การหาศักยภาพน้ำมัน ในแหล่งอาทิตย์ โดยใช้ Time lapse neutron และ ลักษณะเฉพาะของผลบันทึกโคลนเจาะ

นางสาวปุณญา เลิศศรีสันทัด

โครงงานนี้เป็นส่วนหนึ่งของการศึกษาระดับปริญญาตรี

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

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Oil potential in Arthit Field using time lapse neutron and mud log characteristic

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อาจารย์ที่ปรึกษา

การหาศักยภาพน้ำมัน ในแหล่งอาทิตย์ โดยใช้ Time lapse neutron และ ลักษณะเฉพาะของผลบันทึกโคลนเจาะ

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บทคัดย่อ : แบบบันทึกโคลนเจาะ เป็นข้อมูลที่ใช้ในการระบุน้ำมันและแก๊สโดยตรง โดยแบบบันทึกโคลนเจาะจะใช้คู่กับข้อมูลการหยั่งธรณีหลุมเจาะในการประเมินศักยภาพการผลิตของชั้นหินซึ่งในงานวิจัยนี้มีวัตถุประสงค์หลัก เพื่อระบุชนิดของของไหล โดยใช้ข้อมูลองค์ประกอบของคาร์บอน และข้อมูลการวัดค่าความพรุน (neutron porosity) จาก LWD (Logging while drilling) และ WL (Wireline) โดยหากปรากฏรอยแยกที่เกิดจากการซ้อนทับของค่าความพรุน จาก LWD และ WL เราจะตีความให้ชั้นหินกักเก็บนั้นประกอบด้วยของเหลวที่เป็นแก๊ส เนื่องจากค่าความพรุนที่วัดได้ขณะทำการขุดเจาะ และ หลังทำการขุดเจาะ มีค่าแตกต่างกัน และการระบุชั้นหินที่ประกอบด้วยของไหลที่เป็นน้ำมัน เราจะสังเกตจากลักษณะขององค์ประกอบคาร์บอน โดยหากปรากฏเส้นโค้งของคาร์บอน 5 อะตอมในปริมาณที่สูง จะระบุให้ชั้นหินกักเก็บนั้นประกอบด้วยของไหลที่เป็นน้ำมัน เนื่องจาก คาร์บอน 5 อะตอมเป็นองค์ประกอบหลักของน้ำมัน จากการศึกษาหลุมเจาะทั้ง 7 หลุม พบว่าการระบุชั้นหินกักเก็บที่ประกอบด้วยแก๊ส โดยใช้ลักษณะปรากฏของรอยแยกที่เกิดจากการซ้อนทับของค่าความพรุน จาก LWD และ WL ในเทคนิค Time lapse neutron มีความแม่นยำสูงเมื่อเปรียบเทียบจากการระบุโดยใช้ข้อมูลจาก การหยั่งธรณีหลุมเจาะเพียงอย่างเดียว ส่วนการระบุของไหลในชั้นหินกักเก็บ โดยใช้การสังเกตค่าคาร์บอน 5 อะตอม ในแบบบันทึกโคลนเจาะ (ลักษณะเฉพาะของผลบันทึกโคลนเจาะ) พบว่าไม่ค่อยมีความแม่นยำ ทั้งนี้เนื่องจากจำนวนตัวอย่างของหลุมเจาะที่ใช้ในการศึกษา มีจำนวนไม่มากพอ และพื้นที่ของแหล่งอาทิตย์ ส่วนใหญ่ไม่ปรากฏน้ำมัน ดังนั้นข้อมูลที่นำมาใช้ศึกษาการระบุ น้ำมัน โดยใช้ ลักษณะเฉพาะของแบบบันทึกโคลนเจาะจึงมีจำนวนจำกัด

คำสำคัญ : การหยั่งธรณีหลุมเจาะ, ค่าความพรุน, เทคนิค Time lapse neutron, แบบบันทึกโคลนเจาะ

OIL POTENTIAL IN ARTHIT FIELD USING TIME LAPSE NEUTRON AND MUD LOG CHARACTERISTIC

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Abstract : Mud logging is used to determine gas and oil in a reservoir while it is drilled by directional measurements. Mud log and electrical log data are combined to evaluate the producing potential of oil for a formation. The objective of this research is to identify a type of fluid in a reservoir by using carbon component, LWD (Logging while drilling), and WL (Wireline) neutron porosity data. If LWD-LW separation is present because of the difference in the porosity data that is measured while drilling and after drilling, a sand reservoir is interpreted to show the existence of gas. Since hydrocarbons that have five atoms of carbon are main components of oil, a reservoir that contains high proportion of this hydrocarbon would also have oil. Therefore, this characteristic is used to determine oil in a reservoir. Based on the results in 7 wells, the LWD-WL separation in time lapse neutron technique is more accurate to identify gas sand than using only wireline log data. However, C5 component, which is a characteristic of mud log, is inaccurate to identify types of fluid in sand reservoir. Due to the small numbers of well samples as well as lacking of oil reserve in the Arthit field, the data used to identify oil by using mud log characteristic is limited.

Key word : Electrical log, Mud log, LWD (Logging while drilling), WL (Wireline), LWD-LW separation

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Punnaya Lertsrisunthad

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Chapter 1

Introduction

1.1 Rationale

From observation of PTTEP operations in the Gulf of Thailand, there are many cases that reservoir layers were interpreted to contain gas but oil was produced and vice versa. Sometimes hydrocarbons were interpreted as fluid in the sand layers but water was produced. Arthit Asset normally uses LWD (Logging While Drilling) and WL (Wireline Logging) to help interpret and identify reservoir fluid types and properties in sand layers. LWD Triplecombo was performed in many wells for monitoring the hydrocarbon potential. Oil-based mud is commonly used in the Arthit Field, which always contaminates the borehole and surrounding area, and also affects the logging measurements. LWD log records resistivity while drilling but the wireline logs are used to record rock properties after drilling (several hours to several days after drilling). This led the LWD to show a much lower apparent neutron porosity than the WL, as the oil-based mud invasion was affecting the zone where the WL measurement was made. Cleaner, higher porosity, higher permeability reservoirs often show little difference in log responses of neutron and density crossover (indicating gas sands). Affected by oil-based mud invasion, in a gas zone the neutron log will record a lower porosity than the true porosity because gas has a lower hydrogen atom concentration than oil or water. Oil filtrate and water have similar hydrogen concentrations, so neutron log reading will show similar porosity. In LWD log, brine sand will show low resistivity and there will be no separation in the resistivity log. While in the WL log, flushed zone will show higher resistivity than the virgin zone because of mud invasion so there is a separation between shallow and deep resistivities. The LWD and WL neutron logs can be overlayed to show the time lapse difference which can help to identify gas sand from oil sand (Figure 1.1). In this project mud log characterization will also be used to help identifying the oil zone. Liquid hydrocarbon (oil) in mud log will show high C component, especially C5.

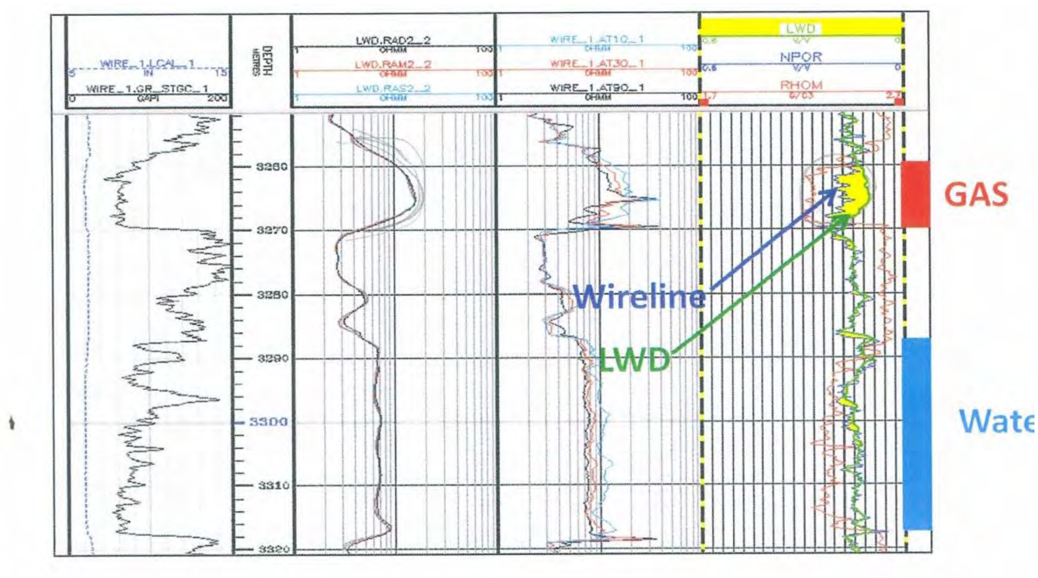


Figure 1.1 Gas affects of neutron measurement between LWD (green) and WL (blue) (Mesinee, 2010).

1.2 Problem Defined

In Arthit Field, reservoir fluid identification based only on classical method using wireline logs is unreliable; i.e. water was identified as hydrocarbon, oil was identified as gas, and gas was identified as oil.

1.3 Objectives

- To improve accuracy of reservoir fluid identification
- To attempt investigating liquid potential (oil) by reinterpreting LWD and WL logs, production results (from near development well) and mud log data.

1.4 Hypothesis

Neutron time lapse technique accompanied by mud log characteristic study can help in differentiating between gas and oil sands.

1.5 Scope of Work

The scope of this study is to employ neutron time lapse technique and mud log characteristic data to distinguish between gas and oil sands.

1.6 Data

The study wells (ARTHIT-14-1x, ARTHIT-14-2x, ARTHIT-14-3x, ARTHIT-14-4x, ARTHIT-14-5x, ARTHIT-15-1x and ARTHIT-15-2x) are located in the central part of the Arthit Area, North Malay basin in the Gulf of Thailand (Figure 1.2). All data in this study is supported by PTT Exploration Public Co. Ltd. and composed of mud log data, LWD log, WL log, production results and some additional geological data.

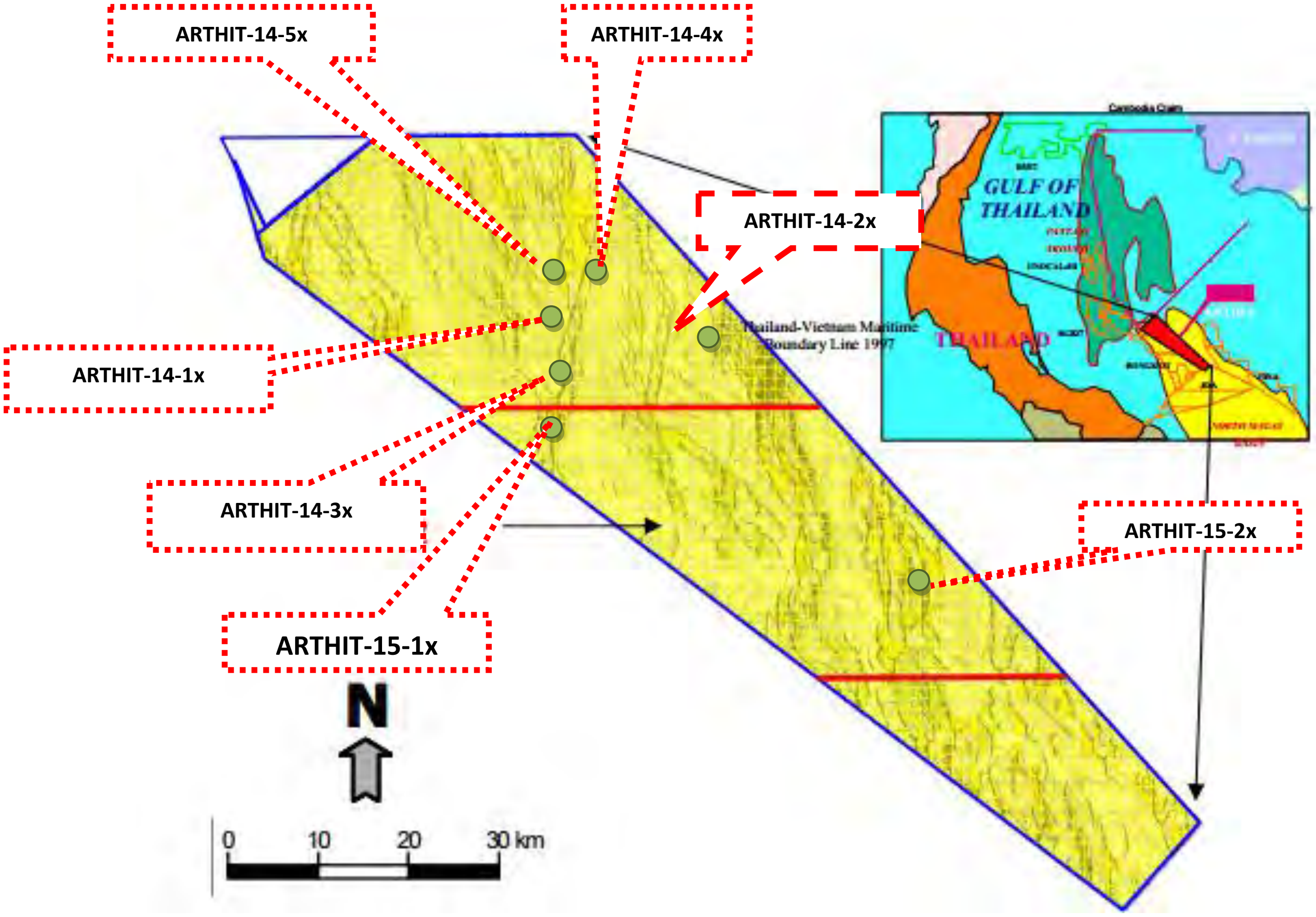


Figure 1.2 Map showing the study wells location in the Arthit Area of the North Malay basin in the Gulf of Thailand.

1.8 Expected outputs

The gas and oil sands that are identified by time lapse neutron technique and mud log characterization.

1.9 Previous works

Using well logs data Pullarp et al. (2010) were able to differentiate between oil and gas sands in several wells and present the results of well AT-9-K from Arthit Field and well BK-DEL-28 from Bongkot Field. The difference in time of measurement by two logs (LWD and WL) which will be affected by oil-based mud differently leading to differences in the neutron log readings. They presented this technique and called it "time lapse neutron".

Pullarp et al. (2011) differentiated oil and gas reservoirs in 2 wells from Arthit and Bongkot Fields by using near and far neutron counts on the wireline neutron log. They normalized the near and far counts with data in clean water bearing sands. They reported that the normalized far count rate is less than normalized near count rate in a gas zone. They can differentiate oil and water by using resistivity log. They suggested that this technique is suitable for formation in Arthit North where the invasion zone is not too deep.

Haworth et al. (1985) proposed the method to identify reservoir fluid types using Light (C_1 - C_5) hydrocarbon gases from mud log data to calculate, the hydrocarbon wetness ratio (Wh), the hydrocarbon balance ratio (Bh), and the hydrocarbon character ratio (Ch).

Rochon (1955) studied mud logging problems from the cases that missed picking up the gas from a gas sand. He reported that the decreasing value of the curves in gas chromatography is salinite of drilling fluids. Moreover he divided the FACTORS AFFECTING GAS ANOMALIES into five classifications 1. Variables which have physical justification for correction by constants (drilling time, size hole, depth), 2. Differences in mud properties, 3. Physical differences in drilling equipment and logging unit set-up, 4. Variations in the hydrocarbon saturation of the sand at the instant it is cut loose by the bit (flushing) and 5. Combustion characteristics of gases. (A butane air concentration will give ten times the meter reading in a test as the same concentration of methane to air.) This accounts for one of the reasons dry gas sands are harder to pick up than sands carrying the heavier gases.

Chapter 2

Regional Geology

2.1 Gulf of Thailand

The Gulf of Thailand is located on the southeast of Thailand. The eastern part is bounded to Cambodia and Vietnam and the southern part is bounded by Malaysia. Gulf of Thailand is locating between latitude 6°-14° N and longitude 94°-103° E.

Leo (1997) proposed that the Gulf of Thailand is composed of two main structural regions. The western half is a region of many small basins. The eastern half contains two large basins; the Pattani Trough and the Malay Basin (Figure 2.1). Sedimentation patterns and environment of deposition were strongly influenced by local sub-basin topography. Lacustrine sediments were deposited in initial basin lows and overlain by approximately 2,000 m of Miocene non-marine sediments. The basement is believed to be composed of late Mesozoic granite and other igneous rocks that are equivalent to the Narathiwat Granite Ridge, or possibly late Paleozoic sedimentary and meta-sedimentary rocks of the Khorat group. Sedimentary section in the Gulf of Thailand is as thick as 9,000 m.

Morley (2004) described that the Gulf of Thailand contains several complex trans-tensional basins. They are made up of asymmetrical grabens and filled with non-marine to marginal marine Tertiary (Eocene) sediments from rifting event. Regional patterns of the grabens and related faults in the Gulf of Thailand strongly suggests that the grabens are the result of the collision of India with Central Asia that started in Eocene (Morley, 2004). The rift basins are developed from a result of oblique-slip extensional tectonics. Geothermal gradient in the Gulf of Thailand is 50 °C/km (Hutchison, 1989).

