The Booch Sandstones (McAlester Formation, Krebs Group), Arkoma Basin, Oklahoma – Outcrops to Well Logs: An Introduction to Oklahoma Fluvial Reservoirs*

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The contents of this article are essentially those posted on the Oklahoma Geological Survey website (http://www.ogs.ou.edu/homepage.php), and related publications (shown below under "References") are available from OGS (http://www.ogs.ou.edu/pubs.php).

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Abstract

The oil- and gas-producing Booch sandstones are in the lower three-fourths of the Desmoinesian McAlester Formation. The Booch interval thickens from the Cherokee Platform south into the Arkoma Basin, where it consists of eight coarsening-upward parasequences bounded by flooding surfaces. The McAlester Formation probably was deposited in ~100,000 years, suggesting that each parasequence represents a fifth-order glacioeustatic cycle.

From base to top, each parasequence consists of a progradational stacking of distal-marine, prodelta, delta-front, deltaplain, and incised-valley deposits, although the upper deposits, and in some case the lower deposits, may be absent. Isopach maps and well-log character suggest that the overall distribution of the Booch sands was controlled by fluvial processes.

The depositional environments of the sandstone reservoirs at the top of most Booch parasequences include distributary-mouth bars, distributary channels, crevasses splays, and/or multi-story channel-fills. Sedimentary structures such as bidirectional cross-lamination, flaser bedding, lenticular bedding, and small-scale cyclicity observed in outcrop are evidence that the Booch deltas were tidally influenced. All the Booch sandstones are associated with deltas or the incised valleys that fed them. The absence of shoreline sandstones between the deltas suggests that wave energy was negligible.

The best Booch reservoirs were fluvially deposited as either incised-valley fill or distributary-channel sands. Extensive winnowing of clays from tidally reworked sands enabled secondary silica, the dominant Booch cementing agent, to nucleate. As a result, the reworked sandstones typically are poorer reservoirs than the coarser channel-fill sandstones in which the grains are coated with clays.

Most of Oklahoma's oil reservoirs are FDD (fluvial-dominated deltaic) and because most FDD reservoirs are highly complex, they are difficult to effectively drain. Boyd (2008) estimates that only 10-15% of the original oil in-place in a "typical" FDD channel-fill reservoir has been produced, in part because of poor production practices during the state's "heyday." A better understanding of Oklahoma's fluvial reservoirs in combination with new completion techniques should sustain the state's oil industry for years to come

References

Anderson, D.S., 2005, Architecture of crevasse splay and point-bar bodies of the nonmarine Iles Formation north of Rangely, Colorado: implications for reservoir description: The Mountain Geologist, v. 42/3, p. 109-122.

Boyd, D.T., 2005, The Booch gas play in southeastern Oklahoma: regional and field-specific petroleum geological analysis: Oklahoma Geological Survey Special Publication SP2005-1, 91 p., 57 figures, 8 tables, 16 plates (http://www.ogs.ou.edu/pubs.php).

Dreyer, T., L.M. Falt, R.K. Hoy, R. Steel, and J.L. Cuevas, 1993, Sedimentary architecture of field analogs from reservoir information (SAFARI): A case study of the fluvial Escanilla Formation, Spanish Pyrenees, *in* S.S. Flint and I.D. Bryant, eds., The geological modeling of hydrocarbon reservoirs and outcrop analogs: International Association of Sedimentologists Special Publication 15, p. 57- 80.

Suneson, N.H. and D.T. Boyd, 2008, Guidebook to the Booch Sandstones: Surface to subsurface correlations: Oklahoma Geological Survey Guidebook 35, 96 p., 112 figures (http://www.ogs.ou.edu/pubs.php).

The Booch Sandstones (McAlester Formation, Krebs Group) Arkoma Basin, Oklahoma: Outcrops to Well Logs

A ~~Model For~~ Introduction to Oklahoma Fluvial Reservoirs

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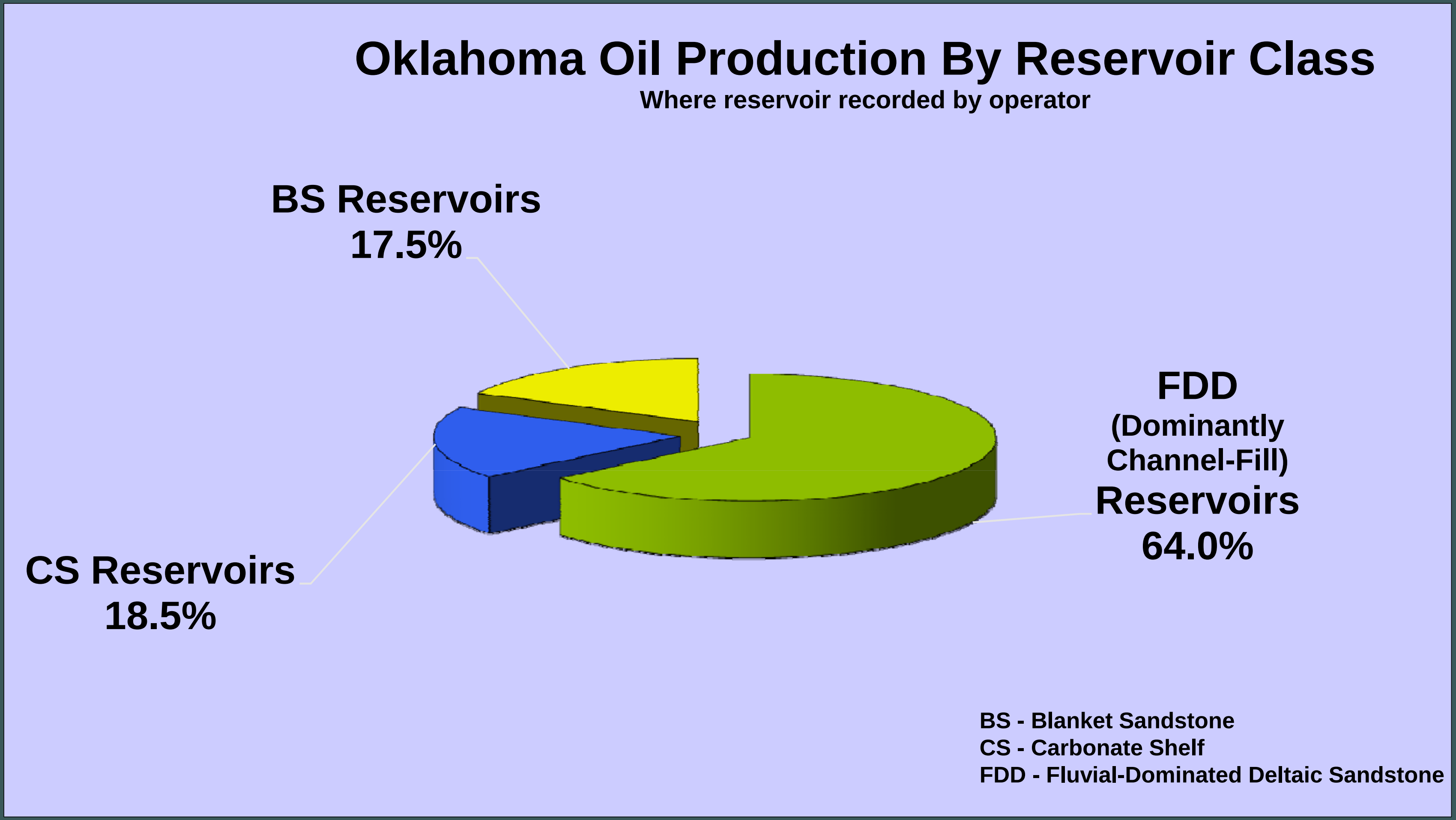
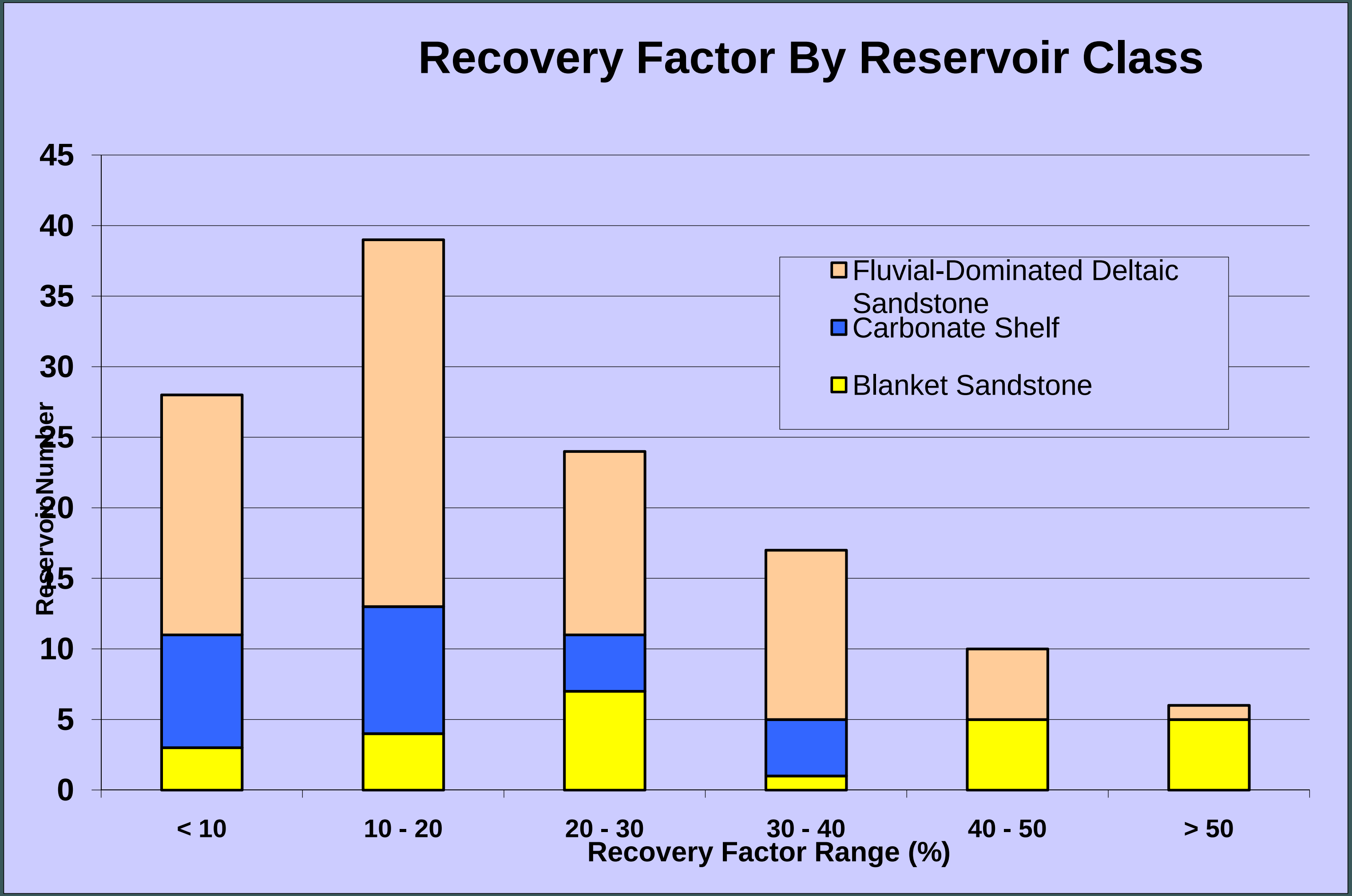
Tulsa Geological Society
September 8, 2009

Why Revisit Oklahoma's Pennsylvanian Fluvial Reservoirs?

- OGS FDD studies and play-based workshops:
  - Morrow oil, Booch oil, Layton and Osage-Layton oil, Skinner and Prue oil, Red Fork oil, Tonkawa oil, Cleveland and Peru oil, Bartlesville oil, Hartshorne oil and gas, Morrow gas, Booch gas
- Fluvial-Dominated Deltaic systems; many did not focus on fluvial part of system
- Excellent base to continue



Most of Oklahoma's oil reservoirs are FDD, and most of those are fluvial, not deltaic (data and figure from Dan Boyd, OGS)



And most of the fluvial reservoirs have been poorly produced. Why?

