Analysis of subsurface structural trend and stratigraphic architecture using 2D seismic data: a case study from Bannu Basin, Pakistan

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Abstract

The present study is focused on the subsurface geology of Bannu Basin, a part of western Indus foreland Pakistan. For this purpose, some regional seismic profiles and deep exploratory wells data have been used in integration.A total of ten mappabale seismic reflection events have been identifed which are representative of specific geological units. In general, based on the seismic the formation trends, the horizons are dipping in the northwest direction of the study area. The area generally deepens toward the northwest due to sediments load toward the northwest. The seismic profile MWI-83 shows a unique faults bounded anticlinal structure that has also been mapped on the two-dimmensional contour maps. This could be regarded as potential hydrocarbon entrapment. The regional seismic profiles are contoured for the entire grid in both time and depth domain to obtain the clearer image of the subsurface individual stratigraphic units. The 2D contour maps for Lower Permian aged Warcha Sandstone, Middle Triassic aged Tredian Formation and Early Jurrasic aged Datta Formation have been prepared using gridded TWT of the seismic profiles. The time and depth contour maps of the Datta Formation and Tredian Formation show a four way clouser oriented in the southeast dierction. The area of the closure was computed which is 24 Sq km approximately. Furthermore, the formation tops of the five wells have been used to correlate the wells for understanding the lateral and vertical variations in the stratigraphic layers. The correlation shows that the Datta Formation's thickness increases at the centre of the basin whereas decreases on the east and south flanks of the basin. Reasons of Wells failure were concluded on the basis of the final well report and concluded that these well failure occur due to poor quality of the data and also due to some mechanical problems. Reservoircharacterization using statistical rock physics and petrophysics coupled with core data analysis can provide further insights into the hydrocarbon exploration.

**Keywords** Structure · Stratigraphy · Seismic data · Bannu Basin · KP · Pakistan

Introduction

The study area is part of the Bannu Basin, Pakistan which is accessible from the Peshawar via main National Highway (N-55) which leads to Karachi. The Chonai-01 and Isakhel 01 wells lie in Districts Lakki Marwat and Mianwali and is almost 250 km from Peshawar. The current research work is carried out in the Bannu Basin, northern Pakistan. The Trans Indus Ranges are tectonically dynamic fold and thrust belts which covers three major geological entities: the Marwat Ranges, Surghar Ranges and the Bannu Basin-Khisor Ranges (Fig. 1) (Abir et al. 2017). The Bannu Basin is less studied by the previous researchers for the purpose of hydrocarbons exploration. Recently acquired public domain 2D seismic lines and wells data in Bannu Basin show existence of salt and indication for the main detachment surface. The

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Fig. 1 Regional Geological Map showing Bannu Basin and Trans Indus ranges (modified after Ali 2010**)
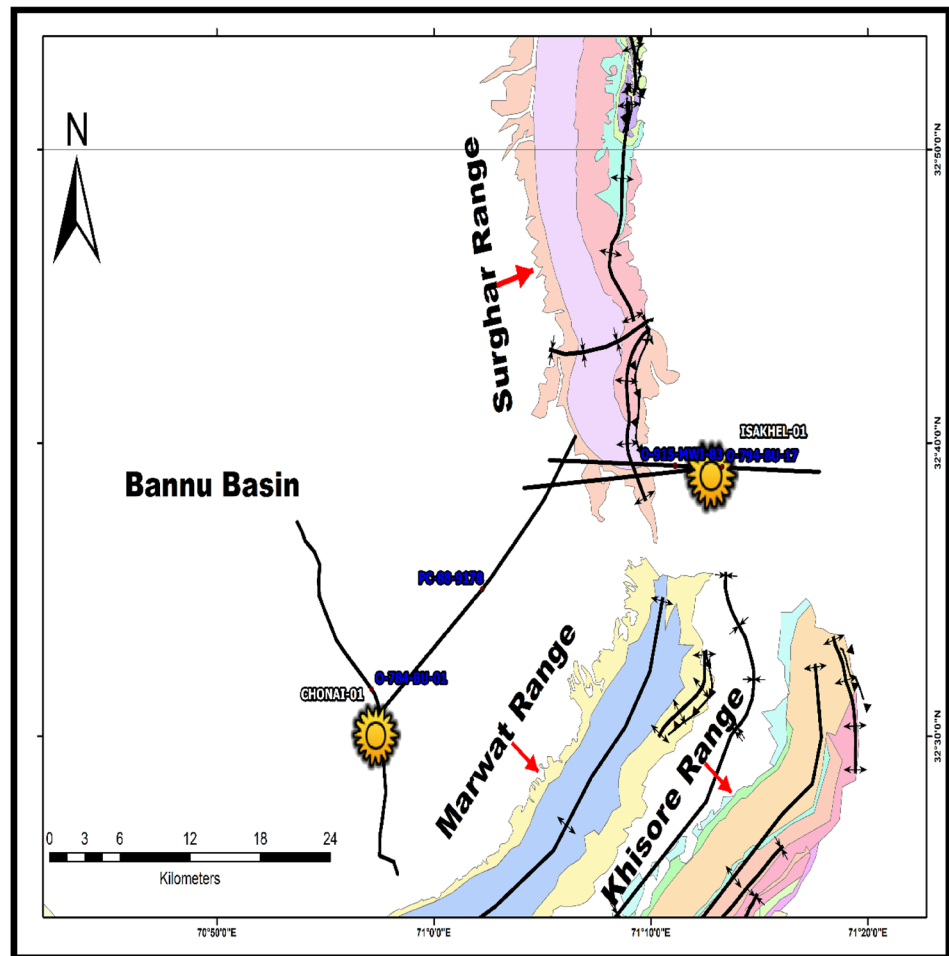
Salt Range Formation probably be the major detachment in the whole area.

The Bannu Basin and Potwar Plateau exhibit structural and stratigraphical similarities suggest that the Bannu Basin is the western extension of the Potwar Plateau (Khan 2013). Structural geology shows that potential traps are established mostly in the anticlines of the Bannu Basin (Burbank and Raynolds 1988). The hydrocarbon traps are mostly structural traps in Bannu Basin dominantly anticlines. Moreover, the transpression zones and salt diapirism all together with various oil seeps nearby the basin enhance the chances of hydrocarbon accretion and show huge prospectivity and probability for future exploitation and exploration (Danilchik and Shah 1967; Abir et al. 2017) (Fig. 2).

The surface geology of Bannu Basin is completely enclosed by Quaternary sandy and alluvial sediments while greater rock outcrops are situated along the Surghar, Khisorand Pezu-Bhittani Ranges (Khan et al. 1986). Petroleum exploitation in the fold-and-thrust belt of northern, Pakistan is underway since 1800s with varied outcomes. The first exploratory well in this area was drilled in 1886 nearby the Kundal oil seep. Since then, a dozen of wells had been

drilled in the Bannu Basin and Trans Indus Ranges (Khan et al. 1986; Alam et al. 2014). Earlier research had proposed thin-skinned distortion pattern for the Bannu Basin (Alam et al. 2014, 2015). The resemblance in the structural geology and stratigraphy proposes the Bannu Basin might be the western portion of the Potwar Plateau (Khan 2013). Both have broader deformational belts than the Kohat Plateau and is recognized to the change in the behavior and nature of the detachment layer. It reflects ductile versus brittle behavior. In Bannu Basin and Potwar Plateau, the superimposing sedimentary wedge floats excellently along sideweak detachment layer of salt, which results in slight interior distortion of wedge (Lillie et al. 1987).The Kohat Plateau is folded and faulted because of its mechanical detachment, which offers resistance for movement (Hemphill 1974). Exploration and Production Companies have drilled almost dozen of wells but unfortunately no discovery despite of that the area is having plenty of oil & gas seeps which indicates presence of petroleum system (Abir et al. 2017) (Fig. 3).

The current study focuses on the seismic interpretation of 2D seismic profiles and correlation of the wells data to understand subsurface structural geology and stratigraphy
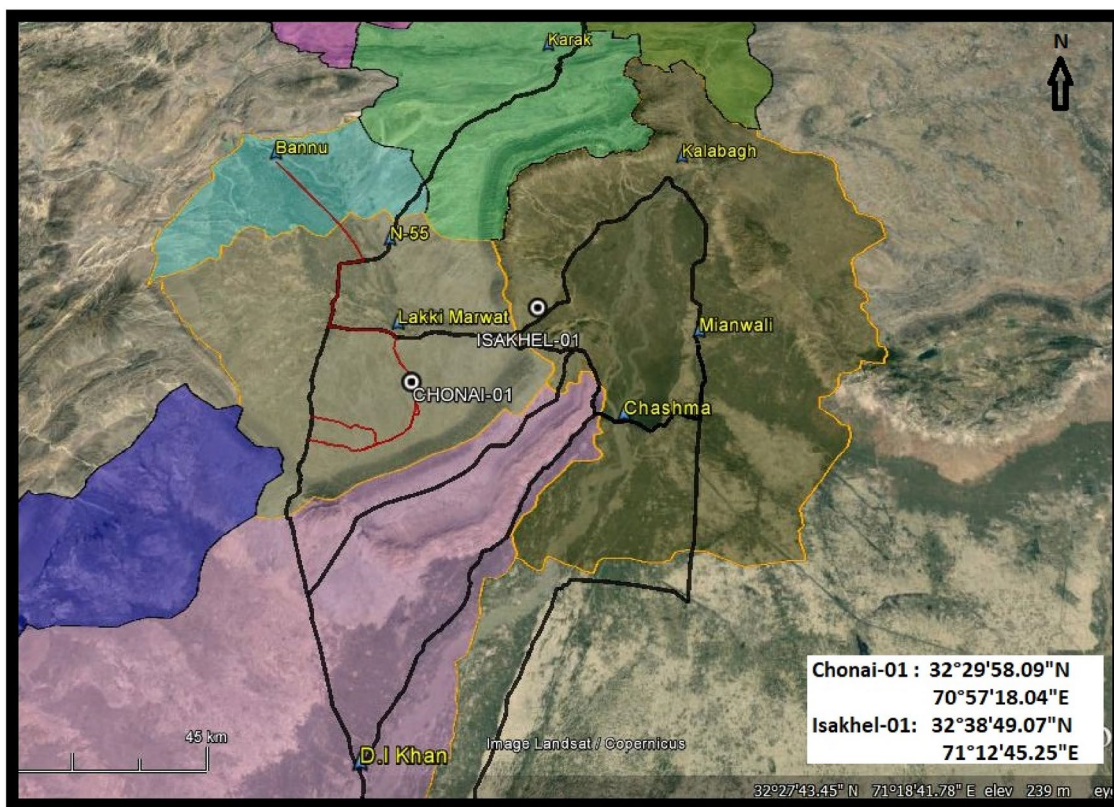
Fig. 2 Google Earth Map showing the location of wells in the study area around the Bannu Basin

of the study area. Following are aims and objectives of the proposed study (Fig. 4).