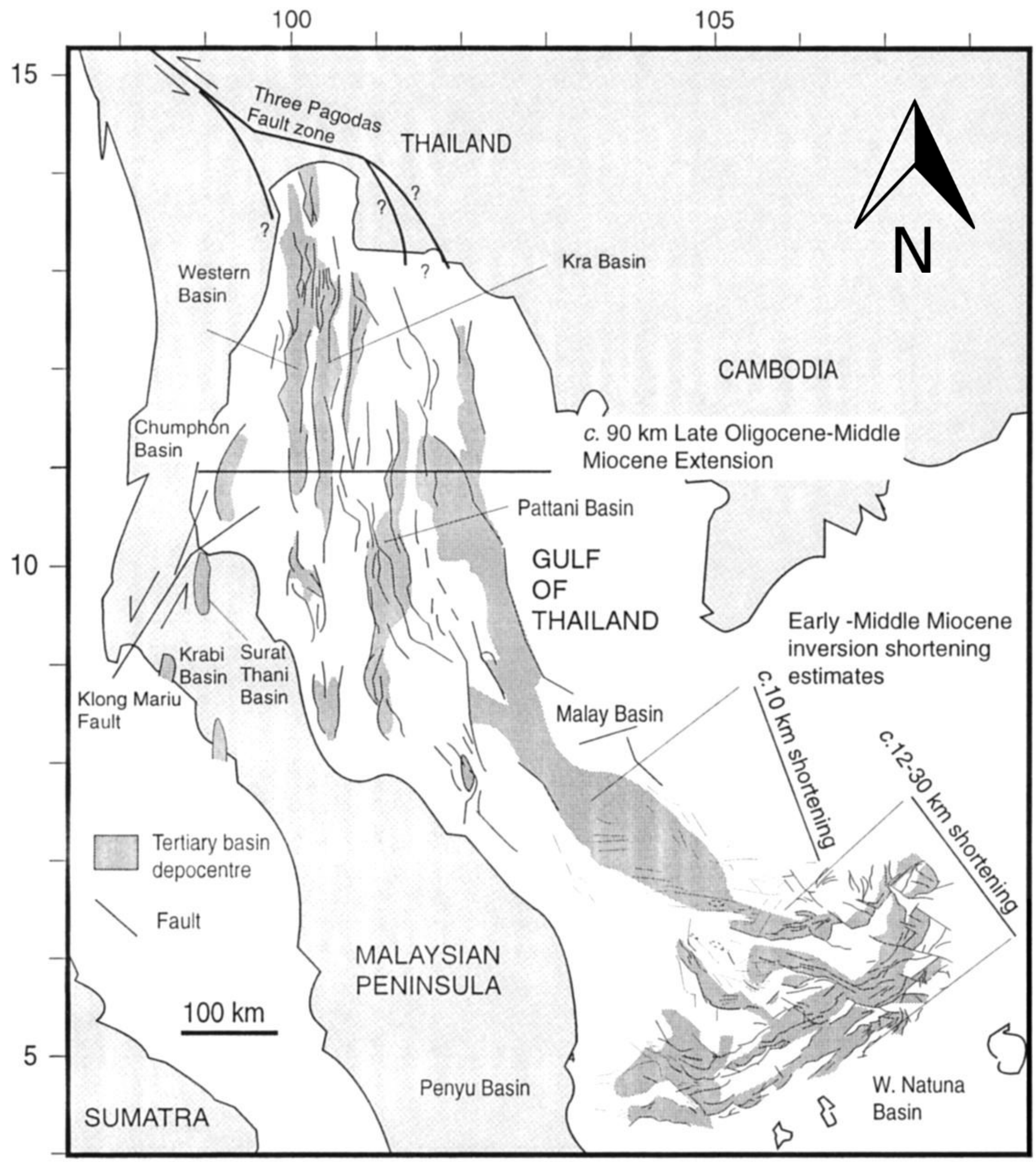


Figure 2.1 Map showing Tertiary Basins in the Gulf of Thailand (Madon et al., 1997).

2.2 Arthit Field

The Arthit field is located on the northwestern margin of the Malay Basin (Figure 2.2). The Arthit field covers approximately 3,933 km^2. The Arthit field consists of blocks 14A, 15A, and 16A. The area of interest is approximately 140 km from North to South and 50 km from West to East. In the west, it is located next to Bongkot field (PTTEP, 2009).

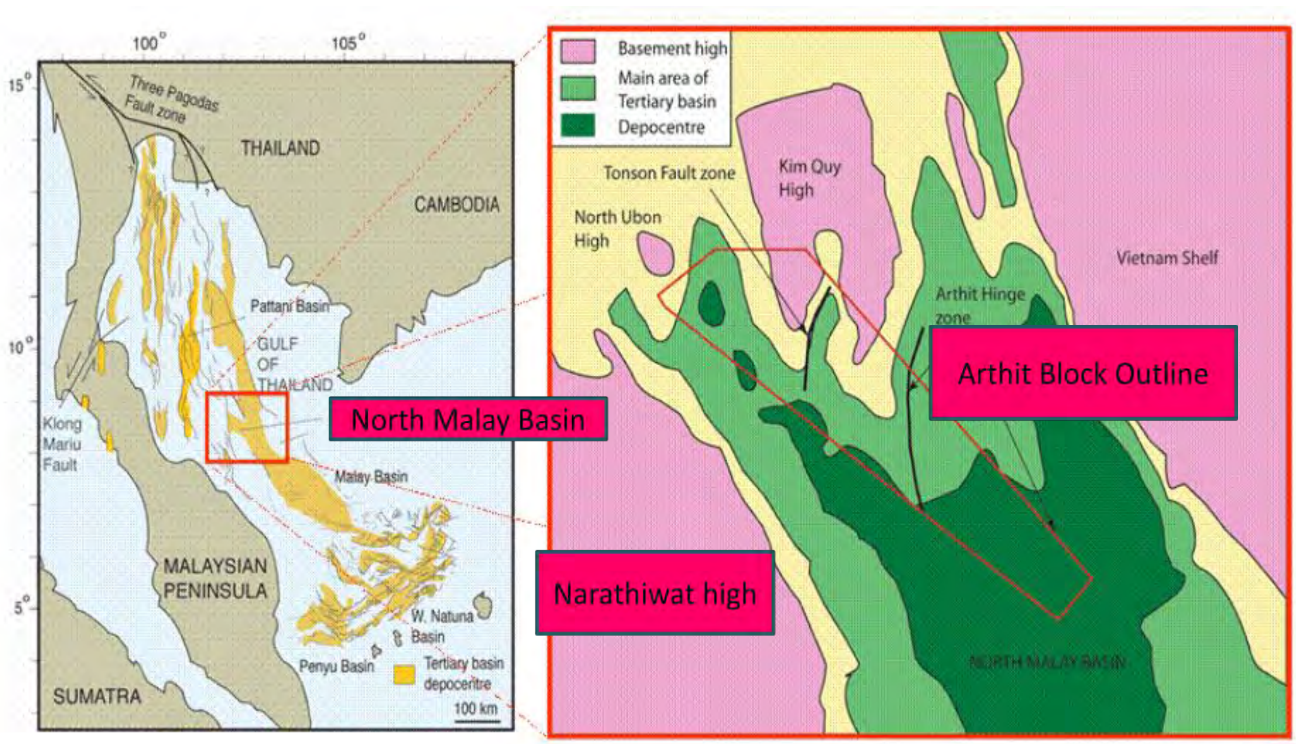


Figure 2.2 Map showing the location of the Arthit Field (PTTEP, 2009).

The Arthit field is located in the most northern part of the North Malay Basin. This area contains several regional structural trends that control the structural closures and play types. There are two principal fault orientations observed in Arthit. There is a pronounced west northwest to east southeast fault orientation that reflects the orientation of the initial rift basins. Superposed on that grain is a second orientation of faults with a strong north northeast to south southwest trend.

A total of ten structural play trends were identified and mapped (Figure 2.3).

These play trends are as follows:

(1) West Arthit Trend

(2) Basement High Trend

(3) Re-Entrant Trend

(4) Ton Son Trend

(5) Basement Ramp Trend

(6) Basement Flank Trend

(7) Hinge Zone Trend

(8) Graben Trend

(9) Horst Trend

(10) Nose Trend

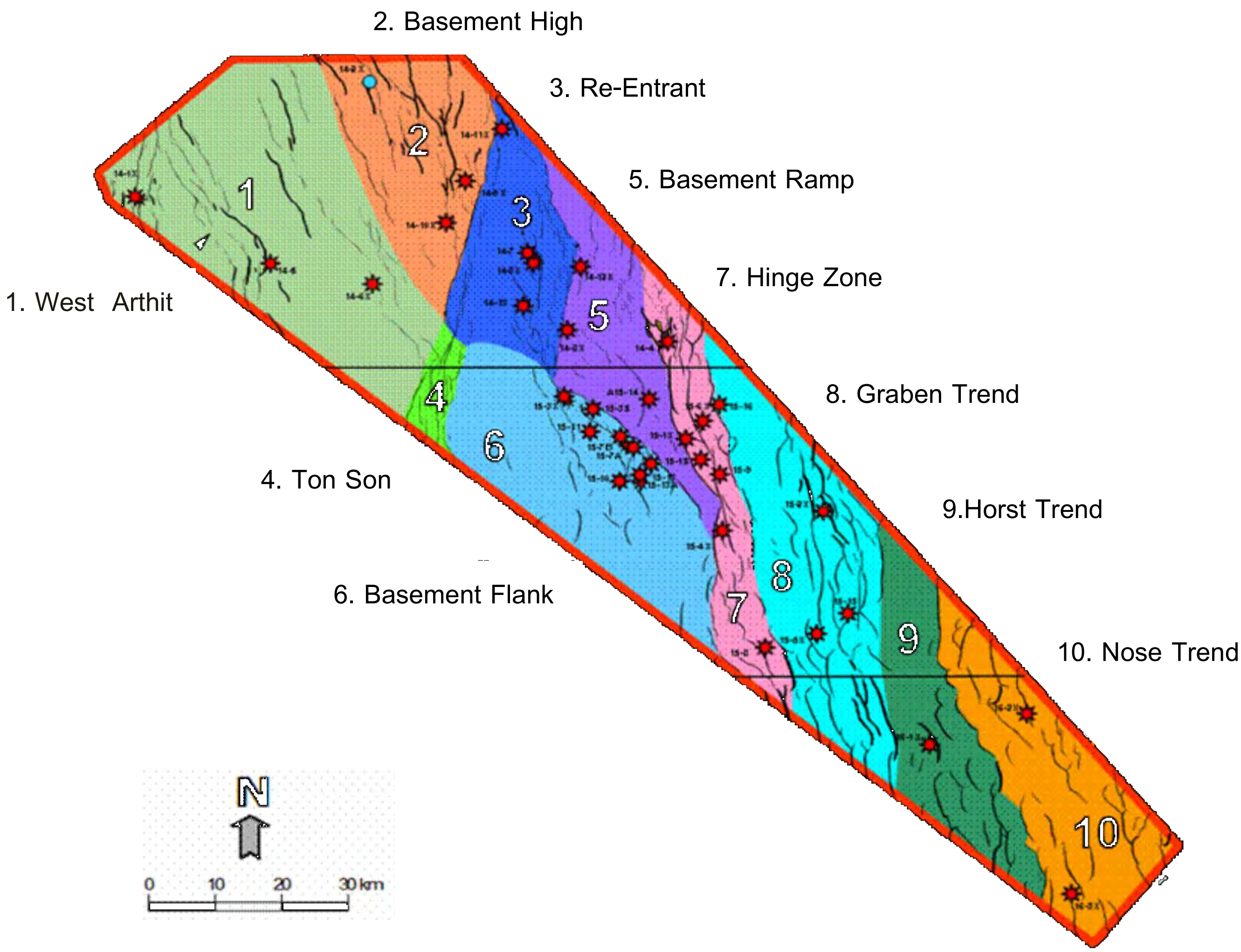


Figure 2.3 Map showing the Arthit structural trends (PTTEP, 2009).

2.2.2 Stratigraphic Units

The North Malay Basin strata can be divided into 4 formations (Figure 2.5) (PTTEP, 2004), which lie on the Pre-Tertiary basement; the most common basement rocks are Permian limestone, Cretaceous granite, Mesozoic carbonate rocks and Paleozoic metaclastic rocks. These rocks are unconformably overlain by Tertiary rocks.

Formation 0 - deposited during the syn-rift phase

Formation 1 and Formation 2 – deposited during the sag phase

Formation 3 – deposited during the regional subsidence phase

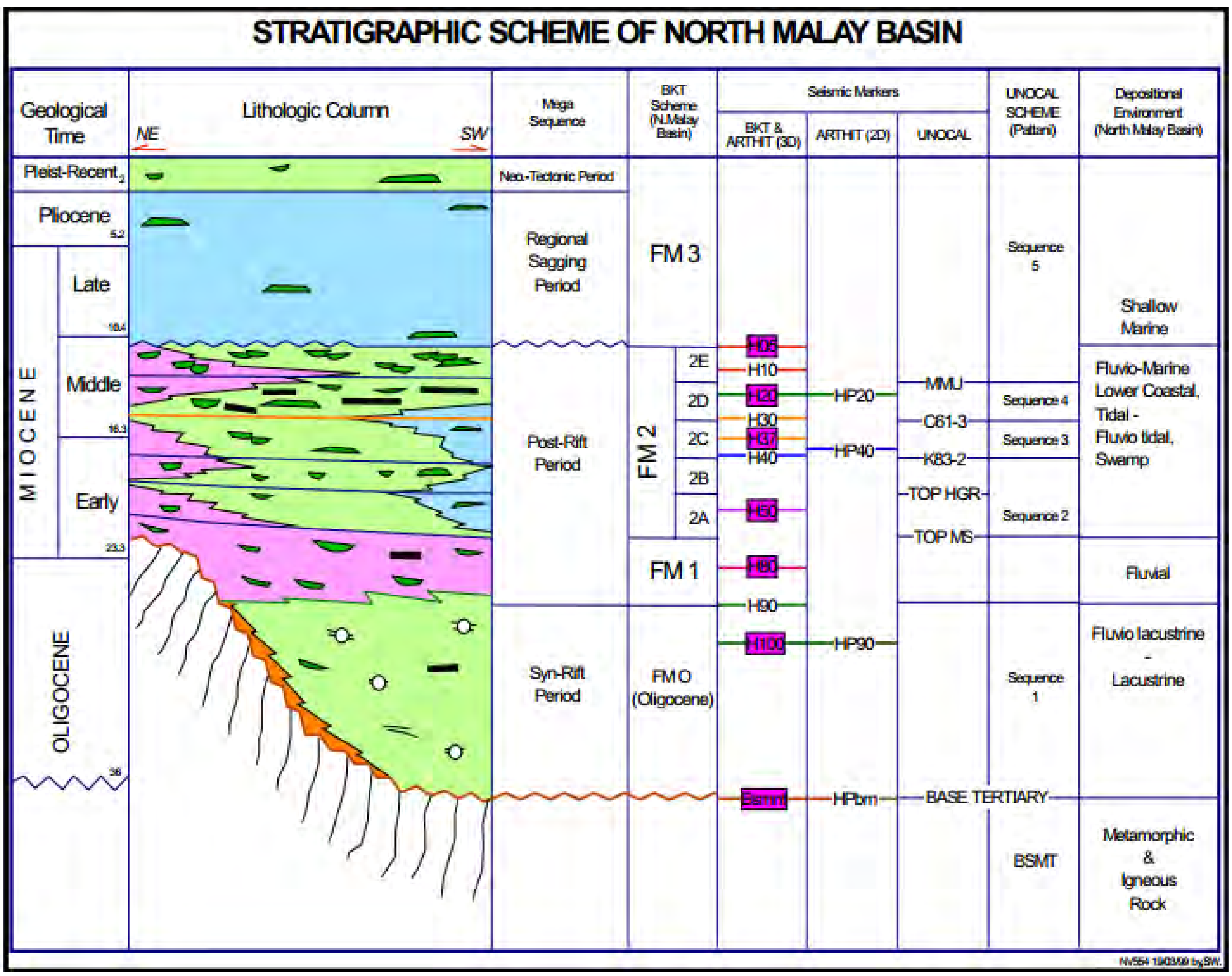


Figure 2.5 General stratigraphy in the North Malay Basin (PTTEP, 2004).

Formation 0

Shale and sandstone with the color of gray to black are rocks in formation 0. The top of this formation is determined by the first appearance of gray clast with a decrease in shale resistivity. The lithology variation is also observed at many areas in this formation as a consequence of deposition during syn-rift period.

Formation 1

Red and reddish grey claystone, siltstone, and sandstone are rocks in formation 1. The top of this formation is determined by the first appearance of red claystone in well cuttings. The gross thickness of each sand bed is up to 20 meters. Since this formation contains thick bed of coarse-grained sand with red oxidized delta plain clay, the depositional environment is fluvio-lacustrine.

Formation 2

Formation 2 is divided to five different lithostratigraphic units because it is the thickest formation. Those five units are 2A, 2B, 2C, 2D, and 2E where 2A is the oldest; 2E is the youngest. This formation deposited during Miocene period. Overall, the depositional environments are delta plain to delta front from lower to upper sequences.

For unit 2A, there are beds ofthick and sharp base sandstone in the trend of basement. Moreover, unit 2A also consists of fine to medium crevasses splay and channel sands. Coal beds widely spread within this unit. Distributaries channels and splays or deltaic plains are the depositional environments of this unit.

For unit 2B, there are beds of thick sharp base sand in the hinge zone and thick vertically stacked sand. Moreover, this unit has more channel interconnection than other units.

For unit 2C, there are many beds that have low resistivity shale and thin beds of coarsening upward sands. The occurrence of beds of thick sharp base sand is isolated from others. The upper of this unit is shaley marine deposit. Although this unit mainly composes of shale, sand is abundant in the central part. Coal beds widely spread, which cover various channelized sand bodies. The delta front to offshore is the depositional environment of this unit.

For unit 2D, there are channelized sandy reservoirs connected to coal and organic delta plain. The environment of deposition is incised valley-fill distributary channels and splays or deltaic plain. Therefore, this unit is regressive compared to unit 2C.

For unit 2E, there are sand, claystone, and coal. However, sand is primarily present in this unit. Each sand bed usually has blocky log motifs, which can be more than 30 meters in a vertical thickness. The fuvio-deltaic channel is the depositional environment of this unit.

Formation 3

Shale interbeded with fine sandstone are dominated in this formation, which rapidly increase in marine fauna content. The environment of deposition is, therefore, offshore marine. This formation has started deposit since Pliocene, which was on top of the 10.4 Ma unconformity.

Chapter 3

Methodology

In this work, the method of study is summarized as a flow chart in Figure 3.1 The first phase of the study involves literature review of previous works. The second phase of study is analysis of the well data. The third phase is evaluating result with actual data.

The research method can be divided into 9 stages as follows;

1. Study the basic knowledge and collect the relevant data from previous works.
2. Learn to interpret mud log, LWD and wireline neutron logs and how to overlay LWD and wireline neutron logs data by using computer program.
3. Interpret data
   - Analyze wireline log data to determine the reservoir properties
   - Shifting the LWD neutron log to overlay with wireline neutron log by using Geolog6.0 program in order to identify the fluid type in the study area.
4. Interpret types of hydrocarbon in the sand by using mud log characterization.
5. Review the production data and the data from well log data
6. Compare the result from 2 methods with production test from the development well that are located near the study wells.
7. Calculate the accuracy of the methods.
8. Discussion and conclusion.
9. Writing report and prepare presentation.

