HYDROCARBON EVALUATION OF LOWER EOCENE AGE LIMESTONE OF QADIRPUR 14&15, CENTRAL INDUS BASIN PAKISTAN

A thesis submitted to Bahria University Islamabad, in partial fulfillment of the requirement for the degree of BS in Geology

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ABSTRACT

The objectives of the study is to evaluate reservoir properties of Sui Main Limestone of lower Eocene age in Qadirpur 14 and 15. Qadirpur gas field located in Sindh province, Pakistan. Qadirpur 14 is located at 28°4"12.37' N, 69°23"32.59' E and Qadirpur 15 is located at 28°5"32.20' N, 69°23"37.32' E. Tectonically the area is located in extensional regime.

To carry out this research, all the logs are required to carry out petrophysical analysis. The methodology to perform petrophysical analysis includes calculation of volume of shale, porosity determination, and hydrocarbon estimation. Log curve behavior shows that there are two pay zones present in Qadirpur 14 and 15. In Qadirpur 14 zone 1 ranges from 1813m to 1825m and zone 2 ranges from 1830m to 1855m. In zone 1 volume of shale is 10.54%, Effective porosity is 13.13%, water saturation is 34.75%, and hydrocarbon saturation is 65.24%. However in zone 2, volume of shale is 20.27%, effective porosity is 14.22%, and water saturation is 34.42%, hydrocarbon saturation 65.57%. Similarly in Qadirpur 15 zone 1 ranges from 1734m to 1750 m and zone 2 ranges from 1756 to 1780m. In zone 1 volume of shale is 17.41%, effective porosity is 13.26%, water saturation is 21.59%, and hydrocarbon saturation is 78.40%. However in zone 2, volume of shale is 24.41%, effective porosity is 15.60%, and water saturation is 23.43%, hydrocarbon saturation 73.56%. Hence result proves that Sui Main Limestone are of high potential as petrophysical analysis suggests very low volume of shale and and good hydrocarbon saturations which is a symbol of good reservoir rock.

ABBREVIATIONS

Rxo	Resistivity of Flushed Zone
Rmc	Resistivity of Mud Cake
Dh	Borehole Size
Rm	Drilling Mud
Rmf	Resistivity of Mud Filtrate
CNL	Compensated Neutron Log
PEF	Photo-Electric Factor
LLS	Laterolog Shallow
LLD	Laterolog Deep
MSFL	Microsphericaly Focused Log
SP	Spontaneous Potential
Ec	Electrochemical Potential
Em	Shale or Membrane Potential
BHT	Borehole Temperature
Fm	Formation
Vsh	Volume of Shale
GRlog	Gamma-ray reading of formation
GRmin	Gamma-ray minimum
GRmax	Gamma-ray maximum
PHID	Density Porosity
PHIN	Neutron Porosity
PHIA	Average Porosity
A	Tortuosity Factor
M	Constant, Cementation factor
RhoM	Matrix Density
RhoF	Fluid Density
RhoB	Bulk Density
F	Formation Factor
Essp	Static Spontaneous Potential
H	Mudcake thickness
Sh	Saturation of Hydrocarbon
Sw	Saturation of Water

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CHAPTER 1

INTRODUCTION

1.1 Location

Qadirpur gas field located in Ghotki and Jacobabad districts of province Sindh. The wells under study are Qadirpur14 and 15, located at 28°4"12.37' N Latitude, 69°23"32.59' E Longitude and 28°5"32.20' N Latitude, 69°23"37.32' E Longitude, respectively (Fig 1.1)

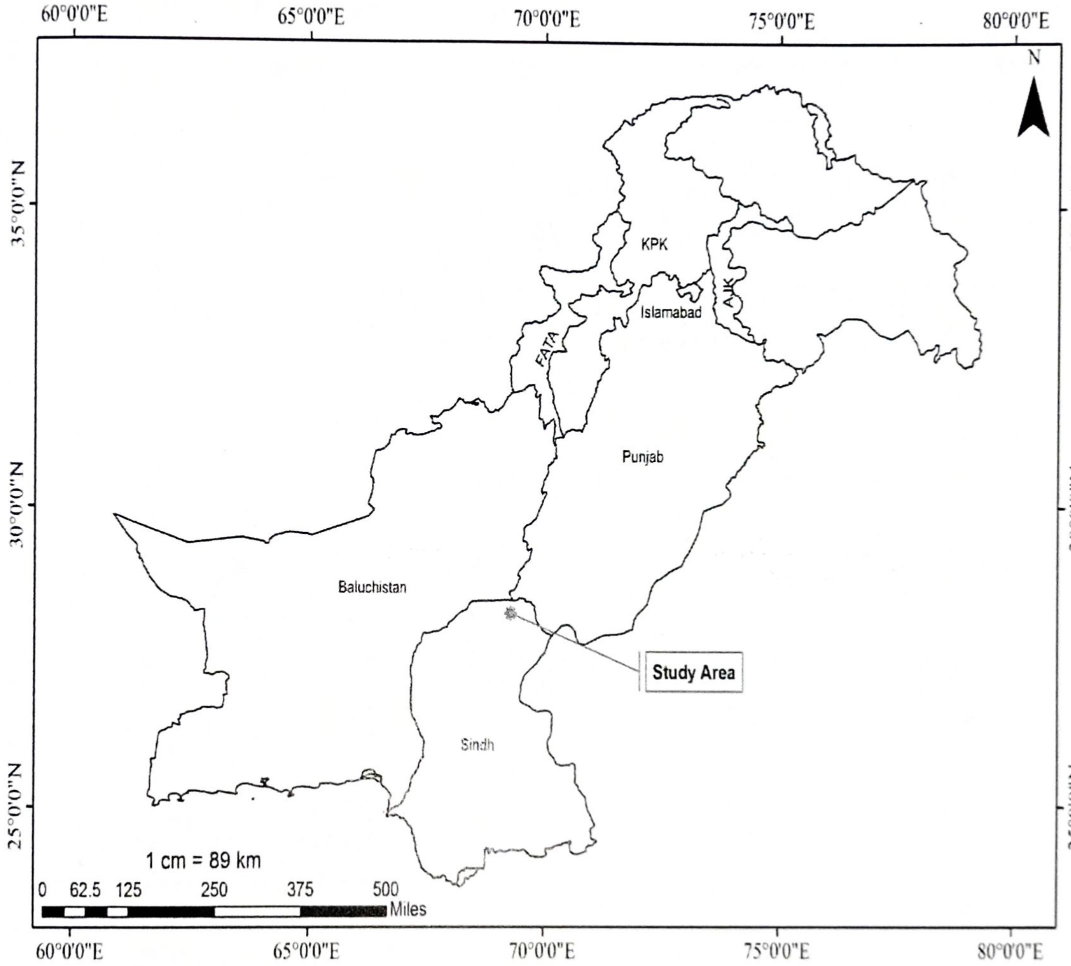

Fig1.1. District map showing location of Qadirpur gas field.

1.2 Objectives of the study

The objective of the study is to evaluate reservoir properties of Sui Main Limestone of lower Eocene age in Qadirpur 14 and 15.

1.3 Data Used

The data for carrying out the thesis has been obtained from Land Mark Resources (LMKR), Pakistan with prior permission from Directorate General of Petroleum Concession (DGPC). This data includes,

(a) SP-GR-CAL-BS

(b) LLD-LLS-MSFL

(c) RHOB-CNL

1.4 Methodology

The methodology adopted to carry out petrophysical interpretation is shown in fig 1.2.

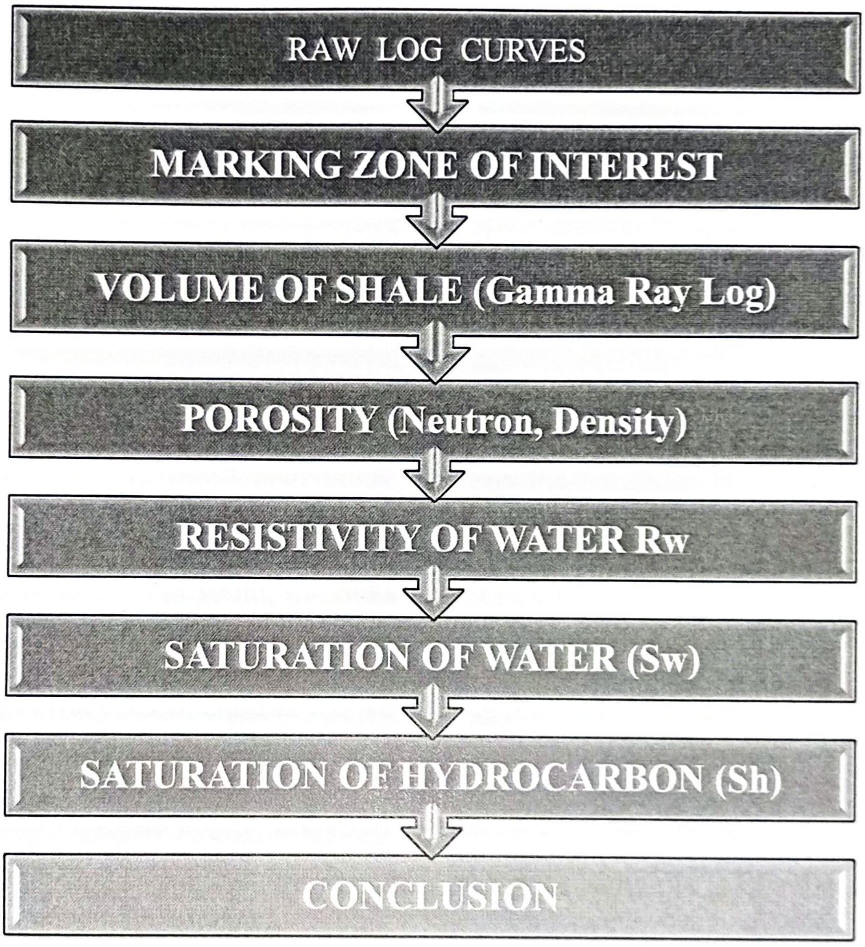

Fig 1.2. Methodology flow chart.

CHAPTER 2

TECTONICS, STRATIGRAPHY AND PETROLEUM SYSTEM

2.1 Sedimentary basins and tectonic settings of Pakistan

Pakistan is divided in two main sedimentary basins in terms of genesis and geological history; Indus Basin and Balochistan Basin, which evolved through different geological processes. Another newly identified smaller basin is Kakar-Khorasan Basin also referred as Pishin Basin. Its existence came due to interaction of Indian and Eurasian plates and is classified as Median Basin. (Qadri,1995).

Tectonically, Pakistan lies along the part of the Tertiary convergence zone and is involved in the interaction of three lithospheric plates. Its territorial limits straddle the Indian, Arabian and Eurasian plates with their triple junction are located to the north west of Karachi. It has a large sedimentary area with proven petroleum potentials (Kazmi and Jan, 1997). Northward movement of the Indian plate accompanied by the anticlockwise rotation, and collision of the Indian plate against the Eurasian were the major tectonic events which gave rise to the local tectonics and influenced sedimentation in the sub basins.

2.1.1 Central Indus Basin

It is separated from Upper Indus Basin by the Sargodha High and Pezu uplift in the north. It is bounded by the Indian shield in the east, marginal zone of the Indian plate in the west. And in south, the Sukkur Rift (a collective name for Jacobabad and Mari Kandhkot Highs) separates it from the Lower Indus Basin.

The oblique subduction in the west along the Chaman Transform Fault Zone is producing exceptionally large variety of structures. The Sulaiman Range represents blind thrust front which suggests that all frontal folds of the fold belt are cored by the blind thrusts. The structures are trending east-west roughly perpendicular to the tectonic transport direction (Qadri, 1995).

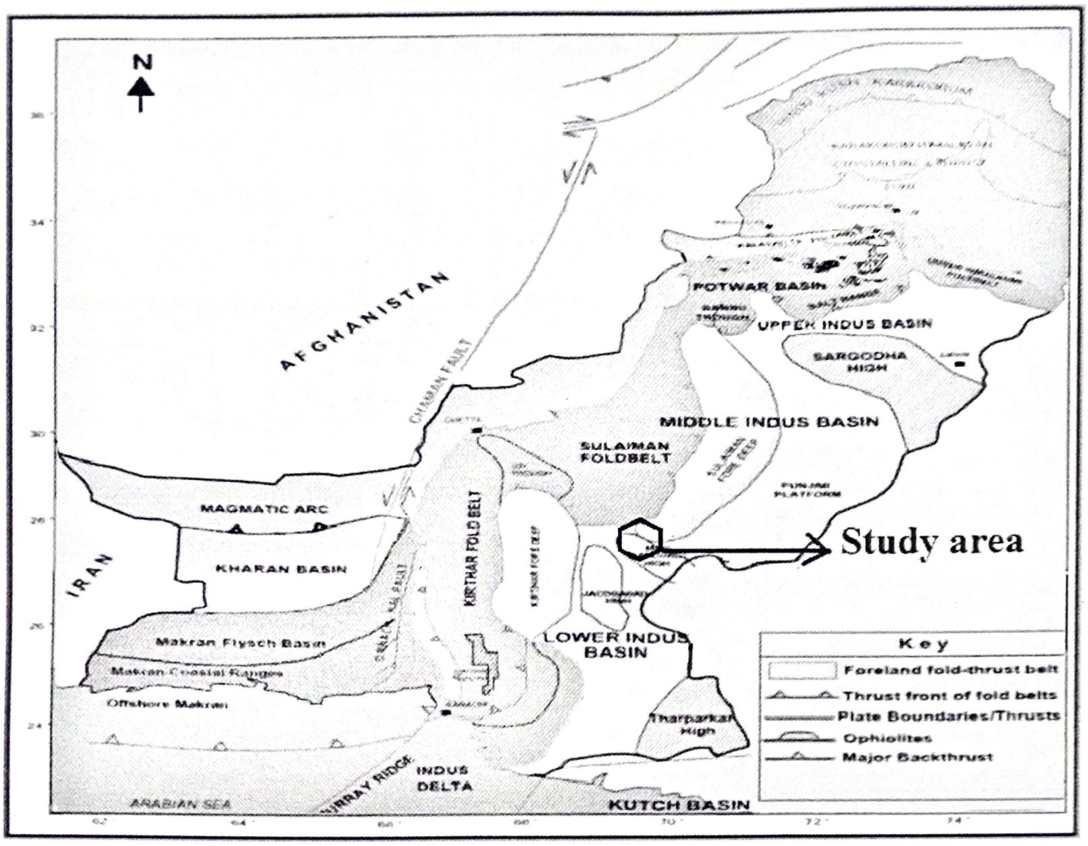

Fig.2.1. Major sedimentary basins of Pakistan showing study area. (Raza et al, 1990).

2.1.2 Regional structural setting of Central Indus Basin

The Central Indus basin is separated from upper Indus basin by Sargodha high and Pezu uplift in North. It is separated by the Indian shield at the east and marginal zone of Indian plate in west. In south, the Sukkur rift (a collective name for Jacobabad and Mari kandhkot highs) separates it from the Lower Indus basin. Sargodha high is considered to be divided both upper and lower Indus basin. The oblique subduction in the west along the Chaman Transform Fault Zone is producing exceptionally large variety of structures. The Suleiman Range represents blind thrust front which suggests that all frontal folds of the fold belt are cored by the blind thrusts. The structures are trending east-west roughly perpendicular to the tectonic transport direction. The major feature of the basement topography is Kharpur-Jacobabad high which divides the lower Indus basin further into two sub basin, named as Southern and Central Indus basin. The oldest formation expose in the basin is Wulgai formation of Triassic age; while the salt range of Precambrian age is oldest rock has been drilled in the basin. Depth of the basin is around 15000 meter (Raza et al, 1989).

2.1.3 Structural style of Central Indus Basin

From east to west, basin consist of three main units given as follows (Qadri, 1995).

(a) Punjab Platform

(b) Sulaiman Depression

(c) Sulaiman Fold Belt

2.1.3.1 Punjab Platform

Punjab platform marks the eastern segment of Central Indus Basin and shows no surface outcrop of sedimentary rocks. Tectonically it is a broad monocline dipping gently towards the Sulaiman depression. The dips are gentle in the Punjab platform area with several salt cored anticlines east of the Indus River (Qadri, 1995).

2.1.3.2 Sulaiman Depression

Sulaiman depression is formed as a result of the collision between two plates. The western flank of the depression includes Zindapir, inner folded zone while Mari Bughti inner Folded Zone lies in the south. On seismic evidence the area shows some buried anticlines which may have been formed at the expense of flow of Eocene shales (Qadri, 1995).

2.1.3.3 Sulaiman Fold Belt

Sulaiman fold belt is a major tectonic feature in the proximity of collision zone and, therefore, contains a large number of disturbed anticlinal features, unlike Upper Indus Basin, the decollement zone in this part was possibly provided by shales. Our study area tectonically lies in the Sulaiman fold and thrust belt. The potential structural traps in the block were developed during the course of collision of Indo-Pak plate and Afghan micro plate. As a result a phase of thin skinned tectonics and a subsequent phase of basement involvement were developed. Typically structures of the area are anticlines formed over back thrust (Qadri, 1995).

2.2 General Stratigraphy

The generalized stratigraphic column of Central Indus Basin is shown in table 2.1 and the stratigraphy encountered in Qadirpur 14 and 15 is shown in table 2.2.

Table 2.1. Generalized Stratigraphy of Central Indus Basin (Ahmed et al, 1977).

AGE		FORMATION	GENERALIZED LITHOLOGY
QUATERNARY		ALLUVIUM	
MIOCENE	UPPER	SIWALIK GP	
	MIDDLE		
	LOWER	NARI/GAJ Fm	
OLIGOCENE			
EOCENE	UPPER	KIRTHAR Fm	
	MIDDLE		
	LOWER	GHAZIJ/SUI Fm	
PALEOCENE		DUNGHAN Fm	
		RANIKOT Fm	
CRETACEOUS	UPPER	PAB SANDSTONE	
		MOGHAL KOT Fm	
		PARH LIMESTONE	
	LOWER	GORU Fm	
		SEMBER Fm	
JURASSIC	UPPER	MAZAR DRIK Fm	
	MIDDLE	CHILTAN Fm	
	LOWER	SHRINAB Fm	

2.2.1 Alluvium

Age of alluvium is recent. Lower contact of alluvium is with Siwalik group which is unconformable. The environment of deposition of alluvium is fluviatile environment. Alluvium is the youngest deposit; it is mainly composed of sandstone with subordinate clay/claystone. Sandstone is light grey, multicolored, transparent, loose, sugary, fine to medium grains, fairly calcareous and high micaceous. Clay/claystone is generally light brown, earthy, soft, sticky, hydrophilic, and slightly calcareous (Ahmed et al, 1977).

2.2.2 Siwalik Group

Age of Siwalik group is Early Pleistocene. Lower contact of Siwalik group is with Nari formation which is Unconformable. The environment of deposition of Siwalik group is Fresh water environment. Siwalik group consist of sandstone with intercalations of siltstone, streaks of clay/claystone and limestone. Sandstone is light grey, brownish, brownish grey, yellowish grey, light brown, fine to medium grained, at places coarse grained, subangular to sub rounded, loose to friable, sugary, at places consolidated, silty, highly micaceous, and fairly calcareous. Siltstone is light grey light brown, earthy, medium hard, occasionally grading to very fine grained sandstone and calcareous. Clay/claystone is khaki, reddish brown, earthy, yellow, soft to moderately indurated, hydrophilic, sticky and slightly calcareous. Limestone is yellow to yellowish brown, light brown, orange, medium hard to hard, compact, massive, crystalline and fossiliferous (Ahmed et al, 1977).

2.2.3 Nari Formation

Age of Nari formation is Oligocene. Lower contact of Nari formation is with Kirthar Formation which is Unconformable. Nari formation consist of sandstone with intercalations of clay/claystone, sandstone is white, off white, light grey, brownish grey, yellowish grey, loose, friable to medium hard, fine to medium grained, sub angular to sub rounded, fairly sorted, poor to fairly cemented in calcareous. Clay/claystone is light grey, yellowish white, brownish grey, soft, sticky, hydrophyllic and calcareous (Ahmed et al, 1977).

2.2.4 Kirthar Formation

Kirthar formation has been divided into four distinct members i.e. Drazinda, Pirkoh, Sirki and HabibRahi members (Qadri, 1995).

