Well Testing For G&G guys (and gals)

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What is Well Test Interpretation?

- Looking at squiggly lines in pressure and/or rate data to divine what’s happening in the completion and/or reservoir
- A science?
- A religion?
- Both?

- Maybe it’s just a tool to aid in understanding the well/reservoir?
Well Testers Agree (Usually) On

- Skin
- Perm (kh)

- The model we used for the analysis is right until we’re proven wrong
  - If wrong, blame the data
  - If data’s good, blame fluid and/or rock properties

- We’re always right ➔ You need to change Your model
What is Permeability?

- The ability of the rock to flow fluids
- A measure of the cross-sectional area of the connected pores in a rock.
- Permeability is a variable. It can change!
- It allows you to calculate what your well SHOULD be producing.
What is Skin?

• A reduction in POTENTIAL flowrate caused by ANYTHING, aka an additional resistance, or pressure drop, to overcome.
  • Damage
  • Non-Darcy effects
  • Partial perforation
  • Plugging

• Just a Fudge factor extra pressure drop in the near wellbore region.
What is Damage?

- Reduction in POTENTIAL flowrate caused by reservoir or foreign material.
  - Drilling mud
  - Plugging with fines
  - Clay swelling
  - Compaction
  - Perforation damage
- Damage can be reduced!
Common Terms
(and what they really mean)

• Wellbore Storage:
  – Something at the beginning of the test that I don’t understand and can’t explain – err, if I stimulate a well & improve the completion, I change the Wellbore Storage without changing the volume of the well bore...but, no one’s going to ask...

• Non-Uniqueness:
  – Something at the end of the test that I don’t understand and can’t explain – err, there’s a good chance that I’m wrong but can’t admit it...just too many unknowns & not enough equations...what’s a fancy word I can use for this so I’m still the smartest person in the room (be sure to pat self on back)?
More Terms...

- **Condensate Banking:**
  - Something in the middle of the test that looks like liquid dropped below the downhole gauge...Oh, crap! I rented them the gauge & they’re going to do the “blame the gauge” trick...hmmm, it IS a gas condensate well...

- **Phase Re-segregation:**
  - Well...that’s weird...what can I call that?

- **Smoothed Data:**
  - I couldn’t get a model to match it, so I “fixed” the data
State of the Art
What We Do Now

- Set Capillary Entry Pressure to Zero
- Derive Diffusion Equation
- Guess a Fixed Reservoir Boundary
- Assume Flow Field is Initially Connected
- Compute Solution
- Smooth Real Data and Make a Comparison
- Guess Again
A Bit of Controversy:

ISN’T LOOKING AT THE MAP FIRST...Just...

CHEATING?

Does Blind Mapping Increase the Validity of the Model?
What if...

- Instead of performing mathematical manipulation with the data and pre-setting the boundaries, we:
  - Apply Thermodynamic Constraints (1\textsuperscript{st} & 2\textsuperscript{nd} Law)
  - Include the Higher Order Terms in the Diffusivity Eqn
  - Include the Concept of Threshold Pressure (pressure drop required to initiate flow from a pore)
  - Treat the System Like a Mass Transfer/Energy Dissipation Process
R&D Session: Blind Energy Map
(After Many Beers...)

• A Closed Solution
• Running Volumetrics – don’t have to reach PSS to get a volume
• More Accurate Permeability-Thickness
• More Accurate Distances to Limits
• Differentiate between Faults, Strat-outs & Gas-Liquid Contacts
• Relative Position of Limits to Each Other
• A Map You can show the G&G guys without getting laughed out of the room
Blind Energy Map – Example 1
From pressure/rate data ONLY

...Now, let’s meet with the G&G team

This is the point to begin integration of Well Testing & Seismic.
Is This One or Two Reservoir Compartments?
Blind Energy Map – Example 1
Blind Energy Map – Example 1

Conclusion:

• The reservoir compartments are **NOT** connected

• The study improved operator's geological interpretation

• ODSI evaluated 18 BFC of gas in place; the well produced 12.7 BCF (depletion drive; high compressibility rock)

• Once the ‘Top’ compartment was depleted, the operator side-tracked to the ‘Bottom’ compartment and encountered virgin pressures
Questions?

• How Long to Generate Results? 2-5 days
• How Much? <$35,000 plus data acquisition costs
• Besides the Pressure & Rate Data, What do You Need?
  – Logs
  – Core/SWC data
  – Fluid Properties
  – Completion/Wellbore Diagram
  – NOT Your Map
Full Study – Example 2

- Working Session with G&G Team
- Well Test Analysis Performed
- Energy Map Generated
- Overlay made of Energy Map
- Energy Map compared to Geologic Map
- Back to the G&G workstation...
- New View of Geology
Blind Energy Map – Example 2

- Reservoir Boundaries, types of boundaries and shape of the reservoir were identified from pressure/rate data only
Blind Energy Map – Example 2

Overview of identified reservoir boundaries

- Boundary 1
- Boundary 2
- Boundary 3

WAVEX Limit & Energy Diagram

Andrus Robertson No.1
Scale: 1” = 1000’

Rinv = 2836’

Radius of Investigation
Blind Energy Map – Example 2

WAVEX Energy Map

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

Boundary 1

Radius of Investigation

Rinv = 2836'

Reservoir Growing at End of Test

WAVEX Blind Energy Map – Example 2

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

Boundary 1

Radius of Investigation

Rinv = 2836'
Blind Energy Map – Example 2

Comments:
- Boundary 1 and Boundary 2 appeared parallel to each other (Observed linear flow on the pressure data)
Blind Energy Map – Example 2

WAVEX Energy Map

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

2076' Bi-Directional Width

380'

1186'

Rinv = 2836'

2076' Bi-Directional Width

Reservoir Growing at End of Test

Scale: 1" = 1000'

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Blind Energy Map – Example 2

WAVEX Energy Map

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Blind Energy Map – Example 2

Reservoir Growing at End of Test
2076' Bi-Directional Width
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2076' Bi-Directional Width
WAVEX Energy Map
Andrus Robertson No.1
380'
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2005'
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Reservoir Growing at End of Test
2076' Bi-Directional Width
Reservoir Growing at End of Test
2076' Bi-Directional Width

2005'
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Scale: 1" = 1000'
Blind Energy Map – Example 2
Final Reservoir Area/Shape
Blind Energy Map – Example 2

WAVEX Energy Map

Reservoir Growing at End of Test

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

2076' Bi-Directional Width

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2076' Bi-Directional Width
Blind Energy Map – Example 2
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Rotate Until Corner Coincides with Fault
The Next Step is to Review the Seismic Data Looking for Amplitude Events along the Edge of the Energy Map.
Energy Map

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

Bi-Directional Width

2076'
WAVEX Energy Map

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test
Reservoir Growing at End of Test

2076' Bi-Directional Width

HUNTER ENERGY
WAVEX Energy Map

Energy Map

Andrus Robertson No.1

Scale: 1" = 1000'

Reservoir Growing at End of Test

Reservoir Growing at End of Test

2076' Bi-Directional Width

2076' Bi-Directional Width
Conclusions...

• Well Testing generates fairly consistent values for skin & perm...and mostly arguments about everything else
• If done independently (without seeing the geologic image first), the credibility of the well test analysis can be improved
• Well Test Analysis can initiate a re-evaluation of the geologic interpretation & Vice Versa
• Best practice: Work separately until the G&G team and the Well Testers have independent models/maps; then work as a team with both sides being willing to change