

Fluid Detection in Carbonate Reservoirs utilizing Gas Analysis-A Case Study*

Ali Abu Ghneej¹, Jalal Dashti¹, Badruzzaman Khan¹, Heyam Ammar¹, Abdulrazaq AL-Nabhan¹, Sunil K. Singh¹, Talal Al-Adwani¹, and Nacif Marai¹

Search and Discovery Article #41116 (2013)

Posted February 28, 2013

*Adapted from extended abstract prepared in conjunction with poster presentation at AAPG International Convention and Exhibition, Singapore, 16-19 September 2012, AAPG©2012

¹Kuwait Oil Company, Kuwait (AGhneej@kockw.com)

Abstract

Explorationists have been continuously developing new technologies and techniques to achieve the goal of discovering Hydrocarbon. Gas detection while drilling and analysis of the data is very vital in evaluating the hydrocarbon potential of the formations. It is particularly significant in exploration of high pressure, tight, fractured carbonate reservoirs in Kuwait, which are drilled with Oil Base Mud (OBM) having high barite content causing severe formation damage.

This paper aims to present the procedure of interpreting gas data collected while drilling and their utility in formation evaluation, identification of productive intervals, fluid characterization and identification of gas/oil and oil/water contacts. Total gas and C1-C5 components readings, synchronized with depth and corresponding lithology, are acquired from the gas detector. The data is verified for any contamination, which may be due to mud containing oil, mud additive or pipe dope etc. The Gas Quality Ratio (GQR) is calculated to determine any contamination in the gas data. If the GQR is in the range of 0.8-1.2, the gas data is considered suitable to carry out gas analysis. As the reservoirs are drilled with OBM, the gas chromatograph gives abnormally high C5 against some sections, which is not considered for the analysis. The good quality data is used to calculate various ratios in sections showing significant gas readings. Recently in few exploratory wells, this gas analysis was carried out for Najmah and Marrat reservoirs. It has been observed that the more useful ratios in these carbonate reservoirs of Kuwait are $C1/C1+C2+C3+C4+C5$, Pixler ratios ($C1/C2$, $C1/C3$ and $C1/C4$), Wetness ($100 * C2+C3+C4+C5/C1+C2+C3+C4+C5$), Balance ($C1+C2/C3+C4+C5$) and Character ($C4+C5/C3$). $C1/C1+C2+C3+C4+C5$, Pixler ratios and Wetness, Balance and Character indicate dry gas in the Upper section of Najmah followed by gas-condensate. These ratios indicate liquid hydrocarbon in Marrat. The results of the gas analyses were integrated with log and core data and were found to be very useful in identification of production test intervals. The gas analyses results have been ratified by production test results. Proper gas analyses on uncontaminated gas data can help to identify test intervals even in wells where log data could not be acquired due to well condition. It is recommended to record good quality gas data and carry out gas analyses in all exploratory wells.

Introduction

Exploration Geologists have been continuously developing new technologies and techniques to achieve the goal of discovering Hydrocarbon. Gas detection while drilling and analysis of the data is very important in evaluating the hydrocarbon potential of the formations. It is particularly significant in exploration of high pressure, tight, fractured carbonate reservoirs in Kuwait, which are drilled with Oil Base Mud (OBM) having high barite content causing severe formation damage.

When a reservoir is drilled, ditch or drill cuttings contain fluids and gases carried to the surface where it is possible to evaluate it and determine quality, type and productivity of fluids and gases contained in the reservoir. Gas is extracted from drilling fluid by agitation in an enclosed chamber called gas trap, which is installed in the possum belly before the shale shaker. This gas moves through flow line to reach Total gas sensor and chromatograph gas detector.

There are many factors that affects the gas reading such as diameter of the hole, increase volume of ditch produces increase amount of gas, mud properties and mud additives, distance between gas trap and well bore and nature of formation.

By analyzing hydrocarbons in the drill cuttings by chromatograph, it will be possible to determine quality of hydrocarbons. Standard sensors used on current wells, measure hydrocarbon components from methane C1, ethane C2 up to Iso pentene IC5 and normal pentane NC5. The ratio of methane to heavier hydrocarbon components ethane, propane, butane and pentane is indicative of gas, oil and water productive potential (Pixler 1969).

Gas evaluation and interpretation while drilling based on gas chromatograph is a geochemical analysis of the drilling mud and drill cuttings to identify and analyze gas-bearing formations, to pick pay zone, to identify fluid contact and to distinguish between productive and non-productive intervals based on fluid characterization.

In this paper, we present our study on the geochemical analysis of formation gases in the Early Jurassic, Toarcian, Middle Marrat Formation and Middle Jurassic, Oxfordian to Early Kimmeridgian, Najmah Formation. The Early Jurassic, Middle Marrat Formation comprises of wackestone to grainstone with thin inter-beds of crystalline dolomite. The dolomitic layers impart better porosity to otherwise tight section. The early Jurassic Lower Marrat is more dolomitic with thick anhydrite inter-beds. The porous dolomitic layers within Middle Marrat Formation have porosity of 10-20 p.u., whereas, Lower Marrat Formation has porosity of 2-5 p.u. The Middle Jurassic Oxfordian to Early Kimmeridgian Najmah Formation is divisible into two units, the Lower Unit is mudstone rich in organic matter and Kerogen and the Upper unit comprises of bioclastic packstone. Below it, the Sargelu Formation, which is also divisible into two units, the lower unit, is dominantly mudstone to wackestone and the upper unit is wackestone to packstone. Both the Formations are very tight with porosity in the range of 2-5 p.u.

Methodology

To evaluate gas quality contained in drilling mud we use Gas Quality Ratio (GQR) to determine any contamination in the gas data ([Figure 1](#)). If the GQR is in the range of 0.8-1.2, the gas data is considered suitable to carry out gas analysis.

$$\text{Gas Quality Ratio} = \text{GQR} = \text{TG} / (\text{C1} + 2*\text{C2} + 3*\text{C3} + 4*(\text{iC4} + \text{nC4}) + 5*(\text{iC5} + \text{nC5}))$$

Another way to evaluate gas quality is the cut off on C1 (Figure 2), a cut off is necessary to be applied in order to remove the bad data that cannot be used for the interpretation (Scattered data, non-interpolated behavior). Normally this cut-off is determined by cross plots between C1 and Wetness or C1 and C1/Sum. The gas readings eliminated come normally from formations containing very low quantity of hydrocarbons or from all hydrocarbons detected which are not associated to a true drilling gas (mainly contamination gas due to the mud).

Only the sections with normal gas distribution are considered in the gas interpretation. The good quality data is used to calculate various ratios in sections showing significant gas readings. Recently, in few exploratory wells this gas analysis was carried out for Najmah and Marrat reservoirs (Figure 3). It has been observed that the more useful ratios used to interpret gas reading in these carbonate reservoirs of Kuwait are:

$$\text{Gas dryness} = \text{C1} / (\text{C1} + \text{C2} + \text{C3} + \text{C4} + \text{C5})$$

$$\text{Pixler ratios (C1/C2, C1/C3 and C1/C4)}$$

$$\text{Wetness (Wh)} = 100 * (\text{C2} + \text{C3} + \text{C4} + \text{C5}) / (\text{C1} + \text{C2} + \text{C3} + \text{C4} + \text{C5})$$

$$\text{Balance (Bh)} = (\text{C1} + \text{C2}) / (\text{C3} + \text{C4} + \text{C5})$$

$$\text{And Character (Ch)} = (\text{C4} + \text{C5}) / \text{C3}$$

The previous equations are plotted to determine fluid type, contacts and evolution. In addition, these ratios are plotted only in sections showing gas readings.