2.2.4.1 Drazinda member

Age of Drazinda member is of Eocene. Upper boundary of Drazinda member was picked by a change in Lithology **from** sandstone, clay,conglomerate to claystone and limestone. Limestone consists of white to light gray color, is moderately hard, sub blocky, in parts slight to moderately argillaceous with traces of carbonaceous matter and contains some common forams. Claystoneconsistsoflight to medium greenish grey color. In the basal part it is soft to firm, sub blocky, amorphous, slightly sticky, calcareous and slightly carbonaceous. Marl is of light to greenish grey color, soft to firm, amorphous, sticky, washable and grading to argillaceous (Qadri, 1995).

2.2.4.2 Pirkoh member

Age of Pirkoh Member is Eocene. The upper boundary of the Pirkoh member was picked by change in lithology from marl to limestone. Lithology consists of limestone that is pale yellowish grey to pale yellowish green, firm, sub blocky, in parts blocky, chalky, in parts slightly argillaceous and chert. Claystone consists of medium to greenish grey, firm, sub blocky, and moderately calcareous (Qadri, 1995).

2.2.4.3 Sirki member

Age of Sirki Member is Eocene. Upper boundary of the Sirki member was picked by change in lithology from limestone toclaystone. Claystone comprises of dark bluish green color, soft to firm and slightly calcareous. Limestone exhibits light yellowish grey color, is moderately hard and contains traces to forams (Qadri, 1995).

2.2.4.4 Habib Rahi member

Age of Habib Rahi member is Eocene. Upper boundary of Habib Rahi member was picked up by a change in lithology from claystone to limestone. Limestone consists of white to light yellowish grey color, firm to moderately hard and blocky. Claystone inheres of medium to dark greenish grey, sub platy, in parts amorphous and slightly calcareous (Qadri, 1995).

2.2.5 Ghazij member

Age of Ghazij member is Eocene. Upper boundary of the Ghazij member is marked by a change in lithology from limestone to shale. Shale inheres light to medium grey color, is sub fissile, slightly calcareous, and slightly carbonaceous and contains traces of disseminated pyrite. Limestone comprises light grey color, is moderately hard, sub blocky to blocky and in parts slightly argillaceous (Qadri, 1995).

2.2.6 Sui Upper Limestone

Age of Sui Upper Limestone is Lower Eocene. Lower contact of Sui Upper Limestone is with Sui shale unit, which is conformable. Environment of deposition of Sui Upper Limestone is shallow marine. Sui Upper limestone consists of limestone with thin bands shales and traces of marl. Limestone (wackestone to packstone) is off white, grey, creamy, dirty white, at places light brown, hard to very hard compact, microcrystalline, biogenic, micritic, dense argillaceous and fossiliferous, shale is greenish grey, light grey, soft to medium grade, moderately indurated, fissile, laminated and slightly calcareous. Marl is dirty white, light grey, soft, pasty and sticky (Qadri, 1995).

2.2.7 Sui shale

Age of Sui Shale is Lower Eocene. Lower contact with Sui Main Limestone is conformable. Environment of deposition of Sui Shale is shallow marine outer shelf deposits. Sui shale unit comprised of shale with thin bands of marl and limestone. Shale is greenish grey, light grey, bluish grey, soft to moderately indurated, fissile, laminated, splintery, pyritic, and slightly calcareous. Marl off white, white grey, soft, sticky, pasty and hydrophyllic. Limestone is off white, light brownish grey, microcrystalline, compact, and dense at places argillaceous and fossiliferrous (Qadri, 1995).

2.2.8 Sui Main Limestone member

Age of Sui Main Limestone member is Eocene. Upper boundary of the Sui Main limestone member is marked by change in lithology from shale to limestone. Limestone exhibits light yellow grey color, contains traces of crystalline calcite and rare traces of chert. Shale is firm to moderately hard, sub platy, sub fissile and is moderately calcareous. Marl consists of light to greenish grey color, in parts sub blocky and contains traces of forams. (Qadri, 1995).

2.3 Borehole stratigraphy

The well is drilled up to the depth of Sui Main Limestone of lower Eocene age. Formations encountered in Qadirpur 14 and 15 are shown in Table 2.2.

Table 2.2. Stratigraphic column of formations encountered in Qadirpur 14&15.

Age	Formation	Lithology	Thickness(m)	
			Well# 14	Well# 15
Quaternary	Alluvium	Upper lithology	90	88
Early Pleistocene	Siwalik	Sandstone and argillaceous material	390	462
Oligocene	Nari	Sandstone, shale and sub-ordinate limestone	250	355
Upper Eocene	Drazinda	Claystone and silty shale	60	137
	Pirkoh Member	Limestone and marl	155	140
Middle Eocene	Sirki Member	Sandstone, siltstone and limestone	66	56
	Habib Rahi	Limestone	168	101
Lower Eocene	Ghazij Member	Shale	382	239
	SUL	Limestone	107	71
	Sui Shale Unit	Limestone and Shale	88	46
	SuiMainLimestone	Limestone	110	92

2.4 Petroleum system of Qadirpur Field

On the surface Qadirpur is covered by Alluvium of floodplain area of the Indus River. It is a NW-SE trending anticline comparatively broad in its Southern half. Potential source rocks include shale of Sembar Formation, but shale of Mughalkot, Ranikot and Ghazij formations are also considered for their source potential. Sui Main Limestone and Sui Upper Limestone is the main producer whereas limestone of Habib Rahi is considered as secondary reservoir.

Ghazij shale and shale within Sui Main and Upper Limestone act as cap rock for Sui Main and Upper Limestone. The Sirki Shale over Habib Rahi Limestone act as a cap rock. The structure surrounding the area include Sui (slightly asymmetrical anticline), Kandkot-Qadirpur structure trend comprising low amplitude domes. Uch (thrust faulted anticline) having compartments formed cross-cutting wrench faults, and fault related closures of the Yasin block and block-22. Near the Northern portion of the eastern flank of the Jacobabad high, fault-related traps as in Yasin block of the lower Indus trough and Mari-Kandkot high, low amplitude structure flat domal uplifts and combined with draping of the sedimentary cover anticipated to form traps.

Central Indus Basin is a gas province containing 70 % of the Pakistan's known gas reserves. The area is likely to provide Ministry of Pakistan's gas production and reserve's base for the foreseeable future. Details of source, reservoir and seal rocks are discussed in detail below (Qadri, 1995).

2.4.1 Source rock

The Cretaceous (Sembar) and Jurassic formations are the potential source rocks in the central Indus Basin. The Sembar contains rich source rocks for gas generation both in the Platform and Trough areas where these source rocks have attained the desired maturity.

Beginning of cretaceous marks the worldwide rising of the sea level which made the organic life flourish. Furthermore basin wide anoxia caused the preservation of organic matter. Time and Temperature conditions were also favorable to turn this preserved organic matter into hydrocarbons. Central Indus Basin was an area of extensional tectonics during Lower to Middle Cretaceous associated with slightly restricted circulation of the sea waters at the north western margin of Indian plate. Lower Cretaceous source rocks (Sembar Formation) were deposited while the basin was opening up and anoxia was prevailing. Similarly Middle to Upper Cretaceous clastic were deposited in a setting favorable for preservation of organic matter.

The source rocks exist in Sembar and Goru Formations of Lower Middle Cretaceous as observed in outcrops in Sulaiman Range and wells drilled in Sulaiman province. In addition the source potential of Upper Cretaceous, MoghalKot Formation at the margin of central Indus Basin is also very good as it was deposited in the slope environment providing anoxic conditions for the preservation of organic matter.

Cretaceous shales of Sembar, Goru and MoghalKot formations are both widespread and thick. They contain abundant organic matter and generally exhibit good source rock characteristics. Moreover, most of the cretaceous sub crops lie within oil window. Source rock analysis of some of these samples from Cretaceous shales indicates that they are fairly mature for hydrocarbon generation. These shales are thick enough to give rise to huge hydrocarbon reserves in the potential and producing reservoirs (Qadri, 1995).

All of the gas/condensate fields discovered in Central Indus Basin (Qadirpur, Sui, Kandhkot, Mazarani, Dhodak, Rodaho, and Mianoetc) have source rocks of their hydrocarbon in Cretaceous.

2.4.2 Reservoir rock

The thick cretaceous sediments present very good reservoir in Indus basin. In the Central Indus Basin (Sulaiman Sub Basin) Pub Sandstone is the reservoir in Pirkoh Gas Field and. Moghalkot formation exhibits good reservoir characteristics in Jandran while Sui Main Limestone and Lower Goru forms the reservoir in Qadirpur field. The Lower Goru sands, with porosity in range from 5-30% also constitute the reservoir in oil and gas fields discovered in Badin Platform / Sindh Monocline area. These include the oil fields of Khashkheli, TandoAlam, and Bobbi etc. MoghalKot formation and Parh Limestone show good reservoir potential for the development of secondary porosity in Limestone. Texture of Pab sandstone indicates good signs of primary (inter-angular) porosity and potential for development of secondary porosity. The famous Mughal Kot oil seepage occurs in basal outcrops of Pab sandstone is another indication of hydrocarbon generation and migration through permeable Pab sandstone (Qadri, 1995).

2.4.3 Seal rock

Sui Shale Unit provides seal for Sui Main Limestone, shales within Mughalkot formation can provide seals for Parh& Mughal Kot formations. Shales of Sembar can also provide seal for fractured Carbonates of Chiltan formation (Qadri, 1995).

Table 2.3. Petroleum system of Qadirpur Field

Type	Formation	Age
Seal/Cap Rock	**Sui Shale Unit**	**Lower Eocene**
Reservoir Rock	**Sui Main Limestone**	**Lower Eocene**
Source Rock	**Sember Formation**	**Cretaceous**

CHAPTER 3
RESERVOIR EVALUATION

This chapter includes the reservoir evaluation (Sui Main Limestone) of Qadirpur field wells-14 and 15. The analysis is carried out to investigate shale volume, porosity, water resistivity, and hydrocarbon saturation.

3.1 Marking zone of interest

Two zones have been marked in Qadirpur 14 and 15.Details of these zones have been given in table 3.1.

Table 3.1. Zones of Qadirpur 14 and 15

Zones	Qadirpur 14	Qadirpur 15
1	(1813m-1825m)	(1734-1750m)
2	(1831-1855m)	(1756-1780m)

3.2 Raw log curves of Qadirpur 14

3.2.1 Zone 1(1813m-1825m)

Zone	Lithology	Starting depth(m)	Ending depth(m)	Total thickness(m)
1	Limestone	1813	1825	13

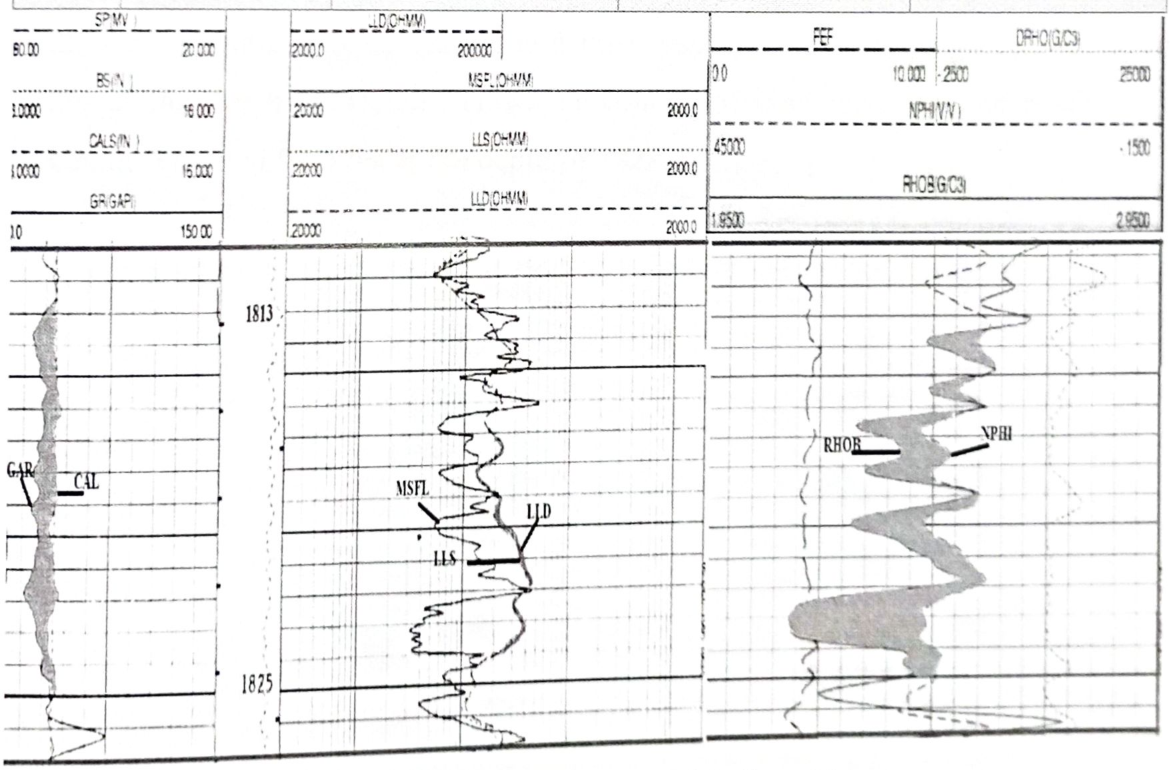

Fig 3.1. Log trends of zone 1 within Sui Main Limestone of Qadirpur 14

The Zone encountered in the formation is marked on the basis of under-gauge caliper reading ranging from 1813m-1825m which shows the formation of mud-cake in the borehole. Also gamma ray is reading low only in that specific zone which confirms the presence of elements with low radioactivity and shale free environment. Resistivity logs also confirm the potential of the zones by the separations in log curves with low MSFL readings but LLS and LLD are reading high. Also there is a considerable separation between LLS and LLD which further supports the presence of fluids in the zones of interest. Neutron-density cross over is used as a supporting evidence in the zone of interest. (Fig 3.1)

3.2.1.1 Volume of shale (Vsh)

Volume of shale is the quantitative measure of dirtiness in the zone of interest. It is usually calculated using gamma ray log. Increasing gamma ray represents high radioactive content in the lithology making it a dirty lithology. On the other hand decreasing gamma ray represents a clean lithology where radioactive content is either absent or very low.

Fig 3.2 represents volume of shale and volume of sand with respect to depth in reservoir of SUI Main Limestone Formation ranging in depth from 1813m-1825m. The average value of volume of shale in this zone are 10.54% while that of sand turned out to be 89.45%. Volume of shale increases and reaches the maximum value of 28.57% at the depth of 1825m and then decreases reaching minimum value of 1.42% at the depth of 1822m. However volume of sand increases and reaches the maximum value of 98.57% at the depth of 1822m.

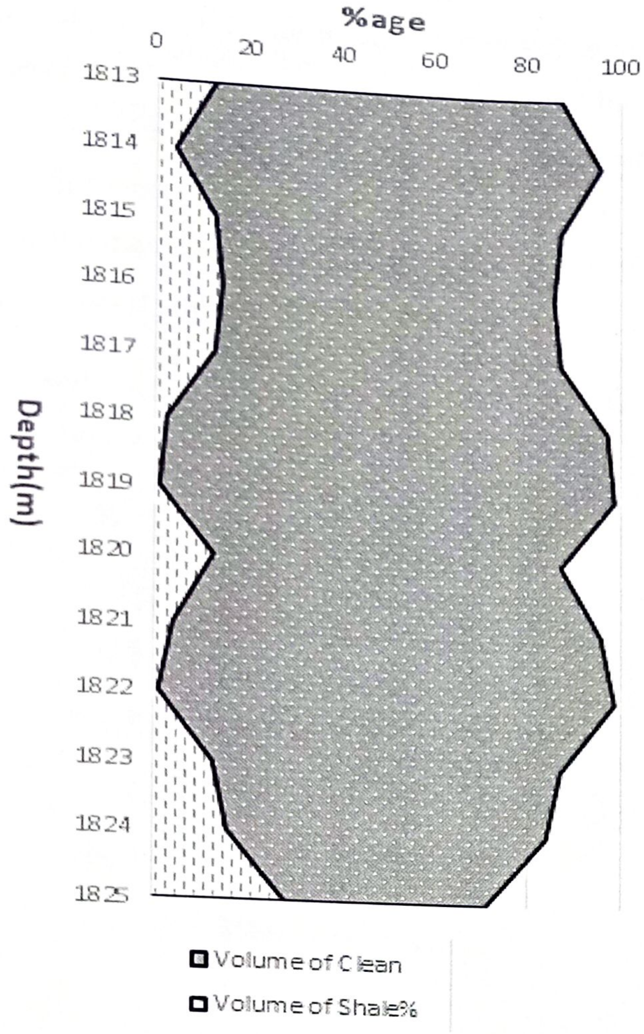

Fig 3.2.Volume of shale and volume of sand in zone-01 of Sui Main Limestone.

3.2.1.2 Calculation of porosity

3.2.1.3 Bulk Density and Density Porosity

The formation density log is the porosity log that measures electron density of a Formation. In geology, bulk density is a function of the density of the minerals forming a rock (i.e. Matrix) and the fluid enclosed in the pore spaces Density porosity gives an account of how dense a lithology is. If density porosity is high, the formation under consideration is not highly dense; rather it has pore spaces which may allow the existence of hydrocarbons. Bulk density and density porosity show indirect relationship. Increase in bulk density results in the decrease in density porosity and vice versa.

As it is evident from fig 3.3 that density porosity and bulk density have inverse relationship. The very low values of density porosity in the beginning reaches to its minimum value of 4.09% at the depth of 1813m however bulk density reaches to maximum value of 2.64 g/cc at the same depth. The maximum value of density porosity is 33.33% at the depth of 1823m, whereas bulk density reaches its minimum value of 2.14 g/cc at the depth of 1823m. The average value of density porosity is 16.95% in the zone of interest and that of bulk density is 2.42 gm/cc.

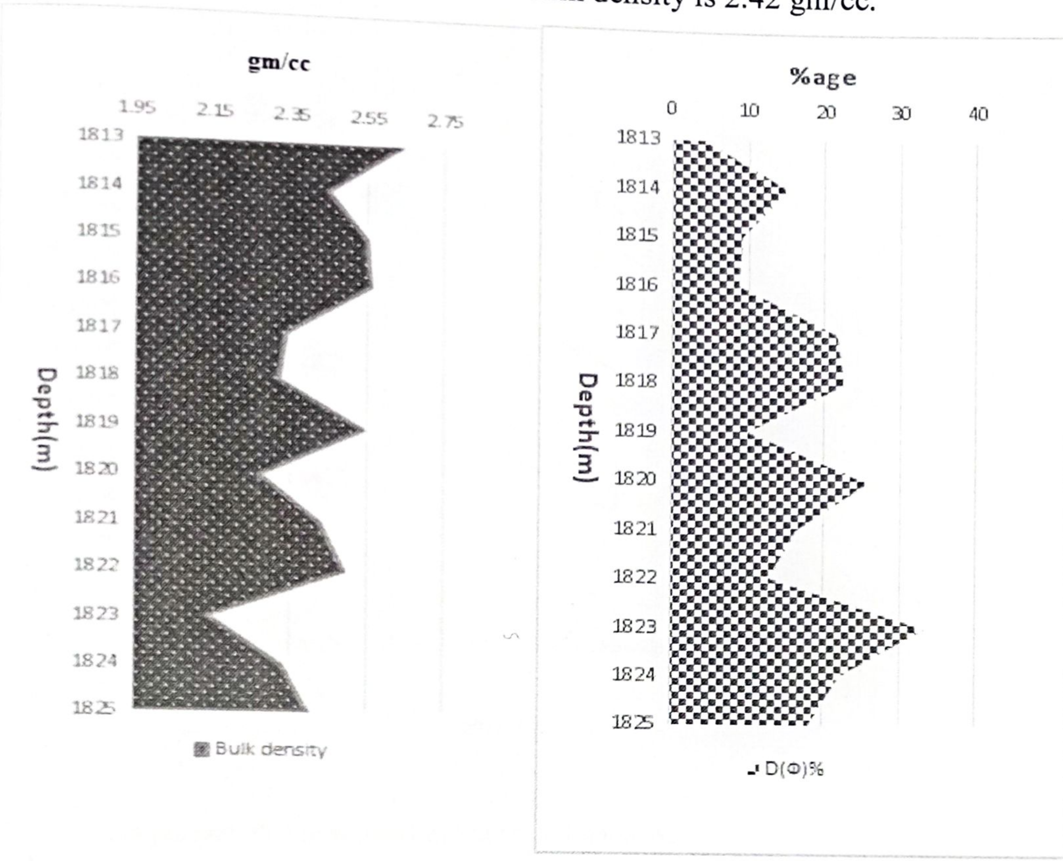

Fig 3.3. Bulk density vs Density porosity in zone-01 of Sui Main Limestone Formation.

