Advanced Formation Fluid Evaluation While Drilling with a New Heavy Gas Detector*

Gionata Ferroni[1], Fabio Rivolta[1], and Roberto Schifano[1]

Search and Discovery Article #40860 (2012)
Posted January 9, 2012

*Adapted from poster presentation at AAPG International Conference and Exhibition, Milan, Italy, October 23-26, 2011

[1]Technical Department, Geolog International, S. Giuliano Milanese, Italy (g.ferroni@geologinternational.com)

Abstract

In this paper, a chromatograph which exploits the benefits of FID technology optimized for the high resolution detection of heavier hydrocarbon gas components is described. The components analyzed span from n-hexane to toluene. Flame Ionization Detector (FID) technology is not new to gas detection on the field, however it had never been applied to the detection of gases heavier than n-pentane.

The instrumentation has been installed and run on a number of wells in different fields and countries, and it has operated as a complement of an advanced surface logging system for a period of two years. Unlike other technologies presently utilized for this scope, this system reduces dedicated equipment and personnel to a minimum.

The results presented show the clear identification of formation fluid contacts with higher accuracy than standard light gas detectors, the recognition of contaminants within the drilling fluid, and the practicality of operating an advanced gas detection system with minimal operational and logistic footprint. Some of the indications obtained challenge common beliefs about gas detection: consistent extraction of heavy hydrocarbon gases from the drilling fluid is possible at relatively low temperatures, provided that the entire gas extraction system is rigorously controlled in terms of gas sample pressure, flow, and temperature. Furthermore, gas data analysis can yield indications on the fluid composition even when the gases analyzed are in extremely low quantity.

The system utilizes known technologies, developed and optimized to obtain new results. The system supports formation evaluation when LWD or wireline can be inconclusive, in the presence of a low porosity pay or fresh water. It can also guide and optimize the MDT testing program. Furthermore, the system takes into account the constraints of drilling operations, and strikes a balance between data accuracy and practicality of the application.

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AAPG International Conference & Exhibition – 23-26 October 2011 / Milan, Italy

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1 Background information

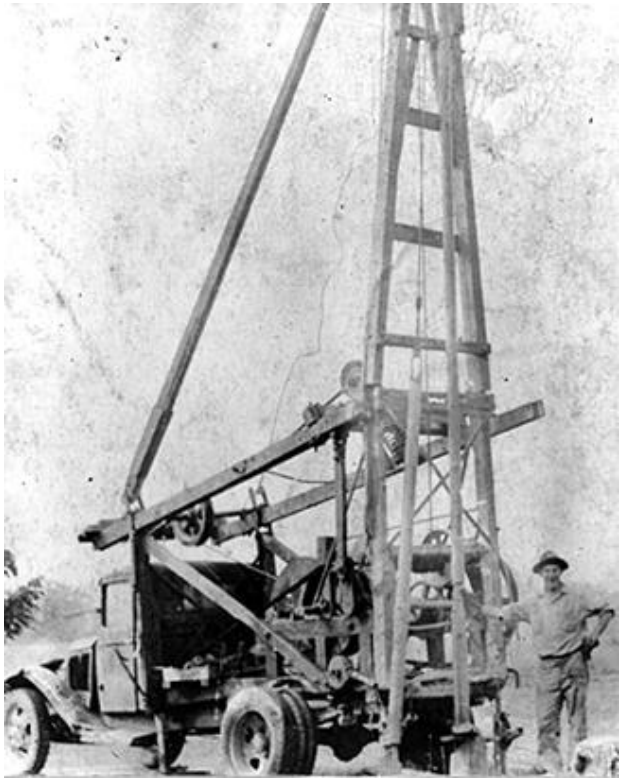
1) Background information

Background Information

Gas Measurement while drilling Oil & Gas wells started in the ‘30ies.

It was always meant to be a Formation Evaluation tool, however it has long been utilized primarily as a mere safety system.

One of the reason is that early gas detection systems lacked the consistency and repeatability to make them reliable for geological interpretation.

