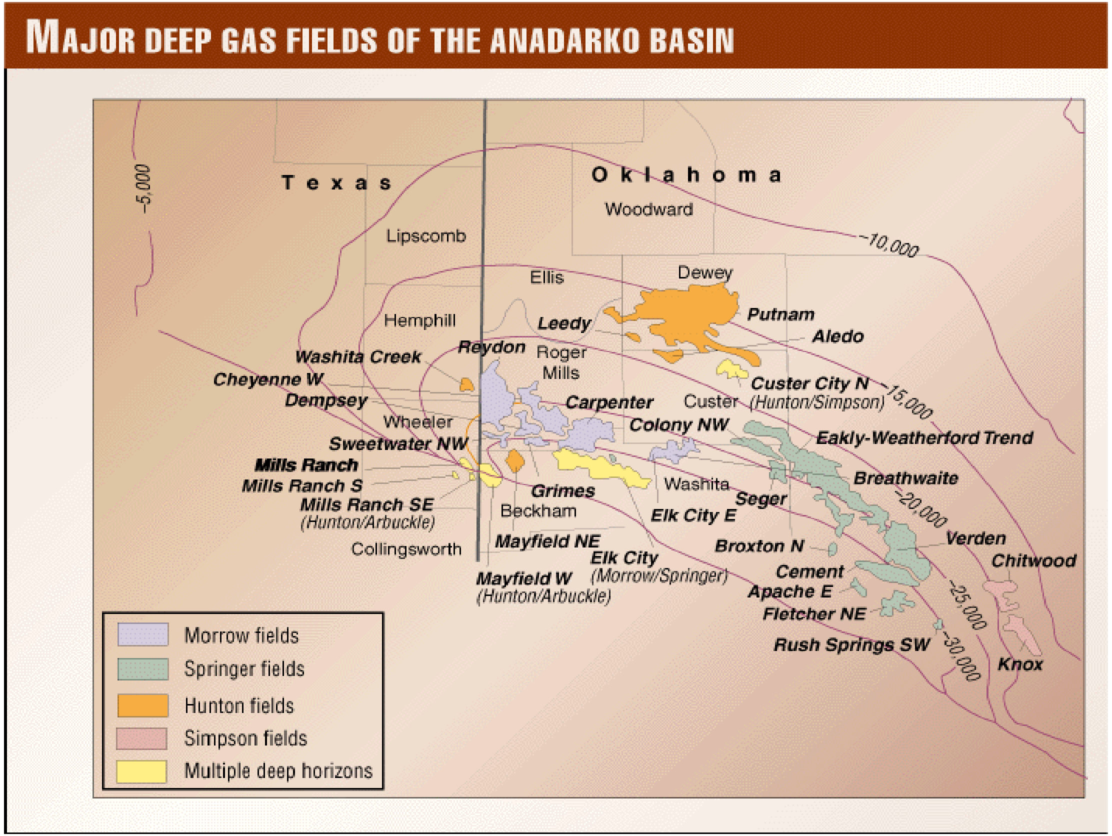
  but now we have Springer shale

Stacked pay potential (in multiple Springer zones)

Key issues:

- *identify the lenses / sweet spots*
- *reservoir optimization (drilling & completion techniques)*

Graphics: Continental Resources



Mississippian-Pennsylvanian Boundary

- Springer units
- Unconformity
- Implications & key questions
  - How are the deposits at the unconformity different than the ones lower in the section?
  - Intercalated siltstones?
  - Any unconformity deposits (like Misener)? If so, how / what?

