Reservoir Fluid Geodynamics:
A New Way to Evaluate Connectivity, Baffling, Aquifer Support and Many Other Concerns*

André C. Bertolini[1], Vinay K. Mishra[1], and Oliver C. Mullins[1]

Search and Discovery Article #42136 (2017)**
Posted November 6, 2017

*Adapted from oral presentation given at AAPG Latin America & Caribbean Region GTW, Optimization of E&P Projects: Integrating Geosciences and Engineering from Block Acquisition through Production, Rio De Janeiro, Brazil, August 22-23, 2017

[1]Schlumberger, Rio de Janeiro, Brazil (ABertolini@slb.com)

Abstract

Reservoir fluid geodynamics (RFG) is enabled by new technology (downhole fluid analysis [DFA]) and new science (asphaltene gradient thermodynamics) and provides the best way to determine the extent of reservoir fluid equilibration. Equilibrium strongly indicates connectivity. When only part of a field is not equilibrated, baffling is often the cause. Asphaltene instabilities with formation of viscous oil/tar at the oil-water contact can be identified. These methods enable identification of dynamic fluid processes in geologic time that directly impact production.

References Cited

Betancourt, S.S., F.X. Dubost, O.C. Mullins, M.E. Cribbs, J.L. Creek, and S.G. Mathews, 2007, Predicting downhole fluid analysis logs to investigate reservoir connectivity: International Petroleum Technology Conference (IPTC), December 4-8, Dubai, U.A.E., IPTC-11488. 11p.

Betancourt, S.S., V.K. Mishra, S. Clinch, G. Guo, M. Malik, J.A. Cañas, L. Chen, and O.C. Mullins, 2016, Understanding fluid complexity and reservoir connectivity using downhole fluid analysis in Wilcox Formation, Gulf of Mexico: Offshore Technology Conference (OTC), May 2-5, Houston, Texas, OTC-27004-MS.

Dumont, H., O.C. Mullins, J. Zuo, A.E. Pomerantz,| J.Forsythe, V.K. Mishra, and G. Garcia, 2016, Compartments, connectivity & baffling analyzed by the extent of equilibration of asphaltene gradients using DFA: Offshore Technology Conference (OTC), May 2-5, Houston, Texas, OTC-27143-MS.

Mullins, O.C., H. Dumont, V.K. Mishra, A. Gomez, T. Wilkinson, B. Winkelman, R.D. Primio, S. Uchytil, N. Nagerajan, S. Strauss, M. O'Donnell, D.J. Seifert, H. Elshahawi, L. Chen, T. Pfeiffer, V. Achourov, M. Zebek, J. Y. Zuo, J. Forsythe, S.S. Betancourt, A.B. Andrews,

and A.E. Pomerantz, 2017, The critical role of asphaltene gradients and data integration in reservoir fluid geodynamics analysis: SPE Annual Technical Conference and Exhibition, San Antonio, Texas, October 9-11, 2017, SPE-18277-MS.

AAPG Latin America & Caribbean Region
BRAZIL 2017 Geosciences Technology Workshop
Co-hosted by

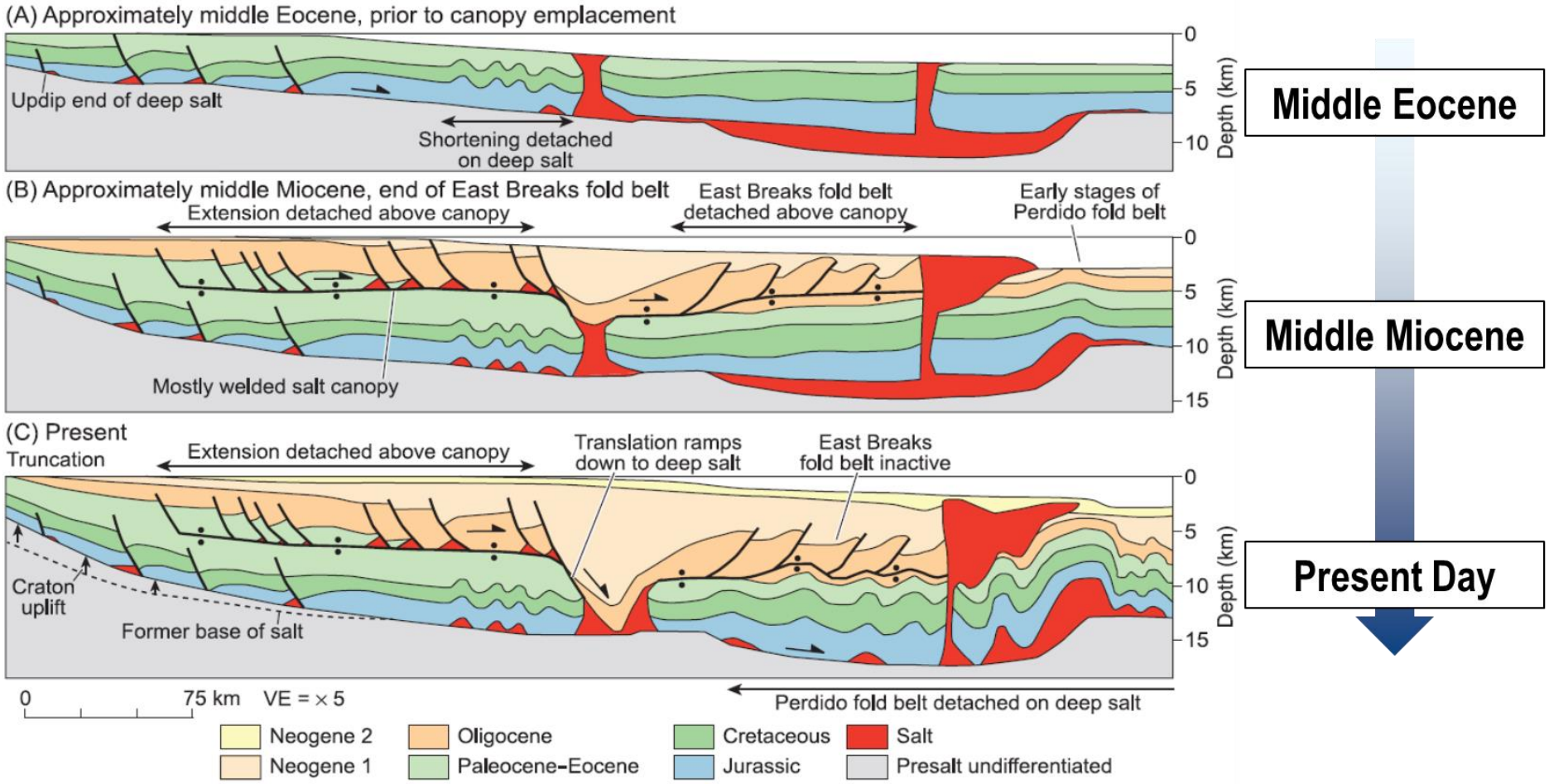
Reservoir Fluid Geodynamics: A New Way to Evaluate Connectivity, Baffling, Aquifer Support and Many Other Concerns