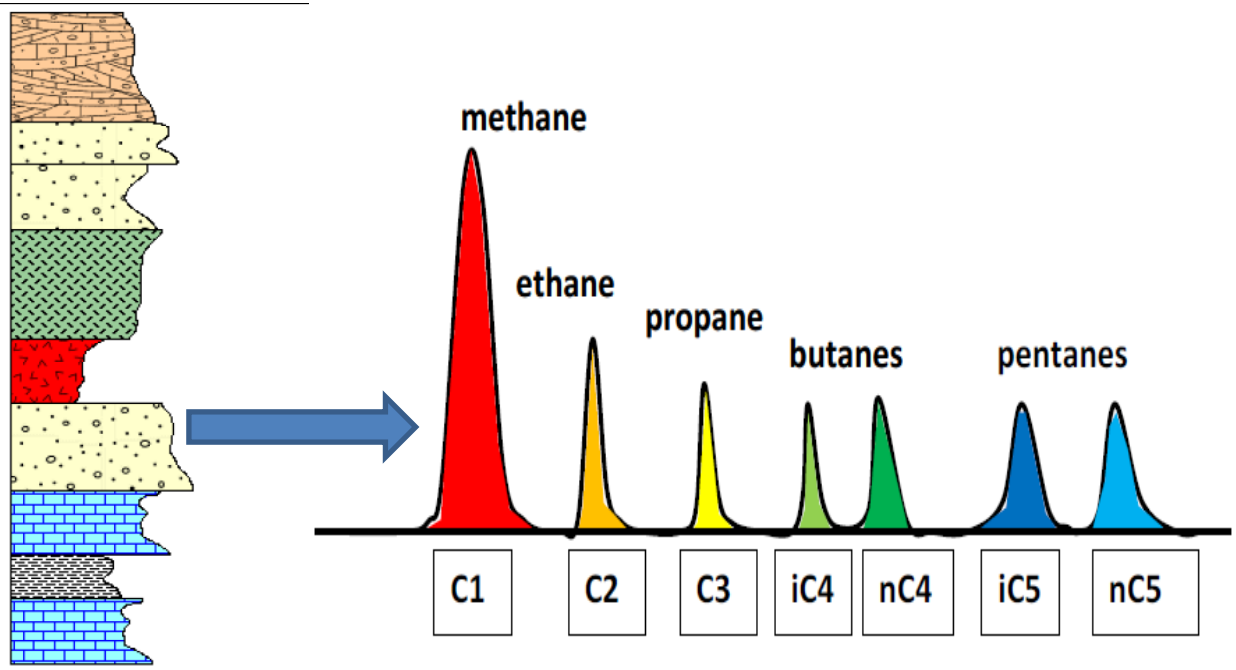


Background Information

The development of modern gas chromatographs has enabled to analyze the gases while drilling with high accuracy.

Drilled gas amounts and composition provide information on the presence of a hydrocarbon reservoir.

They also enable to identify the type of fluid present.



Traditionally only the more volatile hydrocarbons (Methane to Pentane) have been extracted and utilized to characterize oil or gas bearing formations.

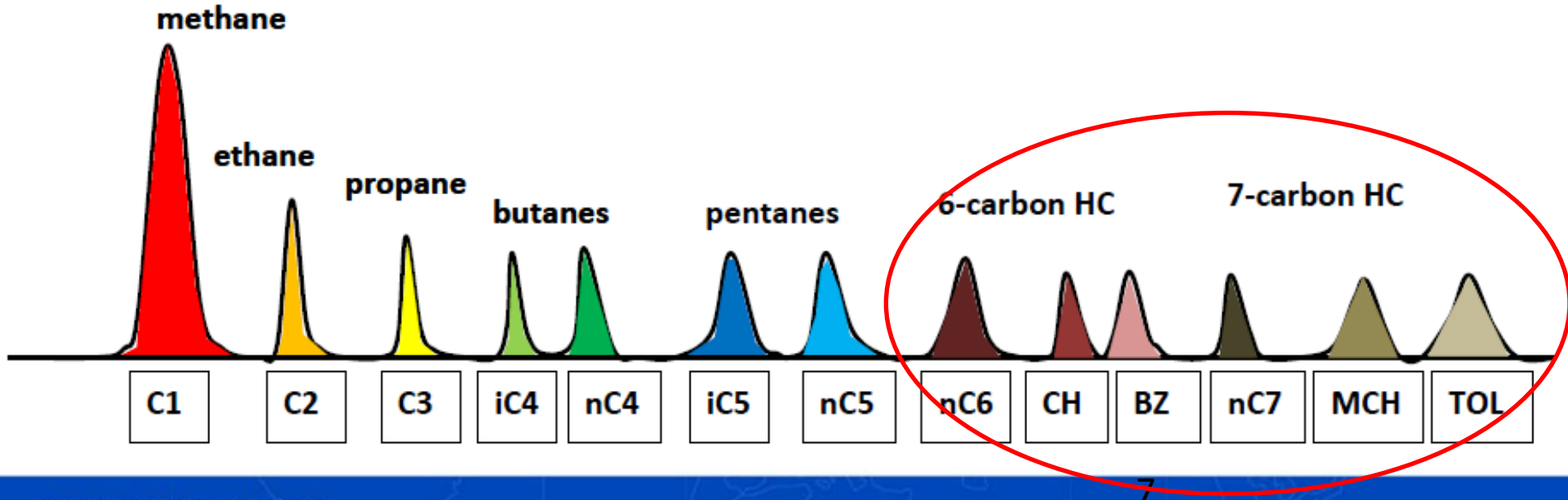
2) System Description

System Description

The new chromatograph presented here, when inserted in an advanced gas extraction system, extends the range of gases analyzed to 6- and 7-carbon hydrocarbons, adding in total 6 more hydrocarbon species to the analysis.