3.2.1.4 Neutron Porosity

Neutron porosity is the measure of amount of liquid filled porosity which is measured by using neutron logs. Neutron logs measure the hydrogen ion concentration in a Formation. In a clean Formation (i.e. shale free) where the pores are filled with water or oil, the neutron measures liquid filled porosity. The neutron log is sensitive mainly to the amount of hydrogen atoms in a Formation. Its main use is in the determination of the liquid filled porosity of a Formation. In formations with a large amount of hydrogen atoms, the neutrons are slowed down and absorbed very quickly in a short distance. The count rate of slow neutrons or capture gamma rays is low in the tool. Hence, the count rate will be low in high porosity rocks.

Fig 3.4 indicates the behavior of neutron porosity in the marked zone of interest. In the beginning, neutron porosity values were high and then abruptly starts decreasing to its minimum value of 8% at the depth of 1815m. The maximum value reach to 19% at the depth of 1825m. The average value of neutron porosity is 12.62%.

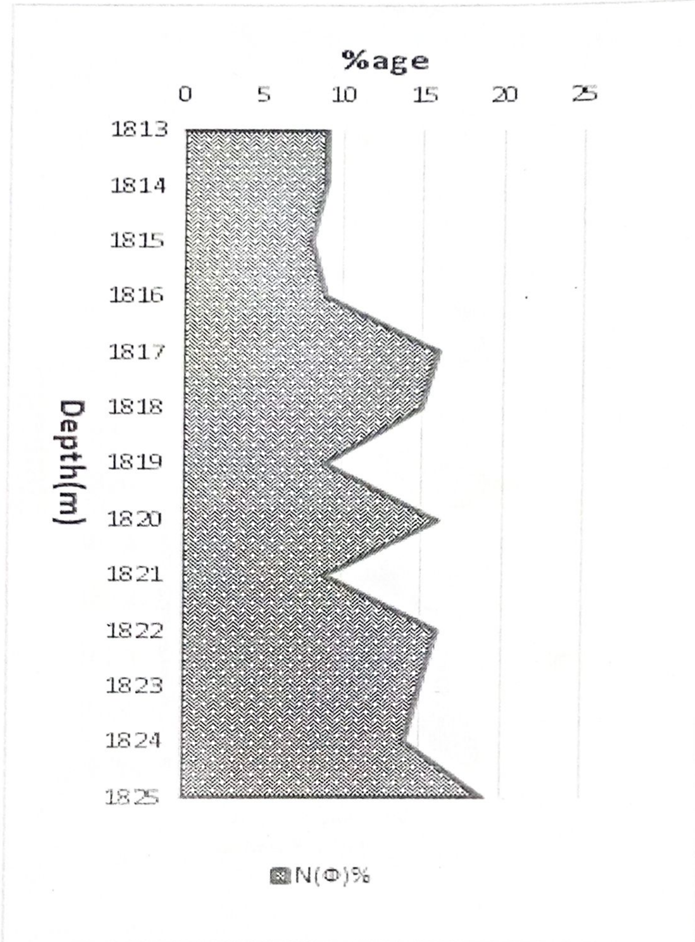

Fig 3.4. Neutron porosity (%) in zone-01 of Sui Main Limestone.

3.2.1.5 Average porosity, effective porosity and their relationship

Fig 3.5 represents the average porosity and effective porosity present in the reservoir zone of Sui Main Limestone Formation ranging from 1813-1825m. In the beginning average porosity is very low to its minimum value of 6.54% at the depth of 1813m and then starts increasing gradually, in the middle there is an abrupt increment and then decrement and the same phenomena repeats in the next interval. The maximum value of 24.16% is observed at the depth of 1823m. However the average value turned out to be 14.78% in the zone of interest which is fair enough for a reservoir to be in a producing state.

Effective Porosity showing almost the same trend as average porosity represents. In start from minimum value of 5.70% at the depth of 1813m start increasing up to the maximum value of 21.05% at the depth of 1823m. The average value of effective porosity is 13.13%.

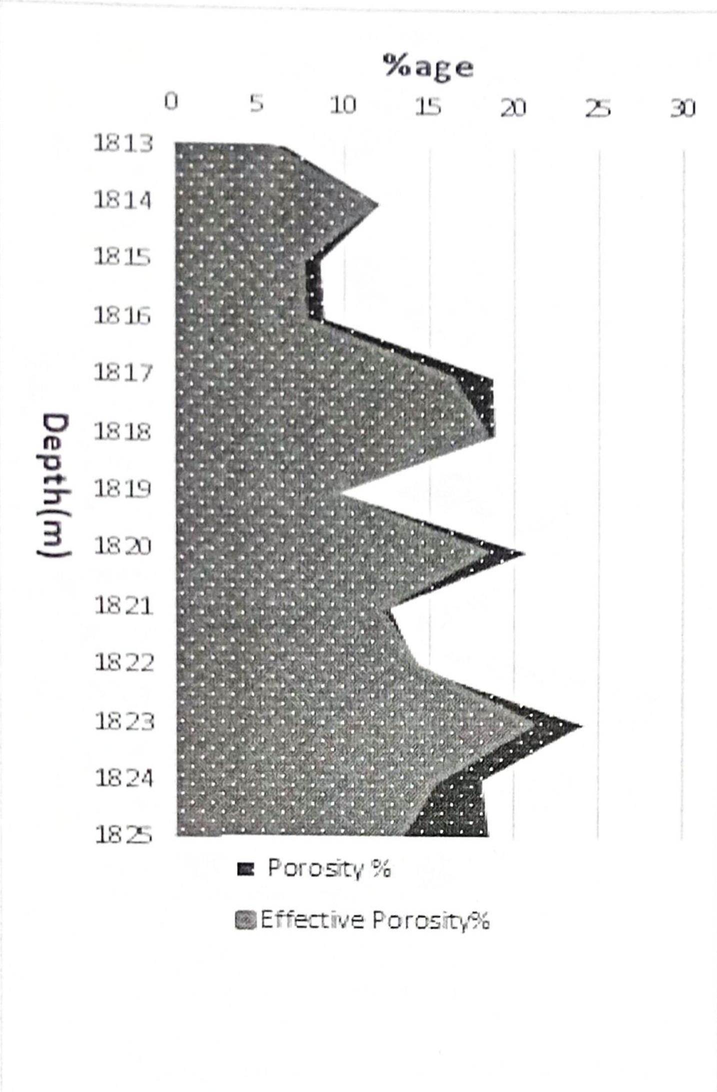

Fig 3.5. Relationship between average porosity and effective porosity in zone- 01 of Sui Main Limestone.

3.2.1.6 Comparison of different porosities

Fig 3.6 represents a composite relationship between different porosities in the reservoir zone. As it is evident from the graph that Neutron porosity and effective porosity have almost a direct relationship. Increasing values of neutron porosity result in increasing effective porosity. Also average porosity, effective porosity and neutron porosity have a direct relationship. Increasing values of average porosity and neutron porosity result in incrementing effective porosity and vice versa.

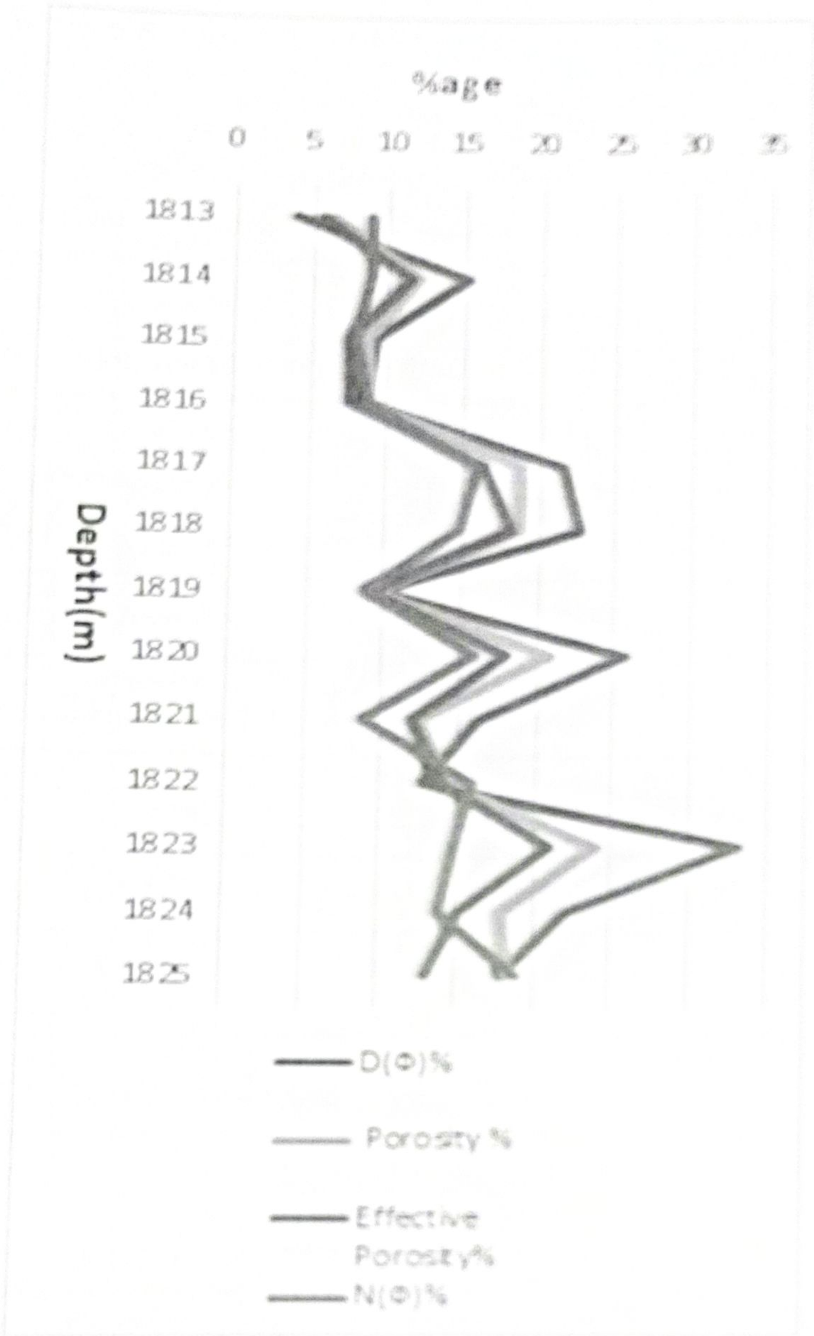

Fig 3.6. Comparison of different porosities in zone-01 of Sui Main Limestone.

3.2.1.7 Estimation of resistivity of water (Rw)

Table 3.2. Steps of Rw determination.

Geothermal Gradient= $B.H.T - S.Temp \div Total\ Depth$
⇓
Formation Temperature= $(Formation\ Top \times G.G) + S.T$
⇓
Rmf@ Surface Temp $\xRightarrow[\text{By Gen 9 Chart}]{\text{Convert}}$ Rmf@ Formation Temp
⇓
Rmf@ Formation Temp $\xRightarrow[\text{By SP-2 chart}]{\text{Convert}}$ Rmfeq
⇓
SSP⇒ SSP Log $(SSP_{max} - SSP_{min})$
⇓
SSP value $\xRightarrow[\text{SP-1 chart}]{\text{Using}}$ Rweq
⇓
Rweq $\xRightarrow{\text{Using Sp-2 chart}}$ Rw

The procedure for the calculation of Rw using Gen 9 charts is as follows:

- ➢ Calculation of Geothermal Gradient

Geothermal gradient = Bottom hole temp – surface temp / total depth

= 146°F-82F°/ 1866m

= 0.0321°F/m.

- ➢ Calculation of formation Temperature = Surface temperature + (Geothermal Gradient * Formation top)

= 82 + (0.0321*1756)

= 82+ 56.36°F

= 138.19°F

- Rmf from log header i.e. 0.319@ 82°F
- Calculation of Rmf at 82°F i.e. 0.319ohm-m
- Calculation of Rmf at formation temperature using Gen-9 charts. i.e.0.18 ohm-m

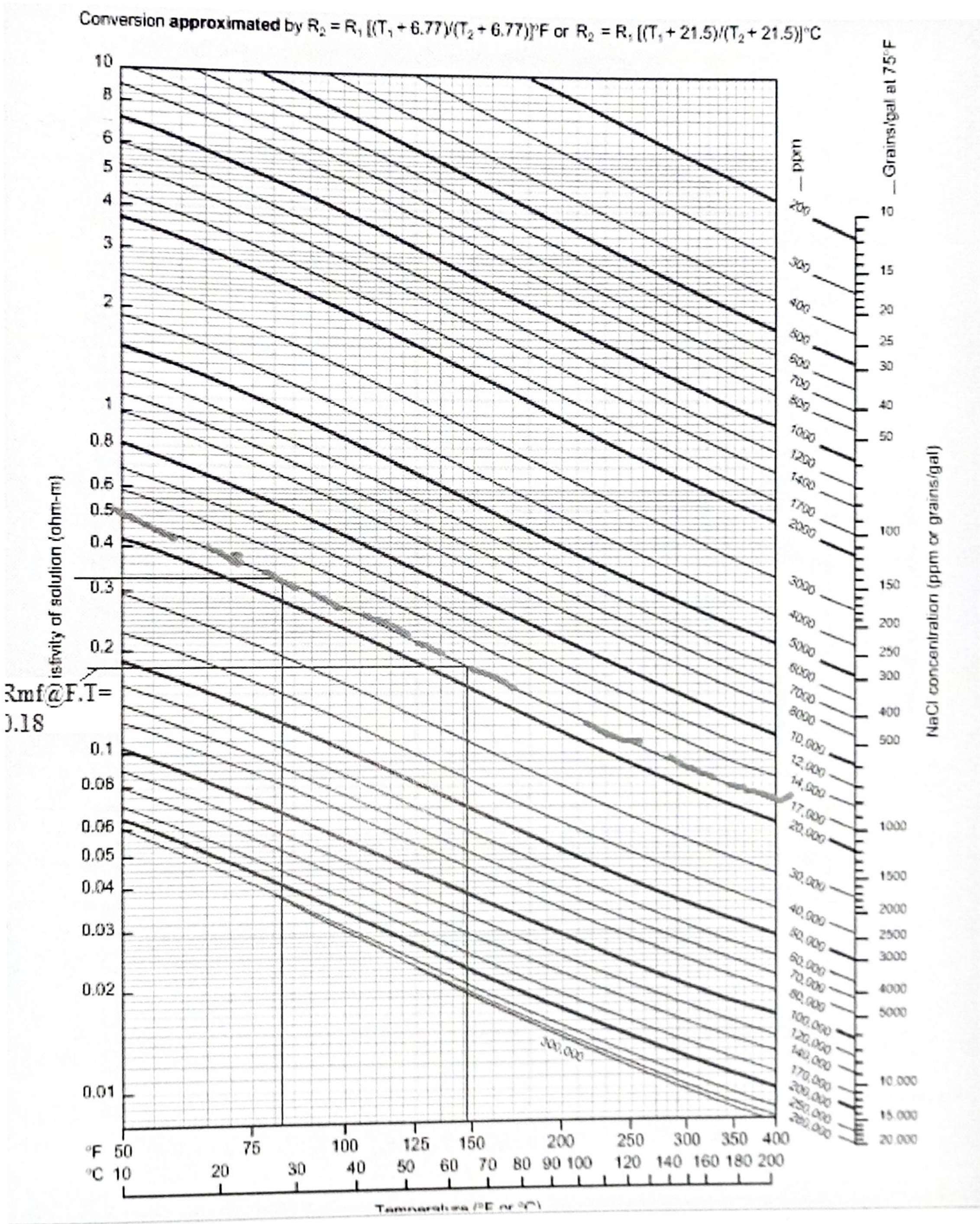

Fig 3.7. Calculation of Rmf at formation temperature for Sui Main Limestone Formation (Shlumberger catalogue, 2001).

Rmf at formation temperature= 0.18 ohm-m

- Calculation of RmfeqasRmf > 0.1 so multiply it with 0.85 = 0.18*0.85=0.153

- Calculation of SSP using SP log i.e. maximum deflection off the SP curve i.e. +8mv

- Calculation of resistivity of water equivalent

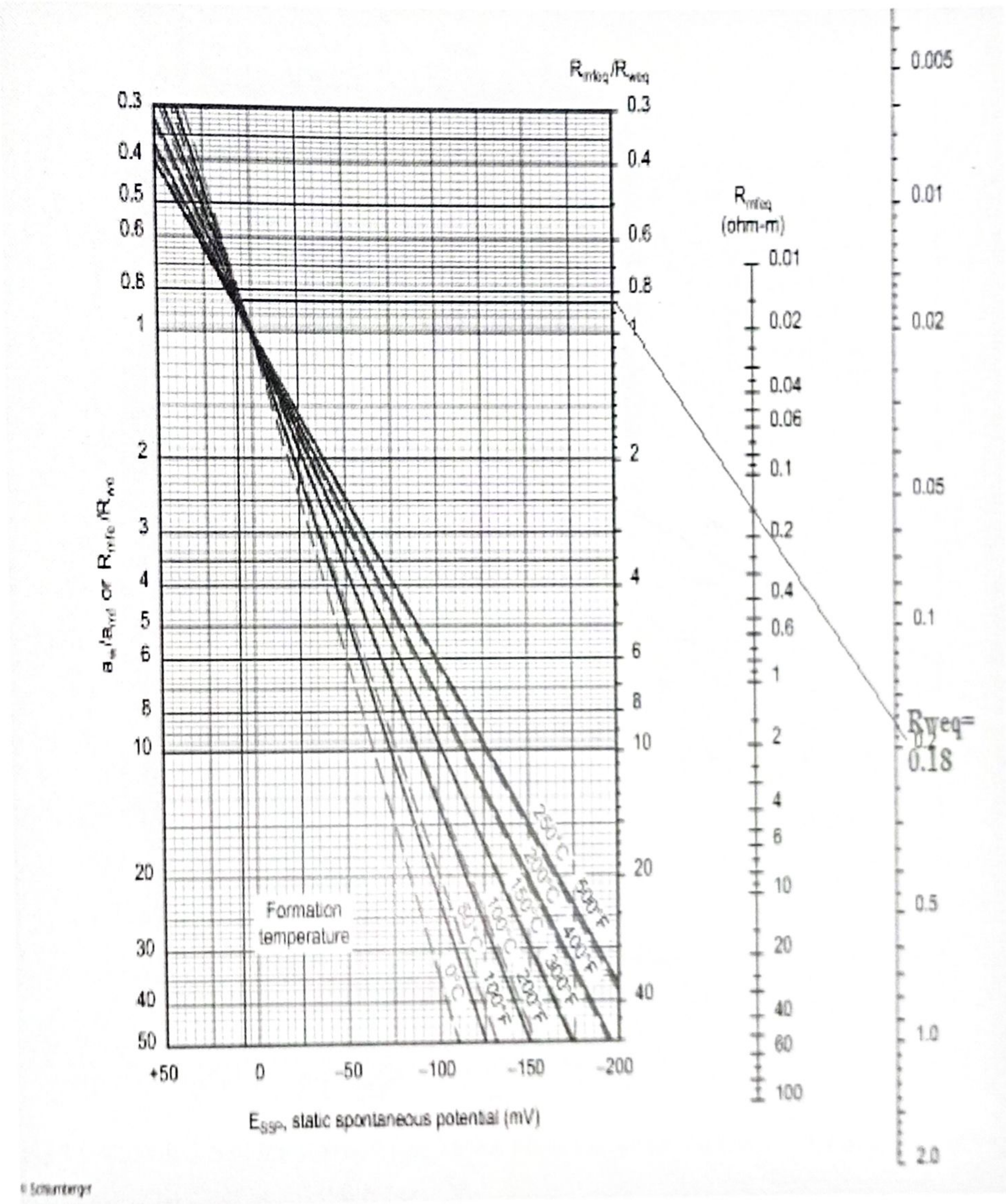

Fig 3.8. Resistivity of water equivalent calculation for Sui Main Limestone Formation (Shlumberger catalogue, 2001).