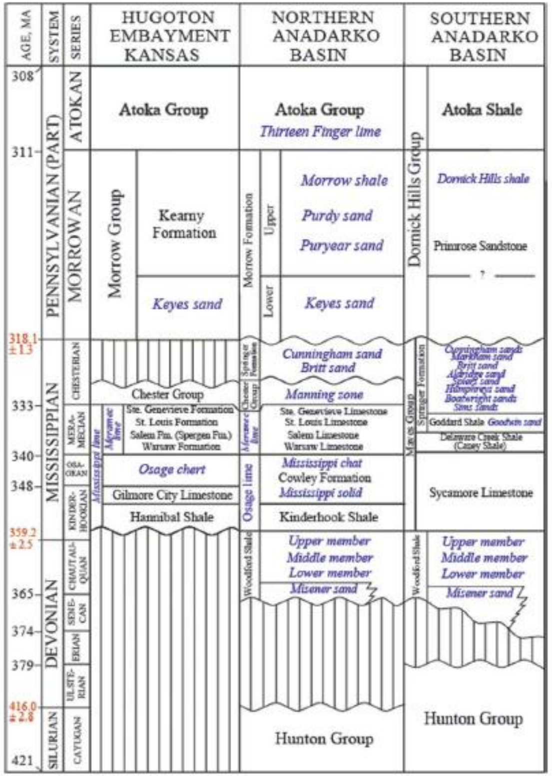


Figure 2. Generalized stratigraphic columns of the Mississippian and portions of the Silurian through Pennsylvanian sections. Italics (blue text) and lower case names indicate informal status. Modified from Bebout et al. (1993) and Henry and Hester (1995). Ages in millions of years from Haq and Van Eysinga (1998), and Gradstein et al., (2004) (red text). Fm., formation; Mbr., Member; Ste., Sainte; St., Saint.

Key Questions -- 2

- What is the nature of the Mississippian / Pennsylvanian boundary?
  – Unconformable / erosional surface
  – Implications:
    - Fluid movement long the boundary, when tilted, and when there are porous lenses
    - Diagenesis – implications for brittleness & also grains
    - Pockets / lenses of finer or courser-grained deposits

Initial Strategies

Fluid flow mapping

Depositional environment:

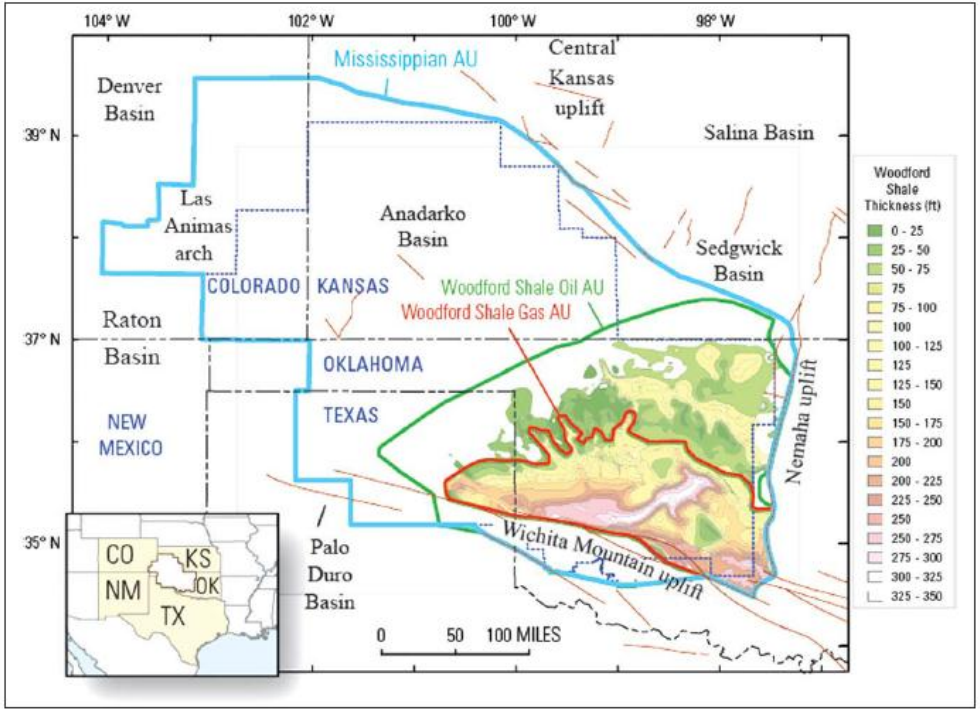
instead of using sequence stratigraphy for stratigraphic traps, look for the migration pathways

How to identify the pathways?

