2D Seismic Interpretation and Well Log Analysis of Fazilpur area, Central Indus Basin, Pakistan

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Abstract* – *Fazilpur area is located in Punjab province in District Dera Ghazi Khan. Geographically the area lies between 29º 15' to 29º 30' North and 70º 10' to 70º 40' East. Stratigraphically, it lies in Sulaiman depression of Central Indus Basin, which is characterized by monoclinal structures. The following study is done for hydrocarbon potential evaluation by integrating the seismic and well log data approaches. The target horizons were marked by making the TD chart using well tops of Choti-01. The target formation in the research area was to test the Sui Main Limestone of Eocene age. The two-way time and depth contour maps prepared as a result of interpretation, have confirmed the presence of Monocline trending East to west. The Time to depth conversion is done using the available stacking velocities on the seismic sections. The Monoclinal structure is shallowing towards east and deepening towards west. Sui Main Limestone of Late Eocene and Dunghan Formation of Early Paleocene are acting as reservoir rocks. Ghazij shale of Eocene age is acting as a regional seal. Petrophysical analysis is done on the well Choti-01 for formation evaluation and potential hydrocarbon baring zones. Two zones, Pirkoh Formation (Zone 1) 15 m in thickness and Sui Main Limestone (Zone 2) 48 m in thickness have been identified on logs respectively. Through the results of petrophysical analysis, zone 2 is more promising for hydrocarbon potential than zone 1 having average Vsh 25% and Vsh 40%, average effective porosity 6% and 3%, average saturation of hydrocarbon 86% and 43% respectively. Due to tight effective porosities in both the zones this well is abundant. Petrophysical analysis at that level of Dunghan Limestone (which is also a proven reservoir) could not be carried out due to the unavailability of well log data.

Key words: Monoclinal structure, petrophysics, Trap

I. INTRODUCTION

The project area which is licensed for exploration is located in Tehsil Rajanpur; district Dera Ghazi Khan, Punjab Province (Figure 1). The Latitude of the area is $29^0$15' to $29^0$30' North and Longitude of the area is $70^0$10' to $70^0$40' East. Seismic data was acquired and processed by Oil and Gas Development Company Limited (OGDCL). Sakhi Sarwar is a large surface anticline trending NNE-SSW about 12 x 5 miles in size. AMOCO drilled Sakhi Sarwar-1 in 1976 down to 4581m, the well was drilled within the Pab sandstone (not fully penetrated) The well was P & A with gas shows. OGDCL acquired same area in 1997 and drilled Choti # 01 well, about 23Kms south east of Sakhi Sarwar #01 to test the SML potential. The well was P&A. The block was awarded to OPL in Dec 2004 for five years. Sakhi Sarwar-1 was drilled with Pab Sandstone as a primary target. The well encountered several mechanical problems due to pressure abnormalities probably due to the pressure differences b/w Ranikot and Pab formations. The well had 3 sidetracks. The well was tested barefoot within the Ranikot & Pab reservoirs. The well flowed max. 0.52 mmscfd @ 48/64" choke with a FWHP of 200 psi and 1500bpd water.

Fig. 1 Location map of Fazilpur (Modified after Google maps).

Fazilpur lies near the western boundary of sulaiman depression, Central Indus Basin. Sakhi Sarwar, Drigri and Kotrun anticlines which lie in the south of Zindapir anticline, a part of Safed Koh trend (N-S trending), are prominent structural features of this area (Kadri, 1995). In the East of area, Punjab Monocline is present and Suleiman Fold and Thrust belt is present in west. This area is a Frontal fault propagation folded zone (Kadri, 1995).The Punjab Platform dips westward into Sulaiman Fore deep. The structural style of the Central Indus Basin is obscured at surface by thick alluvial cover of Siwaliks.

The objectives of the research are to establish stratigraphic correlation with the help of seismic data and well information of Choti-01 and to study the subsurface extent and thickness and Hydrocarbon Potential of Habib Rahi Formation (Eocene), Sui Main Limestone (Eocene) and Dunghan Limestone (Paleocene) in the area.

II. TECTONICS OVERVIEW

Fazilpur Area lies in Central Indus Basin Pakistan. The basin is bounded by Indian Shield to the east and highly folded mountains of Axial Belt to the west (Kadri, 1995). The general west directed dip of Sindh Platform is

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interrupted by gentle arch of north to south oriented Khairpur High which is interpreted as a large basement induced structure (Krois et al, 1998). From East to West direction, Middle Indus Basin comprised of Punjab Platform, Sulaiman Depression and Sulaiman Fold-belt respectively (Kadri, 1995). Oldest rocks exposed in central Indus basin are of Triassic age (Wulgai Formation) while the oldest rocks penetrated through drilling are of Precambrian Salt Range Formation. The basement depth is approximately about 15000 meters in the Trough areas. Precambrian shield rocks are evident along the rim of the Indian Plate (Kadri, 1995).

