Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Tom BLASINGAME
Petroleum Engineering | Texas A&M University
College Station, TX 77843-3116 (USA)
+1.979.845.2292 | t-blasingame@tamu.edu

Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Historical Aspects of Rate and Pressure Analysis

Historical Aspects: *ANCIENT History* (*Johnson/Bollens*)

Loss Ratio: (_D_-parameter)

$$\frac{1}{D} \equiv -\frac{q}{dq/dt} \equiv -\frac{dq}{dQ}$$

Derivative of Loss Ratio: (_b_-factor)

$$b \equiv \frac{d}{dt}\left[\frac{1}{D}\right] \equiv -\frac{d}{dt}\left[\frac{q}{dq/dt}\right] \equiv q\frac{d}{dQ}\left[\frac{1}{D}\right]$$

Example:

Year	y	Δy	r	Δr	Average, Δr	r from Average	r from Graph
1	5700						
2	3500	2200	1.51				
3	2300	1200	1.92	0.33			
4	1700	600	2.84	0.92			
5	1325	375	3.54	0.70			
6	1050	375	3.82	0.28			
7					0.56	4.38	4.4
8						4.94	5.0
9						5.50	5.6

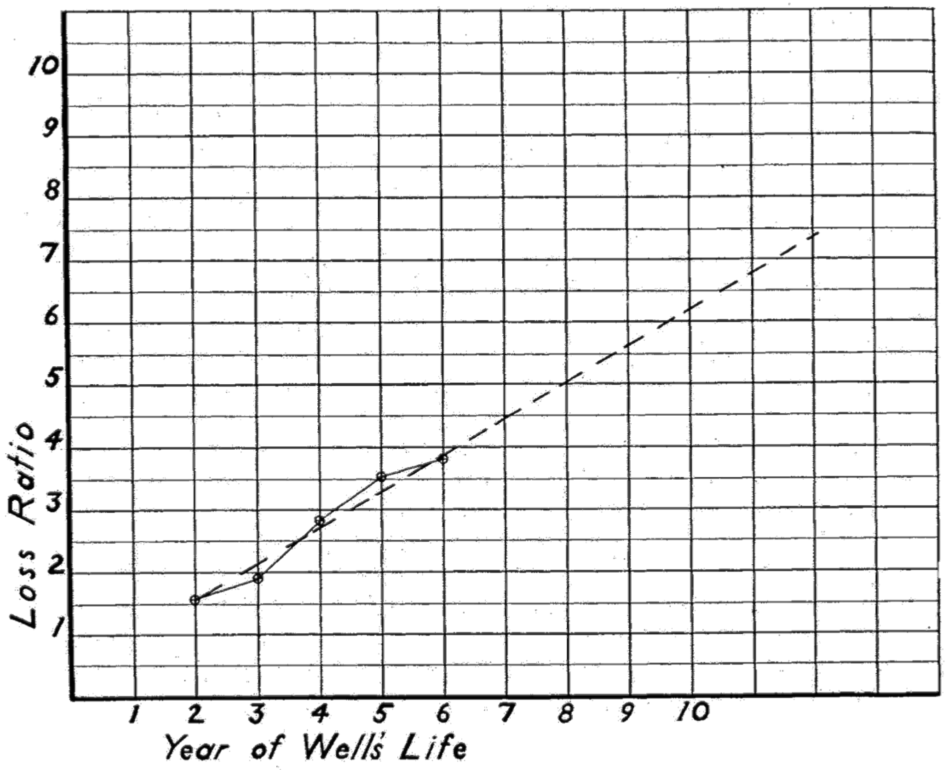


FIG. 1.—EXTRAPOLATION OF LOSS RATIO.

Early Example — Johnson/Bollens (1928)

Johnson, R.H. and Bollens, A.L.: "The Loss Ratio Method of Extrapolating Oil Well Decline Curves," Trans. AIME (1927) 77, 771.

<u>Historical Analysis</u>: _Johnson/Bollens_ (1928)

- **Johnson and Bollens proposed a plot of the _loss ratio_ versus _time_.**
- **A linear plot of _loss ratio_ versus _time_ implies that _b_(_t_) = constant (hyperbolic decline).**
- **A constant _loss ratio_ versus _time_ implies that _b_(_t_) = 0 (exponential decline).**

Historical Aspects: ANCIENT History (Rawlins and Schellhardt)

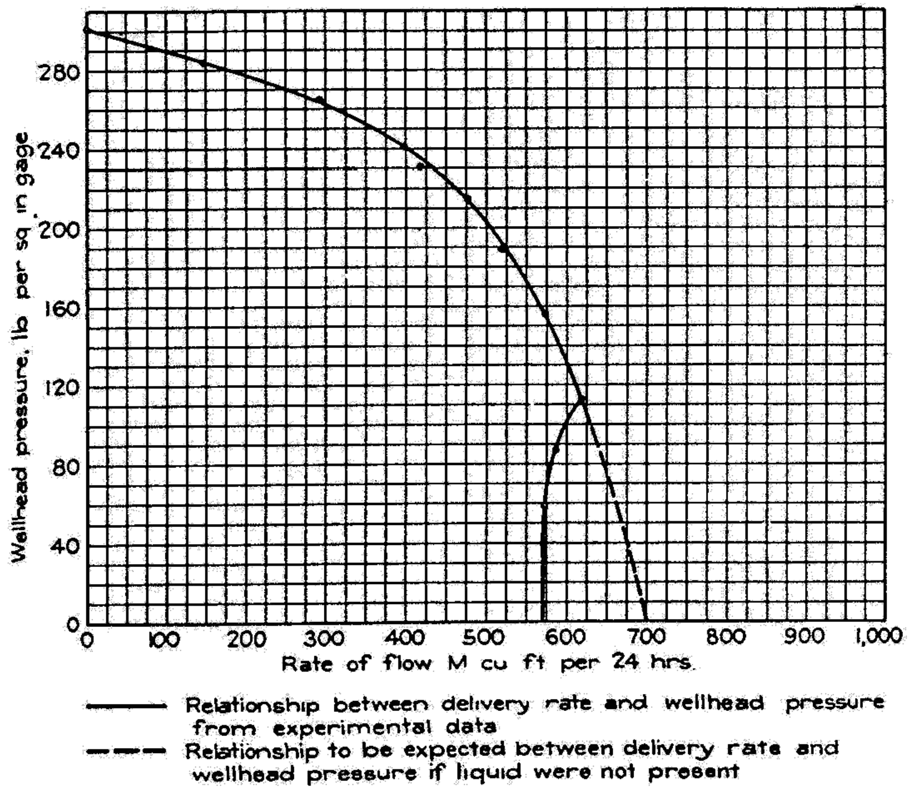


FIGURE 1.—Effect of one kind of liquid condition in a gas well on delivery capacities

First "IPR"-type curve.

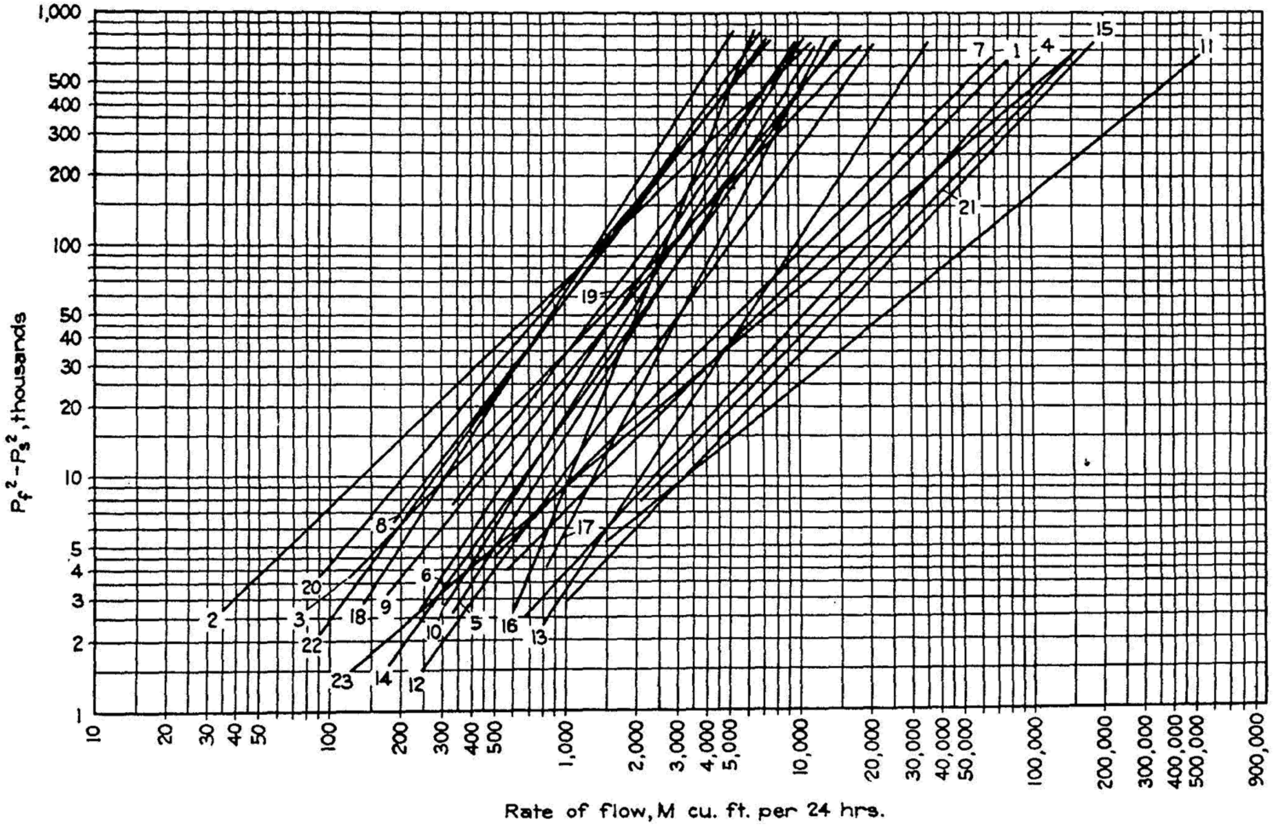


FIGURE 31.—Results of back-pressure tests on 23 gas wells in one field

Example "Back-Pressure" Tests (All from the Same Field)

<u>Historical Analysis</u>: *Rawlins and Schellhardt* (1935)

- This was the first p_{wf} vs. q_g plot (inflow performance relationship — IPR).
- Plots of log[p_{avg}^2-p_{wf}^2] versus q_g — the so-called back-pressure plot.
- The trends on the log[p_{avg}^2-p_{wf}^2] versus q_g plots vary significantly — diverse properties and practices.

Rawlins, E. L. and M. A. Schellhardt: Backpressure Data on Natural Gas Wells and Their Application To Production Practices, Monograph 7, U.S. Bureau of Mines, Washington, DC, (1936).

Historical Aspects: ANCIENT History (Jones)

Jones, P.J.: "Estimating Oil Reserves from Production-Decline Rates," Oil and Gas Jour. (Aug. 20, 1942) 43.

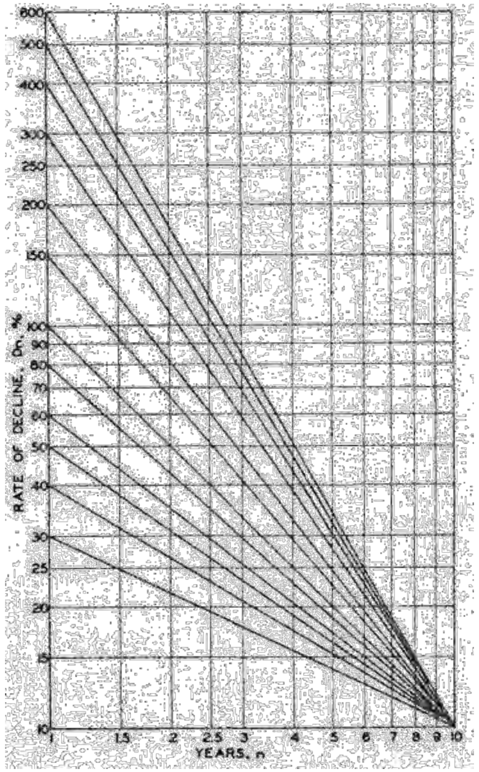


Fig. 37 — Variable rate of decline.

Analysis of Decline Curves

By J. J. Arps,* Member A.I.M.E.

(Houston Meeting, May 1944)

J. J. ARPS 231

P. J. Jones,[21] in 1942, suggested for wells declining at variable rates an approximation whereby the decline-time relationship follows a straight line on log-log paper. This corresponds to an equation:

$$\log D = \log D_0 - m \log t$$

in which D_0 designates the initial decline and m is a positive constant. Integration of this relationship will lead to a rate-time equation of the general form:

$$P = P_0 e^{\frac{D_0 t^{1-m}}{100(m-1)}}$$

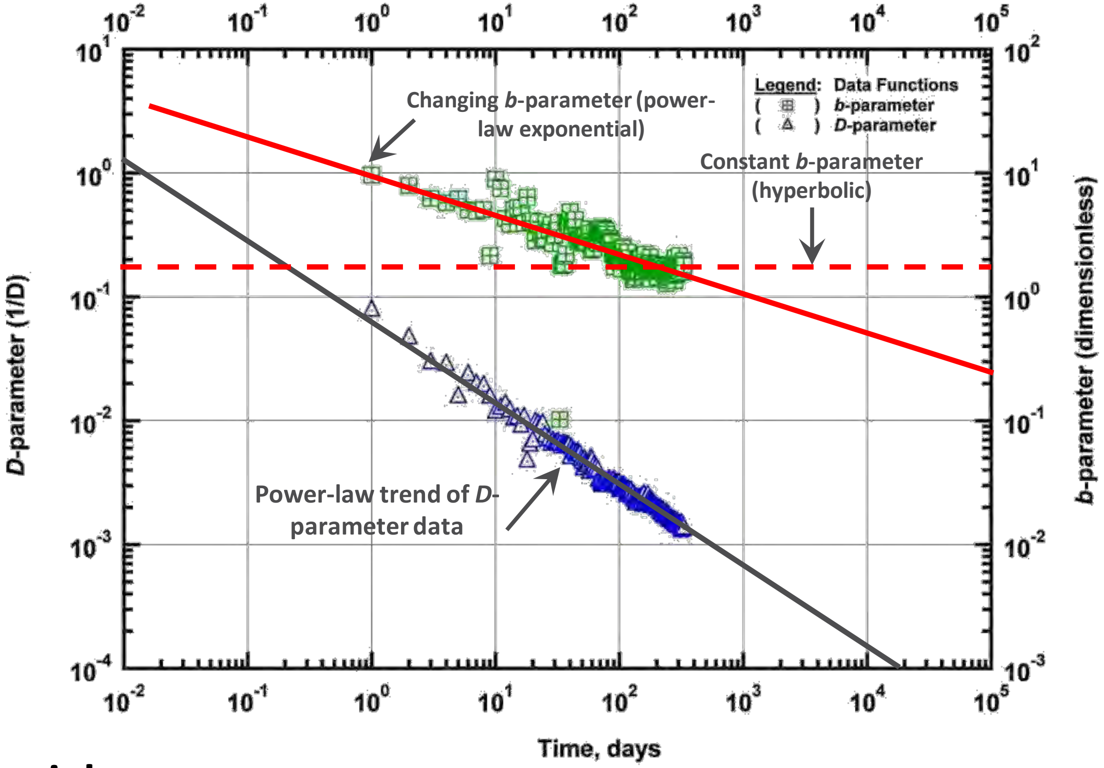
It may be noted that this relationship will not straighten out on semilog or log-log paper, but shows the interesting characteristic of straightening out when the log-log of the production rate is plotted against the log of the time.

Power-Law Exponential: (2008)

$$q = \hat{q}_i \exp[-D_\infty t - \hat{D}_i t^n]$$

$$D \equiv -\frac{1}{q_g}\frac{dq_g}{dt} \qquad b \equiv -\frac{d}{dt}\left[\frac{q_g}{dq_g/dt}\right]$$

Shale Gas Well (300 Days of Production)
D- and *b*-parameters versus Time Plot (Log-log Scale)



Historical Analysis: *Jones* (1942)

- Log[decline rate] versus log [time] validates the power-law exponential concept.
- Jones saw that this function had relevance, but did not demonstrate the approach.
- Interesting that this was 66 years before the PLE relation was observed.

Historical Aspects: Fetkovich — Decline Type Curve Analysis

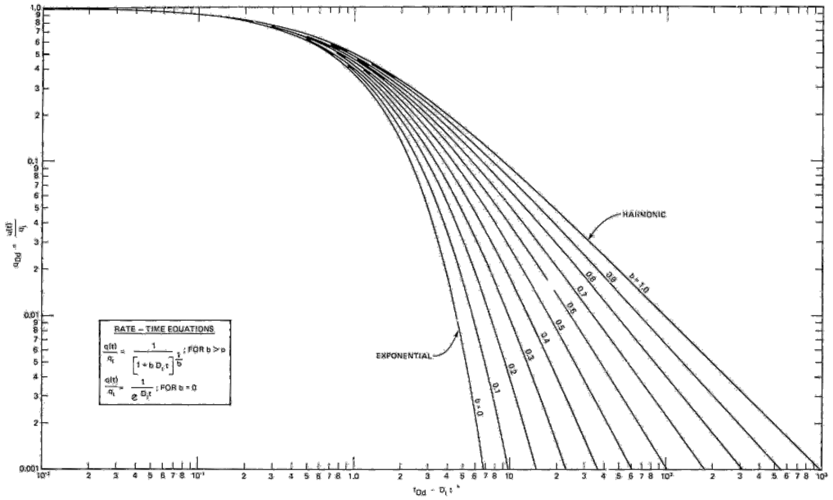


Fig. 1 - Type curves for Arps empirical rate-time decline equations, unit solution ($D_i = 1$).

Fetkovich Decline Type Curve — Arps Stems.

