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Utilizing Seismic and Well Logging Techniques for Locating Hydrocarbon of Kabirwala Area Punjab Platform Pakistan

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Abstract
Nandpur Gas field is situated at a distance of 64 km near District Multan. It lies in Middle Indus Basin Punjab Platform, Pakistan. The structure is dipping at a gentle angle toward the NW-SE. Tectonically the area fall in extensional regime and is dominated by Normal faults, favorable for accumulation of hydrocarbon. The interpretation of Seismic lines, time contour map and depth contour map confirms the Graben structure and stratigraphic traps (Pinchouts) in the study area. The high zone present in the South Eastern part of the contour maps is possible location of hydrocarbon entrapment, which is further confirmed by the presence of the well Nandpur -02.The reservoir quality of the Samana Suk Formation was much better in terms of clean Sandstone, porosity, water saturation and permeability. We use seismic lines, a base map and well data of Nandpur-02 area which was obtained from Landmark Resources, Pakistan. For subsurface mapping, structural interpretation, synthetic seismogram generation of investigated area we used four dip and five strike lines. These seismic lines and well data are in digital format. The reservoir discrimination and modeling is carried out with the help of geophysical parameter.
Keywords: Seismic Interpretation, Time and depth contour map, Generating Synthetic Seismogram, 3D view, Reservoir Estimation

1 Introduction

1.1 Study area

The study area is a part of Kabirwala near district Multan and about 25km Southwest of Shorkot close to the junction of Jhelum and Ravi River Punjab Province of Pakistan. Nandpur-02 is situated at 71° 55’ E (longitude) and 30° 31’ N (latitude) as shown in below (Figure 1).

Nandpur area which is situated in middle Indus basin and bounded by Sargodha high in the north, Indian Shield in the east, Kirthar and Suliman ranges in the West, about 69,000 sq. km area is covered by alluvium Punjab Platform (Raza et al., 1989). The stratigraphic sequence established on the basis of the exploratory wells drilled on Punjab Platform represent the most significant pinch-outs in Pakistan (Quadri et al., 1986).

The foremost objective of this work is the identification the structural traps using seismic and well data. Generation of synthetic seismogram and its correlation with seismic time sections. Preparation of time contour and depth contour maps for delineation of anomalous zones for hydrocarbons in Nandpur Area. Lithological and structural correlation using wells data, Determination of geophysical parameters and their application in reservoir discrimination and also determination of the volume of shale by SP and GR log.

1.2 Location map of the project area

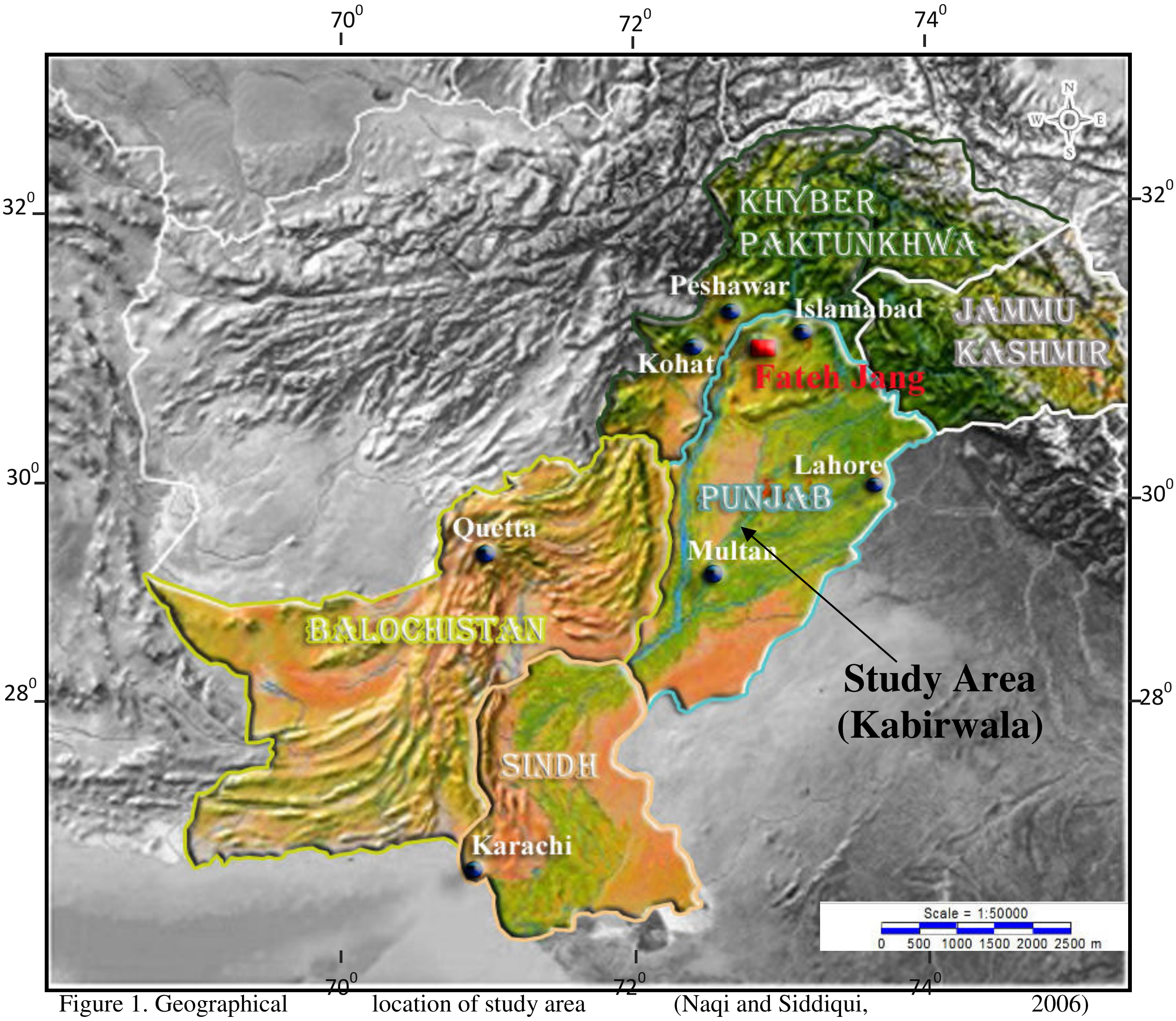

Figure 1. Geographical location of study area (Naqi and Siddiqui, 2006)

The available data for the research purpose is given as below:

- Seismic data, Base map of 2-D seismic lines of Nandpur field of Punjab Platform area
- Well data of Nandpur-02

1.3 Data used

Nine migrated seismic lines (SEG Y files) navigation data of seismic lines, well log data (Las file) and Formation tops form the well Nandpur-02 was available for this project. Available seismic lines and well log data are as follows:

1.3.1 List of migrated seismic lines

Table 1.1: Seismic lines of the study area.

Sr. No	Seismic Line	Orientation
1	O/836-KBR-01	Dip Line
2	O/845-KBR-38	Dip Line
3	O/845-KBR-39	Dip Line
4	O/845-KBR-42	Strike Line
5	O/845-KBR-43	Strike Line
6	O/867-KBR-142	Strike Line
7	O/875-KBR-208	Strike Line
8	O/875-KBR-209	Strike Line
9	O/885-KBR-264	Dip Line

1.3.2 Well log data

Table 1.2: Well log data of the study area.

