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# Structural Interpretation of Seismic Profiles integrated with Reservoir Characteristics of Qadirpur Area

**Aamir Ali[1], Zulfiqar Ahmad[1] and Gulraiz Akhtar[1]**


## ABSTRACT

**Two dimensional seismic interpretations have been carried out in the Central Indus Basin, Qadirpur area to confirm the reservoir characteristics of the producing Sui Main Limestone and Ranikot Formation and to delineate promising locations for test drilling into the Sui Main Limestone and Ranikot Formation. Interpretive results of time contour map indicate that most of the prospect zones of 5 to 10 milliseconds are in the southwest direction at Sui Main Limestone level and 10 to 20 milliseconds in the north and southwest direction at Ranikot level. Results also revealed that prospect zones tend to become thin in the northeast, while it becomes thick in the southwest. The above findings of this study narrate that subsequent changes in thicknesses may be attributed due to the presence of Mari-Kandkot High in the north of study area. Lithology, water saturation and hydrocarbon saturation indicate two productive zones within Sui Main Limestone. Average value of porosity for each productive zone ranges from 20 to 23%, water saturation from 18 to 20%, and hydrocarbon saturation from 78 to 82%. The total reservoir rock volume is calculated to be 8896 acres. The total volumetric recoverable gas reserves are 6.6 Trillion Cubic Feet (TCF).**


## INTRODUCTION

Qadirpur Block (Sind Province) is the concession area operated by OGDCL. The location of the study area that falls within this block in Central Indus Basin is bounded by Sargodha high in the north, Indian Shield in the east, marginal zone of Indian Plate in the west, and Sukkar Rift in the south (Figure 1). The basin is separated from Upper Indus Basin by Sargodha High and Pezu Uplift in the north (Kazmi and Jan, 1997).

Area falls within the latitude of 27° 55' to 28° 09' N and longitude 69° 11' to 69° 31' E and it is approximately 820 sq. kilometers. Qadirpur area administratively lies in Ghotki and Jacobabad districts of Sindh Province. Geologically Qadirpur is situated with the Mari Kandkot High and Middle Indus Basin of Pakistan. The intended 3D seismic data acquisition and processing programme of Qadirpur joint venture encompasses an area of 364 sq km. Previously about 420 lines of 2D seismic survey were carried out by OGDCL in the years of 1990, 1992 and 1998.

In 1990, gas was discovered in Eocene Limestones in Qadirpur area. Until today about 25 wells have been drilled for extensive development of the field. Sui Main Limestone is the main producer of gas in Qadirpur Gas-field area; hence most of the wells were bottomed up to this Formation. On the other hand, Qadirpur-1 and QadirpurX-2 were drilled to Pab/Ranikot (Cretaceous /Paleocene) formations.

## SEISMIC AND WELL DATA

The location of 2D seismic lines of Qadirpur area is shown in base map in figure 2 that has been used in this study. This data was acquired and processed by OGDCL in the years of 1990, 1992 and 1998.Composite suite of logs comprising gamma ray, spontaneous potential (SP), resistivity log (i.e., induction electric log, dual induction focused log, dual laterolog, micro spherically focused log, microlatrolog, Laterolog etc.), porosity logs (i.e., sonic log, density log, neutron log, combination of neutron-density log)) were run in wells (Qadirpur 01 and Qadirpur 05) are also acquired for log interpretation to estimate the reservoir characteristics.

## PETROLEUM PROSPECT

Potential source rocks include shale of Sembar Formation, but shales of Mughalkot, Ranikot and Sirkif 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. The Ghazij Shales act as cap for Sui Main Limestone and Sui Upper Limestone while Sirki Shales over Habib Rahi Limestone act as a cap rock (Kadri, 1995). The generalized stratigraphy of the area is given in figure 3.

## METHODOLOGY

For log interpretation, different types of standard cross plots and mathematical charts have been used. The important reservoir parameters, which were calculated, are; volume of shale, porosity of the formation, resistivity of the formation water, water and hydrocarbon saturation and lithology of the formation. The calculated values are plotted against depth for each particular formation encountered in Qadirpur-01 and Qadirpur-05. Finally, the productive reservoir area is delineated using a depth contour map.

For seismic data interpretation, identification of reflection packages has been done using seismic section (Figure 4A, 4B & 4C); depths of formation tops from well 01 and well 05; average thicknesses from the above mentioned wells;

[1] Department of Earth Sciences, Quaid-i-Azam University, Islamabad.