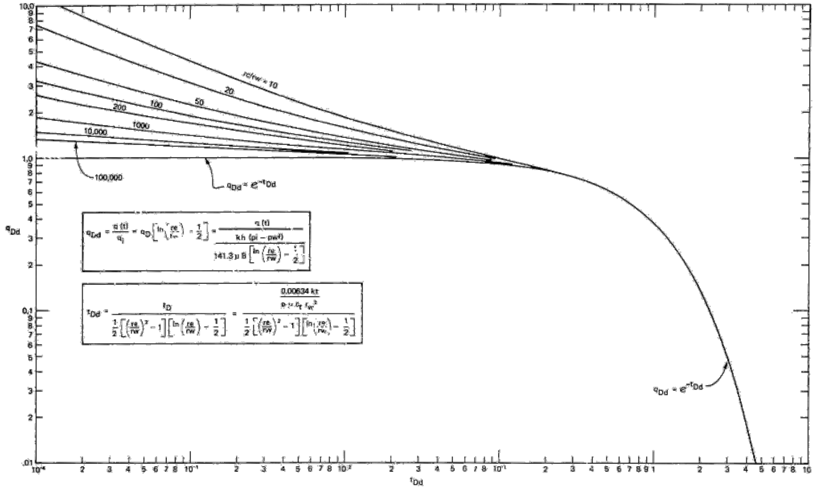
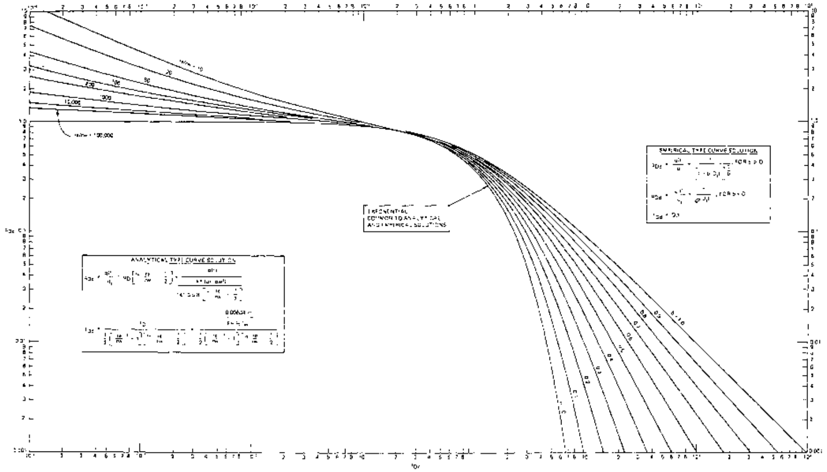


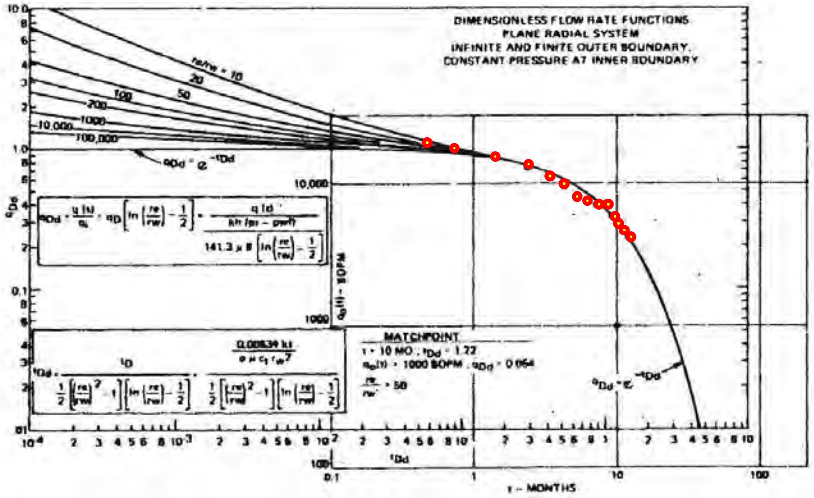
Fig. 3 - Dimensionless flow rate functions for plane radial system, infinite and finite outer boundary, constant pressure at inner boundary.

Fetkovich Decline Type Curve — Analytical Stems.



Composite of analytical and empirical type curves.

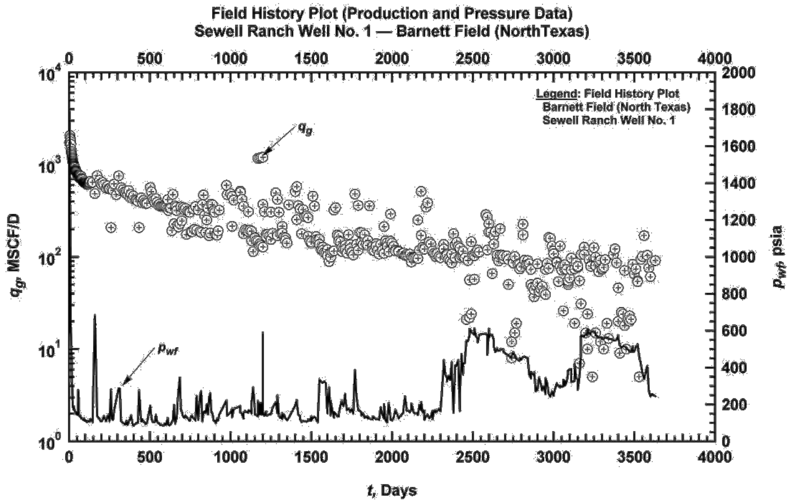
Fetkovich Decline Type Curve — Composite Curve (original curve).



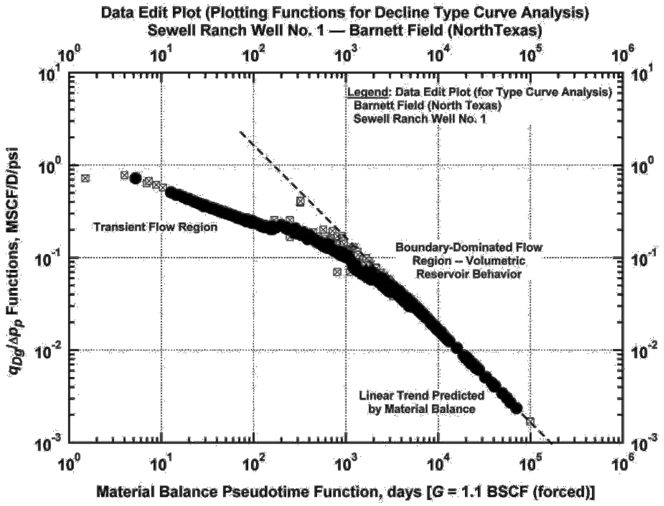
Fetkovich Decline Type Curve — Example Data Case (Well 13 — SPE 004629).

Historical Aspects: Blasingame — Rate Transient Analysis

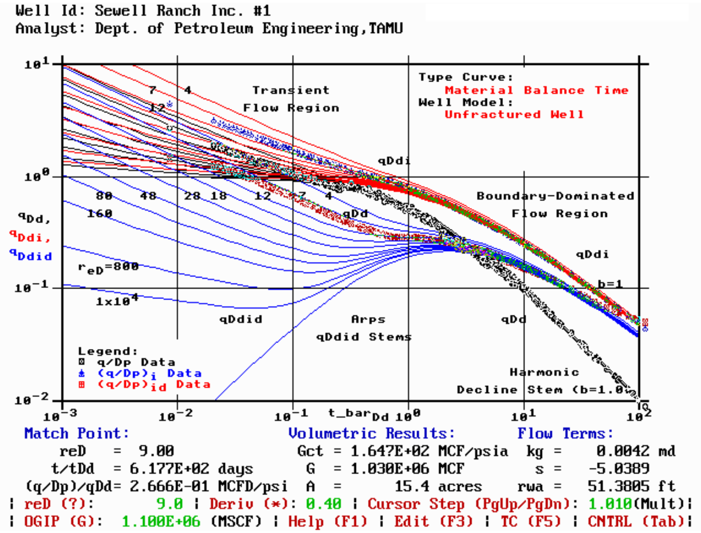
Creator: T.A. Blasingame
Created: ~1998.04.01



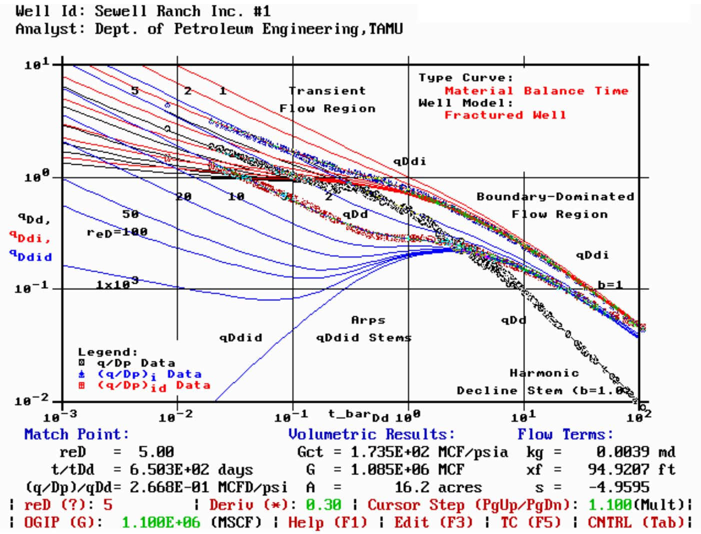
"History Plot" — Gas rate and computed bottomhole pressures.



"Edit Plot" — Gas productivity Index and gas material balance pseudotime.



"WPA Plot" — (original RTA) Unfractured well model.



"WPA Plot" — (original RTA) Fractured well model (infinite conductivity).

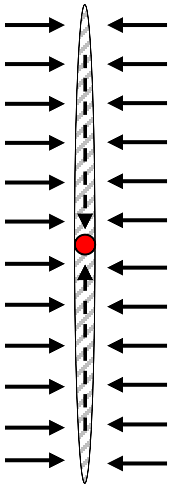
Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Linear Flow Plots
[Please don't call these RTA]

Specialized Time-Rate Analysis — Linear Flow Concepts

Creator: T.A. Blasingame
Created: ~2017

Solution for a Single Fracture: (transient linear flow)



$$p_D = \sqrt{\pi\, t_{Dxf}}$$

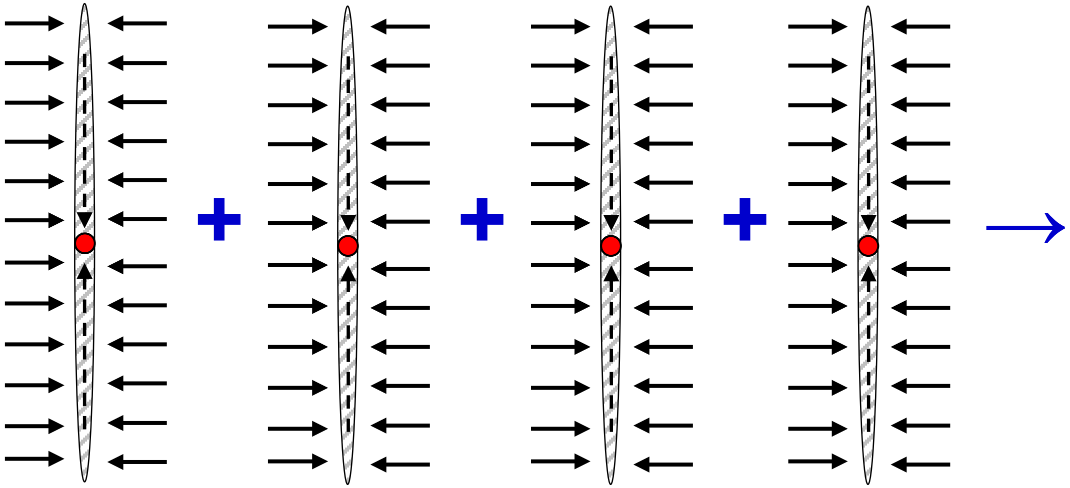
Solving for flowrate divided by pressure drop, we have …

$$\frac{q}{(p_i - p_{wf})} = \frac{1}{8.128494}\,\frac{1}{B}\sqrt{\frac{\phi c_t}{\mu}}\sqrt{k}\,A_{xf}\,\frac{1}{\sqrt{t}} \quad \text{(time in days)}$$

$$\frac{q}{(p_i - p_{wf})} = C\,A_{xf}\,\frac{1}{\sqrt{t}} \qquad \left[C = \frac{1}{8.128494}\,\frac{1}{B}\sqrt{\frac{\phi c_t}{\mu}}\sqrt{k} \right]$$

Note:
These solutions are only valid for transient linear flow [i.e., the case of non-interfering pressure distributions (due to the fractures)].

Additive Fractures: (transient linear flow)



$$\frac{q_{tot}}{(p_i - p_{wf})} = C\,[A_{xf,1} + A_{xf,2} + A_{xf,3} + A_{xf,4} + \ldots + A_{xf,n}]\,\frac{1}{\sqrt{t}}$$

$$\frac{q_{tot}}{(p_i - p_{wf})} = C\,(A_{xf})_{tot}\,\frac{1}{\sqrt{t}}$$

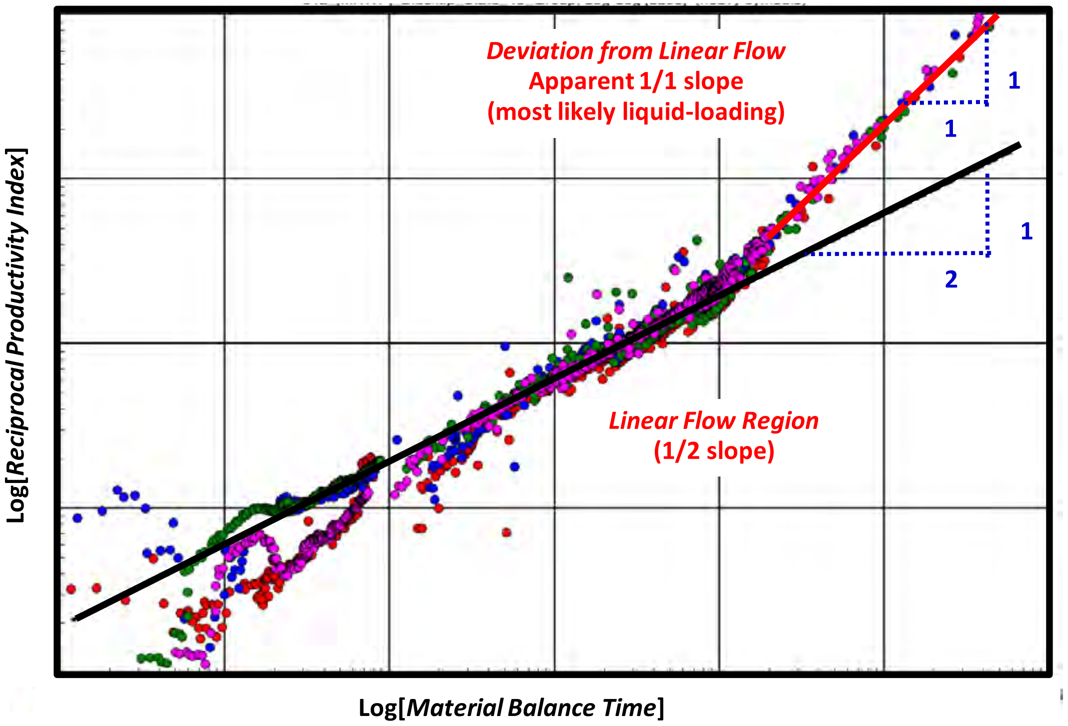
Creator: T.A. Blasingame
Created: ~2017

Specialized Time-Rate Analysis — Linear Flow Concepts

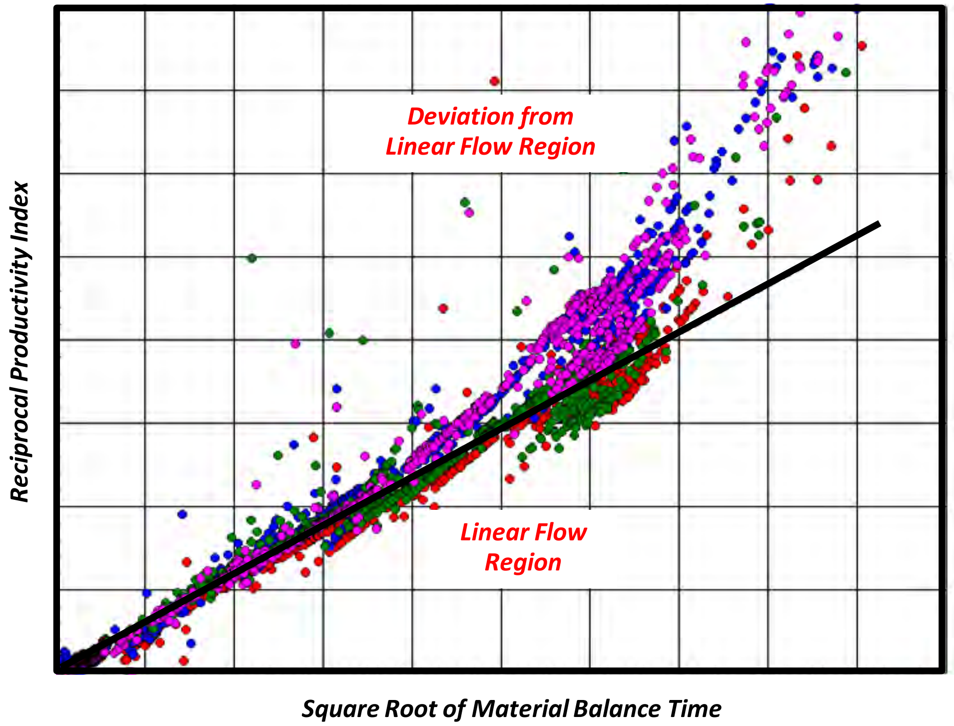
Formation Linear Flow: (*t* = *t* or t_{mb} (material balance time))

- **Log-log diagnostic plot:** log[Δ*p*/*q*] versus log[*t*] (slope = 1:2)
- **"Traditional" plot:** Δ*p*/*q* versus SQRT[*t*] (straight-line portion)
- ***Extrapolation of rate using a linear flow model will over-predict EUR…***

Governing Relation: $\dfrac{(p_i - p_{wf})}{q} = m_{elf}\sqrt{t}$ Solving for the $\sqrt{k}A_{xf,\text{tot}}$ term, $\sqrt{k}A_{xf,\text{tot}} = 8.128494\, B\sqrt{\dfrac{\mu}{\phi c_t}}\dfrac{1}{m_{elf}}.$



