Petrophysical Evaluation of Meyal 10 & Meyal 13 Oil Wells of Meyal Oil Field In Potwar Plateau Using Wireline Logs

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بسم الله الرحمن الرحيم

In The name of Allah,Most Gracious.

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Certificate

This thesis submitted by **Mr. Anjum Taj and Mr. M. Usman Khan** is accepted in the present form by Faculty of Earth & Environmental Sciences, Bahria University, Islamabad as satisfying the partial fulfillment of the requirement for the degree of **Master of Sciences** in **Geology.**

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Dedicated To:

Dedicated to my loving parents whose devotion and inspiration towards knowledge served me as beacon of light, who always pray for my success and prosperity. Whose encouragement, sacrifices and generous support both morally and financially enabled me to achieve this goal.

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Acknowledgement

First of all I pay my deepest thanks to Almighty Allah, who enabled me to complete my thesis successfully.Durood-0-Salam upon the Holy Prophet Hazrat Muhammad (PBUH) due to whom this beautiful universe is created and who is the Prophet of peace and humanity in this universe.

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ABSTRACT

The Meyal Oil Field is one of the major oil and gas providing filed in the Potwar Plateau Upper Indus Basin; Northern Punjab – Pakistan. Field was discovered by Pakistan Oil Field Limited. Sixteen Wells have been drilled so far in this field, which produced 36MMbbl oil and 250BCF of gas from Paleogene carbonates and Jurassic sand.

This study constitutes an important partial aspect of Meyal Oil Field; in this study we evaluate Porosity, water saturation, true resistivety of formation water and volume of shale. Logging tools, principle, brief tool configuration and uses have also been described.

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CHAPTER NO 1
INTRODUCTION

1.1 INTROCUTION:

The potwar plateau is the northern most structural feature of the Upper Indus Basin, bounded by Main Boundary Thrust (MBT) and Kala Chitta Range in the North and Salt Range in the South. Large scale thrusting of sedimentary sequence along basal decollement in the Eocambrian Salt Range Formation rise to this spectacular tectonic feature. The hydrocarbon exploration in the foreland fold and thrust belt of Potwar Plateau is more than a century old and first discovery in the region was made in 1915 at Khaur (M.A.Khan, 1985). Since then, the continued hydrocarbon exploration efforts reflect the high prospectivety of the area.

Meyal has been one of the well defined leads out of the several delineated structures by the seismic survey; subsequently it has experienced several phases of the exploration/exploitation and renewed drilling. Proximity of Meyal to the known potential fields like Dakhni, Pairwali, Durnal, Ratana and Toot made it very attractive for the exploration companies.

Meyal is a salt cored, thrust bounded sub-surface anticline. The first mapping of this area was carried out in 1923 (E.T.Vechell and J.Parkinson 1923). Burma Oil company first drilled three wells from 1916 to 1923 (G.R Gardazum 1982) all the three wells were dry. Later on Attock Oil Company covered this area and they carried out the first detailed mapping of the structure in 1942 (W.D.Gill, 1942). On the basis of this mapping Attock Oil Company drilled two wells. The first well was drilled in 1942-43 (G.R.Gardazi, 1982), which was abandoned as a result of the collapse of 8-5/8 casing.

The second well of Attock Oil company at the same site was drilling 1945 (G.R.Gardazi, 1982) and abandoned because the crossed a thrust at 8000 feet and possible entered Kamlial Formation. After this they remapped the area in 1946 and drilled the well No.3, which was abandoned due to mechanical problems. In 1960-61, Pakistan Oil Field Limited (POL) applied for the Exploration license over the Pindi Gheb area including Meyal Kharpa Structure. Pakistan Oil Field contracted Seismographic service limited to carry out a seismic reflection. So the oil and gas development company carried out a seismic reflection survey in 1965-66. The first commercial discovery of the oil was made in November 1968 (POL report 1989) from Eocene Limestone. After this discovery sixteen wells have been drilled till date to develop this field.

1.2 LOCATION

The Meyal oil field is situated 120 kilometers in southwest direction from Rawalpindi, (Latitude : 33° 17' North and Longitude : 72° 09' East) In Meyal village of Pindi Gheb Tehsil of district Attock and Meyal 10 and Meyal 13 wells are development wells of Meyal Oil field and it lies about:

Meyal 10: (Latitude : 33° 16' 30" and Longitude : 72° 10' 54")

Meyal 13: (Latitude : 33° 16' 42" and Longitude : 72° 08' 21")

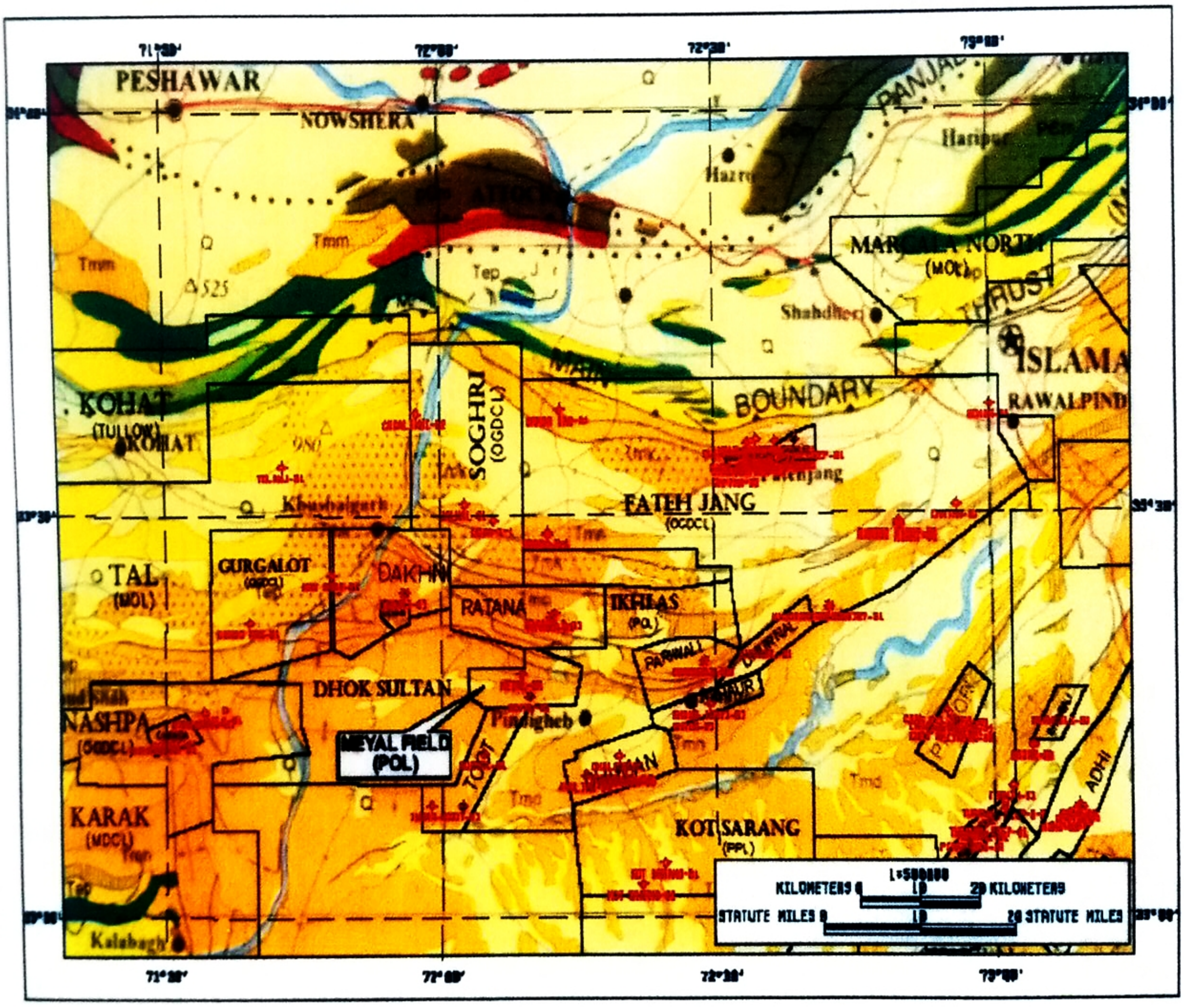

Fig No – 1.1 Showing Map of Study Area

1. 3 EXPLORATION AND DEVELOPMENT HISTORY:

Meyal-Kharpa surface feature had remained a key target for the petroleum geologists from the onset. In Meyal the first AOC well was drilled during 1942-44 which was abandoned at 84900 ft due to collapse of 8 5/8 inches casing. AOC well- 2 was drilled almost at the same site of well – 1, to 10,501 ft during 1945 and was plugged and abandoned due to the belief that the well had crossed a thrust fault and possibly re-entered into Miocene age Kamlial Formation. Well-3 was drilled after re-mapping of the structure on the anticlinal nose at the western end of the structure. After drilling to the depth of 8,100 ft the well had to be abandoned due to mechanical reasons.

Further geological studies were carried out by AOC geologists. Z.H Jafri and N.R Martin in 1955 recommended that the pervious unsuccessful drilling results could not diminish the prospects of the structure. It was also appreciated that subsurface structural definition could not be interpreted solely on the surface geological data.

Pakistan oil fields limited applied for an Exploration license over the Pindi Gheb area, including Meyal-Kharpa structure and seismic reflection and refraction survey was conducted in 1960-61 that was found inconclusive. However, it helped to establish that to the south an anticlinal axis appeared to be rising towards the western part of the fold.

After evaluating all the available geological, seismic and well data another seismic survey was planned over the southern part of the structure. During 1965-66 a seismic survey was conducted that helped in identifying three subsurface highs. The high was located south of the surface anticlinal feature and was selected for testing.

POL spudded its first well in Meyal on November 2, 1967 and drilled to Eocene Chorgali-Sakesar formations to 12,514 ft. After Testing, the well was put on production in November 1968. The sustained production of the well was 1,371 BOPD and 5 MMSCFD as on 1.1.1968. Discovered oil was light having 44.1 API gravity. Reservoir pressure was estimated to be approximately 6,900 Psi.

1.4 PETROLEUM GEOLOGY

Structure

Meyal-Kharpa surface structure is an east-west trending narrow steep faulted anticline with two major thrust cutting the structure longitudinally. The subsurface structure does not lie directly underneath the surface structure.

A southwest shift of subsurface structure to the surface structure exists. This shift is likely to be due to relatively younger transpersonal movement of the blocks. Pervious exploratory attempts were mainly based on the surface geological mapping. Seismic data acquisition during 1965-66 had helped identify the subsurface structure configuration.

At the Eocene level the sub-surface structure is defined as east-west trending pop-up, salt cored doubly plunging, gentle dipping anticlinal fold bounded by thrust faults in the north and south. The eastern part of the fold is slightly tightened than the west one. Most of the wells were drilled in the central part of the Eocene structure. Trapping mechanism in the Meyal field is structural.

CHAPTER NO 2

GEOLOGY OF THE AREA

2.1 GENERALIZED STRATIGRAPHY OF THE AREA.

Sedimentation in the Potwar Basin started in late Precambrian and lasted until the Pleistocene. The deposition was however interrupted several times, with the two major breaks, between the Cambrian and Precambrian and between Eocene and Miocene. From bottom to top, the Stratigraphic section can be divided into four groups.

1. Basement complex
2. Salt range formation
3. Platform section
4. Molassic section

The basement complex is of Precambrian age and consists of metamorphic and volcanic rocks of Indian shield. The Eocambrian salt range formation is evaporates and sedimentary until that forms the level of decollement for the fold and thrust belt. The platform section consists of Cambrian to Eocene shallow water sediments. The Molassic section consists of terrigenous fluvitile sediments. Various cycles of subsidence and uplift, caused by non-organic movements, affected the Pre-Eocene deposition, where as orogenic movements (Himalayan Uplifts) affected Post-Eocene fluvial sedimentation. The stratigraphy exposed in Meyal area is divided into two groups on the bases of the basis of occurrence.

