PETROPHYSICAL INTERPRETATION AND GEOMECHANICAL EARTH MODELING OF MANZALAI-01 AND MANZALAI-05 UPPER INDUS BASIN, PAKISTAN

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ABSTRACT

This work focuses on Petrophysical analysis of Manzalai-01 and Manzalai-05 wells for reservoir characterization of Lockhart and Lumshiwal Formations in Manzalai Field, Kohat basin, Pakistan. In Potwar Sub Basin, Paleogene Carbonates and Jurassic clastic are the main, proven reservoirs and Ratana Field is no exception, where these reservoirs are present within the reachable depth. The whole set of Petrophysics tools such as, Gamma Ray, CALI log, Spontaneous Potential, Resistivity (MSFL, LLS, LLD), Neutron log, and Density logs, along well tops and all the drilling elements were calculated in this work. The main aim of the work was to point out areas of interest which may act as a reservoir, for this purpose properties such as volume of shale, porosities, saturation of water and hydrocarbon saturation were measured that come under Petrophysical interpretation and Pore pressure, Fracture pressure and Overburden that comes under Geomechanically interpretation that marks the zone of interest in Lockhart and Lumshiwal Formation. The normal measured elements of Lumshiwal, the measurements of reservoir properties of Manzalai-01 well represent porosity of 0.038% and average Sw was evaluated as 0.554% and Saturation of H/C is 63.57%. For Lockhart the average porosities are 0.42% and average water saturation of 0.69%. The analysis shows that S_h of Manzalai -01 and Manzalai-05 wells is proven for the production of hydrocarbons to be economically feasible and is already producing.

ACKNOWLEDGMENTS

With the grace of Almighty ALLAH, we have been able to overcome yet another task which was impossible without ALLAH's blessings.

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Moreover, we are very thankful to our family and friends who boosted us morally. Their support, prayers, encouragement, and confidence always provided us the strength to achieve our goals. Lastly, we appreciate all the people who assisted us one way or the other in the successful completion of this thesis.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

The following study covers the Petrophysical analysis of Manzalai-1 and Manzalai-5 gas well by the interpretation of its well logs and the Geomechanically modeling of Manzalai-01 and Manzalai-05 wells to check the mechanical properties and behavior of the rocks under different stresses, to better understand the borehole conditions. This is performed by computing Overburden pressure using Density log and Pore pressure and Fracture pressure using Sonic logs. In the Petrophysics section, mainly a porous and permeable zone is marked in prominent Formations of Manzalai-1 and Manzalai-5 i.e., Lockhart and Lumshiwal Formations. Kohat depression is among the most Petro-prolific regions in our country due to the abundance of both structural and stratigraphic traps. The exploration of Manzalai gas field in 2002 initiated the exploration of Oil and Gas in the SW of Kohat basin with continued production up till now on the basis of economic estimates it will continue to produce till 2032. The preferred objectives are the Paleocene Lockhart (Carbonates) Limestone and Cretaceous (Clastic) Sandstone of Lumshiwal.Manzalai-1 and Manzalai-5 were drilled and completed as producing wells.

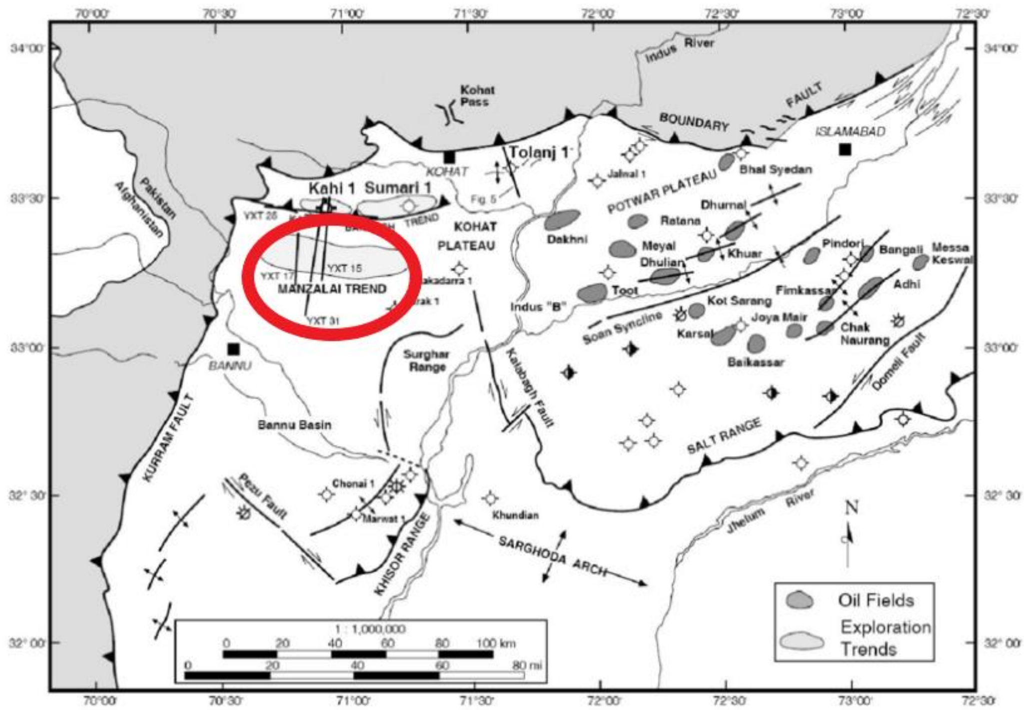


Figure 1. 1 Geological map of Potwar Plateau

1.2 Location

Manzalai is an active gas field situated onshore Pakistan and is run by MOL Pakistan Oil & Gas. The is specifically in block 3370-3 (Tal) and Manzalai area in the region of Gomal, Khyber Pakhtunkhaw.

1.3 Climate

The climate in this field is hot semi-arid. The temperature averages 22,3 °C. The annual rainfall is between the range of about 817 millimeter and 32.2 inches. The weather conditions of the region differ along elevations, for example hilly areas face chilly winters as well as cool summers, while the temperature is high towards south.

1.4 Objectives

The following objective will be achieved in order to complete the research work:

i. To estimate the HC potential of Lockhart and Lumshiwal Formation by Petrophysical analysis, finding Vsh, Φe, S*w*, and S*h*.

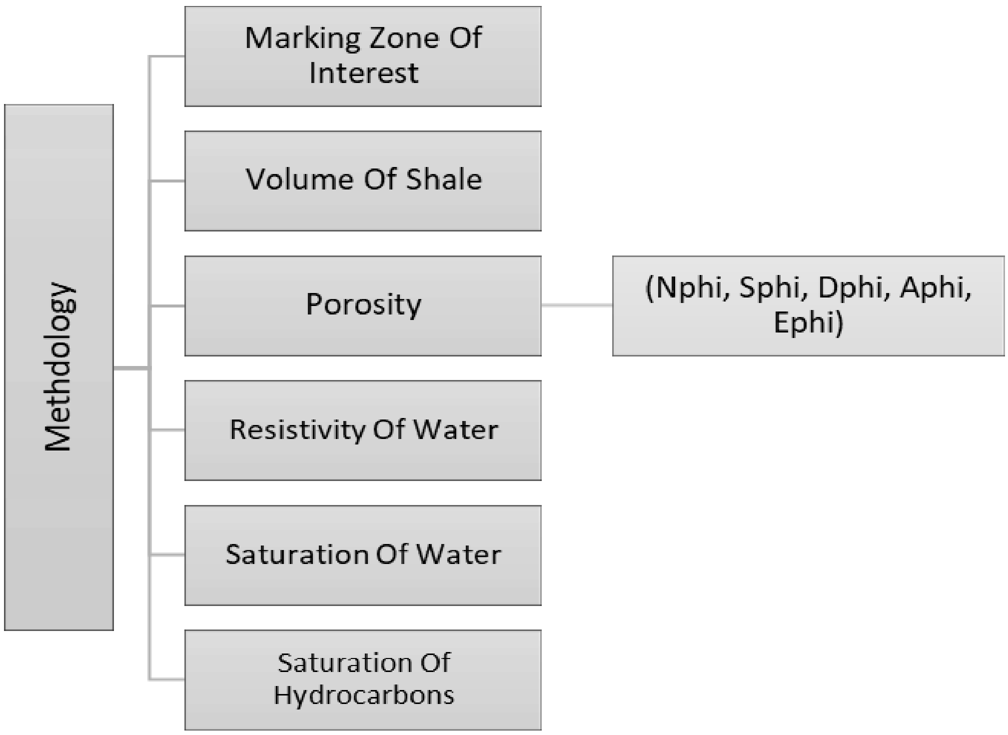
ii. To perform the Geomechanical Earth modeling of Manzalai-01 and Manzalai-05 wells to compute Pore pressure and Fracture pressure along with Overburden pressure.

1.5 Methodology

1.5.1 Petrophysical interpretation

First of all, log curves of strata were guessed that may or may not act as the reservoir. In Zones of the Formation, points where the pattern of Gamma Ray curve was showing minimum, were identified as probable reservoir zones. Cross plots between NPHI and DPHI, the difference between curves of LLS and LLD values indicate the occurrence of some oil and gas in the reservoir zone (which indicate that LLD > LLS). Formations (Lockhart and Lumshiwal) of Manzalai-01 and Manzalai-05 were analyzed for its Hydrocarbon's capability using different equations i.e., the Vsh identification by Gamma Ray log and measurement of Sw by Archie's equation for the quantitative analysis of Wireline logging. The subsequent diagram shows all steps that will be followed to achieve the objective of this research work.

Table 1.1 Concept map showing the steps followed in Petrophysical analysis.



1.5.2. Geomechanics

For the Geomechanically modeling of Manzalai-01 and Manzalai-05 wells we have first computed Overburden pressure using Density log after it pore pressure and fracture pressure were calculated using Sonic log. For pore pressure we used Eaton's equations to calculate these porosities.

1.6 Dataset Availability

We acquired the good data of Manzalai-01 and Manzalai-05 from LMKR by the approval of Director-General of Petroleum Concession (DGPC). This data was basically required for Petrophysical analysis of the Lockhart and Lumshiwal Formations present in the well and Geomechanics.

