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Structural interpretation of seismic Data in the south of Zindapir area, Sulaiman Fold Belt, Pakistan.

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Abstract

Folded and faulted structures commonly form migration, trapping & accumulation of hydrocarbons. Seismic data is a significant source for the understanding of subsurface structural trend and lithology in the subsurface. For this purpose 2 D seismic lines have been interpreted to get stratigraphical and structural information of subsurface. Sakhi Sarwar, Drigri and Kotrun anticlines, lie in the south of Zindapir anticline, a part of N-S trending Safed Koh, which is a first line of folding on the folded flank of Sulaiman foredeep. Study area lies in south of Safed Koh trend, Central Indus Basin. The general stratigraphic horizons were marked on lines 954-FZP-06 and LMT95-09 with the help of well Sakhi Sarwar-01. Seismic line 976-FZP-06 lies in Fazilpur area that shows Sakhi Sarwar anticline with a flower structure present in the core suggesting wrenching along with compression. Time contouring maps of Paleocene, Eocene and Oligocene show that the formations are getting shallow in east. Seismic profiles 914-RPR-03 and 914-RPR-05, lie in NW of Rajanpur area of district D.G. Khan. Reflectors are marked and correlated with the help of wells Drigri-01 and Kotrum-01, located near line 914-RPR-03 and 914-RPR-05 respectively. Depth sections of Drigri and Kotrum anticlines are prepared. These structures lie in the SE of Sakhi Sarwar anticline. Drigri anticline has E-W trend over 17 km approximately and the reverse faults are present on both flanks of a fold. Whereas the cross section of Kotrum anticline shows the amplitude of fold is low suggesting that folding die out at the Southern part. Trend of the fold is NE-SW. Depth sections show that a thickness of sedimentary cover is 8 km approximately. Thickness of Nagri Formation and Chinji Formation (Miocene- Pliocene) is 1700 m approximately. Nari Formation is overlain by Gaj (Vehowa) Formation in the area. Eocene & Paleocene are 1300 m and 800 m thick respectively while the basement is uplifted in the east.

Keywords: Structural interpretation; Drigri; Kotrum; Sakhi Sarwar and Sulaiman fold belt.

1. Introduction

Seismic approach is a significant geophysical method used for investigation of subsurface structural styles and layers in the subsurface. Drigri and Kotrum anticlines are situated in NW of Tehsil Rajanpur, district Dera Ghazi Khan, of Punjab Province. Folded and faulted structures commonly form migration, trapping & accumulation of hydrocarbons. Seismic data is a significant source for the understanding of subsurface structural trend and lithology in the subsurface. For this purpose 2 D seismic lines have been interpreted to get stratigraphical and structural information of subsurface. Sakhi Sarwar, Drigri and Kotrun anticlines which lie in the south of Zindapir anticline, a part of Safed Koh trend (N-S trending), which is a first line of folding on the folded flank of Sub-Sulaiman Foredeep. Research area lies in south of Safed Koh trend, Central Indus Basin. In the East of area, Punjab Monocline is present and Sulaiman Fold and Thrust belt is present in west. This area is a Frontal fault propagation folded zone. Seismic data was acquired and processed by Oil and Gas Development Company Limited. Safed Koh is exposed as a first line of folding on the folded flank of sub-Sulaiman Foredeep. To the North it is separated by Pezu transverse uplift whereas in the south by Mari Bugti. Kotrum and Drigri anticlinal structures lie in south of Safed Koh trend and Sakhi Sarwar anticline. Drigri structure lies in a fault Propagation Folded Zone. The objectives of the research are to establish stratigraphic correlation with the help of seismic data and well information of Sakhi Sarwar-01, Drigri-01 and Kotrum -01 and to study the subsurface extent and thickness of Vehowa Formation (Miocene) and Chitarwata Formation (Oligocene) in the area.

2. Previous Work

A generalized view is obtained by the efforts of various authors Adil Nazeer et al. (2013) and S.H. Soalnagi et al. (2014). An east-west cross-section showing continuation of tertiary sediments of Drazinda syncline is prepared by Hemphill and Kidwai (1973). Yeats and Lawrence (1984) explain the tectonic configuration of the Sargodha Ridge as an outer "swell" due to loading of Indian Shield by the Himalayan thrusts. Lillie et al. (1987), Humayun et al. (1991) and Jadoon et al. (1992) believe the presence of a basal decollement in pelitic rocks or fine carbonates above the crystalline basement at a depth of more than 11 km. Kemal et al. (1991) consider East Sulaiman structural play of narrow straight anticlines as flower structure due to large scale distributive wrench faulting. Waheed and Wells (1990) suggest an early manifestation of the paleodrainage shift due to obduction and shelf reversal recorded in the broadly distributed and marginal marine early Eocene Ghazij Formation in western Pakistan. Kemal et al. (1991) consider East Sulaiman structural play of narrow straight anticlines as Flower Structure due to large scale distributive wrench faulting. Humayon et al. (1991) and Jadoon et al. (1994) interpret the structures of the eastern & central Sulaiman Foldbelt on the basis of surface geology. According to them the sedimentary strata is detached from the basement with a floor thrust in Paleozoic strata and roof-thrust in Cretaceous (Sembar Formation) except in the frontal part of the Sulaiman Foldbelt where it occurs in Eocene sequences. Bender and Raza (1995) suggested that the oblique collision of the Indo-Pakistan plate with the Eurasian plate caused the development of large scale, N-S running, left-lateral strike-slip faults. Bannert et al. (1989), Bannert and Raza (1992), Bannert et al. (1995), Bender and Raza (1995), suggested that the oblique collision of the Eurasian and Indo-Pakistan plates caused the development of large scale, N-S running, left-lateral strike-slip faults in the basement which are responsible for the segmentation of the Indo-Pakistan Plate. Iqbal and Helmcke (2004) suggest that the basement of Indo-Pakistan is involved in structural deformation of Zindapir Anticlinorium and its surroundings. On the basis of paleomagnetic data Lindsay et al. (2005) have evaluated the age span of the Chitarwata Formation in the Zinda Pir Dome as Oligocene at its base and earliest Miocene at the contact with the Vihowa Formation. Ahmad et al. (2007) discuss the cross bedded Sandstone and The cross bedding suggests the activation of erosional phenomena. Hasany et al. (2007) emphasize on exploration activity for Infracambrian sediments in Pakistan due to a Heavy oil discovery in Baghewala-1 in 1991 in Bikaner-Nagur Basin, Rajasthan India. Iqbal and Khan (2012) carried out work on Impact of Indo-Pakistan and Eurasian Plates Collision in the Sulaiman fold belt, Pakistan and suggested that the oblique collision of Indo-Pakistan and Eurasian plates led to the formation of Kirthar Sulaiman foldbelt. Adeel et al. (2013) recommended that subsurface structure pattern of Zindapir Anticlinorium may be investigated in detail using additional seismic data.

