A Combination of Advanced Mud Gas Technology and RockWise™ to Identify Hydrocarbon Bearing Zone; Case Study*

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Abstract

The formation evaluation of any exploratory and or appraisal well is challenging due to scarcity of information with respect to reservoir, its characterization, and expected pressure. It is expected that hydrocarbon bearing reservoirs, especially those with challenges and any type of uncertainty, might possibly be overlooked. These are difficult to interpret from petrophysical logs for the presence or absence of hydrocarbons in case of drilling complications that lead to canceled coring and wire line logging program.

An advanced surface mud gas acquisition and analysis system, based on membrane technology, was utilized for several wells in Kuwait. Advanced mud gas analysis and interpretation of conventional and unconventional carbonate reservoirs identified interesting hydrocarbon bearing zones which were subsequently confirmed by integration of electric log, X-Ray Fluorescence (XRF) analysis, and open hole test data. The analysis is based on the computation of several gas ratios, which utilize gas components (C1-C8), and Aromatics (Benzene and Toluene) within the drill fluid. Gas components are continuously extracted from the drilling mud and monitored at the rig site by mud logging personnel using the advanced gas extraction system.

The purpose of the gas while drilling (GWD) analysis was to support and integrate Formation Evaluation in terms of highlighting the main zones of interest, fluid characterization, and to suggest depth sample intervals. In addition, to reduce

remaining uncertainties after conventional log analysis RockWise™, a service providing advanced elemental analysis on cuttings and core samples at the rig site. It deploys an energy dispersive X-ray fluorescence instrument (ED-XRF) to measure 12 major and 20 trace elements on cuttings of the drilled formation. It also identifies certain bounding surfaces (sequence boundaries), chemostratigraphic zonation, and assess the potential for organic richness based on redox-sensitive proxy elements and enrichment factor ratios.

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A Combination of Advanced Mud Gas Technology and RockWise™ to Identify Hydrocarbon Bearing Zone; Case Study

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Agenda

- Introduction
- Methodology
- Results and examples
- Summary and Conclusion

Introduction

- Advanced mud gas analysis and interpretation of conventional and unconventional carbonate reservoirs identified interesting hydrocarbon bearing zones.
- A lot of valuable data can be observed and measured from mud data.
- Field data will help to predict reservoir quality, fluid contacts and reservoir permeability based on formation gases detected while drilling.
- This study discusses some examples from exploratory wells that have recently been drilled in Kuwait.
- Gas readings were recorded while drilling through Cretaceous and deep Jurassic formations to evaluate hydrocarbon content using Advanced Gas Chromatography, XRF and XRD.

Methodology

Gas Chromatograph

THC=C1+C2+C3+iC4+nC4+iC5+nC5+C6+C7+C8+Benzene+Toluene.

C1% = (C1/THC)*100=C1/ (C1+C2+C3+iC4+nC4+iC5+nC5+C6+C7+C8+Benzene+Toluene)

C1/C2 Ratio: C1/C2 > 22 Gas phase; 14 < C1/C2 < 22 Condensate phase; C1/C2 < 14 Oil phase

Wetness (Wh) = 100*(C2+C3 + iC4 + nC4 + iC5 + nC5)/ (C1+C2+C3 + iC4 + nC4 + iC5 + nC5)

Balance (Bh) = (C3 + iC4 + nC4 + iC5 + nC5) / (C1 + C2)

Gas Liquid ratio = (C1+C2+C3+C4)/(C5+C6+C7+C8)

Light Heavy ratio (LHR) = (C1+C2)/(C3+C4+C5+C6+C7+C8)

Fluid Saturation (FS) = (C1/C3) – (C1/C4)

Porosity Indicator = C1/ROP

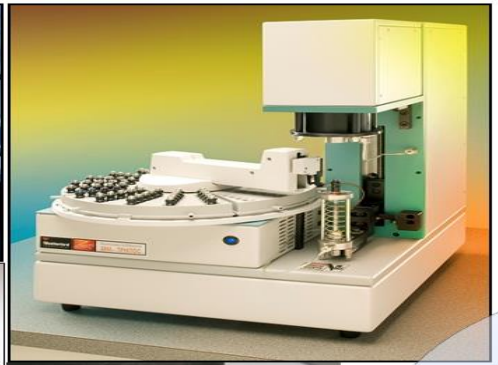
Fluid mobility/potential porosity (FMPP) = (C1+C2) / (C4+C5)

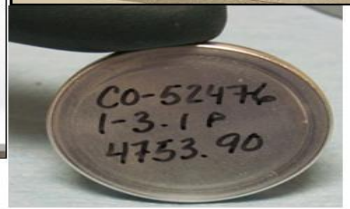
All previous and mentioned ratios were used only through formation gases readings.

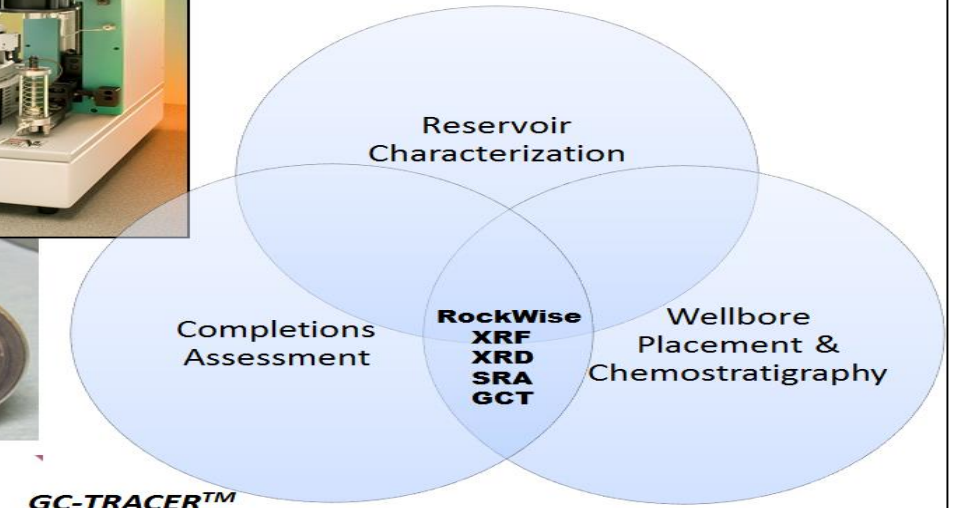
XRF/XRD used to:

- Calculate EGR based on the radioactive elements like Th, U and K measured by the XRF.
- Provide an assessment of relative brittleness of the rock.
- Provide elemental assessment for Organic Richness indicated by elevated concentrations of the paleoredox proxies like V, Ni, Mo, and U.

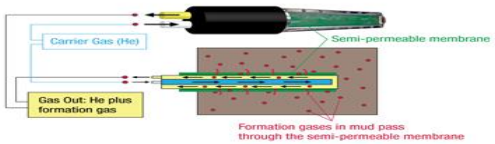
RockWise™ ED, XRF – XRD_ SRA and GCTracer Services





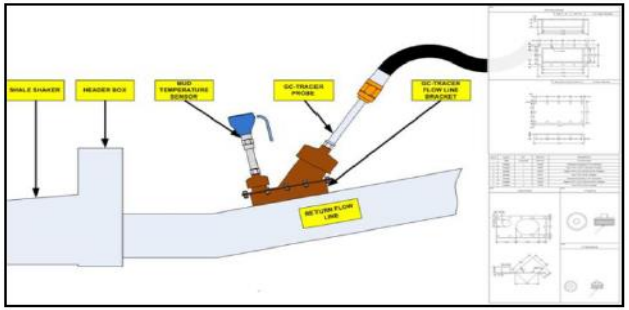


GC-TRACER™

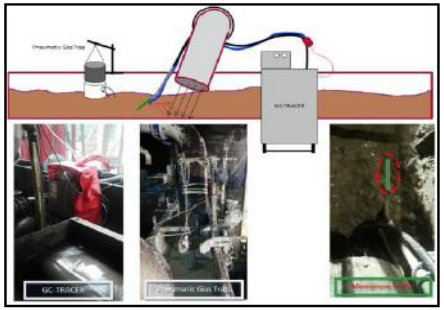


GC-TRACER INSTALLATION

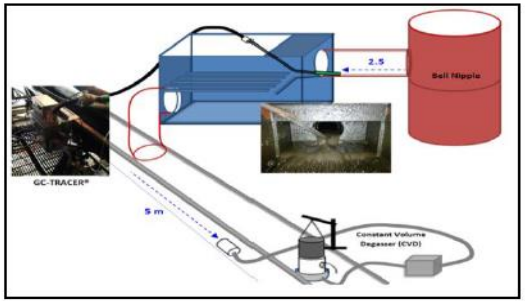
Ideal Probe Installation



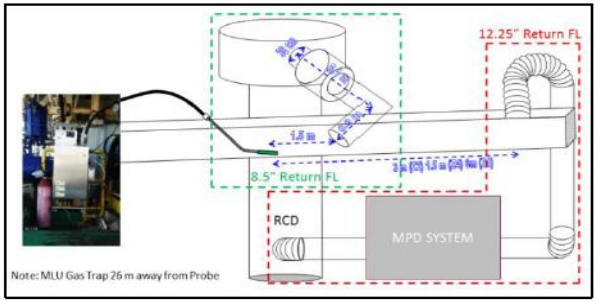
Land Rig



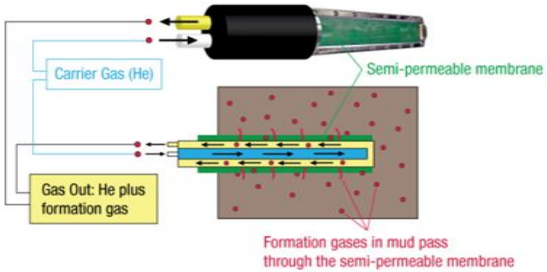
Tender Rig



Jack-Up Rig

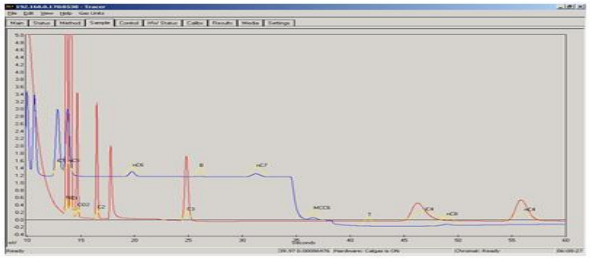


GC-TRACER® Surface-Gas Detector – An Advanced Gas Detection System

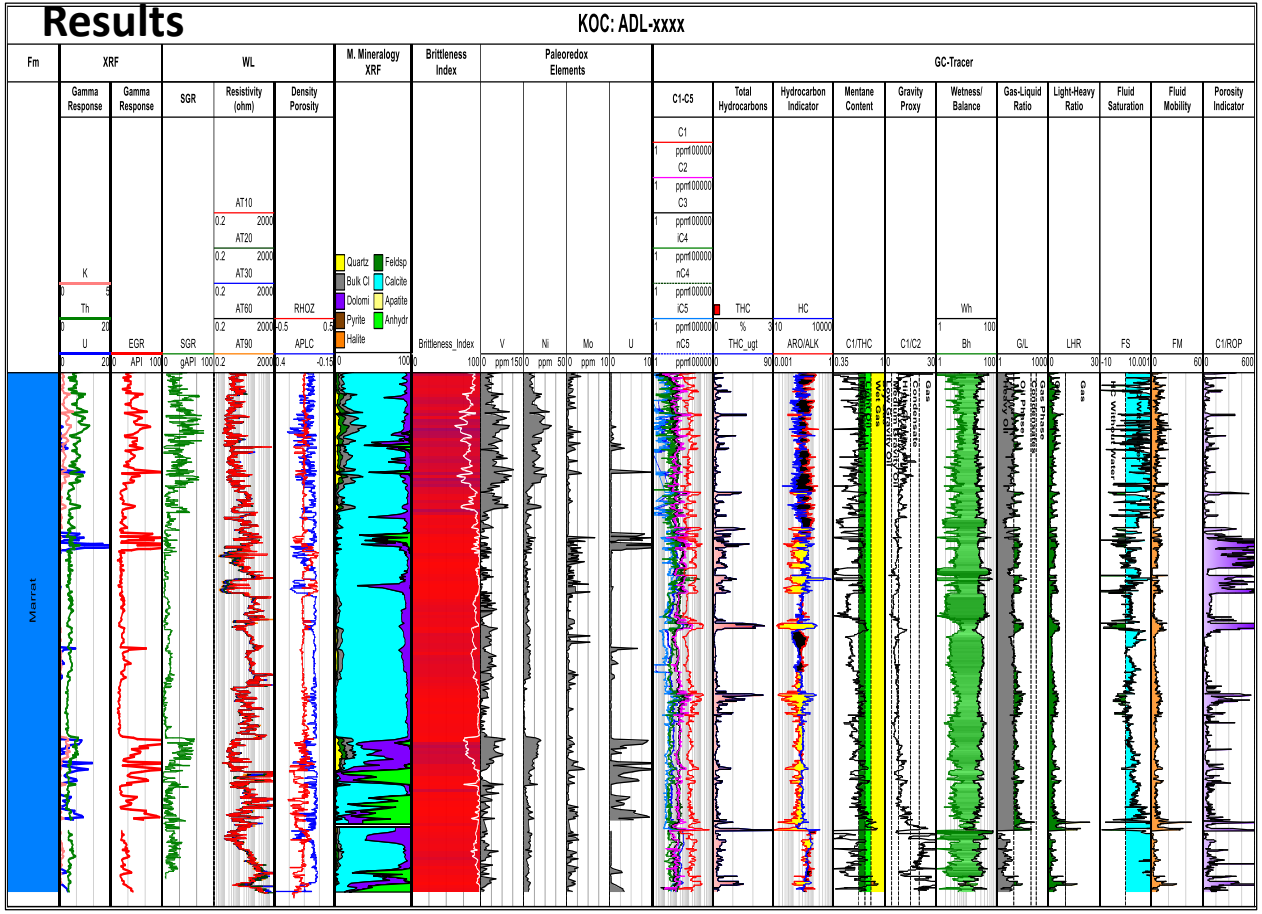


- **Delineation** of Top and Bottom of reservoir.
- **Estimate** the first characterization Fm fluid. Include water saturation Qualitative
- **Identifying** changes in fluid type. Possible contacts.
- **Connectivity** and Compartmentalization.
- **Identify** the significant gas events in Conventional and Unconventional Objectives.
- **Optimize** Fluid sampling. Correlation with neighboring well.
- **Support** to Geosteering to navigate on the fluid