- Geochemical fingerprinting
- Image logs
- Fracture networks / heat flow

- Graphics: USGS

4D PETROLEUM SYSTEM MODEL OF THE MISSISSIPPIAN SYSTEM IN THE ANADARKO BASIN PROVINCE, OKLAHOMA, KANSAS, TEXAS, AND COLORADO



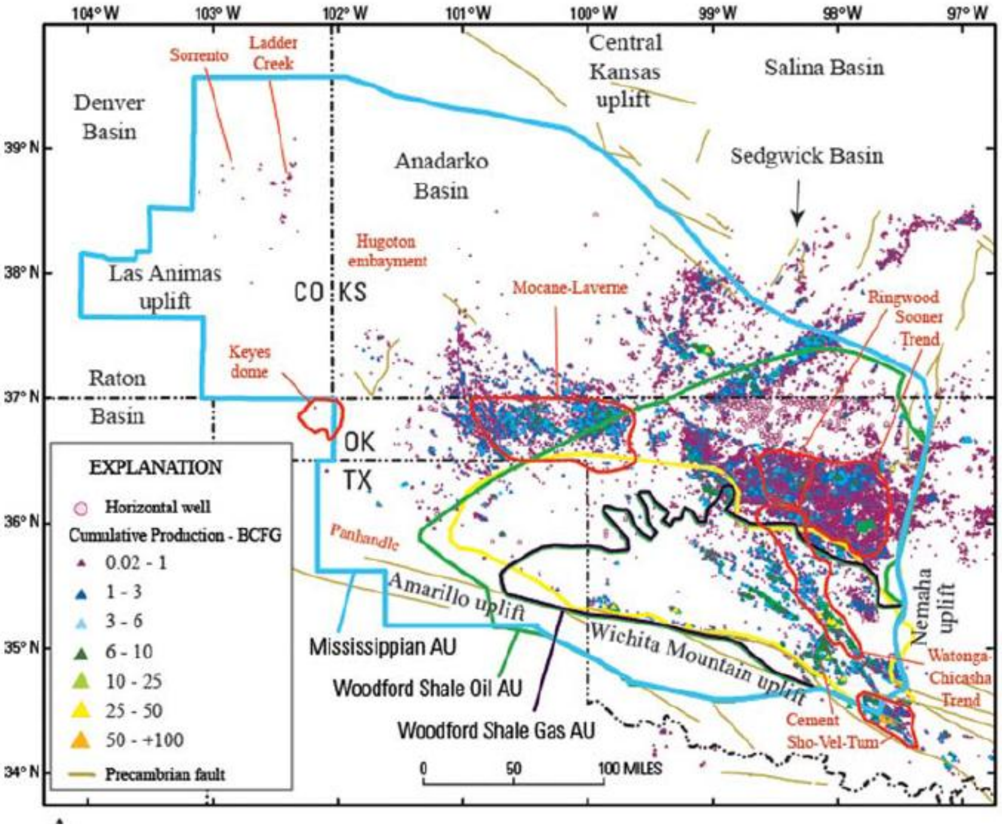
Production

USGS study of Springer & Woodford production(Higley etal)

Questions:

- Reservoir quality of the Springer sands
- The nature of the Springer "shale" – which units is it producing from?

- Graphics: USGS



Thickness

USGS map depicting the thickness of the Mississippian (Where Woodford would go (Woodford Devonian & early Mississippian)

