The Nucleus 54, No. 1 (2017) 38-45

www.thenucleuspak.org.pk

The Nucleus
ISSN 0029-5698 (Print)
ISSN 2306-6539 (Online)

Hydrocarbon Evaluation and New Well Prognosis Based on Seismic and Petrophysical Analysis of Ghauspur Area, Central Indus Basin, Pakistan

U. Shakir[1], M. Ali[1], M. Hussain[2], M. Fahad[1], M.K Abuzar[1], M.A. Khan[1], M.R. Amjad[1], S.M. Siyar[1] and A.R. Tahir[1]

[1]*Department of Earth Sciences, Bahria University Islamabad, Pakistan*

[2]*LMK Resources, Blue area, Islamabad, Pakitan*

mhuroojshakir@gmail.com; mualipol@gmail.com; reality907@gmail.com; fahad.mahmood@bui.edu.pk; skhubaib@gmail.com; mumtazkhan_geo@yahoo.com; raiees@bui.edu.pk; mamoon280@yahoo.com; a_rehman91@yahoo.com

ARTICLEINFO

Article history :
Received : 10 October, 2016
Revised : 27 February, 2017
Accepted : 08 March, 2017

Keywords:
Seismic interpretation
Petrophysical evaluation
Attribute analysis
Well prognosis

ABSTRACT

Reservoirs are characterized by significant heterogeneity at numerous scales ranging from exploration to production and enhanced production scale. The variations of primary depositional facies could be identified using seismic and well log data as it controls the architecture of a reservoir. Seismic data helps in accurate reservoir characterization. The present research is based upon 2D seismic interpretation, attribute and petrophysical analysis of Ghauspur area, Central Indus Basin, Pakistan. Interpretation of seismic lines shows negative flower structure bounded by two normal faults dipping in the northwest (NW) to southeast (SE) direction. Attribute analysis improved geologic visualization and shows the presence of hydrocarbons at well Indus-1B because of low frequency and low amplitude values. Petrophysical characterization of Sui Main Limestone (SML) penetrated in Indus-1B and Badar South-01 wells was evaluated which proved it to be water-wet with no economic potential for hydrocarbons. On the basis of seismic data interpretation, attribute and petrophysical analyses, a new well location is proposed on the crustal part of the structure.

1. Introduction

The area under investigation is Ghauspur which is located in district Sukkur, Upper Sind, Pakistan (Fig. 1). It is located about 20 km North of Sukkur city. Stratigraphically the study area occupies the Central Indus Basin, Pakistan. Structurally the area lies in an extensional regime.

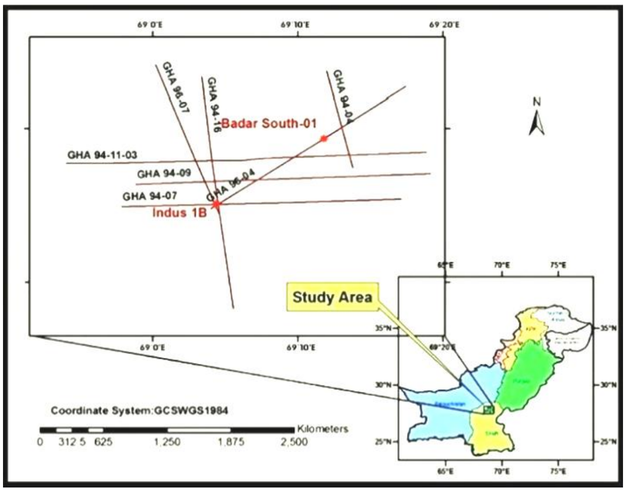

Fig.1: Base map of study area

2. Geological and Tectonic Setting of the Study Area

The Central Indus Basin is separated from the Upper Indus basin by the Sargodha High and Pezu uplift in the North [1] (Fig. 2). The Kohat-Potwar Basin also called Upper Indus basin is a portion of Indian plate deformed by Indian and Eurasian plate collision and over thrust of Himalayas on the north and northeast [1]. Central Indus basin is bounded by Indian shield in the East and marginal zone of Indian plate in the West. In the South, the Sukkur rift comprises of Jacobabad and Mari Kandhkot Highs separate it from the Lower Indus Basin [1] (Fig. 2). Precambrian rocks are largely missing from the basin, although Precambrian shield rocks are evident along the rim of the Indian Plate. The Central Indus Basin consists of Punjab Platform, Sulaiman depression and Sulaiman Fold Belt [2].

3. Stratigraphy of the Study Area

The general stratigraphy of the Central Indus Basin starts from Jurassic Chiltan Limestone and reaches Siwaliks of Miocene-Pliocene age [3] (Fig. 3). The Indus-1B and Badar South-01 has penetrated up to the Cretaceous Pab sandstone.