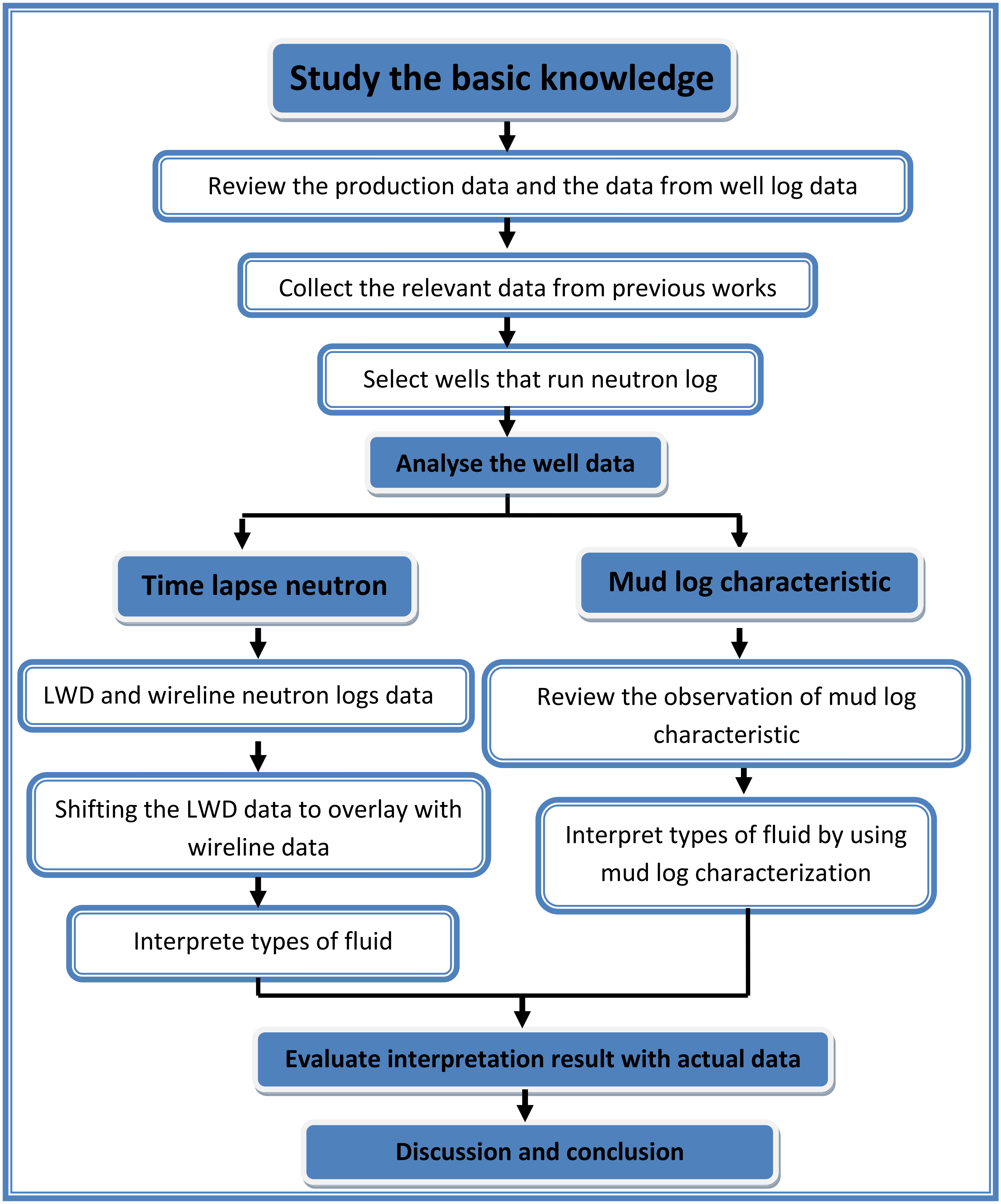


Figure 3.1 Flow chart of methodology.

3.1. Data Acquisition

- Database

3.1.1 Study the basic knowledge from previous works

These research studies on the Application of Time Lapse Neutron and Differentiation of oil and gas reservoirs in The Gulf of Thailand by using well log data in the reports and research example Whittlesey et al. (2009), Pullarp et al. (2010), Rochon (1955) and Pullarp et al. (2011). There are also other research that has studied the effect of oil-based mud in The Gulf of Thailand.

3.1.2 Select wells

In this study, well log data were selected from 7 drilled holes which were drilled in the blocks 14 and 15 (The located of 7 wells are showen in Figure 3.). The reason for the selection is to select drill hole that has been logged with the neutron porosity log. Because we need to use the neutron porosity from the LWD and WL to compare the differences of data on different time. There are ARTHIT-14-1x, ARTHIT-14-2x, ARTHIT-14-3x, ARTHIT-14-4x, ARTHIT-14-4x, ARTHIT-15-1x and ARTHIT-15-2x.

3.2. Data Analysis

- Well log study

3.2.1 Well log study

The interpretation of data from analyzing the rock cuttings from oil-based mud is called mug log. It is widely used in oil and gas exploration. Mud log is able to indicate pressure conditions and fluid type, monitor bit performance, and determine lithology.

In oil and gas industry, the rock properties in a formation are figured out by using wireline logging. Moreover, it can be used to imply other properties, for example, hydrocarbon saturation, formation pressure, as well as make further drilling and production decisions. Logging tools, including sensors, is attached at the end of a wireline. Then, they are released into a borehole and record petrophysical properties. The data measured by logging tools are electrical, acoustic, radioactive, electromagnetic, and nuclear magnetic resonance. Moreover, these tools can measure other properties of rocks and fluids in a formation.

The data from well log is either printed record or electronic version. There are two ways of logging operation. First, it is performed during the drilling process, also called logging while drilling. In this case, formations can be real-time observed and interpreted. Another way is to acquiring data after a well is drilled to the bottom.

3.2.1.1 Characteristics of well logs

Gamma Ray Log

The natural radioactive emission by a formation can be measured by logging called the gamma ray log, which can be documented in open and case holes. The main advantage of using gamma ray log data is to distinguish between argillaceous and non-argillaceous rocks since it detects three main radioactive elements, which are potassium (K), thorium (Th), and uranium (U).Argillaceous rocks, such as shale and mudstone, compose of large amount of potassium and thorium radiation; therefore, they show high values in gamma ray log. On the other hand, non-argillaceous rocks, such as sandstone, dolomite, and limestone show low values in gamma ray log because they contain none or a little amount of these radioactive elements. Moreover, gamma ray log can indicate mineralogy and geochemistry. (Chalermchaikit, 2003)

Resistivity Log

The resistivity log is crucially important information evaluation since it can distinguish hydrocarbons from formation water. Hydrocarbons are resistive; therefore they show high value in resistivity. Others that also have high resistivity are dense limestone, evaporates, meta-sedimentary rocks, and porous rocks that contain either oil or fresh water. On the other hand, formation and solution water is conductive since they contain ions. Therefore, they have low value in resistivity log. In conclusion, the different characteristics are useful to determine fluids in pores. However, clay minerals and few other minerals, such as pyrite, are also conductive. Therefore, the presences of these minerals can reduce the difference in resistivity between hydrocarbon and formation water. Although there are tools that measure conductive, the results are still present as resistivity. (Schlumberger oilfield glossary, 2001) (http://www.glossary.oilfield.slb.com : 21-01-2014)

Density Log

A density of a formation can be determined by using density log, which primarily applies in uncase holes. Density log measures the backscattered gamma rays, which are previously released by a gamma ray source in the logging tool. Therefore, it is sometimes called gamma-ray log. The amount of backscattered gamma rays is directly proportion to the density of formation's electron, which is roughly proportional to the bulk density. A source of gamma rays and detectors are often mounted on a skid, which is pressed against the borehole wall. One of the detectors of density log's tool is a secondary detector, which is more sensitive to mud cake and small borehole irregularities. The data from the secondary detector is then used to correct the measurements from the primary one. The density log is usually combined with neutron log in order to indicate coal and rock strength. (SPWLA glossary, 2000) (http://www.fesaus.org, 21-01-2014)

Neutron Log

Neutron log is primary respond the concentration of hydrogen, which can infer to the apparent porosity. However, the hydrogen concentration also affected by mineralogy and borehole affects. This log cannot determine the difference in source of hydrogen whether it is in pore fluids, such as water, oil, and gas, in water of crystallization, or in water bounded by solid surfaces. However, neutron log reflects the amount of liquid-filled pore volume in clean oil- or water- filled formations. The neutron log is useful when used with other porosity information to confirm the presence of gas as well as to determine mineralogy and shaliness.

The tool of neutron log composes of a continuously emitting neutron source and either a neutron (n-n tool) or a gamma ray (n-g tool) detector. The hydrogen concentration is primary identified from the dissemination of neutron detection because hydrogen atoms are the most effective in the slowing down of neutrons from the source by collision with atomic nuclei since the mass of a hydrogen atom is about the same with a neutron's. There are three types of neutron detections depending upon the tool types: thermal neutrons, gamma rays that generate when thermal neutrons are captured by thermal-neutron absorbers in a formation, and epithermal neutrons, which are neutrons having higher energy than thermal ones. The neutron log can be operated in open or cased liquid-filled wells. The sizes of wells need to be big enough in order to run the tools without touching the formation wall. The curve of neutron log is scaled in either API units or in terms of apparent porosity. (SPWLA glossary, 2000) (http://www.fesaus.org, 21-01-2014)

3.3. Evaluate interpretation result

In order to distinguish porosity values measured at different times, it is necessary to adjust the depth scale of the WL neutron porosity, then overlay the LWD neutron porosity with WL neutron porosity (Figure 3.2). This will allow us to see the separation of LWD neutron porosity data and WL neutron porosity data in case of a gas zone.

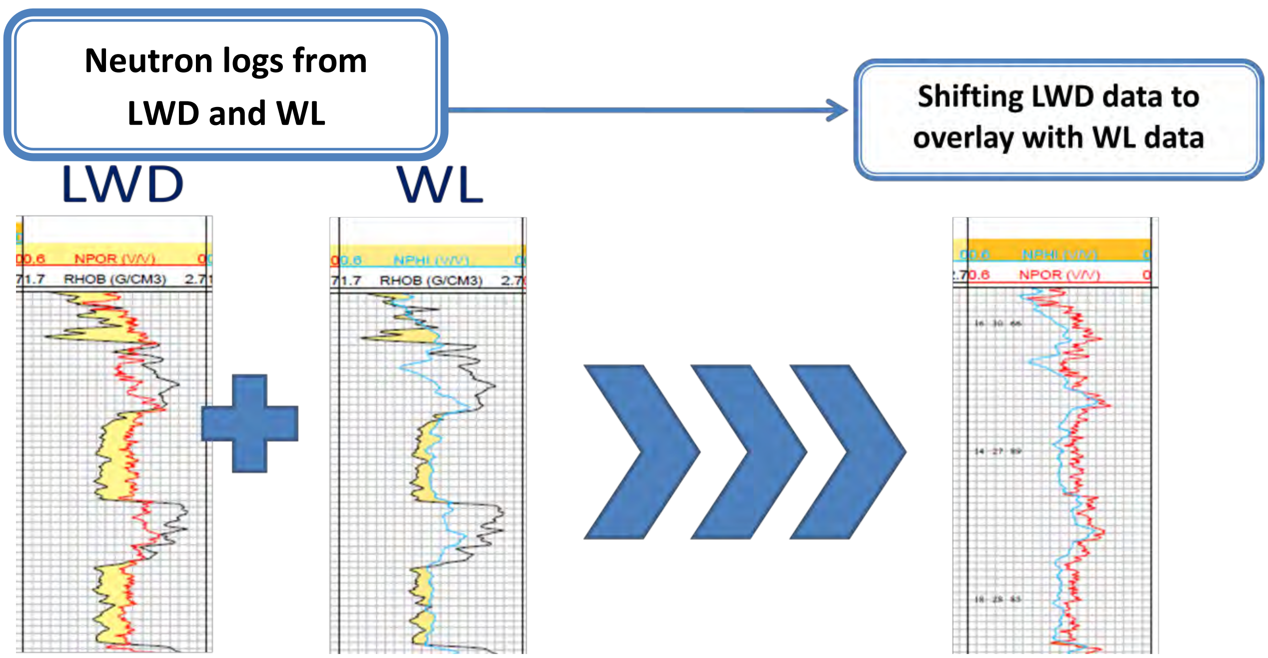
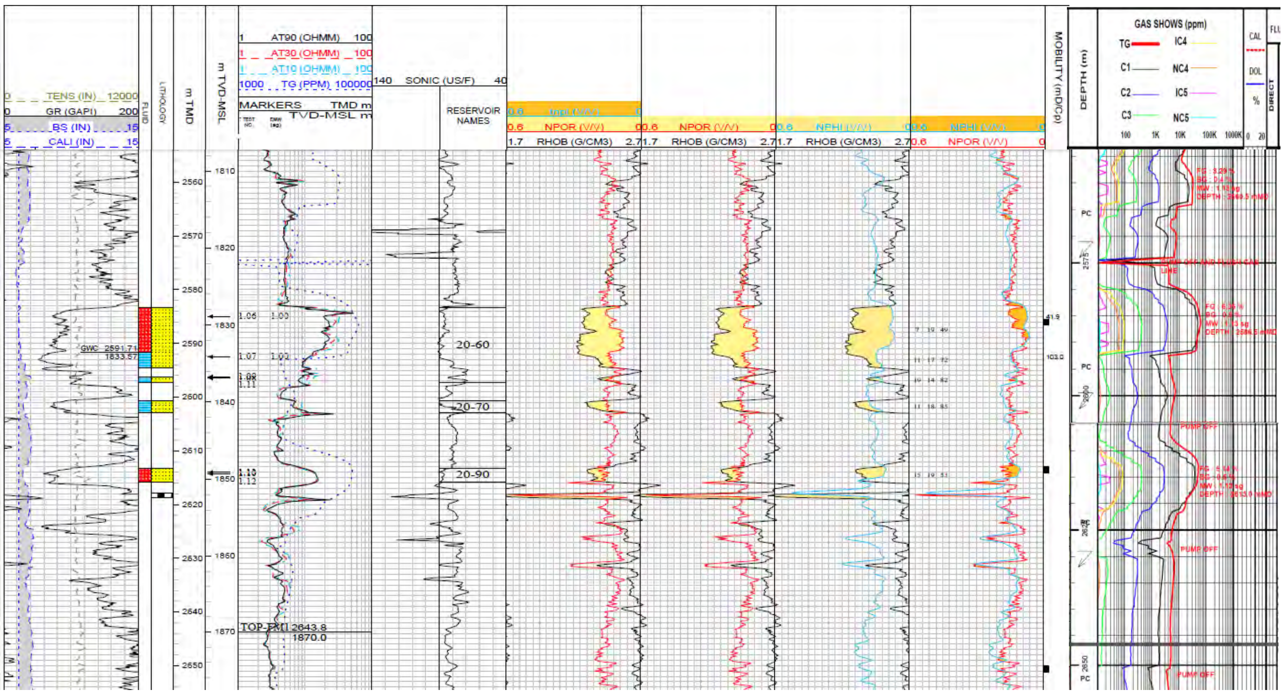


Figure 3.2 LWD neutron porosity overlay with WL neutron porosity. The red line represents the values of neutron porosity from LWD log and the blue line represents the values of neutron porosity from WL log.

The next step is to consider the carbon number of the gas component from mud log in the sand that show separation between LWD and WL neutron porosity logs (Figure 3.3).



Ficture 3.3 Picture shows gas component from mud log compare with sand reservoir which has a separation between LWD and WL neutron porosity logs.

Chapter 4

Result and Interpretation

From the study, the table provides data for each borehole, which includes the MD and TVD depth, resistivity, reservoir_name, density-Porosity crossover, LWD-WL separation, initial interpretation, and my interpretation. The fluid's information in the initial interpretation was from the wireline log provided by PTTEP, while one in my interpretation was determined by using technique time lapse neutron and C5 characteristic.

AT-14-1X

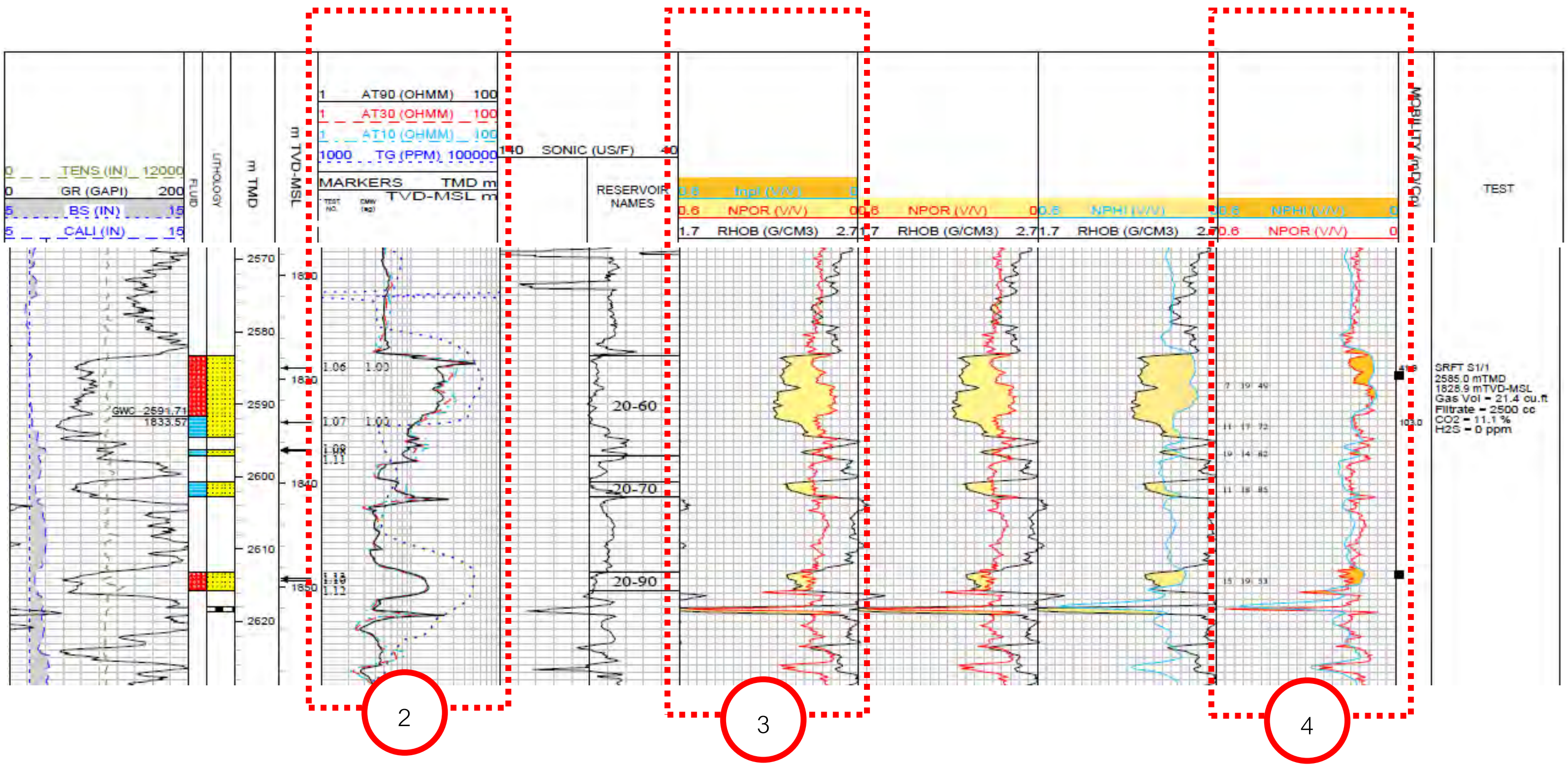


Figure 4.1 Picture shows well log data at of AT-14-1X 2584 mMD. and 2613 mMD.

