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Rigorous Gas Field Production Data Analysis APPEA 2019

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A Word to the Wise

The author acknowledges the assistance of IHS in providing the Production Diagnostics, Flowing Material Balance and Composite Analytical plots in this presentation

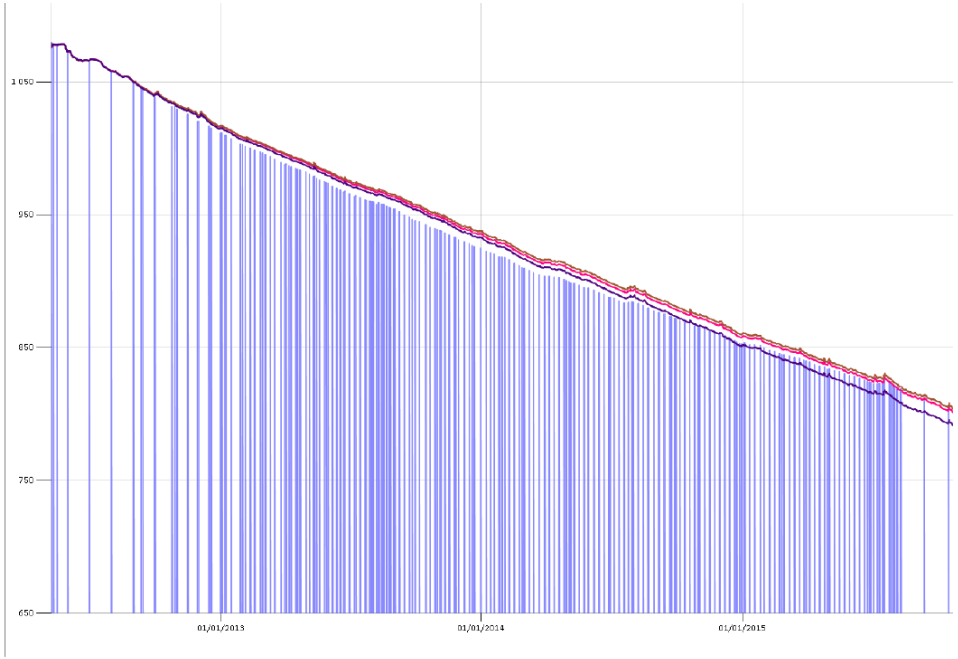
Key Thought of Presentation

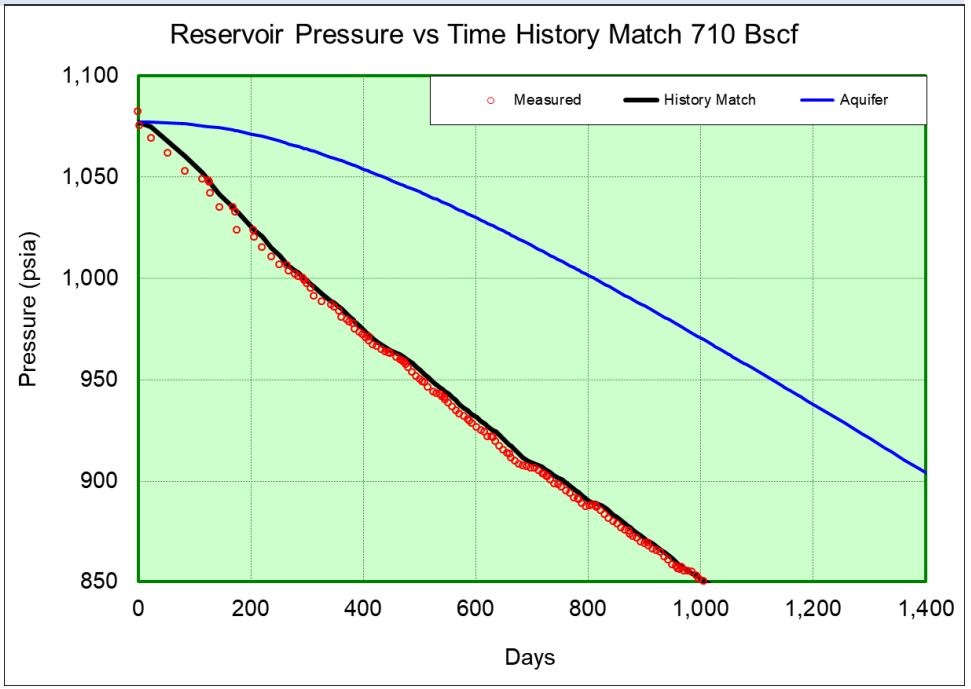
Insight is gained from understanding. It is not likely to be obtained from brute force application of one size fits all techniques, but by using an appropriate combination of techniques that illuminate the underlying physics of the reservoir at hand.