Gas interpretation is a series of simple procedures based on a collection of true gas readings (from gas trap) exactly synchronized with the total depth and associated with right lithology. Exploration geologists have been continuously developing new technologies and techniques to achieve the goal of discovering hydrocarbon. Gas detection while drilling and analysis of the data is very important in evaluating the hydrocarbon potential of the formations. It is particularly significant in exploration of high pressure, tight, fractured carbonate reservoirs in Kuwait, which are drilled with oil base mud (OBM) having high barite content causing severe formation damage.

Gas Acquisition

The gas sample is directly collected from the possum belly using a degasser, QGM (Quantitative Gas Measurement), and continuously sucked to the unit using an adequate suction pump with a constant flow rate of 3 l/min.

After passing through a filter system to eliminate moisture and liquids, a proper and sensitive gas distribution system distributes the same amount of 0.3 l/min to all the Gas Systems present in the Unit.

In this practice, we used Flame Ionization Detector Technology, FID, in both total gas and the standard C1 to C5 chromatograph system (Figure 4).

Application and Case Study in Najmah, Sargelu and Marrat Formations in Some Wells in Kuwait Oil Fields

Before we do our interpretation on gas record, we must ensure that gas reading clear from any contamination. Figure 5, Figure 6, and Figure 7 illustrate all useless values that came from background gases, lithological effect and recycled gas removed to enhance quality of data.

For gas interpretation, we used many equations as mentioned earlier. The first equation, gas dryness C1/Sum (Figure 8) is a good indication for the wetness of the gas, the fluid evolution, and the discontinuities in the fluid. The second method, Pixler ratios (Figure 9), the magnitude of the methane to ethane ratio determines if the reservoir contains oil, gas or water or if its nonproductive water zone (Pixler 1969). Also from Pixler ratio slope line used to indicate permeability of reservoir as steep slope indicate tight zone. The third method is the relation between wetness and balance (Figure 10) that allows us to determine quality and productivity of hydrocarbon contained in drilling fluid. Regarding to character ratio, the presence of a dense hydrocarbon fluid can be confirmed and this should aid in the distinction of a very wet gas from very high gravity oil.

Result

Gas dryness, Pixler ratios, wetness, balance and character indicate condensate gas in the upper section of Najmah followed by very light oil. These ratios indicate liquid hydrocarbon in Marrat. The results of the gas analyses were integrated with log and core data and were found to be very useful in identification of production test intervals (Figure 11 and Figure 12). The gas analyses results have been ratified by production test results. Proper gas analysis on uncontaminated gas data can help to identify test intervals even in wells where log data could not be acquired due to well condition. It is recommended to record good quality gas data and carry out gas analyses in all exploratory wells.

Conclusions

Real time detection of in placed reservoir fluid content in drilling mud can be determined within a minute after the reservoir was drilled by using mud log and well site geochemical log. Gas analysis while drilling as exploration way involves the acquisition of gas samples from gas trap (steel box sits on possum belly) to evaluate and interpret presence of hydrocarbon components C1, C2, C3, IC4, NC4, IC5 and NC5 in drilling fluid and picking hydrocarbon contact by using total gas detector and gas chromatograph detector. This kind of analysis while drilling can be used on wells drilled by water-based or by oil-based mud.

Gas analysis based on gas reading is highly recommended in oil and gas exploration wells since it provides information about quality and productivity of hydrocarbon content. Proper gas analyses on uncontaminated gas data can help to identify test intervals even in wells where log data could not be acquired due to well condition.

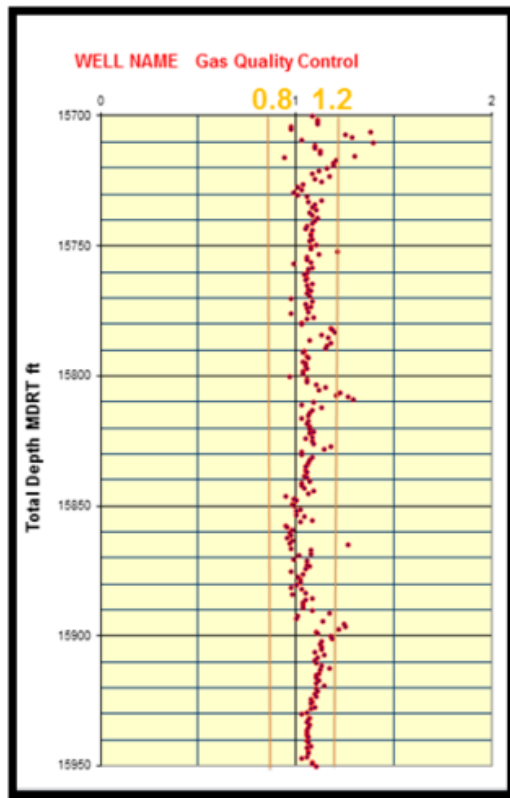
Integration of gas chromatograph during drilling, electrical log and core description will benefit and enhance the confidence of new exploration targets also there are many attempts to develop and improve mud gas analysis to study reservoir characterization and formation evaluation while drilling by develop and upgrade gas detection technology to read hydrocarbon components up to C12. In addition, the extraction of hydrocarbon gases through a gas permeable membrane was first developed by Mr. Brumboiu to develop and enhances the accuracy, repeatability and resolution of gas detection at well site (Brumboiu, et al., 2005).

References Cited

Brumboiu, A., D. Hawker, D. Norquay, D. Law, and Datalog Technology, 2005, Advances in chromatographic analysis of hydrocarbon gases in drilling fluids? The Application of Semi-Permeable Membrane Technology to High Speed TCD Gas Chromatography: Society of Petrophysicists and Well Log Analysts (SPWLA) 2005 Annual Logging Symposium, 6 p.

Pixler, B.O., 1969. Formation evaluation by analysis of hydrocarbon ratios: Journal of Petroleum Technology, v. 21, p. 665-670.

Excellent
GQR



Bad GQR

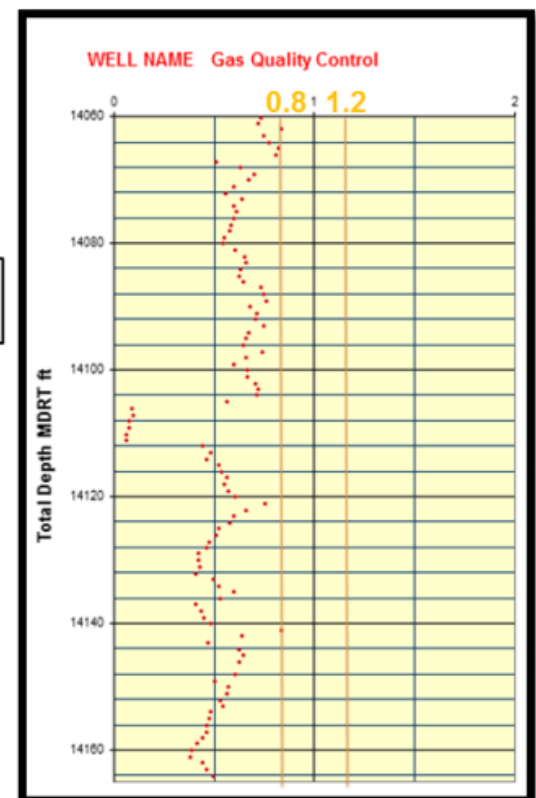


Figure 1. Illustrates the difference between contaminated and uncontaminated gas data.