1.6.1 Well data

Director-General of Petroleum Concession (DGPC) provided the Wireline log data of Manzalai-01 and Manzalai-05which comprised of the following logs in total.

Table 1.2 Logs used for Petrophysical analysis.

No	Log Type
1	Gamma Ray Wireline Log
2	Spontaneous Potential Wireline Log
3	Resistivity Wireline Log
4	Caliper Log
5	Sonic Log

Table 1. 3 Logs used for Geomechanics.

No	Parameters	Log Type
1	Over burden pressure	Density log
2	Pore pressure	Sonic log
3	Fracture pressure	Sonic log

CHAPTER 2
TECTONIC SETTING AND GEOLOGY

2.1. Kohat basin

It is the part of Upper Indus basin which is located on North part of Pakistan between latitudes 32 degree and 34 degrees North and longitudes 70 degree and 74-degree East. It is situated in hilly sequences of Tibetan Plateau, Himalaya, Karakoram, and Hindu-Kush. The sedimentary rocks are underlying this area of Jurassic to Pliocene age. In the NE and NW edges of this area, slate, slaty shale, and sandstone of Pre-Cambrian or Early Paleozoic age are found. Sedimentary sequence was formed on the north-west edge of Indian plate.

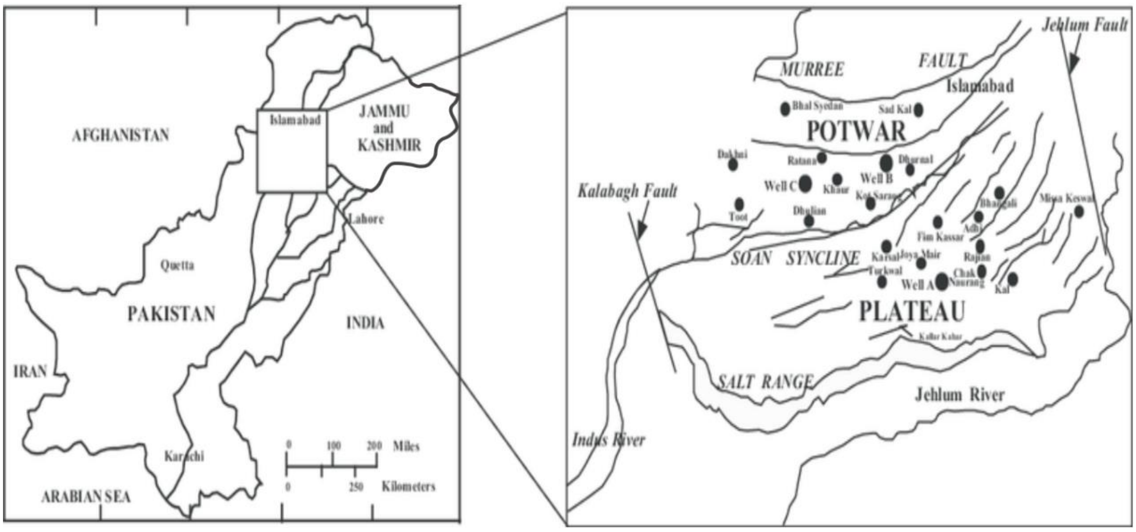


Figure 2. 1 Topographical and Area map of Kohat-Potwar basin

2.2. Tectonic of the area

The Kohat-Potwar plateau lies at south part of the Himalayan and Karakorum orogenic belt which was formed by compressional tectonics post collision between Indian and Eurasian plate. It is bounded by Kala Chitta Hills in the north end, salt-range and trans-Indus range to the South end, west boundary is placed by Kurram-Parachinar range. During Eocene-Paleocene interval there were drastic changes of tectonics and structural in this area. This region of Kohat-Potwar plateau is the most multiplex tectonic area of Pakistan. It is a complex tilted plateau having difficult topographic features, for example, medium to steep dips and asymmetrical structures which may have been the result of large number of thrust and normal faults. This region has many faults systems related to salts and tectonics.

Indian-Eurasian obduction resulted in the formation of several reverse faults. The tectonic potential is greater in Western part then the Eastern. Northern area is more deformed then southern. The head on strike of two plates resulted in the creation of compressional type structures on the upper parts of Indian plate since that time the continued push has formed Himalayan orogeny and related chain of foreland basins. The study area is the complex compression type basin of Himalayan foreland. Its north boundary is marked by Main Boundary Thrust, in south by Surghar range and Indus River flows in the east and the Kurram fault is in its west. Mesozoic sediments are thrusted over Eocene-Miocene along Main Boundary Thrust (Yeats and Hussain 1987). Along the Surghur Range thrust, this deposition is pushed towards south over the loose unconsolidated sediment of the Punjab Foreland. The Mesozoic silt is being compared with sediments along Kurram fault (Ahmad 2003). The Surghar area serves as the main deformational side of Kohat depression, which is geographically divided from (SRT) with the help of Kalabagh fault. Within this area, a wide range of sedimentary rocks including sandstones, shales, gypsum, limestone, evaporites are exposed. The exposed sedimentary rocks (Sandstones, Dissipates, Gypsum, Shale, Limestone) of the Kohat sub-bowl are going in age from Jurassic to Quaternary. The collision of two plates during resulted in creation of compressional type structures on the N and northwestern part of the plate since that time the continued push has formed Himalayan orogeny and related chain of foreland basins.

2.3. Geology of study area

The sedimentary rocks of Jurassic to Pliocene age are present beneath the Kohat-basin area. In northwestern & northeastern sides there lies the slate, slaty shale, and sandstone of Pre-Cambrian. Or early Paleozoic age. In Kohat-Potwar (Upper Indus Basin), N-Pakistan there are more than 5000 meters of marine sediments of (Precambrian to Eocene, with a major unconformity of Ordovician to Carboniferous). Then comes the 10,000 meters of Miocene to Pleistocene alluvial sediments which are overlying the Marine sediments. The continent-continent head on strike resulted in the formation of tectonic basin at the NW edge of Indian Plate. The petroleum exploration in this area started in the mid-nineteenth centuries, having 60 exploration wells. There was the discovery of ten-oil fields, with total 200 million bbl. of total reserves, from which 112 million bbl. was produced. The region has several attractive features for petroleum generation and accumulation including source-reservoir-trap assemblages and thermal maturity regimes. Estimated hydrocarbon resource of the area are 2.4 billion bbl. of oil equivalent. The East-West pattern of Kohat area is among the major hydrocarbons potential areas of North Pak, with many proved and probable systems. Its depositional sequence was deposited on the NW border, within the age range of Jurassic to Quaternary. Large oil and gas exploration activities in this area include Chanda, Nashpa, Makori, Mela, and Manzalai Oil-Gas-condensate field.

2.4. Stratigraphy of manzalai field

The stratigraphy of the Manzalai Field is well recognized from the outcrops as well as from the wells drilled in the field and the areas surrounding. The deposition of Kohat- Potwar basin started from Pre-Cambrian to Pleistocene. The three major unconformities in the area are Ordovician-Carboniferous, Mesozoic-Late Permian, and Eocene-Oligocene. Salt range Formation overlying metamorphic rocks is the oldest sedimentary rocks in this area. The Cambrian rocks are comprised of Sandstone, Silt-stone, Shale and Dolomite represented by Khewra, Kussak, Juttana and Baghanwala Formations. After Cambrian there is unconformity, this cease of deposition was up to Permian. Permian sequence of the basin includes Tobra Formation, Dandot Formation, Warcha sandstone, Sardhai Formation, Amb Formation, Wargal limestone, Chiddru Formation. Then comes the Permian unconformity and after this Triassic sequence starts, which includes Mianwali Formation, Chakjabbi limestone, Tredian Formation, Kingriali Formation, again comes the unconformity and Jurassic sequence starts including, Datta Formation, Shinawari Formation, and Samana Suk Formation. Cretaceous sequence includes Chichali Formation, Lumshiwal Formation, Kawagarh Formation and then Paleocene sequence of Hangu Formation, Lockhart limestone, Patala Formation. Unconformity and then the Eocene sequence, Oligocene is missing, Miocene sequence includes Rawalpindi group. The succession of stratigraphic Formations in Kohat sub-basin is as follows.

2.4.1. Borehole stratigraphy of manzalai wells

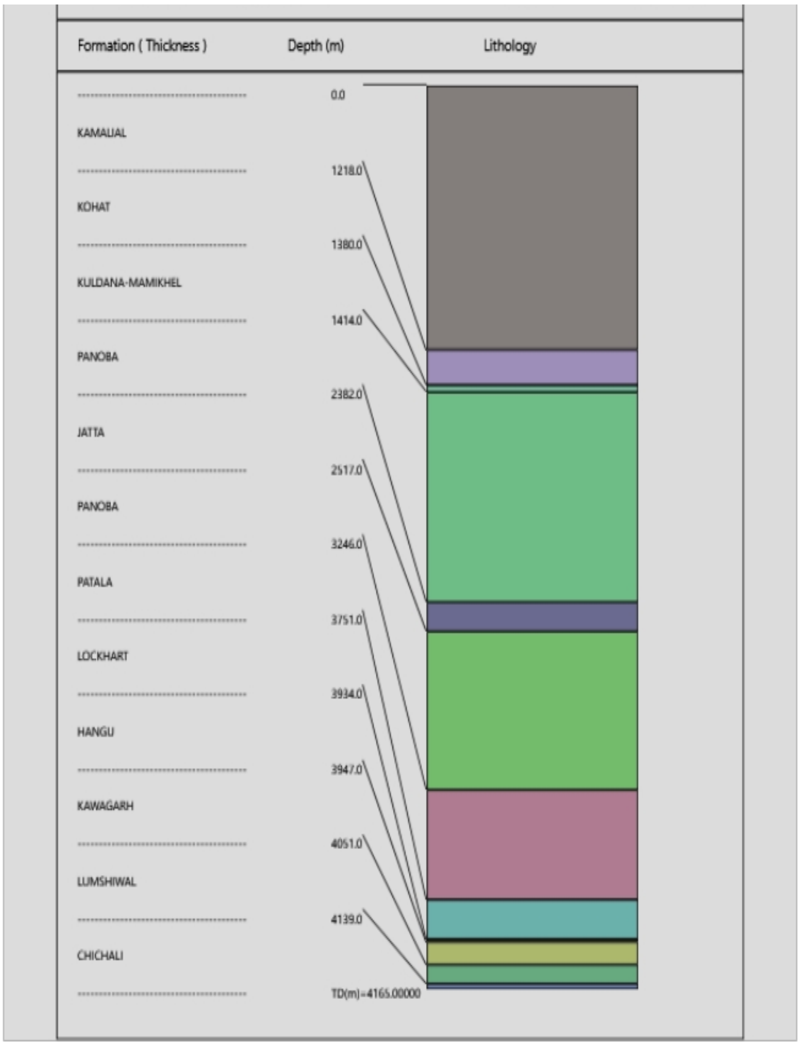


Figure 2. 2 Stratigraphic sequence of Manzalai field.