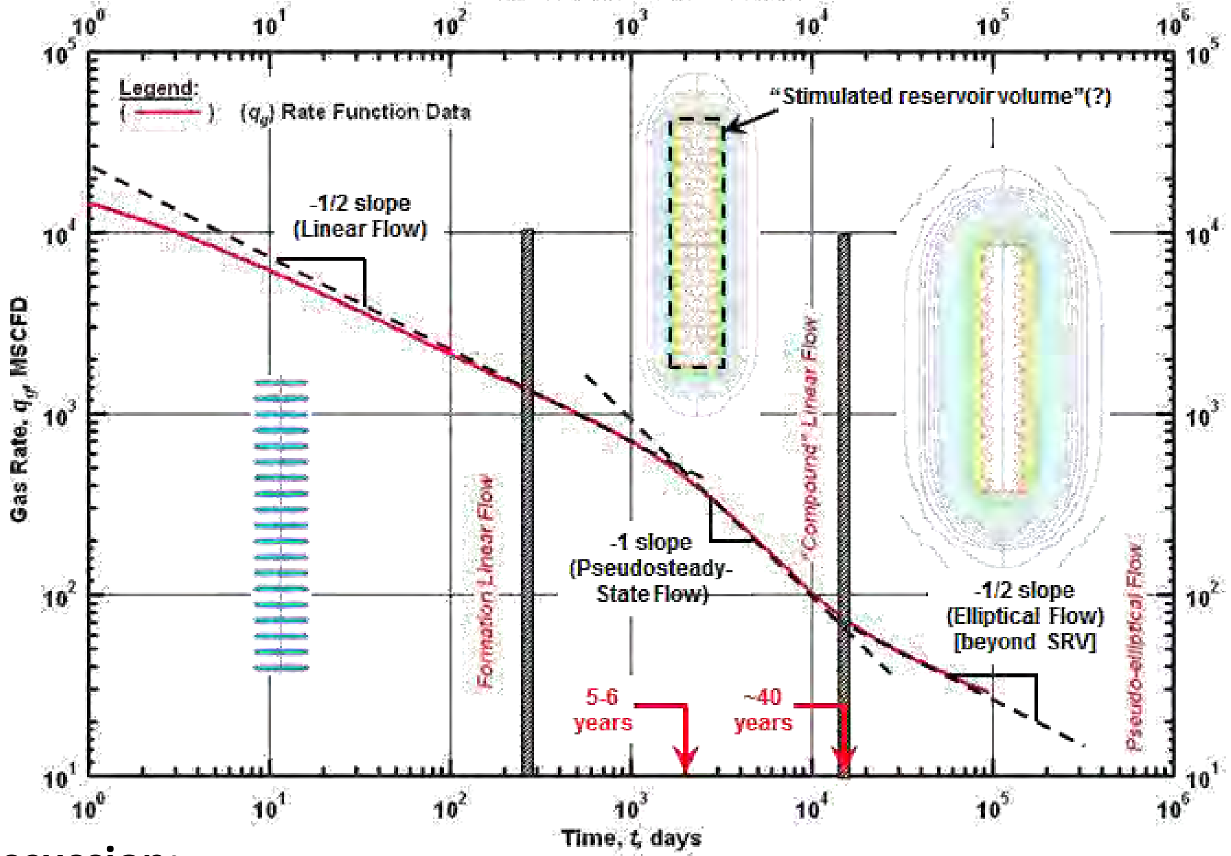
(Log-log plot): Reciprocal productivity index versus material balance time, multiple wells.



(Square root plot): Reciprocal productivity index versus square root of material balance time, multiple wells.

Specialized Time-Rate Analysis (DCA) — Flow Regimes — Multi-Fractured Horizontal Wells

Horizontal Gas Well with Multiple (Transverse) Fractures
van Kruysdijk and Dullaert [1989] Flow Regime Concept — k = 50 nd
(Infinite-Acting Case)



Transient Linear Flow Relation:

$$q_{tot} = C\,(A_{xf})_{tot}\,\frac{1}{\sqrt{t}}$$

$$(A_{xf})_{tot} = A_{xf,1} + A_{xf,2} + \ldots + A_{xf,n}$$

Use of Hyperbolic Flow Relation to Represent Transient Linear Flow:

$$q(t) = \frac{q_{i,hyp}}{(1+bD_i t)^{1/b}}$$

Assuming $b = 2$

$$q(t) = \frac{q_{i,hyp}}{(1+2D_i t)^{1/2}}$$

As $t \rightarrow$ large; $(1+2D_i t)^{1/2} \rightarrow \sqrt{2D_i}\,\sqrt{t}$

$$q(t) \approx \frac{q_{i,hyp}}{\sqrt{2D_i}}\,\frac{1}{\sqrt{t}} \approx a\,\frac{1}{\sqrt{t}} \approx a t^{-1/2}$$

Discussion:
- MFHW model is the "master" solution for unconventional wells.
- Diagnostics can be obscured by clean-up and liquid-loading.
- Very significant time involved for observing a particular flow regime (k = 50 nd).

Creator: T.A. Blasingame
Created: ~2017

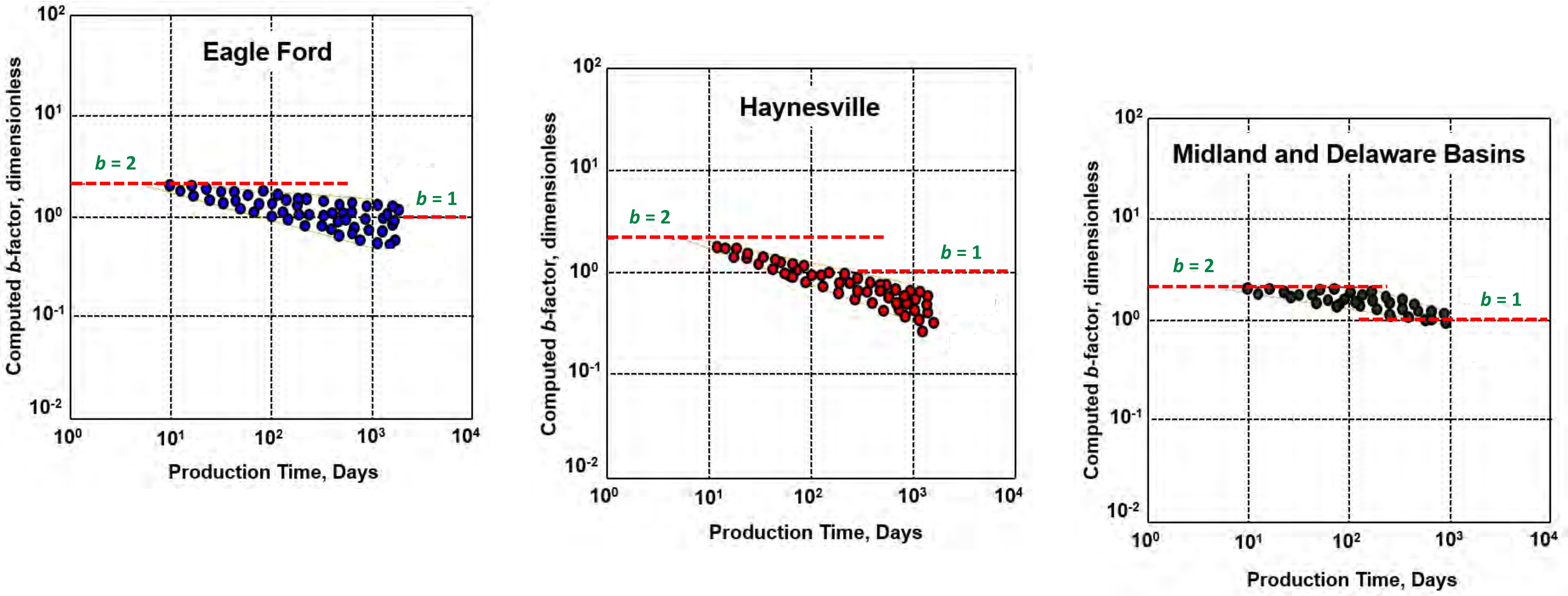
Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Time-Rate Analysis

(Also known as Decline Curve Analysis [DCA])

Time-Rate Analysis —b(t) Play-by-Play

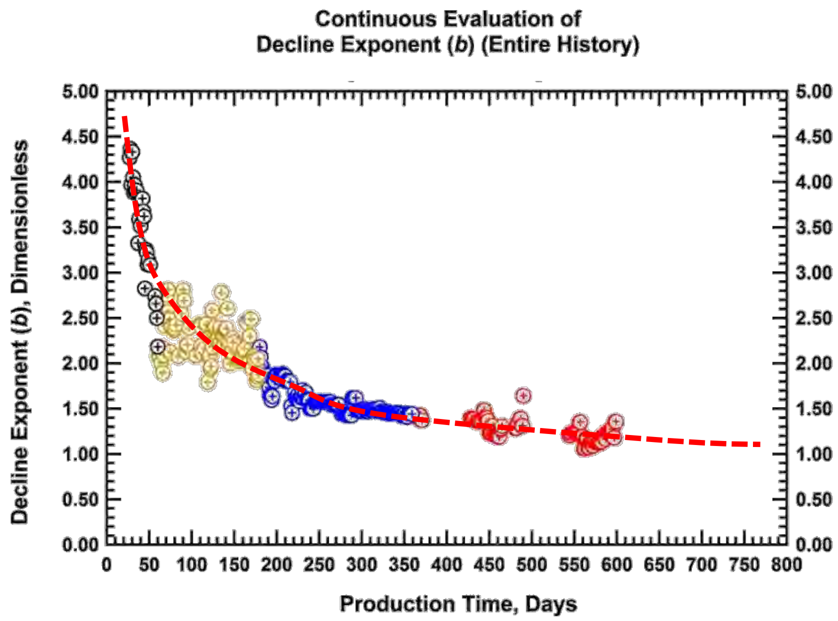
Creator: D. Ilk
Created: ~2017



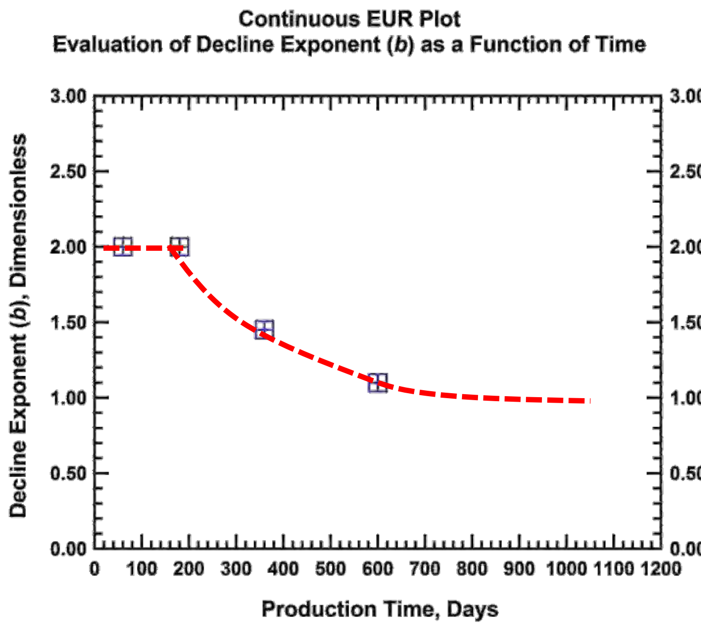
Discussion:
- **A constant "$b(t)$" value is unlikely for more than just a few months.**
- **Decline in "$b(t)$" in some/most cases, behavior can be considered "power-law."**
- **Conceptually, this decline in "$b(t)$" can be used to predict EUR(t).**

Creator: D. Ilk
Created: ~2017

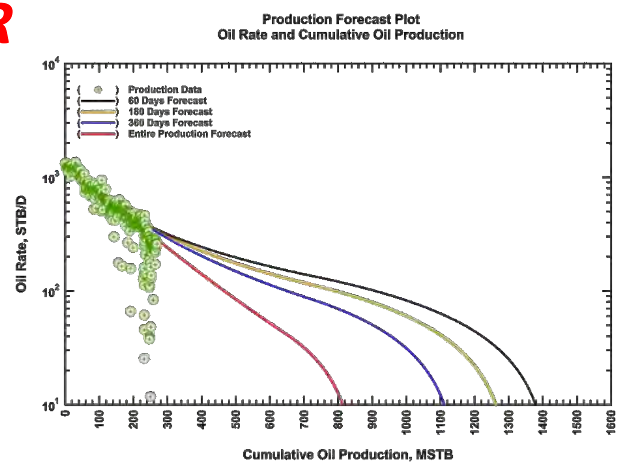
Time-Rate Analysis — Continuous EUR



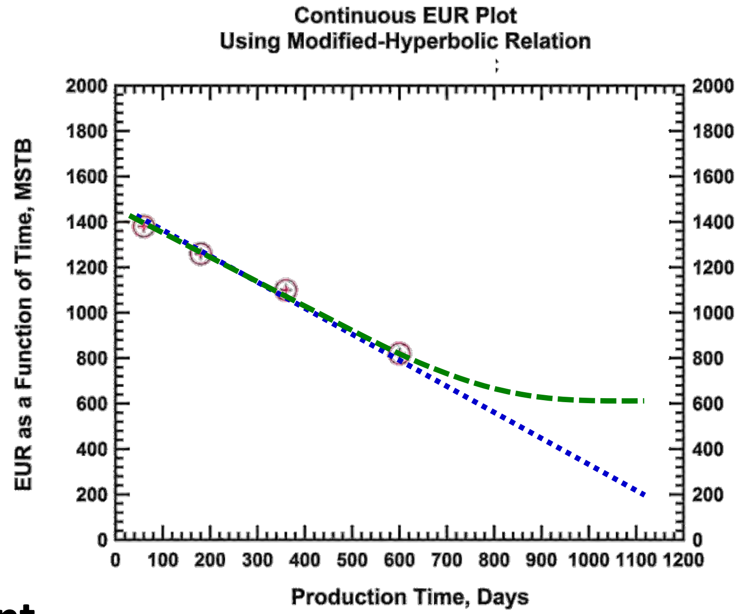
"*b*(*t*) vs. time" — decline exponent versus time.



"*b* vs. time" — *b*-value for a given segment.



"$q_o(t)$ vs. cumulative oil" (see extrapolated trends).



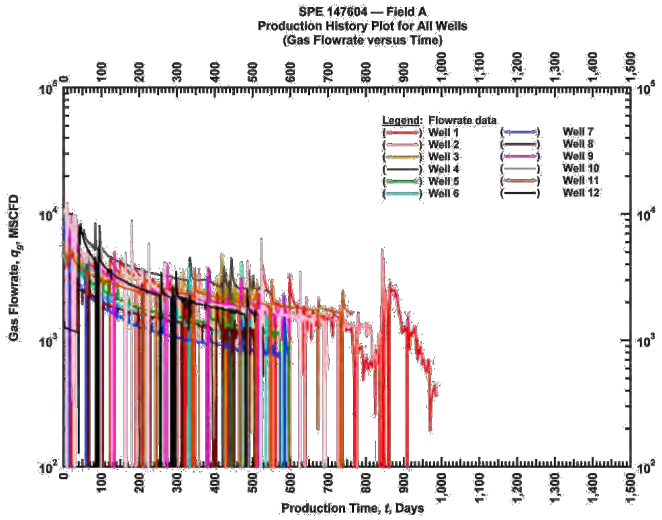
"EUR vs. time" — EUR for a given segment.

Discussion:

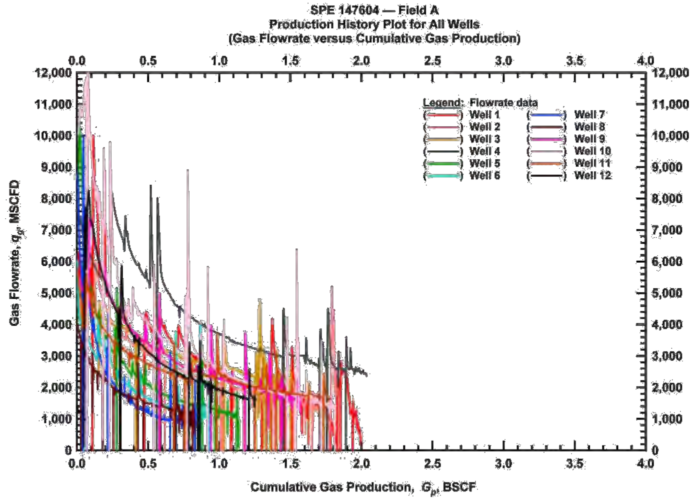
- Illustration of changing EUR as a function of time due to declining *b*-exponent.
- *b*(*t*) data are (relatively) well-behaved, selected constant *b*-values for a given segment.
- Declining EUR with time is characteristic of the declining *b*(*t*) function with time.