A. Surface occurrence
B. Subsurface occurrence

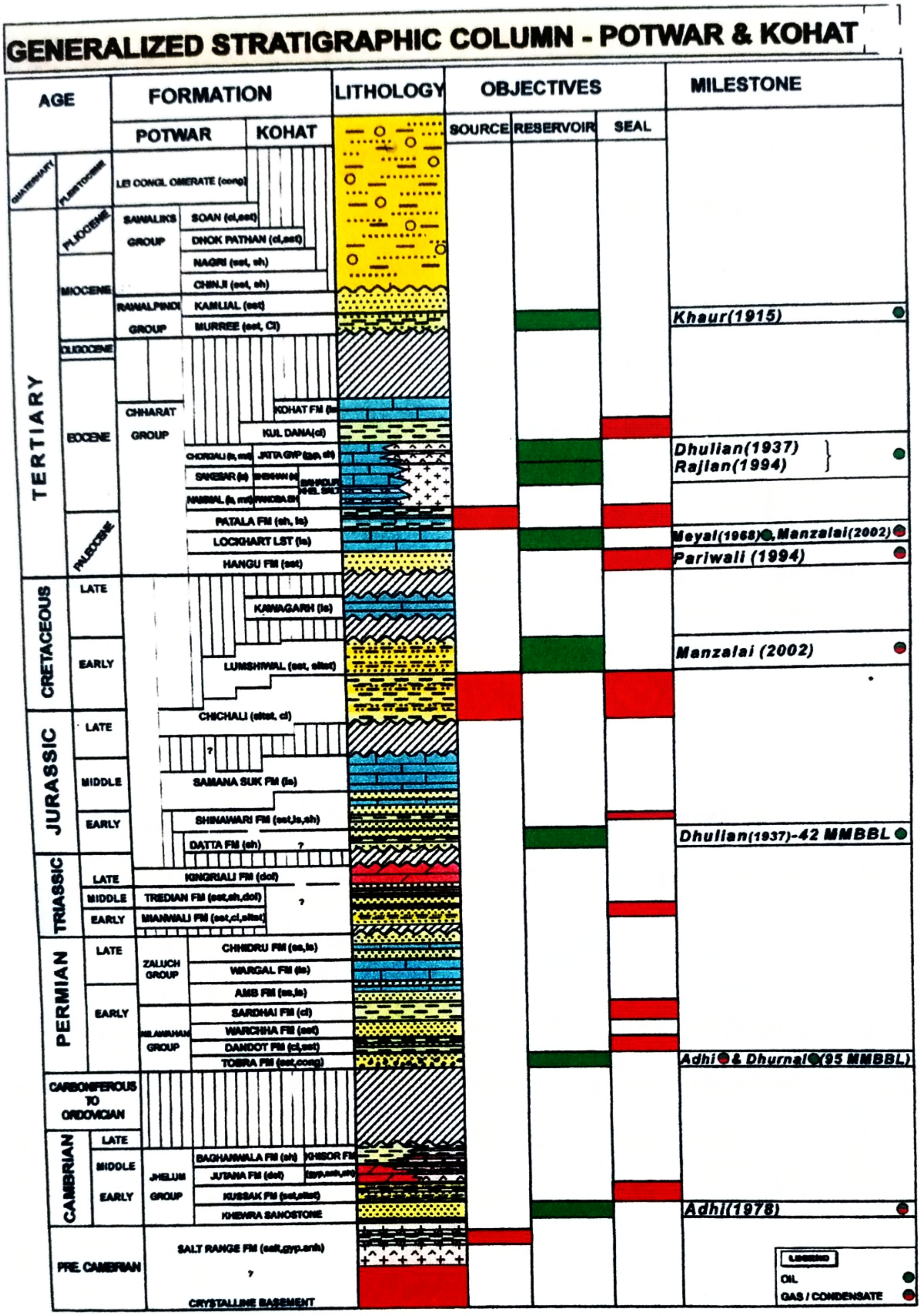

Fig No 2.1 Generalized Stratigraphic Column – POTWAR & KOHAT

2.2 SURFACE OCCURRENCE

2.2.1 NAGRI FORMATION

Lewis first gave the name Nagri formation in the village of Nagri in the Attock district has been designated as the type locality. The Gaj River section in the Dadu District is proposed as the principal reference section.

In Meyal, the formation consists of sandstone with subordinate clay and conglomerates. The sandstone is widely distributed and occurs as yellow, olive, grayish, white or purple colored. It is cross grained than the Chingi formation.

The clay is sandy or silty where as conglomerates show variation in thickness and composition in different areas.

2.2.2 CHINGI FORMATION

Lewis (1937) proposed the name Chingi formation and the same were accepted as such by the Stratigraphic Committee of Pakistan. The section south of Chingi village in the Attock district has been designated as a type locality.

Broadly the formation is divided into two divisions; the lower predominantly is red claystone sequence while the upper predominantly is subordinate ash gray or brownish sandstone. The red claystone of the typical Chingi formation are brighter than those of the Kamlial, this formation shows fluvial environment of deposition (Jaswal *et.al.*, 1997).

2.2.3 KAMLIAL FORMATION

The Stratigraphic Committee of Pakistan has formally established the name Kamlial bed. The term "Kamlial formation" was established by the Pinfold (1918) the section southwest of the Kamlial village has been designed as the type locality.

In Meyal the formation consists of purple gray and dark brick-red sandstone, which is medium to coarse grained and contains interbreds of hard purple intra-formation conglomerates. Due to faulting, its base on muree formation is not exposed.

2.3 SUBSURFACE OCCURENCE

The formation in the subsurface exhibits more or less the same characteristics as are observed at the outcrops. Most wells are drilled in the partly eroded Nagri formation penetrates the complete sequence of Chingi and Kamlial formations.

The Kamlial formation rests conformably on the Muree formation, which form the basal part of Mio-Pliocene succession in Meyal

2.3.1 MUREE FORMATION

The Stratigraphic Committee of Pakistan has formally named the Muree series of pilgrim (1910) as Muree formation (S.M.Ibrahim, 1977). A section exposed on the north of the Dhok Maike in the Attock district has been designated as the type locality.

This formation composed of repetitive sequence of dark red, purple clay and greenish gray sandstone with subordinate intra-formational conglomerate. The main body of the formation is poorly fossiliferous.

2.3.2 FATEH JANG MEMBER

The basal part of the muree formation consists of gray to purple gray, coarse grained quartzose sandstone containing derived large forams and limestone pebbles of Eocene age. These pebbles are yellow green and contain abundant forams of Alveolina and Numulites species. This horizon has been designated as Fetehjang member, represented by irregularly varying thickness of few to 53 meters.

2.4 EOCENE SUCCESSION

2.4.1 KOHAT FORMATION (KOHAT BEDS)

Stratigraphic committee of Pakistan formally accepted the Kohat shales of Eames (1952) as Kohat Formation (S.M.Ibrahim, 1977) the section exposed along the Kohat-Khushalgrah highway is the type locality. The Kohat formation consists of alternations of limestone and shale. It can roughly be divided into two parts. The upper part consists of gray hard, compact limestone with gray marly and highly fossiliferous shale.

In the lower part, fossiliferous is pale red to buff, nodular with brecciated structure sparsely fossiliferous while shale is gray to bluish gray and splintery with occasional gypsum steaks. In Meyal, this formation also shows irregular behavior and varies in thickness from 39 meters to 72 meters.

2.4.2 KULDANA FORMATION (RED CLAYS)

The term Kuldana beds were first proposed by Wynne (1874), and Latif (1970) named it Kuldana formation, which was accepted by stratigraphic committee of Pakistan (S.M.Ibrahim, 1977). The type section is located near the village of Kuldana north Muree hill station in the Hazara district.The formation is usually referred as the red clays in some old reports. This formation is composed of shale and marl with occasional beds of sandstone, limestone, conglomerates, and leached dolomite. In Meyal wells; this formation consists of multicolored shales, which have been variously described as red, reddish brown and purple. The shale is usually silty and brittle but occasionally clayey and soft. At various horizons, bands of gray, green and greenish gray splintery shales are also present. There are occasional thin bands of gray to pale gray, fine grained hard, compact limestone. The basal section is also gypsyferous.

The Kuldana formation has conformable contact with underlying Chorgali formation and is usually 50 meters thick in Meyal, though it varies from 40 to 60 meters in some of the wells. The Kuldana formation is considered to be deposited in restricted environments.

2.4.3 CHORGALI FORMATION

The term “Chorgali beds” by Pascoe (1920) has formally been designated as Chorgali formation by the Stratigraphic Committee of Pakistan (S.M.Ibrahim, 1977).The section exposed in Chorgali pass on the Khair-e-Murat Range has been chosen as the type locality.

The top of this formation consists of turquoise colored marls and light bluish green shales underlain by the gray, argillaceous and fractured limestone with thin, black splintery occasional bituminous shale partings. The limestone contains veins, inclusions and nodules of white to pink anhydride. The basal part consists of grey, highly fractured dolomitic limestone with veins and irregular thin layer of gray to black shale showing bituminous luster. This formation in Meyal is about 73 meters thick and its lower boundary with Sakesar lime stone is not only conformable but also lithologically arbitrary and based upon microfossil evidence (G.R.Gardazi, 1983-83).

2.4.4 SAKESAR LIMESTONE

The term Sakesar limestone was introduced by Gee (1935) for the most prominent Eocene limestone unit in the Salt and Trans Indus Ranges. The Sakesar peak in the Salt range has been designated as the type locality.

The formation is dominantly composed of limestone with subordinate marl generally the formation consists of gray to dark gray, argillaceous, to moderate dolomite, massive to occasionally nodular, at some places highly fossiliferous, fractured limestone. The black occasionally bituminous carbonaceous and at some places highly fossiliferous shale partings are present in the sequence. Calcite and anhydrite veins are quite common and some open fractures are lined with calcite crystallization.Sakesar limestone in Meyal field thickness south-westwards and varies from 86-106 meters.

2.4.5 NAMML FORMATION

The term Nammal Formation has been formally accepted by the Stratigraphic committee of Pakistan for the Nammal limestone and shale of Gee (in Fermor, 1935), Nammal marl of Danilchik and Shah (1967) occurring in the salt and Trans Indus ranges.

The section exposed in the Nammal gorge is the type locality. This section is fossiliferous and contains pelagic planktons including Globorotalia and Globogerinas (Haque 1956). The lower part of the formation predominately consists of gray to dark gray, very argillaceous, pyrite, fossiliferous limestone and marls with thin bands of greenish gray, splintery shales. The Nammal formation is about 33 meters thick in Meyal and conformably overlies the upper Ranikot formation of Paleocene age.

2.5 PALEOCENE SUCCESSION

The Paleocene succession in Meyal oil field consists of the following four formations.

- Upper Ranikot Formation
- Patala Formation
- Lockhart Limestone (khairabad limestone)
- Hangu Formation (Dhak Pass Beds)

2.5.1 UPPER RANIKOT FORMATION

The upper Ranikot formation is subsurface facies developed and recognized in Dhulian, Kharu and Meyal oil fields. This formation is most prominent and well developed in the Paleocene succession, and is about 150 meters thick in the southern wells (P.O.L Well No. 2, 5 and 7) and decreases to about 100 meters towards north, and north east.

The top of upper Ranikot is highly fossiliferous and consist of gray, pyretic, glauconitic, shelly (Lamellibranches) limestone which contains operculina patalensis, ranikotensis. This part, which is about 2.4-3 meter thick, has been called Oyster Bed correlating it with a similar band in Dhulian wells where it marks the top of the Paleocene section. Below the Oyster Bed, the limestone is grey, pyretic and highly fossiliferous containing miscellanea, rotalia Trochidiforms and operculina patalensis becoming vugular and nodular downward with highly fossiliferous shales. The vugs and cavities are filled with calcite. The middle part of this formation is gray to dark Gray argillaceous occasionally slightly dolomitic, nodular, vuggy and fractured limestone with highly fossiliferous, black pyritic shale around nodules.

The basal part consists of dark gray, dense compact argiliiaceous and sparsely fossiliferous limestone with scattered nodules and specks of pyrite, with thin bands and streak of black, fissile and pyritic shales. The upper Ranikot formation lies conformable over the Patala formation and the boundary is transitional. The formation represents shallow marine environment of deposition.

2.5.2 PATALA FORMATION

The Stratigraphic Committee of Pakistan formalized the term Patala formation for the Patala shale of Davies and Pinfold in 1935. (S.M Ibrahim 1945).The section exposed in Patala Nala in the Salt range has been designated as type locality. The Patala formation is predominantly shale facies and its lithological characters are similar to the shales occurring in the basal part of upper Ranikot formation. Therefore the fixation of its upper boundary has always been difficult. Generally it consists of dark gray to black fissile and splintery shales with this and occasionally bands of marly limestone. Its thickness varies from 15-19 meters and lies conformably over the Lockhart lime stone. It shows shallow marine lagoonal environment of deposition.

2.5.3 LOCKHART LIMESTONE

Daves (1930) introduce the term Lockhart Limestone for a Paleocene Limestone unit in the Kohat area and the Stratigraphic Committee of Pakistan have extended this usage. The section exposed near Fort Lockhart in the Samana Range has been designated as type locality of the unit. The Lockhart limestone is mainly gray to dark gray, occasionally brownish gray, hard compact and highly fossiliferous limestone with thin bends of ash gray marls. The limestone is also occasionally dolomitic and shows nodular structure. In its basal part, the Lockhart limestone becomes marly and it is inter-layered with dark to black splintery shale. It shows shallow marine environment of deposition.