2.4.2. Lockhart formation

Lockhart Formation is further discussed here is because of the zones of interest is marked here. It is well exposed in Kohat-Potwar sub basin, Trans-Indus ranges, Kalla-Chitta range, Islamabad, Hazara-Kashmir area (Shah 2009). It is of Makarwal group of Upper Indus. In Kohat area it contains medium to thick bedded, massive, rubbly and brecciated Limestone. Its type locality is in Fort Lockhart with a thickness of 60m at type locality. Foraminifers and Lockhartia are the fossils found in Lockhart Formation. The Formation was deposited in broad shelf and ramp settings environment. It conformably overlies the Hangu Formation and upper contact is conformable with Patala Formation.

2.4.3. Lumshiwal formation

Gee in 1945 proposed the ‘Lumshiwal Sandstone”. Its type locality is in 1Km north of Lumshiwal Nala. It consists of thick to massive bedded Sandstone. The Sandstone is feldspathic, ferruginous and contains carbonaceous material in the upper part. Its thickness is 80 to 120m at type locality. Bivalves, Gastropods, and Belemnites are the fossils present in it, showing Marine shelf clastic environment. Its lower contact is gradational with Chichali Formation and the upper contact is disconformable with Kawagarh Formation.

CHAPTER 3
PETROPHYSICAL INTERPRETATION

3.1. Introduction

Petrophysical evaluation is an important tool to correlate the properties of reservoir such as Permeability, Porosity, and Saturation with the Hydrocarbon's availability. However, the uncertainties are always present in the quantification of Petrophysical properties of rocks, assessed through the well logs and analysis rock physics. The main objective of the Petrophysical evaluation of a Formation is a precise measurement of characters of reservoir like Porosities, content of Clay, Water saturation level, saturation of Hydrocarbons. (Zamanek et al., 1970; Hussain et al., 2017a).

3.2. Petrophysical analysis

Petrophysical characteristics of the Lumshiwal and Lockhart Formation in the Manzalai condensate and gas field has been calculated by analysis of Wireline logging documents of an exploratory Manzalai-01 and Manzalai-05 wells. A comprehensive Petrophysical survey of certain reservoir interval of Lumshiwal and Lockhart Formation was done by utilizing a full set of Wireline logs for instance GR, LLD, DT. The volume of shale (Vsh) is one of the most crucial Petrophysical parameters, necessary to describe quality of reservoir as well as for characterization of reservoir. The calculation of volume of Shale is done to calculate approximately the content of shale in marked zone (reservoir). Generally, the reservoir density is calculated by the density log (RHOB). Evaluation of porosity through data of Wireline logs is a crucial tool that permits a clearer reservoirs characterization, which alternate in economic and technical context (Azzam and Shazly, 2012).

The following calculation was done in the following sequence for the evaluation purpose with the help of Wireline logs:

- Volume Of Shale (Vsh)
- Resistivity of Water (R_w)
- Porosities of Rock (ϕ)
- Saturation of Water (S_w)

- Saturation of HCs (S*h*)

3.3. Statistics of well manzalai-01 and manzalai-05

Following table shows the stats and status of the Manzalai-01 and Manzalai-05 wells.

Table 3. 1 Well statistics of manzalai-01

Well Name	Manzalai-01
Location	Gomal district, Khyber Pakhtunkhaw
Status	Operating
Field	Manzalai Field
Company	MOL
Total Depth	4557M /14950 ft

Table 3. 2 Well statistics of manzalai-05

Well Name	Manzalai-05
Location	Gomal district, Khyber Pakhtunkhaw
Status	Operating
Field	Manzalai Field
Company	MOL
Total Depth	3294M / 10807 ft

3.4. Volume of shale

Volume of shale is the estimation of clay content and detection of Radioactive elements in the targeted zone. There are various methods to evaluate shale volume for example to evaluate the Shale Volume; we can use GR log as well as Density and Neutron log. The Shale Volume is a critical parameter in Wireline logging that enables the accurate estimation of other Petrophysical parameters like EPHI, Saturations etc. It's vital as a limit value of Volume of Shale that is frequently used to distinguish between a non-reservoir zone and reservoir zone.

High value of Gamma ray log indicates dirty lithology whereas low value of Gamma ray log indicates clean lithology. Different formulas can be used to calculate the volume of shale. We use NPHI-DPHI log to evaluate Shale Volume.

Using NPHI-DPHI log, we calculated:

$$Vshale = \frac{(X1 - X0)}{(X2 - X0)}$$

Where,

$$X0 = NPHI_{MA}$$
$$X1 = NPHI + M1 \times (RHOB_{MA} - RHOB)$$
$$X2 = NPHI_{Sh} + M1 \times (RHOB_{MA} - RHOB_{Sh})$$

Table 3. 3: Parameters of Shale volume formula using Neutron-Density log.

Name	**Unit**	**Description**	**Default value**
NPHI_fluid	v/v	NPHI log value in 100% water	1.0
NPHI_shale	v/v	NPHI log value in 100% shale	0.4
NPHI_matrix	v/v	NPHI log value in 100% matrix rock	-0.1
RHOB_fluid	g/cm 3	RHOB log value in 100% water	1.0
RHOB_shale	g/cm 3	RHOB log value in 100% shale	2.4
RHOB_matrix	g/cm 3	RHOB log value in 100% matrix rock	2.65

3.5. Porosities calculation

3.5.1. Average porosity

It is the proportion of total volume of void spaces to the total volume of bulk; we calculate average porosity in Techlog using Neutron-Density log where data type is NRPL for neutron porosity and BULK DENSITY for Density log.

3.5.2. Effective porosity

Effective porosity is the part of the whole void spaces of a material bearing pore spaces that is capable of transmitting a fluid. we calculate effective porosity in Techlog using Neutron-Density log where data type is NRPL for Neutron porosity and BULK DENSITY for Density log.

3.6. Water resistivity

Water Resistivity is the measure of the capability of water to oppose electricity, directly proportional to the quantity of dissolved salt in the water. Water having high dissolved salts will have a low resistivity, and water with low dissolved salts will have high resistivity. Resistivity unit is Ohms i.e., unit of resistivity.

3.6.1. Formula

$R_2 = R_1 [(T_1+6.77)/(T_2+6.77)]$ °F OR $R_2 = R_1 [(T_1+21.5)/(T_2+21.5)]$ °C

3.7. Saturations

3.7.1. Water saturation

Water present in pore spaces of rocks is called water saturation. It helps to determine the occurrence of H/C in reservoir zone.

Low water saturation is the indication of H/C in that zone of reservoir and high-water saturation is the indication of low occurence of H/C in that zone of reservoir.

We use Indonesian equation to calculate the saturation of water:

$$SW_{\text{Indonesia}} = \left\{ \frac{\sqrt{\frac{1}{Rt}}}{\left(\frac{Vsh^{(1-0.5Vsh)}}{\sqrt{Rsh}}\right) + \sqrt{\frac{\phi_e^m}{a.Rw}}} \right\}^{(2/n)}$$

Where,

Table 3. 4 Parameters of water saturation formula using Indonesian-EQ

Name	Unit	Description	Default value
a	unitless	Exponent of Tortuosity	1
m	unitless	Exponent of Cementation	2
n	unitless	Exponent of Saturation	2
Rw	ohm.m	Value of Rw	0.03
R_{sh}	ohm.m	100% shale recording in Resistivity log.	5

3.7.2. Saturation of hydrocarbon

The presence of Hydrocarbons in the targeted or desired Formation other than water saturation is called as saturation of Hydrocarbon. Using the value of the Saturation of water, the Saturation of Hydrocarbon is calculated. It is done by using a formula that follows:

Sh = 1 – Sw

Where: Sh = Saturation of H/C

Sw = Saturation of Water

3.8. Outputs

3.8.1. Petrophysics Of manzalai-01

3.8.1.1 Lockhart

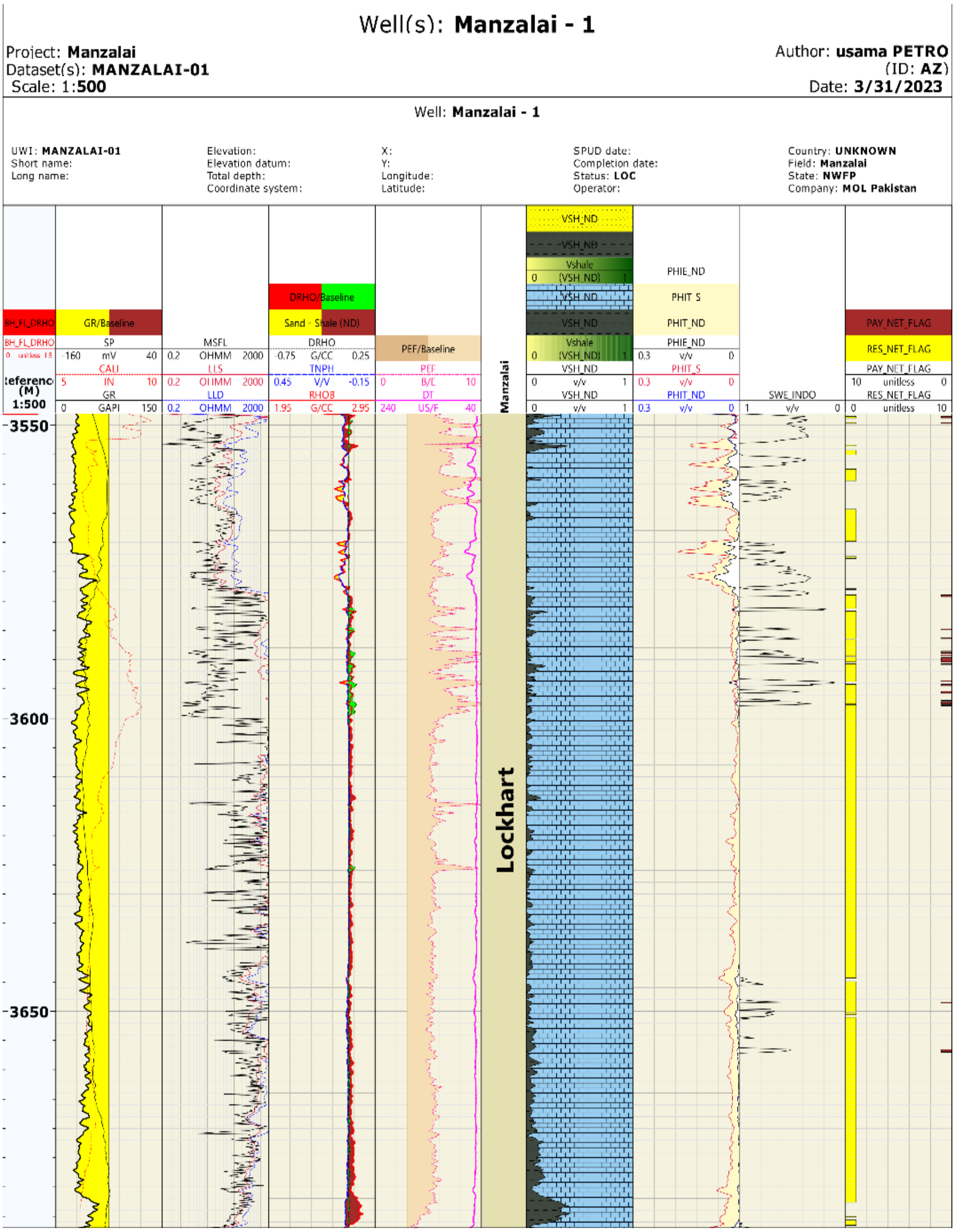


Figure 3. 1 Petrophysics of Lockhart Formation in Manzalai-01.

3.8.1.2. Lumshiwal

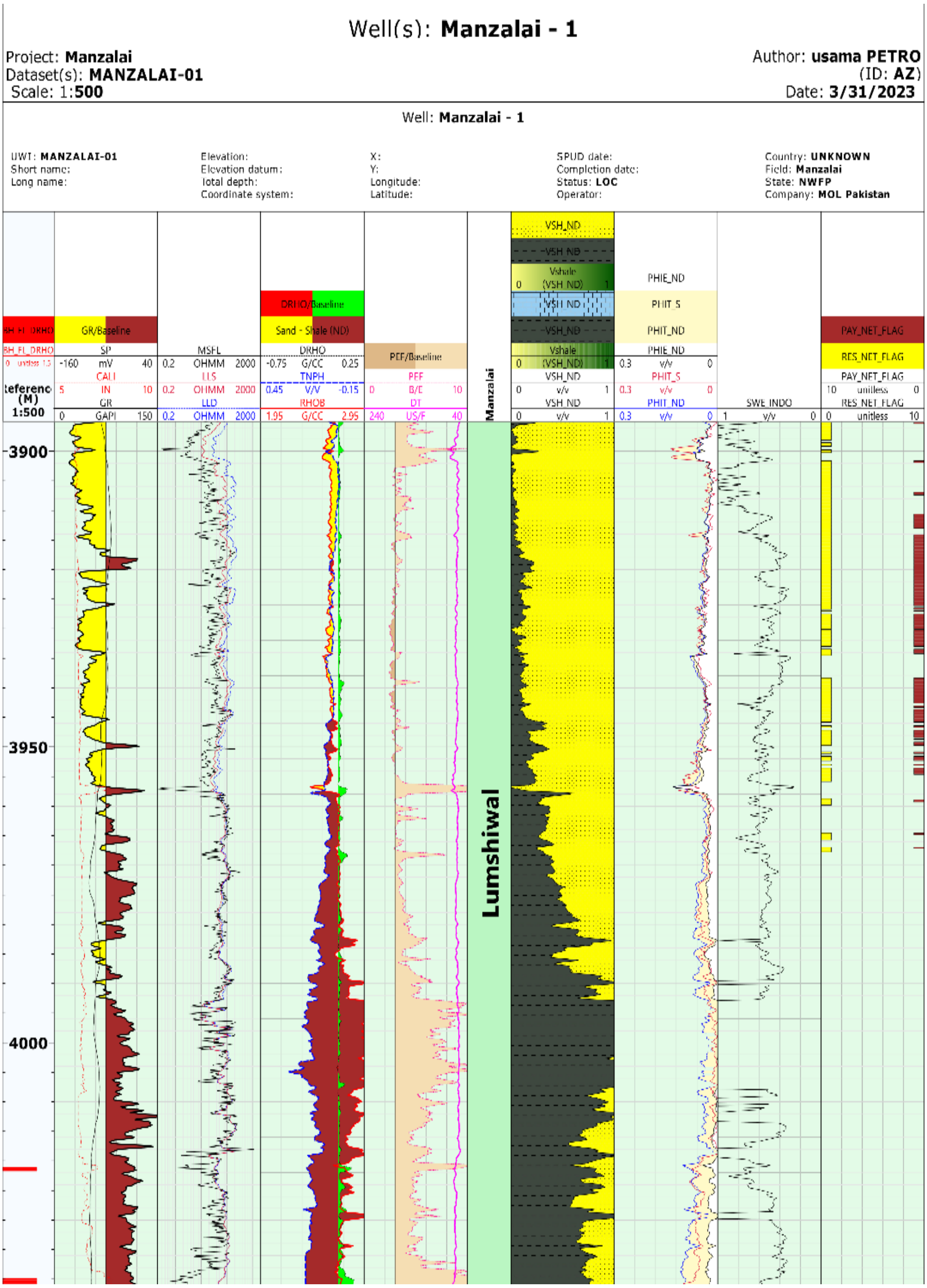


Figure 3. 2 Petrophysics of Lumshiwal Formation in Manzalai-01.

3.8.2. Petrophysics of manzalai-05

3.8.2.1. Lockhart

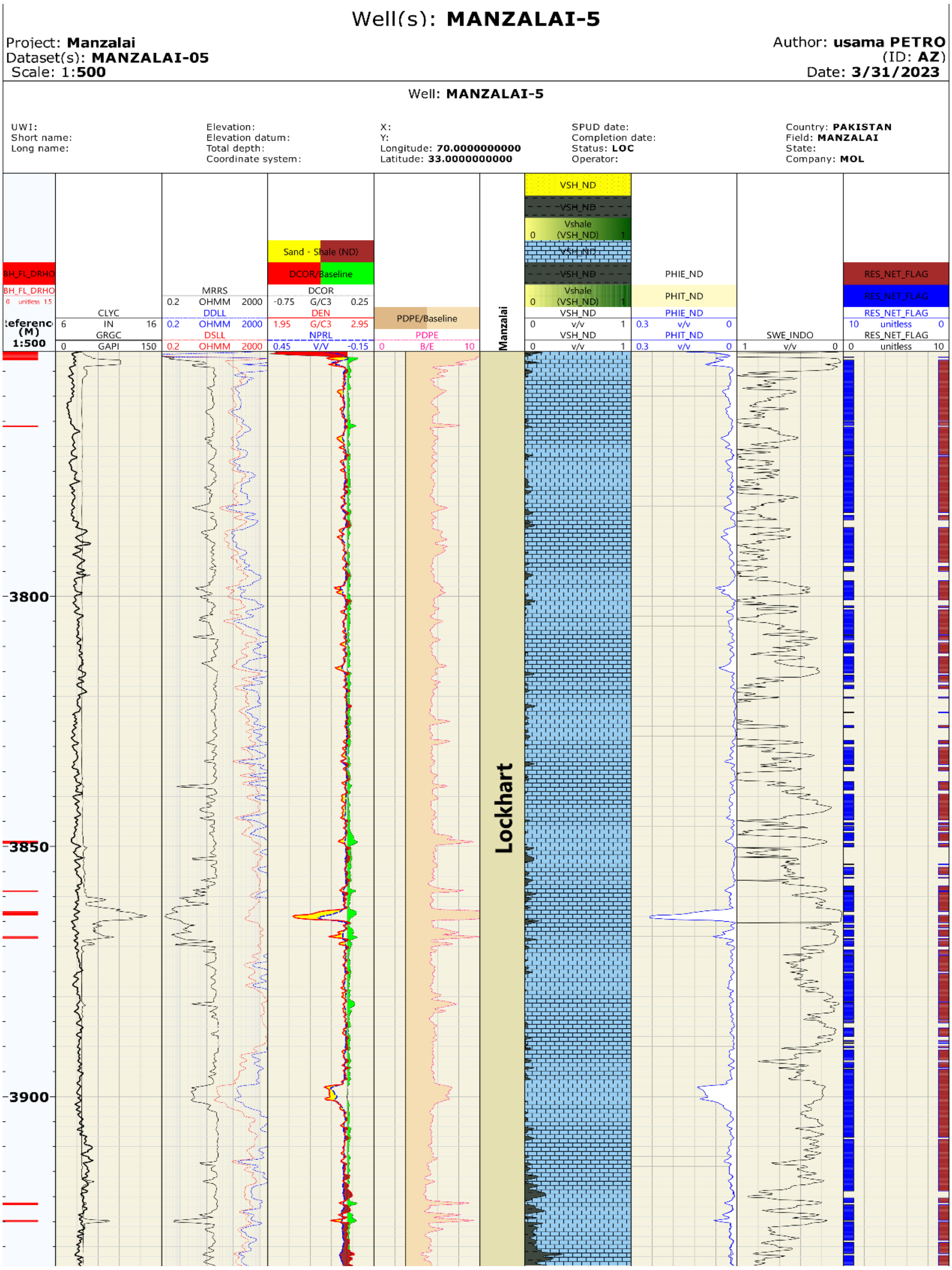


Figure 3. 3 Petrophysics of Lockhart Formation in Manzalai-05.