"Petroleum industry operators tend to label all discontinuous fluvial sandstones as generic 'channel sands.' However, the geometry and facies architecture of various types of fluvial bodies, such as point bars and crevasse splays, are vastly different. The differences may shed light on production issues faced in down-spacing programs, such as drainage area geometries, differential permeability trends, and proportion of accelerated versus new production." (Anderson, 2005)

“The uncertainties associated with resource estimates and recovery factors are often more pronounced in fluvial reservoir sequences than in other, more homogeneous reservoir types. Through careful reservoir description and modeling, there is great potential for improving reliability of resource estimates and recovery factors.” (Dreyer and others, 1993)

So, are Oklahoma's fluvial reservoirs:

- Meandering, braided, or anastomosing?
- High- or low-sinuosity?
- If there are point bars, are they connected?
- If there are point bars, are the lateral accretion prisms compartmentalized?
- If there are channel-floor sandstones, how thick (number of storeys) are they?
- What is the lateral extent of channel-bar sandstones?
- Are we dealing with ribbons, sheets, or something intermediate?

Objective

To better understand Oklahoma's fluvial reservoirs with the hope of improving recovery from known fields

(OK. Now to the Booch)

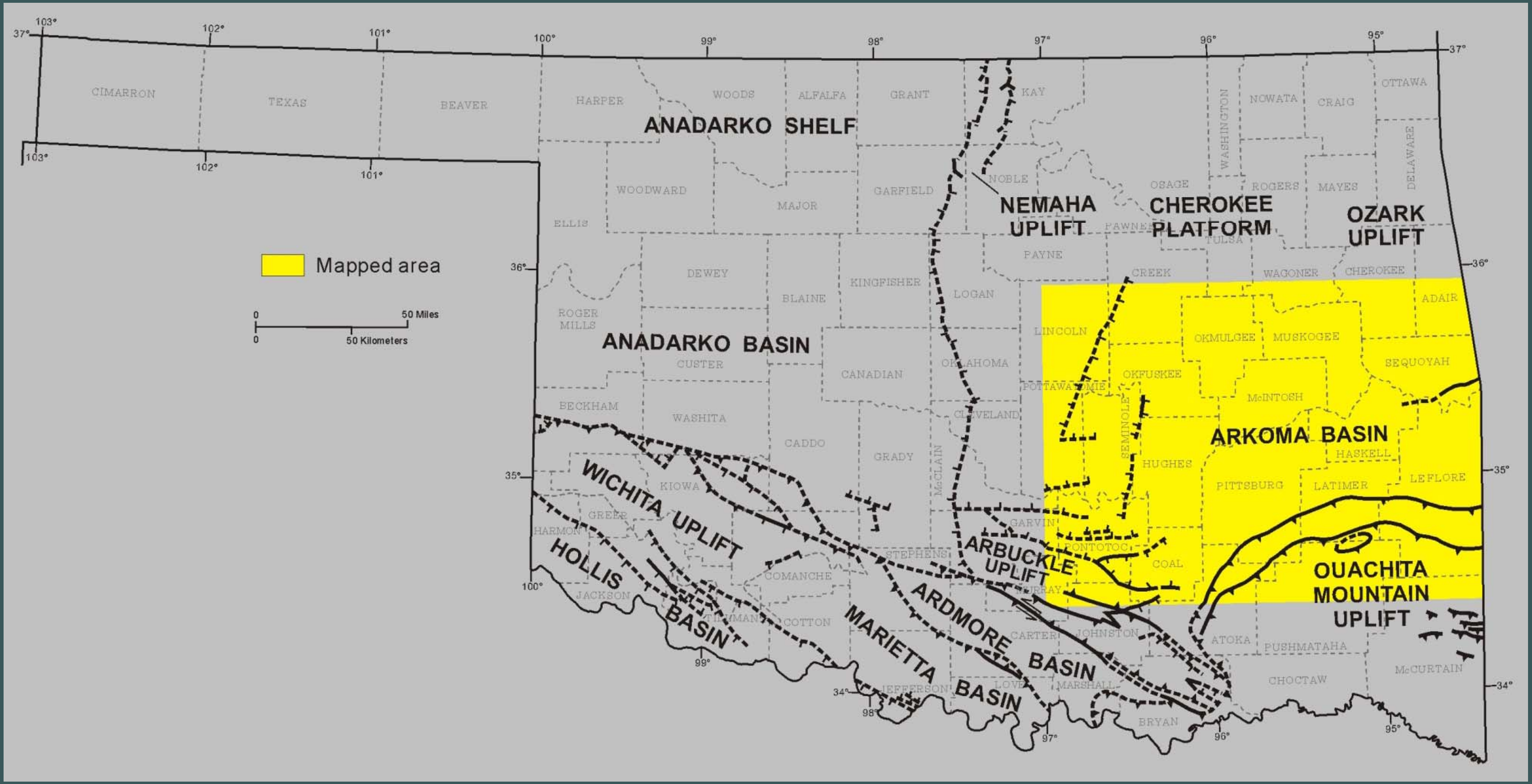
Booch Geology Overview –

- Booch stratigraphy fits into sequence-stratigraphic framework
- Booch sand distribution controlled by fluvial processes: best reservoirs multi-story channel-fills
- Booch distributary-mouth bars tidally reworked; reduced reservoir quality

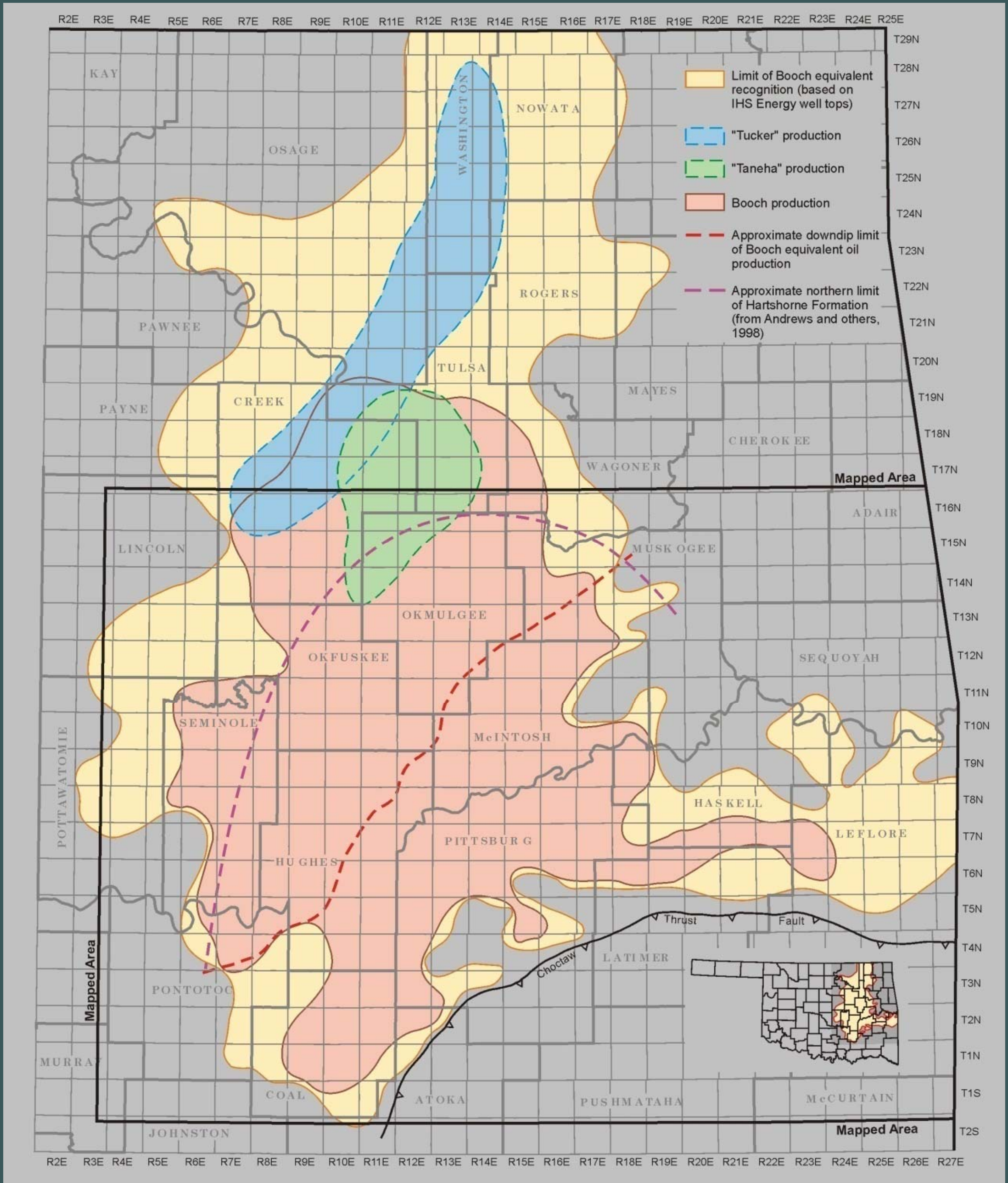
My Booch Interest –

- Relating Booch surface stratigraphy/ nomenclature to subsurface nomenclature
- Matching rock types/environments in Booch outcrops to well-log signatures; assisting small operators

