RESERVOIR EVALUATION OF PAB SANDSTONE BY PETROPHYSICAL INTERPRETATIONS OF BHIT-FIELD, SOUTHERN INDUS BASIN, PAKISTAN.

A thesis submitted to Bahria University, Islamabad in the partial fulfilled of the requirement of the Degree of Master of Science in Geology

SYED KAMRAN ALI SHERAZI

Department of Earth & Environmental Sciences

Bahria University Islamabad

RESERVOIR EVALUATION OF PAB SANDSTONE BY PETROPHYSICAL INTERPRETATIONS OF BHIT-FIELD, SOUTHERN INDUS BASIN, PAKISTAN.

By

SYED KAMMRAN ALI SHERAZI

01-262201-019

Department of Earth & Environmental Sciences

Bahria University Islamabad

2022

Bahria University

Department of Earth & Environmental Sciences

Islamabad Campus, Islamabad

<u>C e r t i f i c a t e</u>

A thesis submitted by **Mr. Syed Kamran Ali Sherazi** to the Department of Earth & Environmental Sciences Bahria University, Islamabad in partial fulfillment of requirements for the degree of Master of Science in Geology (Session 2020 – 2022).

Supervisor Name - Dr. Muhammad Iqbal Hajana

CERTIFICATE OF ORIGINALITY

This is to certify that the intellectual contents of the thesis

RESERVOIR EVALUATION OF PAB SANDSTONE BY PETROPHYSICAL INTERPRETATIONS OF BHIT-FIELD, SOUTHER N INDUS BASIN, PAKISTAN.

Are the product of my own research work except, as cited properly and accurately in the acknowledgements and references, the material taken from such sources as research paper, research journals, books, internet, etc. solely to support, elaborate, compare and extend the earlier work. Further, this work has not been submitted by me previously for any degree, nor it shall be submitted by me in future for obtaining any degree from this university, or any other university or institution. The incorrectness of this information, if proved at any stage, shall authorize the University to cancel my degree.

Signature: ______________________ Date: _____________________

Name of the research Candidate: **SYED KAMRAN ALI SHERAZI**

ABSTRACT

In the field investigation of hydrocarbon producing Late Cretaceous Pab Sandstone Formation in southwest Pakistan, links between architectural aspects of significant sand bodies and reservoir properties were investigated. Central and Southern Indus Basin are collectively known as Lower Indus Basin. Petrophysical study has been performed in the Bhit field wells, Bhit-02, Bhit-03, and Bhit -04, for the purpose of locating hydrocarbons. The location of the study wells' coordinates (26 16 55.4316 N and 67 27 31.7707 E). Pab Formation, which dates from the Cretaceous, has been the subject of this study. The volume of shale, average porosity, effective porosity, water resistivity, saturation of water, saturation of hydrocarbon, hydrocarbon pore volume, and net pay of the reservoir will be estimated using the well log data from Bhit-02, Bhit-03, and Bhit-04 that are run using GeoGraphix software. The reservoir zone of the well Bhit-02 has good hydrocarbon potential, and the typical net pay is between 13 and 18 meters. The reservoir zone of the well Bhit-03 also has a good potential for hydrocarbons; the average net pay estimate for this well ranges from 2 to 8 meters. Data and logs from the Bhit-04 well are missing, and they were not evaluated.

To better understand the depth of the sandy and shale zone of the Pab Sandstone, structural and stratigraphic correlation is done after the interpretation of these wells. Be aware of the structural deformation of the research region as well as the variations in Pab Sandstone thickness from well to well. Crossplots are used to determine the lithology or matrix. Umaa vs. RHOmaa cross plot and M-N lithology cross plot are the cross plots that were employed in this study The Pab Sandstone was primarily made of quartz, feldspar, and some calcite, according to the study of these cross plots. The Pab Sandstone in Bhit-02 and Bhit-03 has a good reservoir for the accumulation of hydrocarbon, according to the findings of this comprehensive study.

ACKNOWLEDGEMENTS

In the name of Allah, the most beneficent and the most merciful, all praises to almighty Allah, the creator of universe, who blessed me with knowledge and enabled me to complete this research work.

I pay my thanks to whole faculty of my research of my department, specially my supervisor, Dr. Muhammad Iqbal Hajana, for giving me an initiative to do this study, His guidance, constant encouragement and constructive criticism enabled me to complete this study.

I am especially indebted to my fellow Mr. Syed Moneeb Akhtar Gardazi and Abdulla for special their time and guiding me to in my whole research. I also acknowledge the faculty members of the department. I also acknowledge the Head of Department and faculty members of the department.

I also acknowledge the help, the encouragement, endless love and support of my family. This thesis would not have been possible without the generous assistance, cooperation and fruitful advices from my teachers, family and friends.

CONTENTS

3 STRATIGRAPHY PAGE

4 PETROPHYSICAL INTERPRETATION PAGE

LIST OF TABLE

TABLE NO **TITLE** **PAGE**

LIST OF FIGURE

FIGURE NO **TITLE** **PAGE**

ABBREVIATIONS

B.H.T-----Bottom Hole Temperature

DGPC-----Directorate General of Petroleum Concession

Fm---------Formation

GR log----Gamma Ray Log

GR max---Gamma Ray Log Maximum

GR min----Gamma Ray Log Minimum

LLD--------Deep Lateral Log

LLS---------Shallow Lateral Log

LMKR------Landmark Resources

MSFL-------Micro-Spherically Focused Log

OGDCL----Oil and Gas Development Company Limited

PEF---------Photo-Electric Factor

pf -----------Density of Fluid

pma --------Density of Matrix

Rmfeq------Resistivity of Mud Filtrate Equivalent

Sh ----------Saturation of Hydrocarbons

SP ----------Spontaneous Potential

Sw ---------Saturation of Water

TD----------Total Depth

Vshl--------Volume of Shale

CHAPTER 01
INTRODUCTION

1.1 General introduction

The energy industry is currently in charge of the economy. Energy industries contribute to the country's political and economic stability. The availability of hydrocarbons and their exploration are inextricably linked to the country's development and prosperity (Alger, 1980).

Finding porous and permeable formations, as well as their size, shape, thickness, and reservoir extent, is the primary goal of hydrocarbon exploration. Well logging is a technique for obtaining this information by measuring the formation's physical, chemical, and lithological parameters (Alger, 1980). This information can be utilized to identify depth, nature, fluid kind and extent, permeability, porosity, mobility, pressure, flow rate, and a plethora of other intricate parameters when paired with other information from core analysis. It has been shown that technical developments can be used in well logging. Measuring down-hole data through wire line cable allows for the recording of a significant amount of data during data collecting. Therefore, computer-assisted well logging has created new opportunities for the exploitation of hydrocarbons. Geophysical well logging was essential to the finding and production of hydrocarbons. It shows what kind of rock the drill has penetrated. Rock cutting can identify the lithologies that are present, but it is not evident where they are found. Although pricey and only providing you with a partial image of the formation fluids, core drilling can be helpful. Well logs are therefore necessary in order to fully examine the formation.

Petrophysical parameters determine the productivity of wells in oil and gas-bearing reservoirs. They are made up of two parts: a rock matrix and a pore network that is interconnected. Pores can range in size from micrometers in sandstones to centimeters in carbonate rocks (Levorsen, 1967). Petrophysical characteristics include porosity, permeability, saturation, and capillarity. Porosity affects the ability of hydrocarbons to store energy, whereas permeability affects how fluids move through rocks. Saturation is the percentage of porosity that is taken up by fluid. Capillarity also determines the amount of accessible hydrocarbons that can be produced.

Petrophysical analysis of rock samples can be used to identify one property at a time. This can be used to specify the reservoir's rock layer, the amount of hydrocarbons present, drilling strategies, and production techniques. Estimates of hydrocarbons originally in place (HIIP) or reservoir capacity are directly impacted by porosity Permeability controls the reservoir that produces evolution. Lithology controls many other factors, such as salt precipitation in the production line, as well as the distinction between a reservoir and a non-reservoir. Fluid saturation has a direct impact on the evaluation of resources related to the potential phase (water-cut, gas coning, erratic flow regime etc.).

Pakistan's largest sedimentary basin is the Indus basin. The Indus basin contains three sub basins, according to research. Upper, Central, and Southern Indus Basin are these. Lower Indus basin refers to both the Central and Southern Indus basins. The Indus basin is divided into the Upper Indus basin and the Central Indus basin by the Sargodha high, and the Central and Southern Indus basins by the Jacobabad high.

1.2 Location of the study area

The study area is more precisely placed in district Badin, in the province of Sindh, Pakistan. It is situated the Tando Allahyar district to the north. Hyderabad district is located to the northwest. Tharparkar and Mirpur Khas district to tits east. In the south India’s Kutch district is situated. Tando Muhammad Khan and Sujawal district to the west. Pab Sandstone from the Cretaceous era is the generating formation in the study region and its adjacent fields. Vredenburg (1908) coined the term used Pab sandstone, which originates in Kirthar Province Pab mountain range. Williams (1959) identified a part of the path on Wirahab Nai west. “Latitude 25° 32’ 11” N: and Longitude 67° 01’ 18” E”, through the Pab range, as the “Somalji trail”. The following the figure 1.1 and Figure 1.2 showing the location of study area as well as wells of Bhit field.

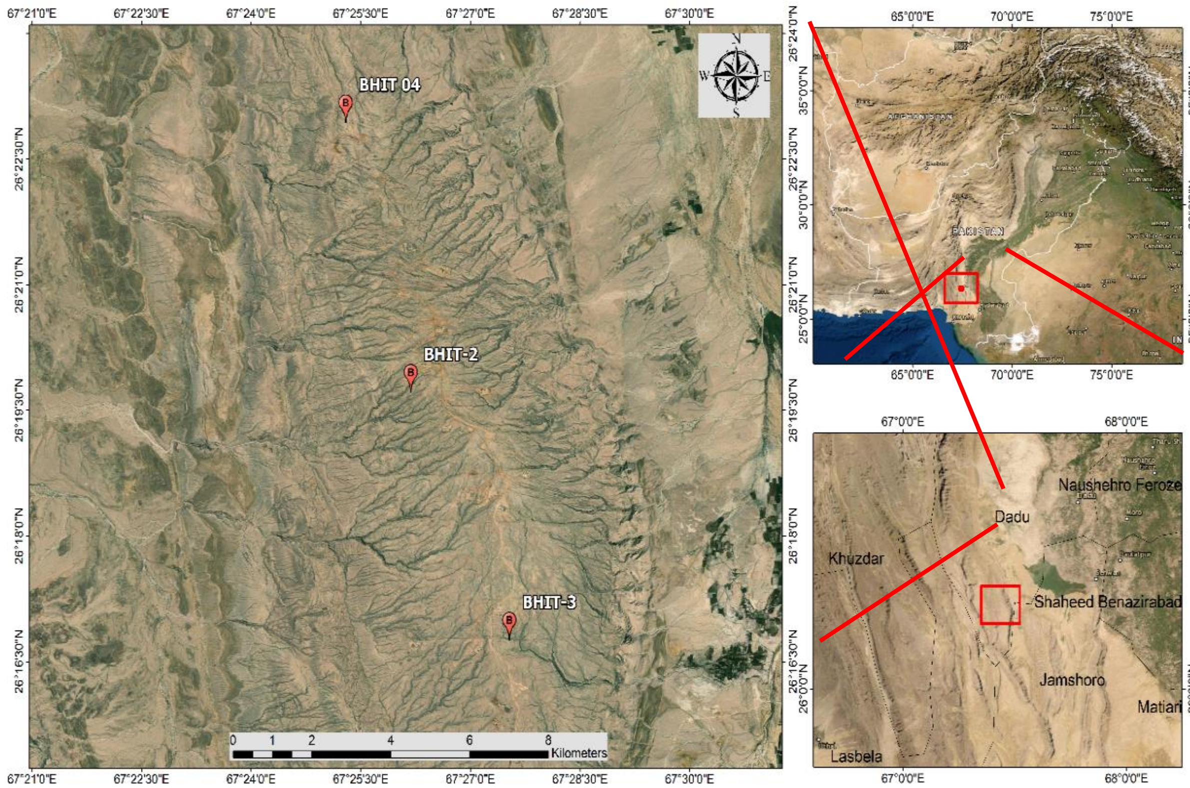

Figure. 1.1: Location Map of Bhit Field, Southern Indus Basin, Pakistan, (GIS)

Figure 1.2 Location of well with in the study area (GIS)

Table 1.1. Geographic coordinates of Bhit 02, 03 & 04

WELL	LATITUDE	LONGITUDE
Bhit-02	**26 19 10.188 N**	**67 26 10.188 E**
Bhit-03	**26 16 55.4316 N**	**67 27 31.7707 E**
Bhit-04	**26 23 05.22 N**	**67 25 17.220 E**

Pab is a proved reservoir in the Kirthar Fold Belt's Bhit, Hallel, Lundali, Mehar, and Zamzama gas fields, as well as in the foredeep area. The Pab Sandstone is a good quality sandstone with a high Net to Gross (NTG) ratio in this location, according to outcrop data. The sequence is thought to have been deposited in fluvial-deltaic settings on the upper shore face. Where the Pab Sandstone is shallow marine to Fluvial–Deltaic sands, the thickest sequence of Pab Sandstone was deposited in and around Badhra, Zamzama, and Bhit. The shallow marine sands are restricted to the basal part, which are agradational sequences, and are overlain by the deltaic part, which consists of laterally amalgamated channels, resulting in a sheet-like sand body that stretches from the Laki Range to the East Diwana and Andhar wells. However, it thins out eastward till it disappears in the area east of the Sakrand and Shahdadpur wells. In west and north-west it shales out in Gaj River section and Khude Range. Considering the wells drilled in the area a producible reservoir area has been identified in Fig.3. However the northern part of the identified area has higher risk as the Pab sands become very thin to absent and reservoir quality is deteriorated, as demonstrated by Mazarani well data.

1.3 EXPLORATION AND HISTORY

Since 1977, exploration activities in the district Badin area of the Southern Indus Basin have been a prolific source of hydrocarbons. Bhit Gas Field, located some 180-km north of Karachi in the Kirthar Region. Bhit is a producing conventional gas field located onshore Pakistan and is operated by ENI Pakistan. The field is located in block Bhit. The Bhit conventional gas field recovered 98.06% of its total recoverable reserves, with peak production in 2011. The peak production was approximately 0.31 thousand bpd of crude oil and condensate and 385 Mmcfd of natural gas. Based on economic assumptions, production will continue until the field reaches its economic limit in 2025. The field currently accounts for approximately 1% of the country's daily output. Remaining recoverable reserves in the field is expected to recover 5.81 Mmboe, comprised of 0.29 Mmbbl of crude oil & condensate and 33.09 bcf of natural gas reserves, (by Carmen, May 12, 2022). Several E&P companies operating in the Badin concession have had a 43 percent exploration success rate, with 1.65. 225 MM bbls of oil and Tcf of gas discovered in nearly 60 fields (PPIS Services, 2011).

The objective reservoir belongs to Cretaceous age Pab Sandstone considered as a potential reservoir. In 1974 first discovery was made from Pab by Oil and Gas Development Company Limited (Humayon et al., 1991). Pab sandstone of Cretaceous age is among the major reservoirs in the area (Mughal et al., 2012).

In 1977 a major discovery has been made by Bhit-2 well although, Kirthar Fold belt has been under exploration since long. Eni-Lasmo Pakistan and partners acquired exploration license in the southern part of kirthar Fold Belt and major discovery of Bhit-2 was a result of exploration activity between 1994- 1997. Major discovery in this area includes Bhit, Zamzama, Badhra and Mahar.

Union Texas Pakistan began petroleum exploration activities in the Badin Block in 1977. The first big oil find was made near Badin in the early 1980s, and since then, other large and small oil and gas discoveries have been discovered. A total of 52 discoveries were made between the end of June 1999 and the end of July 1999, of which are classed as oil fields in 21 of them, and gas fields in 31 of them, with large oil rigs is 10 of them. In peculiar oil fields, little gas cap can be detected. Some gas fields have thin oil columns. Furthermore, certain gas sources have a significant condensate content for production. Exploration in the block is still going well, with a success rate of 43% (Ahmad, 2000). Khaskheli is the largest oilfield in Badin Area. The operating petroleum companies in this region are UPEL, MPCL, PEL, PPL, and NHEPL.

1.4 OBJECTIVES OF THE STUDY

1. Understand the reservoir properties of Pab Sandstone with the help of Petrophysical analysis of Bhit field, wells are (Bhit-02, Bhit-03, & Bhit-04).
2. Identification of the lithology and matrix of the study area with the help of different cross plots and understand the variations in lithology, and stages of deposition with the help of structural correlation of the well data
3. Understand the variations in the thickness of reservoir units with the help of stratigraphic correlation of wells.

1.5 DATA REQUIRED

The well data (LAS files and Formation tops) for present work is issued by DGPC (Directorate General of Petroleum Concession) which is the authority that gives right to student to work in particular block of Pakistan. After the permission from DGPC, LMKR (Land Mark Resources), Pakistan, provided the data which includes:

(i) LAS files of all three wells containing GR log (Gamma ray log), SP log (Spontaneous potential log), LLS, LLD (Resistivity logs), Porosity log (Density log, Neutron log Sonic log) and PEF log.

(ii) Well formation tops and headers of wells.

(iii) Cross Plots, for the identification of lithology.

(iv) Software (GeoGraphix Discovery) for interpretation.

CHAPTER 02

GEOLOGY AND TECTONIC

2.1 GEOLOGY AND TECTONICS OF SOUTHERN INDUS BASIN

The Thar Platform Karachi Trough, Kirthar Foredeep, Kirthar Fold Belt, and Offshore Indus are the main units of the Southern Indus basin, which is located south of Sukhur Rift and between the Central and Southern Indus basins.

To get to the Offshore Indus, the Platform and Trough were employed. The Indian Shield to the east and the Indian Plate's fringe zone to west and define the Southern Indus Basin. The offshore Murray Ridge-oven Fracture plate boundary limits its southward extension. Southern Indus basin exhibits extensional tectonics that prevail structures like tilted fault blocks, associated with normal faulting especially horst and graben (Wandrey et al 2004).