3. General geology of the area

Study area lies in the eastern part of Sulaiman Fold Belt, Central Indus Basin. In East of study area lies Sulaiman Depression and Punjab Monocline, in West- Sulaiman Fold Belt, North- Zindapir Inner Folded Zone and South- Mari Bugti Inner Folded Zone & Sukker Rift. Sulaiman Fold Belt is a major tectonic feature in the proximity of collision zone & therefore contains a large number of disturbed anticlinal features (Kadri, 1995). There are some large anticlines within Kirthar and Sulaiman belts and especially along the eastern margins, are clearly detachments. The northward-striking East Sulaiman structural play domain has narrow, straight anticlines as long as tens of kilometers with limbs that are broken locally by steeply dipping faults with reverse dip separation. These structures interpreted here as flower structure products of large-scale distributive wrench faulting have as prospective reservoirs, Ranikot Formation (Paleocene) and Pab and Sember-Lower Goru Formations (cretaceous) sandstones (Kemal et al., 1991). According to Kazmi and Jan, (1997), folds present in the Area are open, upright, parallel , subparallel, enecholan and faults are high angle thrust faults, strike slip faults (N-W trending). Left lateral faults of the area are Kingri Fault, Domanda Fault, Sulaiman Fault, Chaudawan Fault and Mughalkot.

Bannert et al. (1992) assumed that basement was segmented into three different blocks during the collision of the Indo-Pakistan Plate with the Eurasian Plate. Three basement faults separate these basement blocks from each other and from the central part of the Indo-Pakistan Plate. The Khuzdar Block and the Sulaiman Block are separated by the kirthar Basement Fault, 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

(1) Punjab Platform,
(2) Sulaiman Depression,
(3) Sulaiman Fold Belt (Fig.1)

4. Methodology

Two dimensional seismic data and well tops were collected from LMK Resources by the permission of Directorate General of Petroleum Concessions (DGPC), Ministry of Petroleum and Natural Resources, Islamabad. Interpretation of Seismic data involves conversion of velocity and time in to depth of subsurface reflecting interfaces to convert seismic data in to useful geological and structural image. The reflectors of different subsurface formations were marked with the help of well tops of Sakhi Sarwar-01, Drigri-01 and Kotrum-01 (Appendices- Table 1-3). Seismic stratigraphic analysis involves the interpretation of seismic section in to sequence of reflections that are interpreted as the seismic expression of genetically related sedimentary sequences whereas the structural interpretation is the analysis of subsurface structural styles.

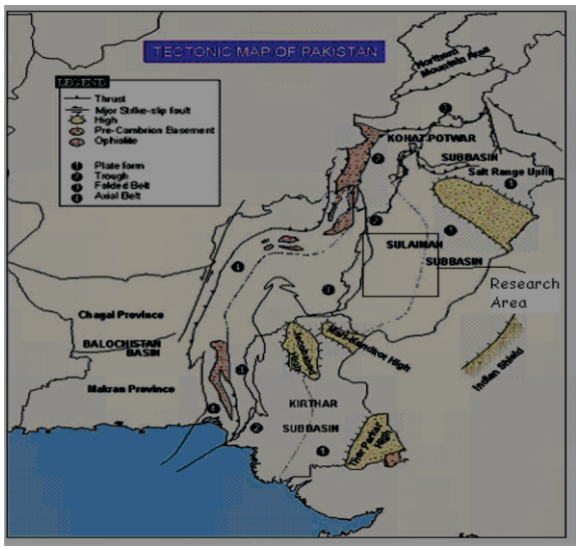

Fig.1. Map showing the location of Research Area. (www.gsp.com)

Analysis of the Seismic velocity is a complex parameter as it varies laterally as well as vertically due to the variation in physical and geological conditions. Mean Average velocity values have been calculated from velocity window provided on the top of the seismic section. Finally mean average velocity graph, time sections and depth sections were prepared to better understand the variation of seismic velocity within the subsurface (Fig. 2)

5. Results and Discussion

Correlation of reflectors on seismic sections is done with the help of well logs and well tops (Tables 1-3) along with the surface geology. Data of wells Drigri-01, Kotrum-01& Sakhi Sarwar -01 is used for data correlation. The Geoseismic models are prepared in Time and Depth domains using average velocities of the correlated reflectors corresponding to various subsurface formations having particular ages. Seismic line 976-FZP-06 shows a cross-section of Sakhi Sarwar anticline (Fig. 3 & 4). A flower structure is present in the core (Fig. 9).

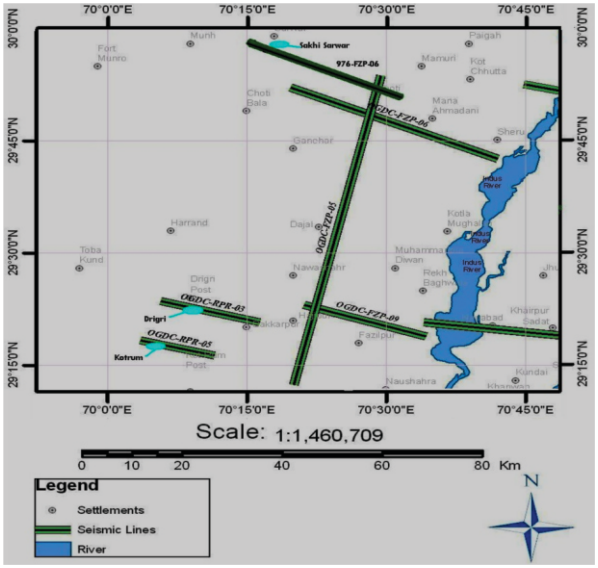

Fig. 2. Base Map showing seismic lines and Well locations

Seismic line 954-FZP-05 (N-S) lies in Fazilpur area. The general stratigraphic successions are marked on lines 954-FZP-06 (south of 976-FZP-06) and LMT-09. They are used for correlation purposes (Fig.11 and 12). Time contouring of Paleocene, Eocene and Oligocene show, the formations are getting shallow in east (Fig 13, 14 and 15). Seismic line 914-RPR-03 shows Drigri (Fig. 5, 6, 10) is a broad anticline where all the formations are folded. Very thick Siwaliks including Dhok Pathan (Pliocene), Nagri (Pliocene) and Chinji (Miocene) Formations (greater than 2000 m) are deposited in this area of Rajanpur. Gaj and Nari Formations are lying below Siwaliks.

Underlying Eocene shales are very prominent. Lower Ranikot shales thinning and pinching into Pab Formations are also noticeable. Pab Formations is fractured and the faults are marked making a pop up structure (Fig. 3 and 4). This area is a Fault propagation folded zone of Sulaiman fold and thrust belt.

Seismic line 914-RPR-05 shows the cross-section of Kotrum anticline (Fig.7 and 8) which is low amplitude fold with an adjacent syncline. Pab Formation is fractured. Lower Ranikot is thinning in east and merges into Pab Formation. Sedimentary cover is about 8 km thick.