Resistivity of water equivalent = 0.18

- Calculation of resistivity of water (Rw)

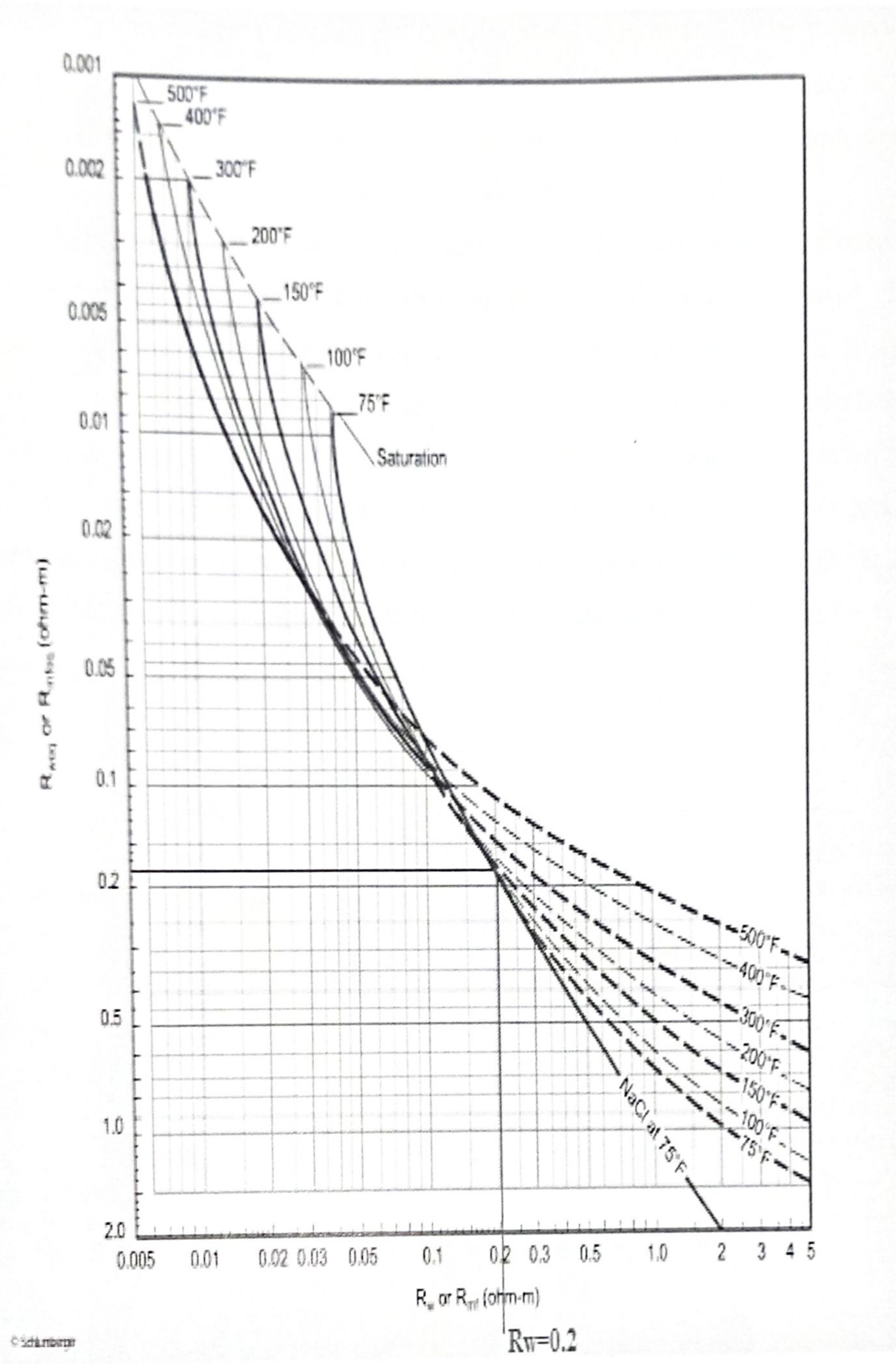

Fig 3.9. Calculation of Rw versus Rweq for Sui Main Limestone Formation (Shlumberger catalogue, 2001).

Resistivity of water turned out to be 0.2 ohm-m for Sui Main Limestone Formation. The calculated water resistivity will be used in the Archie's equation to determine the water saturation and ultimately hydrocarbon saturation.

3.2.1.8 Water and hydrocarbon saturation

The fraction of pore spacing that contains water is termed as water saturation; denoted by Sw. Water saturation gives the indication of hydrocarbon presence in the reservoir. If saturation of water is less, then saturation of hydrocarbon is high, but if Sw is 100% than it indicates hydrocarbons are absent in that interval.

Fig 3.10 shows the saturation of water (Sw) in the reservoir zone of interest. Saturation of water shows a fluctuating behavior in the zone of interest. The maximum value of water saturation appears at the depth of 1813m which is 80.42% and the minimum of water saturation appears to be 12.69% at the depth of 1823m. The average value of Sw is 34.75% in the zone of interest while the percentage maximum value of hydrocarbon saturation appears at the depth of 1823m which is 87.30% and the minimum of hydrocarbon saturation appears to be 19.57% at the depth of 1813m. The average value of hydrocarbon saturation is 65.24% in the zone of interest.

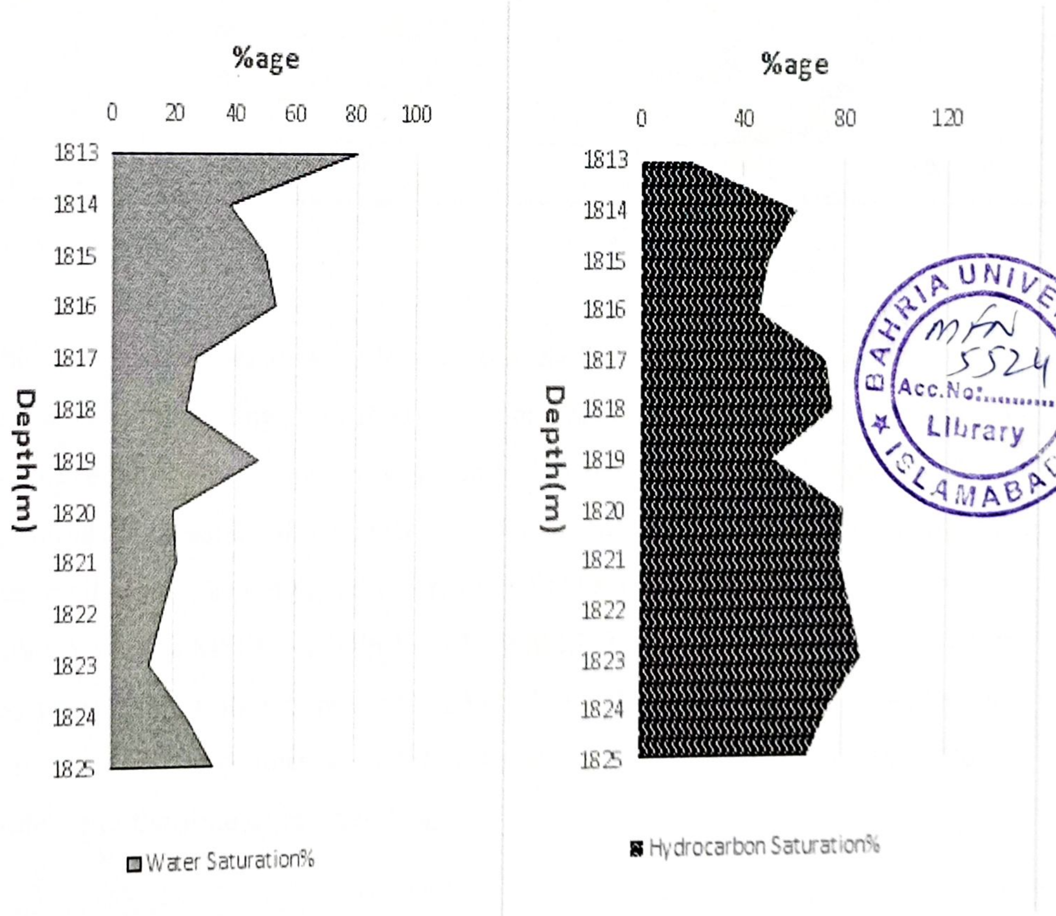

Fig 3.10. Water and Hydrocarbon saturation (%) in zone-01 of Sui Main Limestone.

3.2.2 Zone 02 (1831-1855m)

Zone	Lithology	Starting depth(m)	Ending depth(m)	Total thickness(m)
2	Limestone	1831	1855	25

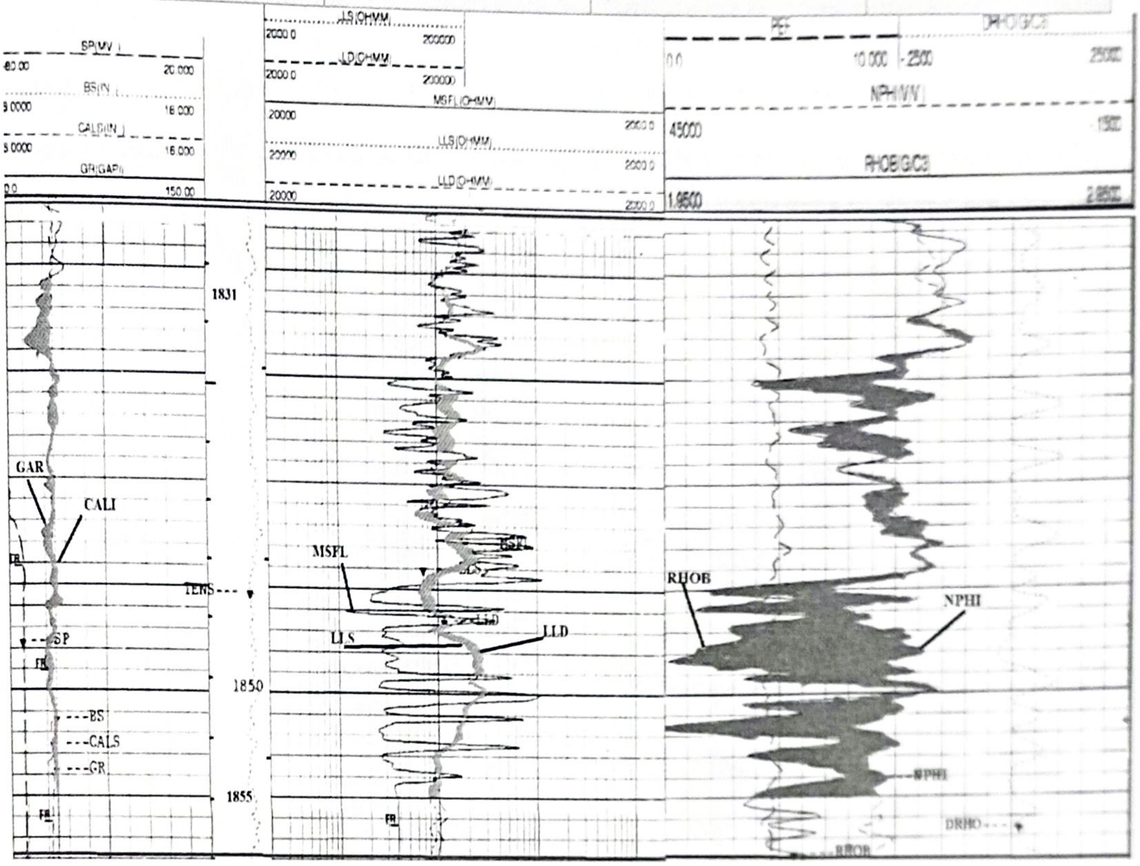

Fig 3.11. Zone 2 of interest.

The zone 2 encountered in the formation is marked on the basis of under-gauge caliper reading ranging from 1831m-1855m which shows the formation of mud-cake in the borehole. Also gamma ray is reading low only in that specific zone which confirms the presence of elements with low radioactivity and shale free environment. Resistivity logs also confirm the potential of the zones by the separations in log curves with low MSFL readings but LLS and LLD are reading high. Also there is a considerable separation between LLS and LLD which further supports the presence of fluids in the zones of interest. Neutron-density cross over is used as a supporting evidence in the zone of interest. (Fig 3.11)

3.2.2.1 Volume of shale

Fig 3.12 represents volume of shale and volume of sand with respect to depth in this zone-02 of Sui Main Limestone Formation ranging in depth from 1831-1855m. The average volume of shale turned out to be 20.57% and that of sand turned out to be 79.42%. Volume of shale is high in start but then gradually start decreasing and reaches to its minimum value of 7.14% at the depth of 1834m. The maximum value of shale i.e28.57% is achieved at the depth of 1835m. However volume of sand initially from low value starts increasing and reaches to its maximum value of 92.85% at the depth of 1834m. The minimum value 71.42% is achieved at the depth of 1837m.

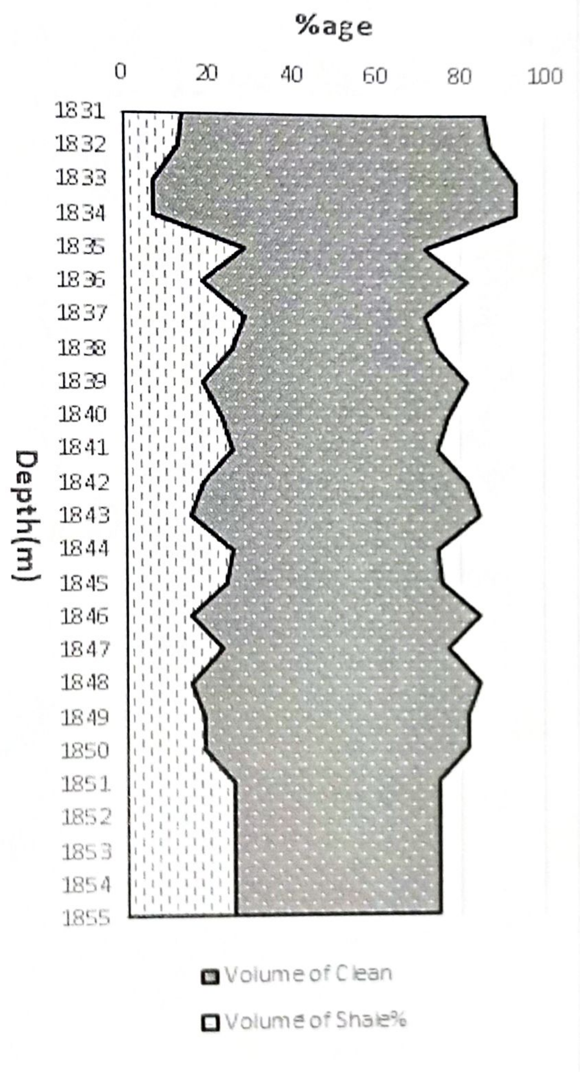

Fig 3.12. Volume of shale and volume of sand in zone-02 of Sui Main Limestone.

3.2.2.2 Calculation of porosity

3.2.2.3 Bulk density and density porosity

As it is evident from fig 3.13 that density porosity and bulk density have inverse relationship. The very low values of density porosity in the beginning reaches to its minimum value of 8.77% at the depth of 1833m however bulk density reaches to maximum value of 2.56 g/cc at the same depth. The maximum value of density porosity is 40.93% at the depth of 1846m, whereas bulk density reaches its minimum value of 2.01 g/cc at the depth of 1846m. The average value of density porosity is 22.38% in the zone of interest and that of bulk density is 2.32 gm/cc.

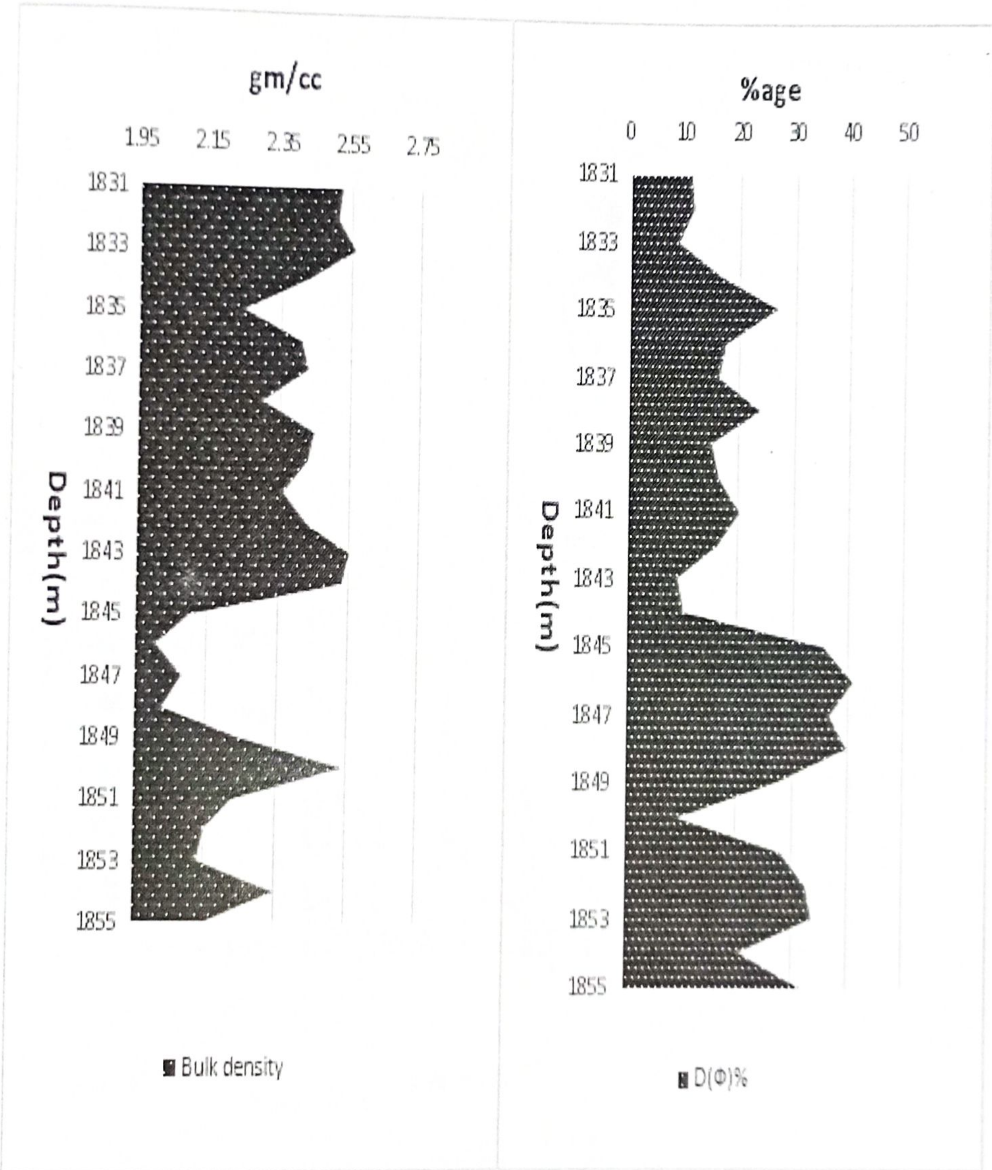

Fig 3.13. Bulk density vs Density porosity in zone-02 of Sui Main Limestone.

3.2.2.4 Neutron porosity

Fig 3.14 indicates the behavior of neutron porosity in the marked zone of interest. In the beginning, neutron porosity values were low and then abruptly starts increasing to its maximum value of 24% at the depth of 1844m. The minimum value reach to 9% at the depth of 1832m. The average value of neutron porosity is 13.84%.

