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Operational Geochemisty at Work: Integrate or Perish!

Dr. Daniel E. McKinney
Sarawak Shell Bhd.

FUELLING MALAYSIAN PROGRESS
shell.com.my/125years

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Where fluid properties affect our business:

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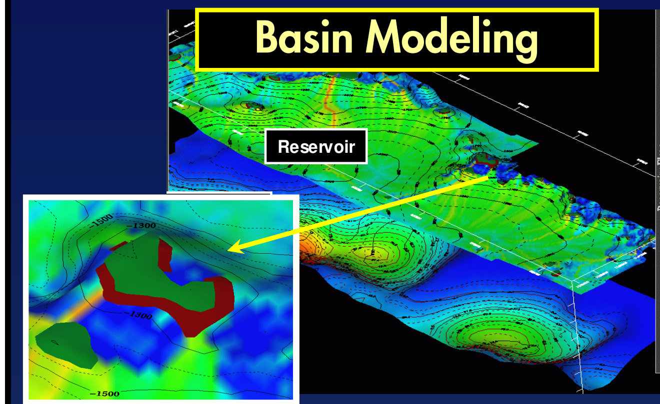
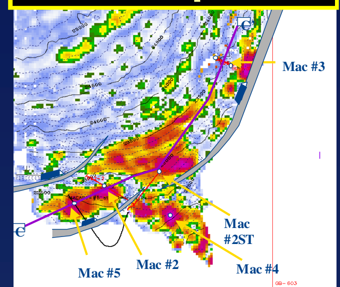
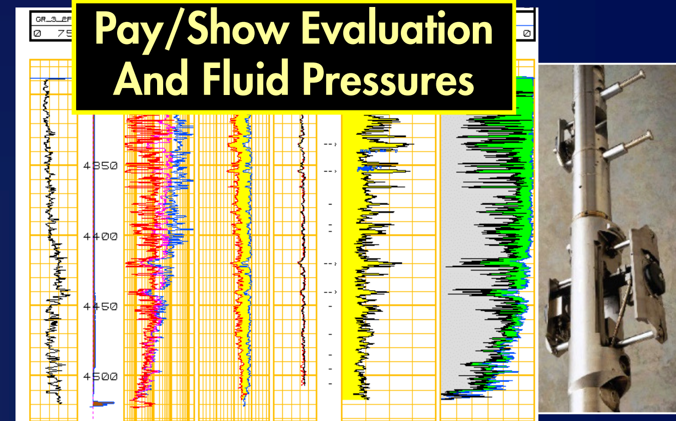
Basin Modeling



Acoustic Fluid Properties

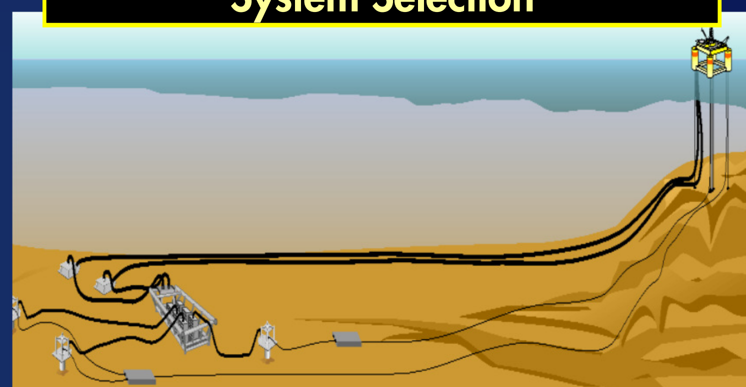


Pay/Show Evaluation And Fluid Pressures

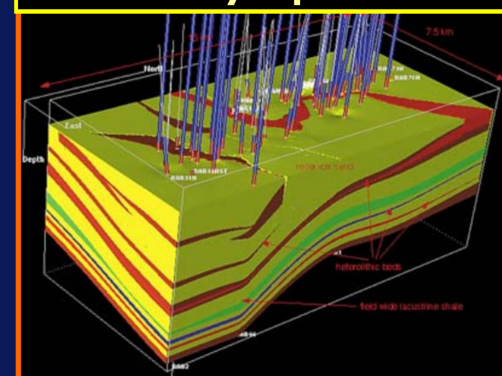


Crude Processing & Refining Requirements

Facility Design, Flow Assurance & System Selection



Reservoir Performance & Recovery Optimisation



Agenda

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The role of Geochemistry in E&P

Workflow = Planning + Execution

Brief word on Technology Application

Examples from Case Studies

- Oil fingerprinting for production allocation.
- Low level H2S evaluation.
- Identifying compartmentalization during operations.

Impact of Geochemistry on the Business

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Exploration

- Source(s) type & distribution
- SR time/temperature, history and kinetics
- Gas vs. Oil expulsion
- Oil-Oil & Oil-Source correlations
- Number/Timing of charge events
- Migration paths

Common

- Reservoir temp/ biodegradation
- Water washing
- Trap failure
- CGR/GOR prediction
- Viscosity and API prediction
- Fill/depletion history

Appraisal, Development and Production

- Reservoir connectivity
- Compositional grading
- Viscosity and API analysis & variation
- CGR/GOR
- Bubble/dew point
- Wax/Asphaltenes
- Emulsions & water chem

IMPACTS ON:

- Regional Acreage Evaluation Prospect Risking
- Portfolio Management, etc.

IMPACTS ON :

- Field Development/Management Options, Produce ability Risk, Surface Facility Design, etc.

Simple Example: Reservoir Temperature and the Impact of Biodegradation

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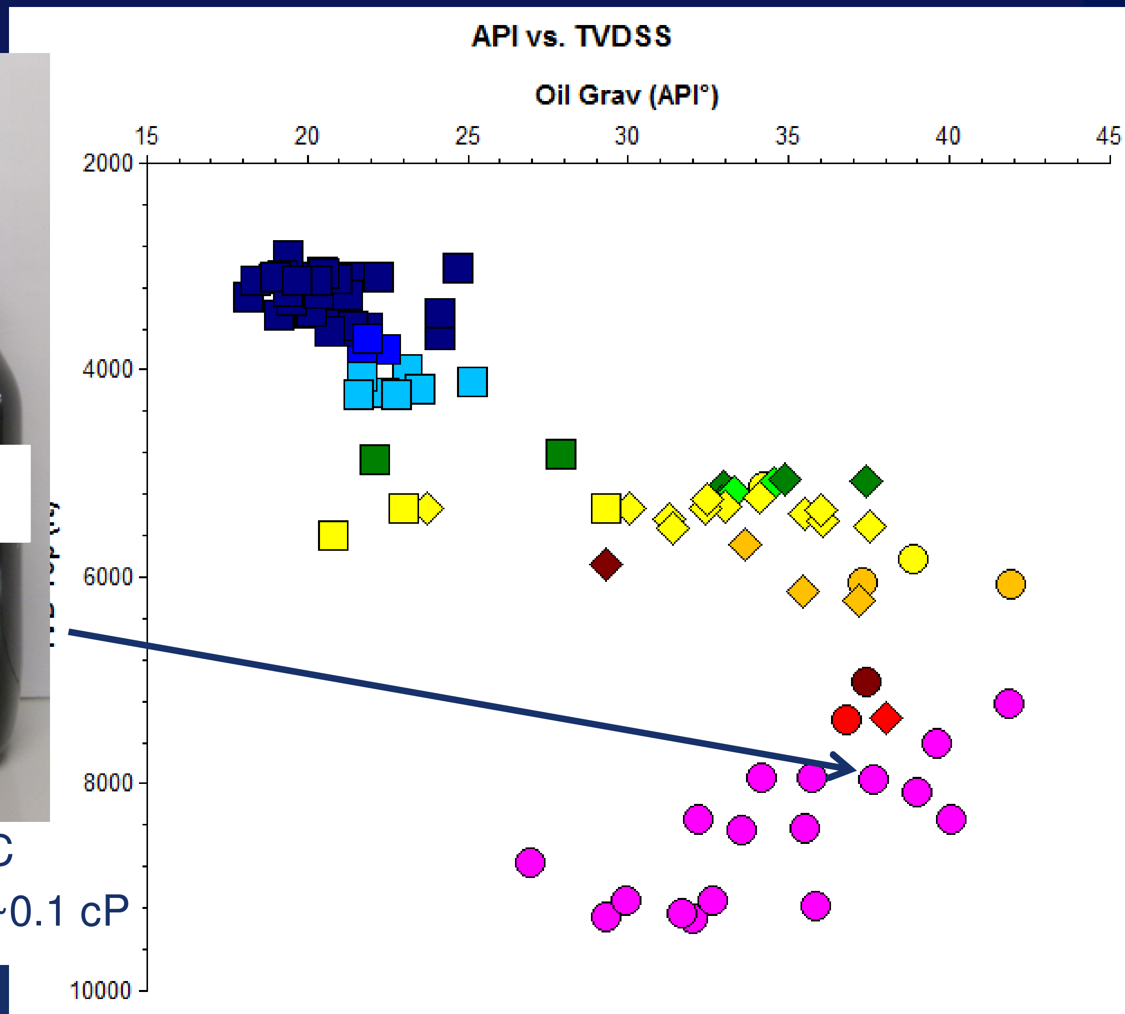
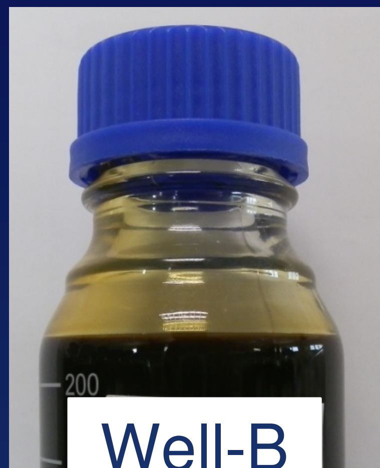
Tres: 90° C
in situ Viscosity: ~0.1 cP



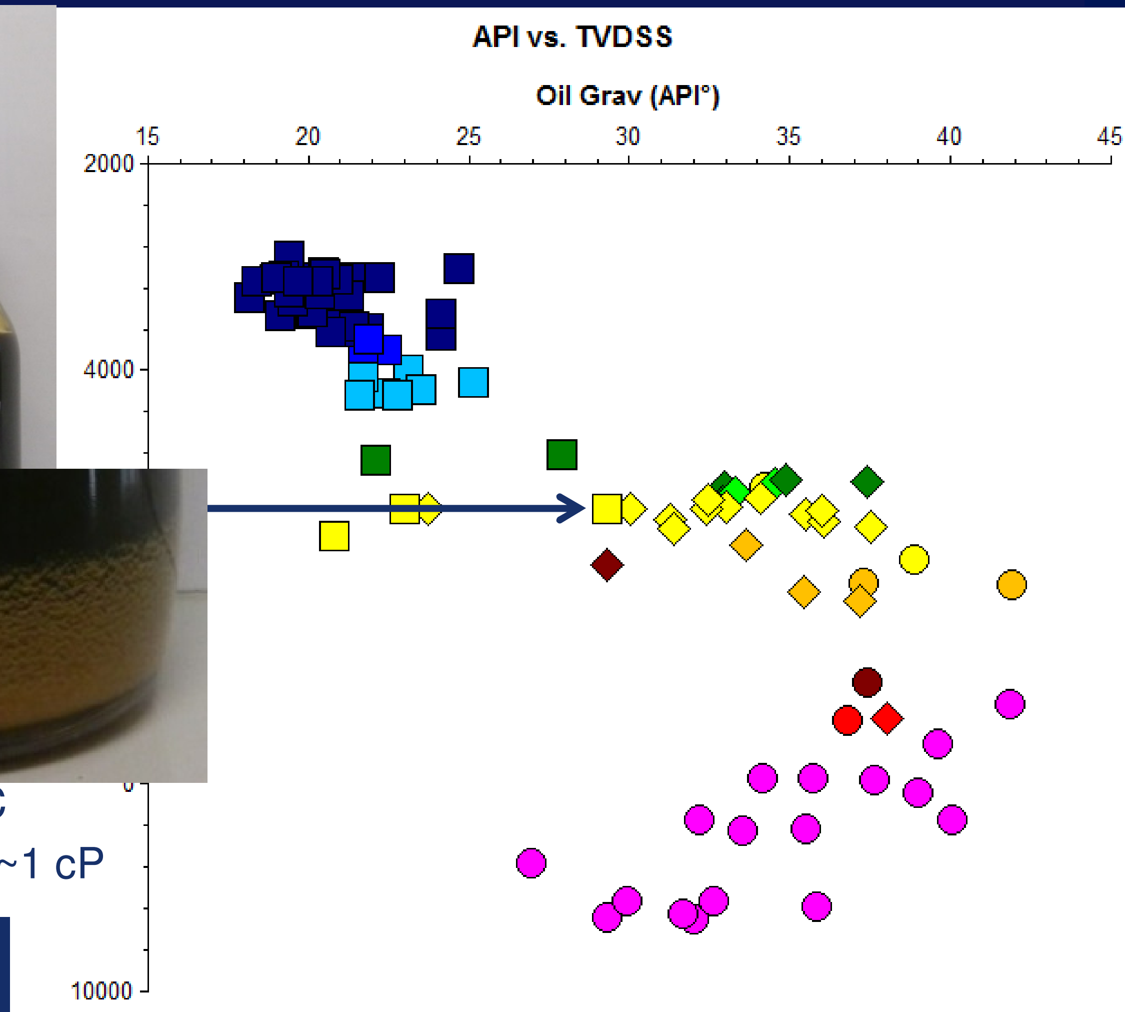
Simple Example: Reservoir Temperature and the Impact of Biodegradation

SPE DISTINGUISHED LECTURER

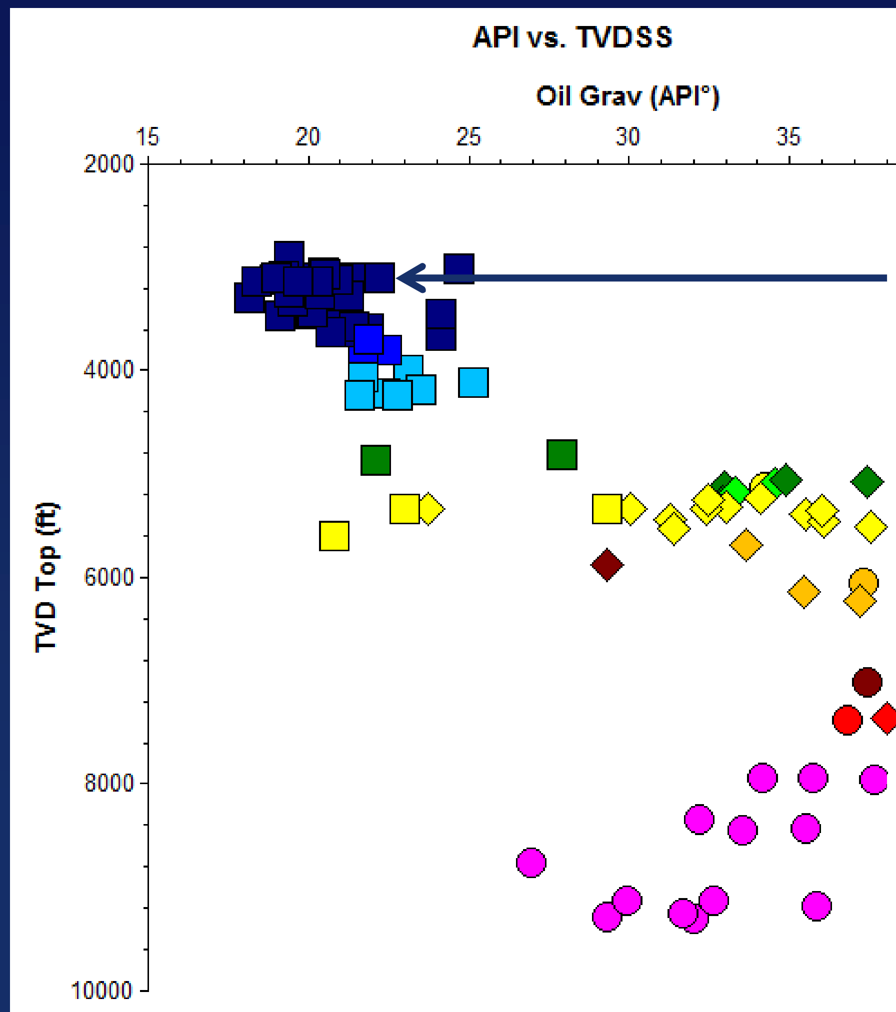


Tres: 70° C

in situ Viscosity: ~1 cP



Simple Example: Reservoir Temperature and the Impact of Biodegradation



Tres: 60° C

in situ Viscosity: 5 cP

Operational Geochemistry at Work

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It is not a spectator sport.

We must bridge the gap between subsurface and surface through:

- Planning
- Flexible Execution
- Delivering Consistent Results

The business driver: Get it right from the start!

What do we mean by "Planning and Flexible Execution"?

Define the objectives and get buy in from ALL stakeholders including:

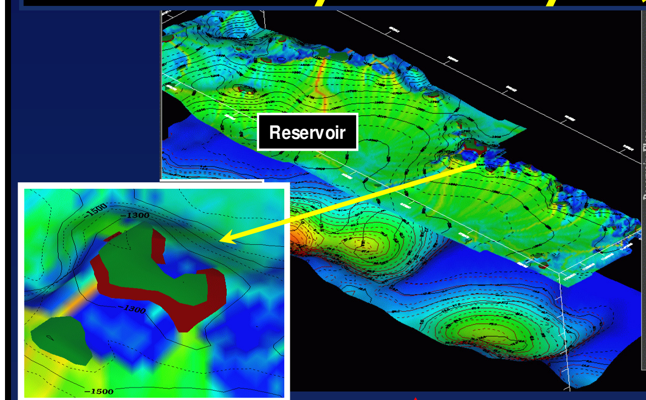
- Sub-surface
- Surface
- Drilling Foremen AND
- Service Providers

Use decision tree analysis to risk objectives.

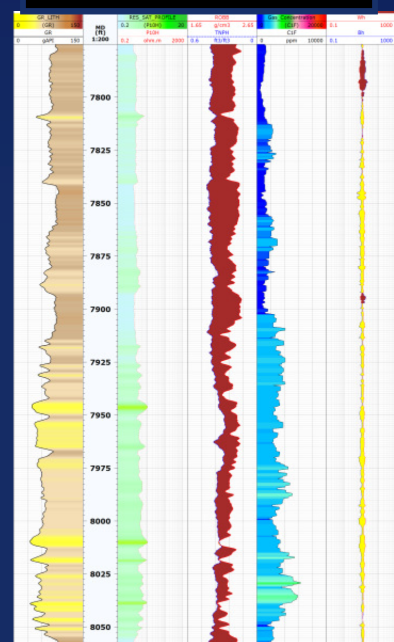
Example: Did the beaver satisfy the objectives?

The Workflow and Tools

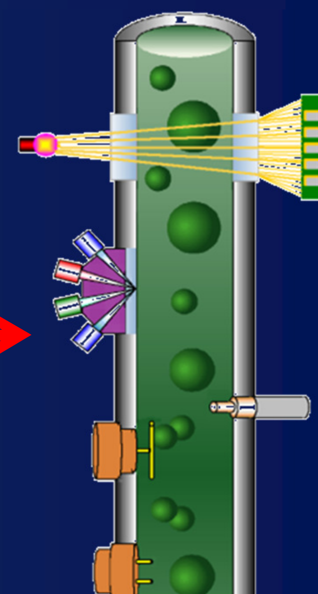
Petroleum System Analysis (PSA)



Drilling & Formation Evaluation



Lab Measurements



Sampling

Refer: McKinney et al., SPE109861

Elshahawi et al., SPE 109684, SPE 94709

And…Apply Technology When Needed

Do we always need the best, most expensive piece of machinery?

It all depends on the objectives!