1. To perform the subsurface structural analysis of the area and delineate the geological model based on available seismic sections/profiles.
2. To develop a stratigraphic model, correlation of wells will be carried out.
3. To determine hydrocarbon play, the structural and stratigraphic data will be integrated.

Methodology

The approach implemented in the proposed work includes the seismic data that are acquired from LMKR is interpreted for demarcating hydrocarbon bearing zones. Poor to fair quality 2D seismic profiles are located in vicinity of Bannu Basin. These were acquired between 1978 and 1979 by the OGDCL (Fig. 5).

The acquired data were interpreted with the help of geological maps and well data. The Chonai-01 and Isa Khel-01 wells provided stratigraphic constraints for seismic interpretation. In addition to that the seismic interpretation,

Geological, structural and stratigraphic modelling are achieved for the explanation of subsurface faults and horizons in study area. This helped us in rebuilding of the geometrical and structural features of the reservoir. KPOGCL's licensed exploration software 'Petrel' by Schulmberger is used for seismic interpretation and wells correlation. Seismic and well data provide an understanding of the subsurface structures of the Bannu Basin. With the help of well and seismic data, the over-all structural style of the Bannu Basin is interpreted and reflects two distinctive structures; salt diapirism and transpressional structures (Fig. 6).

To understand the geology of Bannu Basin, 2D seismic lines in Bannu Basin are interpreted using available seismic and wells data of Isakhel-01 and Chonai-01. The wells correlation and successively the subsurface structural understanding have added worth to the structural interpretation of the basin. In addition to that, by comparing Bannu Basin, structural and stratigraphic similarities for the hydrocarbon accretion will eventually help in defining implications for upcoming petroleum probability and prospect in Bannu Basin.
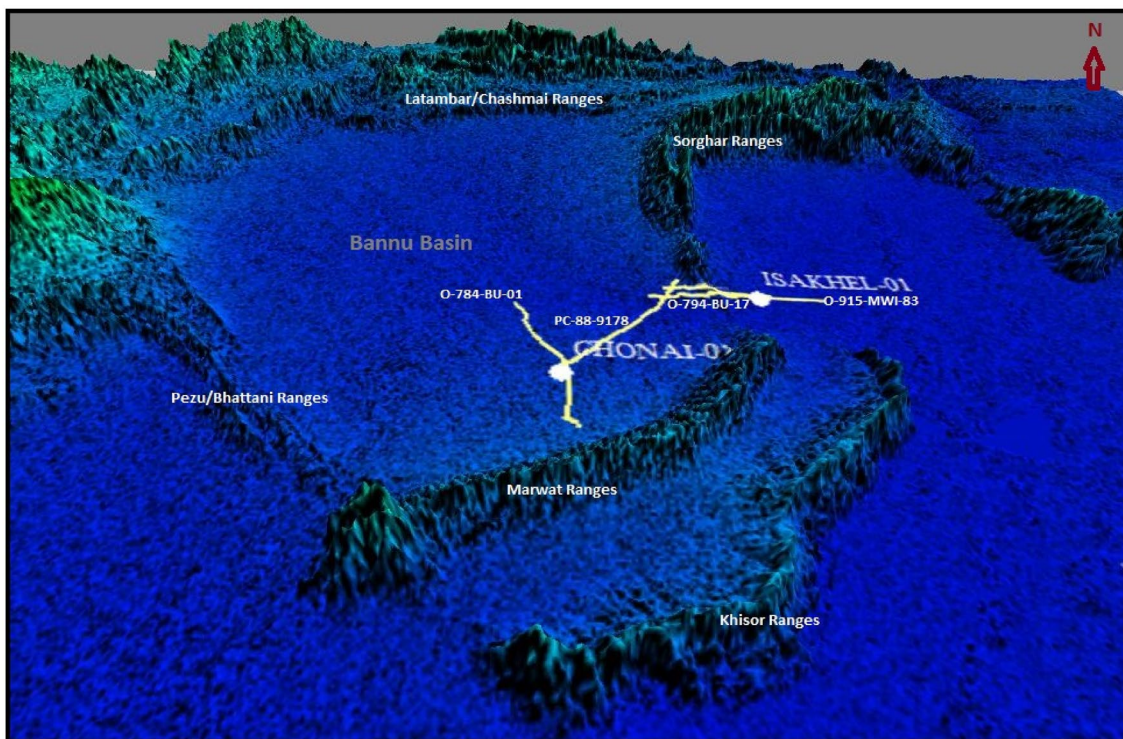
Fig. 3 DEM showing north looking view of the Bannu Basin and its surrounding geological domains. Chonai and Isakhel Well locations are also shown

Stratigraphic framework of the study area

The stratigraphy of the Trans Indus Ranges which surrounds Bannu Basin is well published in Geological Survey of Pakistan (GSP) (Shah 1977; Fatmi 1974) and extra patented reports made by oil companies. Out crops in the Trans Indus Range comprises from Cambrian to recent (Abir et al. 2017). Late Precambrian and early Cambrian times, a shallow shelf and restricted environment prevailed. The deposition of evaporites with some organic shales (source rock). Later shallow marine clastic was followed by a regional uplift and sedimentation break which prevailed until the late Carboniferous period. A widespread marine Transgression occurred at the end of Carboniferous in the southern part of the province resulted in to glacio-fluvial environment at late Carboniferous or early Permian. It was followed in the Permian by Shallow open marine conditions with estuarine influences of the nearby Indian shield to the east. These shallow open marine conditions continued during the Triassic period (Shah 1977).

During Jurassic, the stable shelf environment prevailed, and subsidence was more important in the southern province. The Sargodha highs may have created a barrier between the shallow estuarine to coastal conditions to the north and the marine conditions to the south.

At the end of Cretaceous, a major uplift affected the whole Indus Basin, erosion stripped strata down to the Jurassic period in some places. During the Paleocene and Eocene epochs, a widespread subsidence occurred again. In the southern part of the province, the environment was dominantly near shore with calcareous-argillaceous facies. In the Kohat region, local uplift resulted in a restricted basin environment with deposits of rock salt capped by gypsum and some oil shales. An open marine environment with deposition of shale and limestone prevailed in the middle Eocene epoch. The late Eocene to early Oligocene was the time of first severe orogenic movement which uplifted the Axial-belt. The sea gradually retreated southwards and in the Potwar province, brackish and later fresh water continental environments prevailed through the rest of the tertiary period. Sediments came from adjacent rising mountains (Murree Formation). During the rest of the Tertiary time, orogeny continued especially in the early Miocene and Pleistocene eras. The Axial-belt was uplifted and simultaneously the foredeep was developed at the frontal parts of Sargodha spurs filled with continental clastics (Siwalik group) (Fatmi 1974).
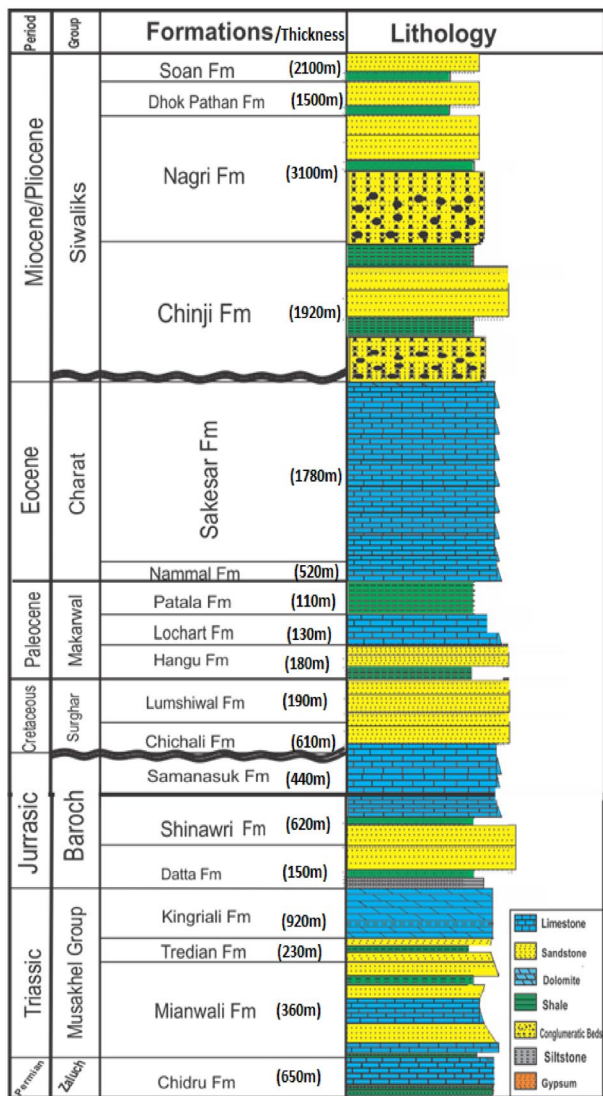
Fig. 4 Generalized Stratigraphic Column of Surghar Ranges modified after (Ali 2010)

