

Fluid Logging

The Advantages of Quantitative Fluid Evaluation While Drilling

10 March 2011

Dr. Martin Niemann

Geoservices – Technical Department

Formation Evaluation Society of Malaysia

Kuala Lumpur, Malaysia



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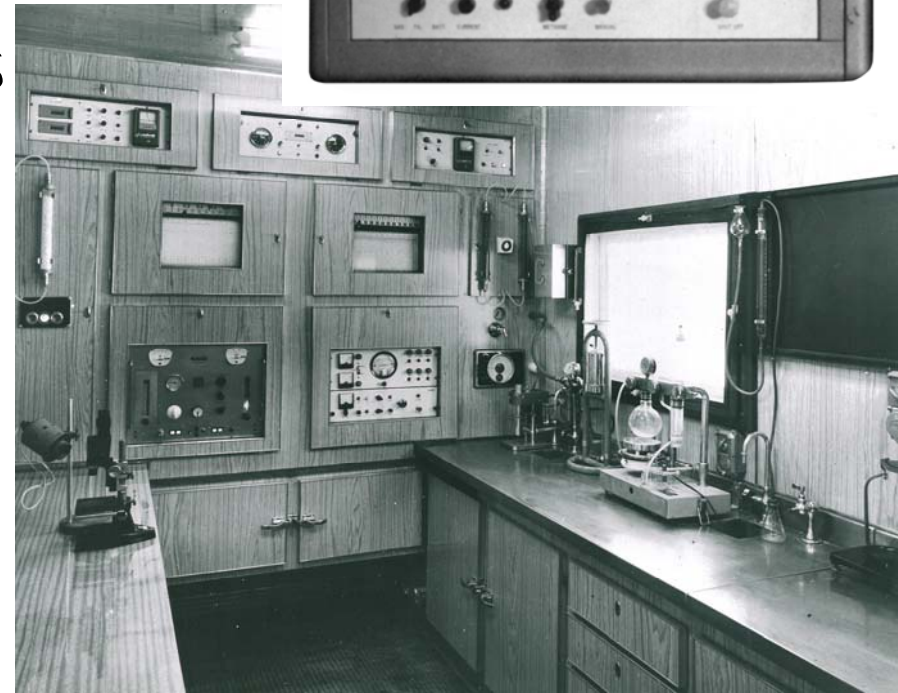
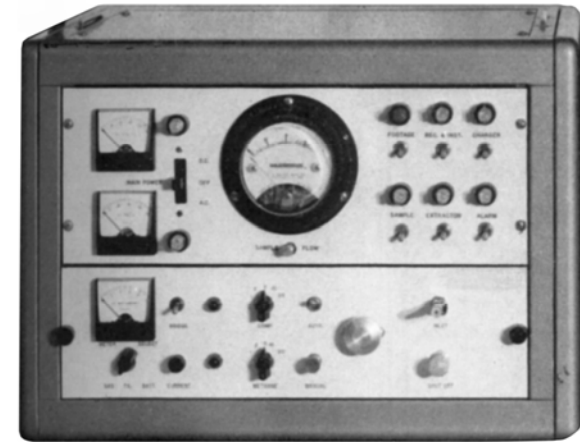
Outline

- The Classic Picture: Mud Logging
- Qualitative Data: Mud Logging Limitations
- The Modern Picture: Fluid Logging
- The Advantages: Quantitative Fluid Evaluation
- The Next Level: Isotope Logging
- Summary



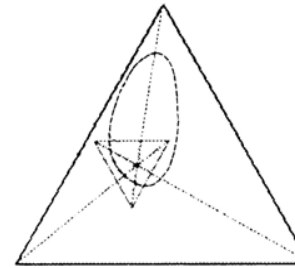
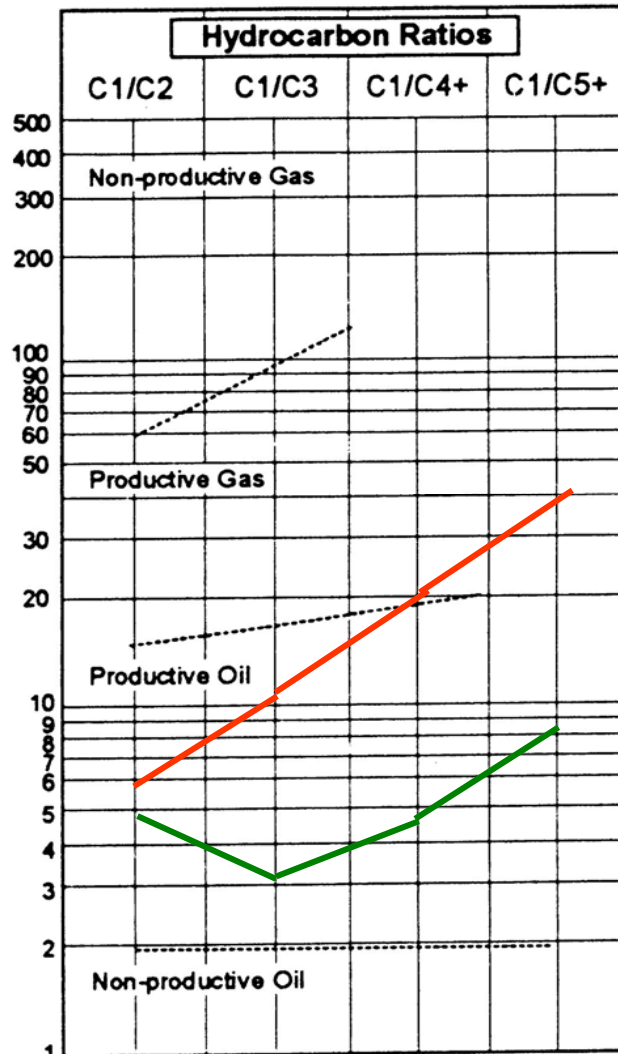
The Classic Picture: Mud Logging

- Mud Logging (ML) is used for over 50 years
 - Lithological description of cuttings
 - Well safety (gas levels)
- Gas analysis – basic ratio analysis
 - Pixler diagrams
 - Triangle plots
 - Wetness, Balance, Character

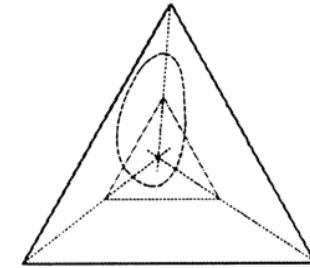


The Classic Picture: Mud Logging

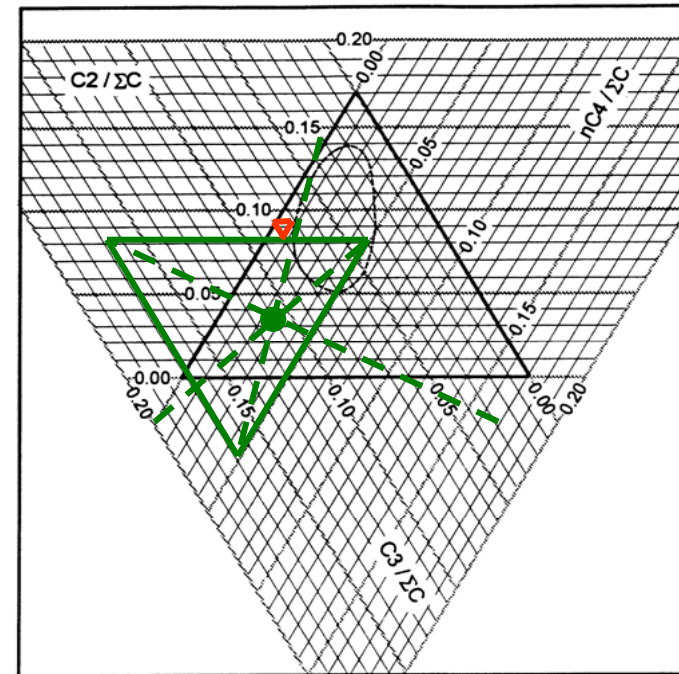
Modified from Ferrie, 1981



Oil-rich zone



Gas-rich zone

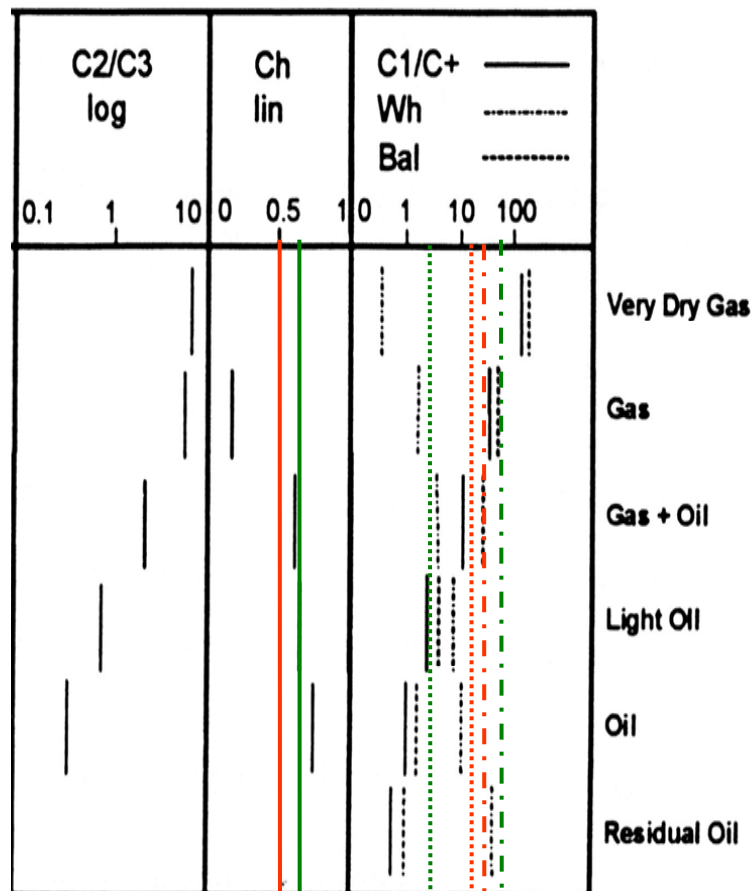


The Classic Picture: Mud Logging

$$\text{Wetness} = \frac{C2 + C3 + C4 + C5}{C1 + C2 + C3 + C4 + C5}$$

$$\text{Balance} = \frac{C1 + C2}{C3 + C4 + C5} * 100$$

$$\text{Character} = \frac{C4 + C5}{C3}$$

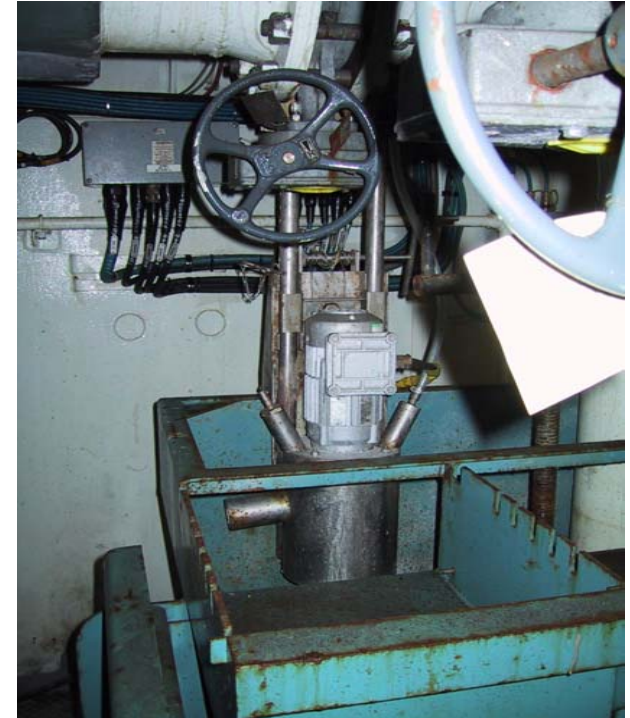


Ranges are indicative only. Limits to be fixed according to local conditions.



The Classic Picture: Mud Logging

- Gas chain
 - Degasser
 - Gas line
 - Analyzer
- ML provides qualitative data only
 - "Gas in air" or "Gas in inert gas"
 - Reason: degasser, not the analyzer
- ML data are not suitable for fluid evaluation



Qualitative Data: Mud Logging Limitations

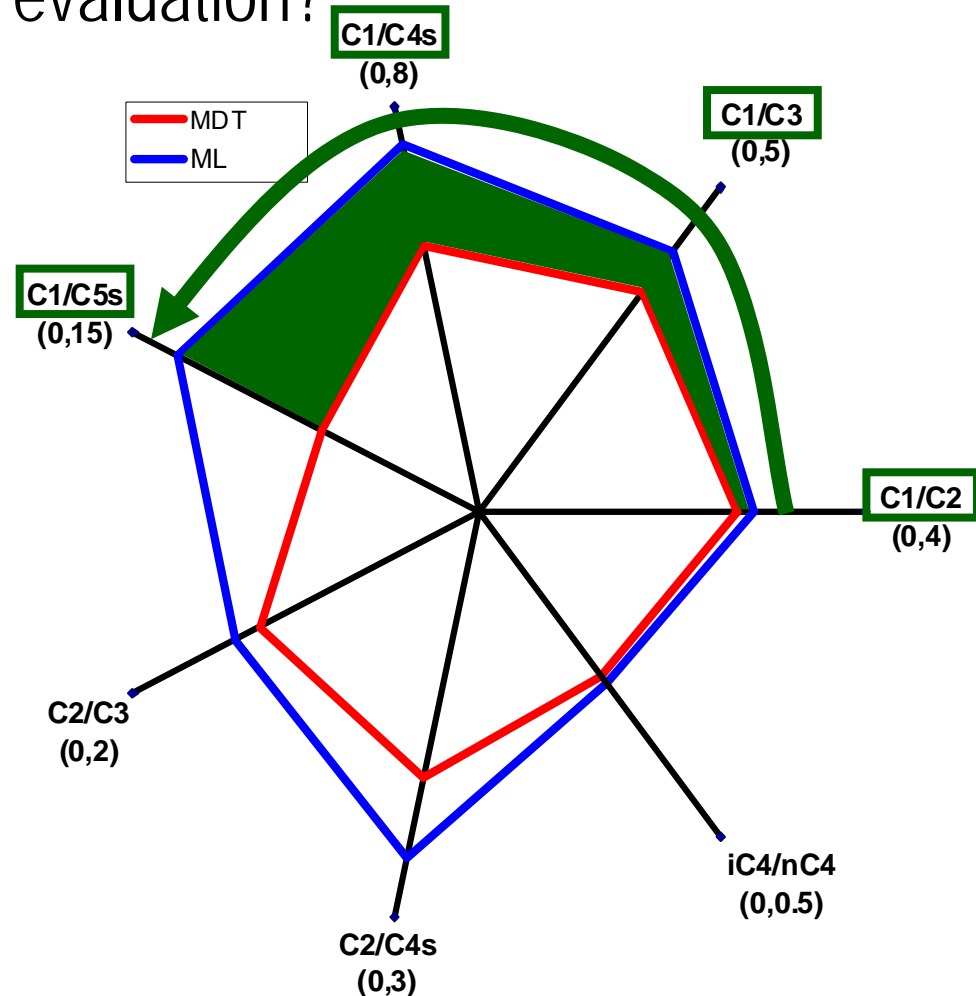
- Why is ML not suitable for fluid evaluation?