Triassic rocks are the oldest rocks found in the area (Jhat Pat and Nabisar wells). Until the Lower/Middle Cretaceous, the Central and Southern Indus basins remained undivided when the Khairpur-Jaccbabad High became a major positive feature. The Chiltan Limestone (Jurassic) and Sembar Formation (lower Cretaceous) lithologies are homogenous over the High. The Lower Cretaceous and Paleocene are well represented in the Khairpur-2, whereas Jhat pat-1 is lacking his whole Cretaceous and Paleocene periods, indicating this. Lower Guru Formation (lower-Middle Cretaceous) sand facies can also be found in Kandhkot and Giandari. This is confirmed by the Khairpur and Jhat Pat wells, both on the High, with Eocene immediately underlying Chiltan Limestone. South of the High, the Paleocene facies are considerably distinct from the north, and are dominated by clastic sediments generated from positive regions i.e. Khairpur-Jacobabad high and Nabisar Arc. On the basis of geology and tectonics of Southern Indus basin it is divided into five units which are Kirthar fold belt, Kirthar foredeep, Thar platform, Karachi trough and offshore Indus basin (Khan et al., 2013). These units possess great importance for exploration point of view because they contain all elements of petroleum system which are necessary for the exploration of hydrocarbon for example in the

Southern Indus Basin Early Cretaceous Sembar shale has been identified which mostly act as the primary source rock in the area (Sheikh et al., 2016). The overlying sands of Pab Formation acts as principal reservoirs. The tectonic units of Southern Indus Basin are discussed below and also shown in figure 2.1.

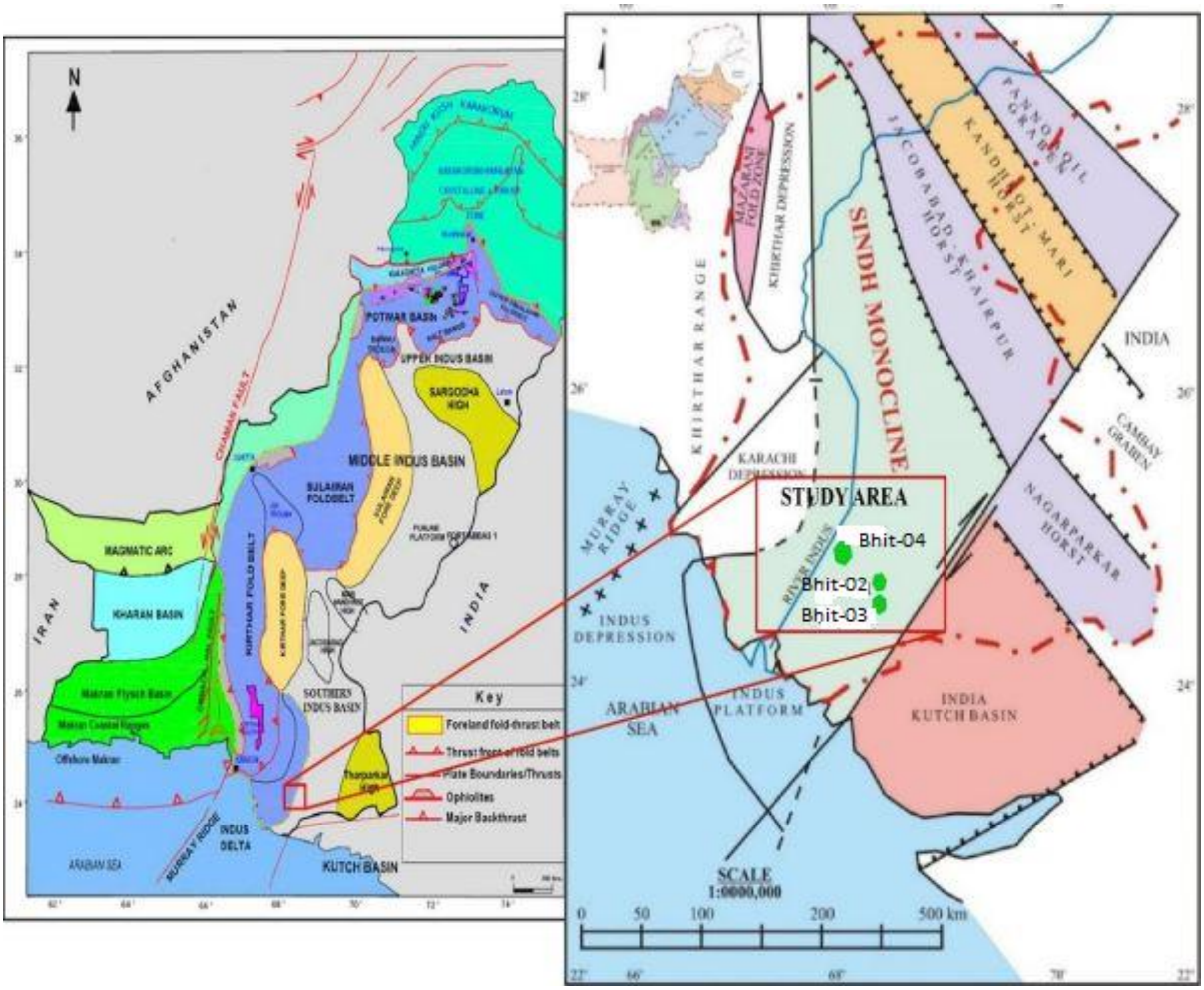

Figure 2.1 Major tectonic units of Southern Indus Basin within the study area. Modified after Kazmi, et al (1997)

2.1.1. Kirthar fold belt

In structural style and stratigraphic equivalent, this north-south trending tectonic structure is similar to the Sulaiman fold belt. This area has rocks dating from the Triassic to the recent epochs. The closing of the Oligocene–Miocene seas is also marked by the Kirthar fold belt's structure. The western half of the Kirthar fold belt, which runs parallel to the Balochistan basin and represents the western limit of the Indus basin, has been badly disrupted. The creation of economic mineral resources of baryte, fluorite, lead, zinc, and manganese has been linked to hydrothermal activity along the western margin.

2.1.2 Kirthar Fore deep

Kirthar Fore is a deep north-south trending ridge that has accumulated sediments with a thickness of over 15.000 meters. The Thar Platform has a faulted eastern border. It is assumed that the sedimentation in this depression was continuous. Based on the correlation of the Khairpur, Mari and Mazarani wells, the upper Cretaceous appears that is missing in this area. In the depression, well developed Paleocene appears, but not in the area of Khairpur-Jacobabad High. Like a lot of potential for source rock maturation in Sulaiman Depression.

2.1.3. Thar Platform

It's a gradually sloping monocline controlled by the geography of the basement, similar to the Punjab Platform. As it approaches the Indian Shield, whose surface expression is the Nagar Parkar High, the sedimentary wedge thins out. It varies from the Punjab Platform in that it displays buried extension tectonic feature produced during the Indian Plate's most recent counter-clockwise movement. On the east, the Indian Shield goes across it, on the west, the Kirthar and Karachi Trough and on the north, the Mari-Bugs. The Inner Folded Zone is a folded inward zone. The Thar Platform, Karachi Trough, and Offshore Indus create a strati-structural cross-section. The platform is a key step forward in the exploitation of Early/Middle Cretaceous Sands (Goru), which serve as reservoirs for all of the region's Oil/Gas Development Corporations.

2.1.4. Karachi Trough

Thick Early Cretaceous sediments characterise the dip, this indicates the end of marine deposition as well. It features a lot of anticlines which are narrow chain with gas sources in them. This area has well-preserved Early, Middle, and Late Cretaceous rocks. Throughout geological time, it has been a trough. The western progradation of a marine delta characterises the Upper Cretaceous. The rock sequence which comprises this trough is of early Cretaceous age and these rocks are also comprise last stages of marine environment. Many gas fields are discovered in this unit due to the presence of narrow structures like anticlines for example Sari, Hundi and Kothar gas fields. In the present study Karachi Trough marks western boundary of study area, behind the Karachi Trough Chaman fault and Oranch Nal fault mark the western boundary of this unit and separate Baluchistan and SIB. Cretaceous sedimentation in this unit is very good like Sands of Lower Goru Formation and Pab Sandstone and the continued deposition of these sediments with Tertiary sediments is marked as K-T boundary which is an interesting feature of Karachi Trough.

2.1.5. Offshore Indus Basin

This area is part of the passive continental margin and appears to have undergone two distinct geological periods (Cretaceous-Eocene and Oligocene-Resent). Sedimentation began in the offshore Indus region during the Cretaceous period. However, since the beginning of the Proto-Indus System in the middle Oligocene, deltaic and underwater fan sedimentation has occurred. Along a Hinge Line parallel to 67°E Longitude, Platform and Depression are two types of offshore Indus. The Offshore platform is divided into the Thar Platform and Karachi Trough deltaic basin by a line that divides Karachi Trough from Thar slope onshore.

2.2 Petroleum Play of Southern Indus Basin

- **Jurassic**

1. Source Rock

The dark color of the Loralai and Anjira members of the Shirinab Formation in the lower Indus basin indicates source rock potential, however they must be examined for TOC and maturity. The organic-rich Chiltan Limestone appears to have produced hydrocarbons. In Pakistan, the Jurassic source rock potential is fair to poor.

2. Reservoir Rock

Jurassic rocks in the Lower Indus basin are largely non-clastic, with limited evidence of porosity development in the Chiltan Limestone. The clastic environment dominates in the southern Indus basin, and it appears to be taking hold near Nagar Parkar due to the presence of the Indian Shield.

- **Cretaceous**

1. Source Rock

Sembar, Goru, and Mughal Kot Formations Cretaceous shales are widespread and thick. They have a lot of organic content and have good source rock qualities in general. The presence of Cretaceous shale suggests that they are ready to produce hydrocarbons. This shale is thick enough to produce significant hydrocarbon reserves in both potential and producing reservoirs. The cretaceous is the source of hydrocarbons in the entire gas condensate field identified in the lower Indus basin.

2. Reservoir Rock

The thick cretaceous deposits in the Indus basin provide some excellent reservoirs. The reservoir in the lower Indus basin is made up of Pab Sandstone, Mughal Kot, and lower Goru sands with porosity ranging from 5 to 30%. The Mughal Kot Formation and Parh Limestone have a lot of potential for secondary porosity development. The texture of Pab sandstone shows good indicators of primary porosity and the possibility for secondary porosity development. Another sign of hydrocarbon formation and transport through permeable Pab sandstone is the well-known Mughal Kot oil seepage, which occurs in the basal outcrops of Pab Sandstone. Other cretaceous rocks with reservoir potential include the Parh Limestone's probable reef and fore reef facies, as well as the Mughal Kot Formation's delta and sub-marine fan facies.

- **Paleocene**

1. Source Rock

In the lower Indus basin, the Ranikot Shale was once thought to be the primary source of all the gas found there. Ranikot has matured to the point that it can produce thermal gas of the quality of Sui, Kandhkot, and Pirkoh, among others. In trough locations (e.g., Sibi Trough, Karachi Embayment), Ranikot Shale has been thrust into the oil window and may have generated liquid hydrocarbons.

2. Reservoir Rock

After the Eocene, Paleocene rocks were thought to be the most productive reservoir. Hydrocarbons have been discovered in interbedded strata of sandstone, shale, limestone, and other minerals in the Lower Indus basin, the majority of which is shale. The majority of reservoirs in the Lower Indus basin are provided by primary and secondary porosities in both sandstone and limestone. The famous Khattan oil Seepage and condensate flow from the Dungan formation identify the central Indus basin as a gas-prone zone.

- **Eocene**

1. Source Rock

Early Eocene source rock study in the lower Indus basin reveals the presence of algal and saproprl type organic substance containing 0.2 to 2.5 percent total organic carbon. The Kirthar formation includes the Habib Rahi limestone appears to include a lot of organic materials. The maturity of these rocks could be attributed to trough areas such as the Sibi Trough and the west of Jacobabad –Khairpur high.

2. Reservoir Rock

The limestone of the Eocene epoch in the middle Indus basin has outstanding reservoir attributes because good porosity development is due to their formation on a solid platform, and porosity maintenance is due to early gas trapping. The major Eocene reservoirs are Pirkoh and Habib Rahi.

Following Table 2.1 showing the petroleum play of Southern Indus basin are,

Table 2.1 Petroleum Play of Southern Indus Basin Pakistan

MESOZOIC		TERTIARY
Cretaceous		Eocene
Source Rock	Sembar Formation Goru Formation Moghal Kot Formation	Habib Rahi
Reservoir Rock	Pab Sandstone Moghal Kot Formation Parh Limestone	Pirkoh Habib Rahi
Jurassic		Paleocene
Source Rock	Chiltan Limestone	Ranikot Shales
Reservoir Rock	Chiltan Limestone	Dungan Formation

CHAPTER 3
STRATIGRAPHY

3.1 Stratigraphy of Southern Indus Basin

Infra-Cambrian to Recent elastic sand carbonates underpin the Lower Indus Basin. The basin's Precambrian basement is exposed in the S-E corner. Sediment thickness increases as you move west. At the base of the Permian and Tertiary, there are some significant unconformities. The Tertiary is in direct contact with the Jurassic series in the eastern half of the southern Indus Basin. My research area is Pab Formation. The Pab formation comprises the quartzose sandstone is, white, cream or brown in color, weathering golden brown medium to coarse grained, thick bedded, to massive, and cross layered characterises the formation. The Pab range has dark grey and calcareous shale, the Laki range has brown and sandy shale, and the Axial Belt has a light grey, white, pale green, and maroon shale. In the Province of Sulaiman and Kirthar as well as the Axial Belt the formation is well-developed, (Kazmi and Jan, 1997).

In the Sulaiman and Kirthar Provinces, the Fort Munro formation is overlain by sandstone, and in the Axial Belt, the Parh limestone is overlying by sandstone. In Part of Sulaiman Province, it is uniformly overlain by the Moro-formation, Kirthar Province, and Axial Belt, and the Ranikot Groups “Carditabeaumonti” beds of Hunting Survey Corporation (1961) differ from the Khadro formation, in other places. The occurrence of lateritic red nodules in the Ranikot Group's basal sandstone deposit indicates a disconformity. The Rakhshani formation is conformably overlain in portions of the Axial Belt’s “Arenaceous Zone,” and the Dungan formation is conformably overlain in parts of the Axial Belt and the Sulaiman Province. Following the figure shows the southern Indus basin depositional stratigraphy. In some areas of Southern Indus Basin Deecan Trap and Khadro Basalts of Paleocene age are marked above the Parh Limestone. Moghal Kot Formation is the strata which is marked between Parh Limestone and Pab Sandstone. Pab Sandstone is good reservoir rock marked in Southern Indus Basin. The age of Pab Sandstone is early Cretaceous. The sediments of Fort Munro Formation are also marked between Moghal Kot and Pab Sandstone in some places near Badin area of Southern Indus Basin. The upper contact of Pab Sandstone is with Ranikot Formation. Ranikot Formation is basically originated from Ranikot Group. Ranikot group is divided into Upper Ranikot and Lower Ranikot Formations. This group also shows some variations in lithology in

Southern Indus Basin. These variations are basalts and named as Khadro Basalts. Similarly in some areas the variations are changed by traps which are named as Deccan Traps as mentioned above. The lithology of Upper Ranikot is Limestone and the lithology of Lower Ranikot is Sandstone. Above the Ranikot Group another group is marked named as Ghazij group. The age of this group is Eocene. In some areas of Southern Indus Basin, the limestone beds are called as Sui Upper and Sui Main limestone. In Sulaiman and Kirthar provinces and axial belt this group is over lain by Kirthar Formation. The age of Kirthar Formation is Eocene. The upper contact of this formation is mostly unconformable but in Southern Indus Basin it is confirmable with Nari Formation in some areas near Badin block. Nari Formation is the member of Momani Group, the other member is called Gaj formation so, the Gaj and Nari Formations are the members of Momani Group of Oligocene age, (Iqbal B. Kadri, 1995). Following table 3.1 is showing the stratigraphy of Southern Indus Basin with age and lithology as well,

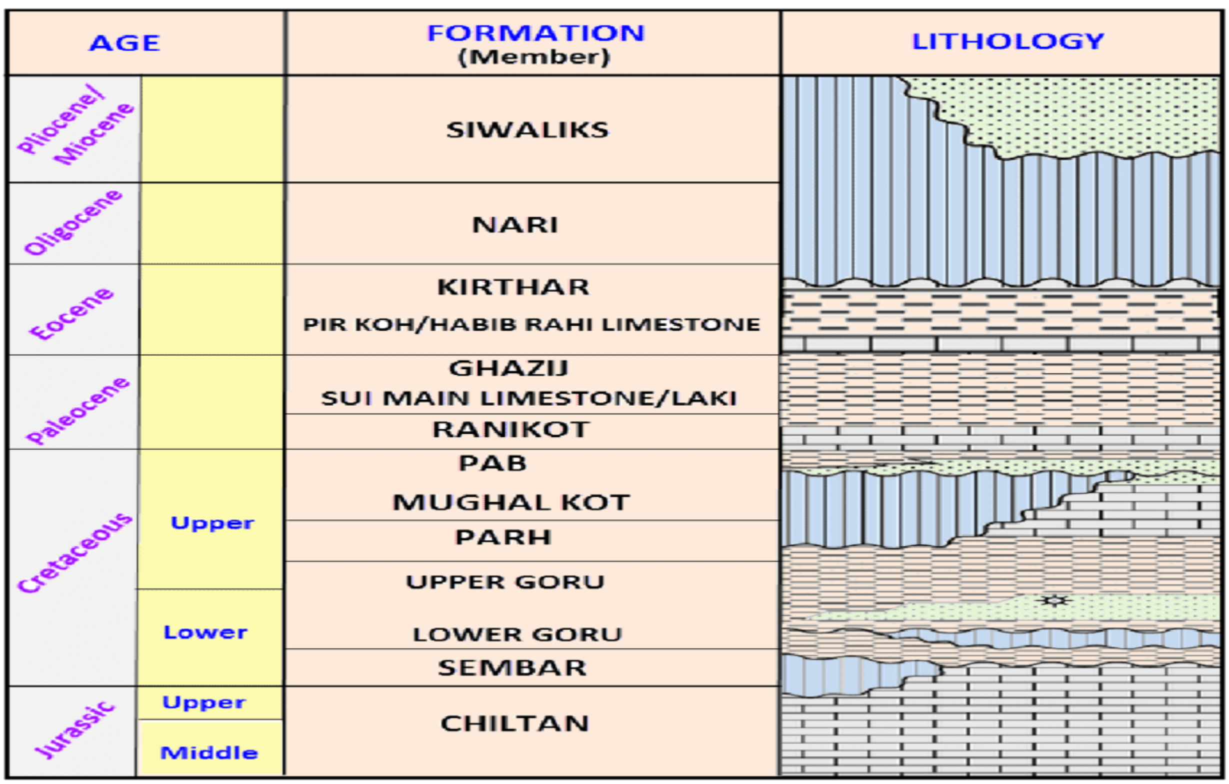

Figure. 3.1. Showing the stratigraphy of Southern Indus Basin along with Pab Formation (modified by Khan, 2016)

The Cretaceous Parh Group is represented by the Sembar Formation with shale, the Goru Formation with shale and marl, and the Parh Formation composed of limestone with some volcanic sills/dykes found close to the western Indus Suture), the Fort Munro Group is represented by the Mughal Kot Formation consisted of shale/mudstone, sandstone, marl and limestone with some volcanics found close to western Indus Suture, the Fort Munro Formation with limestone, the Pab Formation composed of sandstone with subordinate shale with some evidences of Deccan volcanism, and the Vitakri Formation consisted of red muds which is the host of dinosaurs and grey to white sandstone.