- C1-C8
- Benzene
- Toluene
- N_2
- CO_2
- 55 seconds
- Gas In/Out



Results

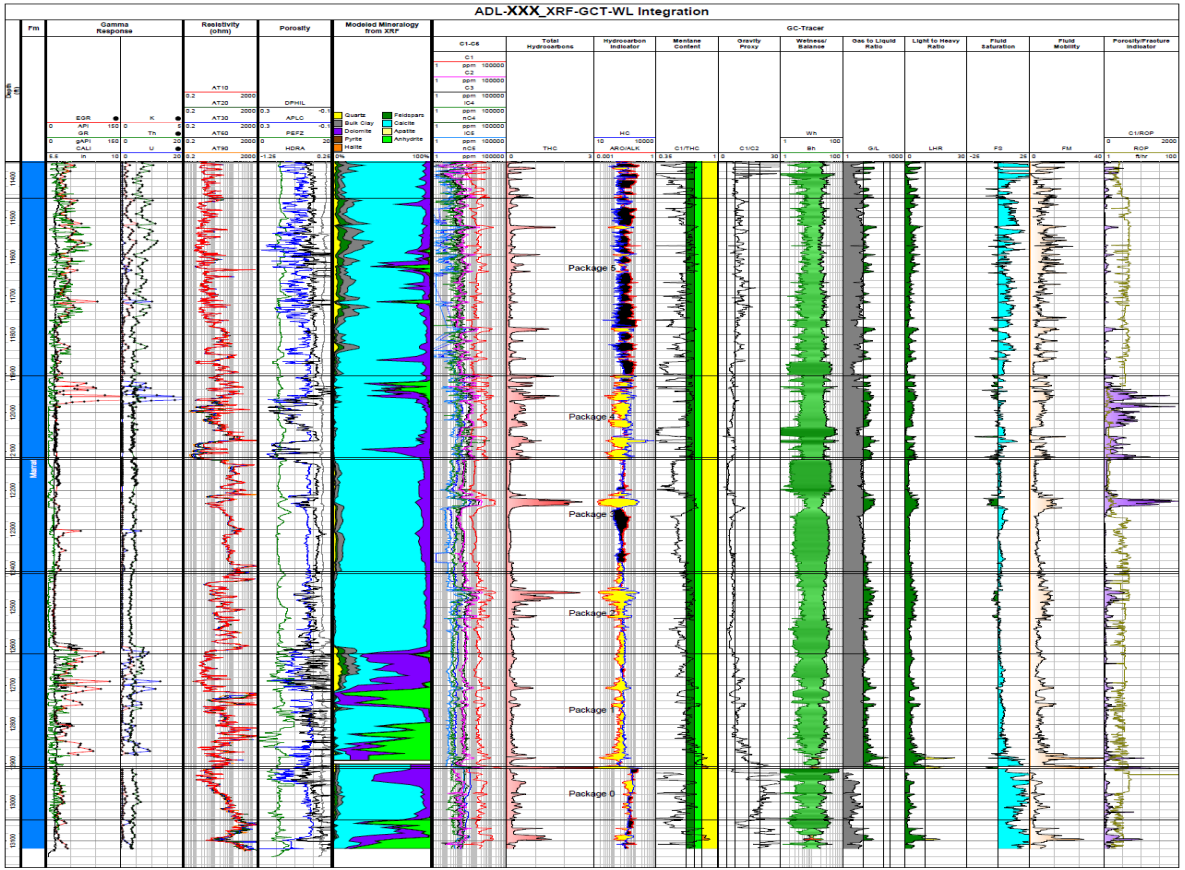


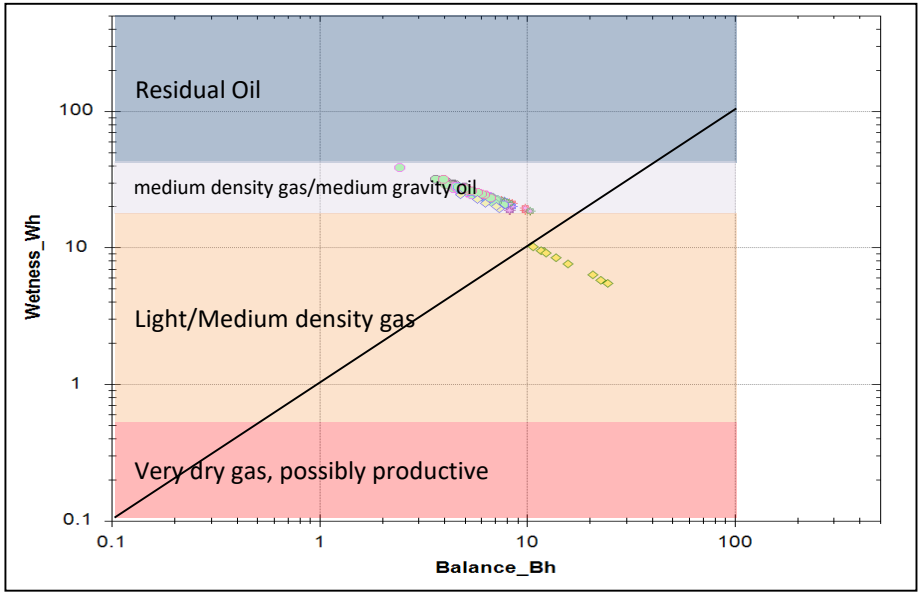
- Identification of Dolomitic Lst intervals in Middle Marrat addressing the highest Porosity . Meanwhile identified the sweet zones and perforation intervals has been advised.

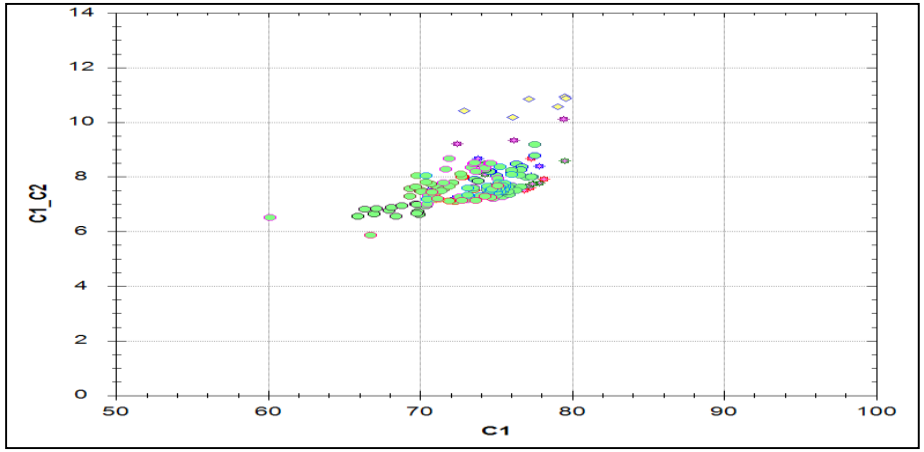
- Elemental Gamma Ray and Wire Line Gamma Ray showing the same responses.