- Limitations

- Flow
- Temperature
- Drilling fluid

- Impacts

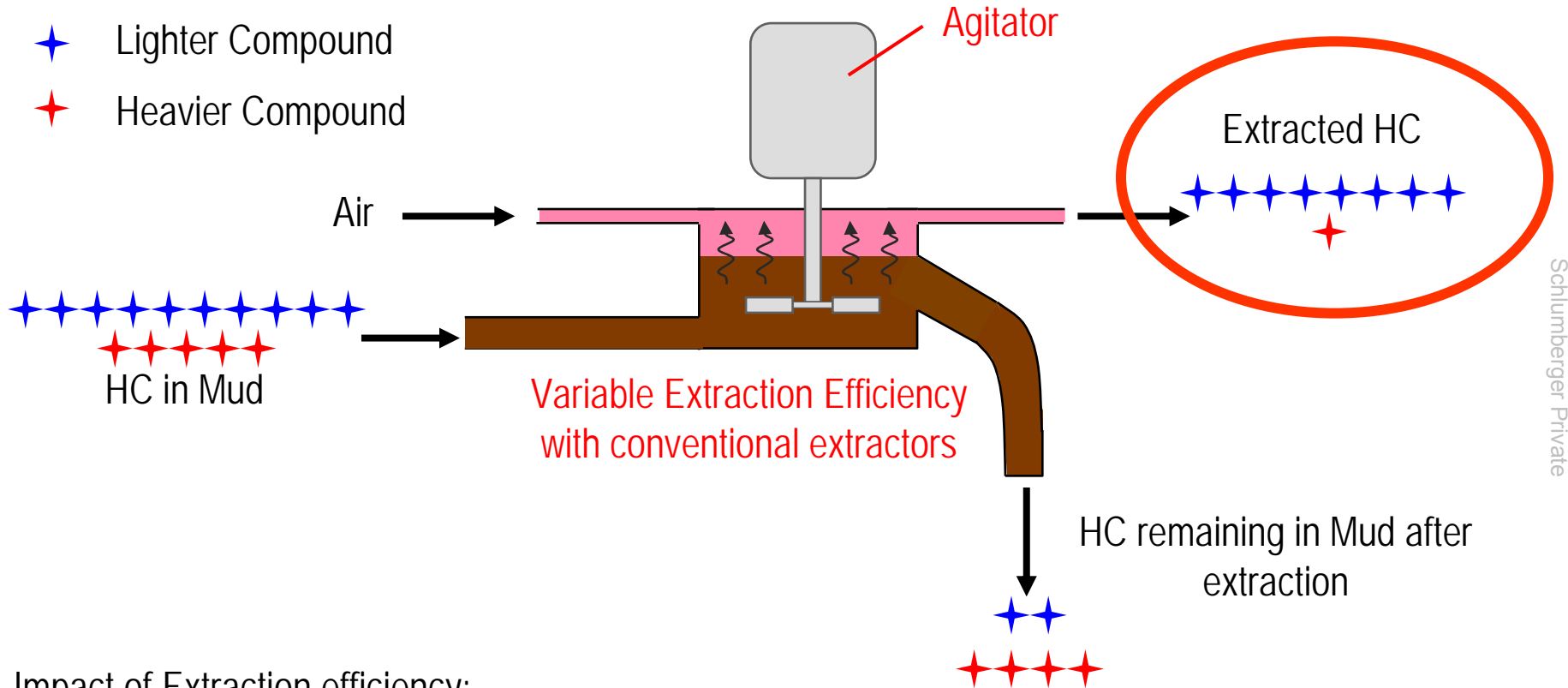
- HC recycling and contamination
- Variable extraction efficiency for each HC species



Qualitative Data: Mud Logging Limitations

★ Lighter Compound

★ Heavier Compound



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Impact of Extraction efficiency:

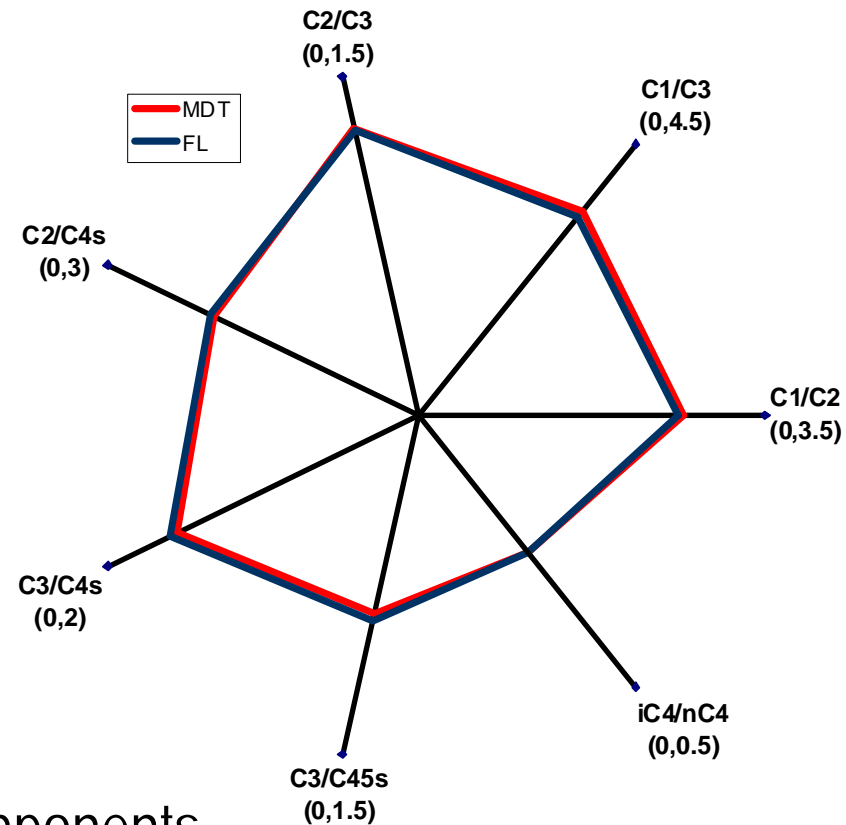
Light hydrocarbon are more easily extracted

Measured composition appears lighter compared to real composition



The Modern Picture: Fluid Logging

- FE provides quantitative data
 - "HC's from formation"
- FE gas chain similar to ML
 - GC-MS to measure beyond C_5
 - Gas line adjusted to transport C_{5+} components
 - Degasser: Fluid Extractor – The Difference

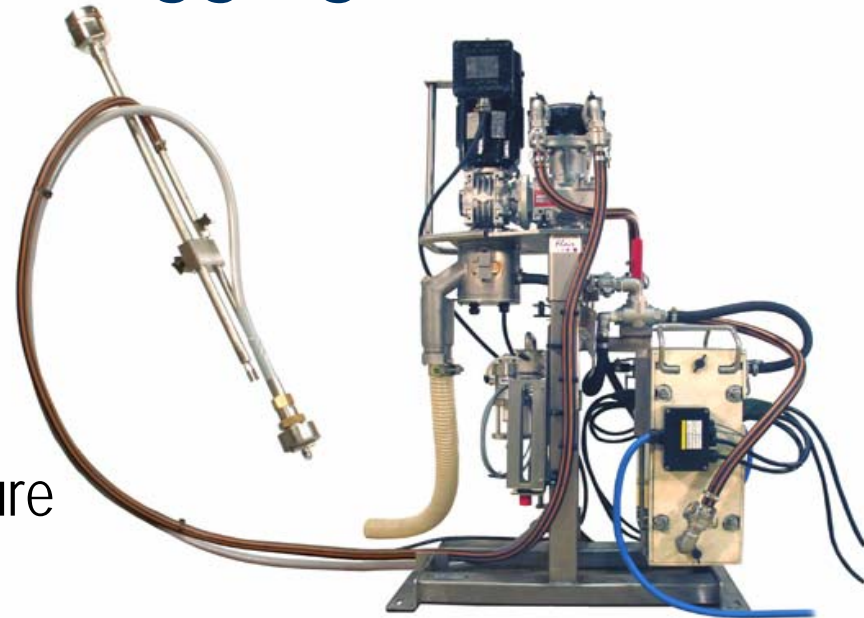


The Modern Picture: Fluid Logging

- Modern fluid extractor
 - Constant mud and air flow
Limitation: Flow ✓
 - Heating of mud to constant temperature
Limitation: Temperature ✓

→ always constant, controlled and repeatable conditions

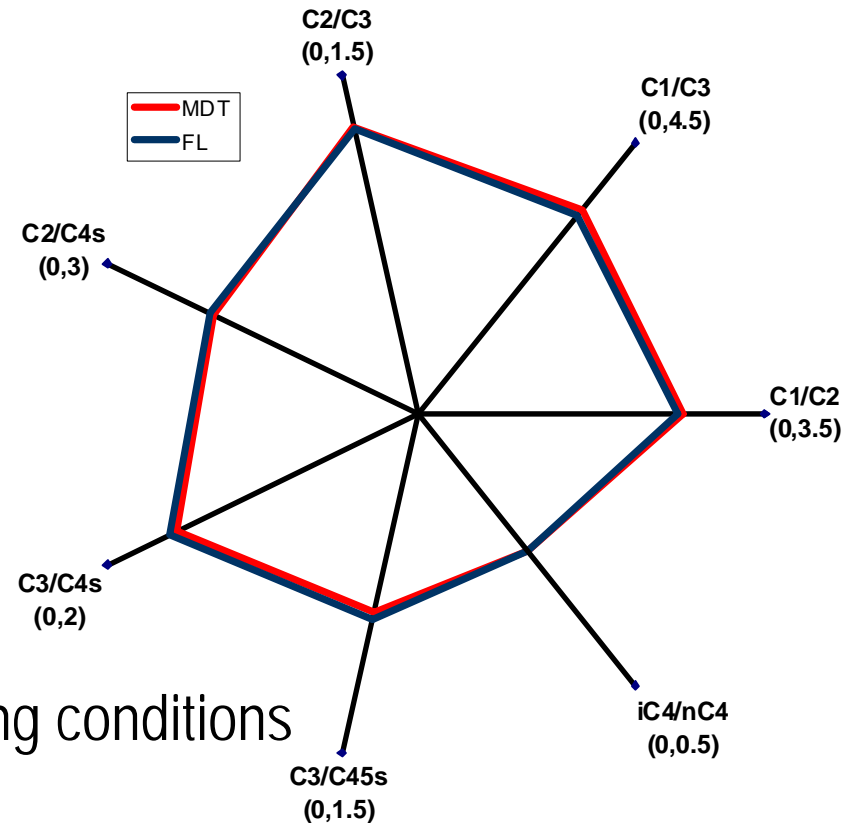
→ Data can be compared!
- Improved extraction due to temperature
 - Still measurement of “gas in air”



The Modern Picture: Fluid Logging

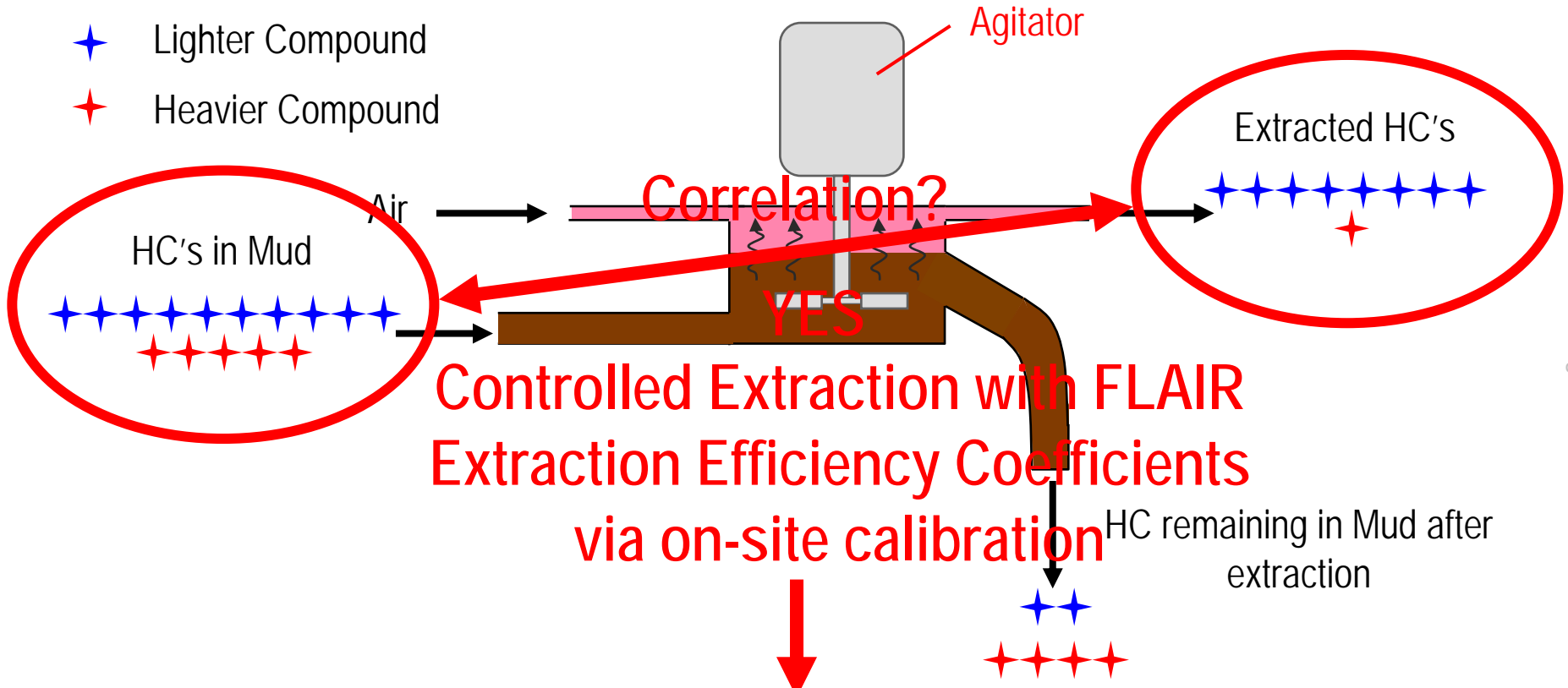
- Goal: "HC's from formation"
from "Gas in air"
- Requirement: "HC's in mud"
 - Calibration of degassing efficiency
 - Feasible only under constant degassing conditions
 - On site calibration on actual mud system