3.2 Stratigraphy of the study area

Pab Sandstone, Fort Munro Formation, Khadro Formation, Bara-Lakhra Formation, Dungan Formation, Laki Formation, Ghazij Formation, Kirthar Formation, Ranikot Formation, and Mughal-Kot Formation are the stratigraphy in my study area. They range in age from the Late Cretaceous to the Eocene. Sandstone, shale, limestone, and dolomites make up this formation, each with its own depositional environment. The stratigraphy of Bhit Field is shown in the table 3.1 below.

Table 3.1 Showing the stratigraphy of Bhit-Field.

ERA	PERIOD	EPOCH	FORMATION	LITHOLOGY
CENOZOIC	**Tertiary**	**Eocene**	Kirthar	Limestone
			Ghazij	Shale, Claystone, Sandstone, Limestone
			Laki	Limestone
		Paleocene	Dungan	Limestone, shale
			Ranikot	Limestone, Sandstone, Shale
			Bara-Lakhra	Sandstone, Limestone
			Khadro	Sandstone, Shale, Limestone
	Cretaceous	**Late**	Pab Sandstone	Sandstone
			Mughal Kot	Mudstone, Shale, Limestone
			Fort Munro	Limestone

3.2.1 Fort Munro Formation

According to Fatmi (1977), the deposit in the northern Sulaiman Province and Axial Belt is generally limestone. The limestone is dark grey to black in color, extremely hard, and thickly bedded, with sandy upper parts and argillaceous lower parts. Light grey to yellow grey, medium hard, argillaceous limestone dominates the formation in the southern section of the Sulaiman Province, intercalate with yellow to greyish yellow marl and calcareous shale, which is slightly nodular in the bottom portion. In the Sulaiman belt, portions of the Kirthar province and the Axial Belt are all affected by the formation only in Quetta region Pakistan. The unit is 100 meters thick in the type section, 53 meters thick in the north east of Pui, 44 meters thick at Murree Brewery Gorge, 90 meters thick at BaraNai, and 248 meters thick in the subsurface at Dabbo Creek. With a transitional contact, the formation conformably overlies the Mughal Kot Formation throughout its entirety.

The Sui and Sulaiman Trough areas are home to the Fort Munro Limestone member. The Fort Munro has a diverse biodiversity and may contain reef-building organisms. This, combined with the presence of the overlying Pab Sandstone, which could act as a reservoir, makes this area of the section look promising in terms of petroleum potential.

3.2.2 Mughal-Kot Formation

Near Mughal Kot, to define the layers between Parh limestone and Pab sandstone, Willims (1959) give the name the Mughal Kot formation. Calcareous mudstone is dark grey and calcareous shale with quartzose sandstone and argillaceous limestone is in light grey intercalation make up the formation. The sandstone is only well developed in the northern section of the Sulaiman region. It belonged to the Late Cretaceous epoch. The Mughal Kot is highly varied structure. It's a dark grey calcareous mudstone with intercalated quartzose sandstone and argillaceous limestone.

3.2.3 Pab Sandstone

The quartzose sandstone, white cream or brown in color, weathering golden brown, medium to coarse grained, thick bedded to massive, and cross layered, are the main features of the formation. Similar to the Parh limestone, marl and argillaceous limestone are intercalated. The Pab range has dark grey and calcareous shale, the Laki range, has brown and sandy shale, and the Axial Belt has light grey, white, pale green, and maroon shale. Sulaiman and Kirthar are two province in Sulaiman, as well as the Axial Belt is a well-developed structure it has a wide range of thickness, ranging from 490 meters at the type section to over 600 meters in portions of the Marri-Bugti highlands, to the south and west of Khuzdar, but squeezing out to utter disappearance. In the Fort Munro anticline, it thickens to 450 meters, but then thins to around 240 meters in the west of Mughal Kot.

The majority of the oil seeps from the Pab Sandstone in the Mughal Kot seepage area. Pirkoh, Loti, Dhodak, and Rodho fields all have Pab Sandstone as a petroleum reserve. The formation is thought to have no potential as a source.

3.2.4 Khadro Formation

Sandstone and shale make up the Khadro Formation, with some limestone thrown in for good measure. Sot medium grained, ferruginous, and calcareous sandstone with olive, yellowish brown, grey, and green color. In the bottom half of the unit, the shale is olive, ale bluish grey, chocolate and reddish brown with Arenaceous limestone in places. Both sandstone and limestone are fossil-bearing rocks. The formation can be found throughout the Axial Belt's Kirthar Province, Calcareous Zone, and sections of the Arenaceous Zone.

3.2.5 Bara-Lakhra

- **Bara Formation**

The majority of this formation is sandstone, with some shale and volcanic debris thrown in for good measure. Fine to coarse grain, mushy and crumbly texture, varicolored sandstone. Massive beds, varying in thickness from millimeters to three meters, are common. It's calcareous, ferruginous, rippled, and cross-stratified. The interbedded shale is soft, earthy and gypsiferous, with dark tones of tones that are similar to sandstone. Both shale and sandstone are carbonaceous in some locations, although shale can be highly carbonaceous and contain coal seams. There are generally ferruginous nodules present. The lowest half of the formation has been observed to have some volcanic material that has weathered from greenish grey to black.

- **Lakhra Formation**

The dominating limestone in the formation is grey and yellowish staining and weathered color is brown, it has orange brown and pinkish brown spots. It has a brecciated texture and is thin to thickly bedded. In some places, sandy, argillaceous, and fossiliferous limestone. Some fossiliferous strata resemble coquina, with sandstone shale interbeds in the lower half and sandstone and shale interbeds in the top half. The sandstone is ferruginous calcareous and transitions to arenaceous limestone in some spots. It is fine to coarse grained with poor-sorted, sparingly and fossiliferous, and have thin to thick bedded and cross layered, it is grey and chocolate in color (weathering grey and brown). Shale is grey in color, weathers golden brown, and grades into clay stone in some spots. Axial Belt and the Kirthar Province have a lot of this structure. Hunting Survey Corporation (1961) incorrectly stated that the formation was not present in the Laki Range. The formation rests directly on top of the Bara formation. It is unconformably overlain by the Laki formation in the Kirthar Province.

3.2.6 Ranikot Formation

The Ranikot Formation age is Paleocene. The Ranikot group's lower half is made up of yellowish brown to olive sandstone and interbeded with shale and limestone. Grey limestone that weathers to brown, as well as grey sandstone and shale of estuarine origin, make up the upper part of the Lakhra formation. The province with the most exposures is Kirthar. In the Axial Belt, it is rather well established, although occurrences in the Sulaiman Province are uncommon. The thickness ranges from 540 meters to 660 meters. The Pab Sandstone and the Moa Formation appear to be unconformably overlain by the group. It is conformably overlain by several units in various regions.

3.2.7 Dungan Formation

Oldham (1890) coined the term "Dungan Limestone" to replace Griesbach's (1881) "Alveolina limestone," which is a thick limestone sequence in the Sulaiman Province's Dungan Hills between the Parh Limestone and the Ghazij Group. The Dungan formation is characterised by nodular to massive limestone, with minor elements such as shale, marl, sandstone, and limestone conglomerate. The major lithology present is limestone, which is dark grey to brown in color with a creamy white appearance and weathers to brown, grey and yellow. In the southern Sulaiman range, dark bluish grey, brown shale which weathered color is grey or greenish, become frequent. The formation is often more than 300 meters thick, however thickness varies depending on location. In some places of the Quetta region, it is said to reach 365 meters high. In most places, the lower contact of the Dungan Formation is unconformable, and it is one of the basin's primary unconformities. Most of the Cretaceous and earlier rock units are bypassed.

3.2.8 Laki Formation

Noetling (1903) coined the term "Laid Series" to describe the lower half of Blanford's "Kirthar Series" (1876). Foraminifers, gastropods, bivalves, echinoids, and algae can be found in abundance in the Laki Formations. It is Eocene in age. Laki Limestone is a component of the Laki Formation. It has a solid and chalky base that is overlain by nodular limestone that is interbedded with calcareous shale, with hard and marly nodules. There are a lot of fossils in shale. The Sohnari members are characterised by varicolored lateritic clay and shale, as well as locally generated yellowish arenaceous limestone beds, where some limestone and lignite seams. Lenticular strata in the member are formed by varies ferruginous sandstone and white, calcareous sandstone. The component is positioned directly above the Ranikot group and is part of the Laki formation.

3.2.9 Ghazij Formation

The Eocene series is characterised by limestone with abundant foraminifera, mollusks, and algae. In areas of the area, shale and marl were the dominant lithologies during the Early Eocene. As previously stated, the Kirthar Province's Eocene sequence has long been used as a benchmark for Eocene stratigraphy in the Indo-Pakistan subcontinent. Shale dominates the Ghazij group, with minor contributions from claystone, sandstone, limestone, conglomerate, and coal, all of which have become rich and commercially important in the area**.** The shale is pale greenish grey or brown, while the limestone is white or light grey. Sandstone is a minor component in some locations, although it is strongly calcareous and grades to sandy limestone. The Ghazij group consists of brown, purple, maroon yellow shale and grey, green or brown sandstone with interbeded to arenaceous limestone and rare conglomerates in the Axial Belt. The sandstone is carbonaceous and coarse to shelly in texture. Sandstone and shale are combined with conglomerate that forms thin beds. Chert and limestone from older Axial Belt rocks are among the pebbles in the aggregate.

3.2.10 Kirthar Formation

In western Sindh, he named the Kirthar Range for Eocene strata between his "Ranikot Group" and "Nari." The Kirthar Formation is mostly limestone, with a little shale and marl thrown in for good measure. With grey, brown or cream weathering, the limestone is light grey, cream-colored or chalky white in hue. It’s densely to massive, with nodular patches and algal and coralline structures thrown in for good measure. Olive, yellow, grey, calcareous, soft and earthy are some of the characteristic of shale. In the Kirthar formation, which contains a 20-meter net interval of organic-rich shales, has the potential to generate light oil and gas in Creek wells. The Kirthar Formation, on the other hand, has lean source rocks with mostly woody kerogen in the Depression area.

3.3 Borehole Stratigraphy

The overall depth to which Bhit-02 well was drilled is 2100 m and the last formation encountered is Fort Munro at the depth of 2042 m (Table 3.2). The total depth of Bhit-03 is 2800 m and the last formation encounter is Mughal Kot at the depth of 2060 m (Table 3.3).And the overall depth to which Bhit-04 well drilled is 3600 m and the last formation encounter is Pab Sandstone at the depth 1989 m (Table 3.4).

Table 3.2 Stratigraphic Succession encountered in Bhit-02

Formation	Formation Age	Formation Top (m)	Formation Thickness (m)
kirthar	Eocene	8.00	438.50
Ghazij	Eocene	446.50	165.50
Laki	Eocene	612.00	480.00
Dungan	Paleocene	1092.00	141.00
Bara-Lakhra	Paleocene	1233.00	385.00
Khadro	Paleocene	1618.00	222.00
Pab Sandstone	Late Cretaceous	1840.00	202.00
Fort Munro	Late Cretaceous	2042.00	25.00

Table 3.3 Stratigraphic Succession encountered in Bhit-03

Formation	Formation Age	Formation Top (m)	Formation Thickness (m)
Kirthar Formation	Eocene	23.00	402.00
Ghazij Formation	Eocene	425.00	152.00
Laki	Eocene	577.00	463.00
Dungan	Paleocene	1040.00	95.00
Ranikot Formation	Paleocene	1135.00	30.00
Pab Sandstone	Late Cretaceous	1700.00	70.00
Mughal Kot	Late Cretaceous	1770.30	290.60

Table 3.4 Stratigraphic Succession encountered in Bhit-04.

Formation	**Formation Age**	**Formation Top (m)**	**Formation Thickness (m)**
Kirthar Formation	Eocene	7.800	459.20
Ghazij Formation	Eocene	467.00	142.00
Laki	Eocene	609.00	418.00
Dungan	Paleocene	1027.00	256.00
Ranikot Formation	Paleocene	1283.00	545.00
Khadro	Paleocene	1828.00	161.00
Pab Sandstone	Late Cretaceous	1989.00	0.50

CHAPTER 04
PETROPHYSICAL INTERPRETATION

4.1 Introduction

In a borehole, a Petrophysical analysis is used to define the zones of interest. Zones of interest are highlighted on log curve based on drilling conditions, resistivity log trends, and neutron density cross over once the logs have been obtained. This chapter deals with the calculations and methods which are utilized for the evaluation of the reservoir properties of Pab Sandstone in the study area. Different reservoir properties like shale volume, PHIA, PHIE, Sw, Sh, BVW, HCPV, net reservoir and net pay are calculated with the help of different formulas.

4.2 Available data

The data which is utilize for current study includes digital well data (LAS files) of all three wells, lower case, headers of wells and software (Geographix discovery). LAS file is imported in the software for generating new curves, lower case are used for the analyzing the total depth (TD) of wells and thickness of formations. The headers are used to get some imported information of wells like name of field, name of well, latitude and longitude of well and surface/subsurface temperature of well bore. All the data is provided by LMKR with the prior permission from DGPC.

4.3 Methodology

The methodology which is adopted for this research work is collectively known as petrophysical interpretation. Methodology explains the procedure and measurements which are done in the completion of research work. The steps and measurements which are adopted for this research work are discussed below and a flow chart is also attached to understand the sequence of these steps. Methodology adopted for petrophysical analysis is shown in figure 4.1

Figure 4.1 Methodology adopted for Petrophysical analysis.

4.3.1 Raw logs Curves

Raw log curves are generated by running the LAS files in the GeoGraphix software. Both LAS files and software are provided by LMKR. Furthermore, these logs are used for the interpretation of reservoir of study area. Three LAS files are provided by LMKR as this research work include the petrophysical interpretation of three different wells. On the basis of these log curves further calculations are made like, volume of shale calculation, porosity calculation saturation of water and saturation of hydrocarbons. Following Raw log curves showing in Figure 4.2 are,

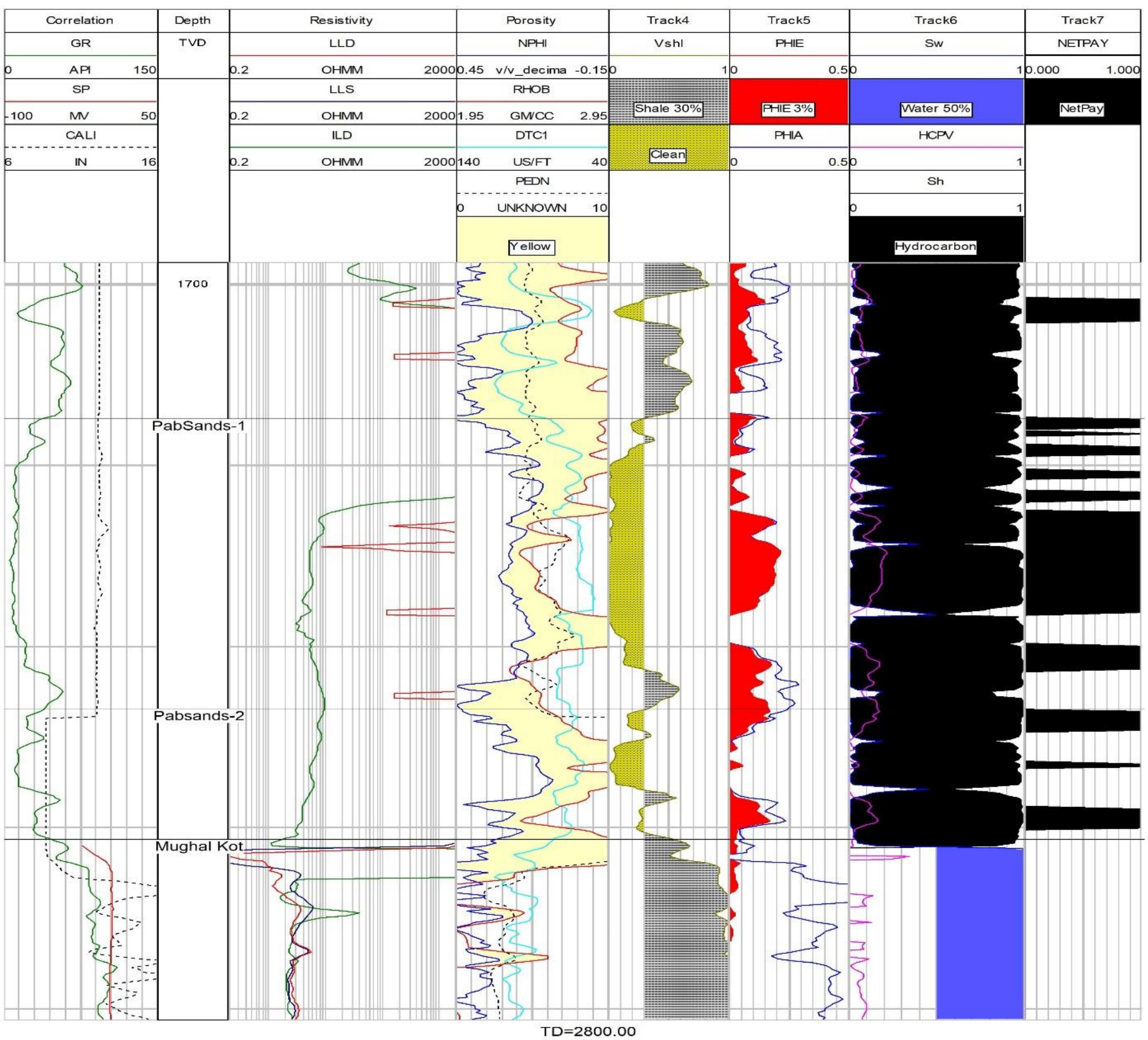

Figure 4.2 General log showing tracks and resultant curves with their scales and units.