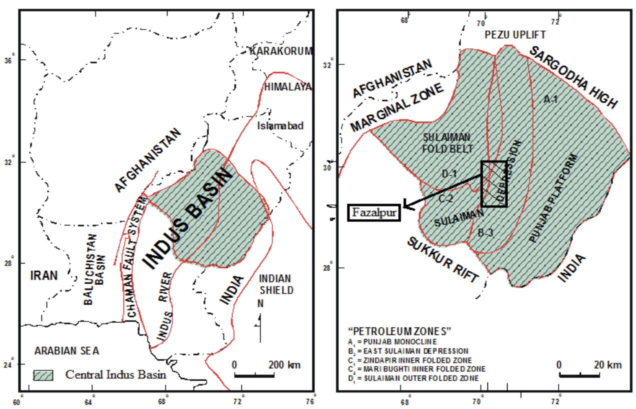

Fig. 2a Generalized tectonic map of Pakistan and location of the Central Indus Basin (Kadri, 1995)

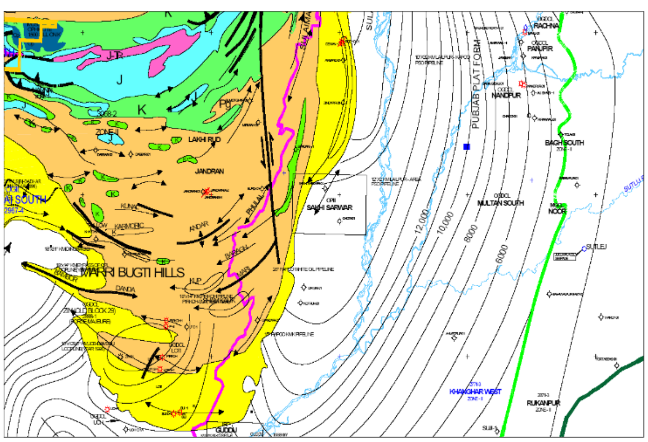

Fig. 2b Generalized Geological map Sakhisarwar Anticline including study area (Courtesy by OGDCL).

Punjab platform marks the eastern segment of central Indus basin with no sedimentary outcrops on surface. Tectonically, it is a broad monocline dipping gently towards the Sulaiman Depression (Figure 2b). Sulaiman Depression is visible on gravity data and is a longitudinally oriented area of subsidence. (Wandrey et al, 2002)

Sulaiman fold belt is a major tectonic feature in the proximity of collision zone and, therefore contains a large number of disturbed anticlinal features. The structural play domain has monoclines and narrow anticlinal structures which lengthens tens of kilometers with limbs that are affected by steeply dipping faults (Krios et al, 1998). During the collision of the Indo-Pakistan Plate with the Eurasian Plate basement was segmented into three different blocks (Bannert et al. 1992). These three basement faults separate these basement blocks from each other and from the central part of the Indo-Pakistan Plate. Kirthar Basement Fault separates the Khuzdar Block and the Sulaiman, the Sulaiman Block and the Hazara Block by the Sulaiman Basement Fault and the Hazara Block and main body of the Indo-Pakistan Plate to the east are separated by the Jhelum Basement Fault (Bender and Raza, 1995). Central Indus may be divided into following broad tectonic divisions (Figure 2a).

1) Punjab Platform,
2) Sulaiman Depression,
3) Sulaiman Fold Belt

Petroleum Prospect

The potential source rock in the area is Sembar Shale. Late Paleocene Dunghan Limestone, Sui main Limestone of Eocene age has good reservoirs characteristics (Kemal, 1992). Ghazij shale of Eocene age is the regional seal in the area for their respective reservoirs and the migration of hydrocarbon is done along the faults. The generalized stratigraphy of the area is given in figure 3 while the borehole stratigraphy of the well Choti-01 is shown in the figure 4.