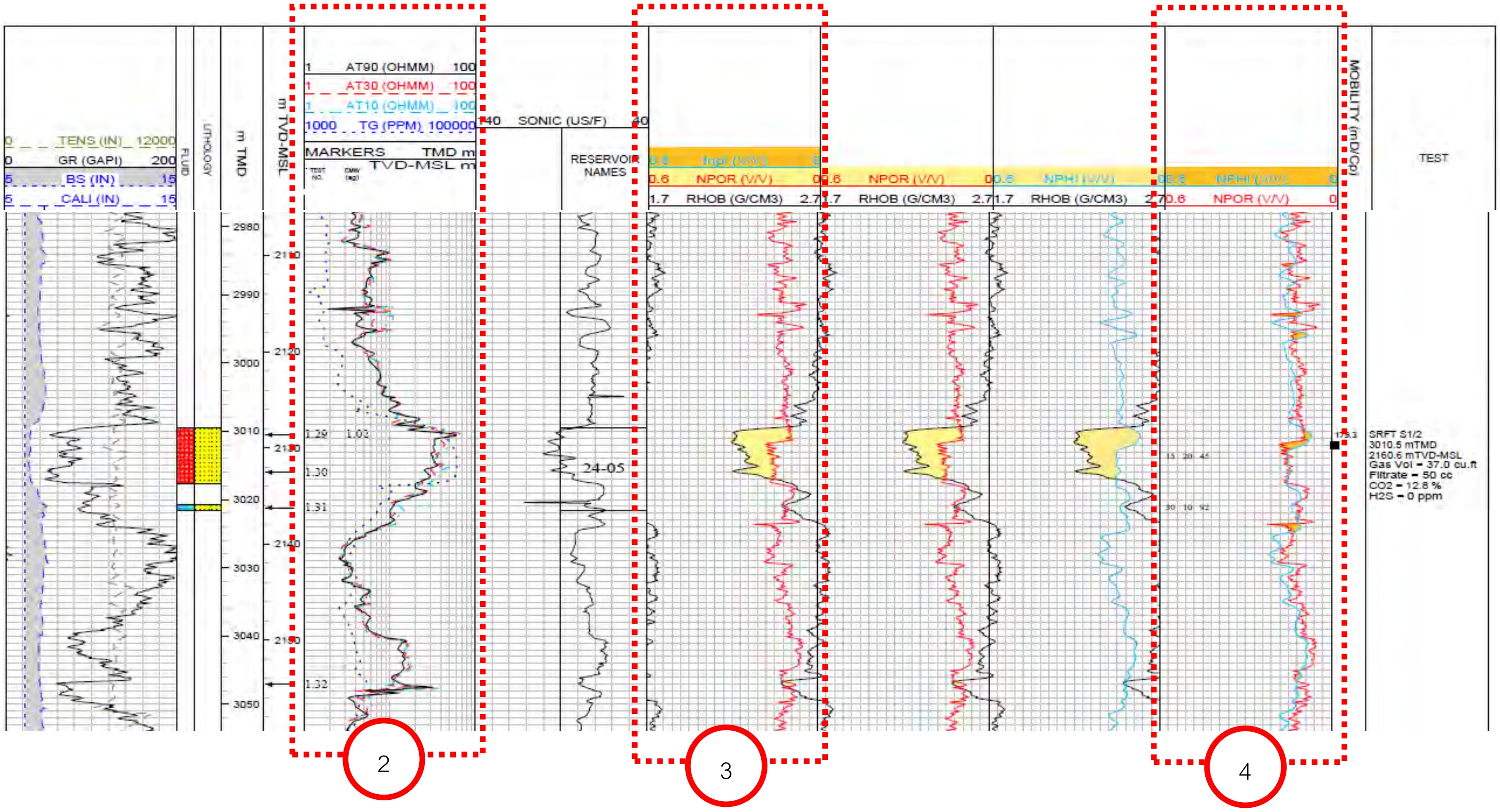


Figure 4.2 Picture shows well log data at 3010 mMD.

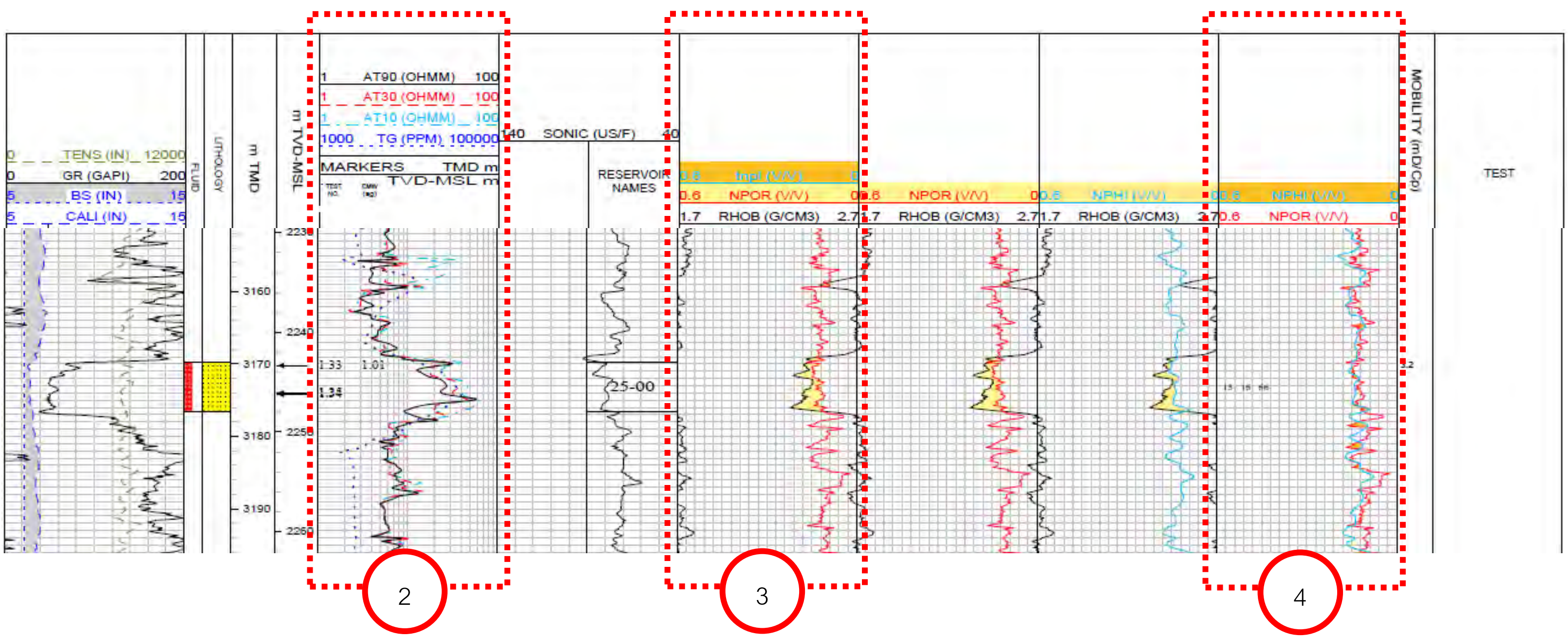


Figure 4.3 Picture shows well log data of AT-14-1X at 3170 mMD.

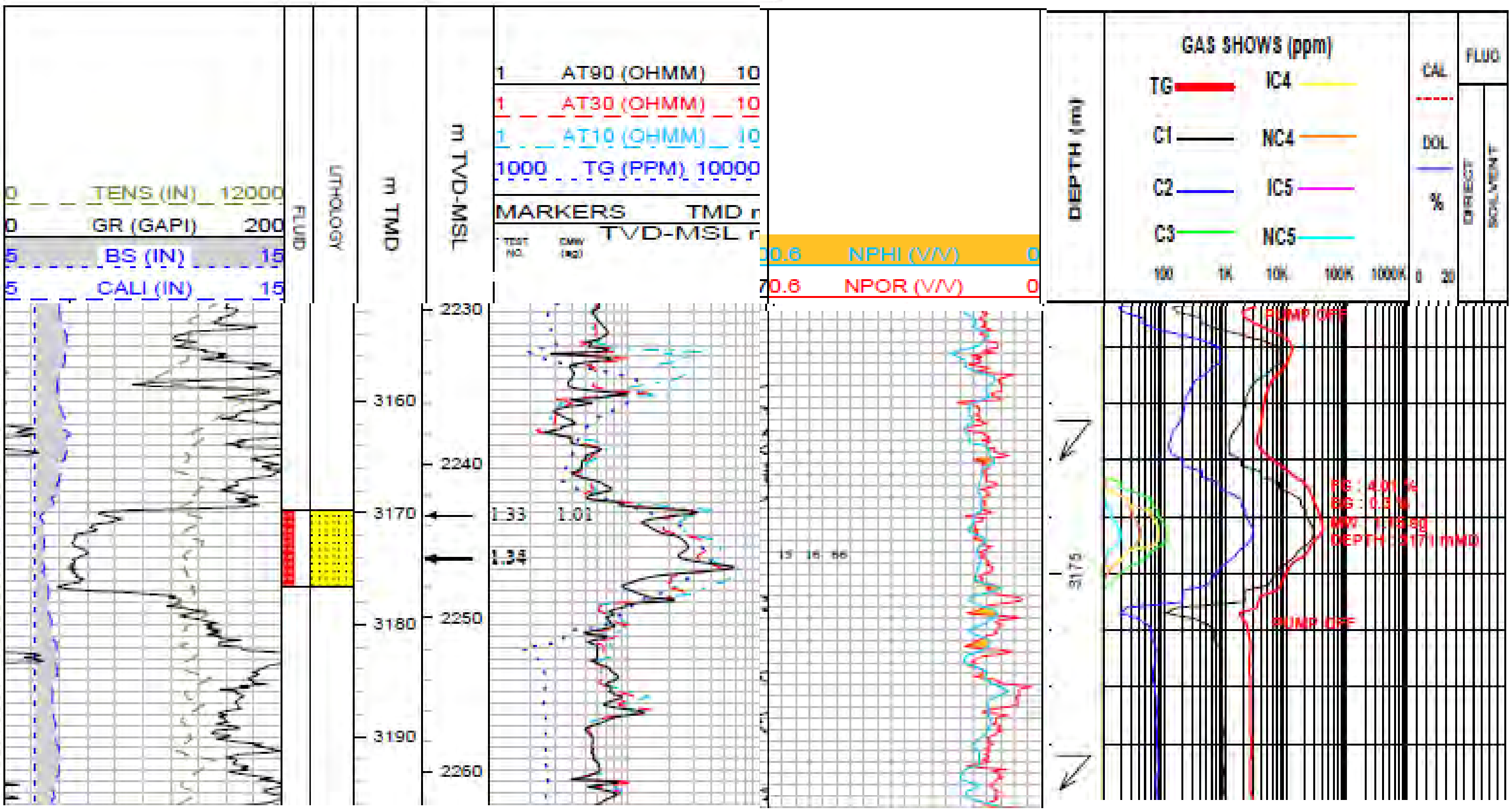


Figure 4.4 Well log data of AT-14-1X at 3170 mMD. compare with mud log, blue line shows high C5 component.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
2584	1828	20	20-1x	✓	✓	Gas	Gas
2613	1849	15	20-2x	✓	✓	Gas	Gas
3010	2128	30	24-1x	✓	✓	Gas	Gas
3170	2243	30	25-1x	✓	✗	Gas?	Oil

Table 4.1 Data table of AT-14-1X at 2584, 2613, 3010 and 3170 mMD.

From AT-14-1x well data, 4 positions (Figure 4.1, 4.2) were observed, at 2584, 2613, 3010 and 3170 mMD. There were high resistivity about 15-30 ohm. (column 2 in each Figure.) as in gas resistivity range at 2584, 2613 and 3010 mMD. accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. According to time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

From Figure 4.3 LWD-WL separation could not be found at the depth of 3170 mMD. Moreover, the data from mud log shows that C5 values are high (Figure 4.4). Based on these two evidence, the fluid in this sand reservoir is oil. On the other hand, samples and production data from adjacent well indicate that the fluid is actually gas.

In conclusion, AT-14-1x there is discrepancy in identified fluid from time lapse neutron technique and C5 characteristic at this position.

AT-14-2X

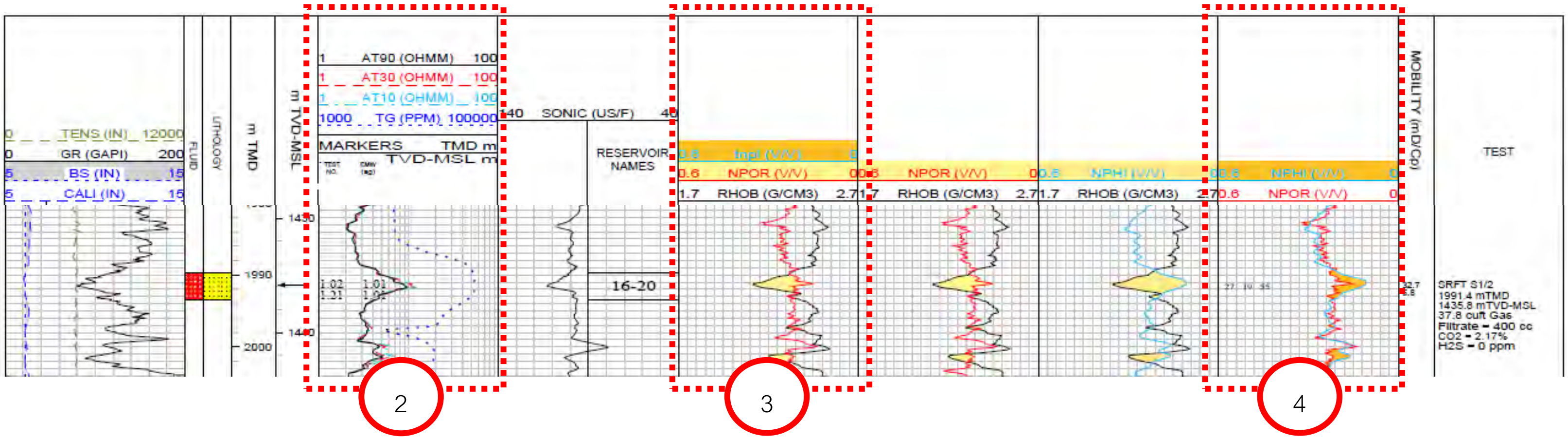


Figure 4.5 The picture shows well log data of AT-14-2X at 1990 mMD.

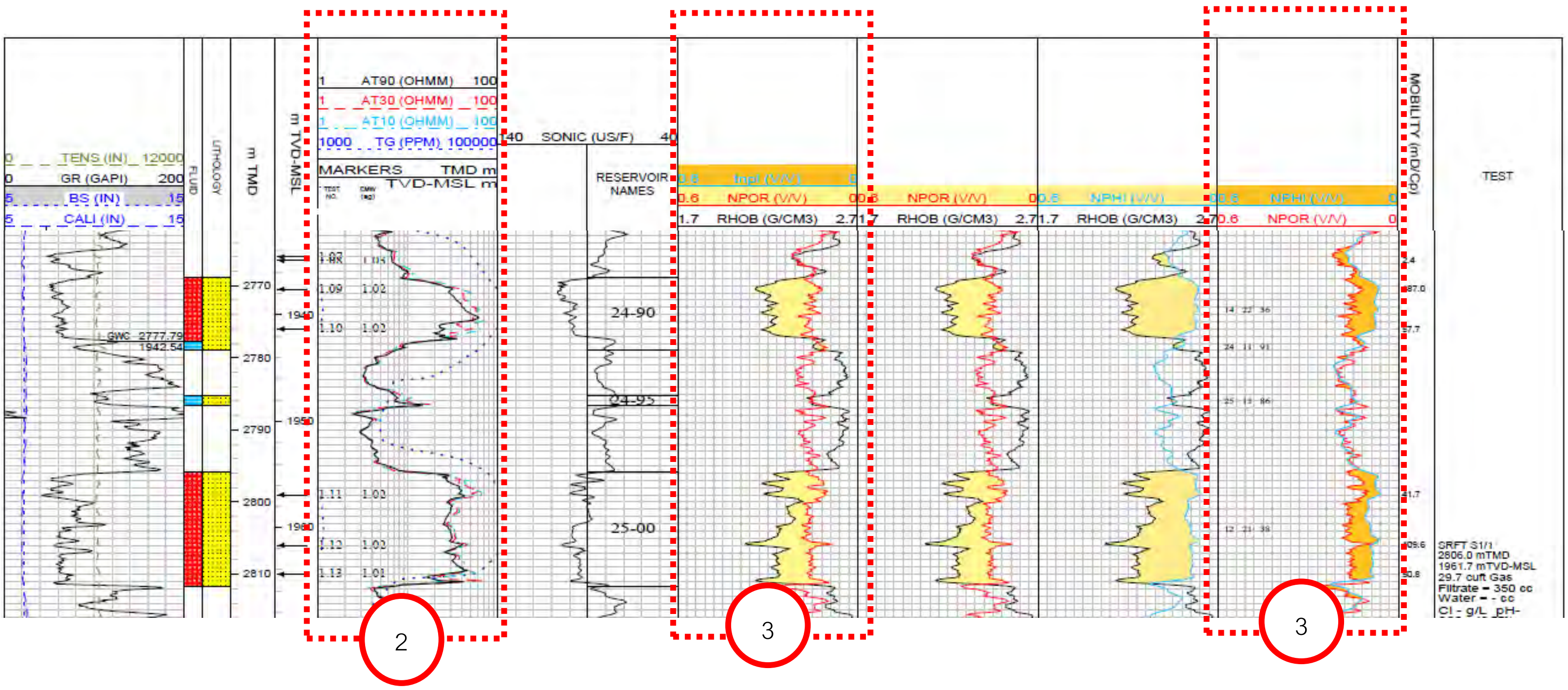


Figure 4.6 The picture shows well log data of AT-14-2X at 2769 mMD. and 2796 mMD.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
1990	1435	10	16-1x	✓	✓	Gas	Gas
2769	1937	50	24-1x	✓	✓	Gas	Gas
2796	1964	30	25-1x	✓	✓	Gas	Gas

Table 4.2 Shows data table of AT-14-1X at 1990, 2769 and 2796 mMD.