Sr. No	Log(Las file) Nandpur-02
1	Sonic (DT)
2	Neutron Porosity (NPHI)
3	Formation density (RHOB)
4	Resistivity (MSFL)
5	Gamma ray (GR)
6	Calliper (CALI)

1.4 Base map of the project area

The (Figure 2) shows the base map of the project area Nandpur Gas Field, Punjab Platform of Middle Indus Basin.

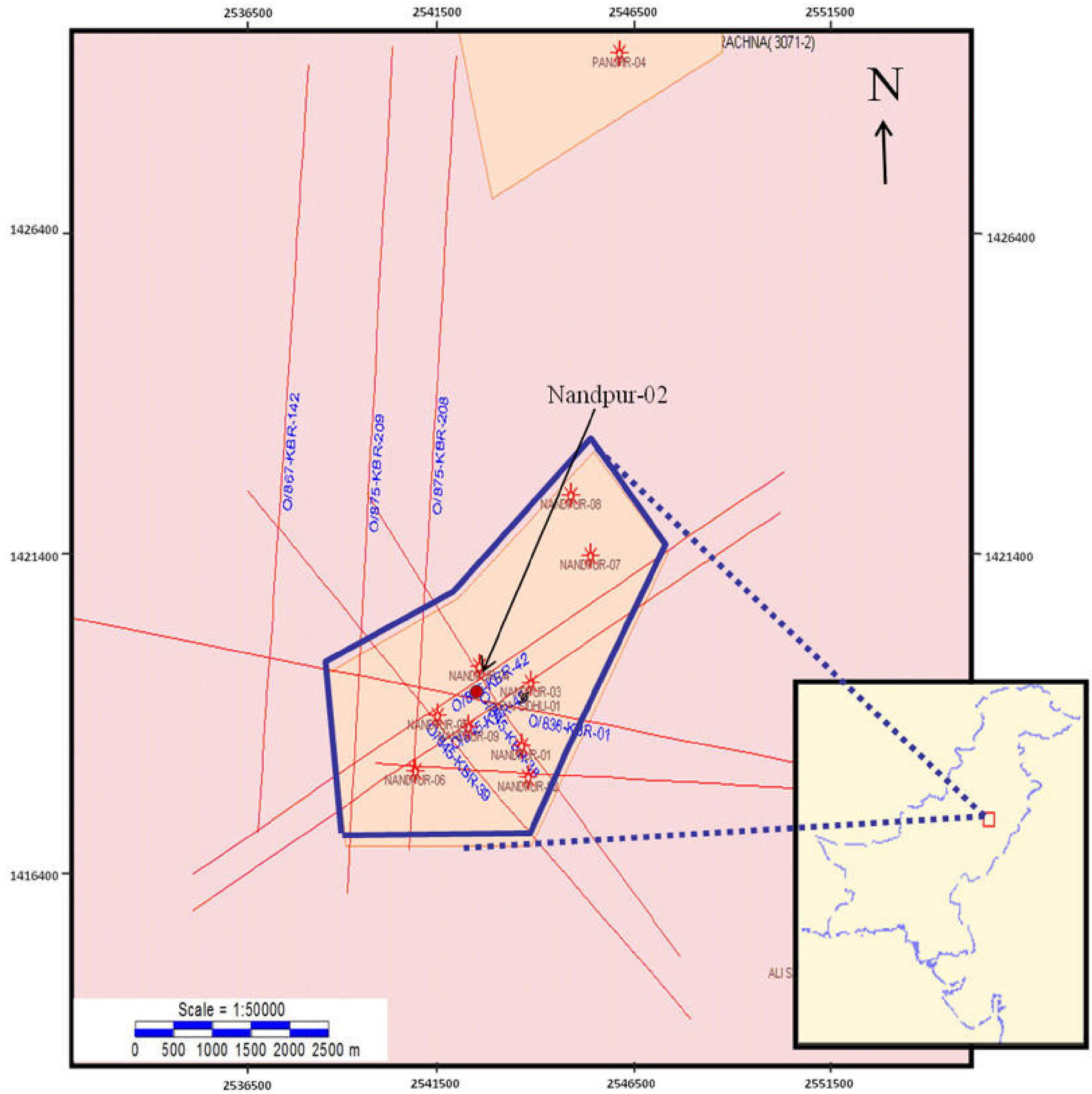

Figure 2. Base map of the study area (Source OGDCL)

2 Theory and Objective

The rifting of Indian Plate as part of Gondwanaland supercontinent started in Late Proterozoic time which resulted in the deposition of Infra-Cambrian sediments over the Pre-Cambrian basement. The rift associated faults (Horst and Grabens Structure) in Bikaner-Nagaur basin is quite pronounced whereas in Punjab Platform the normal faults show minor displacement (Kemal et al., 1991) after a long hiatus of about 250m.y Gondwanaland was once again subjected to rifting during Permo-Triassic time. This rift event is also visible on seismic profile of both Bikaner-Nagaur Basin and Punjab Platform (Searle, 1983).

Punjab Platform is a vast, tectonically undisturbed monocline dipping very gently towards west. Sargodha high in the north and Mari-Jaisalmer high are the southern limit.

The objectives of this research work is to discuss the reservoir estimation with the help of seismic lines and well Nandpur-02 surrounding the Nandpur Gas Fields of Punjab Platform.

2.1 Regional tectonics of Pakistan

Pakistan has been divided into two broad geological zones;

- Gondwanaland Domain
- Tethyan Domain

Pakistan is unique in as much as it is located at the junction of these two diverse domains. The southern part of Pakistan belongs to Gondwanian Domain and is sustained by the Indo-Pakistan Crustal Plate. The northern most and western region of Pakistan fall in Tethyan Domain and present a complicated geology (Kazmi and Jan, 1997).

Pakistan includes almost the three divisions of Landmasses. On the basis of plate tectonic features, geologic structure, orogenic history (age and nature of deformation, magmatism and metamorphism) and lithofacies, Pakistan may be divided into the following broad tectonic zones (Kazmi and Jan, 1997).

- Indus platform and foredeep.
- East Baluchistan fold-and-thrust belt.
- Northwest Himalayan fold-and-thrust belt.
- Kohistan-Ladakh magmatic arc.
- Kakar Khorasan flysch basin and Makran accretionary zone.
- Chagai magmatic arc.
- Pakistan offshore.