Time-Rate Analysis — Suite of Plots — Shale Gas Example

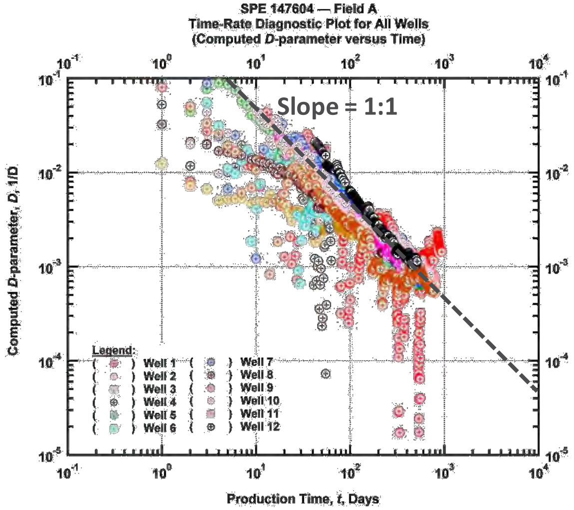
Creator: D. Ilk
Created: ~2017



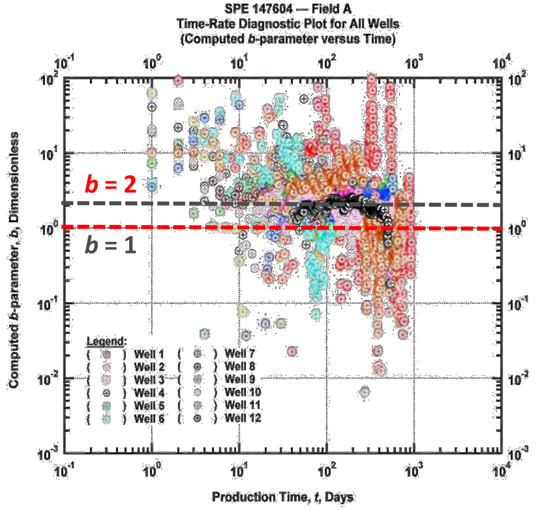
q_g **versus** t



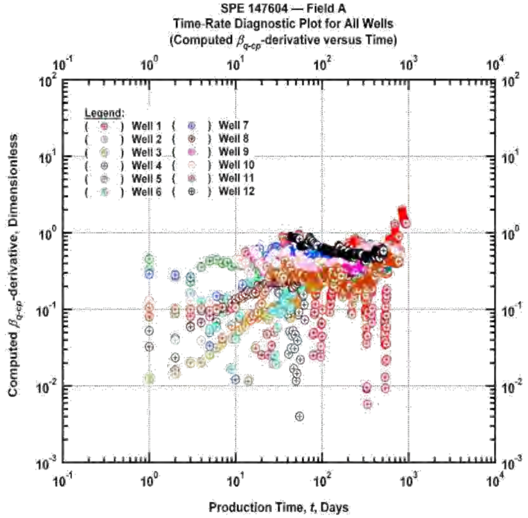
q_g **versus** G_p



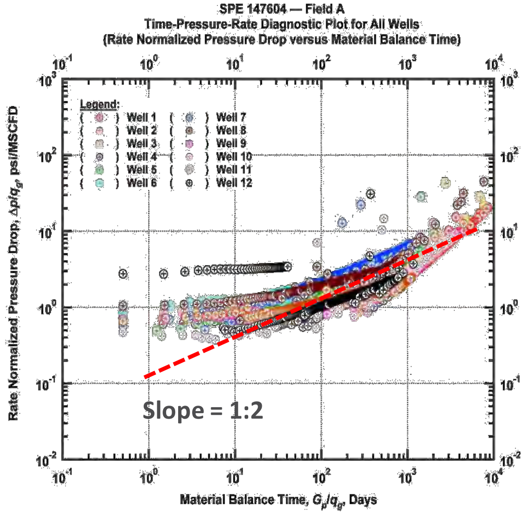
***D*-parameter versus time**



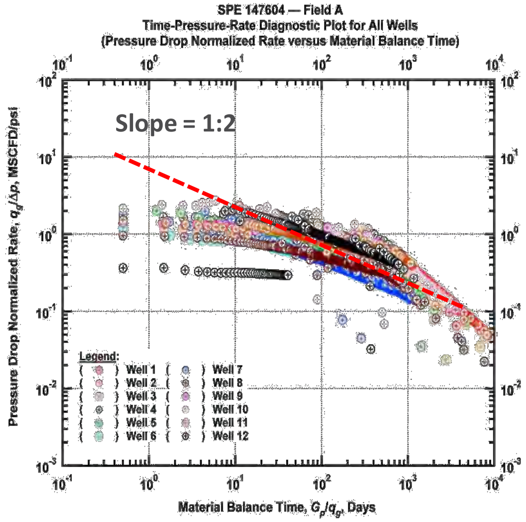
***b*-parameter versus time**



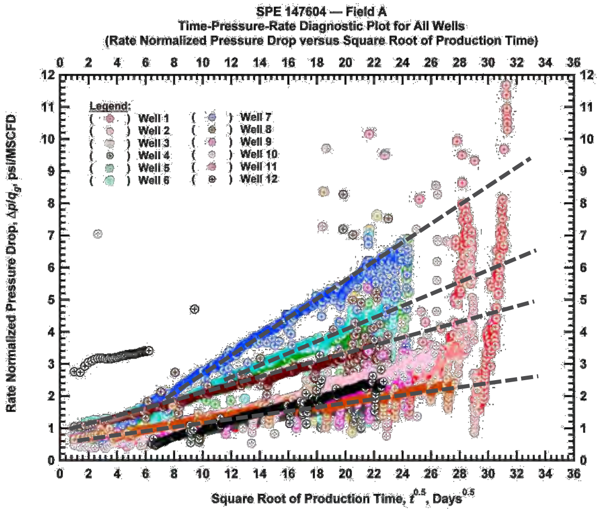
$\beta_{q,cp}$**-parameter versus time**



$\Delta p/q_g$ **versus** G_p/q_g



$q_g/\Delta p$ **versus** G_p/q_g



$\Delta p/q_g$ **versus SQRT(*t*)**

Time-Rate Analysis — Modern Decline Curve Analysis Relations

Standard DCA Relations

"Arps Modified-Hyperbolic"

$$q(t) \equiv \begin{bmatrix} \dfrac{q_{i,hyp}}{(1+bD_i t)^{1/b}} & (t < t_{\lim}) \\ q_{\lim} \exp[-D_{\lim}(t-t_{\lim})] & (t > t_{\lim}) \end{bmatrix}$$

"Switch"Condition:

$$q_{\lim} = q_{i,hyp}\left[\frac{D_{\lim}}{D_i}\right]^{(1/b)} \qquad t_{\lim} = \frac{1}{bD_i}\left[\left[\frac{q_{i,hyp}}{q_{\lim}}\right]^b - 1\right]$$

"Ilk"

$$q(t) \equiv \hat{q}_i \exp[-D_\infty t - \hat{D}_i t^n]$$

"Duong"

$$\frac{q(t)}{Q(t)} = a\,t^{-m} \quad \text{which leads to:}$$

$$q(t) = q_1\, t^{-m}\, e^{\frac{a}{1-m}(t^{1-m}-1)}$$

Proposed in the Last 3-5 Years

"Modified-Wiorkowski" (cumulative)

$$Q(t) = \tilde{Q}\left[1-\tilde{a}\exp[-\tilde{D}_i t]\right]^{\tilde{n}}$$

"Modified-Ilk" (cumulative)

$$Q(t) = \bar{Q}\,[1-\exp[-\bar{D}_\infty t - \bar{D}_i t^{\bar{n}}]]$$

"Zhang"

$$q(t) = q_i \exp[-a(t)\,t]$$

$$\text{where: } a(t) = \beta_l + \beta_e \exp\left[-t^{-n}\right]$$

"Wanderley de Hollanda"

$$q(t) = q_i^*\,\theta_2(\chi, e^{-\eta t})$$

$$\text{where: } \chi = \frac{\pi}{2}\frac{x_i}{L} \text{ and } \eta = \frac{\pi^2}{L^2}\frac{k}{\phi\mu c_t}$$

(θ_2 is the second Jacobi theta function)

Proposed by Students (2020)

"Bessel Function $E_1(x)$"

$$q(t) = q_i E_1(At^B)$$

"Bessel Function $K_0(x)$"

$$q(t) = q_i K_0(At^B)$$

"Logarithmic Distribution"

$$q(t) = q_i\left[1-\left[\frac{1}{2}+\frac{1}{2}erf\left[\frac{\ln(t)-\mu}{\sqrt{2}\,\sigma}\right]\right]\right]$$

"Incomplete Gamma Function"

$$q(t) = q_i\,\Gamma(A, t^B)$$

Hint: This one does not work.

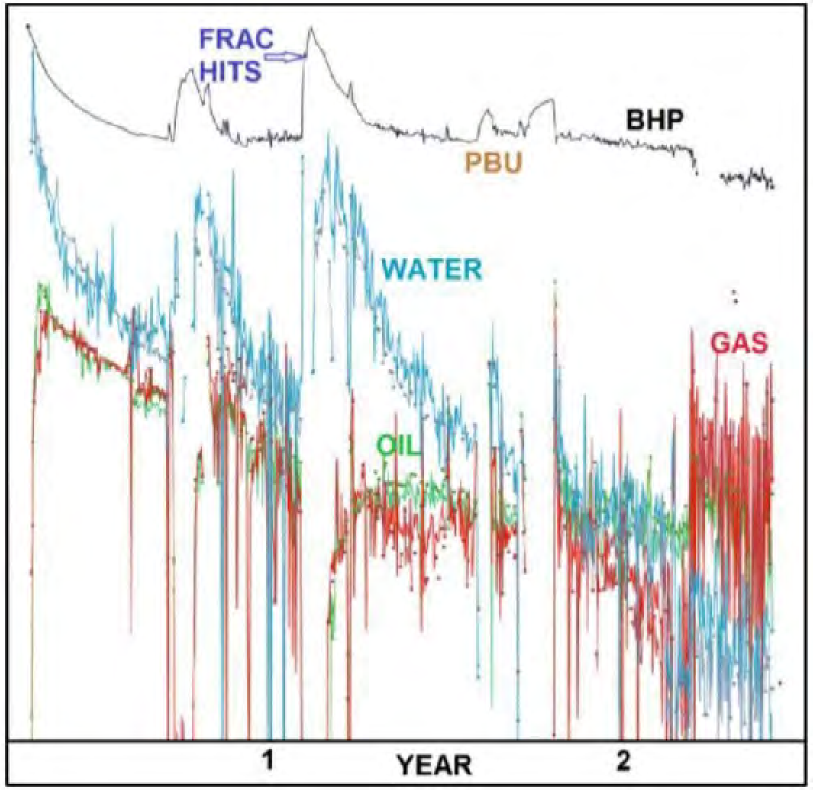
"Modified-Harmonic"

$$q(t) = q_i \frac{1}{[1+At^B]}$$

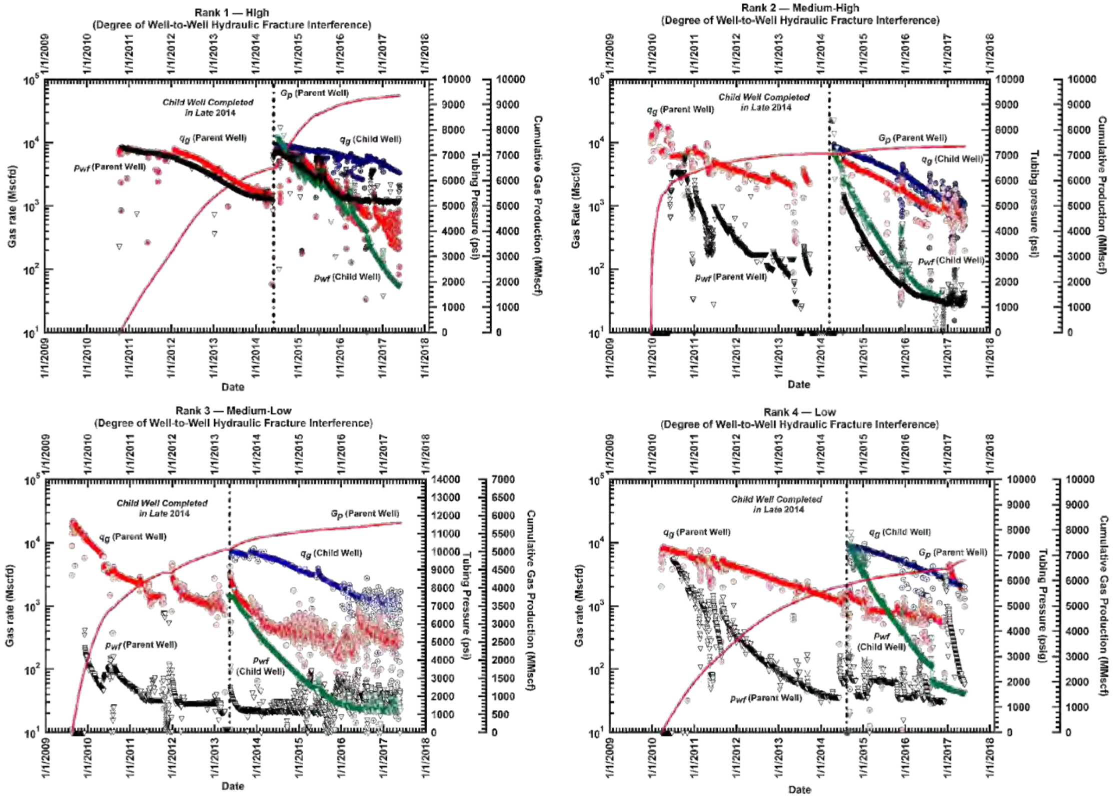
Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Pressure Transient Analysis (PTA)

Pressure Transient Analysis —Value Proposition for Reservoir Pressure Measurement



Rate and pressure functions vs. time, multi-well interference. (Source: SPE 187180)

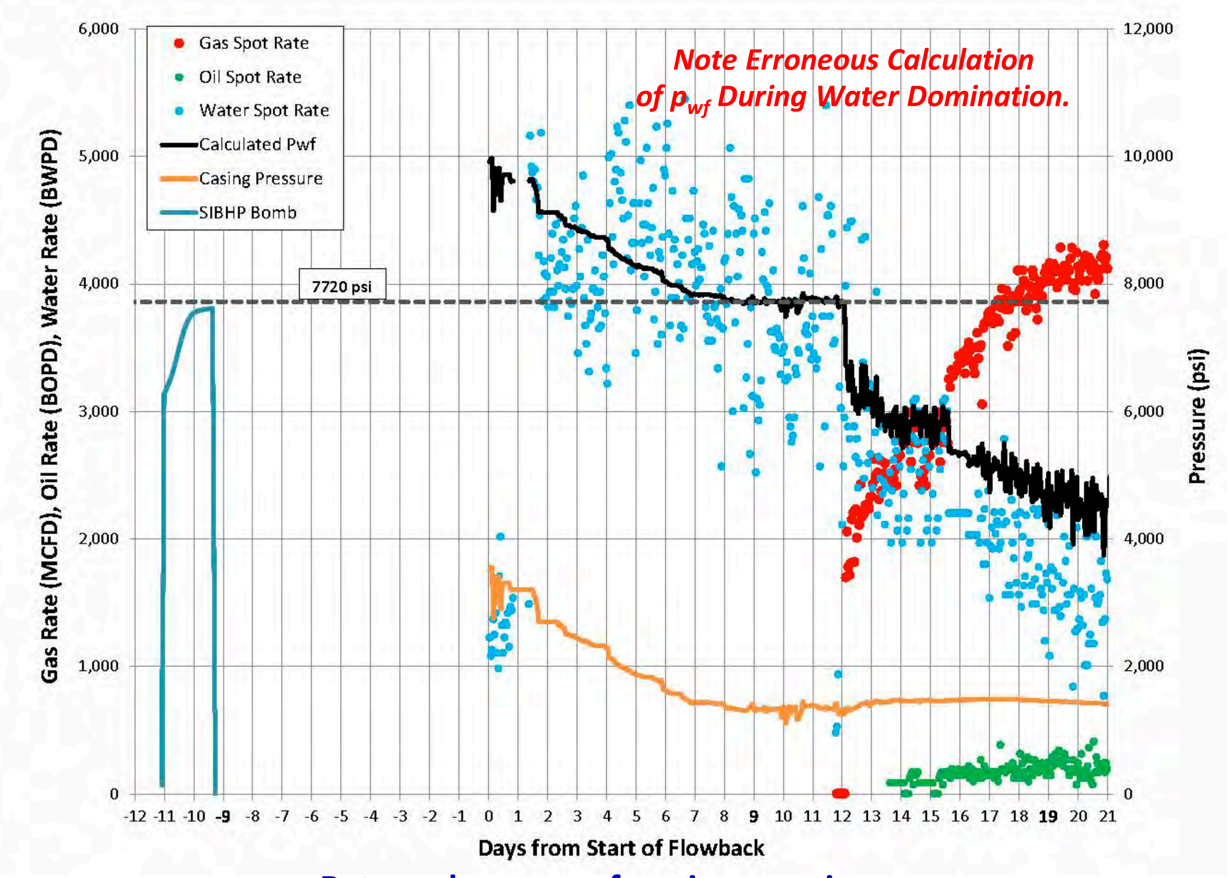


Rate and pressure functions vs. time, examples of "Fracture-Directed Interactions" (or "Frac-Hits"). (Source: URTeC 2670079)

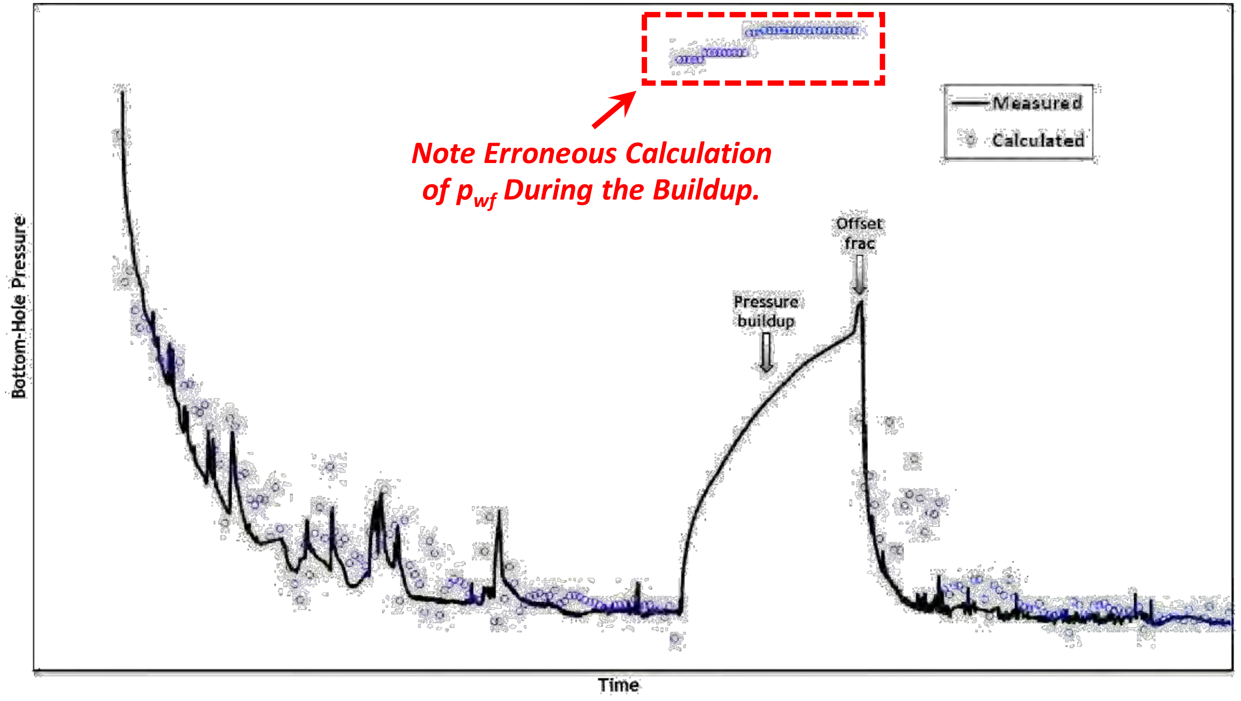
Discussion:

- Characterize reservoir performance without surface/wellbore phase segregation effects.
- Diagnose offset behavior (… *i.e., "well-to-well fracture interaction" or "frac-hits"*).
- Diagnose production interference (… *via hydraulic fracture and/or natural fractures, faults, etc.*).