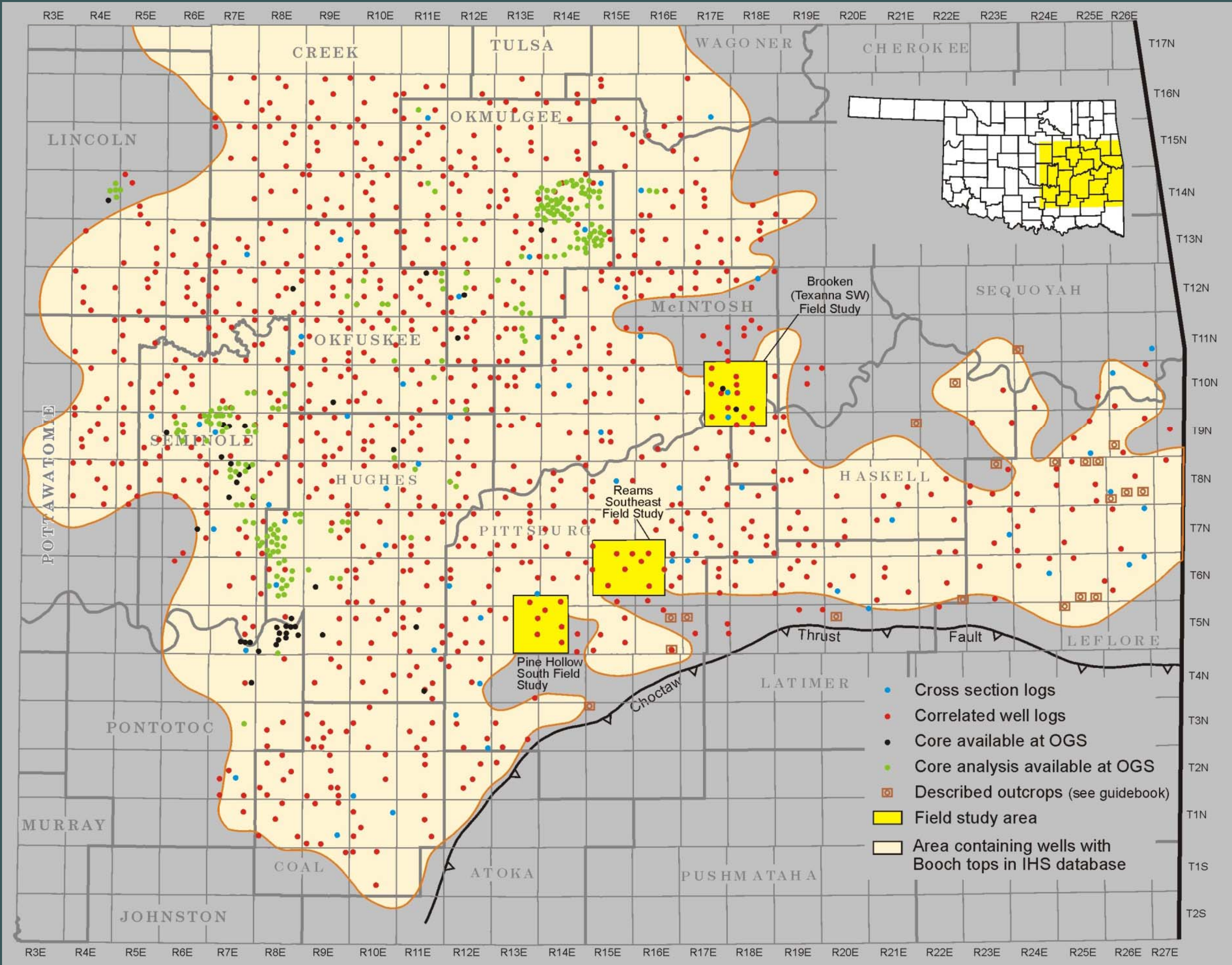
Geologic Provinces of Oklahoma



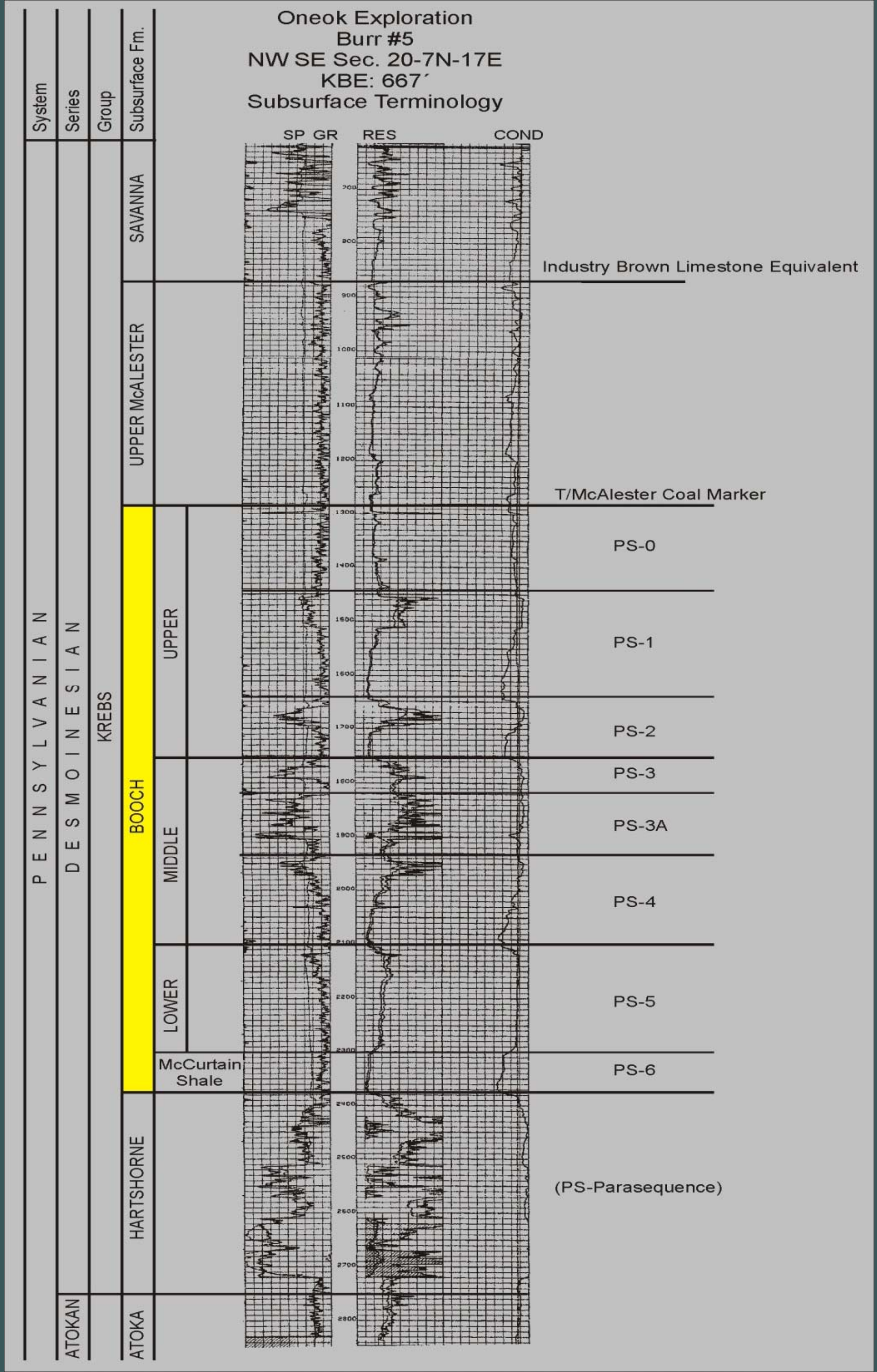
Booch-Equivalent Production



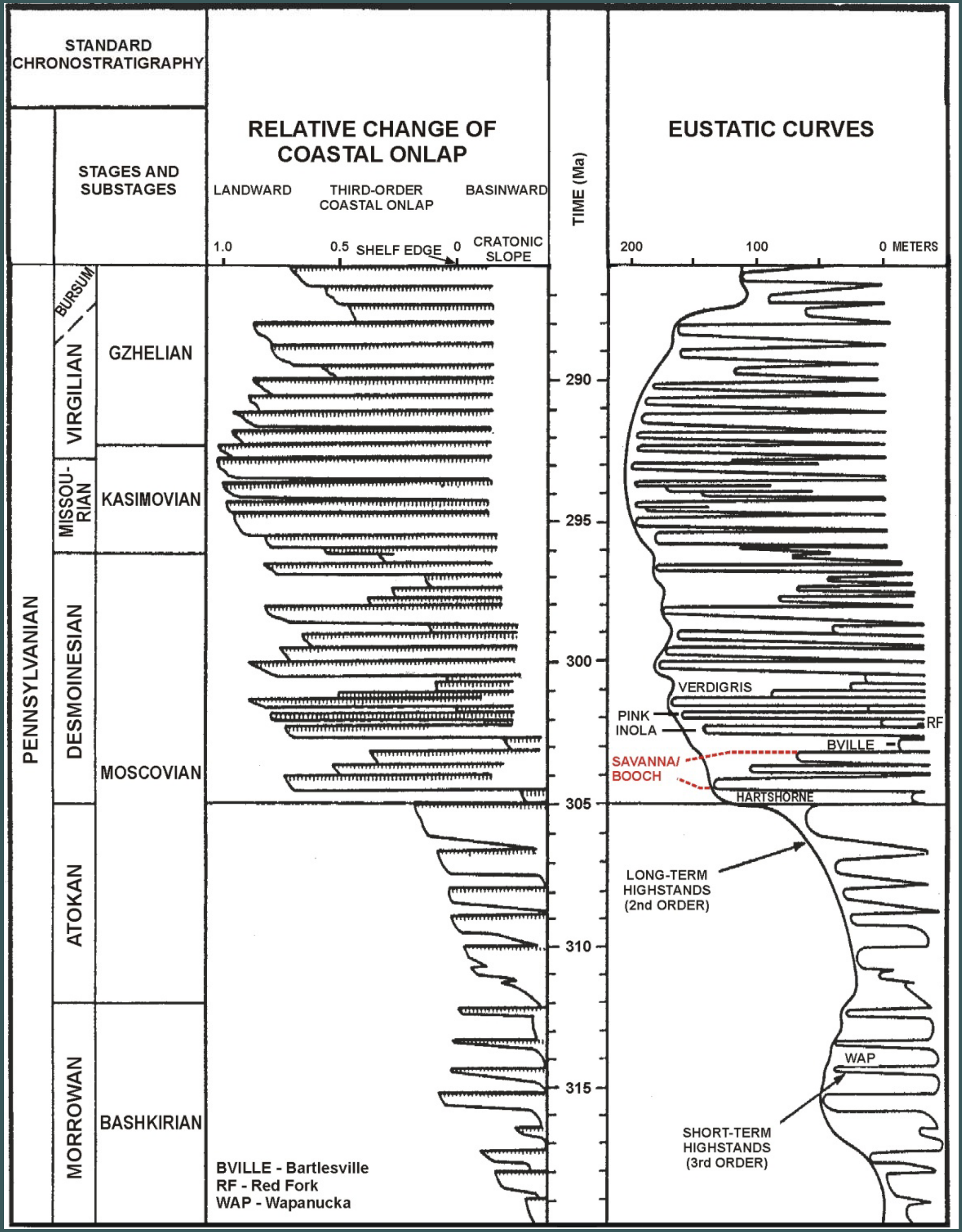
Regional Data Input



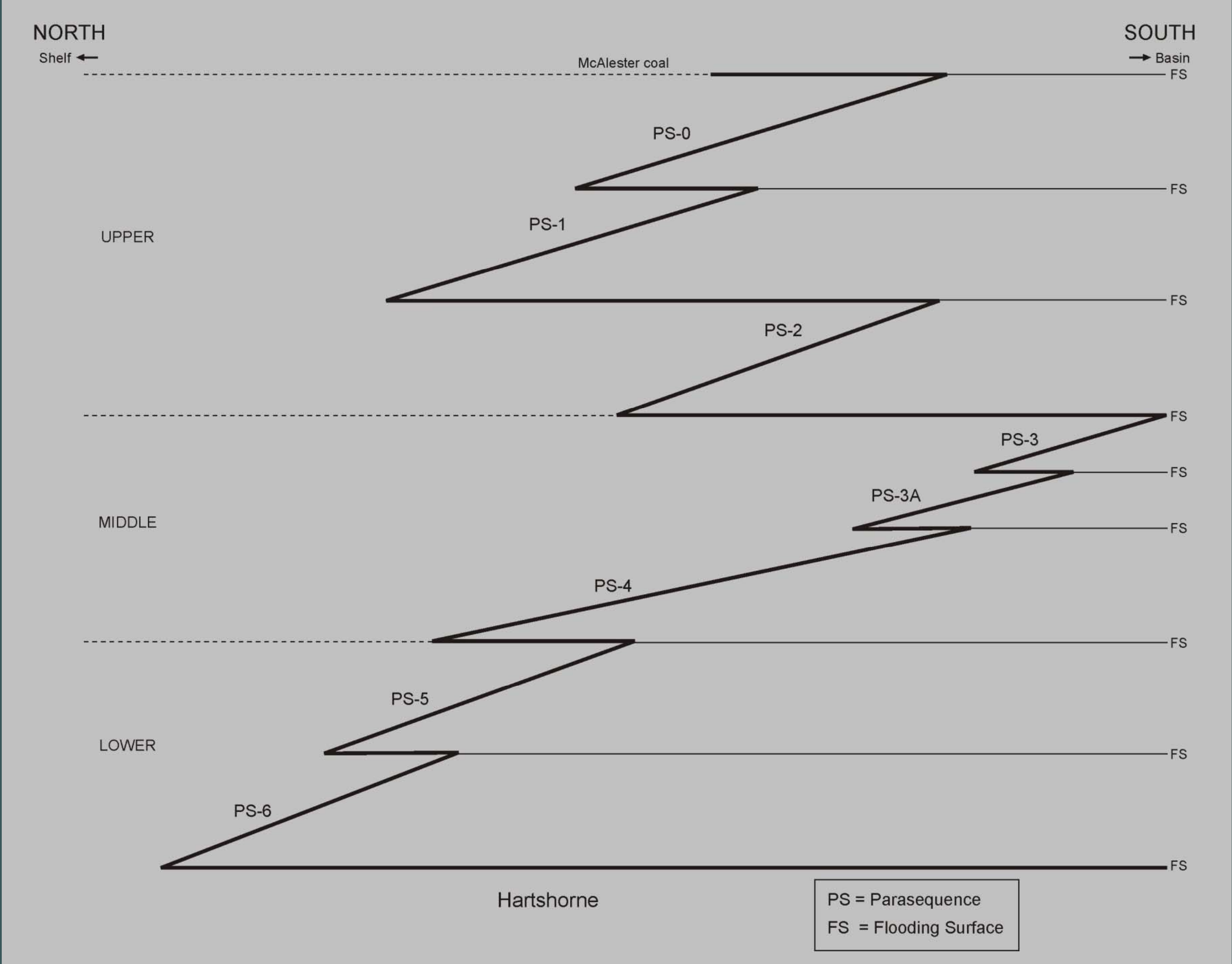
Booch Type Log



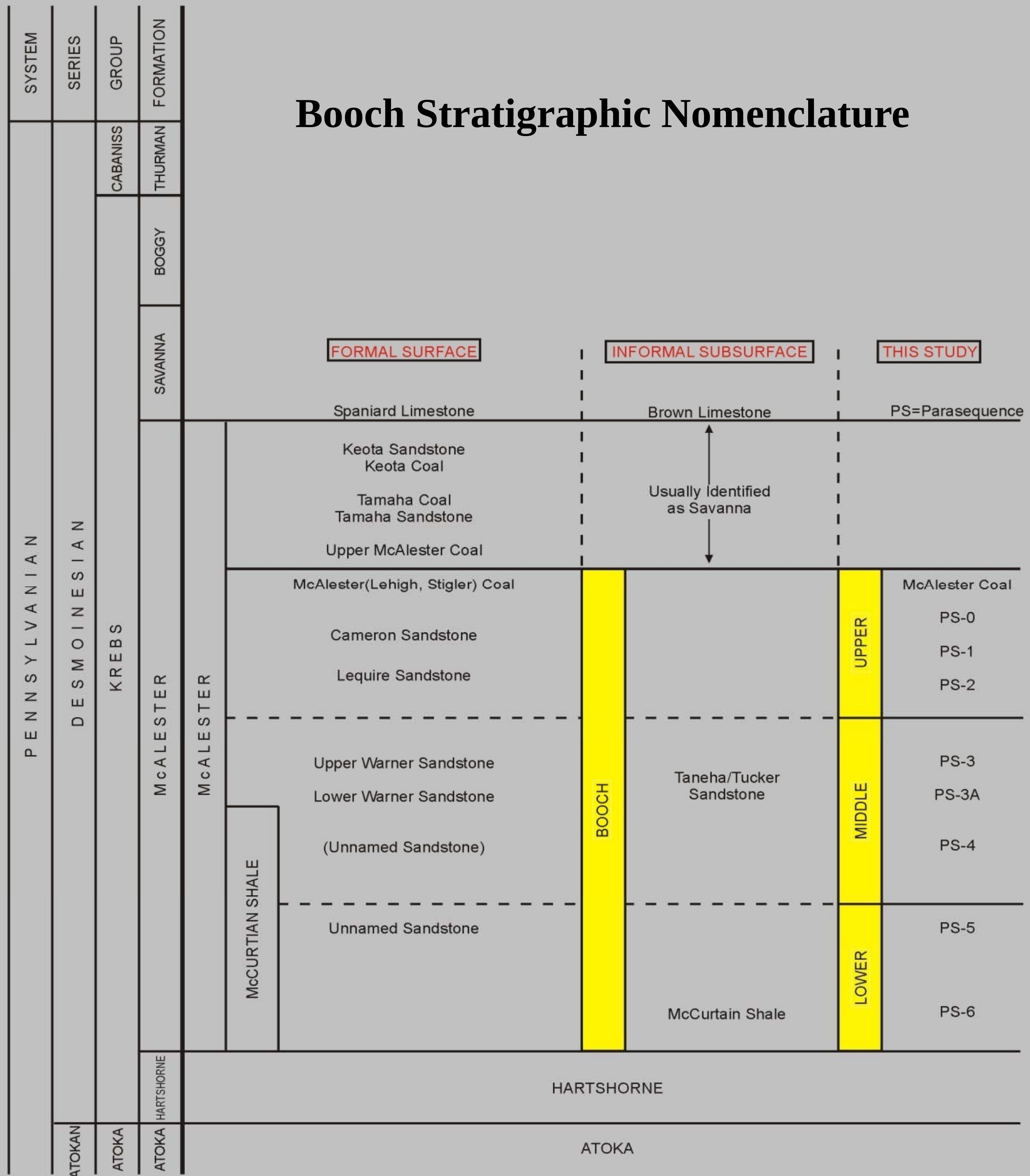
Eustatic Sea Level Curves



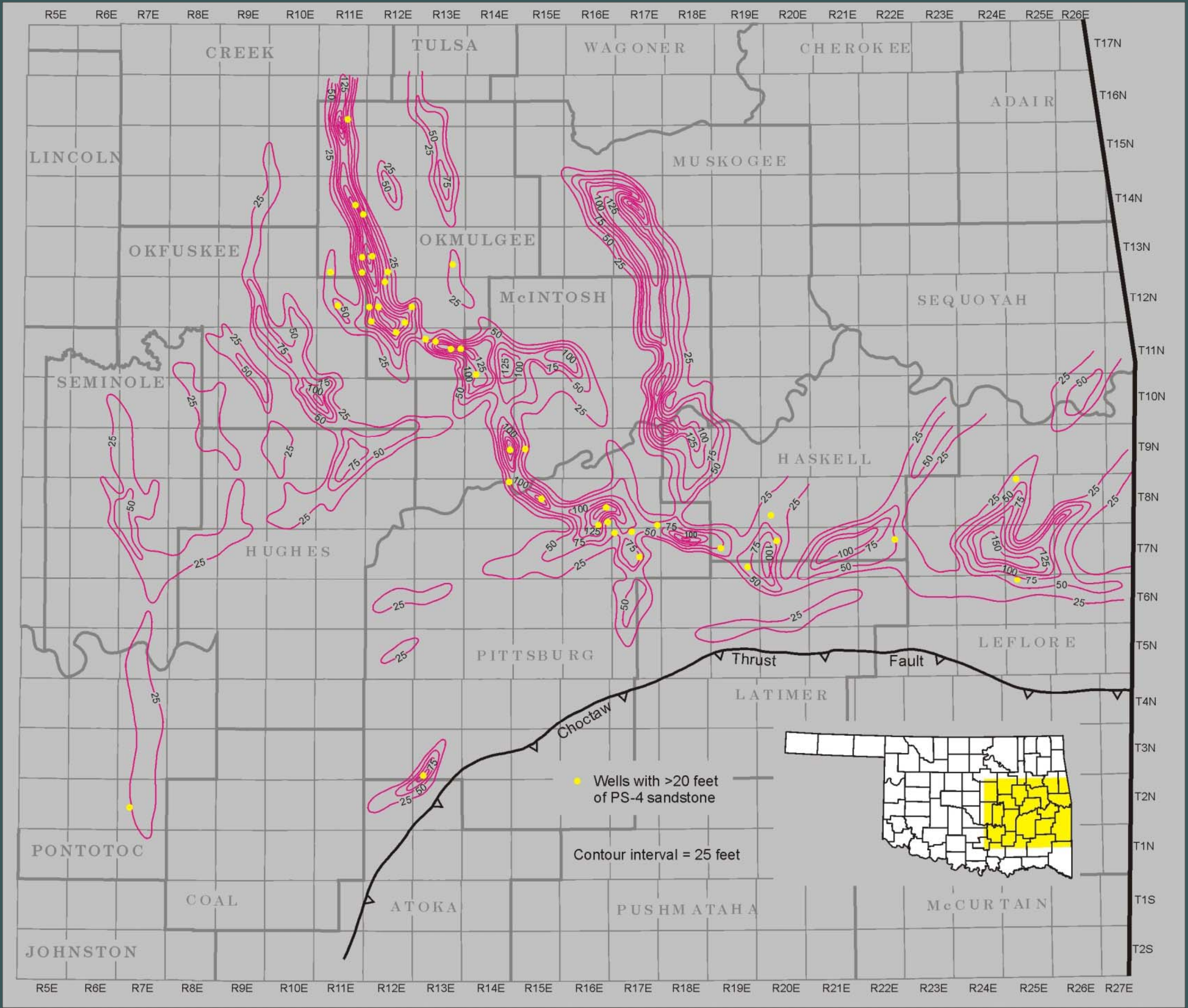
Booch Schematic Progradational History



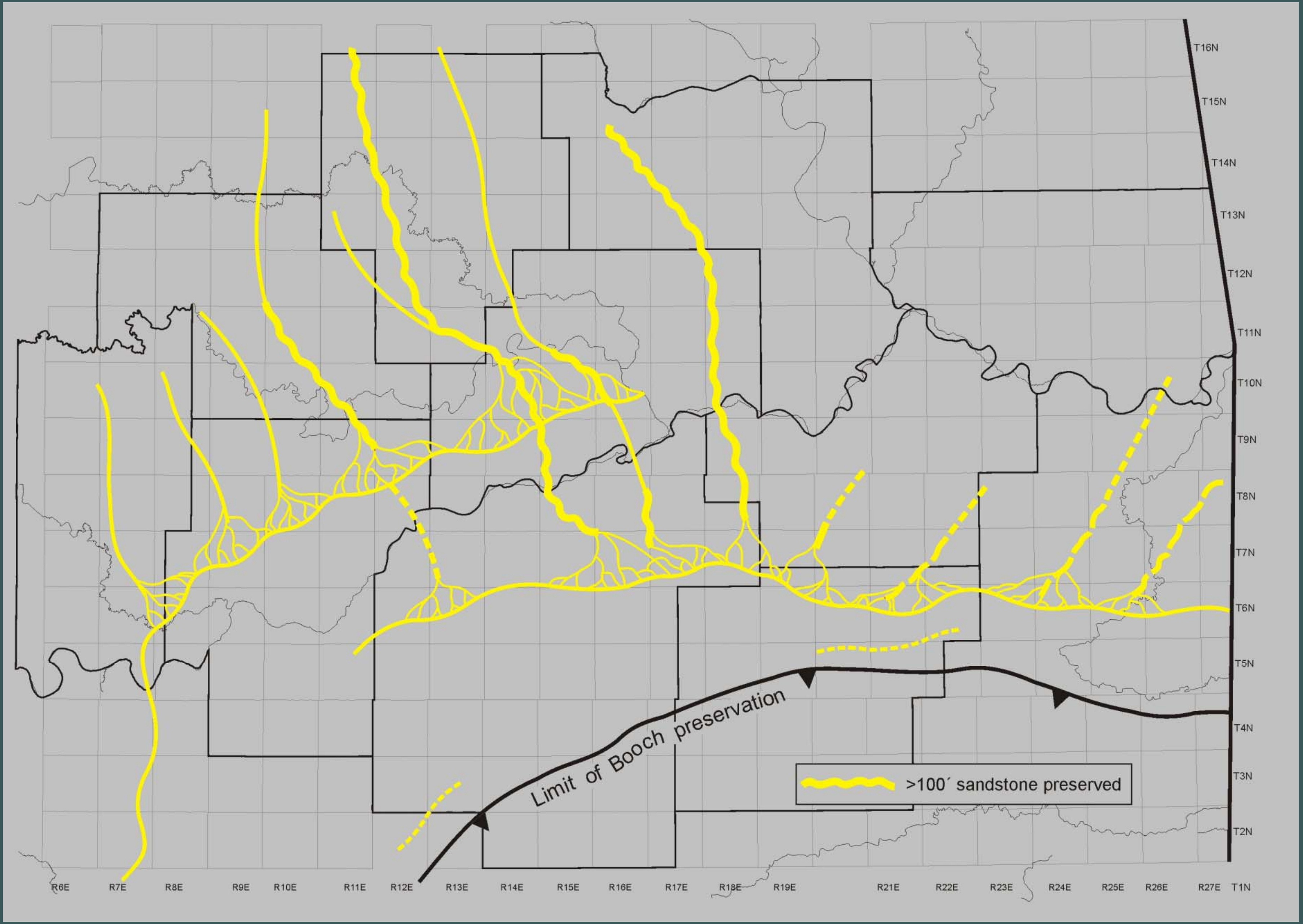