Interpretation

Seismic interpretation plays key role to know about sub surface geology. The interpretation gives us a structural and stratigraphic lead in the form of maps and these maps deliver completed at associated to the subsurface and to realize satisfactory situations in subsurface for accretion of hydrocarbons. The study area comprises of Seismic profiles MWI-83, passing through Isakhel-01 well and Line BU-01 passing through Chonai-01 Well in Bannu Basin, Pakistan. Although the 2D seismic profile data are of fair to poor quality which was acquired by OGDCL and PetroCanda in 1978 and 1979 as follows (Abir et al. 2017).
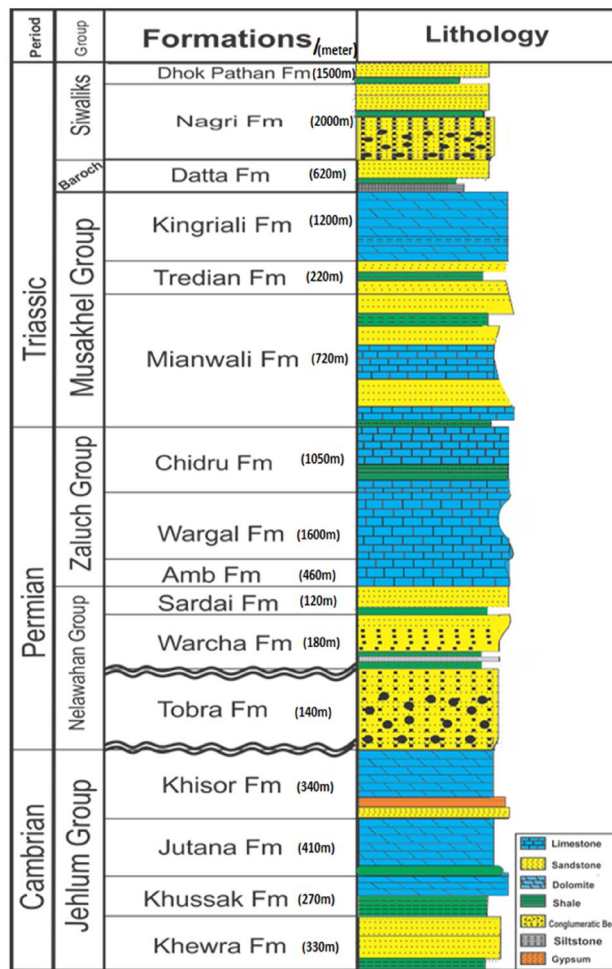

Fig. 5 Generalized Stratigraphic Column of Khisor Ranges modified after (Ali 2010)

- Geophone: SM 4
- Recorder: SN 348&Coba II
- Geophone interval: 2.8 m for Line MWI 83 & 8 m for Line BU 01
- Receiver interval: 50 m for Line MWI 83 & 100 m for Line BU 01

The Exploratory well location is finalized on basis of interpretation of seismic 2D/3D acquired data. 3D seismic gives detail picture of the prospect. 2D Seismic requires less cost as the spacing between the lines is close enough, and 3D is vice versa. The quality of seismic data depends on the fold of data (number of times a seismic wave reflects from the subsurface). For a high cost exploratory well, oil industries go for 3D Seismic for a clearer image of the prospect (Abir et al. 2017).

The work flow of Seismic interpretation is a continuous process, whereby seismic reflections are shown on seismic section to describe geology. The distinct seismic reflections
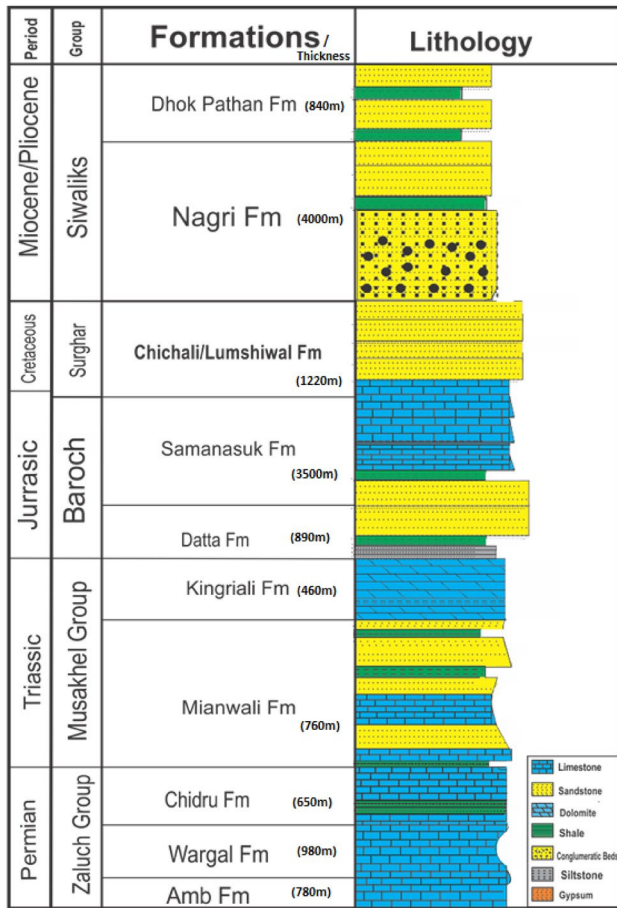
Fig. 6 Generalized Stratigraphic Column of Marwat Ranges modified after (Ali 2010)

Fig. 7 Seismic interpretation workflow

are transmuted to the geological section which explains subsurface structural and stratigraphic image of the region and will illustrate the style and geometry of reservoir. One of the major objective of seismic interpretation is to estimate location of well for Hydrocarbon accretion. The seismic interpretation work flow is shown in Fig. 7.

Base map

The study area Base map shows 2D lines in respect of their geographical reference, i.e. latitude and longitude. Seismic lines on Base map include 3 Dip lines and 1 Strike line. Base map also shows wells (Chonai-01 and Isakhel-01) in the Fig. 8.

Interpretation of seismic lines

The below steps are used for seismic interpretation.

Seismic to well tie

2D Seismic section has incredible and huge coverage and less resolution while the well data have less coverage and high resolution. The exactness will be high in mapping the subsurface structure and geology when low resolution seismic data are tied with high resolution well data. For this reason, Seismic to Well-Tie is ordinarily connected in oil and gas industry. Well-Seismic ties let well information, estimated top to bottom, to be corresponded to seismic data, estimated in time, one method for watching the well tie is that it is the interpreter's eye to develop association in geology and seismic information. The synthetic trace is compared to the real seismic data near the well location, it allows to relate Formation tops identified in a well with specific
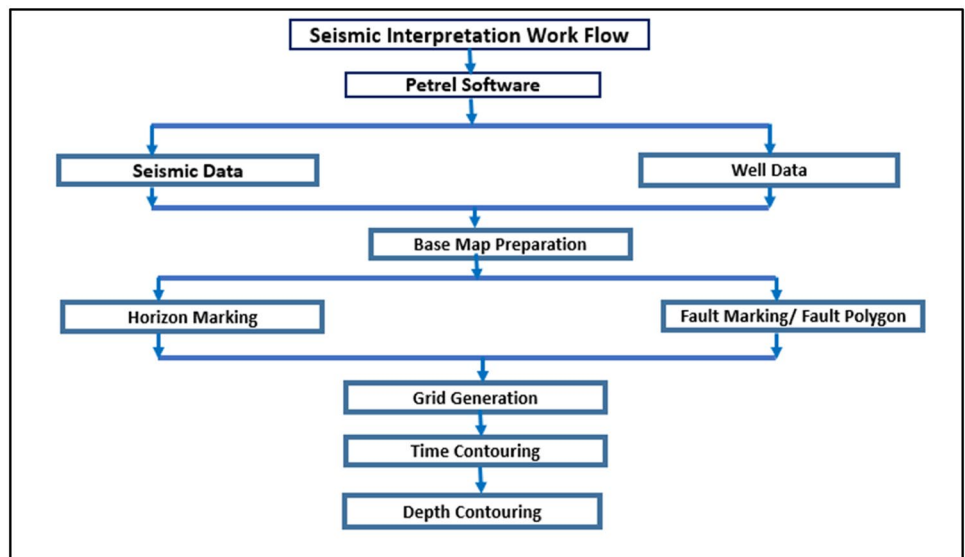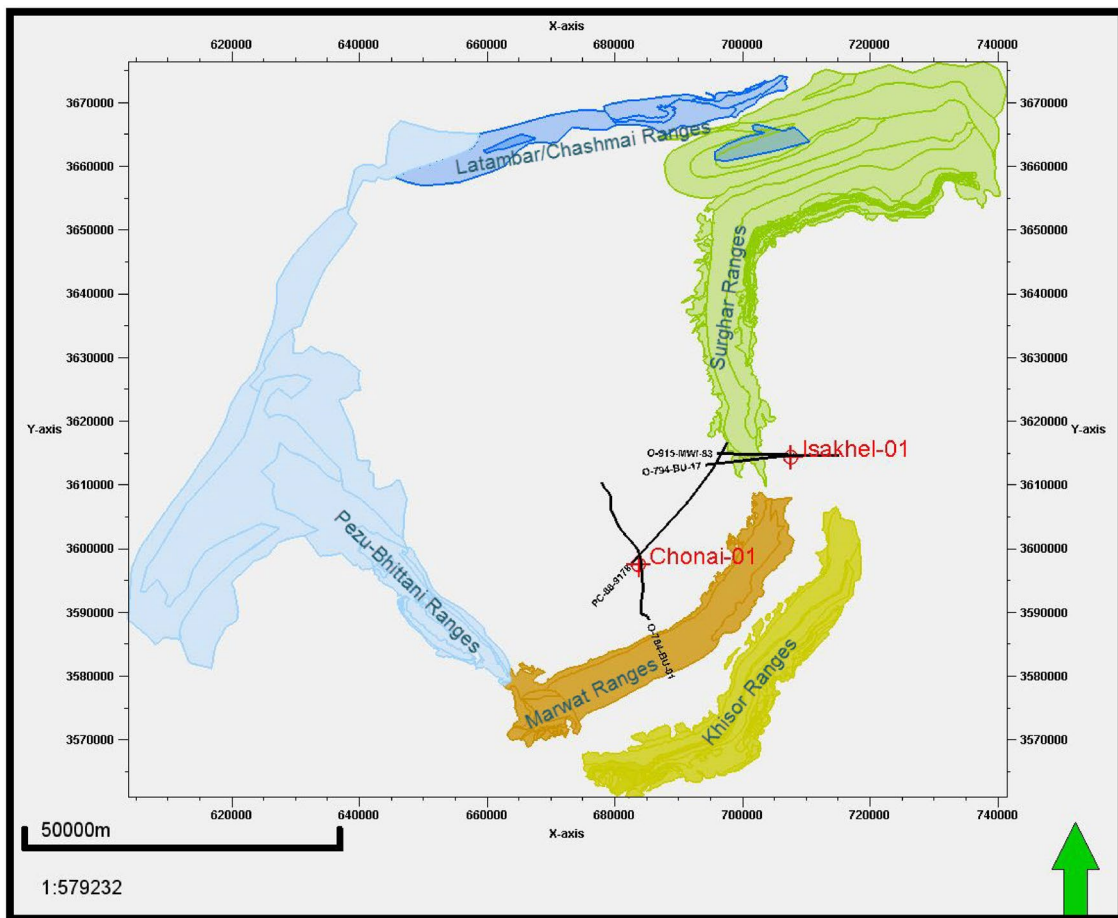
Fig. 8 Base map of study area