"Tech support says the problem is located somewhere between the keyboard and my chair."

The Price of Getting it Wrong

Gas Field under Active Waterdrive. 1000 + Multi Realizations based on a HM P50 Case to derive P10 and P90 GIIP. Subsequent premature water breakthrough ended production 2 years earlier than P90 Forecast





Multi Realization P90 to P10 GIIP range 836 to 867 Bscf: i.e. 3% range in uncertainty in GIIP with less than half the GIIP produced

Sensitivities around a base case model failed identify the most likely solution or the range of outcomes.

In this example analytical methods based on production created a most likely (P50) GIIP outside the multiple realisation history matched range

Data Driven Production Modelling

It is the safest technique in the business since it is the minimum assumption route through the subject of Reservoir Engineering concerning the basic understanding of the physics of reservoir performance.

Data Driven Models	Simulation Driven Models
Independent of geological models	Dependant on facies driven geological models
Immune to petrophysical cutoffs	Sensitive to petrophysical cutoffs
See only connected GIIP	Sees all GIIP whether connected or not
GIIP estimate not an '*a priori*' assumption	GIIP estimate an *'a priori'* assumption
Less degrees of freedom in the solution space	Greater degrees of freedom in the solution space
Data will tell you what's going on!	***Relying on the model to tell you what's going on!***

The Tools and Workflow

Today it is unusual not have FTHP (dynamic data) & good reservoir management practices will have regular PBU (static data)
Production, static and dynamic pressure data, PVT and completions data is all that is needed to utilize the tools available

The Tools

- Log Log Diagnostic plots:
  - Identifies transient vs Pseudo Steady State (PSS) Flow
- Static Material Balances:
  - P/Z plots mislead, Cole and Havlena Odeh plots don't
  - Analytical aquifer models such as PSS Fetkovich do not require an explicit geological description
- Flowing Material Balance (P/Z**):
  - Integrate FTHP/FBHP
  - Clearer visualization of additional energy sources
- Rate Transient Typecurves:
  - Clear identification of transient and PSS flow
  - Can discriminate between aquifer and multitank support under certain circumstances
- Simple Analytical Models:
  - Pressure and rate history matching drawing from GIIP/reservoir and architecture results of the above tools, closes the analysis loop

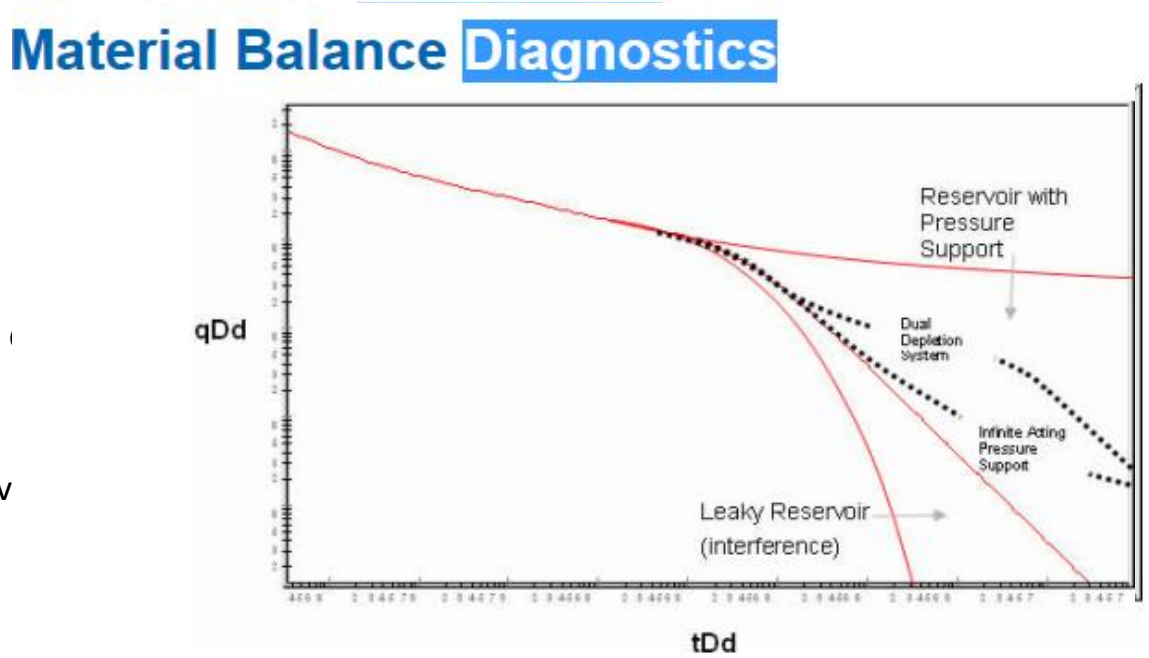
The Workflow

- Step (1) Data quality and diagnostics:
  - Data quality control
  - Diagnostic plots
  - Identification of flow regime(s)
- Step (2) Interpretation and analysis:
  - Drive mechanism and multi-tank behaviour Aquifer characterisation, reservoir architecture
  - GIIP estimation
- Step (3) Modelling, history matching and forecasts:
  - Building simple analytical models utilising material balance, FMB and Type Curve results
  - History match rate and pressure verify GIIP and reservoir architecture

The Pitfalls – Data QC and Diagnostics….