4.3.2 Calculation of Shale Volume

Calculations for the volume of shale are made for the identification of shale and clean zone. As this research is mainly focuses on the reservoir properties of Pab formation so, it was necessary to identify or differentiate the sandy and shaly zones of study area. It is calculated using gamma ray log. By using the formula of volume of shale is calculated and a new curve is generated in track 5. Calculations are made for all three wells and study area is divided into different units on the basis of sandy and shaly zones. The zone where the volume of shale is less than 0.3 or 30% is clean or sandy zone and the zone where the volume of shale is greater than 0.6 or 60% is shaly zone. The area between 0.3 to 0.6 is referred as mix lithology.

The Vshl is estimated using CGR (Computed Gamma Ray) log. The following equation is used to calculate;

Vshl = (GR [log]-GRcln) / (GRshl-GRcln) (Kamel et al 2003)

Where,

Vshl = Volume of shale

GR [log] = GR log value

GRcln = GR value at clean interval

GRshl = GR value at shale interval

4.3.3 Correlation of Wells

Correlation of all wells of the research help us to understand the structural deformation of study areas well as variation in the thickness of Pab Sandstone from one well to another well. As in this research two zone are identify that already mention in targeted zone shaly and sandy zones, but in shaly zone there is no net pay and presence of hydrocarbon that why in this research the mark zones were both shaly and sandy but the discussion of only about the sands of Pab Sandstone that gives the good quantity of net pay that indicate presence of hydrocarbon in it. On the basis of petrophysical interpretation for better understanding of these zones correlation of these wells is carried out. The correlation include both structural and stratigraphic correlation of these wells. Basic purpose of this correlation is to understand the depths of these sandy and shaly zones. These are describe as follows.

4.3.3.1 Structural Correlation

Structural correlation help us to knowing the depth variation of sandy and shaly zone in Pab Sandstone among the all wells. In this research sandy portion where it found the hydrocarbon potential in reservoir and shaly zone where it didn’t have net pay so it will not be discussed. Let have a look on the structural cross section of Bhit-02 and Bhit-03 we can easily understand the variation in depth of all sands and shale zones of Pab Sandstone in these wells. The different depth showing the different depositional environment. We encountered different zone in different depth of the well that are shown in figure below 4.3 and 4.4. Following figure 4.3 can help to understand zones of these wells is given below. The correlation of Bhit-02 and Bhit-03 well respectively. The Bhit-04 well data is missed logs are not run in interested zone of Pab Sandstone. By structural correlation better understanding about the depth variation of sand zone in Pab Sandstone among the all wells. Following figure 4.3 can help to understand zones of these wells is given below.

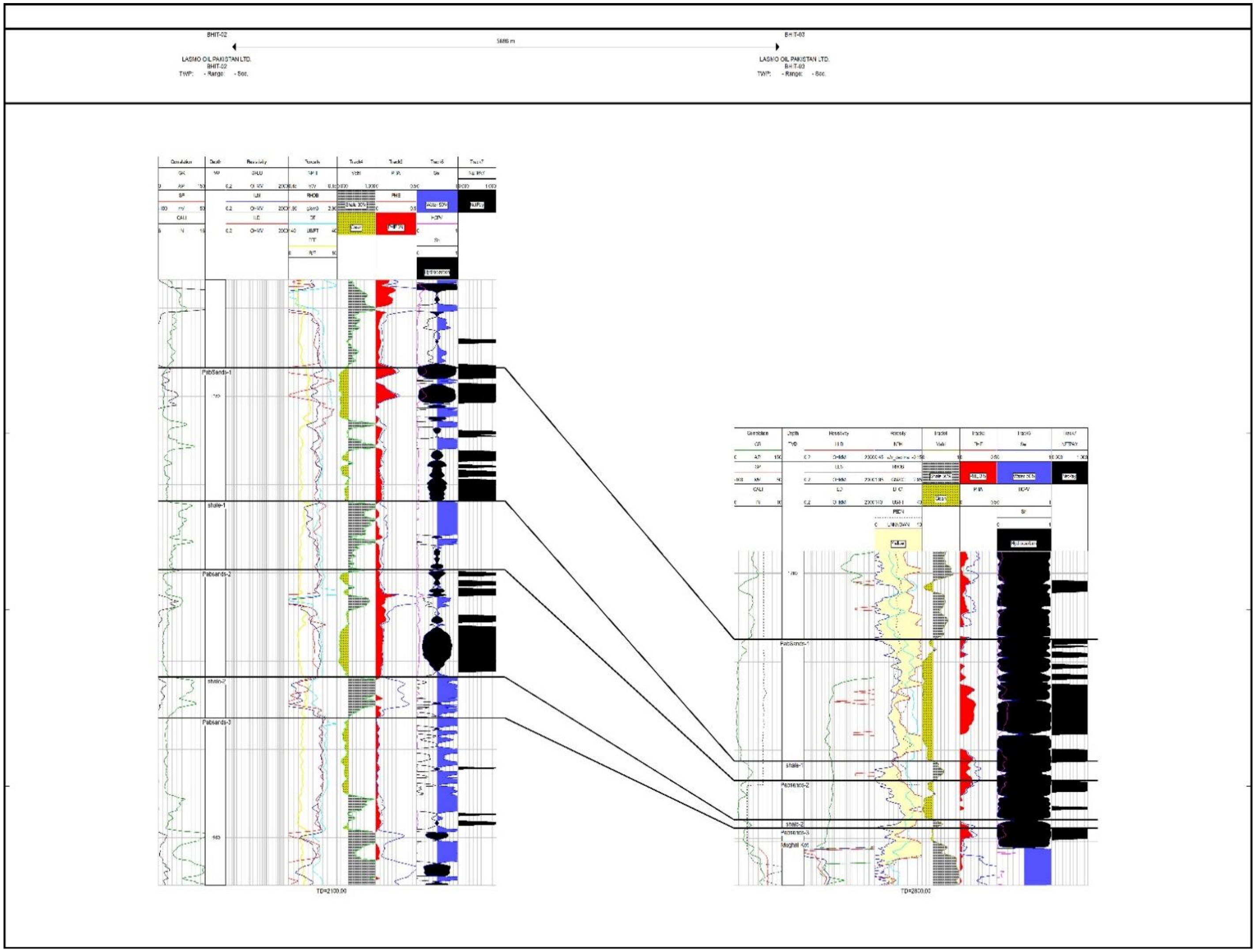

Figure 4.3 Structural correlation of Pab Sandstone in Bhit-02 and Bhit-03

4.3.3.2 Stratigraphic Correlation

Stratigraphic correlation include information related to the stratigraphy of the study area. It is the information about the lithology of study area with thickness of this lithology which is encountered in all different wells. Stratigraphic correlation is define as the correlation of different zones which are encountered in the wells with respect to their thickness. It also include the identification of sand and shales throughout the well depth. In the section of Pab Sandstone. The encountered different sandy zone at different depth interval. The thickness of these sandy zone is important in stratigraphic correlation. In this research only encounter the sands of Pab Sandstone zone where the good quantity of net pay of the reservoir. Depth varies on different interval bed are not above 20m. Mostly, found in the range of 2m, 5m, 10m, 13m highly targeted is 20m in Bhit-02. The thickness of these zones with their depths at which these are encountered is following table 4.1 are given below.

Table 4.1 Thickness of zones of Pab Sandstone in all wells with depth.

Zones of Pab Sandstone formation	Bhit-02		Bhit-03	
	Thickness (m)	Depth (m)	Thickness (m)	Depth (m)
PabSands-1	10	1850-1860	14	1707-1721
PabSands-2	13	1870-1883	5	1723-1727
PabSands-3	7	1890-1897	2	1728-1730
PabSands-4	13	1910-1923		
PabSands-5	7	1955-1962		
PabSands-6	20	1985-2005		

Following figure 4.4 showing the stratigraphic correlation of Pab Sandstone formation in the well Bhit-02 and Bhit-03.

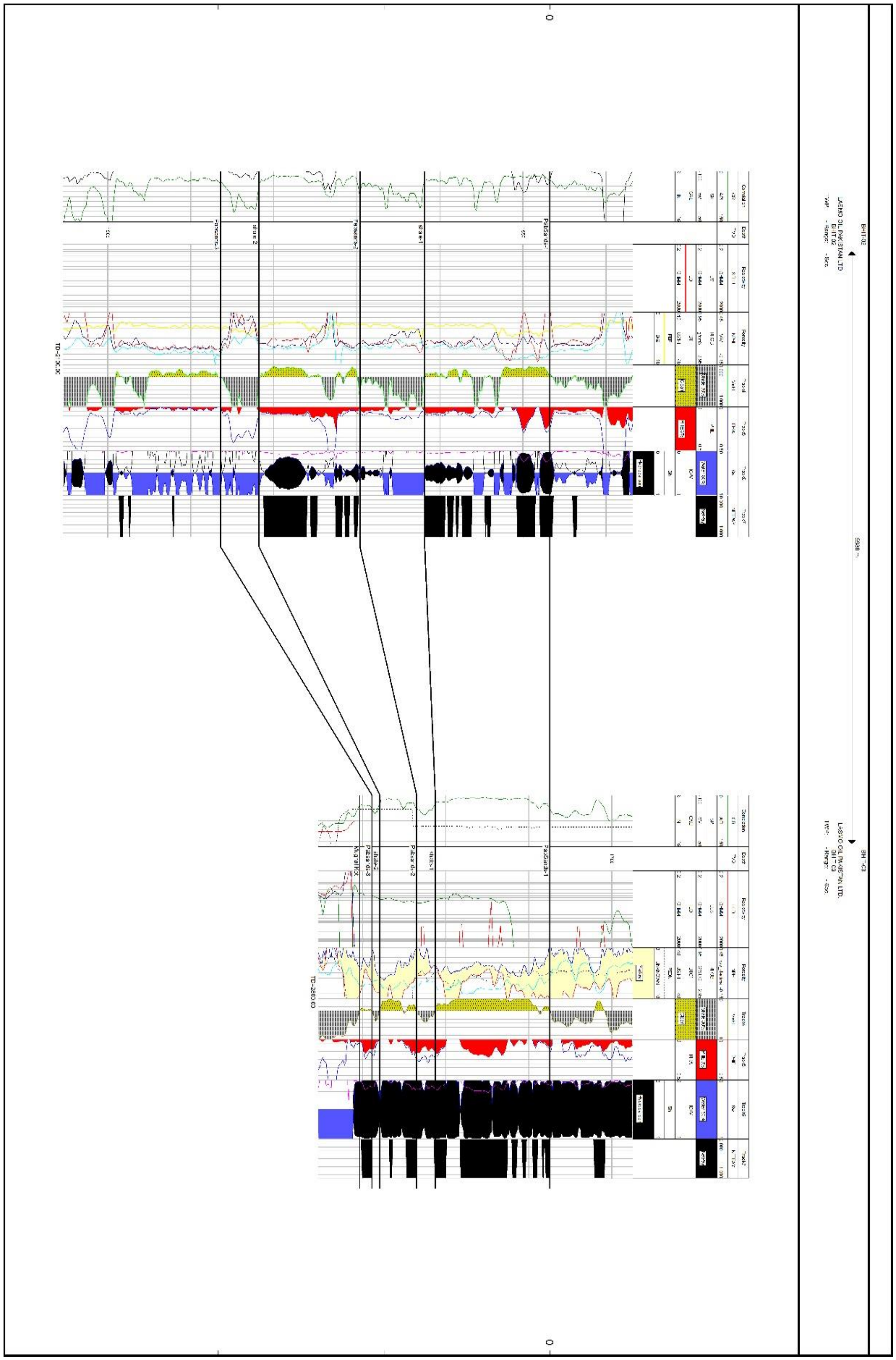

Figure 4.4 Stratigraphic correlation of Pab Sandstone in Bhit-02 and Bhit-03

4.3.4 Matrix Identification

Inaccurate sand interval delineation can have a significant impact on reservoir rock properties such as porosity, permeability, pore-size geometry and net to gross ratio. As a result, it's critical to use a well log cross plot to accurately outline the sand body and assess the petrophysical parameters of the mapped sandstone intervals.

- **Cross Plots**

It is a technique which are used for the used for the identification of matrix or lithology different cross plot are used. In this research for knowing the lithology of Pab Sandstone to used two cross plots for the matrix identification of reservoir zone on the basis of Petrophysical interpretation of Bhit-02, Bhit-03 and Bhit-04. In Bhit-04 the date is missing that why it couldn't interpreted the other wells which divided the reservoir into different zone and the main focus is on sandstone in Pab range. Cross plot provided the good results for matrix identification of sandy zone which is called reservoir zone.

Following two cross plots are used for the matrix identification in reservoir zone of Pab Sandstone and these two cross plots are used in given Bhit-02 and Bhit-03 wells.

1. **M-N Lithology Cross Plot**

This cross plot used for the identification of matrix or lithology in reservoir of the study area. On the X-axis it shows N-lithology component and on Y-axis, M-lithology component is used. The formulas of these components are as follows.

M-lith and N-lith for Matrix Identification M-N Plot

M-lith = ((DTfld - DT) / (RHOB - RhoF)) * 0.01 (Schlumberger 1972)

N-lith = (PHINF - PHIN) / (RHOB - RhoF)

DTfld = 185 us/ft

RhoF = 1.1 g/cc

PHINF = 1 v/v

DT = Sonic log

PHIN = Neutron porosity log

RHOB= Density Log

By using these logs and fluid parameters we can generate new curves for M and N lithology parameters and then used these curve on the cross plots for the matrix identification. The one fact on this log is if DT is not available we use LSDT instead of DT.

2. Umaa vs. RHOmaa Cross Plot

This is the second cross plot for the identification of matrix or lithology. RHOmaa is used as apparent density matrix and Umaa is used as apparent volumetric cross section. This cross plot is used to understand the variations in the ratio of matrix like quartz, dolomite and calcite. On the X-axis there is Umaa and on the Y-axis RHOmaa used and the formulas of these components are as follows.

RHOmaa = (RHOB – PHIA * RhoF) / (1 – PHIA)

Umaa = ((PEF *RHOB)-(PHIA [] * Ufl)) / (1 – PHIA) (Schlumberger 1972)

RhoF = 1.1 g/cc

Ufl = 0.5 b/e

PHIA = Average porosity

PEF = Photo electric effect (PEF log)

RHOB = Density log

By using these logs and fluid parameters, new curve for RHOmaa and Umaa are generated and the values of these curves on different depth intervals where encountered sandy zones. A simple display log of these curves is shown as Below M-N lithology curves are also displayed. A simple display log of these curves is shown in figure 4.5 in which M-N lithology and RHOMaa vs. Umaa curves are displayed.

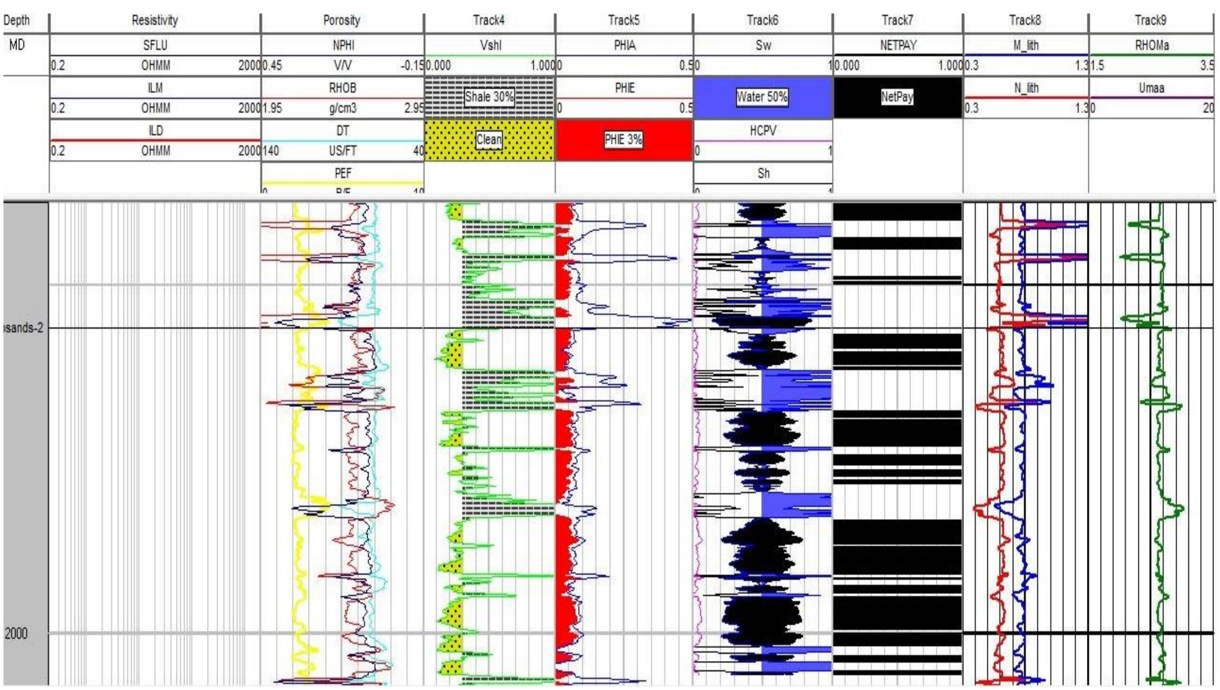

Figure 4.5 Log showing M-N lithology and RHOmaa vs Umaa cross plots curves

4.3.4.1 Matrix Identification of Bhit-02

The well Bhit-02 contain good amount of sands and shales in Pab Sandstone range, this well consist of interbedded shale with sandstone but Bhit-02 well has good potential of hydrocarbons because it contain good amount hydrocarbon where the sands in formation. The sand portion is greater than shale portion that's why it provided good amount of hydrocarbons. In this well just sand portion is discuss because the interest in reservoir zone which is sands of Pab Sandstone. And behalf of this it carry just interpreted sandstone in given formation depth and thickness. It just marked sand portion in Pab Sandstone. The M-N lithology showing the matrix lithology. RHOmaa and Umaa are also measured at the same depths and resultant value are plotted on a plots. After the plotting of these point, that in first cross plot the value are lies between quartz and calcite. Its shows sand having mostly composition of quartz, feldspar and calcite. Two crossplots are used for the accuracy of results in Pab Sandstone. The M-N cross plot the table 4.2 showing the value which is chosen from the log is as shown below.