Limitation: Drilling fluid ✓



The Modern Picture: Fluid Logging

- ★ Lighter Compound
- ✦ Heavier Compound



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$$\begin{array}{c}
 \text{Extracted HC} \\
 \text{★ ★ ★ ★ ★} \\
 \text{✦}
 \end{array}
 \times
 \begin{array}{c}
 \text{EEC} \\
 \text{Coefficient}
 \end{array}
 =
 \begin{array}{c}
 \text{HC's in Mud} \\
 \text{★ ★ ★ ★ ★} \\
 \text{✦}
 \end{array}$$

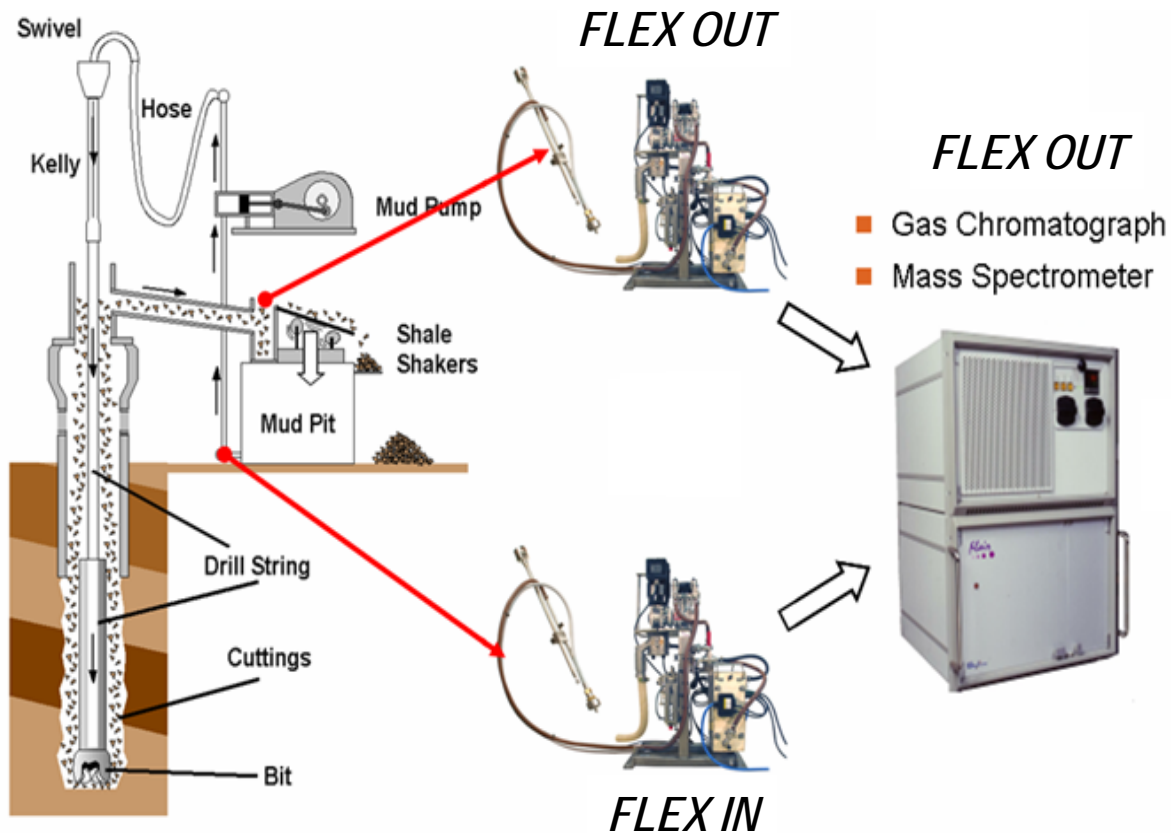
Impact: Degassing efficiency ✓

The Modern Picture: Fluid Logging

- “HC’s in mud” to “HC’s from formation”
 - Recycling of HC’s and contamination
 - Flex OUT – Flex IN



The Modern Picture: Fluid Logging



Quality Assurance

FLEX OUT AND FLEX IN have to work under identical conditions
FLEX OUT and FLEX IN have to have the same efficiency



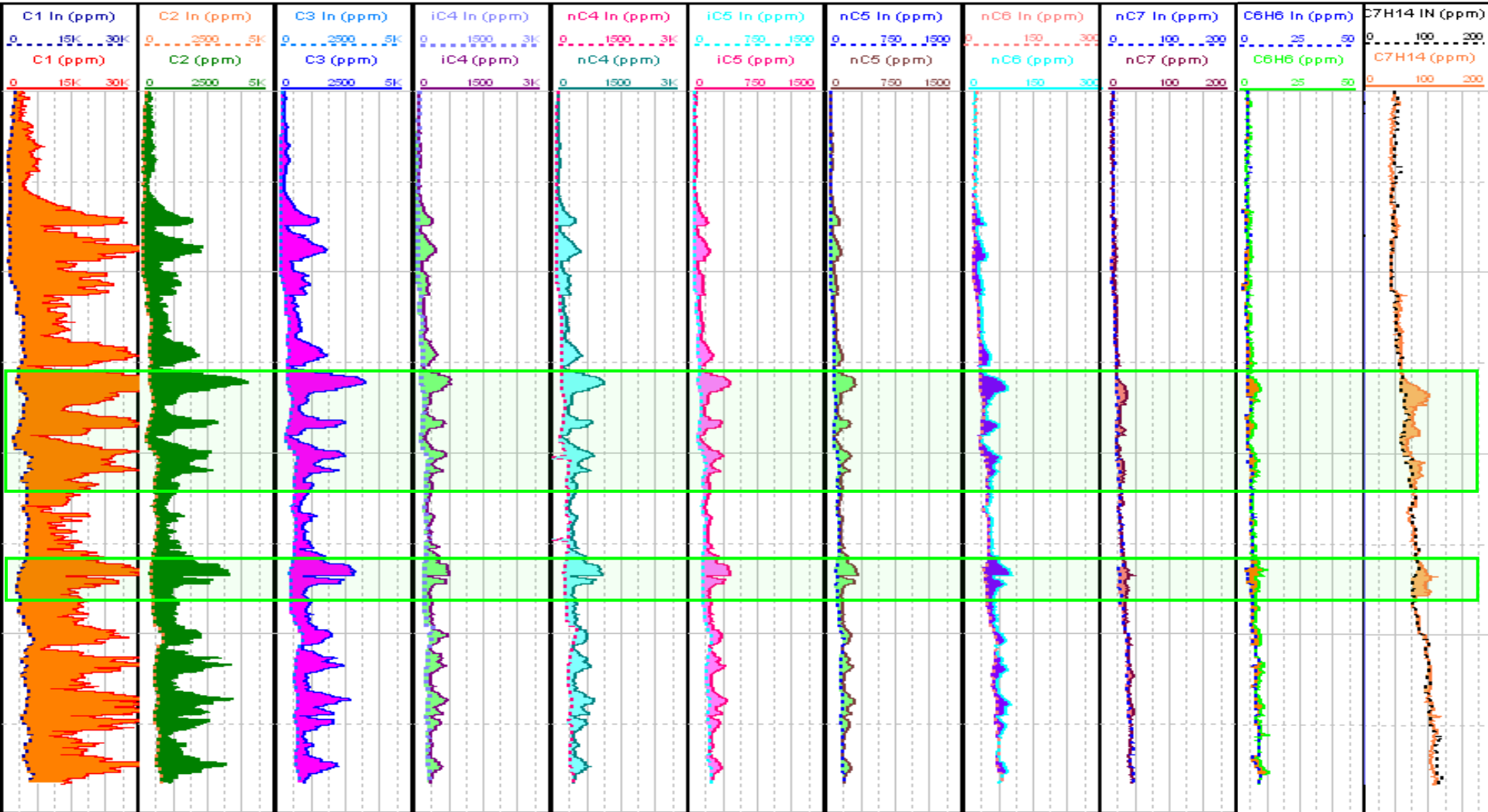
The Modern Picture: Fluid Logging

- “HC’s in mud” to “HC’s from formation”
 - Recycling of HC’s and contamination
 - Flex OUT – Flex IN
 - Both degassers work under identical conditions (P, T, flow, time)
 - Suitable synchronization (@ bit) process

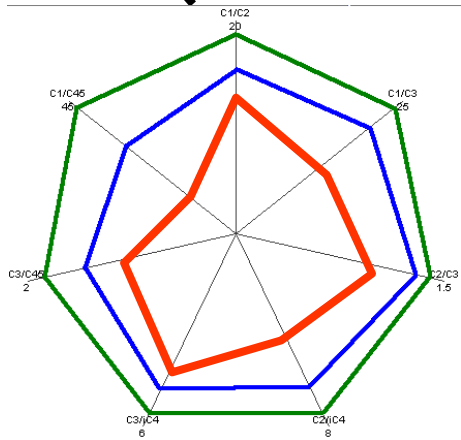
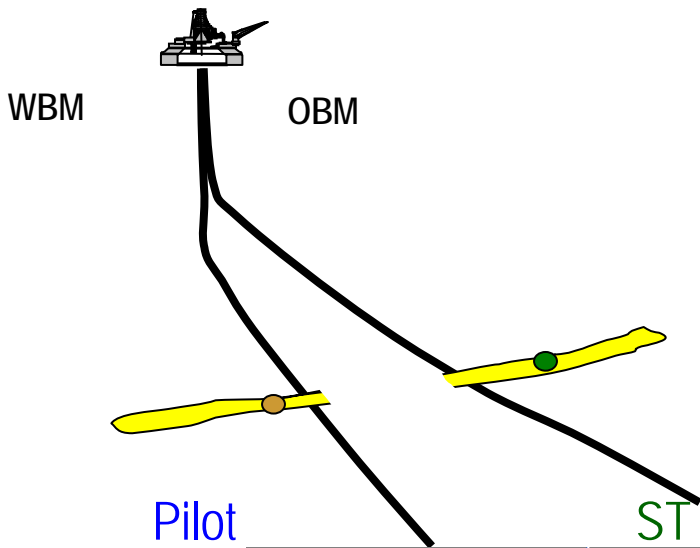
Impact: HC recycling ✓



The Modern Picture: Fluid Logging



The Modern Picture: Fluid Logging



Extracted Gas
No EEC correction applied

Semi-quantitative data

EEC WBM (Pilot Hole)

	C1	C2	C3	iC4	nC4	iC5	nC5
Correcting coefficients	1.01	1.2	1.6	2	2.2	2.7	2.9

EEC OBM (Sidetrack Hole)

	C1	C2	C3	iC4	nC4	iC5	nC5
Correcting coefficients	1.2	1.6	2.2	3.1	3.6	5.7	6.7

PVT

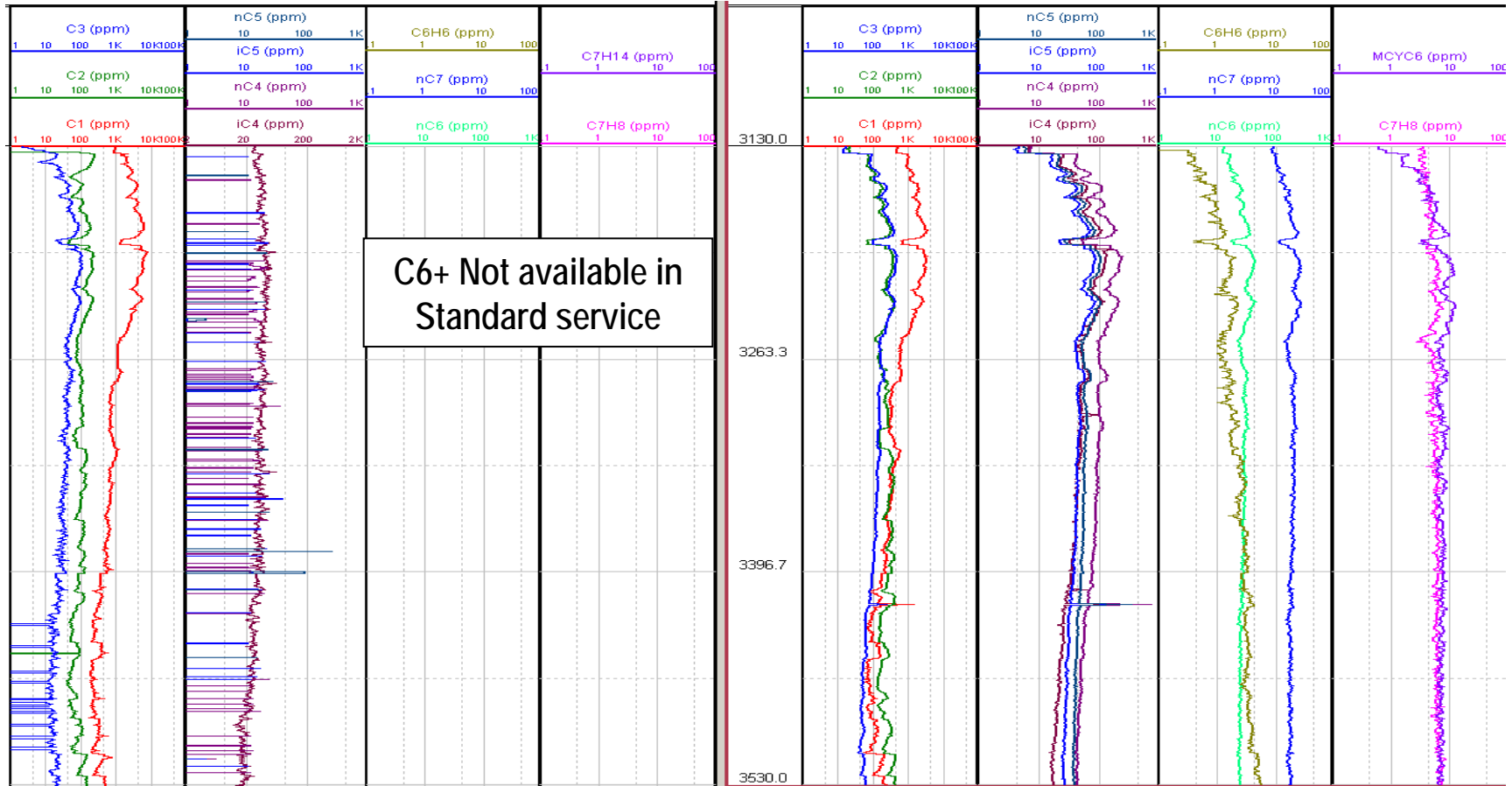


Formation fluid composition
(corrected for Recycling and respective EECs)