August, 2017

André C. Bertolini, Vinay K. Mishra and Oliver C. Mullins

Schlumberger

Geodynamics is routinely used to interpret Seismic, Geology, Image Logs…

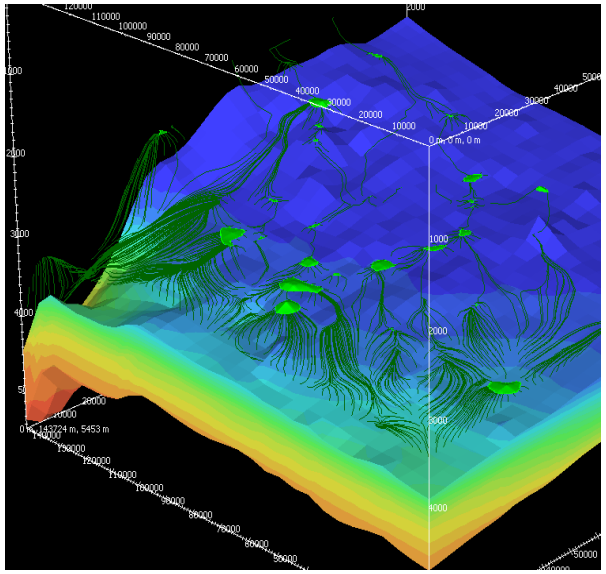


A Large Missing Component of Reservoir Understanding and Modeling

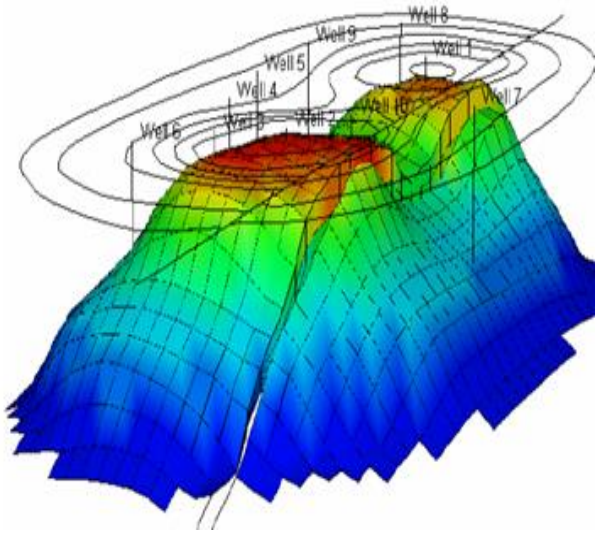
Basin modeling gives fluid type, timing, volumes INTO reservoir

Almost No Modeling of *in-Reservoir* Fluid Geodynamics

Modeling of Production in Eclipse



No Modeling

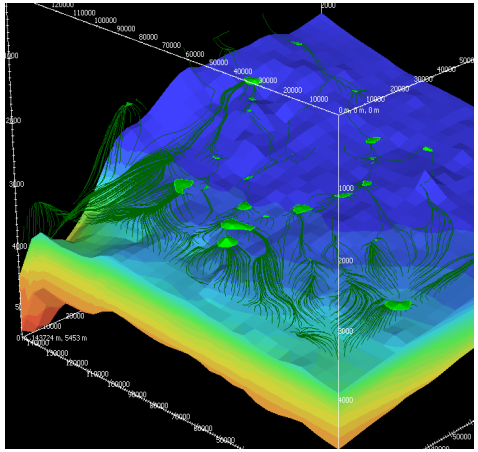


Geologic Time Line

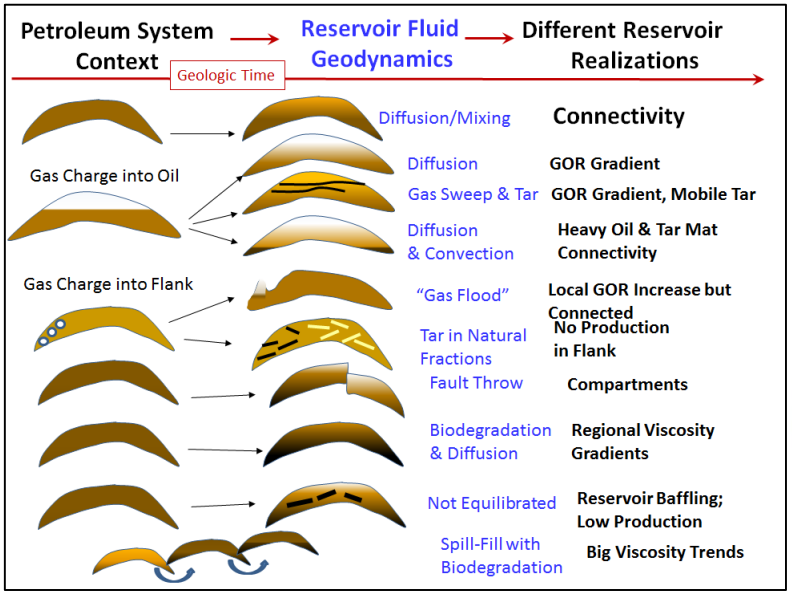
Production Time Line

A Large Missing Component of Reservoir Understanding and Modeling

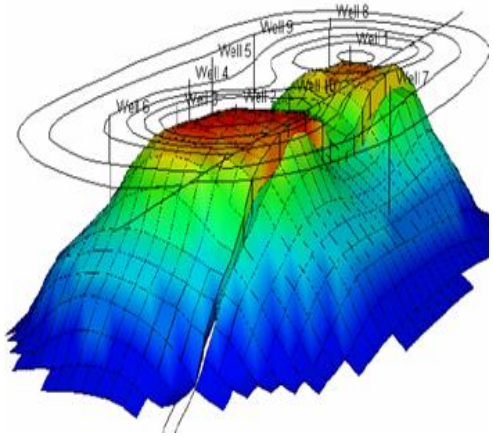
Basin modeling gives fluid type, timing, volumes INTO reservoir



Almost No Modeling of *in-Reservoir* Fluid Geodynamics



Modeling of Production in Eclipse

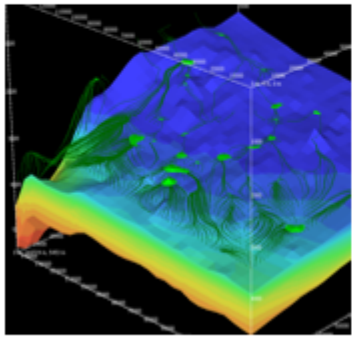


Geologic Time Line

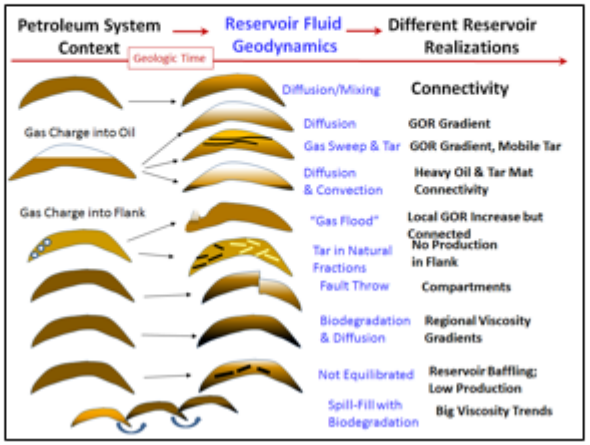
Production Time Line

A Large Missing Component of Reservoir Understanding and Modeling

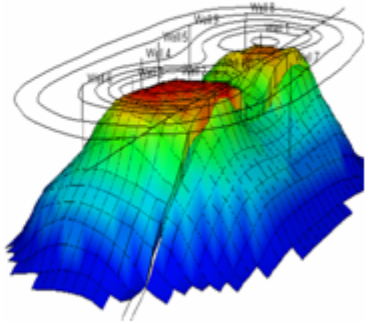
Basin modeling gives fluid type, timing, volumes INTO reservoir



Almost No Modeling of *in-Reservoir* Fluid Geodynamics

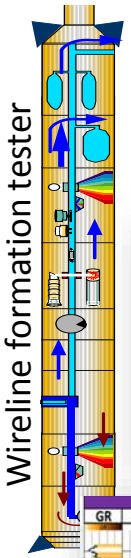


Modeling of Production in Eclipse

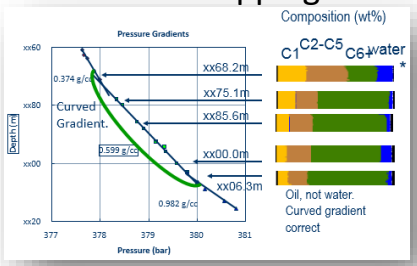


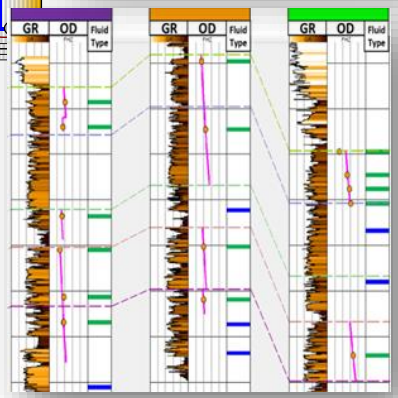
RFG refers to study of the process after reservoir filling and before present day that have an impact on reservoir connectivity assessment and production performance.