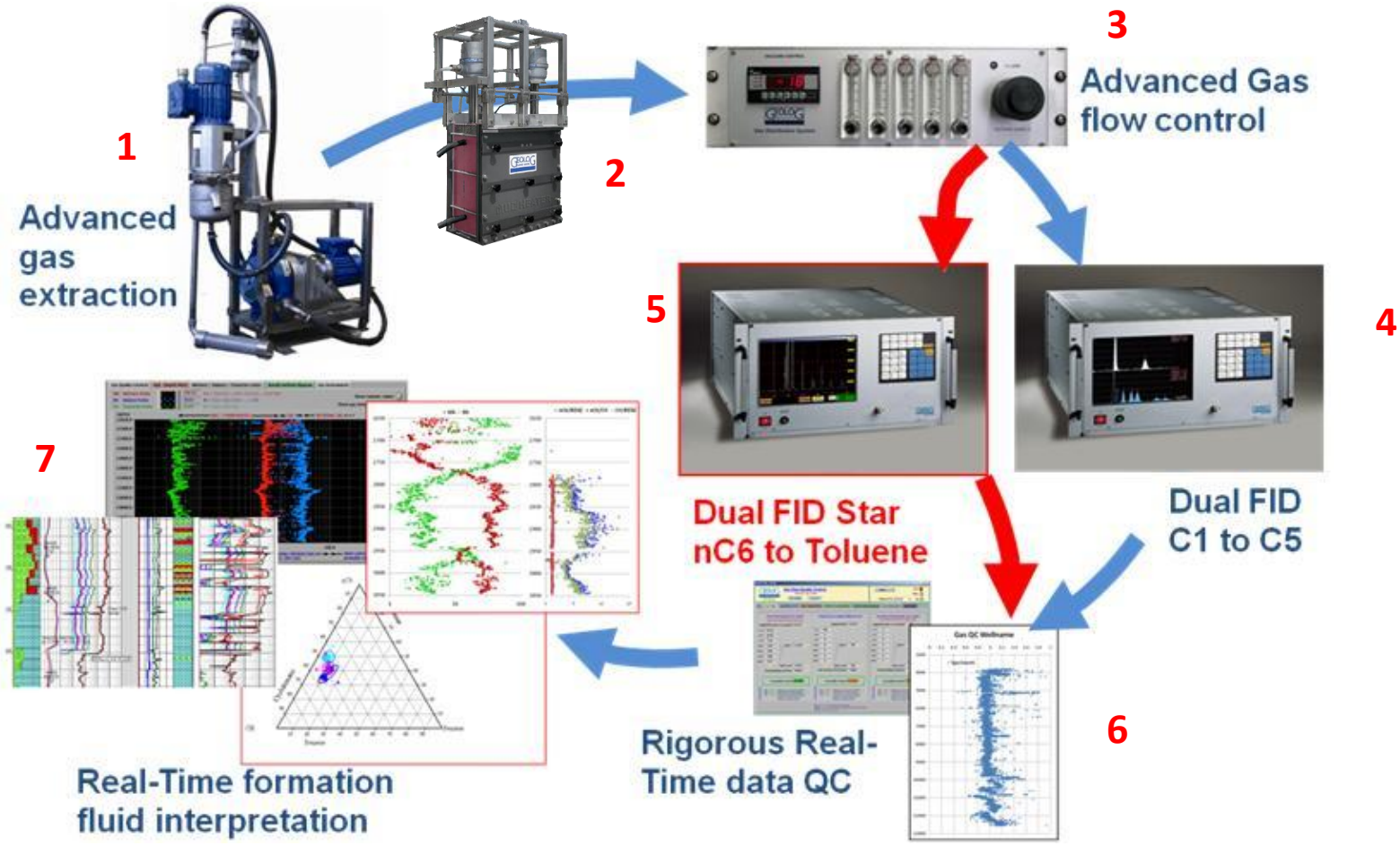
The new detector explores the realm beyond pentane, to analyze heavier alkanes, aromatics and cyclo-alkanes, chosen for their abundance and significance. It does so utilizing FID technology, optimal for hydrocarbon detection, and advanced capillary chromatography.

These technologies were never coupled before for this type of analysis.



System Description

The analyzer is part of an advanced gas detection system which comprises a number of crucial elements:

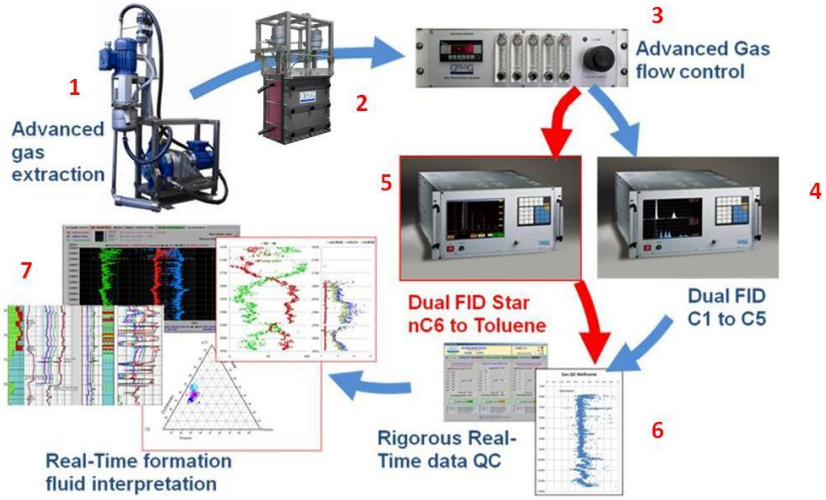


System Description

1 **A constant volume gas extractor**. This type of extractor enables to grant the repeatability of the reading and removes one of the main offenders in gas data quality: the variations in mud level and flow.

2 **A mud heater**. Since gas extraction is dependant on gas solubility, which decreases rapidly with low temperatures, a mud heater guarantees that gas level changes are not related to surface temperature change.

3 **A constant flow control sample distribution system**. Without such system, the gas sample going to the detector would be influenced by external factors such as temperature, sample density, and pressure losses along the gas sample line, jeopardizing reading repeatability.



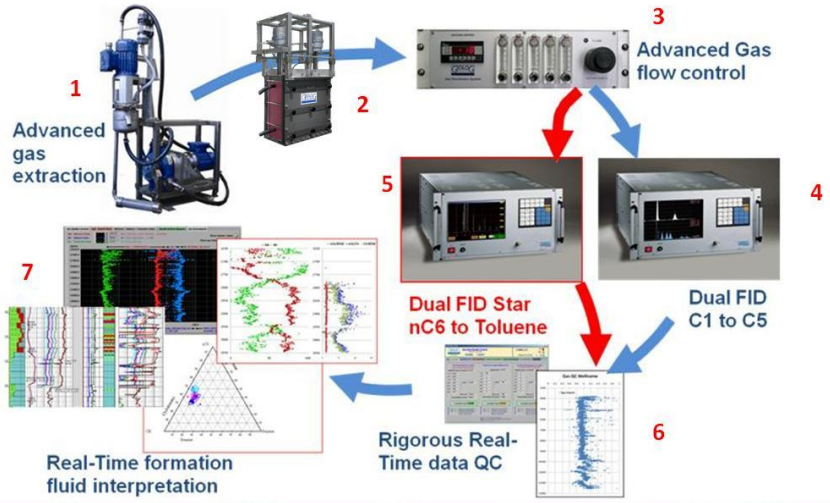
System Description

4 **A high resolution light gas analyzer**, in parallel with the heavy alkanes detector. A DualFid™ FID Chromatograph has been utilized. This detector has a double chromatographic column which separates the ultra-light hydrocarbons on one side, enabling ideal separation of C1 from C2, and the fraction from C3 to C5 on the second column. This solution achieves the ideal compromise between speed of analysis and accuracy.