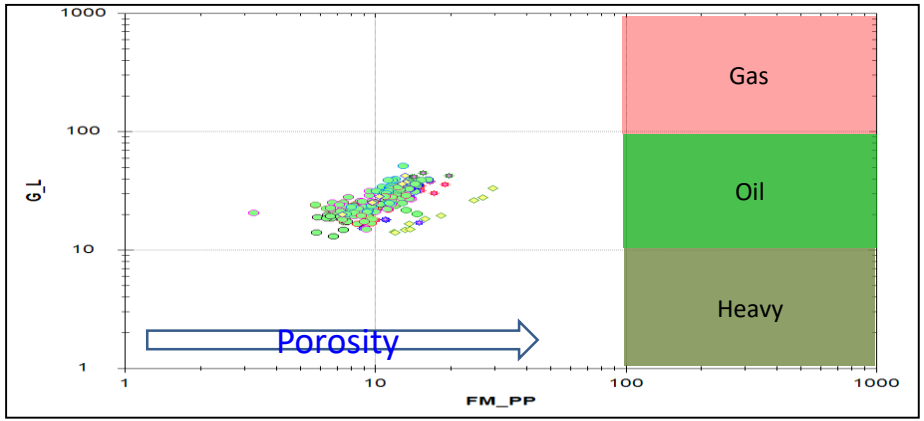
- Average Brittleness Index , easily and successfully used to qualitatively differentiate the brittle and ductile intervals.

- Chemostratigraphic zonation was built and nine different packages were determined based on distribution of minerals within the Najmah, Sargelu, Dharuma, and Marrat formations. The clarity and sensitivity of the packages are sufficient to be applied on future well correlations.