Booch Stratigraphic Nomenclature



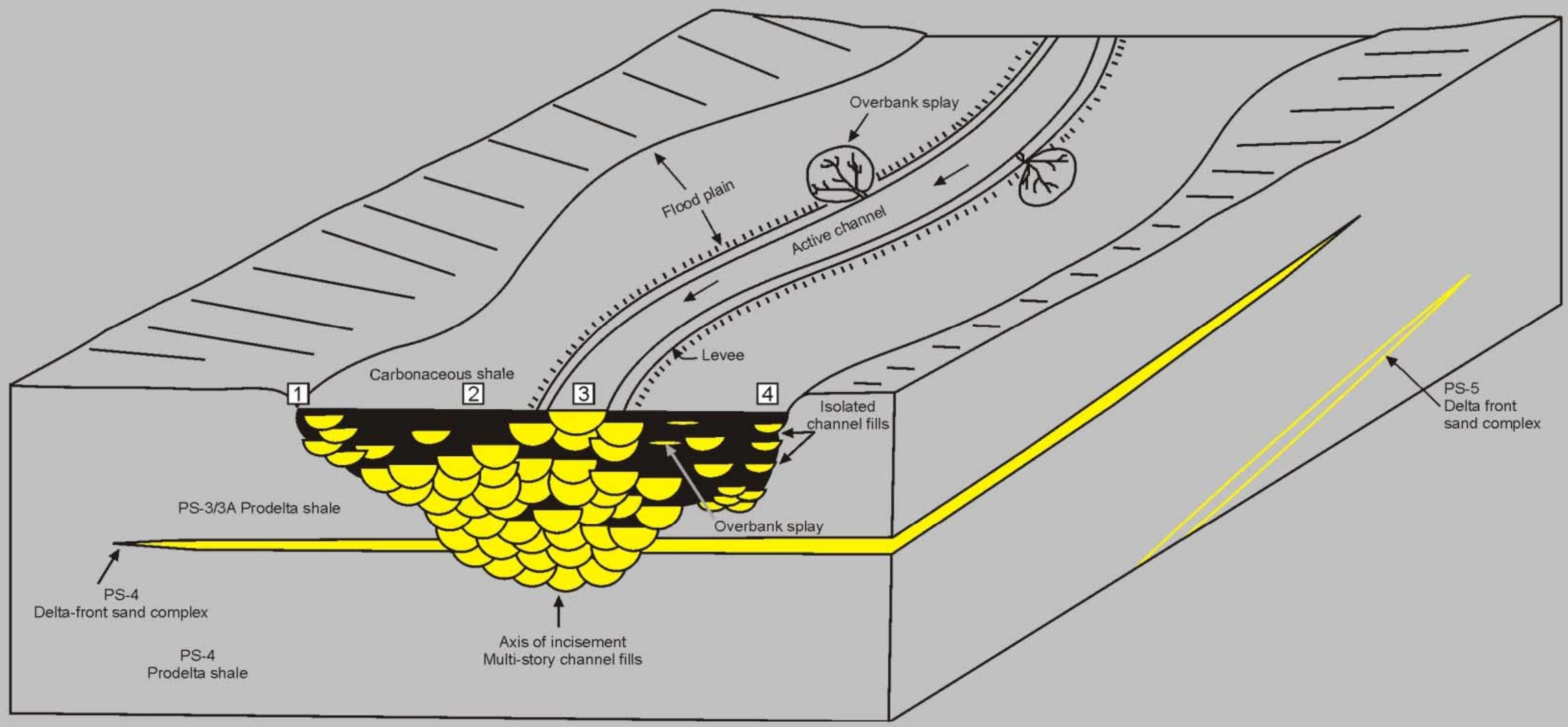
Middle Booch Gross Sand Isopach



Schematic Middle Booch Depositional Systems

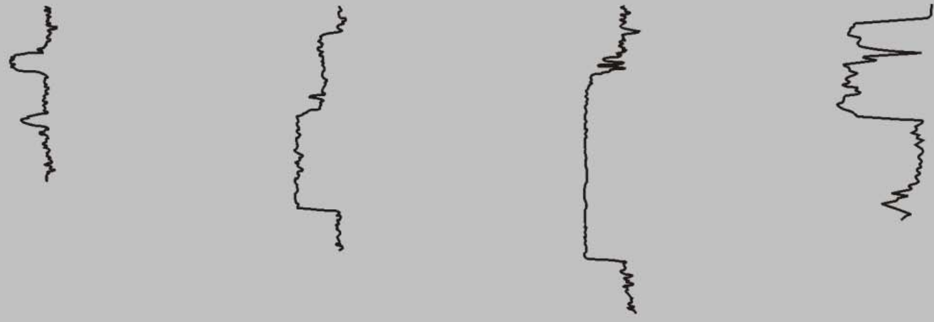


Incised Valley Block Diagram

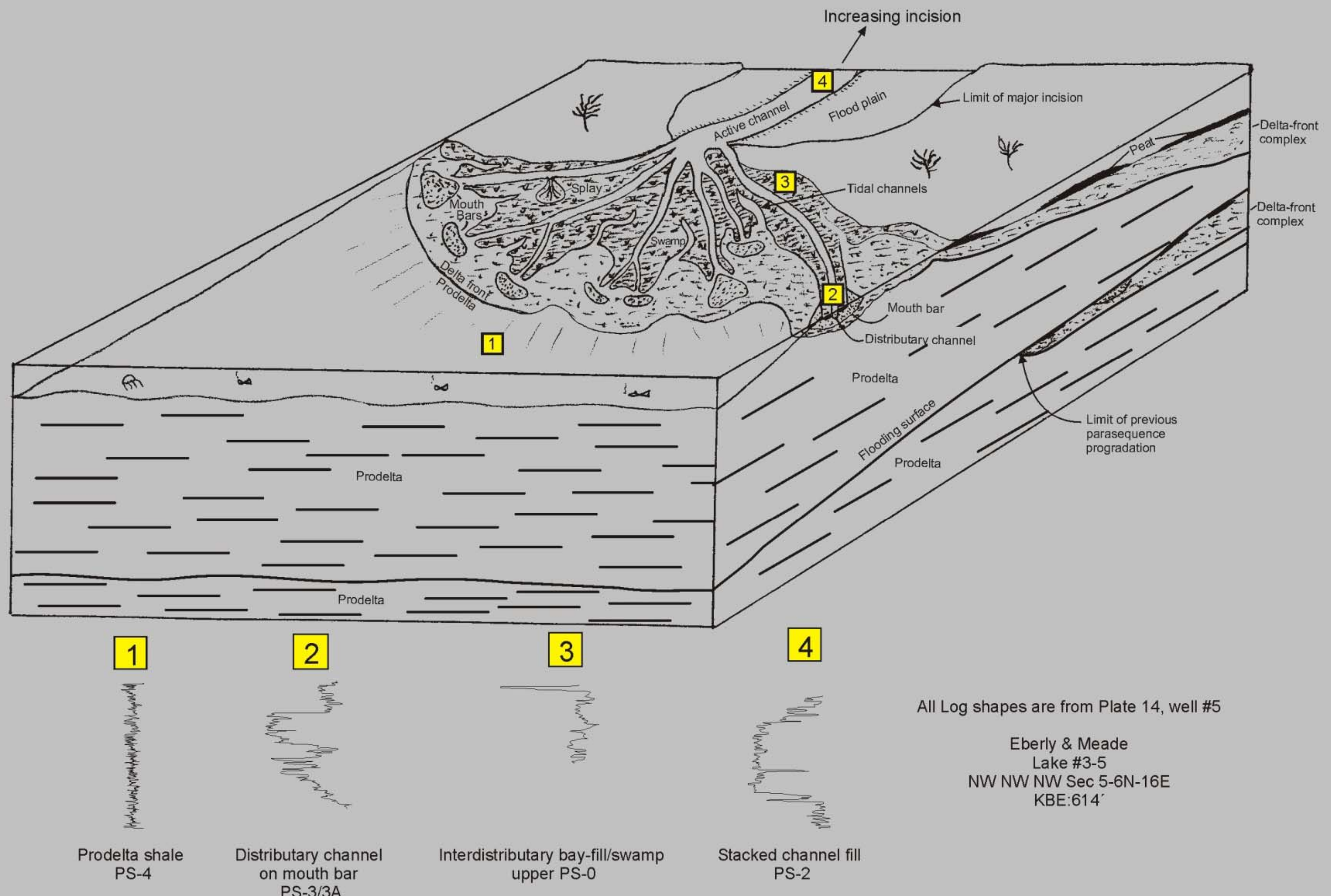


Log signatures from cross section *A-A´* (Plate 10)

1	2	3	4
Well #1	Well #2	Well #3	Well #6
McKee #B-1	Addington #A-1	McKee #E-1	Davis #B-1
SW Sec 24-10N-17E	NE Sec 24-10N-17E	NW SW Sec 19-10N-18E	NE SE Sec 17-10N-18E