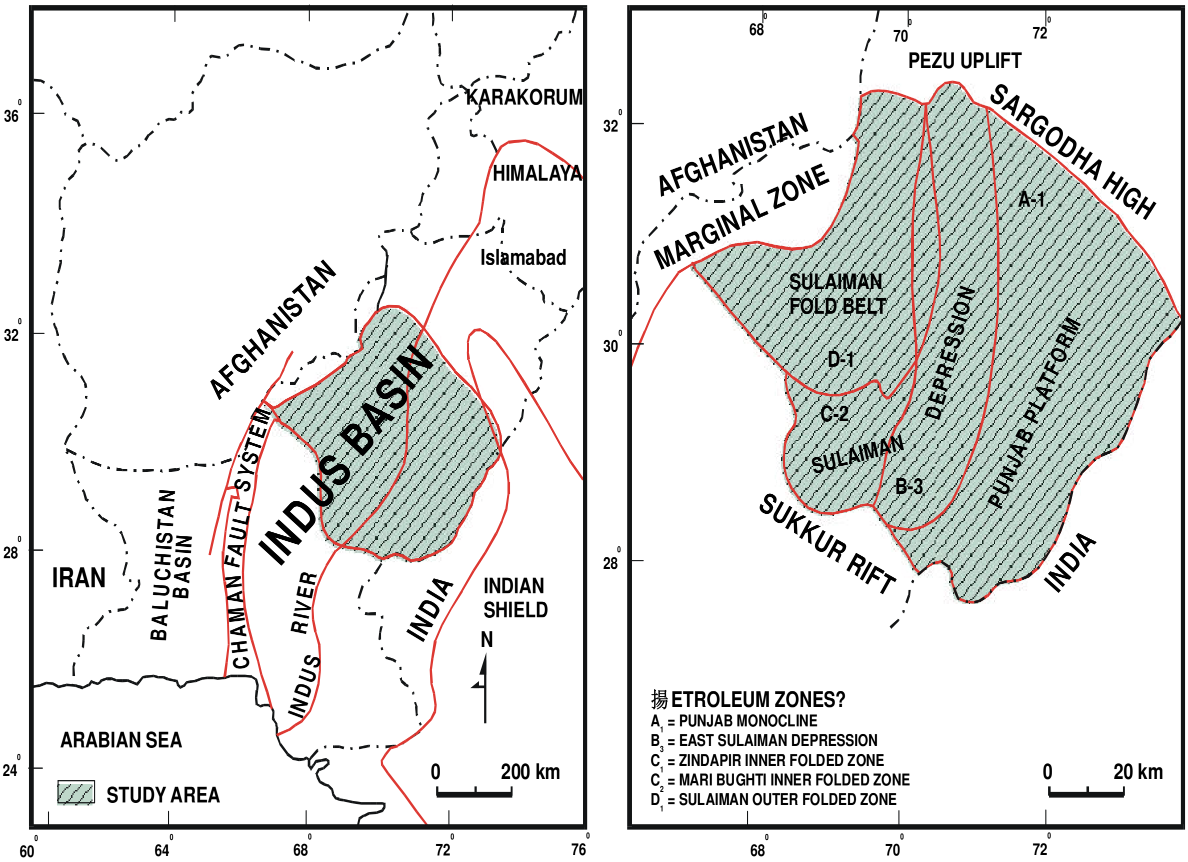

Figure 3. Location map showing the tectonic regime (Raza et al., 1989)

The platform shows Paleozoic, Mesozoic and Cenozoic in moderate thickness are present over the basement (Platform), which continues as a platform area into India where petroliferous basins are locally formed. Sedimentary deposition progressing in continental and shallow marine setting from Precambrian Salt Range Formation as penetrated in wells and early Cambrian carbonate dominate the shelf area similar to strata preserved in modern Arabia and Iran. Low amplitude flexures and normal faulting characterize the platform, stratigraphic traps and structural traps are common.

2.2 Punjab Platform

Middle Indus basin lies in Punjab platform. This basin is very important in terms of its natural gas yield. Hydrocarbon search started in mid-1950's when Shelldrilled first exploratory well, Karampur-1 in 1958, which provided an evidence for occurrence of heavy oil in Infracambrian. Total 23 wells in Punjab Platform, only 12 were drilled for Infracambrian and Paleozoic targets. So far three gas discoveries have been made in Cretaceous aged Lumshiwal Formation and Jurassic aged Samansuk Formation, demonstrating to an extent, optimistic hydrocarbon prospects. (Hasany et al., 2007).

2.3 Sedimentary basins of Pakistan

In terms of genesis and geological history, Pakistan is divided in two main Sedimentary Basins. Indus Basin and Balochistan Basin, which evolved through different geological episodes and was finally welded together during Cretaceous/Paleocene. Another newly identified smaller basin is Kakar- Khorasan Basin also referred as Pishin Basin. This basin came into existence due to interaction of Indian and Eurasian plates and is classified as Median Basin (Quadri, 1986)

2.4 Structural geology of the study area

Platform areas are relatively much stable areas where generally mono- clinal strata rest atop crystalline basement (Indian Shield). Cambrian to Siwaliks aged rocks seem to onlap against this basement. There seems to be no activity related to the basement.

However, the overlying strata are affected by the plate collision. Platform areas form south-eastern part of Lower Indus Basin This unit marks the eastern segment of Central Indus Basin and shows no surface outcrops of sedimentary rocks. Tectonically, it is a broad monocline dipping gently towards the Sulaiman Depression. The Pre- Cretaceous non-orogenic movements tilted the area eastward during the Paleozoic and westward since Mesozoic resulting from the collision of Indian and Eurasian plates.

Central Indus Platform Basin rests on the continental margin of Indo-Pakistani Plate. It is bounded in south by Jaisalmer-Mari-Kandhkot High, while Sulaiman Range defines the western boundary. The Sargodha Ridge (Kirana Hills) markes the north-eastern boundary. The Punjab Platform dips westward into the Sulaiman Foredeep. The structural style of the Central Indus Platform Basin is obscured at surface by thick alluvial cover. (Quadri, 1986).

2.5 Stratigraphy and Sedimentation

The sedimentary rocks present in basin west of Arvali Range (Bikaner-Nagaur) include Infracambrian, Cambrian, Permo-Cambrian, Jurassic and Paleocene-Eocene sediments overlain by alluvium and desert sand of Pleistocene-Recent ages. Only the heavy oil from Jodhpur Sandstone is producing (Quadri, 1986). The stratigraphic nomenclature applied to Mesozoic and Tertiary rock units in Sulaiman fold belt is not used in Punjab Platform. However, in Punjab Platform the nomenclature of the Kohat- Potwar basin is applied.