Case Study Example

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Oil Fingerprinting for Compartmentalization and Forward Thinking During Exploration/Appraisal

Chua et al., IMOG 2015

Tools for Assessing Reservoir Continuity

- Geological and sediment controls on gross depositional environment.
- Static and dynamic pressure.
- Fluid property variations both laterally and vertically.
- Fluid fingerprinting.
- Structural assessment of faults and seals.

Overview of Heavy Mineral Analysis (HMA)

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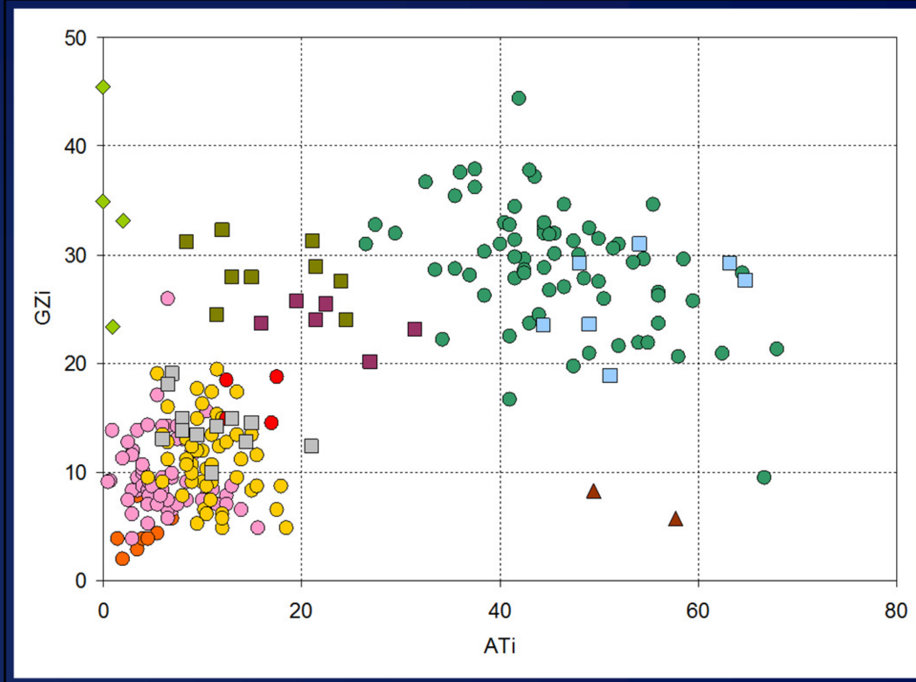
What is HMA?

- Analysis of core and drill cuttings for metamorphic minerals such as zircon, garnet, tourmaline, rutile and apatite.
- It has been proven useful in other deep water depositional environments and application to stratigraphic compartmentalization.
- In this study, the garnet-zircon index (GZi) and apatite-tourmaline index (ATi) were most useful to define vertical and lateral stratigraphic changes.

Key reference: Morton & Hawsworth, 1999, Sediment. Geol. 124, 3-29.



Multi-Dimensional Gas Chromatography (MDGC)

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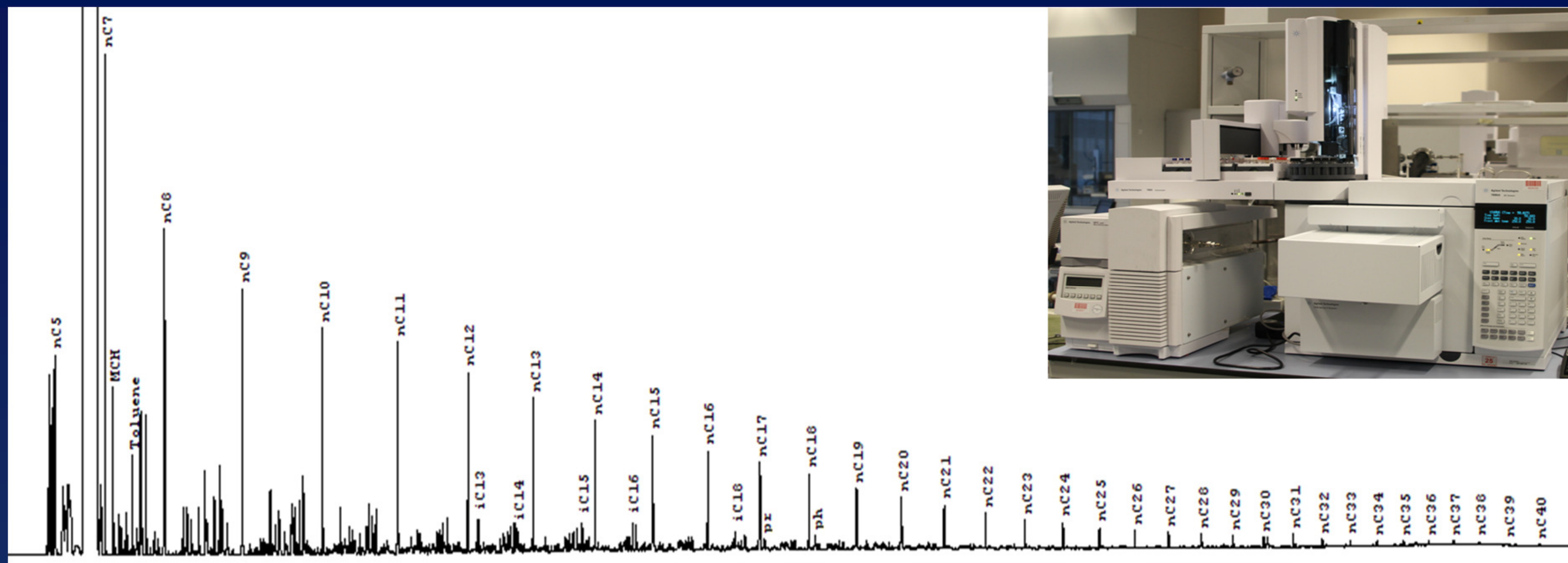
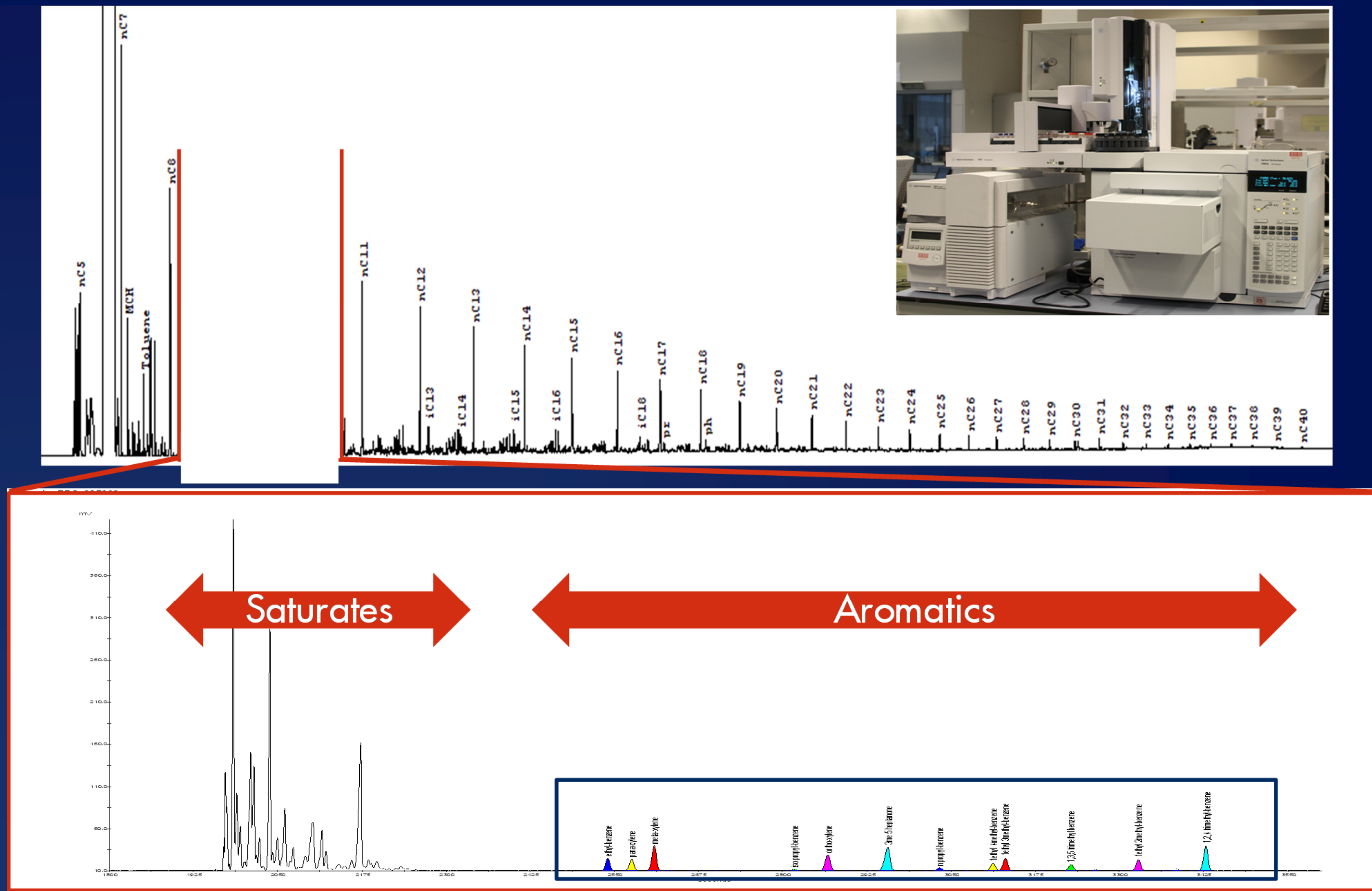


Key references: Kaufman et al., 1987; Westrich et al. 1999; Rojas et al., 2013.

Multi-Dimensional Gas Chromatography (MDGC)



MDGC Output

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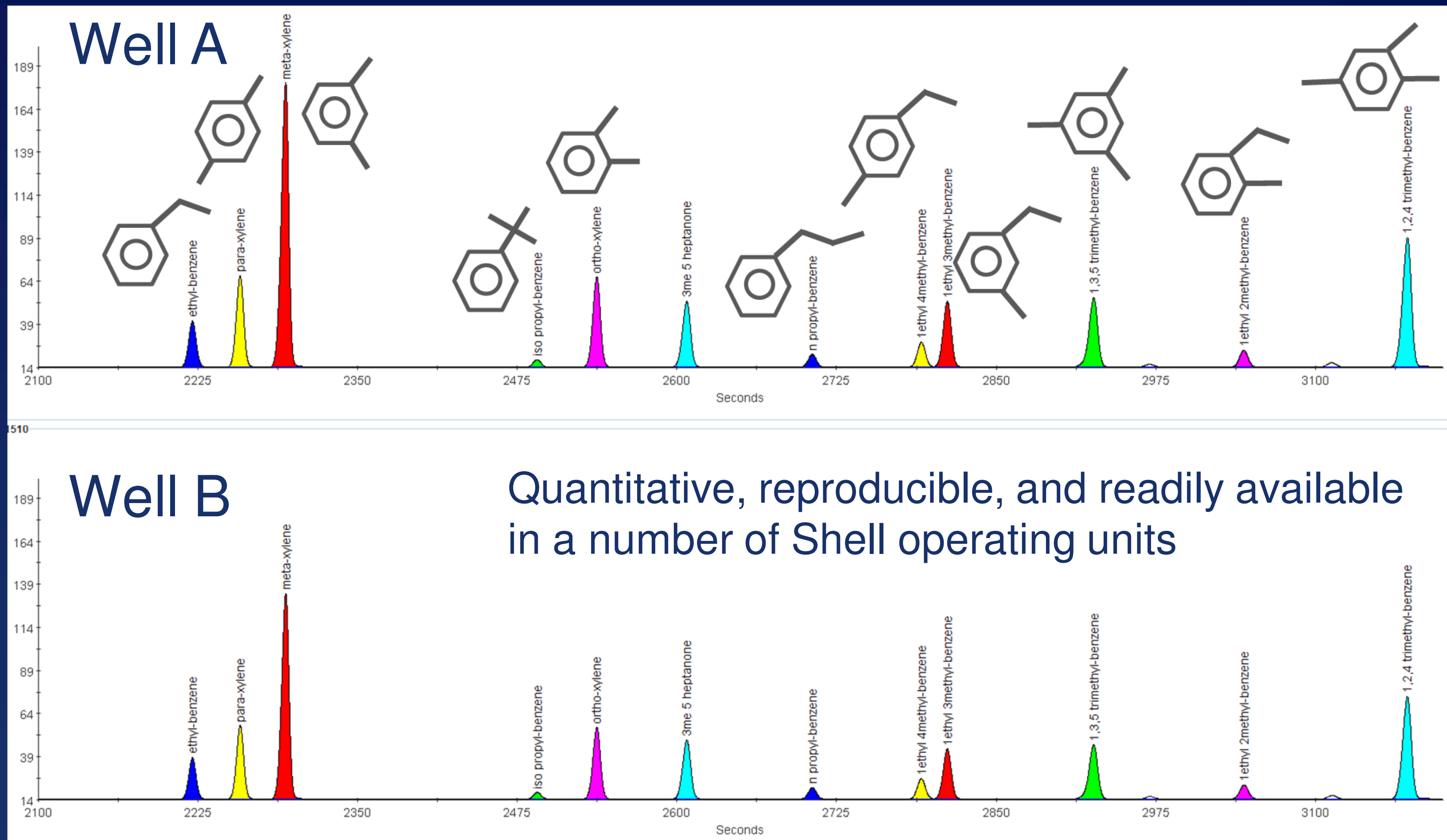
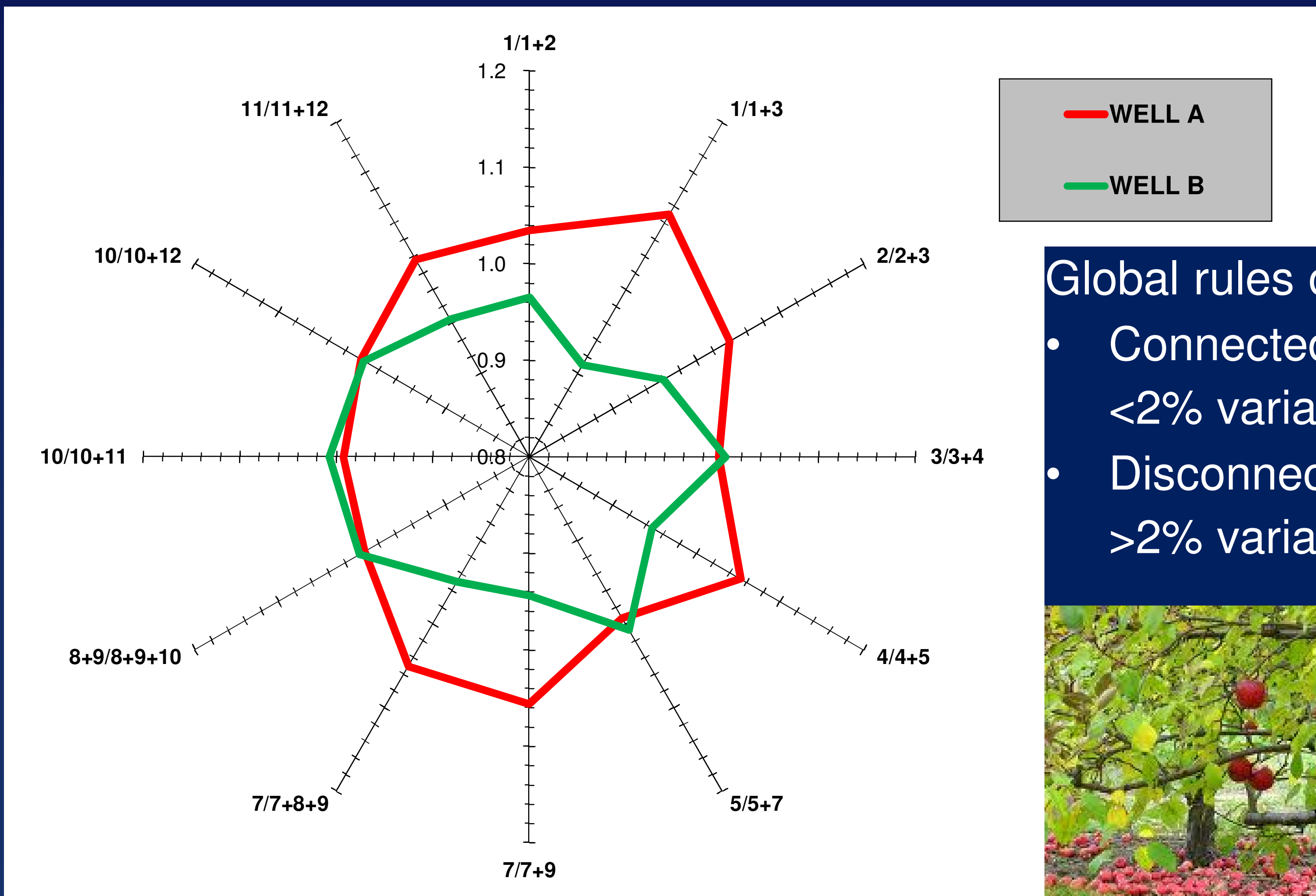


Typically, for reservoir connectivity questions, the difference in fluid fingerprints is subtle.

MDGC Output-Spider Diagrams



Global rules of thumb:

- Connected reservoirs: <2% variability.
- Disconnected reservoir: >2% variability.