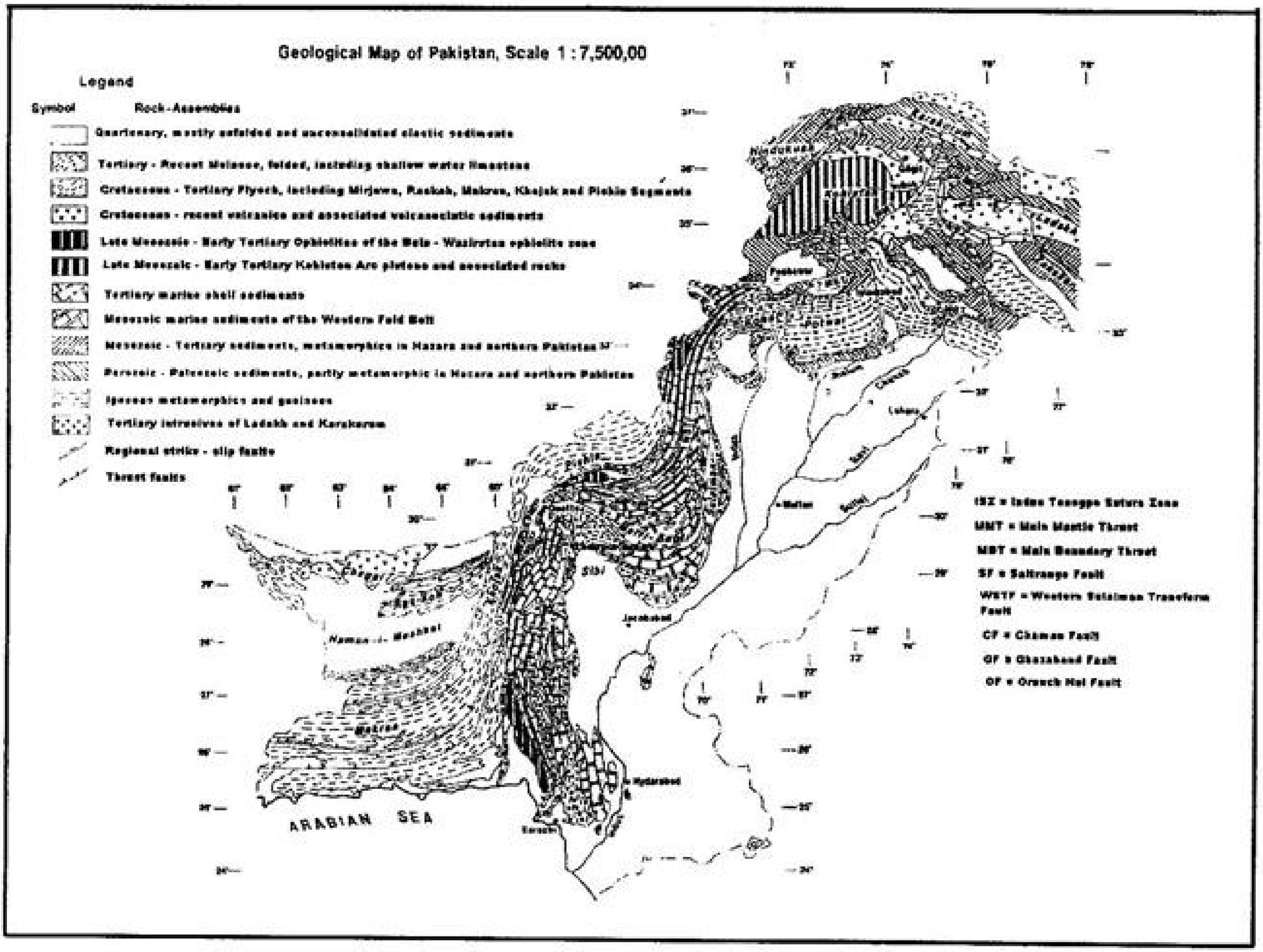


**Figure 1- Map showing the location of the area of interest (After Bender and Raza, 1995).**

interval and average velocities derived during processing of seismic data; geologic and seismic characteristics of different lithologies; and vertical seismic profile (VSP) data of well 01 and well 05.

Time and depth contour maps (Figure 5 to 8) of productive reservoir formations have been constructed using the time read directly from the tops of particular horizons and average velocities derived from interval velocities.

Faults are also recognized on the basis of discontinuities in reflections (Figure 4A, 4B & 4C) falling along an essentially linear pattern; Misclosures in tying reflections around loops; Divergence in dip not related to stratigraphy; Diffraction patterns, particularly those with vertices, which line up in a manner consistent with local faulting; Distortion or disappearance of reflections below suspected fault lines (Badley, 1985).

In stratigraphic interpretation lateral continuity and variation in sedimentary deposits and different episodes of sedimentation effected by tectonic activity and recognition of time depositional units separated by unconformities is studied. In seismic data, erosional unconformities are recognized on the basis of truncation below and base lap above the unconformity (Dobrin and Savit 1988).

## RESULTS

The seismic lines have been interpreted which resulted in the construction of time contour, depth contour maps and time section.

From correlative study of all seismic lines with time contour and depth contour maps, following results of structural interpretation are deduced:

No definite fault trend is present but localized normal faults do exist due to extensional tectonics during Eocene. Very few cross faults can also be seen.

The normal faults make local scale horst and graben geometries favorable for the accumulation of oil.

From stratigraphic interpretation, studying and analyzing the seismic data and contour maps, following results are deduced:

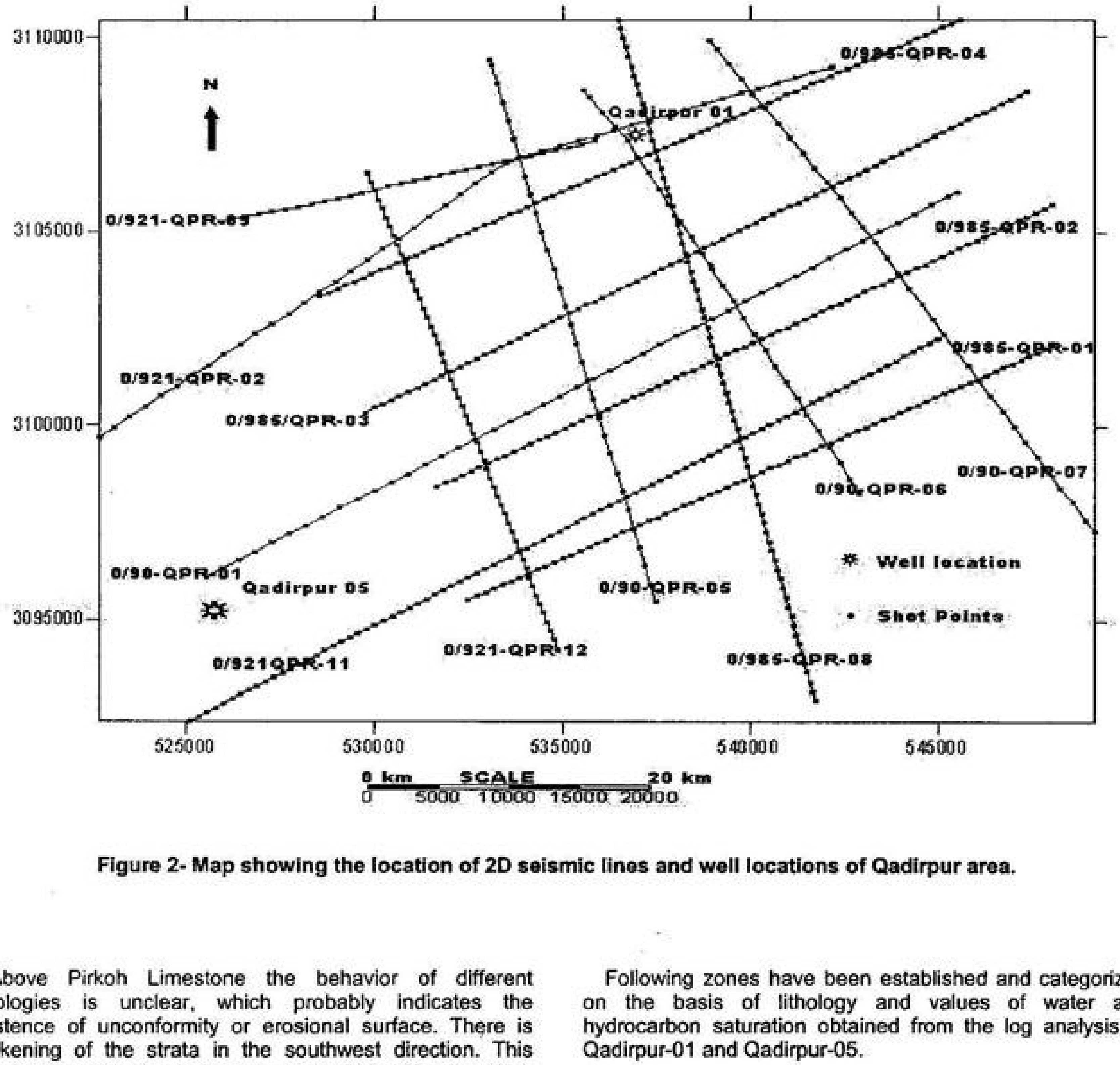


**Figure 2- Map showing the location of 2D seismic lines and well locations of Qadirpur area.**

Above Pirkoh Limestone the behavior of different lithologies is unclear, which probably indicates the existence of unconformity or erosional surface. There is thickening of the strata in the southwest direction. This effect is probably due to the presence of Mari-Kandkot High in the northeast of the study area. There is clearly a change in the depositional environment indicated by phenomenon of thinning and thickening. There is thinning of the strata in the northeast direction.

To evaluate the hydrocarbon potential of wells, following reservoir parameters are calculated (Schlumberger, 1968).

Average porosity ($\Phi_{av}$)
Average volume of shale ($Vsh_{av}$)
Average water saturation ($Sw_{av}$)
Net pay thickness (H)
Productive area (A)

Evaluation of water saturation and hydrocarbon saturation in the Sui Main Limestone suggest the possibility of four prospect zones encountered at variable depths as discussed.