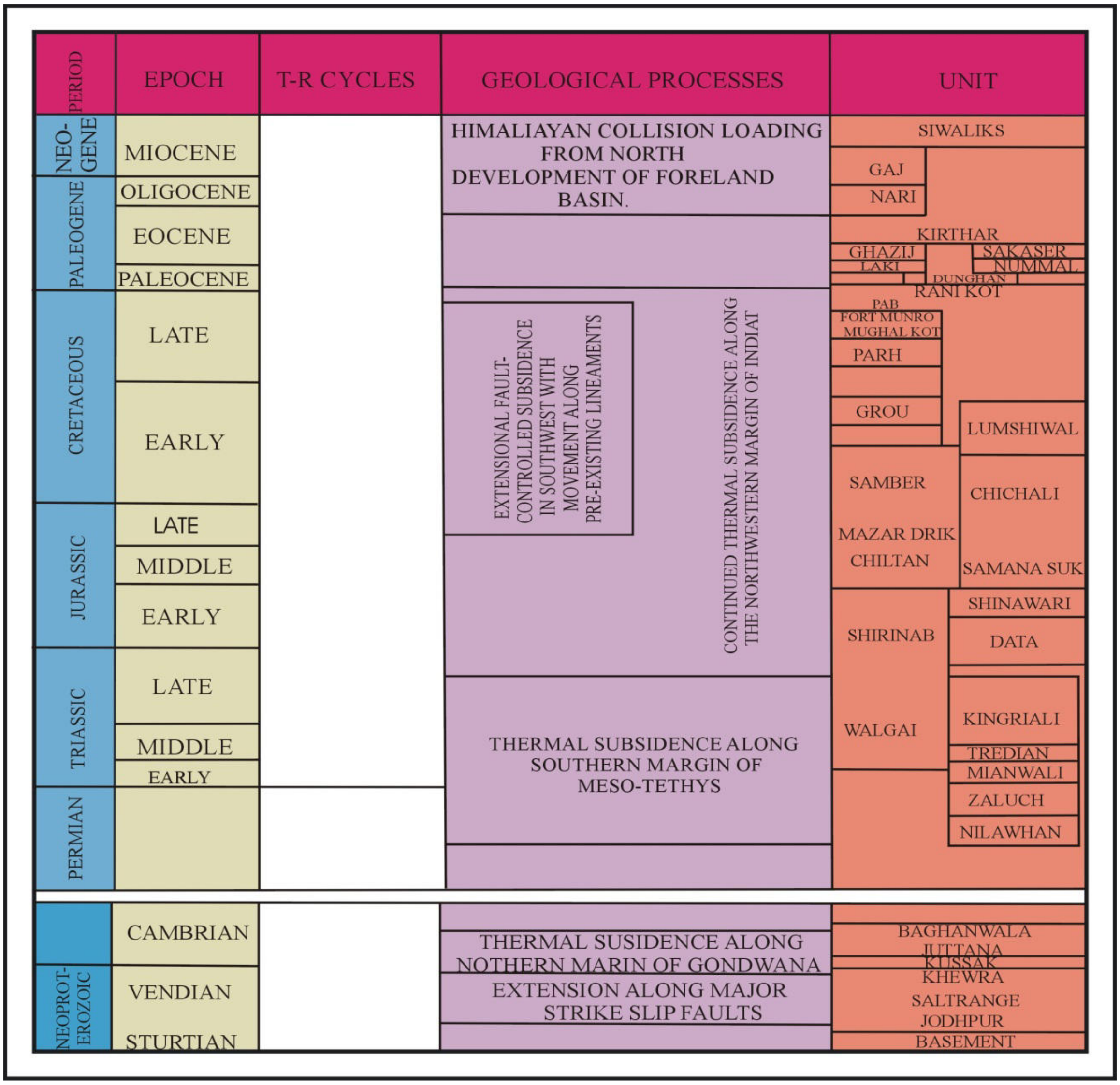

Figure 4. Generalized stratigraphy of the Central Punjab Platform (M.Ibrahim shah, 1977)

2.6 Reservoir rocks characteristics and Stratigraphic Pinchouts

Six stratigraphic units in the Infracambrian are recognized. Oil production has been reported from Bilara Carbonate and Jodhpur Sandstone in Baghewala-1 (Peters et al., 1995). Mesozoic carbonates and sandstone of Shinwari Formation, Samna Suk and Lumshiwal Formations are the known reservoirs which are productive in the Nandpur and Panjpir gas fields. The other probable reservoir is the sandstone of Khewra, Kussak of Cambrian age. Dandot and Warcha of Nilawahan Group, Chhidru of Permian age and Datta of Jurrassic age.

There is a greater likelihood of finding stratigraphic traps in the sedimentary package from Jurassic to Eocene especially in the Cretaceous sandstone units. Stratigraphic traps, as in Mesozoic may also be explored in Cambrian which includes Kussak and Khewra -Nagaur sandstone. These formations were exposed during long depositional hiatus followed by erosion which lasted about 200 Ma (Riaz et al., 2003).

Most of structural/stratigraphic traps in these areas have not been explored so far, however high resolution seismic techniques including 3-D should be employed to locate prospective source-reservoir traps. Advance seismic interpretation techniques like amplitude versus offset, amplitude analysis should be done to understand the reservoir better.

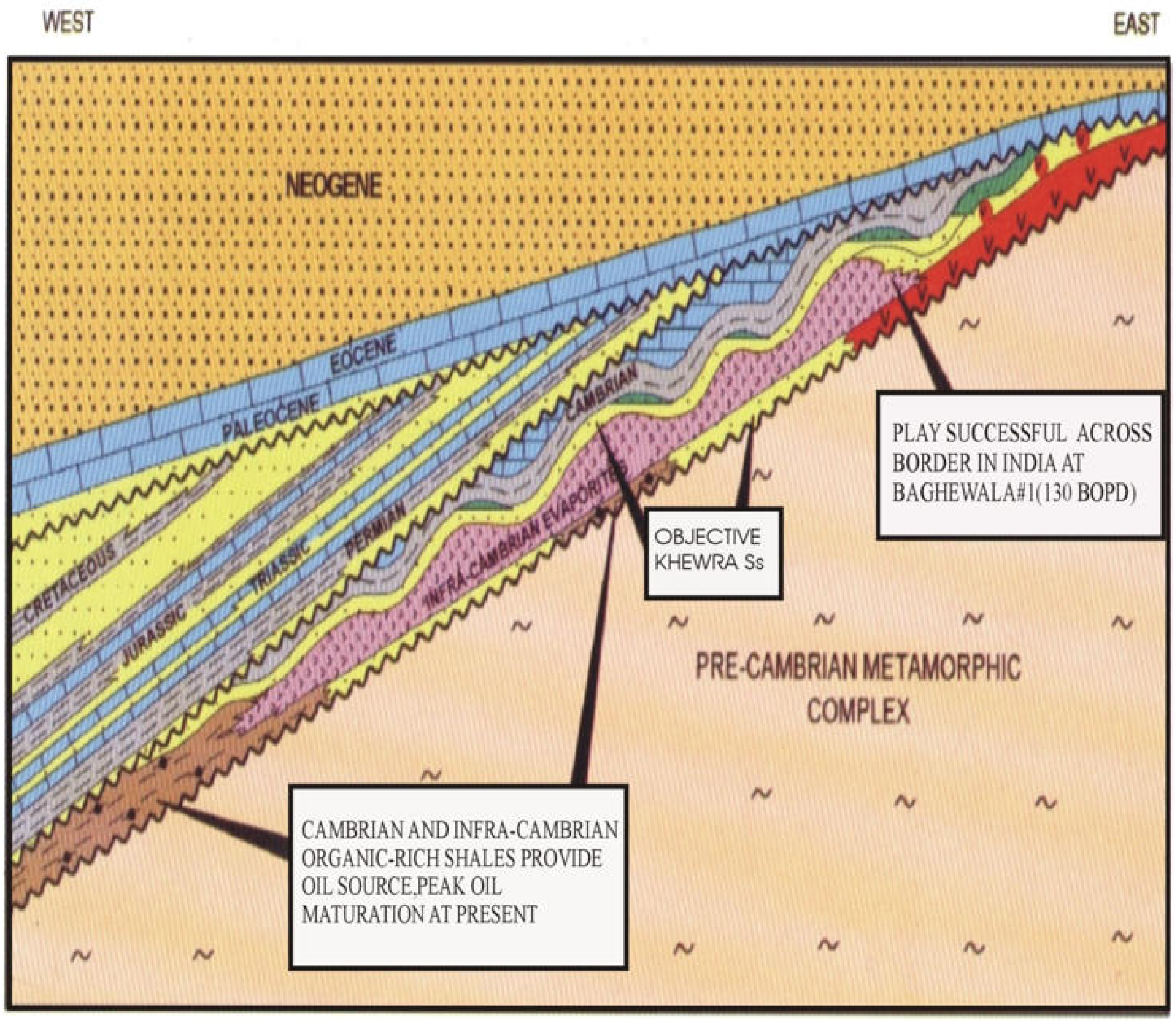

Figure 5. Punjab Platform and truncation of Mesozoic and younger formations (Riaz et al., 2003)