Cross Section Cartoon Through Our Example

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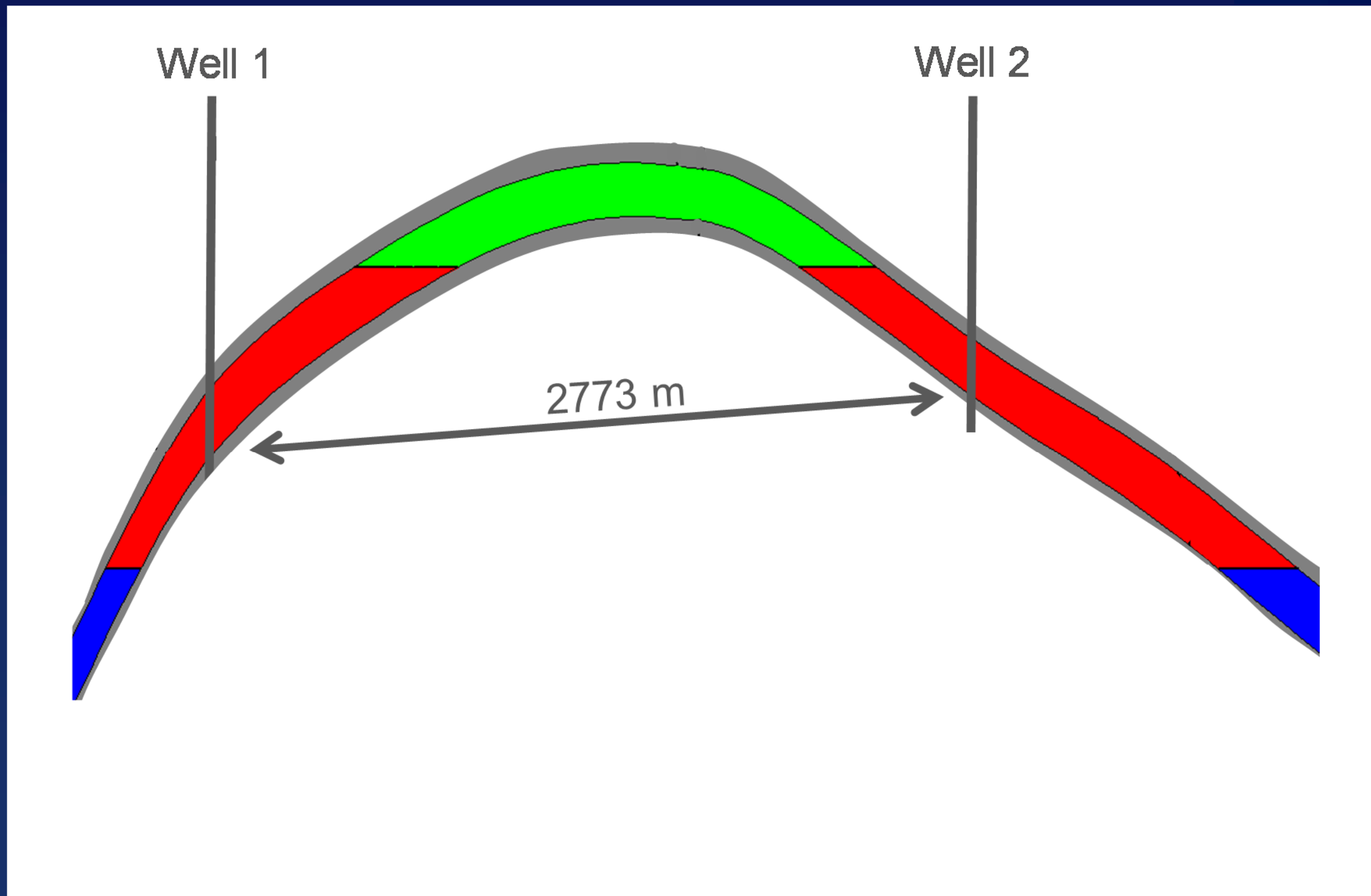
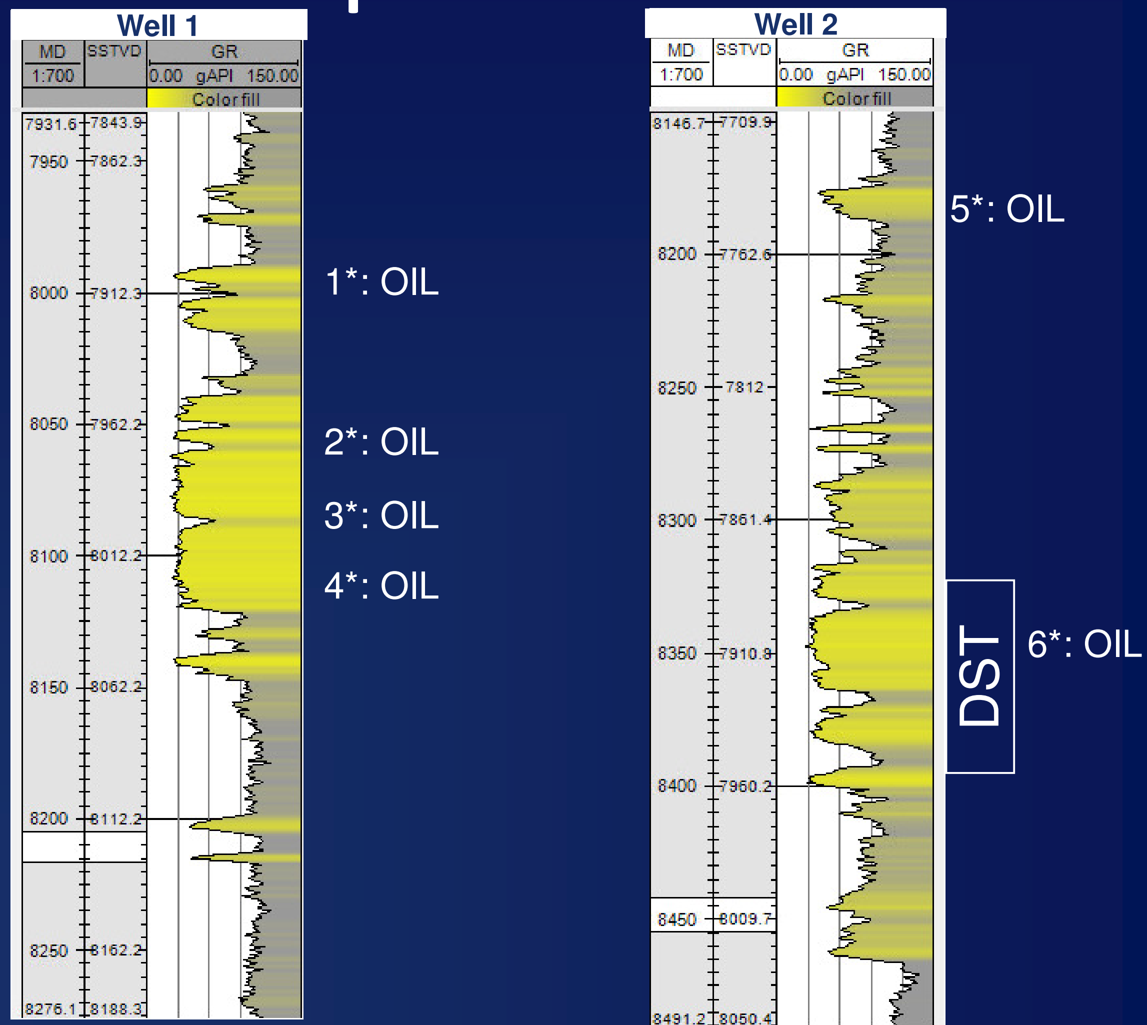


Log Character and Fluid Sample Set



*Open-hole sampling points DST = Drill stem test

Results from exploration & appraisal drilling

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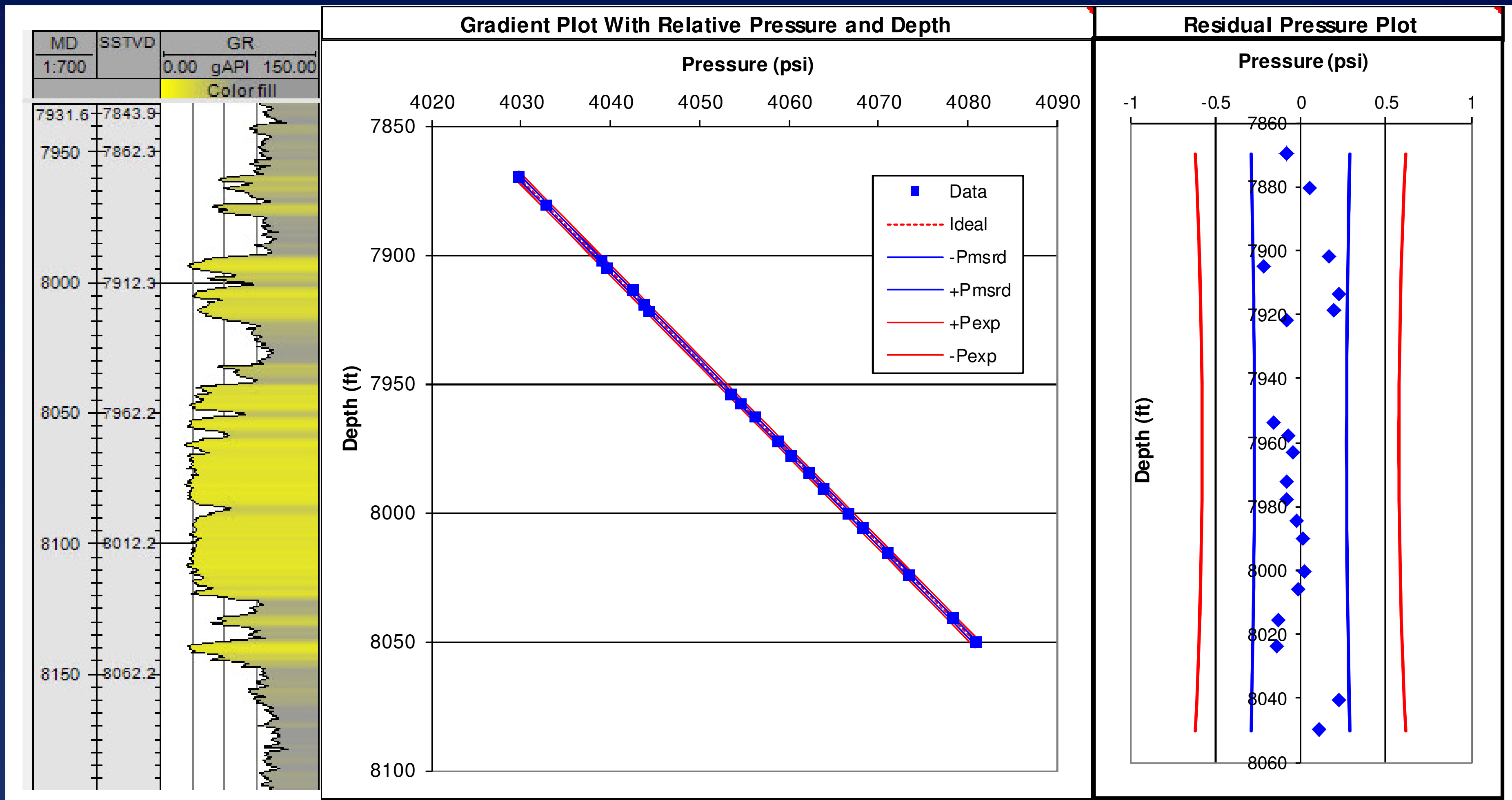
Residual pressure plot: Well-1



No obvious pressure breaks observed between the upper and lower sands.

Heavy Mineral Associations

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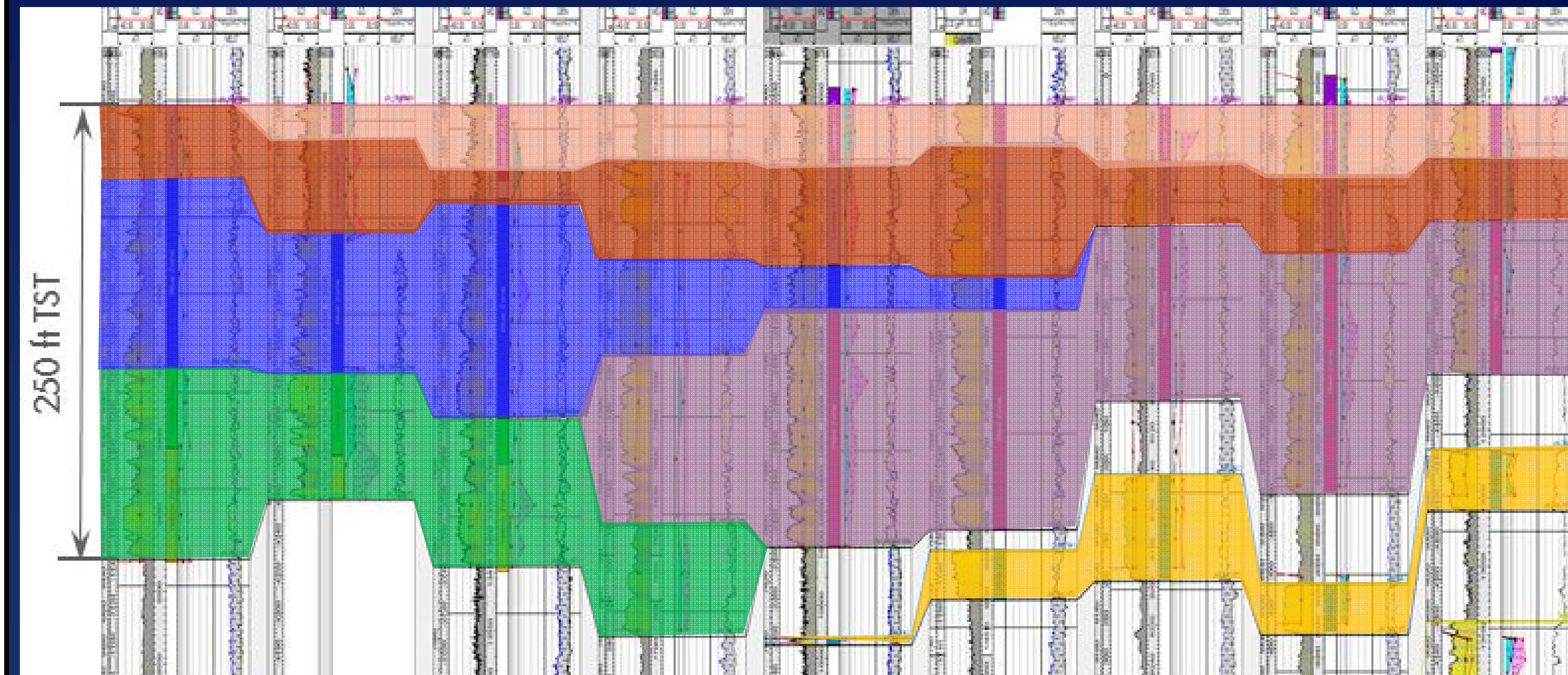
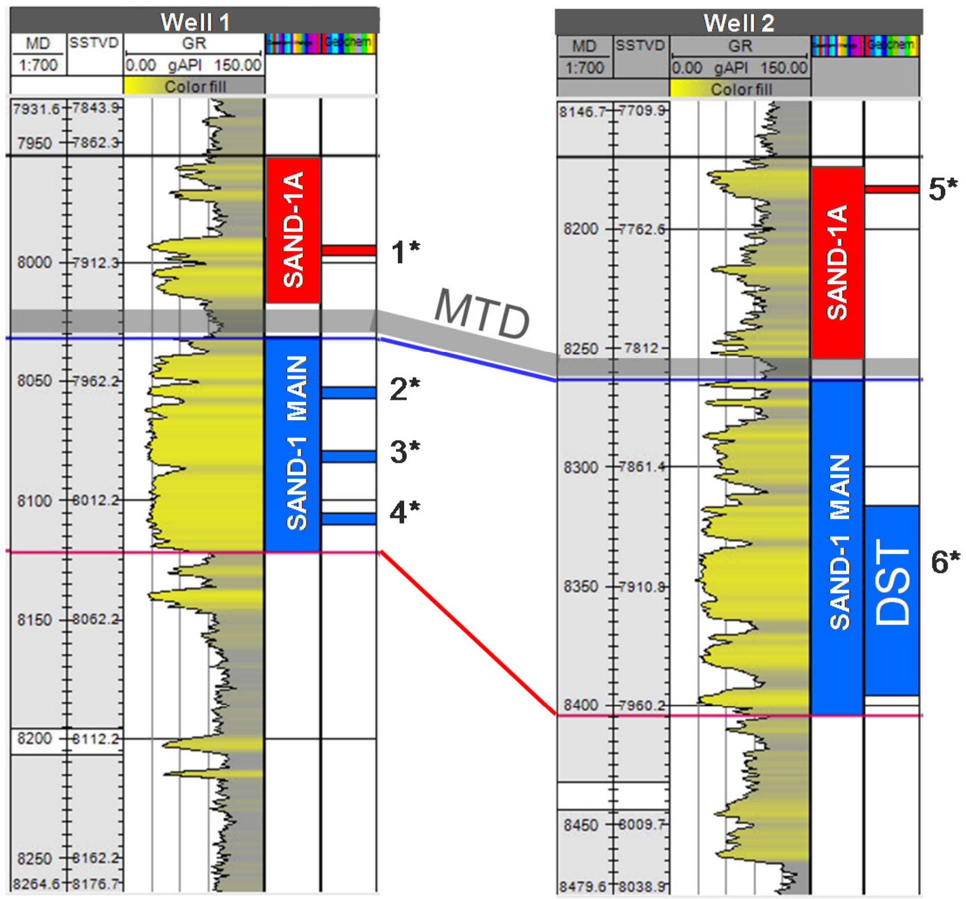
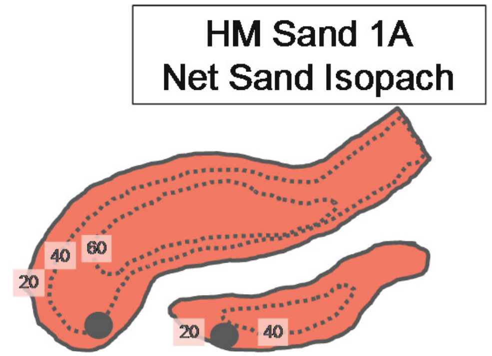
Basic Heavy Mineral Stratigraphy across the field defines fan lobe architecture.



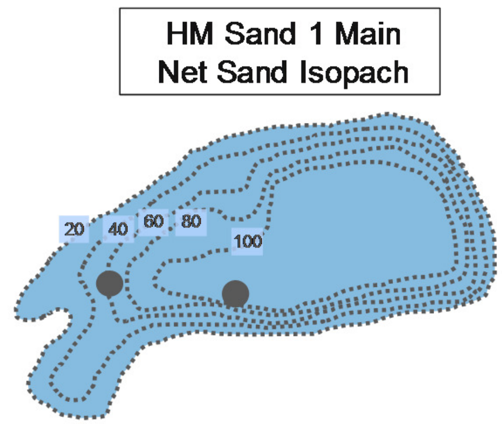
HMA Output



Both zones are separated by a mass transport deposit (MTD)

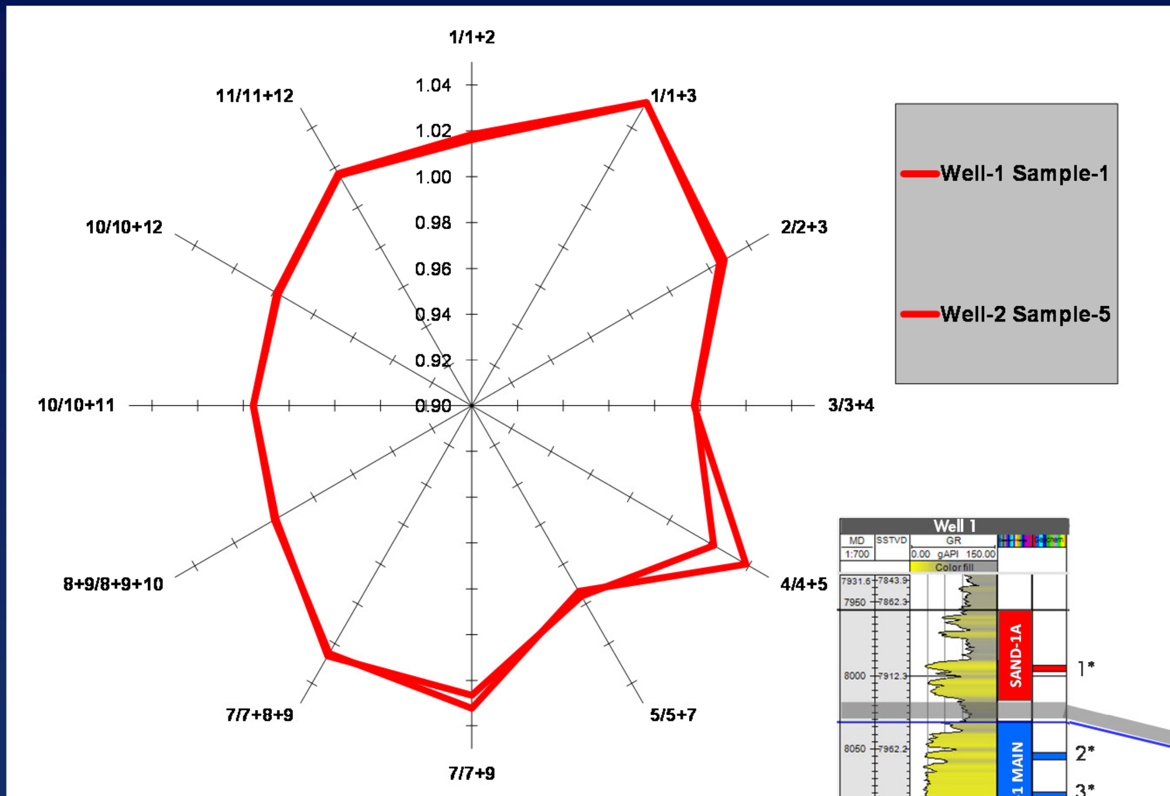


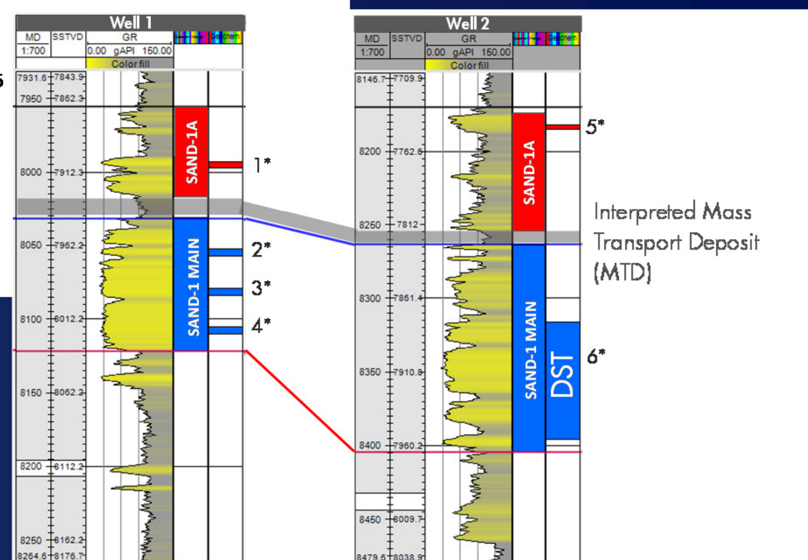
Sand 1A is thinner, more channel-like and not aerially extensive.