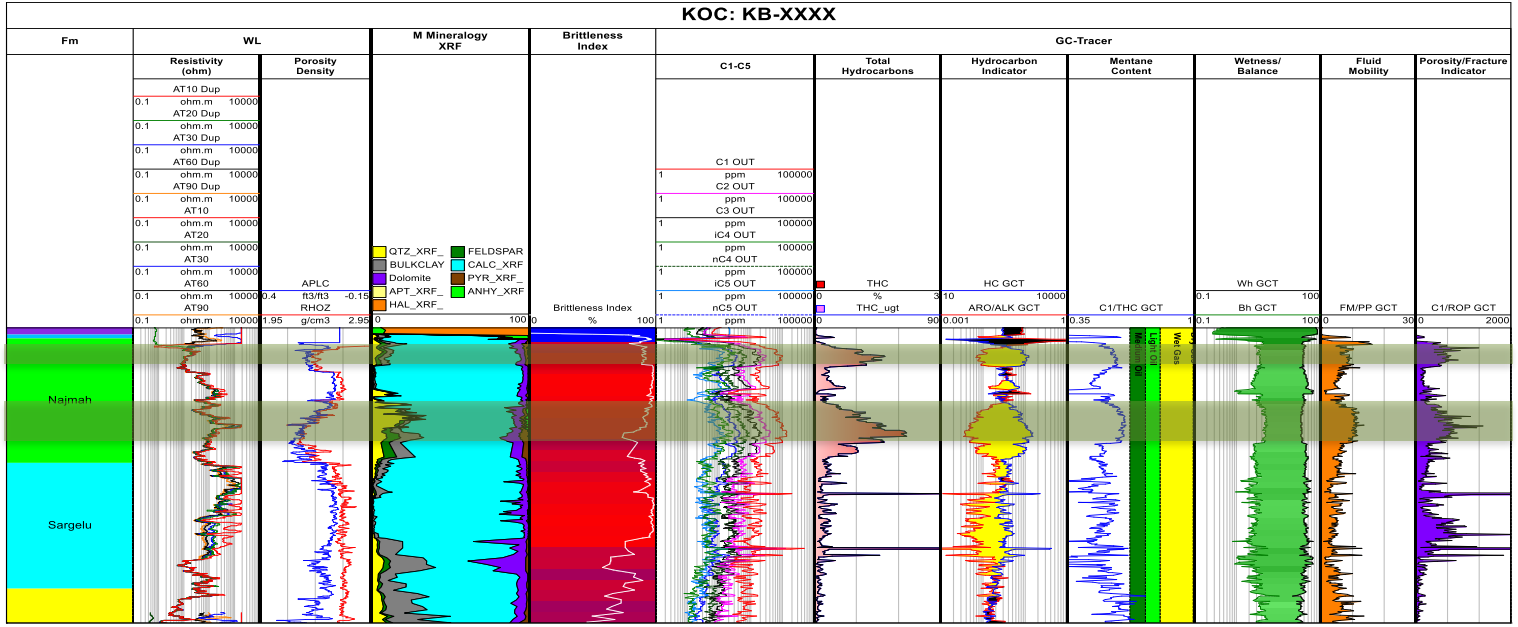






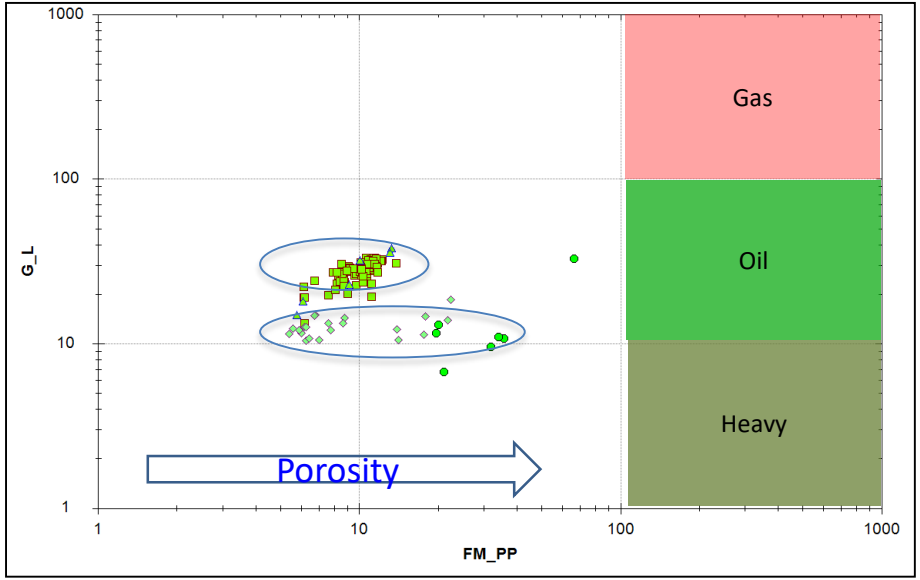


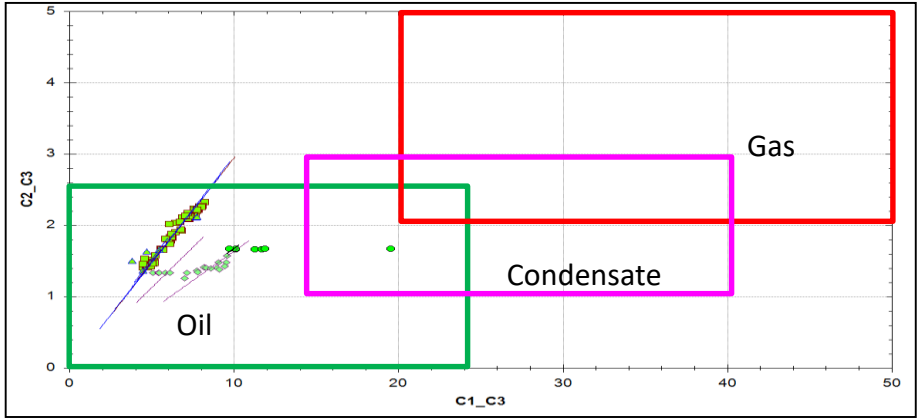
- **C1% between 70% to 78% is indicating Medium oil**
- **C1/C2 between 6 to 08 indicating medium**
- **The Wetness vs Balance cross plot plots the U Marrat & M Marrat in the Medium Oil Group**
- **Gas/liquid ratio plots in oil zone**
- **Porosity indicator showing porous intervals**

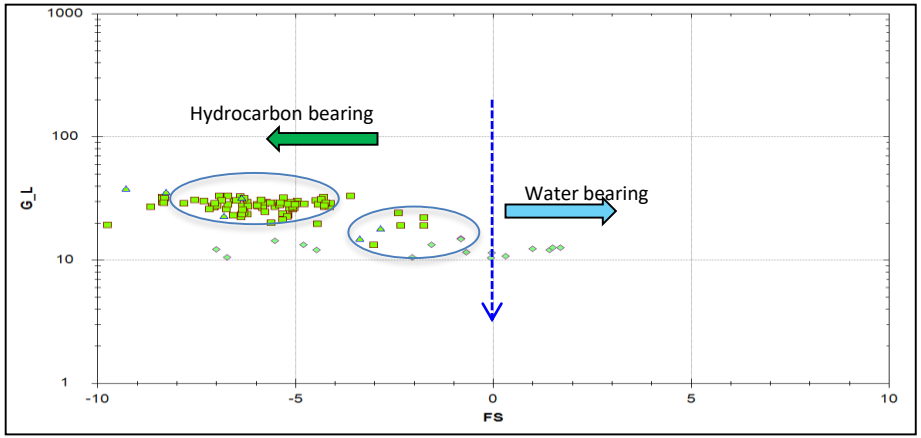


