Orientation on the Oil and Gas Industry
Discussion: *World Oil Resources (Circa 1920)*

- The known deposits of oil and gas in 1920.
- Offshore deposits would not have been discovered.
- Most deposits were discovered by seeps.
AUSTRALIA AND NEW ZEALAND
A moderate production of oil may ultimately be attained in New Zealand, but there is apparently only a remote chance that oil fields of more than local importance will be found in either Australia or New Zealand. Some 60,000 barrels of oil have been produced in New Zealand, and seepages have been noted in as yet untested localities. Small quantities of oil and gas found at various localities in southeastern Australia appear to indicate that with further drilling and with more detailed structural mapping in Australian areas oil fields will be found. No major production is, however, probable.

AFRICA
Africa is quite certainly devoid of major oil deposits, the surface of much of the continent being covered by rocks definitely barren of oil. Such oil production as is now obtained in Africa (1,100,000 barrels annually) comes almost entirely from the Egyptian fields on the Red Sea coast opposite the Sinai Peninsula, a tiny amount also being produced in Algeria. Some oil manifestations occur in British and Italian Somaliland, south of the Gulf of Aden; in Madagascar; doubtfully in Portuguese East Africa; in Natal; in Angola; and at various localities around the shore of the Gulf of Guinea; but it appears unlikely that extensive or other than locally important development is probable in any of these regions.

Discussion: World Oil Resources (Circa 1920)
● Note predictions in red text (all are wrong).
● Production analysis came about due to taxation.
● Early correlation of ultimate recovery given as "appraisal."
Formation Evaluation
Developments In Well Logging

1846 — First temperature log by Lord Kelvin
1883 — Single electrode resistivity log patented by Fred Brown
1912 — First surface resistivity survey (Conrad Schlumberger)
1927 — First multi-electrode electrical survey in a wellbore (in France)
1929 — First electrical survey in California (also Venezuela, Russia, India)
1931 — First SP log, first sidewall core gun
1932 — First deviation survey, first bullet perforator
1933 — First commercial temperature log
1936 — First SP dipmeter
1937 — First electrical log in Canada (for gold in Ontario)
1938 — First gamma ray log, first neutron log
1939 — First electrical log in Alberta
1941 — Archie’s Laws published, first caliper log
1945 — First commercial neutron log
1947 — First resistivity dipmeter, first induction log described
1948 — First microlog, first shaped charge perforator
1948 — Rw from SP published
1949 — First laterolog

(http://www.spec2000.net/02-history1.htm).
Developments In Well Logging

1952 — First microlaterolog
1954 — Added caliper to microlog
1956 — First commercial induction log, nuclear magnetic log described
1957 — First sonic log, first density log
1960 — First sidewall neutron log (scaled in porosity units)
1960 — First thermal decay time log
1961 — First digitized dipmeter log
1962 — First compensated density log (scaled in density/porosity units)
1962 — First computer aided log analysis, first logarithmic resistivity scale
1963 — First transmission of log images by telecopier (predecessor to FAX)
1964 — First measurement while drilling logs described
1965 — First commercial digital recording of log data
1966 — First compensated neutron log
1969 — First experimental PE curve on density log
1971 — First extraterrestrial temperature log Apollo 15
1976 — First desktop computer aided log analysis system LOG/MATE
1977 — First computerized logging truck
1982 — First use of email to transmit data via ARPaNet (predecessor to Internet)
1983 — First transmission of log data by satellite from wellsite to computer center
1985 — First resistivity microscanner.

Orientation to Practice/Reservoir Scales

**Discussion:** Orientation to Practice/Reservoir Scales
- Schematic explains wireline log acquisition approach.
- Reservoir scales — at least 12 orders of magnitude ($1 \times 10^{12}$).
- Big questions: How to upscale? How to downscale?
## Common Well Logs — and What They Measure