Graphics: USGS

Debra K. Higley

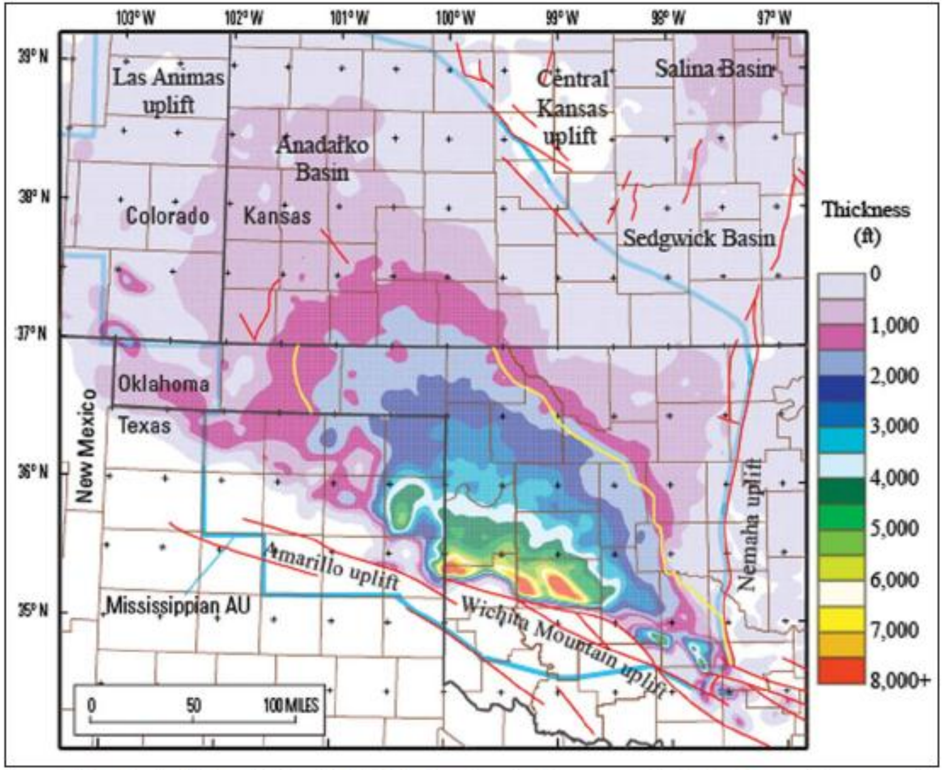


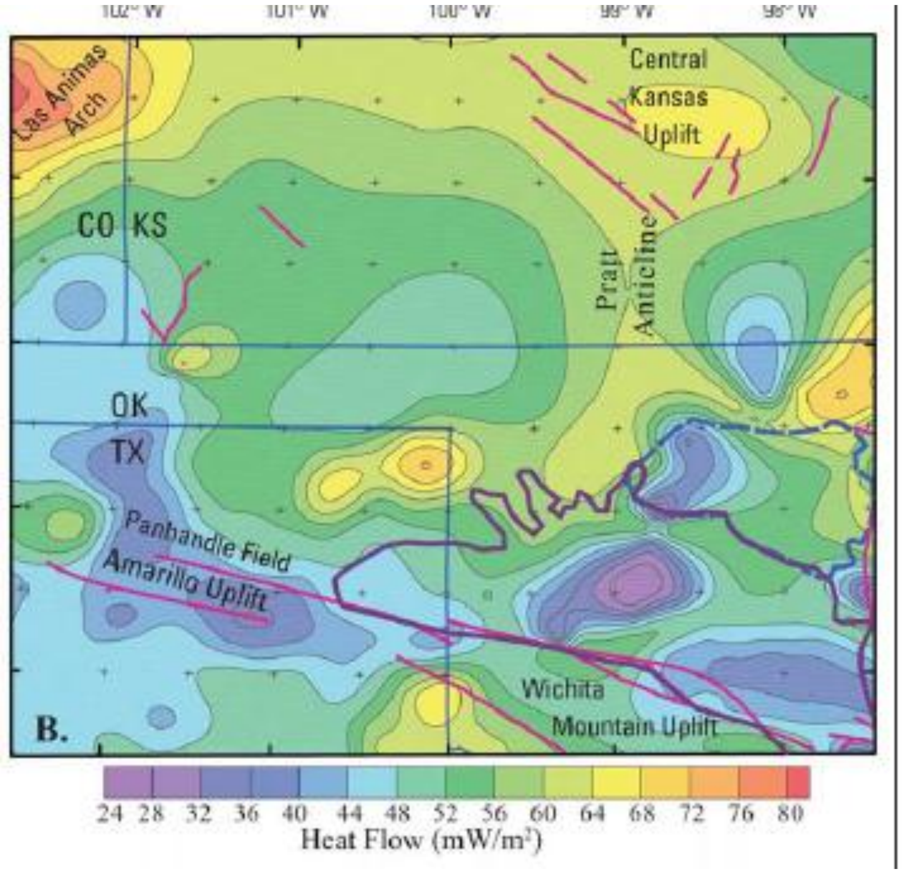
Figure 4. Maps showing thickness (in feet) of the Mississippian section (Fig. 2), as represented by the Springer model layer across the Anadarko Basin Province. The Oklahoma portion of the basin incorporates faults and elevations on the top of the Springer Formation from Andrews (2001, Plate 5); yellow lines delineate the extent of the Springer within the Oklahoma portion of the basin. Eastern extent of Chesterian strata in the Oklahoma portion of the basin is approximated by the 1,500-ft elevation contour. Also evaluated were formation data derived from more than 220 well logs located north of the Wichita Mountain and Amarillo Uplifts, as well as modified formation elevations from IHS Energy (2009, 2010a). Displayed Precambrian fault lines (red) are from Adler et al. (1971).