5 **The mentioned DualFid Star chromatograph**, with the same FID detector and a capillary column able to separate the 6 heavier hydrocarbon gases from other species and contaminants which may be present in the fluid.

6 **A Real-Time automated data QC system**. This software constantly compares the gas data readings from separate instruments, and raises a flag when the data don't match, enabling prompt response from the field engineer on site.

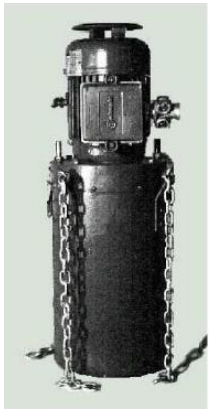
7 **A dedicated interpretation software package**. This software is used offline by the field specialist to make the most of the gas data.



System Description

Keeping in mind what is still considered “standard”…

Standard Gas Trap



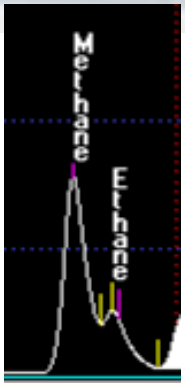
No control of mud flow

No control of sample flow

Gas Sample pump

Standard Chromatograph

Insufficient separation C1/C2. Slow.



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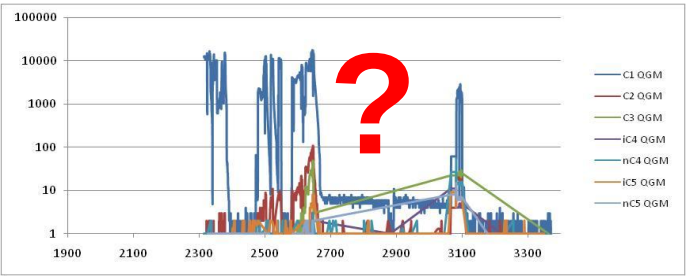
Real-Time data QC?



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Data interpretation?

System Description

A Practical Solution

Any system designed to measure and analyze data on the field (on a drilling rig) ultimately needs to pass a "practicality" test. The DualFid Star has been thought from the beginning as a field instrument, hence its characteristics have been chosen with this in mind.

Detection Technology: several technologies are presently being utilized to detect hydrocarbons on the field. Geolog has tried several of them: Thermal Conductivity Detection, IR, Mass Spectrometry, and FID – Flame Ionization Detection. The latter, FID, has resulted to be the one which provided the best package in terms of accuracy and practicality. FID remains the "weapon of choice" when it comes to measuring hydrocarbons. Coupled with capillary chromatography it enables to separate and measure hydrocarbon gas species maintaining a linear response across a range of 6 orders of magnitude.

System Description

Modular approach: the gas detection system presented here has been designed to adapt to diverse operational needs. Hence, it has been engineered in a modular way. It is based on a "skeleton" structure which enables a standard but high quality gas detection of gases from C1 to nC5, on which various advanced modules can be attached depending on the detection needs. These modules comprise of course the DualFid Star heavy gas detector, plus a mud heater when needed (in case of cold mud, in deepwater), plus a double gas chain if recycled gas needs to be measured, and dedicated software packages to enhance data processing and interpretation.

Ease of Use: one of the fundamentals of field gas detection and analysis is that personnel must be able to run their system without having to develop a completely specialistic skillset. It is very impractical to bring analysis specialists to the field. It is much more practical to train logging geologists and engineers in utilizing a field detector. Even more so if the detector utilized is very familiar to them in terms of working principle, detection system and software. This choice, to utilize a known technology, has enabled to bring to the field a new service, providing a new dataset, without the need for a larger footprint on the deck (crucial in offshore operations) and without the need of dedicated personnel for the maintenance of the instrumentation.