Following zones have been established and categorized on the basis of lithology and values of water and hydrocarbon saturation obtained from the log analysis of Qadirpur-01 and Qadirpur-05.

**Zone I: Depth ranges from 1301to 1306m**

In this zone hydrocarbon (gas shows) are seen, so it is a gas-bearing zone and it is our first zone of interest.

**Zone II: Depth ranges from 1313 to 1317m**

In this zone hydrocarbon (gas shows) are seen, hence it is a gas-bearing zone of 4 m thickness and it is referred to second zone of interest.

**Zone III: Depth ranges from 1335 to1340 m**

In this zone hydrocarbon (gas shows) are seen, hence it is a gas-bearing zone of 5 m thickness and it is referred to third zone of interest.

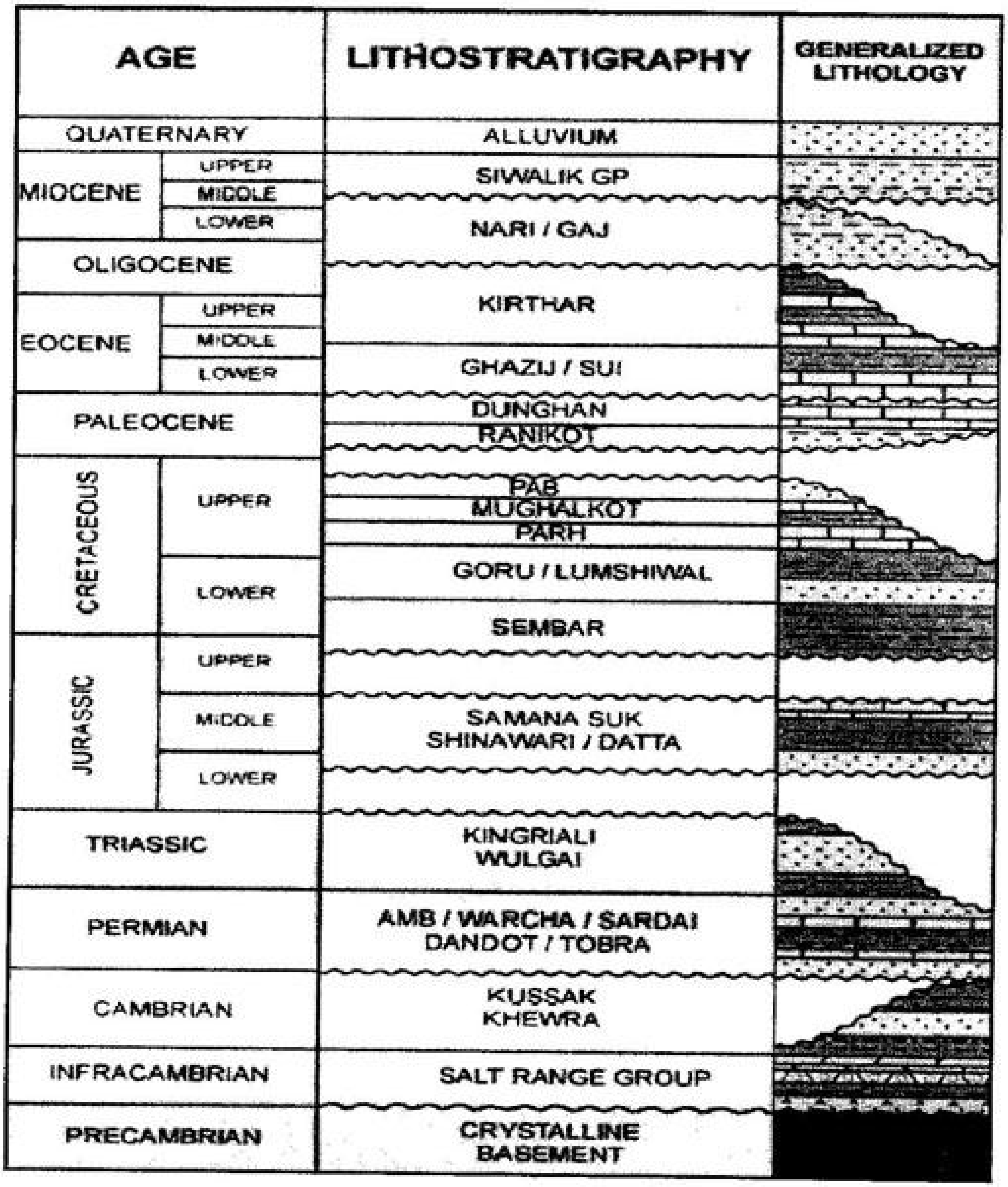


**Figure 3- Generalized Stratigraphy of Punjab Platform, Central Indus Basin ( After Raza and Ahmad, 1990).**

#### Zone IV: Depth ranges from 1350 to 1359 m

This is also a gas-bearing zone 9 m thick and it is referred to fourth zone of interest.

In production tests, the zones II and I don't show good results when they are tested for hydrocarbon production; therefore these zones have been ignored for perforation.

Zone III and IV are perforated on the basis of production test as they show good results when tested.

#### CALCULATION OF AVERAGE POROSITY

Porosity plays an important role in production of the well. If the porosity (Φ) is greater than 6%, formation is regarded as productive formation. Porosity of each meter is averaged out to calculate total reservoir pore volume.