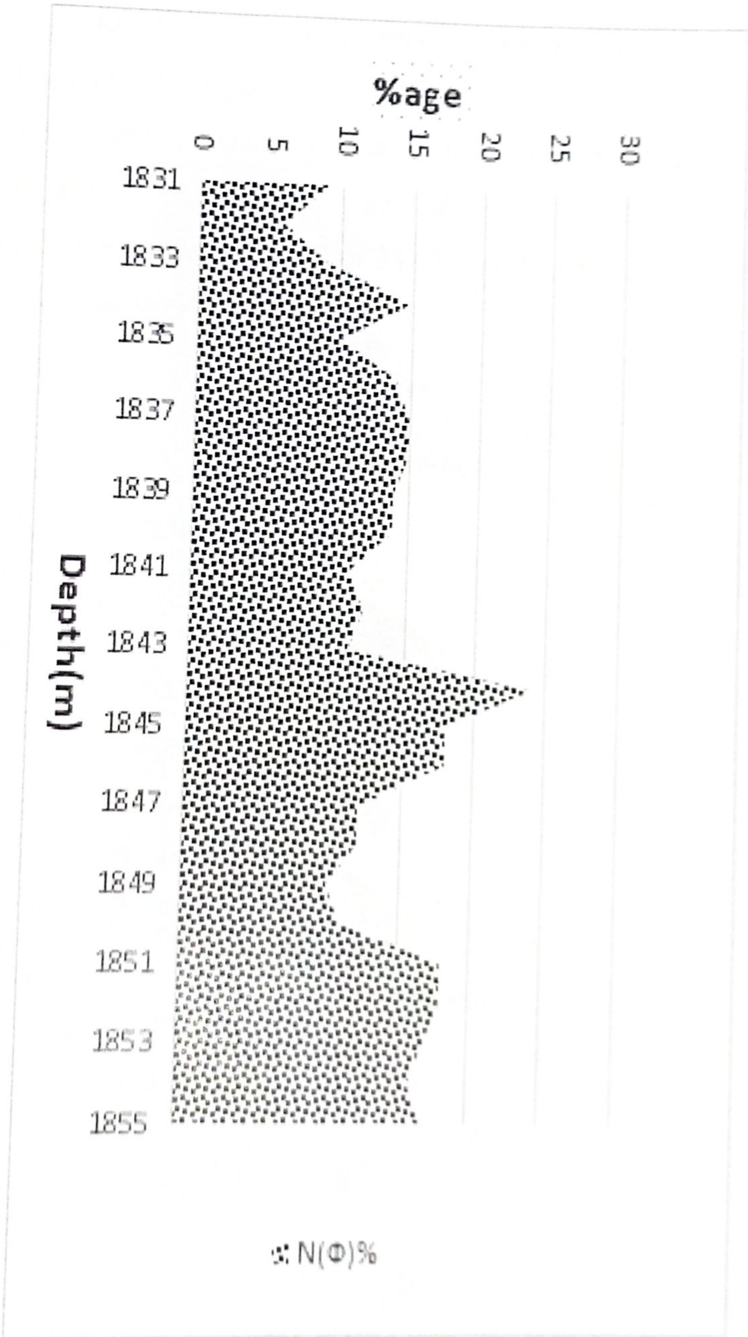

Fig 3.14. Neutron porosity (%) in zone-02 of Sui Main Limestone.

3.2.2.5 Average porosity, effective porosity and their relationship

Fig 3.15 represents the average porosity and effective Porosity present in the reservoir zone of Sui Main Limestone Formation ranging from 1831-1855m. In the beginning average porosity is very low to its minimum value of 8.84% at the depth of 1832m and then starts increasing gradually, in the middle there is an abrupt increment and then decrement and the same phenomena repeats in the next interval. The maximum value of 29.46% is observed at the depth of 1846m. However the average value turned out to be 18.11% in the zone of interest which is fair enough for a reservoir to be in a producing state.

Effective Porosity showing almost the same trend as average porosity represents. In start from minimum value of 7.71% at the depth of 1832m start increasing up to the maximum value of 24.83% at the depth of 1846m. The average value of effective porosity is 14.22%.

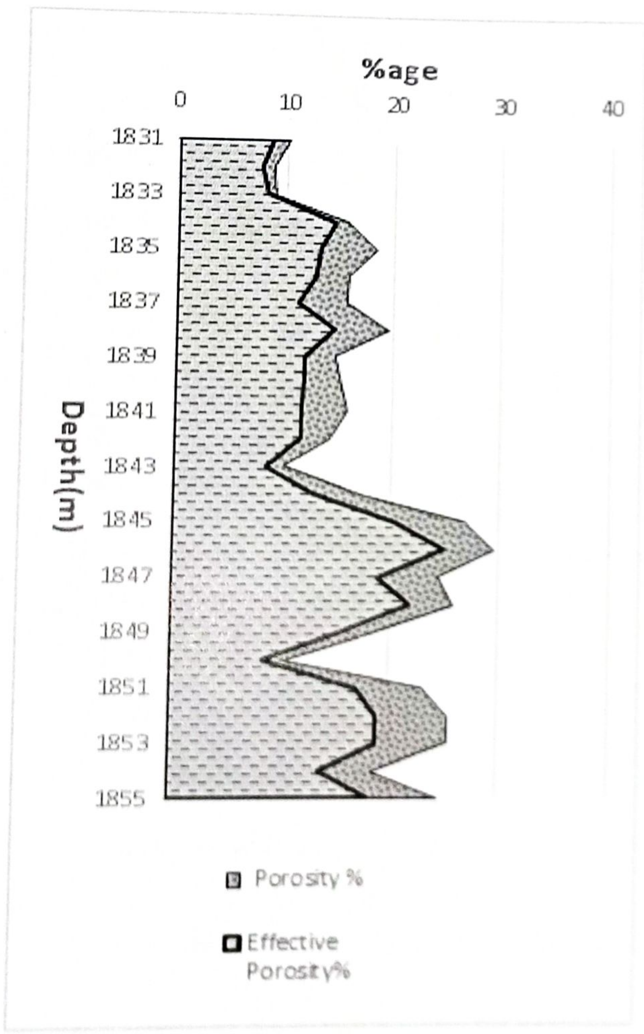

Fig 3.15. Relationship between average porosity and effective porosity in zone-02 of Sui Main Limestone.

3.2.2.6 Comparison of different porosities

Fig 3.16 represents a composite relationship between different porosities in the reservoir zone. As it is evident from the graph that Neutron porosity and effective porosity have almost a direct relationship. Increasing values of neutron porosity result in increasing effective porosity. Also average porosity, effective porosity and neutron porosity have a direct relationship. Increasing values of average porosity and neutron porosity result in incrementing effective porosity and vice versa.

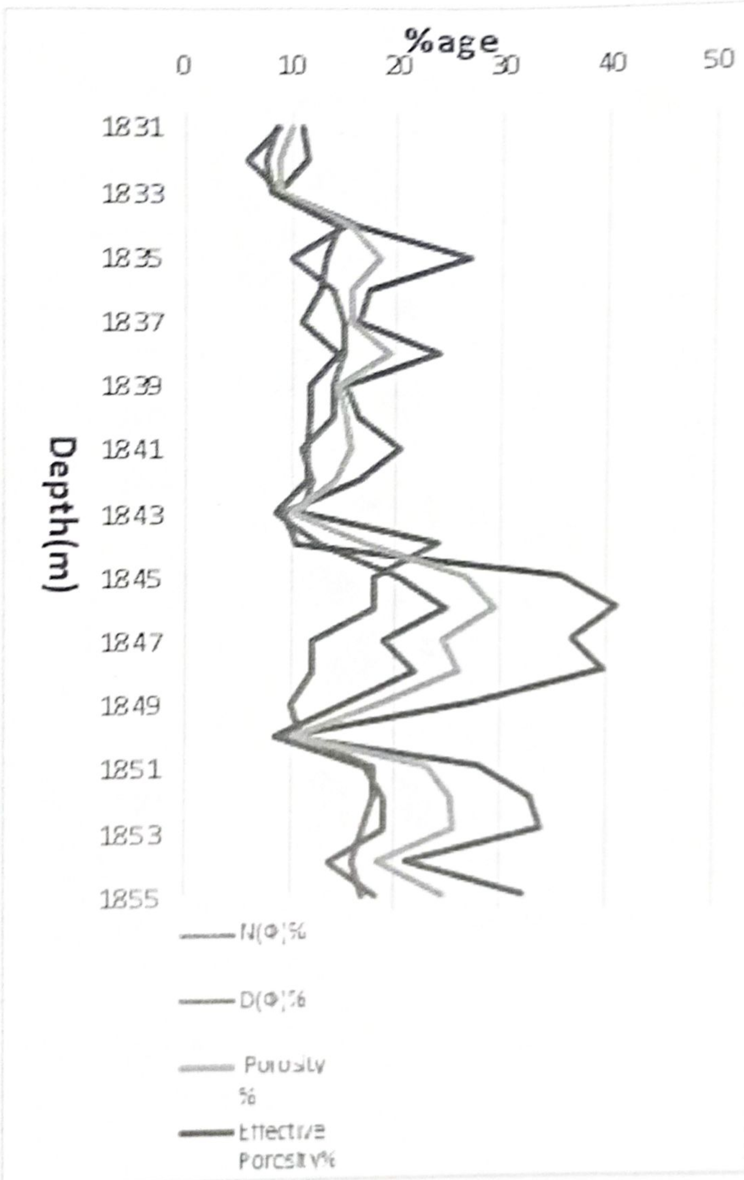

Fig3.16. Comparison of different porosities in zone-02 of Sui Main Limestone.

3.2.2.7 Water and hydrocarbon saturation

Fig 3.17 shows the water and hydrocarbon saturation in the reservoir zone of interest. The maximum value of water saturation appears at the depth of 1832m which is 59.50% and the minimum value of water saturation appears to be 15.46% at the depth of 1848m. The average value of Sw is 34.42% in the zone of interest. While the percentage maximum value of hydrocarbon saturation appears at the depth of 1848m which is 84.72% and the minimum value of hydrocarbon saturation appears to be 40.49% at the depth of 1832m. The average value of hydrocarbon saturation is 65.57% in the zone of interest.

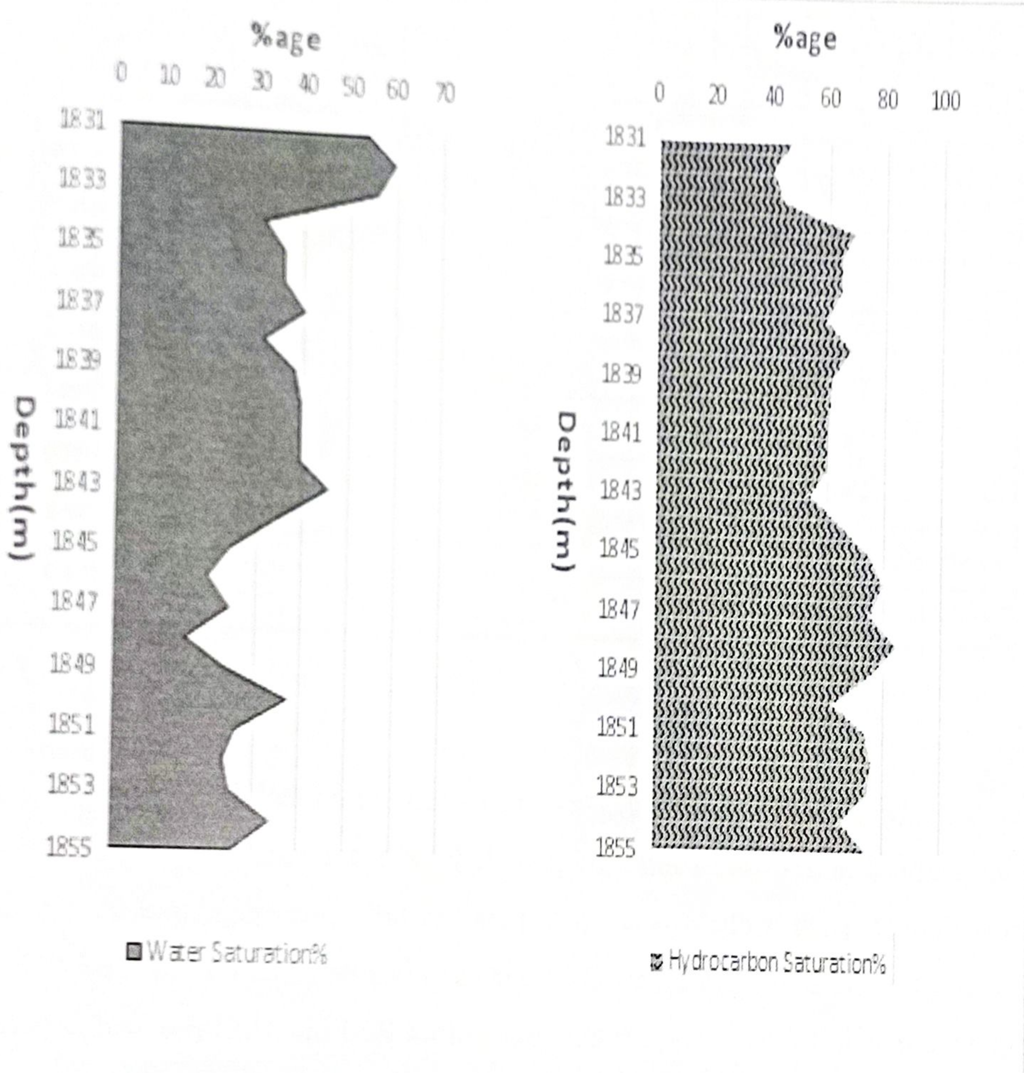

Fig 3.17. Water and Hydrocarbon saturation (%) in zone-02 of Sui Main Limestone.

3.3 Raw log curves of Qadirpur 15

3.3.1 Zone 1 (1734-1750m)

Zone	Lithology	Starting depth(m)	Ending depth(m)	Total thickness(m)
1	Limestone	1734	1750	17

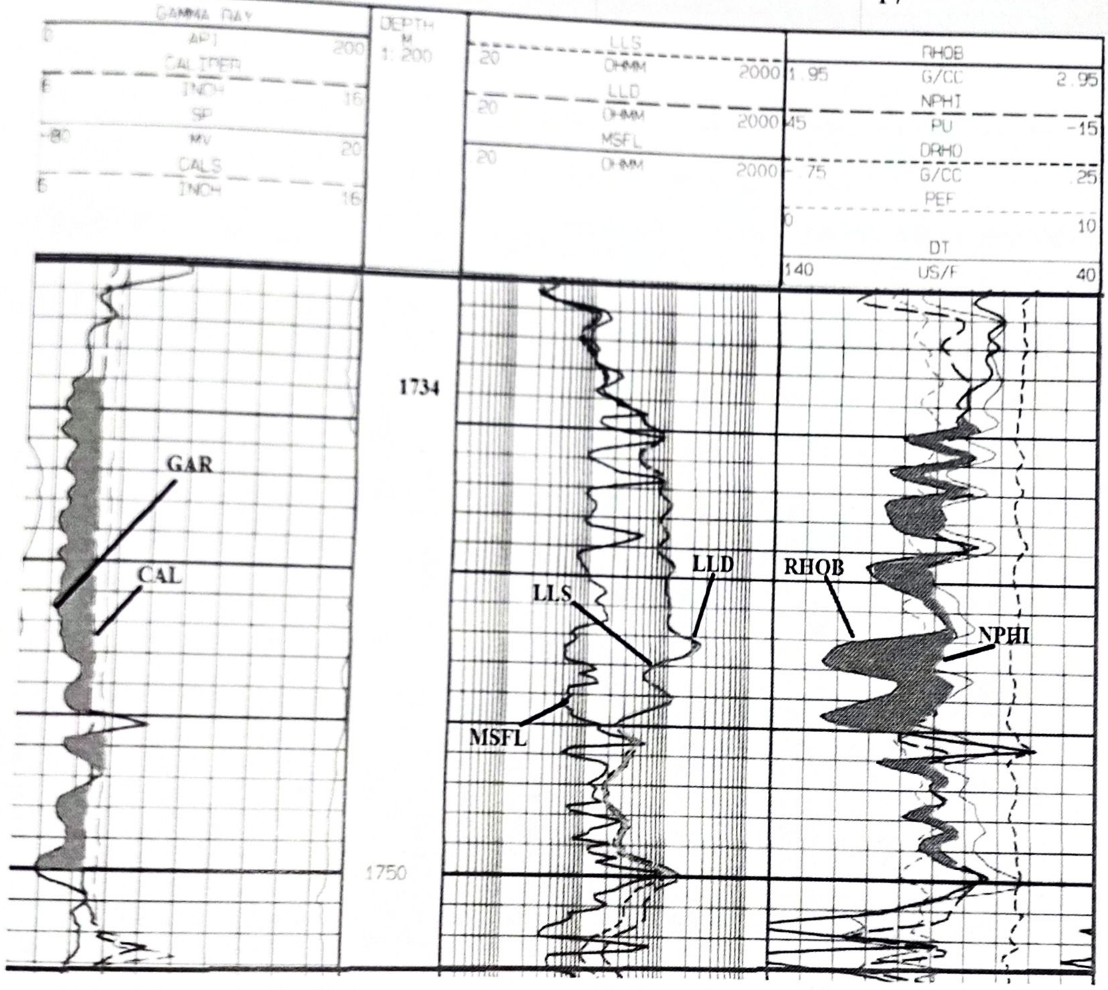

Fig 3.18. Zone 1 of interest.

Zone-01 is marked on the basis of under-gauge caliper reading which shows the formation of mud-cake in the borehole ranging from 1734-1750m. Gamma ray is reading very low in the zone and resistivity logs also confirm the potential of the zones, Where MSFL reads low and LLD and LLS are reading high. The considerable separation between LLD and LLS further supports the presence of fluids in the zones of interest.

Fig 3.18 represents zone-01 showing low gamma ray, under-gauge caliper, cross over between density and neutron.

3.3.1.1 Volume of shale (Vsh)

Volume of shale is the quantitative measure of dirtiness in the zone of interest. It is usually calculated using gamma ray log. Increasing gamma ray represents high radioactive content in the lithology making it a dirty lithology. On the other hand decreasing gamma ray represents a clean lithology where radioactive content is either absent or very low.

Fig 3.19 represents volume of shale and volume of sand with respect to depth in reservoir of Sui Main Limestone Formation ranging in depth from 1734-1750m. The average value of volume of shale turned out to be 17.41% while that of sand turned out to be 85.58%. Volume of shale first increases and reaches the maximum value of 50.64% at the depth of 1747m and then decreases reaching minimum value of 0% at the depth of 1750m. However volume of sand decreases in the beginning and reaches the minimum value of 49.35% at the depth of 1747m and then increases reaching the maximum value of 100% at the depth of 1750m.

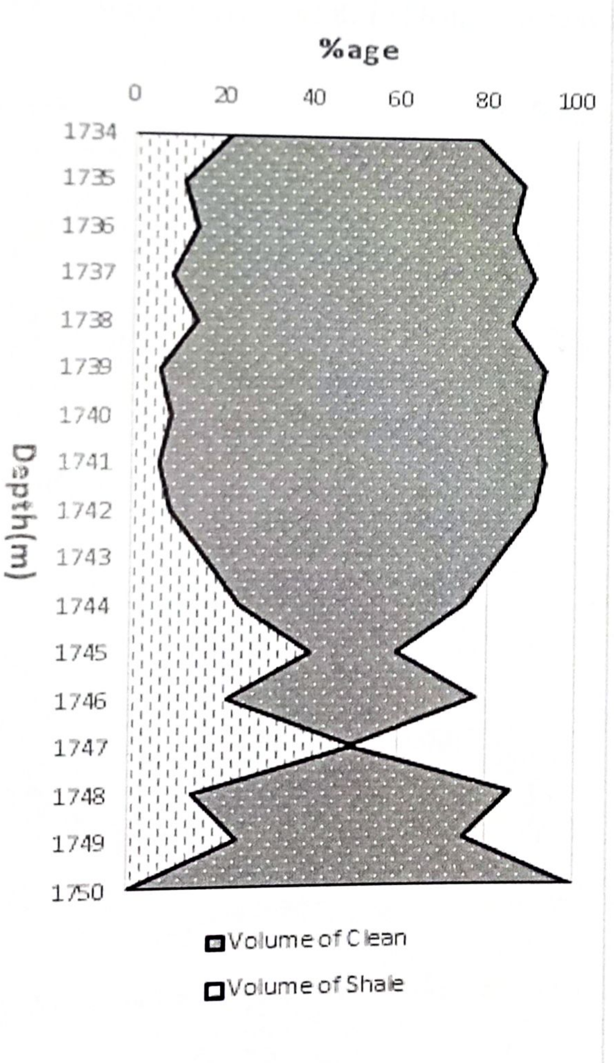

Fig 3.19. Volume of shale and volume of sand in zone 1 of Sui Main Limestone.

3.3.1.2 Calculation of porosity

3.3.1.3 Bulk density and density porosity

The formation density log is the porosity log that measures electron density of a Formation. In geology, bulk density is a function of the density of the minerals forming a rock (i.e. Matrix) and the fluid enclosed in the pore spaces Density porosity gives an account of how dense a lithology is. If density porosity is high, the formation under consideration is not highly dense; rather it has pore spaces which may allow the existence of hydrocarbons.

As it is evident from fig 3.20 that Bulk density and density Porosity have converse relationship. Density porosity reaches to its minimum value of 6.43% at the depth of 1750m however bulk density increases in the beginning and reaches its maximum value of 2.6 g/cc at the same depth of 1750m. The maximum value of density porosity is 32.47% at the depth of 1743m where bulk density reaches its minimum value of 2.15g/cc at the depth of 1743m. The average value of density porosity is 19.26% in the zone of interest and that of bulk density is 2.38gm/cc.