Reservoir Fluid Geodynamics



Fluid mapping

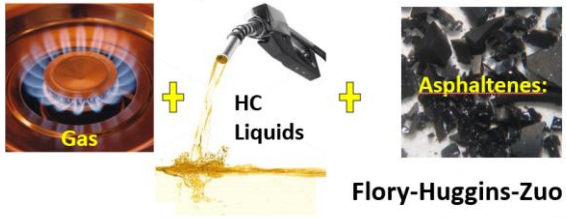




Pressures and DFA data

Gas-Liquid

Fluid- (dissolved) Solid



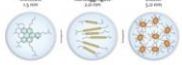
Cubic EoS Gas-Liquid

Van Der Waals EoS 1873

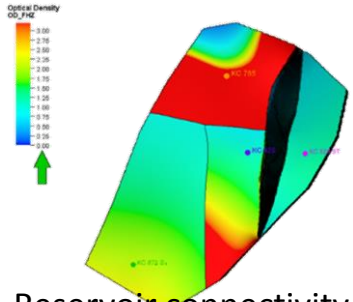
Peng-Robinson EoS 1976

Flory-Huggins-Zuo EoS

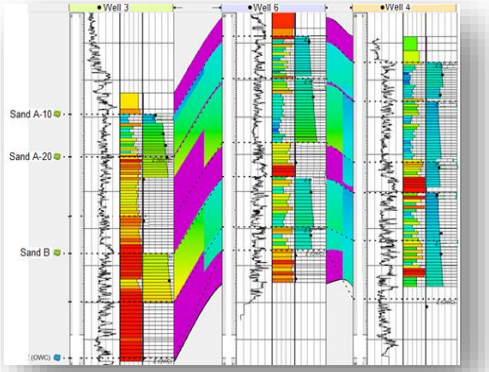
Yen-Mullins Model 2010



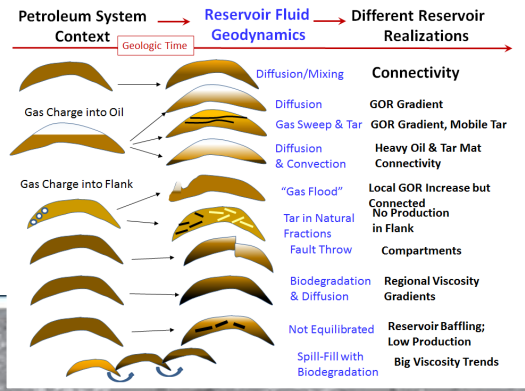
$$\frac{OD(\lambda^1)}{OD(\lambda^2)} = \frac{\phi^a(\lambda^1)}{\phi^a(\lambda^2)} = \exp\left\{\frac{RT}{\nu^a \rho_a \Delta b(\lambda^2 - \lambda^1)} + \frac{RT}{\nu^a\left[(\delta^a - \delta^2)^2 - (\delta^a - \delta^1)^2\right]} + \left[\left(\frac{\nu^a}{\nu^2}\right)^{\lambda^2} - \left(\frac{\nu^a}{\nu^1}\right)^{\lambda^1}\right]\right\}$$