3 Case History

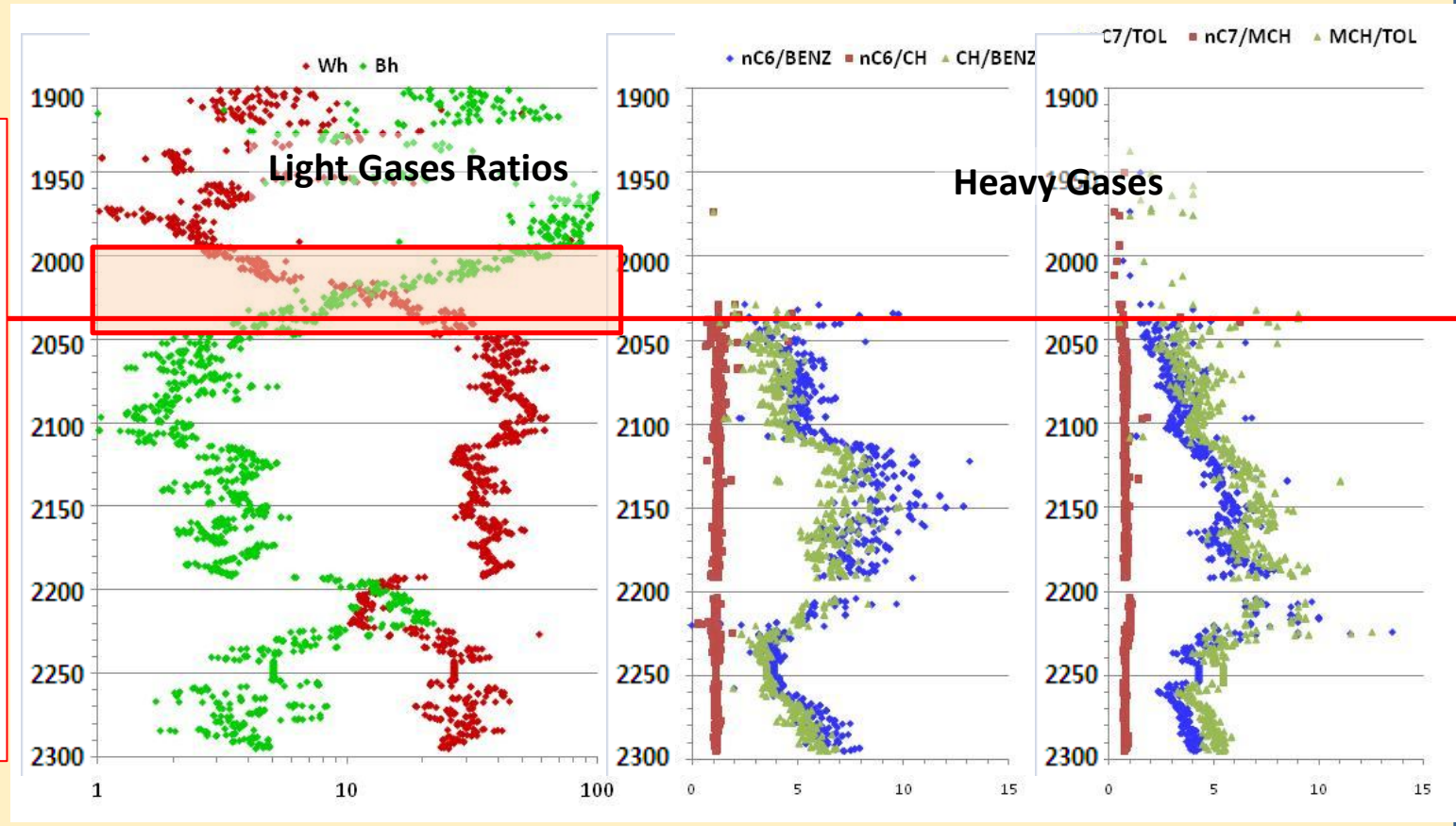
3) Case History

Gas-Oil contact picked accurately with heavy gas detector

DualFid Star

In this well, light alkane data (on the left) were insufficient to accurately pinpoint the fluid contact.
The typical gas ratios Wetness (Wh) and Balance (Bh) cross over at the Gas-Oil Contact, but the possible fluid contact has an uncertainty of at least 35 meters.

GOC is in fact identified with accuracy thanks to the heavy alkane analysis (on the right). The sheer presence of heavier gases, absent in the overlying formation, is an indication of change in the fluid composition, as the oil leg is entered.