* Corresponding author

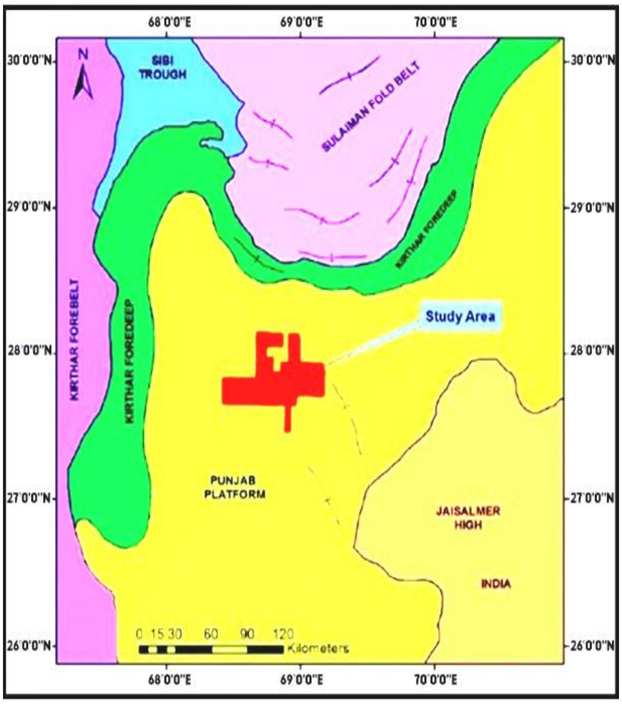

Fig. 2: Highlighted study area and map of central Indus basin

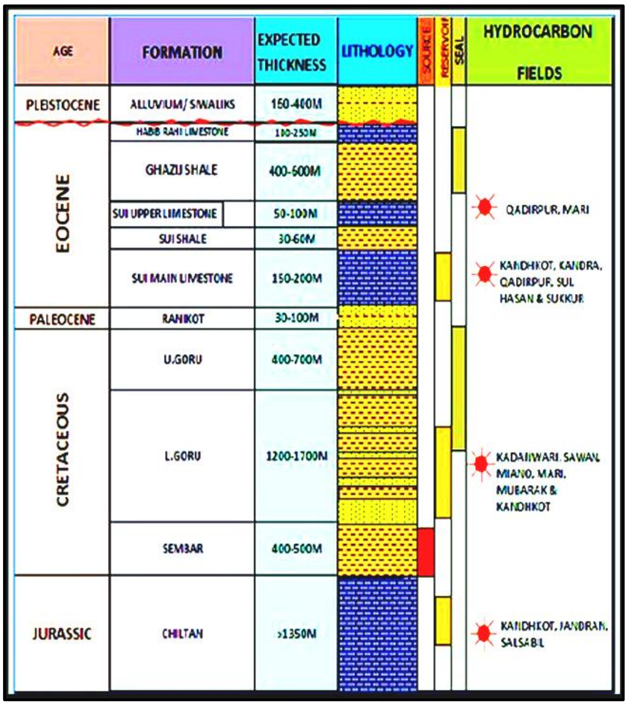

Fig. 3: Stratigraphic column of study area

4. Petroleum Play of the Area

The carbonates of Jurassic Chiltan Formation having TOC upto 0.74 % in the Central Sulaiman Fold Belt are source rocks [4], while Cretaceous shales of Sembar, Goru and Mughal Kot formations acting as a source rock in the area of Middle and Lower Indus Basin [5-7]. The Lower Eocene SML is the most prolific producing reservoir in the Middle Indus Basin. Additional reservoirs are Eocene SUL and Habib Rahi Limestone, Late Cretaceous Pab sandstone, Early Cretaceous Lower Goru sands and Jurassic Chiltan Limestone [6, 7]. The possibility of hydrocarbons in Lower Goru sands and Chiltan Limestone is an upside potential. Ghazij and Sui shales are effective seals for SML and SUL, while Upper Goru and Sembar formations are providing effective seal for Lower Goru sands and Chiltan Limestone respectively [5, 6, 8]. The hydrocarbons trapping mechanism in the region is dominantly structural [7]. However, stratigraphic traps may be a possible exploratory target for Lower Goru sandstone reservoir.

5. Results and Discussions

5.1 Synthetic Seismogram Generation

Well log data of Badar South-01 has been used to generate synthetic seismogram (Fig. 4). The formation tops of Badar South-01 are compared with the reflections data of seismic line GHA-94-04 (Fig. 5), which help in improving the seismic to well tie process [2]. This was done by laying the synthetic trace directly on top of the appropriate seismic trace and adjusting the synthetic trace vertically until the two coincide. Through trial-and-error process, at what point the synthetic trace" best fits" the seismic data was determined and the reflectors Pirkoh Limestone, Habib Rahi Limestone, SML and Chiltan Limestone on seismic line were marked as shown in Fig. 5.

5.2 Seismic Data Interpretation

The seismic interpretation is the transformation of seismic reflection data into a structural portrait by the usage of corrections, migration and time depth conversion [9]. The horizon interpretation was carried out on all seismic lines after performing seismic to well tie using synthetic seismogram. The faults are typically identified on the basis of the break in continuity of the reflectors. In Middle Indus basin all the faults visible at Chiltan level are considered to be major faults, we try to pick all possible major faults which die out at Eocene level. Four normal faults were marked on the basis of the clear breaks in the continuity of reflectors. Area lies in transtensional tectonic settings where there are small component of extension and since we are using 2D Seismic data so it is always difficult to interpret strike slip fault on 2D seismic however in deeper strata en-echelon features are quite visible.

The dip of all faults is NW-SE. Through steepness of the normal faults and literature survey negative flower structure has been interpreted which is formed due to normal faulting (strike slip component) in the study area [11-13] (Fig. 6).

