Estimating Resources and Reserves in Tight Sands: Geological Complexities and Controversies*

Creties Jenkins[1]

Search and Discovery Article #120020 (2009)
Posted November 30, 2009

*Adapted from presentation at AAPG Geoscience Technology Workshop, "Geological Aspects of Estimating Resources and Reserves," Houston, Texas, September 9-11, 2009

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Abstract

Tight gas sand wells have highly-variable performance, with estimated ultimate recoveries (EUR's) ranging from less than 10 MMCF to more than 10 BCF per well. While drilling and completion practices play a critical role in determining EUR, there are also a number of geological and petrophysical factors that strongly affect it. Many of these factors are poorly understood, and there is considerable controversy over their nature, influence, and predictability. These factors include:

1. The nature of the gas accumulation as either "basin-centered" or "conventional": Basin-centered accumulations are interpreted as areally-extensive, overpressured, gas-charged compartments with technically recoverable volumes ranging from tens to hundreds of trillions of cubic feet of gas. However, if the recoverable gas is actually contained in low-permeability conventional traps, then the associated gas volumes are much smaller. Which of these is more common and how do we distinguish them?

2. Petrophysical properties: Relationships between porosity and permeability vary by lithofacies and basin, and saturations can be difficult to calculate from logs, given variations in Archie parameters, Rw, and mineralogy. It is not unusual to have a gas-in-place uncertainty of plus or minus 50%, even in fields with large datasets and long production histories. What can be done to reduce this uncertainty?

3. Net pay thickness: Multiple cutoffs (permeability, porosity, clay volume, water saturation) are used to count net pay, and the cutoff values tend to be different for every reservoir. How do we calibrate the cutoffs? Can we reasonably compare net pay thickness from one reservoir to the next? How do we verify that poorer quality pay actually contributes?

4. The hydraulic connectivity of producing sandbodies. Some fields can effectively drain sandbodies with a well spacing of 80 acres, whereas others are encountering untapped sandbodies at a 10-acre spacing or less. Can we predict the degree of connectedness and how it changes across a field, using geoscience data, or can we only understand this through pilot infill drilling projects and well testing?

5. The role of "sweet-spots": A small minority of wells commonly have much higher EUR's than the rest. What geological factors are responsible for this and what tools and techniques can we use to identify them? Should we accept the notion that these are "statistical plays" and that the large variation in EUR's can neither be understood nor used to high-grade drilling opportunities?

6. The enigma of natural fractures: Tremendous effort has been devoted to locating fractures, which can serve as higher permeability gas conduits. Techniques used for this purpose include seismic attributes, core description, and remote sensing, among many others. Have any techniques (or combination of techniques) been shown consistently to predict where fractures will occur? Further, when found, do these fractures contribute gas or water?

7. Contributions of other lithologies: Tight sands are charged from coals or shales that may be in stratigraphic contact with the sands over very large areas. Do these lithologies "re-charge" the sands as they are depleted, and if so, how do we quantify their contribution?

8. Well decline behavior: Tight sand wells exhibit very flat initial decline-curve behavior due to transient flow and/or contributions from multiple layers. This decline steepens with time as wells transition to boundary-dominated flow. What geological factors control this behavior and how can these insights be used to help predict the long-term decline behavior of wells?

This presentation briefly explores these factors, followed by a discussion with participants regarding their experiences in tight gas

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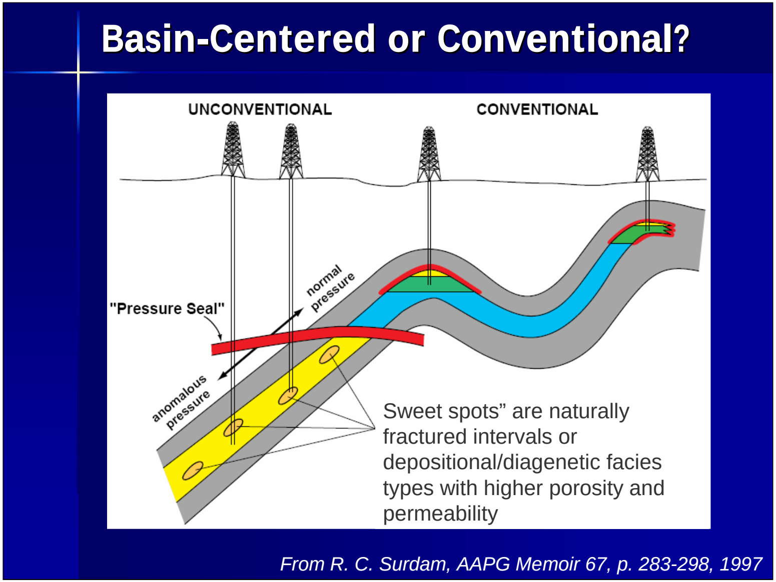
Estimating Resources and Reserves in Tight Sands: Geological Complexities and Controversies