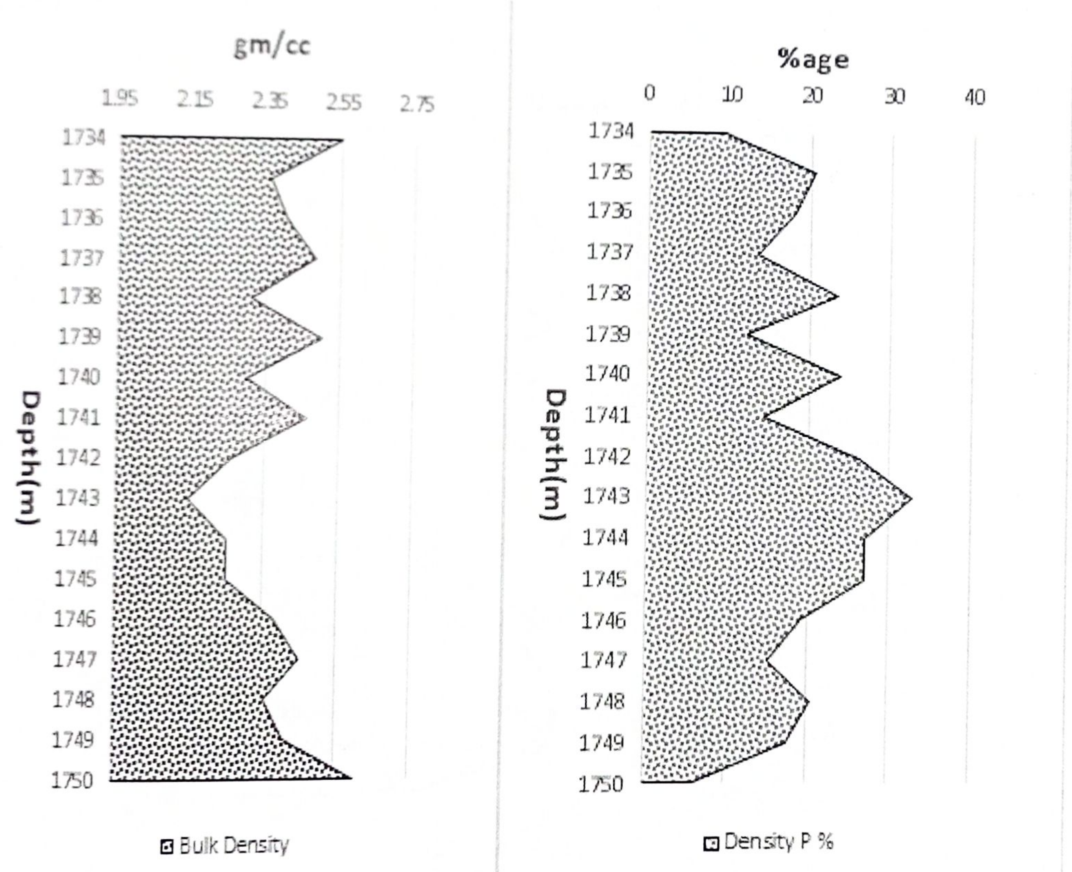

Fig 3.20. Behavior of Bulk density and Density porosity in the zone 1 of Sui Main Limestone respectively.

3.3.1.4 Neutron Porosity

Neutron porosity is the measure of amount of liquid filled porosity which is measured by using neutron logs. Neutron logs measure the hydrogen ion concentration in a Formation. In a clean Formation (i.e. shale free) where the pores are filled with water or oil, the neutron measures liquid filled porosity. The neutron log is sensitive mainly to the amount of hydrogen atoms in a Formation. Its main use is in the determination of the liquid filled porosity of a Formation.

In formations with a large amount of hydrogen atoms, the neutrons are slowed down and absorbed very quickly in a short distance. The count rate of slow neutrons or capture gamma rays is low in the tool. Hence, the count rate will be low in high porosity rocks.

Fig 3.21 elucidates the behavior of neutron porosity in the marked zone of interest. In the beginning, neutron porosity tends to decrease and reaches its minimum value of 5% at the depth of 1747m and then gradually starts climbing up reaching its maximum value of 21% at the depth of 1745m. The average value of neutron porosity is 13.35%

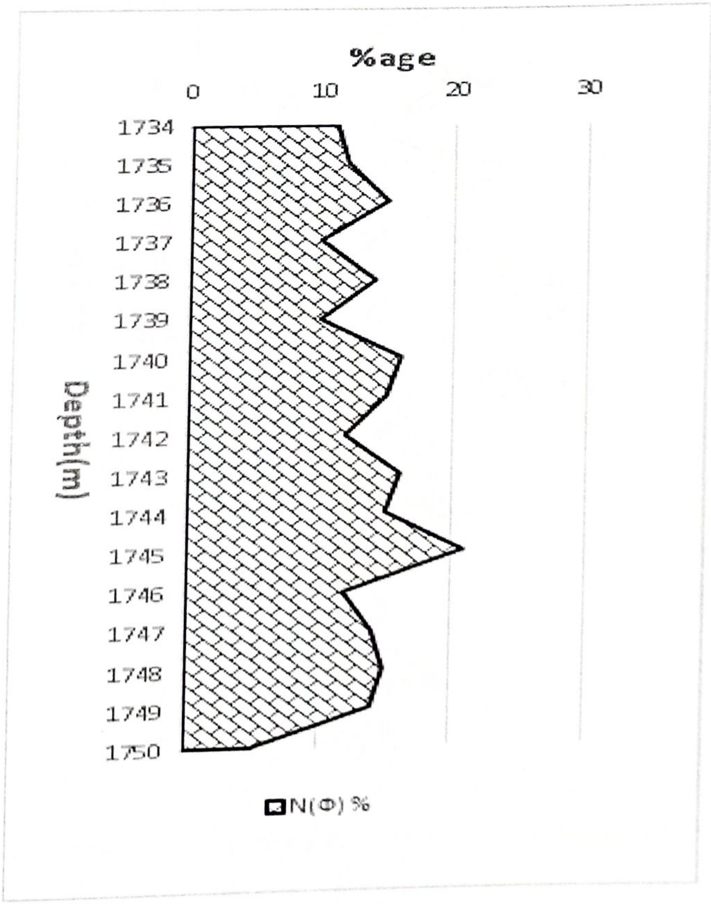

Fig 3.21. Neutron porosity (%) in zone 1 of Sui Main Limestone.

3.3.1.5 Average porosity, effective porosity and their relationship

Fig 3.22 represents the average porosity and effective porosity present in reservoir zone of Sui Main Limestone Formation ranging from 1734-1750m. Average porosity shows a gradual increasing trend where it reaches maximum value of 24.37% at the depth of 1743m and then it starts decreasing with a little fluctuation. The minimum value is attained which is 5.71% at the depth of 1750m. However the average value turned out to be 16.3% in the zone of interest which is fair enough for a reservoir to be in a producing state.

Effective porosity first from very low value of 5.71% at the depth of 1750m starts increasing up to the maximum value observed at the depth of 1743m which is 20.25%. The average value of effective porosity is 13.26%.

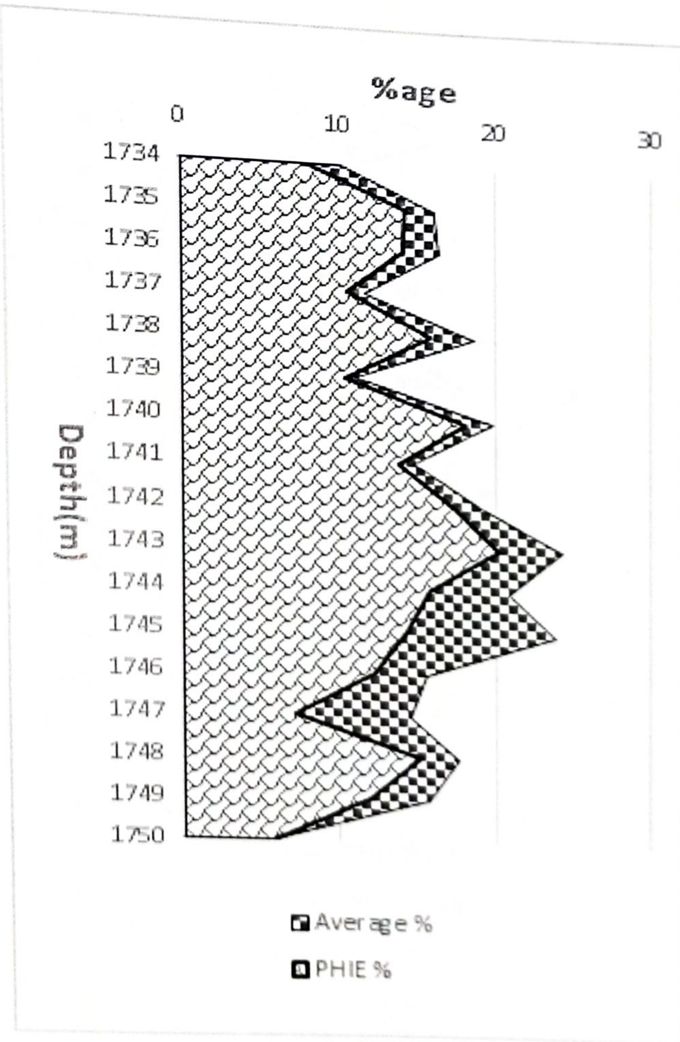

Fig 3.22. Relationship between average porosity and effective porosity in zone 1 of Sui Main Limestone.

3.3.1.6 Comparison of different porosities

Fig 3.23 represents a composite relationship between different porosities in the reservoir zone. As it is evident from the graph that Neutron porosity and effective porosity have almost a direct relationship. Increasing values of neutron porosity result in increasing effective porosity. Also average porosity, effective porosity and neutron porosity have a direct relationship. Increasing values of average porosity and neutron porosity result in incrementing effective porosity and vice versa.

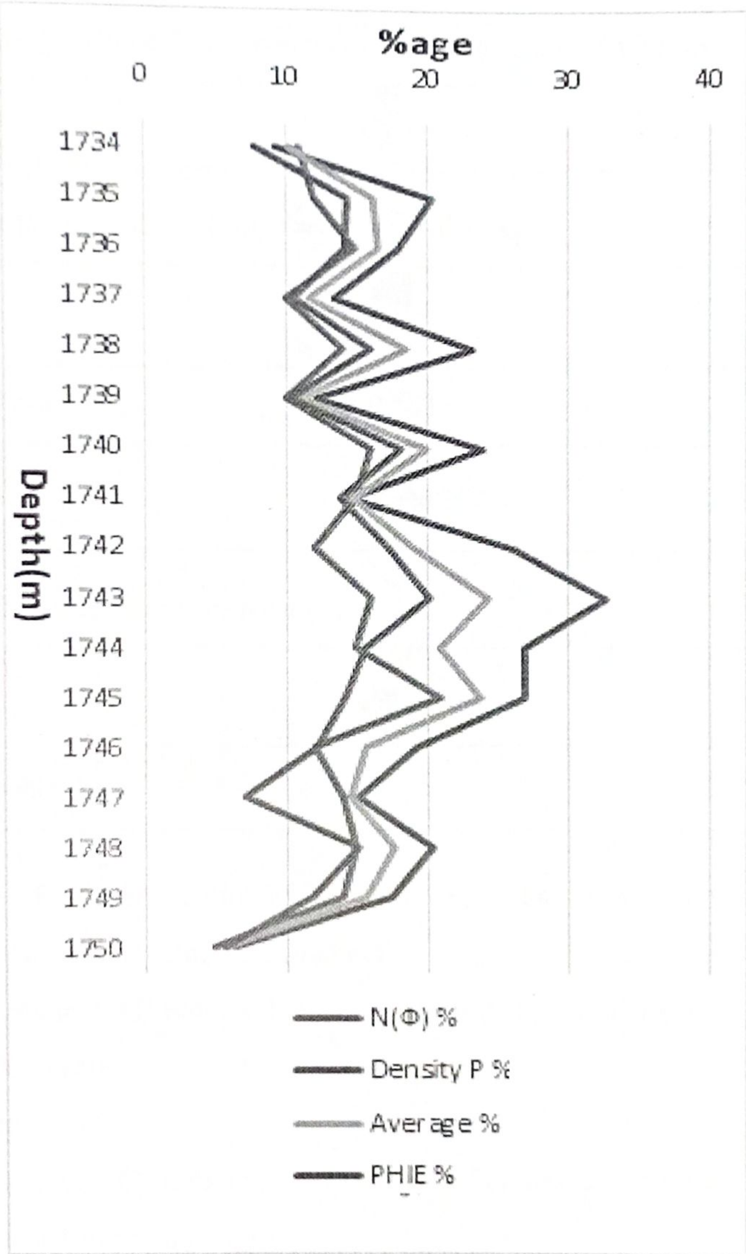

Fig 3.23. Comparison of different porosities in zone 1 of Sui Main Limestone.

3.3.1.7 Estimation of resistivity of water (Rw)

Table 3.3. Steps of Rw determination.

Geothermal Gradient= $B.H.T - S.Temp \div Total\ Depth$

↓

Formation Temperature=$(Formation\ Top\ \times G.G) + S.T$

↓

Rmf@ Surface Temp $\xrightarrow[\text{By Gen 9 Chart}]{\text{Convert}}$ Rmf@ Formation Temp

↓

Rmf@ Formation Temp $\xrightarrow[\text{By SP-2 chart}]{\text{Convert}}$ Rmfeq

↓

SSP⇒ SSP Log $(SSP_{max} - SSP_{min})$

↓

SSP value $\xrightarrow[\text{SP-1 chart}]{\text{Using}}$ Rweq

↓

Rweq $\xrightarrow{\text{Using Sp-2 chart}}$ Rw

The procedure for the calculation of Rw using Gen 9 charts is as follows:

- Calculation of Geothermal Gradient

Geothermal gradient = Bottom hole temp – surface temp / total depth

= 150°C-86°C/ 1780m

= 0.0359°C/m.

- Calculation of formation Temperature = Surface temperature + (Geothermal Gradient * Formation top)

= 86 + (0.0359*1695)

= 86+ 60.85°C

= 146.85°

- Rmf from log header i.e. 0.365@ 86°F
- Calculation of Rmf at 86°F i.e. 0.365ohm-m
- Calculation of Rmf at formation temperature using Gen-9 charts. i.e. 0.235 ohm-m

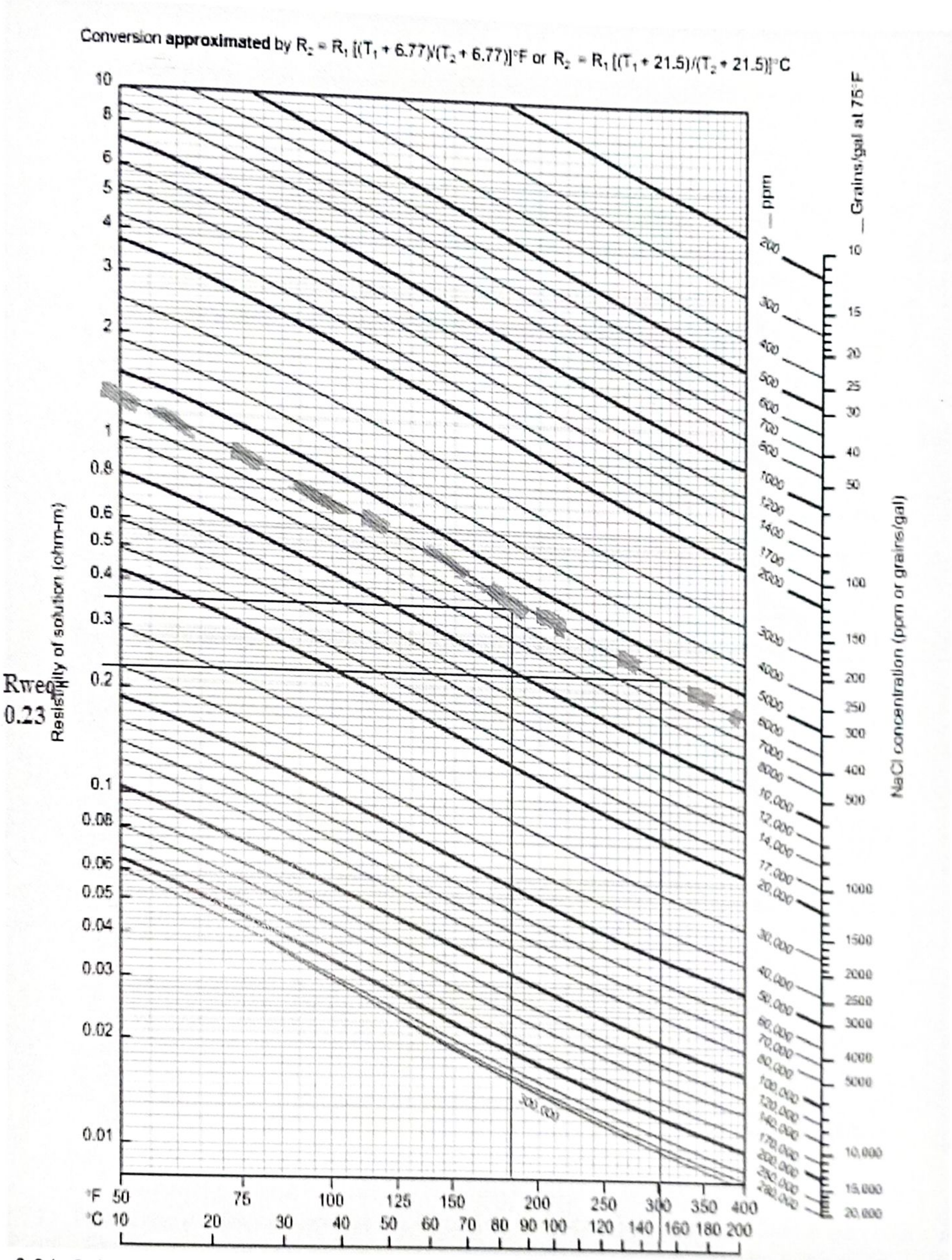

Fig 3.24. Calculation of Rmf at formation temperature for Sui Main Limestone. (Shlumberger catalogue, 2001).

Rmf at formation temperature= 0.23 ohm-m

- Calculation of Rmfeq as Rmf> 0.1 so multiply it with 0.85 = 0.23*0.85=0.195
- Calculation of SSP using SP log i.e. maximum deflection off the SP curve i.e. +8mv
- Calculation of resistivity of water equivalent

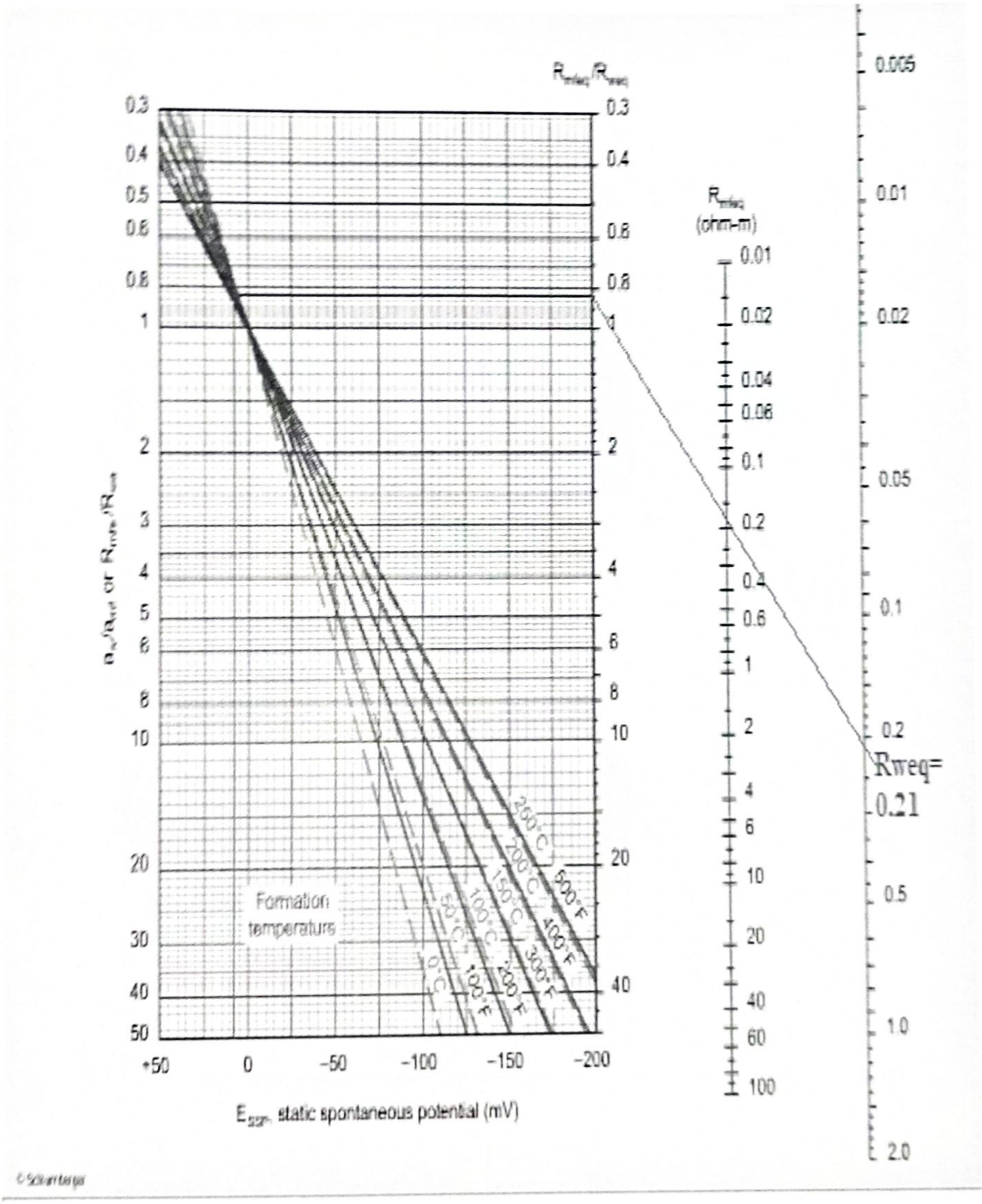

Fig 3.25. Resistivity of water equivalent calculation for Sui Main Limestone (Shlumberger catalogue, 2001).