Drigri and Kotrum structures lie in the SE of Sakhi Sarwar anticline. Folding is prominent in the cross sections. Cross section of Drigri anticline

shows that it is extended E-W over 17 Km approx. and the Thrust Faults are present on both flanks of a fold. Kotrum is situated between a Sulaiman Range in west and Indus River in east. At surface Pliocene-Pleistocene strata is exposed. The amplitude of Kotrum is low. When these cross sections are compared with the surface structure it seems that the gentle anticlinal fold is in the eastern side of 914-RPR-05 and an adjacent broad syncline in north-west. These anticlines are separated by a Syncline in the NW from Sakhi Sarwar, as it is located between SP 110-220 of 914-RPR-03 and SP 100-270 of 914-RPR-05. If these folds are considered to be a part of a same anticlinal fold then the trend of the fold is in NE-SW direction, with Drigri as a more uplifted one, showing a plunge in SW. Drigri is a fault propagation fold. These folds may develop as a result of thrusting to accommodate the deformation above the tip line of the thrust. Also Choti, Karar and Sakhi Sarwar anticlines lie in the N-NE. Pliocene-Pleistocene strata is 2000-2200 approx. thick. Nagri and Chinji Formations 1700 m approx. thick have been deposited (Kotrum-01). Nari Formation (Oligocene) is overlain by Gaj Formation in the area. Gaj Formation and Nari Formation are 326m thick in Drigri structure and thickened to 707m in Kotrum anticline. Their trend is throughout fractured in the section. It could be due to the flowage of intraformational clay or the underlying Drazinda shales have provided the flow. A very strong reflector of Habib Rahi Limestone is present with a fracture visible under SP 200 in 914-RPR-03 and SP 260 in 914-RPR-05. Thickness of Habib Rahi Limestone is increasing in south (38 m in Drigi-01 and 76 m in Kotrum-01). The interesting feature is of flowage of shales of Ghazij Formation (500 m approx.), Upper Ranikot Formation and Lower Ranikot Formation from 2.3 – 3.0 seconds in west of the seismic section 914-RPR-03. They are thickening in west which is a very prominent feature in the seismic section. Another very prominent feature is a fracture in Pab Formation under SP 280 in 914-RPR-03. Either the depression is a subsidence due to overburden of Ghazij Formation & Ranikot Formation as they have thickened in west or it could be an unconformity. There is a transition zone as the Lower Ranikot Formation thins in east. Eocene & Paleocene sediments are 1300 m & 800 m approx. respectively. Thick Cretaceous, Jurassic and Triassic sediments are correlated from the east with a Well Bahawalpur East-01. Basement is uplifted in the east.

Safed Koh range includes Kotrum, Sakhi Sarwar, Zindapir, Rodho, Afiband and Dhodak structures (Shuaib et al., 1993). Overall Strata is Folded showing the area has been under compression. Faults present in Area of Study are Reverse Faults which disrupts the Ghazij, Lower Ranikot and underlying strata. Drigri anticline extends under V.P 200 to 370 almost 17 Km. For Hydrocarbon prospects this Area can be explored further as in South the important Gas Fields are present like Mari and Sui etc. In North of Drigri the Domanda, Gulan, Saviragha, Dhodak, Rodho, Afiband, Zindapir, Sakhi Sarwar and Choti anticlines are present. Drazinda, Domanda/Sriki and Ghazij Shales of Eocene age shows the flowage which is obvious in the Depth Section of 914-RPR-03, also shales of Ranikot Formation (Paleocene) show the increase in the thickness west ward. The Plastic flow of Cretaceous Shales is also obvious in the depth section, mentioned as Cretaceous1 and Cretaceous2. Overall, the thickening is observed in Formations having the presence of Shales along the Faults. The isopach maps of Jurassic, Late Cretaceous, Early Paleocene, Middle-Late Eocene, prepared by Shuaib et al., 1993 show the maximum thicknesses of Formations along Kotrum, which indicates that it was the deeper part of the basin at that time, which provided the maximum space of accommodation for sediment deposition. General Trend of Formations in the Sulaiman Foredeep/ Depression is that the Formations are uplifted towards the East (Punjab Monocline)

The frontal Sulaiman and Kirthar ranges are the most prospective and productive line of folding so far in the middle Indus. The Sakhi Sarwar structure in the Eastern Sulaiman Range is a fault propagation fold (Humayon, 1991). The Domanda, Dhodak, Rodho, Zinda pir, Fort Munro, Pirkoh, Loti, Uch and Mazarani structures along the deformation front of the Sulaiman and Kirthar ranges are thrusted anticlines, probably having a fault bend origin (Kemal et al., 1991). Drigrianticline is extended E-W over 17 Km approx. and the reverse Faults are present on both flanks of a fold. In East the Punjab Monocline is a stable area. Basement is gradually dipping westward and it is more than 9 km deep beneath the deformation front in the Eastern Sulaiman Foredeep (Kemal et al., 1991). Basement lies at 8km depth in this area. It is uplifted East ward towards the Punjab Monocline.

Seismic line 976-FZP-06 lies near a well Sakhi Sarwar-01. Seismic inversion model show the Sakhi Sarwar Anticline (Fig. 3 and 4).

The time and depth sections of 914-RPR-03 and 914-RPR-05 show the cross-sections of Drigri & Kotrum structures respectively (Fig. 5, 6, 7 & 8).

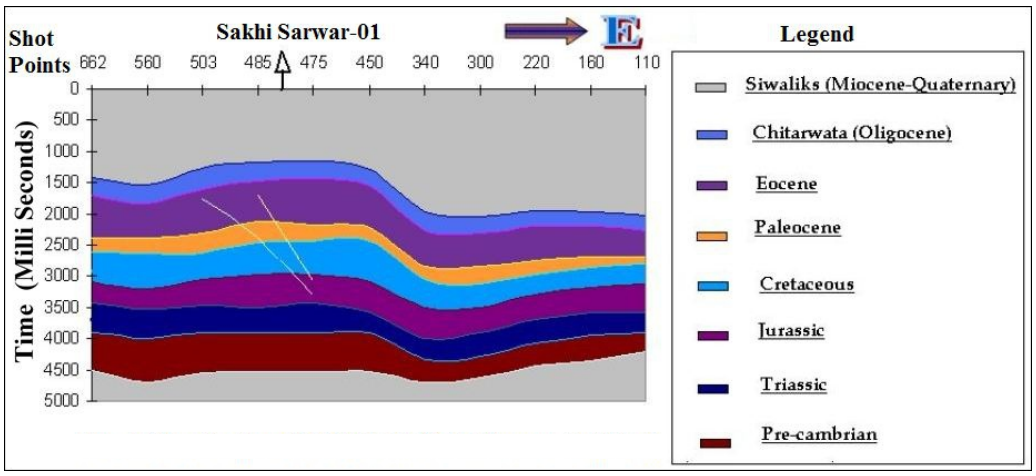

Fig. 3. Time section of 976-FZP-06 (Sakhi Sarwar Anticline).