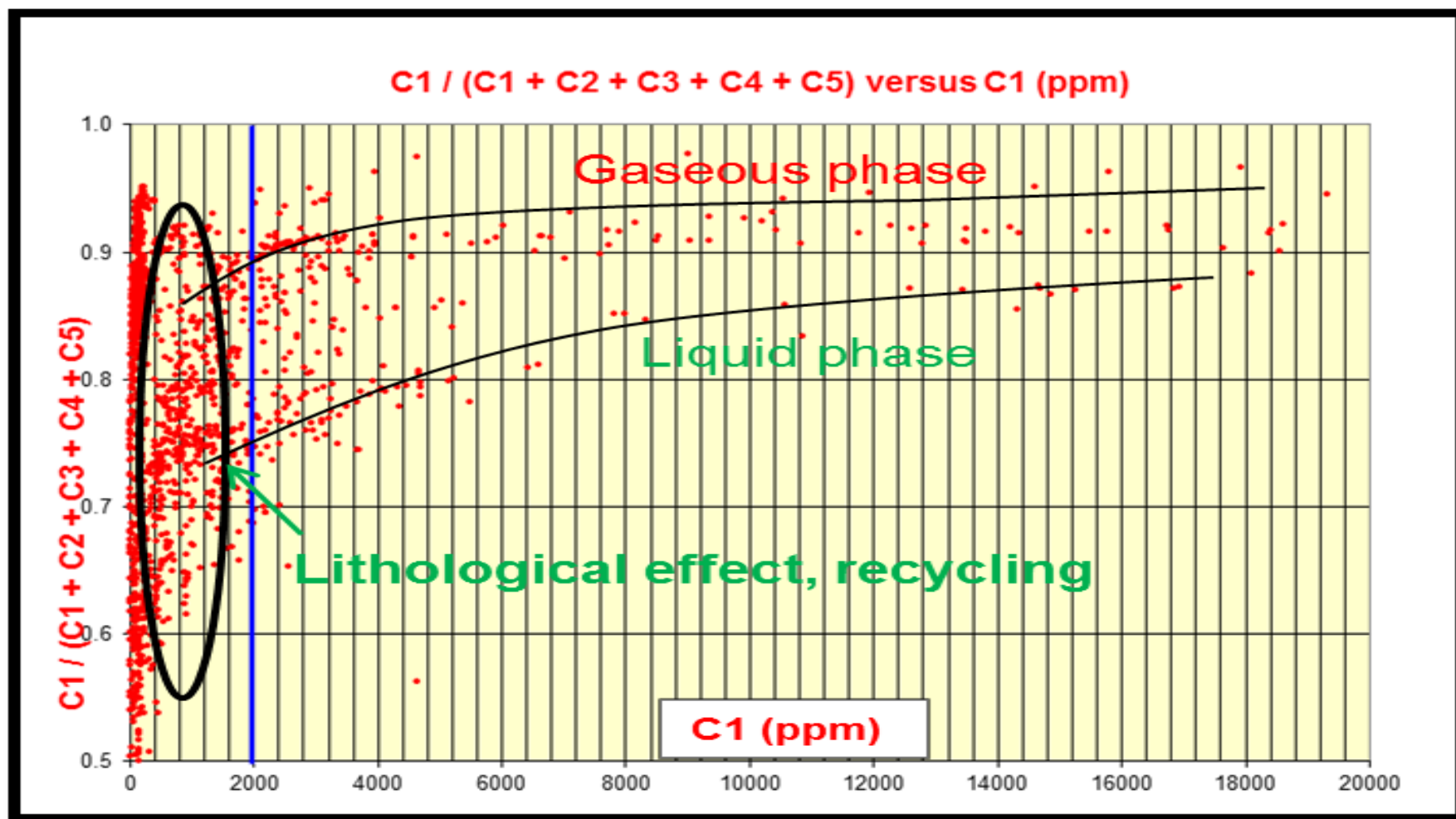
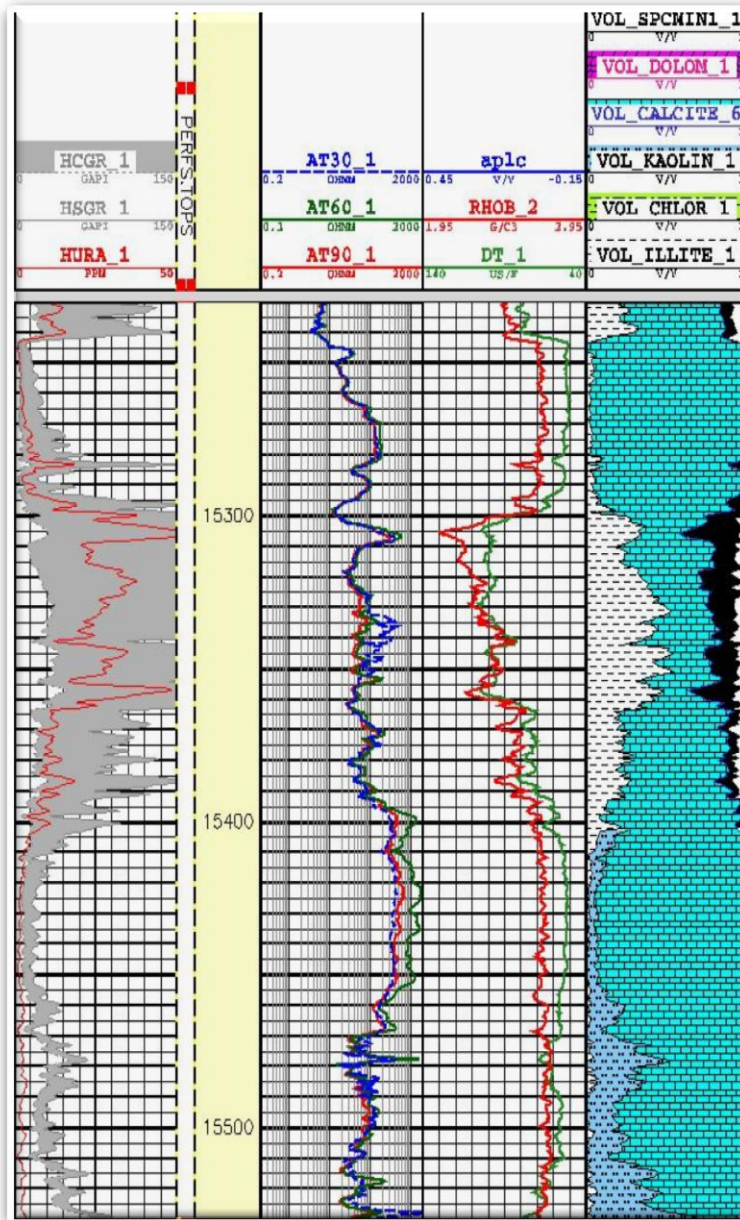
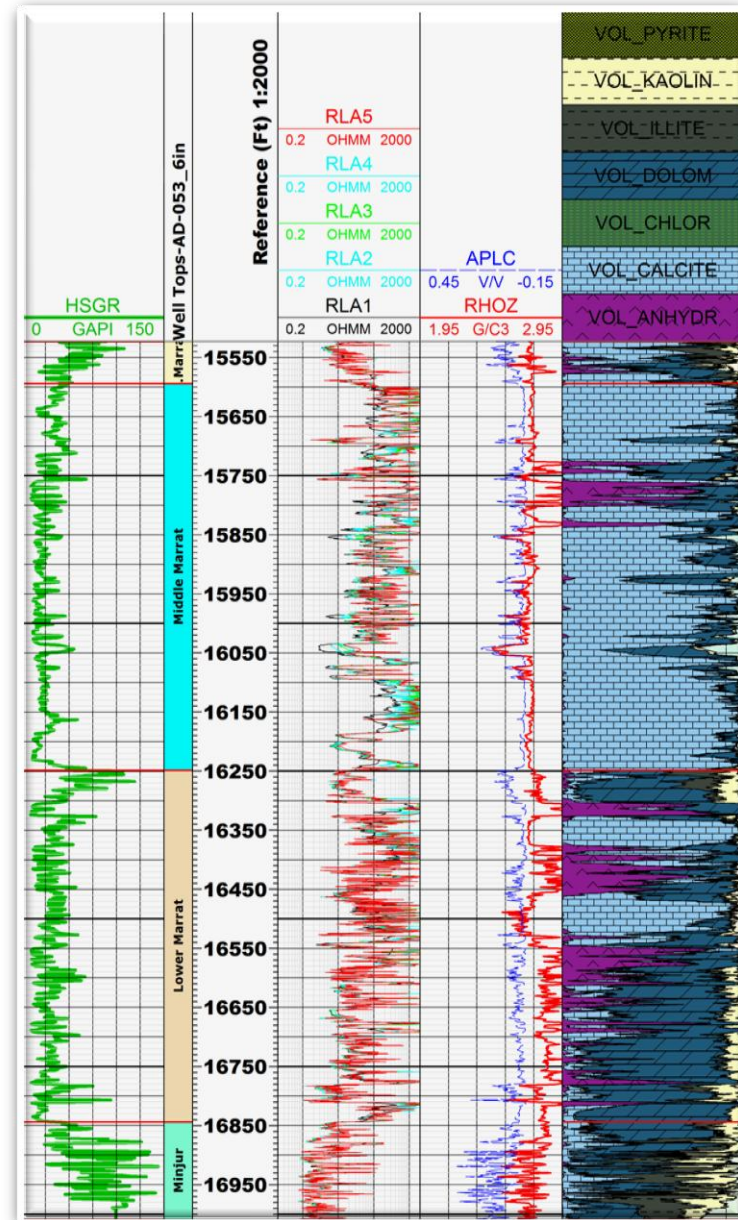