Resistivity of water equivalent = 0.39

➢ Calculation of resistivity of water (Rw)

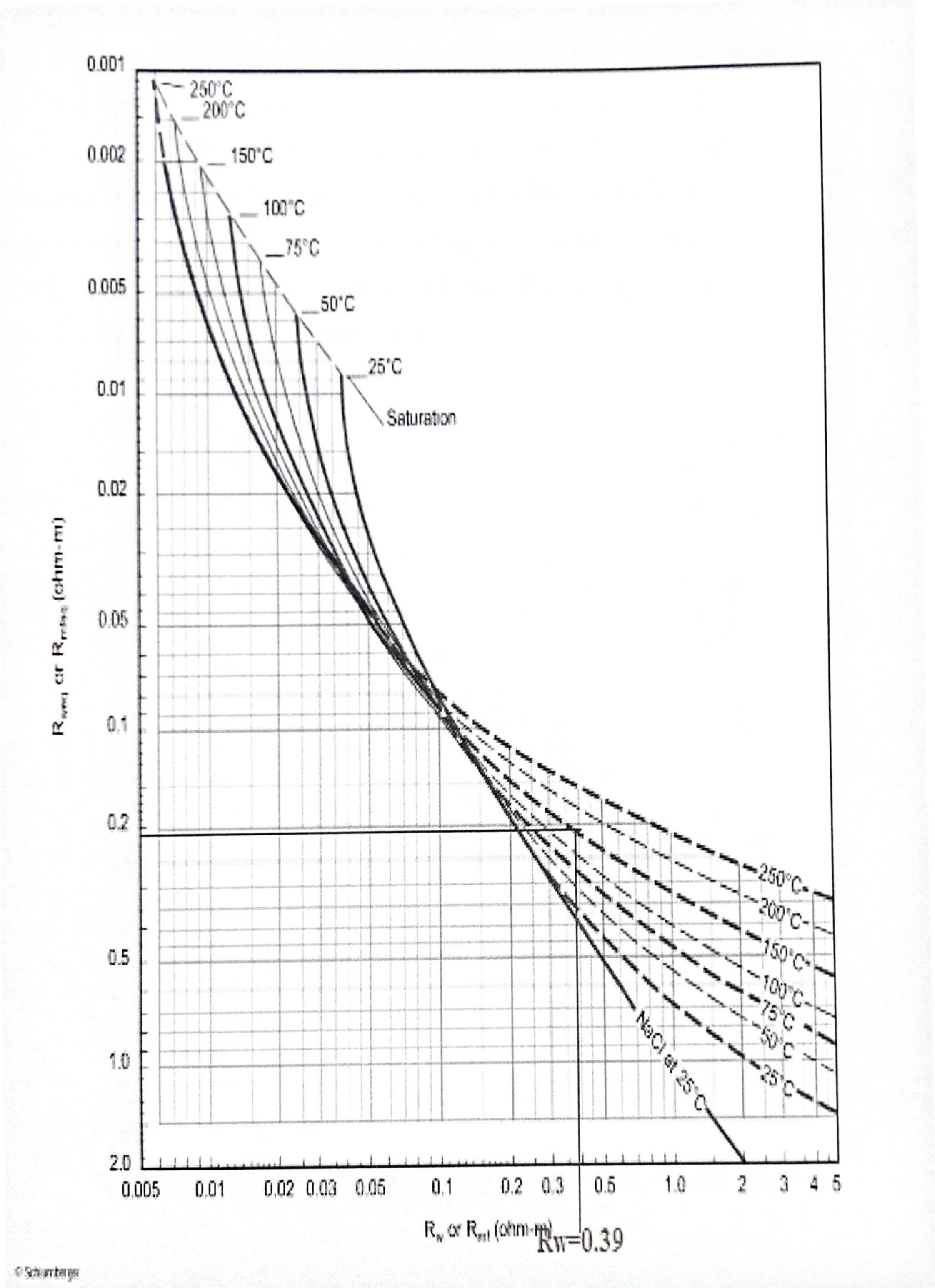

Figure 3.26. Calculation of Rw, Rweq for Sui Main Limestone (Shlumberger catalogue, 2001).

Resistivity of water turned out to be 0.025 ohm-m for Sui Main Limestone Formation. The calculated water resistivity will be used in the Archie's equation to determine the water saturation and ultimately hydrocarbon saturation.

3.3.1.8 Water and hydrocarbon saturation

Fig 3.27 shows the water and hydrocarbon saturation in the zone of interest. The average value of saturation of water (Sw) is 21.59% in the zone of interest. Maximum value water saturation is 57.54% at the depth of 1734m and sudden decrease to very low values in the middle zone. The declining reaches to the minimum value of 8.29% at the depth of 1740m.Whilethemaximum value of hydrocarbon saturation is observed at 1740m which is 91.70% and minimum value of 42.45% is observed at the depth of 1734m. The average value of hydrocarbon saturation is 78.40% in the zone of interest.

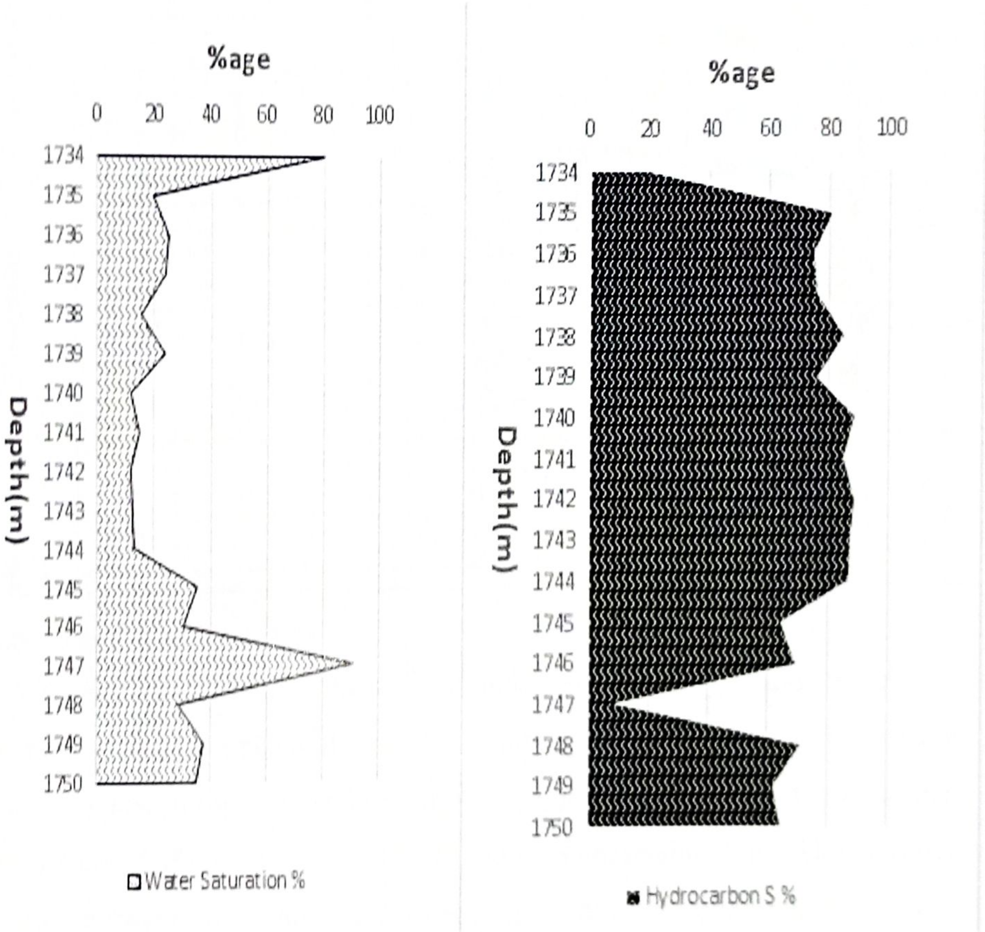

Fig 3.27. Water and Hydrocarbon saturation (%) in zone-01 of Sui Main Limestone.

3.3.2 Zone 2 (1756-1780m)

Zone	Lithology	Starting depth(m)	Ending depth(m)	Total thickness(m)
2	Limestone	1756	1780	25

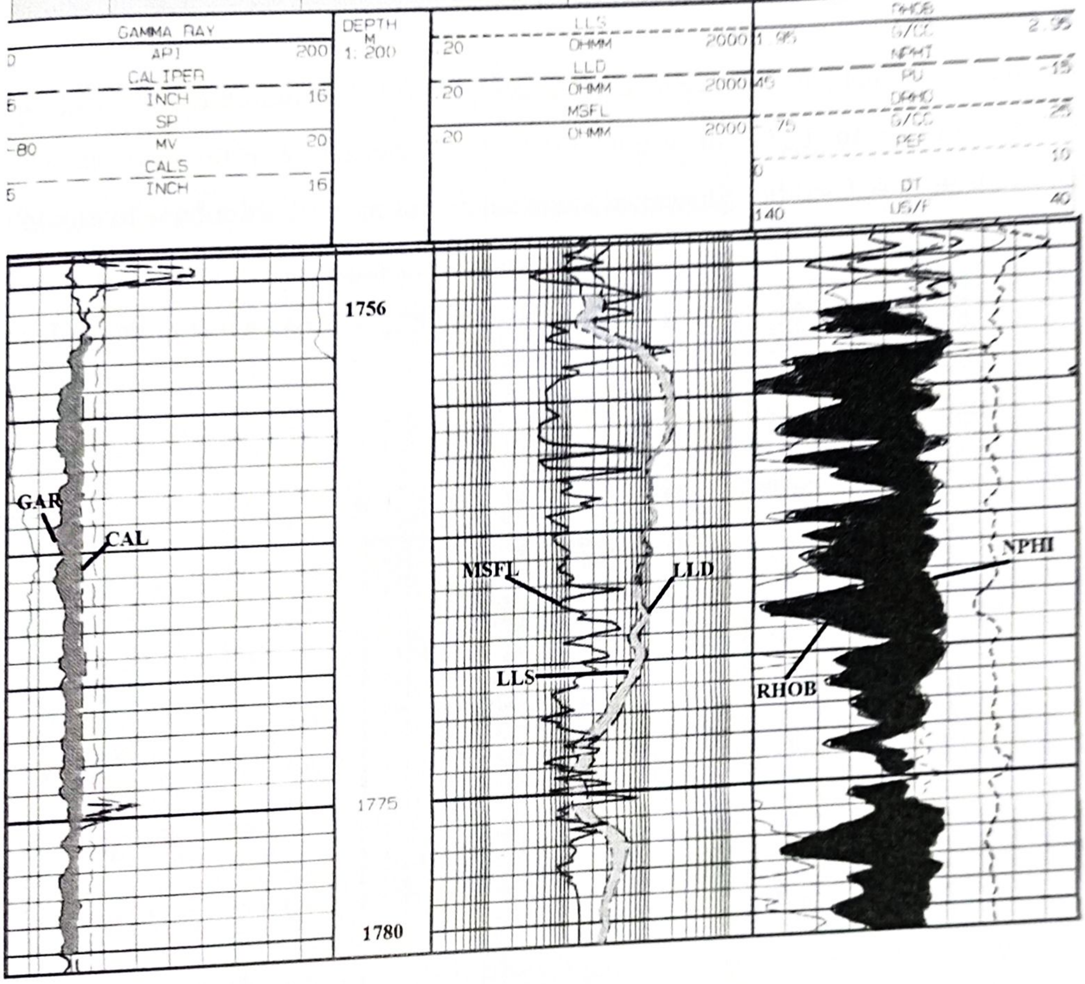

Fig 3.28. Zone 2 of interest.

Zone-02 is marked on the basis of under-gauge caliper reading which shows the formation of mud-cake in the borehole ranging from 1756-1780m. Gamma ray is reading very low in the zone and resistivity logs also confirm the potential of the zones, Where MSFL reads low and LLD and LLS are reading high. The considerable separation between LLD and LLS further supports the presence of fluids in the zones of interest.

Fig 3.28 represents zone-02 showing low gamma ray, under-gauge caliper, cross over between density and neutron.

3.3.2.1 Volume of shale

Fig 3.29 represents volume of shale and volume of sand with respect to depth in this zone-02 of Sui Main Limestone Formation ranging in depth from 1756-1780m. The average volume of shale turned out to be 24.41% and that of sand turned out to be 75.58%. Volume of shale is high in start but then gradually start decreasing and reaches to its minimum value of 14.28% at the depth of 1766m. The maximum value of shale i.e32.46% is achieved in the beginning at the depth of 1757m. However volume of sand initially from low value starts increasing and reaches to its maximum value of 85.71% at the depth of 1766m. The minimum value 67.53% is achieved in the beginning at the depth of 1757m.

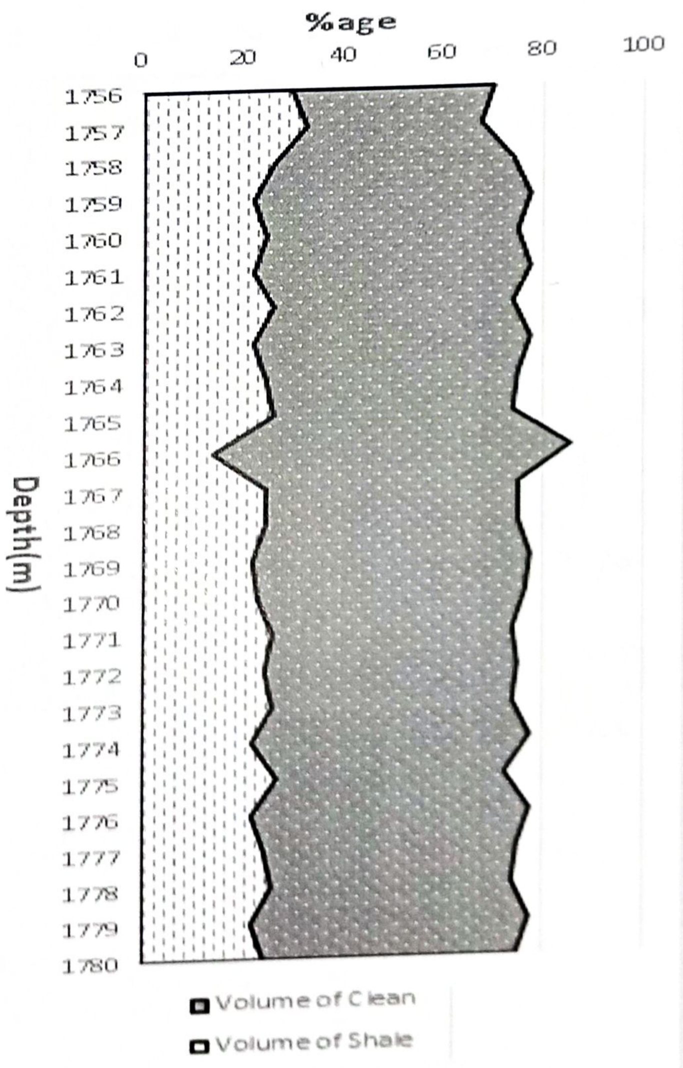

Fig 3.29. Volume of shale and volume of sand in zone-02 of Sui Main Limestone.

3.3.2.2 Calculation of porosity

3.3.2.3 Bulk density and density porosity

As it is evident from fig 3.30 that density porosity and bulk density have inverse relationship. The very low values of density porosity in the beginning reaches to its minimum value of 9.81% at the depth of 1756m however bulk density reaches to maximum value of 2.55 g/cc at the same depth. The maximum value of density porosity is 45.39% at the depth of 1760m, whereas bulk density reaches its minimum value of 1.97 g/cc at the depth of 1760m. The average value of density porosity is 28.44% in the zone of interest and that of bulk density is 2.22 gm/cc.

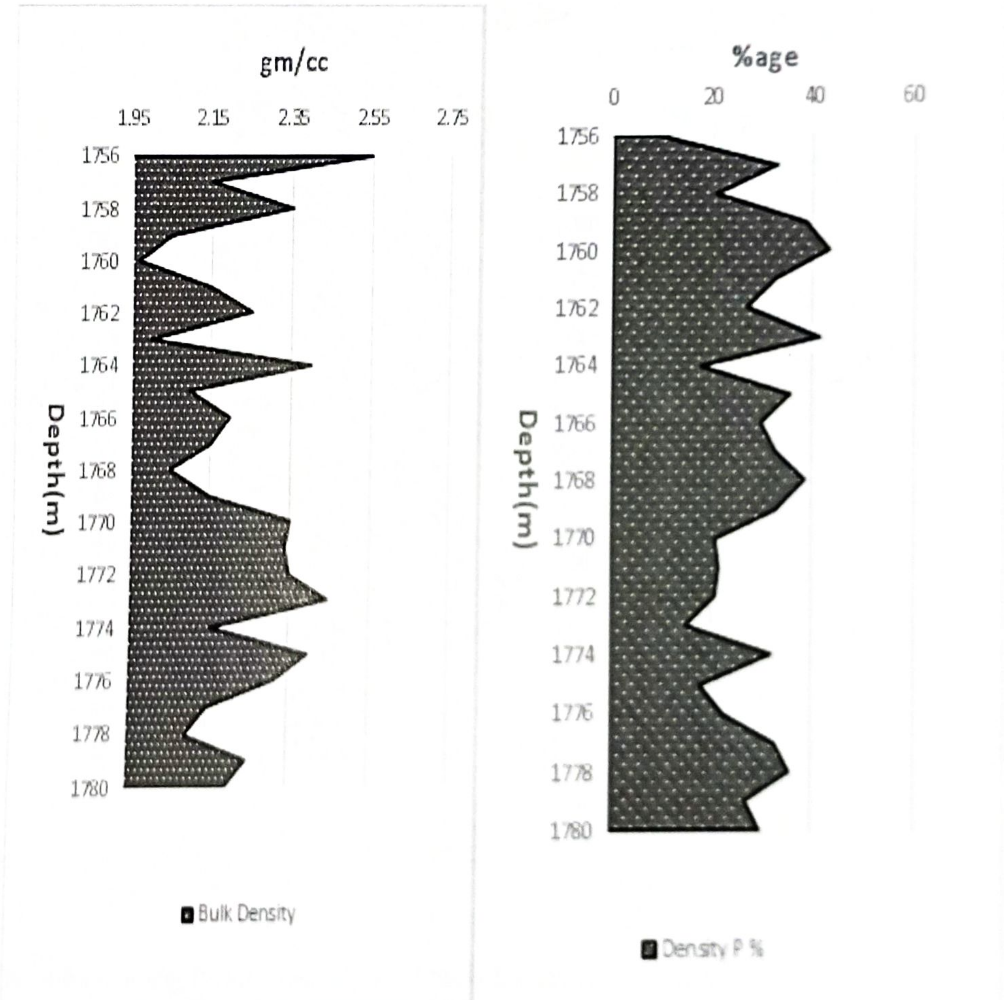

Fig 3.30. Bulk density vs Density porosity in zone-02 of Sui Main Limestone.