2.5.4 HANGU FORMATION (DHAK PASS BEDS)

The Hangu shale and Hangu sandstone of Daves (1930) from the Kohat area have been formalized by the stratigraphic committee of Pakistan as Hangu formation. This was earlier called Dhak Pass Beds.

In Pakistan Oil Field Well no 2. Where this sequence was continuously cored, the stratum below the last limestone band of Lockhart (Khairabad) to the total depth 32 meters thick was correlated as Dhak Pass. The successional strata with a five feet thick band of black carbonaceous shale containing nodules of pyrite, following by two feet of dark gray, medium to coarse grain, well sorted hard and well-indurate quartzose sandstone with hematite and trace of glauconite. The remaining 30 meters of the strata are alternations of the light gray to black gray, medium to fine grained, usually hard, occasionally cross bedded, sandstone and dark gray to black, carbonaceous, pyretic (in the form of concertinos) and silty sandy shale. The whole section was found to be unfossiliferous.

2.6 JURASSIC SUCCESSION

2.6.1 DATTA FORMATION

The name Datta formation was introduced by Danilchik in 1961 and replaces the name "Variegated Stage" of Gee 1945 (S.M.Ibrahim 1977). This formation is best developed in the Trans-Indus and Salt range. In Meyal wells, this formation is considered to be equivalent to the Trans-Indus Range and salt range. In Meyal two units are recognized. The upper one is known as variegated stage and the lower one as the main oil sand.

2.7 TRIASSIC SUCCESSION

2.7.1 MIANWALI FORMATION

The name Mianwali series was used by Gee in 1959 and latter modified by "Kummel" into formation (S.M.Ibrahim, 1977). There are three members have been recognized in salt range and Trans-Indus ranges (Kummel (1966)), which are:

1. Narmia Member
2. Mitiwali Member
3. Kathwai Member

On the basis of lithological similarities of theses strata with those of Dhulian, they have been assigned Triassic age and considered to be correlated with the Mitiwali Member of the Mianwali formation (G.R.Gardazi, 1983).

2.8 SOURCE ROCK

Source rock may be defined as "*fine-grained sediment that in its natural setting has generated and released enough hydrocarbons to form a commercial accumulation of oil and gas*". Basically the source rocks are clay and carbonate, deposited under low energy, reducing condition. Shale source rock typically contain 0.5 to 5% organic carbon, while carbonate source rock sometime have as little as 0.3% (H.D.Hedbery, 1964)

The Source rock in Potwar Plateau is Mianwali formation (Triassic), Datta formation (Jurassic) and Patala formation (Paleocene) (H.Rehman, 1963). In Meyal, Patala, Chorgali-Sakesar and Datta formations are served as source rocks.

The Patala formation shows shallow marine depositional environment and is dominantly composed of black marine shale and limestone. This shale is dark gray to black, splintery and fissile in nature. This limestone occurred occasionally. The Eocene age formation include Chorgali-Sakesar of the Eocene age also serve as source rock in Meyal. Both formations have shallow marine to supratidal environment of deposition.

The Chorgali formation is predominantly composed of turquoise color marl and lightly bluish green shale with light gray argillaceous lime stone with dominantly secondary porosity; the Sakesar formation is composed of fossiliferous limestone with nodular structure.

2.9 RESEROIR

The petroleum reservoir is the part of the rock that contains the pool of oil or gas. The reservoir rock extends beyond the limits of the pool and is generally considered to be any rock that contains interconnected pores with sufficient permeability to allow the oil and gas phase production. Petroleum reservoirs occur in particularly every type of rock: sandstone, siltstone, fracture shale, basement rocks, limestone, chalk and dolomites. In Meyal oil field there are three reservoirs.

a. Eocene Reservoir

b. Paleocene Reservoir

c. Jurassic Reservoir.

2.9.1 EOCENE RESERVOIR

The initial production from Meyal was obtained from Eocene Limestone.

The Eocene strata from top to Nammal formation to the base of Kuldana formation are 159 meters thick in Meyal. The top 50 to 67 meters of this sequence overlies the "Main oil Horizon" which has been described as chemical limestone, below this horizon the limestone is coarse grained, fractured and highly fossiliferous.

The Eocene Reservoir was discovered in 1968, and was developed over approximately 5,846 acres spacing and reached peak production of 7000 bbls/d and 40mmscf/d oil and gas respectively. Today the Eocene reservoir has produced approximately 200 bbls/d and 10.00 mmscf/d gas.

The Eocene reservoir has abnormally high pressure, the maximum pressure from this reservoir was calculated in Jan, 1979 i.e. 4876 Psi. The pressure behavior indicates both laterally and vertically communication of hydrocarbon (DeGolyer and MacNaughton 1979). Evidences from cores taken from the "Main Oil Horizon" indicates that this zone is highly fractured with very low matrix porosity range 3% to 5% (G.R Gardazi, 1983-83)

2.9.2 PALEOCENE RESERVOIR

The Paleocene reservoir may be divided into three stratigraphic units.

1. Upper Ranikot Formation
2. Patala formation.
3. Lockhart Formation

The upper Ranikot formation is 150 meters thick; the top consists of fossiliferous and shelly limestone where as basal part consists of sparsely fossiliferous limestone. The underlying Patala formation consists of an argillaceous, foraminiferal limestone bounded by shale. The limestone has been termed as "Patala Main Limestone". The formation shows marked facies changes with in the limits of the field. Cores from Paleocene Reservoir revealed a slightly porous and impermeable limestone with highly fractured porosity. The regular production from Paleocene started in May, 1971. The maximum oil production was taken in May, 1977 is 2412 bbls/d, and while the maximum gas production was also taken in the same year is 2243 mmscf/d.

2.9.3 JURASSIC RESERVOIR

The Jurassic reservoir is 80 meters thick in Meyal. It is represented by the Datta formation which is divided into two parts. The upper part consists of mudstone, claystone and shale with minor sandstone and has been termed as "Variegated Beds" in the Potwar region. The lower unit called "Main Oil Sand" is more or less massive, coarse to medium grained and sometimes gritty, quartzose sandstone. The variegated member is 80 meters thick. The primary porosity of Jurassic is quite variable while the average porosity is 8.5%. The value of permeability ranges from 1.2 to 860 millidarcie.

The reservoir started production in October 1976 and has produced oil unto 100 bbls/d. in the same year the gas production was 3.5 mmscf/d. The maximum recovery was taken in 1987 i.e. 1150 bbls/d of oil and 130 mmscf/d of gas.

2.10 CAP ROCKS (SEAL ROCK)

2.10.1 KULDANA FORMATION

The Kuldana formation acts as cap rock over Eocene reservoir i.e. Chorgali and Sakesar formations. The formation consists of multi colored shale; the shale is usually silty and brittle, but occasionally clayey and soft with thin bands of compact limestone. This formation lies conformable on Chorgali formation and it is 150 meters thick in Meyal.

2.10.2 NAMAL FORMATION

The Nammal formation consists of shale, marl and argillaceous limestone it is about 33 meters thick in Meyal field and provides top seal for Paleocene reservoir.

2.10.3 DHAK PASS FORMATION (HANGU FORMATION)

This formation serves as seal rock for Data reservoir. The thickness of this formation in Meyal is up to 13 meters.

At some places the upper part of Datta formation which is made up of varied colored shale, silt stone. Sandstone and claystone also serve as a cap rock for lower oil bearing sandy portion of same formation.

2.4 TRAPPING MECHANISM

The trap is one of the basic requirements of petroleum reservoir. It is the place where the oil and gas are barred from further motion. From traps the oil and gas can not escaped until released by drilling. The common types of traps are: Structural traps, Stratigraphy trap and Combination of the earlier.

The traps in Meyal oil filed are almost structural. Most of the structures are not filled unto the spill point (Structure closer) because these structures are younger then the generation and migration of petroleum in Meyal. The structure in Meyal is 2m.a old, which is formed by last episode of collision between continental plates while the main source formation of Meyal oil filed is of Paleocene age, which shows that the generation and migration of oil started 4m ago.

CHAPTER NO 3

METHODOLOGY USED FOR LOG INTERPRETATION

3.1 SPONTANEOUS POTENTIAL LOG

The spontaneous potential log is a record of direct current voltage differences between the naturally occurring potential of a moveable electrode in the well bore, and the potential of a fixed electrode located at the surface. It is measured in mill volts Electric currents arising primarily from electrochemical factors within the borehole create the Sp log response. These electrochemical factors are brought about by the differences in salinities between mud filtrate and formation water resistively within permeable beds. Because a conductive fluid is needed in the borehole for the SP log to operate it cannot be used in non-conductive (i.e. oil based) drilling mud.

Tool can be run in:

1. Open hole

In a bore hole filled of:-

1. Gas or air
2. Water or water-based mud

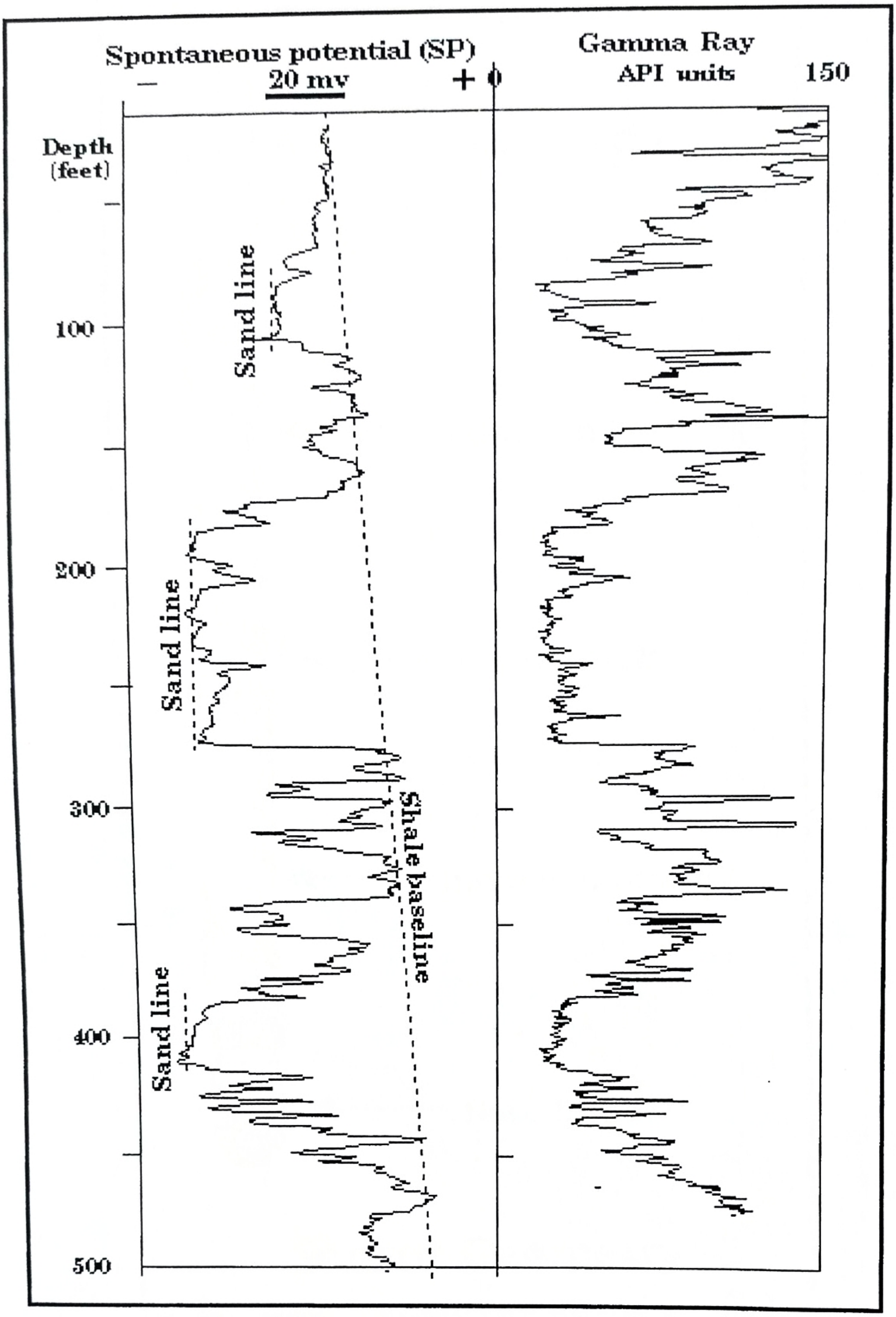

Fig No 3. 1 Showing the trend of SP Curve

(Schlumberger Log Interpretation and Applications by Schlumberger)