Pressure Transient Analysis — Implications of Errors and Inconsistencies in Pressure Data



Rate and pressure functions vs. time.
(Source: URTeC 1934785)

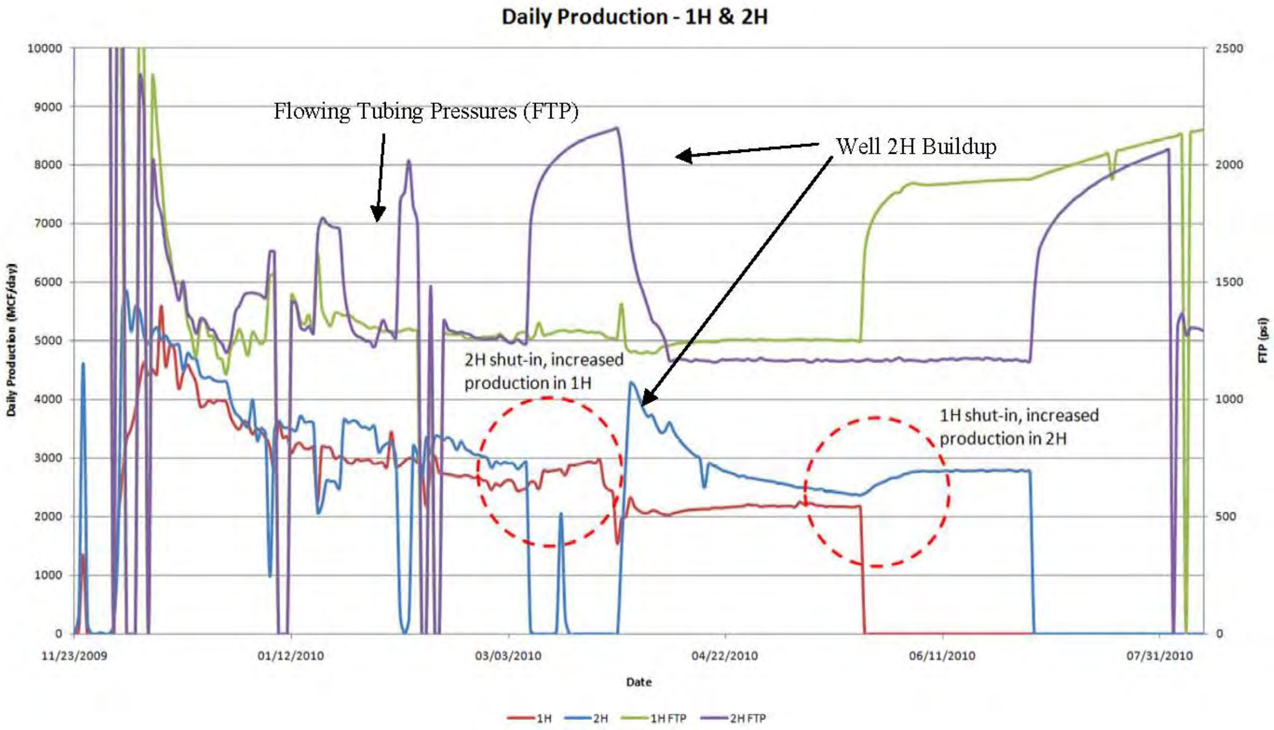


Comparison: $(p_{wf})_{meas}$ and $(p_{wf})_{calc}$ vs. time.
(Source: SPE 178608)

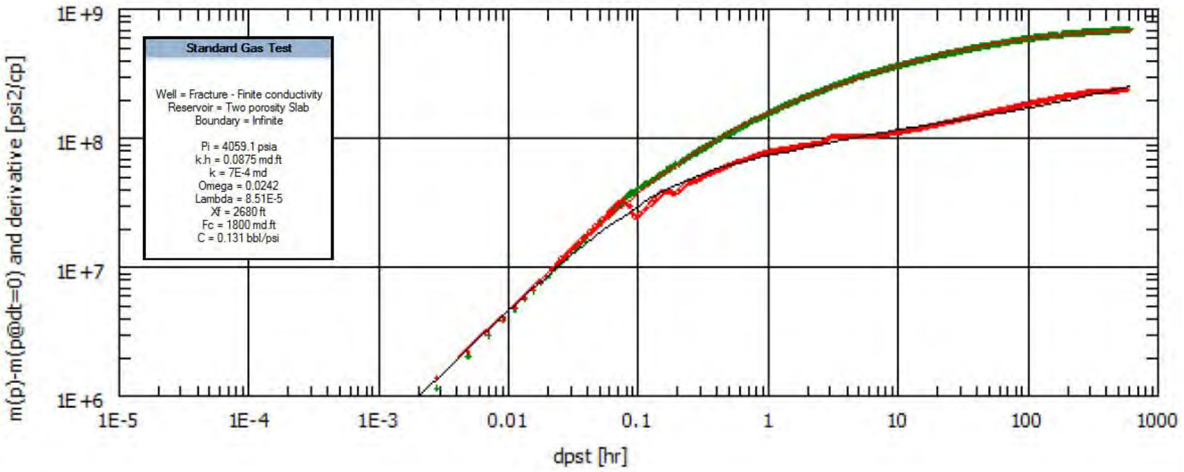
Discussion:

- **Surface pressure measurements influenced/biased by operational practices.**
- **Downhole measurements less affected by operations (minor issues w/choke changes).**
- **Gauge failure (rare) or gauge losing calibration (uncommon, but it does happen).**

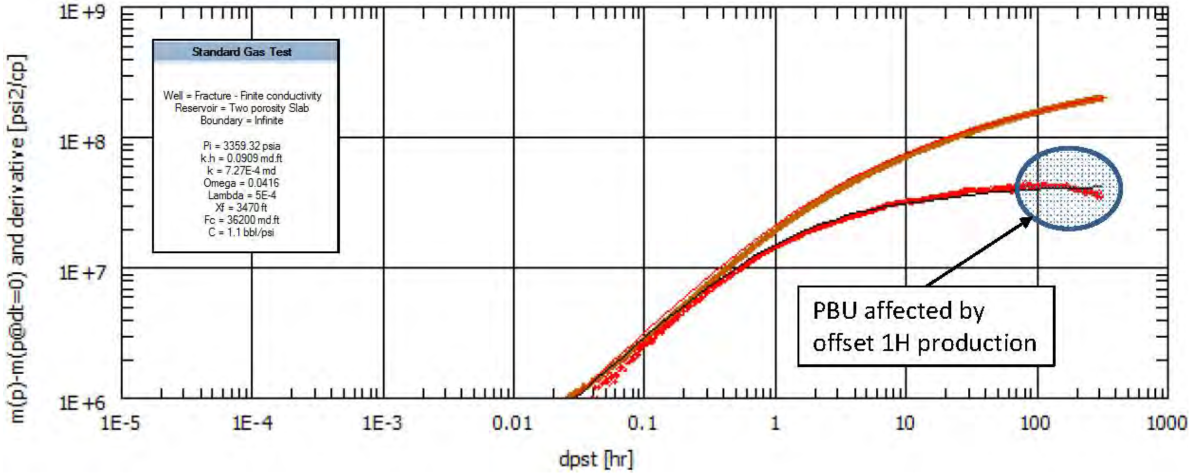
Pressure Transient Analysis — PTA Cases in Marcellus (Gas Shale) [SPE 145463 (Mayerhofer)]



Gas production rates and flowing tubing pressures show communication between the two wells.



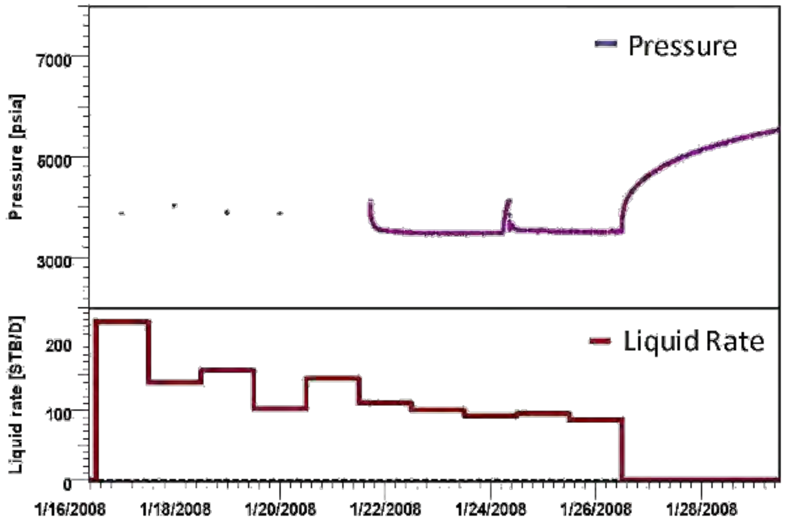
First post-frac buildup (final interpretation with dual-porosity slab interpretation and DFIT matrix permeability).

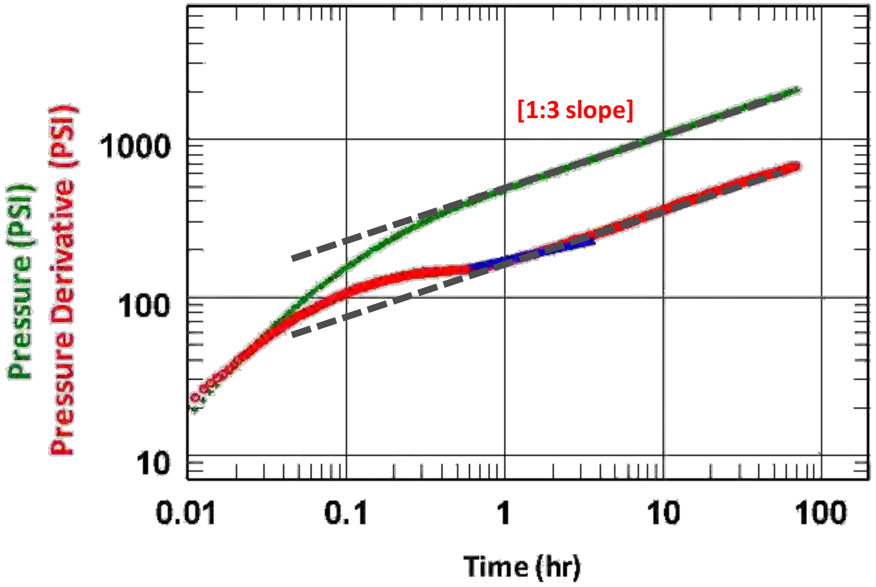


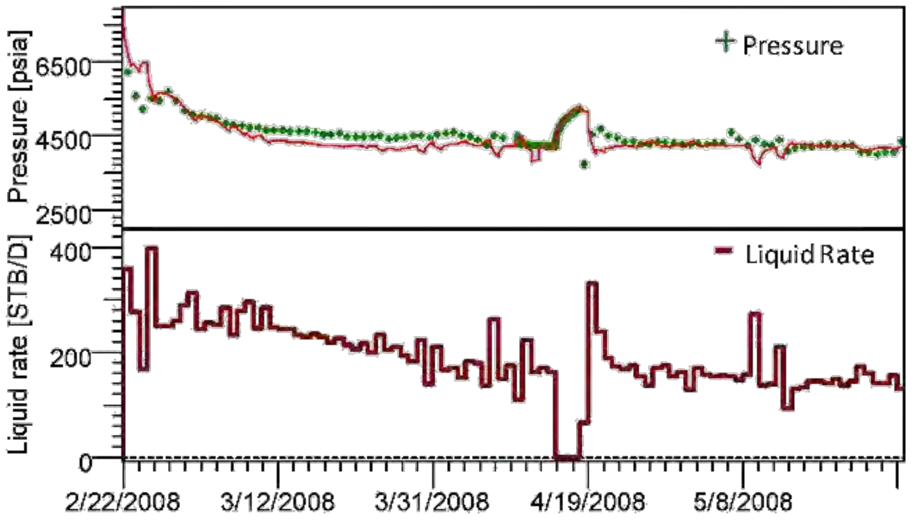
Second post-frac buildup after 5 months of production affected by Well 1H offset production (dual-porosity slab interpretation with DFIT matrix permeability).

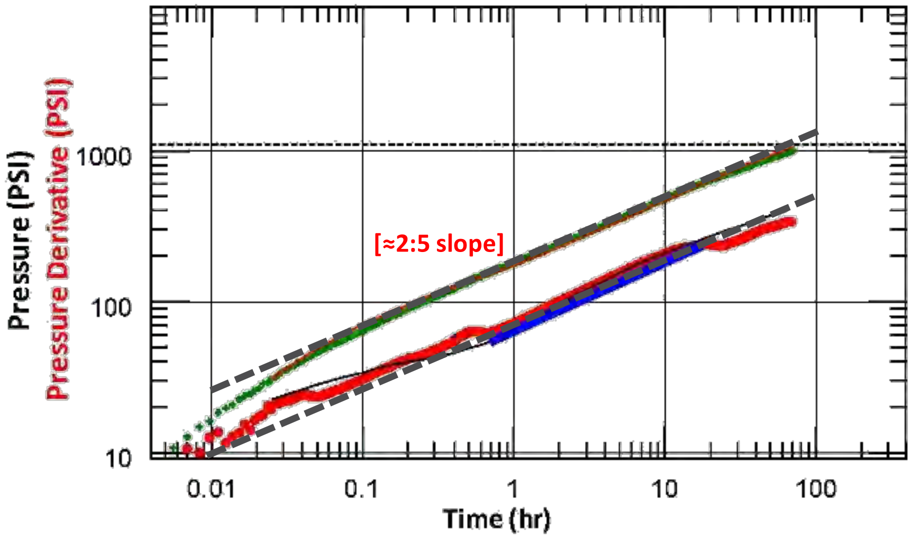
Mayerhofer, M. J., Stegent, N. A., Barth, J. O., & Ryan, K. M. (2011). Integrating Fracture Diagnostics and Engineering Data in the Marcellus Shale. Society of Petroleum Engineers. doi:10.2118/145463-MS.

Pressure Transient Analysis — PTA Cases in Bakken (Oil Shale) [SPE 162473 (Kurtoglu)]







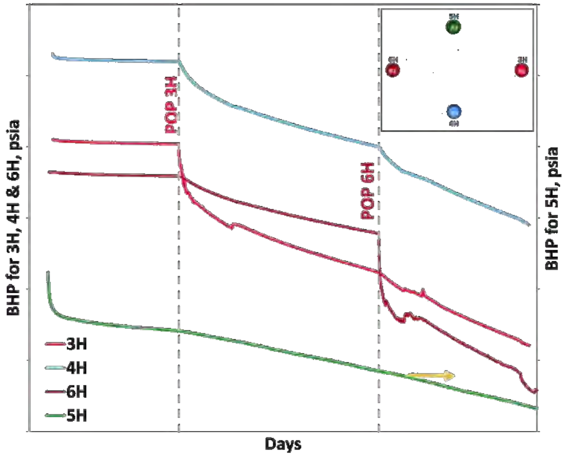


Questions:

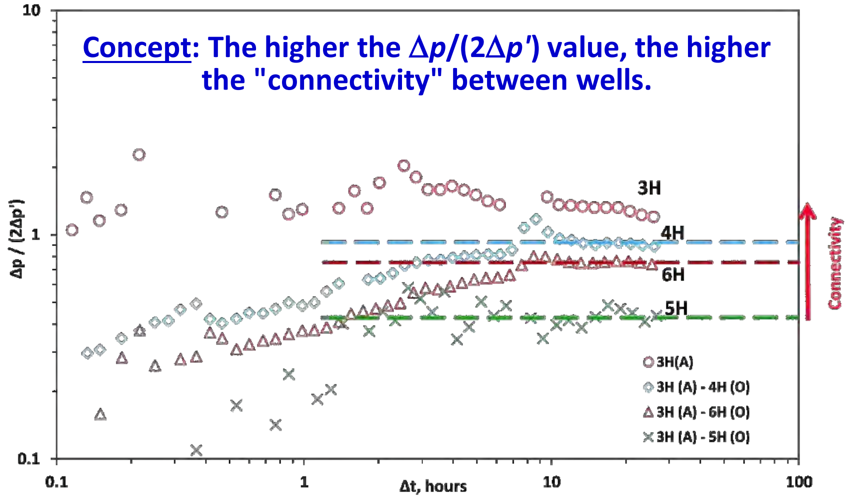
- **What causes the "sub-linear" (< 1:2 slope) trends?**
  - —Anomalous diffusion?
  - —Multiphase flow effects?
  - —Well geometry effects?
  - —Fracture spacing effects?
  - —Fractal effects?
- **Are these features artifacts?**
  - —Data acquisition effects?
  - —Producing time effects?
  - —Phase behavior effects?
  - —Wellbore storage effects?
- **Property estimates?**
  - —Permeability? [X]
  - —Fracture half-length? [X]
  - —Fracture conductivity? [?]

Kurtoglu, B., Torcuk, M.A., & Kazemi, H. (2012) Pressure Transient Analyses of Short and Long Duration Well Tests in Unconventional Reservoirs. Society of Petroleum Engineers. doi:10.2118/162473-MS.

Pressure Transient Analysis — Quantifying Pressure Interference [SPE 191407 (Chu)]

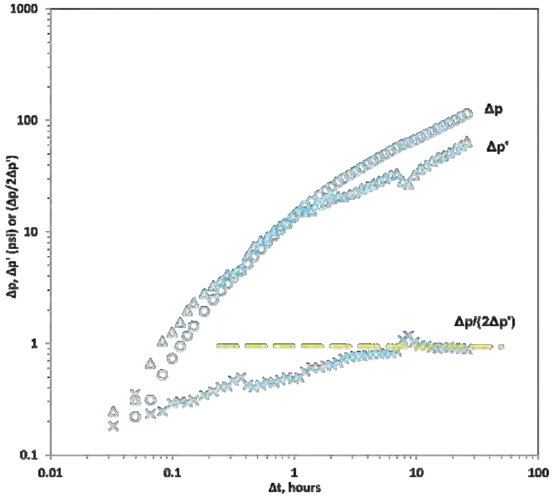


Pressure response due to Well 3H being "put-on-production" (or POP'd).