Main Reservoir is thicker (>100 ft. net sand) and more extensive.

Oil Fingerprinting Results





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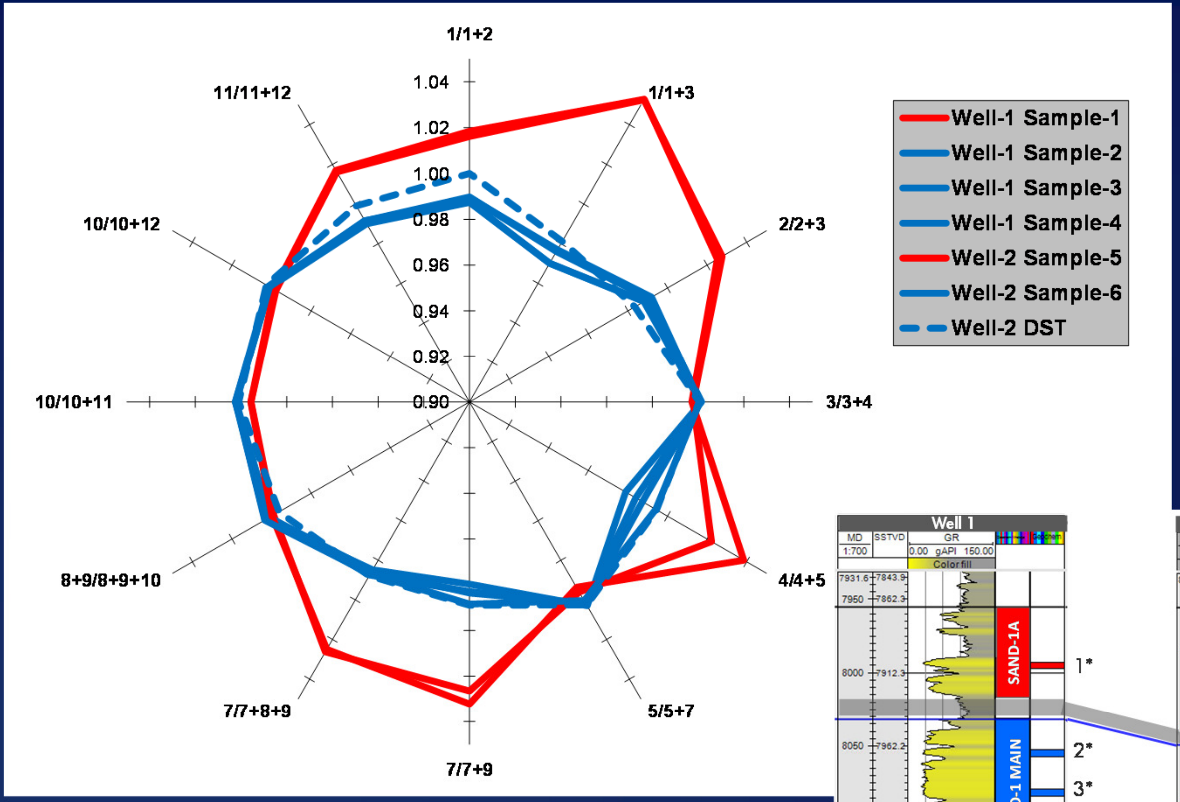
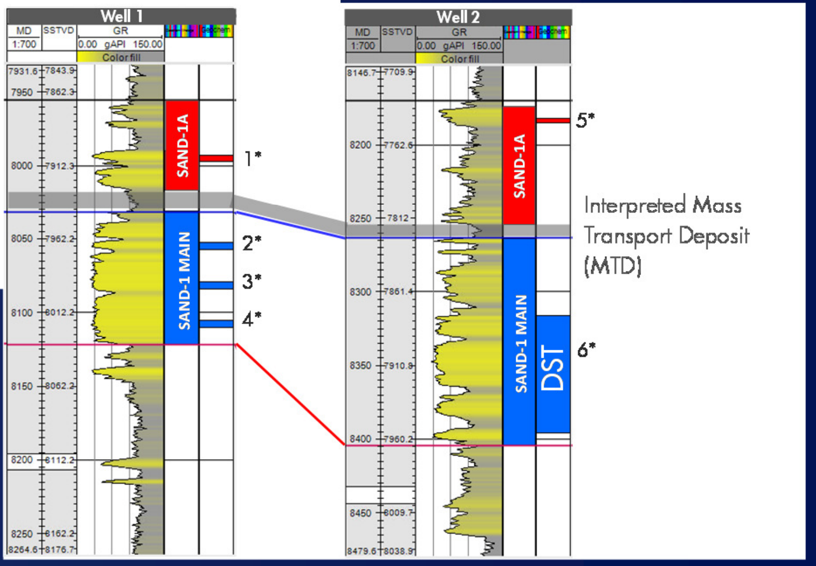
Oil Fingerprinting Results





Summary of Exploration & Appraisal Results

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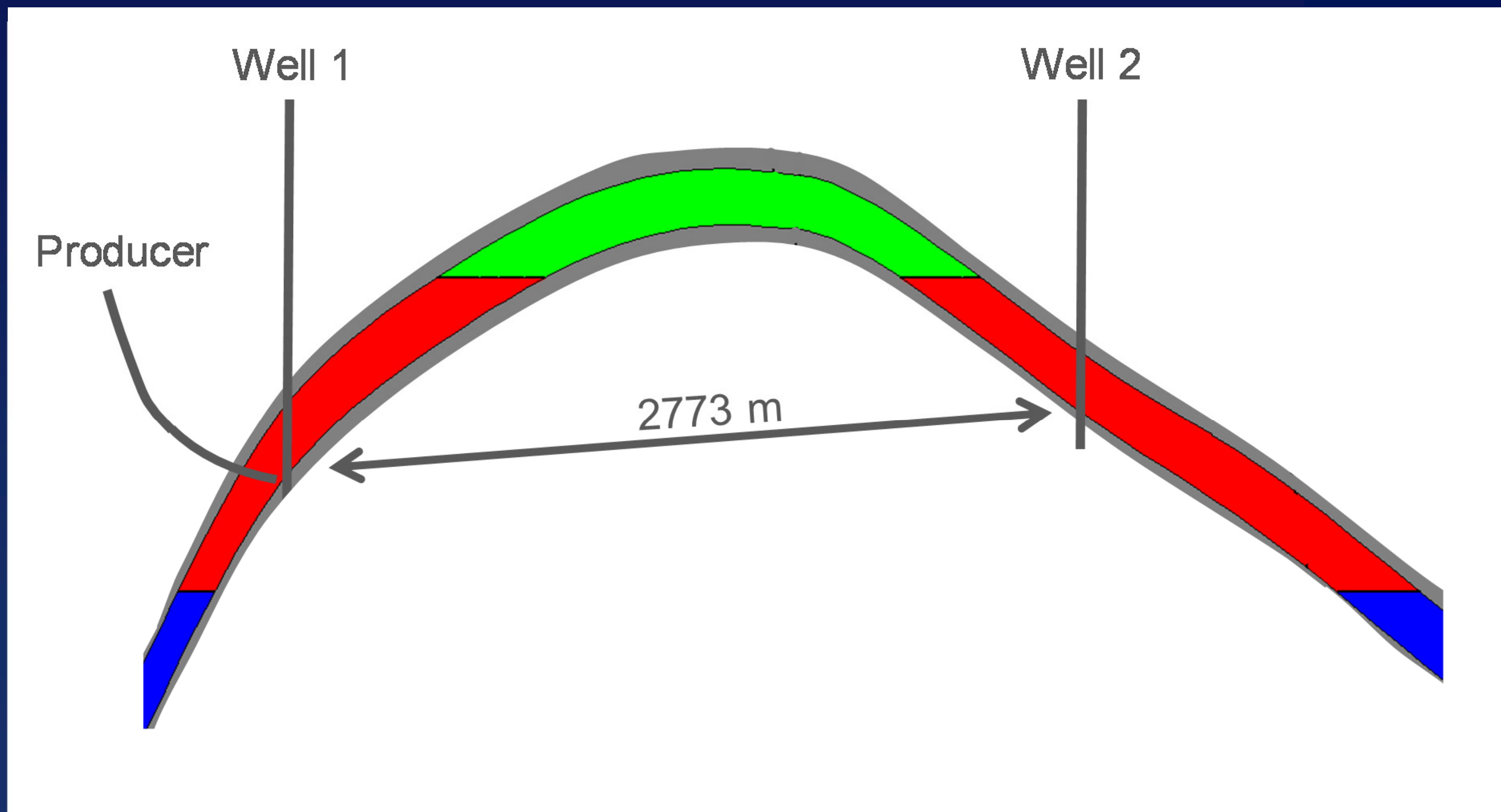
Sand-1:

- Sand-1A and Sand-1 Main in pressure equilibrium.
- HMA indicates two separate sand systems.
- Geochemical fingerprinting indicates they may act as two separate flow units during production.

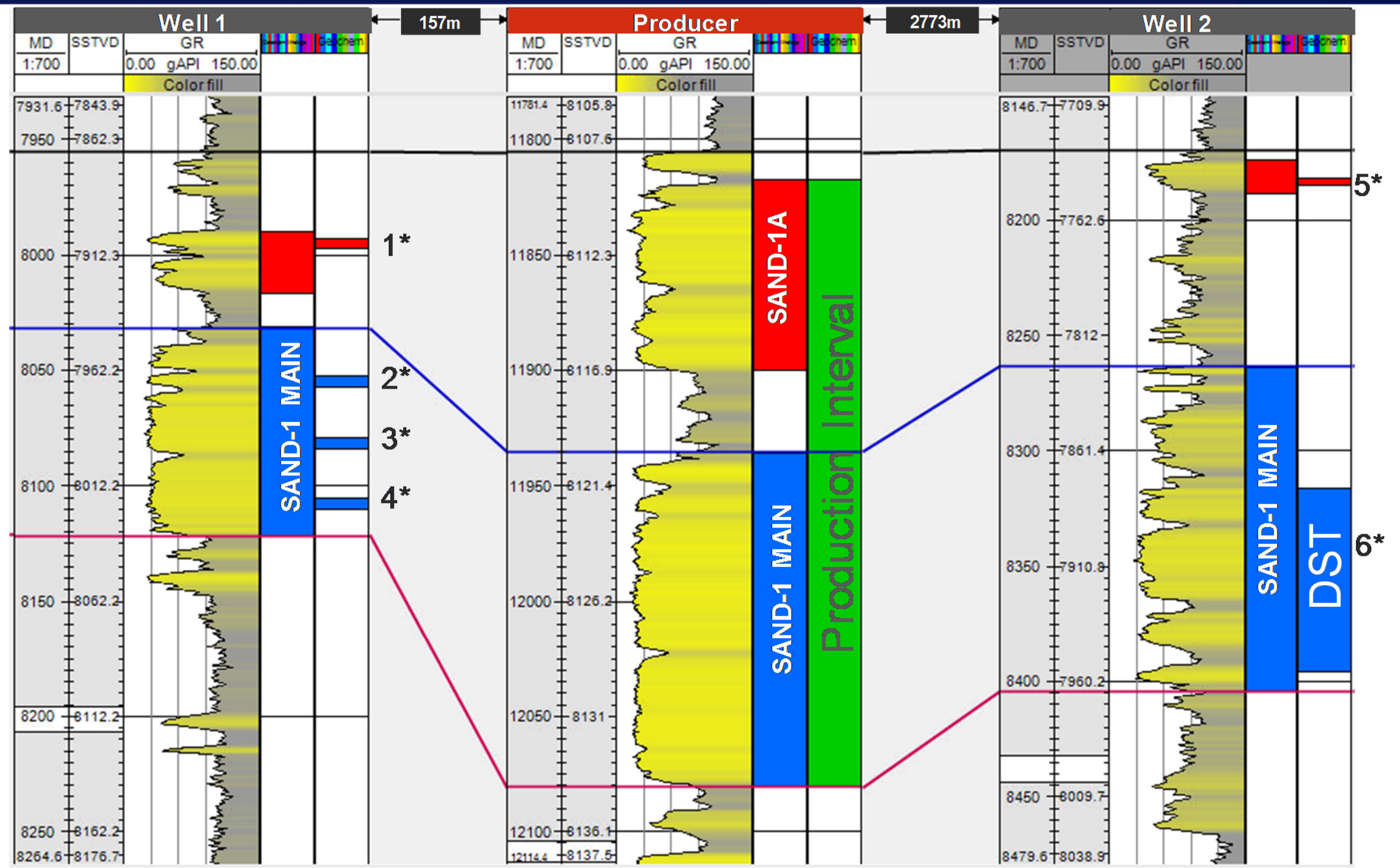
Thus, the initial “Wells, Reservoir and Facilities Management (WRFM)” document explicitly included sample collection and geochemical fingerprinting from each well at start-up.

Production and Surveillance

Cross Section Cartoon Through the Reservoir



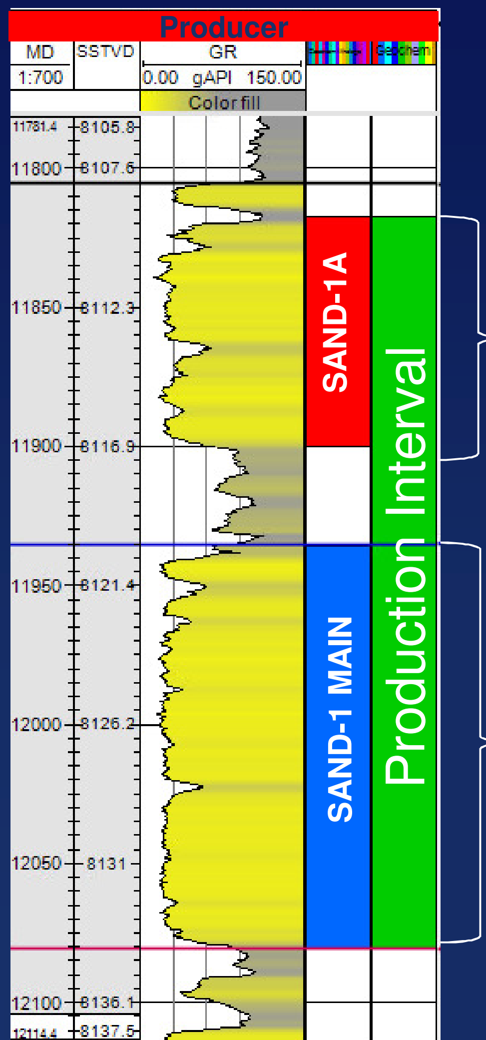
Log Character and Fluid Sample Set



*Open-hole sampling points

DST = Drill stem test

Reservoir Engineering Allocation For Producer



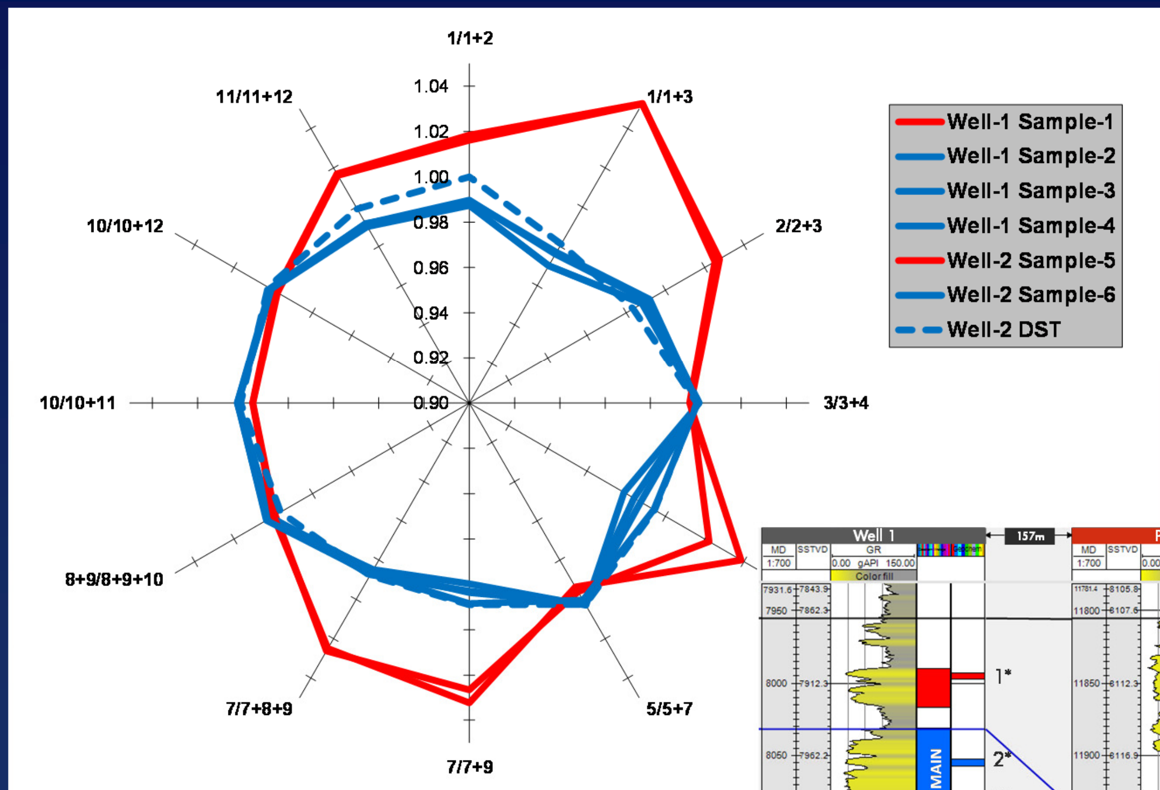
Assume oil viscosity between units is the same.