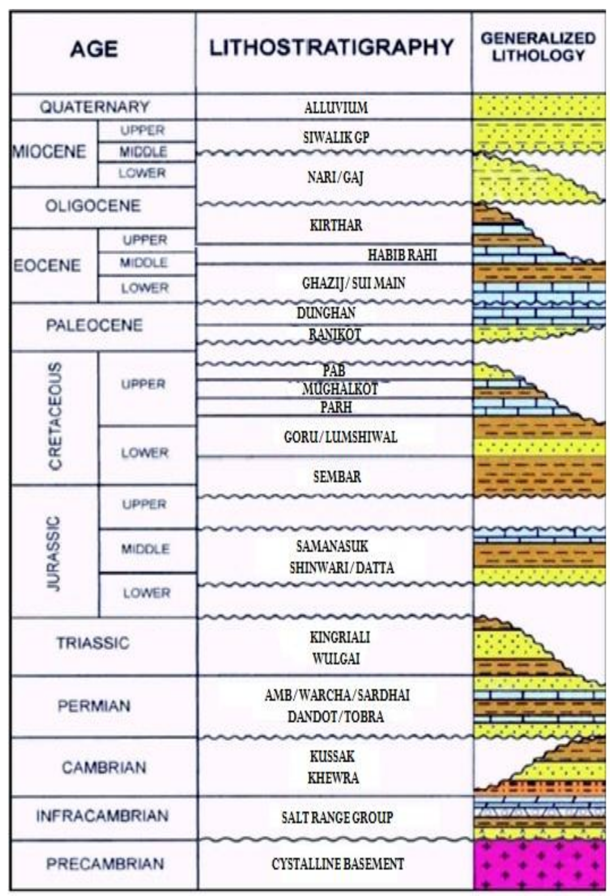

Fig. 3 Generalized stratigraphic column of central Indus basin (Kadri, 1995)

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Formations	Depth	Thickness
Alluvium	0	-
Nagri	147	1147
Chinji	1294	1121
Gaj-nari	2415	757
Drazinda	3172	192
Pirkoh	3364	16
Sirki	3380	170
Habib Rahi	3550	49
Ghazij	3599	413
Sui Main Limestone	4012	428
Dunghan	4440	

Fig. 4 Borehole stratigrapgy of Choti-01. (Provided by LMKR)

III. METHODOLOGY

Seismic approach is a significant geophysical method used for investigation of subsurface structural styles and layers in the subsurface. Folded and faulted structures commonly form migration, trapping & accumulation of hydrocarbons. Seismic data is a substantial source for the understanding of subsurface structural trend and lithology in the subsurface. For this purpose 2D seismic lines have been interpreted to get stratigraphical and structural insight of subsurface. The array length was 39 m and the source interval was 100m and the geophone interval was 2.08 m. The recording was done by OGDCL in June- July 1997. Nature of the seismic lines along with the well point is shown in the base map (Figure 5).

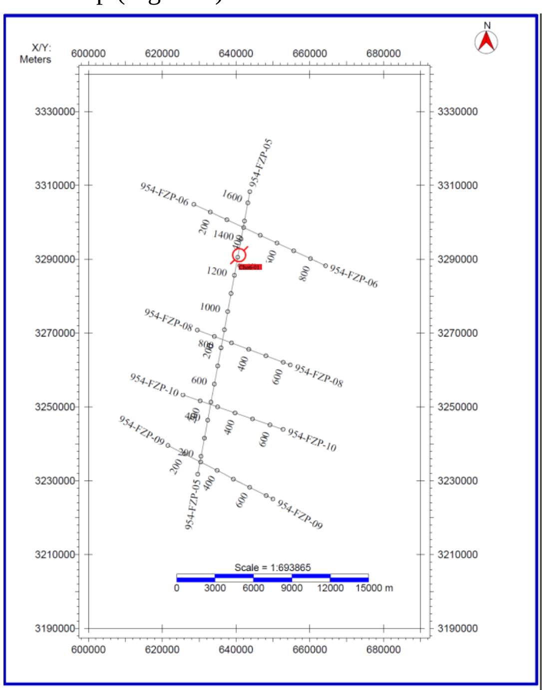

Fig. 5 Base map showing seismic lines and well point.

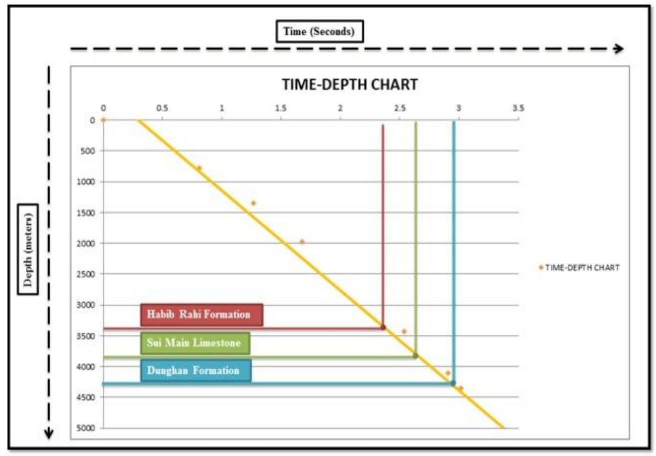

Fig. 6a TD chart made by using well choti-01

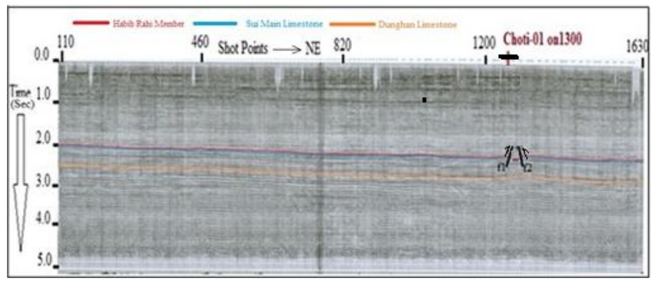

Fig. 6b Interpreted section of line 954-FZP-05.