3.8.2.2. Lumshiwal

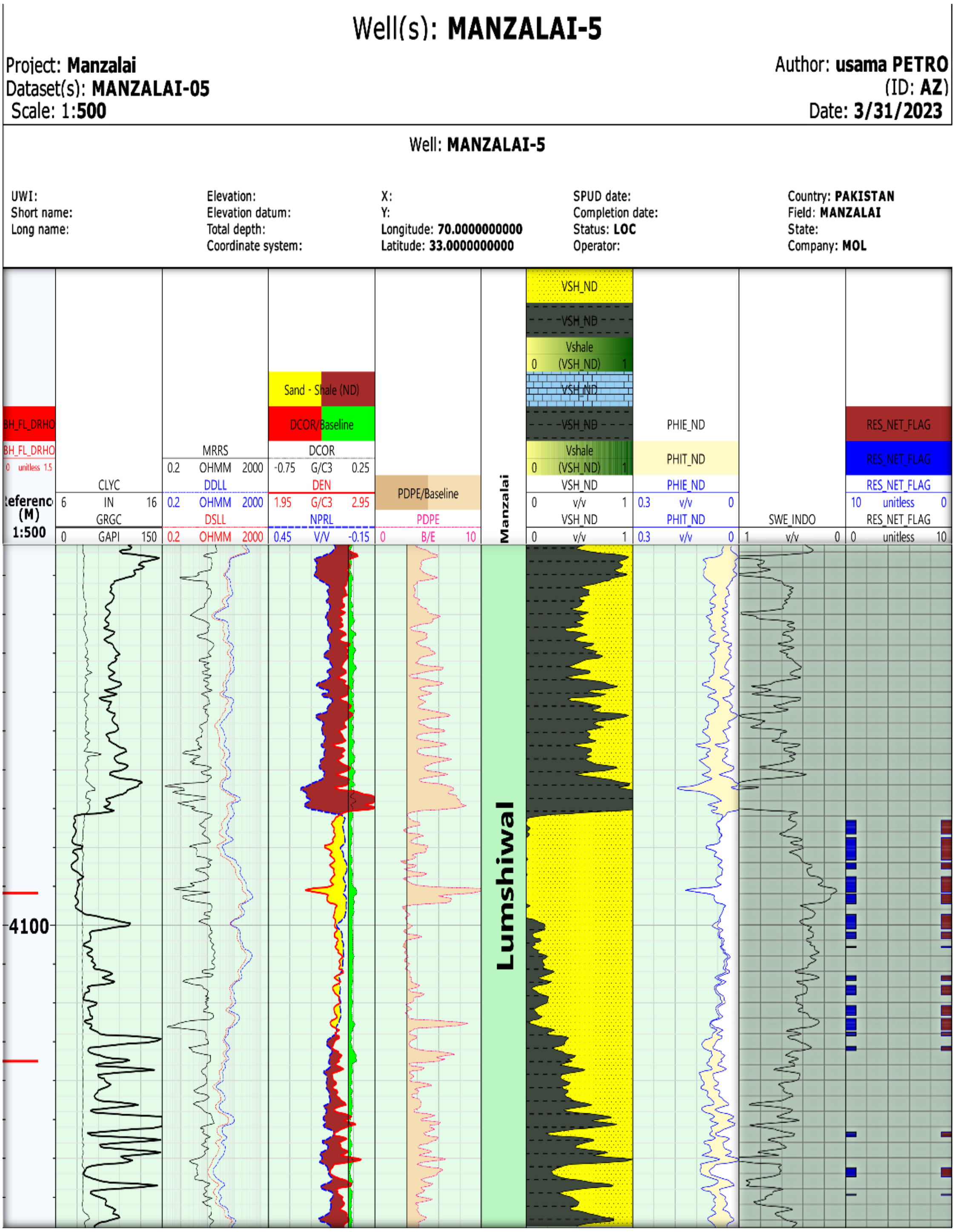


Figure 3. 4 Petrophysics of Lumshiwal Formation in Manzalai-05.

3.8.3. Cross plots

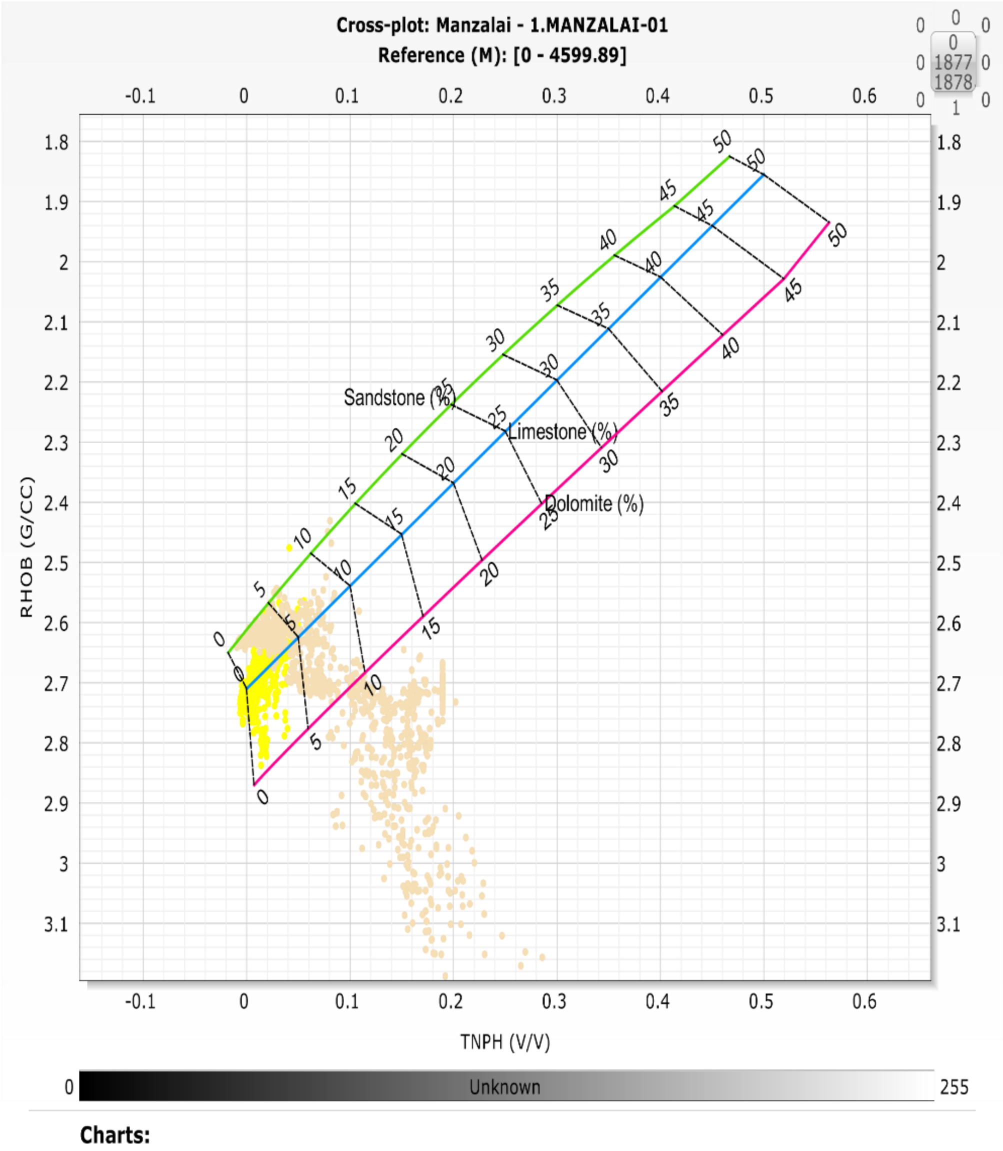


Figure 3. 5 Crossplots of Manzalai-01.