Heat Flow

Why does it matter?

- Maturation
- Diagenesis
- Pressure
- Conduits & migration pathways
- Determining faulting and fracture networks if heated fluid present

Graphics: USGS



Migration Pathways

Flow paths and accumulations

Springer (with Woodford

Yellow line: oil/gas generation boundary

4D Petroleum System Model of the Mississippian System in the Anadarko Basin Province, Oklahoma, Kansas, Texas, and Colorado

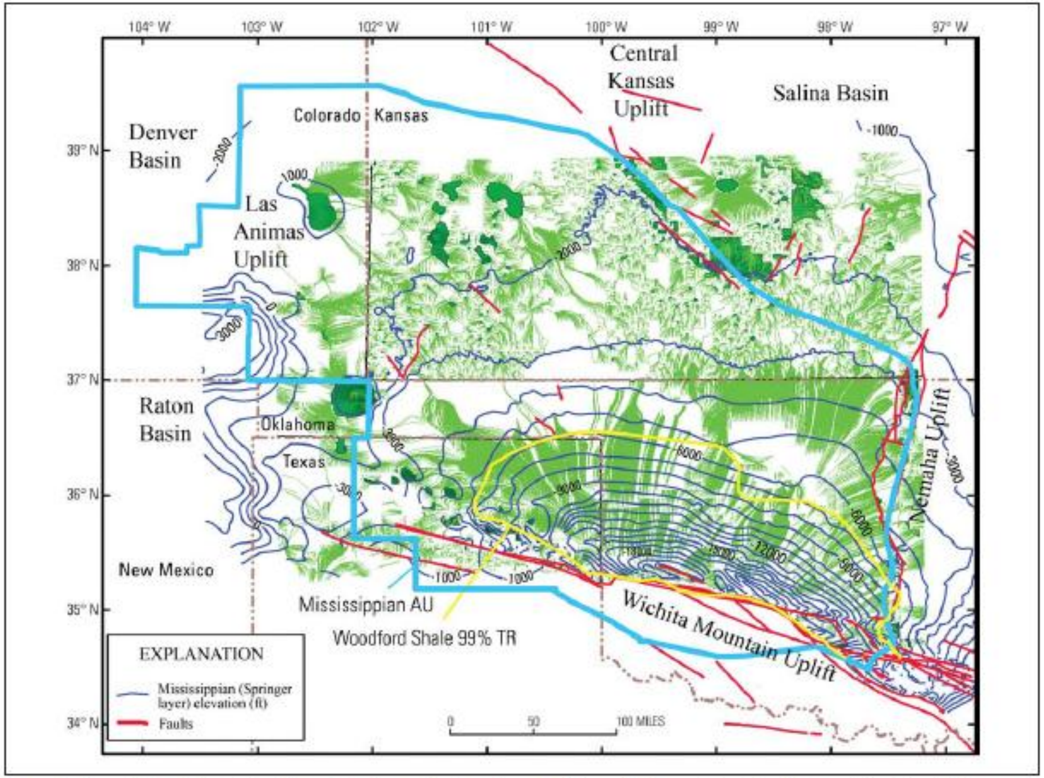
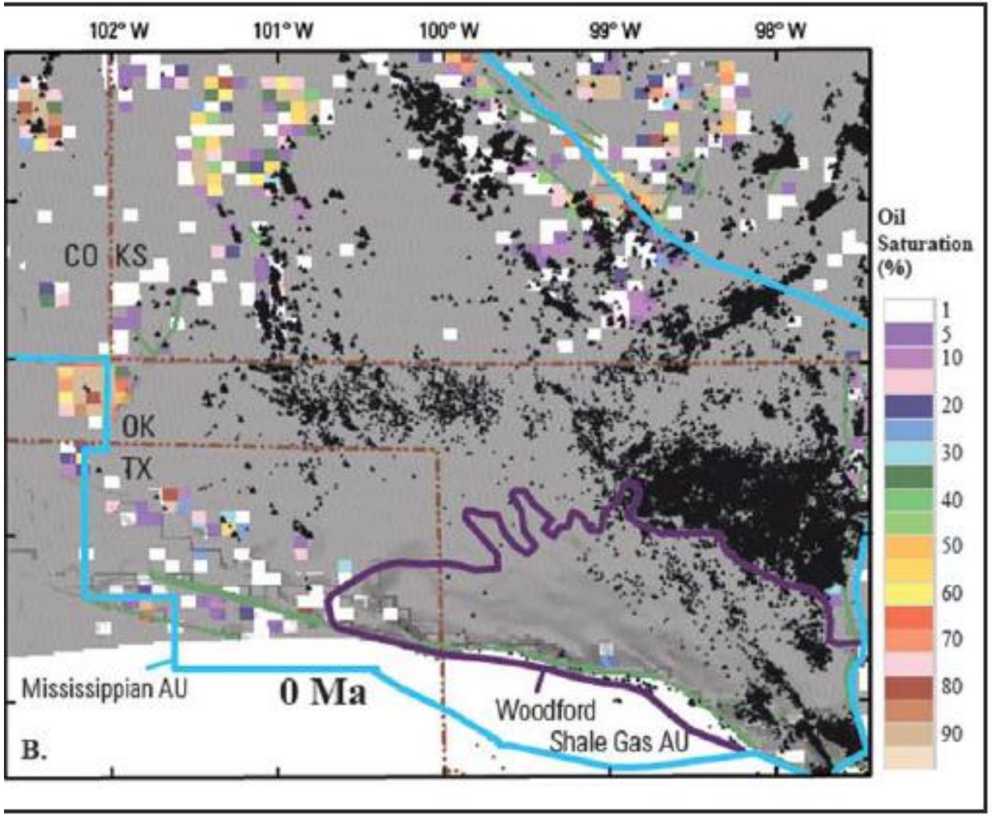


Figure 9. Present-day oil-migration flow paths (green lines) and accumulations (dark green) on the Springer (Mississippian) layer and sourced from the Woodford layer. Contours are elevations relative to sea level on top of the Springer layer based on Andrews (2001, Plate 5), IHS Energy (2009, 2010a), and evaluation of well logs from more than 200 wells. The yellow line is the oil/gas generation boundary of the Woodford Shale based on the 99% transformation ratio (TR). This line approximates the southern boundaries of the Mocane-Lavern Field and the Sooner Trend areas (Fig. 3A). Faults (red) are modified from Adler et al. (1971) and Andrews (2001, Plate 5). Contour interval is 1000 ft.

Oil Saturation

Woodford Shale Gas / Mississippian (Higley, USGS)



Key Questions - 3

- Springer stress regimes and pore pressure
- Migration / mechanical flow
- Springer Cation Exchange Capacity – how "sticky" is the shale?
- Chemical flow / adsorption factors (salinity / CEC makes it easier for the generated or migrating oil to travel

Conclusions

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- New tests of physical information