3 Seismic Data Interpretation

Nine (09) lines over the fields of Nandpur were studied and interpreted to examine the idea of seismic relationship i.e. structural, stratigraphic what so ever of Permian strata as source rock for their gas production. It is the study of reflector geometry on the basis of reflection time. In structural analysis, the main objective is to search out traps containing hydrocarbons. The most common structural features associated with the oil, are anticlines and faults.

- Stratigraphic analysis
- Structural analysis

3.1 Marking reflectors

Interpretation of seismic sections

The study area Nandpur falls in the Punjab Platform which is a gently dipping broad monocline. Punjab platform is tectonically the least affected area because of its greater distance from the collision zone.

The line 885-KBR-264 interpreted as a dip line oriented as W-E and flower structure

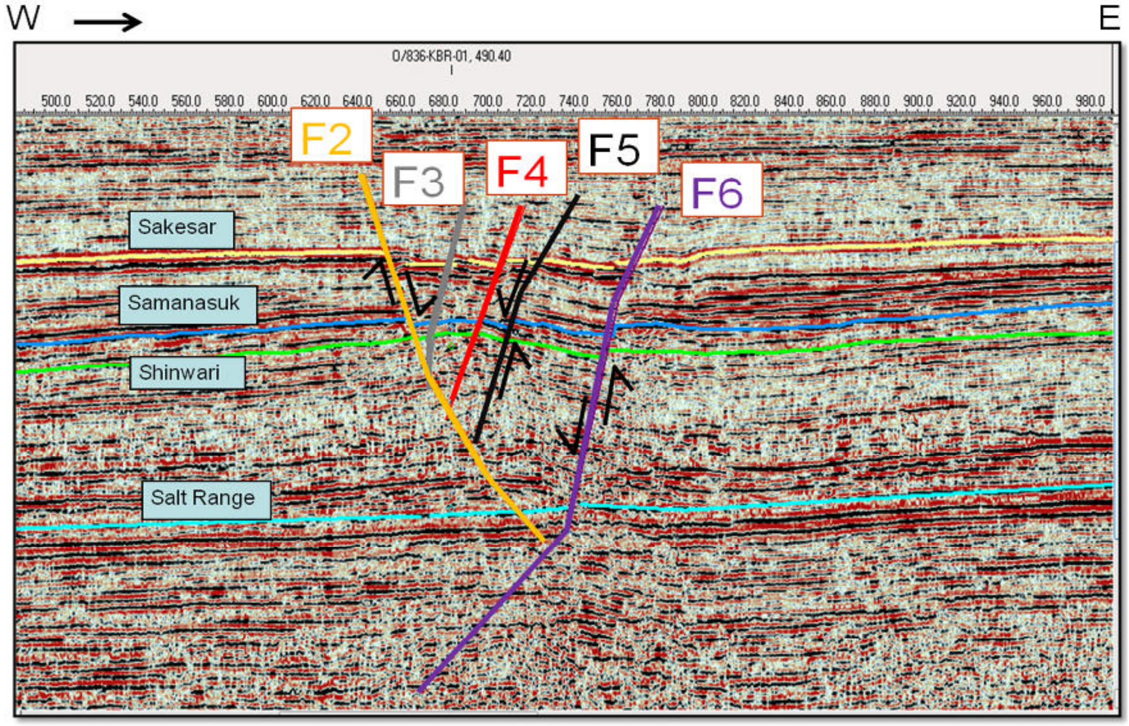

Figure 6. Interpreted seismic section Line 885-KBR-264

3.2 Time and depth structure map

A map of seismic time section is intended to show the structure in the subsurface. Obviously it doesn't show structure directly. Structure is a matter of depth, and the map is in travel time of sound waves. To make a map that is more truly related to the subsurface shapes, depths must be calculated from the times. The idea of converting the times to depths is very realistic to show the subsurface structures. For this purpose time and depth contour maps of Sakesar Formation.