More often that not, only after model(s) generate non sensical results, does Data QC and Diagnostics becomes important
As Abraham Lincoln famously said *"Give me six hours to chop down a tree and I will spend the first four sharpening the axe."*

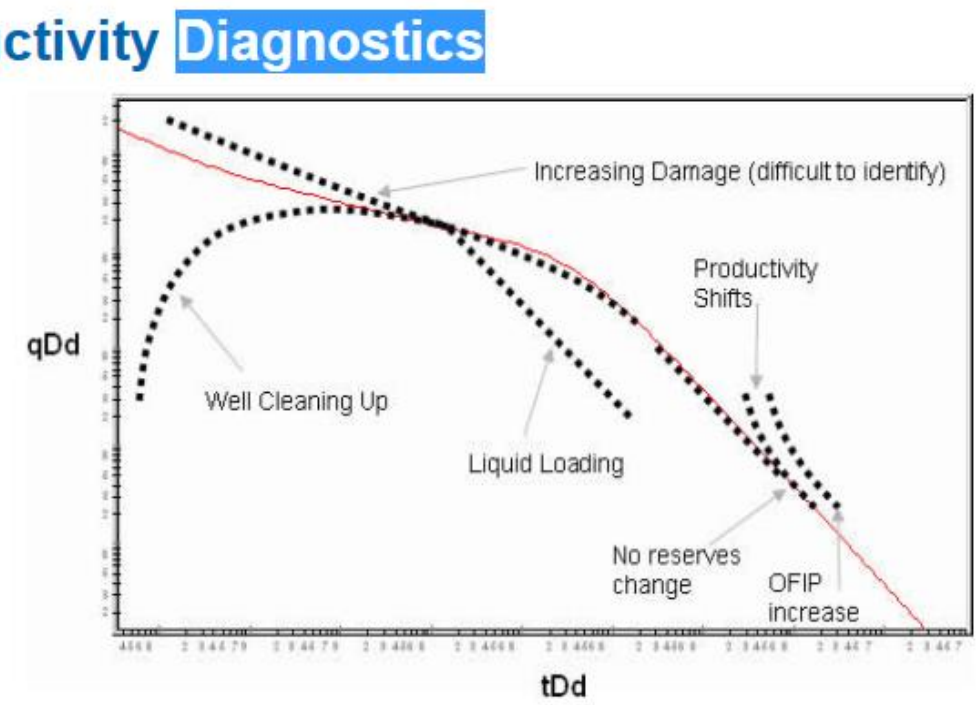
- In reality there are two types data good or bad, and some of the bad encountered:
  - Pressures not corrected to reservoir datum
  - P* used when PTA clearly shows late time boundary dominated behavior
  - FTHP and Rate trends inconsistent
  - Physically impossible outliers included
  - Production misallocation
- Bad news doesn't improve with age nor does bad improve with more complex analysis
- Log Log Diagnostics provide the insight into reserv architecture and drive mechanism(s):
  - Transient vs PSS
  - Productivity shifts
  - Early time vs Late time behavior
  - Rate sensitivity behavior
  - Particular useful if there have been shut in periods



Discriminating Between Additional Sources of Energy

Being able to discriminate between potential sources of additional energy is crucial for reservoir management
Is it possible to use Production Data Analysis to determine if additional energy is Aquifer and/or multitank pressure support?