Creties Jenkins
DeGolyer and MacNaughton

AAPG GTW on the Geological Aspects of Estimating Resources and Reserves, Houston, Sept. 11, 2009



Presenter's Notes:

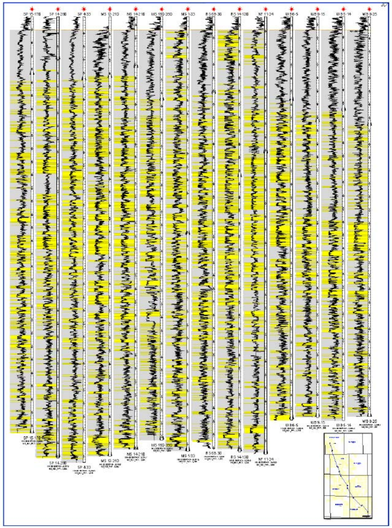
1. <u>The nature of the gas accumulation as either "basin-centered" or "conventional":</u> Basin-centered accumulations are interpreted as areally-extensive, overpressured, gas-charged compartments with technically recoverable volumes ranging from tens to hundreds of trillions of cubic feet of gas. However, if the recoverable gas is actually contained in low-permeability conventional traps, then the associated gas volumes are much smaller. Which of these is more common and how do we distinguish them?

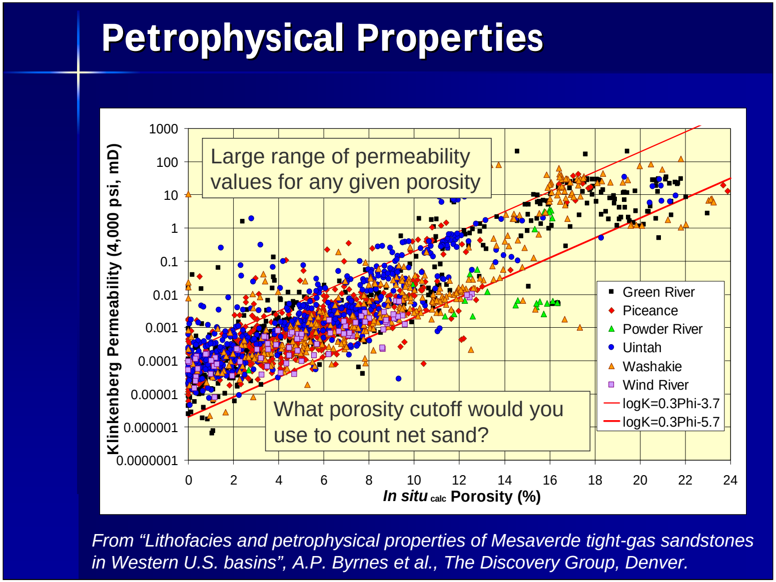
Pinedale "Non-Sand" Pay?

Petrophysical Model Cut-Offs
- Effective Porosity >4%
- Total Water Saturation <65%
- Vshale <40%
- Average Gross Lance 5,781'
- Average Pay Thickness 1,417'

Core analysis shows entire interval to be gas saturated.

How much gas could be recovered from the 4,364 feet of Lance not in pay count?





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2. Petrophysical properties: Relationships between porosity and permeability vary by lithofacies and basin, and saturations can be difficult to calculate from logs, given variations in Archie parameters, Rw, and mineralogy. It is not unusual to have a gas-in-place uncertainty of plus or minus 50%, even in fields with large datasets and long production histories. What can be done to reduce this uncertainty?