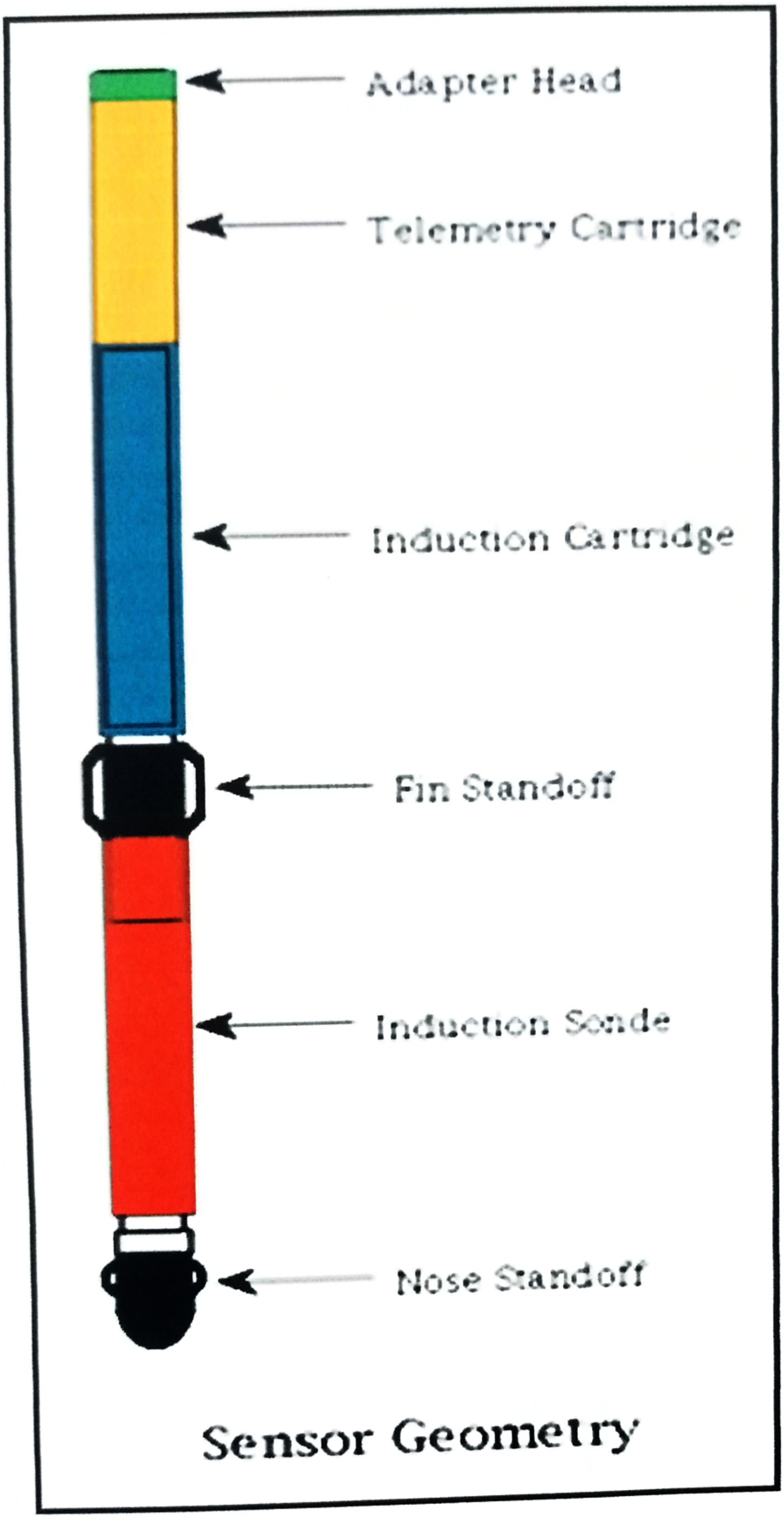

Fig No 3.2 Showing Schematic diagram of SP tool

(Halliburton Log Interpretation and Principles by Halliburton)

3.2 GAMMA RAY LOG

Gamma ray logs measure natural radioactivity in formation and because of this measurement, they can be used for identifying lithologies and for correlating zones.

Shale-free sandstones and carbonates have low concentrations of radioactive material, and give low gamma ray readings. As shale content increases, the gamma ray logs response increase because of the concentration of radioactive material in shale. How ever clean formation (I.e. low shale content) may also produce high gamma ray response if the sandstone contains potassium feldspar, micas, glauconite, or uranium rich waters. (Trend of Gamma Ray curve is showing in fig 3.2)

Beside their use with identifying lithologies and correlating zones, gamma ray logs provide information for calculating the volume of shale in a sandstone or carbon.

Tool can be run in:

1. Open hole
2. Cased hole

In a bore hole filled of:-

1. Gas or air
2. Water or water-based mud

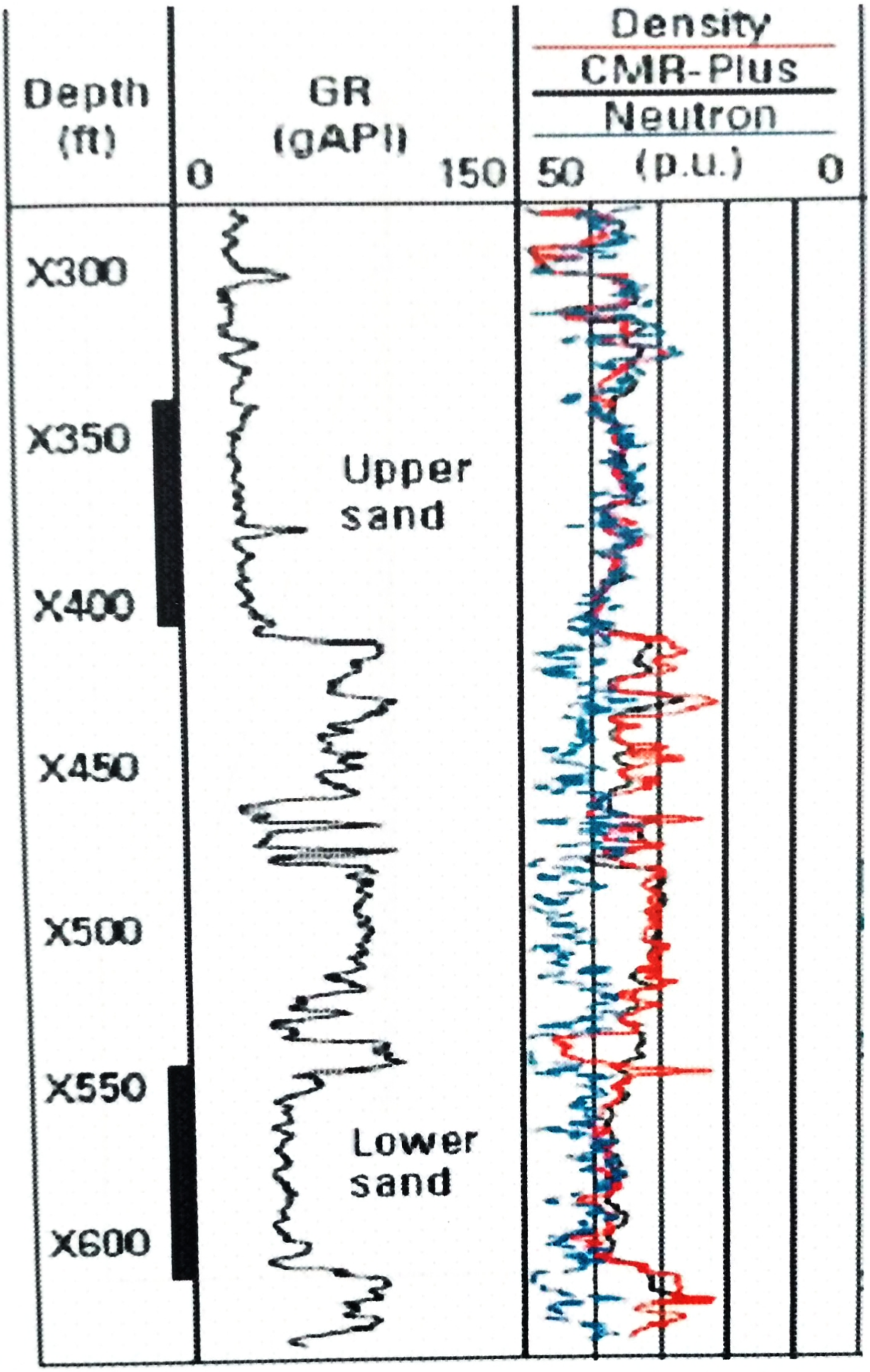

Fig No 3.3 Showing the trend of GR Curve

(Schlumberger Log Interpretation and Applications by Schlumberger)

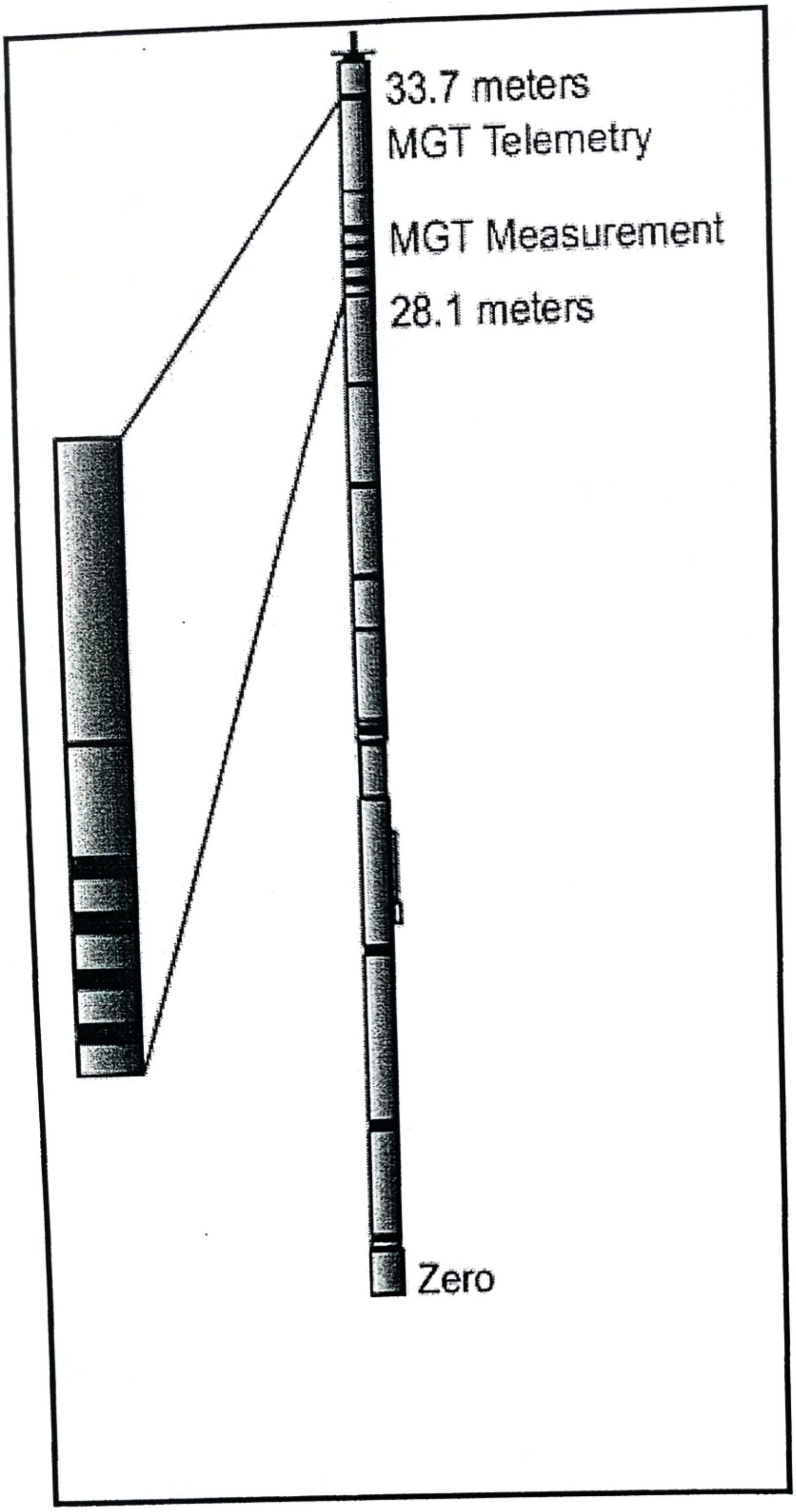

Fig No 3.4 Showing Schematic Diagram of Multi Sensor GR tool

(Halliburton Log Interpretation and Principles by Halliburton)

3.3 SONIC LOG

The sonic log is a porosity log that measures interval transit time (delta T) of a compressional sound wave traveling through one foot of formation. The sonic log device consists of one or more sound transmitters, and two or more receivers. Modern sonic logs are borehole compensated devices (BHC*).