reflectors on the seismic section. In study area, Chonai-01 well data are used to generate seismic to well tie for correlation of seismic and well data and later on for marking of geologically interested events.

Horizons interpretation

To recognize and identify horizons in a seismic section, the structural and stratigraphic study is too important. A horizon is a layer in the earth and its manifestation in the seismic data. Initially horizons are understood on the seismic near to well then the connection of that seismic section is used for marking the similar horizons on all other lines. The horizons are shown on all lines in the lead area to the degree of data quality (Yilmaz 2001).The purpose of the synthetic seismogram is to allow identifying events from log data and then relate these events to reflection in seismic data, which gives idea about the polarity of seismic data (Vail, 1987). Horizons were selected and named with support of the well tops of Chonai-01. The horizon spicked are named as Lumshiwal,

Samanasuk, Shinawari, Datta, Tredian, Mianwali and Warcha Formationas shown in Fig. 9.

Faults interpretation

The Second stage in seismic interpretation is to identify geological structures i.e. folds, faults, overlap, anticlines and synclines, as oil & gas migrates from territories of high potential to low potential. It is confined along these geometries. It is easy to interpret the structural traps such as anticlines and faults, and it is hard to identify stratigraphic traps. The kind of structural traps and geometry rely on the forces (Yilmaz 2001). The geology and tectonics of the area give us a clue about the stresses direction, normally thrust/reverse faults are mostly found in compressional regimes. The normal faults occur in extensional regimes and associated traps are usually in the shape of horst, graben and tilted fault block. There are triangular zones, pop-up, duplexes and imbricate structures in compressional regimes (Moghal et al. 2007). The current study area comprises of normal faults in Chonai-01 well area shown on line BU-01 (Fig. 10), whereas
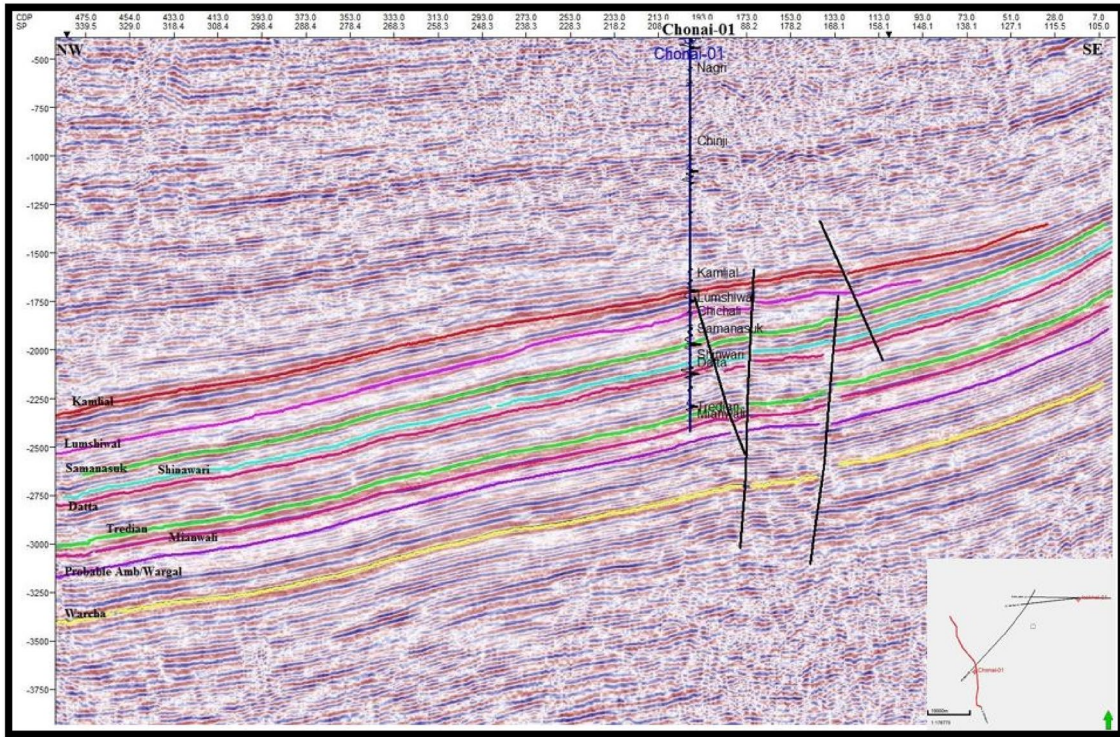
Fig. 9 Interpreted section of Dip line BU-01 w.r.t Marwat ranges showing Well-Tie by using Chonai-01 well
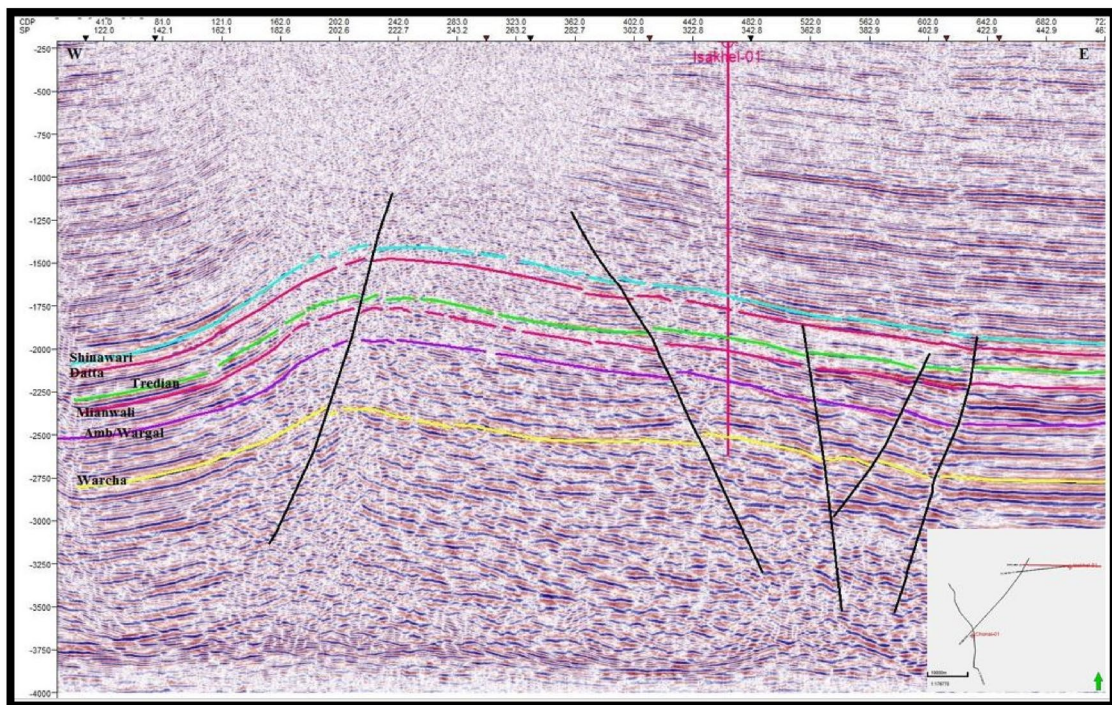