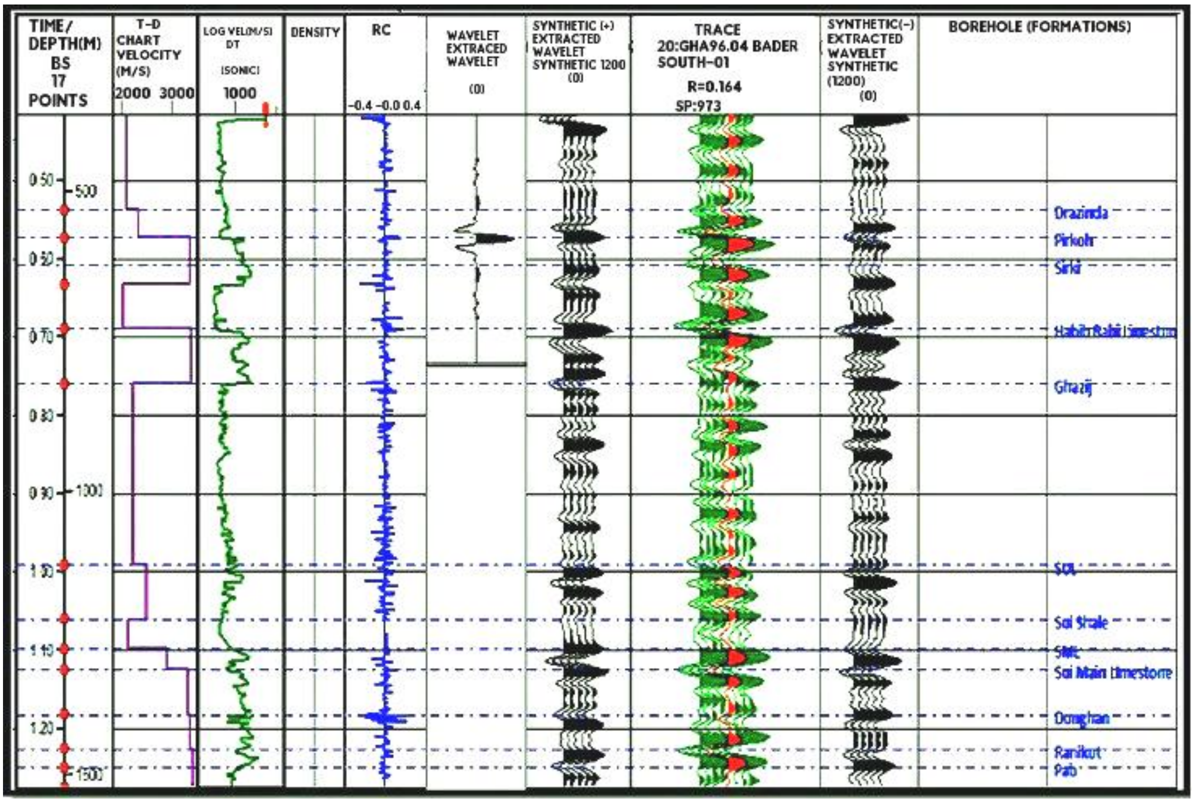

Fig. 4: Synthetic Seismogram of Well Badar South-01

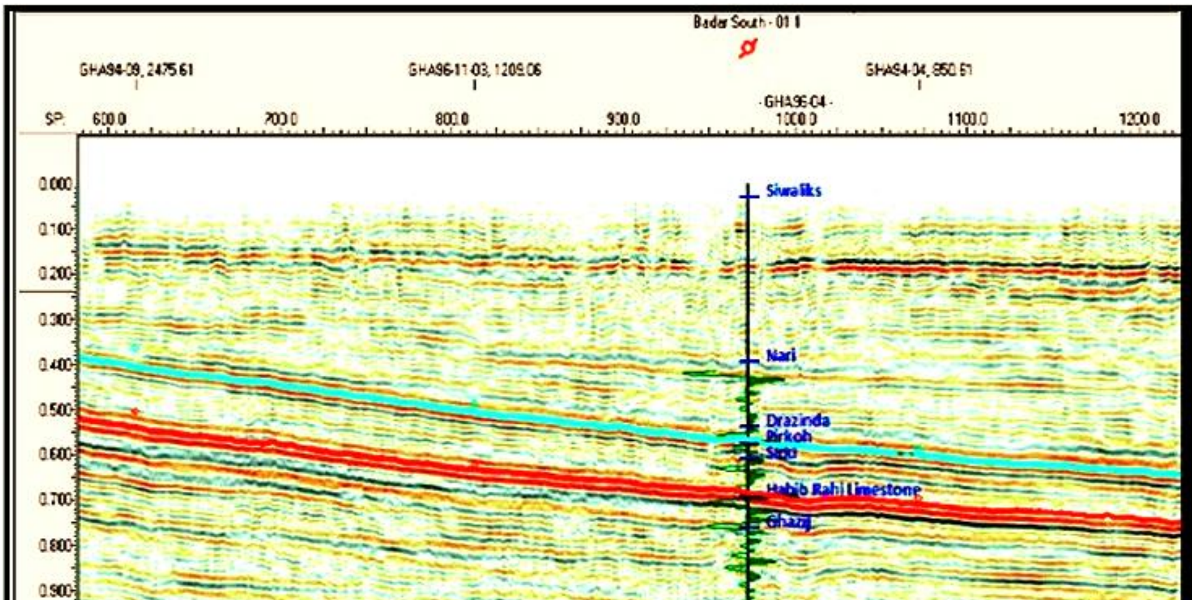

Fig. 5: Correlation of Synthetic Seismogram with Seismic line GHA 96-04

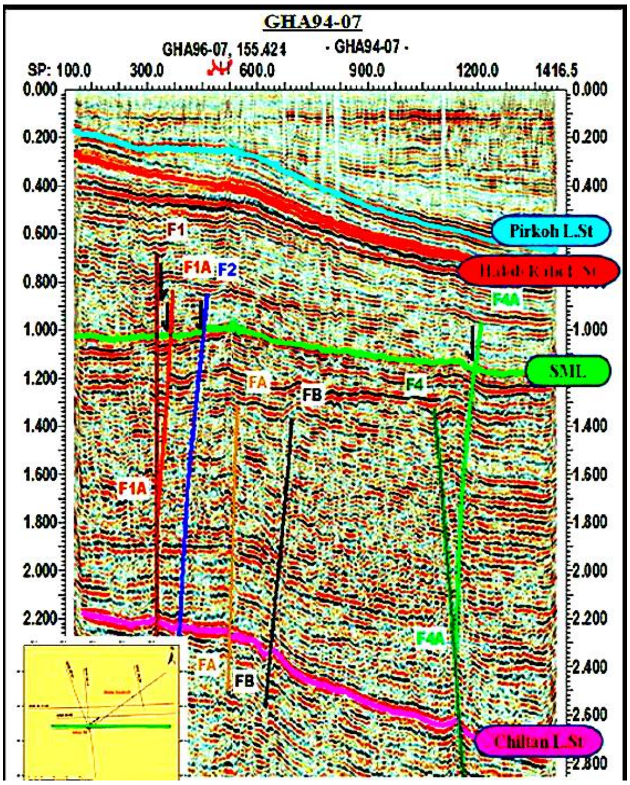

Fig. 6: Horizon and Fault Interpretation of Seismic Line GHA94-07

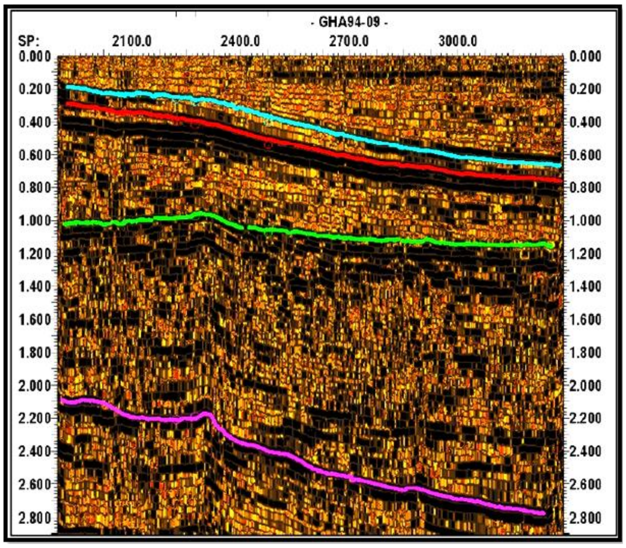

Fig. 7: Instantaneous amplitude attribute section GHA94-09 showing strong events at picked horizons

5.3 Seismic Attributes Analysis

Three seismic attribute analysis were employed i.e. instantaneous amplitude, instantaneous phase and mean amplitude. The