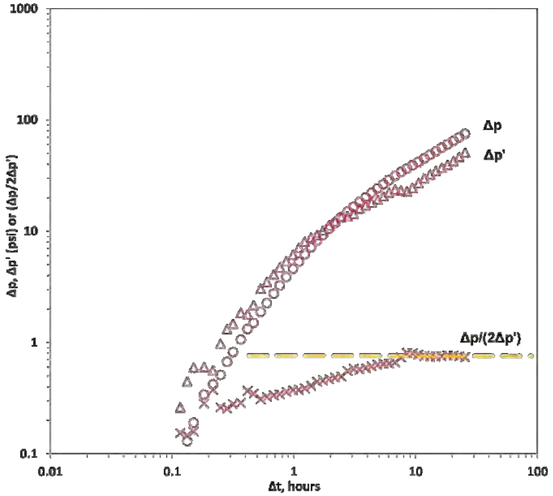


Chow Pressure Group (pressure derivative function) For all for 4 wells due to Well 3H being "POP'd."

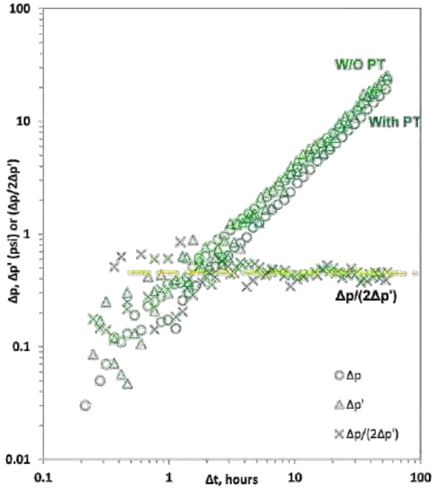
Chu, W., Scott, K., Flumerfelt, R., and Chen, C.-C. (2018) A New Technique for Quantifying Pressure Interference in Fractured Horizontal Shale Wells. Society of Petroleum Engineers. doi:10.2118/191407-MS



Pressure interference response in Well 4H. (due to Well 3H POP)



Pressure interference response in Well 6H. (due to Well 3H POP)



Pressure interference response in Well 5H. (due to Well 3H POP)

Pressure Transient Analysis (PTA), Rate Transient Analysis (RTA), and Decline Curve Analysis (DCA) Methods for Wells in Unconventional Reservoirs

Rate Transient Analysis (RTA)

Rate Transient Analysis — What Do You Want to Estimate?

***Average Reservoir Pressure*:**

RTA/PTA — Calculated using reservoir model.

PTA — Use the Arps/Smith Plot:

$$p_{ws} = \overline{p} - \frac{1}{b}\frac{d}{\Delta t}p_{ws}$$

***SRV — Stimulated Reservoir Volume*:**

RTA — SRV estimated from reservoir model.

FMB — SRV estimated using:

$$\frac{q}{(p_i - p_{wf})} = \left[\frac{1}{b_{pss}}\right] - \left[\frac{1}{b_{pss}N}\right]\frac{B_o}{B_{oi}}\frac{N_p}{(p_i - p_{wf})c_t} \quad \text{[FMB]}$$

$$\frac{(p_i - p_{wf})}{q} = \left[b_{pss}\right] + \left[\frac{1}{Nc_t}\frac{B_o}{B_{oi}}\right]\frac{N_p}{q} \quad \text{[RTA]}$$

Square Root Time Plot:

$$\frac{q}{(p_i - p_{wf})} = n_f A_{xf}\sqrt{k}\frac{1}{\sqrt{t}} \quad = c\frac{1}{\sqrt{t}}$$

OR

$$\frac{(p_i - p_{wf})}{q} = \frac{1}{n_f A_{xf}\sqrt{k}}\sqrt{t} \quad = \frac{1}{c}\sqrt{t}$$

***Reservoir Properties*: k, x_f, n_f, s_f, natural fracture properties, …**

RTA — Combines $q(t)$ and $p_{wf}(t)$ + reservoir model.

PTA — Analysis of $p_{wf}(t)$ + reservoir model.

$q(t)_{Forecast}$

DCA — Use an $f(t)$ proxy model (decline curve analysis).

RTA — Combines $q(t)$ and $p_{wf}(t)$ + reservoir model.

PTA — Superposition of $p_{wf}(t)$ + reservoir model.

***Data*:**

Time-Rate-Pressure (TRP) Data.

Completions Data.

Phase Behavior (PVT) Data.

Reservoir Properties.

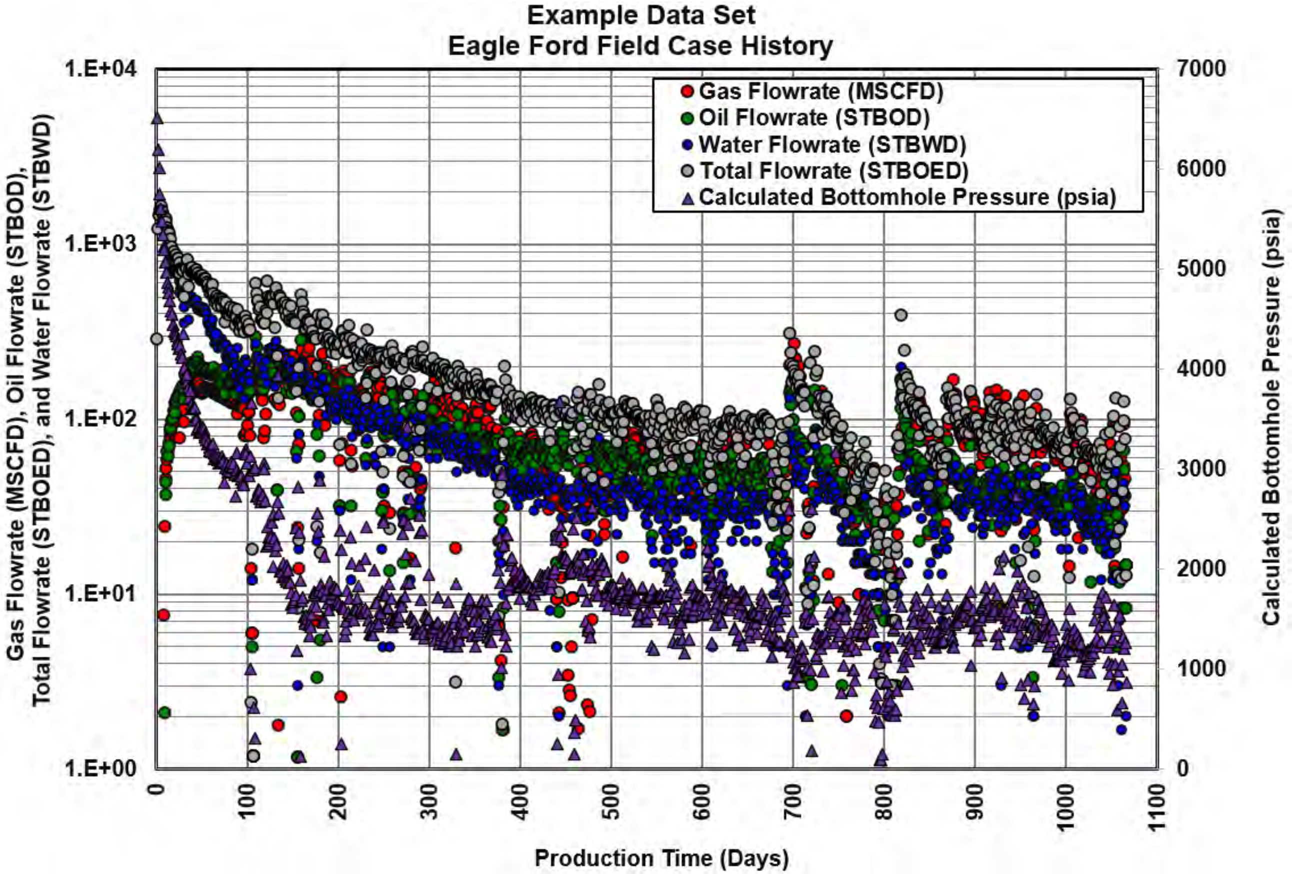
Rate Transient Analysis — What Can We do to our Data?

Data Operations:

- Auxiliary functions:
  - Productivity Index and other normalizations.
  - Time root functions.
- Smooth the Data:
  - Averaging, smoothing algorithms, splines, etc.
  - Wavelets.
- Calculus:
  - Integration (cumulative).
  - 1st and 2nd derivatives.
  - Other mathematical operations/operators.
- Mathematical Transforms:
  - Laplace Transform.
  - Other transform(s).
- AI algorithms:
  - Outlier rejection methods.
  - Training models.
  - ...

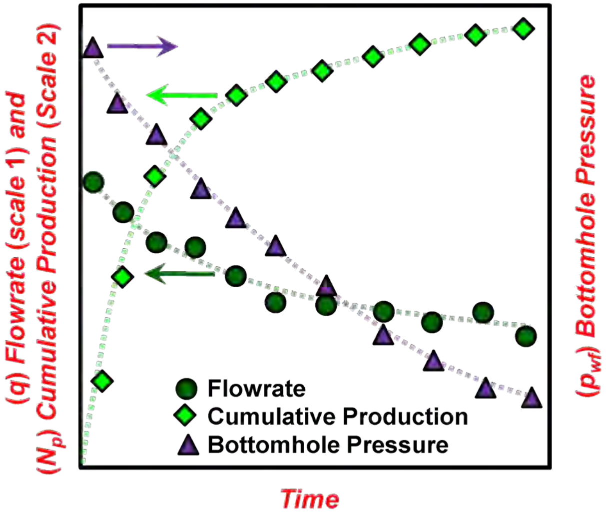
Guidance:

- (advice) Do not "over-smooth" data.
- (advice) Do not "over-edit" data.
- There is a balance, must maintain data fidelity.

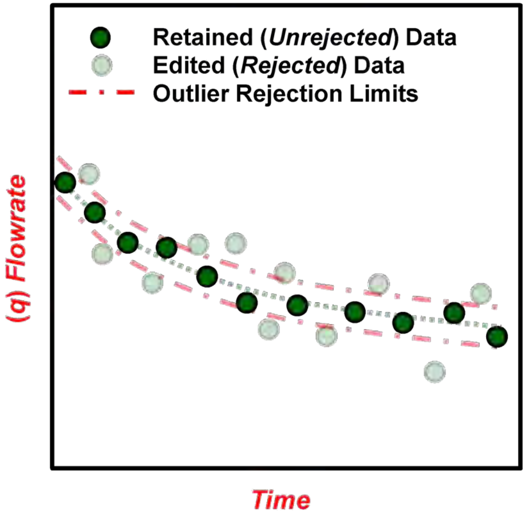


Rate Transient Analysis — Basic Data and Diagnostic Plots

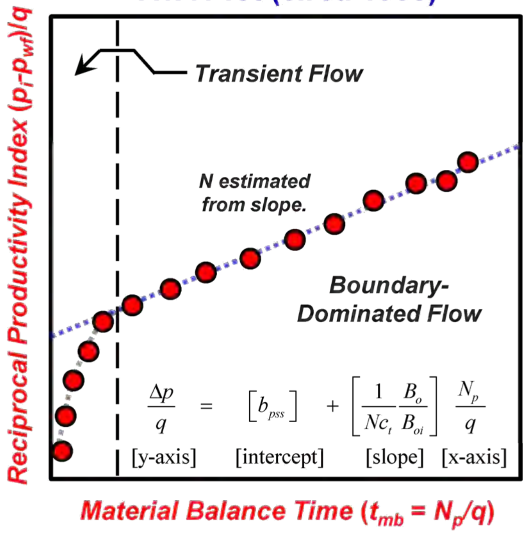
Base Rate and Pressure Data



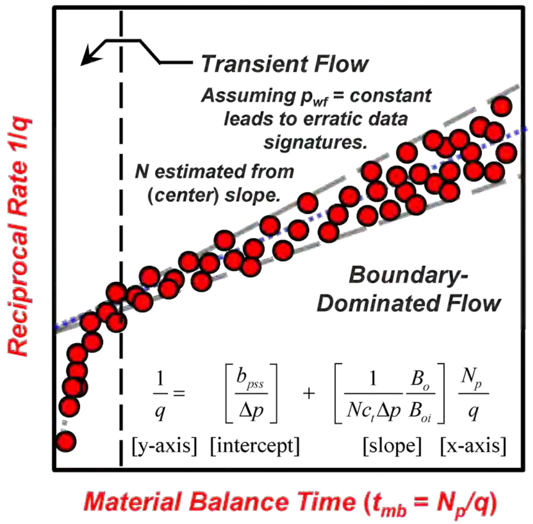
Data Editing Plot



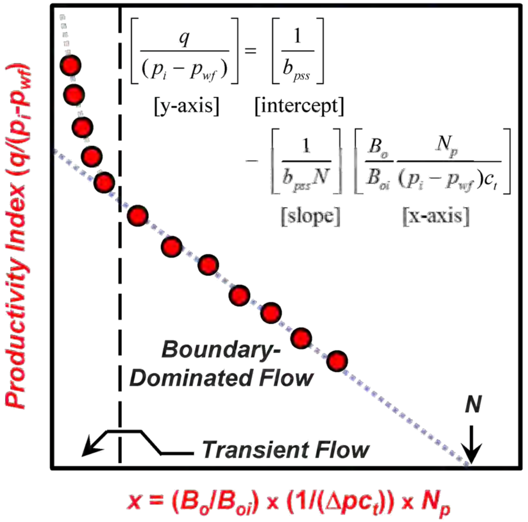
RTA Plot (circa 1985)



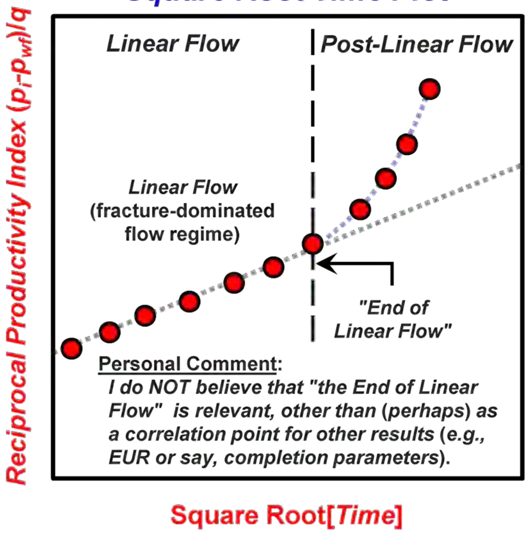
Reciprocal Rate Plot (circa 2009)



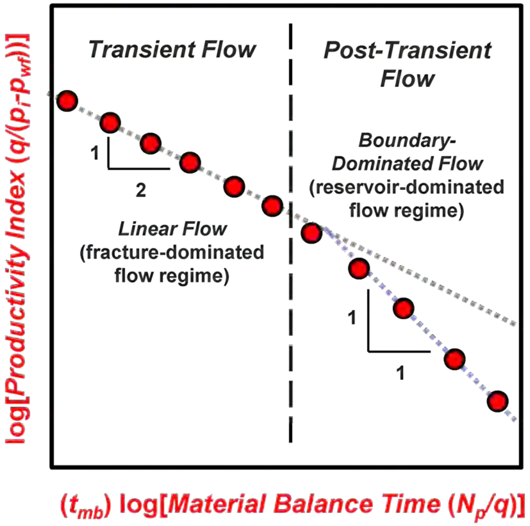
FMB Plot (circa 1998)