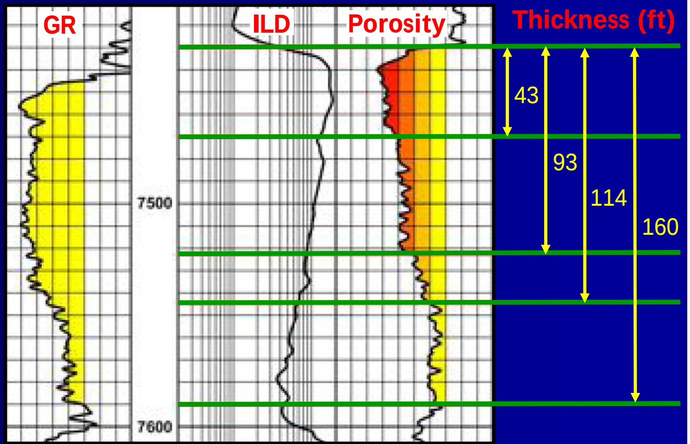
Characteristic of most sandstones, permeability at any given porosity increases with increasing grain size and better sorting though this relationship is further influenced by sedimentary structure and the nature of cementation. Samples exhibiting permeability greater than the empirically defined high limit generally exhibit an anomalous lithologic property that influences core plug permeability such as microfracturing along a fine shale lamina, a microfracture, etc. Conversely, cores exhibiting permeability below the lower limit can exhibit such lithologic properties as churned-bioturbated texture, cross-bedding with fine-grained or shaly bed boundaries that are sub-parallel or perpendicular to flow and act as restrictions to flow, or high clay content.

Permeability in low porosity samples and particularly below approximately 1% is generally a complex function of final pore architecture after cementation and is only weakly correlated with original grain size.

The estimated range in permeability at any given porosity increases with porosity and can be as great as four orders of magnitude for > 12% but decreases to approximately 20X near =0%.

Although in unconsolidated grain packs the influence of size and sorting can be quantified, in consolidated porous media the influence of these variables and particularly the influence of sedimentary structure can be non-linear and non-continuous. For example coarse grain size results in high permeability but if the sand was deposited in a trough cross-beddedstructure and there is some orientation of bedding in the core that is not parallel to flow then the permeability can be significantly reduced. The rock classification system used works to both quantify and make continuous these parameters but has limits.

Net Pay Thickness



From Scott Rees, NSAI, DUG Workshop, April 2009

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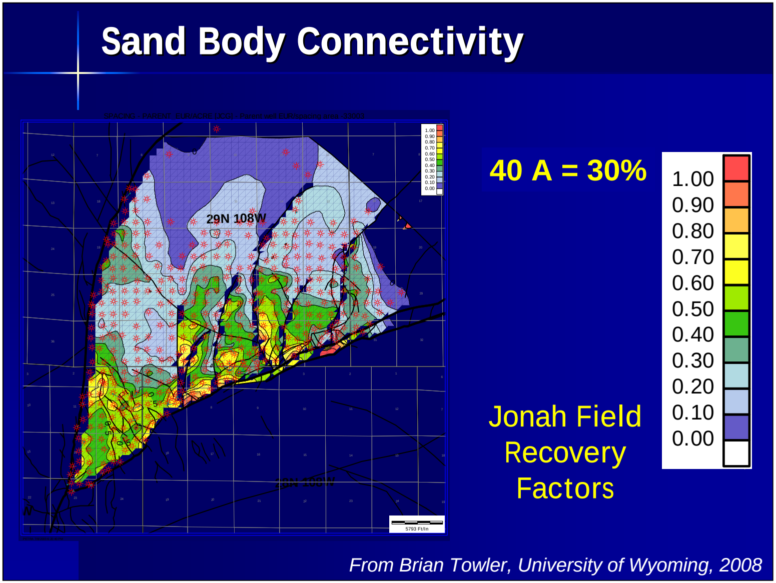
3. Net pay thickness: Multiple cutoffs (permeability, porosity, clay volume, water saturation) are used to count net pay, and the cutoff values tend to be different for every reservoir. How do we calibrate the cutoffs? Can we reasonably compare net pay thickness from one reservoir to the next? How do we verify that poorer quality pay actually contributes?