<table>
<thead>
<tr>
<th>Log</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamma Ray</td>
<td>Lithology/Mineralogy</td>
</tr>
<tr>
<td>Spontaneous Potential</td>
<td>Porosity</td>
</tr>
<tr>
<td>Sonic</td>
<td>Fluid Type</td>
</tr>
<tr>
<td>Density</td>
<td>Fluid Saturation</td>
</tr>
<tr>
<td>Neutron</td>
<td>Permeability</td>
</tr>
<tr>
<td>Resistivity</td>
<td>Stratigraphy</td>
</tr>
<tr>
<td>Nuclear Mag. Resonance</td>
<td>Downhole Pressure</td>
</tr>
<tr>
<td>Photoelectric Effect</td>
<td>Geophysics</td>
</tr>
<tr>
<td>Wireline Testing</td>
<td></td>
</tr>
<tr>
<td>Well Test</td>
<td></td>
</tr>
<tr>
<td>Dipmeter</td>
<td></td>
</tr>
<tr>
<td>Borehole Image</td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td></td>
</tr>
</tbody>
</table>

Background on Well Completions
And Production Operations
How is Oil and Gas Produced from Wells?

- **Procedure:**
  - The well is "completed" (drilled and lined with pipe) through the zone or zones of interest. The pipe is then "perforated" at particular locations and oil and/or gas are then produced to the surface using natural or artificial lift.

- **Practice:**
  - Although gas wells virtually always produce to surface under their own energy (except in case of water or condensate loading), oil wells often require pumping or other gas injection (gas lift) methods (i.e., artificial lift) to produce fluid to surface.
  - In some parts of the world, oil is actually mined just like other minerals such as coal.
Well Deliverability:

- The first efforts to analyze well performance were an attempt to quantify well potential — \textit{not to estimate reservoir properties.}

- The original well deliverability relation was \textit{completely empirical} (derived from observations), and is given as:

\[ q = C\left(p^2 - p_{wf}^2\right)^n \]

- This relationship is rigorous for low pressure gas reservoirs, \((n=1\) for laminar flow).
Discussion: Well Deliverability (4-point test)

- Probably oldest "reservoir engineering" technique.
- Assumption of pseudosteady-state flow is the weakest link in analysis.
- Does not directly relate time, rate, and pressure performance.

\[ q = C\left(\bar{p}^2 - p_{wf}^2\right)^n \]
The reservoir is the primary consideration; but we also need to address:
- The well completion.
- The tubulars.
- The surface facilities.
- The reservoir fluid(s).

**Petroleum Flow System:** (after Fonseca)
- Every component requires design.
- Monitor everything (within reason) — rates, pressures, ...
- Maintenance is a key aspect of production operations.
Common Pressure Transient Test Data:
- Bottomhole pressures (high frequency/high resolution)
- Separator flowrates (on the hour or day (at best))

Common Production Data:
- Wellhead pressures (daily)
- Separator flowrates (daily)

Surface Measurements
- Pressure
- Temperature

Manual or Automated Rate Control

Bottomhole Measurements:
- Pressure
- Temperature

Production Separation/Measurement Systems

Downstream:
- Pressure
- Temperature
- Flowrate
- Fluid sampling

Separation/Measurement Systems:
- Measurements are taken where/when convenient.
- Data acquisition/control systems may not be synchronized.
- Accuracy in rate/volume measurements is critical.
Artificial Lift — Rod Pumps

- **Sucker Rod Pumps:**
  - "Pump Jacks" are very familiar in mature oil fields.
  - Easy to install and operate, relatively low maintenance.
  - Limited by depth and certain producing conditions (i.e., gas-blocking, foaming, flowing/surging well behavior).

- **Gas Lift:** (image on next page)
  - Conceptually very efficient — gas injection lightens fluid column and enables much more efficient production.
  - VERY simple in operation, virtually no maintenance.
  - Does require design and occasional operation intervention (changing the gas lift valves/mandrels).
  - Requires a source of natural gas.
Artificial Lift — Gas Lift

Typical gas-lift installation.
Note spacing and unloading sequence of gas-lift valves (or mandrels).
**Hydraulic Fracturing:** A hydraulically-created fracture can "split" the formation to allow a direct conduit for production to the well.