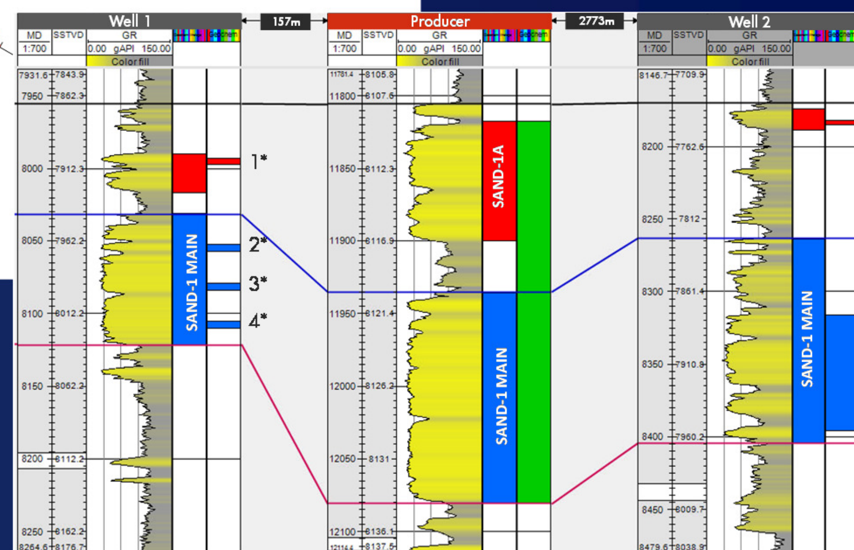
Average Permeability (k) = 900 mD
True stratigraphic thickness (h) = 43 ft.
kh = 38700 mD ft.

Average Permeability (k) = 670 mD
True stratigraphic thickness (h) = 68 ft.
kh = 45560 mD ft.

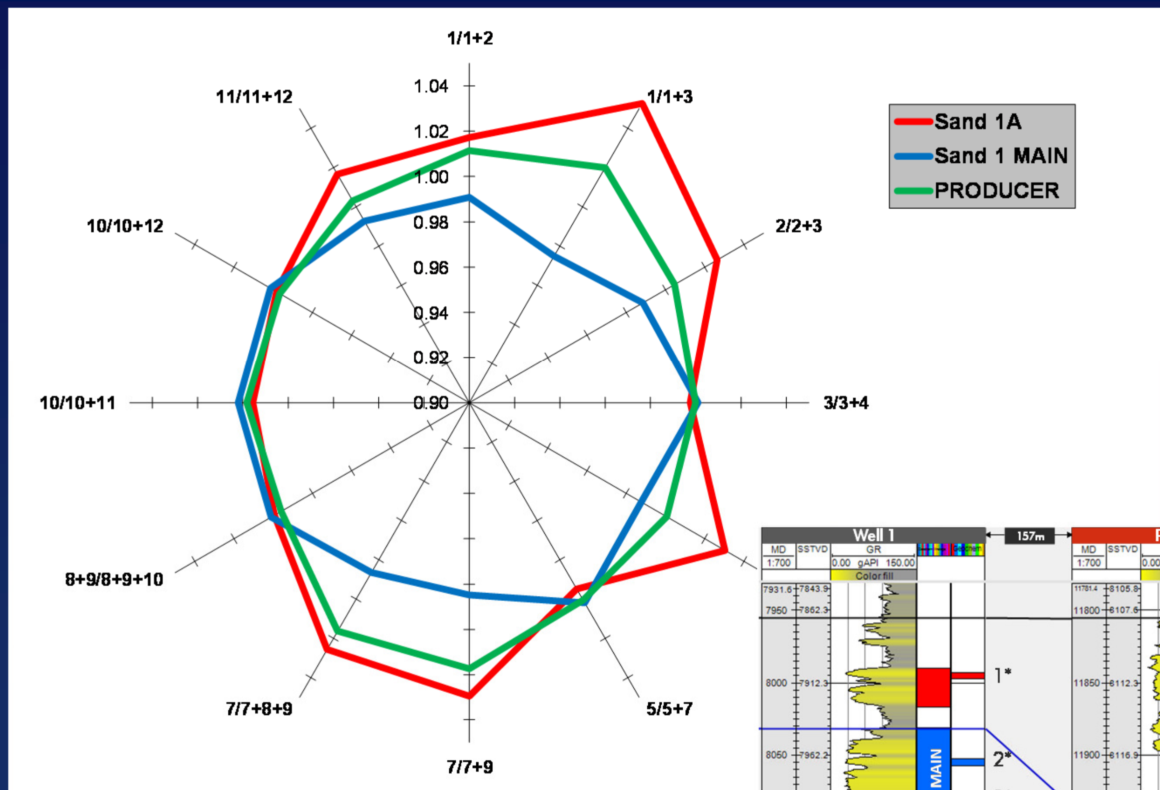
Theoretical mixture: 38700:45560
~45:55 Sand-1A:Sand-1 Main

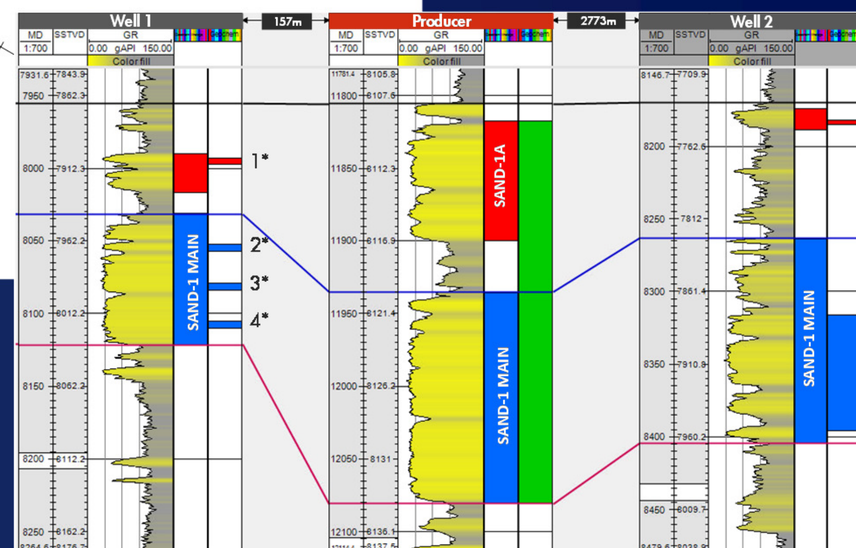
Production Data



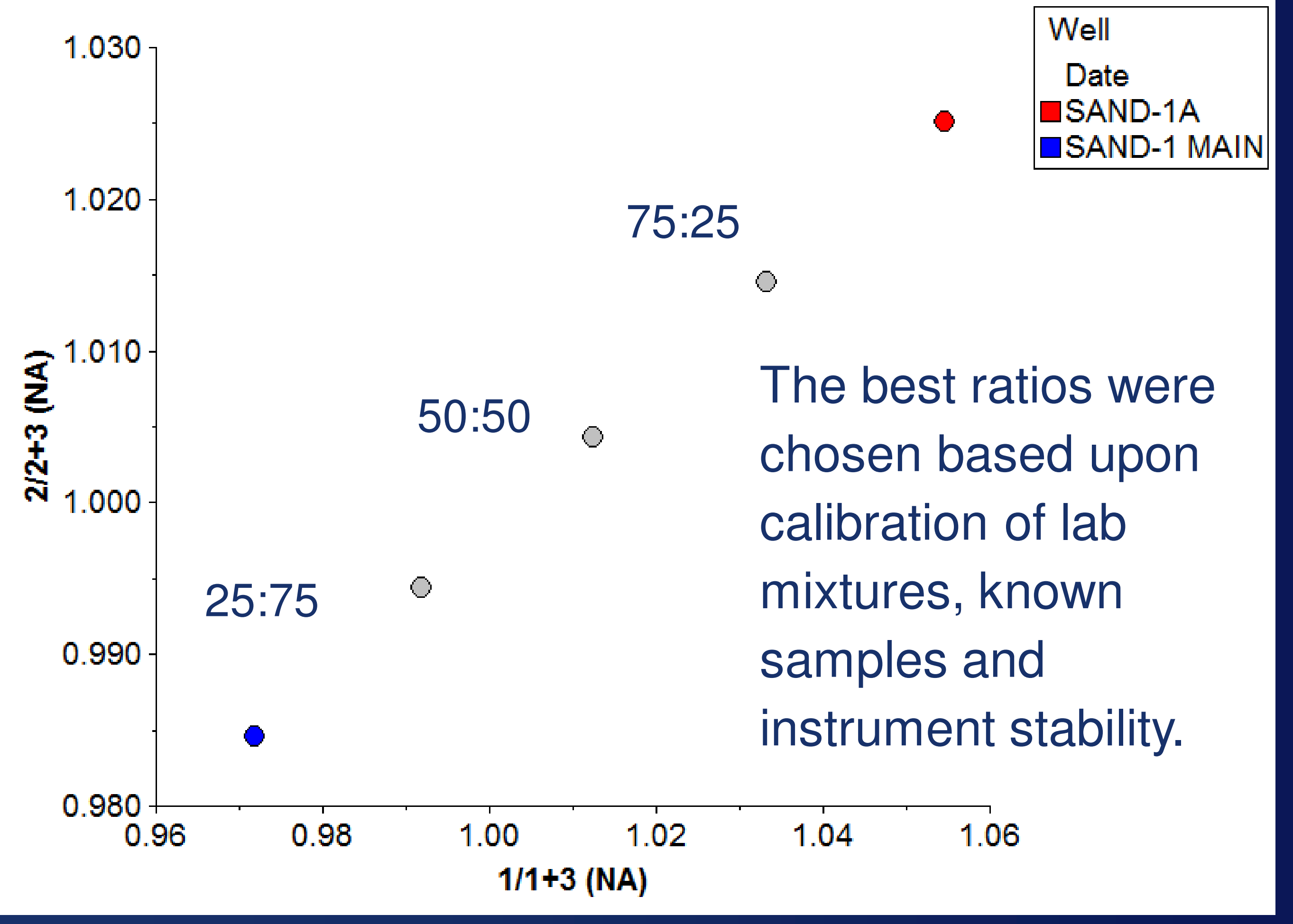


Production Data



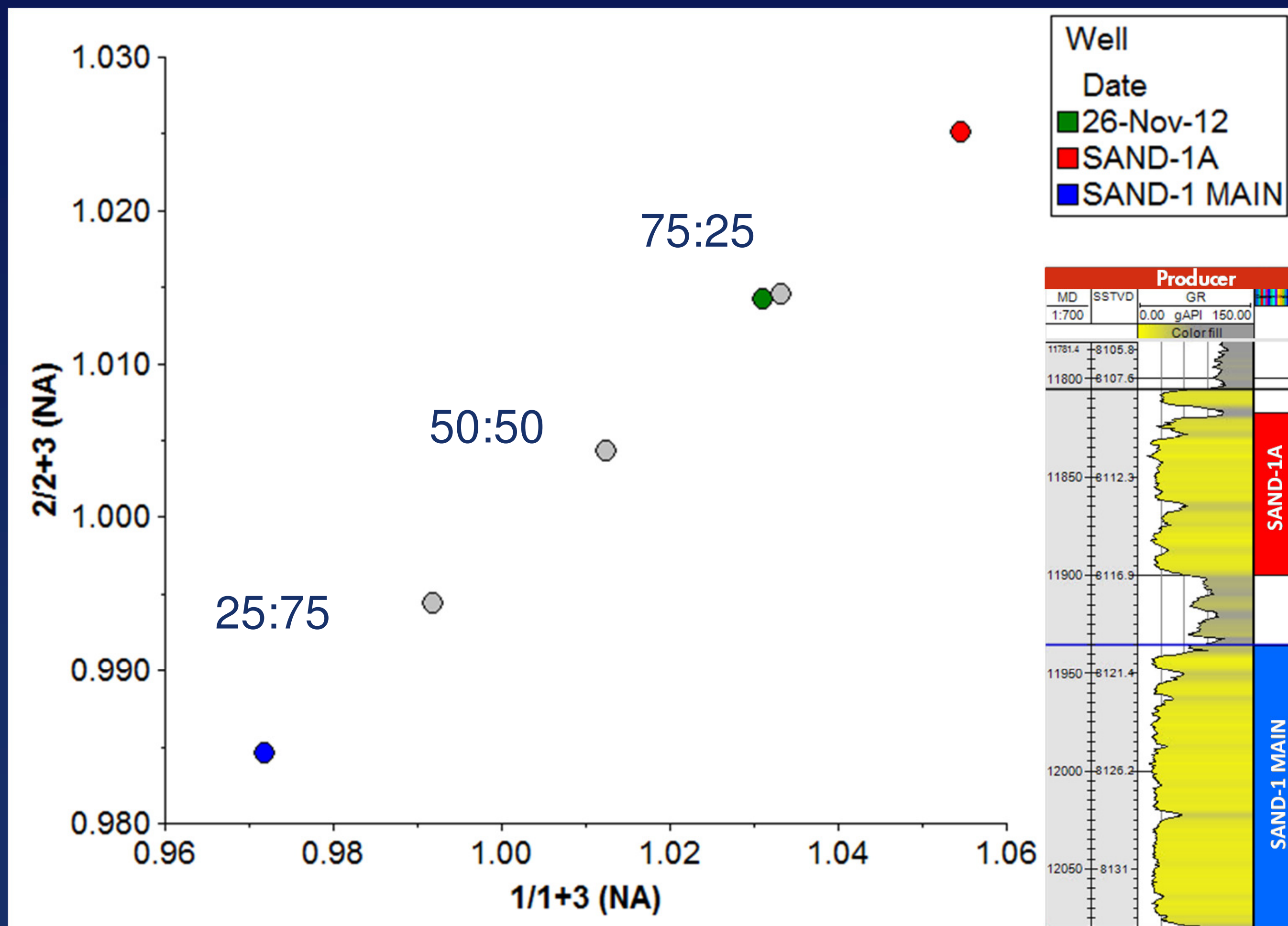


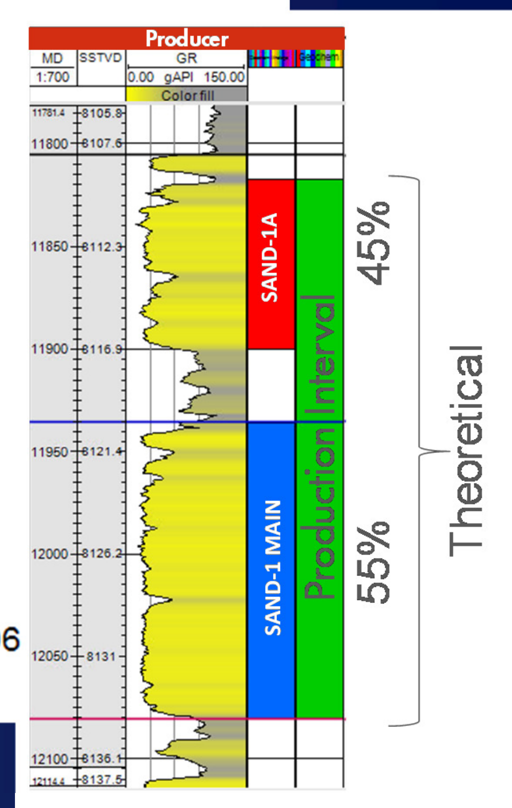
Mixing Model Using Select Ratios



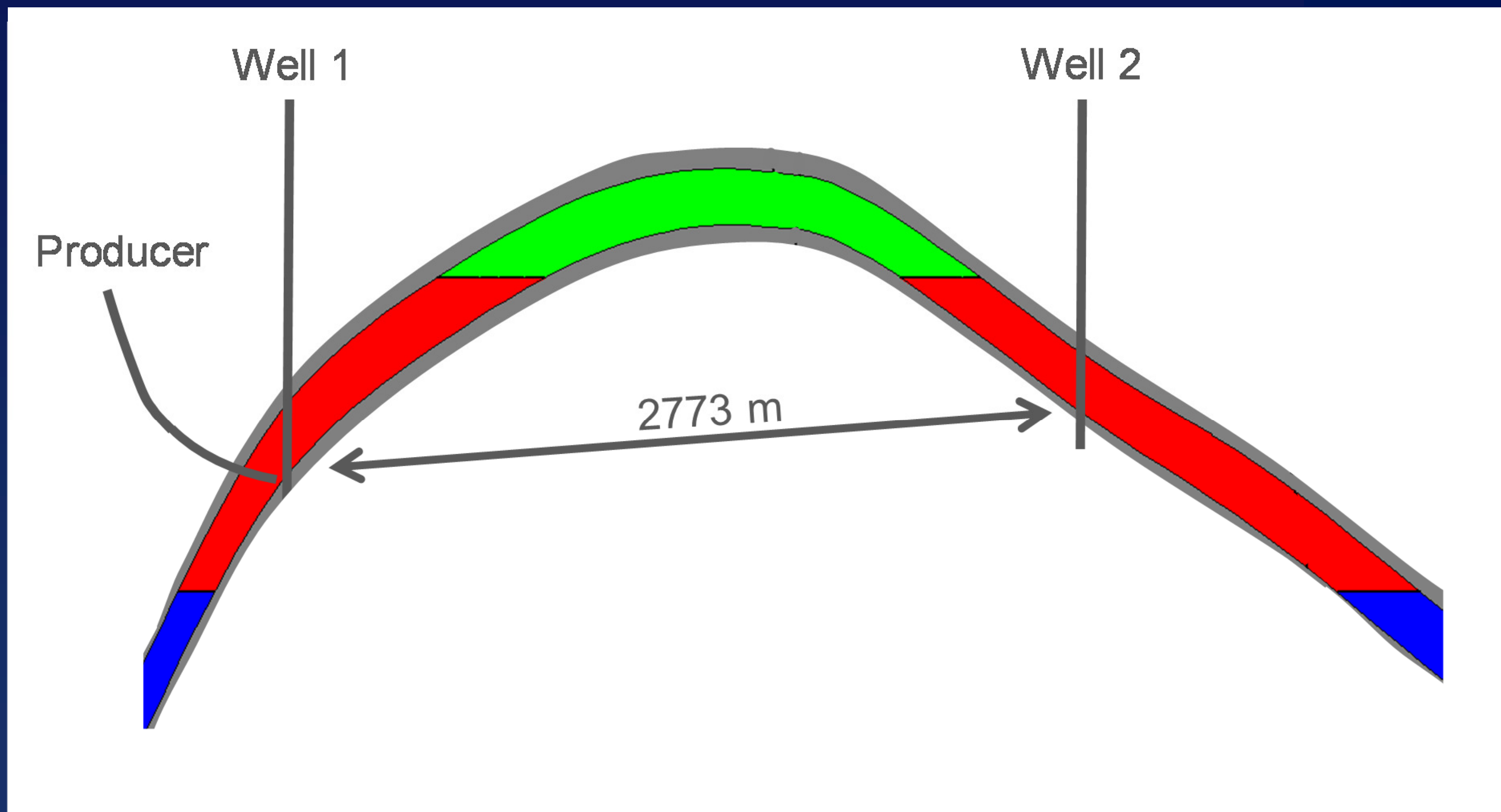
The best ratios were chosen based upon calibration of lab mixtures, known samples and instrument stability.

Initial Results & Prediction: What's Going On?