Figure 2. Cut off all values, which cannot be used in gas analysis by using $C1$ versus gas dryness $C1/\text{Sum}$.



Najmah-Sargelu Section



Middle Marrat Section

Figure 3. Showing well log interpretation in Najmah, Sargelu and middle Marrat Formations in state of Kuwait.

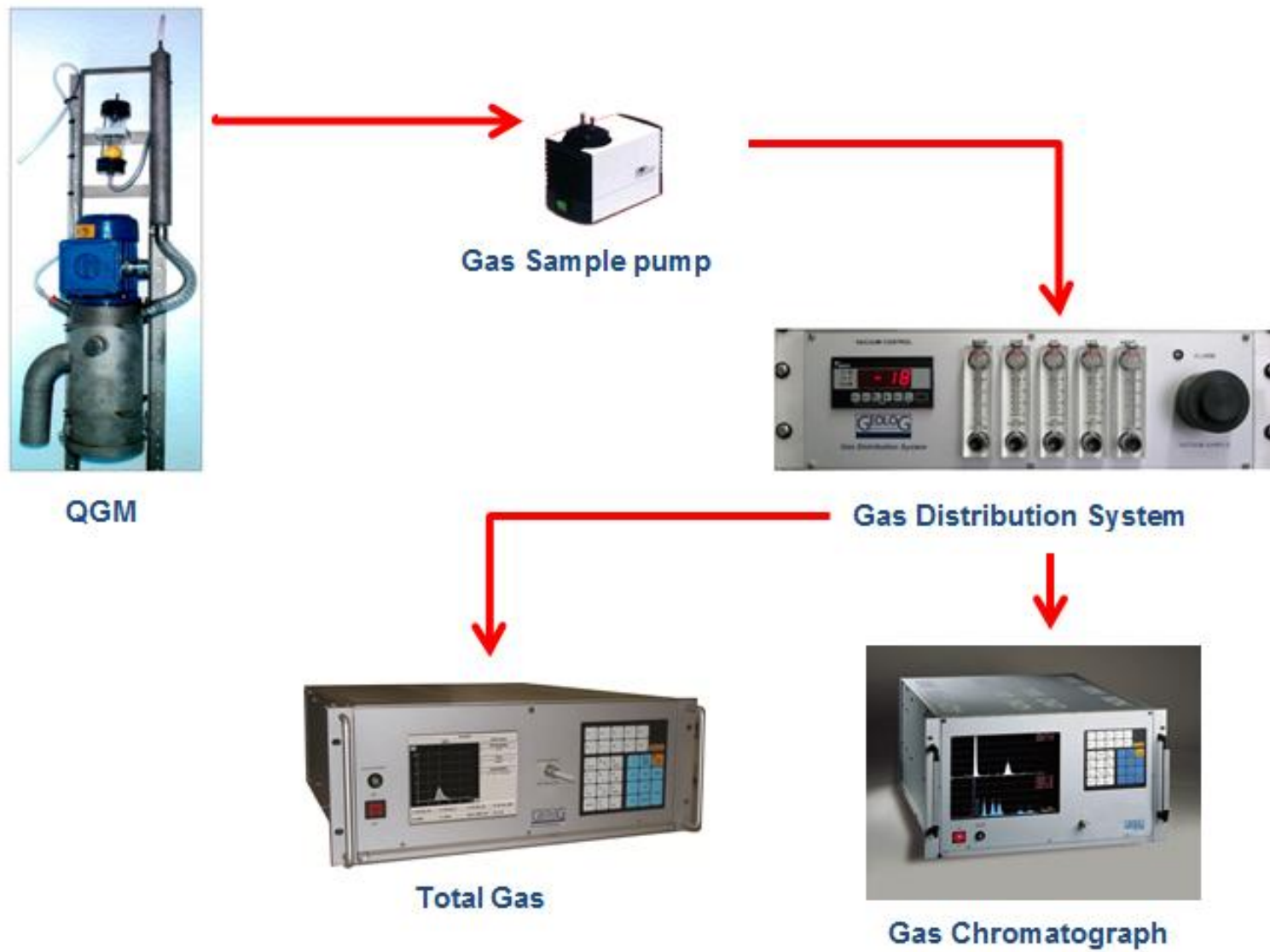
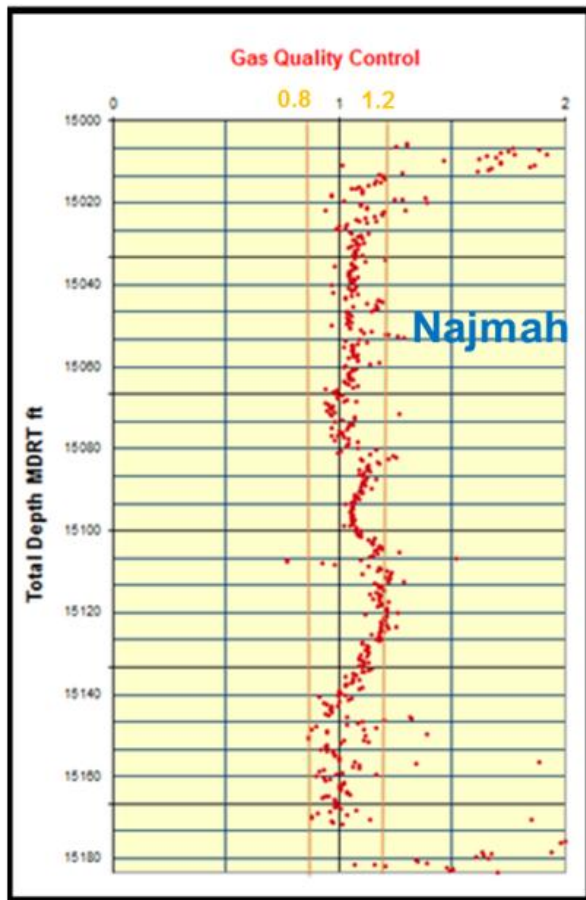


Figure 4. Showing the movement of the gas sample from gas trap QGM to Gas detector in mud unit.