Quantitative data

The Benefits: Quantitative Fluid Evaluation

Deep Water Environment - Mud Temperature at flow line **15 °C**



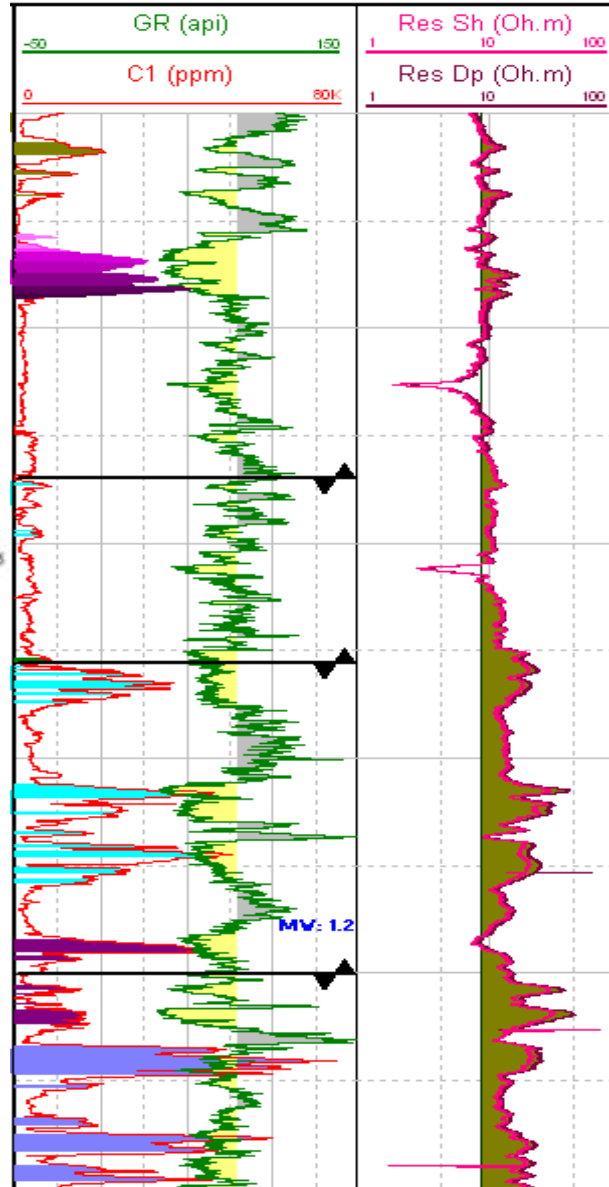
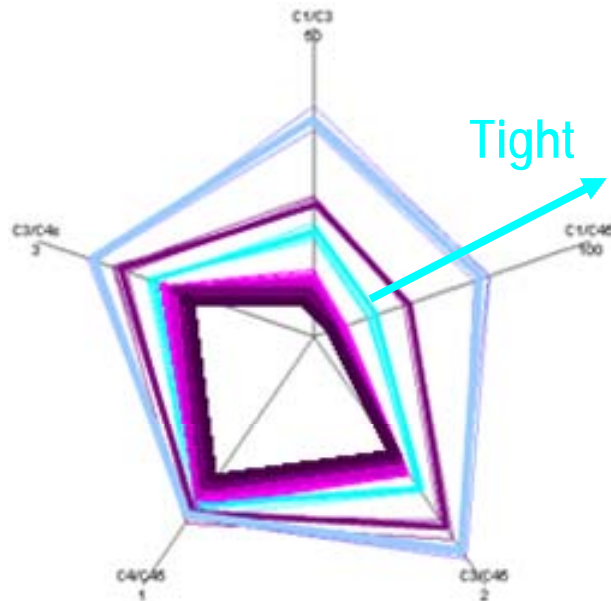
Standard Gas Data

FE Data



The Benefits: Quantitative Fluid Evaluation

Tight Formations



PVT CONDENSATE?

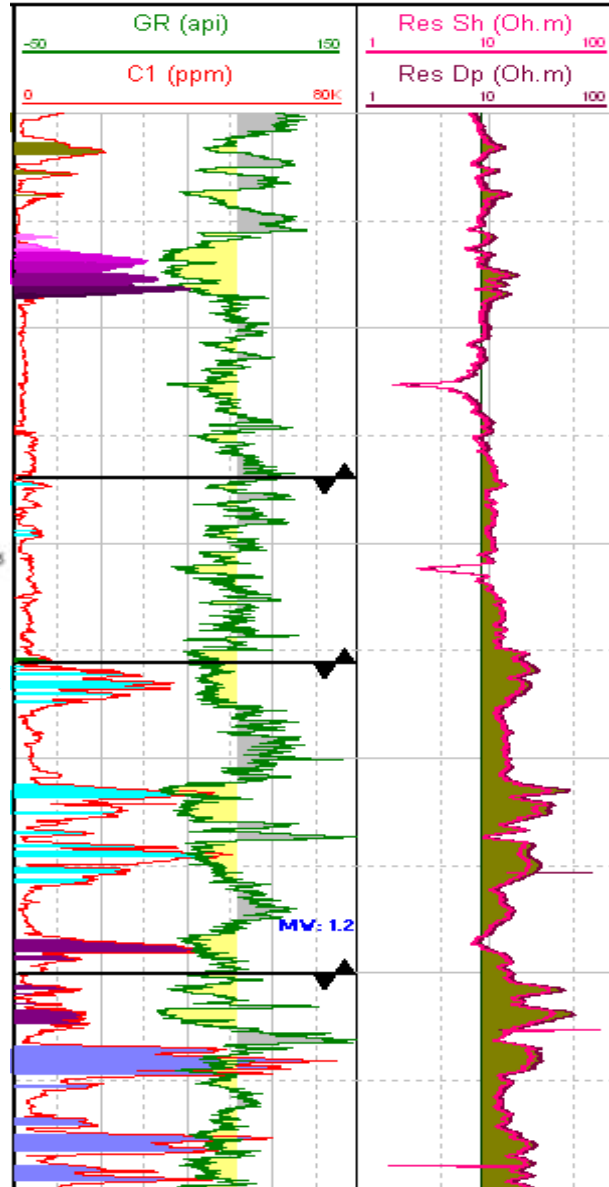
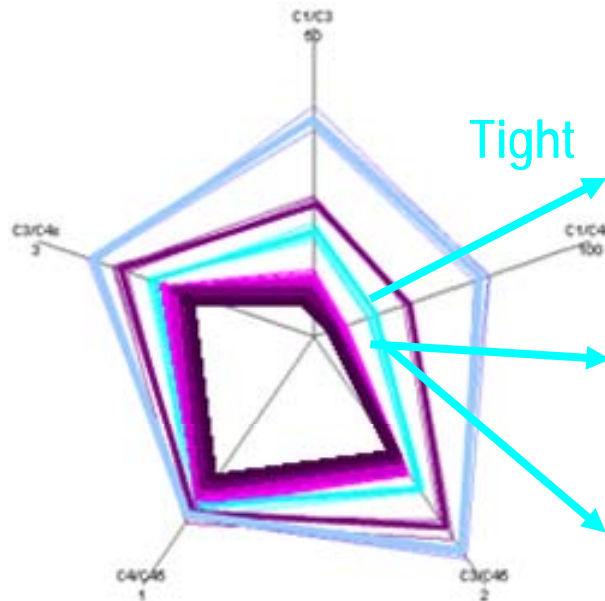
Fluid typing is possible if reference fluid sample is available from offset wells / block.

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The Benefits: Quantitative Fluid Evaluation

Fluid Similarities/
Connectivity



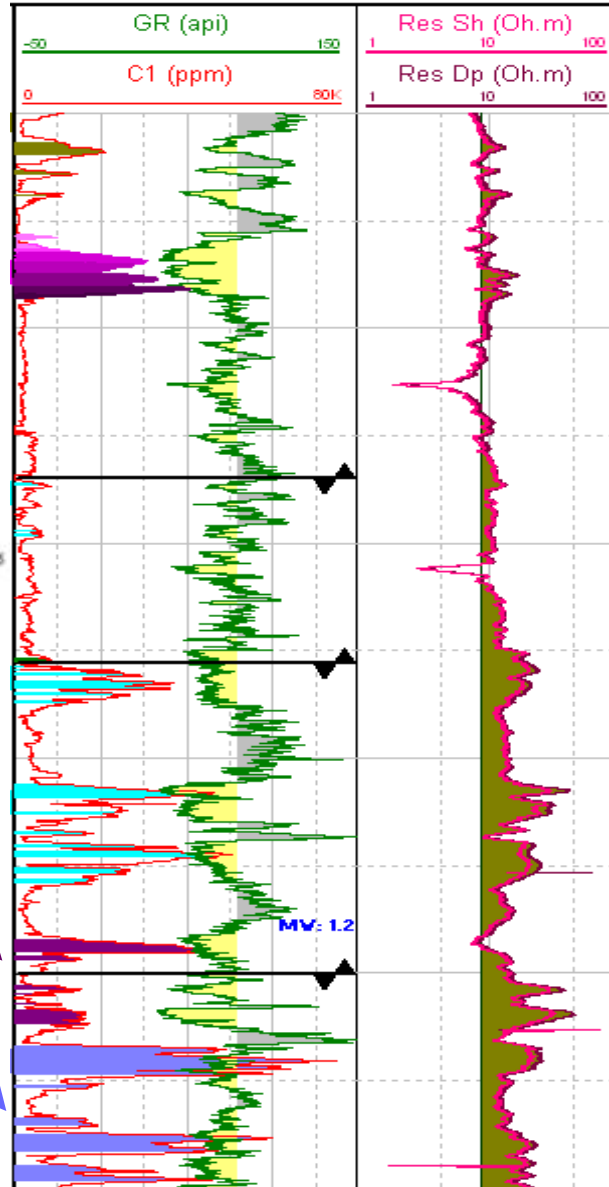
 PVT CONDENSATE

Fluid typing is possible if reference fluid sample is available from offset wells / block.



The Benefits: Quantitative Fluid Evaluation

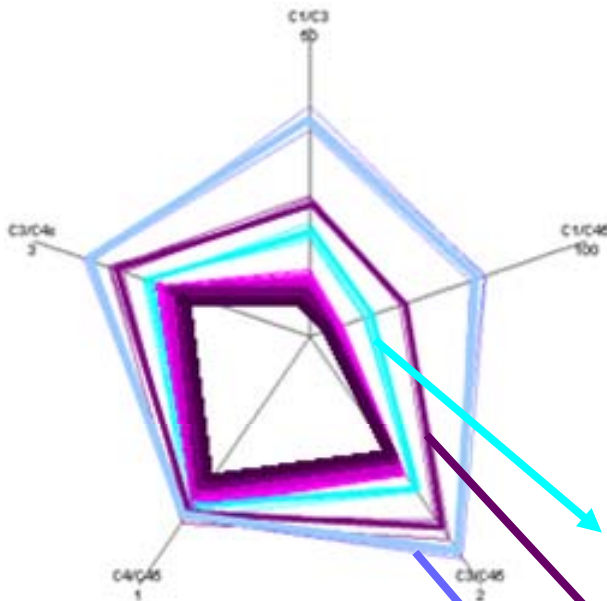
Fluid Dissimilarities/
Barriers



- PVT CONDENSATE?
- PVT "WET" GAS
- PVT "DRY" GAS

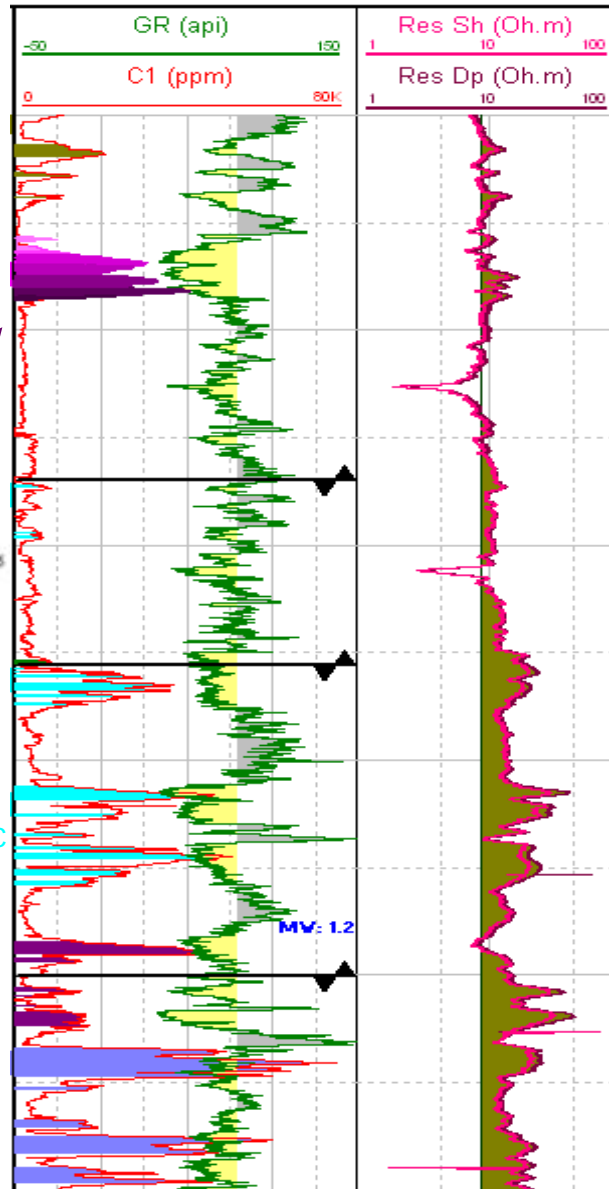
Fluid typing is possible if reference fluid sample is available from offset wells / block.