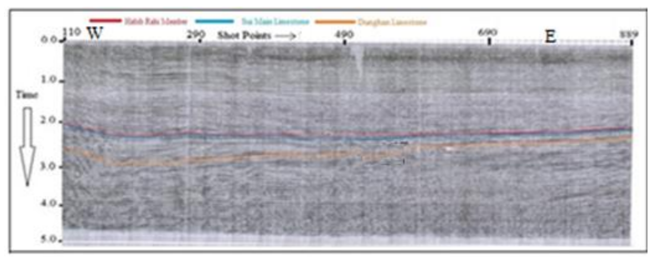

Fig. 6c. Interpreted section of line 954-FZP-06

For structural interpretation, foremost step is to identify and mark the target horizons on the seismic section. This task is completed with the help of existing well data of Choti -01, from which depth of each reflector is taken and then by solving the available stacking velocity of seismic sections, TD chart is prepared (Figure 6a) and horizons are marked. Then using the formula $S = v\,t/2$, depth of the reflectors are calculated and correlated with the well depth. Three horizons are chosen up on the given seismic section on the base of continuity and strong character of the reflectors. After correlation of the data i.e from seismic to well tie, the three reflectors marked, are named as:

1. Habib Rahi Formation
2. Sui Main Limestone
3. Dunghan Limestone

A. Horizons Interpretation

Data quality of the seismic sections is fair to good and Fault correlation and horizon identification was difficult on some sections. Constant misties have been observed in data.

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Habib Rahi Formation is of Eocene age. It is represented by red color on seismic section.

Sui Main limestone of Eocene age is marked as second horizon on seismic section and it is colored blue.

Dunghan limestone of Paleocene Age is marked and represented in orange colored reflector.

The discontinuity in the reflector represents the faults. The Faults were observed only on the two seismic lines i.e. FZP-05, 06.The observed faults F1 and F2 marked on the seismic sections which are minor faults originating and truncating at the level of Eocene. The interpreted scanned seismic sections have been shown in figure 6a and 6c.

B. Time-Depth Contour Maps/Interpretation

For making the contour maps time and depth values are plotted against the latitude, longitude in the software kingdom. Average velocities taken from the velocity functions are used for depth conversion. Time and depth contour maps of Habib Rahi Member, Sui Main Limestone and Dunghan Limestone are shown in figure 7a, 7b, 7c and 8a, 8b and 8c respectively. Time-depth contouring of Paleocene, and Eocene show, the strata is getting shallower in the south east direction. Closure at Choti-01 is about 100 ms at Eocene level, if we use average velocity of 3200 m/s approximately for Eocene level this closure turns to be ~170m in depth.