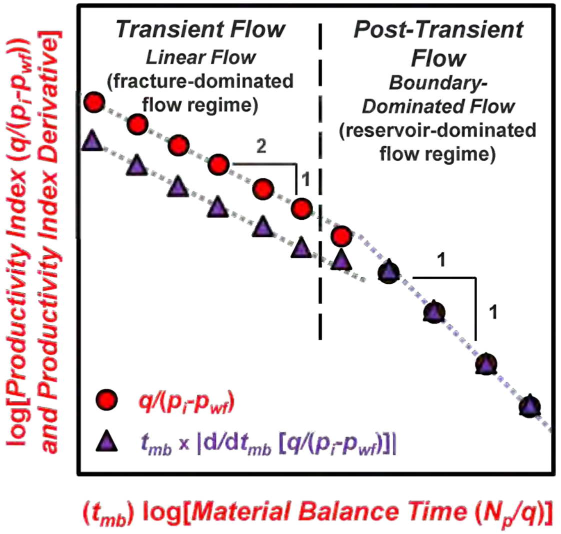
Square Root Time Plot



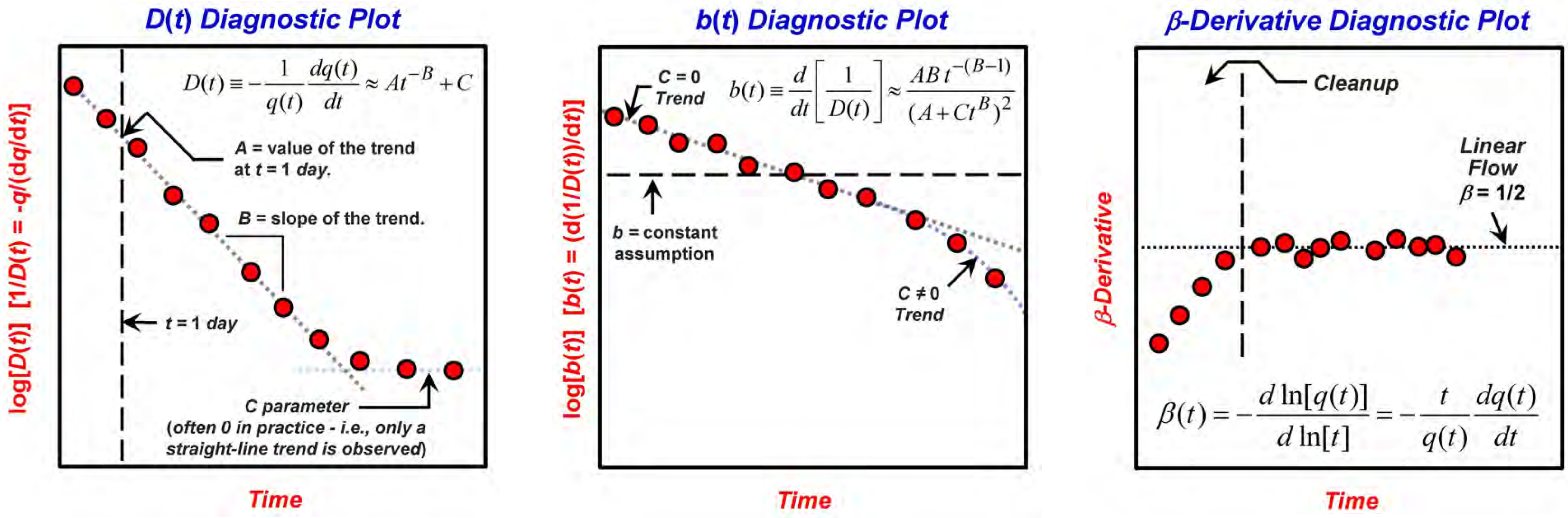
(Simple) RTA "Diagnostic" Plot



RTA "Diagnostic" Plot



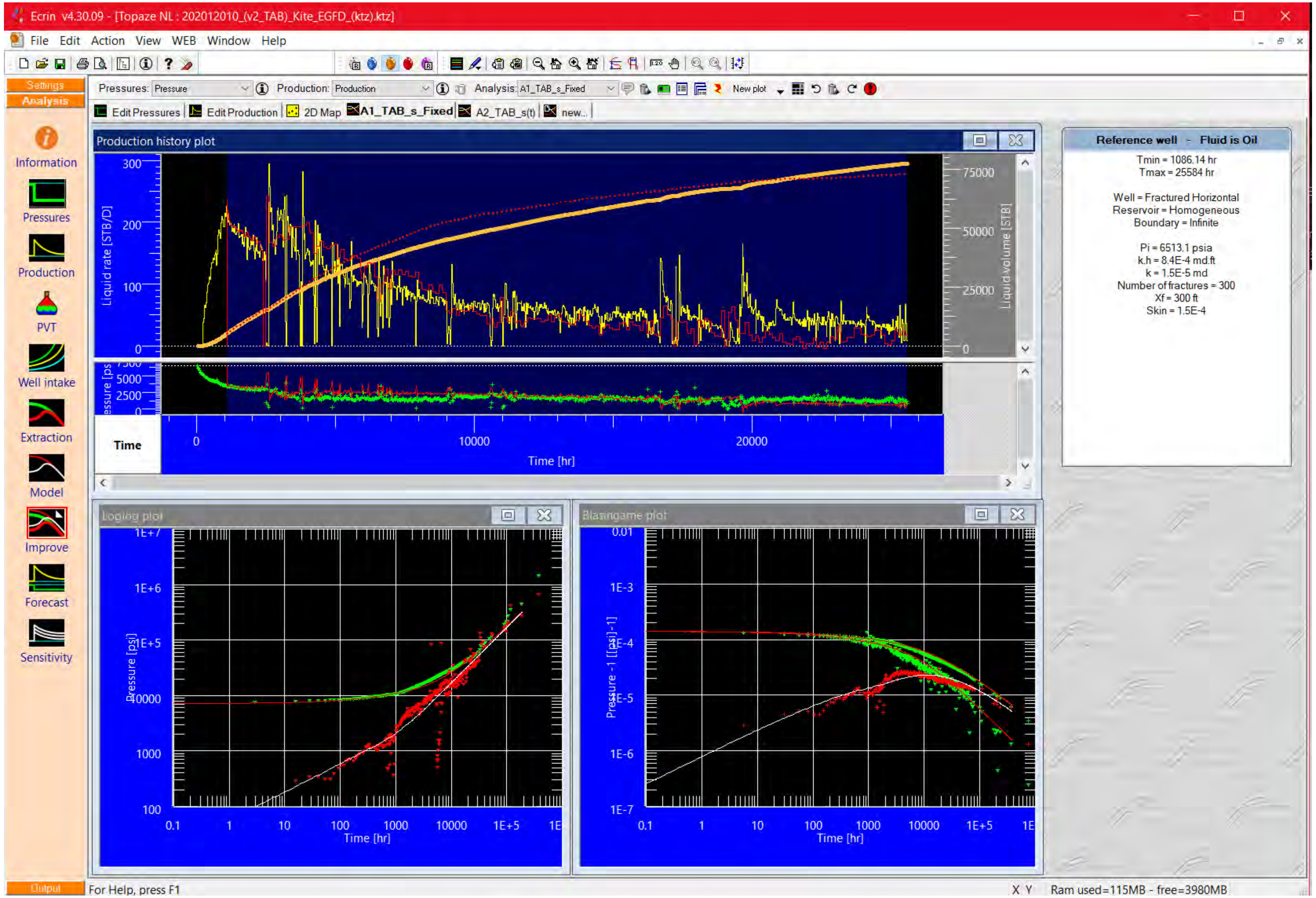
Rate Transient Analysis — Advanced Time-Rate Analysis Plots



Discussion:

- $D(t)$ is the "decline parameter" and represents the combined behavior of the rate and rate derivative functions.
- $b(t)$ is the "decline exponent" and represents the behavior of the second derivative of rate function.
- $\beta(t)$ is the "β-derivative" and is a function taken from pressure transient analysis; it yields the slope of a power-law trend.

Rate Transient Analysis — Example RTA (Eagle Ford, TX-USA) (constant skin case)



Background:

Daily q_g, q_o, and q_w.
Daily $p_{wf,cal}$.
Full completion history.
Relevant PVT data.
Selected/necessary reservoir data.

Interpretation:

Multi-fracture horizonal well model.
Flowrate data are erratic.
Pressure data not as erratic as rate.
PI and *RPI* functions are "reasonable."

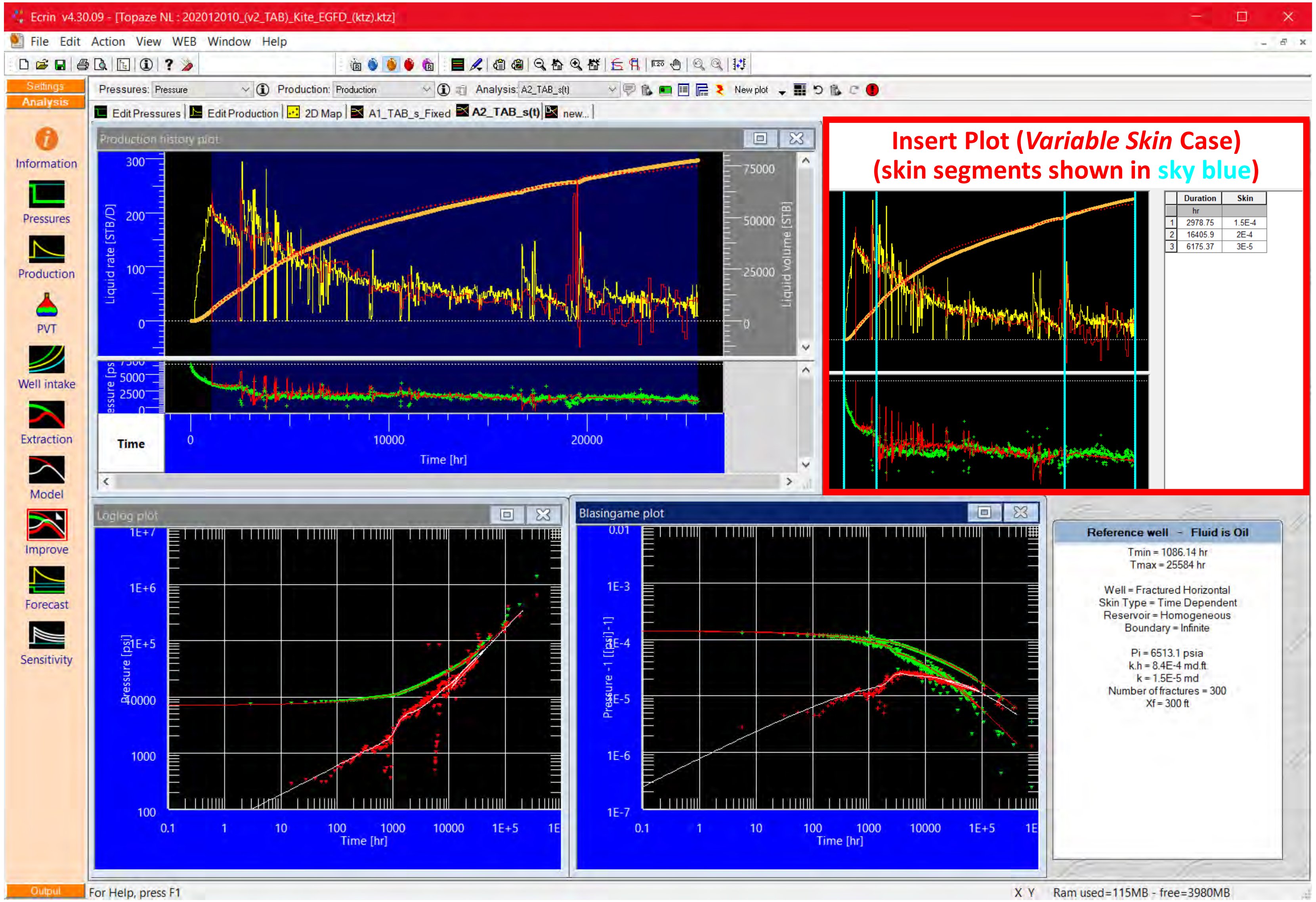
History Match: **Normal MFHW**

s_f = 1.5x10^{-4} (fracture face skin)
n_f = 300 (number of fractures)
x_f = 300 ft (fracture half-length)
k = 8.4x10^{-4} (formation permeability)

Comment:

Some mismatch in rates/cumulative.
Minor mismatch in pressure.

Rate Transient Analysis — Example RTA (Eagle Ford, TX-USA) (time-variant skin case)



***Background*:**
- Daily q_g, q_o, and q_w.
- Daily $p_{wf,cal}$.
- Full completion history.
- Relevant PVT data.
- Selected/necessary reservoir data.

***Interpretation*:**
- Multi-fracture horizonal well model.
- Flowrate data are erratic.
- Pressure data not as erratic as rate.
- *PI* and *RPI* functions are "reasonable."

***History Match*: Normal MFHW**
- $s_f = s_f(t)$ (*time-variant skin*)
- $n_f = 300$ (number of fractures)
- $x_f = 300$ ft (fracture half-length)
- $k = 8.4\text{x}10^{-4}$ (formation permeability)

***Comment*:**
- *Rates/cumulative matches very good.*
- *Pressure match slightly better.*

Comments
On
SPE

SPE =

Your Career Survival Guide

Contents:

- Career Management
- Skills Development
- Maintenance Learning
- Networking
- Technical Info/Tools/Refs
- Tips, tricks, and hacks

SPE Organizational Growth (2008-2019)

2008 Data:

- Professional Members: 68,627 [↑ high oil prices]
- Student Members: 23,546 [↑ high oil prices]
- Student Chapters: 211 [10%/year growth]
- U.S. PETE Faculty: ≈100-150 [my best guess]

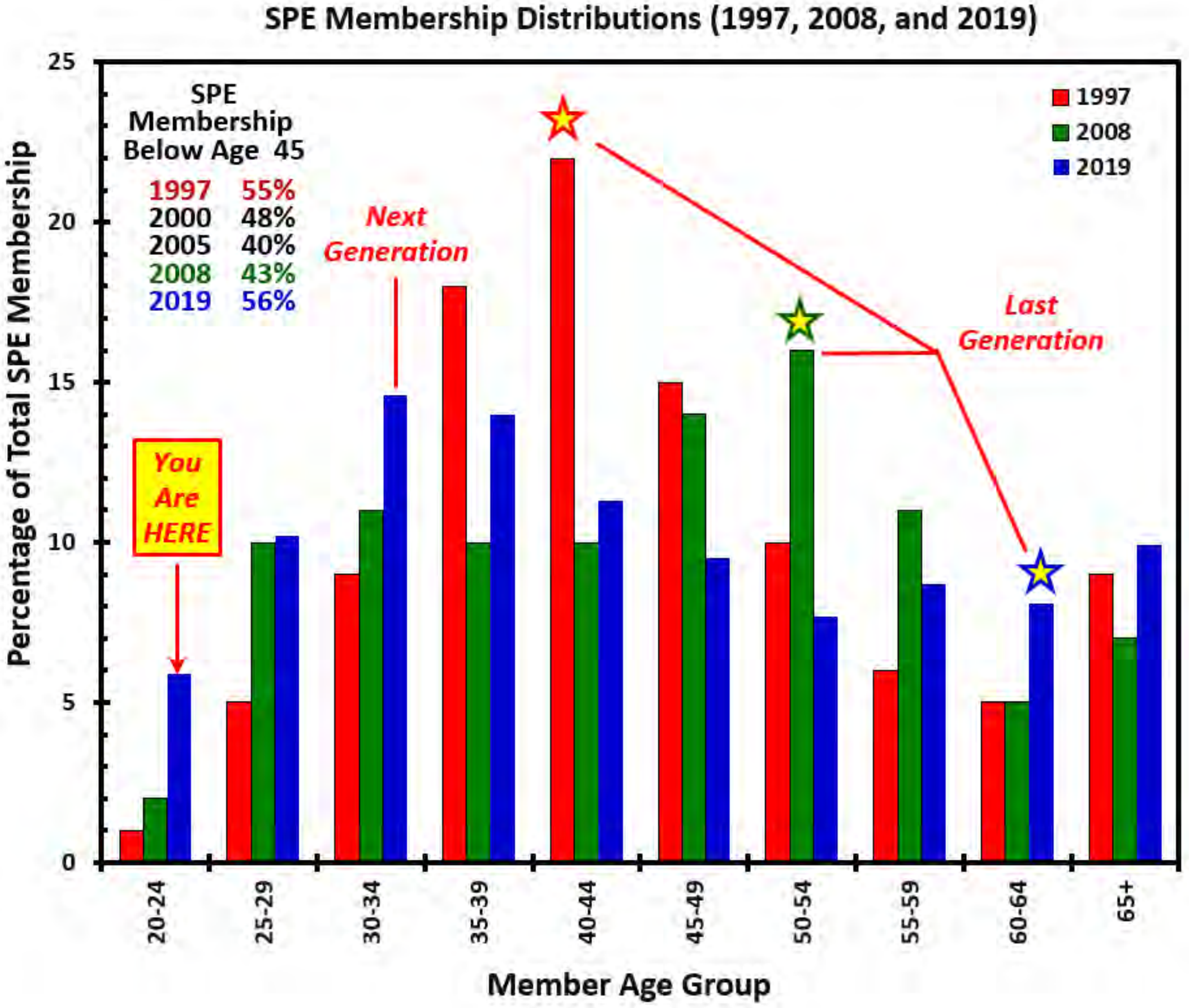
2019 Data:

- Professional Members: 83,930 [↓ COVID-19]
- Student Members: 69,704 [↓ COVID-19]
- Student Chapters: 411 [↕ Currently at ~410]
- U.S. PETE Faculty: ~300 [data/best guess]

The most significant single challenge for professional societies is how to remain relevant — I NEED YOUR HELP WITH THIS.

Also what member benefits are SPE members willing to pay for, and what specific benefits do they want?