Idealized Booch Tidal Delta



All Log shapes are from Plate 14, well #5

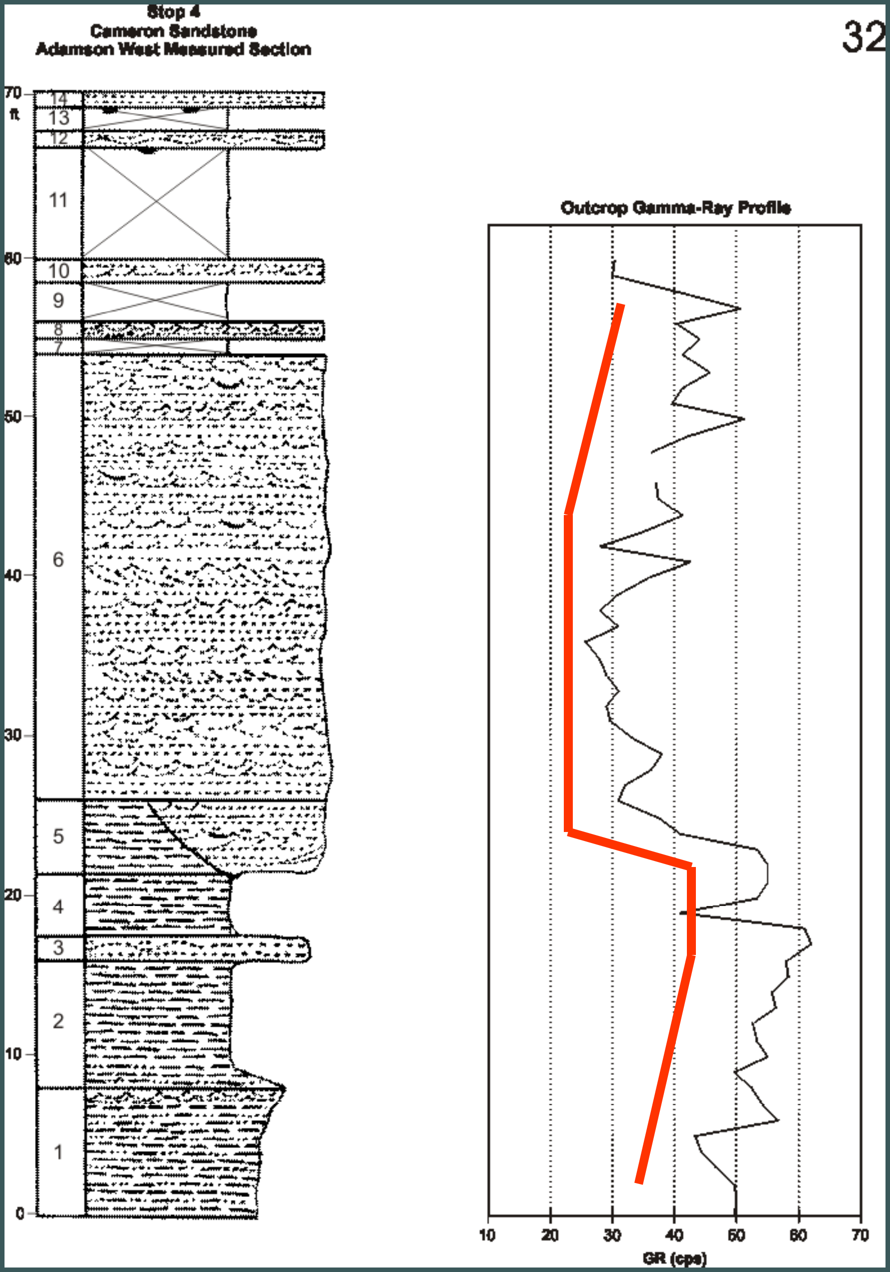
Eberly & Meade
Lake #3-5
NW NW NW Sec 5-6N-16E
KBE:614´

Adamson Outcrop
PS-1 (Cameron)

Herringbone cross-stratification, Adamson outcrop, Cameron Sandstone (PS-1)

Herringbone cross-stratification, Adamson outcrop, Cameron Sandstone (PS-1)

Flaser bedding, Adamson outcrop, Cameron Sandstone (PS-1)