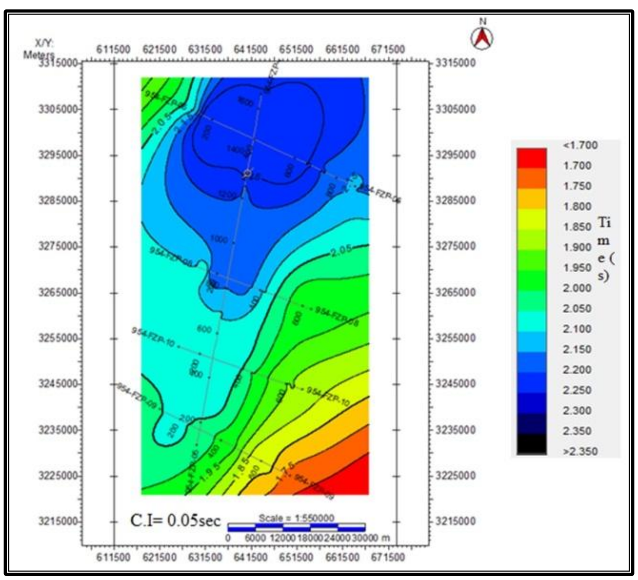

Fig. 7a Time contour map of Habib Rahi Formation

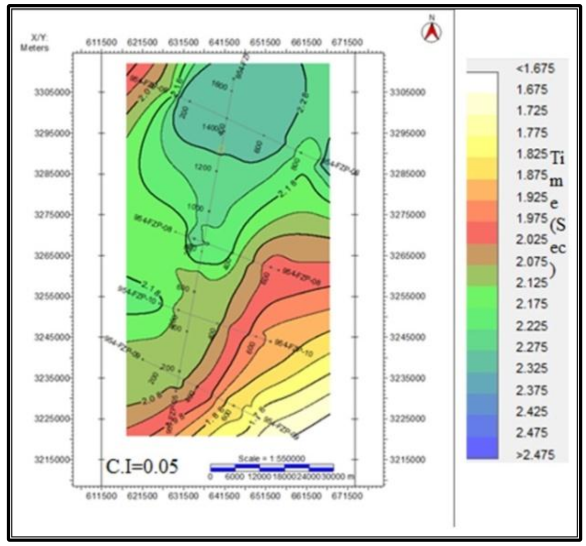

Fig. 7b Time contour map of Sui main Limestone

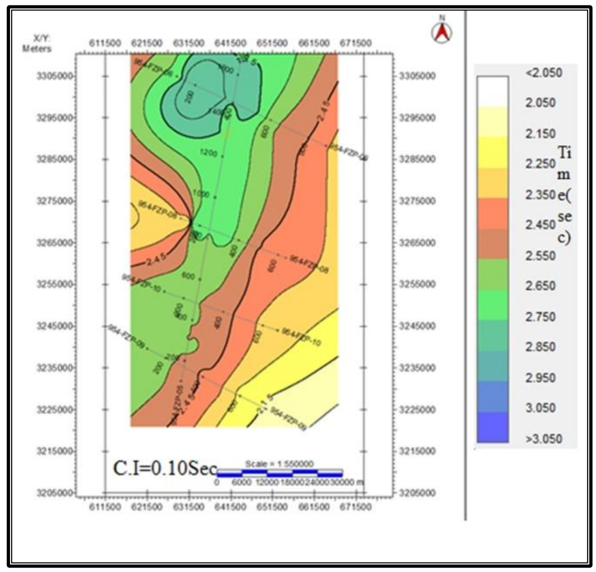

Fig. 7c Time contour map of Dunghan Limestone.

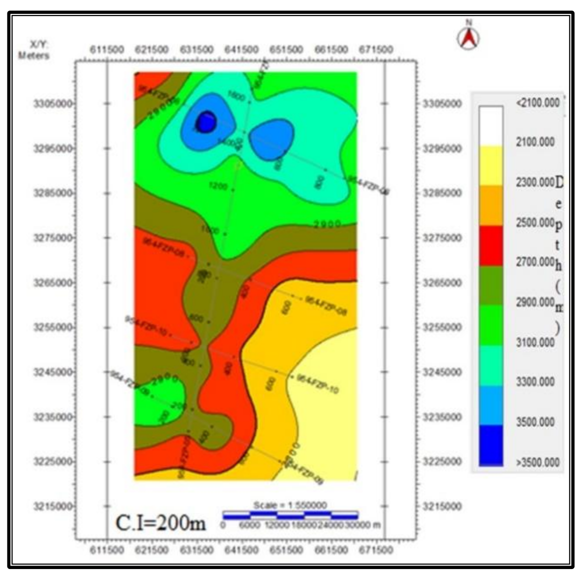

Fig. 8a Depth contour map of Habib Rahi Formation.

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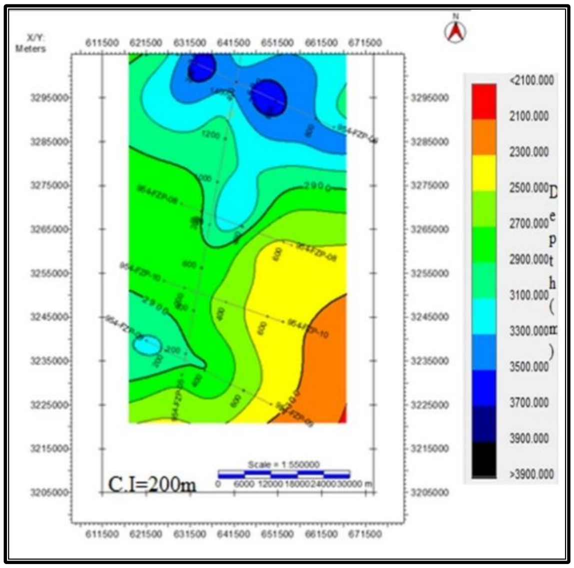


Fig. 8b Depth contour map of Sui main Limestone.