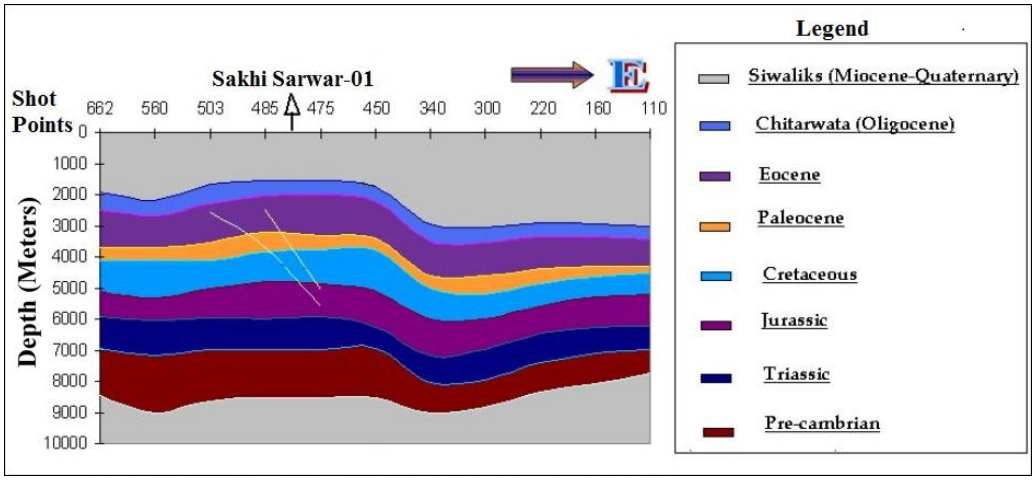

Fig. 4. Geoseismic model of 976-FZP-06 (Sakhi Sarwar Anticline).

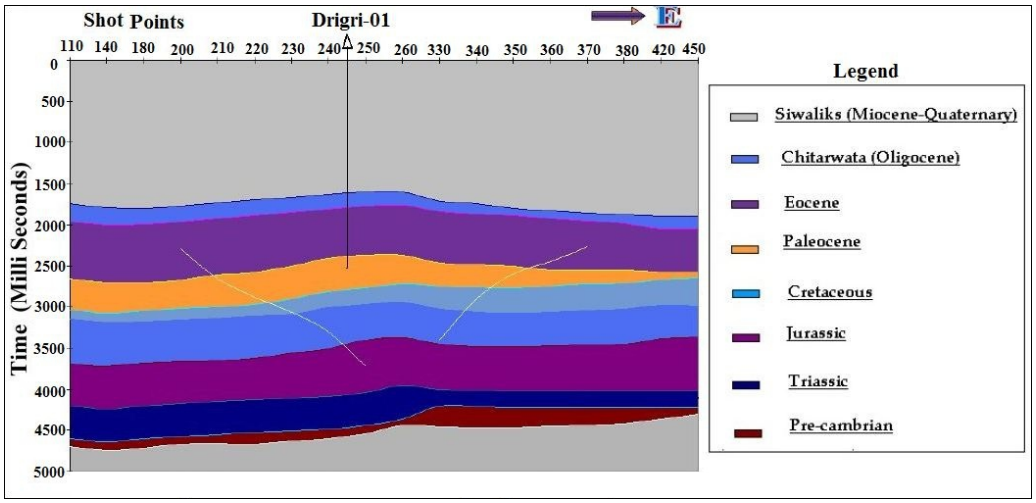

Fig. 5. Time section of 914-RPR-03 (Drigri Anticline)

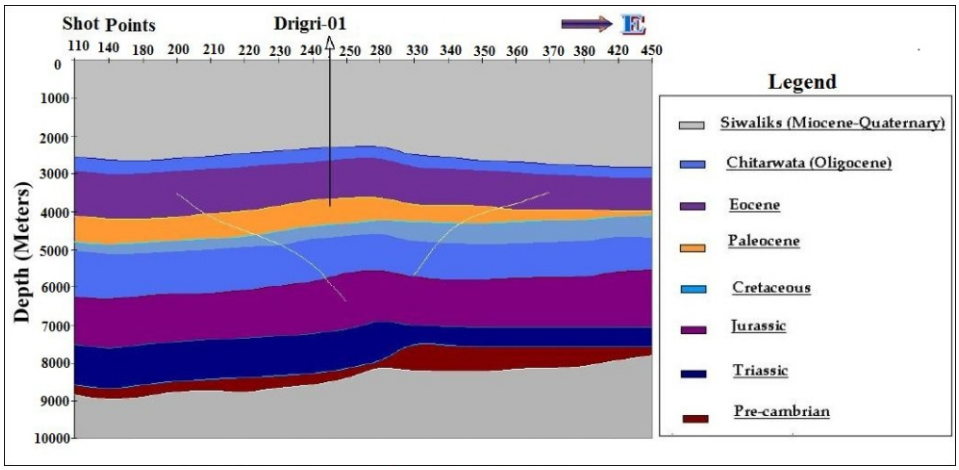

Fig. 6. Geoseismic model of 914-RPR-03 (Drigri Anticline)

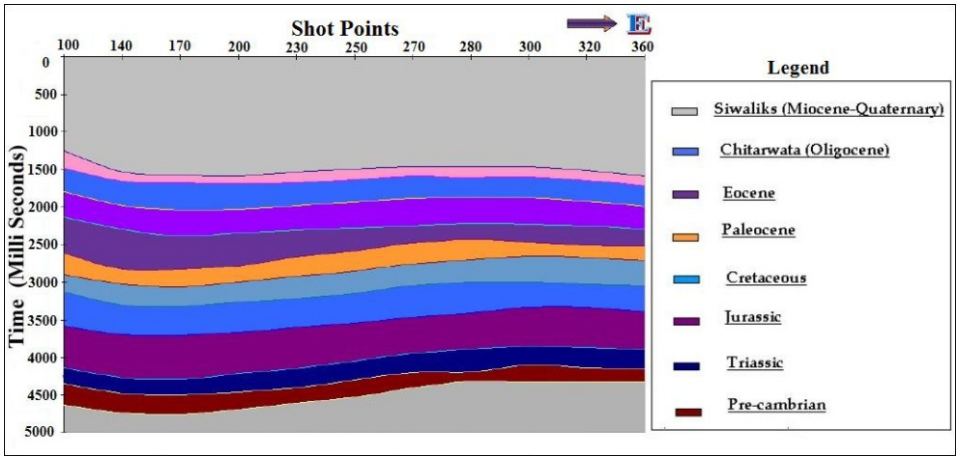

Fig. 7. Time section of 914-RPR-05 (Kotrum Structure)