3.3 Time and depth structure map of Samana Suk Formation.

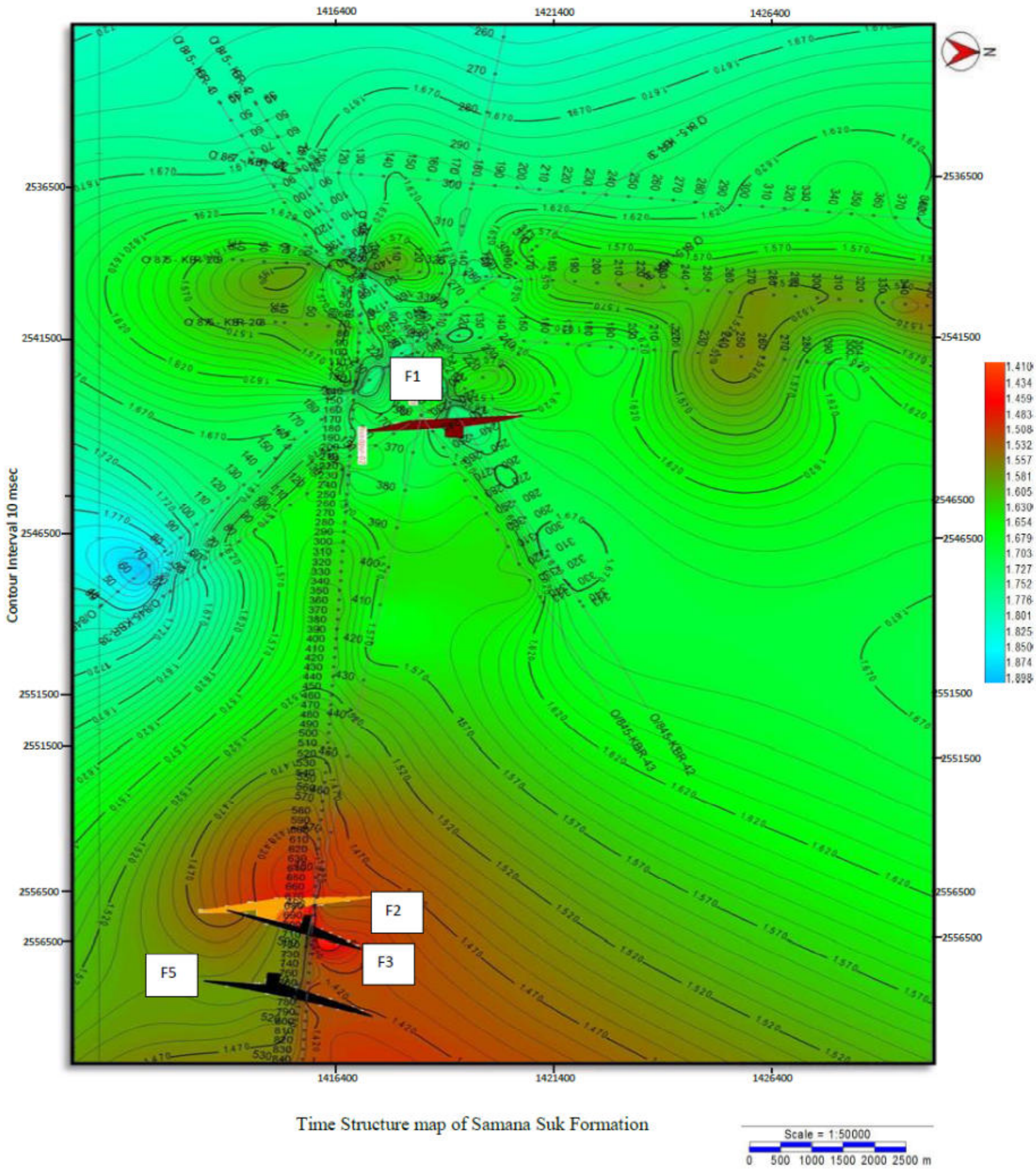

Figure 7. Time structure map of Samana Suk Formation

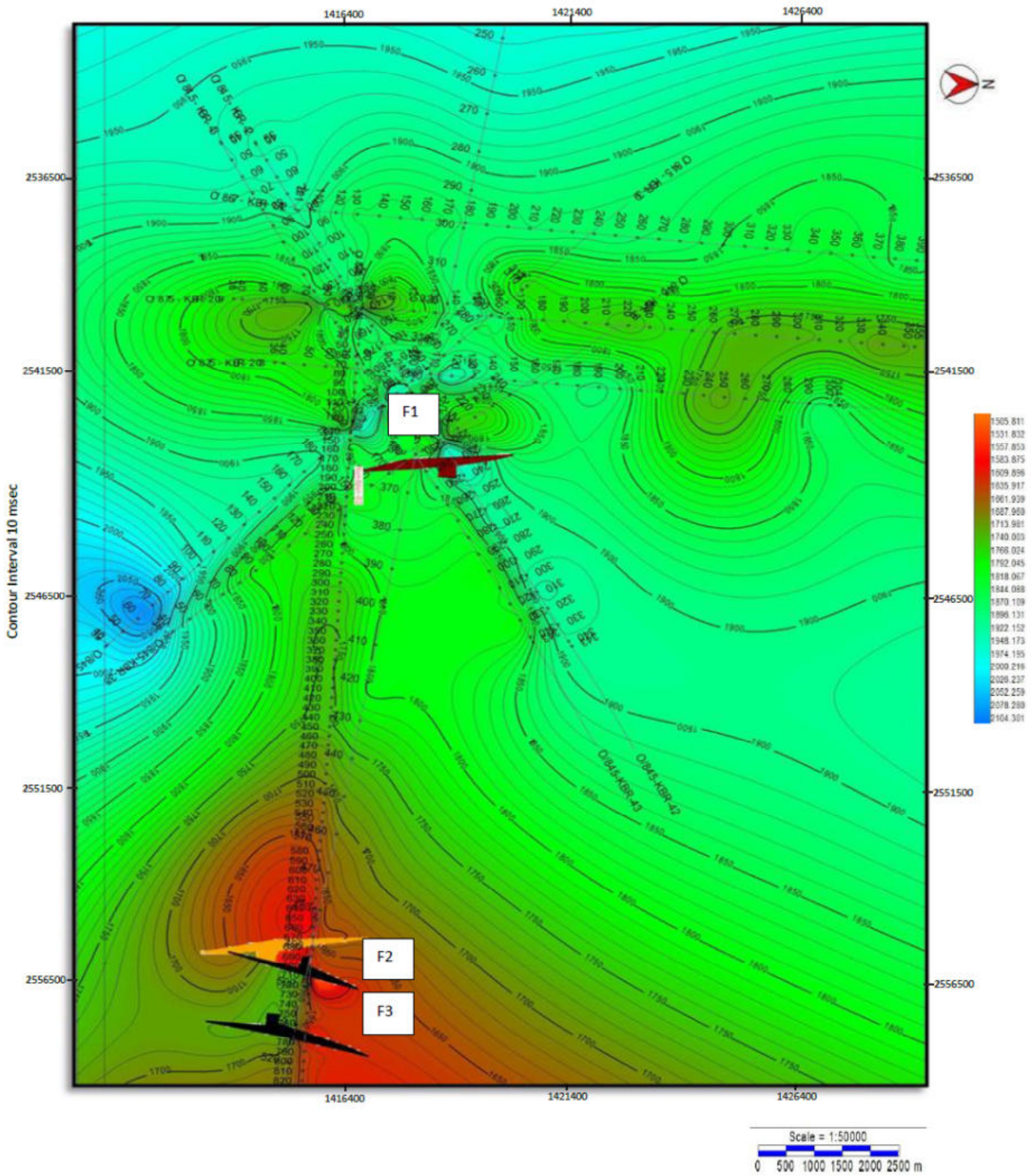

Figure 8. Depth structure map of Samana Suk Formation

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Vol.5, No.10, 2015

3.4 3-D Time structure map of Samana Suk Formation

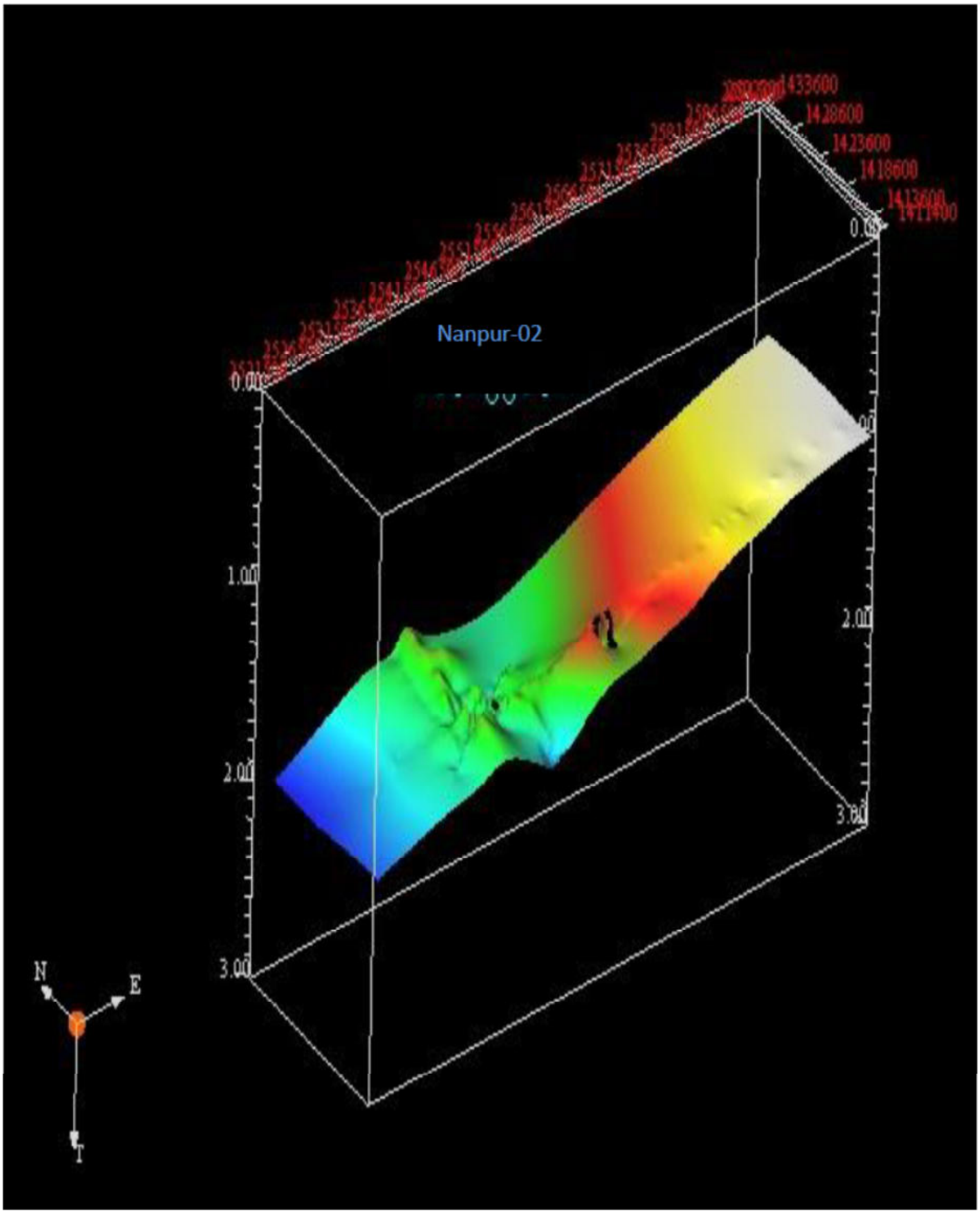

Figure 9. 3-D Time structure map of Samana Suk Formation

4 Geophysical Well Logging

Well logging, also known as borehole logging. The log may be based either on visual inspection of samples brought to the surface (geological logs) or on physical measurements made by instruments lowered into the borehole (geophysical logs).

Basic objective of well logging is the formation evaluation. The properties of a formation that can be estimated from the well log measurements include lithology and bedrock thickness, porosity, permeability, and the proportions of water and hydrocarbons occupying the pore spaces. Actually the data comes in two