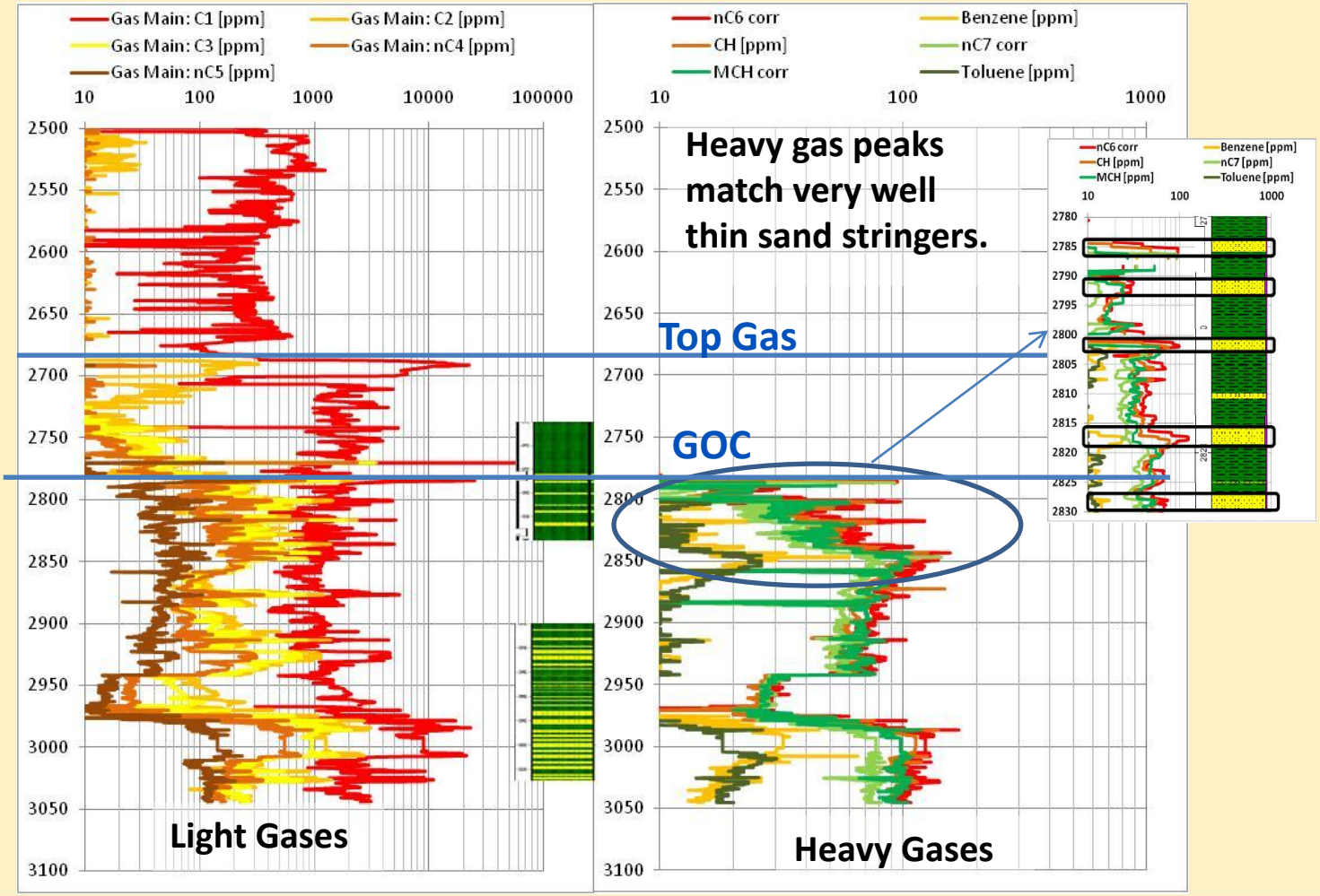


Identification of Oil Reservoir with heavy gas detector

DualFid Star – heavy gas detection

Light Gases do not provide sharp indication of top of oil. Heavy Gases (nC6 to Toluene) do.

Gas-Oil Contact (GOC): gradual increase of C3-C5, but clear identification from heavy species at 2784m.

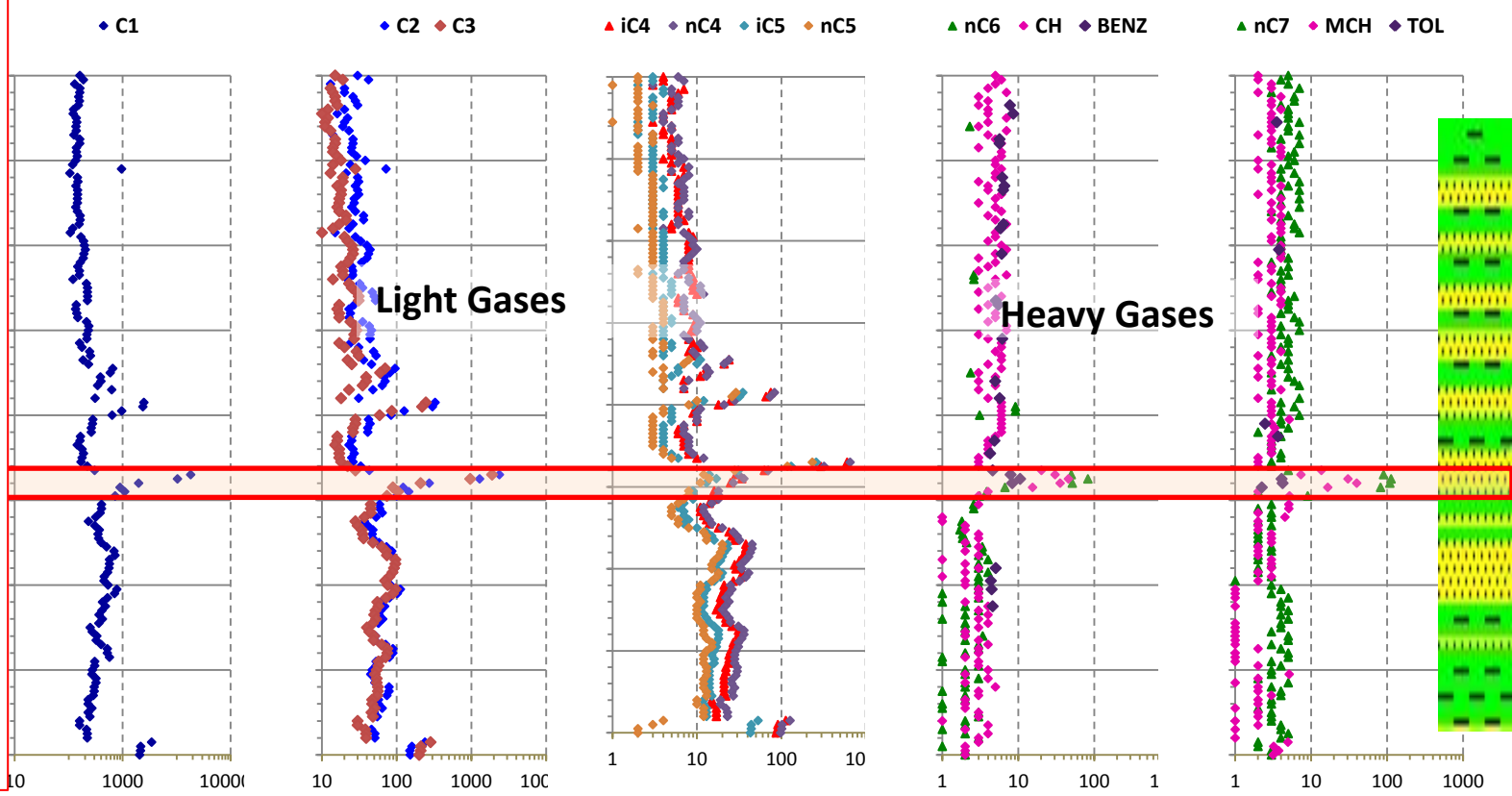


identified unprognosed condensate interval with heavy gas detector

The Oil Company expected a possible condensate stringer in this section but it was not firmly prognosed. Data from GEOLOG's Gas Detectors DualFid and DualFid Star confirmed presence of Condensate.