Formula for average porosity is

$$\Phi av = \frac{n1.\Phi1+n2.\Phi2+n3.\Phi3...}{n_1+n_2+n_3..........}$$

The equation will be: $\mathbf{\Phi av = \Sigma (n.\Phi) / \Sigma n}$

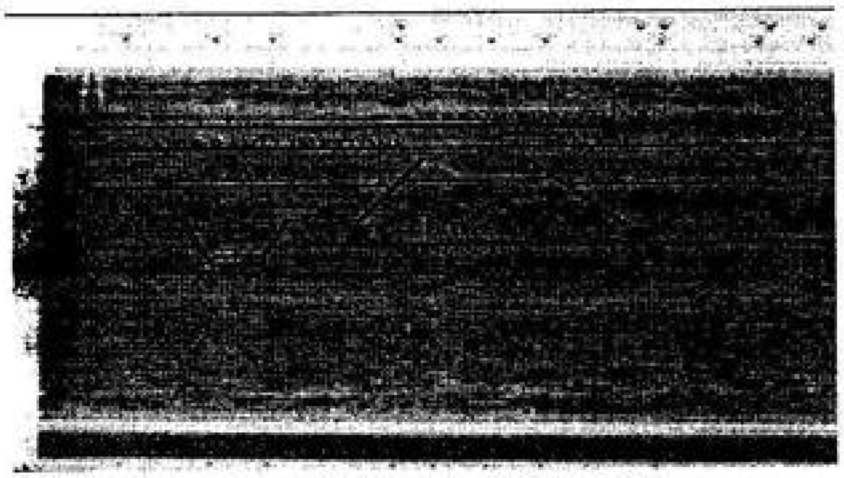

Figure 4A- Line No. 985-QRP-03

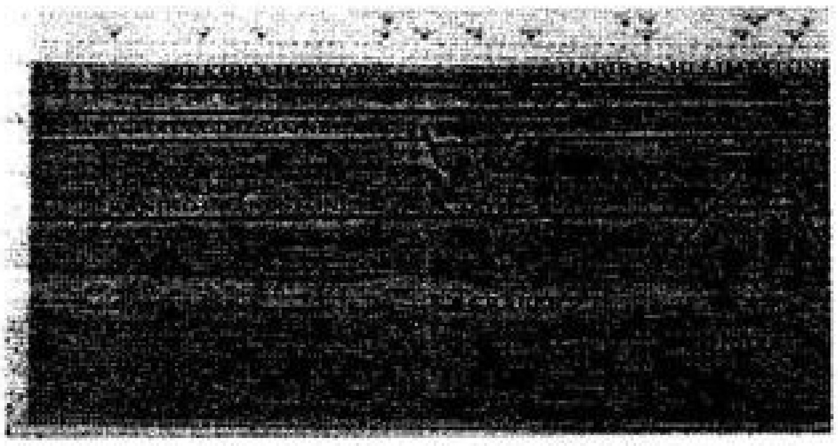

Figure 4B- Line No. 921-QRP-11

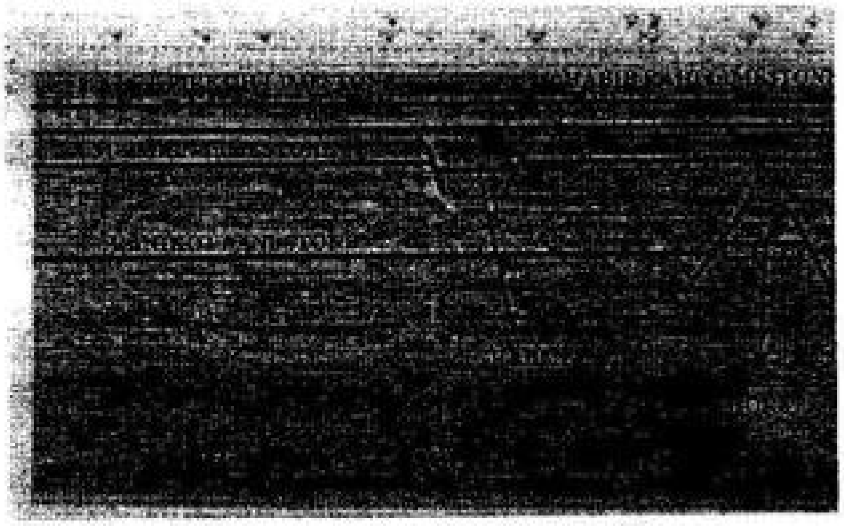

Figure 4C- Line No. 90-QRP-06

**Figure 4- Seismic sections showing the identified horizons and structural style present in the area.**

On the basis of calculation for each zone of Sui Main Limestone (Figure 9) the average porosity is found to be 20 to 30%. This indicates that limestone has high fracture porosity.

## CALCULATION OF AVERAGE WATER SATURATION

Water saturation is an important factor in the quality of Reservoir. Generally if the water saturation is greater than 30% then it will not be a productive formation. The average water saturation is calculated by following formula:

Sw (Water Saturation) = $(\Sigma n.Sw)/\Sigma n$

Evaluation of water saturation of each zone of Sui Main Limestone (Figure 11 & 12), Sw appears to be 18 to 22%.

## CALCULATION FOR HYDROCARBON SATURATION AND THICKNESS

Hydrocarbon saturation is calculated by following equation:

Total fluid = Hydrocarbon + Water
SH + Sw = 1
SH = 1 - Sw

Evaluation of hydrocarbon saturation of each zone of Sui Main Limestone (Figure 13 & 14), SH appears to be 78 to 82%.

Hydrocarbon thickness is defined as "The product of porosity (Φav), net pay thickness (h), and hydrocarbon saturation (SH) ".

Hydrocarbon thickness = **Φav*h* (1 - SH)**

## NET PAY THICKNESS (h)

Net pay thickness is defined as "The thickness of the reservoir which can produce commercial quantities of hydrocarbon"

Total thickness of the reservoir zone=14m
Net pay thickness=14m
Net pay thickness= h = 14x3.281=45.934feet

## CUT OFF

It provides the information about the shale content (Figure 10) or volume of shale present in the rock. If the formation having porosity (Φav) is greater than > 6%, volume of shale (Vsh) is less than < 30% and water saturation (Sw) is less than < 30%, formation has been categorically accepted to be a reservoir.

## RESERVOIR ROCK VOLUME

Reservoir rock volume is defined as "the product of productive area of field (A) and net pay thickness".

Reservoir volume is expressed as = **A*h**

Where the calculated area (A) in units of cm squares of the total reservoir area.

Following the scale given in figure 15 gives
1.65cm = 1 Km
Then, 2.72 square cm = 1.0 sq km
1sq cm = 0.3673sq km
98sq cm = 98 * 0.3673 sq km = 36sq km
1sq km =247.1arces
36sq km = 247.1x36 = 8895.6 acres
h = 45.934 feet