instantaneous amplitude gave a clear indication of strong continuous reflection character at the four selected levels confirming the presence of major

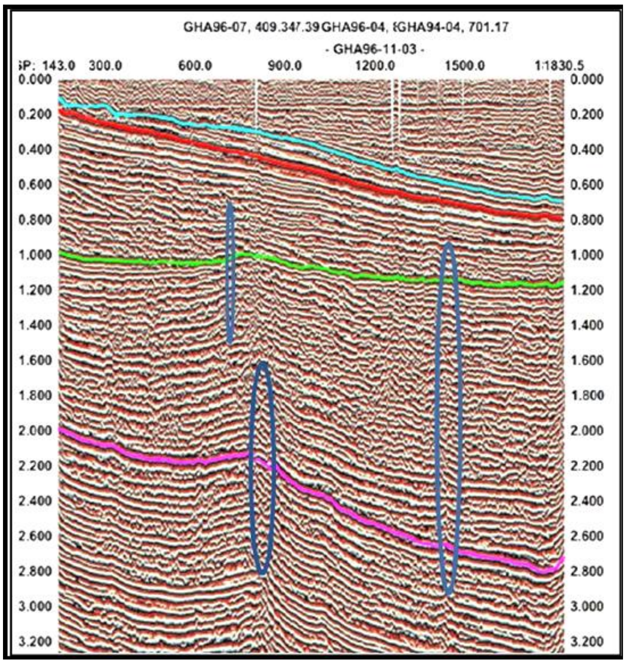

Fig. 8: Instantaneous phase attribute showing chaotic reflections at faults

stratigraphic events (Fig. 7). The instantaneous phase shows well developed bedding and removed all amplitude information from the seismic data [10]. This makes the continuity of seismic reflections easier to follow (Fig. 8). The mean amplitude attribute applied on the SML horizon grid depicts prominent anomaly near dip line GHA 94-09 at shot point 2320.