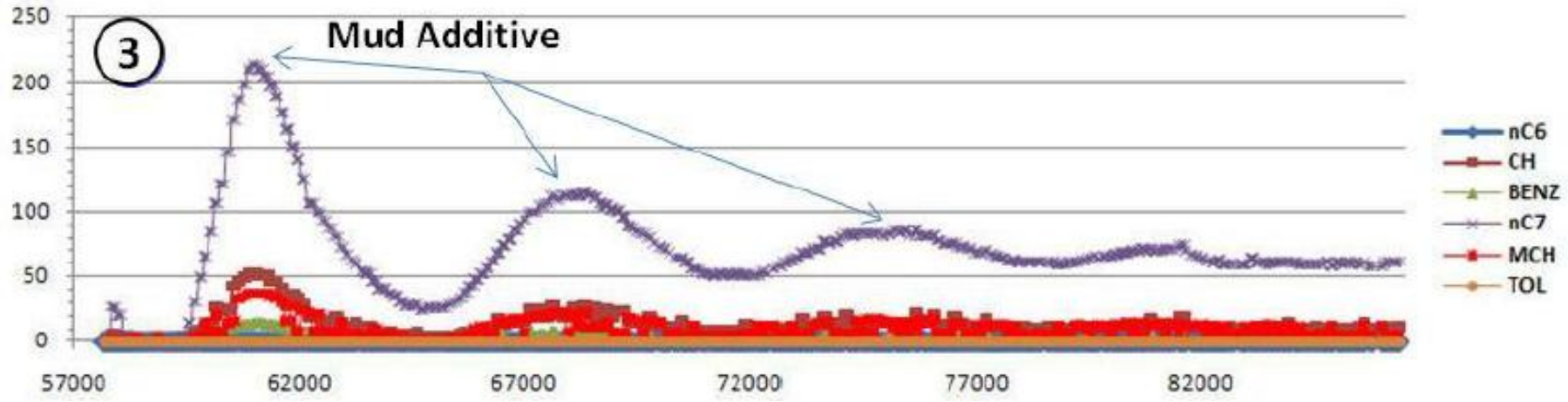
DualFid Star

While light gases (on the left, C1 to C5) indicate the presence of more than one gas shows, the heavier fraction is unaffected, except for the single 2-meters interval where all mesaured heavy species appear. This formation fluid indication was obtained in the presence of only minimal amounts of heavy gases (10 to 100 ppm).



Identification of volatile contaminants

This anomalous peak was caused by contaminants liberated by a mud additive, and recycled into the mud system. The conditions of pressure and temperature in the well caused reactions of the hydrocarbon components of the additive.



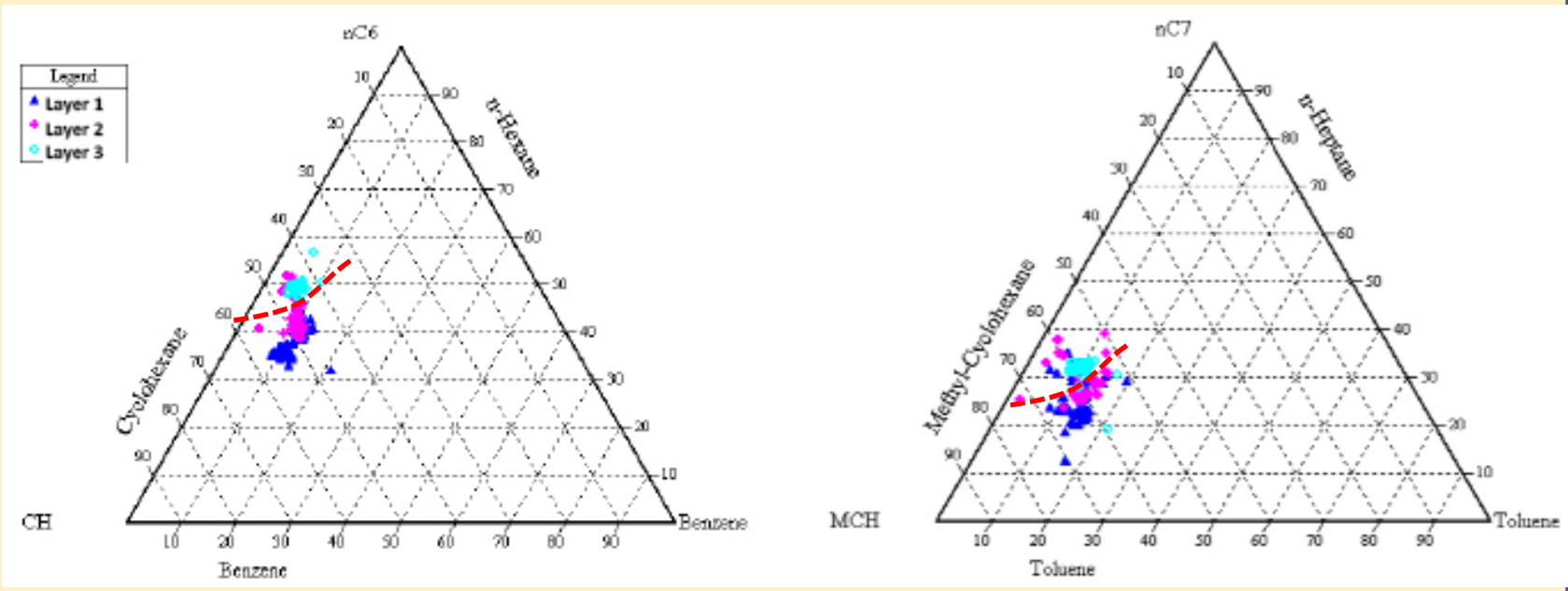
When gas analysis was performed, the contribution of the contaminants was subtracted to obtain the correct fluid composition.