Reservoir connectivity

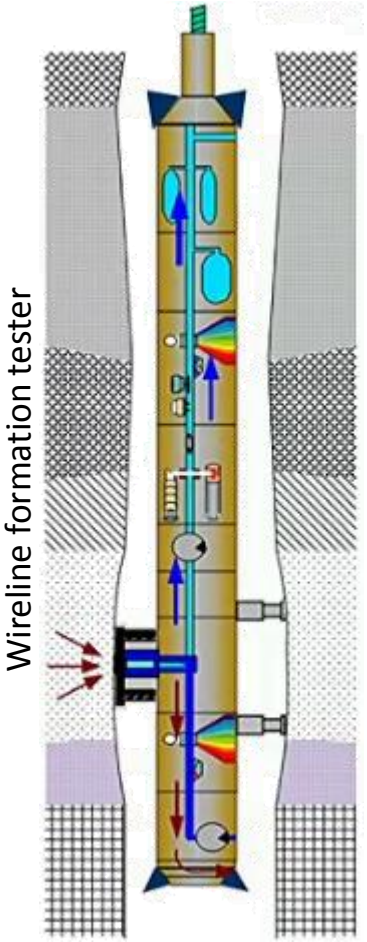


DFA prediction among the wells

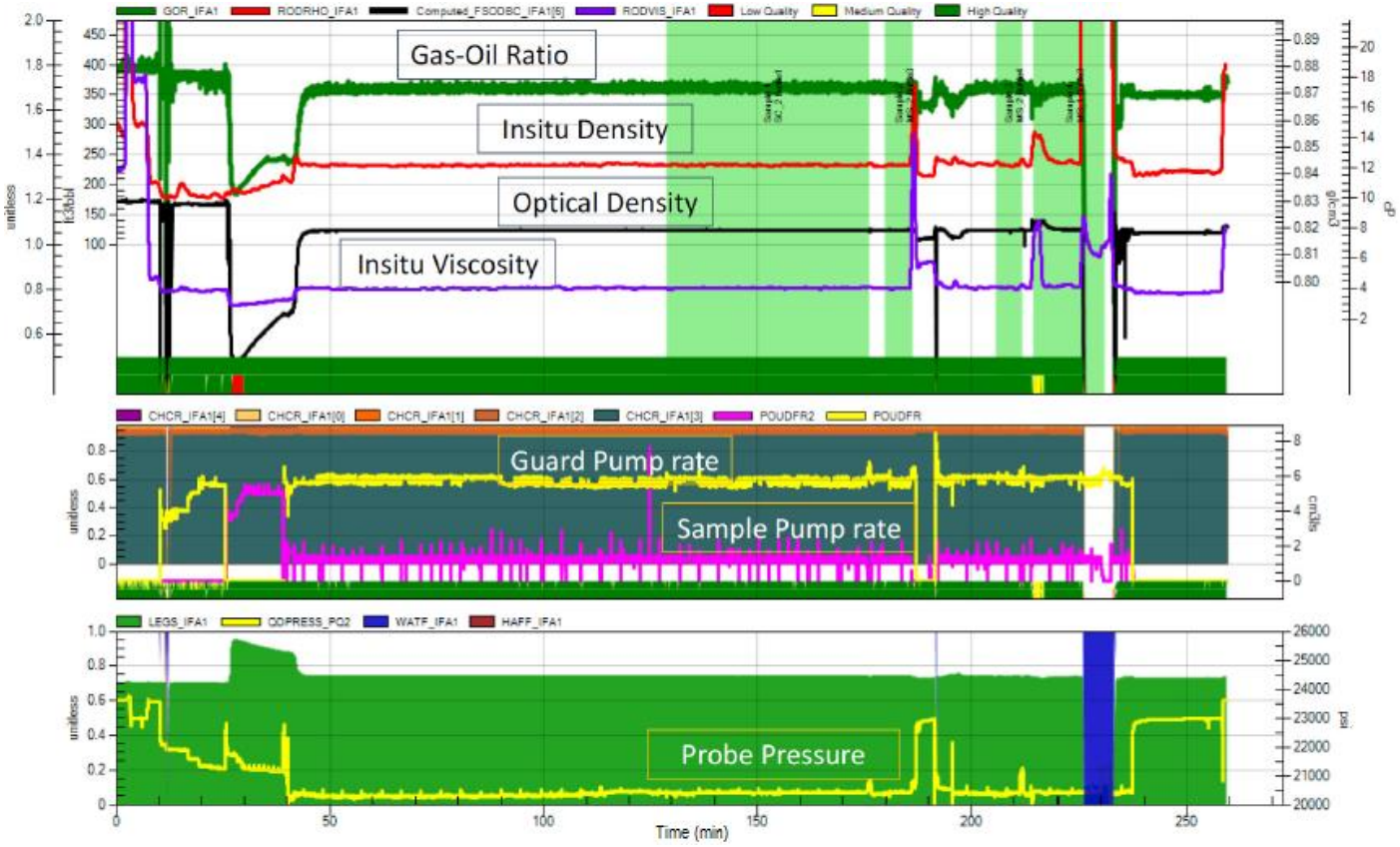


RFG universal workflow

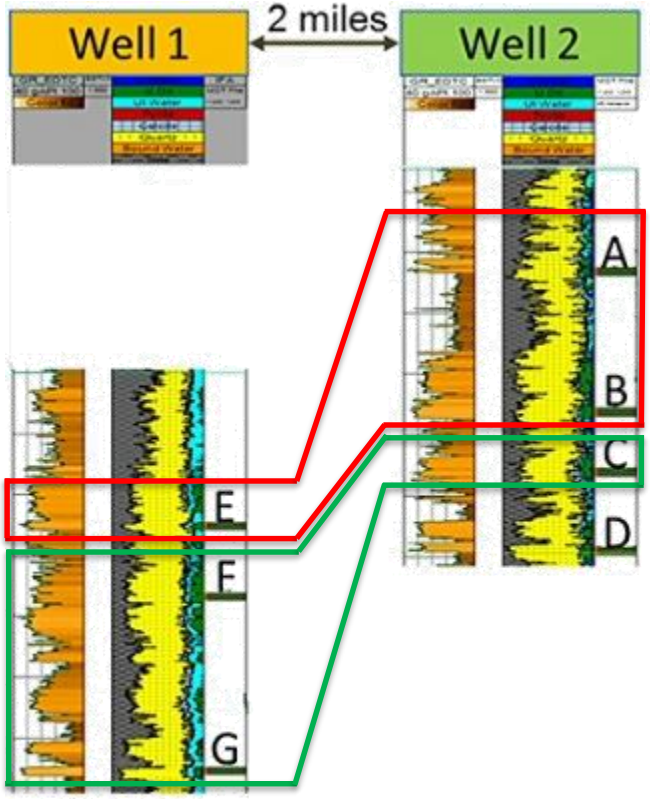
Downhole Fluid Analysis (DFA) station

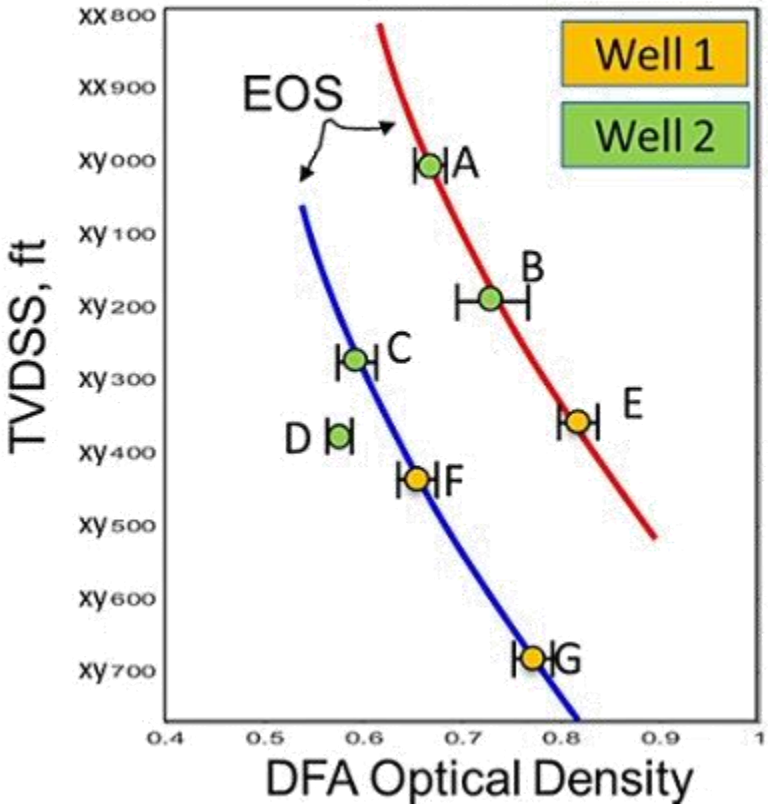


Wireline formation tester



Equilibrium asphaltene gradients in oil columns



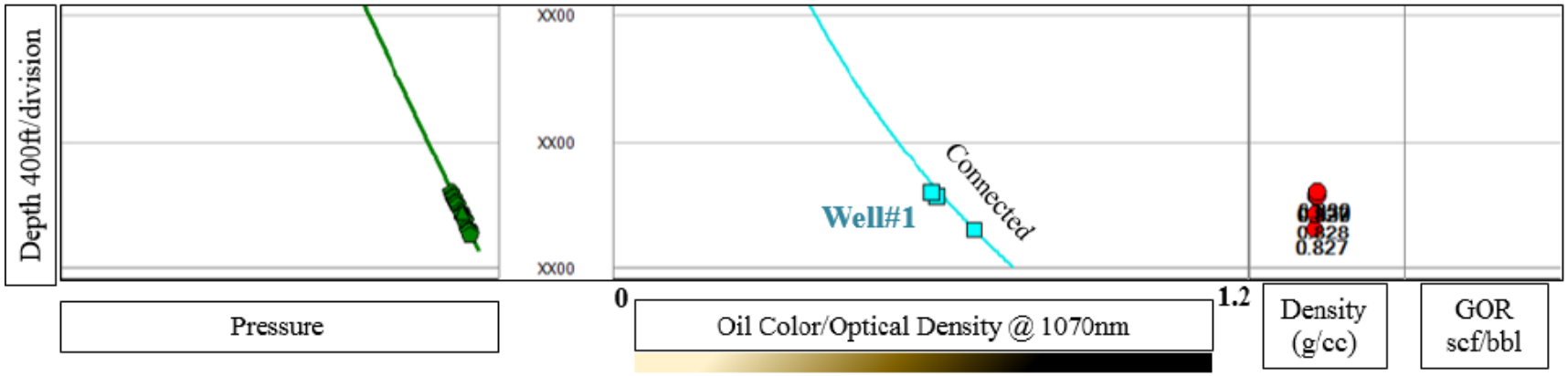


Case Study 1:

GoM deep water field – evaluating connectivity prior to production

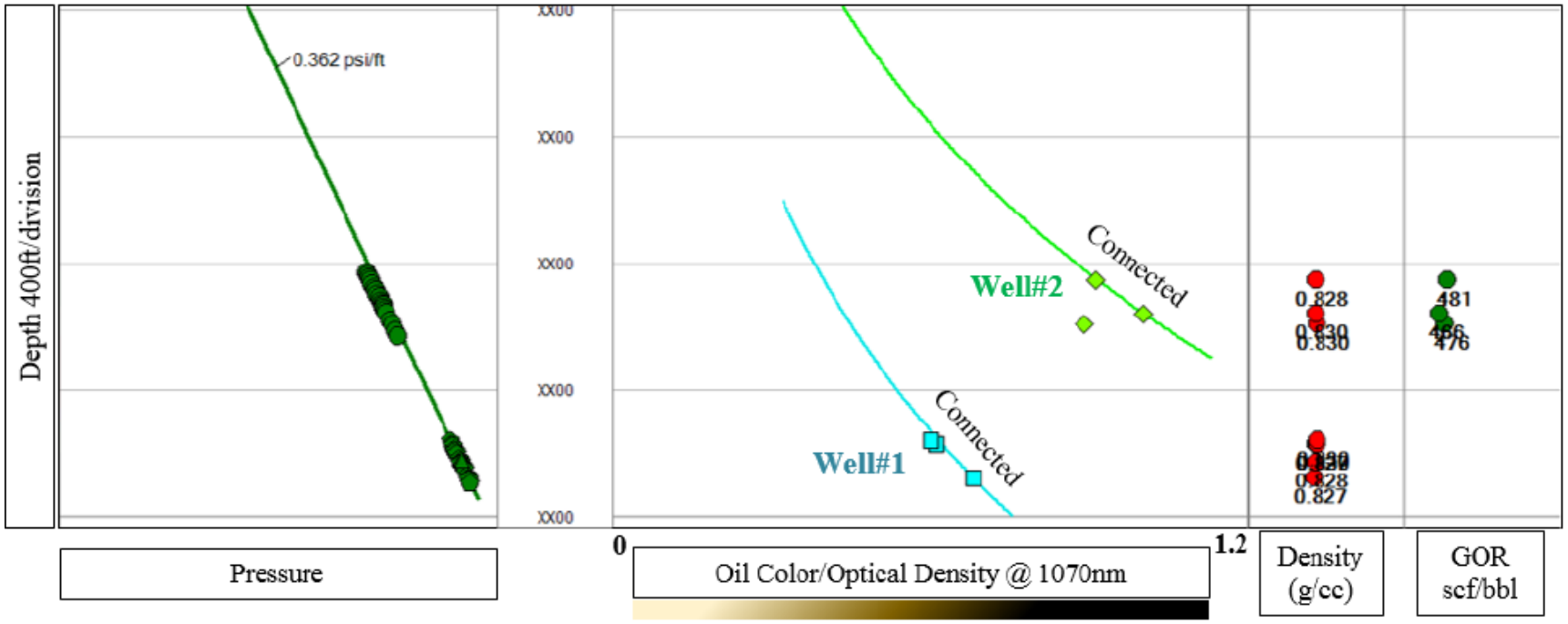
OTC-27143-MS

Black oil with low GOR – Gravity term dominates



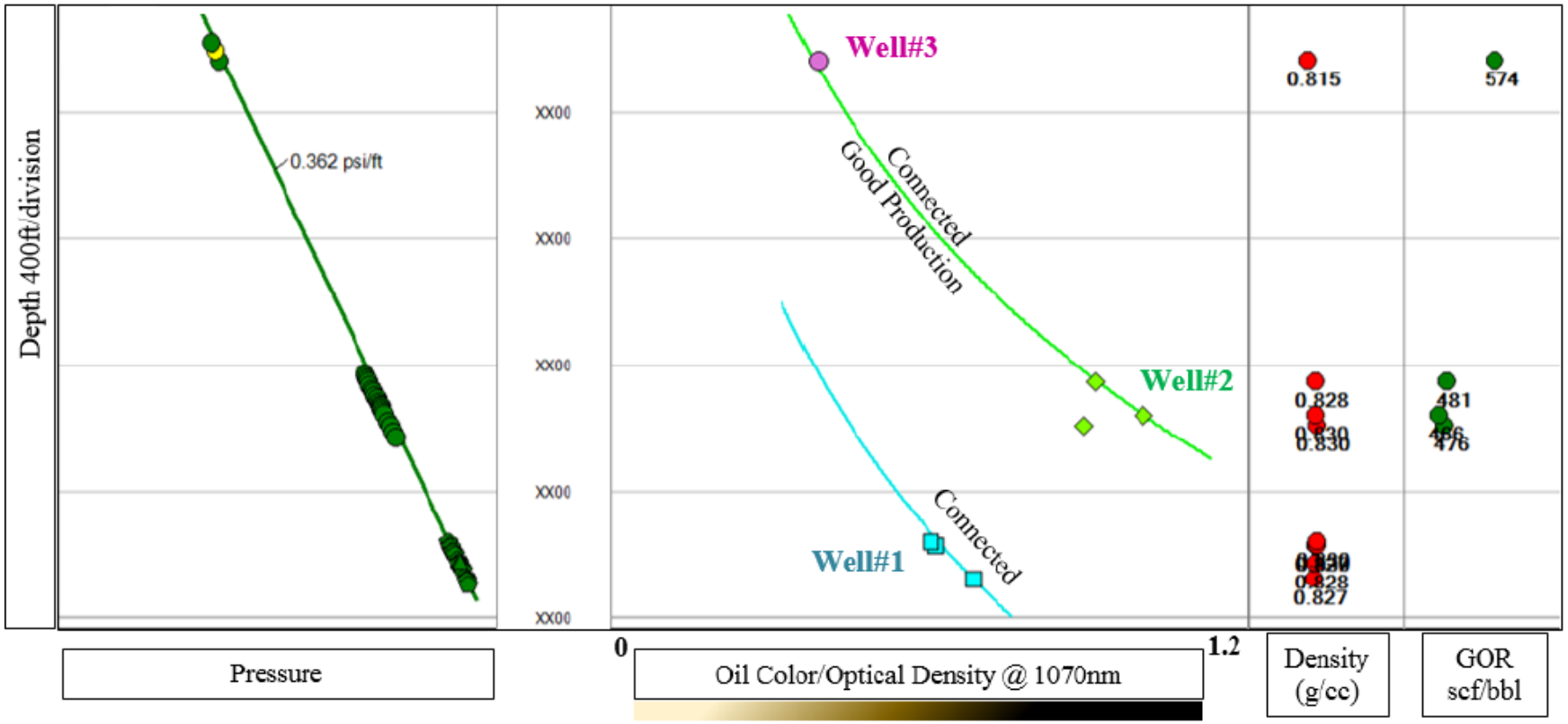
- FHZ EoS obtained with 2 nm asphaltene size (3 DFA stations)
- Vertical equilibrium of the asphaltene is consistent with vertical connectivity from other sources
- Pressure communication amongst these points is also consistent with connectivity

Darker color oil at much shallower depth



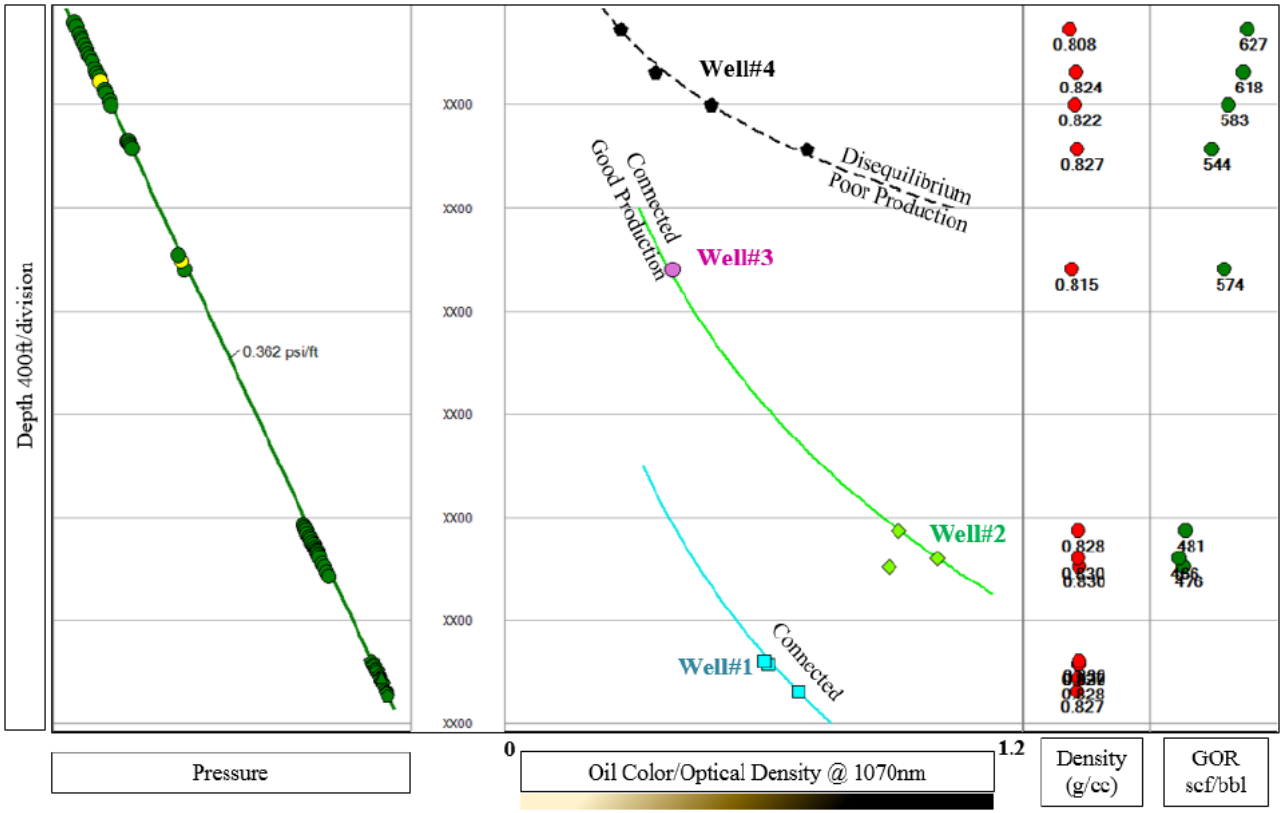
- Pressure regime is a necessary but insufficient condition for flow connectivity
- Pressure response and fluid properties were a match within error bars (suggestion connectivity)
- The oil in W#2 has a darker color (even at much shallower depth)