5.4 Mapping

On the basis of horizons of interest, contour maps were generated. In order to make a contour map, initially faults were correlated and grids were constructed for contour generation. Two wells were available, by using wells velocities we converted time to depth. Contour maps of the Pirkoh Limestone and Habib Rahi Limestone signify that there is no prominent high (shallow or low values) because no faults cut through it. The gradual change of contour values from western side to the eastern side indicates that Pirkoh Limestone is deepening towards east. Depth contour map of the SML indicate only one prominent high on which Indus-1B was drilled (Fig. 9). The structures present are bounded by regional faults which are NW-SE dipping. The throw of the fault is very small 0.04 sec which can also be calculated from the seismic section and implies that the fault is sealing. At the level of Chiltan Limestone, a horst structure is present which is bounded by the fault from the eastern side. On Time and Depth contour maps all the faults displayed are fault polygons.

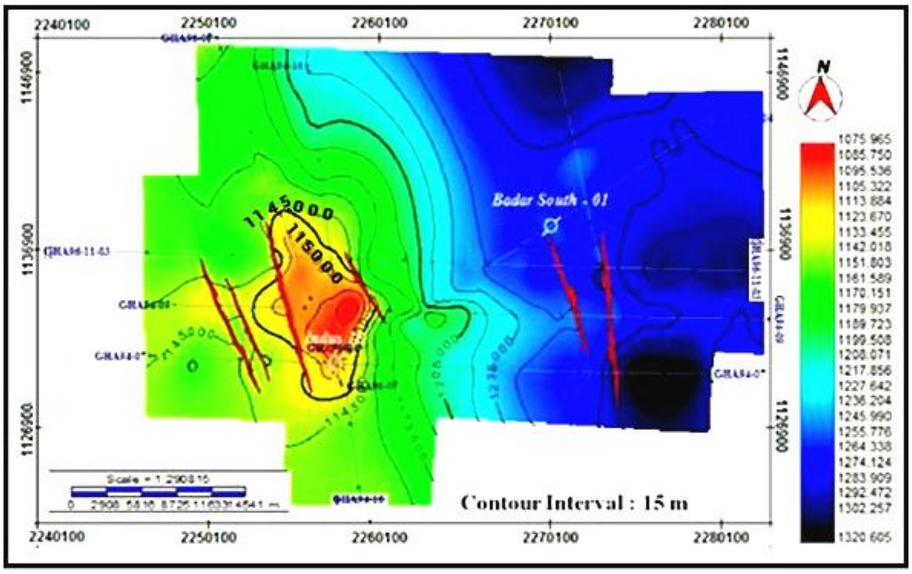

Fig. 9: Depth contour map of Sui main limestone

5.5 3D Model

A 3D model was constructed to disclose the subsurface picture of the study area. Using 3D model, subsurface structure, and its closure and reservoir area can be demarcated. 3D visualization of the SML grid showing location of both wells Indus-1B and Badar South-01 are presented in Fig. 10.

5.6 Petrophysical Interpretation of Indus-01B and Badar South-01 wells

Petrophysical analyses for the SML in Indus-1B and Badar South-01 wells were conducted. Analyses was performed to calculate the volume of shale (*Vsh*), Porosity (ϕ), water saturation (*Sw*), and hydrocarbon saturation (*Shc*). GR log is used to measure the amount of shale as a function of depth [13]. It was observed that volume of shale in Indus-1B well is increasing in the upper part of the reservoir but after a depth of 1190 m there is general decreasing trend in shale volume till 1235m. In Badar South-01, the volume of shale decreases gradually from a depth of 1320 m to 1435m. The interval of the SML shows good reservoir characteristics. In Indus-01, in SML permeable and impermeable zones are marked by SP and GR logs. The GR log values are low throughout SML However, at a depth of 1120 m to 1240 m; there are regular fluctuations in GR log below and above the shale baseline. In Indus-1B, the values of Vsh, average porosity, Effective porosity, average water saturation, and hydrocarbon saturation are 29 %, 15.45 %, 13.19 %, 90 % and 10 % respectively (Fig. 11). The petrophysical analysis result of well Indus-1B is shown in Table 1a.

In Badar South-01, the values of Vsh, average $\phi_{T,}$ average $\phi_{E,}$ Sw and Shc are 14 %, 16.15 %, 13.82 %, 93 % and 07 % respectively (Fig. 12). The SML has fair to good porosity in Indus-1B and Badar South-01 [14,15]. SML in Badar South-01 seems to be a good reservoir as compared to SML of Indus-1B.