Schlumberger, Por-11 & Por-12, Neutron Porosity vs Bulk Density, TNPH (rhof = 1 g/cm3, NaCl = 0 kppm)

- **Scale:** Scale 1: [TNPH - RHOB]
- **Zonation: Manzalai**
- Lockhart   Lumshiwal

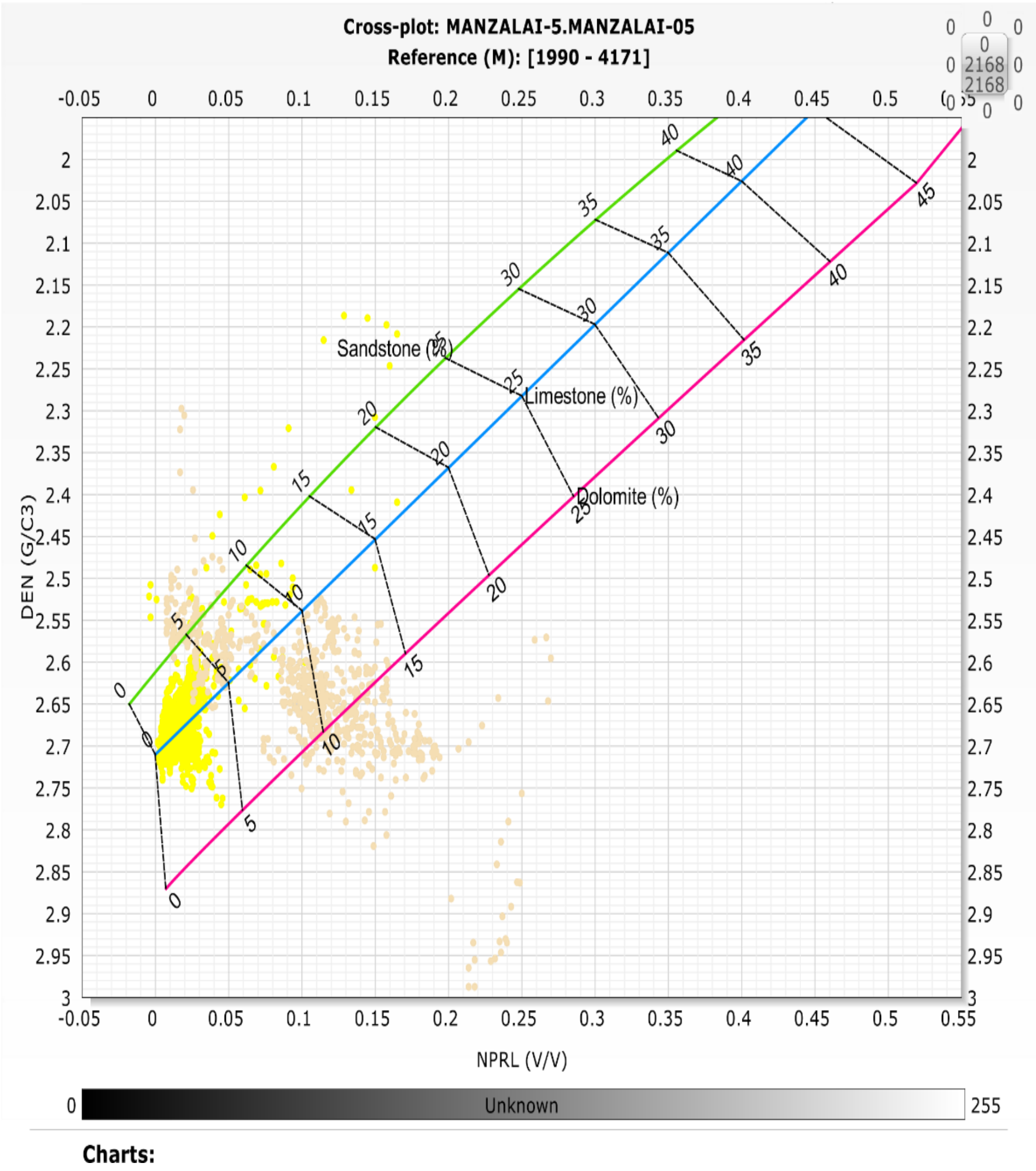


Figure 3.6 Crossplots of Manzalai-05.

Schlumberger, Por-11 & Por-12, Neutron Porosity vs Bulk Density, TNPH (rhof = 1 g/cm3, NaCl = 0 kppm)

- **Scale:** Scale 1: [NPRL - DEN]
- **Zonation: Manzalai**
- Lockhart Lumshiwal

3.8.4. Correlation

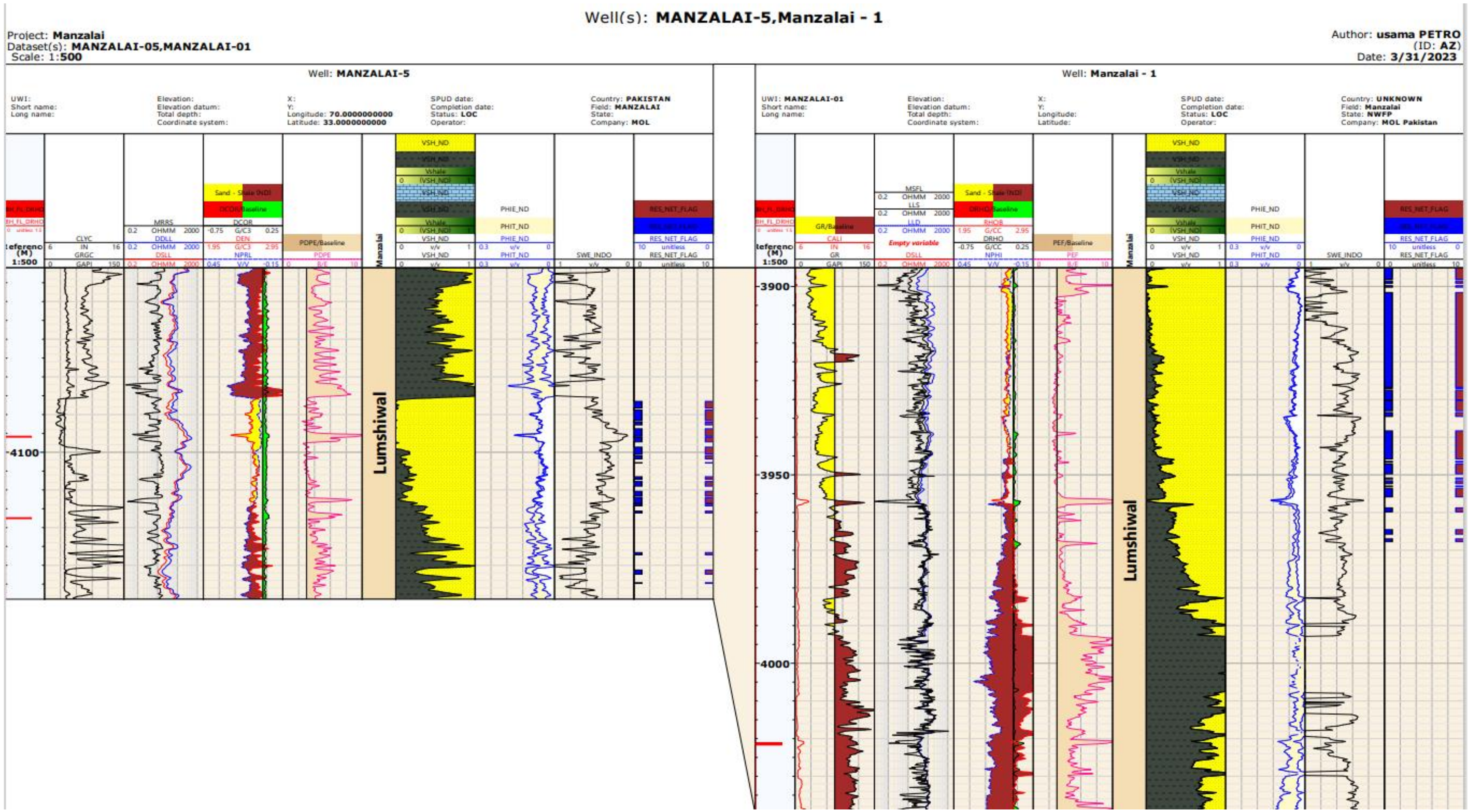


Figure 3. 7 Correlation of Lumshiwal Formation in Manzalai field.

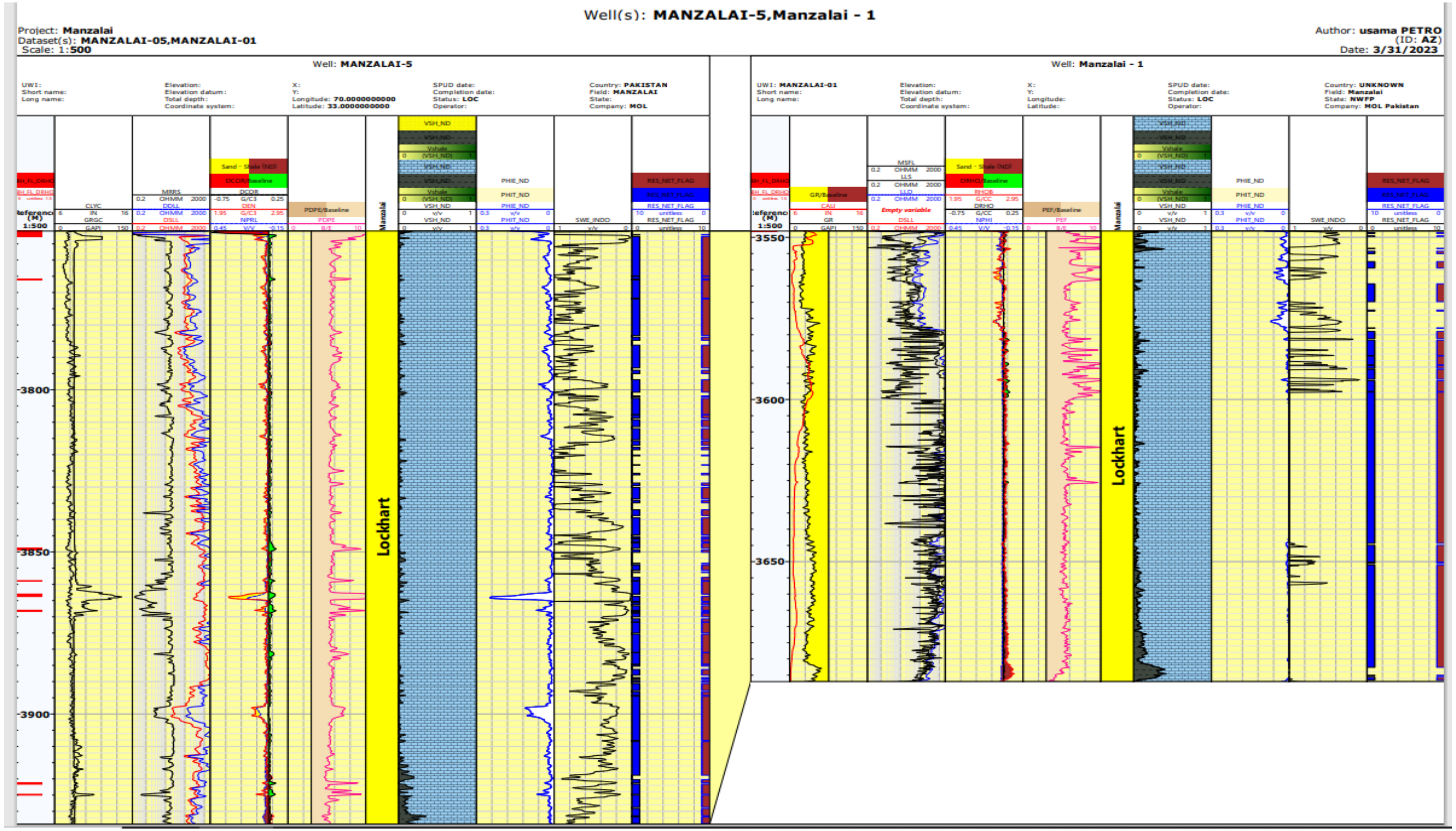


Figure 3.8 Correlation of Lockhart Formation in Manzalai field.