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The Benefits: Quantitative Fluid Evaluation

Compositional Grading

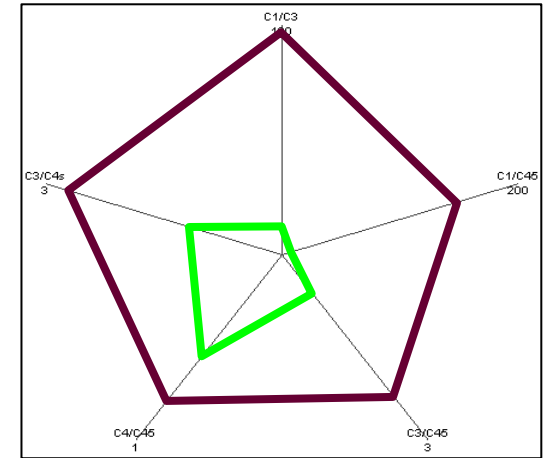
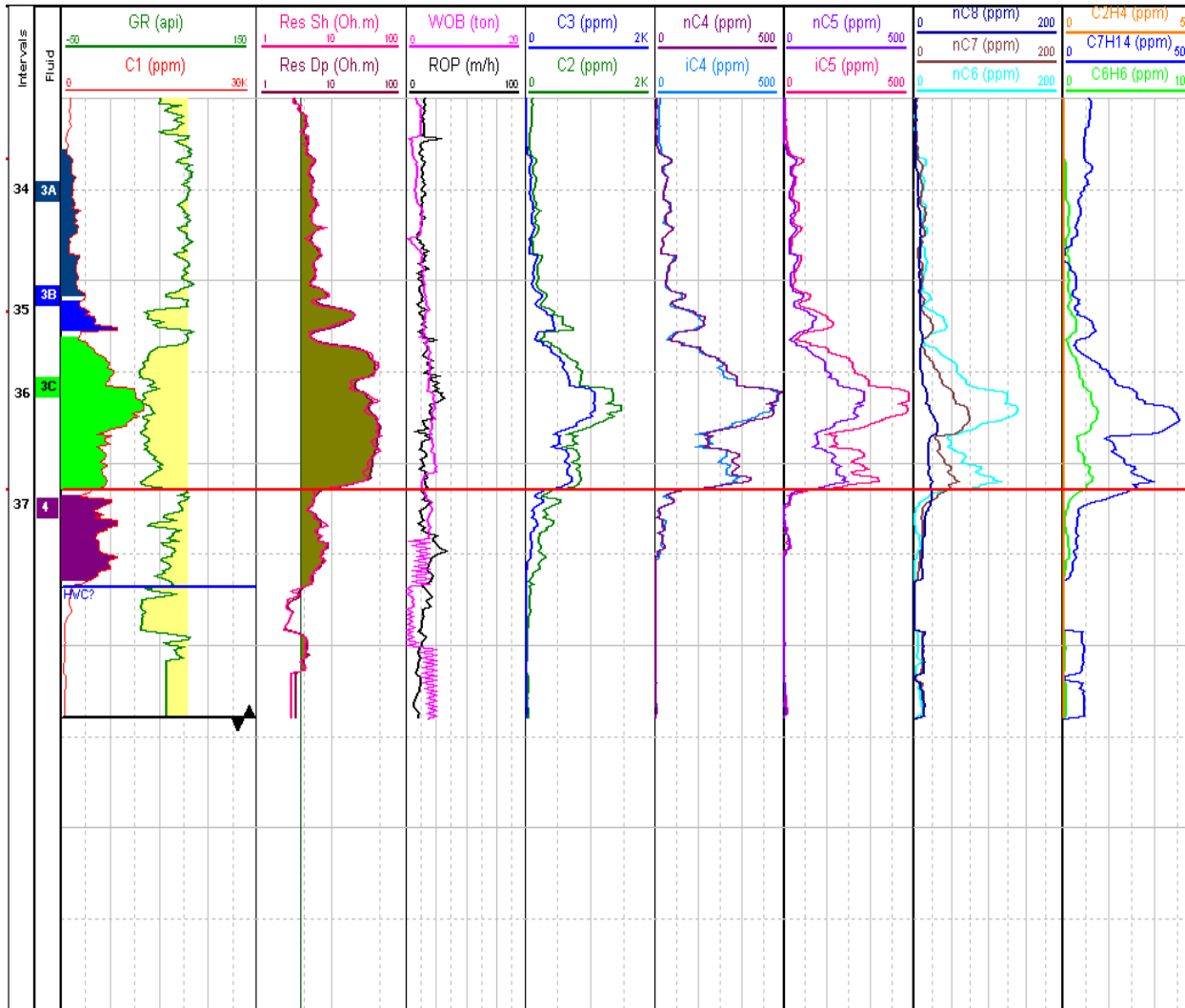


 PVT OIL

Fluid typing is possible if reference fluid sample is available from offset wells / block.



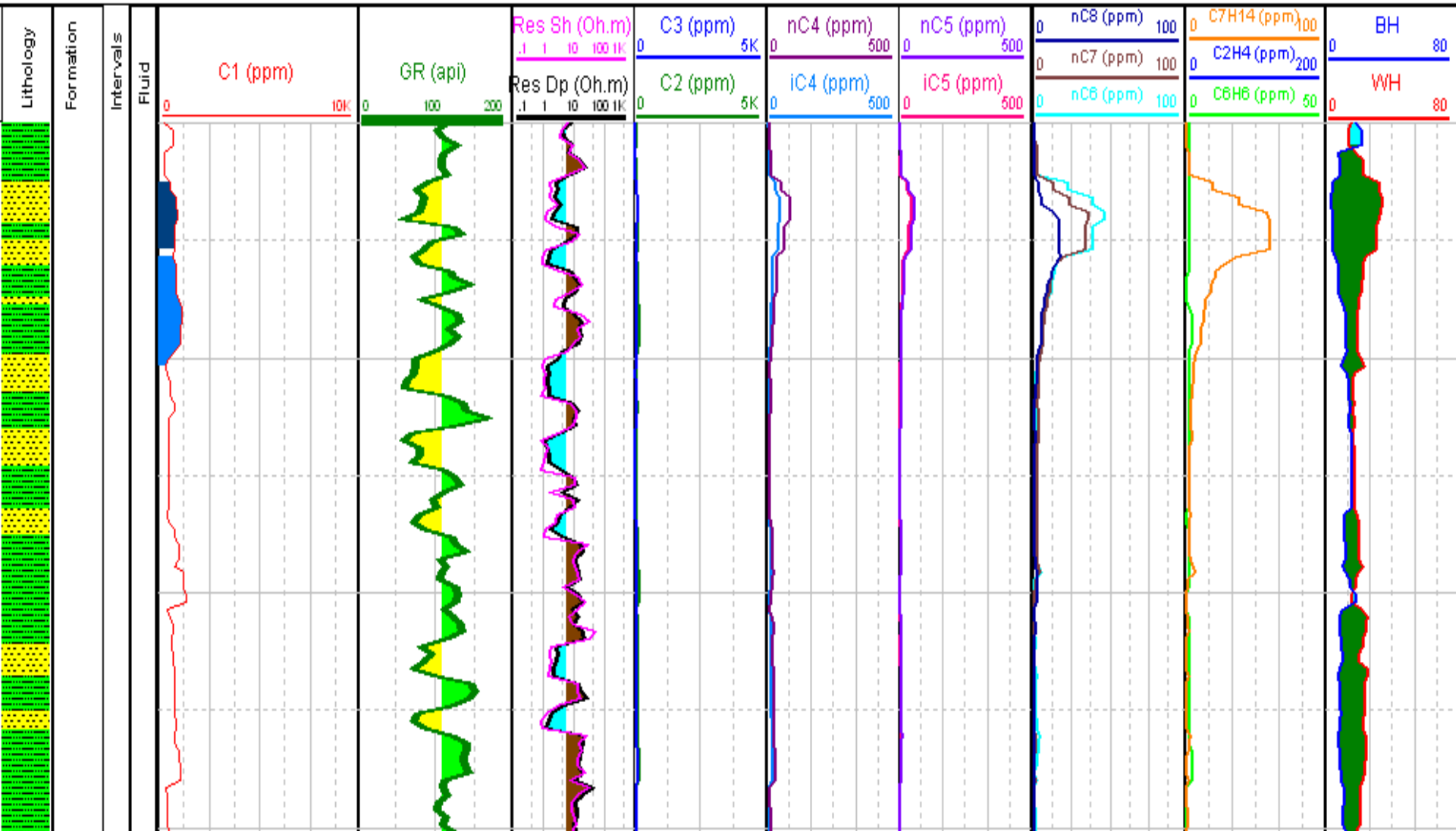
The Benefits: Quantitative Fluid Evaluation



Confirmation of a sealing fault based on abrupt fluid change



The Benefits: Quantitative Fluid Evaluation



The Benefits: Quantitative Fluid Evaluation

Fluid Typing

C1-C5 composition

Component	%
Methane	83.6
Ethane	7.88
Propane	4.65
IsoButane	0.92
n-Butane	1.6
IsoPentane	0.76
n-Pentane	0.58

Condensate

Fluid composition

Component	%
Nitrogen	0.1
CO2	2.868
Methane	75.064
Ethane	7.09
Propane	4.207
IsoButane	0.845
n-Butane	1.487
IsoPentane	0.745
n-Pentane	0.574
C6	1.332
C7	1.469
C8	1.056
C9	0.688
C10	0.463
C11+	2.012

C1-C5 composition

Component	%
Methane	98.392
Ethane	1.357
Propane	0.052
IsoButane	0.021
n-Butane	0.045
IsoPentane	0.072
n-Pentane	0.060

Dry gas

Altered oil

Fluid composition

Component	%
Nitrogen	0.23
CO2	1.67
Methane	33.55
Ethane	0.87
Propane	0.27
IsoButane	0.11
n-Butane	0.23
IsoPentane	0.17
n-Pentane	0.16
C6	0.59
C7	1.1
C8	1.59
C9	1.70
C10	2.67
C11+	55.03

The Next Level: Isotope Logging

Isotopes

- Different forms of the same element with nuclei that have the same number of protons but different numbers of neutrons

Carbon isotopes

- ^{12}C : 6 protons/ e^- + 6 neutrons
- ^{13}C : 6 protons/ e^- + 7 neutrons
- ^{14}C : 6 protons/ e^- + 8 neutrons

All three carbon isotopes are on position 6 in the PSE

- Isotope = the same place (Greek)

H 1							He 2
Li 3	Be 4	B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18

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The Next Level: Isotope Logging

The δ -Notation

$$\delta^{13}\text{C} = \left[\frac{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{Sample}}}{\left(\frac{^{13}\text{C}}{^{12}\text{C}} \right)_{\text{Standard}}} - 1 \right] \bullet 10^3 \text{ (‰; vs. V - PDB)}$$



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The Next Level: Isotope Logging



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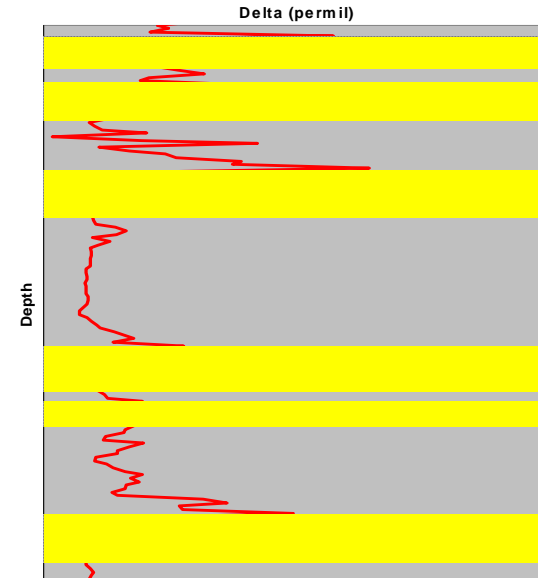
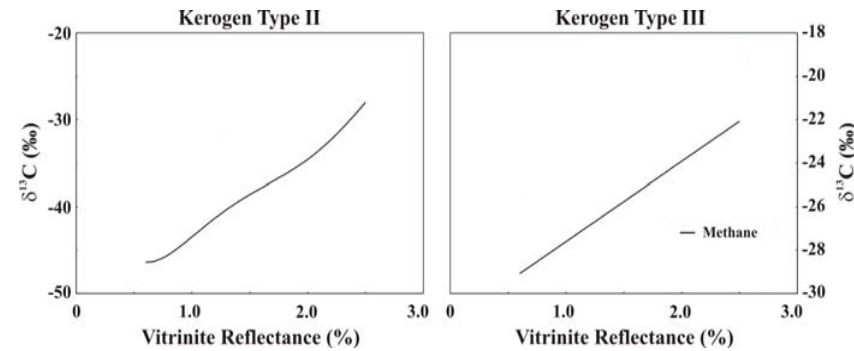
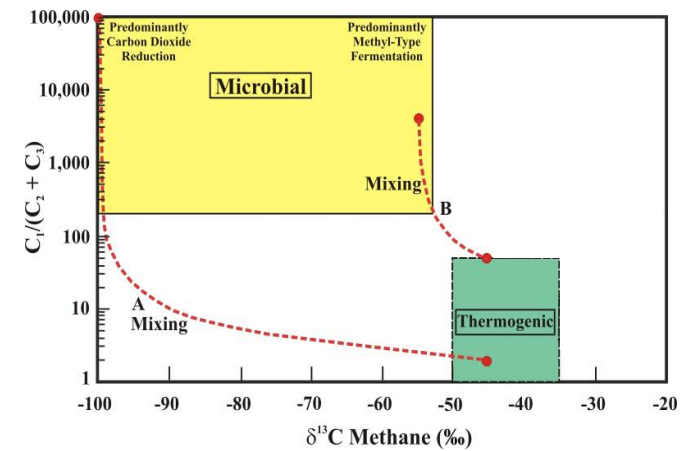
Isotope Logging