At AT-14-2x, initial interpretation is consistent with my interpretation. There were high resistivity about 10-30 ohm. (column 2 in each Figure.) as in gas resistivity range at 1990, 2769 and 2796 mMD. (Figure 4.5, 4.6) accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. And interpretation from time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

AT-14-4X

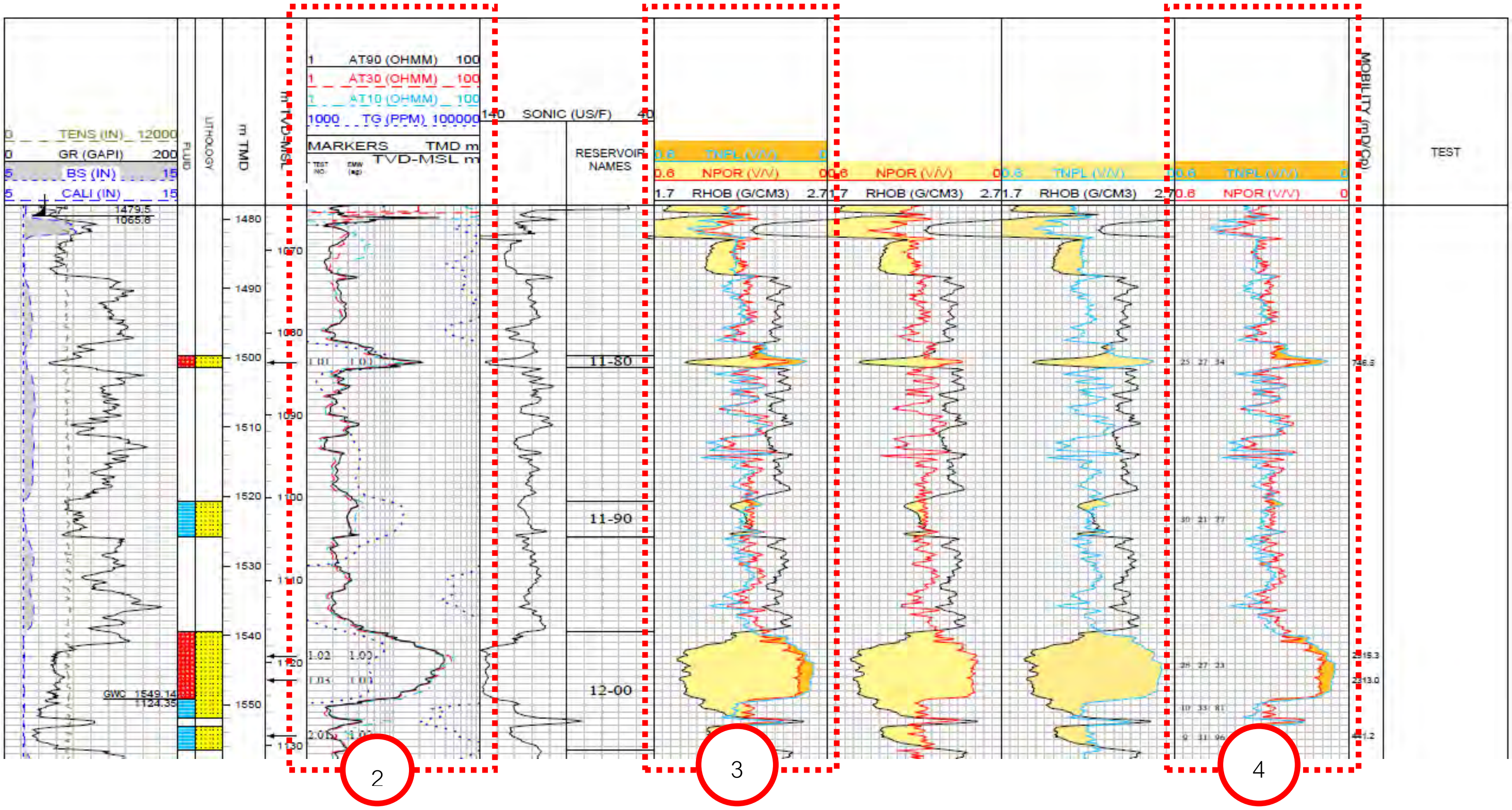


Figure 4.7 Picture shows well log data of AT-14-4X at 1500 mMD. and 1540 mMD.

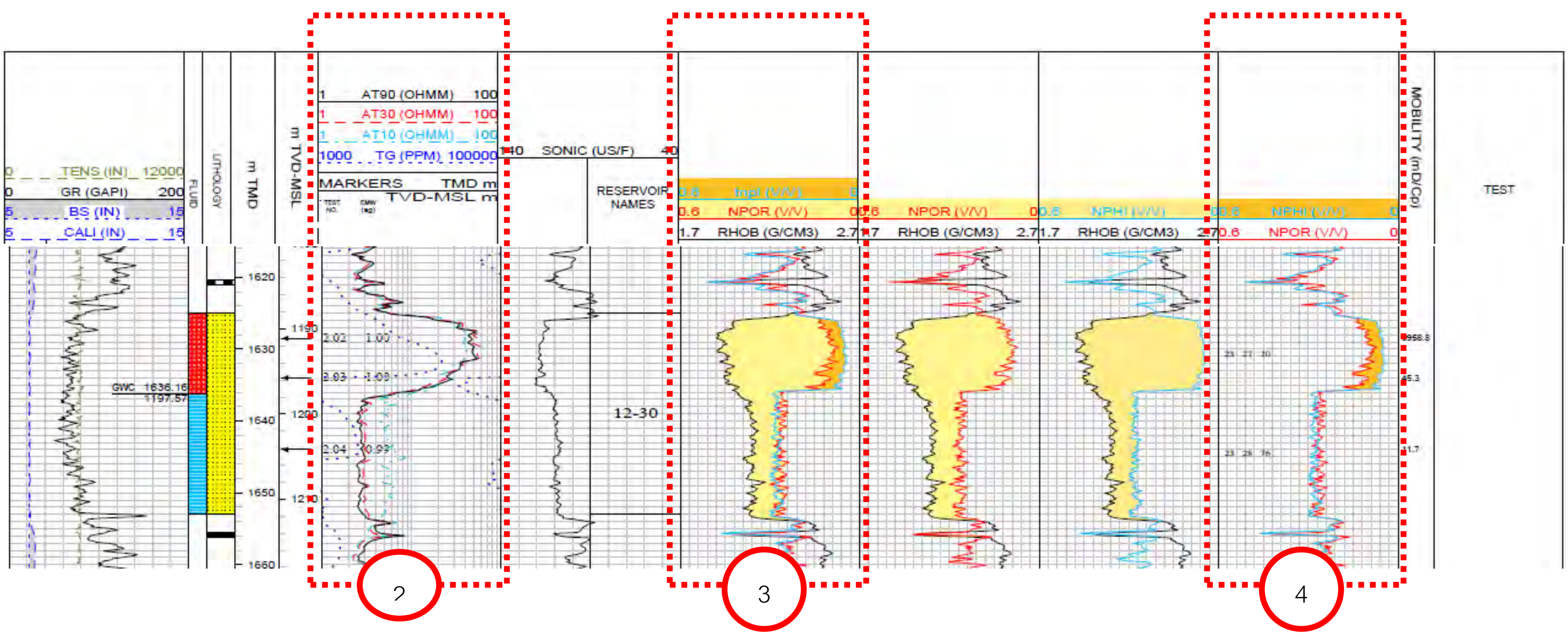


Figure 4.8 Picture shows well log data of AT-14-4X at 1625 mMD.

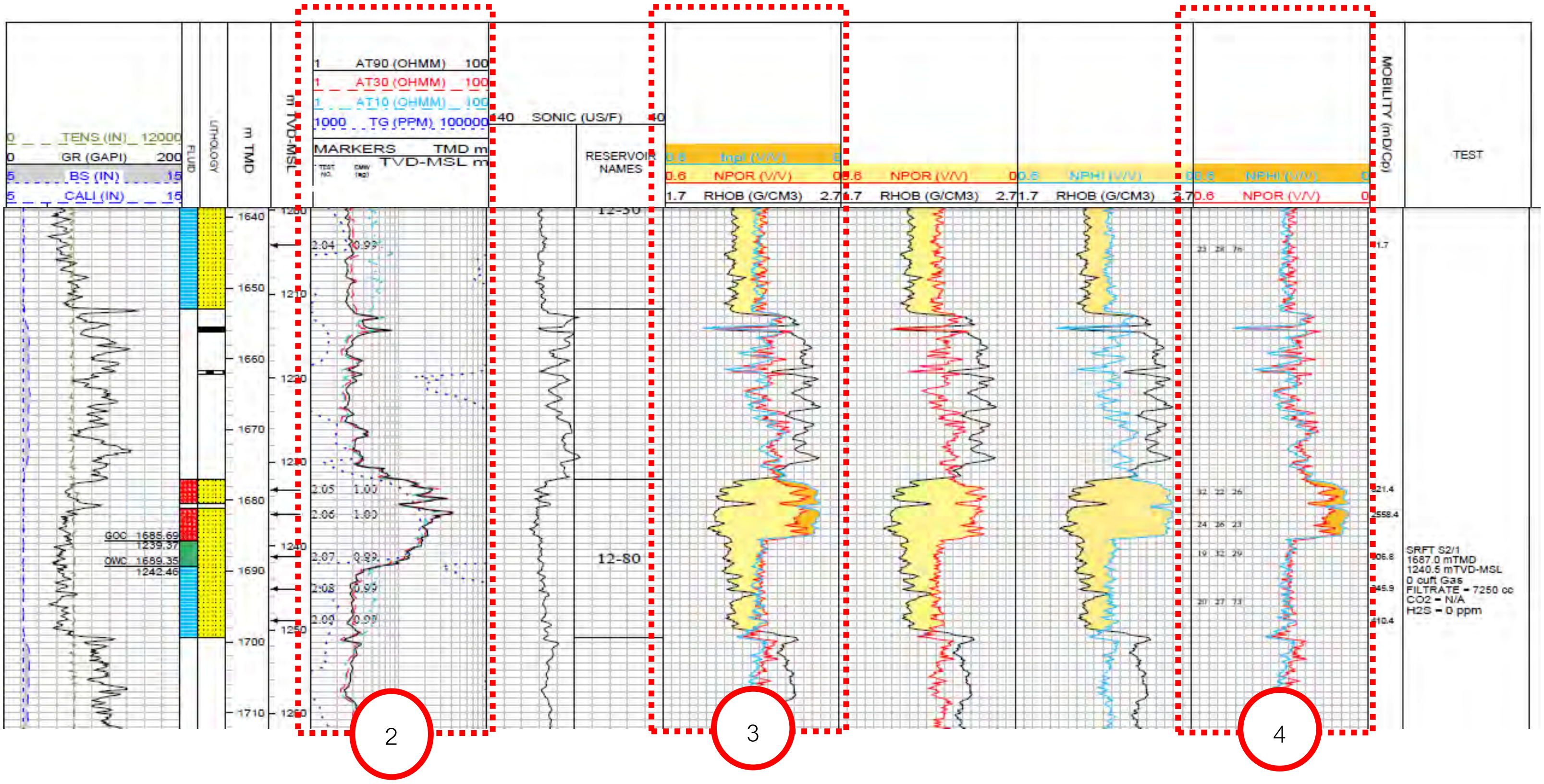


Figure 4.9 Picture shows well log data of AT-14-4X at 1677 mMD. and 1685 mMD.

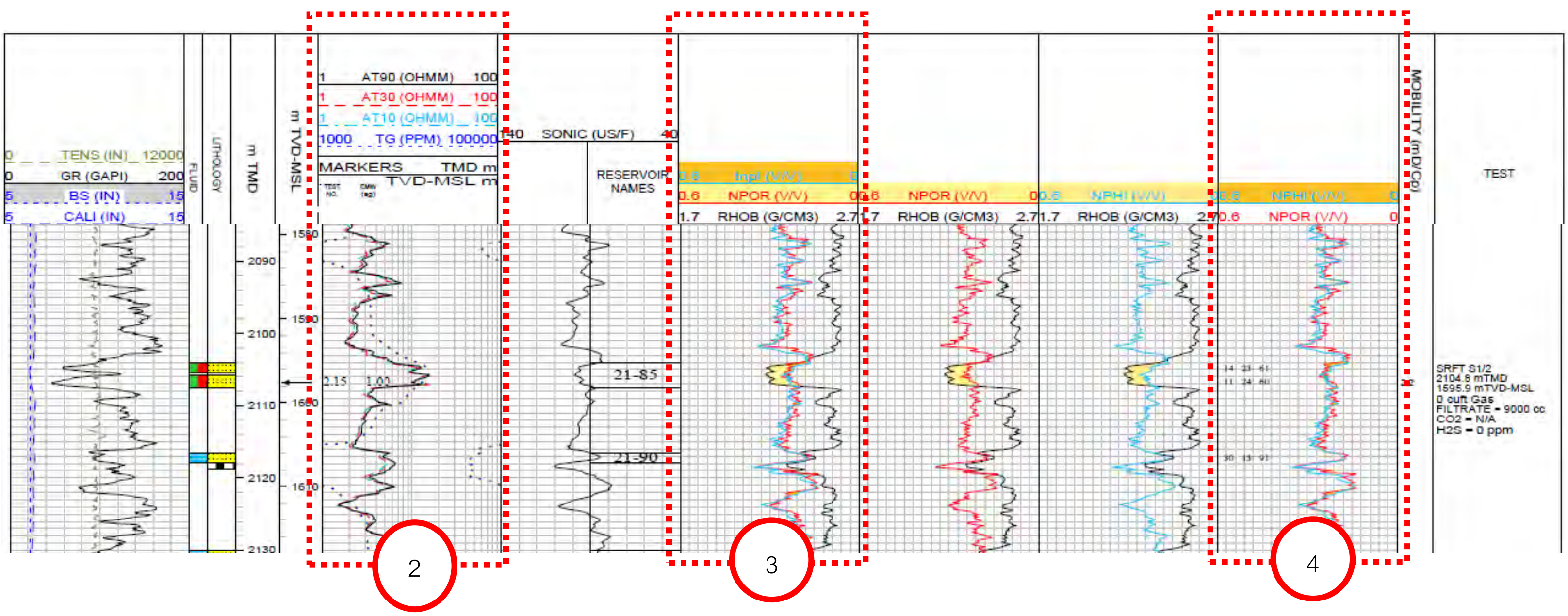


Figure 4.10 Picture shows well log data of AT-14-4X at 2104 mMD.

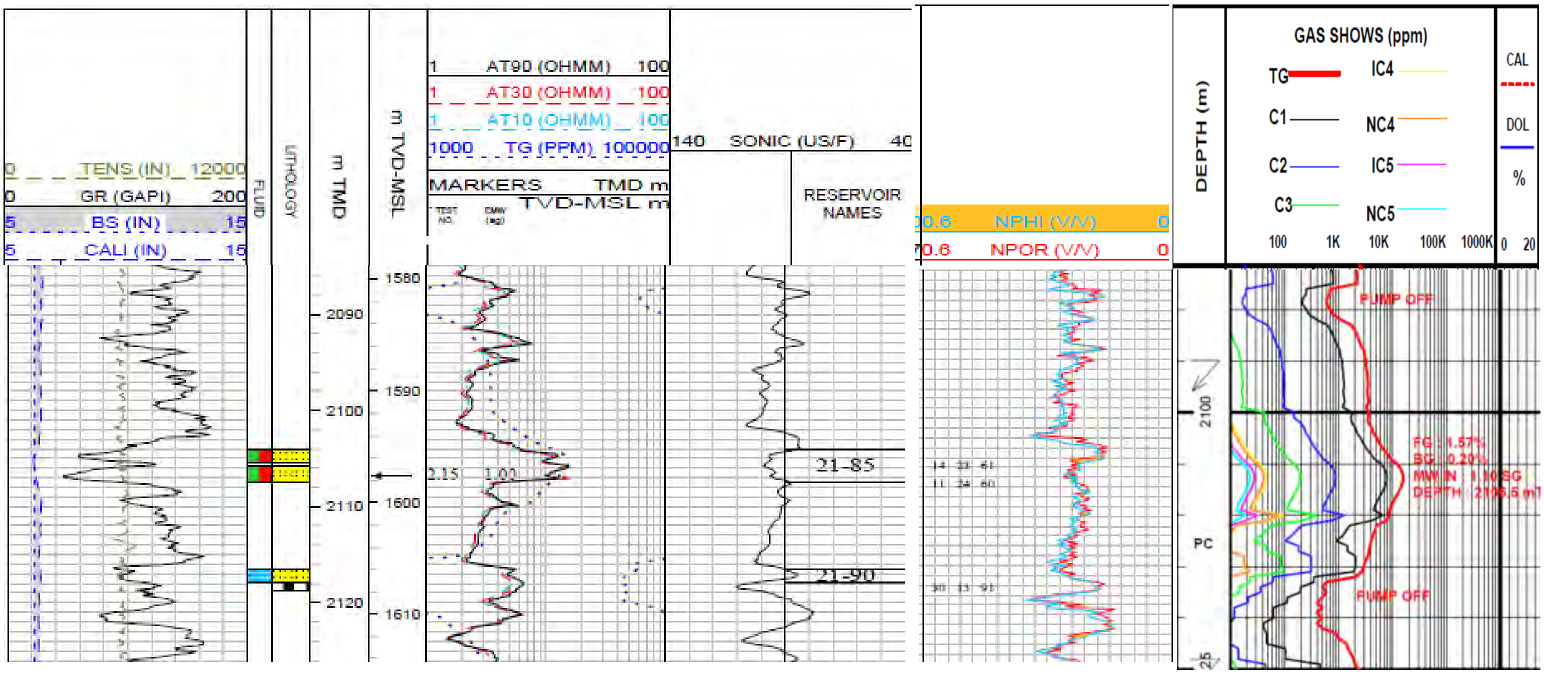


Figure 4.11 Well log data of AT-14-4X at 2104 mMD. compare with mud log, blue line shows high C5 component.