forms one from the continuous logs as mentioned above and secondly, by the analysis of continuous log samples cuttings and cores obtained during drilling (Schlumberger, 1968).

4.1 Well log interpretation of Nandpur-02

Company	OGDCL
Well Field	Nandpur Gas
Location	District Multan
Longitudes	70.3^{O}E -74.00^{O}E
Latitudes	27.50^{O}N - 32.00^{O} N

4.2 Well logs investigation

The well logs analysis for Nandpur-02 has been done according to the stratigraphy of the Punjab platform. Samana Suk formations encountered in this well. The zones are marked on the basis of well logs analysis and lithologic description has been made. The logs used in this interpretation are DT, NPHI, RHOB, MSFL, LLD, LLS.

4.3 Synthetic Seismogram

Synthetic seismogram is generated using sonic and density log, the well picks encountered on different depths are marked on the synthetic at their respective depths and also correlated with litho log.

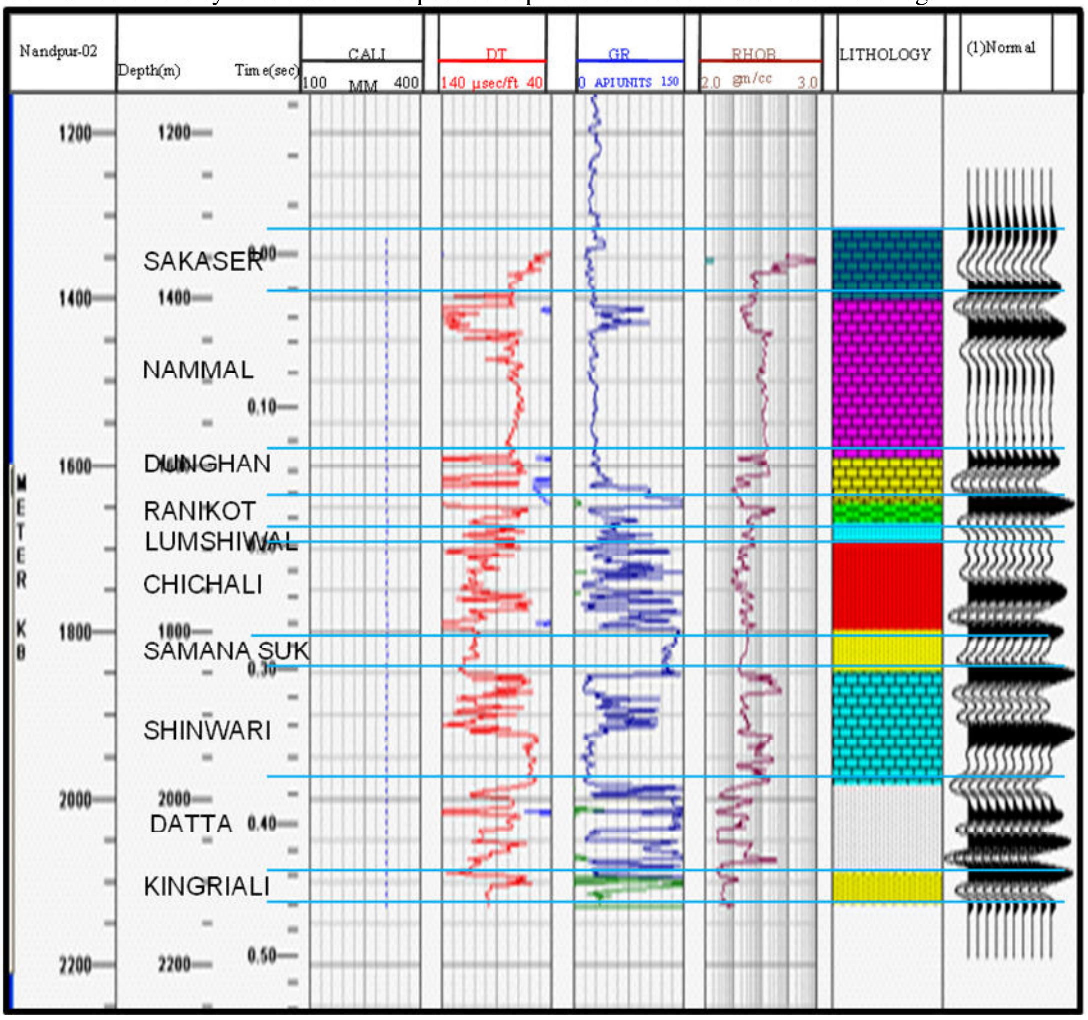

Figure 10. Correlation of synthetic seismograph with Formation of the well Nandpur-02