Fluid Characterization identified while drilling with Heavy Gas Detector

DualFid Star

Ternary Diagram: heavy components are ideally plotted on ternary diagrams, to identify formation fluid composition changes.

The diagrams utilized here show the relative composition of the three 6-carbon isomers and the three 7-carbon isomers which the system is measuring.



The data are clearly concentrated towards a precise composition. This, in itself, is a confirmation of the quality of the gas detection. Furthermore, the colour-coding utilized shows the compositional change across the Oil-Water Contact (the sample points in light blue).

This ratio distribution can be used as a model for a field or a block, provided that it has initially been calibrated with formation fluid test data.

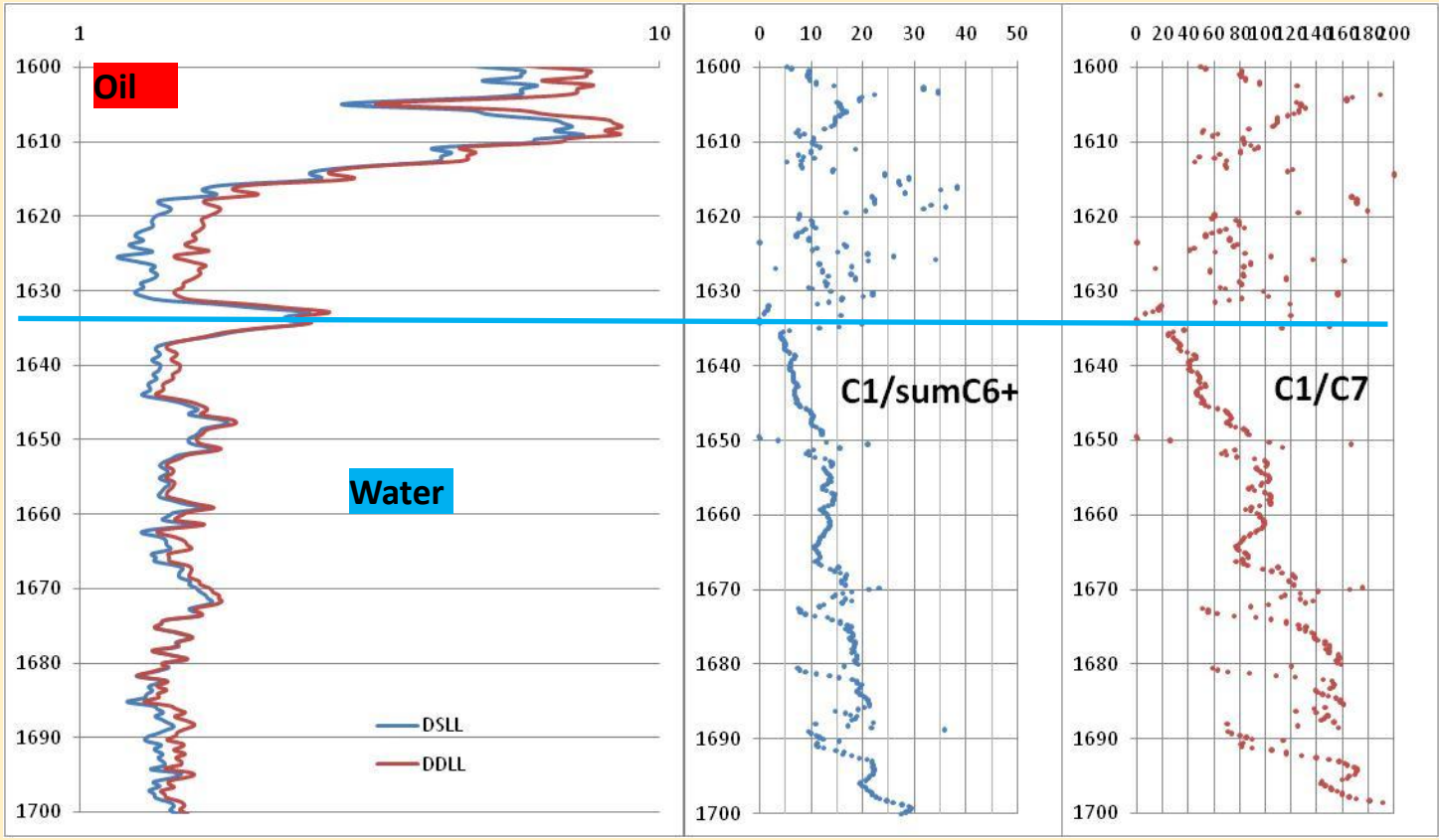
OWC identified before Wireline with heavy gas analyzer while drilling

The post-mortem resistivity data confirms DualFid Star OWC pick.

DualFid Star

When compared with wireline data, it is apparent that the heavy gas data provide crucial information enabling to recognize the Oil-Water contact.

In fact, the light gases only indicate that, across the OWC, gas levels decrease slightly. However, in this case, the attention should be shifted towards the aromatic hydrocarbons



The ratios shown in the chart show a clear trend shift in correspondance with the OWC identified by the resistivity log (on the left).

4 Conclusions

4) Conclusions

Conclusions

Conclusions:

✓The DualFid Star system utilizes known technologies, developed and optimized to obtain new results.

✓The systems improves the quality of gas data, providing more accurate information about reservoir fluid contacts

✓The system supports formation fluid evaluation when LWD or wireline can be inconclusive. It can also guide and optimize the MDT testing program.

✓The system takes into account the constraints of drilling operations, and strikes a balance between data accuracy and practicality of the application.