- No gas samples (Isotubes, Vaccutainers, etc)
- Continuous measurement of $\delta^{13}\text{C}-\text{C}_1$ in real time while drilling
- Measurement performed on mud gases
- Utilization of new technology
 - GC-IRMS not applicable at the rig site
 - No chromatography, no combustion

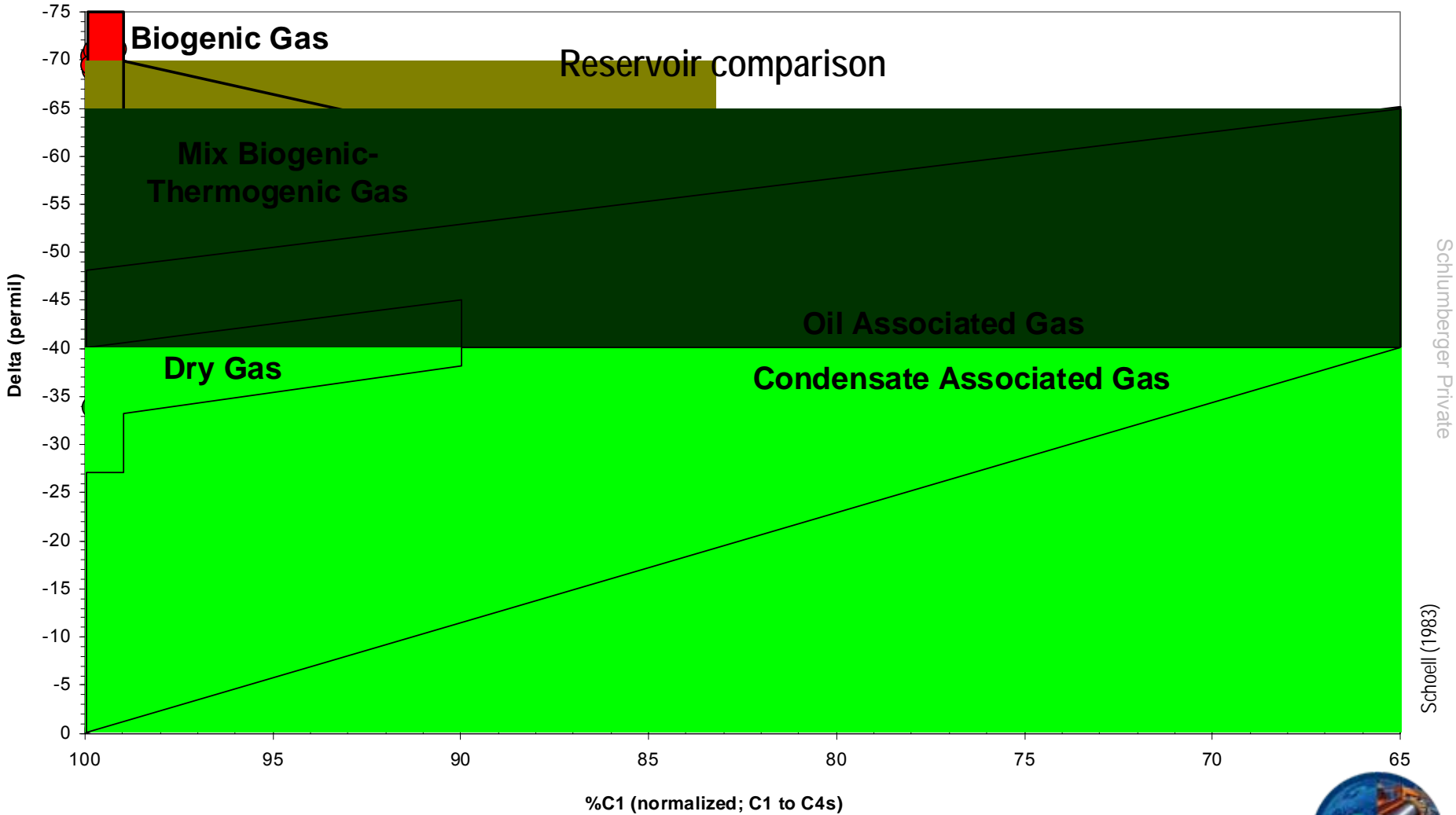


Isotope Logging

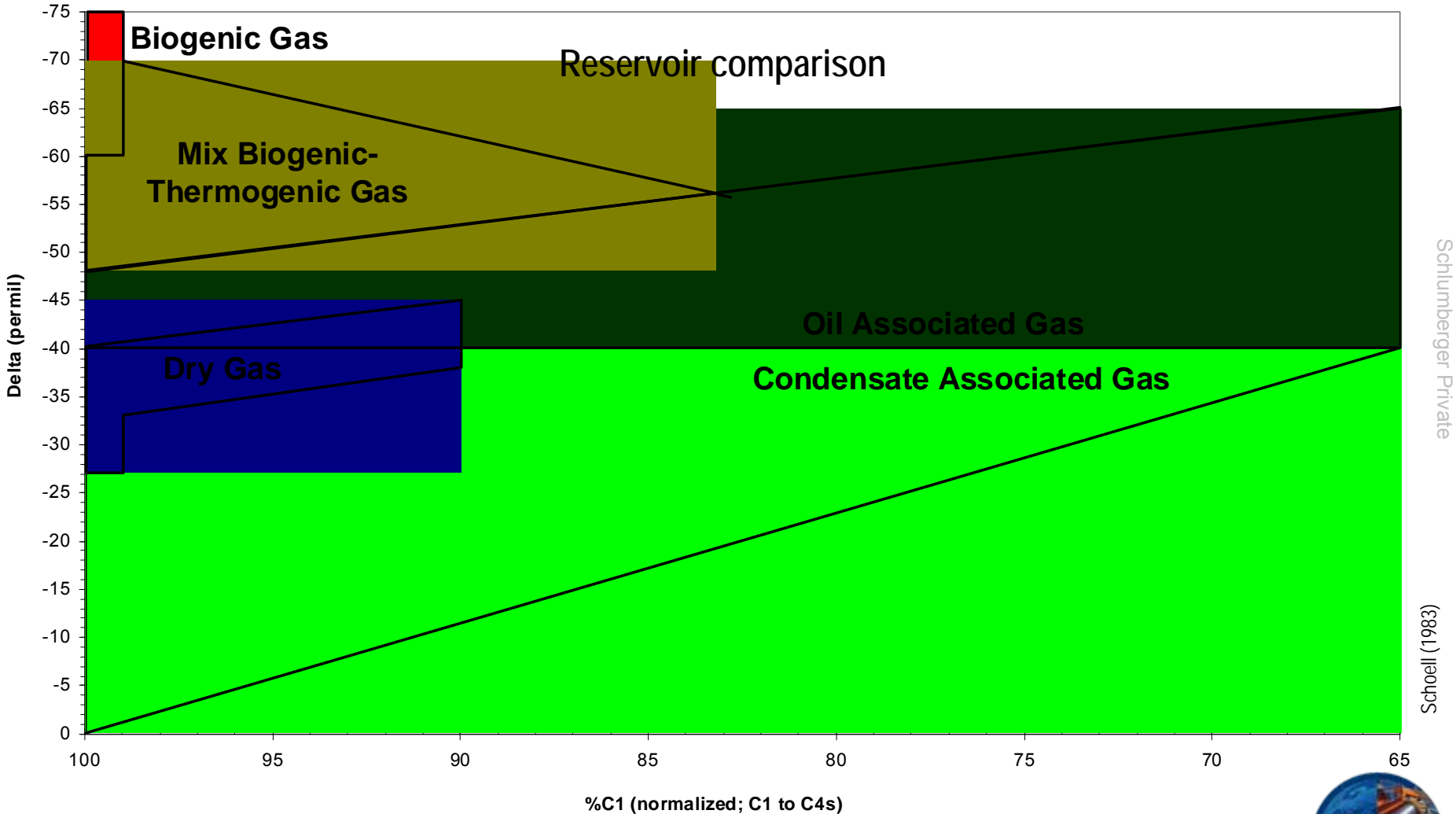
- Gas generation pathway: biogenic vs. thermogenic
- Geochemical system: source and maturity
- Correlation of reservoirs
- Defining reservoir continuity or compartments
- Identification of in-reservoir processes
- Sealing characteristics of cap rock, faults
- Defining reservoir tops
- Possible fluid associations