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**Sketch of a restricted vertical fracture.**

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**Hydraulic Fracturing: (single vertical fracture)**

- Fracture is produced by hydraulic pressure.
- Fracture propagates perpendicular to least principal stress.
- Fractures at depth are vertical (cannot "lift" overburden).
Introduction to Reservoir Fluids
## Classification of Reservoir Fluids (Schlumberger)

### Classification of Reservoir Fluids: GOR, Oil and Gas Gravities

<table>
<thead>
<tr>
<th></th>
<th>GOR (scf/bbl)</th>
<th>API Gravity (°API)</th>
<th>Gas Gravity (air = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet gas</td>
<td>15–100,000</td>
<td>50–70</td>
<td>0.65–0.85</td>
</tr>
<tr>
<td>Condensed gas</td>
<td>3–15,000</td>
<td>50–70</td>
<td>0.65–0.85</td>
</tr>
<tr>
<td>Volatile oil</td>
<td>3,000</td>
<td>40–50</td>
<td>0.65–0.85</td>
</tr>
<tr>
<td>Non-volatile oil</td>
<td>100–2,500</td>
<td>30–40</td>
<td>0.80–0.90</td>
</tr>
<tr>
<td>Heavy oil</td>
<td>0</td>
<td>10–30</td>
<td></td>
</tr>
<tr>
<td>Tar/bitumen</td>
<td>0</td>
<td>&lt;10</td>
<td></td>
</tr>
</tbody>
</table>

### Classification of Reservoir Fluids: Composition (mol% Cₙ)

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
<th>C₅</th>
<th>C₆+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry gas</td>
<td>88</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Condensate</td>
<td>71</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Volatile oil</td>
<td>60</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Nonvolatile oil</td>
<td>41</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>Heavy oil</td>
<td>11</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>Tar/bitumen</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### C₇+ Fraction, Oil FVF and Color of Typical Reservoir Fluids

<table>
<thead>
<tr>
<th></th>
<th>Nonvolatile Oil</th>
<th>Volatile Oil</th>
<th>Condensate Gas</th>
<th>Wet Gas</th>
<th>Dry Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase system</td>
<td>Bubblepoint</td>
<td>Bubblepoint</td>
<td>Dewpoint</td>
<td>Dewpoint</td>
<td>No change</td>
</tr>
<tr>
<td>C₇+</td>
<td>&gt; 20%</td>
<td>20–12.5%</td>
<td>&lt; 12.5%</td>
<td>&lt; 4%</td>
<td>&lt; 0.8%</td>
</tr>
<tr>
<td>B₀ † at P₀ ‡</td>
<td>&lt; 2</td>
<td>&gt; 2</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Color</td>
<td>Dark</td>
<td>Colored</td>
<td>Light color</td>
<td>Clear, white</td>
<td>No liquid</td>
</tr>
</tbody>
</table>

† B₀, oil formation volume factor
‡ P₀, bubblepoint pressure

### Discussion: PTA — Classification of Reservoir Fluids
- Generic guidelines on properties of reservoir fluids.
- Useful to assess dominant component(s) and properties.
- Often assume that a system is dry gas or non-volatile oil.
Classification of Reservoir Fluids (McCain)

- **Black Oil Reservoirs:**
  - GOR < 1,000 SCF/STB
  - Density less than 45° API
  - Reservoir temperatures < 250°F
  - Oil FVF < 2.00 (low shrinkage oils)
  - Dark green to black in color
  - C7+ composition > 30%

- **Volatile Oil Reservoirs:**
  - 1,000 < GOR < 8,000 SCF/STB
  - Density between 45-60° API
  - Oil FVF > 2.00 (high shrinkage oils)
  - Light brown to green in color
  - C7+ composition > 12.5%

- **Gas Condensate Reservoirs:**
  - 7,000 < GOR < 100,000 SCF/STB
  - Density greater than 60° API
  - Light in color
  - C7+ composition < 12.5%

- **Wet Gas Reservoirs:**
  - GOR > 100,000 SCF/STB
  - No liquid is formed in the reservoir.
  - Separator conditions lie within phase envelope and liquid is produced at surface.

- **Dry Gas Reservoirs:**
  - GOR > 100,000 SCF/STB
  - No liquid produced at surface.