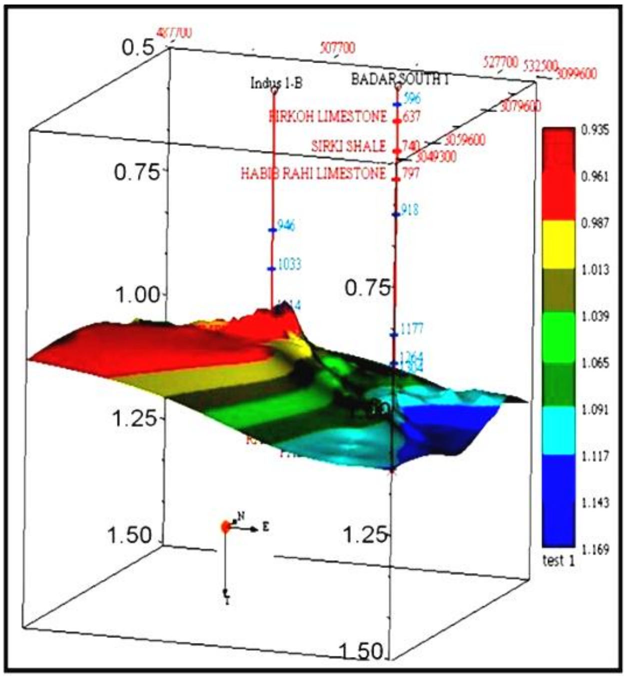

Fig. 10: 3D visualization of SML grid

In Badar South-01, the reservoir (SML) seems to be clean in nature due to low GR values. Similarly, the petrophysical properties i.e. Vsh is lower in Badar South-01 while average $\phi_{T,}$ average ϕ_E are higher than in Indus-1B. Because of more water saturation, both the wells are