3.4.2.4 Neutron porosity

Fig 3.31 indicates the behavior of neutron porosity in the marked zone of interest. In the beginning, neutron porosity values were so high and then abruptly starts decreasing to its minimum value of 9% at the depth of 1769m. The maximum value reach to 21% at the depth of 1757m. The average value of neutron porosity is 12.8%.

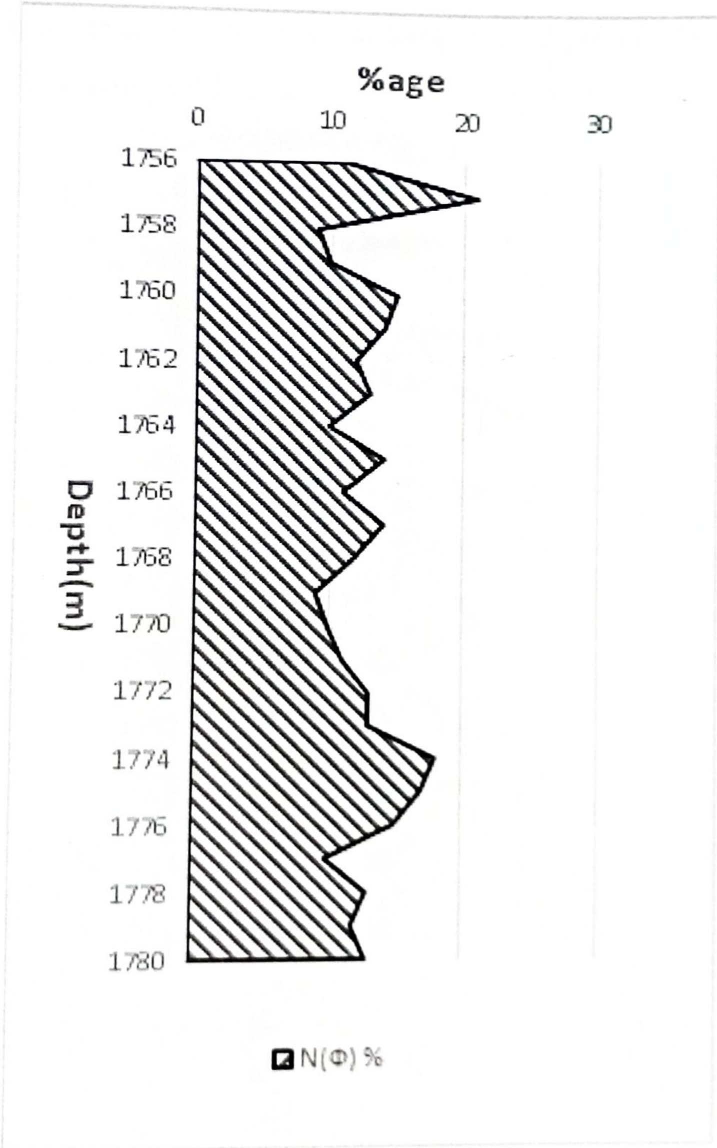

Fig 3.31. Neutron porosity (%) in zone-02 of Sui Main Limestone.

3.3.2.5 Average porosity, effective porosity and their relationship

Fig 3.32 represents the average porosity and effective Porosity present in the reservoir zone of Sui Main Limestone Formation ranging from 1756-1780m. In the beginning average porosity is very low then starts decreasing to its minimum value of

10.17% at the depth of 1756m, in the middle there is an abrupt increment and then decrement and the same phenomena repeats in the next interval. The maximum value of 29.13% is observed at the depth of 1760m. However the average value turned out to be 20.62% in the zone of interest which is fair enough for a reservoir to be in a producing state.

Effective Porosity showing almost the same trend as average porosity represents. In start from minimum value of 7.13% at the depth of 1756m start increasing up to the maximum value of 21.94% at the depth of 1760m. The average value of effective porosity is 15.60%.

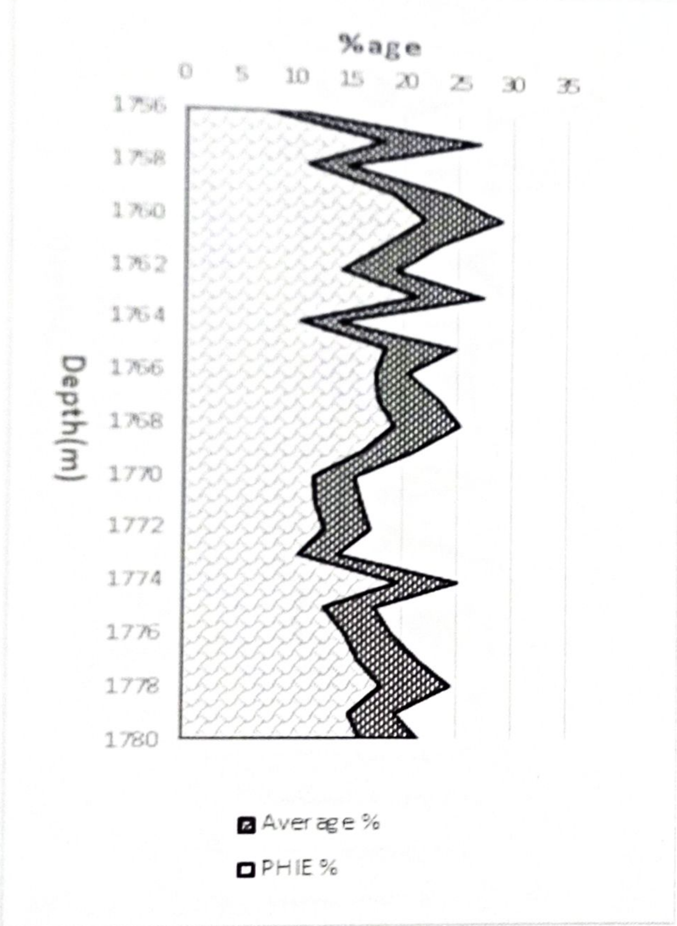

Fig 3.32. Relationship between average porosity and effective porosity in zone-02 of Sui Main Limestone.

3.3.2.6 Comparison of different porosities

Fig 3.33 represents a composite relationship between different porosities in the reservoir zone. As it is evident from the graph that Neutron porosity and effective porosity have almost a direct relationship. Increasing values of neutron porosity result in increasing effective porosity. Also average porosity, effective porosity and neutron porosity have a direct relationship. Increasing values of average porosity and neutron porosity result in incrementing effective porosity and vice versa.

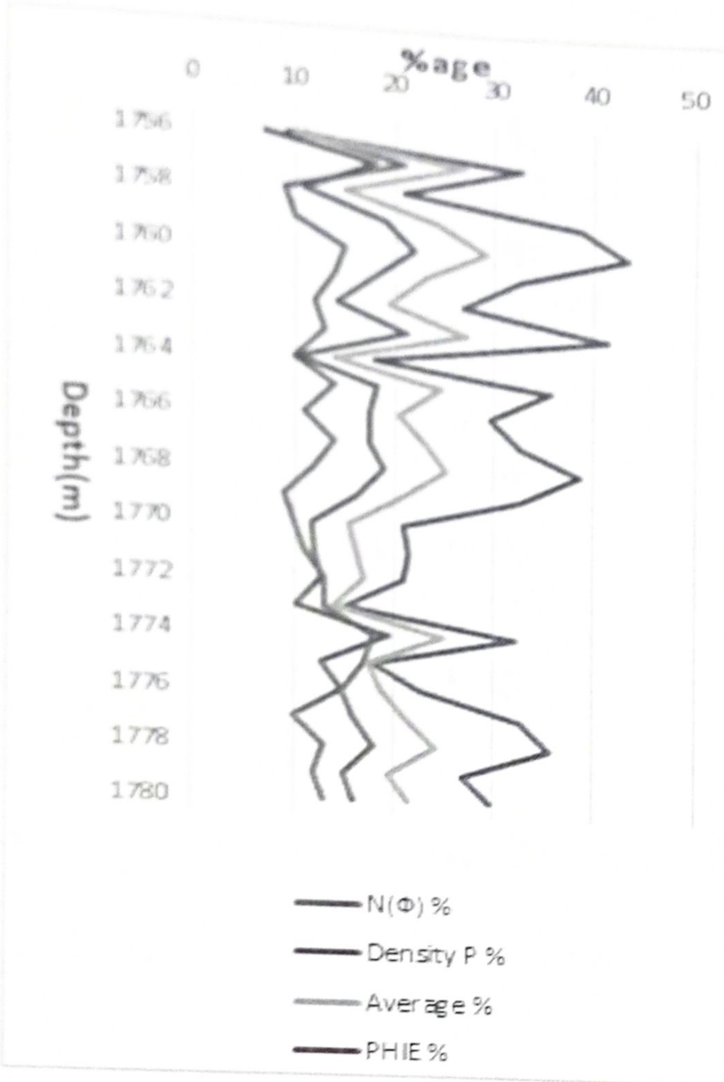

Fig 3.33. Comparison of different porosities in zone-02 of Sui Main Limestone.

3.3.2.7 Water and hydrocarbon saturation

Fig 3.34 shows water and hydrocarbon saturation in the reservoir zone of interest. The maximum value of water saturation appears at the depth of 1756m which is 71.43% and the minimum value of water saturation appears to be 9.04 at the depth of 1760m. The average value of Sw is 23.43% in the zone of interest. While the maximum value of hydrocarbon saturation appears at the depth of 1760m which is 90.95% and the minimum value of hydrocarbon saturation appears to be 28.56% at the depth of 1756m. The average value of hydrocarbon saturation is 76.56% in the zone of interest.

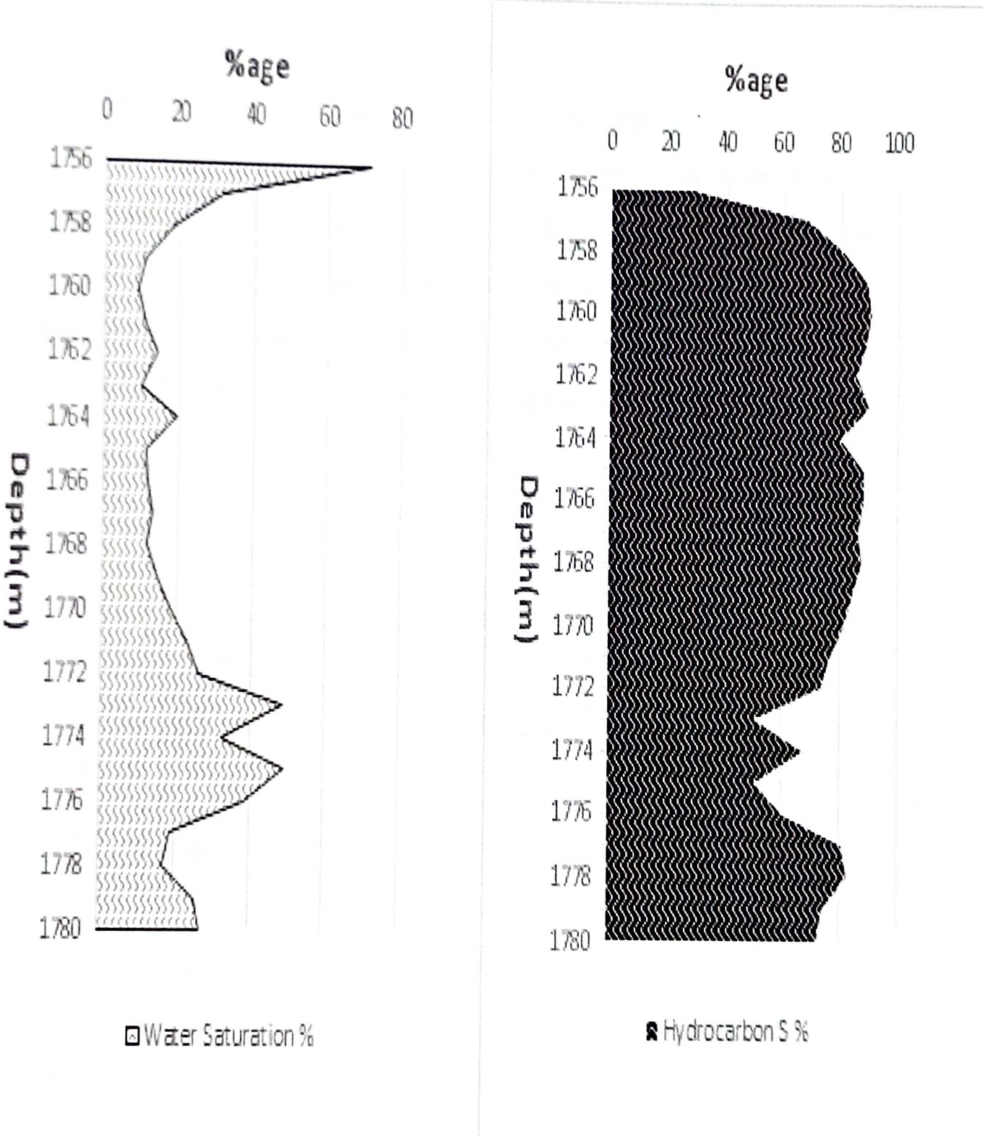

Fig 3.34. Water and Hydrocarbon saturation (%) in zone-02 of Sui Main Limestone.

CONCLUSIONS

On the basis of logs behavior two zones have been marked in Sui Main Limestone of Qadirpur 14 and 15. Petrophysical analysis revealed that:

a) Volume of shale in zone 1 and zone 2 of Qadirpur 14 are 10.54% and 20.27% respectively, effective porosity in zone 1 and zone 2 are 13.13% and 14.22% respectively, whereas water saturation of zone 1 and zone 2 are 34.75% and 34.42% respectively.

b) Similarly volume of shale in zone 1 and zone 2 of Qadirpur 15 are 17.41% and 24.41% respectively, effective porosity in zone 1 and zone 2 are 13.26% and 15.60% respectively, where as water saturation of zone 1 and zone 2 are 21.59% and 23.43% respectively.

On the basis of petrophysical interpretation both the zones marked within Sui Main Limestone of Qadirpur 14 and 15 have fair to good hydrocarbon potential.

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APPENDIX

Qadirpur 14- Zone 1

Depth (meter)	Vshale %	Vclean %	D(Φ) %	Φavg %	Φe %	Sw %	Sh %
1813	12.857	87.142	4.093	6.546	5.7	80.42	19.574
1814	4.285	95.714	15.204	12.102	11.58	38.6	61.392
1815	12.857	87.142	9.356	8.6783	7.562	49.97	50.021
1816	14.285	85.714	8.771	8.885	7.616	53.6	46.399
1817	12.857	87.142	21.637	18.818	16.39	27.27	72.729
1818	2.857	97.142	22.807	18.903	18.36	24.35	75.646
1819	1.428	98.571	9.941	9.47	9.335	47.9	52.095
1820	12.857	87.142	25.73	20.865	18.182	20.08	79.917
1821	4.285	95.714	16.374	12.687	12.143	21.62	78.374
1822	1.4285	98.571	12.865	14.432	14.226	16.8	83.197
1823	12.857	87.142	33.333	24.166	21.059	12.69	87.309
1824	15.714	84.285	22.222	18.111	15.265	24.76	75.239
1825	28.571	71.428	18.128	18.564	13.26	33.72	66.274

Qadirpur 14- Zone 2

Depth (meter)	Vshale %	Vclean %	D(Φ) %	Φavg %	Φe %	Sw %	Sh %
1831	14.286	85.714	11.111	10.056	8.619	53.517	46.483
1832	12.857	87.143	11.696	8.848	7.710	59.508	40.492
1833	7.143	92.857	8.772	8.886	8.251	55.902	44.098
1834	7.143	92.857	16.374	15.687	14.567	31.334	68.666
1835	28.571	71.429	26.901	18.450	13.179	35.379	64.621
1836	18.571	81.429	17.544	15.772	12.843	35.540	64.460
1837	28.571	71.429	16.374	15.687	11.205	40.317	59.683
1838	25.714	74.286	23.977	19.488	14.477	31.528	68.472
1839	18.571	81.429	15.205	14.602	11.890	38.188	61.812
1840	22.857	77.143	16.374	15.187	11.716	39.164	60.836
1841	25.714	74.286	20.468	15.734	11.688	39.465	60.535
1842	18.571	81.429	16.374	14.187	11.552	39.510	60.490
1843	15.714	84.286	9.357	10.178	8.579	45.721	54.279
1844	25.714	74.286	10.526	17.263	12.824	34.873	65.127
1845	24.286	75.714	35.673	26.836	20.319	24.608	75.392

1846	15.714	84.286	40.936	29.468	24.837	20.131	79.869
1847	22.857	77.143	36.842	24.421	18.839	24.749	75.251
1848	15.714	84.286	39.766	25.883	21.816	15.280	84.720
1849	18.571	81.429	27.485	18.743	15.262	23.925	76.075
1850	18.571	81.429	9.942	10.471	8.526	37.089	62.911
1851	25.714	74.286	28.070	23.035	17.112	26.135	73.865
1852	25.714	74.286	32.749	25.374	18.849	23.966	76.034

Qadirpur 15- Zone 1

Depth	Vshale %	Vclean %	Density P %	Average %	PHIE %	Sw%	Sh %
1734	22.08	77.92	9.36	10.18	7.93	80.36	19.64
1735	11.69	88.31	20.47	16.23	14.34	19.48	80.52
1736	14.29	85.71	18.13	16.56	14.20	25.39	74.61
1737	9.09	90.91	13.45	11.73	10.66	23.92	76.08
1738	14.29	85.71	23.39	18.70	16.03	15.29	84.71
1739	6.49	93.51	12.28	11.14	10.42	24.08	75.92
1740	9.09	90.91	23.98	19.99	18.17	11.59	88.41
1741	6.49	93.51	14.62	14.81	13.85	15.03	84.97
1742	9.09	90.91	26.32	19.16	17.42	11.63	88.37
1743	16.88	83.12	32.75	24.37	20.26	12.58	87.42
1744	24.68	75.32	26.90	20.95	15.78	13.05	86.95
1745	40.26	59.74	26.90	23.95	14.31	35.64	64.36
1746	22.08	77.92	19.30	15.65	12.19	30.61	69.39
1747	50.65	49.35	15.20	14.60	7.21	91.35	8.65
1748	14.29	85.71	20.47	17.73	15.20	29.05	70.95
1749	24.68	75.32	17.54	15.77	11.88	38.14	61.86
1750	0.00	100.00	6.43	5.72	5.72	35.44	64.56

Qadirpur 15- Zone 2

Depth	Vshale %	Vclean %	Density P %	Average %	PHIE %	Sw%	Sh %
1756	29.9	70.13	9.36	10.18	7.14	71.43	28.57
1757	32.5	67.53	32.75	26.87	18.15	31.41	68.59
1758	26.0	74.03	21.05	15.03	11.12	18.71	81.29
1759	22.1	77.92	38.60	24.30	18.93	10.65	89.35
1760	24.7	75.32	43.27	29.14	21.95	9.04	90.96
1761	22.1	77.92	32.75	23.37	18.21	10.84	89.16
1762	26.0	74.03	26.90	19.45	14.40	14.15	85.85
1763	22.1	77.92	41.52	27.26	21.24	9.85	90.15
1764	24.7	75.32	18.13	14.06	10.59	19.43	80.57
1765	26.0	74.03	35.67	24.84	18.39	11.32	88.68
1766	14.3	85.71	29.82	20.41	17.50	11.90	88.10
1767	24.7	75.32	32.75	23.37	17.61	13.41	86.59
1768	24.7	75.32	38.60	25.30	19.06	12.05	87.95
1769	22.1	77.92	32.75	20.87	16.27	14.94	85.06
1770	23.4	76.62	21.05	15.53	11.90	18.56	81.44
1771	26.0	74.03	21.64	16.32	12.08	23.12	76.88
1772	24.7	75.32	21.05	17.03	12.83	26.41	73.59
1773	26.0	74.026	15.20	14.10	10.44	48.84	51.16
1774	22.1	77.922	32.16	25.08	19.54	32.28	67.72
1775	27.3	72.727	18.13	17.56	12.77	49.38	50.62
1776	22.1	77.922	22.81	18.90	14.73	38.70	61.30
1777	24.7	75.325	32.75	21.37	16.10	19.16	80.84
1778	26.0	74.026	35.67	24.34	18.02	17.33	82.67
1779	22.1	77.922	26.90	19.45	15.16	25.55	74.45
1780	24.7	75.325	29.82	21.41	16.13	27.38	72.62