Strong indicator of reservoir connectivity



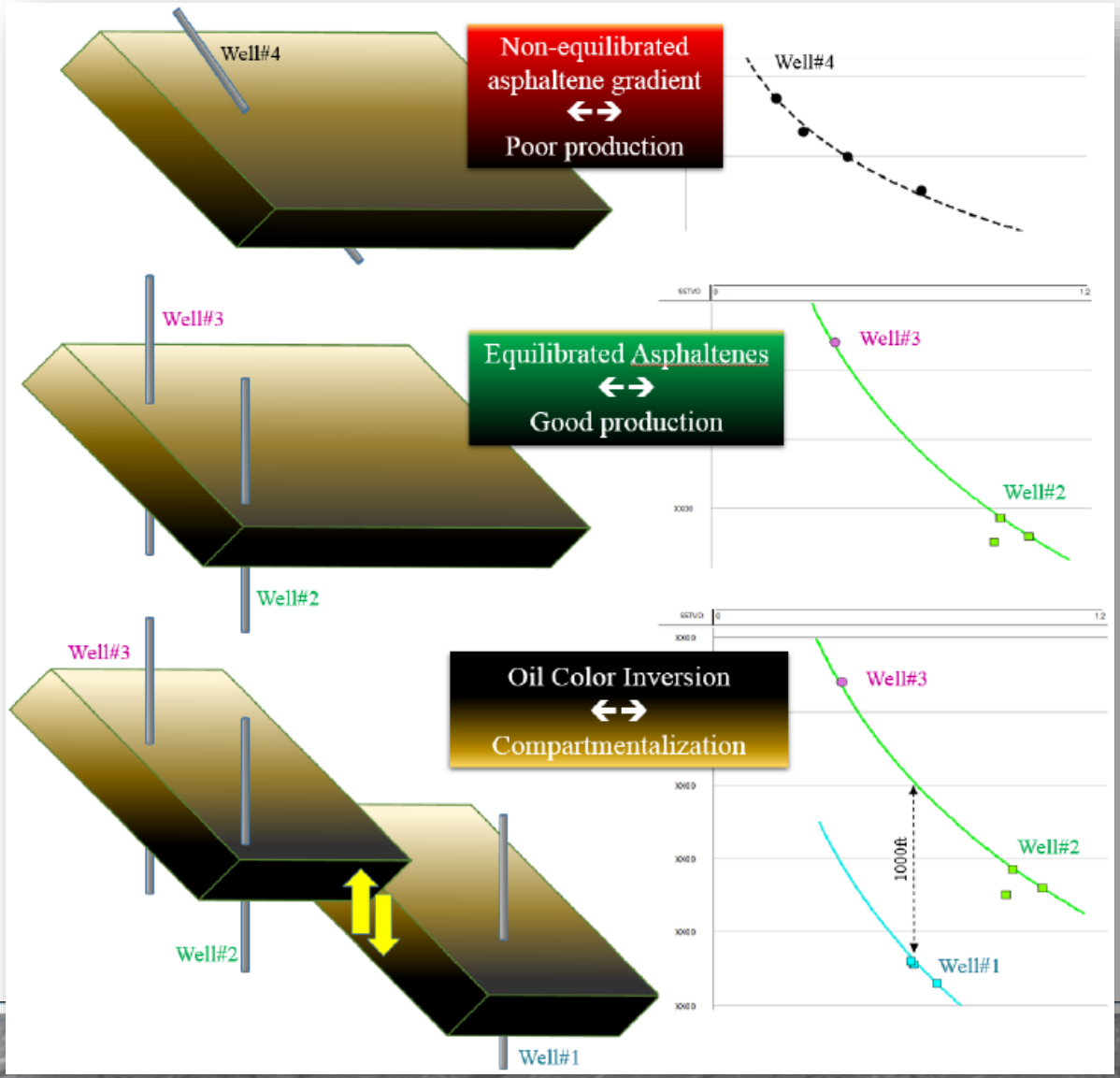
- W#3 DFA falls along the FHZ EoS from W#2.
- It is a strong indicator of connectivity between W#2 and W#3

Non-equilibrated asphaltene gradient



- W#4 OD showing a trend that does not fit the 2nm FHZ EoS
- The oils appear “connected” but with poor connectivity as they are out of equilibrium

Key results


Well#4
Non-equilibrated asphaltene gradient
Poor production
Well#4
Well#3
Equilibrated Asphaltenes
Good production
Well#3
Well#2
Well#2
Well#3
Oil Color Inversion
Compartmentalization
Well#3
1000ft
Well#2
Well#2
Well#1
Well#1

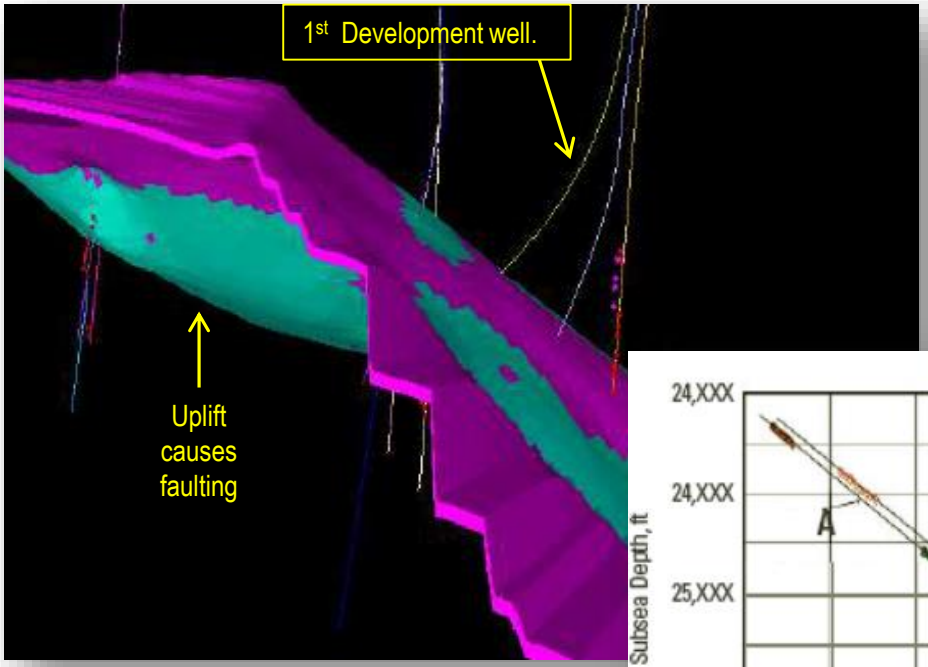
Case Study 2:

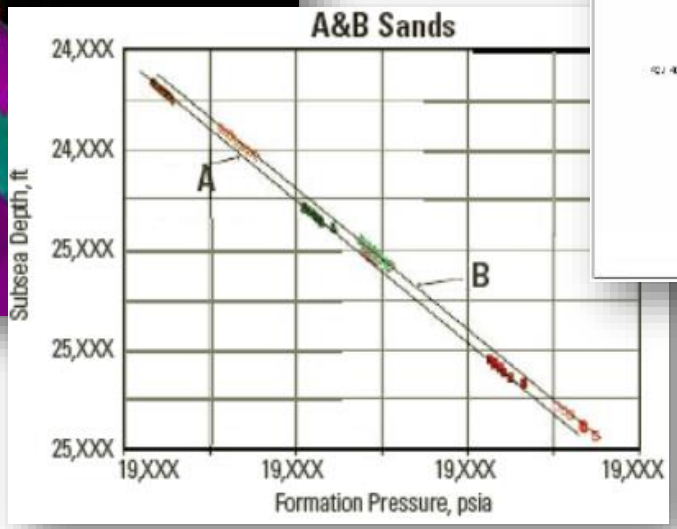
GoM field: Sealing faults?