Before
Gas
Quality
Control



After
Gas
Quality
Control

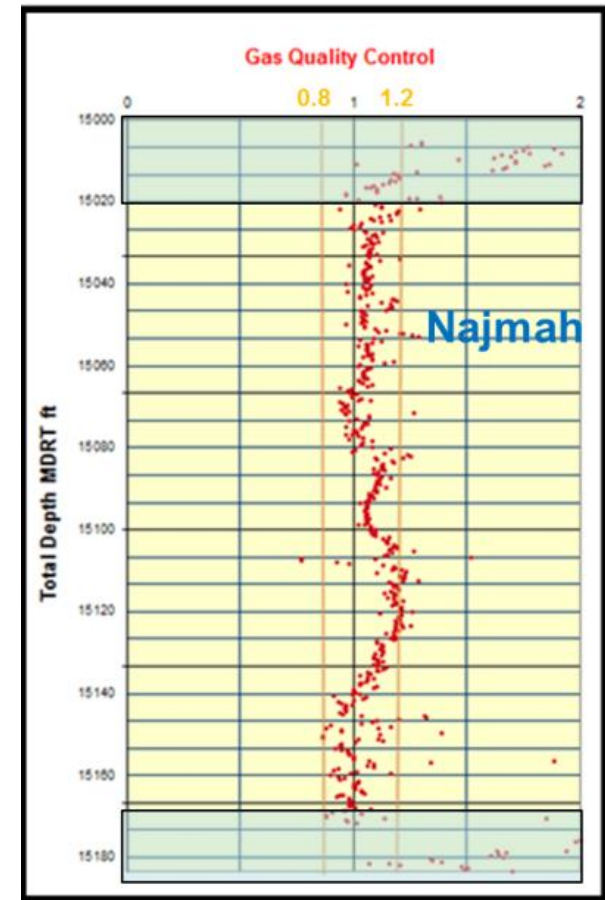


Figure 5. Showing GQR in exploration well #1, which removed all data out of range.

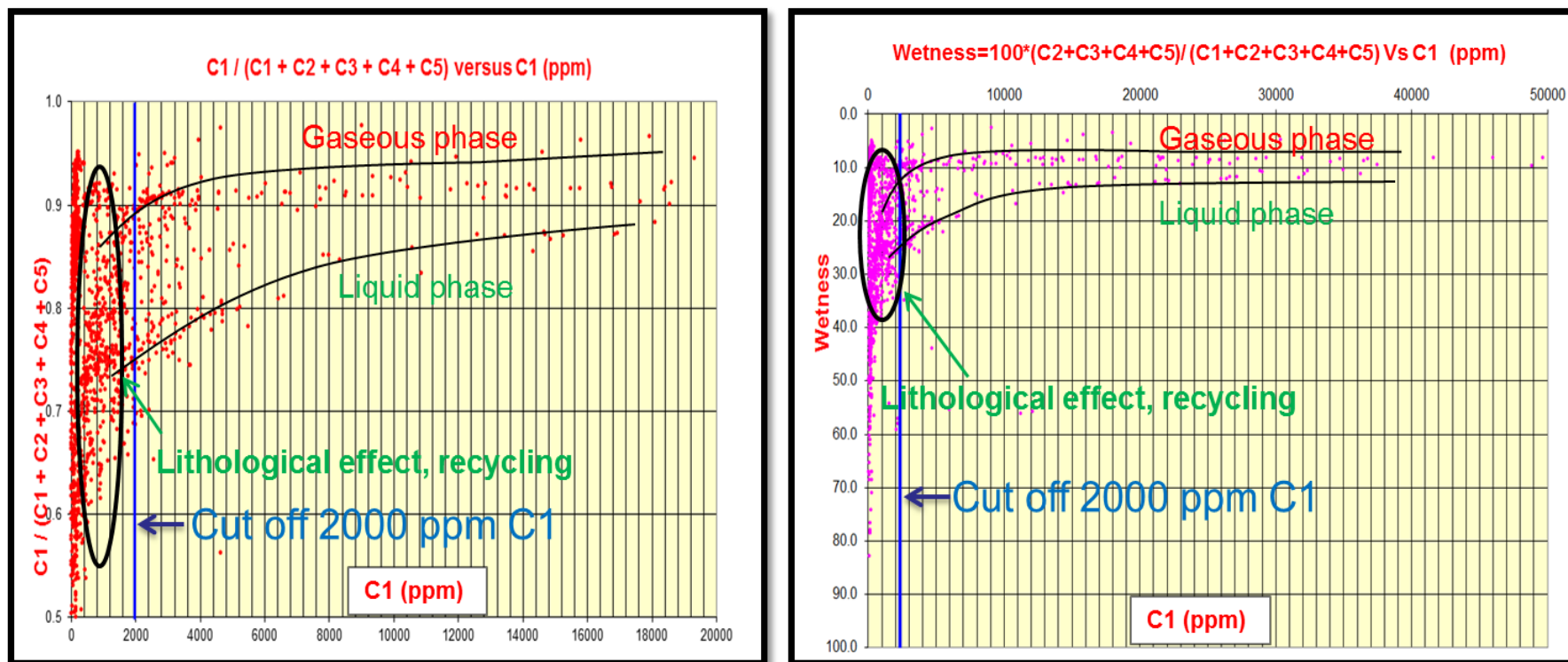


Figure 6. Showing cut off in exploration well #1 and type of fluid contained in drilling mud.