From:
**Fluid Types and Petroleum Products**

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**a. Reservoir Fluid Types.**


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**b. Petroleum products identified according to carbon number.**

Orientation — Pressure Transient Analysis
**PTA — Plots/Flow Regimes/Analysis**

<table>
<thead>
<tr>
<th>Flow Regime</th>
<th>Cartesian</th>
<th>Plot</th>
<th>Log-log</th>
<th>Semilog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellbore storage</td>
<td>Straight line</td>
<td>$\sqrt{\Delta t}$</td>
<td>Unit slope on $\Delta p$ and $p'$</td>
<td>Positive $s$</td>
</tr>
<tr>
<td></td>
<td>Slope $\rightarrow C$</td>
<td>$\Delta t$</td>
<td>$\Delta p$ and $p'$ coincide</td>
<td>Negative $s$</td>
</tr>
<tr>
<td></td>
<td>Intercept $\rightarrow \Delta t_c$</td>
<td>$\sqrt{\Delta t}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear flow</td>
<td>Straight line</td>
<td>$\sqrt{\Delta t}$</td>
<td>Slope $=\frac{1}{2}$ on $p'$ and on $\Delta p$ if $s = 0$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slope $= m_{f} \rightarrow L_f$</td>
<td>$\Delta t$</td>
<td>Slope $&lt; \frac{1}{2}$ on $\Delta p$ if $s \neq 0$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept $\rightarrow$ fracture damage</td>
<td>$\Delta t$</td>
<td>$p'$ at half the level of $\Delta p$</td>
<td></td>
</tr>
<tr>
<td>Bilinear flow</td>
<td>Straight line</td>
<td>$\sqrt{\Delta t}$</td>
<td>Slope $= \frac{1}{4}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slope $= m_{ slid} \rightarrow C_{ id}$</td>
<td>$\Delta t$</td>
<td>$p'$ at $\frac{1}{4}$ level of $\Delta p$</td>
<td></td>
</tr>
<tr>
<td>First IARF (high-$k$ layer, fractures)</td>
<td>Decreasing slope</td>
<td>$p'$ horizontal at $p'_D = 0.5$</td>
<td>Straight line</td>
<td></td>
</tr>
<tr>
<td>Transition</td>
<td>More decreasing slope</td>
<td>$\Delta p = \lambda e^{-2s}$ or $B'$</td>
<td>Straight line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$p'_D = 0.25$ (transition)</td>
<td>$&lt; 0.25$ (pseudosteady state)</td>
<td>$\Delta p_{hr} \rightarrow s$</td>
<td></td>
</tr>
<tr>
<td>Second IARF (total system)</td>
<td>Similar slope to first IARF</td>
<td>$p'$ horizontal at $p'_D = 0.5$</td>
<td>Straight line</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta p_{hr} \rightarrow s$</td>
<td>$\Delta p_{hr} \rightarrow s$</td>
<td></td>
</tr>
<tr>
<td>Single no-flow boundary</td>
<td></td>
<td>$p'$ horizontal at $p'_D = 1.0$</td>
<td>Straight line</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\Delta p_{hr} \rightarrow s$</td>
<td>$\Delta p_{hr} \rightarrow s$</td>
<td></td>
</tr>
<tr>
<td>Outer no-flow boundaries (drawdown tests only)</td>
<td>Straight line</td>
<td>$\Delta p$ and $p'$ coincide</td>
<td>Unit slope for $\Delta p$ and $p'$</td>
<td>Increasing slope</td>
</tr>
<tr>
<td></td>
<td>Slope $= m' \rightarrow \phi A_h$</td>
<td>$\Delta p$ and $p'$ coincide</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion: PTA — Plots/Flow Regimes/Analysis**

- **Wellbore Storage (WBS):** Universal phenomena.
- **Infinite-Acting Radial Flow (IARF):** Traditional Flow Regime ($k > 0.01$ md).
- **Fractured Wells:** Linear and Bi-Linear flow possible.
Properties Obtained from PTA

RESERVOIR PROPERTIES OBTAINABLE FROM VARIOUS TRANSIENT TESTS

- **DST's**
  - Reservoir behavior
  - Permeability
  - Skin
  - Fracture length
  - Reservoir pressure
  - Reservoir limit
  - Boundaries