Interval transit time in microseconds per foot is the reciprocal of the velocity of a compressional sound wave in feet per second. A sonic device porosity curve is sometimes recorded in tracks number 2 and number 3 along with delta T curve.

The interval transit time is dependent upon both Lithology and porosity. Therefore and matrix velocity must be known to derive sonic porosity.

Tool can be run in:

2. Open hole

In a bore hole filled of:-

3. Gas or air
4. Water or water-based mud

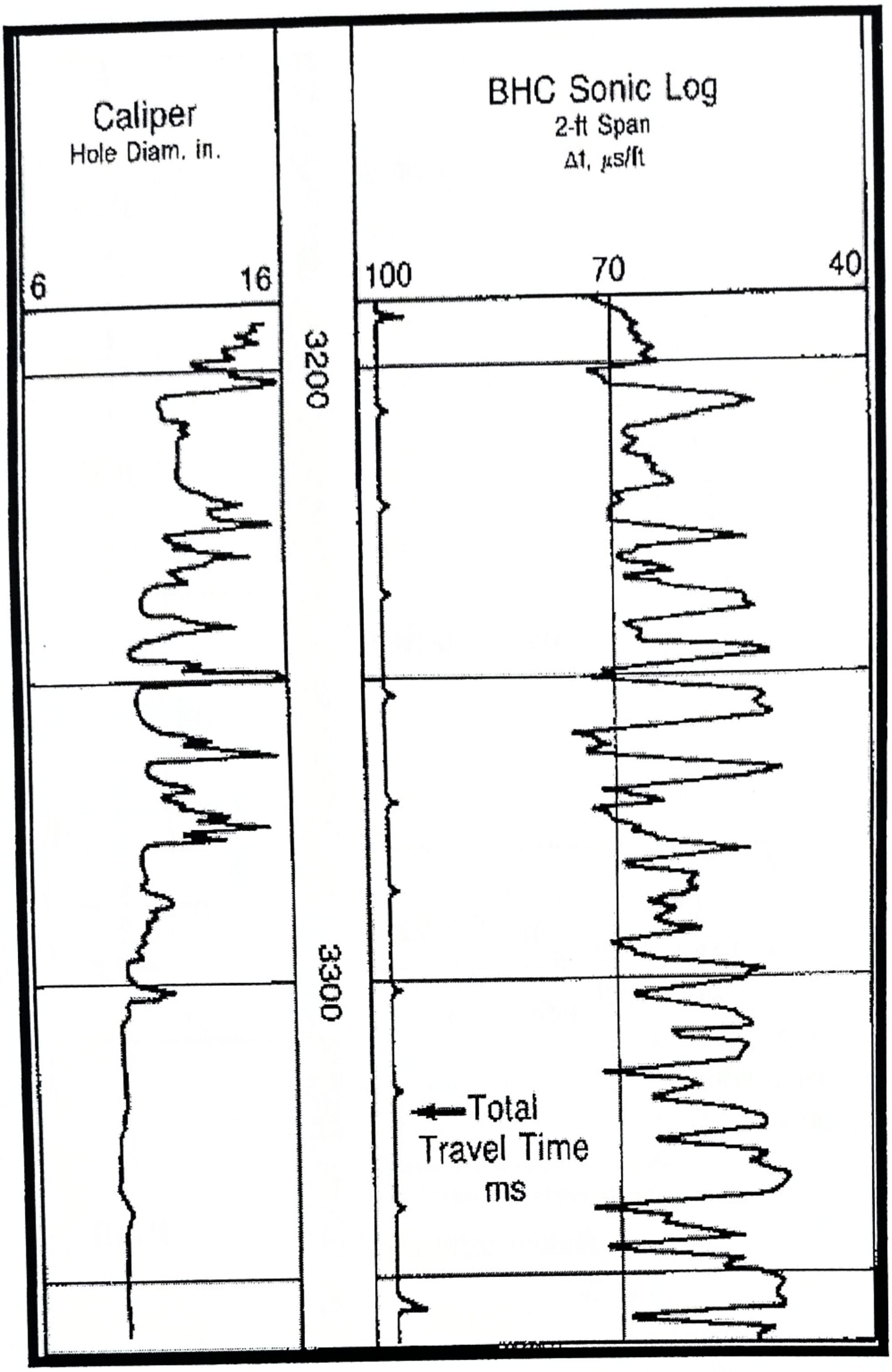

Fig No 3.5 Showing the trend of Sonic Curve

(Basic well log analysis for geologists by George Asquith)

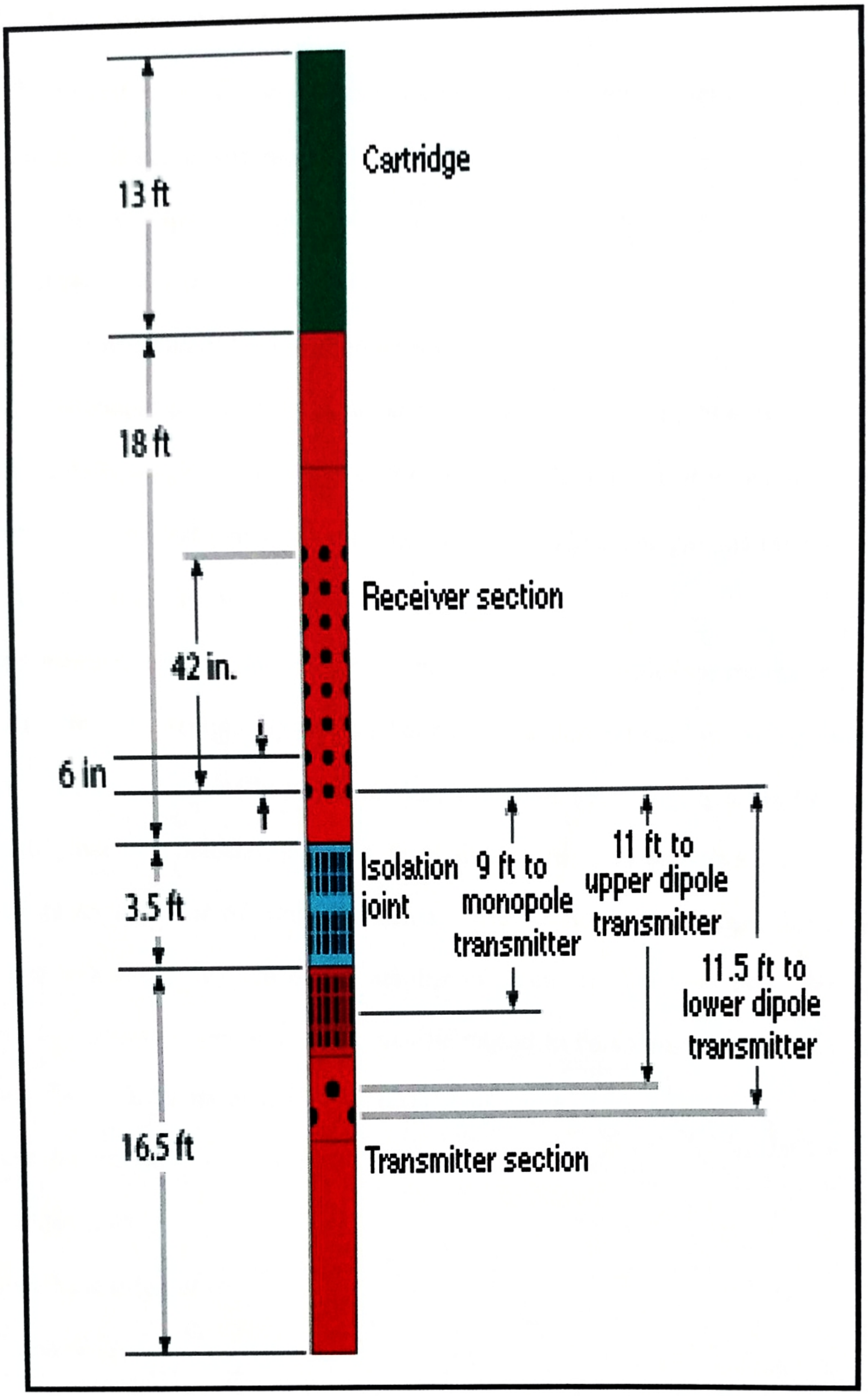

Fig No 3.6 Showing Schematic Diagram of Sonic Tool

(Schlumberger Log Interpretation and Applications by Schlumberger)

3.4 DENSITY LOG

The formation density log is a porosity log that measures electron density of the formation. It can assist the geologist to

1. Identify evaporties minerals
2. detect gas bearing zones
3. Determination of hydrocarbon density
4. Evaluation shaly and reservoirs and complex lithologies.(Schlumberger, 1972)

The density logging device is a contact tool which consists of a medium energy gamma ray source that emits gamma rays into a formation. The gamma ray source is either Cobalt-60 or Cesium- 137.

Gamma rays collide with electrons in the formation: the collisions results in a loss of energy from the gamma ray particle i.e. the interaction between incoming gamma ray particles and electrons in the formation, Compton Scattering. Scattered gamma rays which reach the detector, located a fixed distance from the gamma ray source are counted as an indicator of formation density. The number of Compton Scattering collisions is a direct function of the number of electrons in a formation (electron density) consequently; electron density can be related to bulk density of a formation in gm/cc. Fig no 3.7 is showing trend of density ray curve.

Tool can be run in:

1. Open hole

In a bore hole filled of:-

1. Gas or air
2. Water or water-based mud

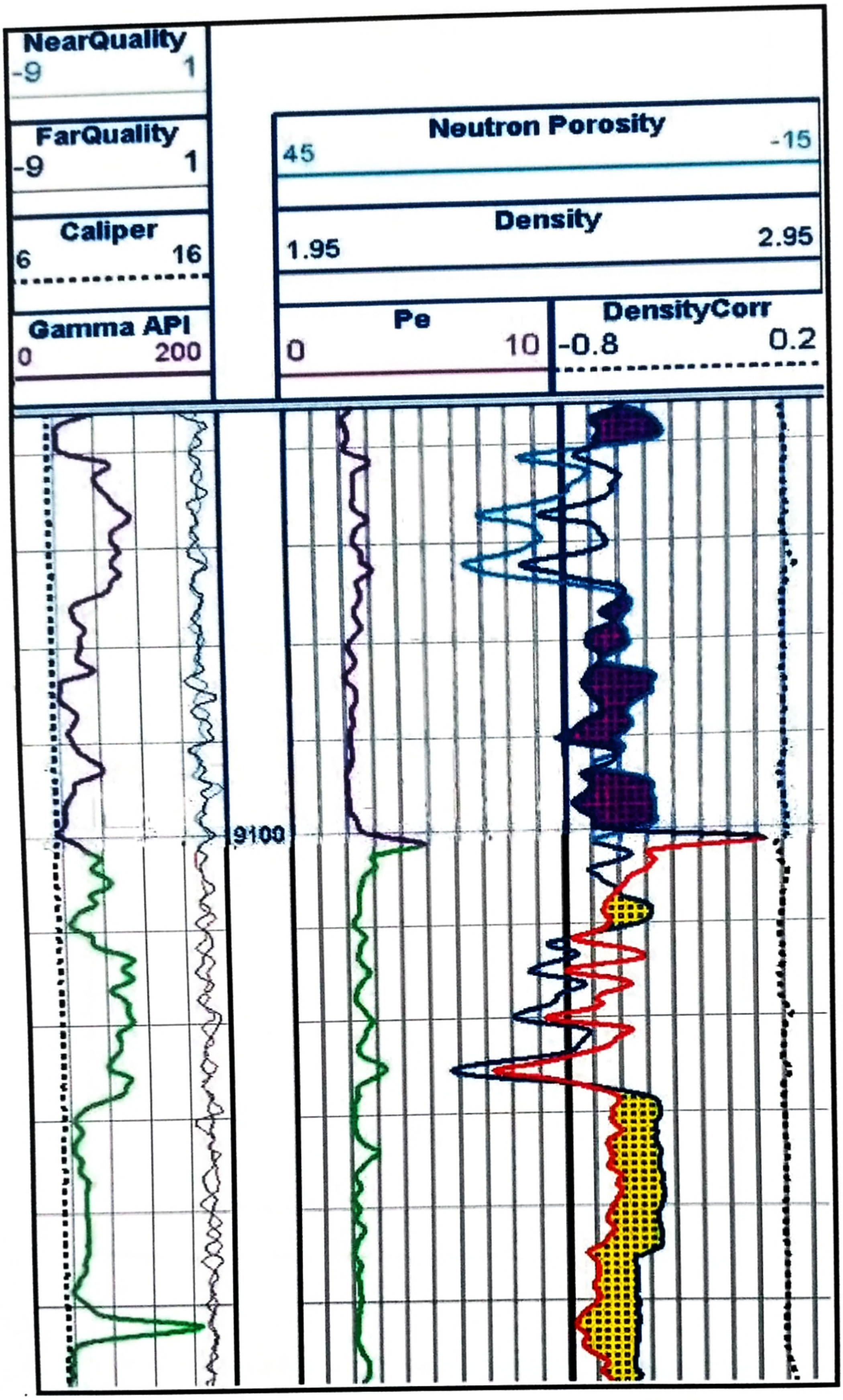

Fig No 3.7 Showing Density Curve

(Schlumberger Log Interpretation and Applications by Schlumberger)