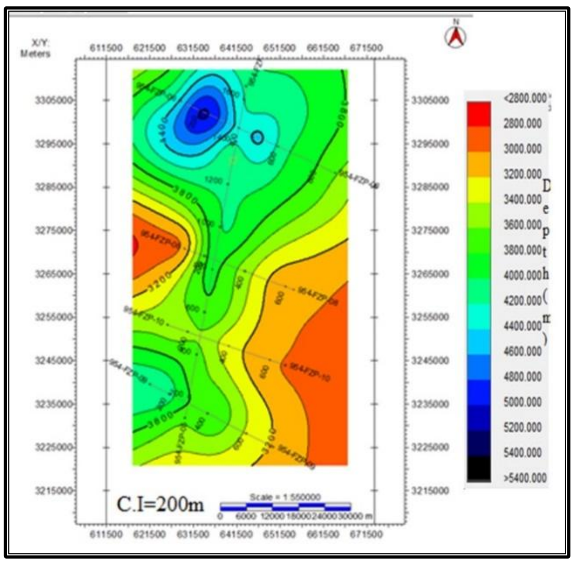
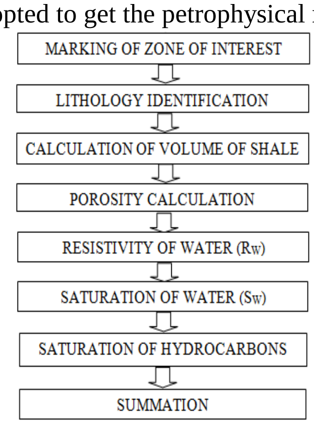


Fig. 8c. Depth contour map of Dunghan Limestone

C. Petrophysical Analysis

The objective of petrophysical analysis is to attain information from the well, i.e. Choti-01. Following methodology is adopted to get the petrophysical results.



D. Raw Logs Data

The raw log data was acquired from Directorate General of Petroleum Companies (DGPC). The data comprised the raw log curves. The wire line log of Choti-01 well has been evaluated. Suite of logs includes gamma-ray log (GR), Neutron log, Sonic and resistivity log. Average parameters for the well have been computed after consideration of a range of different cutoff values of porosity, volume of shale and hydrocarbon saturation.

E. Zone of Interest

First of all the clean zones were marked using the Gamma Ray Log. Then the log trends of Neutron and Density logs have been recognized at clean zones. Cross-overs are observed between Neutron and Density log curves. These crossovers are sign of hydrocarbons in the particular zone. Resistivity curves also have shown the presence of hydrocarbons. Two zones of interest marked are shown in Table 1.

Table 1. Zones of Interest.

Zones	**Formations**	**Starting Depth**	**Ending Depth**	**Thickness**
Zone 1	Pirkoh Formation	3364	3379	15
Zone 2	Sui-Main Limestone	4012	4060	48

F. Lithology Confirmation

Gamma ray log was used to differentiate between clean and dirty zones. PEF is also used to check our lithology which is Limestone.

G. Calculation of Shale Volume (VSH)

Volume of shale is calculated by using the Gamma Ray Log. As in the quantitative assessment of the shale content, it is assumed that the radioactive minerals are absent in clean rocks and are compared to the shaly rocks. To calculate the volume of shale we have used the following formula:

Volume of shale (VSH) $= GR_{log} - GR_{max} / GR_{max} - GR_{min}$

Where,

GR_{log} = *Gamma ray log reading.*

GR_{max} = *Maximum Gamma ray deflection.*

GR_{min} = *Minimum Gamma ray deflection.*

Using the above mentioned formula volume of shale of two marked zones is calculated. (Figures 9a & 10a).

H. Porosity calculation

In our analysis, porosity values at different depths were computed by using Neutron and Density Logs. Then average porosities were calculated by combining Neutron and

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Density values. Our final product was effective porosity. It was calculated by using following formula.

*Effective Porosity= Vsand * Porosity avg*

The graphs of Effective porosity versus depth in Zone 1 and Zone 2 are shown in figure 9b and 10b.

Avg. Porosity = (Density porosity + Neutron porosity) /2

I. Saturation of Water (S_W)

The fraction of pore space containing water is named as water saturation denoted by “Sw”.

$$Sw = (F*(Rw/LLD))\ ½$$

The graphs of the Effective porosity versus Depth in Zone 1 and zone 2 are shown in figure 9c and 10c.

J. Saturation of Hydrocarbons (S_H)

Calculation of the saturation of hydrocarbon is a very significant step, because the reservoir potential to yield hydrocarbons is checked. The Formula for the calculation of hydrocarbon saturation is,

$$S_h = 1 - S_w$$

Where,

S_h= Saturation of Hydrocarbon

S_w = Saturation of Water

The graphs of Saturation of Hydrocarbon versus depth in Zone 1 and Zone 2 are shown in figure 9dand 10d.

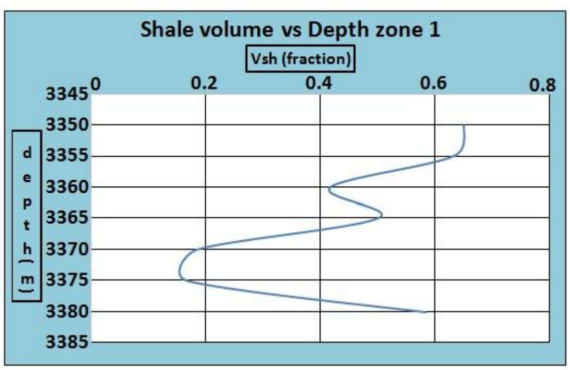

Fig. 9a Depth vs. Volume of Shale in Zone 1 (PirKoh Fm).