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Vol.5, No.10, 2015

4.4 Interpreted Samana Suk Formation

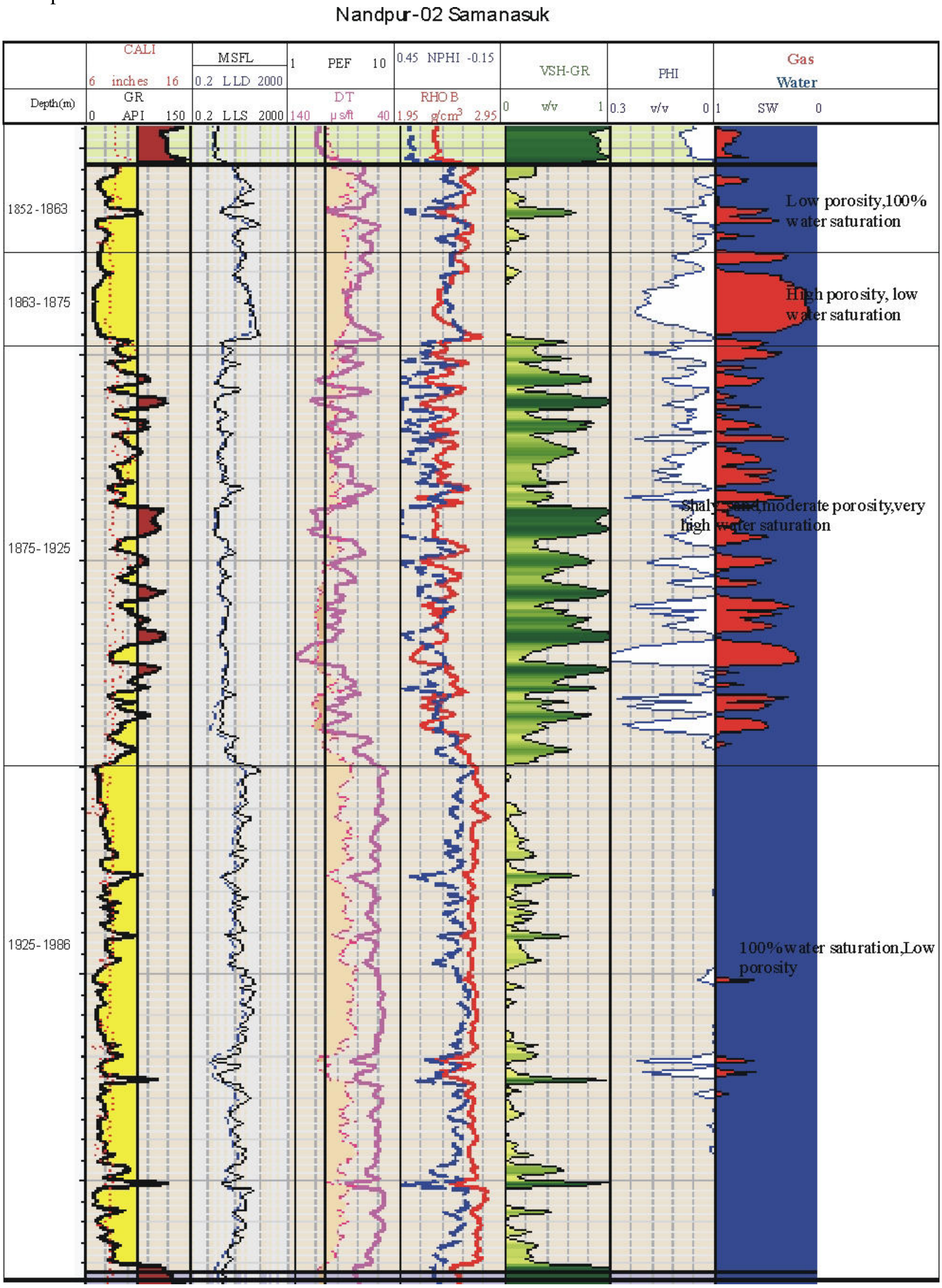

Figure 11. Well log interpretation of Samana suk Formation Nandpur-02.

5 Results of well log analysis Nandpur-02

Depth	Description of Well Nandpur-02 of Samana Suk Formation
1848-1863	Low porosity and 100%water saturation zone
1863-1875	High porosity and very low water saturation
1875-1925	Shaly sand, with moderate porosity and very high water saturation
1925-1986	Zone with very low porosity, seems compact and 100%water saturation

5.1 Cut-offs

The following cut-offs were selected to define the Net Pay from the Gross Interval for Nandpur-02.

Well Name	Porosity	Water Saturation	Volume of Shale
Nandpur-02	Above 8%	Less than 60%	Less than 35%

The reservoir may deliver hydrocarbons but total volumes delivered will likely not to be significant when compared to volumes delivered form reservoir section having 20 to 200-md permeability. Water Saturation Cut-off of 60% was applied. The shale volume cut-off was 35% and the porosity should be greater than 8%.

5.2 The results after Cut-offs s given below

SAMANASUK FORMATION		
Net Thickness	**Net Porosity**	**Hydrocarbon Saturation**
105 ft.	15.16	.691

Volumetric reserves estimation of Samana Suk formation

$$OGIP = \text{constant} \frac{\times A \times H \times SH \times \text{Ø}}{FVF}$$

$$OGIP = \frac{43560 \times 2964 \times 105 \times .691 \times .15}{1.25}$$

$$= 11241\text{mmscf}$$

Where
OGIP= Original Gas in Place
A = Area
H = Thickness
SH = Hydrocarbon Saturation
Ø = Porosity
FVF= Formation Volume Factor
MMSCF= Metric Million Standard Cubic Feet

6 Discussion

- Four horizons are marked on the basis of continuity and character of seismic traces.
- For Structural interpretation faults have been marked on the seismic sections. The identified faults are normal faults, which make horst and graben geometries favorable for the accumulation of hydrocarbons.
- Time and depth Structure maps shows that the subsurface structure present is gentle anticline.
- The time structure map of the Samansuk Formation has been prepared with contour interval of 10 msec as shown in (Figure 8). A few high and low zones are present in the maps. The high zone present in the south eastern part of the contour maps could be a possible location of hydrocarbon entrapment, which is further confirmed by the presence of the well Nandpur -02.
- The depth structure map of the Samansuk Formation has been prepared with contour interval of 10 msec as shown in (Figure 9). The contours show that the structure is dipping at a gentle angle towards

the higher values of the time i.e. from NW-SE Tectonically/Structurally the area lays in extensional regime.

- The 3-D Time Structure map of Samana Suk Formation is dipping from east to west show the gentle anticline.

7 Conclusions

Following conclusions drawn from this study findings.

1. The seismic data confirms the Grabens structure and stratigraphic traps (Pinchouts) in the study area favorable for the accumulation of hydrocarbon.
2. The high zone present in the south eastern part of the contour maps could be a possible location of hydrocarbon entrapment, which is further confirmed by the presence of the well Nandpur -02.
3. The reservoir is encountered in the Samana Suk Formation which is further confirmed through well log analysis.
4. In Samana Suk Formation the average water saturation is 30%, average porosity is 14% and net pay thickness is 105m.
5. The reserves calculated for the Samana Suk Formation is 11241mmscf.

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