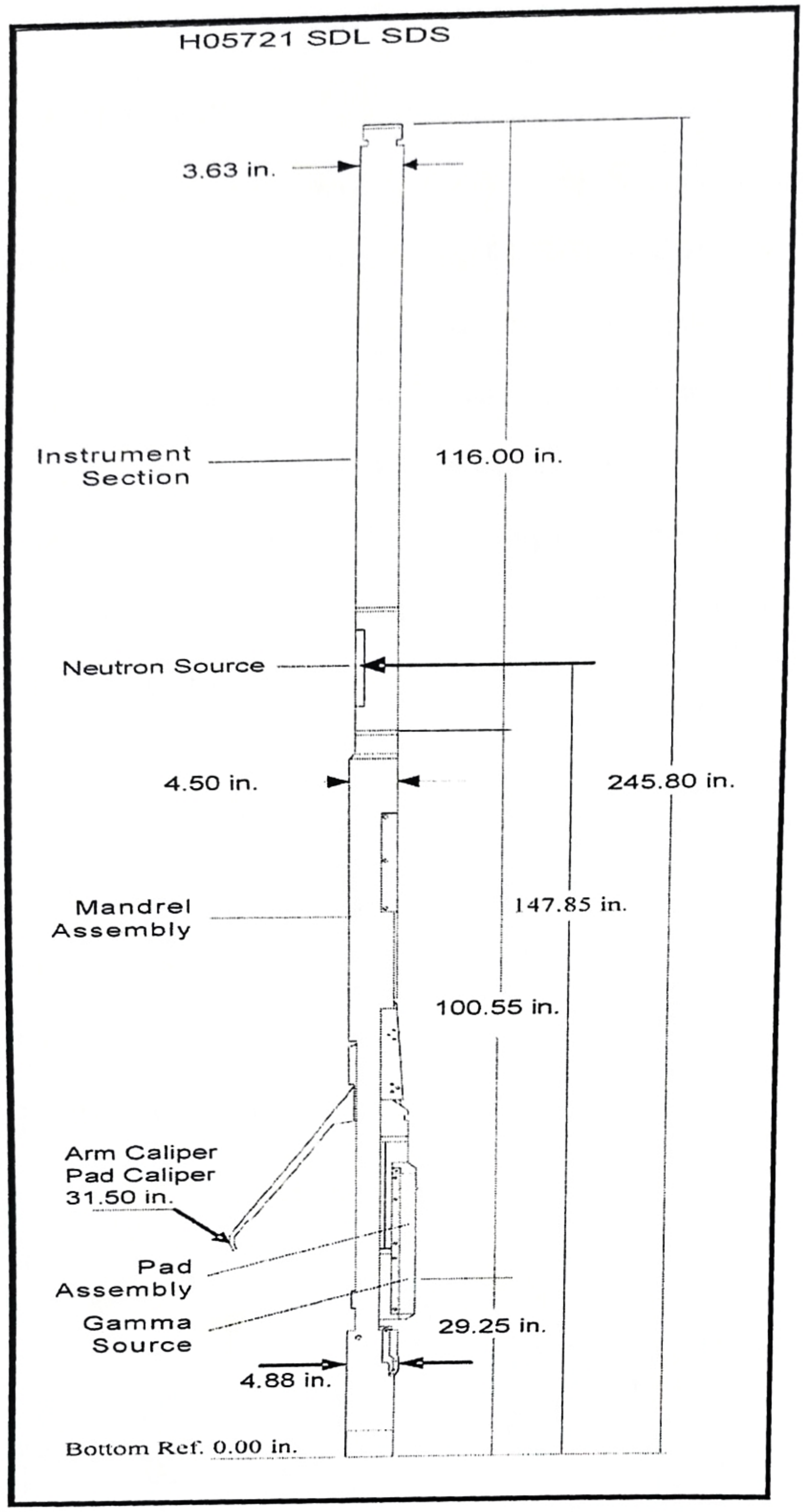

Fig No 3.8 Showing Schematic diagram of Spectral Density Tool

(Halliburton Log Interpretation and Principles by Halliburton)

3.5 INDUCTION LOG

Transmitter coil induce an alternating current in the formation. Reservoir coil sense the response of the formation, both in magnitude and formation. This response is proportional to the formation conductivity. Multiple transmitter and receiver coils are used in an effort to minimize borehole an invasion effect of the tool.

Newer versions of tools make better and digitally recorded measurement of the in-phase of out of the phase parts of the single and operate as different frequencies, in order to improve the accuracy of the tool. The trend of induction log curve is shown in the figure no 3.9.

Tool can be run in:

1. Open hole

In a bore hole filled of:-

1. Gas or air
2. Water or water-based mud

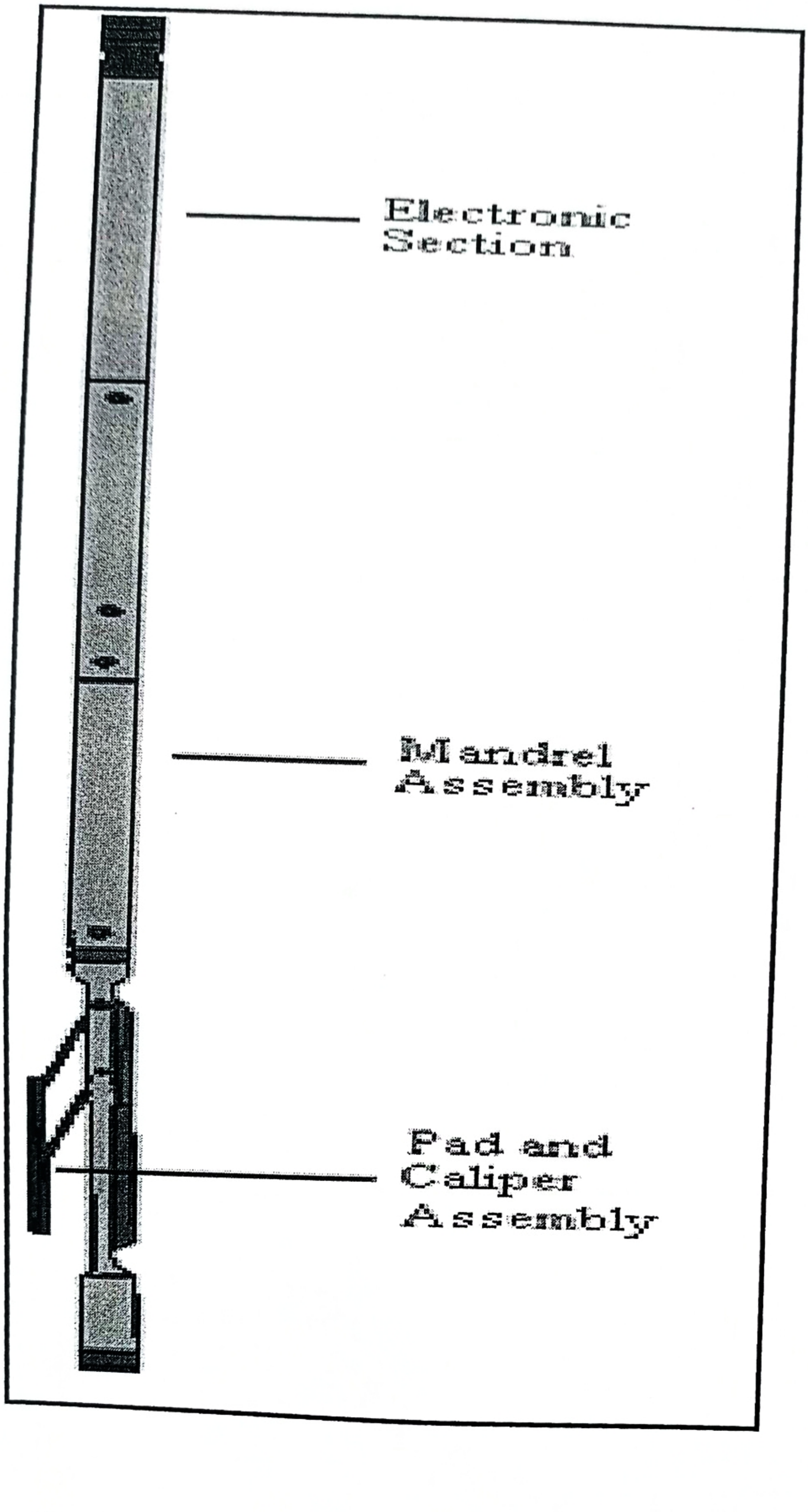

Fig No 3.9 Showing Schematic diagram of MSFL Tool

(Schlumberger Log Interpretation and Applications by Schlumberger)

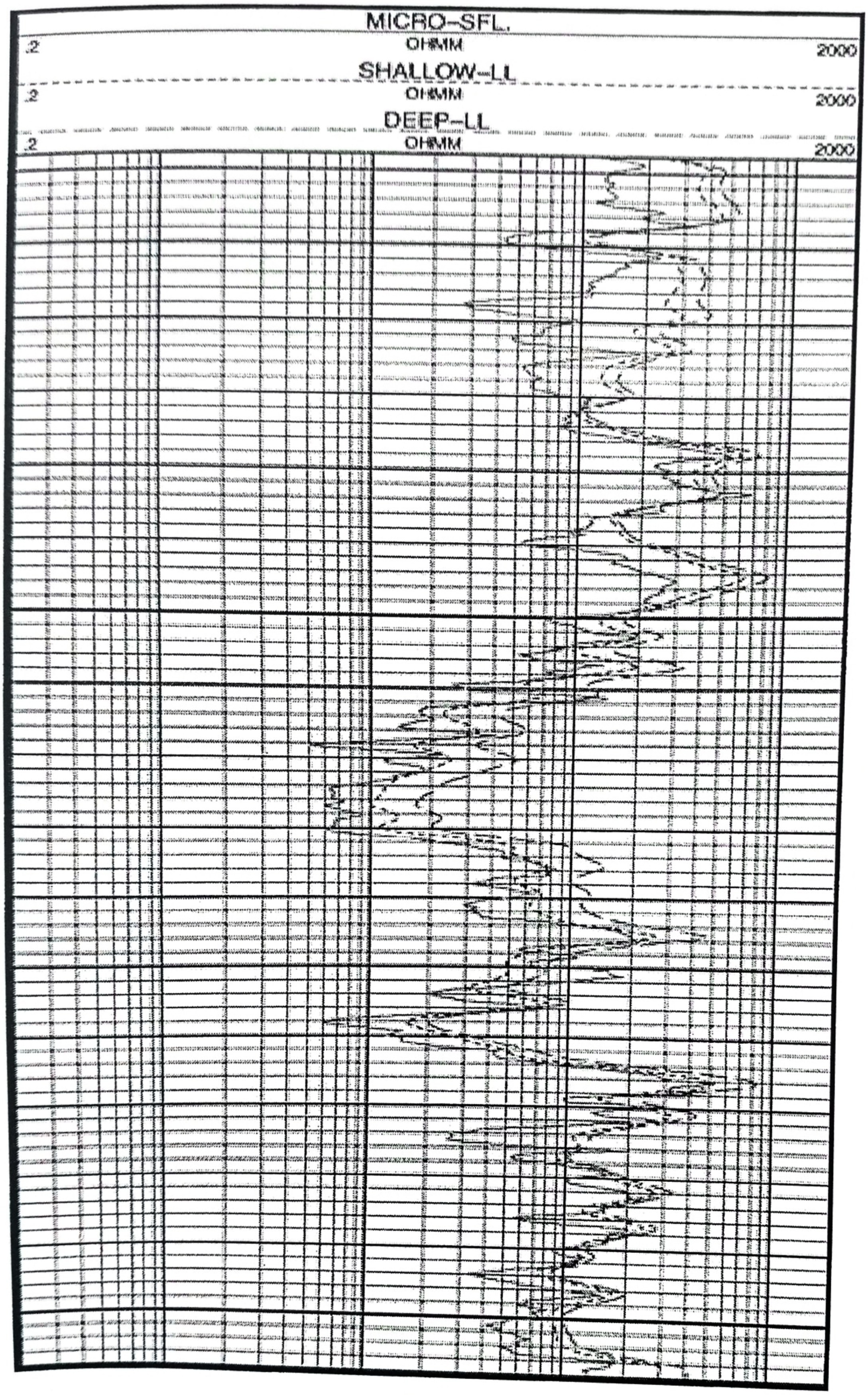

Fig No 3.10 Showing Induction Log curve

(Halliburton Log Interpretation and Principles by Halliburton)