3.8.5. Summaries and analysis

3.8.5.1. Manzalai-01

Table 3. 5 Summary of Manzalai-01.

Manzalai-1												
Well	**Zones**	**Flag Name**	**Top**	**Bottom**	**Reference unit**	**Gross**	**Net**	**Net to Gross**	**Av_Shale Volume**	**Av_ Porosity**	**Av_ Water Saturation**	**Av_ hydrocarbon Saturation**
Manzalai -1	Lockhart	ROCK	3548	3687	M	139	135.775	0.977	0.043	0.006	0.69	0.31
	Lockhart	RES	3548	3687	M	139	111.1	0.799	0.047	0.002	0.9	0.1
	Lockhart	PAY	3548	3687	M	139	4.42	0.032	0.036	0.007	0.481	0.519
	Lumshiwal	ROCK	3895	4599.889	M	704.889	63.551	0.09	0.111	0.038	0.554	0.446
	Lumshiwal	RES	3895	4599.889	M	704.889	52.73	0.075	0.113	0.033	0.585	0.415
	Lumshiwal	PAY	3895	4599.889	M	704.889	34.29	0.049	0.123	0.037	0.501	0.499

Cut-offs

- VCLAY < 30%
- PHIE > 01% for Lockhart, 05% for Lumshiwal
- Sw< 65%
- Sh = (1-Sw)

3.8.5.2. Manzalai-05

Table 3. 6 Summary of Manzalai-01.

Manzalai-5												
Well	**Zones**	**Flag Name**	**Top**	**Bottom**	**Reference unit**	**Gross**	**Net**	**Net to Gross**	**Av_Shale Volume**	**Av Porosity**	**Av_Water Saturation**	**Av_hydrocarbon Saturation**
Manzalai - 5	Lockhart	ROCK	3751	3934	M	183	182.625	0.998	0.031	0.016	0.265	0.735
	Lockhart	RES	3751	3934	M	183	141.125	0.771	0.03	0.02	0.281	0.719
	Lockhart	PAY	3751	3934	M	183	100	0.546	0.032	0.021	0.21	0.79
	Lumshiwal	ROCK	4051	4139	M	88	30.875	0.351	0.101	0.054	0.338	0.662
	Lumshiwal	RES	4051	4139	M	88	19	0.216	0.093	0.063	0.331	0.669
	Lumshiwal	PAY	4051	4139	M	88	18.75	0.213	0.091	0.063	0.328	0.672

Cut-offs

- VCLAY < 30%
- PHIE > 01% for Lockhart, 05% for Lumshiwal
- Sw< 65%
- Sh = (1-Sw)

CHAPTER 4
GEOMECHANICS

4.1. Introduction

Geomechanics is the study of surface of earth and the phenomenon taking place in it under the influence of natural physical factors. Geomechanics is the study of how soils and rocks deshaped in response to changes of stress, pressure, temperature, and other parameters.

Geomechanics also helps us to model fluid movement and predict how fluid removal or injection leads to changes in permeability, fluid pressure, and in situ rock stresses that can have significant effects on reservoir performance.

4.2. Geomechanical modeling

A Geomechanical model reveals the mechanical behavior of rock and wellbore and is used to better manage the drilling programs. According to Geomechanics, well drilling generates significant changes in the local stress field of the Formation due to losses of supporting material.

The mechanical earth model (MEM) is a collection of the data needed to make quantitative and qualitative predictions of the subsurface Geomechanical environment. These data include the stresses in the earth, pore pressure, rock elastic properties, strength and fabric, and non-numerical data.

4.3. Over-burden

Overburden stress is the pressure exerting by the upper rocks on the underplayed rocks, upper rocks are usually younger in age than the older rocks that are under-laid, but the situation can be different older rocks sometimes underplayed on the younger rocks due to thrusting.

Overburden stress of rocks on the under-laid rocks can be measured using density log. We use extrapolation method to calculate the overburden of Manzalai-01. Overburden pressure will always be greater than Pore pressure.

4.4. Pore pressure

Pore pressure is the pressure exerted by the fluids in the pore spaces of rocks. We calculate pore pressure by using the Sonic log in which we input data of vertical stress, resistivity and shale indicator.

Table 4. 1 Inputs needed for Pore pressure evaluation.

Name	Unit example	Description
Vertical stress	psi	Overburden stress. Mandatory input.
Shale flag Shale flag 2		The Shale Flag is used as shale Formation indication directly. When Shale Flag 2 is also used, it is only shale when both of Shale Flags agree it is shale.
Shale indicator Shale indicator 2		With Shale indicator, you can discriminate the shale/non-shale interactively with cutoff lines graphically. When two shale indicators are selected, it is only shale when both of them agree shale. Shale indicators are used only when Shale Flag is not selected.
Compressional slowness or Compressional velocity	us/ft or m/s	Mandatory input for Eaton Slowness, Bowers Original, Bowers and Traugott Slowness methods.
Resistivity	ohm.m	Mandatory input for Eaton Resistivity and Traugott Resistivity methods.
Non-Shale PP		Select a pore pressure curve here. It will be used for non-shale zone when the following parameter is on: Parameters > No-shale zones > use input.

4.5. Fracture pressure

The Fracture pressure is also called the fracture gradient. The maximum well pressure that does not fracture the Formations is called the Fracture pressure. We calculated the Fracture pressure by using the sonic log.

We use Eton method to calculate the Fracture gradient in which we mainly input pore pressure and vertical stress.

Table 4. 2 Inputs needed for fracture pressure evaluation.

Name	**Unit example**	**Description**
Vertical stress	psi	Vertical stress, mandatory input.
Pore gradient	psi	Pore Pressure, mandatory input.
Poisson ratio	unitless	Effective Poisson ratio. Using dynamic elastic Poisson ratio may significantly underestimate the fracture gradient.
Calibration points	psi or ppg	Leak-off test, Formation integrity test.

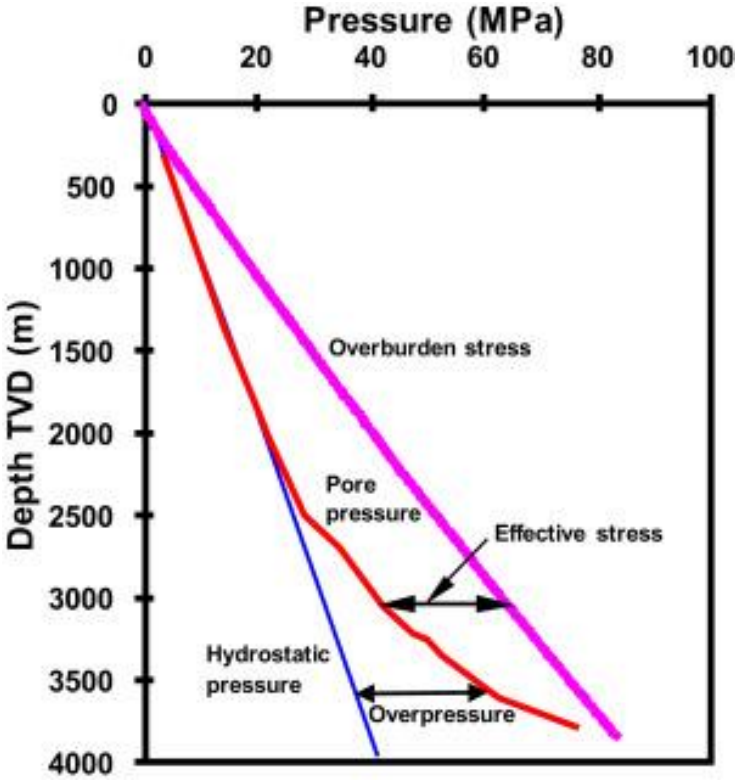


Figure 4. 2 Diagram showing normal Curve for Pore Pressure, Fracture pressure and over burden.

Fig 4.1 showing the normal curve line for pore pressure, over burden and fracture pressure taken from the Formulas and calculation for Drilling, production, and workover (2016).