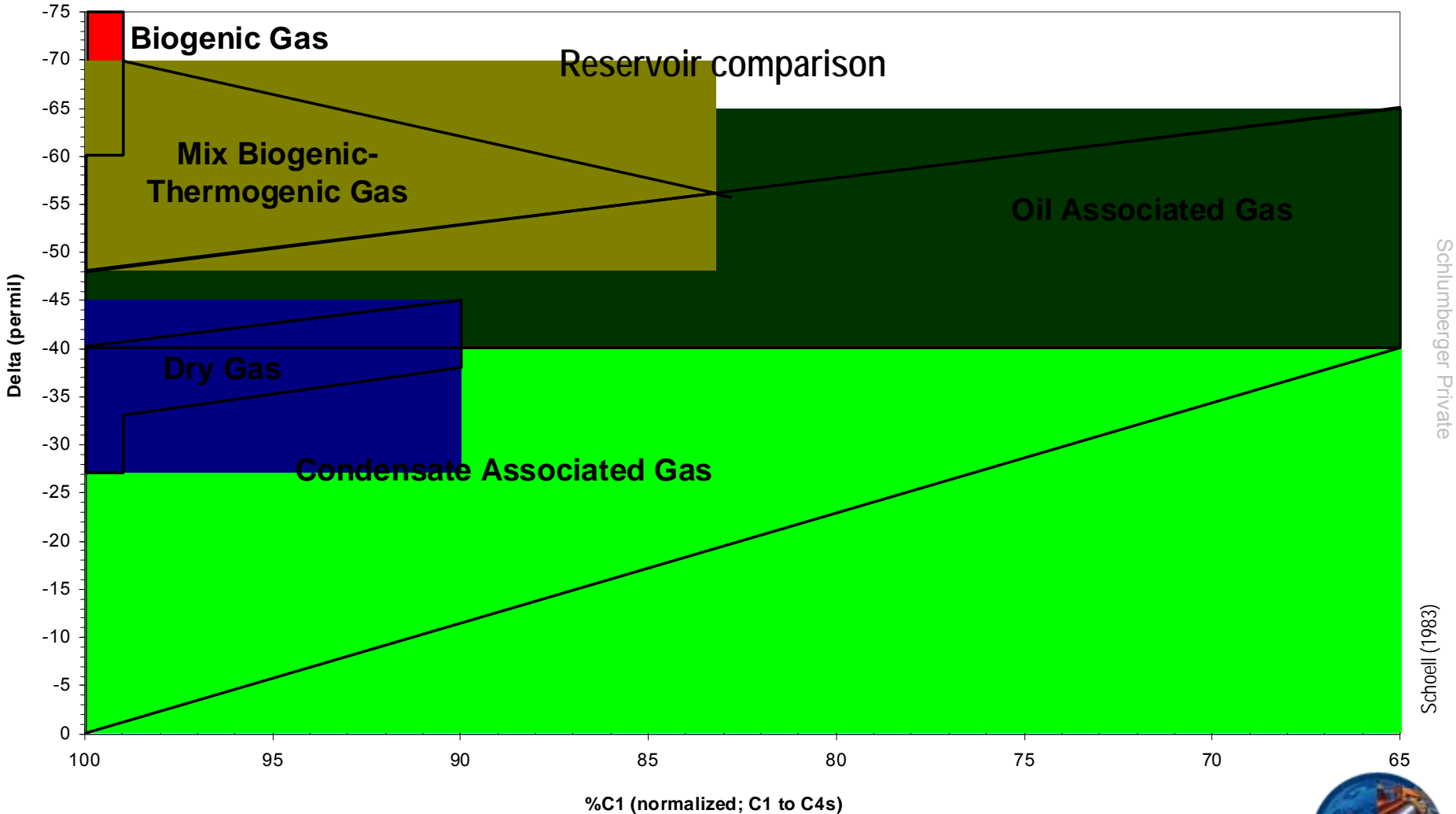
The Next Level: Isotope Logging



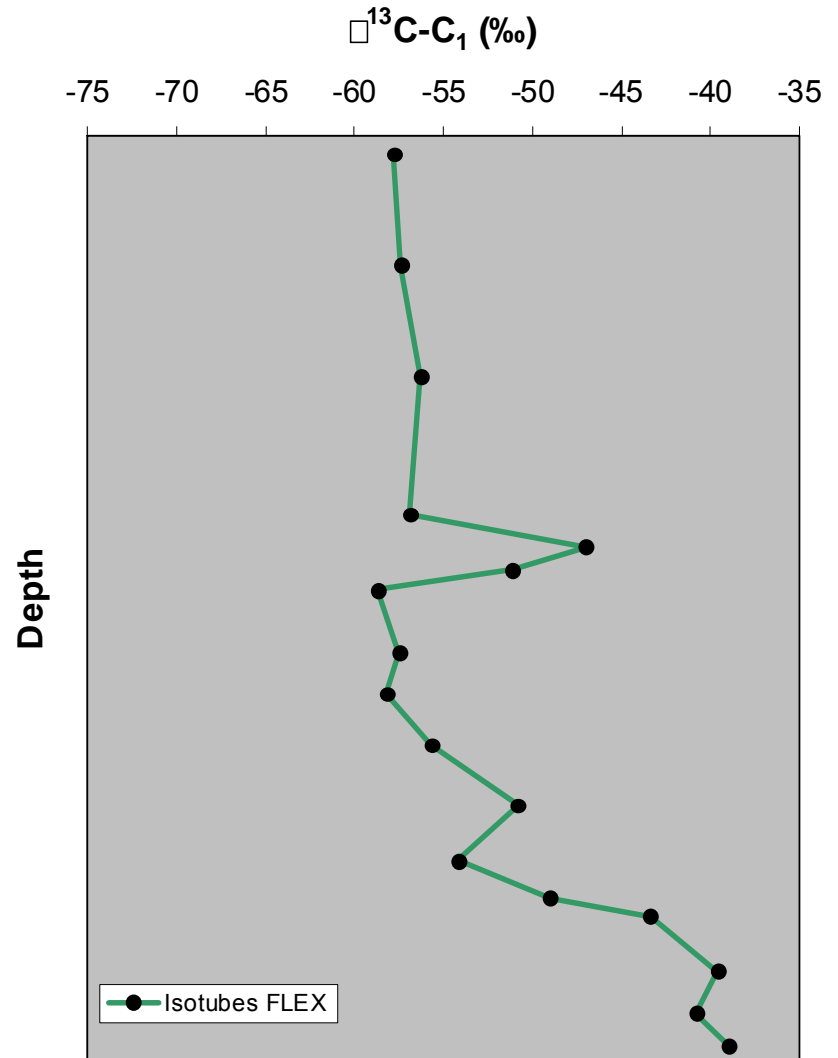
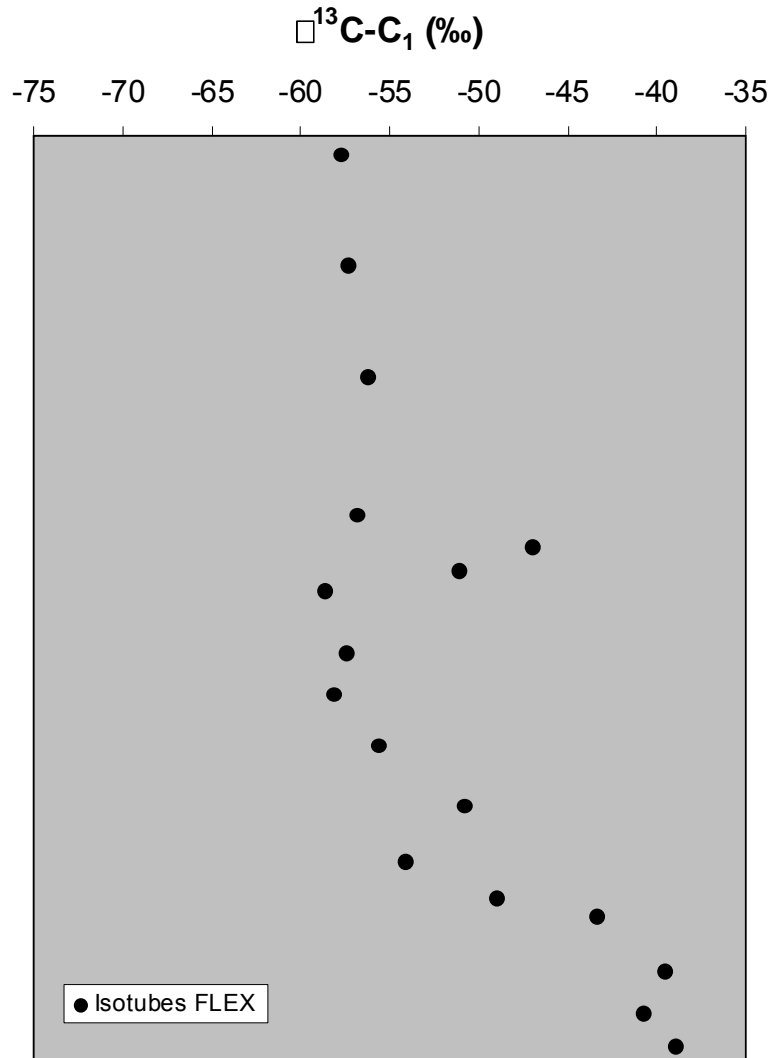
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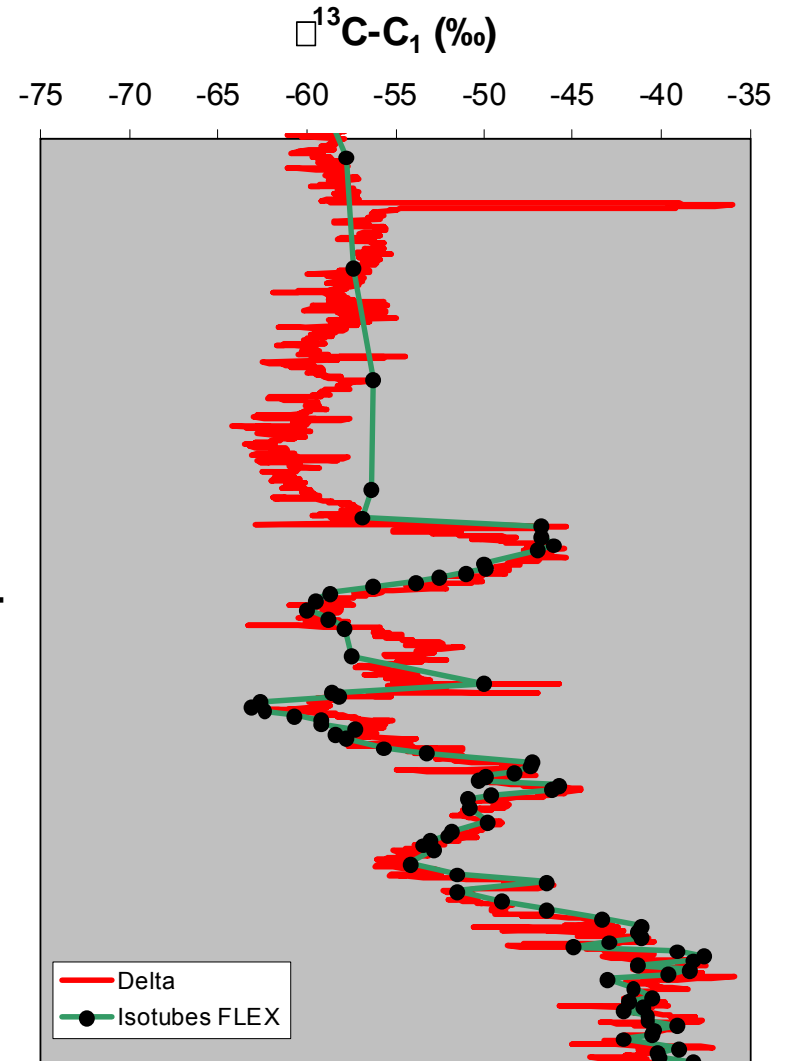
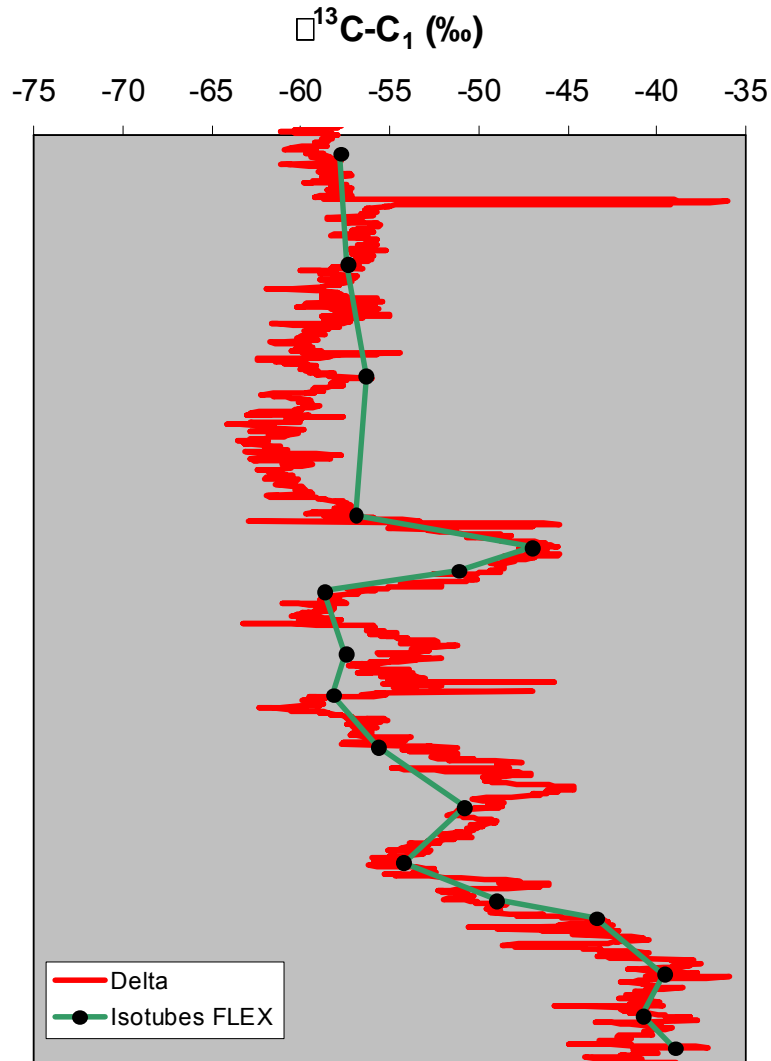
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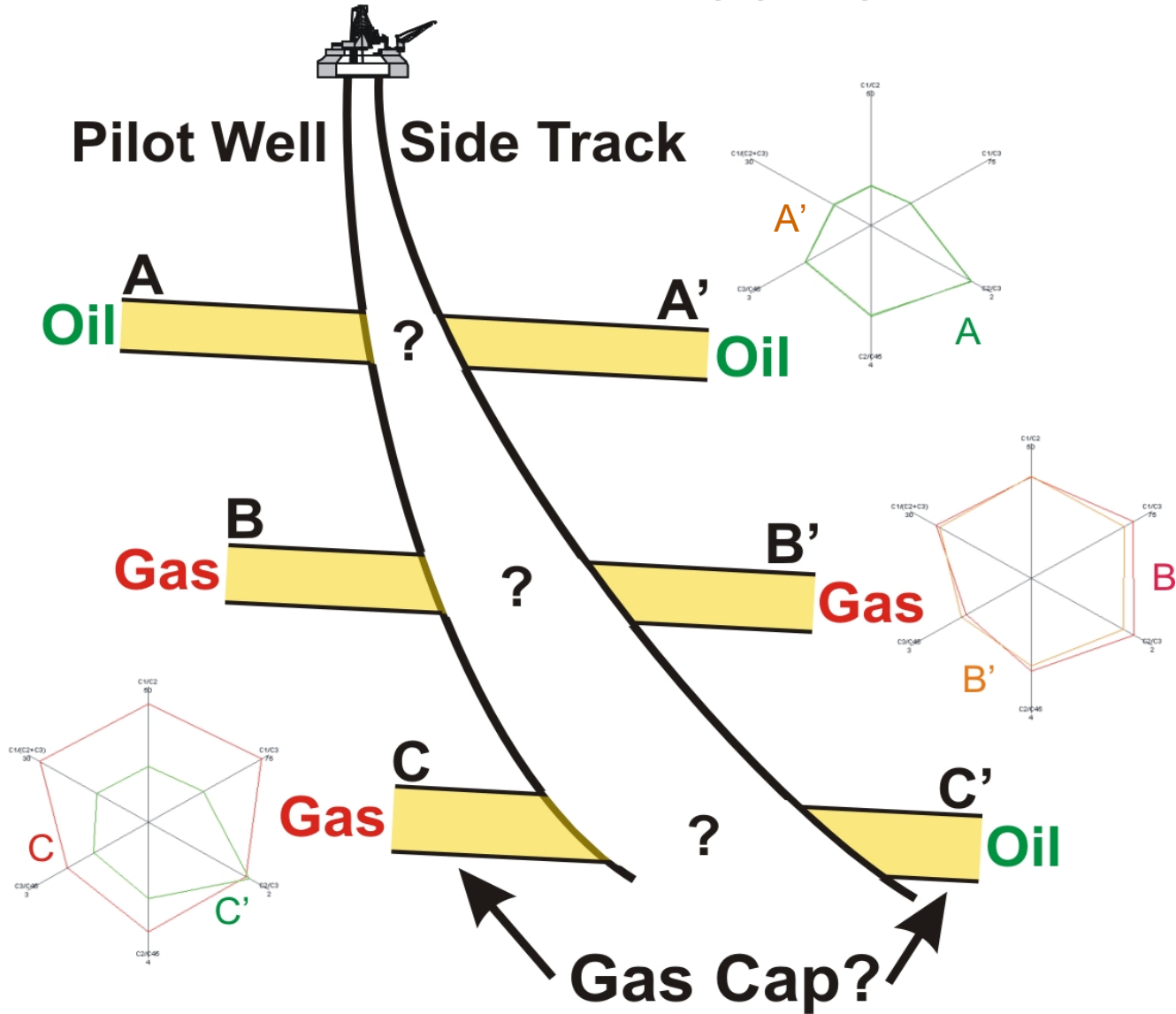
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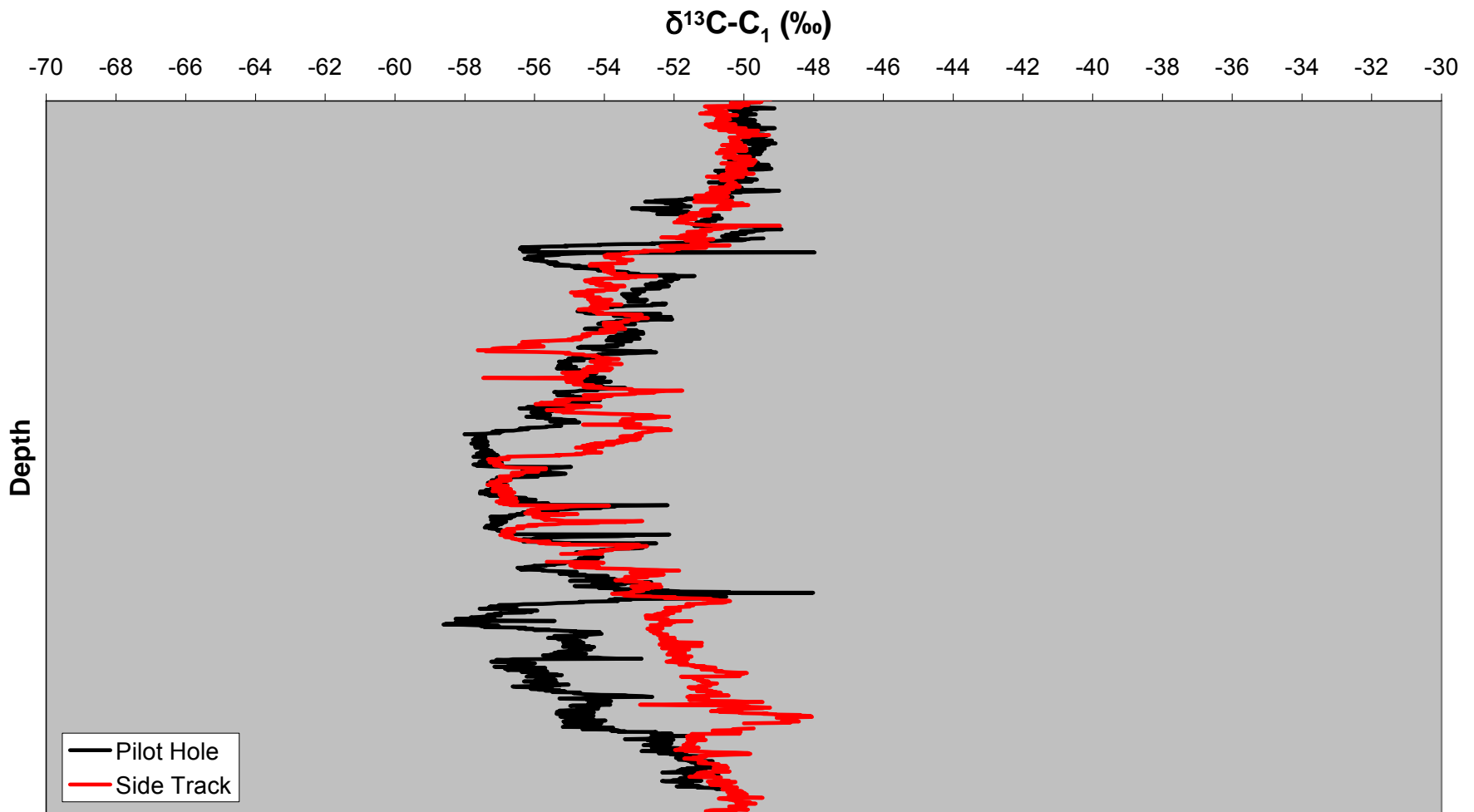
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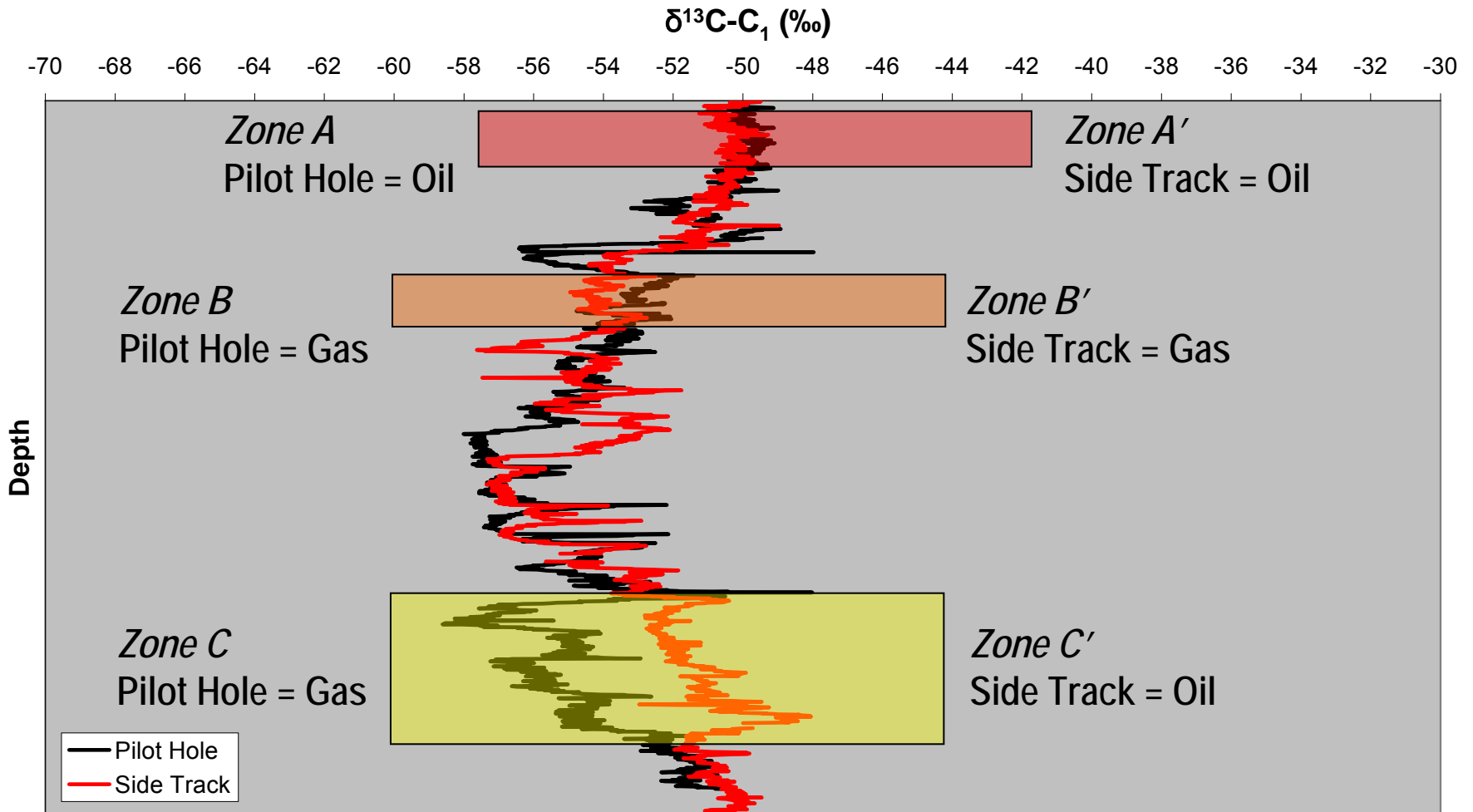
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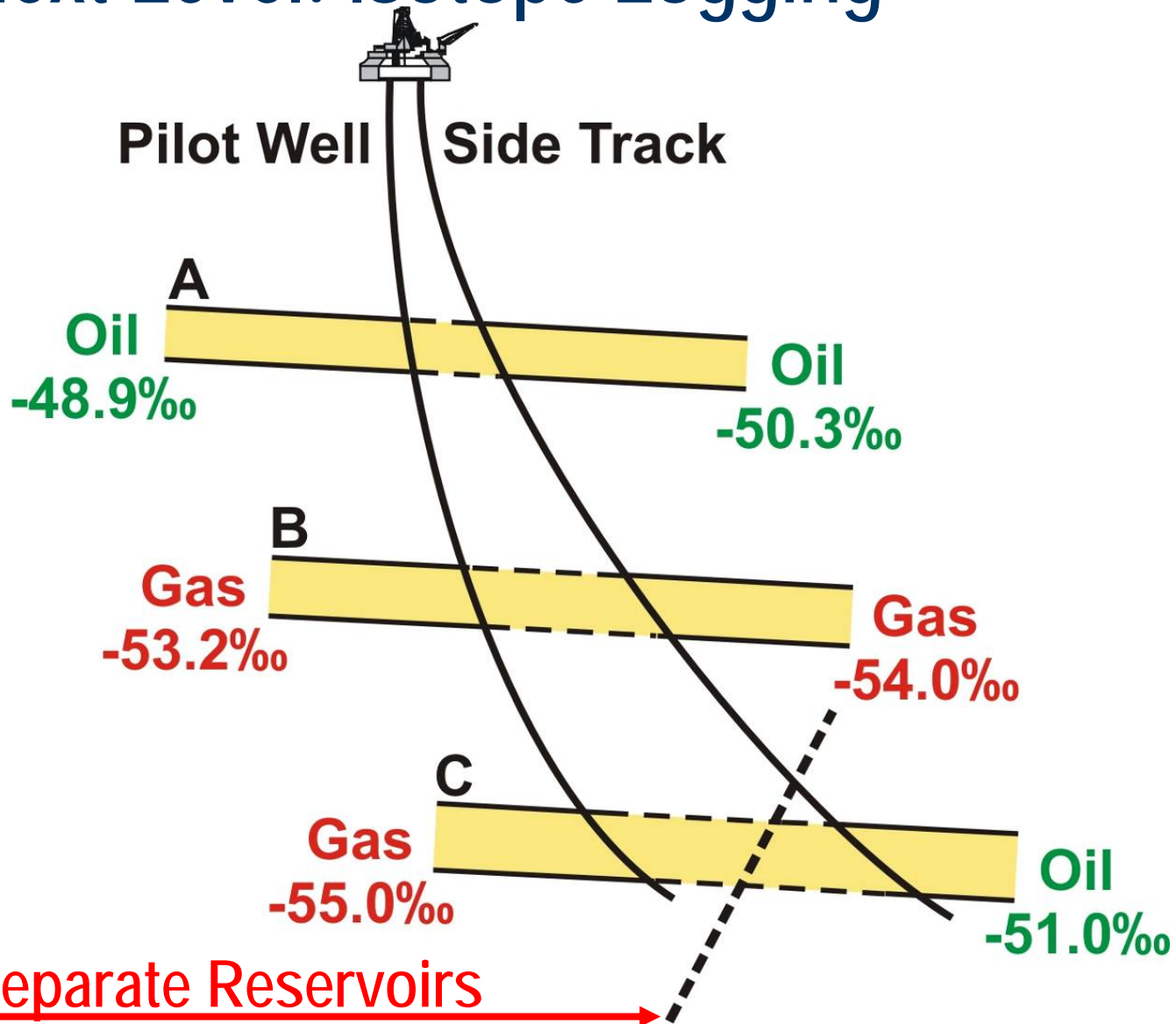
The Next Level: Isotope Logging