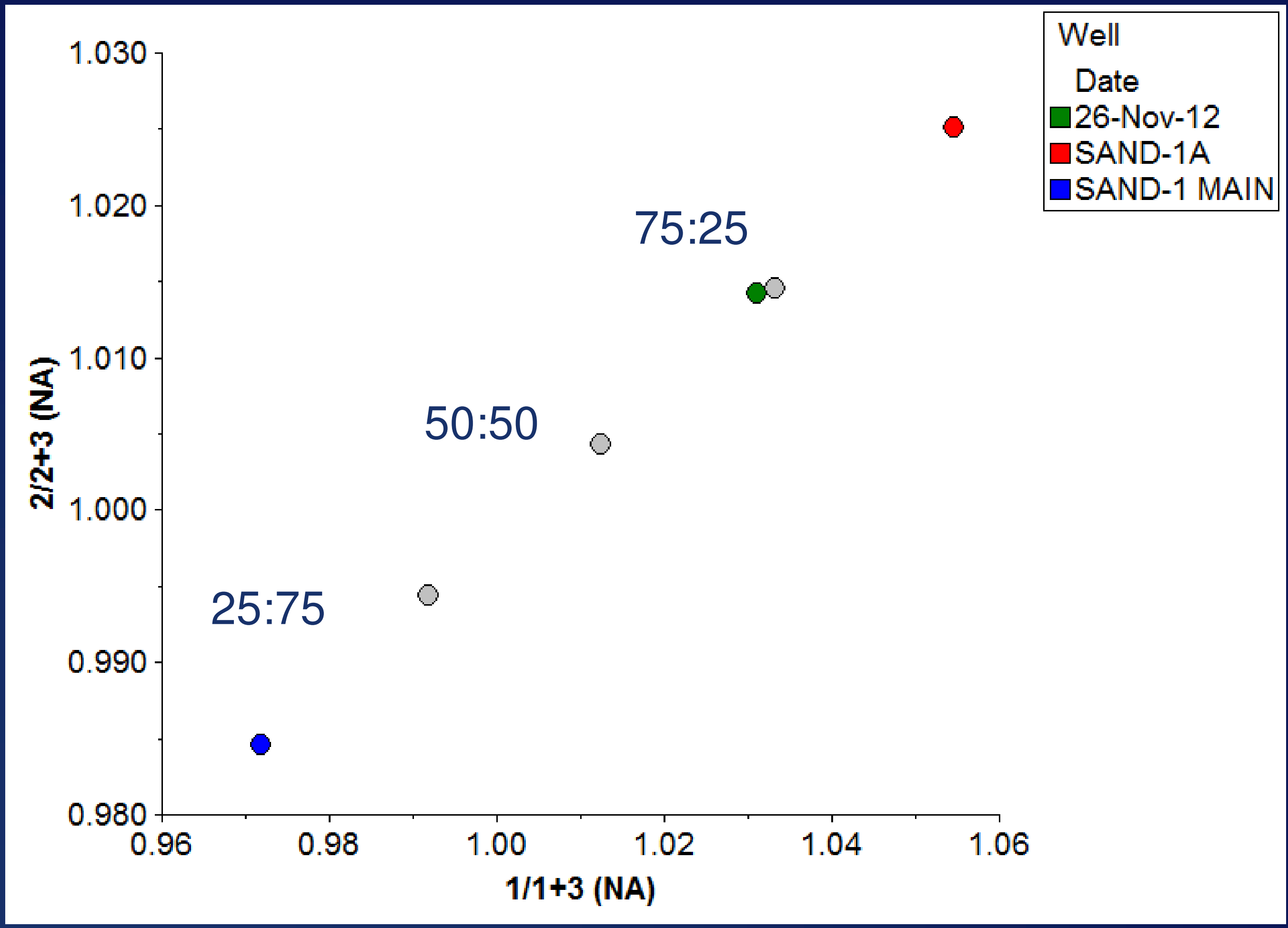




Explanation of Results



Time Lapse



Well
Date
26-Nov-12
SAND-1A
SAND-1 MAIN
75:25
50:50
25:75
1.030
1.020
1.010
1.000
0.990
0.980
0.96
0.98
1.00
1.02
1.04
1.06
2/2+3 (NA)
1/1+3 (NA)

Time Lapse

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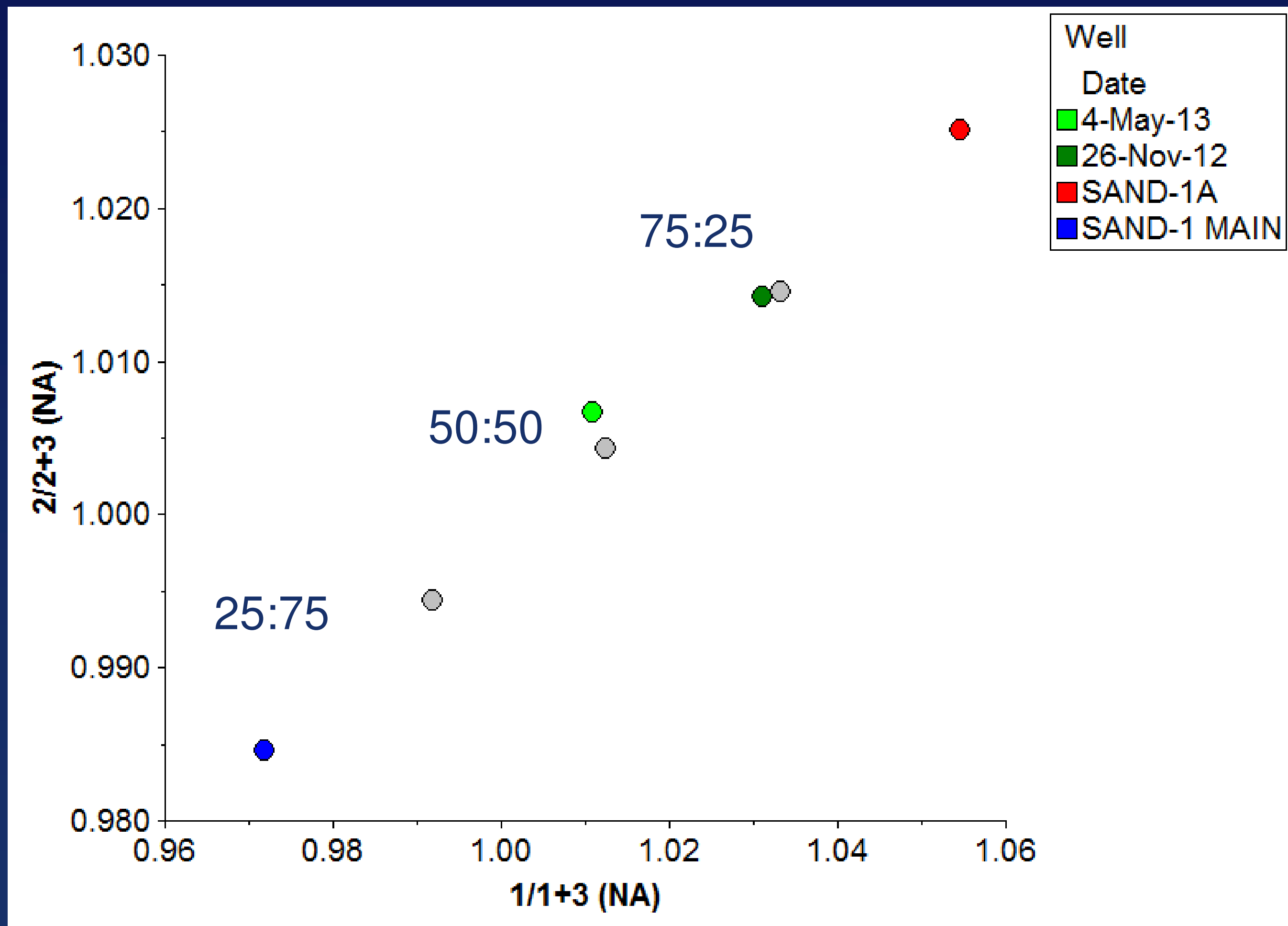
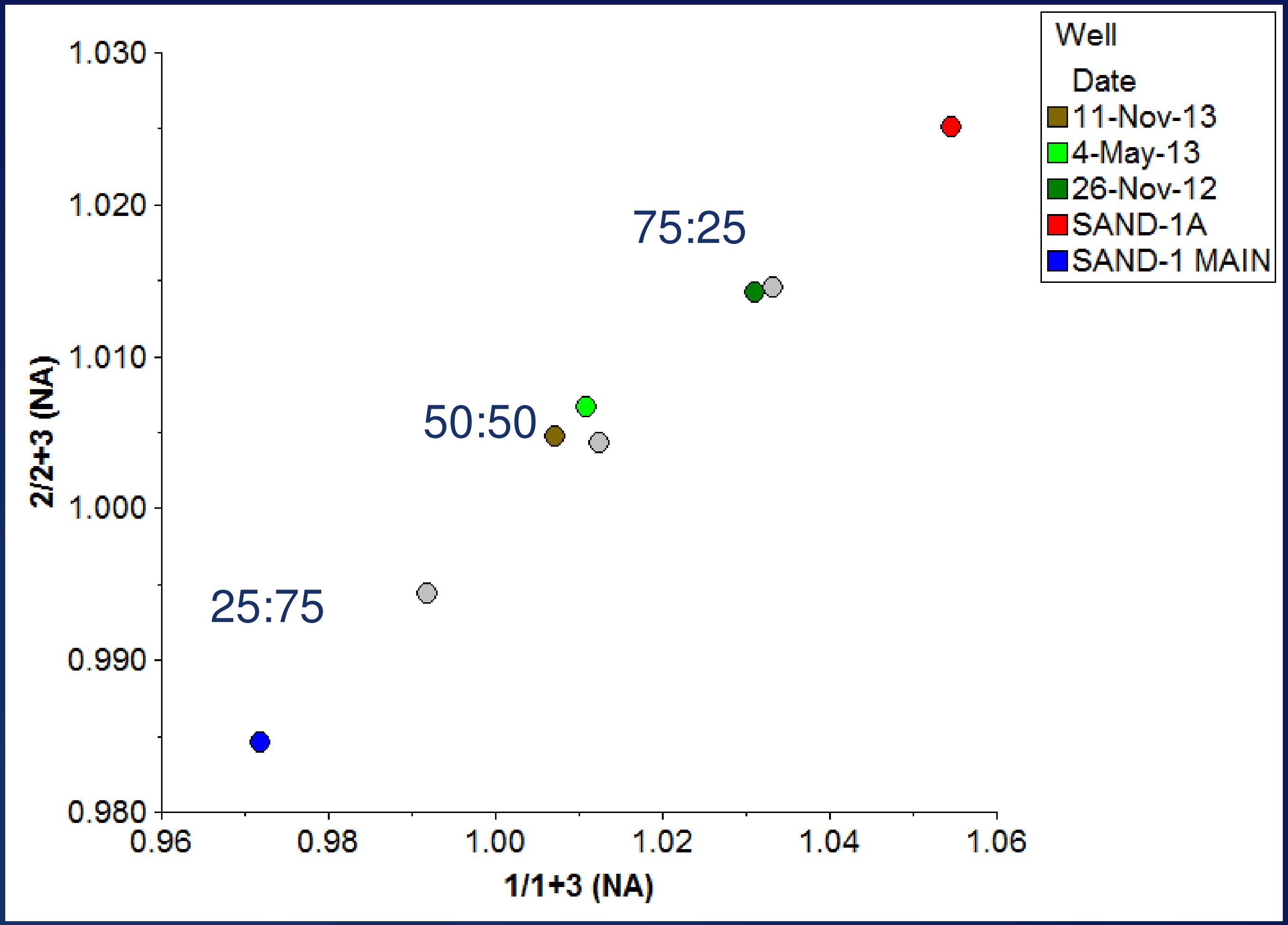
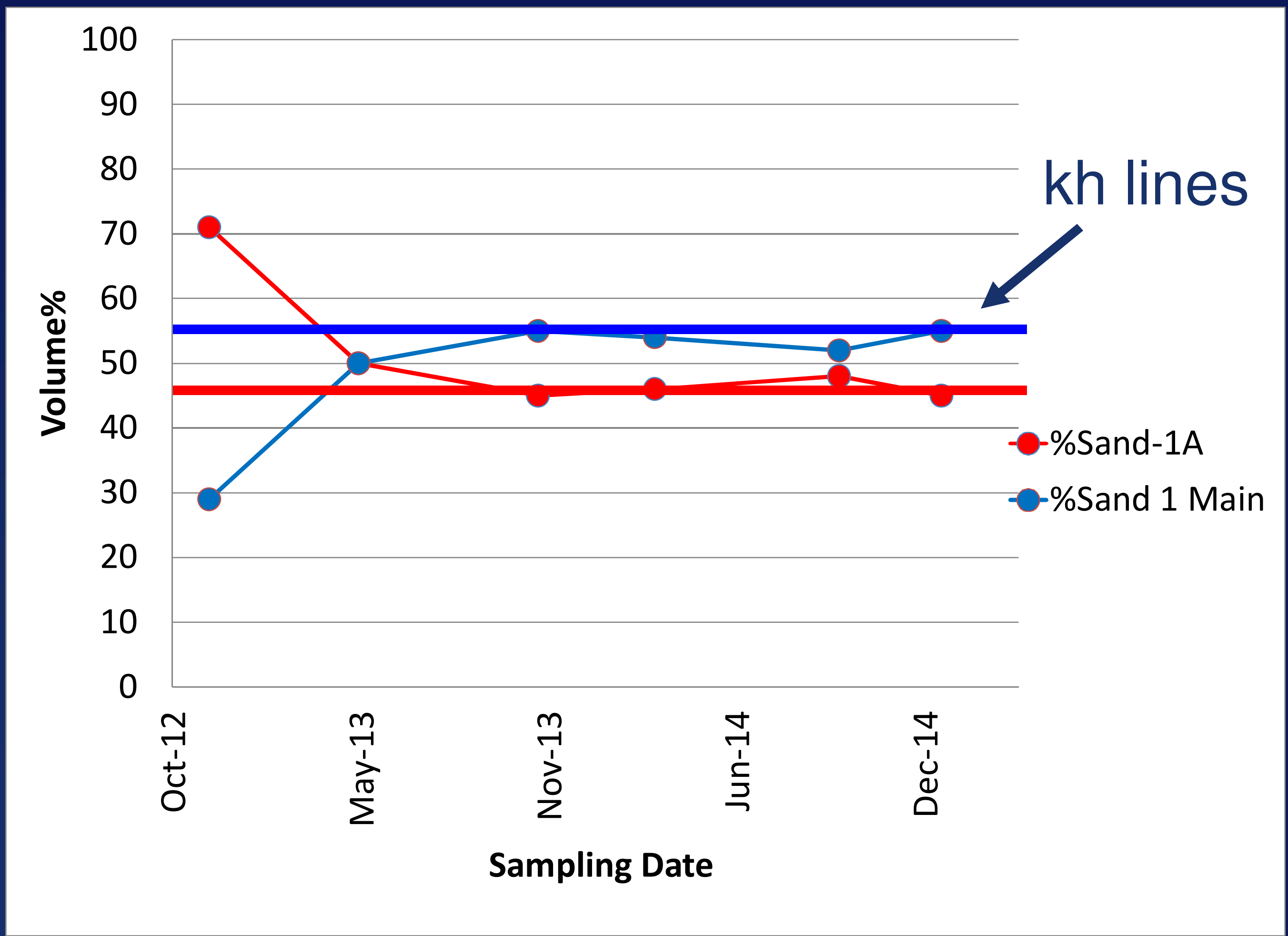


Time Lapse



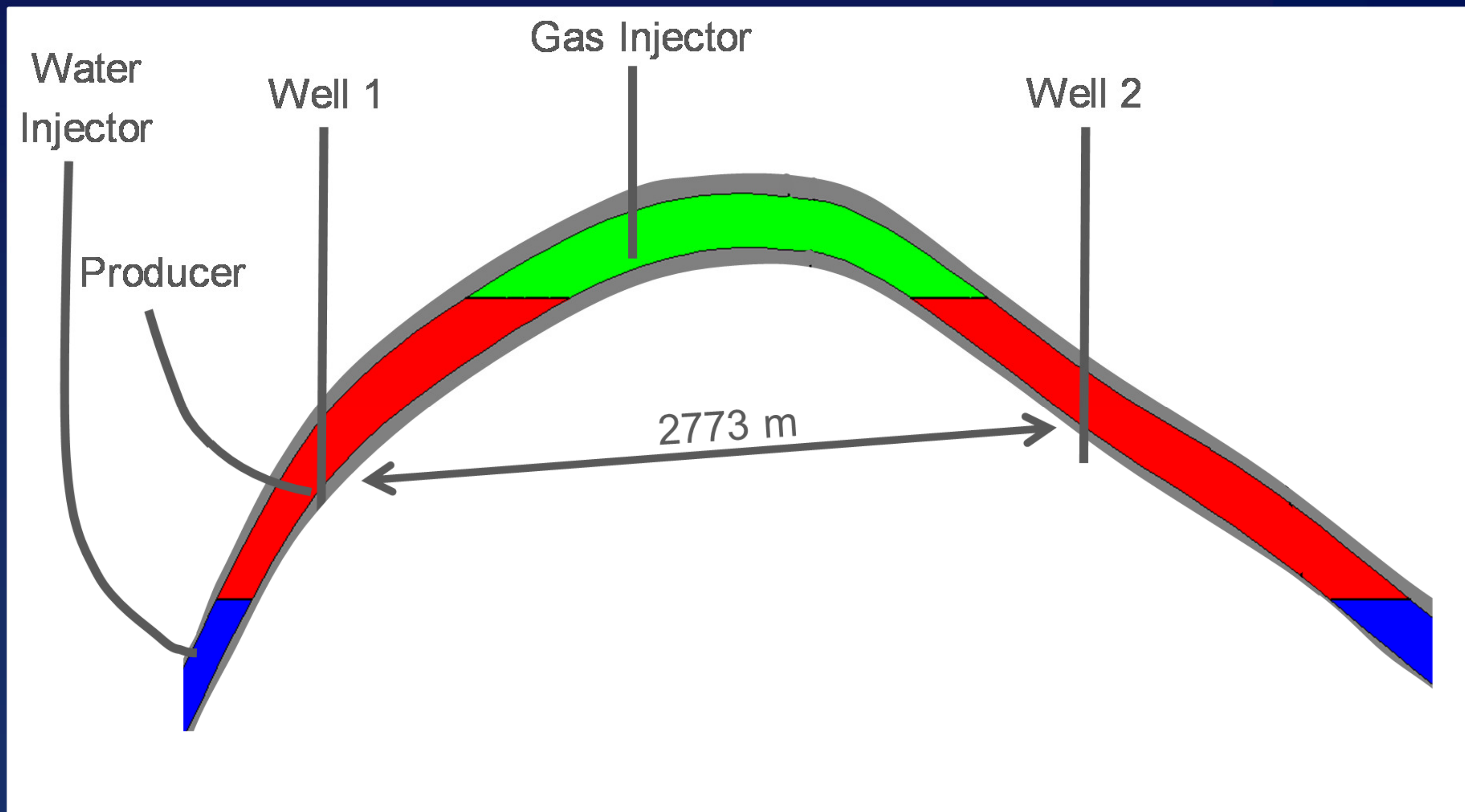
Well
Date
11-Nov-13
4-May-13
26-Nov-12
SAND-1A
SAND-1 MAIN
75:25
50:50
25:75
2/2+3 (NA)
1/1+3 (NA)
1.030
1.020
1.010
1.000
0.990
0.980
0.96
0.98
1.00
1.02
1.04
1.06