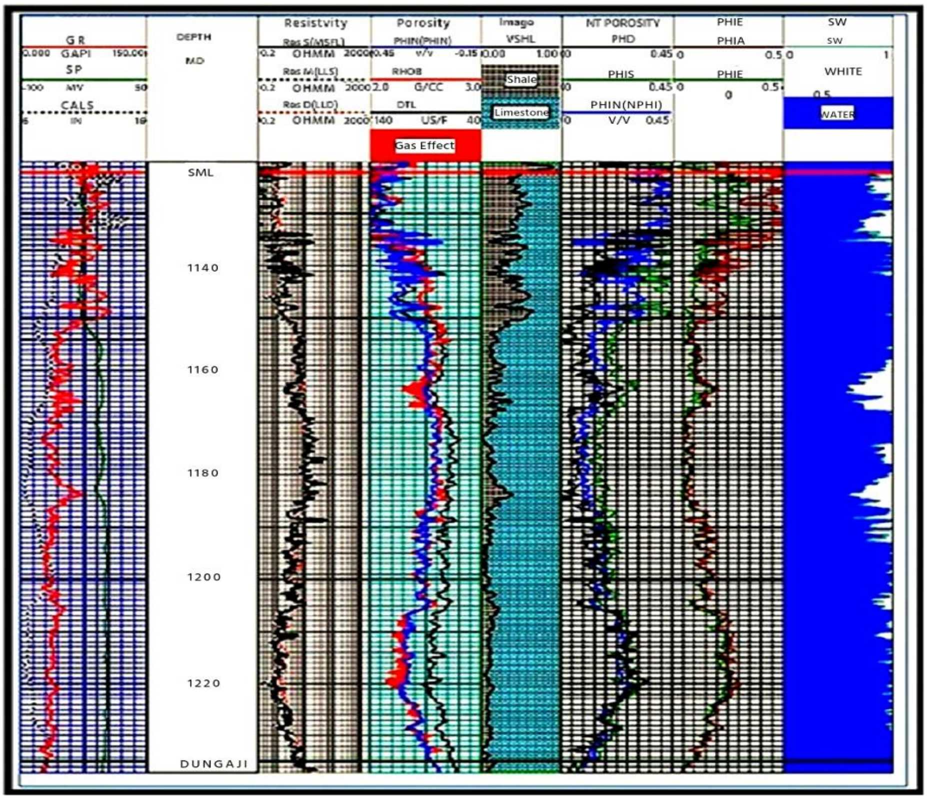

Fig. 11: Well Interpretation of well Indus 1B

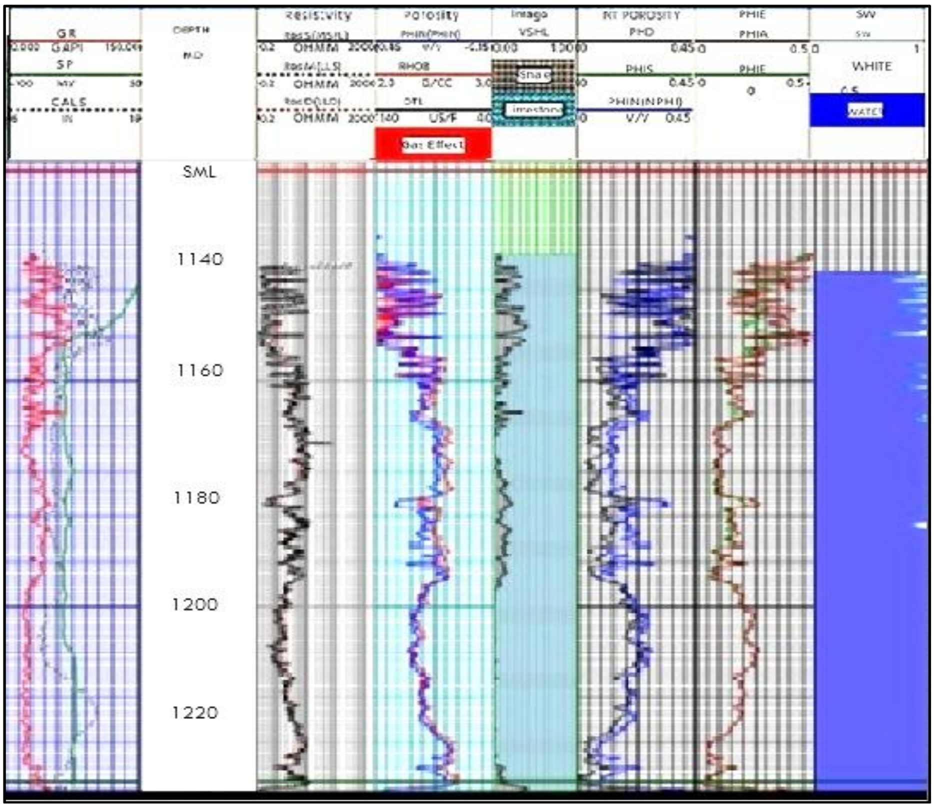

Fig. 12: Well interpretation of Badar South-01

water wet. The Indus-1B and Badar South-01 are abandoned and suspended wells, which may be due to high water saturation at the reservoir (SML) level. Petrophysical analysis result of well Badar South-01 are shown in Table 1b.

5.7 Well Prognosis

The probable new well location is predicted on the bases of contour maps and attributes analysis. The map shows the shallow closing contour based on which well location is finalized. The horst structure is bounded by faults as shown in (Fig. 13). The well location is finalized on apex of structure as can be seem from the seismic line (Fig. 13 & 14). The new well location is proposed at SP 750 on line GHA94-16 on the basis of mean amplitude attribute (Fig. 15). The petroleum prospect for the new predicted well is the same as that of Indus-1B and Badar South-01. Details of the new proposed well are given in Table 2. Geological chance of success is 40% for the proposed well as calculated in Table 3.

Table 1(a & b): Petrophysical Analysis Results of wells Indus 1-B and Badar South-01

(a) Badar South-01

Interval		Shale vol. %	Average porosity		Saturation
Formation top (m)	Formation base (m)		Total porosity %	Effective porosity %	Water saturation %
1300	1440	14	16.15	13.82	93 (Water wet)

(b) Indus-1B

Interval		Shale vol. %	Average porosity		Saturation
Formation top (m)	Formation base (m)		Total porosity %	Effective porosity %	Water saturation %
1120	1240	29	15.45	13.19	90 (Water Wet)

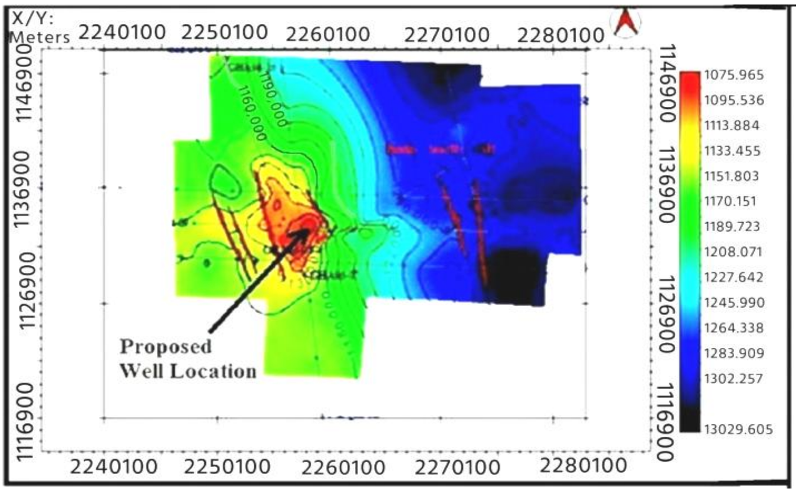

Fig. 13: Probable new well location on contour map

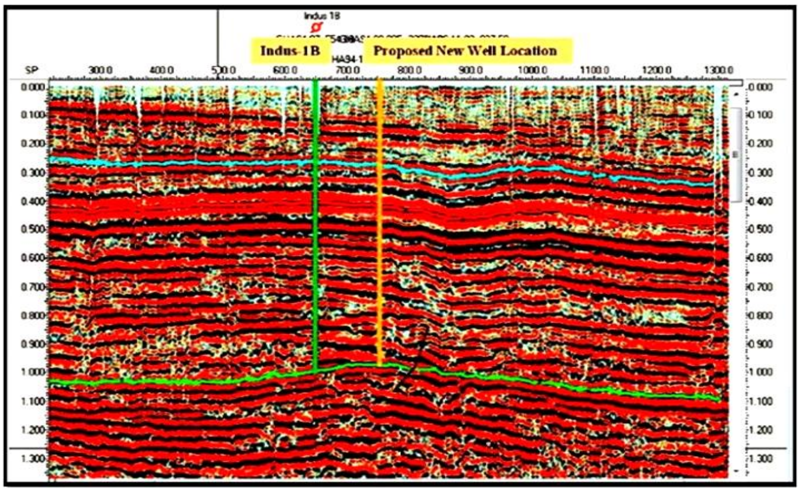

Fig. 14: Proposed new well location on seismic line GHA94-16

Table 2: Well prognosis of newly proposed well

Block details	Well details
Block Name	Block: 2768-9 (Sukkur)
Well Name	Probable new well
Classification	Exploratory
Location	Seismic Line No. Ghause 94–16 at shot point # 750
Co-ordinates	Latitude: 27° 53" 51 .024'N and Longitude: 69° 04" 5.97' E
Primary Objective	Sui Upper Limestone and Sui Main Limestone
Total Depth	±4474 Feet
Formation at TD	Sui Main Limestone (Eocene)
Area/Region	Panno Aqil, Sindh, Pakistan

Table 3: Geological risk calculation for prognoses well

Source	1
Seal	1
Reservoir (Presence and Quality)	0.8
Trap	0.5
Migration	1
Geological Chance of Success	40%

The probable formation thickness that will be encountered in the well is calculated by generating depth contour maps of prospective horizons and adding the average thickness of other formations from adjacent wells (Fig. 15). The same was calculated by stratigraphic correlation between Indus-1B, Badar South-01 and new exploratory well.