4.6. Outputs

4.6.1. Manzalai-01

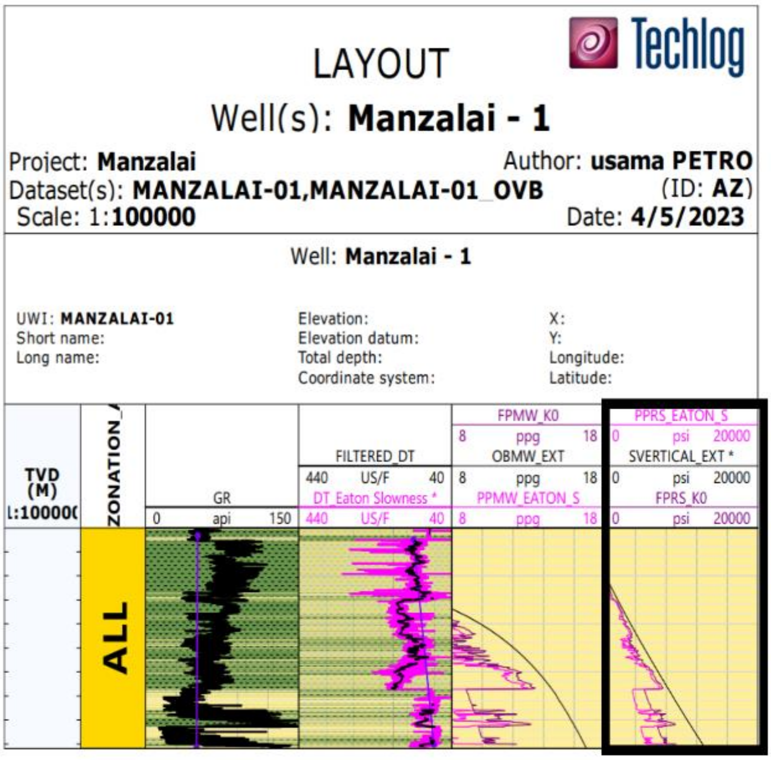


Figure 4. 2 Column showing overburden of Manzalai-01

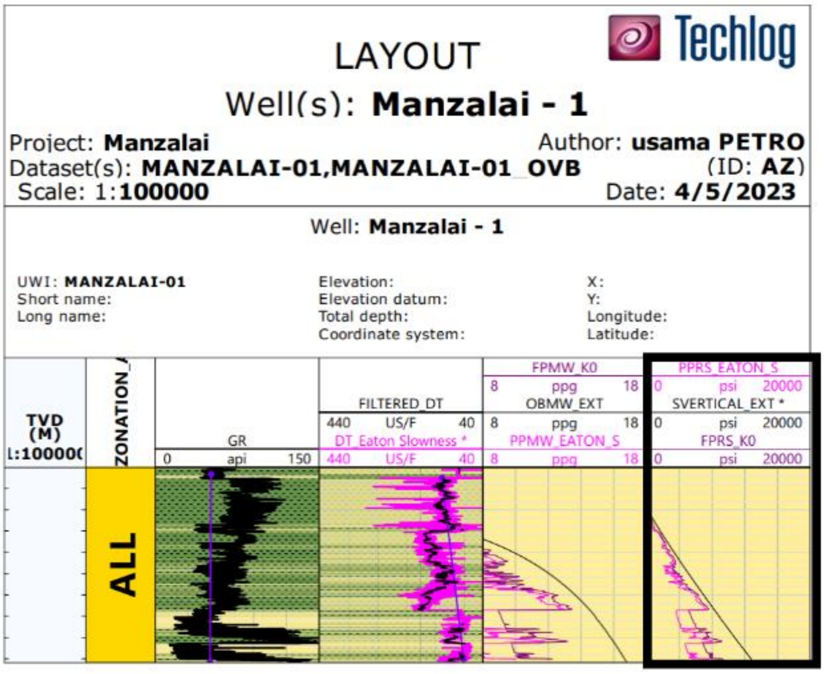


Figure 4. 3 Column showing pore pressure and fracture pressure of Manzalai-01

4.6.2. Manzalai-05

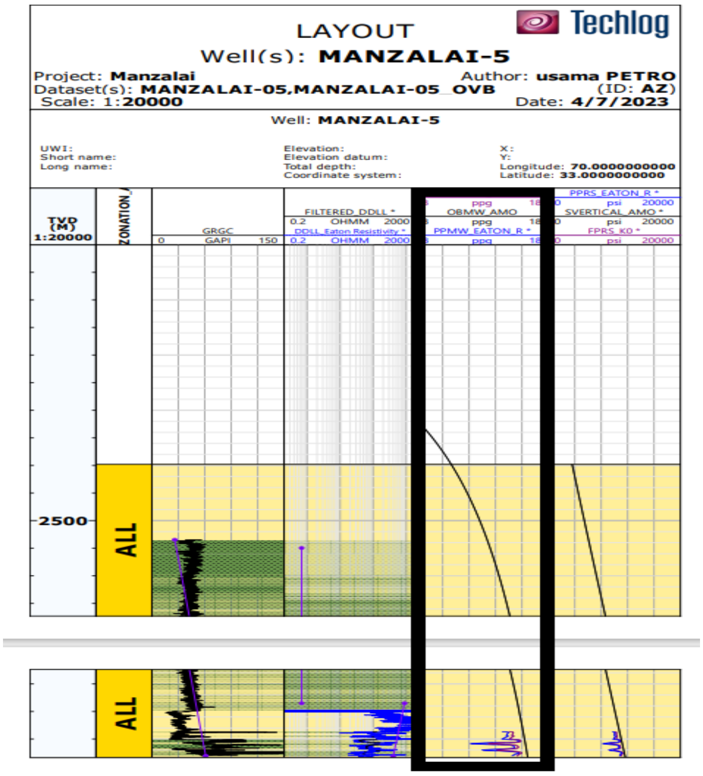


Figure 4. 4 Column showing overburden of Manzalai-05

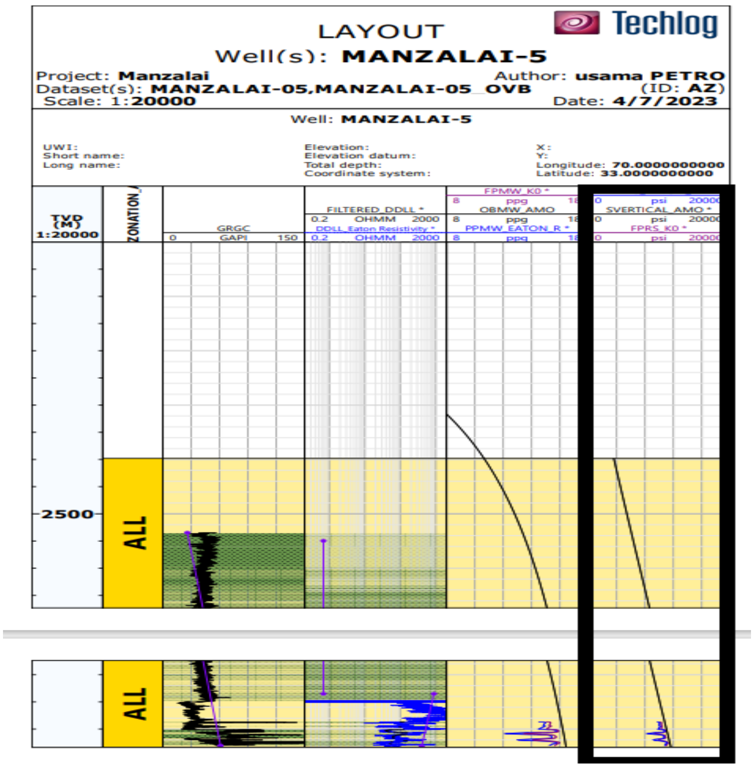


Figure 4. 5 Column showing pore pressure and fracture pressure of Manzalai-05

CONCLUSIONS

Marked zone of Lockhart and Lumshiwal Formation in Manzalai-01 and Manzalai-05 of Manzalai field, Potwar Basin is the principal reservoir. The average calculated parameters of Lumshiwal for the evaluation of reservoir properties of Manzalai-01 well depict an average porosity of 0.038% and average Water Saturation is calculated as 0.554% and Hydrocarbons Saturation is 63.57%. For Lockhart the average porosities are 0.42% and average water saturation of 0.69%. The analysis shows that S_h of Manzalai -01 and Manzalai-05 wells is proven for the production of Hydrocarbons to be economically feasible.

These values indicate that the marked zone of Manzalai-01 and Manzalai-05 well have the potential to be a reservoir. The value of Vsh is low and Saturation of Hydrocarbon is significantly high. From cutoff of Shale, Porosity and Saturation of Water, the economic value of Hydrocarbon is to find out how much the well is productive. It is concluded from the interpretation that the zone of interest of Lockhart and Lumshiwal Formation has the potential to be reservoir and contain Hydrocarbons.

In conclusion, this study has investigated the geomechanics of a borehole where pore pressure, overburden pressure, and fracture pressure were found to be within normal ranges. The analysis of normal pressures in the subsurface formations has provided valuable insights into the vertical stress distribution and the mechanical behavior of the surrounding geological materials. By considering normal conditions, we have gained a comprehensive understanding of the load-bearing capacity and stability of the formations, which is essential for designing and constructing geotechnical structures with confidence. This research contributes to the body of knowledge in geomechanics by highlighting the significance of studying normal geomechanical parameters and their implications for practical applications. Moving forward, further investigations can focus on extending this understanding to different geological settings and expanding the knowledge base to enhance the safety, sustainability, and efficiency of future geotechnical engineering projects.

REFERENCES

Ahmed, N., Kausar, T., Khalid, P., and Akram, S. (2018). Assessment of Reservoir Rock Properties from Rock Physics Modeling and Petrophysical Analysis of Borehole Logging Data to Lessen Uncertainty in Formation Characterization in Ratana, Journal of Geological Society of India, p.736-7742.

GB, A., CR, G. (1982). Basic well log analysis for geologists, Tulsa, Oklahoma, USA.

Lyons, W.C., Lapeyrouse, N.J. (2016). Formulas and calculation for Drilling, production, and workover.

Moghal, M., Saqi, M., Hameed, A., and Bugti, M. (2007). Subsurface Geometry of Potwar Sub-Basin in Relation to Structuration and Entrapment, Pakistan Journal of Hydrocarbon Research, p. 61-72.

Moradi, A.A., Moradzadeh, A., and Bakhtiari, M.R. (2011). Methods of water saturation estimation; Historical perspective, Journal of Petroleum and Gas Engineering, p. 45-53.

Thompson, D.M., and Woods, A.M., (1993). Development geology reference manual: AAPG methods in exploration series, No. 10. AAPG.

Tuttle, M.L.W., Charpentier, R.R., Brownfield, M.E. (1999). The Niger Delta, Petroleum System; Niger Delta Province, H, USGS, of Petroleum Geologists. Bulletin. Vol. 51, p. 761-779.

Yar, M., Haider, S.W., Nabi, G., Tufail, M. and Rahman, S. (2019). Reservoir Characterization of Sand Intervals of Lower Goru Formation Using Petrophysical Studies; A Case Study of Zaur-03 Well, Badin Block, Pakistan. Int. J. Econ. Environ. Geol. Vol. 10, p. 118-124.

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