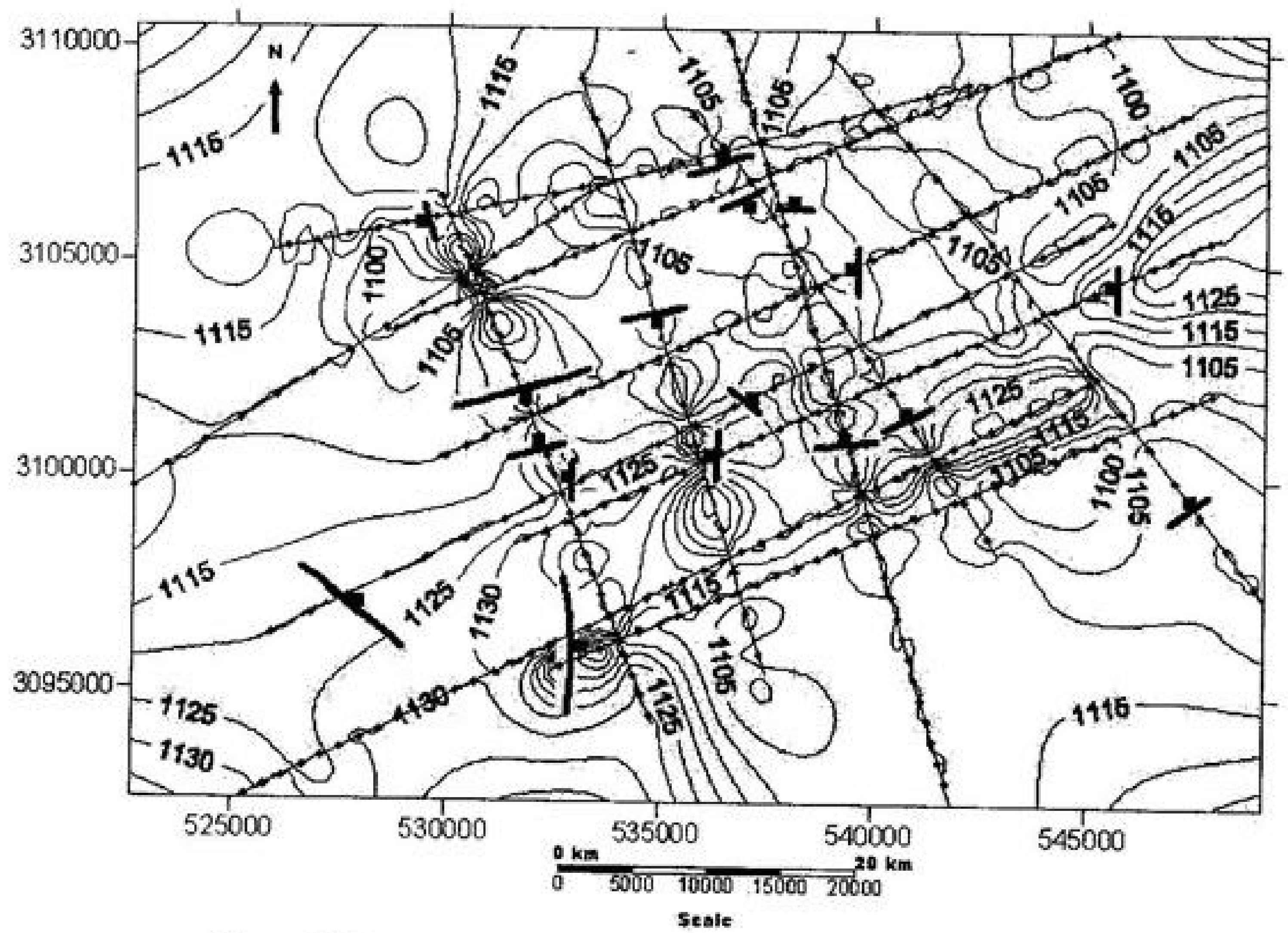


Figure 5- Time contour map on the top of the Sui Main Limestone.

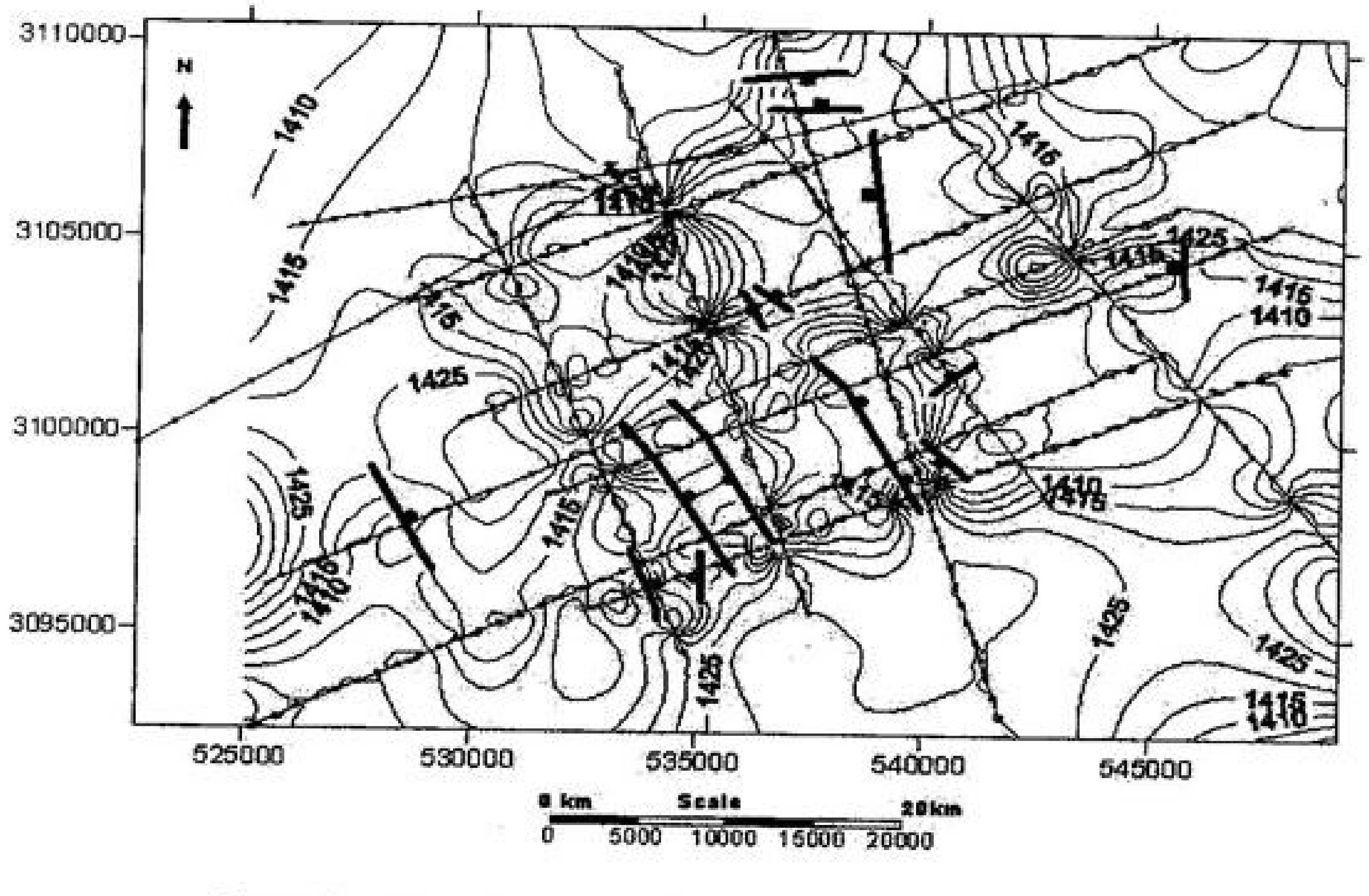


Figure 6- Time contour map on the top of the Ranikot Formation.