Adamson Outcrop

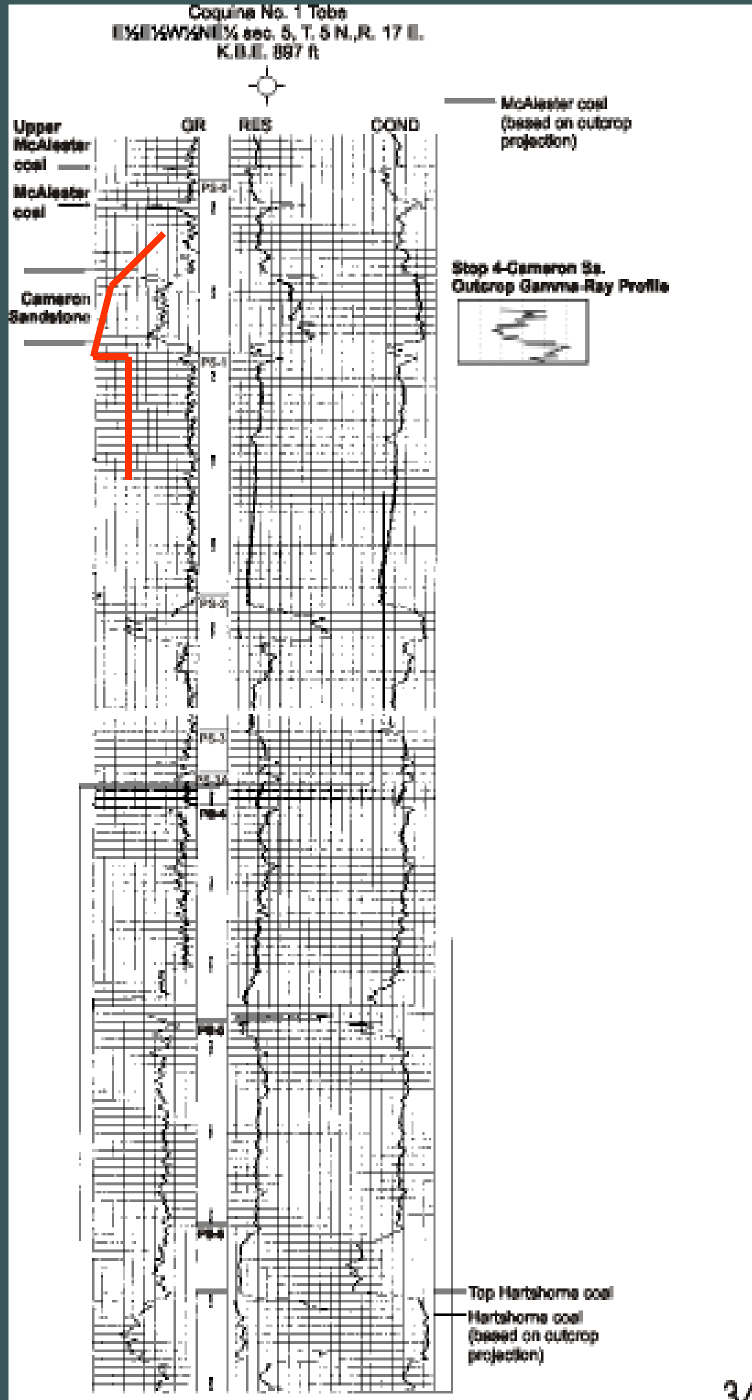
Cameron Sandstone

Measured section and gamma-ray profile

Note abrupt, erosional base of sandstone

Sandstone ~30 ft thick

McAlester coal ~150 ft above base of ss



Coquina No. 1 Tobe

- ~1.2 mi NE of outcrop
- Cameron Sandstone
  - ~80 ft thick
- Sandstone has abrupt base
- Base of sandstone ~160 ft below McAlester coal
- Hartshorne at base of log

Interpretation – Cameron Sandstone

Outcrop –

X-stratification, ripples → high energy

flaser beds, herringbone x-strat → tidal reworking

sharp base ← lower bar-facies eroded

SUM – tidally reworked distributary-mouth bar

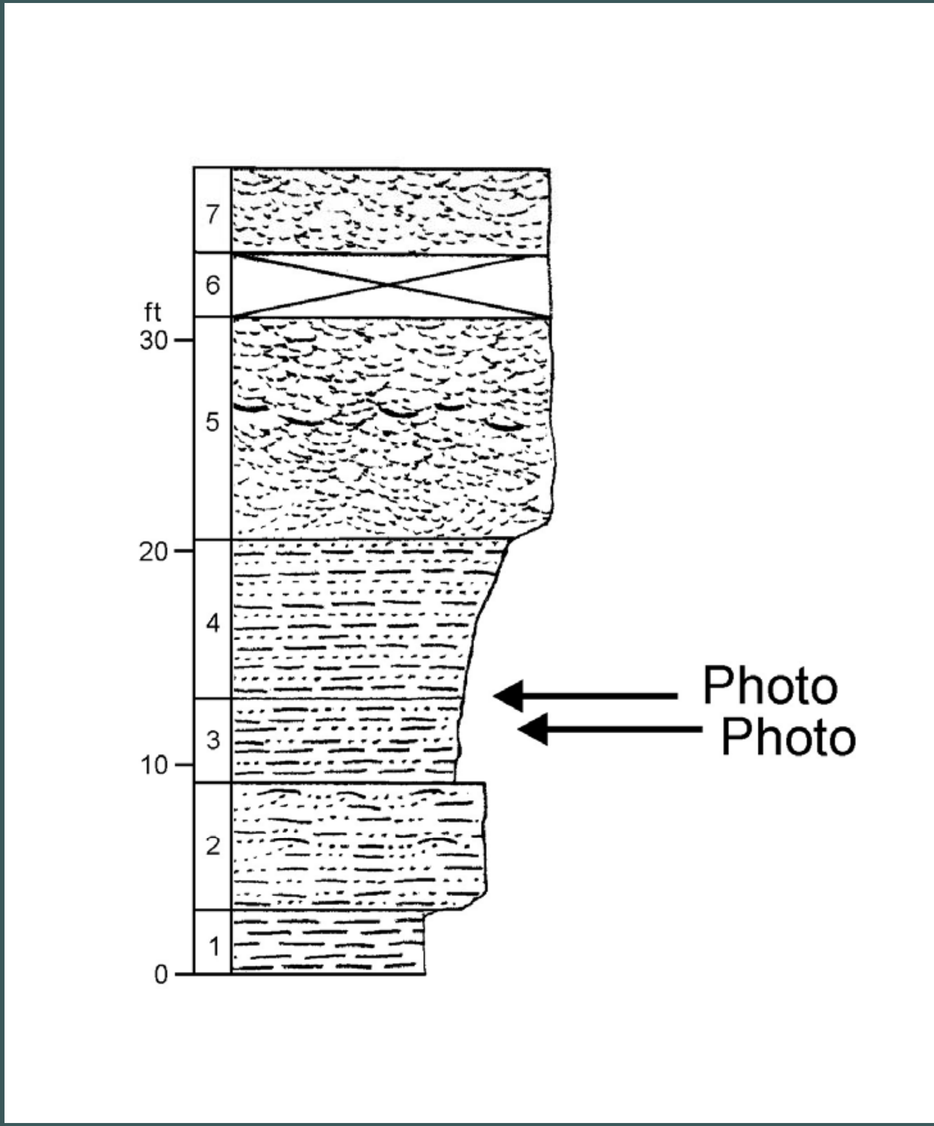
Tobe # 1 –

Multi-story incised-valley fill

BUT ONLY 1.2 MILES FROM OUTCROP!

New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)

Graphic Columnar Section, New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)



Section consists of two coarsening-upward sequences, typical of distributary-mouth bars

Cyclic stratification, New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)

Cyclic stratification, New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)

Cyclic stratification, New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)

Cyclic stratification, New Spiro Lake outcrop, Warner Sandstone (PS – 3/3A)

Interpretation – Warner Sandstone A

Outcrop –

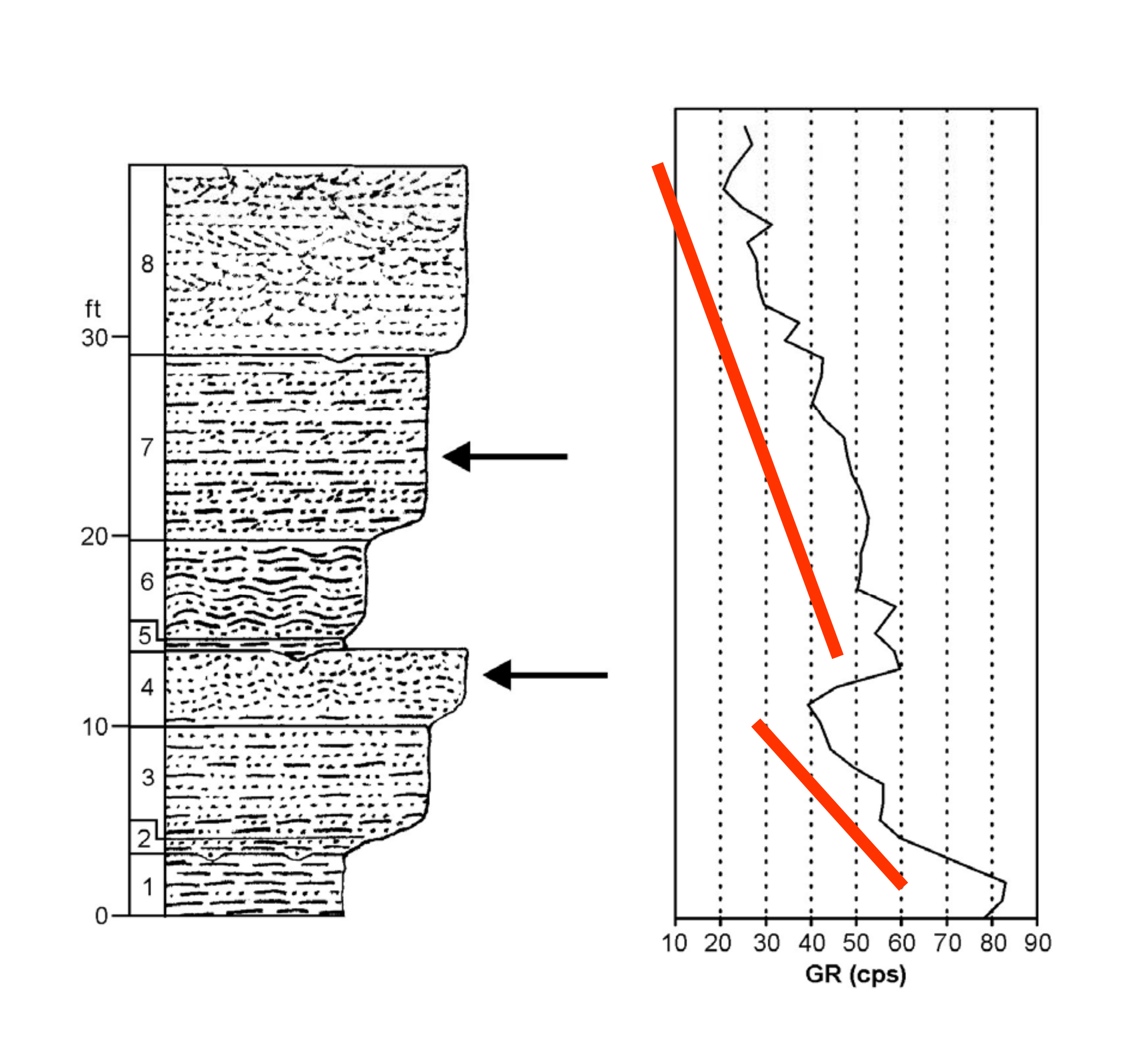
- Cyclic beds, lenticular and flaser bedding, ss and sh drapes → tidal reworking
- 2 CUSs → distributary-mouth bars (two parasequences, especially evident in next outcrop)

Panama RR Cut outcrop, Warner Sandstone (PS – 3/3A)