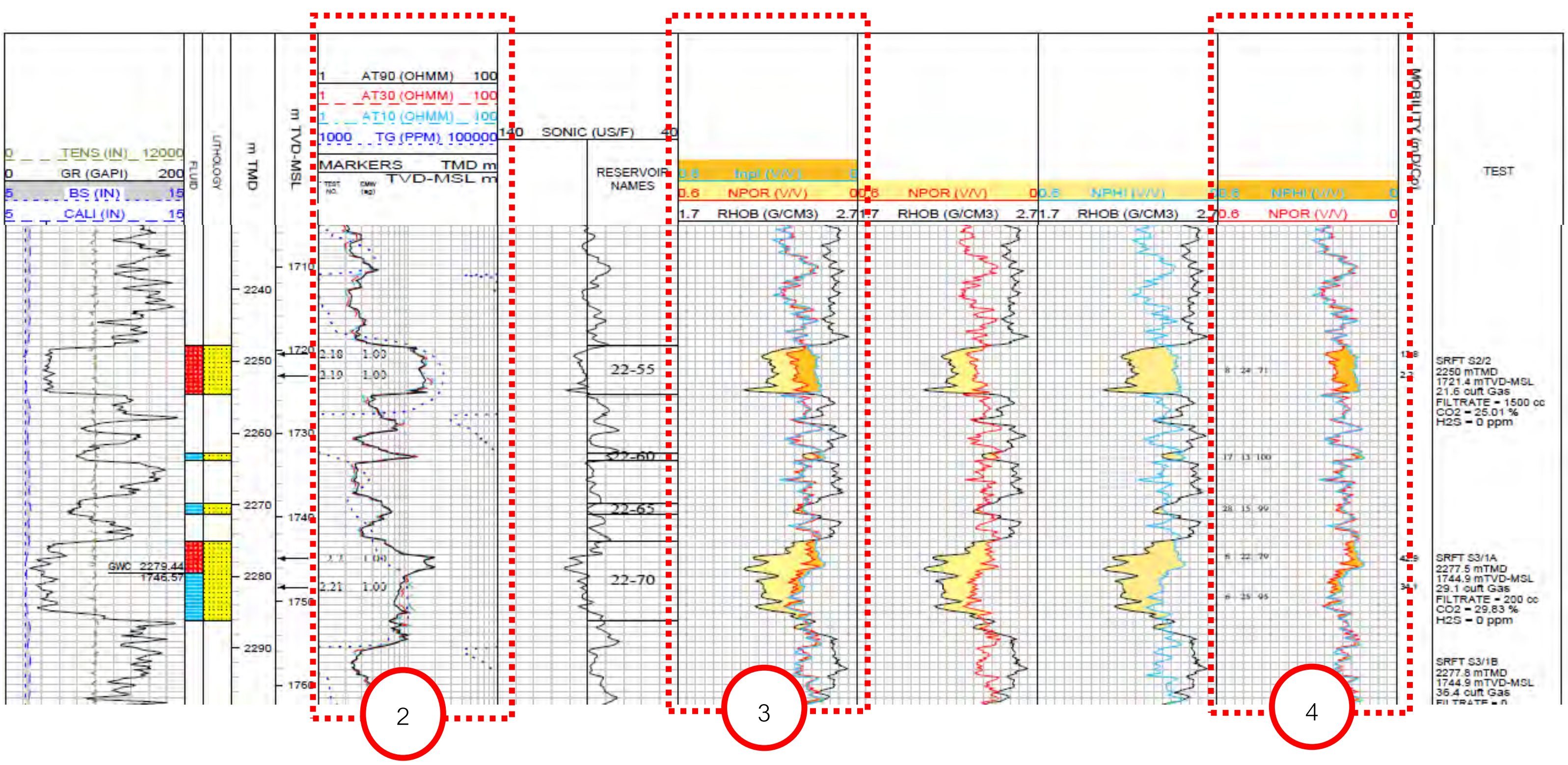


Figure 4.12 Picture shows well log data of AT-14-4X at 2248 mMD. and 2275 mMD.

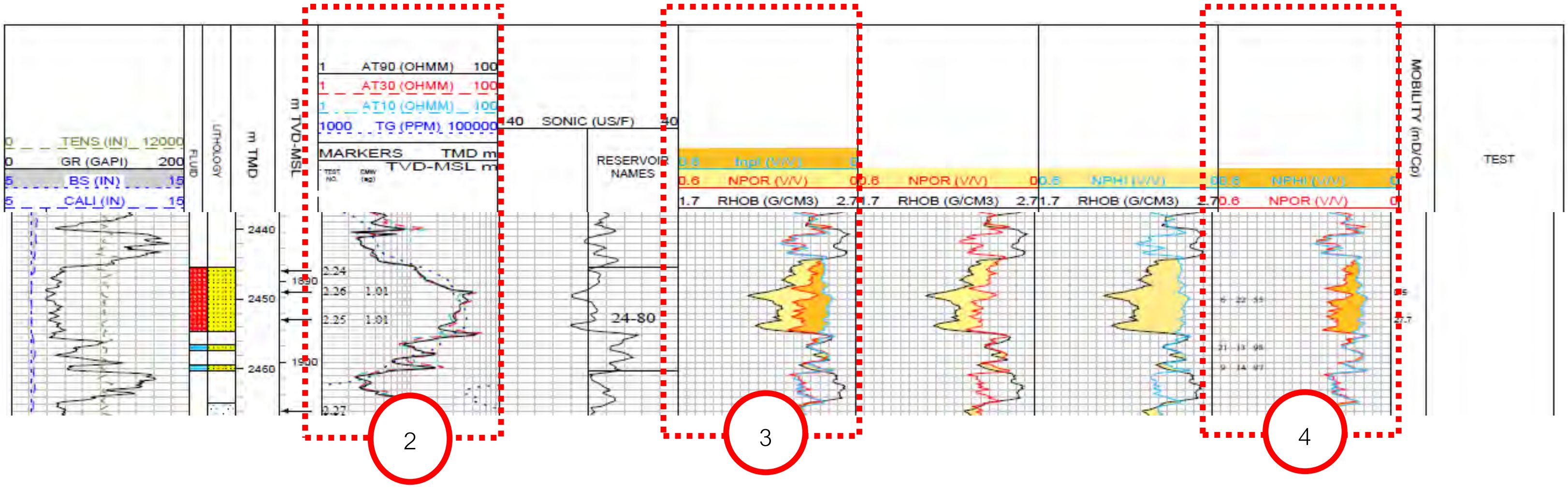


Figure 4.13 Picture shows well log data of AT-14-4X at 2446 mMD.

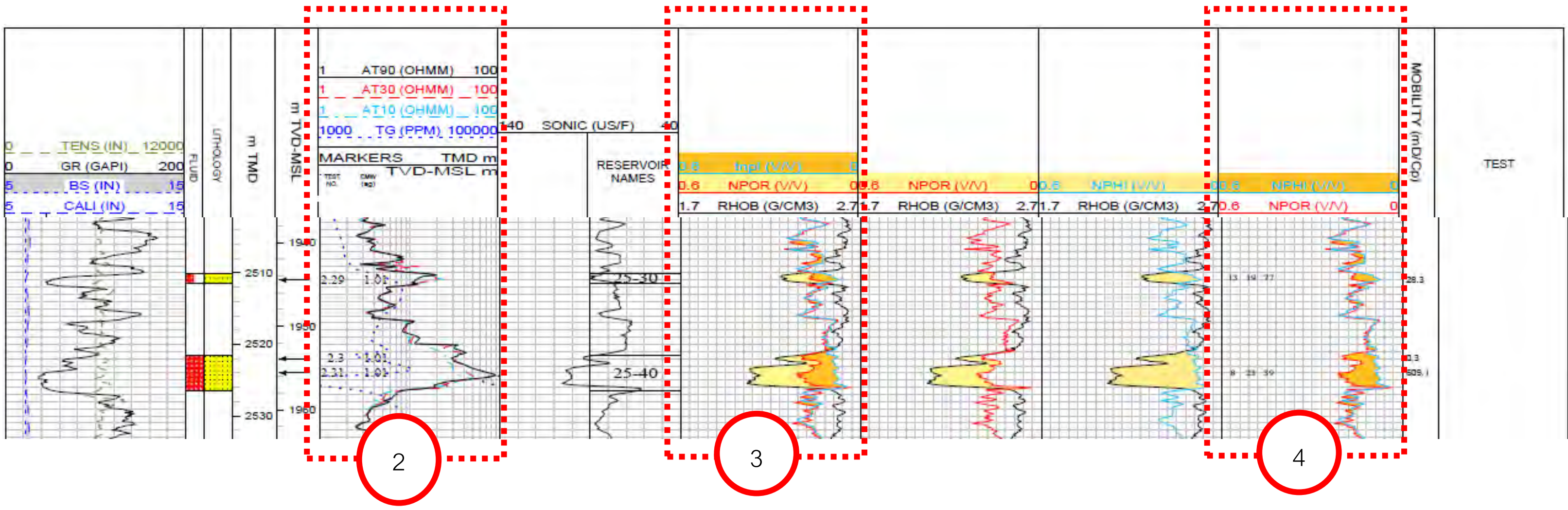


Figure 4.14 Picture shows well log data of AT-14-4X at 2510 mMD. and 2522 mMD.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
1500	1083	20	11-1x	✓	✓	Gas	Gas
1540	1116	40	12-1x	✓	✓	Gas	Gas
1625	1188	40	12-2x	✓	✓	Gas	Gas
1677	1232	30	12-3x	✓	✓	Gas	Gas
1685	1240	10	12-3x	✗	✗	Oil	Oil
2104	1595	10	21-1x	✗	✗	Oil ? Gas ?	Oil
2248	1720	15	22-1x	✓	✓	Gas	Gas
2275	1744	20	22-2x	✓	✓	Gas	Gas
2446	1888	30	24-1x	✓	✓	Gas	Gas
2510	1944	20	25-1x	✓	✓	Gas	Gas
2522	1954	40	25-2x	✓	✓	Gas	Gas

Table 4.3 Data table of AT-14-4X at 1500, 1540, 1625, 1677, 1685, 2104, 2248, 2275, 2446, 2510 and 2522 mMD.

From AT-14-1x well data, 11 positions (Figure 4.7, 4.8, 4.9, 4.12, 4.13, 4.14) were observed, at 1500, 1540, 1625, 1677, 1685, 2104, 2248, 2275, 2446, 2510 and 2522 mMD. There were high resistivity about 15-30 ohm. (column 2 in each Figure.) as in gas resistivity range at 1500, 1540, 1625, 1677, 2248, 2275, 2446, 2510 and 2522 mMD. accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. According to time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

From Figure 4.9 we found that LWD-WL separation is not appear at the depth of 1685 mMD, so it can be interpreted as oil (my interpretation) and the appearance of Density-Porosity crossover (column 3 in Figure 4.9 at depth 1685 mMD.) is not appear so these can be implied to oil sand too (initial interpretation).

From Figure 4.10 we found that LWD-WL separation (column 4 in figure 4.10)is not appear at the depth of 2104 mMD, and the data from a mud log shows that C5 or values are high (Figure 4.11). Based on these evidence, the fluid in this sand reservoir can be interpreted as oil. Samples from SRFT (Slimhole Repeat FormationTester : SRFT tool can be recovered two fluid samples from two different depths.) also indicate that the fluid is oil, which conform with result from C5 characteristic.

AT-14-5X

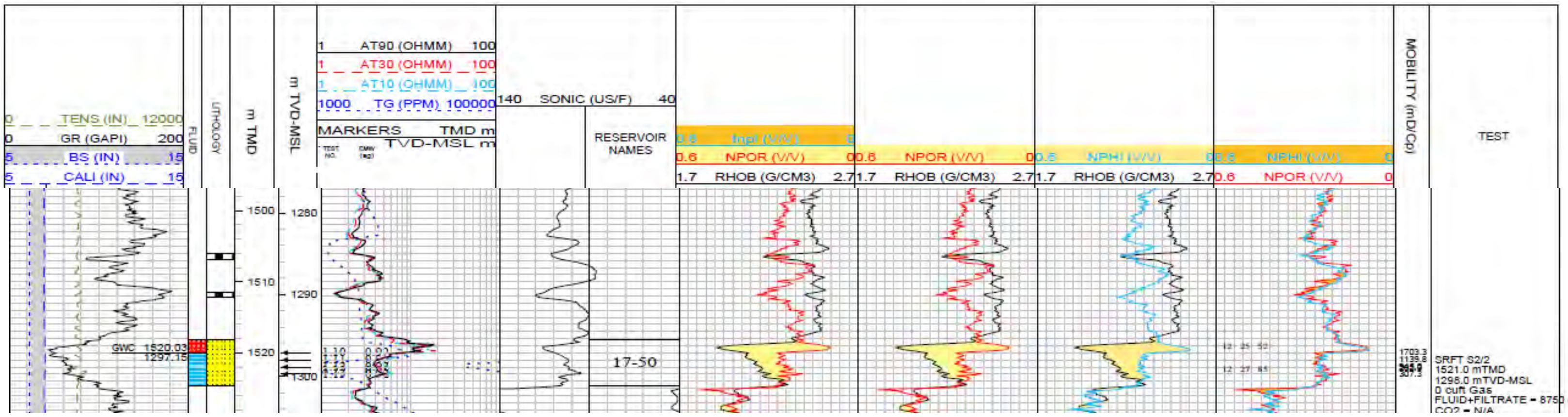


Figure 4.15 Picture shows well log data of AT-14-5X at 1518 mMD.

At the depth of 1518 mMD (Figure 4.15) in AT-14-5x well, there is a point that the fluid in the reservoir can be identified as gas. However, this finding is not consistent with the technique time lapse neutron because LWD-WL separation is not found.

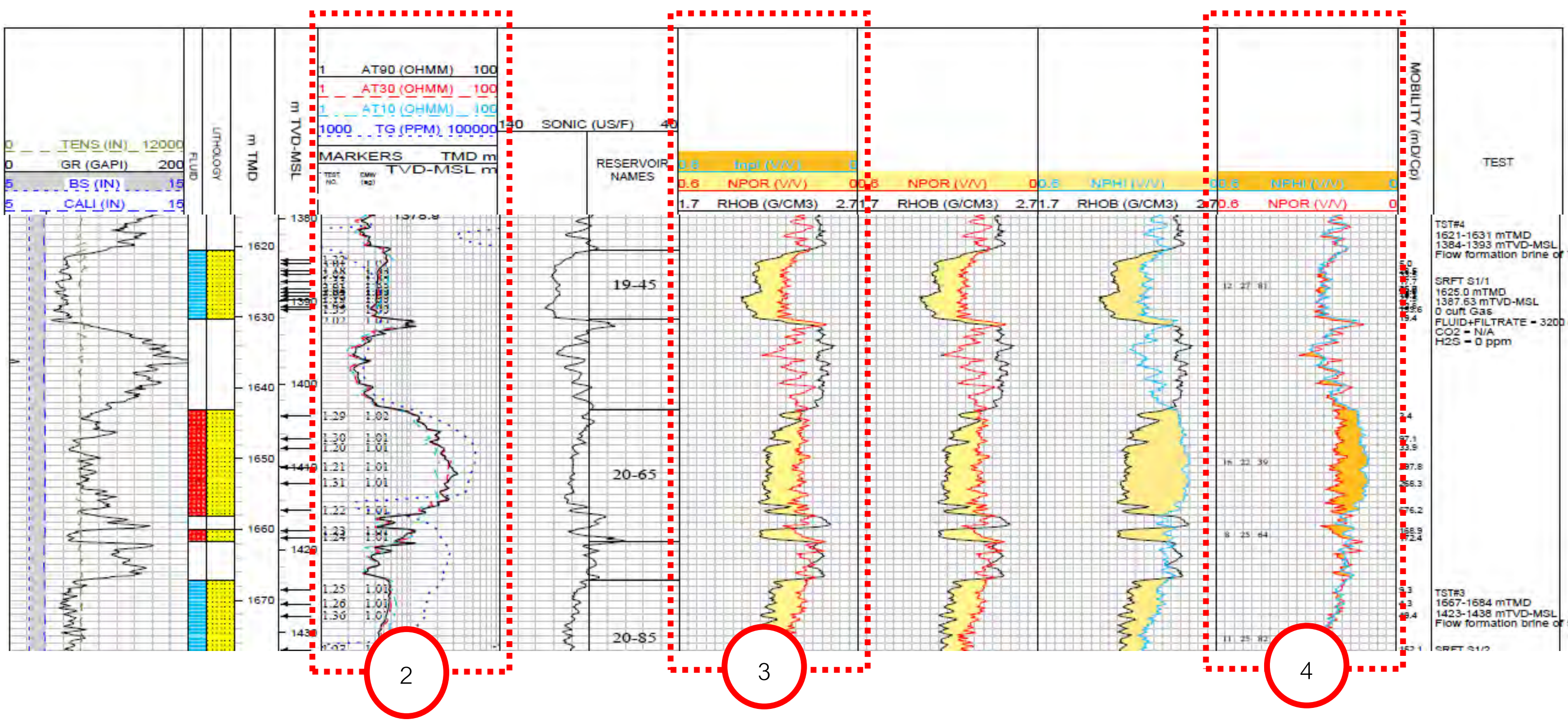


Figure 4.16 Picture shows well log data of AT-14-5X at 1644 mMD.