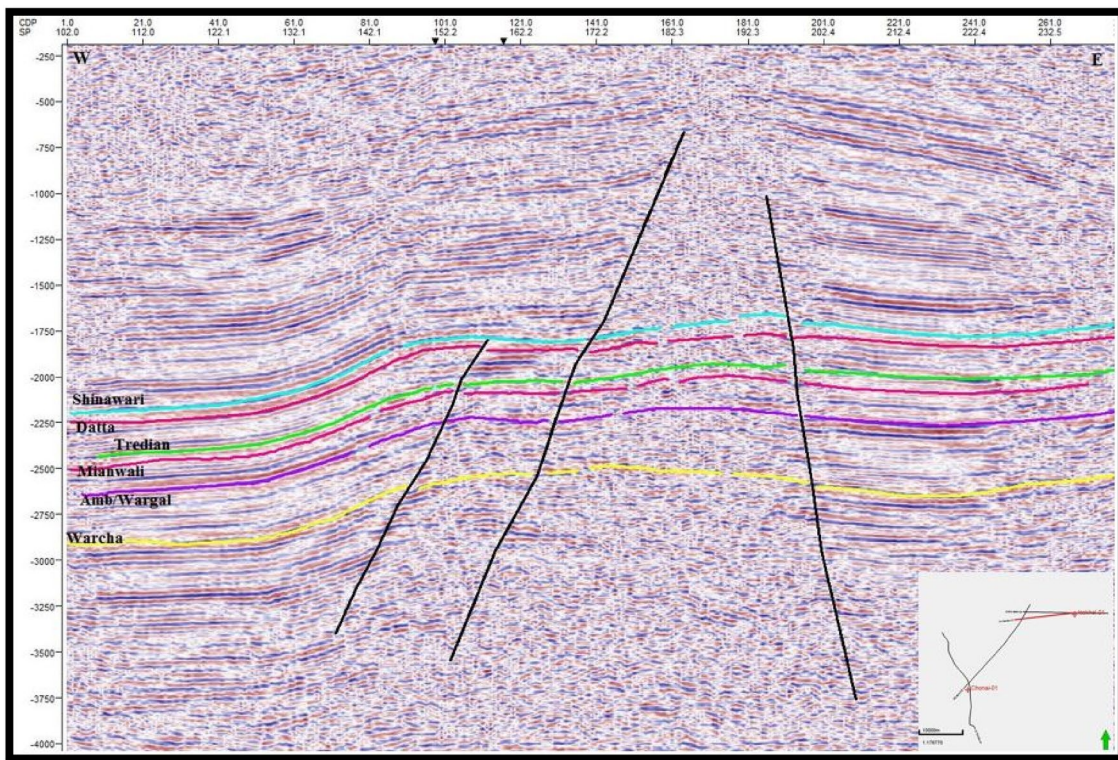**Fig. 10** Interpreted Section of dip line MWI-83 w.r.t Surghar ranges

Fig. 11 Interpreted section of dip line BU-17 w.r.t Surghar ranges

reverse faults are also present on eastern side of study area shown on line MWI-83 (Fig. 11).

The Fig. 9 shows the interpreted seismic profile BU-01 oriented northwest-southeast direction, the deepest Formation interpreted on this profile is Warcha Sandstone of Early Permian age showing parallel set of reflection configurations. The lithological composition of this Formation is mainly sandstone therefore the acoustic impedance contrast is more pronounced. The shallowest Formation interpreted on this profile is Miocene aged Kamliwal Formation which is on lapping on sediments of Samanasuk. Samanasuk Formation below the Kamlial showing some truncated reflection which is representative of a sequence boundary, therefore, it is interpreted that the Samansuk Formation is an unconformity. A total of four faults have been interpreted on the seismic profile BU-01, that are normal in nature cutting the Kamlial to Warcha Formation. Two of these normal faults are oriented in northwest direction near the exploratory well drilled, whereas other two are southeast oriented. The exploratory well drilled Chinai-01 is also shown on the profile. The Formations interpreted are tied to well data as shown in Fig. 9. Figure 10 shows interpreted profile MWI-83 with exploratory well Isakhel-01penetrating deep to Warcha Sandstone. A series of reverse faults have been identified on this particular profile with an anticline type push up structure lying under deeply buried acoustic basement. This anticlinal type structure may serve as hydrocarbon trap.

The Chonai prospect is a combination of fault bounded and unconformity play. The target reservoir Formations include Lumshiwal, Shinawari and Datta Formation. Isakhel structure in promising four way dip closure located on the east of study area. Target horizons are Datta, Tredian, Warcha and Khewra Formations. Isakhel well is drilled on eastern flank of anticline. The TD Formation in Isakhel well is Khewra Formation at 4354 m depth.

Time and depth contour maps

The Contours are the lines which joins the points of same height, elevation and thicknesses. The datum might be ocean level either above or underneath ocean level (Gadallah and Fisher 2009). The time contour maps are created by transforming the time sections into depth section trailed by gridding for horizons of interest for the entire seismic survey. The time contour maps show a specified kind of structure developed at specific horizon. These maps are then used in volumetric estimation, reservoir studies, economics and field development.
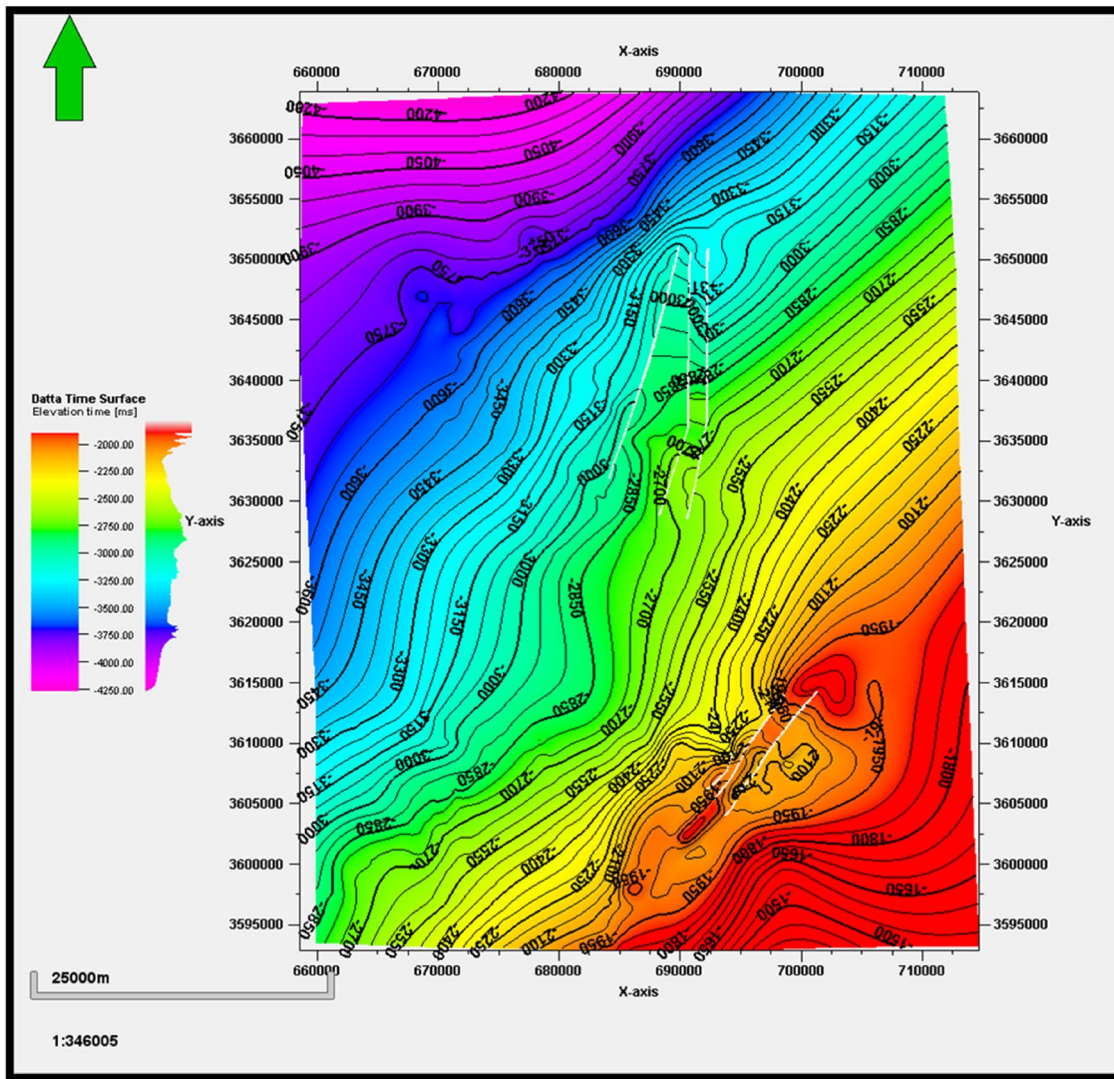
Fig. 12 Two way time (TWT) contour map on top of Datta Formation

Time and depth contour maps of Datta formation

The Time contour map of Datta formation is created at 40 ms contour interval, and time range is from 2000 to 4250 ms. The time contour map of Datta horizon shows a four way closure in SE direction near Isakhel well as shown in the Figs. 12 and 13. The depth map shows that the top of Datta Formation is around 3000 m, while the deeper part in the N-W corner reaches up to 5250 m as shown in Fig. 14.

After Interpretation of seismic data, structural lead of four way closure on Line MWI-83 is converted in to prospect. The identified lead on Datta TWT Contour map is of area about 24Sq.Km. Contour map of Tredian Formation is created at 40 ms contour interval, and time range is from 2250 to 4000 ms. The time contour map of Tredian horizon displays a four way closure in SE direction near Isakhel well. TWT contour map of Tredian Formation generally shows dipping trend in SW direction as shown in the Fig. 15. Time contour map of Warcha Sandstone is developed at 40 ms contour interval, and time range is from 2600 to 4400. The time contour map of Tredian horizon displays a four way closure in SE direction near Isakhel well. TWT contour map of Tredian Formation generally shows dipping trend in SW direction as shown in the Fig. 16.