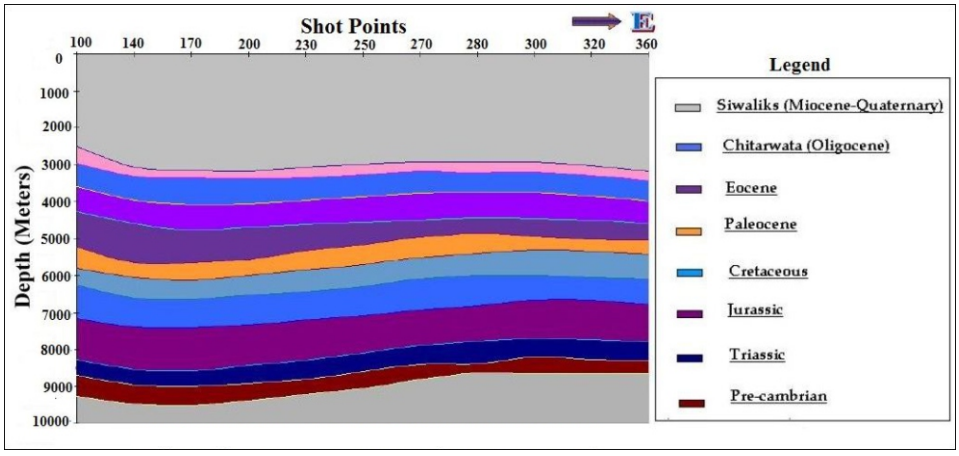

Fig. 8. Geoseismic model of 914-RPR-05 (Kotrum Structure)

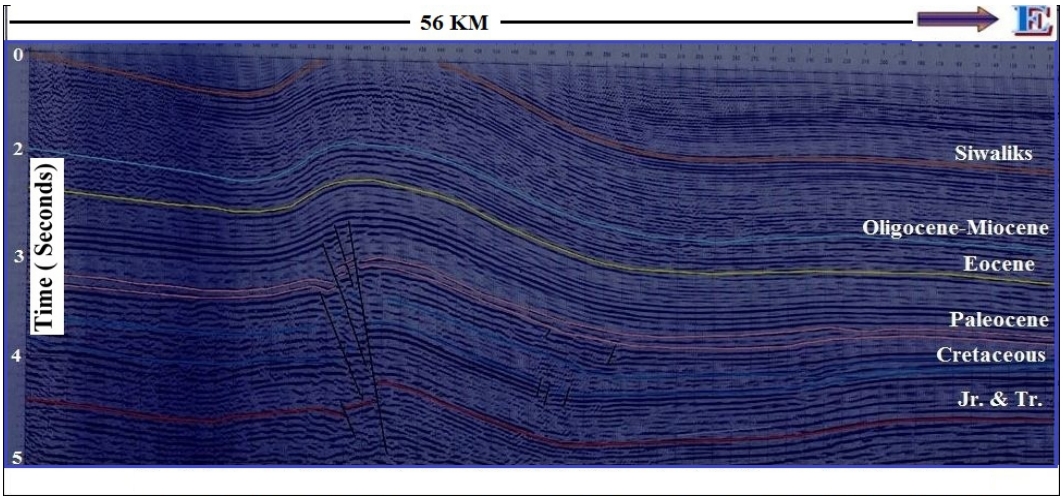

Fig. 9. Interpreted Seismic section of 976-FZP-06 showing Sakhi Sarwar Anticline (56 km).

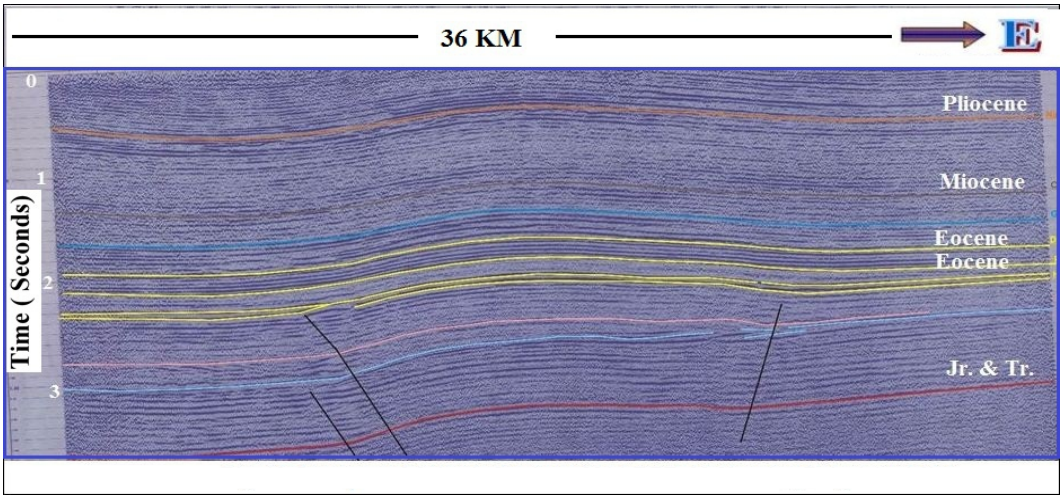

Fig. 10. Interpreted Seismic section of 914-RPR-03 showing Drigri Anticline (36 km)

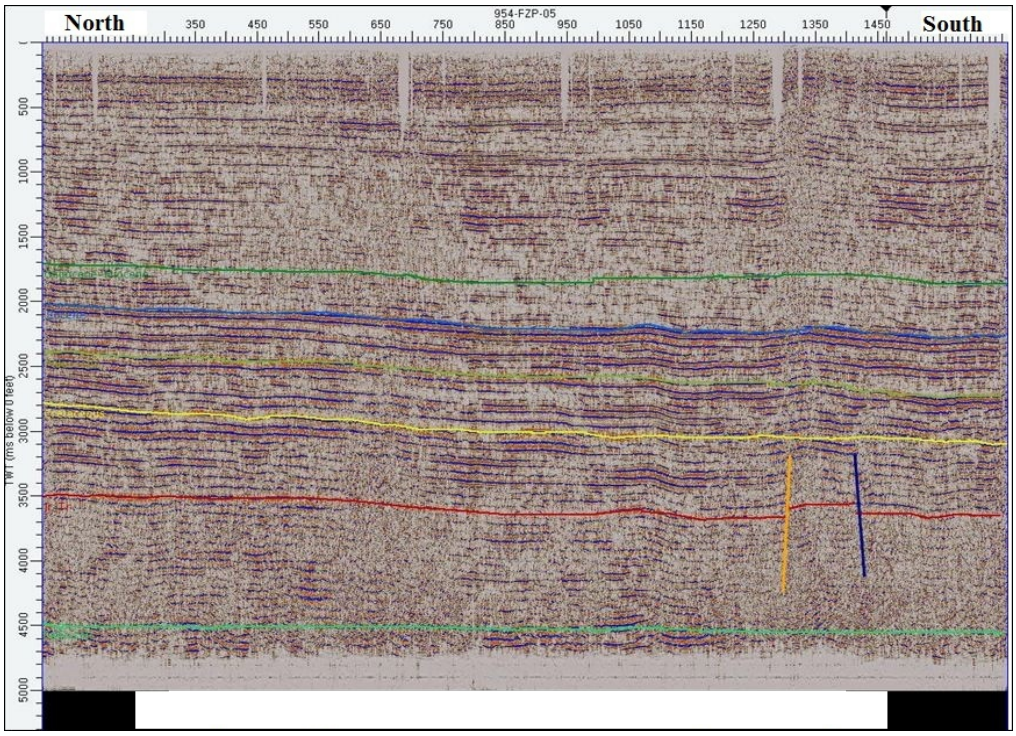

Fig. 11. Interpreted Seismic section of 954-FZP-05 (north-south orientation)