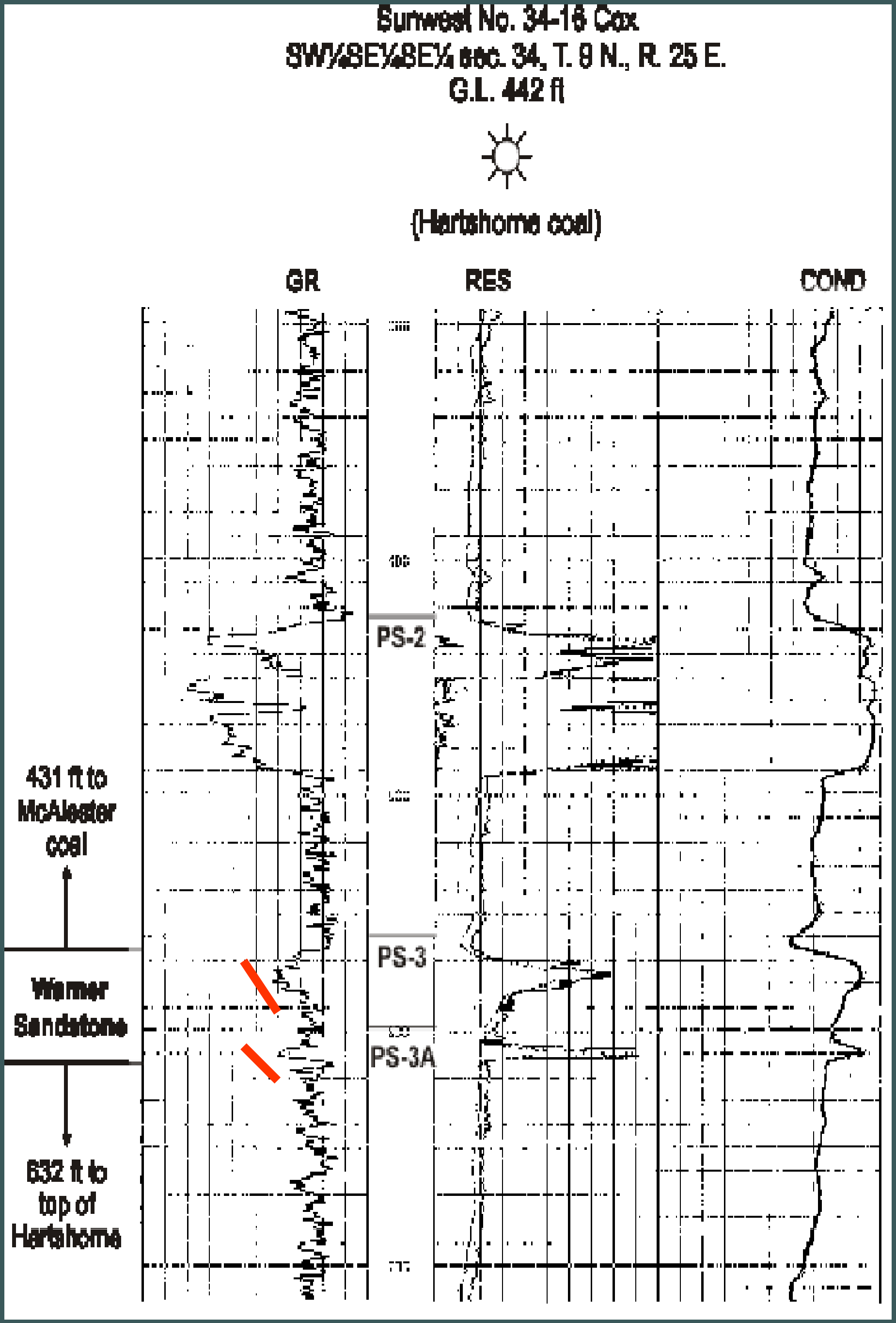
Cyclic, repetitious stratification, Panama RR Cut outcrop, Warner Sandstone (PS – 3/3A)

Draping and flaser bedding, Panama RR Cut outcrop, Warner Sandstone (PS – 3/3A)

Graphic Columnar Section and Gamma-Ray Profile, Panama RR Cut outcrop, Warner Sandstone (PS – 3/3A)



Section consists of two upward-coarsening sequences typical of a distributary-mouth bar separated by a flooding surface



Sunwest No. 34-16 Cox

Warner Sandstone

- ~1.5 mi NE of outcrop
- Warner – 2 ss; lower ~8 ft thick, upper ~15 ft thick
- Both – rapidly coarsen upward

Interpretation – Warner Sandstone B

Outcrop –

Lower sequence – lenticular and flaser bedding, drapes
→ tidal reworking

Parasequence boundary (also angular unconformity)
→ slumping, dewatering, soft-sediment processes

Upper sequence – cyclic units, drapes → tidal reworking

Cap – ss, large-scale x-strat → high energy
→ distributary channel

SUM – 2 tidally-reworked DMBs capped by dist channel

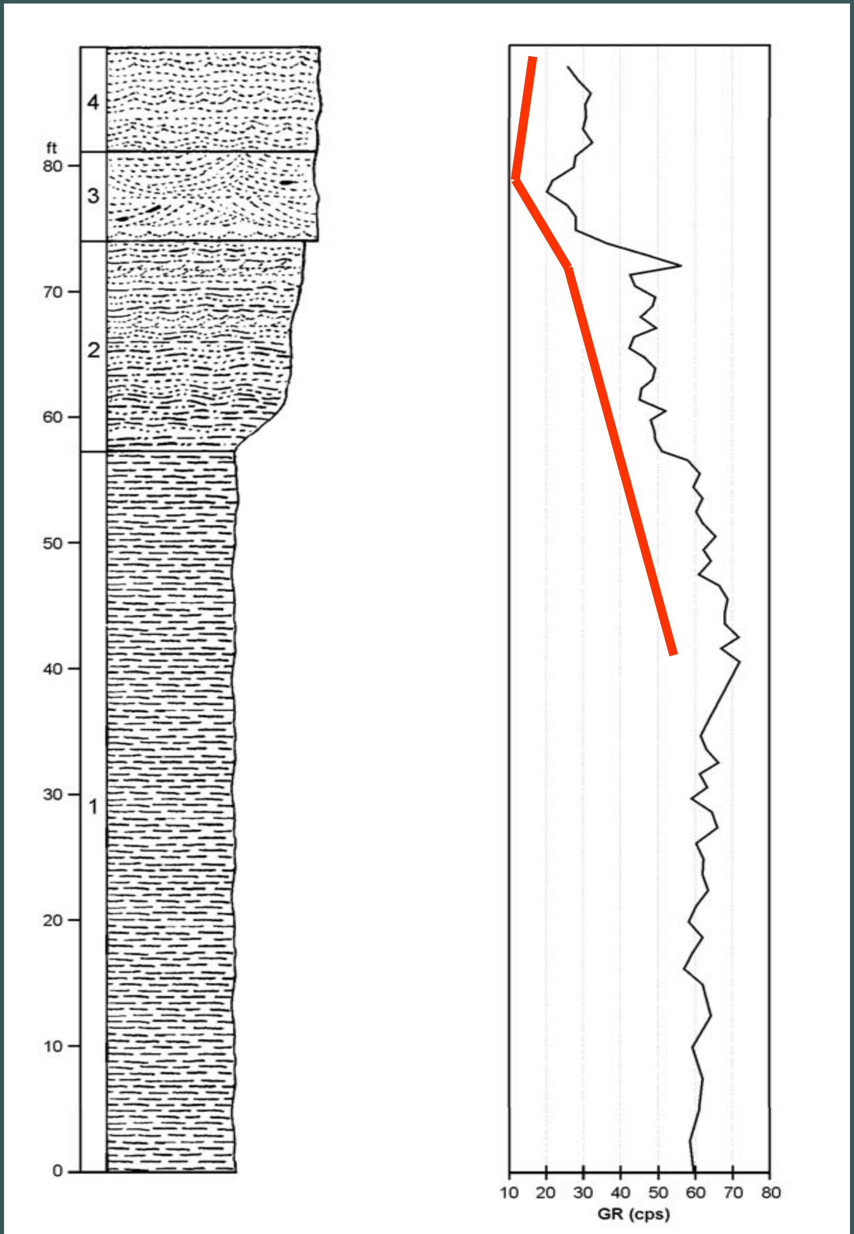
No. 34-16 Cox –

2 thin, rapidly CUSs → distributary-mouth bars

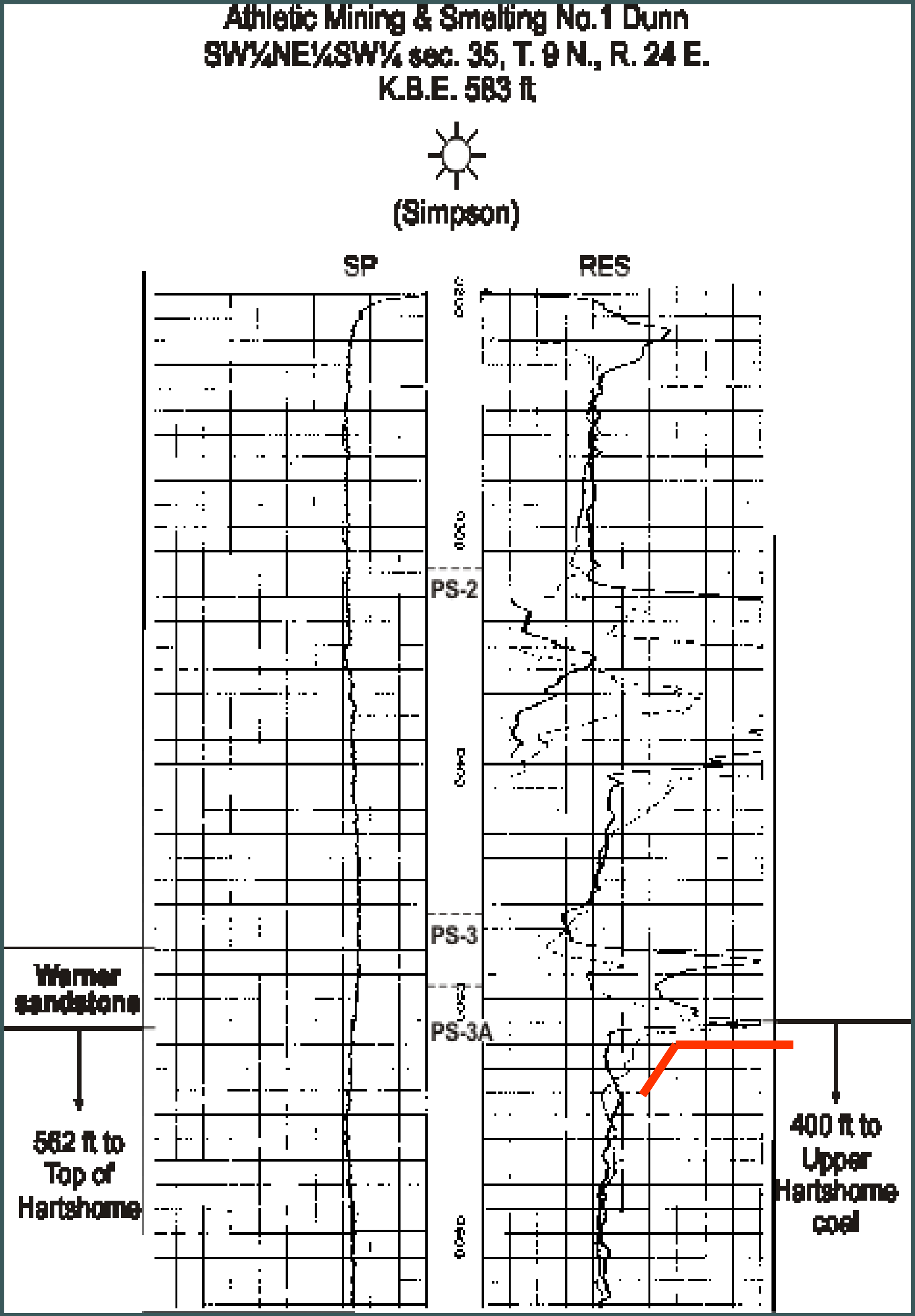
Carter Lake outcrop, Warner Sandstone (PS-3/3A)

Carter Lake outcrop, Warner Sandstone (PS – 3/3A)

Graphic Columnar Section and Gamma-Ray Profile, Carter Lake outcrop, Warner Sandstone (PS – 3/3A)



Section shows coarsening-upward sequence. Marine shales at base overlain by distributary-mouth bar. Distributary channel, possibly tidally influenced, at top.