In order to understand the real time well-based stratigraphic architecture of the Bannu Basin, a total of 05 wells formation tops have been plotted and correlated. The seismic data provide acoustic impedance-based stratigraphy of the region in time domain, where velocity information can be used to get the depth domain subsurface stratigraphy. However, wells data provide direct measurments on depth
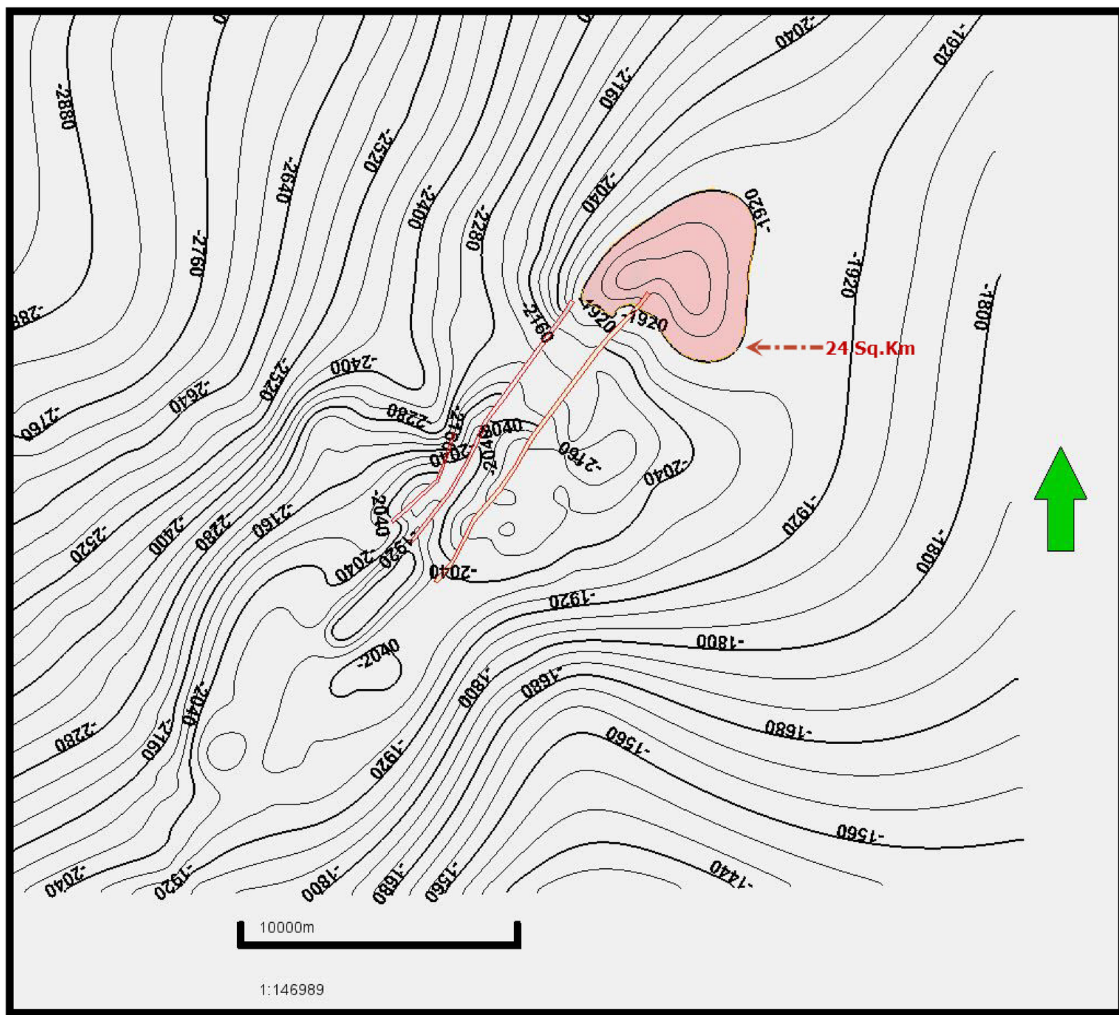
Fig. 13 Structural lead in SE, area is 24 Sq.km Approx

domain stratigraphy, and the lateral and vertical extents of each formation. The seismic-based stratigraphy has been discussed in the aforementioned chapter. This chapter pertains to correlate available wells in the vicinity of Bannu Depression to understand the variations in geological units.

Figure 17 shows the well correlation for the wells drilled in the study area. The deepest well encountered is Isakhel-01 by OGDCL in 1993 which is around 4680 m comprising complete stratigraphic succession from Cambrian to Jurassic age and the shallowest well is Pezu-01 with 2222 m of depth comprising sucession from early Jurassic to late Jurassic age. Isakhel Well no.01 was drilled to a depth of 4680 m in Khewra Formation. The Paleocene and Eocene formations were found missing, and rest of the formations were encountered according to the Geological Drilling Order (GDO). The Petro Canda drilled Chonai-1 Well in 1990 in the south-east of Bannu Basin. The Mianwali Formation was encountered at the end. The Chonai well was drilled upto 3900 m. There

is difference in thickness and facies extension from east to west. The composite stratigraphic corelation reflects it (Fig. 17) which is totally based on wells drilled in the area.

Chonai-01 well represents the erosional products of southward-advancing Himalayan thrust sheets, having sucession from Recent up to Triassic Mianwali Formation with a total depth of 3900 m. Marwat-01 well had been drilled in 1970 by PPL. It characterizes the stratigraphy from Miocene upto Cambrian Jutana Formation.

Correlation is hanged on Samanasuk Formation which is common in all five wells i.e. from Pezu-01 to Isakhel-01 well in order to patterned the subsurface geology. From east to west, in general, we have thining of sucession and uplifting toward Surghar ranges. Some formations are pinching out in west direction i.e. Shinwari which elobrates that their was less sediment accumulation rate in that particular age (Tables 1 and 2).
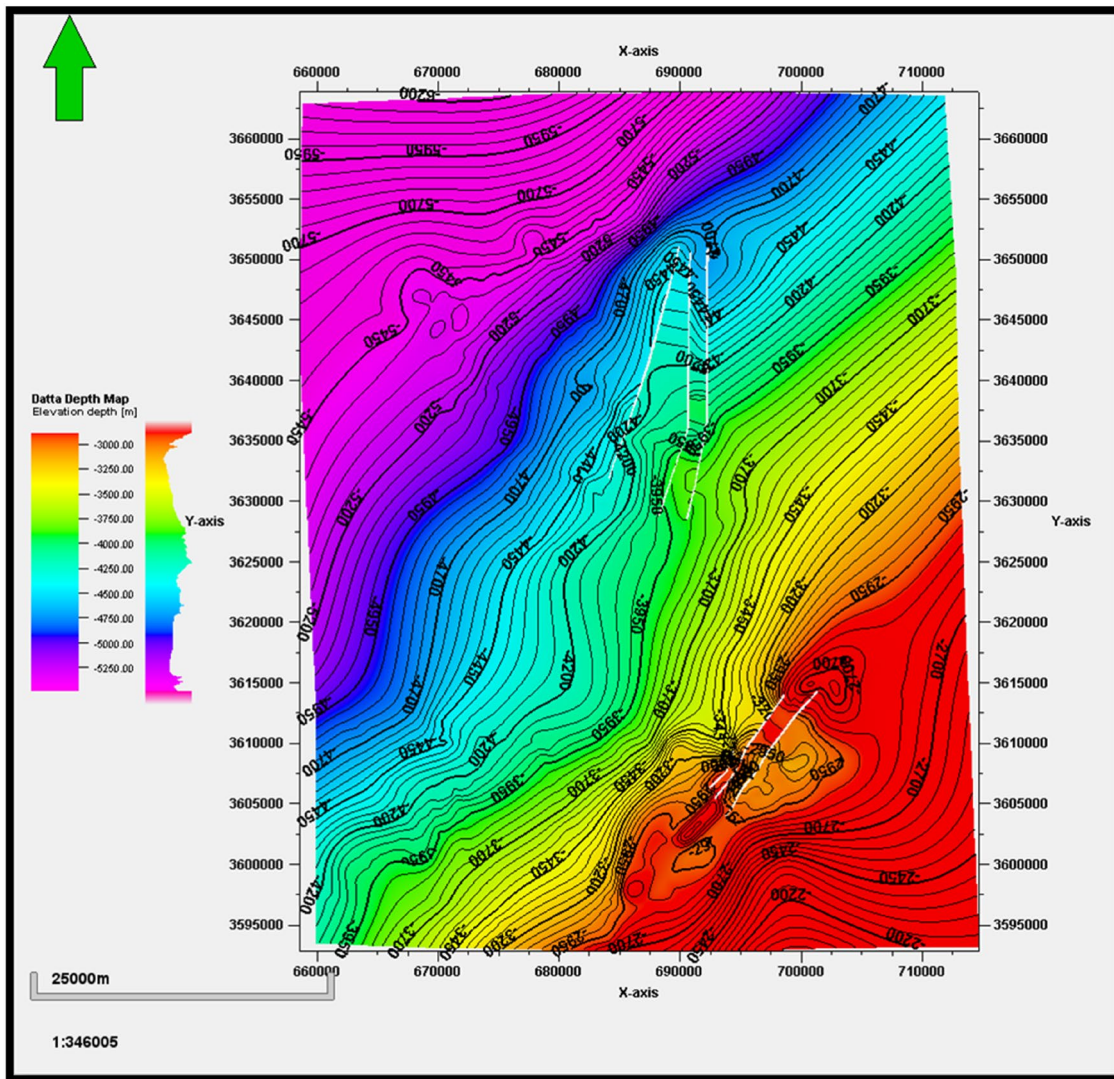
Fig. 14 Depth contour map of Datta formation

Fence diagram (Fig. 18) shows the stratigraphic correlation of these wells in 3D view, which helps to clearly understand the subsurface geological changes more easily. Figures 17 and 18 show the subsurface Stratigraphy of Chonai 01 Isakhel & other surrounding Wells. Samamsuk formation is taken as a bench mark in the basin, and sub-surface Stratigraphy extends to Cambrian Age. Moreover, the Shinwari Formation thins toward the center of the Bannu Basin as we move from the east toward west or vice versa. Further, it is clear from the Isakhel&Marwat Wells that the Siwaliks overlies Samana Suk Formation wherever we go from the Centre of Bannu Basin (Chonai Well) toward the Marwat Ranges (Southern Side). This reflects a major erosional Unconformity between Jurrasic and Siwaliks. The Sub stratigraphy of the Wells demonstrates that Paleocene, Eocene and Miocene Rocks are missing in the Eastern Side, being confirmed from the Isakhel 01 Well as well.