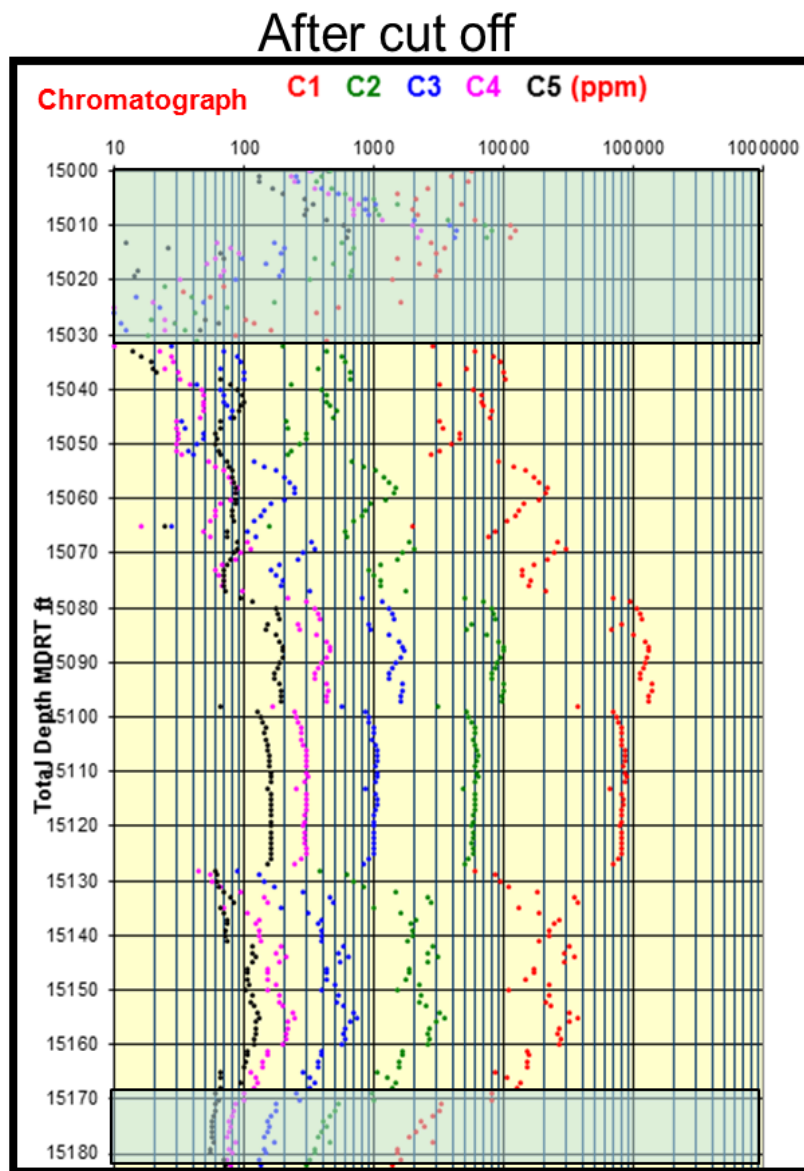
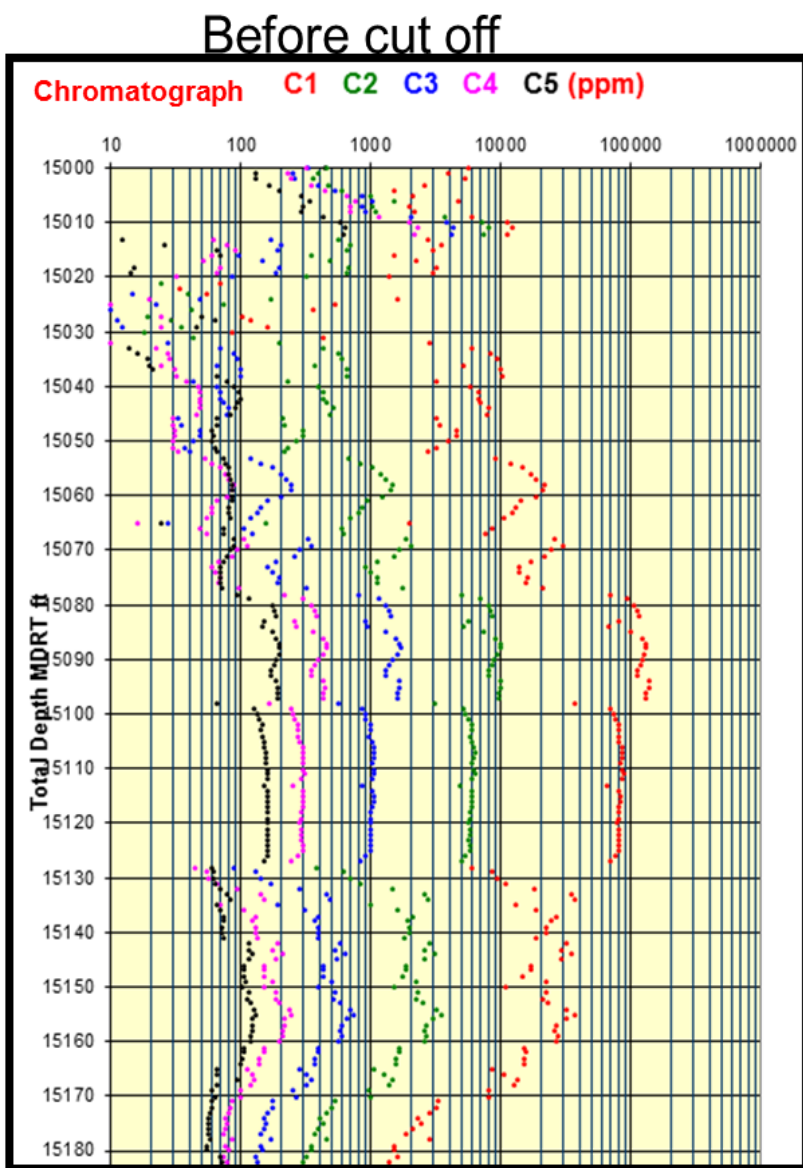
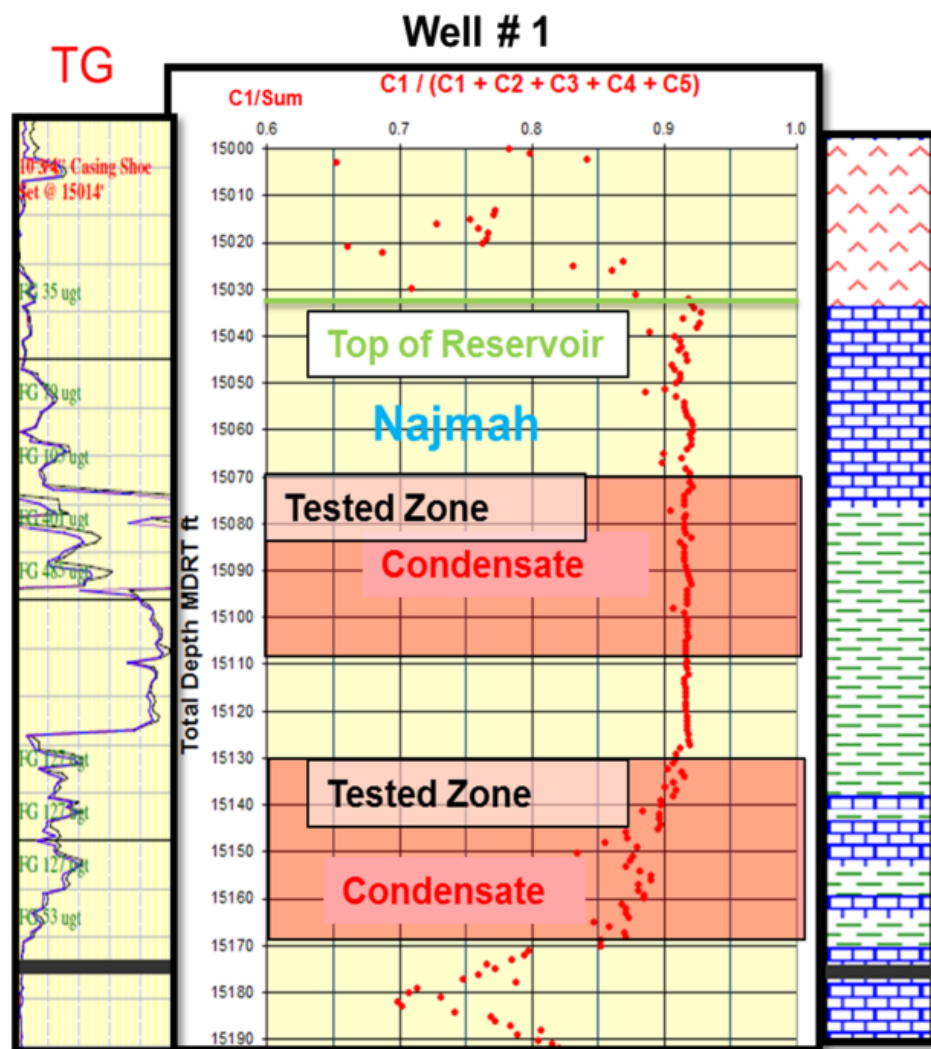


Figure 7. Showing other example of cut off in exploration well #1.