SPE Membership Profile (... Evidence of the "Big Crew Massacre")



$$\textbf{SPE} = \int_{t_{start}}^{t_{end}} \textbf{Skills}\, dt$$

t_{start} = … *when you start your SPE membership.*
t_{end} = … *retirement, where fishing is your day job.*

Technical Knowledge — Skills, Needs, Standards
(... Has not changed significantly since 1940's)

Skills that Define a Petroleum Engineer:

- General Knowledge/Skills (Math, Engineering, etc.)
- Oil and Gas Drilling Systems
- Production Engineering and Operations
- Petrophysics, Formation Evaluation, and Geology
- Reservoir and Well Performance, Reservoir Fluids
- Petroleum Project Evaluation (Reserves/Economics)
- Integrated/Multidisciplinary Teams

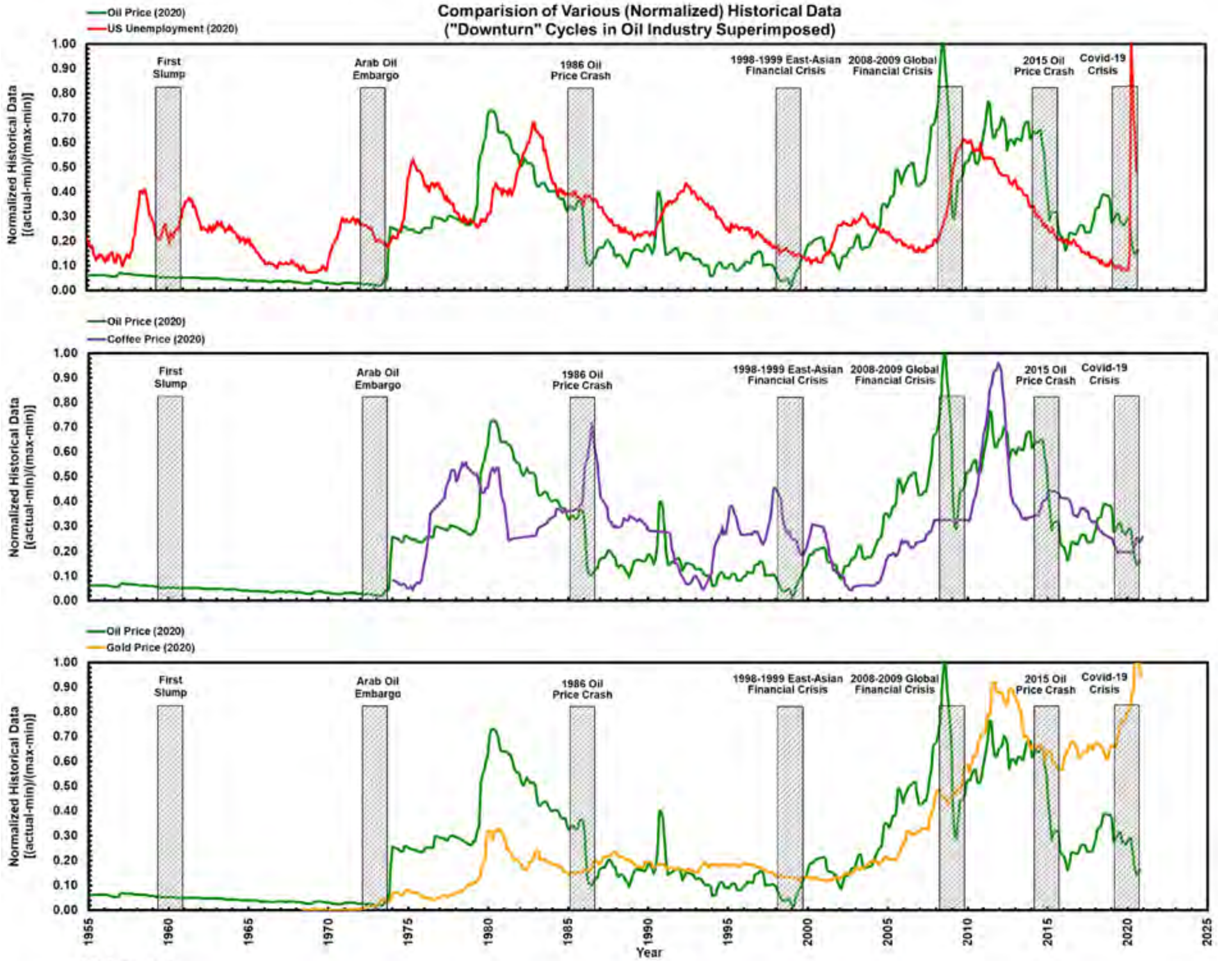
Emerging Needs/Skills that Must be Emphasized:

- Unconventional Reservoir Technologies
- Statistics/Data Manipulation (*i.e.*, "Data Analytics")
- HSE+S (+ the so-called "Sustainability" aspects)
- ESG = Environmental, social & corporate governance
- Integration: DRLG, CMPL, RESR, PROD, FACL, …

Standardization:

- Traditional Areas: North America/Western Europe
- Emerging Areas: FSU/Africa/S.E. Asia/Middle East
- COMPANIES need to help SPE establish standards

Commodity Businesses are Cyclical
(... Oil Price Appears to be a Leading Indicator)



References:
1. (Unemployment) https://data.bls.gov/
2. (Gold Price) https://goldprice.org/gold-price-history.html
3. (Oil Price) https://www.macrotrends.net/1369/crude-oil-price-history-chart
4. https://www.macrotrends.net/2535/coffee-prices-historical-chart-data

$$\text{SPE} = \frac{d(you)}{dt}$$

(Network, skills development, leadership, volunteerism)

What Can You Do for SPE as a Student?

Participate:
- Participate in your Student Chapter.
- Participate in your Regional Section.
- Participate in a program committee.
- Engage with technical expert(s).
- Participate in the e-mentoring program.
- Nominate a colleague for an award.

Create:
- Write a paper. (but have a good mentor)
- Create an event in your Student Chapter.
- Create a community service experience.
- Create a training opportunity for students.
- Create a technical event in your Chapter.
- Create a social/networking event.

Why Should I Volunteer?

Benefits of Volunteerism:
- Learning SPE from the bottom-up.
- Learning how to function in an organization.
- Learning how to lead without authority.
- Learning how to create.
- Learning how to work with others.
- Learning how to create from scratch.

How Do I Volunteer?

Society of Petroleum Engineers

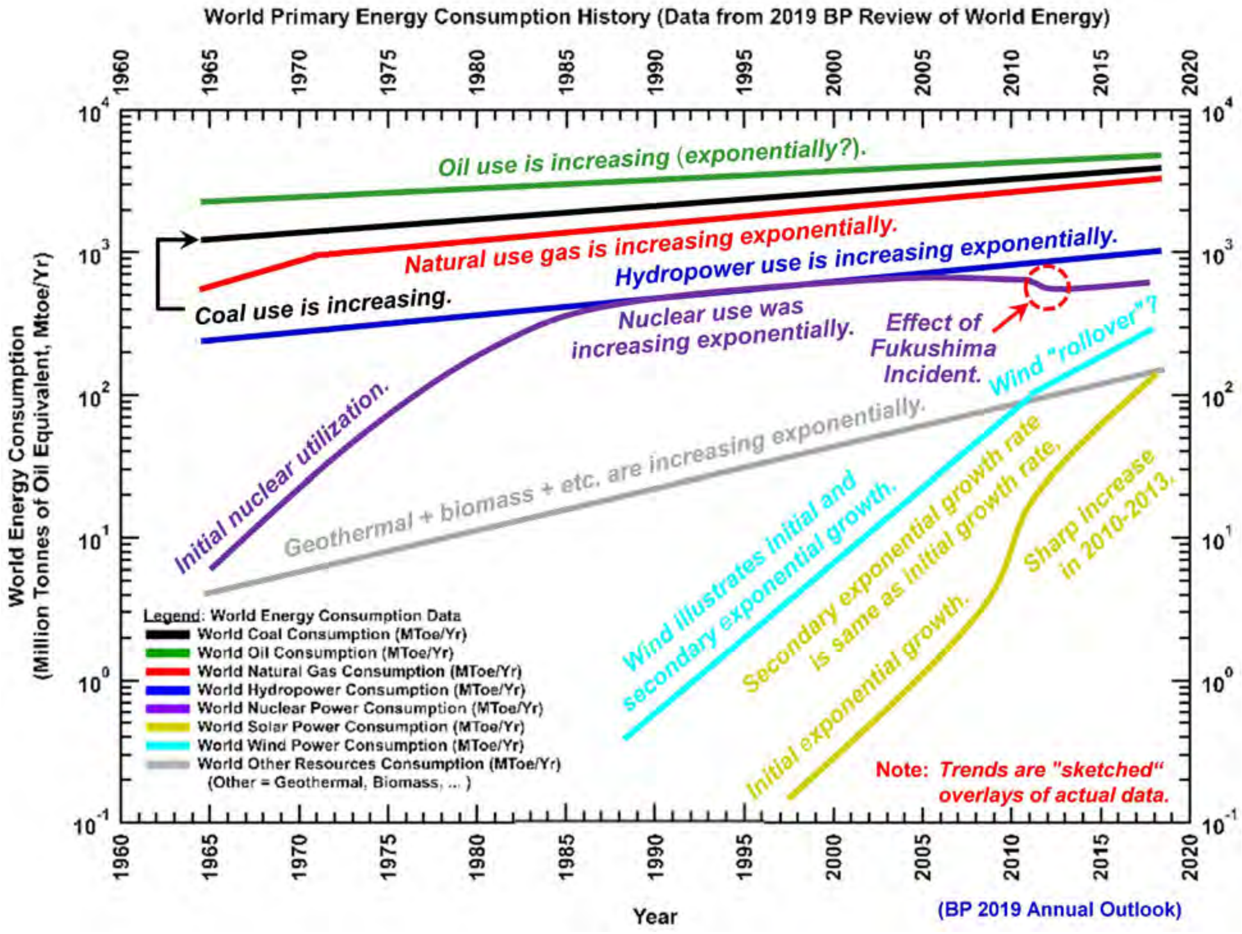
https://www.spe.org/en/volunteer/

$SPE = |World|^T$

(Translation: SPE transforms the World)

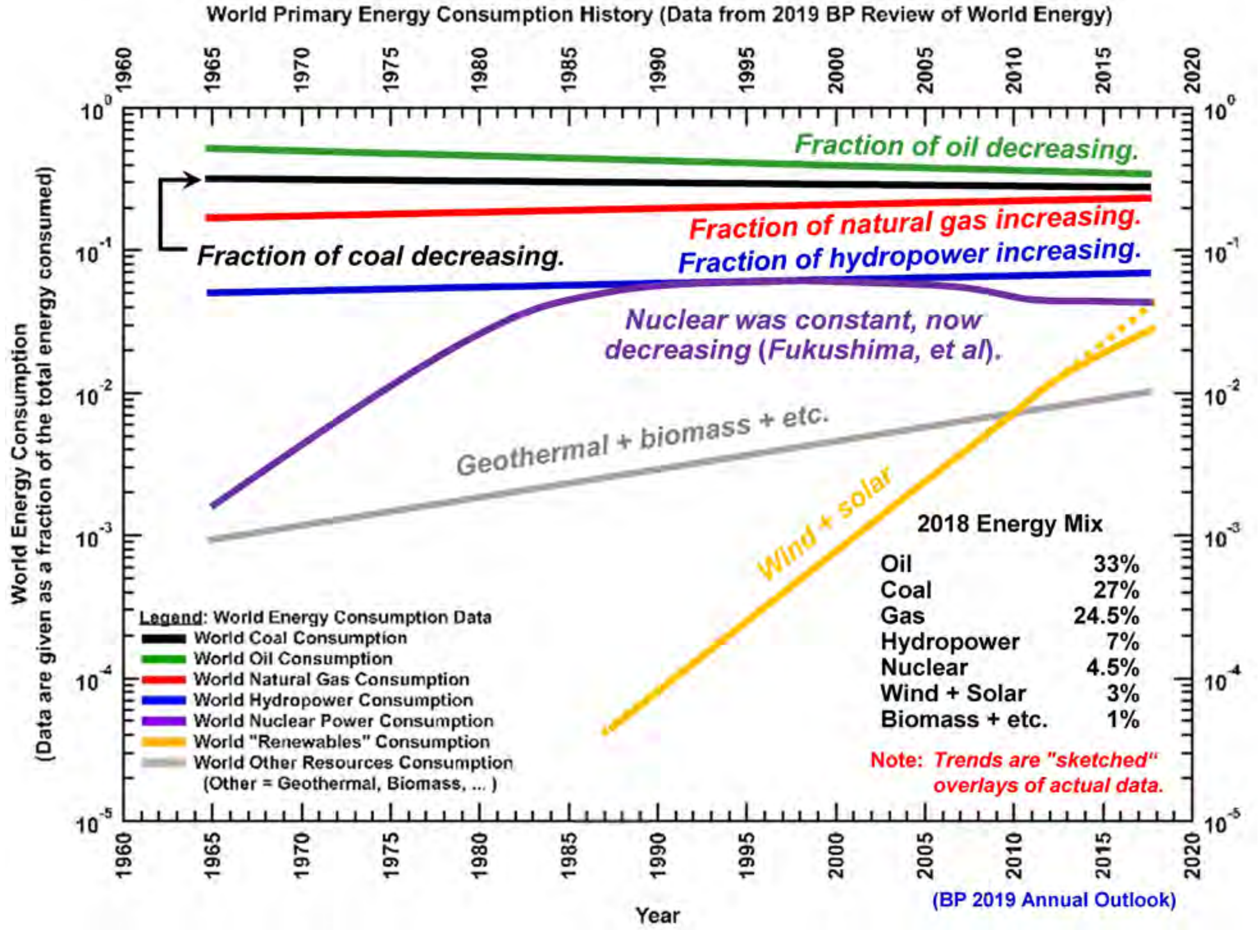
| Tom BLASINGAME | Petroleum Engineering | Texas A&M University | College Station, TX 77843-3116 (USA) | t-blasingame@tamu.edu |

We are Energy Transition"
(... Our world has a gigantic appetite for energy ...)



Consumption of ALL energy sources are increasing at independent exponential rates ... A-L-L.

We are Energy Transition"
(... Oil and gas are the keys to the future energy mix ...)



Fraction of all energy sources except for oil, coal, and nuclear are increasing at independent exponential rates.

SPE
+ = #WeAreSPE
You

(Translation: A wee bit of career advice …)

| Tom BLASINGAME | Petroleum Engineering | Texas A&M University | College Station, TX 77843-3116 (USA) | t-blasingame@tamu.edu |

What We Do Really Matters …
(*The contract you are signing is to take care of …*)

Billions of people *without access to*:

0.7 - 2.1	*Clean/secure water*	[US CDC[1], WHO[2]]
1.8	*Adequate sanitation*	[US CDC[3]]
0.95	*Electricity*	[IEA[4]]
2.6	*Clean cooking*	[IEA[5]]
0.8 - 2	*Sufficient/secure food*	[UN[6]]
1.2	*Safe and secure housing*	[WRI[7]]
0.264	*Any education*	[UNESCO[8]]
4(+)	*Internet*	[UN[9]]

To put this in context: (what is a "billion"?)

1 Billion seconds = 31.69 years
= 11,574 days
= 16,666,666.6667 minutes

References:
1. https://www.cdc.gov/healthywater/global/wash_statistics.html#:~:text=Access%20to%20WASH,world's%20population)%201%2C%203.
2. https://www.who.int/news-room/detail/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who
3. https://www.cdc.gov/healthywater/global/wash_statistics.html#:~:text=An%20estimated%20790%20million%20people,access%20to%20adequate%20sanitation%2015.
4. https://www.iea.org/commentaries/population-without-access-to-electricity-falls-below-1-billion
5. https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking
6. https://www.un.org/en/sections/issues-depth/food/index.html#:~:text=Considering%20all%20people%20in%20the,in%20North%20America%20and%20Europe.
7. https://www.wri.org/news/2017/07/release-12-billion-people-living-cities-lack-access-affordable-and-secure-housing
8. https://unesdoc.unesco.org/ark:/48223/pf0000259338
9. https://www.itu.int/dms_pub/itu-s/opb/pol/S-POL-BROADBAND.18-2017-PDF-E.pdf

Career Guidance 101
(*Sort of a checklist/list of reminders …*)

What is Good? Great? Ambition?
- Good MANAGERS do things right… (*… your strengths*)
- Good LEADERS do the right things… (*… your values*)
- Great achievements = desire to succeed... (*… fact of life*)
- Great achievers make great sacrifices… (*… e.g., family*)
- Ambition is fine, but know your limitations (*… trust me*)

Your Career Choices…
- Your value is your skills set… (*... harsh, but true*)
- Inexperience is your limitation … (*... listen/learn/lead*)
- 70% of young engineers want management... (*>3% get it*)
- Are you fit for command… (*... yes … no … maybe?*)
- Choices? (*… there are no "wrong" choices*)
- Commitments? (*... you are only as good as your word*)

Learn How to Work …
- You are paid to complete tasks… (*… don't waste time*)
- You are paid to make decisions… (*… don't be afraid*)
- You will make mistakes… (*… but never put others at risk*)
- You are no longer in school… (*… no "grades" but …*)
- You work with incomplete data… (*… analyze, don't guess*)

$$\text{SPE Student Chapters} = \lim_{fun \to \infty} \left[\text{Students} + \text{Leadership} + \text{Learning} \right]$$

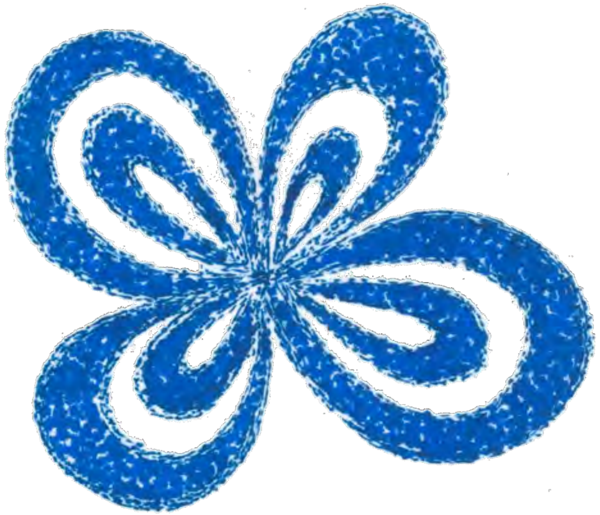
TAMU-SPE 2019-2020 SPEi Annual Report Photos

TAMU-SPE 2019-2020 Photo Mural (Student Prepared)

It is not an exaggeration to say that being the SPE Student Chapter Advisor is my favorite job! There is never a dull moment (literally), and watching students evolve into Young Professionals is one of the most rewarding aspects of my career.

So what is Tom Really Like?

Napkin Art (drawn on a flight)



Marriage Counseling (in NZ)

December in College Station

My Favorite Place and Best Friends

Tom with Granddaughter

2020 Summer Internship (stump remover)

Family in "Hobbiton"

View from NZ Home

Tom's Biography

Tom BLASINGAME
Petroleum Engineering
Texas A&M University
College Station, TX 77843-3116 (USA)
+1.979.845.2292 — t-blasingame@tamu.edu

Role:
- Professor, Texas A&M U.
- B.S., M.S., & Ph.D. — Texas A&M U.


[2019] (removed overalls straps for photo)


[2019] (China visa photo)


[2012] (civilized photo)


[2008] (self-image)


[how others see me]

Counts: (October 2020)
- Over 170 Technical Articles
- 16 Ph.D./72 M.S. Graduates

Historical Technical Contributions:
- (1980's) Material Balance DCA (so-called "Rate Transient Analysis" (or RTA))
- (1990's) Analysis of Water-Oil-Ratio (WOR) Behavior
- (1990's) Direct Estimation of p_{avg} from Pressure Buildup Tests
- (2000's) Pressure Integral and "Beta" Derivative for PTA and RTA Methodologies
- (2000's) DCA and CEUR Relations for Unconventional Reservoirs
- (2010's) Diagnostic Analysis of Time-Rate Data (*i.e.*, the *qDb*-plot)
- (career) Correlations for Rock and Fluid Properties
- (career) Deconvolution Methods (approximate, direct, and numerical)

Historical Professional Recognition:
- SPEi Distinguished Member (2000)
- SPEi Distinguished Service (2005)
- SPEi Uren Award (2006)
- SPEi Lucas Medal (2012)
- SPEi DeGolyer Service Medal (2013)
- SPEi Distinguished Faculty Award (2014)
- SPEi Honorary Member (2015)
- SPEi Director (Reservoir) (2015-2018)
- SPEi President (2021)

Research Interests: (2020)
- Time-Rate ("Decline") Analysis
- Early-Time "Flowback" Analysis
- Time-Rate-Pressure (RTA) Diagnostics
- Pressure Transient Analysis in Shales
- Production/Completion Correlations
- Numerical Analysis/Interpretation of Data
- Phase Behavior of Reservoir Fluids
- Analytical Solutions for Reservoir Behavior