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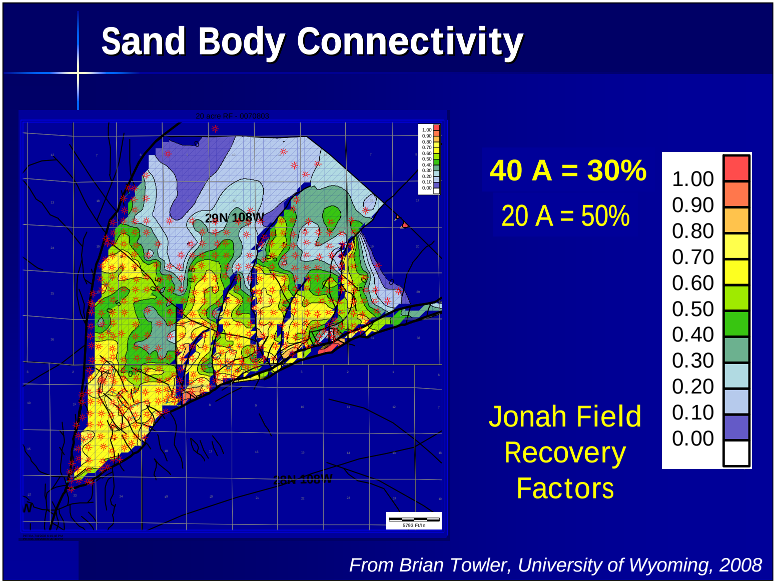
4. <u>The hydraulic connectivity of producing sandbodies</u>. Some fields can effectively drain sandbodies with a well spacing of 80 acres, while others are encountering untapped sandbodies at a 10-acre spacing or less. Can we predict the degree of connectedness and how it changes across a field using geoscience data, or can we only understand this through pilot infill drilling projects and well testing?

These RF are based on volumetric infill analysis completed for the LTRMP.

Recovery Factors are based on the full field, previous numbers only took into account the economic area.

The slide is animated to show how the RF changes with infill drilling (one map for each RF).



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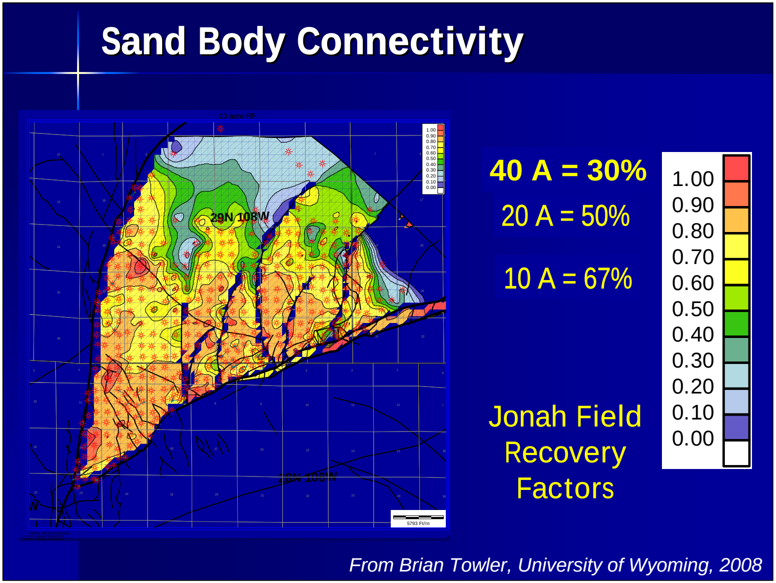