Table 4.2 values chosen from log on different depth of well Bhit-02

Depth(m)	M-lith	N-lith	RHOmaa	Umaa
1845m	0.80	0.68	2.69	7.3
1851m	0.83	0.69	2.74	12
1858m	0.81	0.67	2.66	6.8
1865m	0.82	0.65	2.77	8.5
1869m	0.79	0.66	2.63	6.7
1880m	0.83	0.65	2.60	5.8
1890m	0.85	0.59	2.68	6.9
1900m	0.82	0.63	2.62	9.1
1913m	0.80	0.67	2.70	8.8
1923m	0.82	0.68	2.70	6.9
1943m	0.83	0.69	2.67	6.5
1990m	0.85	0.67	2.6	6.0
2003m	0.84	0.65	2.63	5.4
2009m	0.79	0.59	2.73	10
2042m	0.81	0.63	2.62	5.4

Following the figure 4.6 showing the M-N lithology and RHOmaa vs Umaa cross plots curves are;

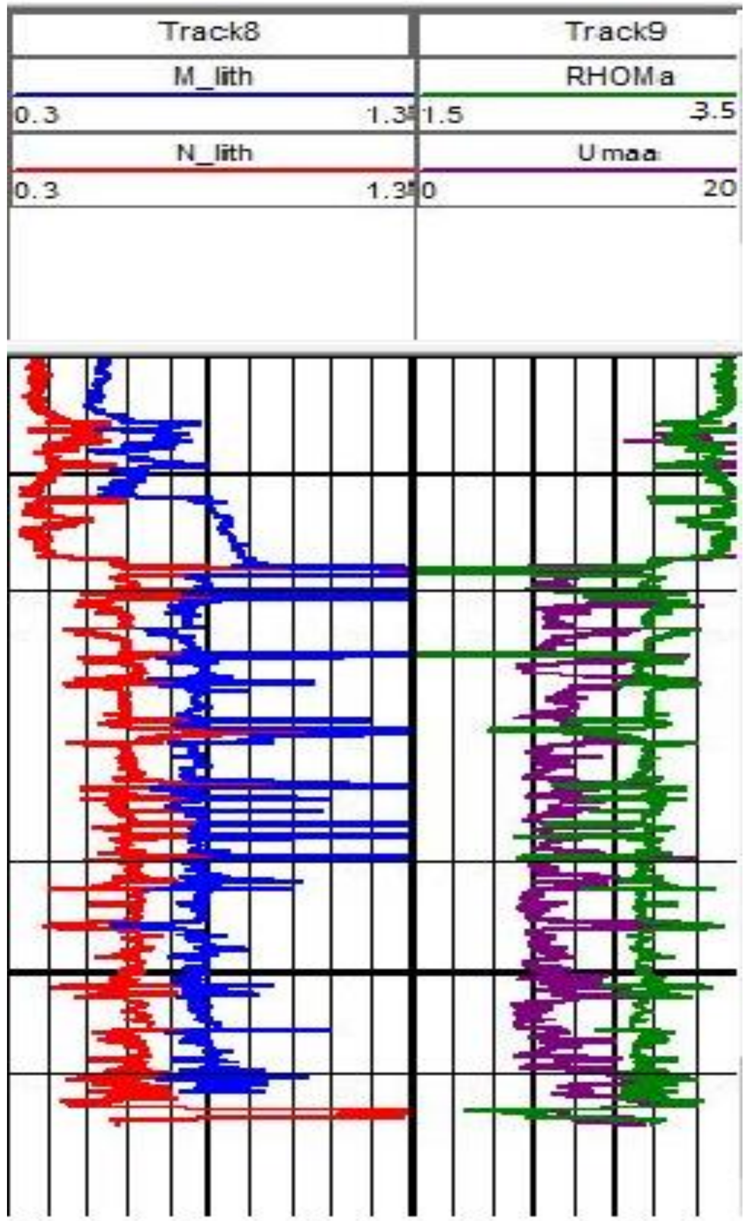

Figure 4.6 M-N lithology and RHOmaa vs Umaa cross plots curves

Following the figure 4.7 showing the M-N lithology of Bhit-02 well is given below.

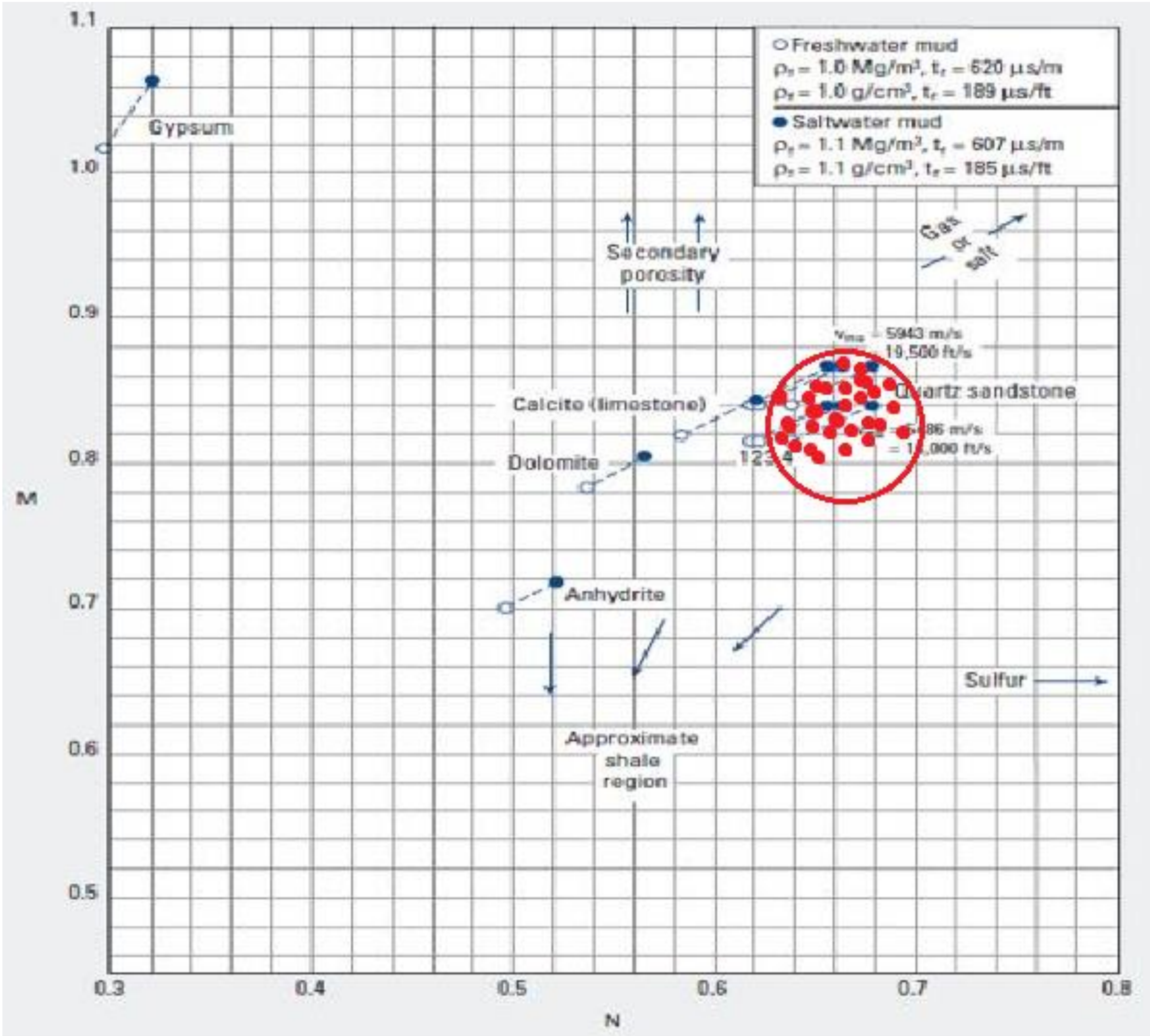

Figure 4.7 M-N lithology cross plot of well Bhit-02

With the result of this cross plot values are lies between quartz, feldspar and calcite zone. Mostly found in quartz zone. For further, move on RHOmaa vs. Umaa cross plot. As shown figure 4.8 given below

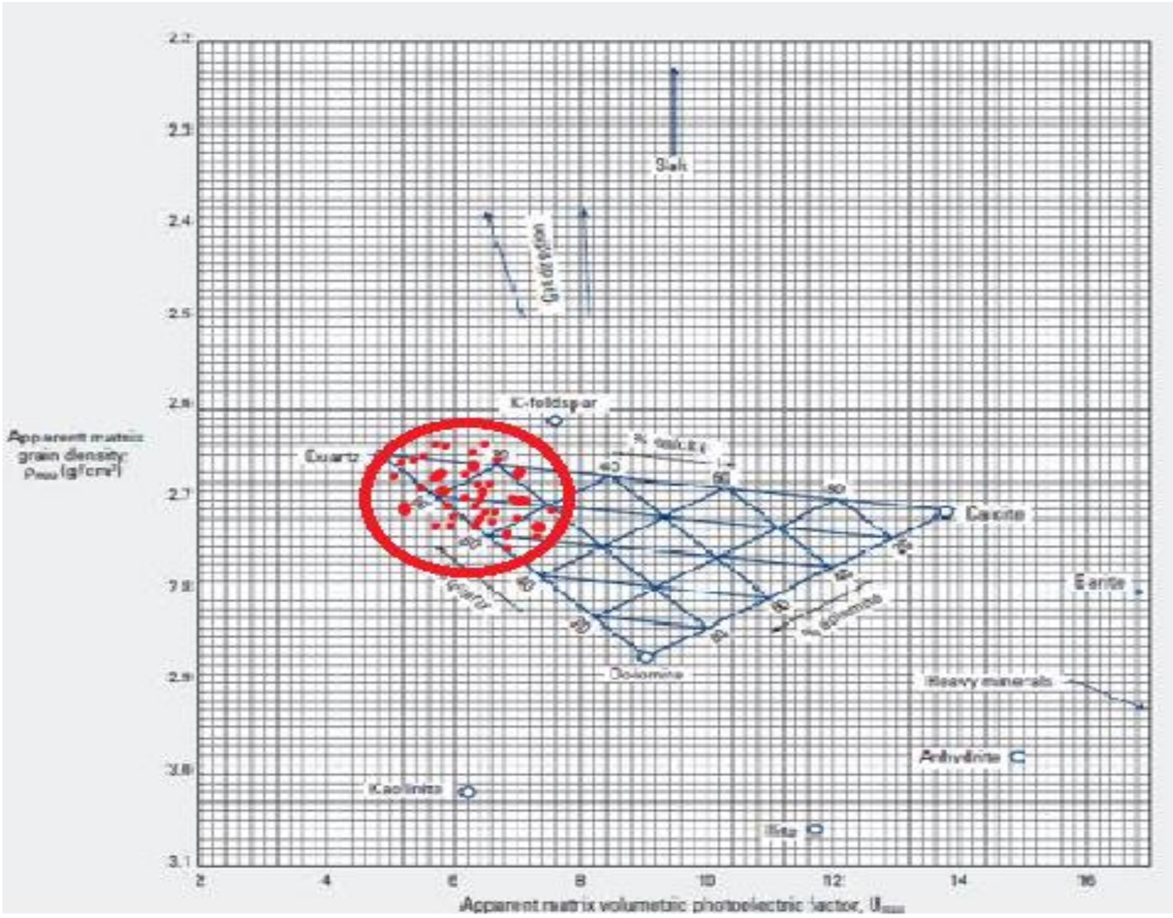

Figure 4.8 RHOmaa vs. Umaa crossplot of well Bhit-02

For understanding better results the second crossplot also analyzed and the results shows that the concentration is quartz to calcite and also little patch of feldspar. So it is conclude that the sand of Pab Sandstone is mostly composed with quartz. 70%, feldspar 20% and calcite 10% present in the formation.

4.3.4.2 Matrix Identification of Bhit-03

The well Bhit-03 contain good amount of sands and shales in Pab Sandstone range, this well consist of interbedded shale with sandstone but Bhit-03 well has good potential of hydrocarbons because it contain good amount of sand in Pab Sandstone. The sand portion is greater than shale portion that's why it provided good amount of hydrocarbons. In this well just sand portion is discuss because the reservoir zone which is sands of Pab Sandstone. And behalf of this just interpreted sands zone in given formation depth and thickness. It just marked sand portion in Pab Sandstone. M-N lithology and RHOmaa and Umaa are also measured at the same depths and resultant value are plotted on a plots. After the plotting of these point it can see that it mostly composed quartz, feldspar and also little portion of calcite. In this well discussed both shaly and sandy portion in only watching the composition of shale and sandstone in their given depth of reservoir area. But mostly the point taken from sands of Pab Sandstone Formation.

Two crossplots are used for the accuracy of results in Pab Sandstone. The M-N cross plot the table showing the value which is chosen from the log is as shown in table 4.3 are given below.

Table 4.3 values chosen from log on different depth of well Bhit-03

Depth(m)	M-lith	N-lith	RHOmaa	Umaa
1700m	0.84	0.62	2.71	6.11
1702m	0.85	0.64	2.70	5.89
1705m	0.82	0.62	2.69	6.01
1710m	0.85	0.67	2.68	6.55
1715m	0.84	0.68	2.66	6.81
1722m	0.83	0.65	2.64	6.79
1732m	0.81	0.63	2.68	7.11
1740m	0.79	0.62	2.66	7.21
1750m	0.80	0.65	2.67	7.34
1760m	0.81	0.66	2.63	7.24
1770m	0.79	0.67	2.61	7.51

Following the figure 4.9 M-N lithology and RHOmaa vs Umaa cross plots curves are;

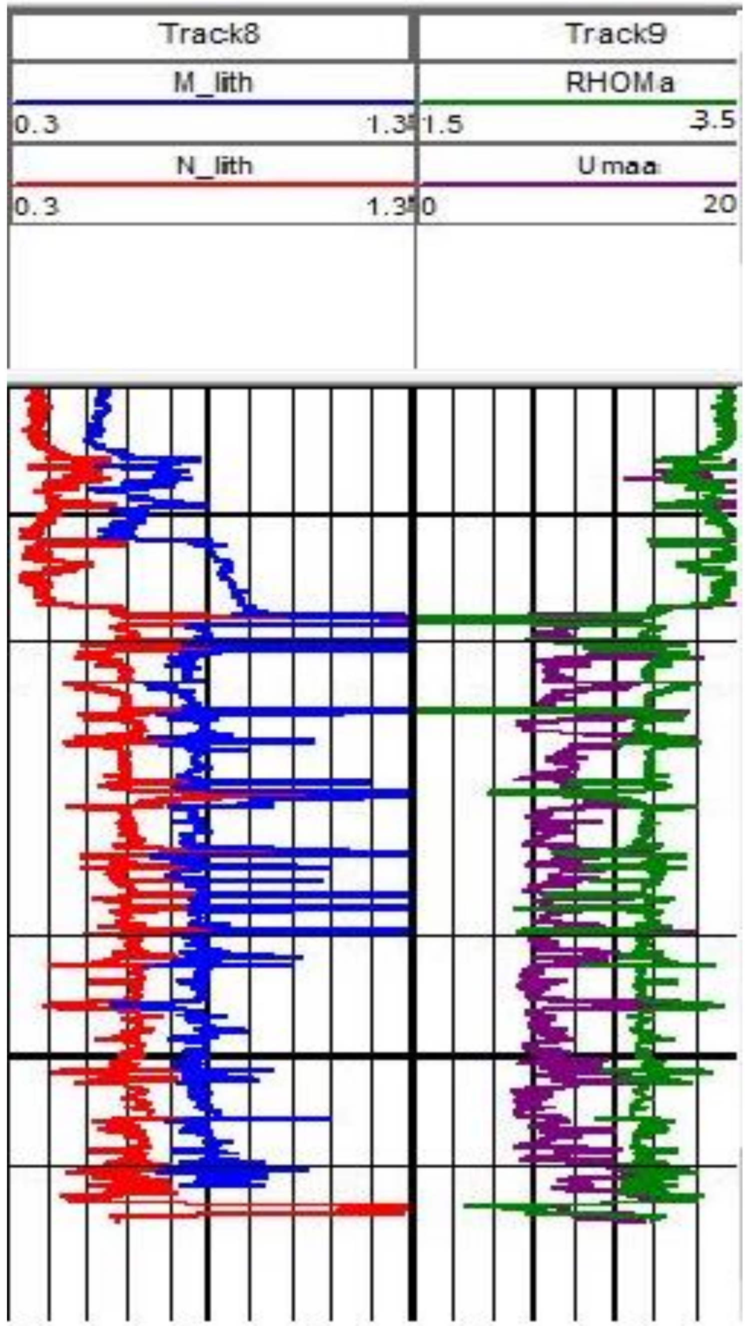

Figure 4.9 M-N lithology and RHOmaa vs Umaa cross plots curves

Following the figure 4.10 showing the M-N lithology of Bhit-03 well is given below.