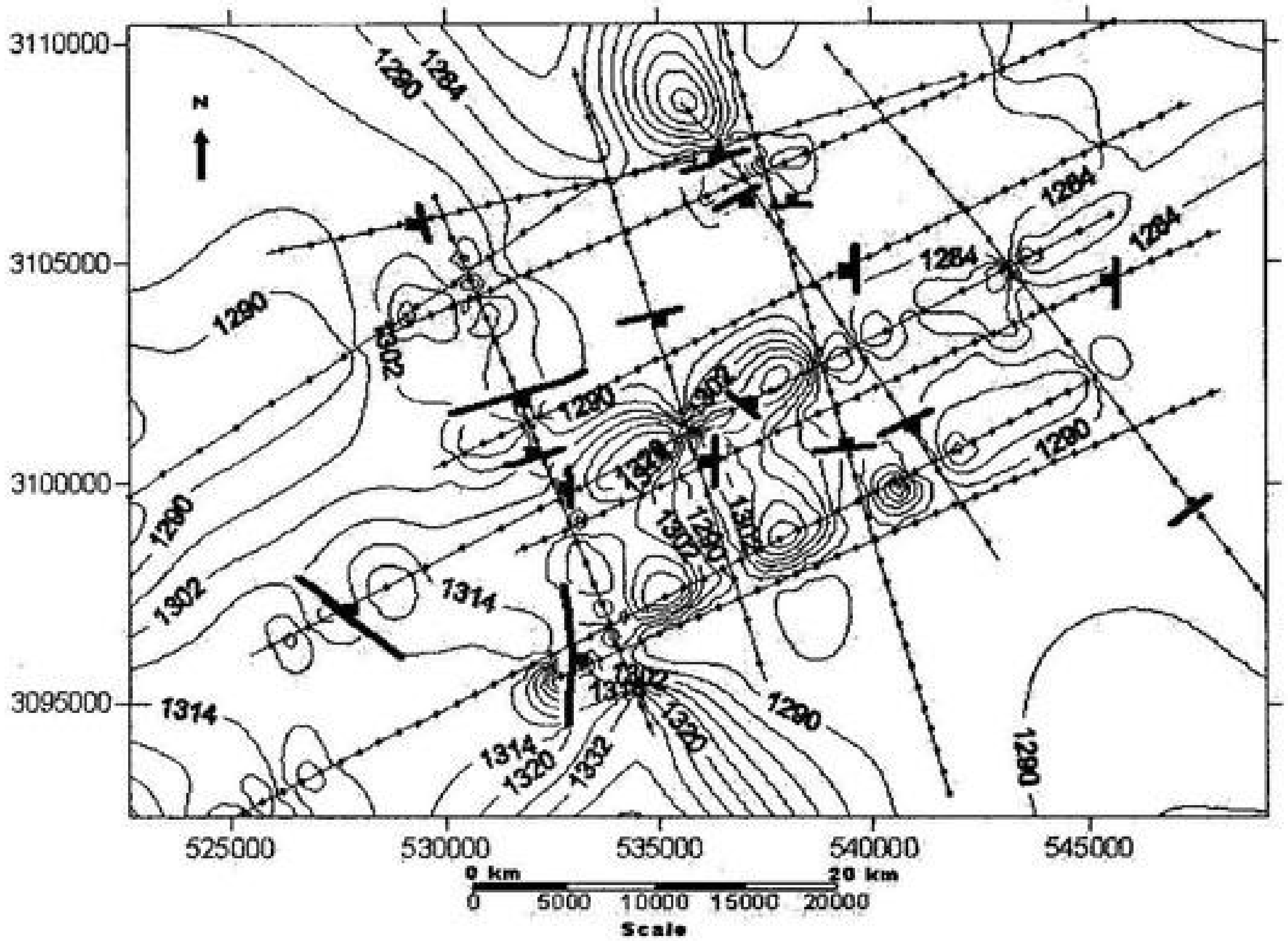


Figure 7- Depth contour map on the top of the Sui Main Limestone.

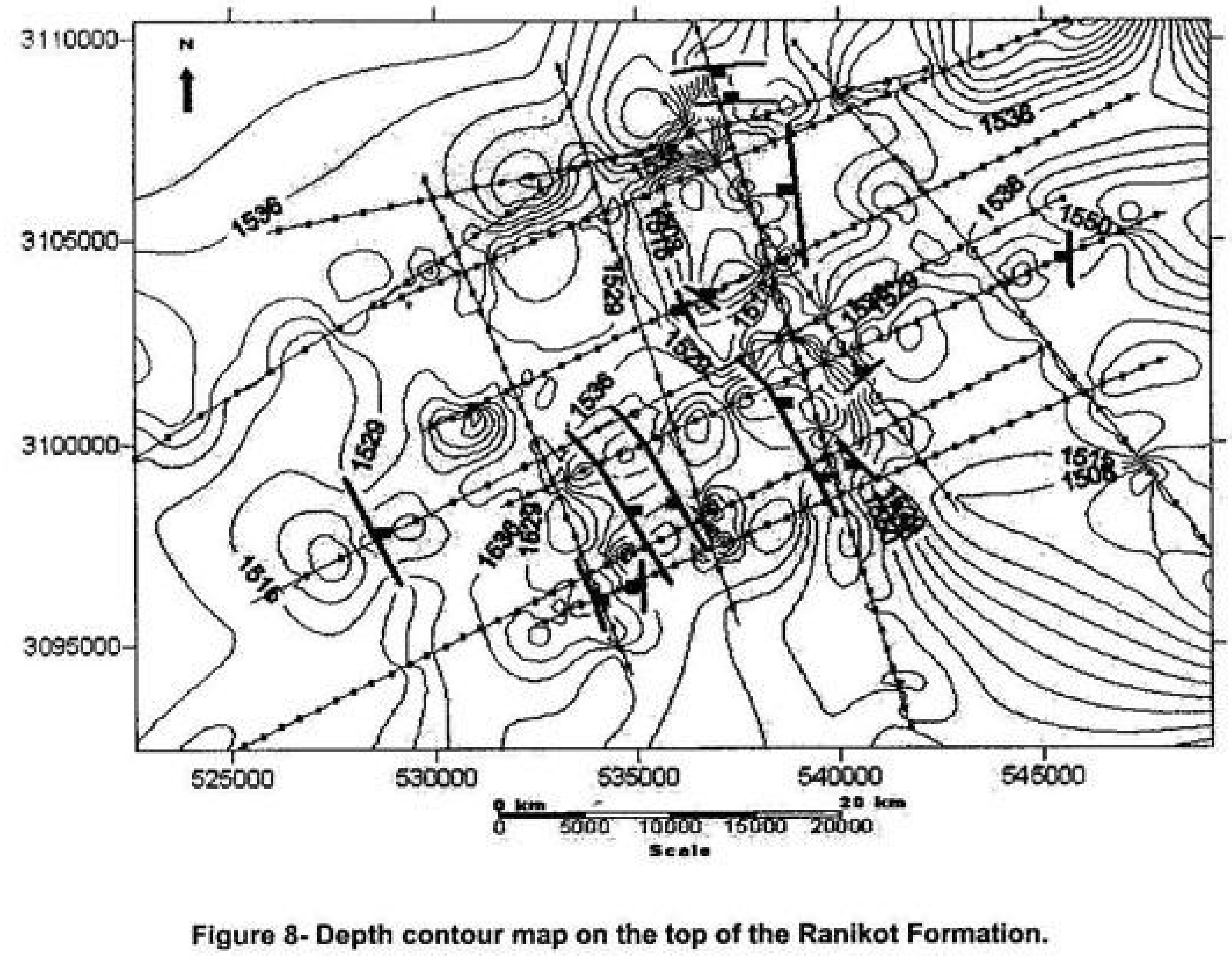


Figure 8- Depth contour map on the top of the Ranikot Formation.

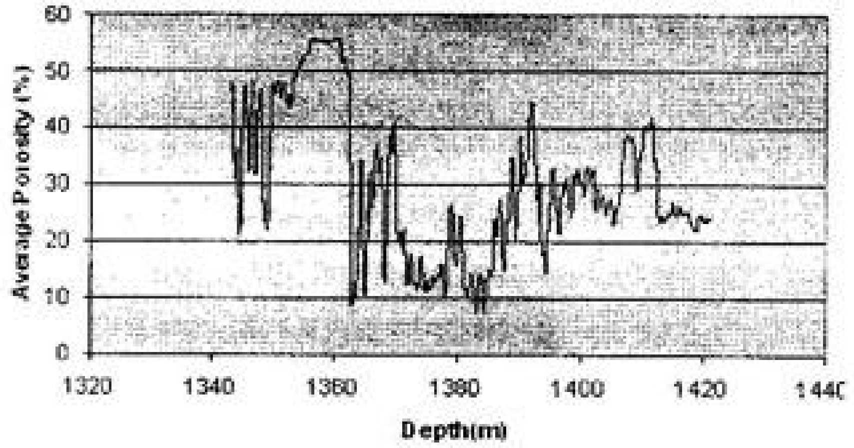


Figure 9- Average porosity of Sui Main Limestone (Using Bulk Density, Sonic and Neutron Porosity).