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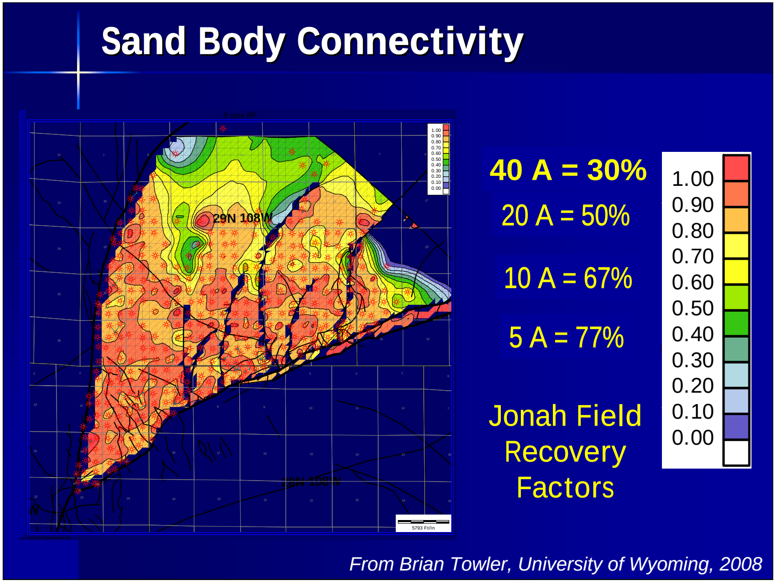

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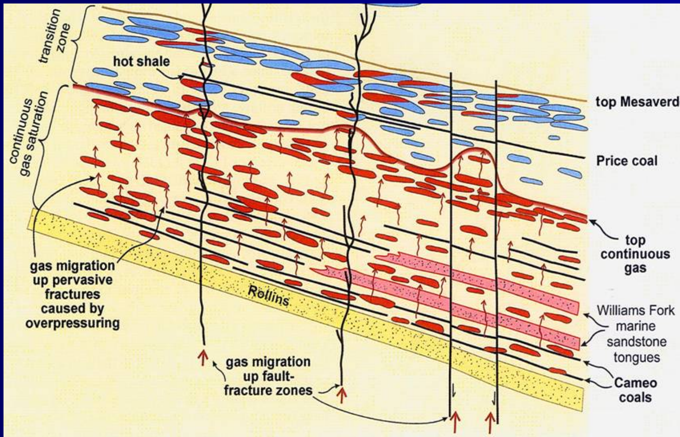
Sweet Spots



From Larry Meckel

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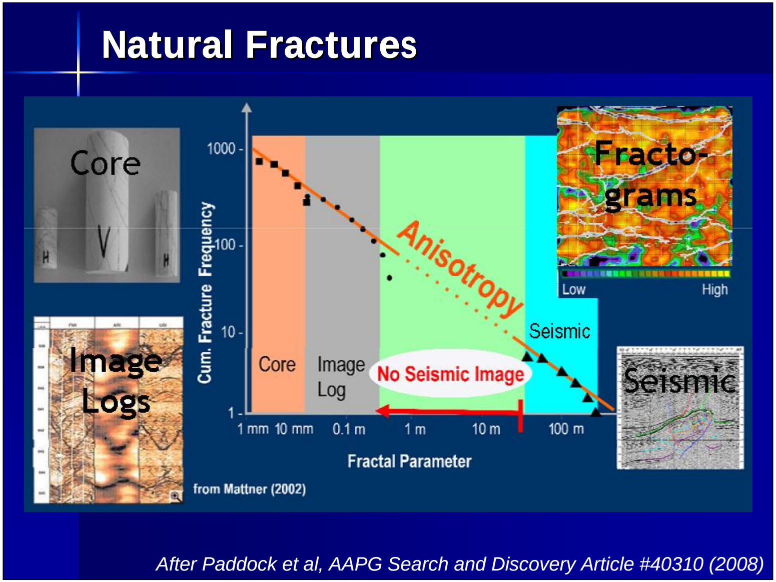
5. <u>The role of "sweet-spots"</u>: A small minority of wells commonly have much higher EUR's than the rest. What geological factors are responsible for this and what tools and techniques can we use to identify them? Should we accept the notion that these are "statistical plays" and that the large variation in EUR's can neither be understood nor used to high-grade drilling opportunities?