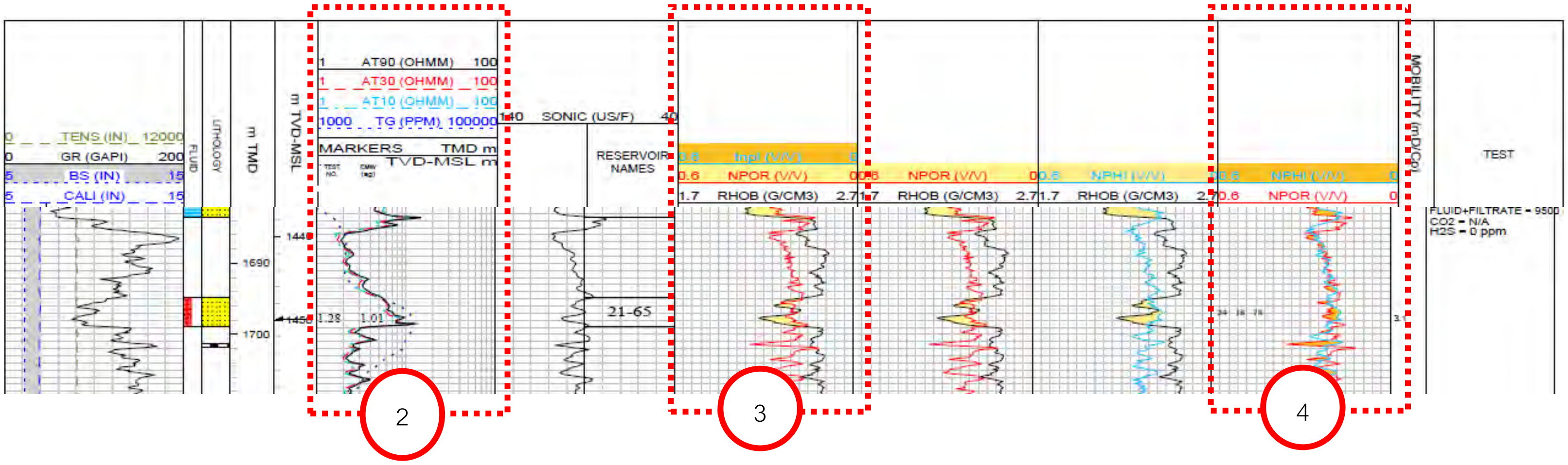


Figure 4.17 Picture shows well log data of AT-14-5X at 1695 mMD.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
1644	1404	30	20-1x	✓	✓	Gas	Gas
1695	1448	10	21-1x	✓	✓	Gas	Gas

Table 4.4 Well log data of AT-14-5X at 1644 and 1695 mMD.

At AT-14-5x, initial interpretation is consistent with my interpretation. There were high resistivity about 10-30 ohm. (column 2 in each Figure.) as in gas resistivity range at 1644 and 1695 mMD. (Figure 4.16, 4.17) accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. And interpretation from time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

AT-15-1X

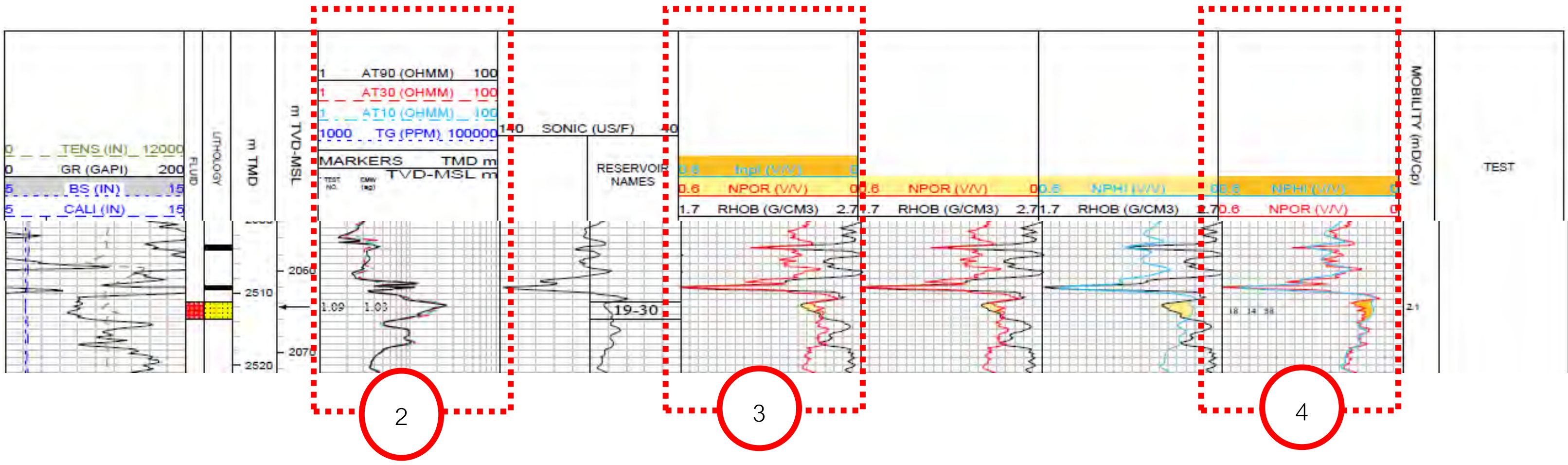


Figure 4.18 Picture shows well log data of AT-15-1X at 2511 mMD.

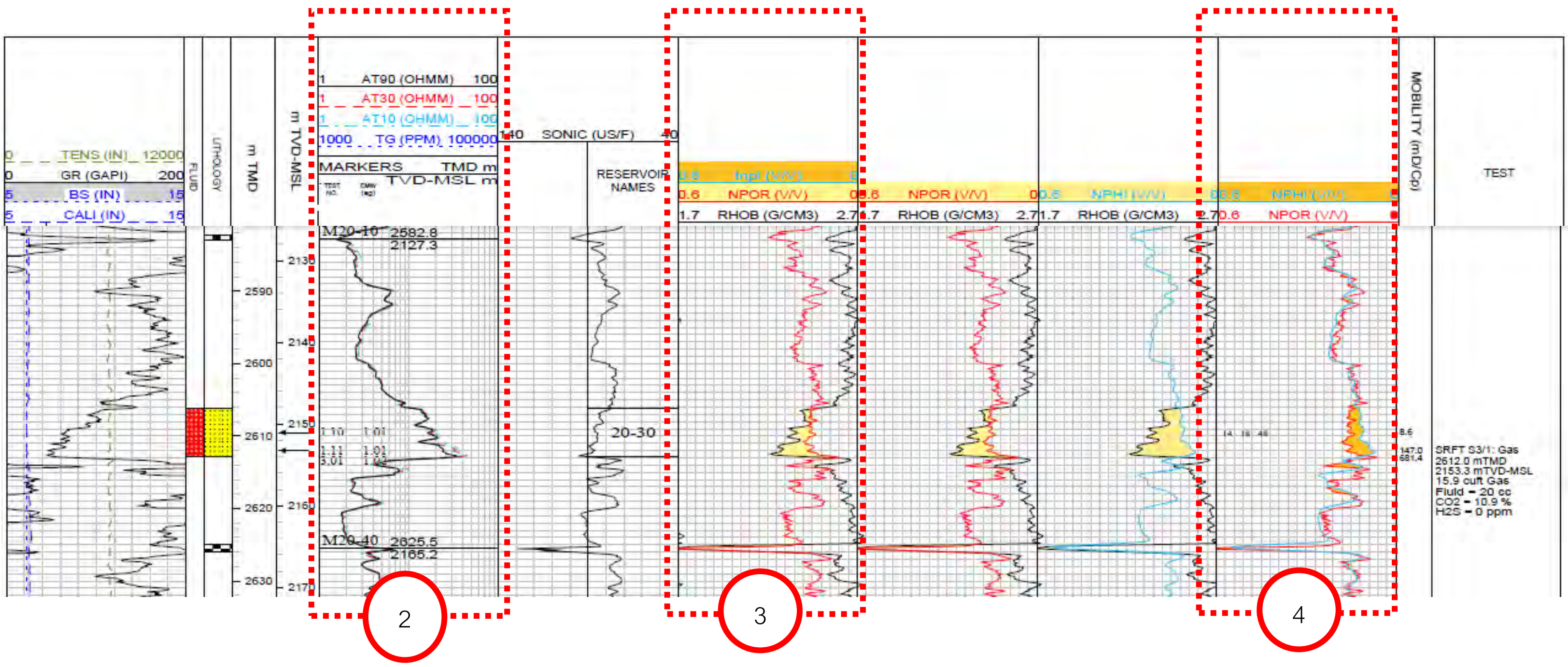


Figure 4.19 Picture shows well log data of AT-15-1X at 2606 mMD.

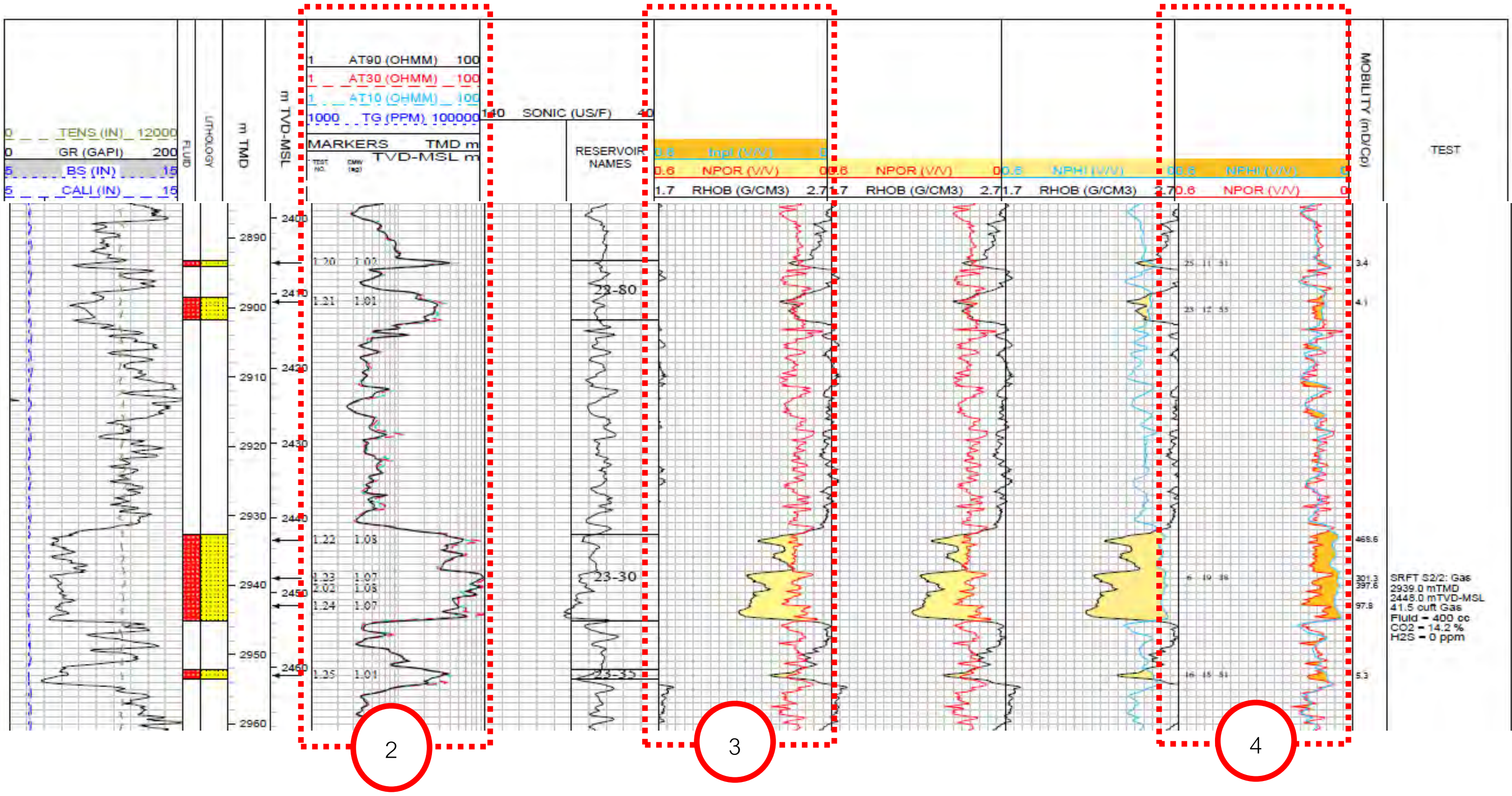


Figure 4.20 Picture shows well log data of AT-15-1X at 2893, 2898, 2932 and 2952 mMD.

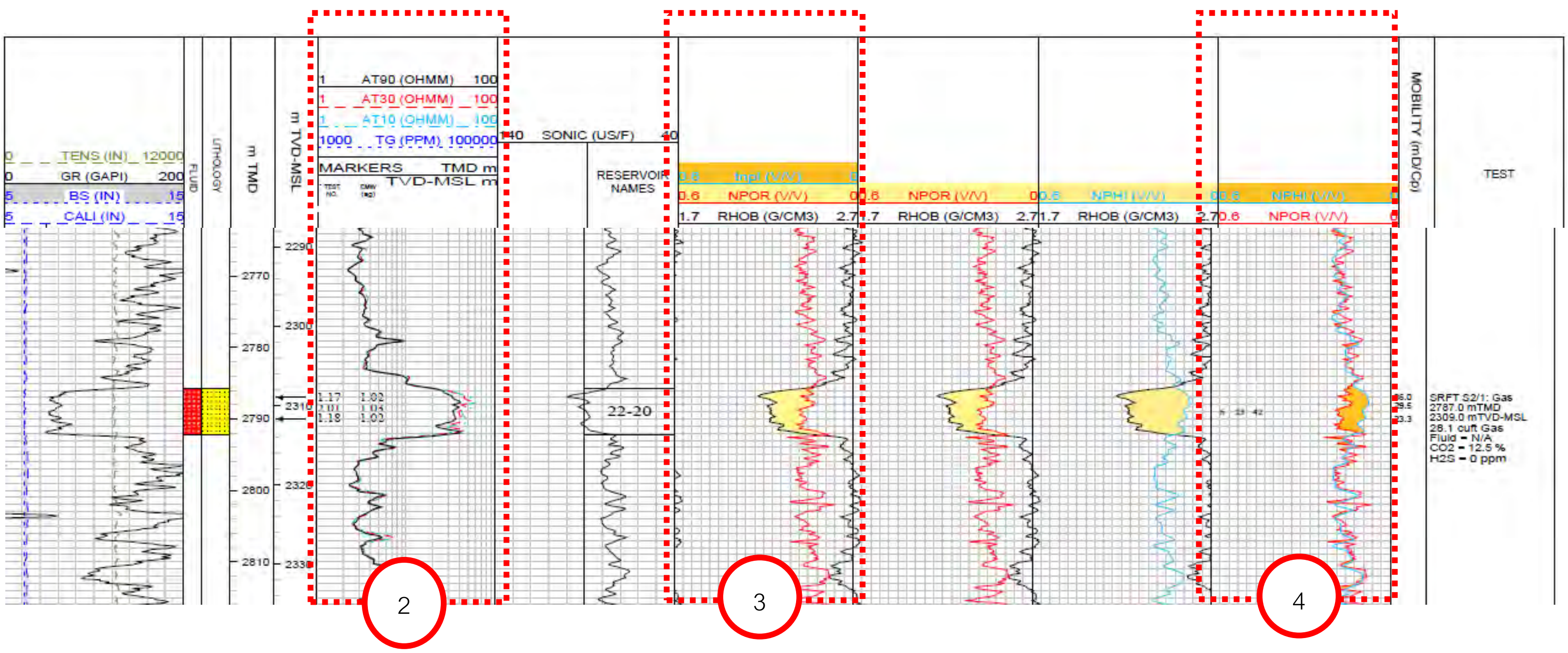


Figure 4.21 Picture shows well log data of AT-15-1X at 2785 mMD.

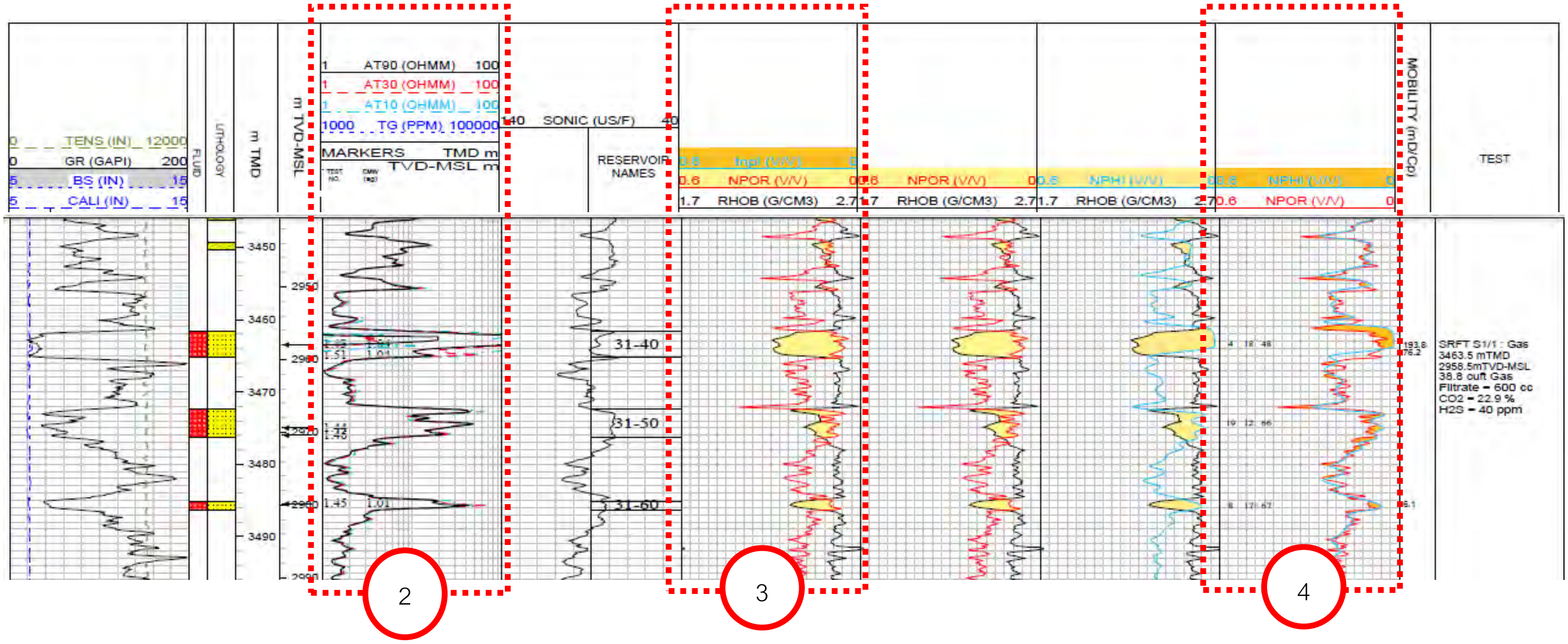


Figure 4.22 Picture shows well log data of AT-15-1X at 3462, 3472 and 3485 mMD.