The interpretation of regional seismic profiles coupled with well data helped in unfolding the subsurface geology in a part of western fold and thrust belt of Pakistan. The Bannu Basin-part of highly deformed and tectonically complex thrust belt of Pakistan is important for its hydrocarbon perspectives. Such geological provinces are important for understanding the complex tectonics interplay as well as natural resources exploration in structurally disturbed rock formations. For this purpose, the regional seismic profiles and deep exploratory well data in the vicinity of Bannu Basin have been used in integration to study the subsurface structure, nature of faults, stratigraphy and the horizontal and vertical extents of the rock formations encountered in the wells.
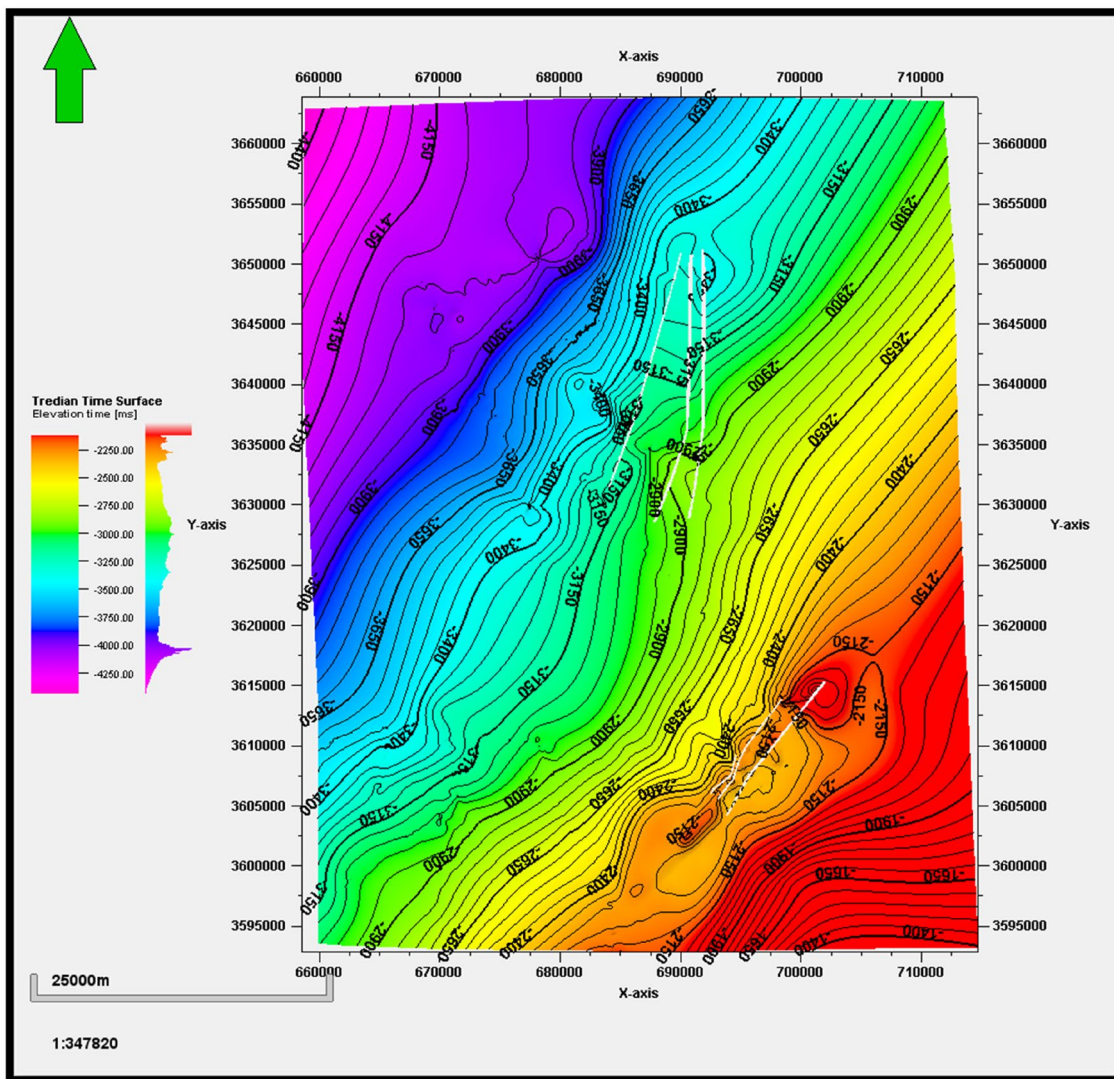
Fig. 15 Two way time (TWT) contour Map on top of Tredian formation

Conclusions of seismic interpretation

1. Seismic data interpretation reveals that various faults vertically cut the subsurface geological formations.
2. These faults are generated due to the extensive forces happening at trailing edges of the collisional plate boundary in the northwestern belt.
3. Based on the interpretation of these time and Depth Contour maps, it is inferred that region has a well-defined trapped of 24 Sq. Km.
4. Chonai- 1 well was possibly drilled at the edge of a small doubtful structure.

5. Isakhel-01 drilled on the structure which is fault bounded.
6. Structures are breached, as evident from Seismic interpretation.

Conclusions of wells correlation

1. Shinwari Formation thins in centre of Bannu Basin and Eastward (Isakhel Well), Thickening in West (Pezu Well) & Truncated in South (Marwat Well).
2. There is Erosional Unconformity between Samasuk and Siwaliks. Sub-surface Stratigraphy of Wells dem-
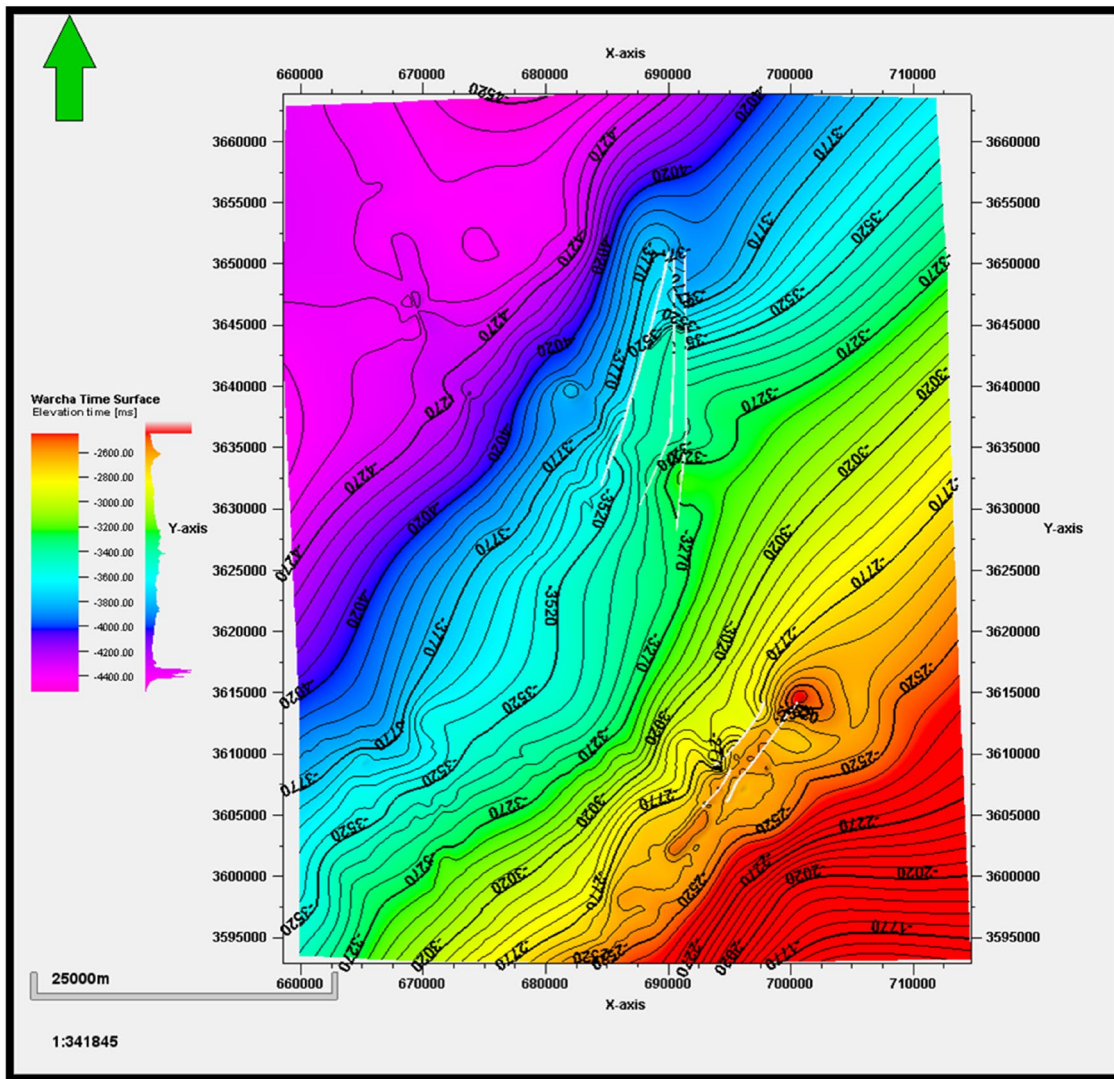
Fig. 16 Two Way Time (TWT) contour Map of Warcha Sandstone

onstrates that Paleocene, Eocene and Miocene Rocks are missing in Eastern and southern side, being confirmed from Isakhel 01 Well and Marwat Well.