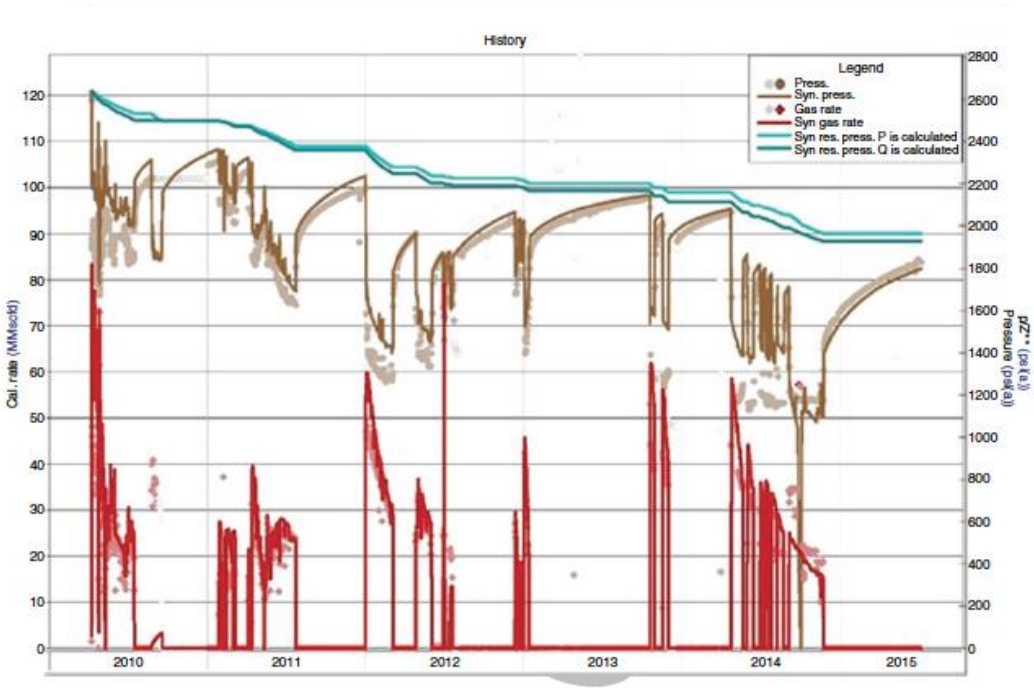
- Lets look an example of integrating static material balances and RTA Type curves where flowing data and field shut in data is available
- Static Material Balance Cole diagnostic plots indicates additional sources of energy
- Typecurve for vertical well in a uniform reservoir indicates repeated productivity shifts, but once well is back on production productive shift are parallel to unit negative slope line
  - The repeated productivity shifts parallel to the negative unit slope line indicate increasing GIIP with time suggesting multitank behavior
  - After periods of shut in the Typecurve trend parallels the unit negative slope line i.e. volumetric depletion drive



Putting it All Together

So we've covered a lot, let's put it all together illustrating the workflow that captures GIIP and Forecasting

- Step (1) Data quality and diagnostics:
  - P* static pressures discarded, last known PBU data utilized
  - Static build up pressures overlay FMB derived P/Z** pressures
- Step (2) Interpretation and analysis:
  - Multi-tank behavior is characterized on a FMB plot by repeated offset transient 'stems' that fail to merge to a single P/Z** depletion line
  - Analysis of this early time data using FMB provides an estimate of the volume well-connected to the wellbore
- Step (3) Modelling, history matching and forecasts:
  - Simple composite analytical model to represent the multi-tank system
  - This consists of a wellbore in the centre of a small tank which is surrounded by and connected to a larger tank with lower permeability



- Whilst it is tempting to draw a line of "best fit" through the FMB data, this fails to identify multi-tank behaviour and may lead to misunderstanding of how the field will physically produce

Rigorous Gas Production Data Analysis

Automated data gathering, increased computing power, fit for purpose software and specialized analysis i.e. Flowing Material Balance and Rate Transient Analysis (RTA) provides capabilities unheard of 20 years ago…

Although these significantly enhance the capabilities of engineers in grasping the underlying physics of reservoir behavior, the two key deliverables: gas in place (GIIP) estimation and production forecasting remain unchanged

Production Data Analysis may appear simplistic, but it is Reservoir Engineering and requires judicious thought as we as Reservoir Engineers live in a world characterized by uncertainty and non uniqueness

Thinking outside the box by considering alternate geological realizations that honor pressure and production data is time spent better, than attempting to finesse simulation models

The reservoir physics, just the reservoir physics ma'am….

A Word to the Wise

Bernard Tomic's nickname is "Tomic the Tank Engine"….Don't let it become yours….

- Observations:
  - Computing power enables multiple realizations to be evaluated with automatic history matching. Such detail may give the impressions of accuracy.
  - Analytical methods based on rigorous production data identifying the key reservoir drive mechanisms and architecture may show GIIP interpretations outside the range from automatic history matching.
  - An anchored (biased) multi realization base (P50) model may unrealistically limit the range of GIIP uncertainty.

- Conclusions:
  - Analytical methods based on rigorous production data have no pre-conceived reservoir interpretation:
    - They will unbiasedly identify the reservoir drive mechanism and key reservoir architecture
  - Such methods can readily bracket the range of GIIP in gas fields and are an important quality control check at the early stages of multi realization:
    - Analytical methods should be used to constrain simulation rather than verify results
    - If the GIIP ranges are not congruent STOP, something is not right!

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