The Next Level: Isotope Logging

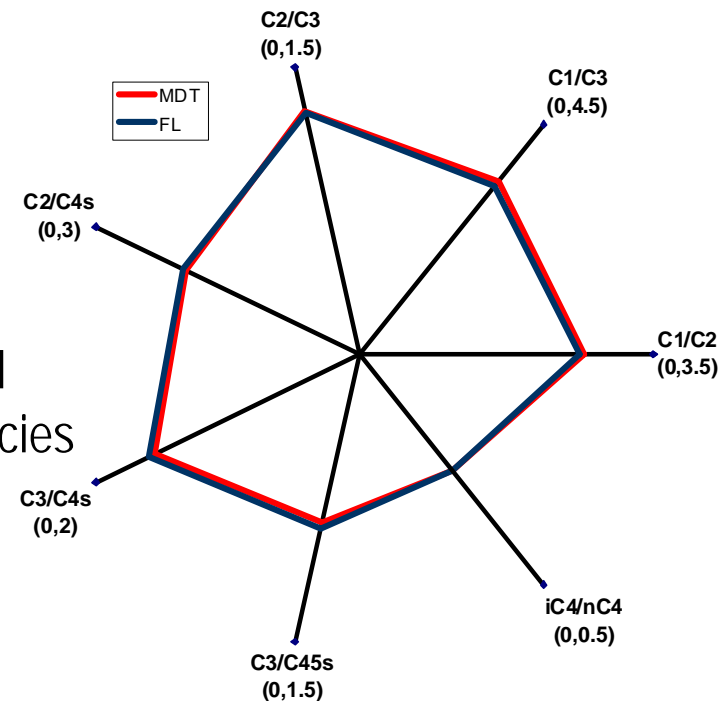
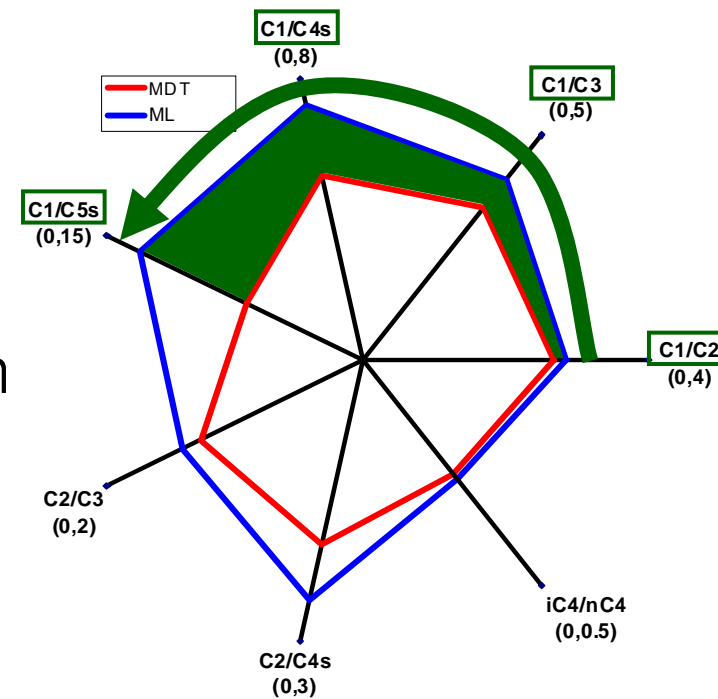


The Next Level: Isotope Logging



Summary (1/2)

- ML gas data are not suitable for fluid evaluation
 - Qualitative data ("gas in air")
 - Extraction is variable and not controlled
 - Limitations: flow, temperature, drilling fluid
 - Impacts: recycling, extraction efficiency
- FL data → fluid evaluation
 - Quantitative data ("HC's from formation")
 - Comparable with PVT analysis data
 - Constant and controlled extraction conditions
 - Extraction efficiency calibration on actual drilling fluid
Extraction efficiency coefficients for different HC species
 - Recycling correction, elimination of contaminants



Summary (2/2)

- Advantages
 - Data comparable with PVT – real time information about reservoir fluid
 - Comparable data (single or multiwell)
 - Efficient mud gas extraction at low temperatures
 - Fluid sampling optimization
 - Reservoir compartmentalization/ connectivity
 - Compositional grading
 - Data available independent of well condition
- Isotope Logging
 - Additional level of information → integrated interpretation
 - Dramatically improved depth resolution due to continuous measurement
 - Data available in real-time



Thank you for your attention



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