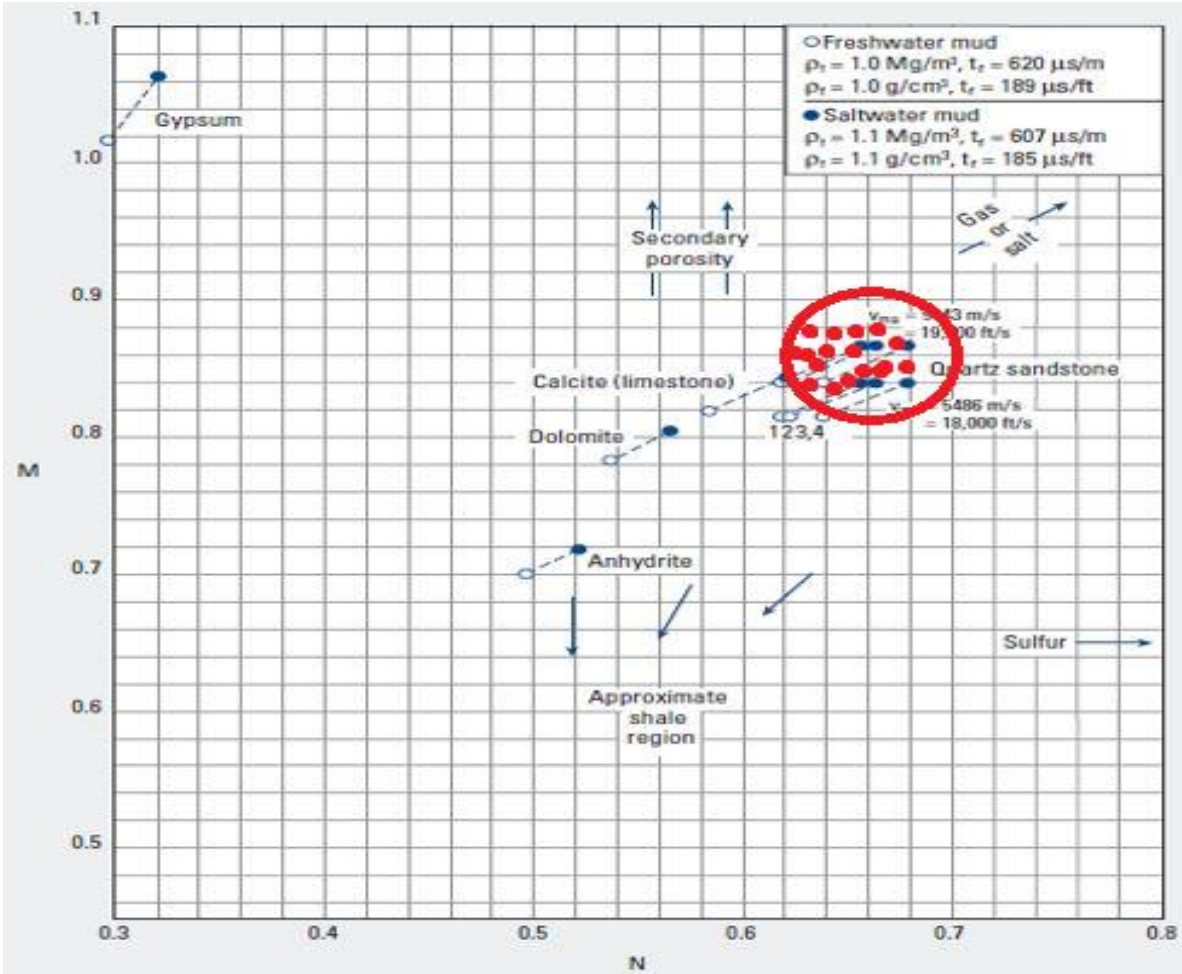

Figure 4.10 M-N lithology cross plot of well Bhit-03

With the result of this cross plot the values lies between quartz, feldspar zone and little mixing of calcite. Mostly found quartz to feldspar and calcite zone. For further let move on RHOmaa vs. Umaa cross plot. As shown in figure 4.11 are given below.

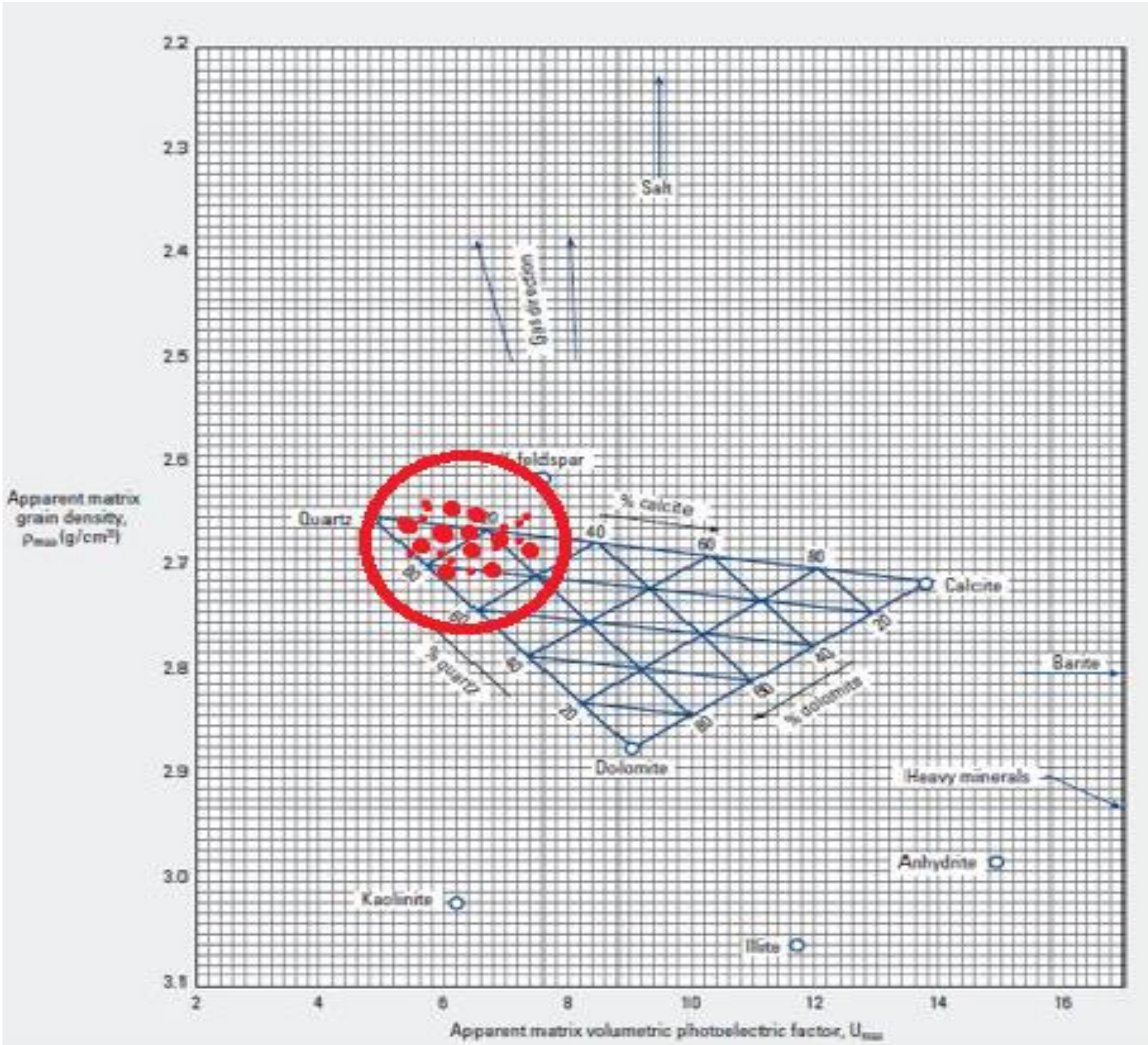

Figure 4.11 RHOmaa vs. Umaa crossplot of well Bhit-03

For understanding better results the second crossplot also analyzed and the results shows that the concentration is quartz to calcite. So it is conclude that the sand of Pab Sandstone is mostly composed with quartz. The Pab Sandstone is mostly composed with quartz. 65%, feldspar 20% and calcite 15% present in the formation. By keeping all these results in mind, some important properties of study area are described as follows:

1) Sands Pab Sandstone in Bhit-02 are good reservoir rock. They are good reservoirs for the accumulation of hydrocarbons.

2) In Bhit-03, Pab Sandstone are good reservoir and mostly act as reservoir rock.

3) Among all two wells, Bhit-02, contains largest net pay zone of approximately 18m with thickness at the depth of 1985m to 2005m and Bhit-03, contains largest net pay zone approximately 8m, with thickness at the depth of 1707m to 1721m.

4) Lithology of study area composed mostly of quartz and calcite and the percentage of these two varies from well to well.

4.3.5 Density Porosity

Density Porosity is used to calculate the Total Average Porosity and Effective Porosity. Two logs are used to calculate Density Porosity that is Density Log (RHOB) and Neutron (NPHI).The density log is a continuous record of a formation's bulk density. Overall density of a rock – (Solid matrix and fluid). The qualitative and semi-quantitative use of density log in Geology is to describe the General Lithology, Shale Textural changes and Mineral Identification. Its principle of measurement is Density tool is to subject the formation to a bombardment of medium-high energy 0.2 – 2.0 Mev gamma rays and measured their attenuation. Density log is normally plotted on linear scale across track 02. Most often with a scale between 1.95 and 2.95 and its Unit is g/cm3. Following the formula for Density Porosity Calculation,

Density Porosity;

PHID = (RhoM - RHOB [log]) / (RhoM - RhoF) (Alberty 1994)

Where;

RhoM = Matrix density

RhoF = Density of fluids 1 or 1.1 g/cc

This is the formula which is used for the calculation of density porosity. The value for matrix density is used as 2.65 because this work is based on Pab Sandstone which is sand and the matrix density for sand is 2.65 g/cc. Density porosity is calculated for all three wells.

4.3.6 Total / Average Porosity

Total or average porosity is calculated with the help of density porosity and neutron porosity. The Total Average Porosity is used to define total number of Pore spaces in rock. The formula is given below;

PHIA = PHID [log] + NPHI [log] / 2 (Kamel et al 2006)

Result and × 100 that is Average Porosity percentage

PHIA = Average porosity

PHID [log] = Density porosity

NPHI [log] = Neutron porosity

4.3.7 Effective Porosity

The Effective Porosity is used to define interconnected pore spaces. The formula is given below;

PHIE = Average Porosity × (1 – Vshl)

PHIE = PHIA[log] × (1 – Vshl)[log] (Kamel et al 2006)

Result and × 100 that is Effective Porosity percentage

4.3.8 Water Saturation

After the calculation of porosity, the next step involves in this interpretation is calculation for the saturation of water. The formula which is used for the calculation of water saturation is expressed as follows;

SwI = sqrt (1/RT) / (Vshl^ (1-0.5*Vshl) / sqrt (Rshl) + sqrt (PHIE^m / (a*Rw))

SwI = water saturation (Indonesian expression)

Rw = formation water resistivity

RT = observed bulk resistivity = LLD [log value]

Vshl = volume of shale (log value)

Rshl = shale resistivity

A = constant (often taken to be 1)

M = cementation factor (varies around 2)

- **Resistivity of water:**
    1. Conversion of Rmf into Rmfeq
        - If the Rmf at the surface temperature is less than 0.1, the user should prosed SP-02 chart.
        - Rmfeq If not then = 0.85 * Rmf (at BHT)
    2. Look at the SP deflection on the log.
    3. Determine Rweq using the SP-01 chart.
    4. To convert Rweq to Rw use the SP-02 chart.

The water resistivity (Rw) of Bhit Field by using this method, first Rmf convert into Rmfeq. The Rmf at BHT is record 0.074 at maximum temperature 58 DEGC which should be converted into Fahrenheit that is 136°F. After that by using SP-02 chart, the value of Rmfeq is 0.052. Than by taking -30 SP deflection with the help of SP-01 chart, the Rweq is 0.024 than finally used SP-02 chart the result of Resistivity of water Rw is 0.045,. This result is following figures 4.12 and figure 4.13.

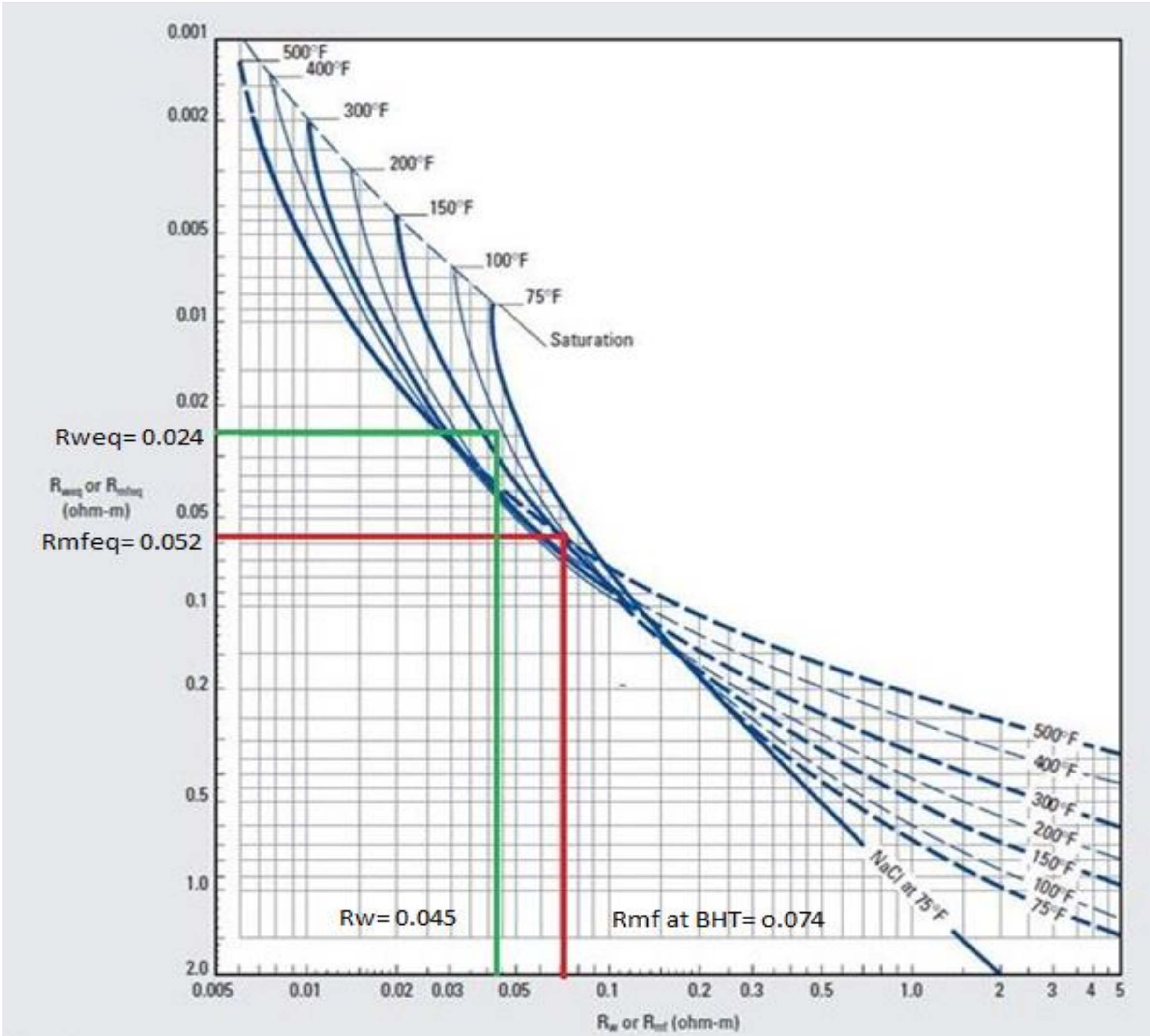

Figure 4.12 Showing SP-02 chart with calculated Rmfeq and Rw of the well Bhit 02, 03

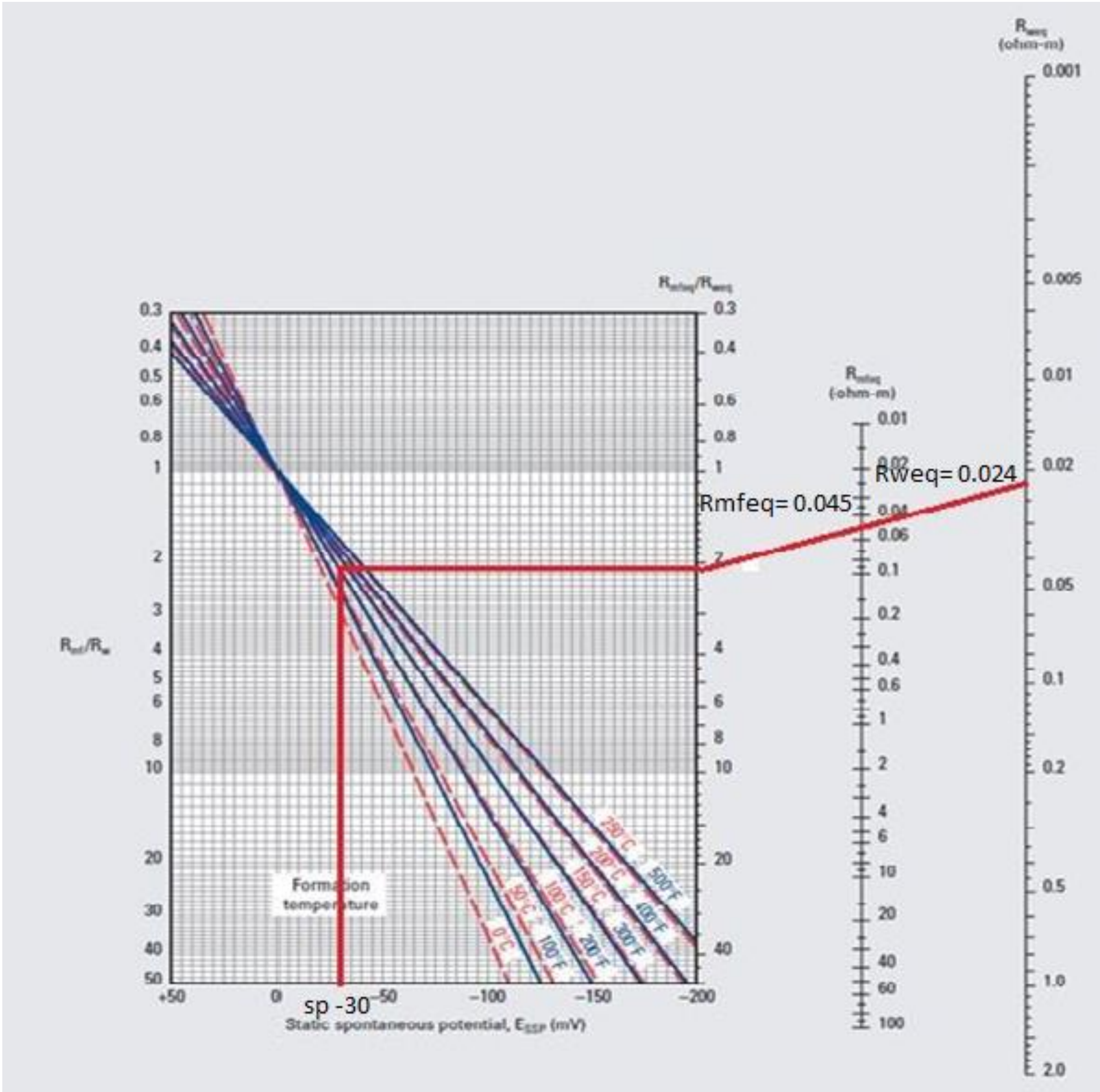

Figure.4.13 Showing SP-01 chart with SP deflection and Rweq of Bhit 02, 03

4.3.9 Saturation of Hydrocarbon

In saturation of hydrocarbon we calculate Amount of Hydrocarbon, pore volume and identification of Net Reservoir and net pay. The Saturation of Hydrocarbon derived from the given formula,

$Sh = 1 – Sw$ (Ramadan et al 2018)

Results × 100 then we have the results in percentage

4.3.10 Hydrocarbon Pore Volume

Hydrocarbon pore Volume is find by the resultant of Saturation of water, Effective porosity. The formula is given below,

HPV = (1-SwA [log]) × PHIE [log] **(**Ramadan et al 2018)

Result × 100 percentage of Hydrocarbon Pore Volume

4.3.11 Net Reservoir

The Net reservoir will be measured where the cut off parameter will be applicable cut off parameters are, Volume of Shale. Cut of parameters for net reservoir are volume of shale is less than 30% and effective porosity is greater than or equal to 4%.