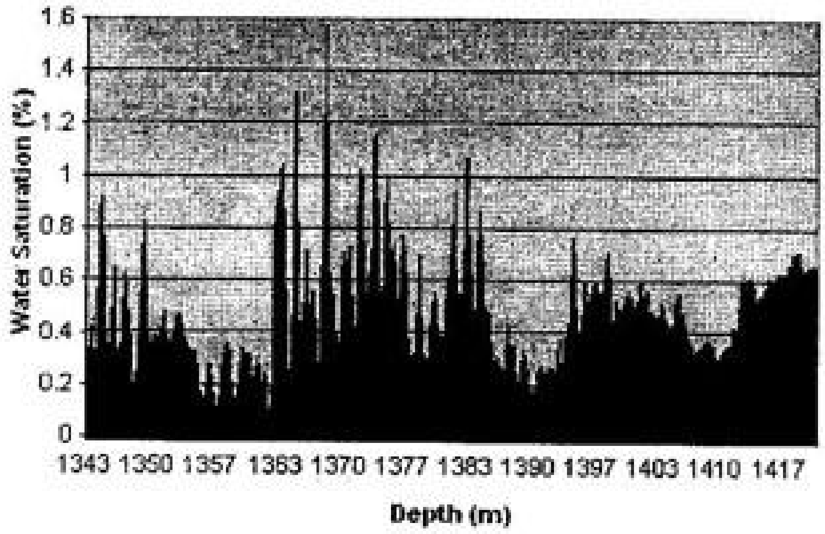


Figure 12- Water saturation of Sui Main Limestone using Well-05.

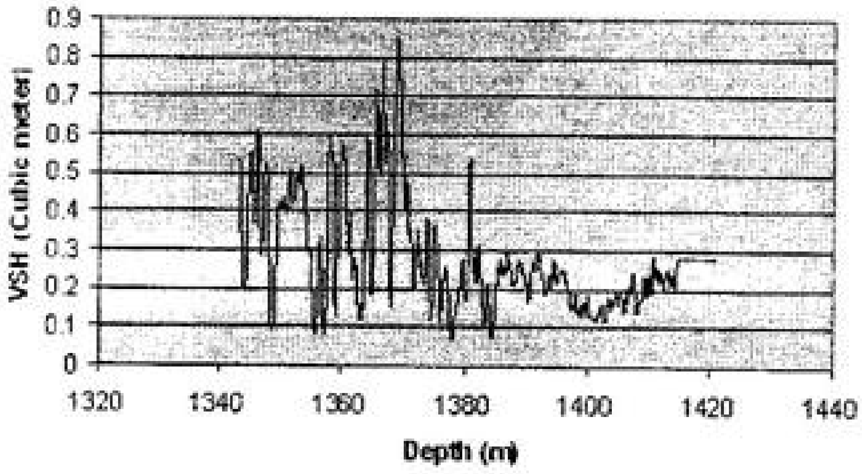


Figure 10- Volume of shale using Gamma ray log of Sui Main Limestone.

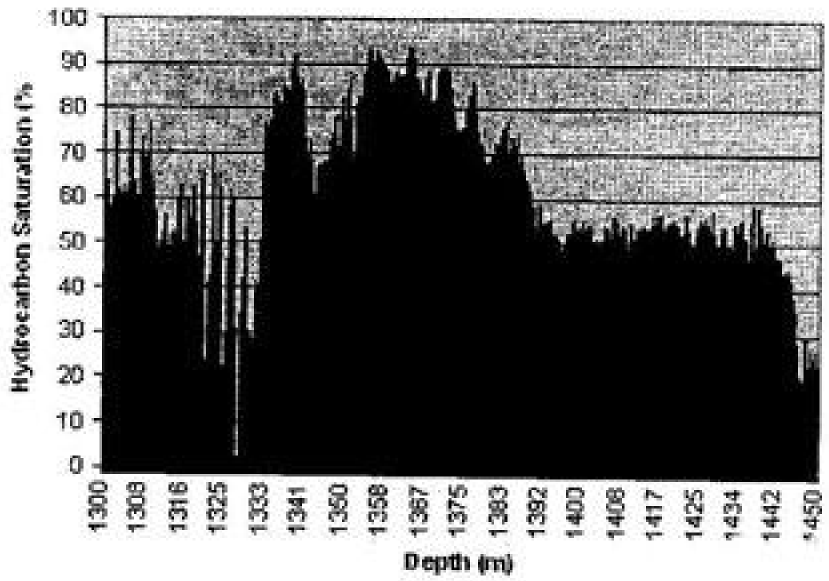


Figure 13- Hydrocarbon saturation of Sui Main Limestone using Well-01.

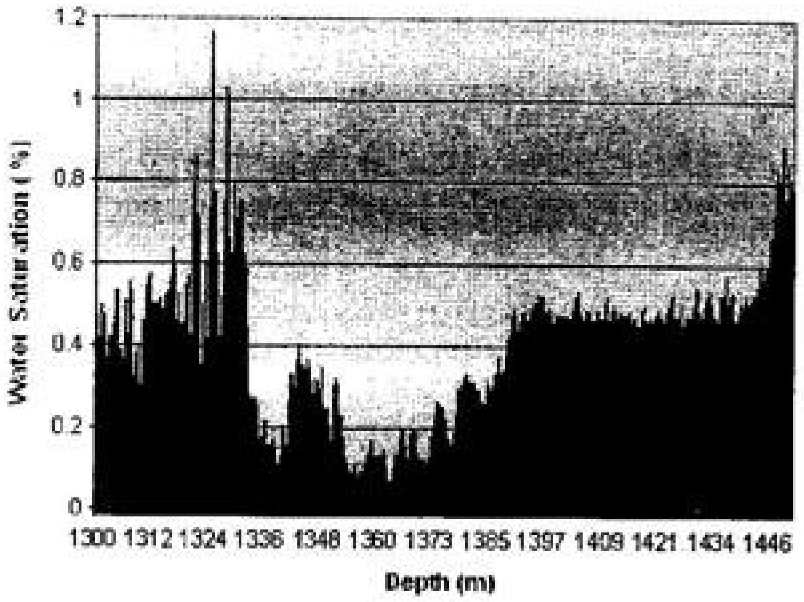


Figure 11- Water saturation of Sui Main Limestone using Well-01.