Paleoredox Elements (V, Ni , Mo & U) and Advanced Gas analysis suggested presence of significant hydrocarbon oil bearing on the above selected Intervals. XRD showing presence of Dolomite through the same selected intervals.

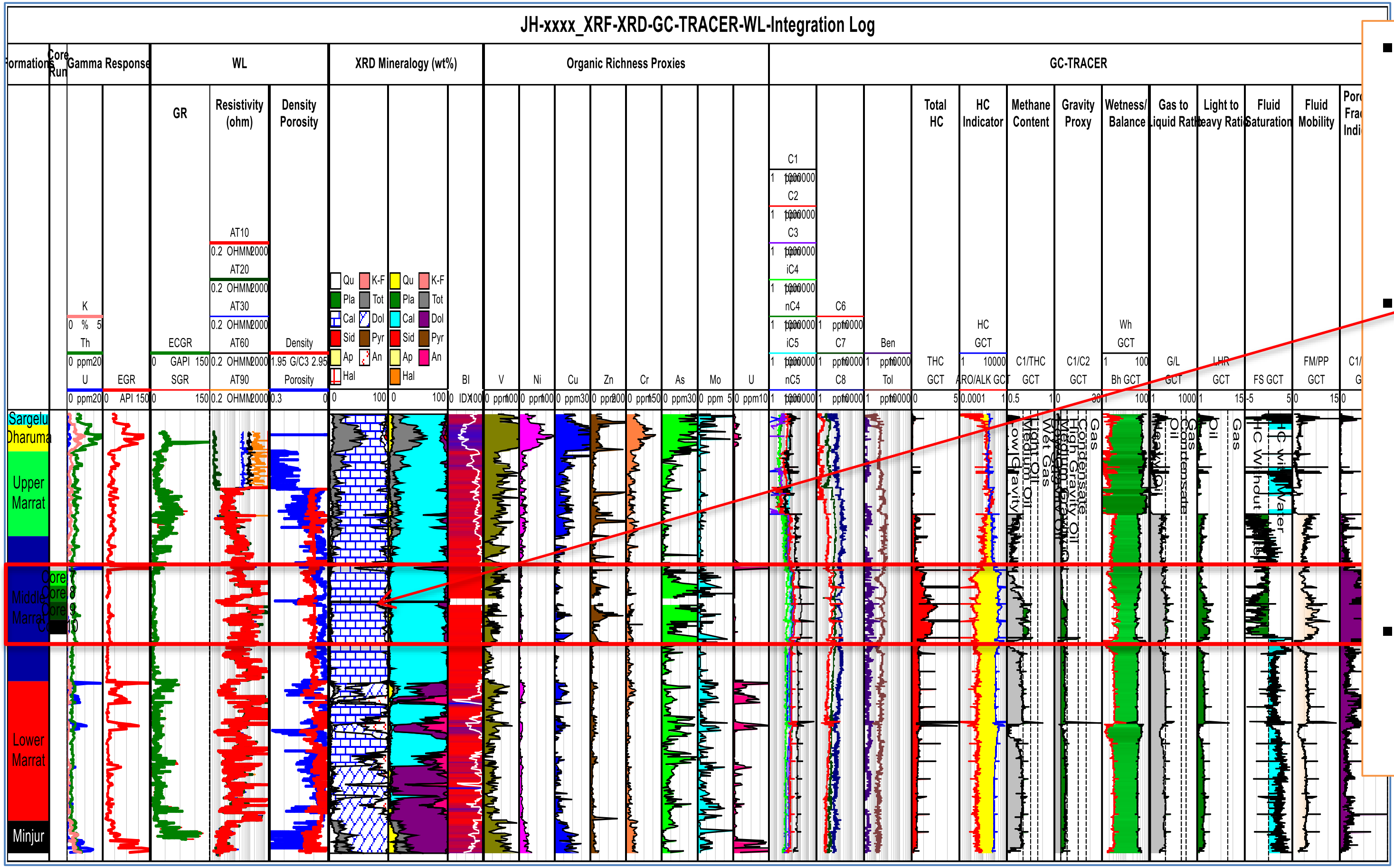
2 interested intervals were picked through Najmah reservoir based on gas analysis. Well test results confirm the presence of hydrocarbon through the same intervals selected while drilling based on gas analysis and XRF/XRD.