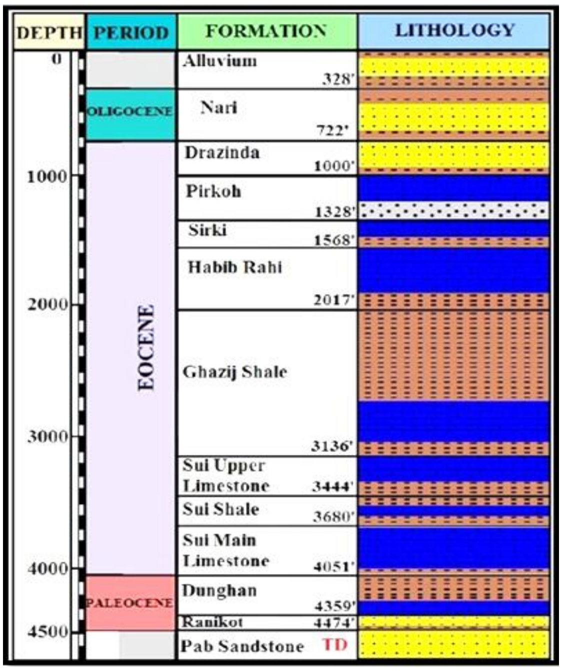

Fig. 15: Well prognosis of newly proposed well

6. Conclusions

Ghauspur are mainly comprises of extensional tectonics with faults having minor throw. Since most of the faults terminate in Eocene strata, therefore, these belong to the Eocene age. Seismic attributes at SML level justify the prospect zone. Petrophysical analysis on Indus-1 Band Badar South-01 shows that SML bears good porosity but the formation overall in both wells is water wet. Based on the defined amplitude attribute, a new well location is proposed toward east on the crustal part of the structure which is lies at SP 750 on seismic line GHA94-16.

References

[1] A. Farah, S.G. Abbas, K.A. DeJong and R.D. Lawrence, "Evolution of lithosphere in Pakistan", Tectonophysics, vol. 105, pp. 207-227, 1984.

[2] N. Ezekwe, "Petroleum reservoir engineering practice: Porosity of reservoir rocks", Boston, Pearson Education, Inc., 2010.

[3] M. H. Rider, "The geological interpretation of well logs, New York: John Wiley and Sons, 1996.

[4] I. B. Kadri, "Petroleum geology of Pakistan", Pakistan Petroleum Limited, pp.275, 1995.

[5] L.A. Leverson, "Geology of petroleum", 2nd Ed., San Francisco, Freeman, W.H. and Company pub., pp. 724, 1972.

[6] C.L. Liner, "Interpreting Seismic Data", Treatise of Petroleum Geology / Handbook of Petroleum Geology: Exploring for Oil and Gas Traps, Special volume, The American Association of Petroleum Geologists, 1999.

[7] H.A. Raza, S.M. Ali and R. Ahmed, "Petroleum geology of Kirthar sub-basin and part of Kutch Basin", Pakistan Journal of Hydrocarbon Research, vol. 2, pp. 29-73, 1989.

[8] S.M.I. Shah, "Stratigraphy of Pakistan", Geological Survey of Pakistan Memoirs, vol. 22, pp. 1-138, 2009.

[9] M.E. Badley, "Practical Seismic Interpretation", Dordrecht, Holland: D. Riedel Publishing Company and International Human Resources Development Cooperation, pp. 256-260, 1985.

[10] M.B. Dobrin and C.H. Savit, "Introduction to Geophysical Prospecting", New York: McGraw-Hill, pp. 867, 1988.

N.K. Siddiqui, "Sui Main Limestone: Regional geology and the analysis of original pressures of a closed-system reservoir in central Pakistan", Bulletin of American Association of Petroleum Geologists, vol. 88, no. 7, pp. 1007-1035, 2004.

[11] H.R. Tainsh, K.V. Stringer and J. Azad, "Major Gas Fields of West Pakistan", Bulletin of the American Association of Petroleum Geologists, vol. 43, no. 1, pp. 2675-2700, 1959.

[12] B.E. Wandrey, Law, S.A. Haider, "Sembar Goru/Ghazij composite total petroleum system, Indus and Sulaiman-Kirthar geologic provinces, Pakistan and India", U.S. Geological Survey Bulletin 2208-C, vol. 56, pp. 220-275, 2004.

[13] A. Zia, M. Awais, M. Ishaq, S. Hamid, N. Akhtar and L. Sheikh, "Application of well log Analysis to assess the petrophysical parameters of the early eocene Sui Main Limestone (SML) in Kharnhak-1 well, Middle Indus Basin, Pakistan",. Iranian J. Oil & Gas Sci. & Tech., vol. 5, no. 2, pp. 1-20, 2016.