- **Buildup tests**
  - Reservoir behavior
  - Permeability
  - Skin
  - Fracture length
  - Reservoir pressure
  - Boundaries

- **Step-rate tests**
  - Falloff tests
  - Interference and pulse tests
  - Communication between wells
  - Reservoir type behavior
  - Porosity
  - Interwell permeability
  - Vertical permeability
  - Properties of individual layers
  - Horizontal permeability
  - Vertical permeability
  - Skin
  - Average layer pressure
  - Outer boundaries

Discussion: Properties Obtained from PTA

- **Drawdown Tests (DD):** Difficult in practice (rates!).
- **Buildup Tests (BU):** Most common PTA approach.
- **Falloff Tests (FO):** Same as buildup tests (injection wells).
PTA — Example Pressure Transient Tests

Type Curve Analysis — SPE 12777 (Buildup Case) (Well in an Infinite-Acting Homogeneous Reservoir)

Reservoir and Fluid Properties:
- \( r_w = 0.29 \text{ ft} \), \( h = 107 \text{ ft} \),
- \( c_i = 4.2 \times 10^{-3} \text{ psi}^{-1} \), \( \phi = 0.25 \) (fraction)
- \( \mu_i = 2.5 \text{ cp} \), \( B_i = 1.06 \text{ RB/STB} \)
- \( \phi_i = 0.237 \) (dim-less)

Production Parameters:
- \( q_i = 174 \text{ STB/D} \)
- \( t_i = 150 \text{ hours} \)
- \( k = 10.95 \text{ md} \)
- \( \phi_i = 0.25 \) (fraction)
- \( \mu_i = 2.5 \text{ cp} \)

Match Results and Parameter Estimates:
- \( C_{De} = 0.0311 \text{ bbl/psi} \)
- \( \alpha = 1.06 \text{ RB/STB} \)
- \( \beta = -1.93 \text{ (dim-less)} \)
- \( \phi = 0.25 \) (fraction)
- \( \mu = 2.5 \text{ cp} \)
- \( c_i = 0.09 \text{ psi} \)

Legend:
- \( p_D \) Data
- \( p_{Df} \) Solution
- \( p_{Dg} \) Solution

Legend: Radial Flow Type Curve
- \( p_D = 1/2 \)
- \( p_{Df} = 1 \)
- \( p_{Dg} = 1 \)

Type Curve Analysis — SPE 18160 (Buildup Case) (Well in an Infinite-Acting Dual-Porosity Reservoir (tm) — \( \omega = 0.237, \alpha = 1 \times 10^{-3} \))

Reservoir and Fluid Properties:
- \( r_w = 0.29 \text{ ft} \), \( h = 7 \text{ ft} \),
- \( c_i = 2 \times 10^{-3} \text{ psi}^{-1} \), \( \phi = 0.05 \) (fraction)
- \( \mu_i = 0.3 \text{ cp} \), \( B_i = 1.5 \text{ RB/STB} \)
- \( \phi_i = 0.057 \) (fraction)

Production Parameters:
- \( \phi_f = 0.5755 \text{ RB/Mscf} \)
- \( \mu_f = 0.0174 \text{ cp} \)
- \( B_g = 30 \text{ ft} \)

Match Results and Parameter Estimates:
- \( \phi_f / \phi = 0.018 \text{ psi}^{-1} \), \( C_{De} = 1 \) (dim-less)
- \( t_{Dxf} / C_f = 150 \text{ hours} \), \( k = 678 \text{ md} \)
- \( C_f = 0.0311 \text{ bbl/psi} \), \( s = 1.93 \) (dim-less)
- \( \omega = 0.237 \) (dim-less), \( \alpha = \phi \cdot 0.001 \) (dim-less)
- \( \lambda = 2.13 \times 10^{-5} \) (dim-less)
- \( \phi_f = 0.01 \) (dim-less)
- \( C_f = 1000 \) (dim-less), \( x_f = 37 \text{ hours} \)

Legend:
- \( p_D \) Data
- \( p_{Df} \) Solution
- \( p_{Dg} \) Solution

Legend: Type Curve
- \( p_D = 1/2 \)
- \( p_{Df} = 1 \)
- \( p_{Dg} = 1 \)