Net Reservoir = Vshl <0.3, PHIE >= 0.04

4.3.12 Net Pay

The Net Pay will be measured where the cut off parameters will be applicable cut off parameters are Volume of Shale. Cut of parameters for Net Pay is shale volume is less than 30%, and effective porosity is greater than 3% and Saturation of Water is less than 50%.

Net Pay = Vshl < 0.3, PHIE >= 0.04, Sw < 0.5

The following table 4.4 showing the cut of parameters that the values utilize for petrophysical analysis in GeoGraphix Discovery software are given below.

Table 4.4 Values utilize for petrophysical analysis in GeoGraphix Discovery software

Well name	GR max	GR min	Rho mat	Rho fluid	Rw	constant			Cutoff parameters		
						a	m	n	Vshl	PHIE	Sw
Bhit-02	80 API	20 API	2.67 GM/CC	1.1 GM/CC	0.03 OHMM	1	2	2	<30%	>3%	<50%
Bhit-03	75 API	10 API	2.67 GM/CC	1.1 GM/CC	0.015 OHMM	1	2	2	<30%	>3%	<50%

4.4 Tracks on Logs

In this research displayed seven tracks on the log and every track contain several logs. The logs are main components in Petrophysical interpretation. The three log are given and other to operate by using different software for finding aspects with the help of these tracks correlation track, resistivity track and porosity basically these first three tracks are given and others are we operate i.e. volume of shale track, porosity track, saturation of water track and bulk volume of water track and net pay is the last one. Correlation track is first track and it contains logs which used for the correlation of wells which are drilled in the study area like gamma ray log (GR log), spontaneous potential log (SP log) and caliper log. Bit size is also displayed in this track. The scale of gamma ray log is ranging from 0 to 150 API, scale of SP log is ranging from -100 to 50 mv and scale of caliper log is ranging from 6 to 16 inches. GR log is used to estimate the volume of shale with the help of formula briefly described in methodology section. SP log is also used for estimate the shale content and also SP deflection is used for the calculation of Rw which is also explained in methodology section. Caliper log is used to understand the geometry of well. The correlation between caliper log and bit size is used to understand the hole size and shape of bore hole. The caliper log helps in the measurement of variations in bore hole diameter with depth. It also helps in the determination of mud cake, washouts and bad hole flag. If the value of caliper log is greater than bit size than it’s the indication of washouts and if it is smaller than it’s the indication of mud cake. Hole rogusity is a difference between caliper log and bit size and if it is greater than 2 than it’s called bad hole.

Next to first track is depth track in which depth of well bore is displayed in meters. In the second track resistivity logs are displayed these are LLS, LLD and MSFL. LLD is true resistivity and used for the calculation of water saturation. Third track contain porosity logs, these logs are used to determine the porosity of rocks. These logs are neutron porosity log (NPHI), bulk density log (RHOB) and sonic porosity log (DT). The scale of neutron porosity log is ranging from -0.15 to 0.45 v/v, scale of bulk density log is ranging from 1.95 to 2.95 g/cm3 and the scale of sonic porosity is ranging from 140 to 40 µs/ft. Bulk density log (RHOB) is used to calculate density porosity while neutron porosity is used for calculation of total average porosity (PHIA) and finally effective porosity (PHIE) is calculated with the help of average porosity and resultant curve is displayed in the track four with the scale 0 to 1 and if the results are multiplied with 100 than it will be in percentage with scale of 0 to 100.

Similarly new curve for volume of shale is displayed in fifth track with scale ranging from 0 to 1 or 0 to 1. In the track 6 saturation of water is displayed with scale ranging from 0 to 1. The procedure of calculation of water saturation is explained in methodology section. Track 6 is also showing the concentration of hydrocarbon pore volume and scale is again 0 to 100%. The final track contains net pay and the determination of net pay is also described above.
After the interpretation the correlation of the well with the help of log. Different scales are given if not we adjust in it. Also mark over targeted formation by using x-section in GeoGraphix software. Where mark total thickness of formations. Similarly by using given parameters and given scale identifying the results and outcomes that tells the presence of hydrocarbon or not. Now following results of research that interpreted by using GeoGraphix software of Bhit Field wells are Bhit-02, 03 & 04.

4.5 Petrophysical interpretation of Bhit-02

The first well is Bhit-02, it is located in southern Indus Basin, district Badin Pakistan. Location of this well is latitude is 26’19”10.188 N and longitude is 67’26”10.188 E. The given LAS file was uploaded on (GeoGraphix Discovery) software. In well data eight formations were present but only reservoir zone discussed with Petrophysical properties of Pab Sandstone. And also discuss about the sand portion in the Pab Sandstone range. Different zones was marked that is both shaly and sandy zone that are shown in figure 4.4. On the basis of this interpretation the total TD of Bhit-02 well is 2100m. Different logs are run in it for the calculation of the volume of shale, saturation of water, effective porosity & net pay in Bhit-02 well. The top of Pab Sandstone is started from 1840 m to 2024 m. On 2024 m. Below the Pab Sandstone the next formation is fort-munro. So the top used in this well is Pab Sandstone and the bottom is fort-munro is present on vary depths. In this well interpreted reservoir area that is Pab Sandstone. In Pab zone both the presence of shale and also presence of sand. Both portion are marked in the figure 4.14. In this research only discuss about the sandy portion in Pab Sandstone which give the good quantity of net pay. The marked zones are shown figure 4.14 both shale and sand portion but reservoir is only discuss where sand is present where good quantity of net pay in the sand zone in varies depths that is pabsands-1, pabsands-2, pabsands-3, pabsands-4, pabsands-5 and pabsands-06. Good net pay is present in pabsand-1, pabsands-02, pabsands-5, and pabsands-06 shown in table 4.5, because presence of shale is less then sand. These zone with their depth and thickness are describe in following table 4.5 is given below.

Table 4.5 showing the interpreted zones of Pab Sandstone in well Bhit-02

Age	**Formation**	**Zones**	**Zone tops/depth (m)**	**Thickness (m)**
Early Cetaceous	Pab Sandstone	PabSands-1	1850-1860	10
		PabSands-2	1870-1883	13
		PabSands-3	1890-1897	7
		PabSands-4	1910-1923	13
		Pabsands-5	1955-1962	7
		Pabsands-6	1985-2005	20

The table contain interpreted zones and their depth of Sands of Pab Sandstone. In this well the target zones are just sands and their thickness was discuss because net pay has good quantity in this sandy zone. The zonation criteria is displayed on figure 4.14 as given below.

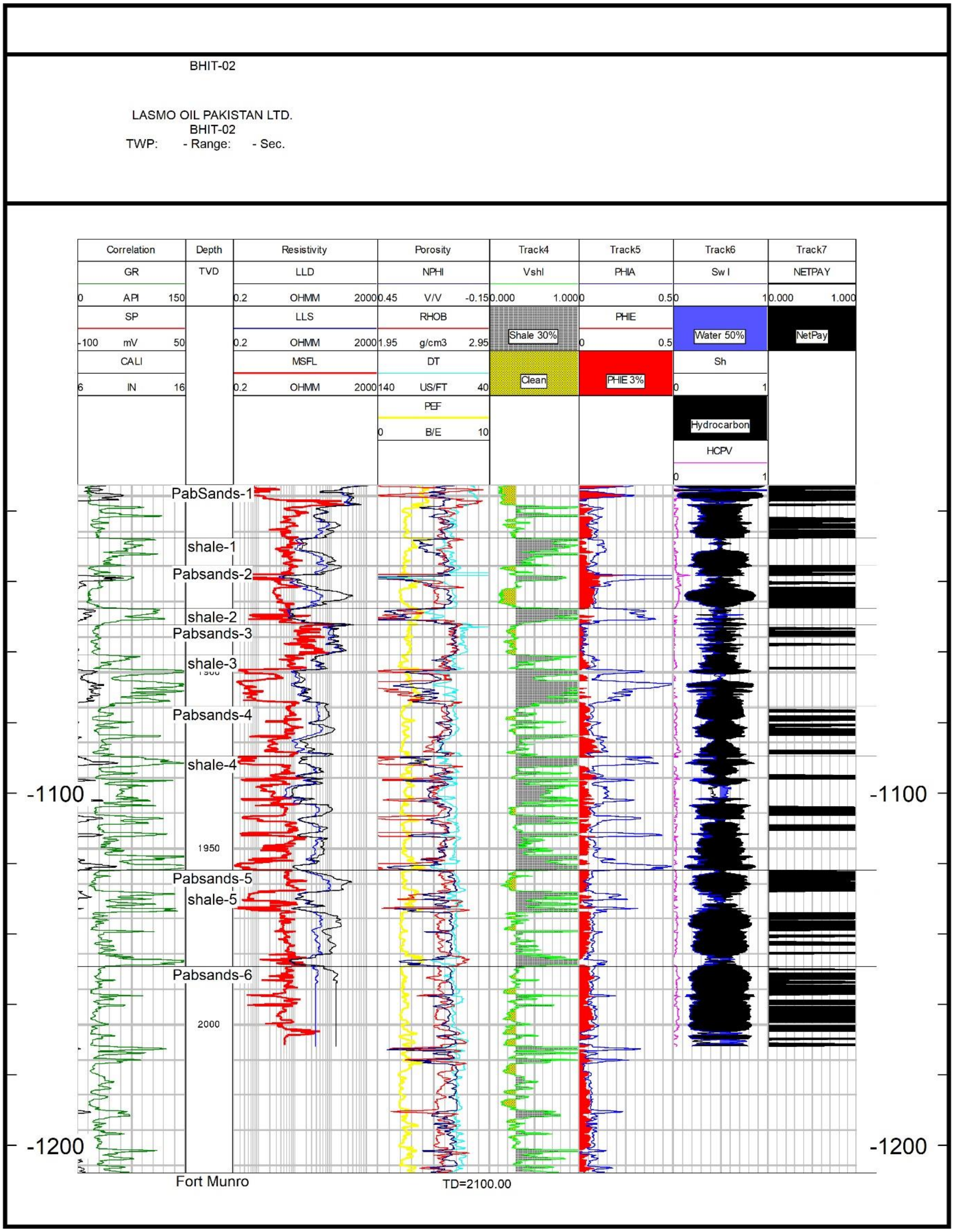

Figure 4.14. Interpreted log section of Pab Sandstone in well Bhit-02

In above log it’s very easy to understand the petrophysical results of Pab Sandstone. By understanding these results Pab Sandstone into divided different zones. These results or petrophysical parameters are described in following table 4.6.

Table 4.6 showing the petrophysical parameters of Pab Sandstone in well Bhit-02

Zones	**Lithology**	**Depth& Thickness (m)**	**Vshl %**	**PHIE %**	**Sw %**	**Sh %**	**HCPV %**	**Net Pay (m)**
PabSands-1	Sand	1850-1860, 10	30	2.3	40	60	0.3	10
PabSands-2	Sand	1870-1883, 13	20	3	30	70	0.1	13
PabSands-3	Sand	1890-1897, 7	70	0.05	90	10	<0	2
Pabsands-4	Sand	1910-1923, 13	80	0.1	70	30	0.1	8
Pabsands-5	Sand	1955-1962, 7	30	0.1	20	80	0.5	5
Pabsands-6	Sand	1985-2005, 20	10	0.1	10	90	0.5	18

After the interpretation the results are described in the above table 4.3 we found good net pay. Low saturation of water, good hydrocarbon potential low hydrocarbon pore volume in sand portion. So in Bhit-02 the good quantity of net pay in sandy portion in its productive zone.

4.6 Petrophysical interpretation of Bhit-03

The second one well of research area is Bhit-03 which is located in district Badin, in Southern Indus basin, location is latitude is 26’16”55.4316 N and longitude is 67’27” 31.77 E. On the basis of Petrophysical analysis of Bhit-03 Well is categorized into two zones Sandy zone and Shaly zone which is display in figure 4.5 respectively. By the results of different curve we identifying its top and thickness of total formations that are present in the log. Following table

4.4 showing thickness of Pab Sandstone and its tops from varies depths. In this well both shaly and sandy zones are marked but only the discussion about sands zone where good results of net pay. Three zones are marked in sandy zone that is PabSands-1, PabSand-2, and PabSands-3 as shown in figure 4.5, where the presence of hydrocarbon in the sands of Pab Sandstone in various depth. In this interpretation only discuss about the sandy zone because good net pay results refer to presence of hydrocarbon. These zone with their depth and thickness are describe in following table 4.7 is given below.

Table 4.7 showing the interpreted zones of Pab Sandstone formation in well Bhit-03

Age	**Formation**	**Zones**	**Zone tops/depth (m)**	**Thickness (m)**
Early Cetaceous	Pab Sandstone	PabSands-1	1707-1721	14
		PabSands-2	1723-1727	4
		PabSands-3	1728-1730	2

The table contain interpreted zones and their depth of Sands of Pab Sandstone. As in figure 4.5 both sandy and shaly zone are marked but only reservoir zone where good results of net pay that indicate the presence of hydrocarbons. On the other hand shaly portion that we see in taken zones. The first zone PabSands-1 is started from 1707m to 1721m, having 14m of thickness. The second zone PabSand-2 is started from 1723m-1727m, having 4m of thickness. And the third and final zone PabSand-03 is started from 1728m-1730m, having thickness of 2m. Following figure 4.15 showing the interpreted in Bhit-03 well and their results given below.

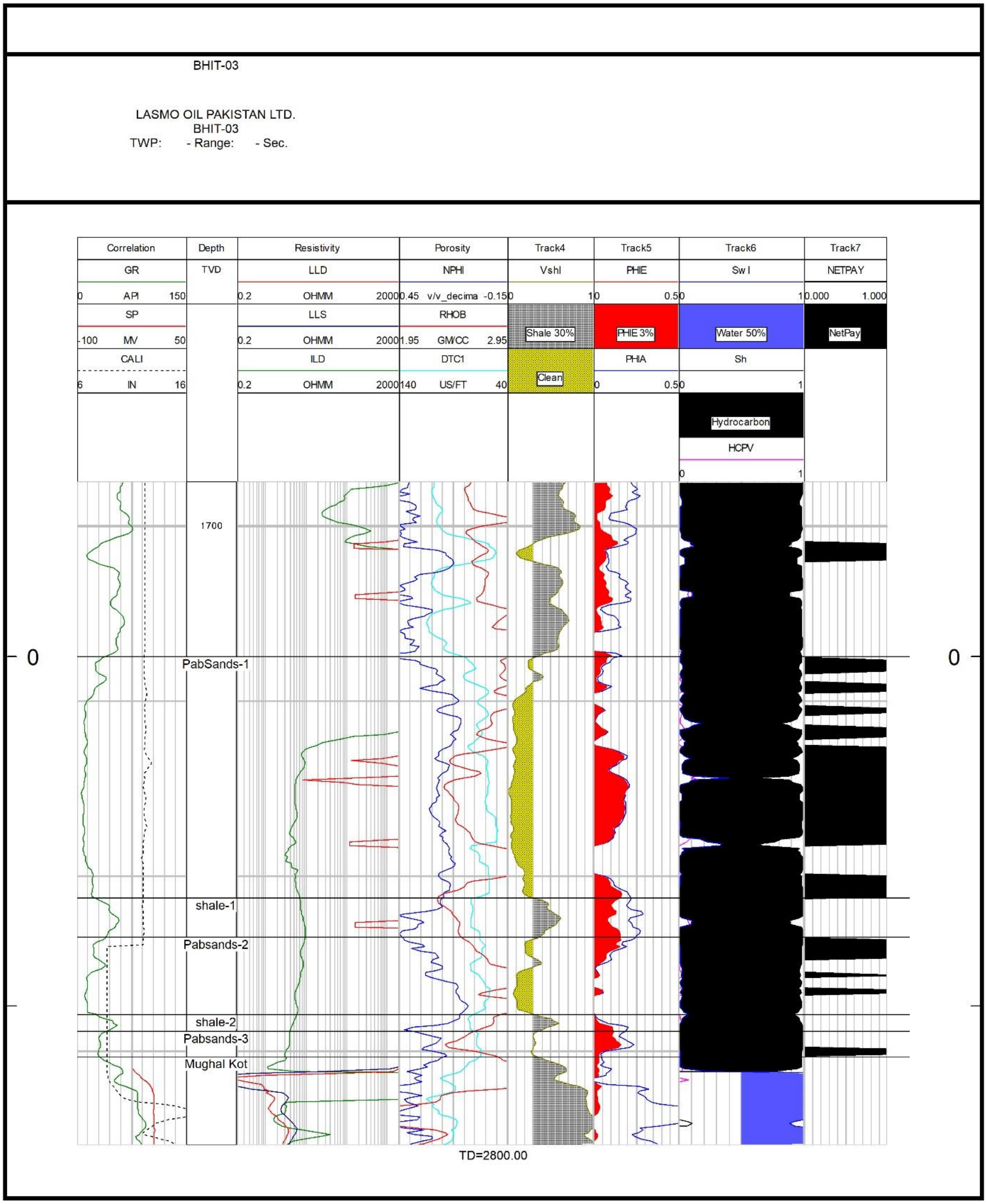

Figure 4.15. Interpreted log section of Pab Sandstone in well Bhit-03

In above log it’s very easy to understand the petrophysical results of Pab Sandstone. By understanding these results Pab Formation is divided into different zones. These results or petrophysical parameters are described in following table 4.8 given below.