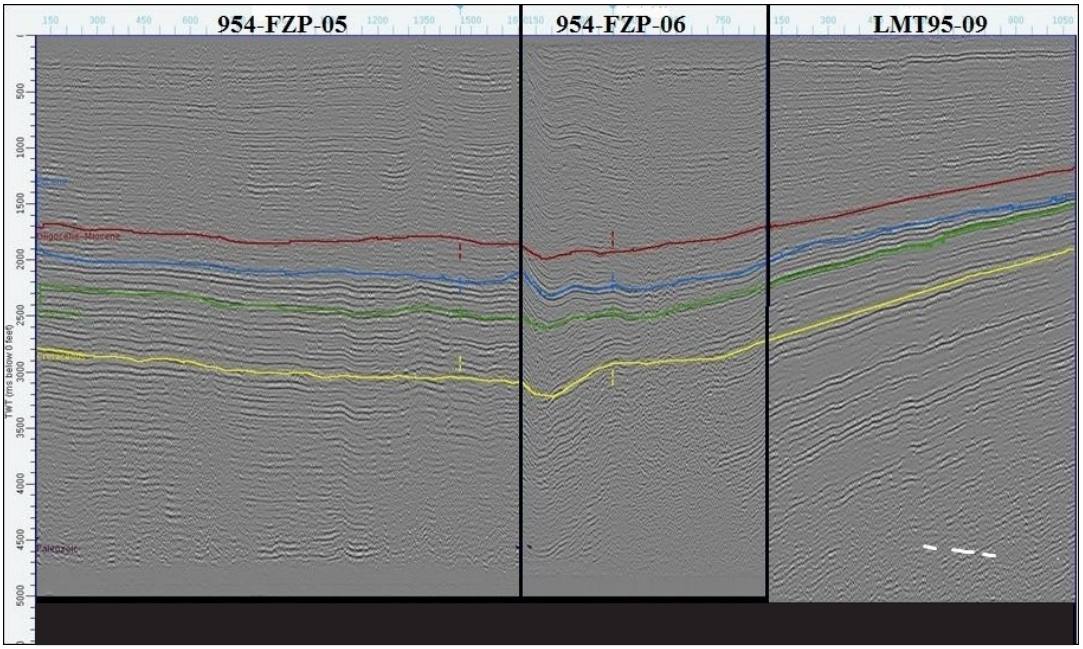

Fig. 12. Combined and Interpreted Seismic sections of 954-FZP-05, 954-FZP-06 & LMT95-09