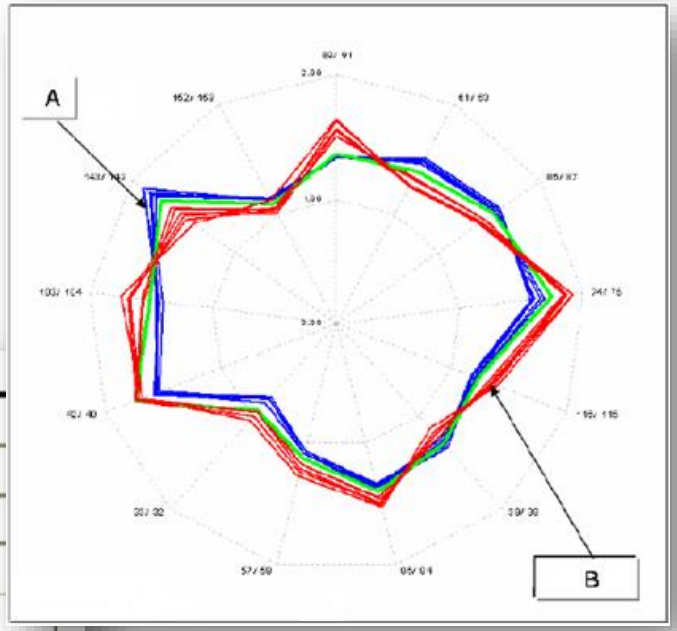
IPTC-11488

GoM field

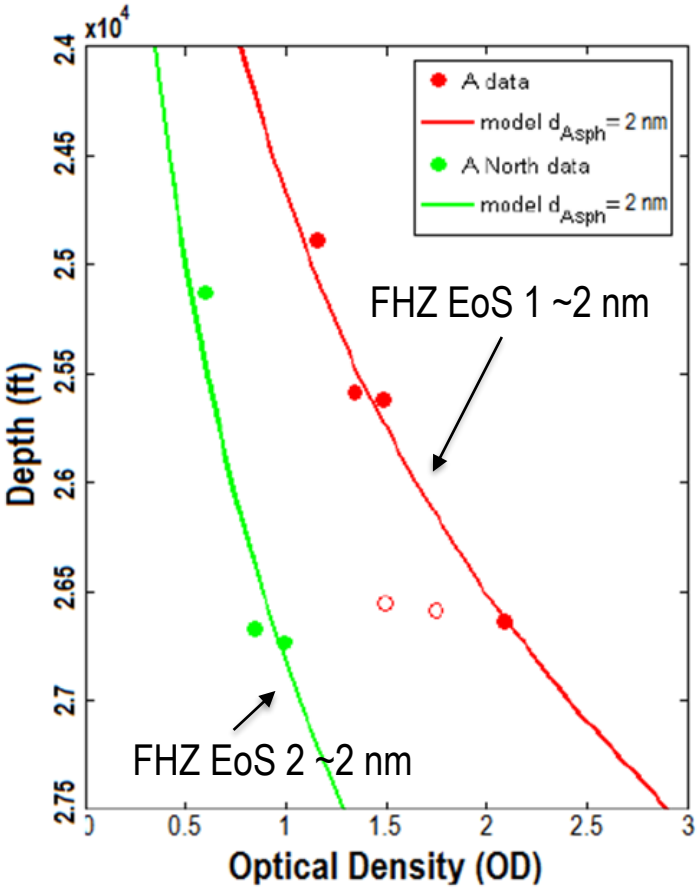
Exploration and appraisal wells along with the first development well. Reservoir contains a low GOR black oil and consists of two stacked sands that are not in pressure communication