3. Cambrian to Triassic- Formation are Thickening Eastward as evident from Fence Diagram.

4. The Depocentre of Datta Formation is southward.

Recommendations

1. We recommend focusing excellent 3D Seismic data acquisition in Bannu Basin and along Structures in south of basin, particularly Marwat, Khisor and Sheikh Budin Ranges.
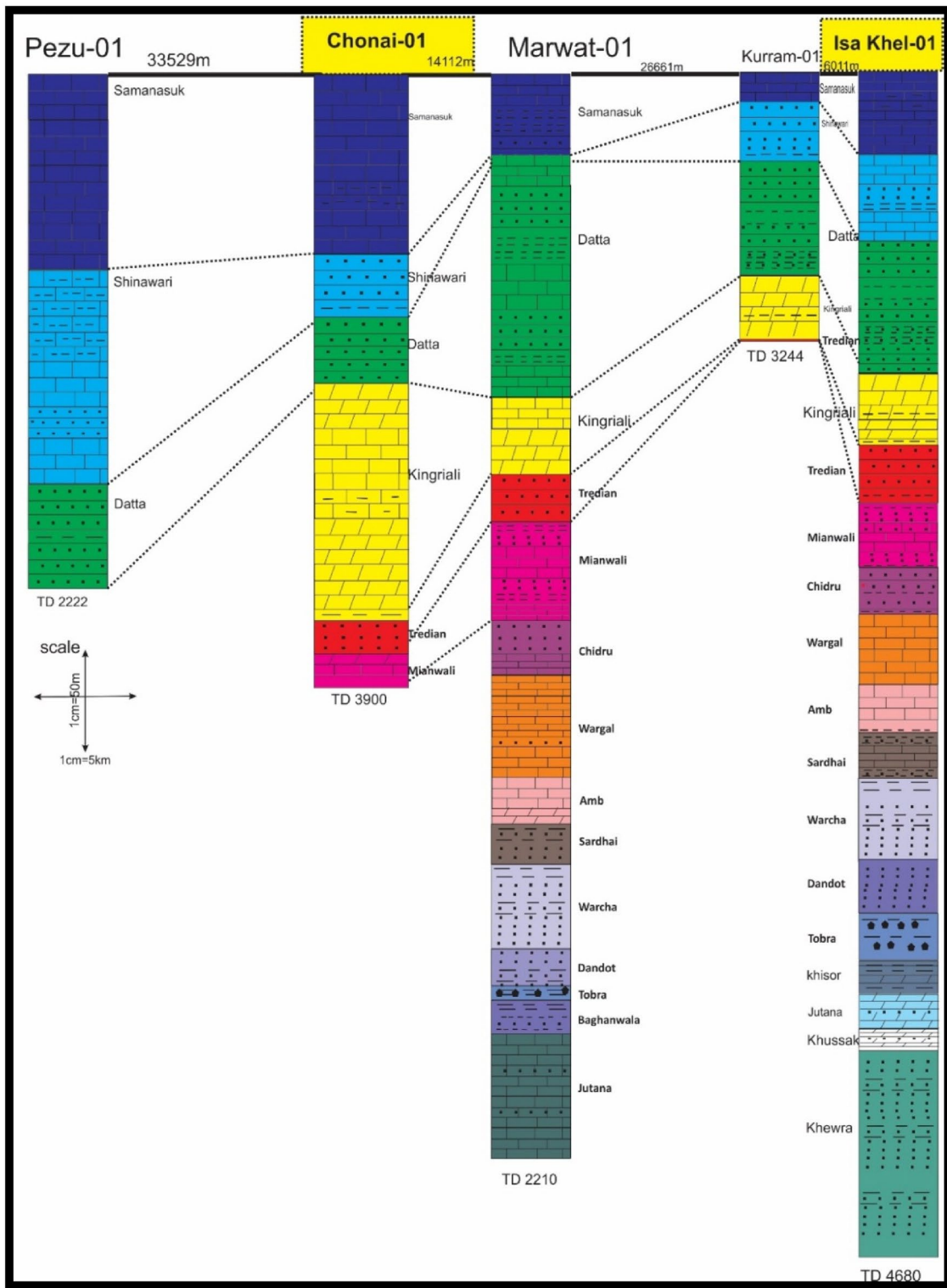2. 3D basin modeling would be helpful in order to minimize geological risks for further exploration.

Fig. 17 Correlation of 05 Wells in Bannu Basin

Table 1 Table showing complete stratigraphy of Isakhel Well

Well name: is a KHEL-01	Operator: OGDCL	Depth: 4680 M		
Latitude: 32 38 50.34	Long: 71 12 46.52	Well type: Exploratory		
Status: abondoned	Province Punjab	Drilling year: 1993		
S. No	Formations	Formation age	Top (m)	Thickness (m)
1	Alluvium	Recent	0	85
2	Soan	Pliocene	85	241
3	Dhok Pathan	Pliocene	326	717
4	Nagri	Pliocene	1043	1353
5	Chinji	Miocene	2396	414
6	Samana Suk	Middle Jurassic	2810	130
7	Shinawari	Middle Jurassic	2940	138
8	Datta	Early Jurassic	3078	208
9	Kinriali	Late Triassic	3286	114
10	Tredian	Middle Triassic	3400	91
11	Mianwali	Early Triassic	3491	101
12	Chhidru	Late Permian	3592	76
13	Wargal	Late Permian	3668	109
14	AMB	Late Permian	3777	76
15	Sardhai	Early Permian	3853	72
16	Warcha	Early Permian	3925	132
17	Dandot	Early Permian	4057	85
18	Tobra	Early Permian	4142	73
19	Khisor	Middle Cambrian	4215	51
20	Jutana	Middle Cambrian	4266	54
21	Kussak	Middle Cambrian	4320	34
22	Khewara	Early Cambrian	4354	326

Table 2 Table showing complete stratigraphy of Chonai-01 Well

| Well name: CHONAI-01	Operator: Petro-Canada	Depth: 3900 m		
Latitude: 32 29 59.31	Longtitude: '70 57 19.18	Well type: Exploratory		
Status abandoned	Province: NWFP	Drilling Year: 1990		
S. No	Formations	Formation age	Top (m)	Thickness (m)
1	Soan	Pliocene	0	415
2	Dhok Pathan	Pliocene	415	498
3	Nagri	Pliocene	913	972
4	Chinji	Miocene	1885	577
5	Kamilial	Miocene	2463	22
6	Sakesar	Eocene	2484	28
7	Nammal	Eocene	2512	11
8	Patala	Paleocene	2522	68
9	Lumshiwal	Early Cretcaeous	2590	290
10	Chichali	Early Cretcaeous	2880	51
11	Samana Suk	Middle Jurassic	2931	285
12	Shinawari	Middle Jurassic	3215	100
13	Datta	Early Jurassic	3315	105
14	Kingriali	Late Triassic	3420	375
15	Tredian	Middle Triassic	3795	52
16	Mianwali	Early Triassic	3847	53
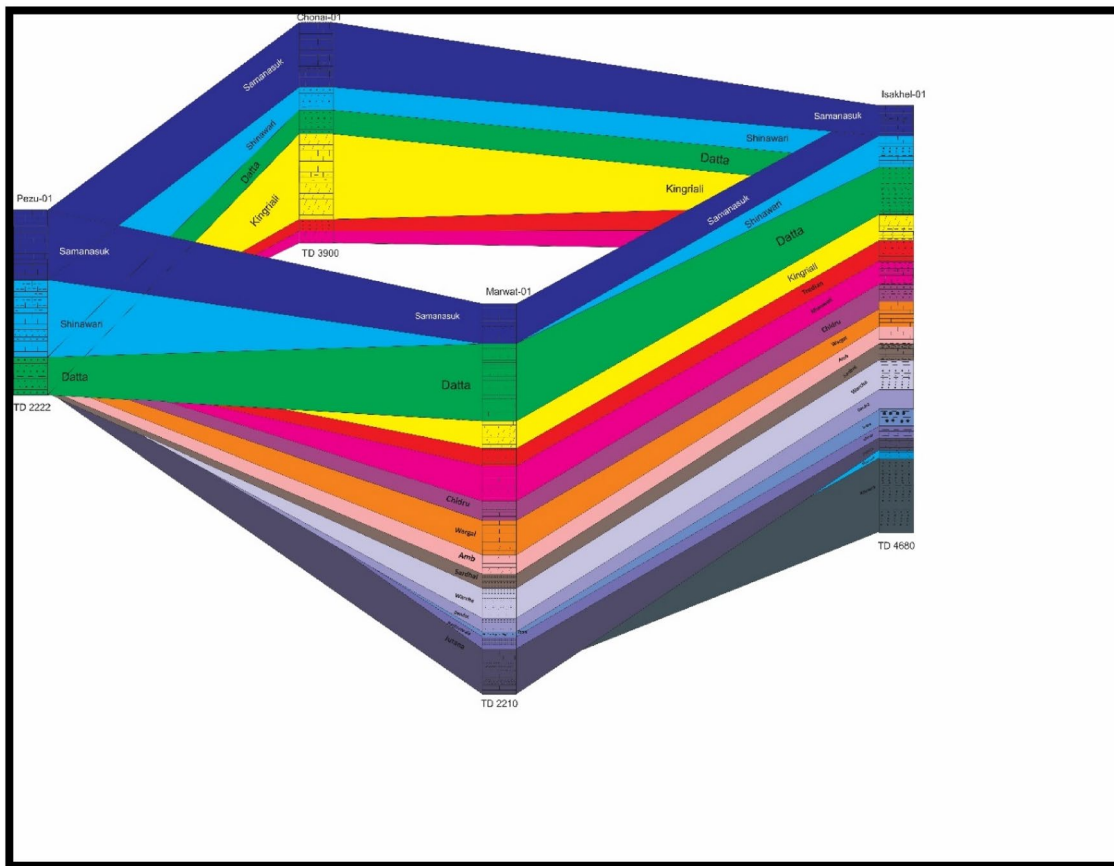
Fig. 18 Fence diagram showing three dimensional Stratigraphy

3. Relationship between Structuration and Hydrocarbon Peak generation may be interpreted for successful discovery.

4. It is recommended to study in detail the Source and Migration Pathway for successful discoveries. As Seepages have not been completely understood and presence of Seepages have deceived Explorationists.

5. Further, well core cuttings and geochemical analysis would be more helpful in providing detailed insights into source rock analysis.

6. Reservoir characterization using statistical rock physics and petrophysics can provide further insights into hydrocarbons potential and exploration.

Compliance with ethical standards

Conflict of interest No conflict of interest found in this paper.

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