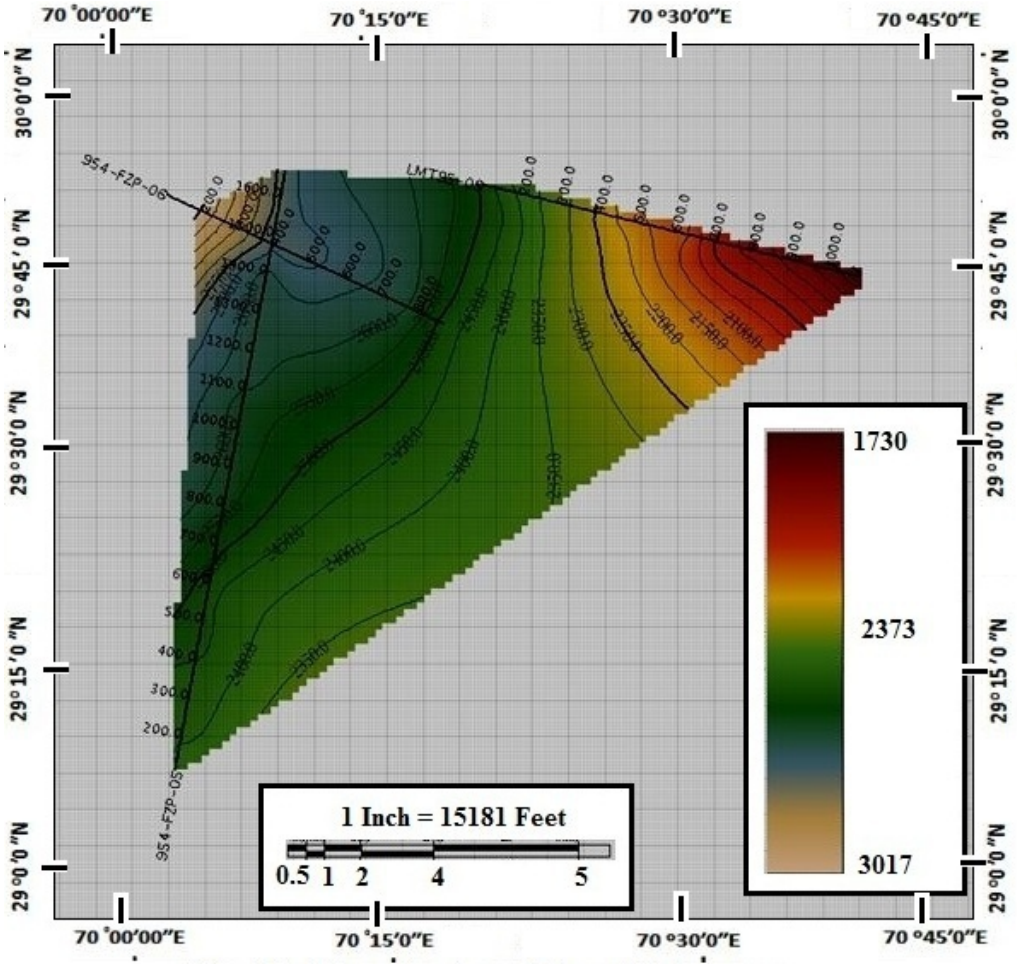

Fig. 13. Time Contour Map of Paleocene

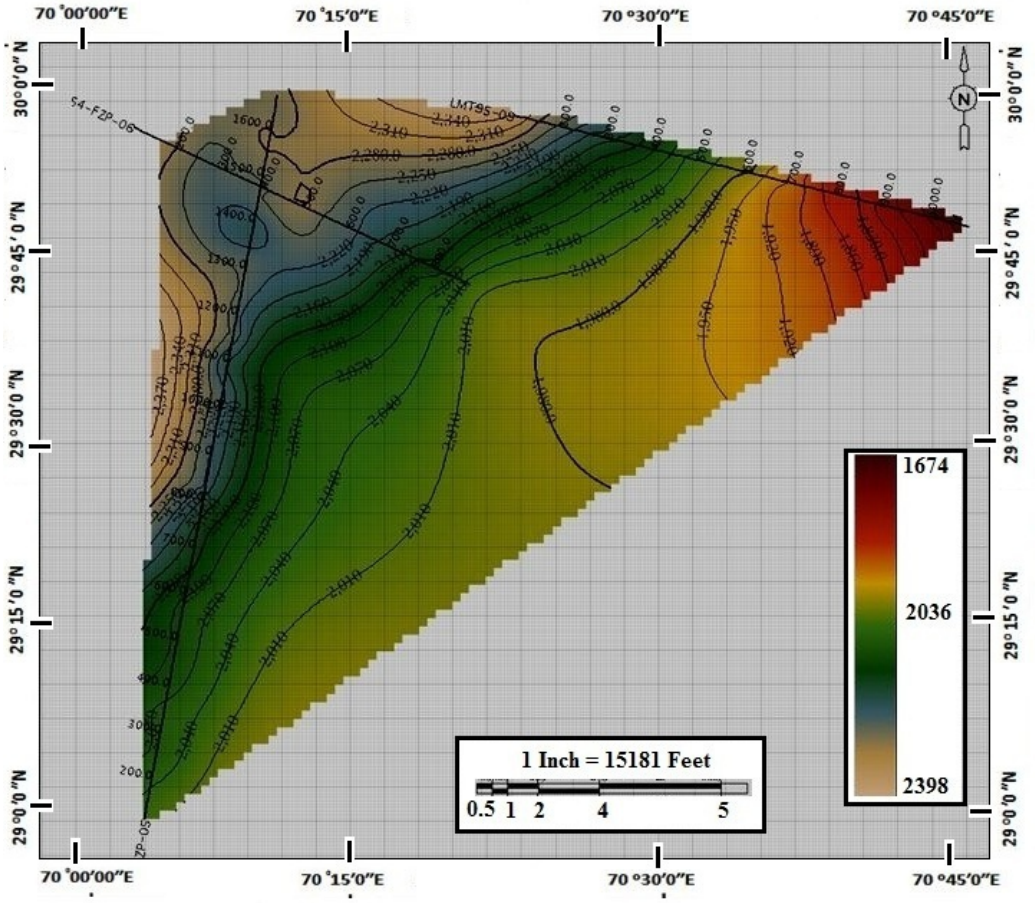

Fig. 14. Time Contour Map of Eocene

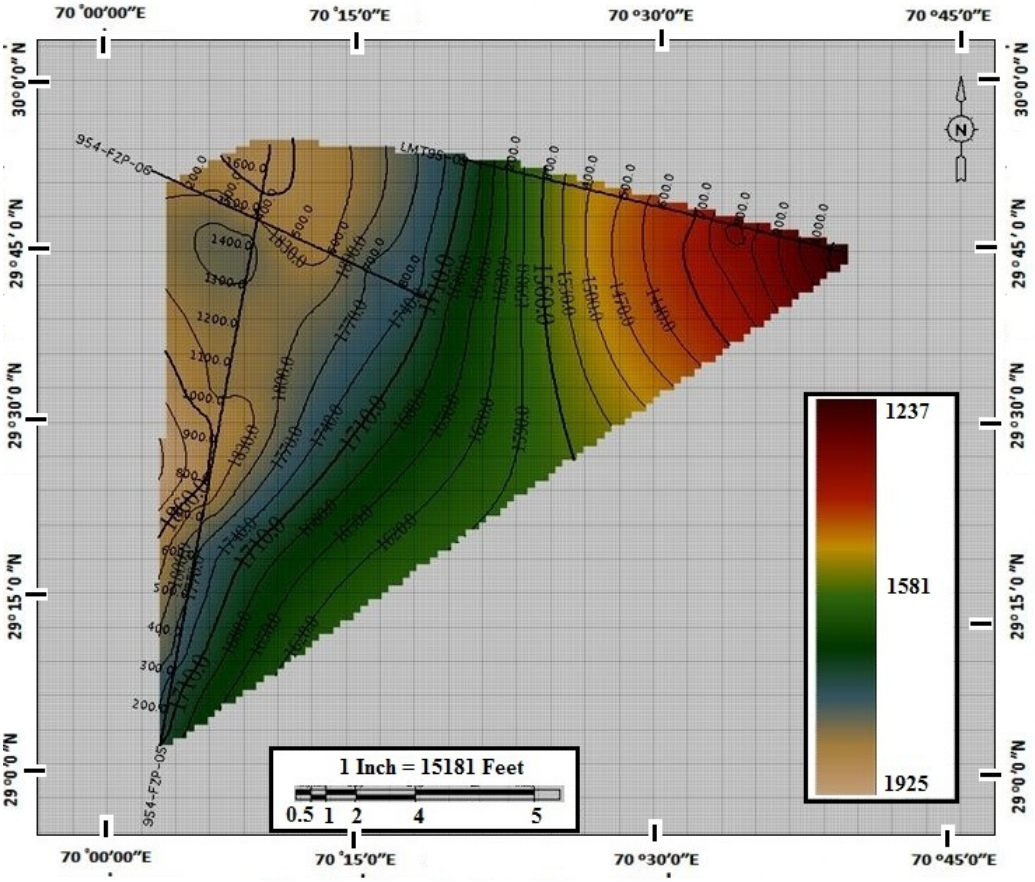

Fig. 15. Time Contour Map of Oligocene.

5. Conclusions

Seismic and well data show Siwaliks are fairly thick in the study area. Gaj (Miocene) and Nari (Oligocene) are thickening southward.Eocene strata show a thick deposition of Ghazij Formation which is thickening in the core of Drigri. Ghazij, Dunghan, Lower Ranikot and the lower strata shows reverse faults on both the flanks of Drigri anticline. It extends about 17 km in E-W direction. Kotrum anticline lies in South of Drigri, which shows the folding of low amplitude. Shales of Eocene, Paleocene, Cretaceous age show the flowage which is obvious in the Depth Section of 914-RPR-03. They show the increase in their thicknesses along the Core of Drigri Anticline. Sakhi Sarwar anticline is having a positive flower structure at the core which supports the wrenching in area along with compression. Time contour maps show the general trend of formations in the Sulaiman Foredeep/Depression. They are uplifted towards the East (Punjab Monocline).The overall structural trend shows the intensity of folding of Sulaiman belt dies in this area. The depth of basement is greater than 8 km approximately.