C1/Sum Ratio

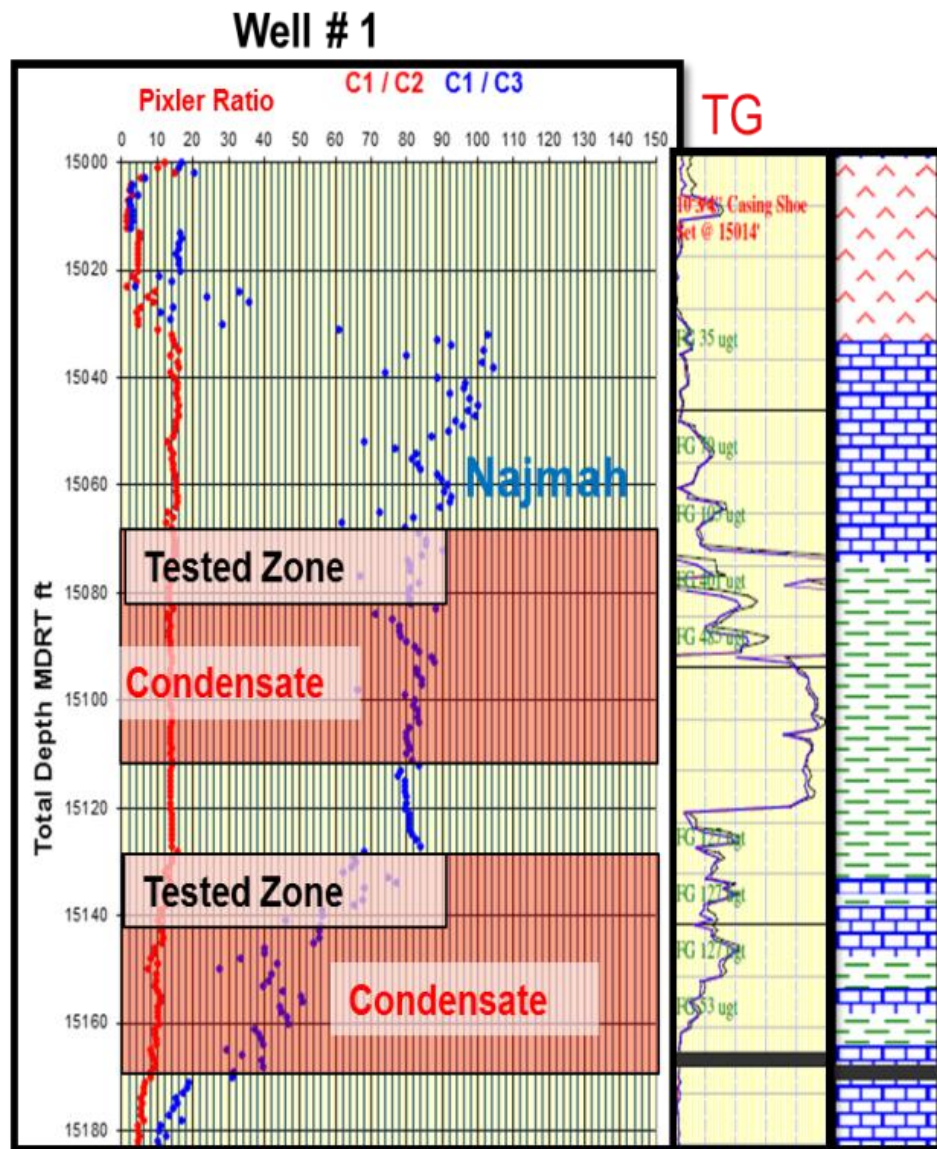
C1/Sum > 0.95 : dry gas

C1/Sum 0.85 - 0.95:
possible condensate or light oil

C1/Sum 0.6 - 0.85 :
Possible productive oil

C1/Sum < 0.6 : residual oil

Figure 8. Use of gas dryness to identify top of reservoir and quality of hydrocarbon.



Pixler Ratio

$C1/C2 > 35$: dry gas

$C1/C2$ 10 - 35 : condensate or light oil

$C1/C2$ 2 - 10 : productive oil

$C1/C2 < 2$: residual oil

Figure 9. Use of Pixler ratio to identify productivity and quality of Hydrocarbon.

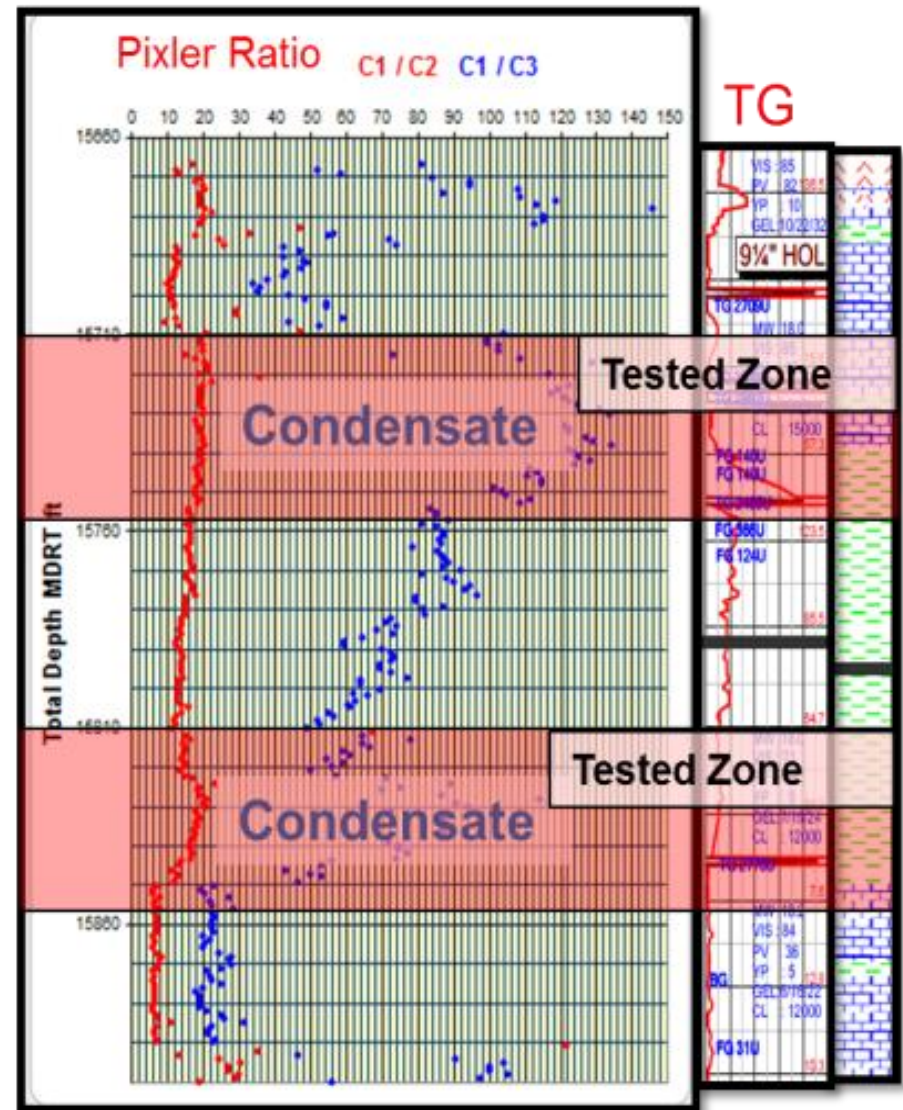
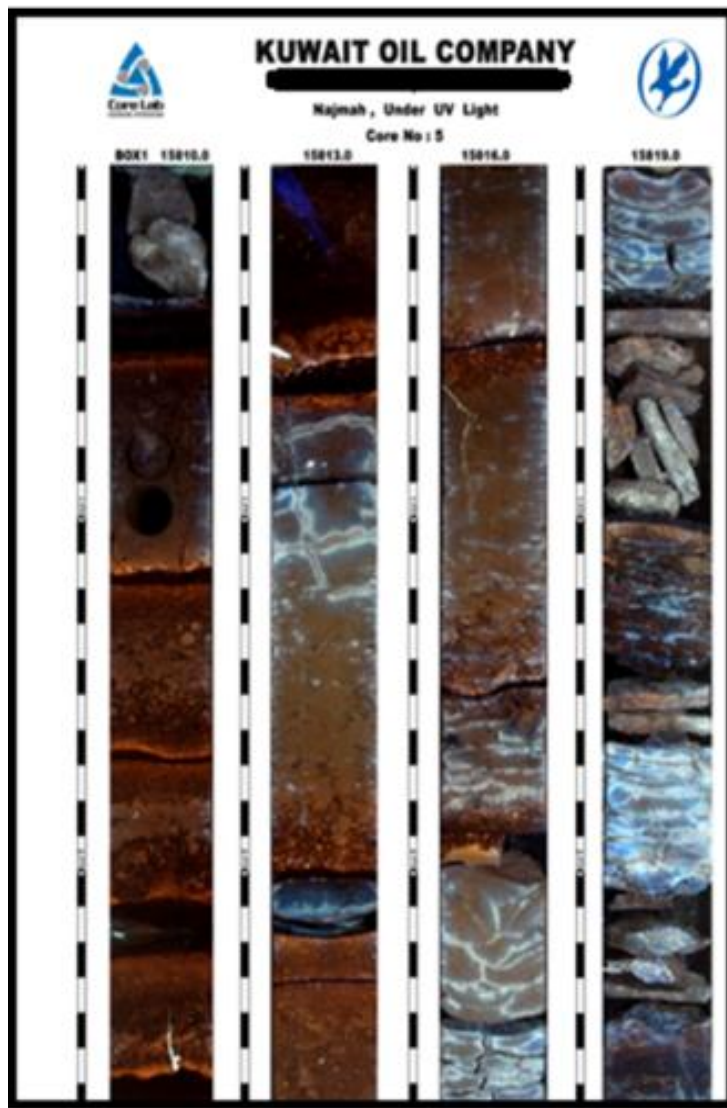