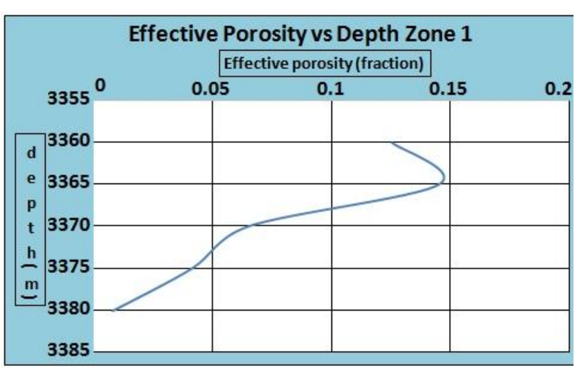

Fig. 9b Depth vs. Effective porosity calculated in zone 1.

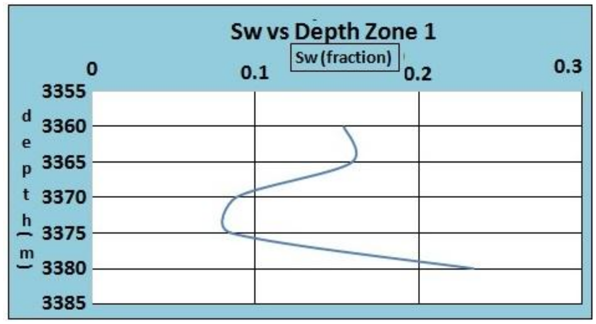

Fig. 9c Depth vs. saturation of water calculated in zone 1

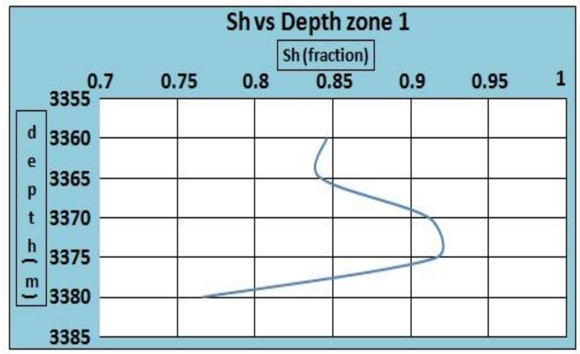

Fig. 9d Depth vs. saturation of hydrocarbon calculated in depth zone 1.

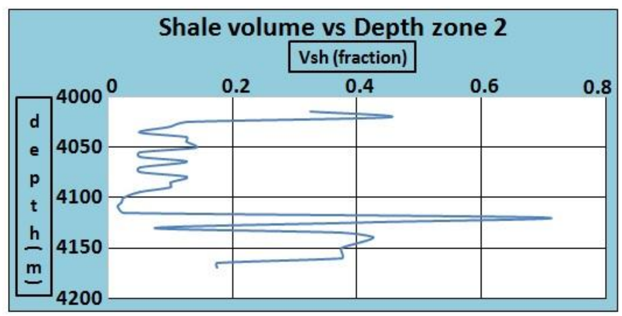

Fig. 10a Depth vs Volume of shale in zone 2 (SML).

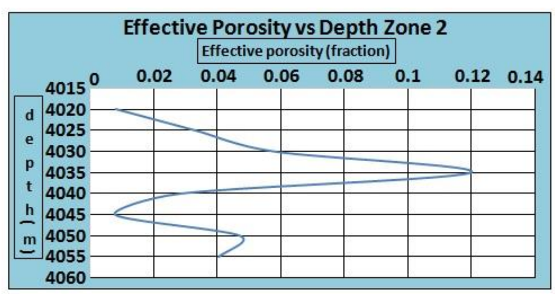

Fig. 10b Depth vs Effective porosity calculated in zone 2.

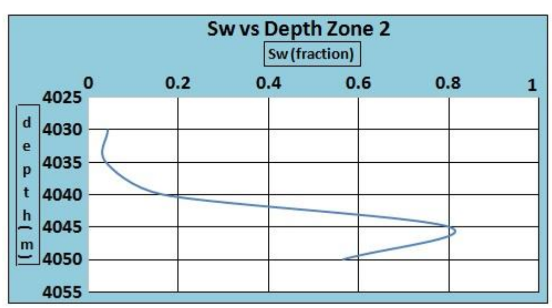

Fig. 10c Depth vs. saturation of water calculated in zone 2.