3.6 LATEROL LOG

A very low frequency current flow from the tool, though a borehole in the formation. Electrode arrays on either side of the source electrode force the measurement of the current into horizontal disk-shaped pattern around the borehole. Formation resistivety is determined by monitoring the amount of current flowing from the tool. The tool makes the electric contact with the formation. Laterol log tool have some limitations and those are shown below in table no 3.6

Tool can be run in:

1. Open hole

In a bore hole filled of:-

1. Gas or air
2. Water or water-based mud

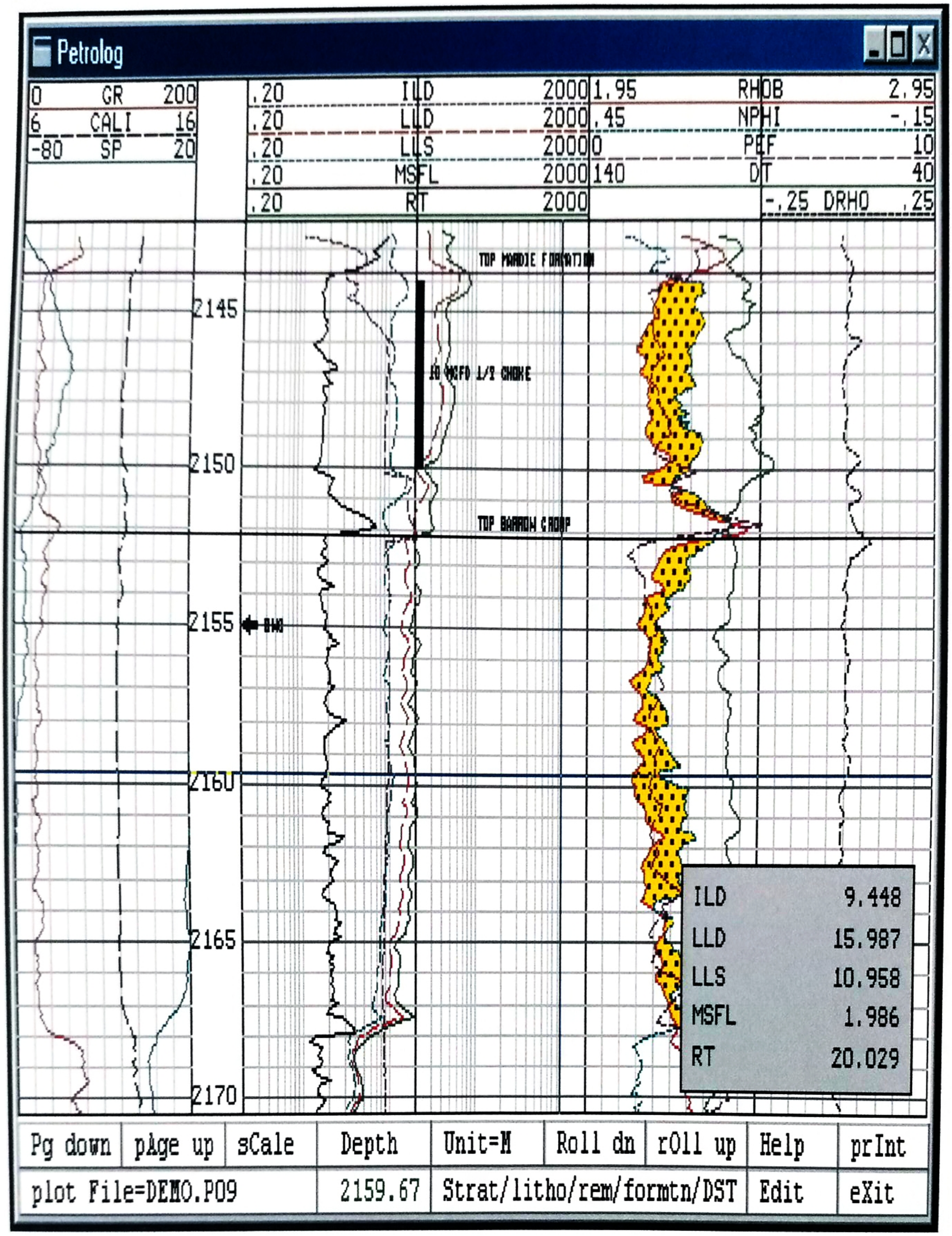

Fig No 3.11 Schematic figure showing Laterolog Presentation

(Software Screen)

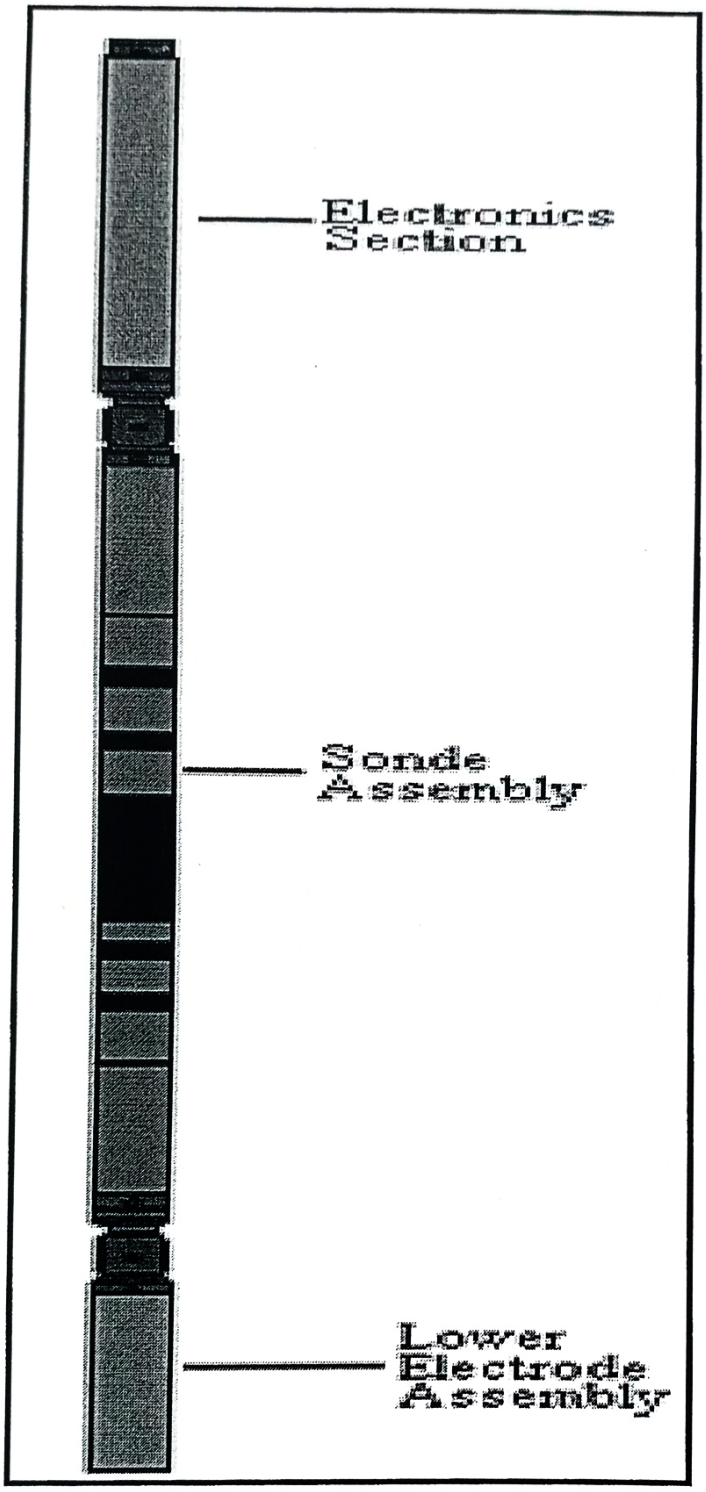

Fig No 3.12 Schematic diagram of DLT Tool

(Halliburton Log Interpretation and Principles by Halliburton)

CHAPTER NO 4

PETROPHYSICAL INTERPRETATION

4.1 INTRODUCTION

Meyal 10 and 13 are the vertical exploration well drilled by Pakistan Oilfields Limited in 1984, objective of this report is to calculate Porosity, Saturation of water, True resistivety of formation using wire line logs.

4.2 AVAILABLE DATA

We calculated porosity, saturation of water and true resistivety by using wireline logs. The logging suite includes Induction laterolog, micro resistivety, Density, Neutron, and Gamma ray logs of Meyal 10 and Meyal 13.

4.3 PETROPHYISCAL EVALUATION

The Petrophysical evaluation carried out for well 10 and 13 is detailed in this section.

4.3.1 LITHOLOGY

Lithology is confirmed by means of core samples.

4.3.2 SHALE VOLUEM

Volume of shale can be calculated by SP log or GR but the most widely used now a days Is GR log. in the quantitative evaluation of shale content, it is assumed that radioactive minerals are absent in clean rocks as compare to shaly rocks.

The Sp log can be used to calculate the volume of shale in a permeable zone by the following formula:

$$V_{sh} \text{ (in \%)} = 1.0 - PSP/SSP$$

Where as;

V_{sh} = volume of shale

PSP = pseudo static spontaneous potential (SP of shaly formation)

SSP = static spontaneous potential of a thick clean sand or carbonate.

For determination from GR log we use the following formula:

$$(V_{sh}) \text{ volume of shale} = GR_{log} - GR_{min} / GR_{max} - GR_{min}$$

Where as;

GR_{log} is the Gamma ray reading for formation

GR_{min} is the minimum gamma ray (clean formation)

GR_{max} is the maximum gamma ray (shale)

Calculation of volume of shale in Meyal 10 and 13 in the given formation is:

For Meyal 13 (11200 – 12260)

$V_{sh} = GR_{log} - GR_{min} / GR_{max} - GR_{min}$

$Vsh = 28 - 8 / 65 - 15$

$Vsh = 20\%$

For Meyal 10 (12500 -13100)

$V_{sh} = GR_{log} - GR_{min} / GR_{max} - GR_{min}$

$Vsh = 28 - 10 / 100 - 10$

$Vsh = 20\%$

4.3.3 POROSITY CALCULATION

Porosity is the measure of the void spaces in the material, and it is measured as a fraction 0-1 or as percentage 0 – 100 %. Consolidated rocks e.g. sandstone, limestone, shale, granite potentially have more complex "dual" porosities as compare to alluvial sediments. The rock itself may have certain low porosity, and the fractures cracks and joints or dissolution features may create a second (higher) porosity. The interaction of these porosities is complex and often makes simple models highly inaccurate.

The fraction of interconnected void spaces to bulk volume is considered as effective porosity. Porosity is either primary or secondary. Primary porosity is formed between the grains. In ancient rocks its maximum limit is up to 47.6%, which is found in ideally packed, well rounded grains. Porosity in sandstone is depending on packing, orientation, well rounded grains and digenesis. There are more then seven techniques commonly used to determine porosity and include open hole logs, which are sonic, neutron , density and resistivety logs and combination of neutron density , neutron sonic cross-plots.

In this work porosity is determined by using neutron, density and sonic determination methods all these porosity values are calculated from Schlumberger's wire line logs. We also used neutron – density and Apparent neutron porosity - true neutron porosity cross plot for calculation of the porosities , neutron - density cross plot is showing in fig 4.1 and apparent - true neutron porosity cross plot is showing in fig 4.2.