AM&S No. 1 Dunn

Warner Sandstone

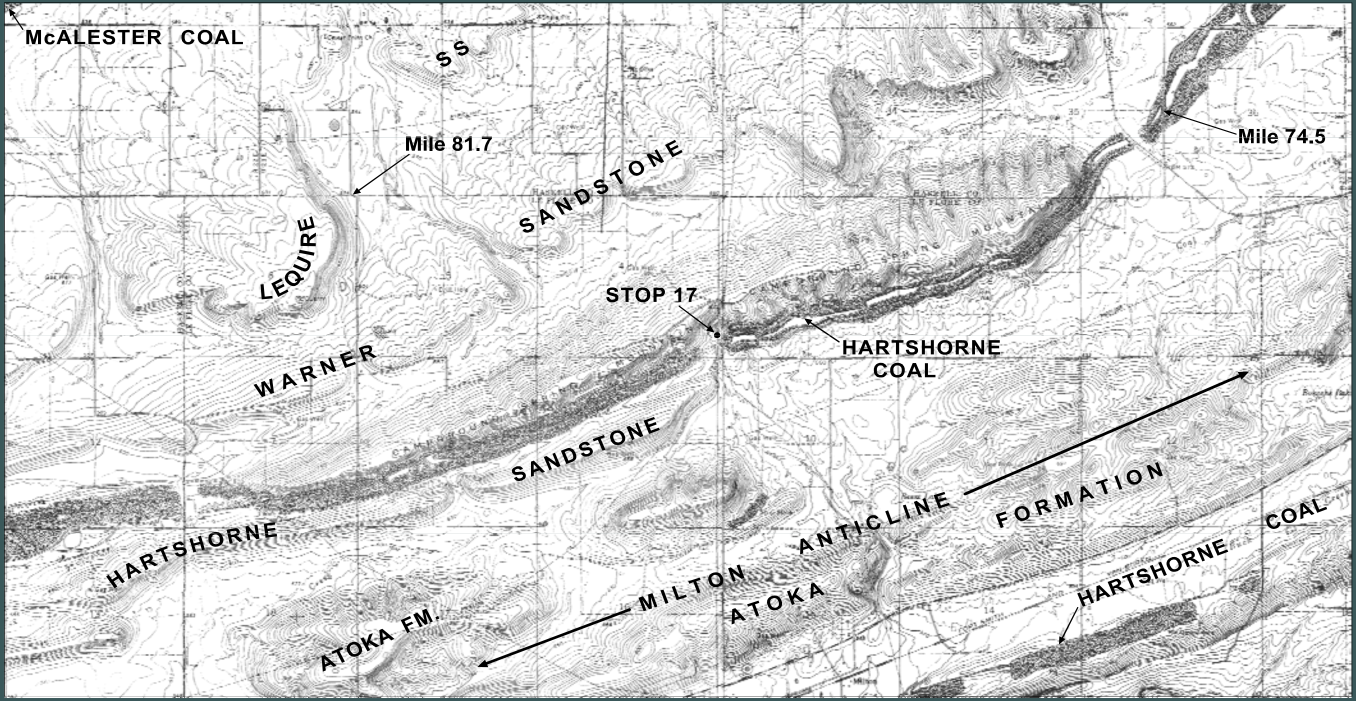
- ~1.2 mi NW of outcrop
- Lower sandstone ~15 ft thick; abrupt base
- Underlying shale coarsens upward

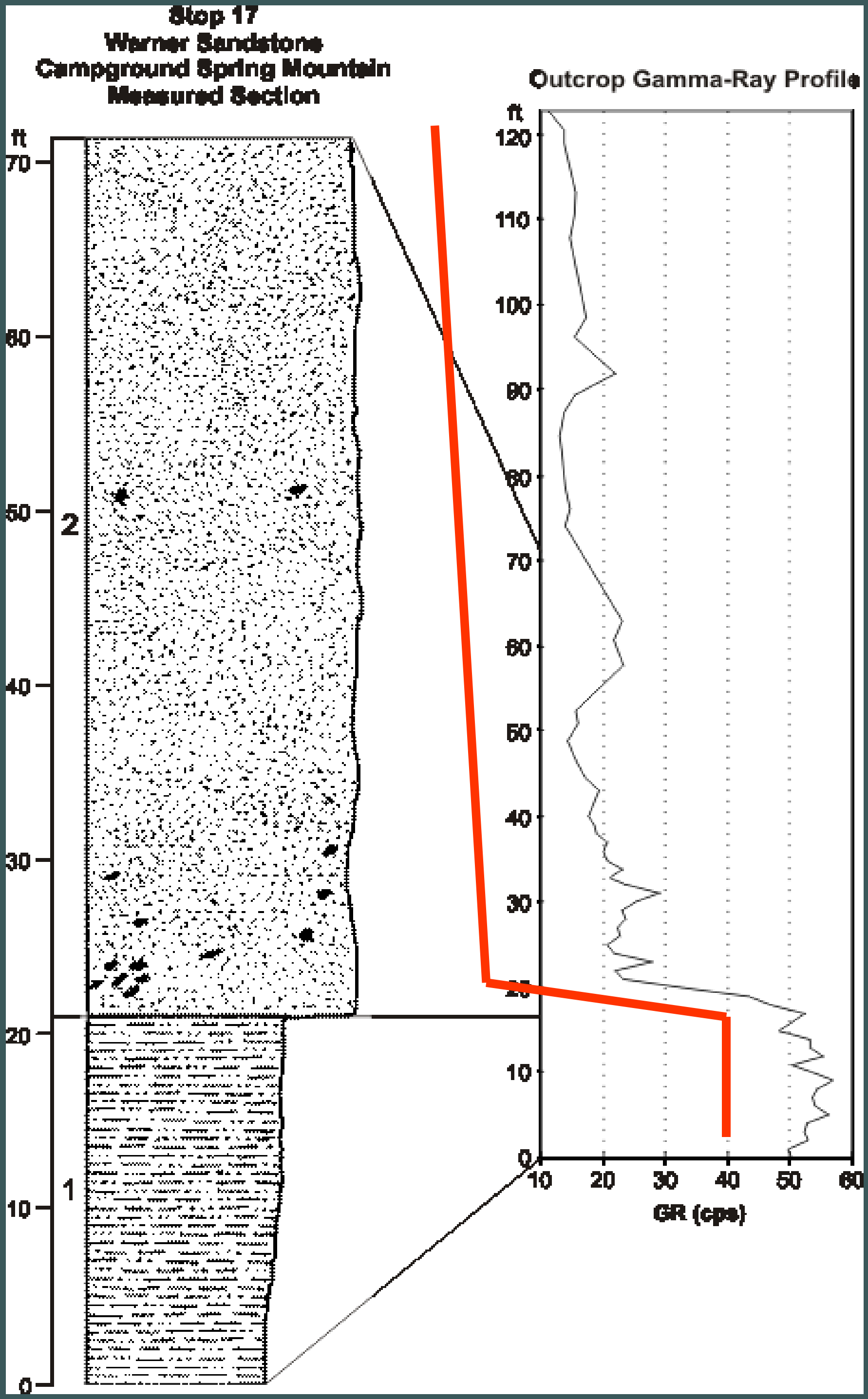
Interpretation - Warner Sandstone C

Outcrop –
- Dark marine shale at base
- Ss -little evidence for tidal reworking
- Cap – thick ss, large-scale x-strat → tidal or distributary channel
- CUS → distributary-mouth bar

No. 1 Dunn –
- 2 sandstones, typical of Warner
- Lower – shale coarsens upward, ss w/ abrupt base → distributary-mouth bar eroded by channel

Warner Sandstone (?) – Campground Spring Mountain

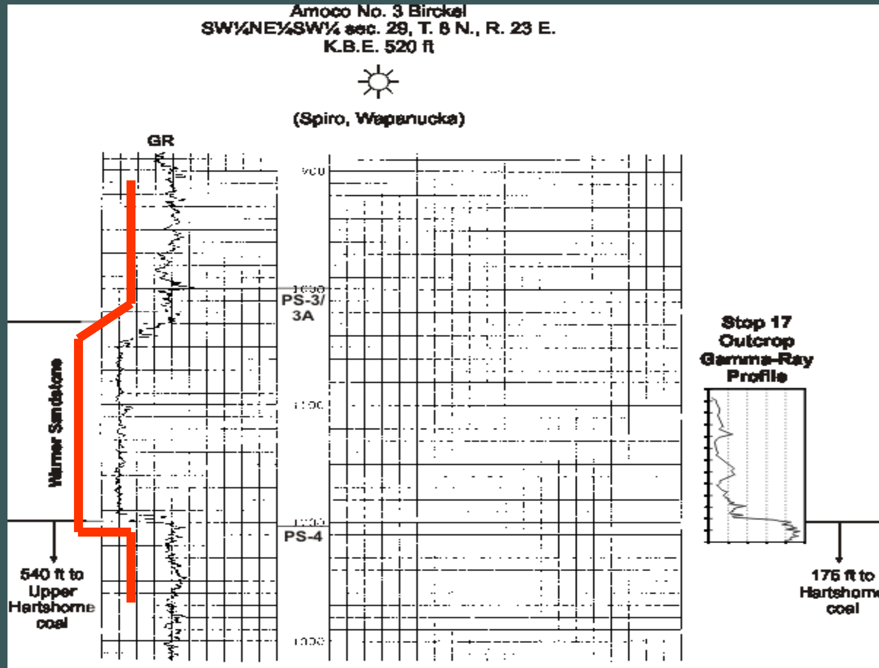




Campground Spring Mountain

Warner(?) Sandstone

- 100+ ft crs- to med-gr porous sandstone, poorly exposed
- Rip-ups throughout base
- Base ~150 ft above Hartshorne coal

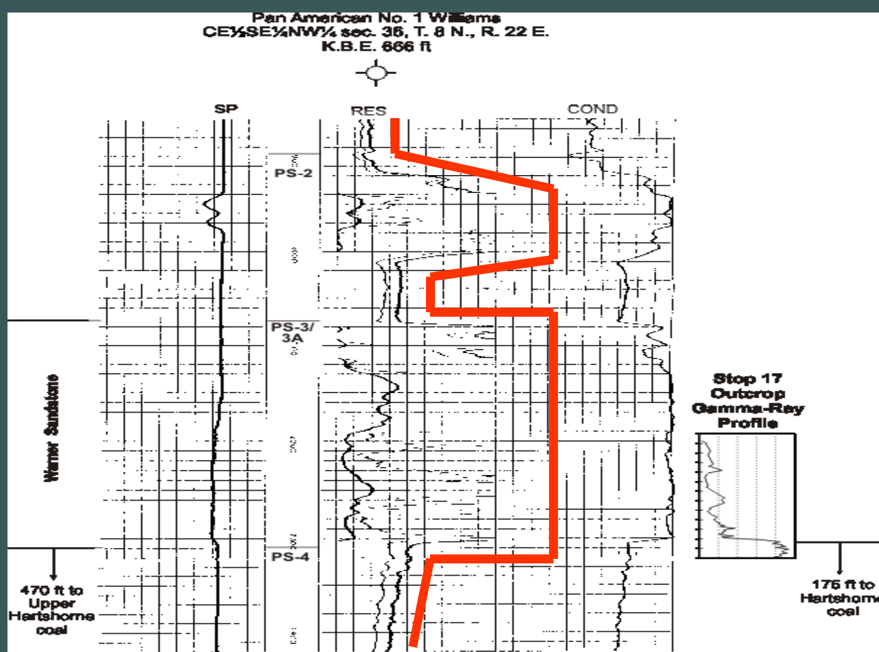


Amoco No. 3 Birckel

~4.5 mi SW of outcrop

Ss ~170 ft thick, abrupt base

Base ~540 ft above Hartshorne coal



Pan Am No. 1 Williams

~4.5 mi SW of outcrop

Ss ~225 ft thick, abrupt base

Base ~470 ft above Hartshorne coal

Interpretation – Warner(?) Sandstone

Outcrop, No. 3 Birckel, and No. 1 Williams –

- Thick sandstone w/ abrupt base → multi-story
  - incised-valley fill

BUT WHERE DOES THIS FIT IN TO STRATIGRAPHY AND REGIONAL GEOLOGY???

Conclusions

Stratigraphy

- Booch not equivalent to McAlester
- Surface names correlate w/ subsurface names and tops of parasequences

Sequence Stratigraphy

- Records eight progradational cycles (all sourced from the north)

Reservoir Characteristics

- All are sandstones (occurring near cycle tops)
  - Best are channel-fills
  - Tidally reworked deltaic strata are poorer
- Can “view” reservoir types on surface

Thank you!