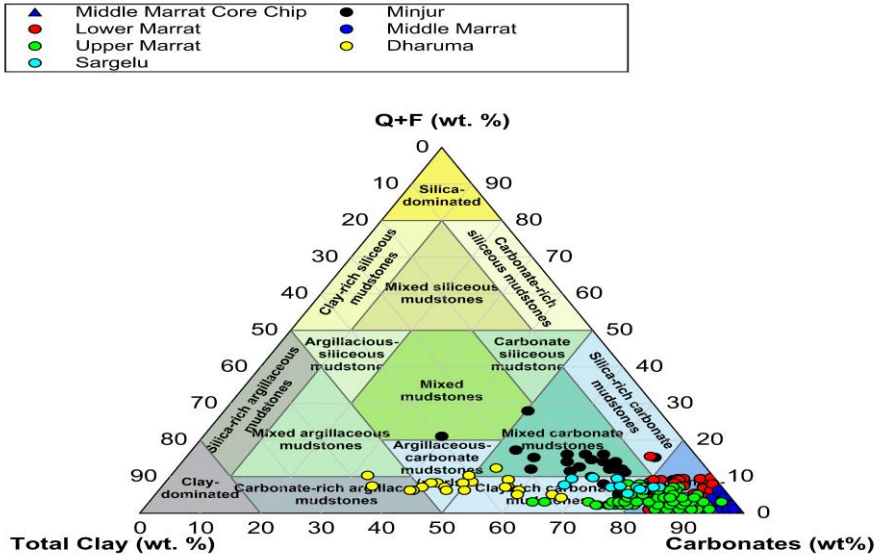


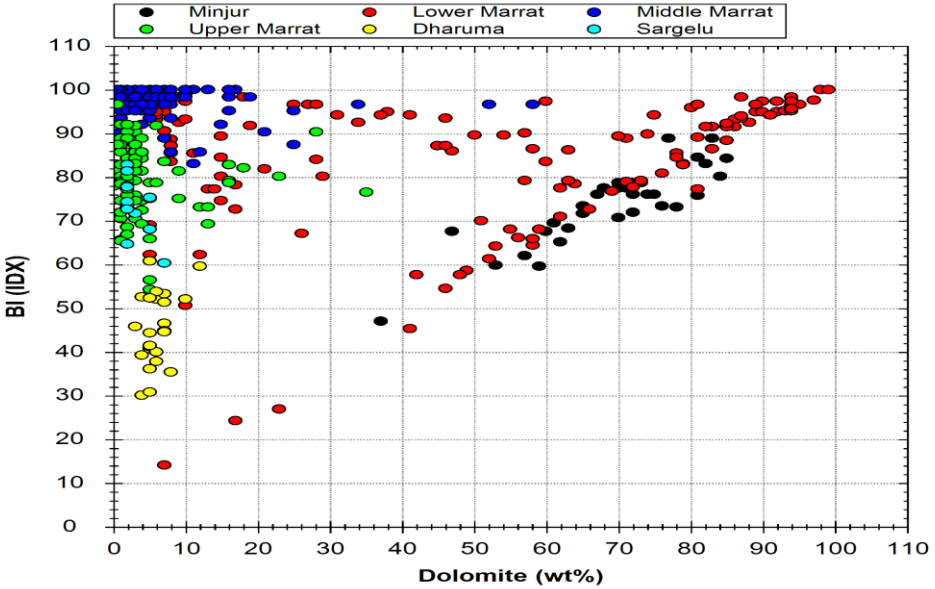


- **Oil phase identified**
- **Increase C1/C3 indicating increased fluid maturity**
- **Majority groups below the 0 mark on the FS vs. G/L indicating Hydrocarbon bearing zone and above 0 indicates possible water or tight formations**
- **Porosity indicator putting question mark for porosity**