Time Lapse

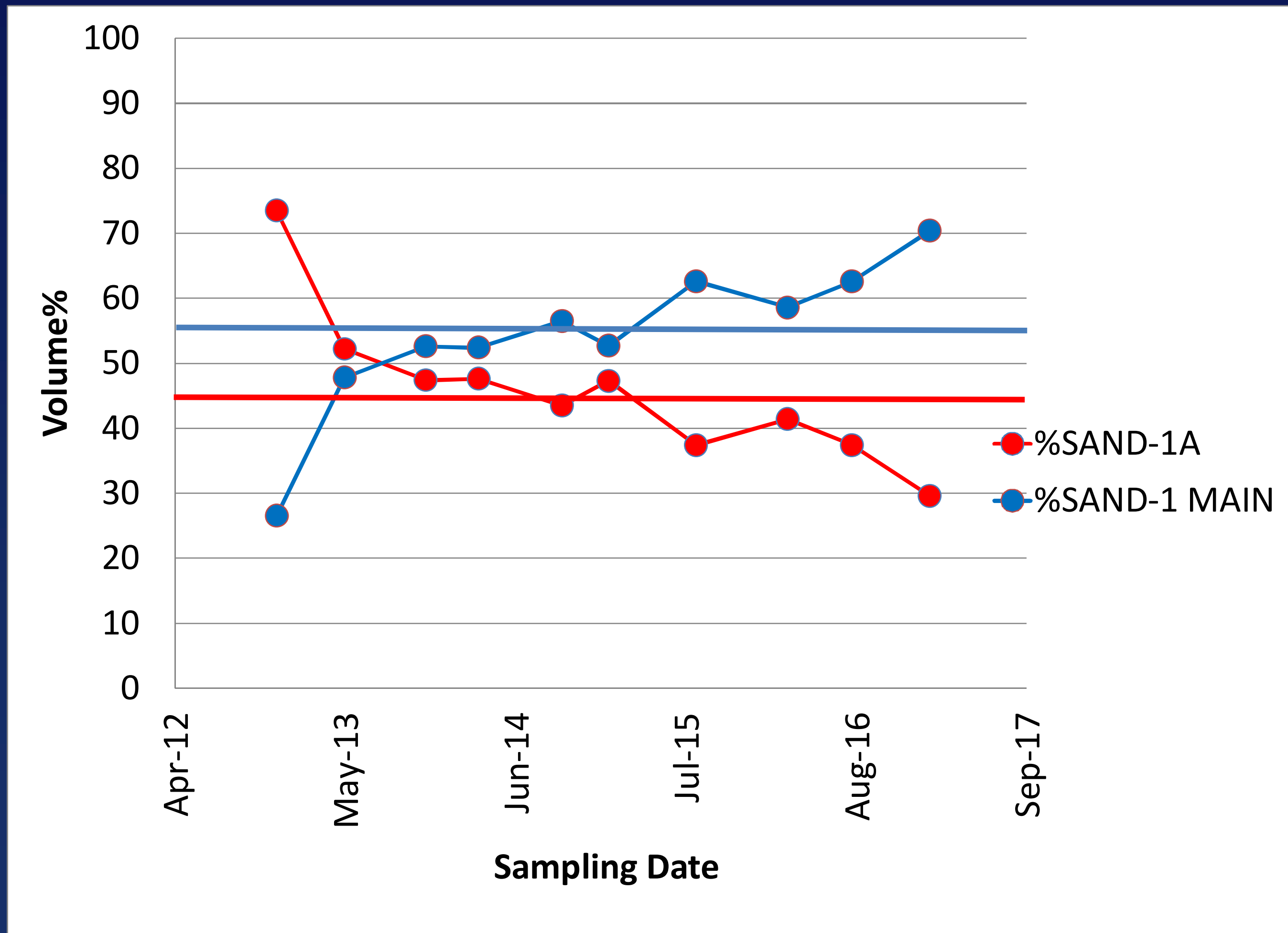


kh lines
Volume%
100
90
80
70
60
50
40
30
20
10
0
Oct-12
May-13
Nov-13
Jun-14
Dec-14
Sampling Date
%Sand-1A
%Sand 1 Main

Reservoir Monitoring in the Future



Time Lapse


100
90
80
70
60
50
40
30
20
10
0
Volume%
Apr-12
May-13
Jun-14
Jul-15
Aug-16
Sep-17
Sampling Date
%SAND-1A
%SAND-1 MAIN

Case Study #1 Summary

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- Reservoir architecture was established by the integration of a complete set of sub-surface data in the exploration/appraisal phase.
- Results indicated two separate units within Sand-1.
- WRFM system initiated critical baseline sampling and time lapse to monitor changes through production life.

Case Study #1 Summary

SPE DISTINGUISHED LECTURER

Business Impact:

- Material balance and impact on Phase II development for by-passed oil
- Monitor water and gas sweep efficiency.
- Avert or avoid production logging for reservoir contribution.
  - Cost differential is at least 4X orders of magnitude for PLT vs. geochemical fingerprinting.

Case Study Examples

SPE DISTINGUISHED LECTURER

Identifying Compartmentalization during Operations

McKinney et al., SPE 109861

Tools for Assessing Compartmentalization

- Geological and sediment controls on gross depositional environment.
- Static and dynamic pressure.
- Fluid property variations both laterally and vertically.
- Fluid fingerprinting.
- Structural assessment of faults and seals.

Introduction and Framing

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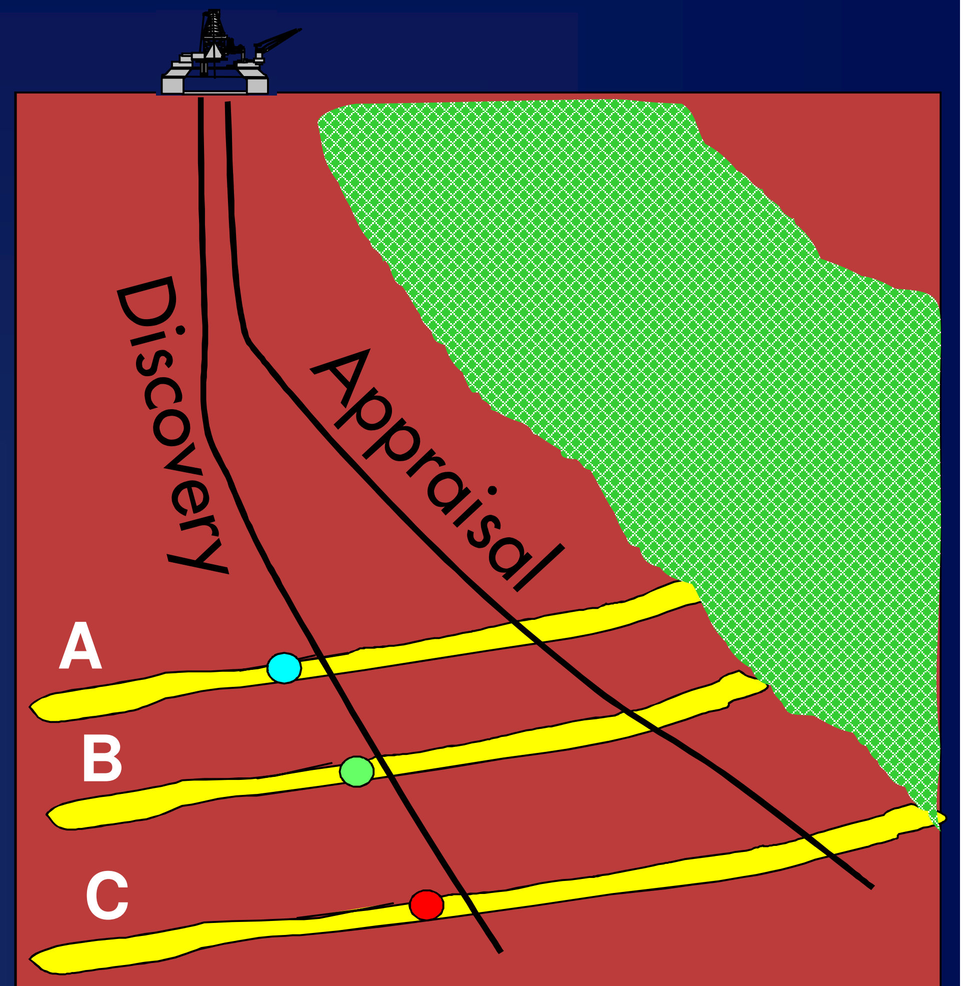
Sub-salt discovery well found the following fluid distributions:

Sand A: Black Oil

Sand B: Water

Sand C: Gas/Condensate

Note trajectory of the well and impact on wireline logging!



Apply Technology Where Needed

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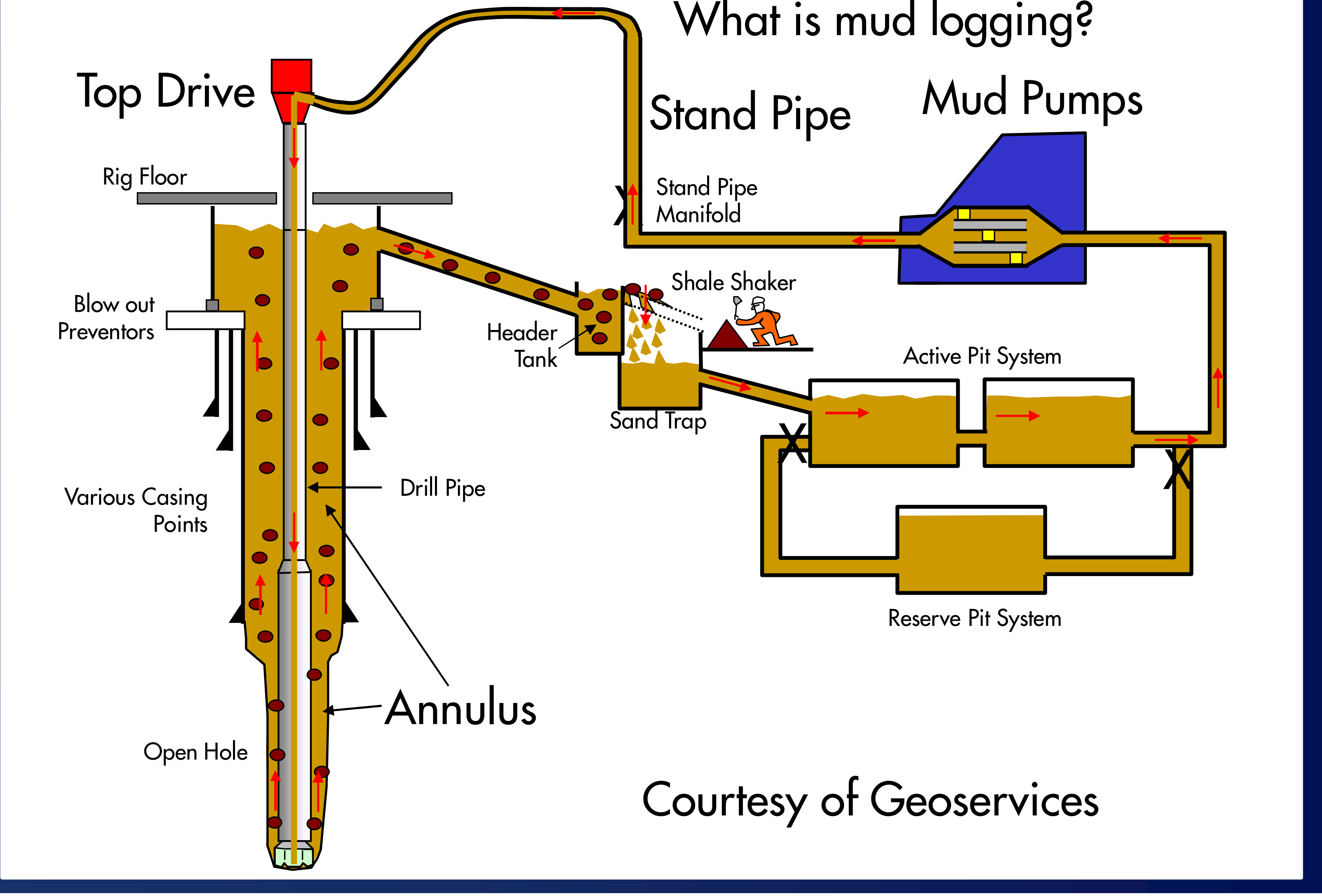
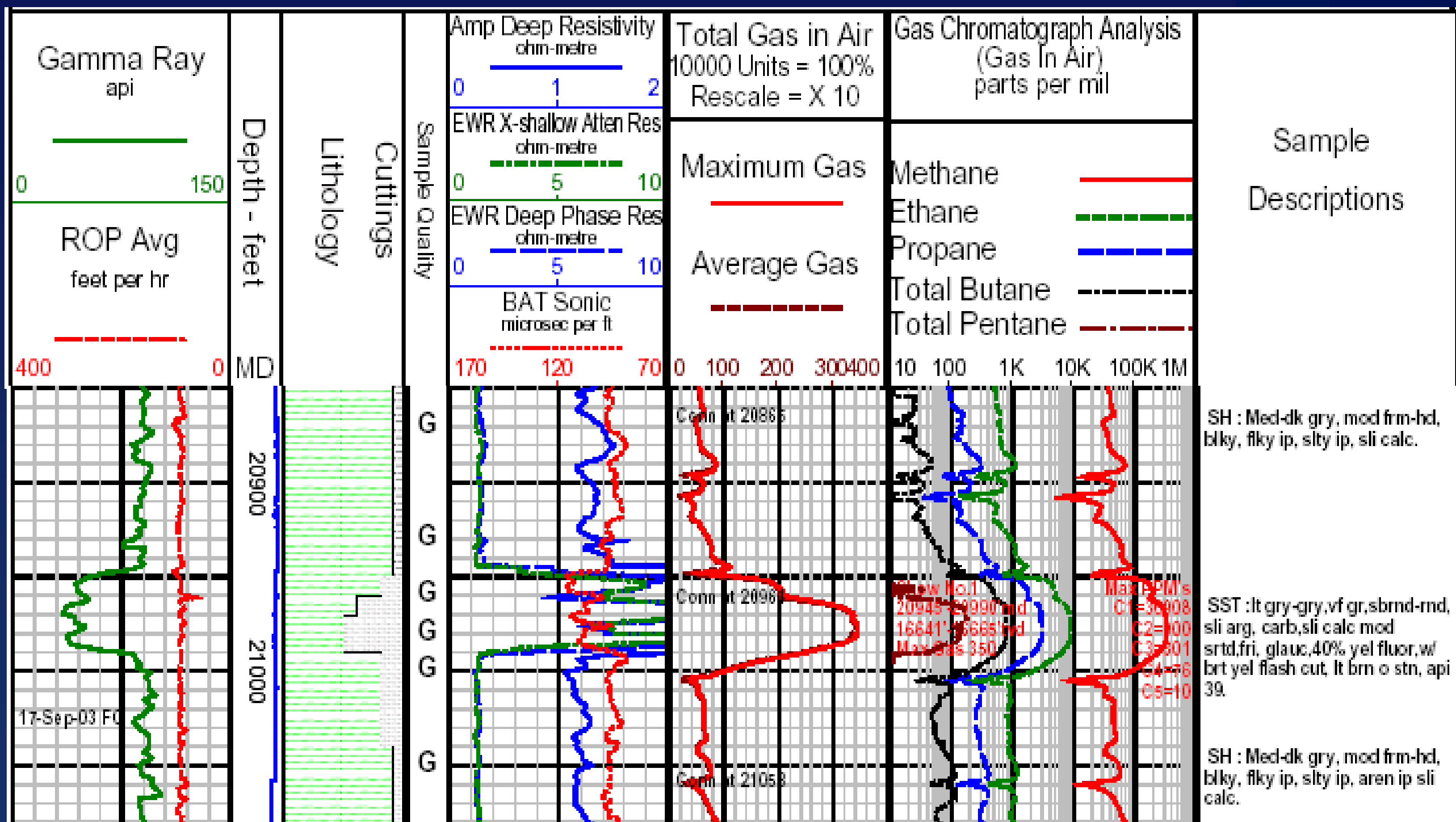


Courtesy of Geoservices

Apply Technology Where Needed



Typical mud logging product: mud gas C1-C5, cuttings description, fluorescence, & show analysis.

Apply Technology Where Needed: Advanced Mud Gas Logging

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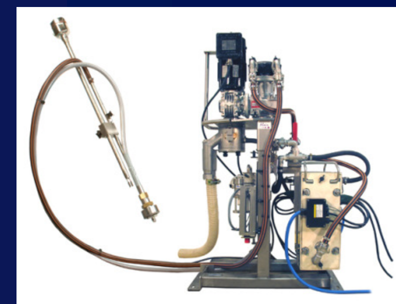
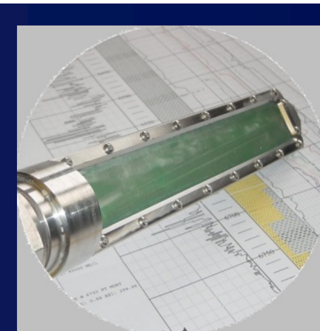


Advanced mud gas logging (AMG) infers advances in all aspects of mud gas logging:

- Efficient mud gas extractors, less prone to drilling and environmental effects.
- Improved gas transfer lines.
- Modernized analytical devices (e.g., gas chromatography-mass spectrometry).



Data sets are now both precise and quantitative.

Key References: Ellis et al. (1999 IMOG), Brumboiu et al. (SPE 62525), Kandel et al., (SPE 75307), Breviere et al. (2007 IMOG), Stankiewicz et al. (2007 IMOG), McKinney et al. (SPE 109861, SPE 112947, 2011 IMOG).

Appraisal Well Results

Gas Wetness (WH) =

(C2+C3+C4s+C5s)/

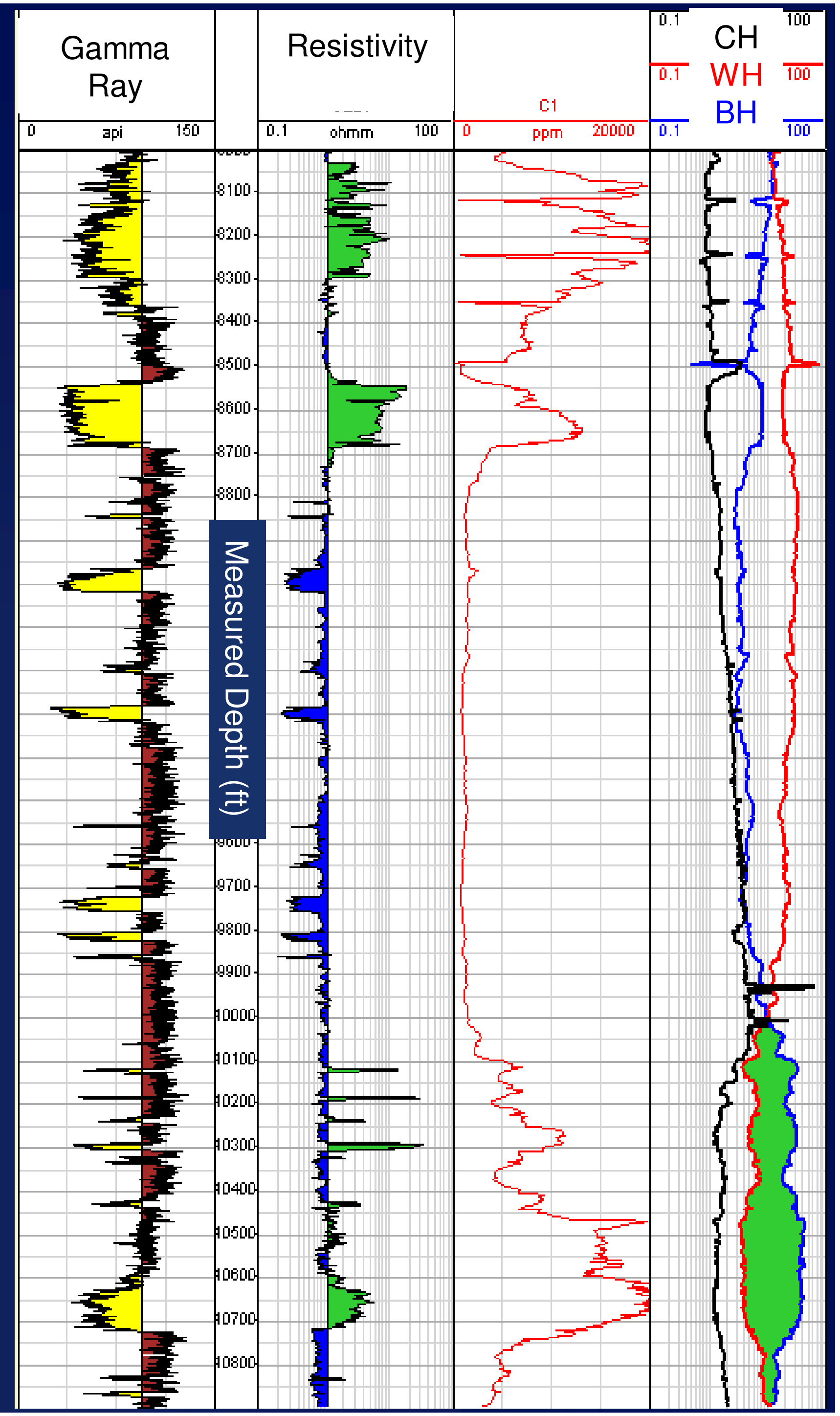
(C1+C2+C3+C4s+C5s)*100

Gas Balance (BH)=

(C1+C2)/(C3+C4s+C5s)

Gas Character (CH) =

(C4s+C5s)/C3



Haworth et al, (1985), AAPG, v.69, p1305-1310.

