Predicting Initial Production of Granite Wash Horizontal Wells Using Old Well Logs and Cores

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Granite Wash Workshop

Strong correlation, eh?

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Method and Outline for Talk

• Determine production contribution log (IP FOM)
  – Based on volumetrics and permeability
  – Petrophysics and Log Analysis Steps
• Sum over a reservoir interval and upscale to reservoir-scale permeability derived from well production data (PI parameter)
• Use PI to predict initial production of potential horizontal wells
  – Generate maps of PI parameter
  – Compare to production data

Note: more slides are included here than will be covered in the talk.

Twelve-Step Granite Wash Log Analysis

**Groundwork**
1. Geology discussions
2. Core & cuttings study
3. Log triage and repair
4. GR & neutron environmental corrections
5. Facies analysis

**Calculations**
6. VShale
7. Total & effective porosity
8. Saturation
9. Permeability & production
10. Flagging
11. Summations
12. Fraccability
Truax
1d) Tx panhandle granite wash characteristics

- Source material is mostly uplifted Paleozoic sediments & carbonate, plus Precambrian granite, diabase, and granodiorite. There are a few thin beds of limestone and shale interspersed. Composition varies widely.
- The depositional environment is primarily stacked deltas, river channels, and turbidites. Paleoslopes range from steep to quiescent. There are many beds that contain re-worked material.
- Feldspar content, grain size, and alteration vary widely and wildly, vertically and areally. Chorite is ubiquitous.
- Reservoirs are often separated by 10-30 ft thick marine and terrestrial shales and flooding deposits.
1e) Tx panhandle granite wash exploitation

- There are about 100,000 vertical wells through the granite wash; many reach below to the Morrow and other horizons.
- Perms of present-day reservoirs are typically near 500 nd.
- Two or three 5000-ft laterals are typically drilled per section in one horizon. There are often stacked laterals.
- Slickwater fracs appear to be the most effective.
- Fracking severely “bashes” adjacent producing wells where pressures have been lowered.
- Prospecting is done by sifting through production data and old logs.
- Recently there has been some drilling of “pilot” holes, or vertical holes before the turn, with coring and logging.
1f) box 11

1h) box 10
1i) core and hi-res log

2a) Core permeability vs porosity

Slope: 3 p.u. per log cycle

Intercept: Tuning Parameter

Core perm (md)

Core Porosity

y = 0.0001e^{0.014x}

R² = 0.96

Klinkenberg
2b) More core permeability

![Core permeability graph]

2c) What is core porosity?

![Core porosity data]
2d) What is core porosity?

2e) Volume fractions of a formation

- Dry Solids: $V_{\text{dry solids}}$ or $1 - \phi_t$
- Wet Solids: $V_{\text{wet solids}}$ or $1 - \phi_e$
- Total porosity: $\phi_t$
- Effective porosity: $\phi_e$
- Matrix: $V_{\text{matrix}}$
- Dry Clays & Silt: $V_{\text{ds}}$
- Clay-bound water: $V_{\text{wo}}$
- Capillary-bound water: $V_{\text{cap}}$
- Free water: $V_{\text{wf}}$
- Oil: $V_{\text{oil}}$
- Gas: $V_{\text{gas}}$
- Shale: $V_{\text{sh}}$
- Effective water: $V_{\text{we}}$
- Hydrocarbons: $V_{\text{hc}}$
- Total water: $V_{\text{wt}}$
- Total irreducible water: $V_{\text{BVIW}}$

- $S_{\text{wt}} = V_{\text{wt}} / \phi_t$
- $S_{\text{we}} = V_{\text{we}} / \phi_e$

Free Fluid: FFI or $\phi_f$
3a) Triage: Decent log

3b) Triage: Jumpy log
4e) Log Facies based on six wells

- Use Buckles plot to assess irreducible water for log facies
- Include results in Tixier or Coates perm calculations

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9) Definitions

Log curve

\[ \text{IP FOM} = \sqrt{k_r \phi S_h} \]

Log summation across interval

\[ PI_{\text{Indicator}} \equiv \sum h_i \sqrt{k_r \phi S_h} \]

Example 1a
Example 3

Example 4
(sorry about the poor resolution)
Reservoir Accounting

1. The initial production rates of a horizontal well in linear flow will be driven primarily by a lumped parameter $J_{lt}$, which is dependent on both rock quality (perm $- k$) and stimulation effectiveness (total frac surface area $A_f$), and pressure drawdown imposed on the well.

2. For comparing wells of similar initial reservoir pressures we can skip normalizing the initial formation volume factor $B_i$, initial viscosity $\mu_i$, and approximate initial total compressibility $c_{ti}$ using hydrocarbon saturation $S_h$. The permeability $k$ is effective to primary hydrocarbon phase.

3. The flow rate of each flow unit ($i$) will be proportional to the net pay $h$, the fracture half-length propagated in each unit $x_f$, and its flow capacity. Fracture design related variations in $x_f$ can be modeled as needed, for simplicity assume rectangular geometry – equal in all units.

4. Early life total flow rate in in tight reservoirs is the sum of the individual flow units; ignore crossflow. The total well rate is the sum of the net pay and flow capacity of each flow unit. For simplicity, the flow units can be the log sampling interval $\frac{1}{2}$ feet intervals.

5. The productivity index indicator is defined and in LINE’s experience is correlated to well performance; and can be used as a rock quality index.

6. The upscaled* values of permeability can be calculated from the PI indicator for the tuning to well production results.

Review SPE 139097, 166468, and 166468 for theory and methods to normalize pressure drawdown, and completion practices.

Lookback – Hz. Kansas City Oil Program

- The Kansas City is a matrix-flow dominated prolific reservoir in the Granite Wash play in Wheeler TX.
- Identical completion practices and pressure drawdown was used in Linn operated wells.
- Clear correlation between highest oil production rates seen in these hz. wells compared to log-calculated productivity index.
IP and Net Pay comparison

Truax

Dyco Granite Wash ‘A’ Example
IP vs. Productivity Indicator

Productivity Indicator = Net Pay * Sqrt(Epor x K* x Shc)

Initial correlation based on 3 wells with data.

R² = 0.8579

y = 19455x

Existing Wells
Productivity Estimate
Linear (Existing Wells)
Dyco Granite Wash ‘A’ Example

Log Estimated vs. Actual Productivity

"Single" wells exhibit increased productivity that suggests significant contribution from natural fractures.

Dyco Granite Wash ‘B’

Permeability Upscaling

Most likely perms based on 75% cluster efficiency.
Dyco Granite Wash ‘B’
PI Indicator vs. Peak Rate

PI Indicator vs. Peak Gas Rate (Mcfpd)

$y = 13749x$
$R^2 = 0.5402$

2009 Completion
2nd or 3rd Well in Section
Damage (Low FCD)

Productivity Index = Net Pay x Sqrt(Epor x k* x SHC)

Dyco Britt
PI Indicator
2 Stream IP vs PI Indicator - Britt

First Wells
Second Wells
Linear (First Wells)
Conclusions

- Maps based on PI can be used as supplements to more traditional net pay maps.
- PI is a valuable predictor of performance of proposed wells.
- This concept has been used over the past few years to improve bottom line success.