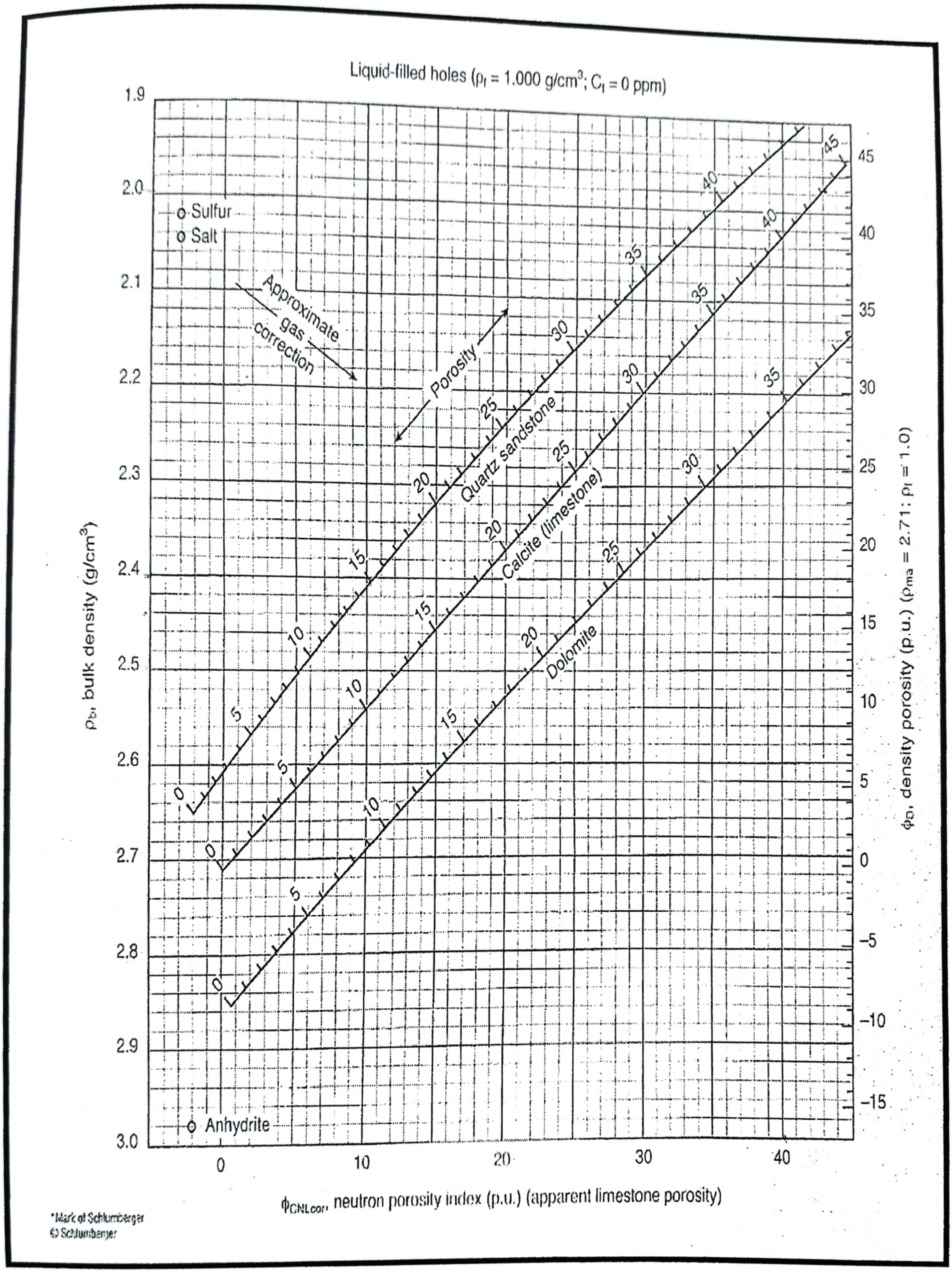

Fig No 4.1 Showing Neutron – Density Cross plot

(Schlumberger Log interpretation)

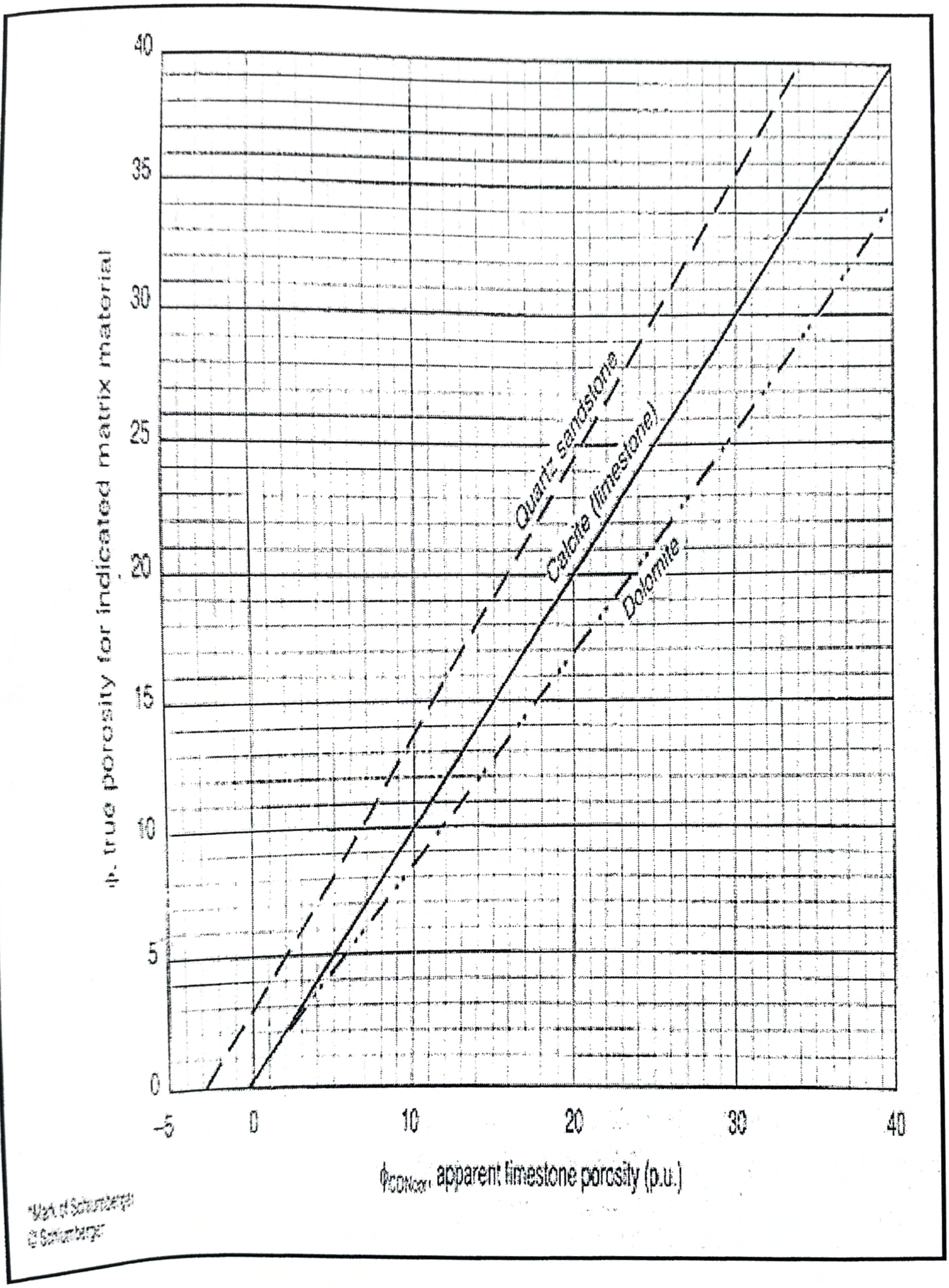

Fig No 4.2 Showing Apparent and true Neutron porosityCross plot

(Schlumberger Log interpretation)

4.3.4 Sonic Porosity

Sonic porosity can be determined by the formula:

$$Ø_{Sonic} = \Delta t_{log} - \Delta t_{ma} / \Delta t_{f} - \Delta t_{ma}$$

Where as;

$Ø_{Sonic}$ is the sonic porosity

Δt_{log} is interval transit time for formation

Δt_{ma} is interval transit time for matrix

Δt_{f} is interval transit time for fluid in the well bore.

(Fresh Mud = 189; salt mud = 185)

Calculated Sonic Porosity of different clean zones of Meyal 13 is showing in the table no 4.1.

Sonic Porosity of Clean Zone (Meyal 13) Calculated from ISF – SONIC-GR-SP for Sandstone with Fresh Mud	
Depth Zone	**Porosity**
11220-11250	11.4
11270-11320	10.2
11365-11400	9.0
11400-11420	3.38
11510-11550	4.8
11650-11670	7.14
11750-11778	4.88
11940-11970	3.38
12050-12065	4.38
12240-12270	4.88

Table No 4.1 Showing Sonic Porosity of Different Zones of M-13

4.3.5 Neutron Porosity

Neutron logs are porosity logs that measure the hydrogen ion concentration in a formation. In a clean formation (i.e. Shale- free) where the porosity is filled with water or oil, the neutron measures liquid filled porosity.

Neutron logs responses vary, depending on differences in detector type, spacing between source and detector and Lithology i.e. sandstone, limestone, dolomite.

4.3.6 Density Porosity

The formation density log is a porosity log that measures electron density of a formation. It can assist the geologist to identify evaporate minerals, gas bearing zone, determine hydrocarbon density and evaluate shaly sand reservoirs and complex lithologies.

The formula for calculating density porosity is

$$Ø_{den} = ρ_{ma} − ρ_{b} / ρ_{ma} − ρ_{f}$$

Where;

$Ø_{den}$ is density derived porosity

$ρ_{ma}$ stands for matrix density

$ρ_{b}$ stands for bulk density

$ρ_{f}$ stands for fluid density (1.1 salt mud, 1.0 fresh mud, and 0.7 gas)

Density porosity of clean zone of Meyal 10 Calculated For Fresh Mud From LDL CNL GR				
Depth	Density Porosity ØD	Bulk Density	Neutron Porosity ØN	True Neutron Porosity
12700-12730	8	2.75	0.9	7
12820-12840	6	2.675	0.5	5
12880-12910	3	2.7	0.4	4
12920-12940	6	2.65	0.5	5

Table No 4.2 Showing Density & Neutron Porosity of different Zones of M-10

Density porosity of clean zone of Meyal 13 Calculated for Fresh Mud From LDT CNL GR				
Depth	Density Porosity ØD	Bulk Density	Neutron Porosity ØN	True Neutron Porosity
13510-13530	9	2.47	0.7	11
13560-13580	5	2.575	0.3	6
13600-13620	9	2.45	0.6	8
13710-13740	6	2.55	0.4	7
13810-13820	4	2.6	0.3	5

Table No 4.3 Showing Neutron & Density Porosity of different Zones of M-13

4.3.7 WATER RESISTIVITY (Rw)

Water resistivety is the most sensitive parameter in the determination of water saturation. The Sp curve is used in determine the value for Rw but in some cases Sp does not develop and is not useable , therefore Rwa method can be used for determination of Rw.

Rwa is the resistivety of an unknown mixture of water and Chlorine in the pore spaces.Rw in the water bearing rocks is equivalent to Rwa.

<u>Rw in Meyal Reservoirs</u>

Eocene

Water resistivety (Rw) of the Eocene Reservoirs is estimated to be 0.314 to 0.464 ohm/m having total dissolved solids (TDS) 12,759 to 19585 ppm (NaCl Equivalent)

Paleocene

Water resistivety (Rw) of the Paleocene Reservoirs is estimated to be 0.05 to 0.60 ohm/m having total dissolved solids (TDS) 13, 3475 to 13, 7451 ppm (NaCl Equivalent)

Jurassic

Water resistivety (Rw) of the Paleocene Reservoirs is estimated to be 0.060 to 01.570 ohm/m having total dissolved solids (TDS) 3,788 to 24, 0712 ppm (NaCl Equivalent)

4.3.8 SATURATION OF WATER (Sw)

The receptivity of a formation is key to determine the Saturation of hydrocarbon (Sh), water saturation is the fraction of pore space containing water and denoted by Sw and the remaining fraction containing oil or gas is termed as hydrocarbon saturation (Sh) there are many methods for calculation of saturation of water present in the formation but the most suitable is Archie equation and that is

$$S_w = (F * R_w / R_t) ½$$

Where;

S_w is the Water Saturation

F is the formation Factor

N is cementation exponent

R_t is the true formation resistivety as measured by reading from resistivety log

R_w is the resistivety of formation water.

Calculated Water Saturation (Sw) of Meyal 13 of clean Zone	
Depth Zone	**Calculated Sw**
12340-12370	0.44
12370-12400	0.44
12420-12440	0.70
12440-12470	0.80
12490-12510	0.48
12600-12620	0.70
12920-12940	0.44
12950-12970	0.44
12980-13020	0.36
13060-13090	0.63
13110-13160	0.63
13240-13300	0.70

Table No 4.4 Showing Water Saturation of different Zones of M-13

CHAPTER NO 5

CONCLUSIONS

5.1.1 CONCLUSIONS

1. Meyal – Kharpa Surface structure is an east-west trending narrow steep faulted anticline with two major thrusts cutting surface longitudinally.
2. Porosity ranges in Jurassic is 4 to 9.
3. Porosity ranges in Paleocene is 5 to 7.
4. Water Saturation is from 40- 70 in Jurassic and 30 – 70 in Paleocene and in Eocene it is ranging 30-80, so we have different Oil Water contact in Meyal Oil Field.
5. Three Different Oil Water Contact has been marked in Meyal Oil field.
6. Sand of Jurassic shows good porosity and water saturation
7. On the bases of wireline logs the upper and middle part of Sakesar is marked as zone of interest, where as upper part of Lockhart is also marked as zone of interest.

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