Appraisal Well Results

Sand A: Mud Gas and LWD indicate oil.

Sand B: Mud Gas and LWD indicate oil.

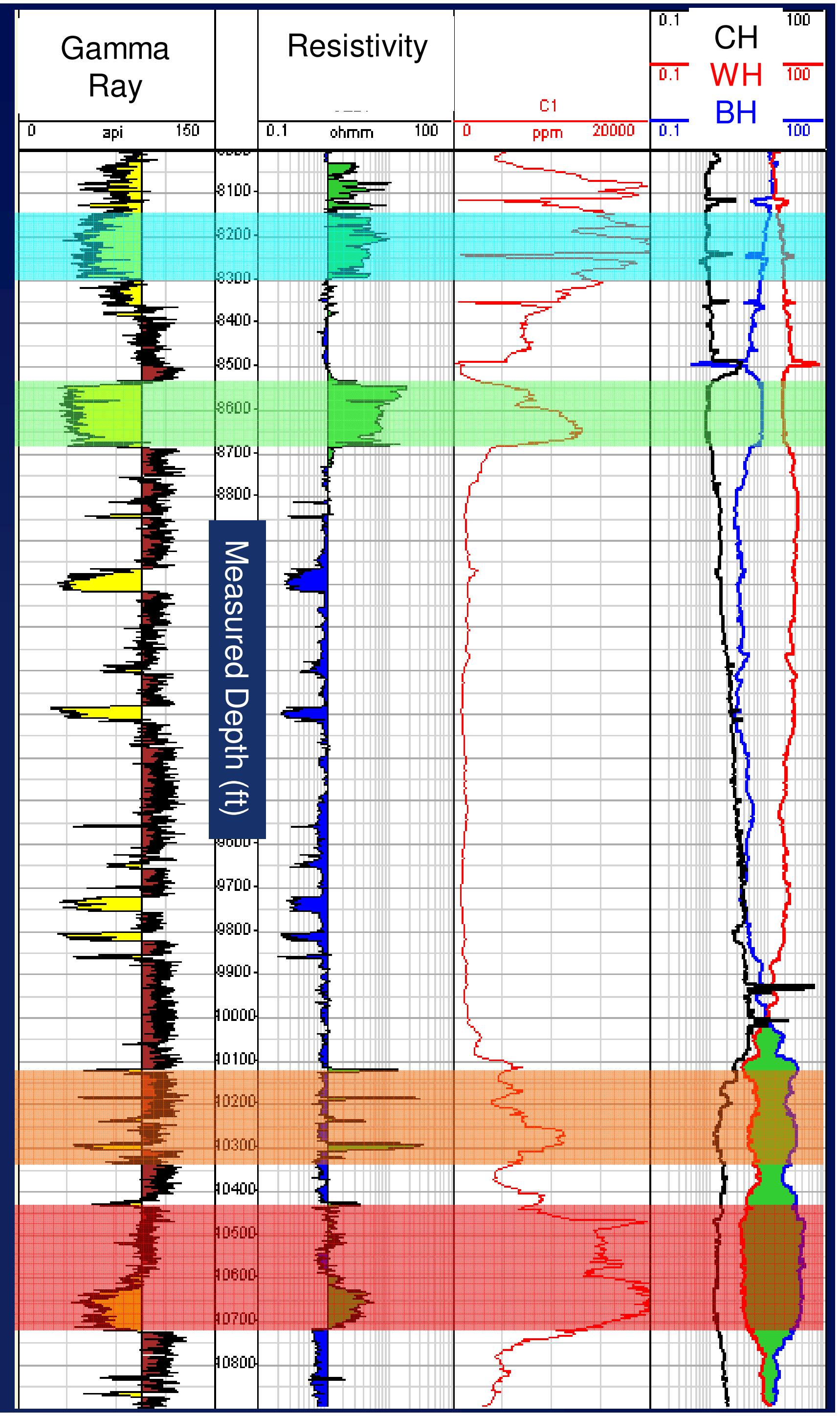
Sand C: LWD ambiguous but mud gas indicates gas/condensate.

A

B

C-U

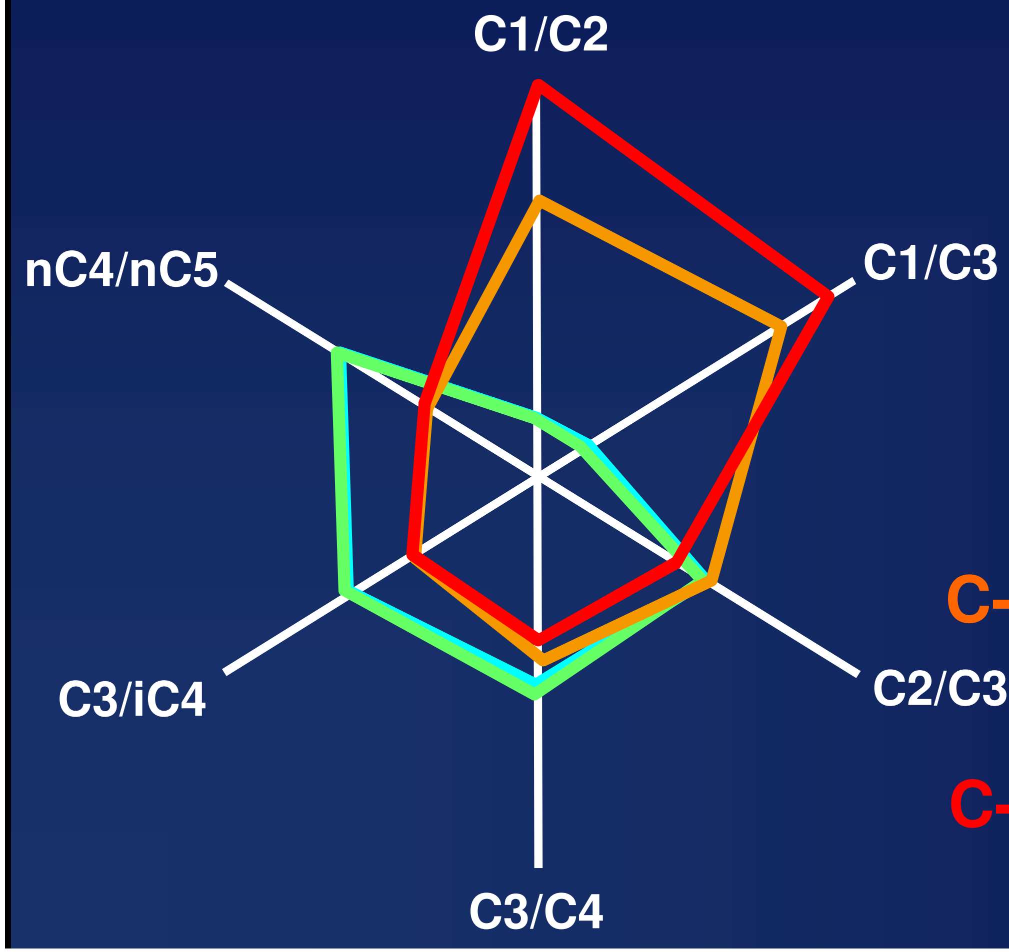
C-L

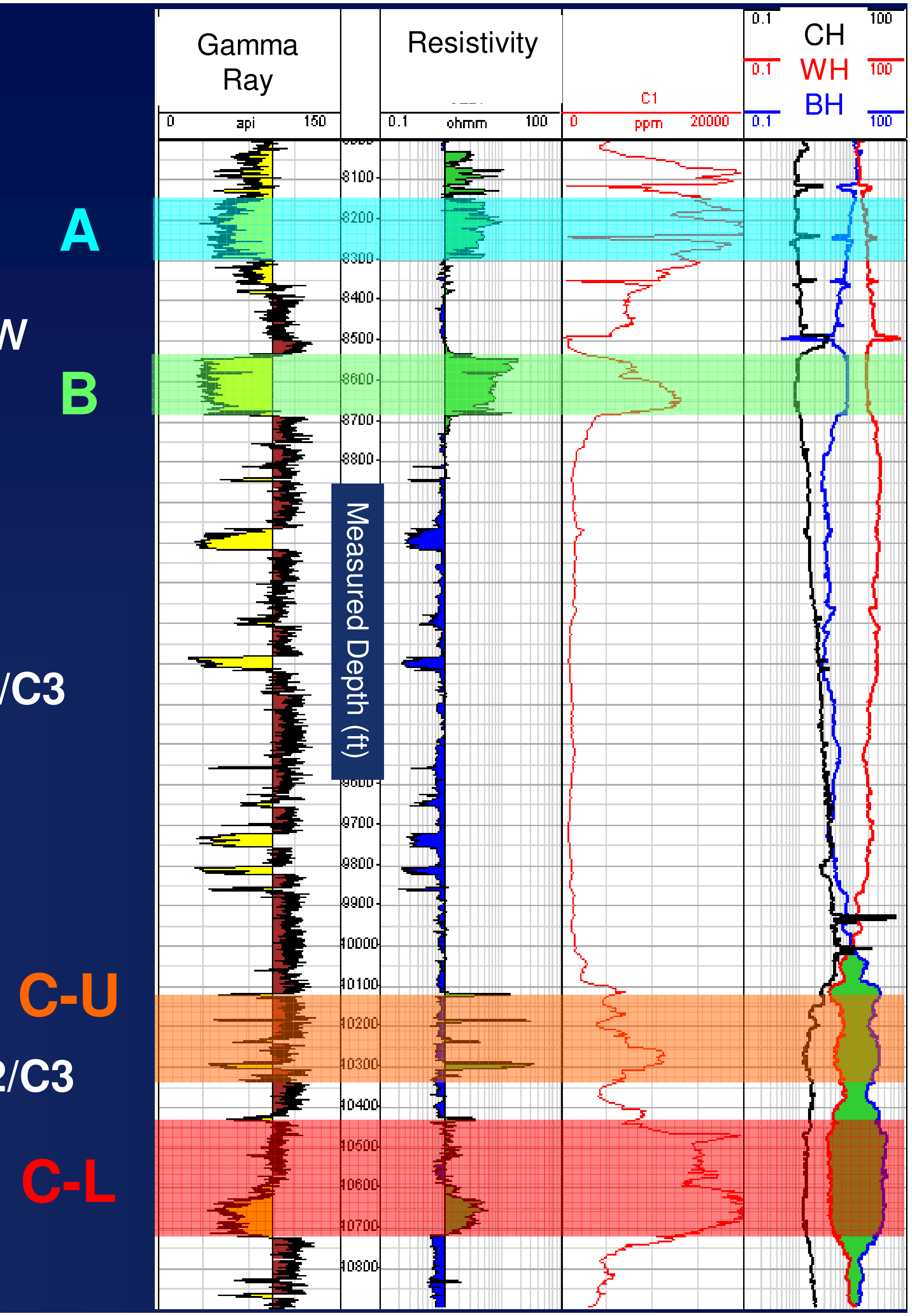


Haworth et al, (1985), AAPG, v.69, p1305-1310.

A & B have nearly identical AMG data indicating similar fluids.

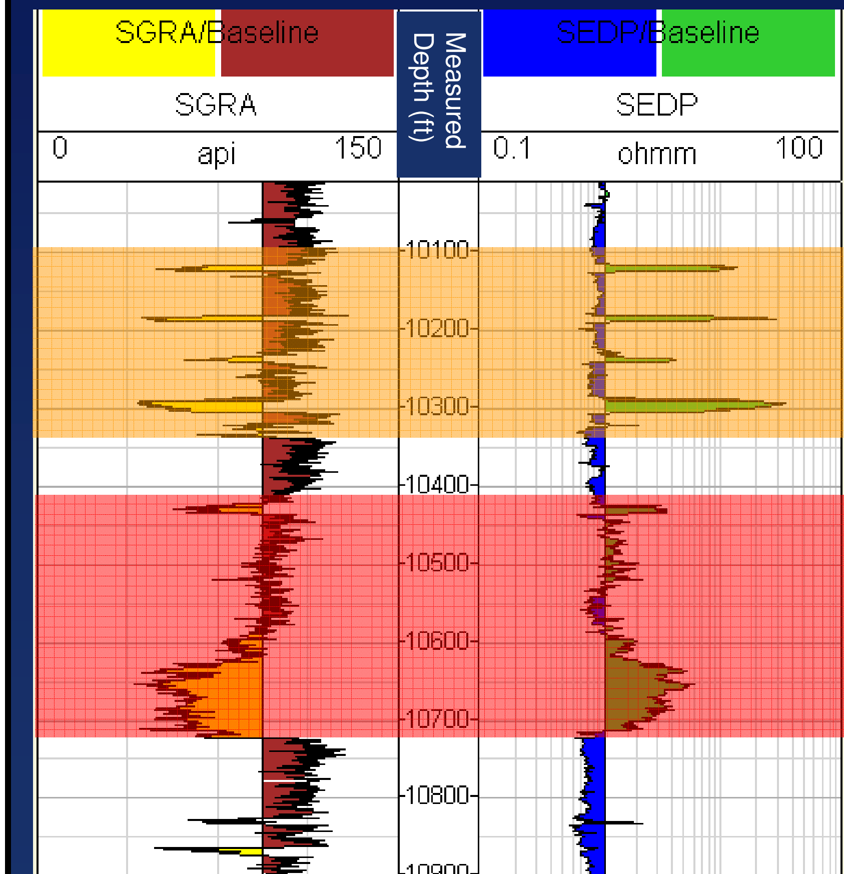
Sand C: Upper & Lower show variability—vertical barrier?





Sand C: AMG Compositional Results

Subtle variation in “Pixler ratios” between Upper and Lower members indicates barriers (fluid density inversion).



C1/C2 = 47

C1/C3 = 73

Barrier?

C1/C2 = 68

C1/C3 = 87

Barrier?

Downdip well composition?

C1/C2 = 81

C1/C3 = 139

B.O. Pixler (1969), SPE 2254

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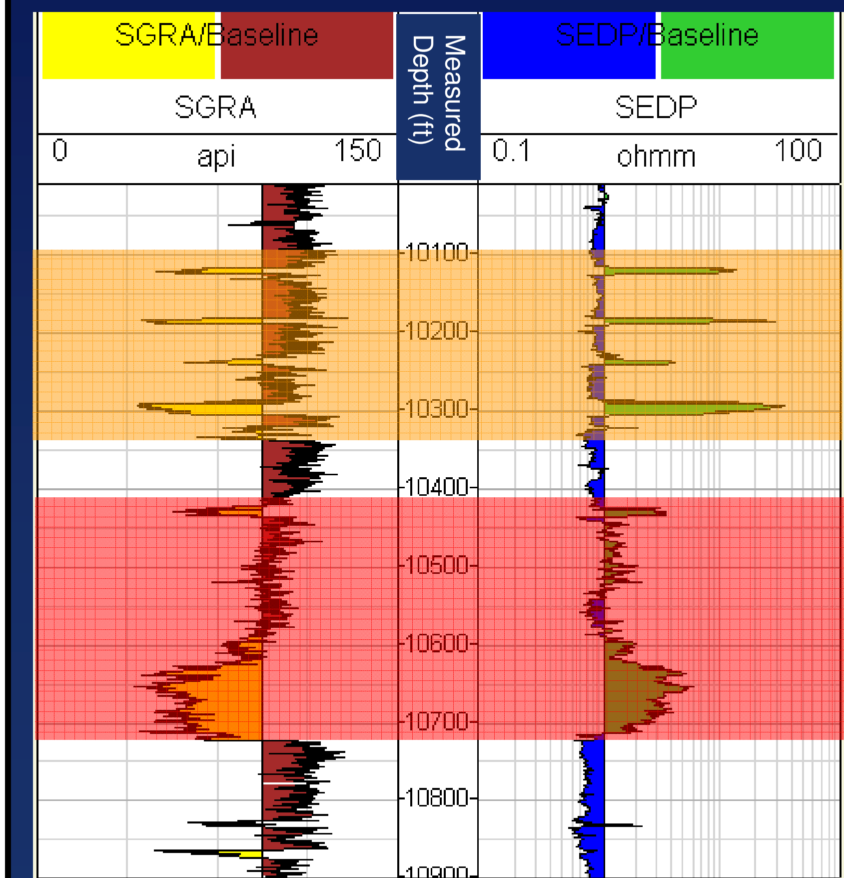
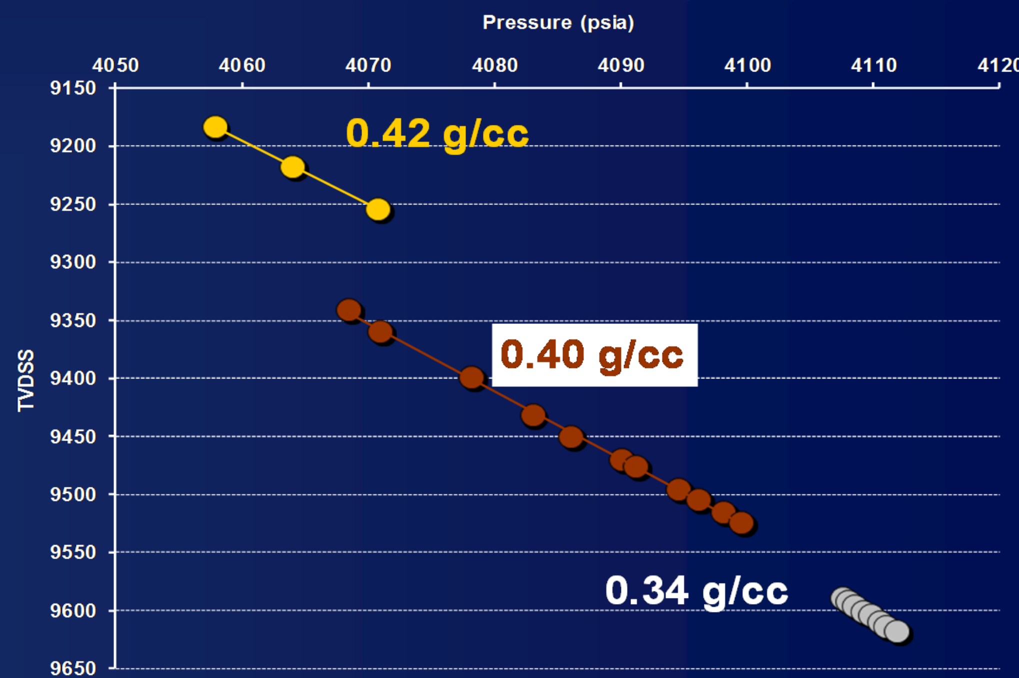
Sand C: Formation Testing

Pressure gradient data confirm both vertical and lateral barriers and the density inversion highlighted by AMG.





Value of Information: What if…?

Appraisal data gathering during development can be tricky because of competing well objectives.

What if the team decides against advanced mud gas deployment (added cost) and not risking the well to gather formation testing data? What value is lost?

- Full understanding of geology and compartmentalization?
- Volumetric uncertainty and ultimate recovery for the reservoir and for the well?
- Intervention, side-track, and new completion?

Summary: Integrate or Perish!

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- From an exploration point of view: "Knowing where your hydrocarbons come from helps you understand…"
- From a reservoir development point of view: "The reservoir fluid chemistry has a story to tell…"
- Integrating these two "truths" into our daily business can bridge the gap between subsurface and surface.

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