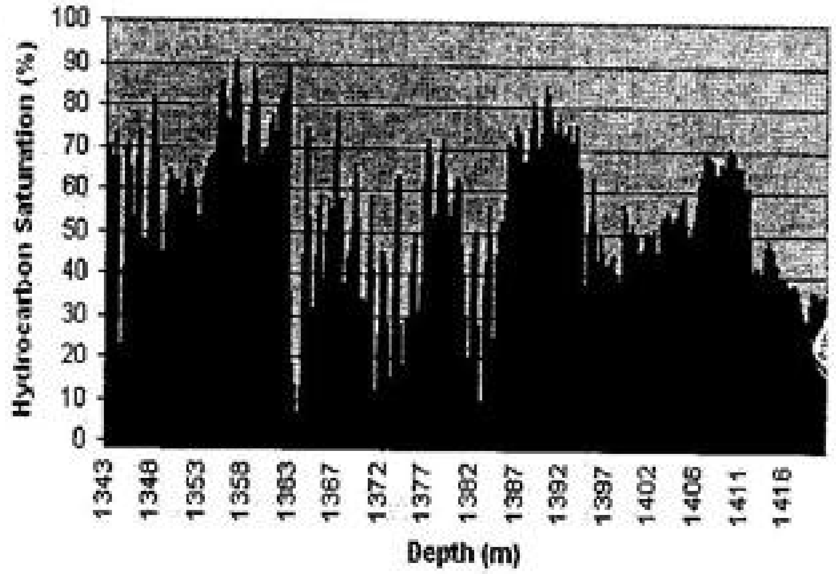


Figure 14- Hydrocarbon saturation of Sui Main Limestone using Well-05.

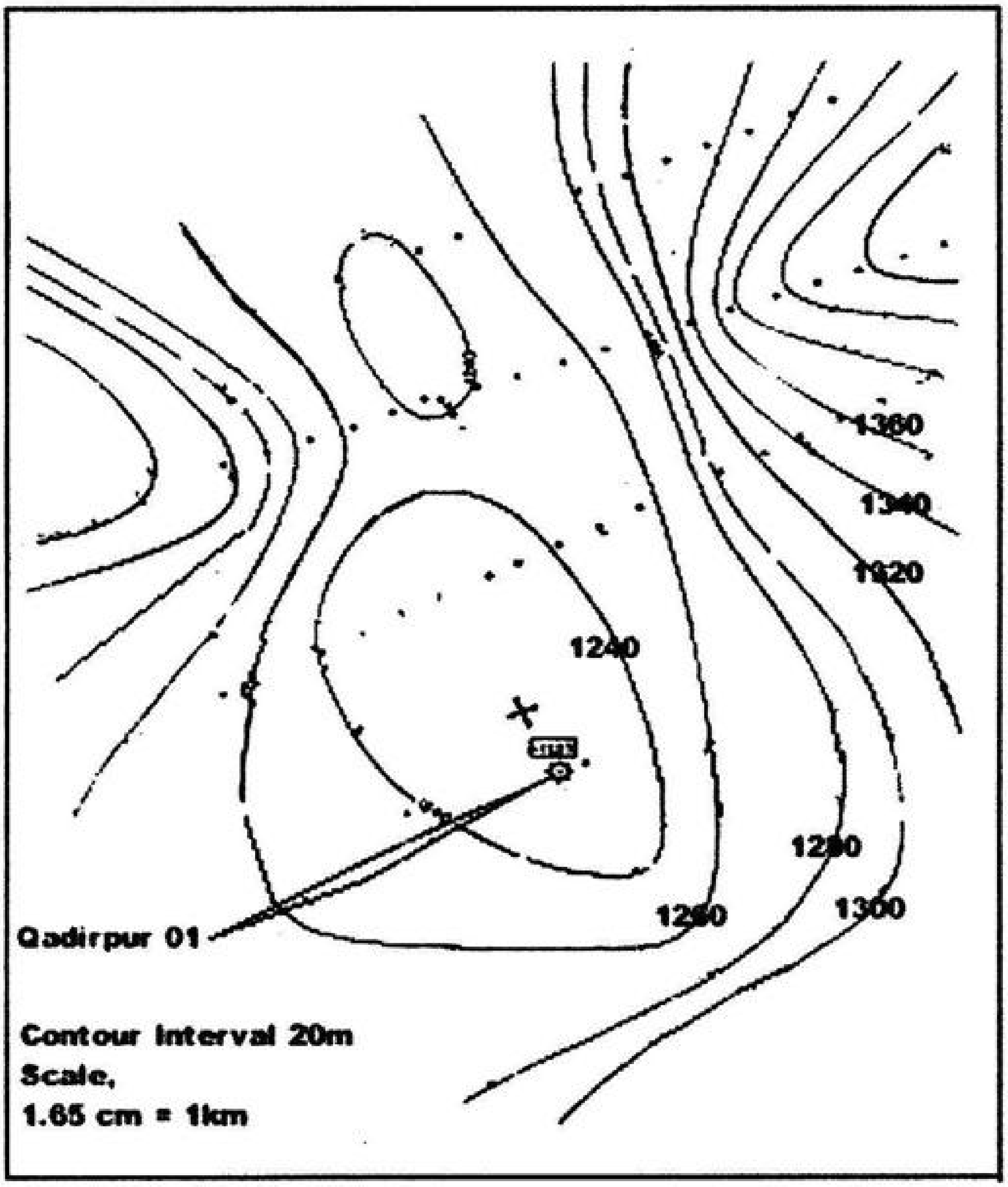


**Figure 15- Calculation of reservoir area using centimeter graph and depth contour map on top of Sui Main Limestone.**

**ORIGINAL GAS IN PLACE**

Original gas in place is calculated by following formula:

**Gr** = [43560 x Area x Net pay x porosity x (1 - Sw) x (Pf2/Pf1) x RF]

**Gr** = [43560 * A * h * Φ * (1 - Sw) * (Pf2/Pf1) * RF]

**Gr** = Volumetric recoverable gas reserves in standard cubic feet (SCF)

**RF** = recovery factor

Data procured from Qadirpur well #1 and Qadirpur well #5 suggest the following:

| | | |
|---|---|---|
| Net Pay | h | = 45.934 |
| Average porosity | $\Phi_{av}$ | = 0.22 |
| Area of reservoir | A | = 8895.6 |
| Water Saturation | $S_w$ | = 0.22 |
| Recovery Factor | RF | = 0.75 |
| Surface pressure | Pf1 | = 15psi |
| Reservoir pressure | Pf2 | = 1980psi |

Gr = [43560 * A * h * Φ * (1 - $S_w$) * (Pf2/Pf1) * RF] Gr = 6.58287480090TCF

## CONCLUSIONS

Following conclusions are made from this study:

1. All the sedimentary strata are generally dipping towards southwest.
2. No definite fault trend can be observed or in other words, there are localized leads or prospects present at the level of Sui Main Limestone.
3. The closures have values ranging from 5-10 milliseconds, generally in the southwest at the level of Sui Main Limestone.
4. At Ranikot level, there is a gentle trend of faults in the northwest to southeast direction. Very few localized cross faults can also be seen.
5. The closures have values of 20-25 milliseconds toward north and 15-20 milliseconds towards the south at Ranikot level.
6. The localized normal faults with gentle trend exist due to extensional tectonic activity in early Paleocene.
7. The prospective zones lie in the southwest of the study area at Sui Main Limestone level, and in the north and southwest at Ranikot level.
8. Lithology, water saturation and hydrocarbon saturation indicate two productive zones within reservoir formation (Sui Main Limestone).
9. Average values of porosity for each productive zone ranges from 20 to 23%; average values of water saturation ranges from 18 to 20%, and average values of hydrocarbon saturation ranges from 78 to 82%.
10. The total reservoir rock volume is calculated to be 8896 acres.
11. The total volumetric recoverable gas reserves are 6.6 Trillion Cubic Feet (TCF).

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