Table 4.8 showing the petrophysical parameters of Pab Sandstone in well Bhit-03

Zones	**Lithology**	**Depth& Thickness (m)**	**Vshl %**	**PHIE %**	**Sw %**	**Sh %**	**HCPV %**	**Net Pay (m)**
PabSands-1	sandstone	1707-1721, 14	8	2	10	90	0.2	8
PabSands-2	sandstone	1723-1727, 4	5	0.05	60	40	0.1	2
PabSands-3	Sandstone	1728-1730, 2	2	0.15	10	90	0.2	1.5

After the interpretation the results are described in the above table 4.5 that indicate good net pay. Low saturation of water, good hydrocarbon potential low hydrocarbon pore volume in sand portion. As in the depth of 1707m-1721m, good result and excessive amount of hydrocarbon is present as well as in the depth of 1723m-1727m, the net pay is 2m and also presence of hydrocarbon. And the last depth in sandy zone is 1728m-1730m, the net pay is 1.5m also indicate the presence of hydrocarbon. So in Bhit-03 well sandy portion is productive zone.

4.7 Petrophysical interpretation of Bhit-04

The third well of this research is Bhit-04. Its locality is in Badin area, Southern Indus Basin Pakistan. The latitude and longitude is 26’23”05.22 N & 67’25”17.22 E. The results showing that the Pab Sandstone is in given depth is mixed by Sand and Shale. The total depth this Bhit-04 is 3600m, and the targeted zone is Pab Sandstone that is in the depth of 1989.00m to 1989.50m respectively and the total thickness of this bed is 25.50m. In this well data is missing there are missing of logs and the given area is too small which it couldn’t run for Net

Pay of the reservoir. The depth and thickness is too short and it cannot run for interpretation and couldn't to calculate the shale volume, effective porosity, and the water saturation, hydrocarbon saturation, Hydrocarbon pore volume and Net pay of the reservoir. If data is given it must be interpreted the Bhit-04 log. Following figure 4.16 showing the results of Bhit-04 well.

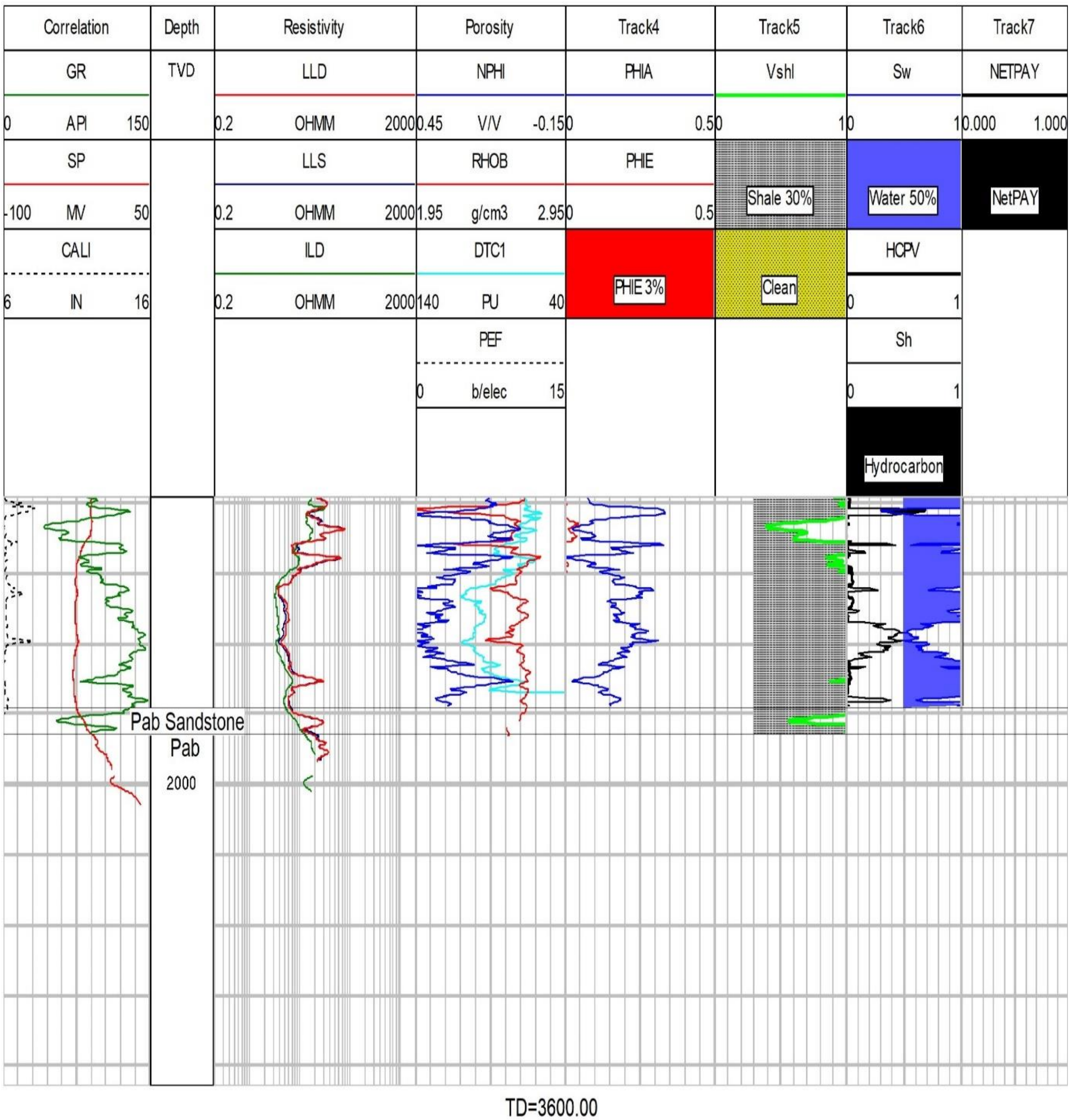

Figure 4.16 Interpreted log section of Pab Sandstone in well Bhit-04

In above log it's very easy to understand the petrophysical results of Pab Sandstone. The data is missing in this log. Very small depth of Pab Sandstone. There is no interpretation because all given thickness is shale and resistivity and porosity logs are not displayed in the LAS file. In Bhit-04 I don't have the logs in formation of Bhit-04 that's why it's not cooperating in the research because of the data is missing as shown in figure 4.16.

.

DISCUSSION

Petrophysical analysis has been carried out on the Bhit field wells, Bhit-02, Bhit-03, and Bhit-04, for the purpose of hydrocarbon exploration. The location of the study wells' coordinates (26 16 55.4316 N and 67 27 31.7707 E). Pab Sandstone, which dates back to the Cretaceous, has been the subject of this investigation. The volume of shale, average porosity, effective porosity, water resistivity, saturation of water, saturation of hydrocarbon, hydrocarbon pore volume, and net pay of the reservoir will be estimated using the data from the well logs of Bhit-02, Bhit-03, and Bhit-04 performed by Geographix software. The reservoir zone of the well Bhit-02 has good hydrocarbon potential; the well's typical net pay ranges from 13 to 18 m. The reservoir zone of the well Bhit-03 also has a good potential for hydrocarbons; the average net pay estimate for this well ranges from 2 to 8 meters. Data and logs from the Bhit-04 well are missing, and they were not evaluated.

So in Bhit-02 the good quantity of net pay in sandy portion in its productive zone. In the second well Bhit-03 low saturation of water, good hydrocarbon potential low hydrocarbon pore volume in sand portion. As in the depth of 1707m-1721m, net pay zone of approximately 8m, good result and excessive amount of hydrocarbon is present as well as in the depth of 1723m-1727m, the net pay is 2m and also presence of hydrocarbon. And the last depth in sandy zone is 1728m-1730m, the net pay is 1.5m also indicate the presence of hydrocarbon. So in Bhit-03 well sandy portion is productive zone. Bhit-04 is the third and last well in my study. Because the logs for Bhit-04 are missing from the LAS file, it won't cooperate with the research because the information isn't there. Since the wells Bhit-02 and Bhit-03 are nearby to one another, their petrophysical analysis results are practically identical, and both are giving good hydrocarbon exploration. After these wells have been interpreted, structural and stratigraphic correlation is done in order to better understand the depth of the sandy and shale zone of the Pab Sandstone. Recognize the structural deformation of the studied area as variations in Pab Stone thickness between wells. Crossplots are used for identification of matrix or lithology. The cross plots which are used in this research is M-N lithology cross plot and Umaa vs. RHOmaa cross plot. After the analysis of these cross plots it is concluded that the Pab Sandstone mostly composed quartz, feldspar and somewhere calcite were present. As the results of this overall research the Pab Sandstone in Bhit-02 and Bhit -03 have good reservoir for the accumulation of hydrocarbon.

Conclusion

This research assessed the Sands of Pab Sandstone reservoir by interpreting the geophysical data from three wells, Bhit-02, Bhit-03, and Bhit-04. These wells are situated in Pakistan's southern Indus Basin in Sindh's Badin district. These wells' petrophysical interpretation split the Pab Sandstone's sands into various sand and shaly zones. Shale volume, average porosity, effective porosity, water resistivity, water saturation, hydrocarbon saturation, hydrocarbon pore volume, net reservoir, and net pay are all calculated in this petrophysical interpretation. Following the analysis of these data, it is stated that the Bhit-02 has a good economic potential for hydrocarbons, with the largest bed located between 1985 and 2005 meters below the surface and a net pay zone of around 18 meters. It has a good hydrocarbon potential, a strong net pay, low water saturation, and low hydrocarbon pore volume in the sand portion. Therefore, Bhit-02's producing zone has a good amount of net pay in the sandy portion. Bhit-03, the second well, has a low water saturation level, good hydrocarbon potential, and a small amount of hydrocarbon pore space in the sand. In the same way as the net pay zone between 1707 and 1721 meters is around 8 meters, a good result, and an excessive quantity of hydrocarbon are present, the net pay zone between 1723 and 1727 meters is 2 meters and there is also hydrocarbon present. Additionally, the final depth in the sandy zone is 1728–1730 meters, and the net pay of 1.5 meters also indicates the presence of petroleum. So in Bhit-03 well sandy portion is productive zone. Bhit-04 is the third and last well in my study. Because the logs for Bhit-04 are missing from the LAS file, it won't cooperate with the research because the information isn't there. Because the wells Bhit-02 and Bhit-03 are close to one another, their petrophysical analysis results are practically identical, and both are offering good hydrocarbon exploration. Understanding the difference in thickness and lithology of distinct zones of Pab Sandstone as well as the identification of the matrix that makes up the reservoir zones of Pab Sandstone allows us to better understand other aspects of the rock. For the matrix/lithology identification different cross plots are used like M-N cross plot and RHOmaa vs. Umaa cross plots. According to the study of these cross plots, the wells Bhit-02 and Bhit-03's sands are primarily made of quartz, feldspar, and minute amounts of calcite. So it is conclude that in Bhit-02, sand of Pab Sandstone is mostly composed with quartz, 70%, feldspar 20% and calcite 10% present in the formation and Bhit-03, the Pab Formation is mostly composed with quartz. 65%, feldspar 20% and calcite 15% present in the formation.

The Pab Sandstone formation in Bhit-02 and Bhit-03 are good reservoirs for the accumulation of hydrocarbons, and their sands zone is productive at an economically viable level based on all these findings.

RECOMMENDATIONS

Bhit-04's logs are missing from the LAS file, hence it won't cooperate with the research because the information isn't there. If it was accessible, it must be translated.

If Core date availability is possible that also refer to find out the porosity and permeability of rock.

By 2-D and 3-D seismic interpretation to understand the structural deformation of the study area as variation in thickness of Pab Sandstone from well to well.

By getting rock sample can be subjected to two categories of laboratory analysis i.e. (RCAL) routine core analysis and (SCAL) special Core analysis.

By RCAL attempt to find the basic properties of reservoir rock such as, porosity, Grain density, permeability and fluid saturation by the other hand SCAL is an extension an attempt to measure data that is more representative of the reservoir conditions such as, Electrical Properties, Wettability, Capillary Pressure and Relative Permeability.

More better understanding of Bhit field to visit on the area of Bhit field for knowing procedure and future estimation of exploration by seismic survey.

If I obtain further formation data for Bhit-03, I will discover a more productive zone where I can locate hydrocarbon between 1707 and 1770 meters.

References

Allemann, F. (1979). Time of emplacement of the Zhob Valley ophiolites and Bela ophiolites, Baluchistan (preliminary report). *Geodynamics of Pakistan. Geological Survey of Pakistan, Quetta*, 215-242.

Kazmi, A.H., Muhammad, Q. J. (1997). *Geology & Tectonics of Pakistan*, ISBN 969-8375-007

Abbas, S. G., Kakepoto, A. A., & Ahmad, M. H. (1998). *Iron ore deposits of Dilband area, Mastung district, Kalat Division, Balochistan*. Geological Survey of Pakistan (GSP), Information Release (IR) No.(679): 19p.

Khan, A. S., Kelling, G., Umar, M., & Kassi, A. M. (2002). *Late Cretaceous Pab Formation in the Central Kirthar Foldbelt, Pakistan*: The Influence of Flood and Storm on the Sand Body Characteristics. In Proc. PAPGSPE Annual Tech. Conf (pp. 2-4).

Alam, M. S. M., Wasimuddin, M., & Ahmad, S. S. M. (2002). *Zaur Structure, A Complex Trap in a Poor Seismic Data Area. In BP Pakistan* Exploration & Production Inc. Annu. Tech. Conf. (ATC), Islamabad, Pakistan, November (pp. 2-4).

Ahmad, N., Fink, P., Sturrock, S., Mahmood, T., & Ibrahim, M. (2004). *Sequence stratigraphy As predictive tool in lower goru fairway, lower and middle Indus platform, Pakistan*. PAPG, ATC, 1, 85-104.

Asim, S., Qureshi, S. N., Asif, S. K., Abbasi, S. A., Solangi, S., & Mirza, M. Q. (2014). *Structural and stratigraphical correlation of seismic profiles between Drigri Anticline and Bahawalpur High in Central Indus Basin of Pakistan*. International Journal of Geosciences, 5(11), 1231.

Bjorlykke, K. (1984). *Formation of secondary porosity*: How important is it? Part 2. Aspects Of porosity modification. 277-286.

Besse, J., & Courtillot, V. (1988). *Paleogeographic maps of the continents bordering the Indian Ocean since the Early Jurassic*. Journal of Geophysical Research: Solid Earth, 93(B10), 11791-11808.

Bannert, D., Cheema, A., Ahmed, A., & Schäffer, U. (1993). *The Structural Development of The Western Fold Belt,-Pakistan.* Geologisches Jahrbuch, Vol B80, P.3-60.

Bloch, S., & Helmold, K. P. (1995). *Approaches to predicting reservoir quality in sandstones*. AAPG bulletin, 79(1), 97-114

Beswetherick, S., & Bokhari, S. W. (2000). *The subsurface appraisal of the Bhit Gas field*, a Case study. In Proceedings of the SPE-PAPG annual technical conference (pp. 239-257).

Eschard, R., Albouy, E., Deschamps, R., Euzen, T., & Ayub, A. (2003*). Downstream evolution Of turbiditic channel complexes in the Pab Range outcrops* (Maastrichtian, Pakistan). Marine and Petroleum Geology, 20(6-8), 691-710

Ellouz-Zimmermann, N., Deville, E., Müller, C., Lallemant, S., Subhani, A. B., & Tabreez, A. R. (2007). *Impact of sedimentation on convergent margin tectonics*: Example of the Makran accretionary prism (Pakistan). In Thrust belts and foreland basins (pp. 327-350). Springer, Berlin, Heidelberg.

Humayon, M., Lillie, R. J., & Lawrence, R. D. (1991). *Structural interpretation of the eastern Sulaiman foldbelt and foredeep, Pakista*n. Tectonics, 10(2), 299-324.

Ibrahim, M. (2007). Seismic inversion data, a tool for reservoir characterization/modeling, Sawan gas field—a case study. In Proceedings of the Annual Technical Conference. (ATC), pp.

Kadri, I. (1995). *Petroleum Geology of Pakistan*: Pakistan Petroleum Limited Karachi. Pablishers, Karachi, Pakistan, pp.26-37.

Khattak, F. G., Shafeeq, M., & Ali, S. M. (1999). *Regional trends in porosity and permeability Of reservoir horizons of Lower Goru Formation, Lower Indus Basin, Pakistan*. Pakistan Journal of Hydrocarbon Research, 11, 37-50.

Mahmud, S. A., & Sheikh, S. A. (2009, November). *Reservoir potential of lower nari Sandstones (Early Oligocene) in southern Indus basin and Indus offshor*e. In Annual Technical Conference (ATC) (pp. 7-8).

Patriat, P., & Achache, J. (1984). *India–Eurasia collision chronology has implications for Crustal shortening and driving mechanism of plates*. Nature, 311(5987), 615-621.

Rowlands, D. (1978). *The structure and seismicity of a portion of the southern Sulaiman Range*, Pakistan. Tectonophysics, 51(1-2), 41-56.

Raza, H. A., Ahmed, R., Alam, S., & Ali, S. M. (1989). *Petroleum zones of Pakistan*. Pakistan Journal of Hydrocarbon Research, 1(2), 1-20.

Siddiqui, R. H., Asif Khan, M., & Qasim Jan, M. (2007). *Geochemistry and petrogenesis of the Miocene alkaline and sub-alkaline volcanic rocks from the Chagai arc, Baluchistan, Pakistan*: Implications for porphyry Cu-Mo-Au deposits. Journal of Himalayan Earth Sciences, 40, 1-23.

Siddiqui, R. H., Khan, M. A., Jan, M. Q., & Ogasawara, M. (2009). *Petrogenesis of Plio-Pleistocene volcanic rocks from the chagai arc, Balochistan, Pakistan*. Journal of Himalayan Earth Sciences, 42.

Shah, S. M. I. (2009). *Stratigraphy of Pakistan memoirs of the geological survey of Pakistan*. The Geological Survey of Pakistan, 22.