Figure 11. An example in Exploration well #2 in Najmah Formation showing integration between Pixler ratio results with Core description, which contains Hydrocarbon show.

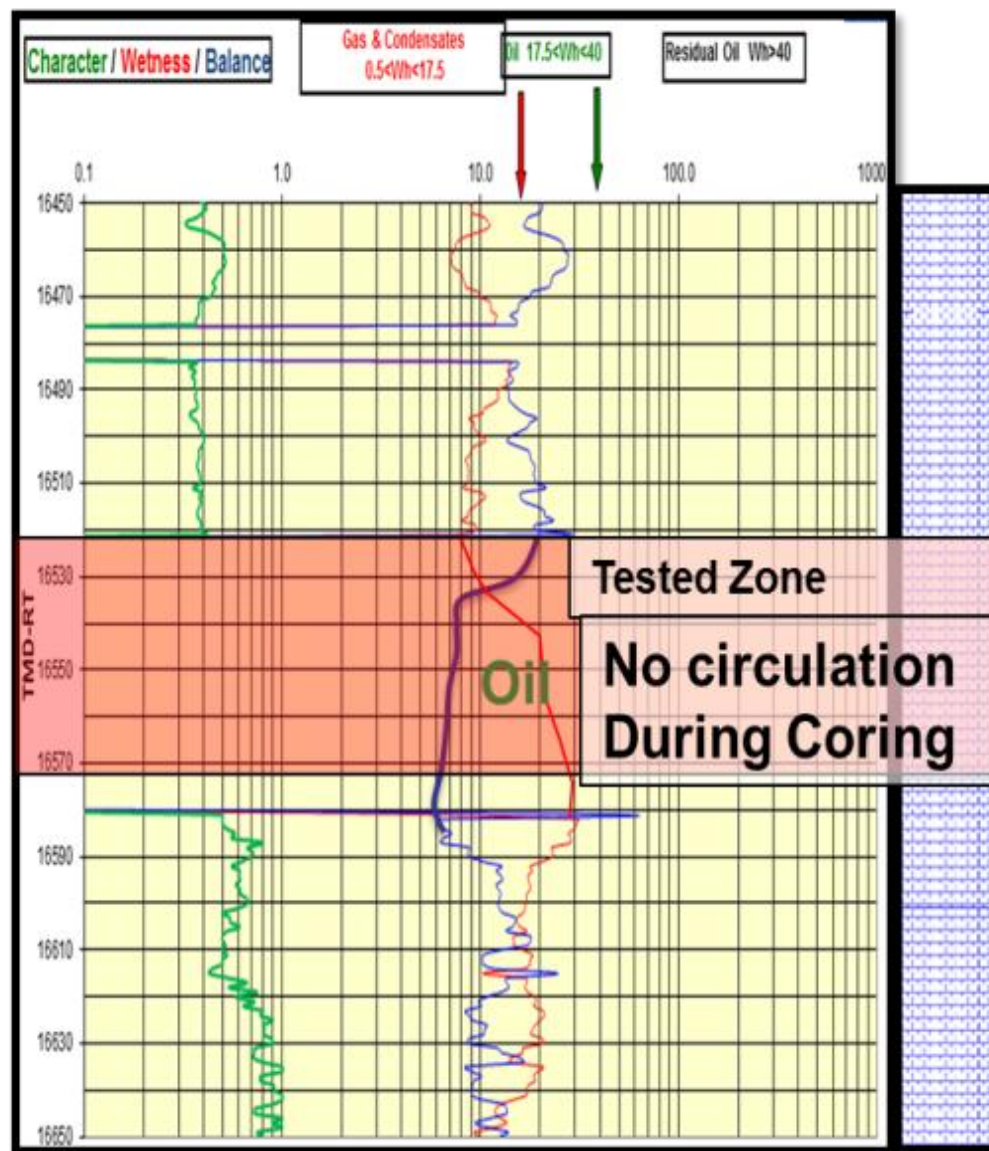
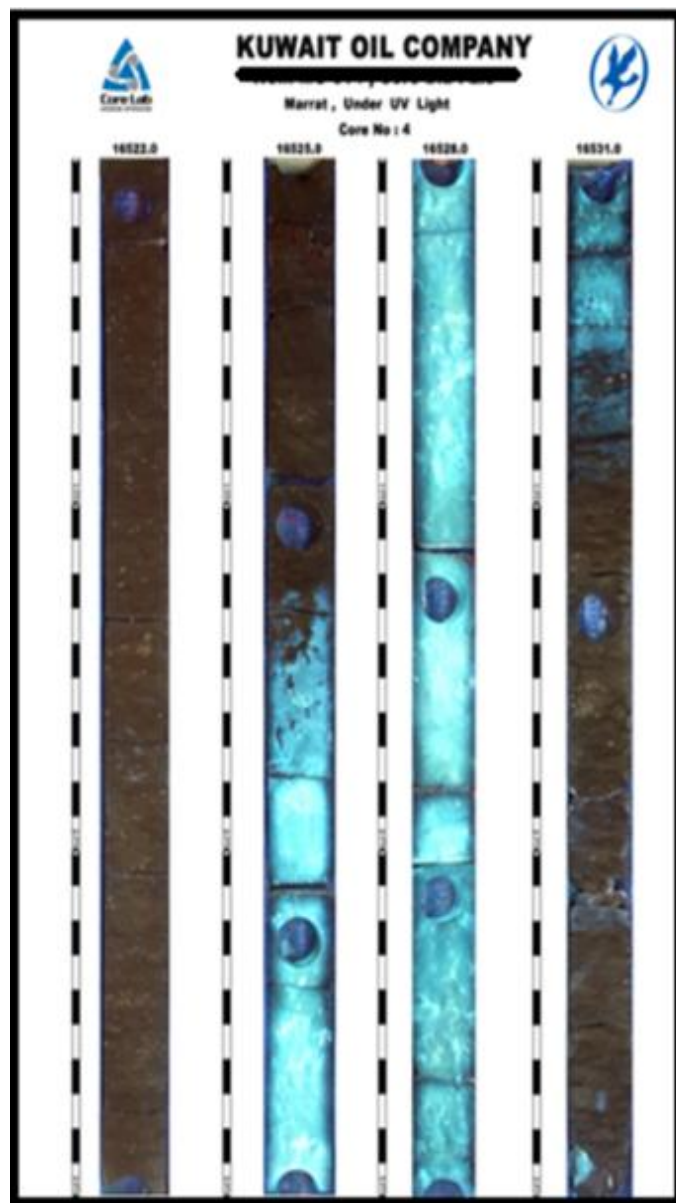


Figure 12. An example in exploration well#3 in Middle Marrat Formation showing integration between Pixler ratio results with core description, which contains hydrocarbon show.