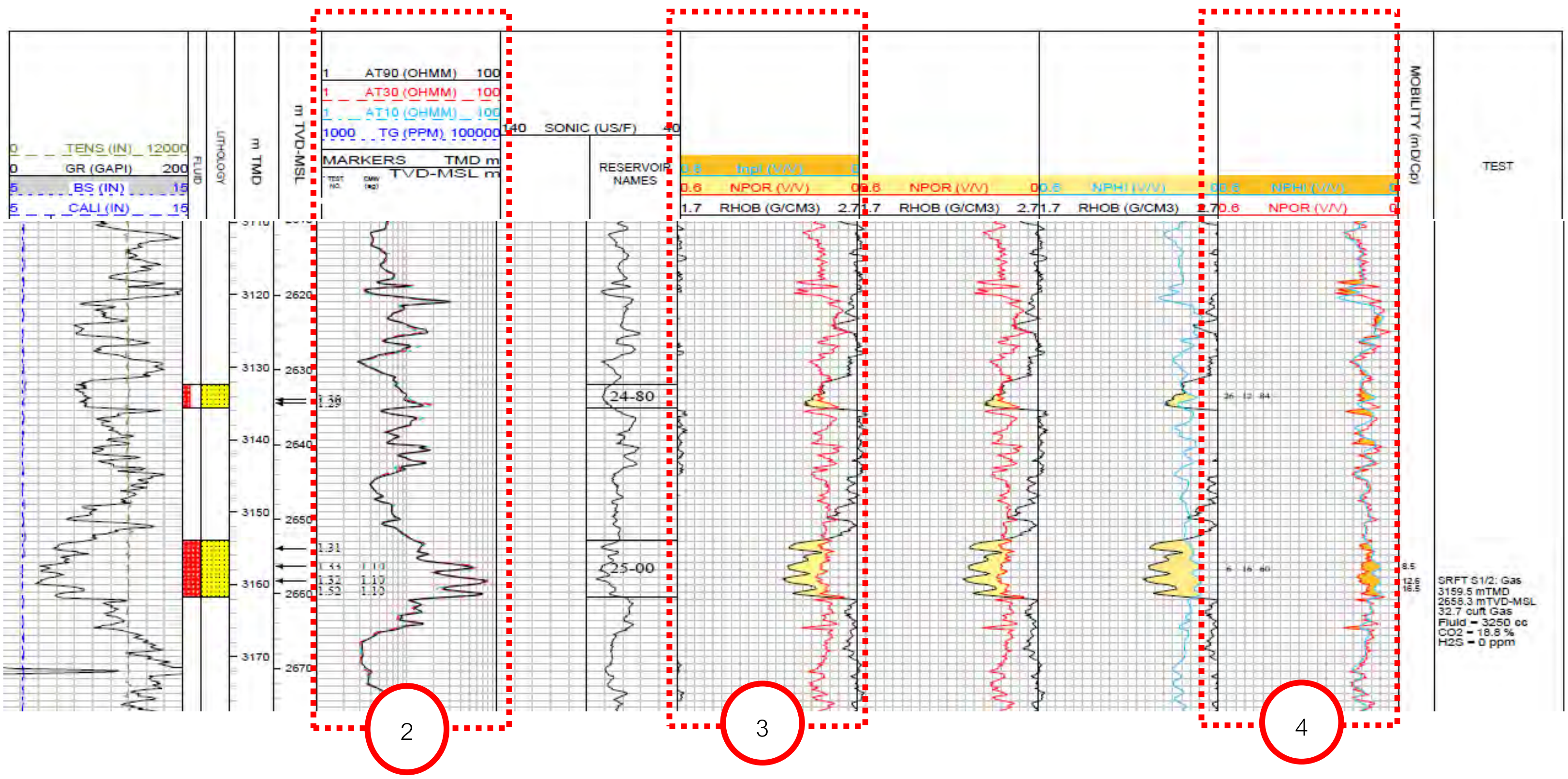


Figure 4.23 Picture shows well log data of AT-15-1X at 3132 and 3154 mMD.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
2511	2054	20	19-1x	✓	✓	Gas	Gas
2606	2148	30	20-1x	✓	✓	Gas	Gas
2893	2405	30	22-1x	✓	✓	Gas	Gas
2898	2411	30	22-1x	✓	✓	Gas	Gas
2932	2442	60	23-1x	✓	✓	Gas	Gas
2952	2450	40	23-2x	✓	✓	Gas	Gas
2786	2308	40	22-1x	✓	✓	Gas	Gas
3462	2967	80	31-1x	✓	✓	Gas	Gas
3472	2697	40	31-2x	✓	✓	Gas	Gas
3485	2980	40	31-3x	✓	✓	Gas	Gas
3132	2632	15	24-1x	✓	✓	Gas ?	Gas
3154	2652	50	25-1x	✓	✓	Gas	Gas

Table 4.5 Well log data of AT-15-1X at 2511, 2606, 2893, 2898, 2932, 2952, 2786, 3462, 3472, 3485, 3132 and 3154 mMD.

At AT-15-1x, initial interpretation is consistent with my interpretation. There were high resistivity about 20-80 ohm. (column 2 in each Figure.) as in gas resistivity range at 2511, 2606, 2893, 2898, 2932, 2952, 2786, 3462, 3472, 3485, 3132 and 3154 mMD. (Figure 4.18, 4.19, 4.20, 4.21, 4.22, 4.23) accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. And interpretation from time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

AT-15-2X

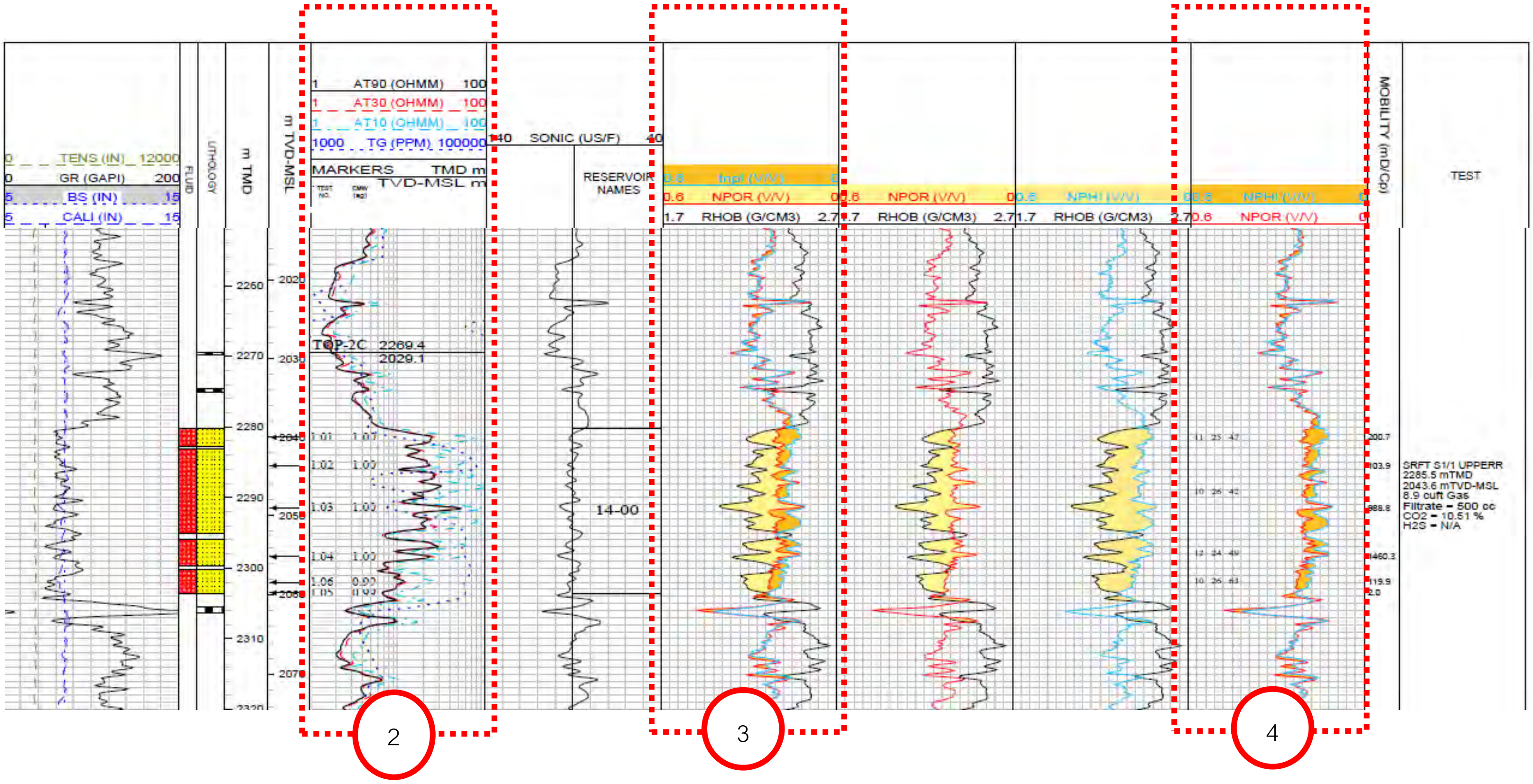


Figure 4.24 Picture shows well log data of AT-15-2X at 2280 mMD.

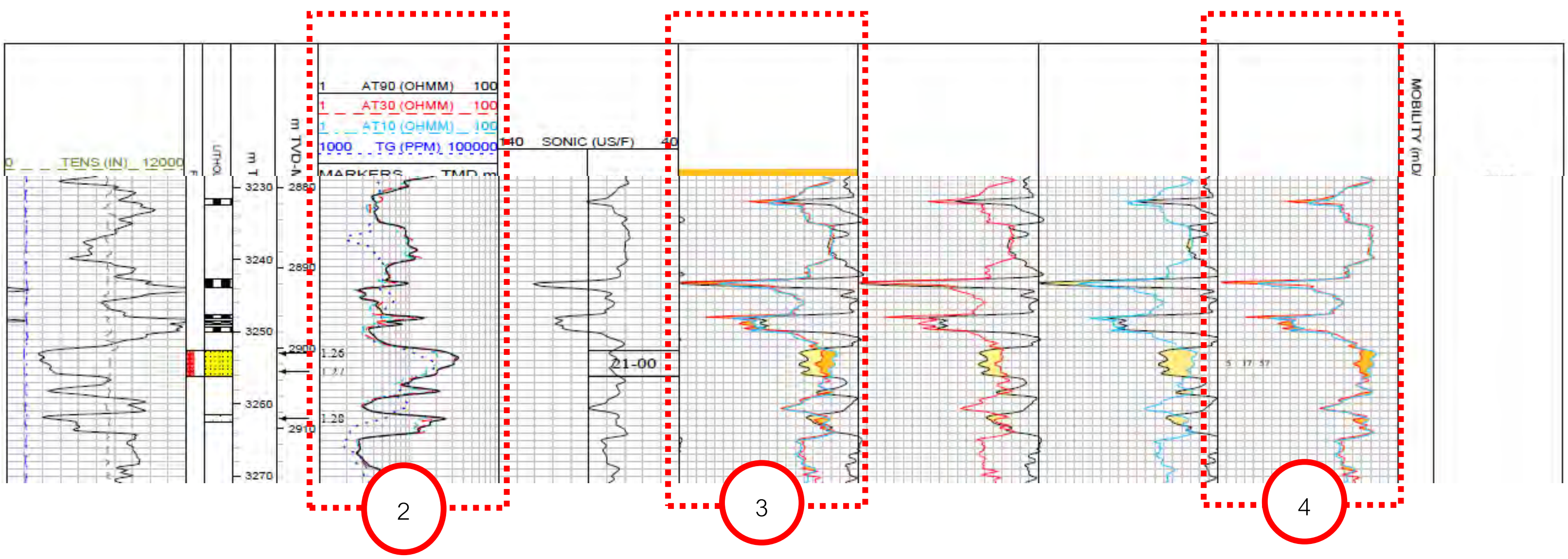


Figure 4.25 Picture shows well log data of AT-15-2X at 3252 mMD.

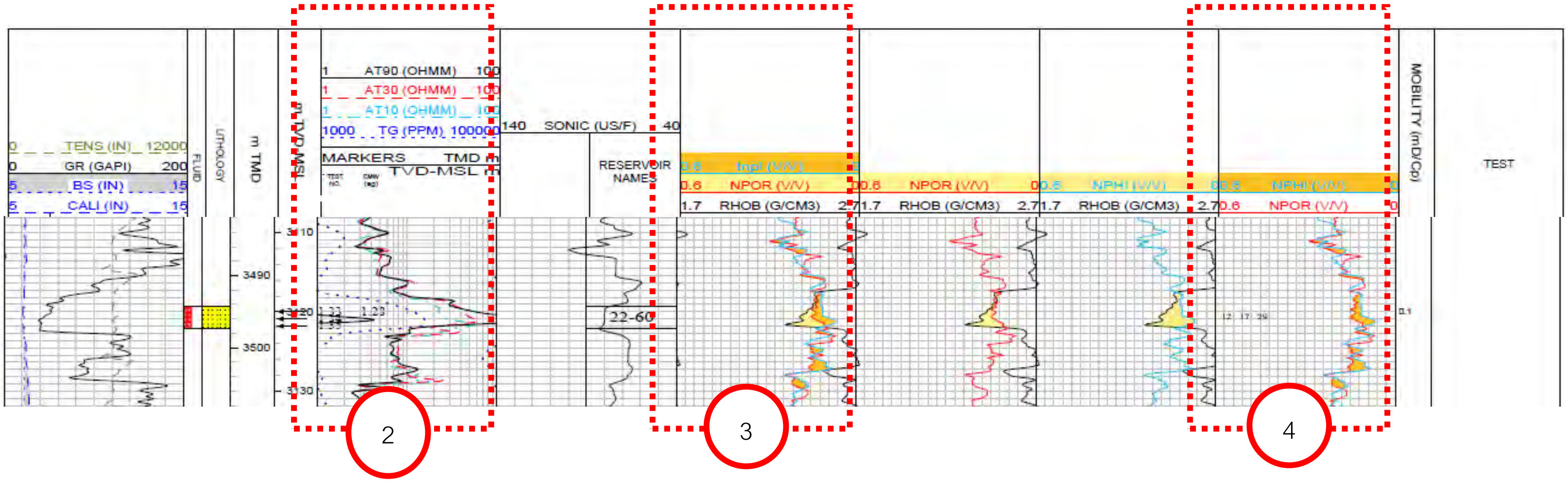


Figure 4.26 Picture shows well log data of AT-15-2X at 3494 mMD.

Depth(m)		Res. (ohm.)	Reservoir_name	Density-Porosity crossover	LWD-WL separation	Initial Interpretation	My Interpretation
MD	TVD						
2280	2038	30	14-1x	✓	✓	Gas	Gas
3252	2900	30	21-1x	✓	✓	Gas ?	Gas
3494	3119	80	22-1x	✓	✓	Gas ?	Gas

Table 4.6 Well log data of AT-15-2X at 2280, 3252 and 3494 mMD.

At AT-15-2x, initial interpretation is consistent with my interpretation. There were high resistivity about 30-80 ohm. (column 2 in each Figure.) as in gas resistivity range at 2280, 3252 and 3494 mMD. (Figure 4.24, 4.25, 4.26) accompany with the appearance of Density-Porosity crossover (column 3 in each Figure.). These can be indicated as gas bearing sand for an initial interpretation. And interpretation from time-lapse neutron technique, LWD-WL separation (column 4 in each Figure.) is also observed at these depth as well. These can be implied to gas bearing sand too.

Chapter 5

Discussion and Conclusion

5.1 Disussion

There are many cases found in the identification of oil method and observing C5 component in Arthit field. Although LWD-WL separation and density-porosity separations are found in the gas sand, the value of C5 component is high. One of the reason might be high pressure gradient and high temperature in the Arthit field; therefore, oil probably converts to gas. Moreover, mud logging can also be a source of problems, such as slow drilling time, small holes, and spurious gas kicks. These problems could lead to incorrect data from the mud log.

5.2 Conclusions

The results of this study can be summarized as follows:

1. Time lapse neutron technique is one of effective tools to support fluid identification, especially in the area with OBM invasion (must be well which has LWD neutron porosity and WL neutron porosity).
2. Identification of Oil by observing C5 component, we found that the accuracy is 62.37 %.
3. Most of the study areas are gas field; therefore, the case study of C5 characteristic cannot be concluded about its accuracy.
4. There are small numbers of wells that have LWD and WL neutron porosity log in the Arthit field. Thus, the samples used to study in this research are limit.

Appendix

Glossary

Basin : An enclosed area or topographic depression that facilitates the accumulation of water and/or sediment.

Deposition : The accumulation of any rock and/or organic material into layers by natural agents such as water or wind.

Drilling fluid invasion : It is a process that occurs in a well being drilled with higher wellbore pressure (normally caused by excessive mud weights) than formation pressure. The liquid component of the drilling fluid (known as the mud filtrate) also called as spurt, continues to "invade" the porous and permeable formation until the solids present in the mud, commonly bentonite, clog enough pores to form a mud cake capable of preventing further invasion.

Fault : A fracture or zone of fractures along which there has been displacement of the sides relative to one another, parallel to the fracture.

Graben : An elongate part of the Earth's crust bounded by faults on its long sides and relatively down-dropped compared to its surroundings.

Lacustrine : Pertaining to an environment of deposition in lakes, or an area having lakes. Because deposition of sediment in lakes can occur slowly and in relatively calm conditions, organic-rich source rocks can form in lacustrine environments.

Logging : The cabin that contains the surface hardware needed to make wireline logging measurements. The logging unit contains at the minimum the surface instrumentation, a winch, a depth recording system and a data recorder. The surface instrumentation controls the logging tool, processes the data received and records the results digitally and on hard copy. The winch lowers and raises the cable in the well. A depth wheel drives the depth recording system. The data recorder includes a digital recorder and a printer.

Logging While Drilling : The measurement of formation properties during the excavation of the hole, or shortly thereafter, through the use of tools integrated into the bottomhole assembly. LWD, while sometimes risky and expensive, has the advantage of measuring properties of a formation before drilling fluids invade deeply.

Marine : A descriptive term that means; occurring in/or pertaining to the sea.

Reservoir : A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system.

Sediment : Solid fragments of rock, chemical precipitation, or organic mater, that were deposited by some natural agent such as wind or water and that settle into layers.

Tertiary : A geologic time term to identify rocks formed during and a time span from about 65 to 1.6 million years before the present.

Well Log : A detailed record obtained during well drilling, correlating with depth Information such as changes in electrical resistivity, spontaneous potential, radioactivity, and rock type.

Wireline Log : A continuous measurement of formation properties with electrically powered instruments to infer properties and make decisions about drilling and production operations. The record of the measurements, typically a long strip of paper, is also called a log. Measurements include electrical properties (resistivity and conductivity at various frequencies), sonic properties, active and passive nuclear measurements, dimensional measurements of the wellbore, formation fluid sampling, formation pressure measurement, wireline-conveyed sidewall coring tools, and others.

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