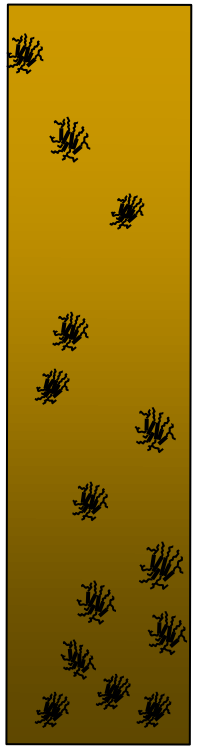


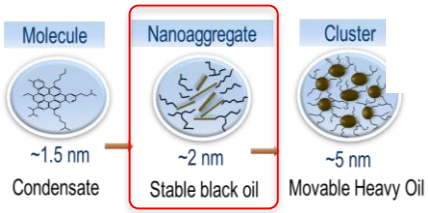


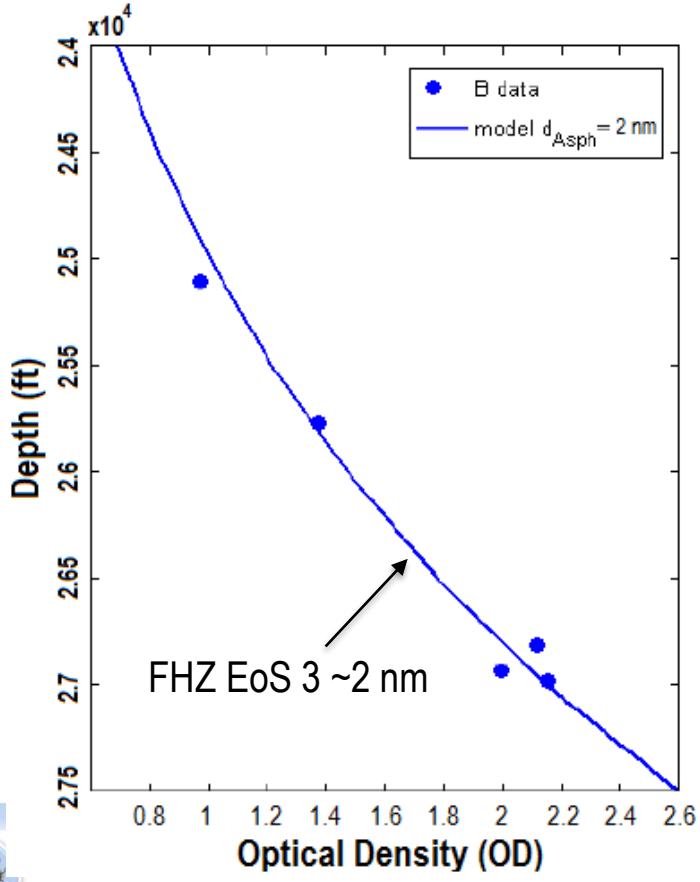


DFA connectivity analysis confirmed in production







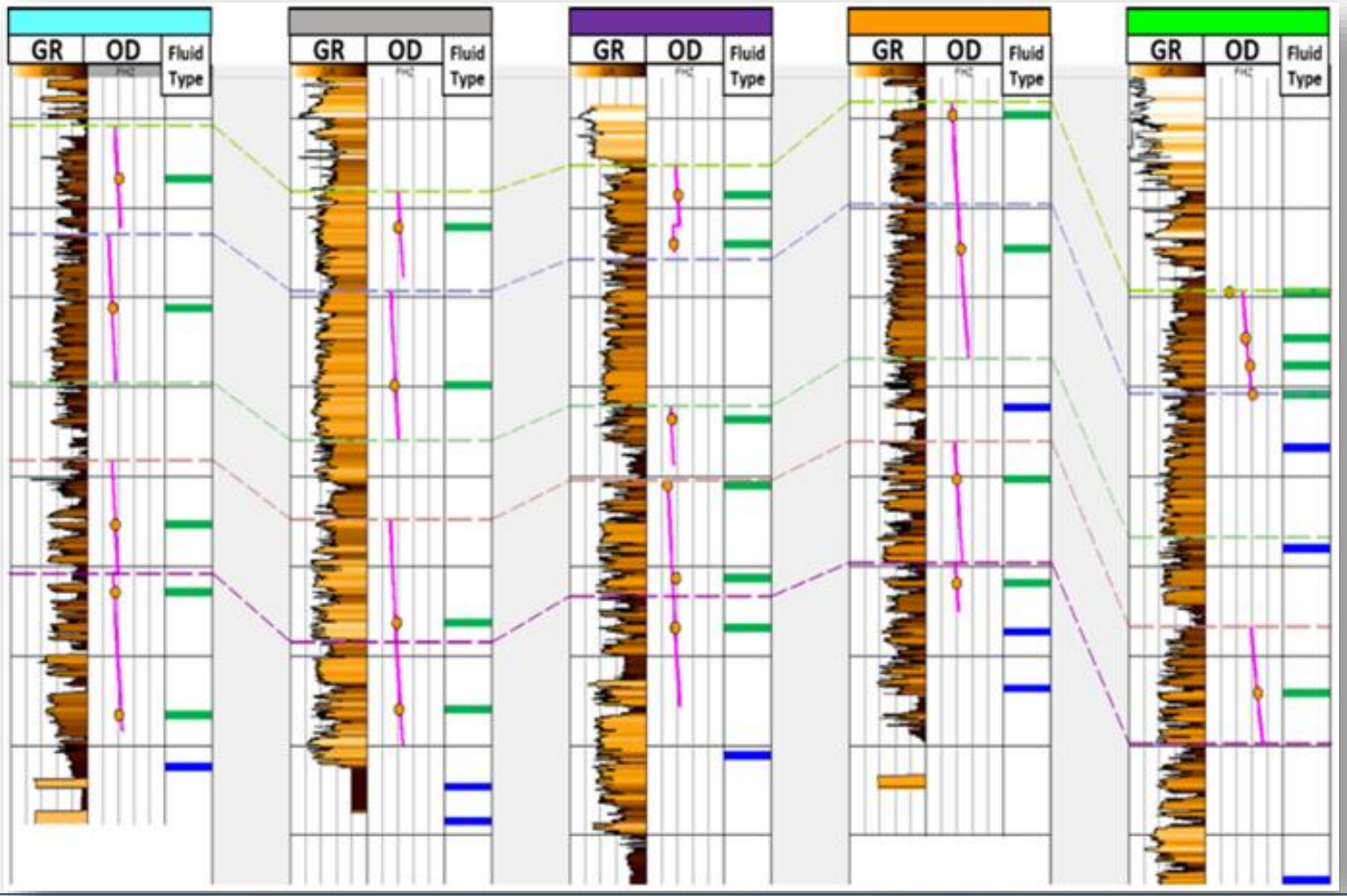


Case Study 3:

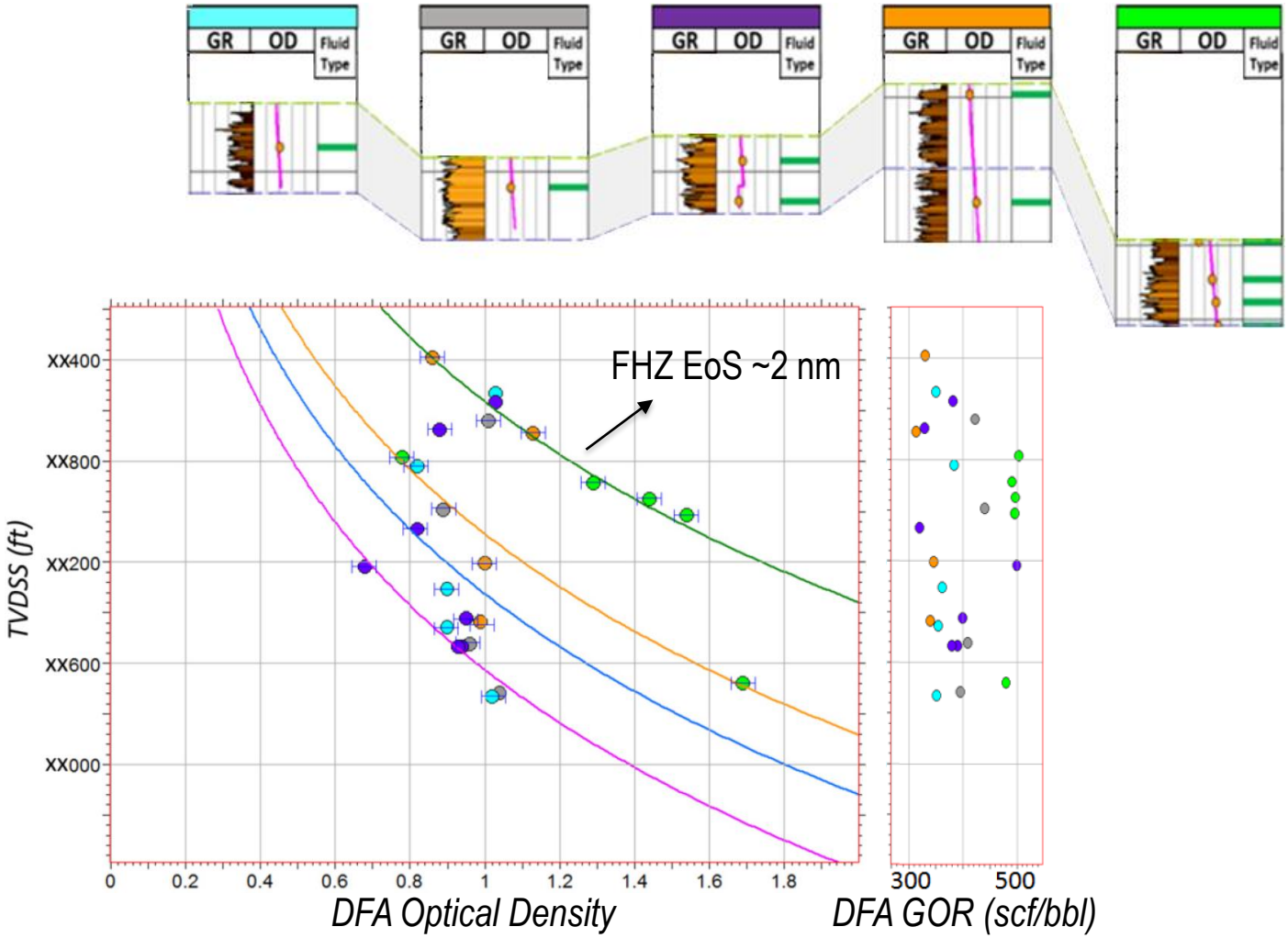
Wilcox formation Gulf of Mexico: ultra-high reservoir pressures and turbidite petroleum system

OTC-27004-MS

Sand correlation using biostratigraphy and location of DFA



Connectivity analysis from biostratigraphy aligned with DFA measurements



RFG recognized by clients

Society of Petroleum Engineers

SPE-187277-MS

The Critical Role of Asphaltene Gradients and Data Integration in Reservoir Fluid Geodynamics Analysis

Oliver C. Mullins, Hadrien Dumont, Vinay K. Mishra, SCHLUMBERGER; Alexandra Gomez, CHEVRON; Tim Wilkinson, Ben Winkelman,TALOS; Rolando Di Primio, LUNDIN; Steven Uchytil, Nagi Nagarajan, Steve Strauss, HESS; Martin O'Donnell, PREMIER; Douglas J. Seifert, SAUDI ARAMCO; Hani Elshahawi, SHELL; Li Chen, Thomas Pfeiffer, Vladislav Achourov, Murat Zeybek, Julian Y. Zuo, Jerimiah Forsythe, Soraya S. Betancourt, A. Ballard Andrews, Andrew E. Pomerantz, SCHLUMBERGER

This paper was prepared for presentation at the 2017 SPE Annual Technical Conference and Exhibition held in San Antonio, Texas, 9-11 October 2017.

Abstract

Reservoir fluid geodynamics (RFG) has recently been launched as a formal technical arena that accounts for fluid redistributions and tar formation in reservoirs largely after trap filling. Elements of RFG, such as analysis of biodegradation, have long been in place; nevertheless, RFG is now strongly enabled by recent developments: 1) downhole fluid analysis (DFA) allows routine elucidation of reservoir fluid gradients, 2) the development of the first equation of state for asphaltene gradients allows identification of equilibrium vs. geodynamic processes of reservoir fluids and 3) RFG analyses of 35 oilfields systematize a multitude of RFG processes and show their direct impact on wide-ranging production concerns.

Conclusions

- DFA data and RFG studies provide a cost-effective approach to investigate connectivity and other reservoir challenges;
- Equilibrated asphaltenes→ reservoir connectivity (proven in production);
- Disequilibrium. Geodynamic processes and baffling. Charging, diffusion, convection, phase change, etc;
- Long list of reservoir concerns addressed by RFG.