Table 2. Well tops of Drigri-01

Well Name	DRIGRI-01	Type	EX	Status	ABD
Operator	OGDC	Spud date	02/09/1992	Compl.date	28/11/1992
Depth(m)	3250.0	Latitude	29 22 04.92	Longitude	70 10 54.28
K.B.E	149.02	Province	PUNJAB	Formation	GHAZIJ

Sr.no	Formation Age	Formation	Top(m)	Thickness(m)
1	PLIOCENE	DHOK PATHAN	0.0	847.0
2	PLIOCENE	NAGRI	847.0	1011.0
3	MIOCENE	CHINJI	1858.0	406.0
4	OLIGOCENE-MIOCENE	GAJ-NARI	2264.0	326.0
5	EOCENE	DRAZINDA	2590.0	302.0
6	EOCENE	PIRKOH	2892.0	22.0
7	EOCENE	SIRKI	2914.0	225.0
8	EOCENE	HABIB RAHI	3139.0	38.0
9	EOCENE	GHAZIJ	3177.0	73.0

Table 3. Well tops of Kotrum-01

Well Name	KOTRUM-01	Type	EX	Status	ABD
Operator	OGDC	Spud date	16/12//1997	Compl.date	18/08/1979
Depth(m)	4797.9	Latitude	29 16 52.40	Longitude	70 09 28.20
K.B.E	138.54	Province	PUNJAB	Formation	PAB SANDSTONE

Sr.no	Formation Age	Formation	Top(m)	Thickness(m)
s1	MIOCENE-PLEISTOCENE PLIOCENEN	SIAWALIK	0.0	2073.0
2	MIOCENE	GAJ	2073.0	172.0
3	OLIGOCENE	NARI	2245.0	535.0
84	EOCENE	DRAZINDA	2780.0	220.0
5	EOCENE	PIKOH	3000.0	15.0
6	EOCENE	SIRKI-DOMANDA	3015.0	215.0
7	EOCENE	HABIB RAHI	3230.0	76.0
8	EOCENE	GHAZIJ	3306.0	502.0
9	PALEOCENE	DUNGHAN	3808.0	18.0
10	PALEOCENE	UPPER RANIKOT	3826.0	419.0
11	PALEOCENE	LOWER RANIKOT	4245.0	180.0
12	LATE CRET/EARLY CRET	PAB	4425.0	372.9

References

Ahmad, A., Ahmad, N., Wali, N., Manshoor, S.A., 2007. Source potential and maturity trends of Lower Permian sediments in the Punjab platform and adjoining areas, Pakistan. Annual Technical Conference, Pakistan, Proceedings, 139-154.

Nazeer, A., Solangi., Sarfraz, H., Brohi, I.A., Usmani, P., Napar, L.D., Jahangir, M., Hameed, S., Ali, S.M., 2013. Hydrocarbon Potential of Zinda Pir Anticline, Eastern Sulaiman Fold Belt, Middle Indus Basin, Pakistan, Pakistan Journal of Hydrocarbon Research. 22, 23, 73-84.

Bannert, D., Cheema, A., Ahmed, A., 1989, Interpretation of LANDSAT-MSS imagery of the Sulaiman and Kirthar ranges in western Pakistan. Hydrocarbon Development Institute Pakistan-BGR, Internal Report, 83, 2068.

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

Bannert, D., Iqbal, Helmcke, D., 1995. Surface and subsurface evidence for the Existence of the Sulaiman Basement Fault of the North Western Indian Plate in Pakistan. Second south Asia Geological congress- Colombo, Srilanka, 21.

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

Hasany, S.T., Aftab, M., Siddiqui, R.A., 2007. Refound Exploration opportunities in Infracambrian and Cambrian sediments of Punjab Platform, Pakistan. Annual Technical Conference, Islamabad, Pakistan. Proceedings, 31-62.

Hemphill., Kidwai, 1973. Stratigraphy of the Bannu and Dera Ismail Khan areas, Pakistan. U.S. Geological survey, 716-B, 36.

Humayun, M., Lillie, R.J., Lawrence, R.D. 1991. Structural interpretation of the eastern Sulaiman Fold Belt and Foredeep, Pakistan. Tectonics, 10, 299-324.

Iqbal, M., Helmcke, D., 2004, Geological interpretation of Earth quakes data of Zinda Pir Anticlinorium, Sulaiman Fold Belt, Pakistan. Pakistan journal of Hydrocarbon Research, 14, 41- 47.

Iqbal M., Khan, M. R., 2012. Impact of Indo-Pakistan and Eurasian Plates Collision in the Sulaiman Fold Belt, Pakistan. Search and Discovery Article #50575 (www.searchanddiscovery.com/.../2012/50575iqbal/ndx_iqbal.pdf).

Jadoon, I.K., Lawrence, R.D., Lillie, R.J., 1994. Seismic data, geometry, evolution and shortening in the active Sulaiman fold and thrust belt of Pakistan. American Association of Petroleum Geological Bulletin, 78, 758-774.

Kadri, I.B., 1995. Petroleum Geology of Pakistan, Pakistan Petroleum Limited, Karachi, Pakistan, 275.

Kemal, A., Balkwill, H.R., Stoakes, F.A., 1991. Indus Basin Hydrocarbons plays, International Petroleum Seminar on new directions and strategies for accelerating Petroleum Exploration and Production in Pakistan, 16-57.

Lillie, R.J., Johnson, G.D., Yousaf, M., Zamin, A.S.H., Yeats, R.S., 1987. Structural development within the Himalayan Foreland Fold-and Thrust Belt of Pakistan. Sedimentary Basins and Basin-Forming Mechanisms. Canadian Society of Petroleum Geologists, Memoir, 12, 379-392.

Solangi, S.H., Abbasi, S.A., Ali, A., Asim, S., Lashari, R.A., Brohi, I.A., Siddiqui, I., 2014. Study of Subsurface Structural Trend and Stratigraphic Architecture Using Seismic Data -A Case Study from Zindapir Inner Folded Zone, Sulaiman Sub-Basin, Pakistan. Sindh University Reservoir Journal, 46, 373-380.

Waheed, A. Wells, N. A., 1990, Changes in paleocurrents during the development of an obliquely convergent plate boundary, Sulaiman fold-belt, southwestern Himalayas, west-central Pakistan. Sedimentary Geology, 67, 237-261.

Yeats, R.S., Lawrence, R.D. 1984. Tectonics of the Himalayan thrust belt in northern Pakistan. In: Haq, B.U., Milliman, J.D. (Eds.), Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan, Van Nostrand Reinhold, 77-198.

Appendices

Well tops of Sakhi Sarwar-01, Drigri-01 & Kotrum-01 are shown in Tables 1, 2 & 3 respectively.

Table 1. Well tops of Sakhi Sarwar-01

Well Name	SAKHI SARWAR-01	Type	EX	Status	ABD
Operator	AMOCO	Spud date	10/01/1976	Completion date	13/10/1976
Depth(m)	4580.9	Latitude	29 55 23.00	Longitude	70 20 03.00
K.B.E	238.43	Province	PUNJAB	Formation	PAB SAND STONE

Sr.no	Formation Age	Formation	Top(m)	Thickness(m)
1	MIOCENE-PLIOCENE	NAGRI EQUIVALENT	0.0	878.7
2	MIOCENE-PLIOCENE	CHINJI EQUIVALENT	878.7	1188.7
3	OLIGOCENE	CHITARWATA	2067.4	508.7
4	EOCENE	DRAZINDA	2576.0	156.0
5	EOCENE	PIRKOH	2732.1	150.6
6	EOCENE	SIRKI	2882.7	224.3
7	EOCENE	HABIB RAHI	3107.0	76.1
8	EOCENE	GAZIJ	3183.1	895.9
9	PALEOCENE	DUNGHAN	4078.9	96.0
10	PALEOCENE	RANIKOT	4174.9	193.1
11	LATE CRE/EARLY CRE	PAB	4368.0	212.9