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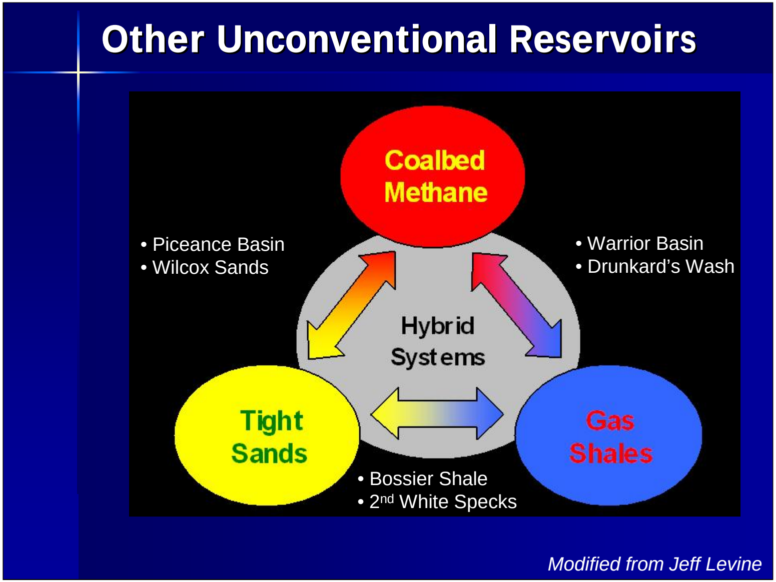

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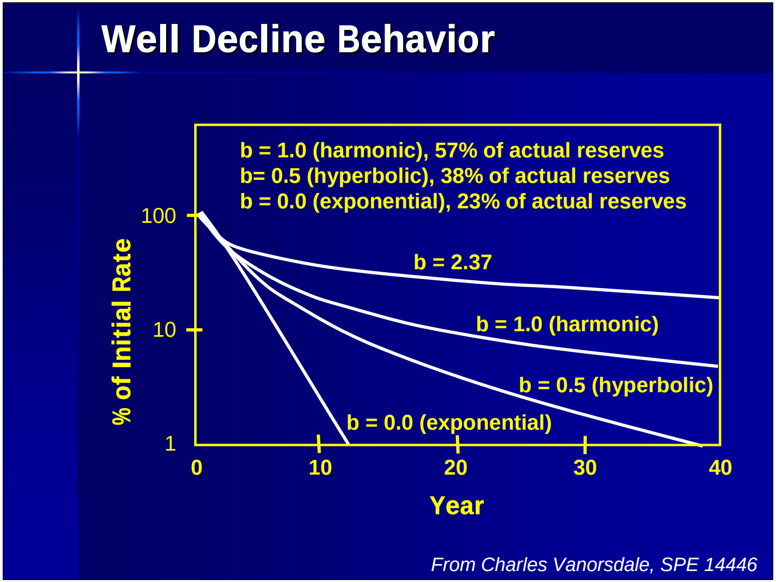

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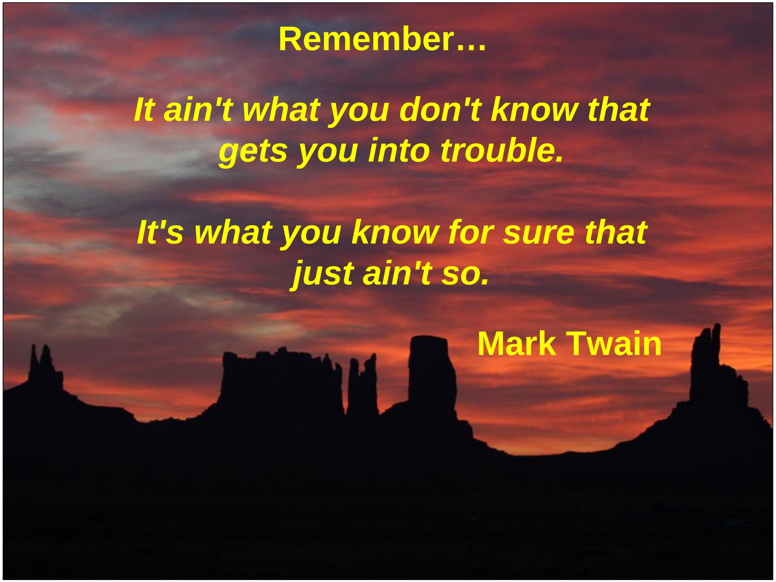
Summary of Issues

- Basin-centered or conventional
- Petrophysical properties
- Net pay thickness
- Sandbody connectivity
- Sweet spots
- Natural fractures
- Other unconventional reservoirs
- Well decline behavior


Remember…
It ain't what you don't know that gets you into trouble.
It's what you know for sure that just ain't so.
Mark Twain