Type Curve Analysis — SPE 9975 Well 12 (Buildup Case) (Well with Infinite Conductivity Hydraulic Fractured)

Reservoir and Fluid Properties:
- \( r_w = 0.33 \text{ ft} \), \( h = 45 \text{ ft} \),
- \( c_i = 6.4 \times 10^{-3} \text{ psi}^{-1} \), \( \phi = 0.057 \) (fraction)
- \( \mu_i = 0.0174 \text{ cp} \), \( B_i = 1.2601 \text{ RB/Mscf} \)
- \( \phi_i = 0.0034 \) (fraction)

Production Parameters:
- \( q_i = 325 \text{ Mscf/D} \)
- \( t_i = 37 \text{ hours} \), \( k = 0.076 \text{ md} \)
- \( C_i = 1000 \) (dim-less), \( x_i = 3.681 \text{ ft} \)

Legend:
- \( p_D \) Data
- \( p_{Df} \) Solution
- \( p_{Dg} \) Solution

Legend: Infinite Conductivity Fracture
- \( p_D = 1/2 \)
- \( p_{Df} = 1 \)
- \( p_{Dg} = 1 \)

Type Curve Analysis — SPE 9975 Well 5 (Buildup Case) (Well with Infinite Conductivity Hydraulic Fractured)

Reservoir and Fluid Properties:
- \( r_w = 0.33 \text{ ft} \), \( h = 30 \text{ ft} \),
- \( c_i = 6.37 \times 10^{-3} \text{ psi}^{-1} \), \( \phi = 0.05 \) (fraction)
- \( \mu_i = 0.0297 \text{ cp} \), \( B_i = 0.5755 \text{ RB/Mscf} \)

Production Parameters:
- \( q_i = 1500 \text{ Mscf/D} \)
- \( t_i = 3.681 \text{ ft} \), \( k = 0.0253 \text{ md} \)
- \( C_i = 1000 \) (dim-less), \( x_i = 279.96 \text{ ft} \)

Legend:
- \( p_D \) Data
- \( p_{Df} \) Solution
- \( p_{Dg} \) Solution

Legend: Infinite Conductivity Fracture
- \( p_D = 1/2 \)
- \( p_{Df} = 1 \)
- \( p_{Dg} = 1 \)

a. Case 1 — Unfractured well, homogeneous reservoir.

b. Case 2 — Unfractured well, dual porosity reservoir.

c. Case 3 — Fractured gas well, low fracture conductivity.

d. Case 4 — Fractured gas well, high fracture conductivity.
Example — "East Texas Gas Well"
**Pressure Transient Analysis (Tight Gas)**

Production Data Analysis Plot for East Texas Gas Well
"Summary" History Plot — Rate and Pressure Functions

**Discussion:** Production History Plot — East TX Gas Well

- Good rate and pressure histories.
- Unique case — have both bottomhole and "production" pressure data.
- Analyzed data using both pressure transient and production analysis methods.
"Blasingame" Plot: Production Analysis — East TX Gas Well

- Used surface pressure measurements converted to pwf.
- Minor issues with early-time analysis, good match of performance.
- Excellent match of rate data (red circles).
Discussion: "Log-Log" Plot (Well Test Analysis) — East TX Gas Well

● Used high frequency bottomhole pressure measurements (pws).
● Consistent match of bottomhole and "production" pressure data.
● Note that the "match" is produced from the production analysis.
Simple Data Plots
**Discussion: Various Pressure Plots...**

- **Wellbore Storage:** $\Delta p$ vs. $\Delta t$ (not shown) and $\log(\Delta p)$ vs. $\log(\Delta t)$ yield straight lines.
- **Linear Flow:** $\Delta p$ vs. $\sqrt{\Delta t}$ and $\log(\Delta p)$ vs. $\log(\Delta t)$ yield straight lines.
- **Radial Flow:** $\Delta p$ vs. $\frac{1}{\sqrt{\Delta t}}$ yields a straight line.
Discussion: The Kangaroo as Presented in Different Coordinates

- Simplistic, but effective at explaining what coordinate transforms do to data.
- Beware of "root" plots (e.g., square root and fourth root).
- Note also the effects of the logarithm.