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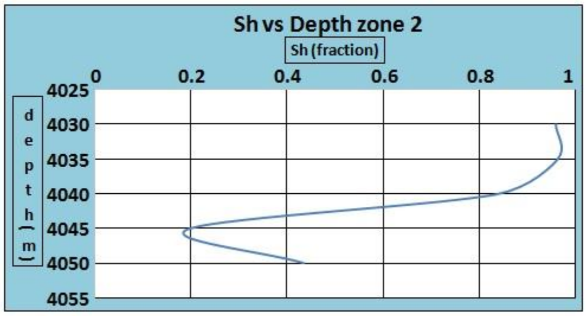

Fig. 10d Depth vs. saturation of hydrocarbon calculated in depth zone 2.

IV. RESULTS

1. According to literature, structures of Punjab platform and Sulaiman depression are relatively flat having very less structural variations.
2. Seismic sections clearly delineate deepening of the strata towards north western side. This is further confirmed by the time and depth contour mapping.
3. Very minor intraformational reverse faults have been observed but they uncorrelatable.
4. In Pirkoh Formation Zone 1 ranges from 3364m to 3379m in depth, having total thickness of 15 meters whereas in Sui Main Limestone Zone 2 is starting from 4012m to 4060m in depth. It has total thickness of 48 meters.
5. Zone 1 and zone 2 are having Volume of shale 40% and 25% respectively. This shows zone 2 is cleaner than zone 1.
6. The effective porosity of Pirkoh Formation and Sui Main Limestone is 3% and 6% respectively.
7. Hydrocarbon saturation is 43% in zone 1 for Pirkoh Formation while it is 86% in Zone 2 for Sui main limestone.

V. DISCUSSIONS

The research work done on Fazilpur area exhibited the relatively flat features with minor structural variations. The study is conducted with the aid of seismic and wireline log data. The structure studied through geology and literature review, clearly delineated on the seismic data with intra formational and minor reverse faults, at the level of Paleocene and Eocene age. The contour maps generated indicate west ward deepening of the strata forming monocline in the subsurface. Petrophysical analysis is performed on Pirkoh Formation and Sui Main limestone, in which Sui Main limestone showed more promising behavior as a reservoir rather than Pirkoh Formation.

VI. CONCLUSIONS

The study reveals that the project area shows positive signs of having hydrocarbon potential. Punjab platform and Sulaiman depression developed as a result of compressional regime with reverse faults. The study area mainly comprises of monocline having one limb dipping towards north-west direction. No major faults were observed on the selected seismic lines. Localized leads or prospects present at the level of Eocene and Paleocene. The time values are ranging from 2.3 to 2.4 sec approximately near the structure, where the Choti -01 well is drilled. Petrophysical analysis done on the SML level is showing the fair potential in the area under study but due very tight nature of the strata is not able to produce. Dunghan was not tested for petrophysics due to the unavailability of the log data. Time and Depth structure maps confirm the presence of valid structure at Paleocene and Eocene level. Petrophysical analysis of Zone 2 (Sui Main Lime stone) reveals that reservoirs of Paleocene and Eocene are tight. Major risk for this area is reservoir quality.

RECOMMENDATIONS

Well log data at the depth of Dunghan Formation was not available. If log data of the Dunghan Formation was provided, further interpretation would have been performed and a preferable insight of the reservoir could be developed of the area.

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REFERENCES

[1] Bannert, D., Raza H.A., 1992. The segmentation of the Indo-Pakistan Plate. Pakistan Journal of Hydrocarbon Research, 4(2), 5-18.

[2] Bender, F.K., Raza, H.A., 1995. Geology of Pakistan. Borntraeger, Berlin, Stuttgart, 414.

[3] Kadri, I.B, 1995, Petroleum Geology of Pakistan, PPL Pakistan., p.262-292

[4] Kemal, A., 1992. Geology and New trends for petroleum exploration in Pakistan. In Proceedings of International Petroleum Seminar on New Directions and Strategies for Accelerating Petroleum Exploration and Production in Pakistan. pp16-57.

[5] Kemal, A., Balkwill H.R., and Stoekes F.A., 1992, Indus basin hydrocarbon play: Proceedings of International Petroleum Seminar, Ministry of Petroleum and Natural Resources, Islamabad, Nov.1991, p.78-105.

[6] Krois, P., Mahmood, T. and Milan, G., 1998, Miano Field: A case history of model driven exploration. Pakistan Petroleum Convention 98, Islamabad, Pakistan, p. 112-134.

[7] Raza, H.A., Ali, S.M., &Ahmed, R., 1990a, Petroleum geology of kirthar sub-basin and part of kutch basin Pak. J, hydro. Res., 2(1): 29-74.

[8] Wandrey, C.J., Law, B.E. and Shah, H.A., 2002, Sembar Goru/Ghazij Composite Total Petroleum System, Indus and Sulaiman-Kirthar Geologic Provinces.

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