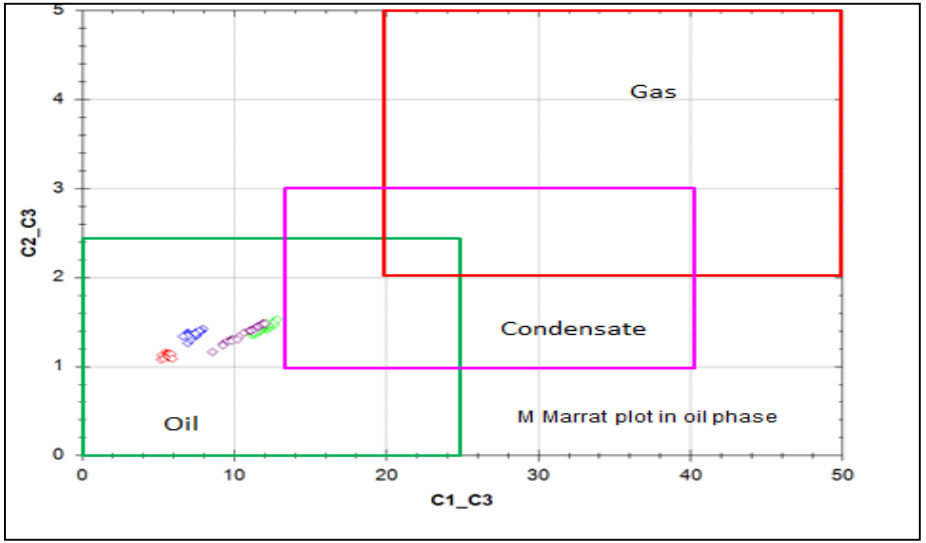
- Porous intervals were identified through targeted formation with XRD direct measured mineralogy , brittleness index .
- Dolomite layers from XRF analysis, confirmed by Density Porosity and resistivity from wire line data as shown on the XRD-XRD-GCT-WL Integration Log .
- Perforation intervals have been advised based on XRF-XRD-GCTracer Data.

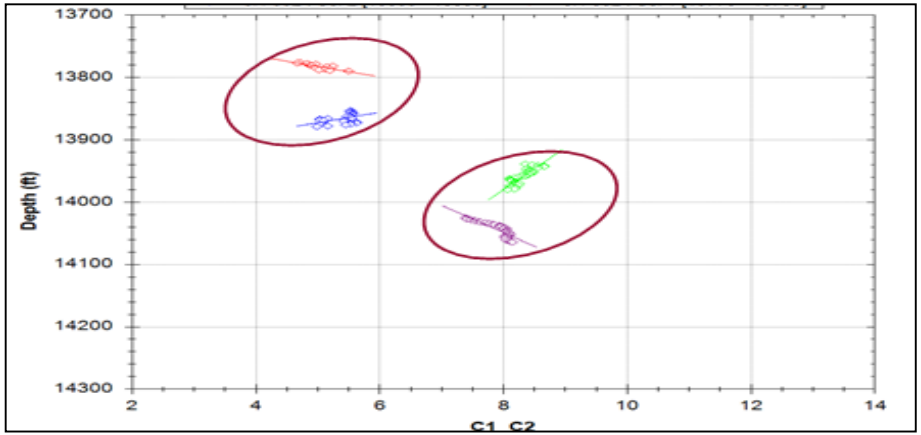


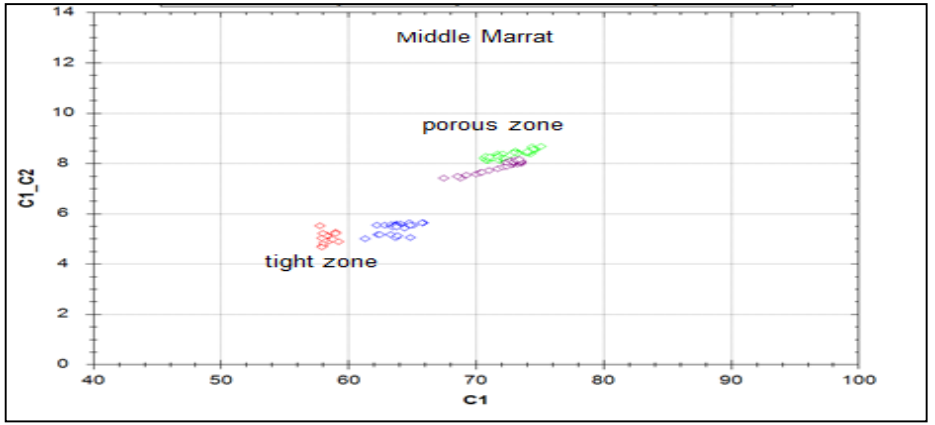


Detailed Mineralogical Composition for all analyzed formations within carbonates typing and content of silicates.

Brittleness Index Vs Dolomite and Total Carbonates through analyzed Formations: Direct proportion between BI Vs Carbonates: BI Increase with Carbonates increase. And Reverse Proportion between BI Vs Total Clay: BI Decrease while Total Clay increase.







- **C1% between 60% to 75 % and C1/C2 between 5-8 indicating medium gravity oil in M Marrat**
- **Increase in C2/C3 leading to better fracture permeability**
- **Presence of 2 zone with deferent porosity behavior in Middle Marrat**

Summary and Conclusion

- The advanced mudlogging techniques were confirmed as a reliable approach for reservoir evaluation while drilling.
- Gas chromatograph and XRF/XRD data able to identify reservoir sweet zone, fluid contacts, dolomitization intervals in carbonate reservoirs.
- Data quality enabled direct comparison among mud gas, elemental and mineralogy cutting analysis versus core, and well test and wire line data, when available.
- Surface data are always available while drilling, whatever the hole conditions, drilling challenges, well type.