Contributions to Geophysics and Geodesy Vol. 49/3, 2019 (249–263)

Understanding the hydrocarbon prospect of Buzdar block, Southern Indus basin, Pakistan, by using 2-D seismic data: A case study

Hamid HUSSAIN[1,*], Zhang SHUANGXI[1,2,3], Muhammad ABID[4]

[1] Department of Geophysics, School of Geodesy and Geomatics, Wuhan University, Wuhan, Hubei, 430079, P.R. China

[2] Key Laboratory of Geospace Environment and Geodesy of Ministry of Education, Wuhan University, Wuhan, Hubei, 430079,P.R. China

[3] Collaborative Innovation Center of Geospace Information Science, Wuhan University, Wuhan, Hubei, 430079, P.R. China

[4] School of Ocean and Earth Science Tongji University, Shanghai, P.R. China

Abstract: The sub-surface structural analysis to understand the geology and tectonics of an area is always useful to locate the hydrocarbon resources. Oil and gas based energy supplies have become a vital source for Pakistan, which is passing through an era of severe energy crisis. The study area, Buzdar block, in the southern Indus Basin is tectonically an extensional regime and is expected to have a huge hydrocarbon potential. In this study, we did the interpretation of the migrated seismic lines of the 872-SGR-527, 872-SGR-529, 872-SGR-531, 872-SGR-532 of Buzdar block, District TandoAllahyar, Sindh. The lines 872-SGR-529, 872-SGR-531, 872-SGR-532 were oriented W–E whereas the line 872-SGR-527 was oriented NW–SE. The obtained data was analysed and three reflectors were marked named top Khadro Formation, top lower Goru formation and top Chiltan limestone (probable). Through this study faults have been also marked on seismic lines which are normal faults by nature; collectively form horsts and grabens which is the evidence of effect of extensional tectonics in the area. Time contour maps were also generated. After that, time was converted into depth with the help of well velocity from VSP data for lower Goru formation and average velocity for Chiltan limestone (probable) from regression analysis. Finally, depth contour maps were generated which helped to know the basic mechanism of tectonic movement in the area. On the basis of present analysis we propose that a well may be drilled at Lower Goru formation near fault F1 on western side at a depth of 1370 meters and at 1290 meters near fault F4 on eastern side.

Key words: Buzdar block, 2-D seismic data, time-depth analysis, probable well location, hydrocarbon potential

*corresponding author: e-mail: hamidhussain@whu.edu.cn

doi: 10.2478/congeo-2019-0013

1. Introduction

Geographically, Buzdar block is located in district Tando Allah yar at a location between Mirpurkhas and Hyderabad. Previously this block was known as Sanghar south. The study area lies between 25°15′00″ N to 25°26′00″ N and 68°40′00″ E to 68°48′00″ E. Geologically the area falls in Southern Indus Basin as shown in Fig. 1 (*Kazmi and Rana, 1982*).

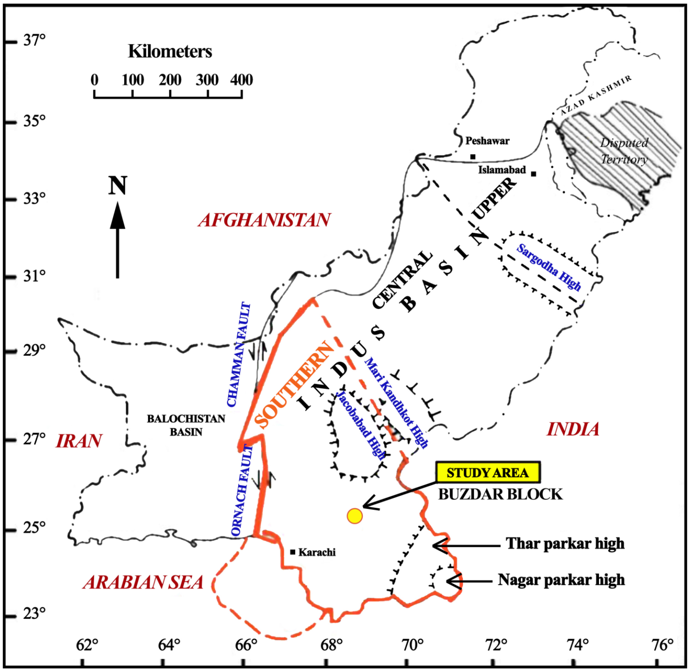

Fig. 1. Location map of the study area (modified *Kazmi and Rana, 1982*).

1.1. Tectonics

Pakistan is divided into three basins upper Indus basin, central Indus basin and southern Indus basin (*Wandrey et al., 2004*). The area under study in southern Indus basin exhibits extensional tectonics and as a consequence, normal faults are generated showing horst and graben structure. The southern Indus basin (550 × 250 km) is characterized by tectonic up warping on the western margin of the Indo-Pakistan subcontinent (i.e. the eastern part of Pakistan). The southern Indus basin, is characterized by several structural highs (Sibi, Jaccobabad, Khairpur, Mari-Khandkot and Hyderabad) (*Zaigham and Mallick, 2000*).

The proposed geological models also illustrate the potential for appropriate environments for development of hydrocarbon source rocks, sufficient heat for thermal maturity and structures for reservoirs and seals, suggesting more bright prospects in the southern Indus basin (*Zaigham and Mallick, 2000*). The southern Indus basin is located just south of Sukkur Rift – a divide between Central and Southern Indus basins and is bounded by the Indian Shield – to the east and the marginal zone of Indian plate to the west. Its southward extension is confined by off-shore Murray Ridge-Oven Fracture plate boundary (*Kadri, 1995*).

1.2. Stratigraphy and Petroleum play

The stratigraphic property of the study area is shown in Table 1. The southern Indus basin is a broad north-south–trending sedimentary basin having thick Tertiary sequences underlain by Mesozoic rocks and overlain by Quaternary sediments. The sedimentary section of Lower Indus Basin in the South Eastern Pakistan starts from rocks ranging from Triassic age upto recent age (*Kazmi and Jan, 1997*). Stratigraphically, the shale series of the Early Cretaceous Sember Formation and the Lower Goru Formation are the main documented oil and gas source rock units in the southern Indus basin (*Hussain et al., 1991*). Upper Paleocene marine transgressive shales are the secondary source rock series, deeply buried in the western half of the southern Indus basin (*Zaigham and Mallick, 2000*). In the southern Indus basin, the main oil and gas productive reservoir rock units are the Cretaceous Lower Goru sandstones. The basal transgressive sandstones of the Early Cretaceous Sember Formation may be important hydrocarbon targets. Moreover, hydrocarbon targets may also exist in the Jurassic Chiltan Limestone, Paleocene, and Eocene formations. The upper Goru shales are the main reservoir seal in the southern Indus basin. The intra-formational shales of the lower Goru provide regional seal for all of the sand units of the lower Goru formation. Hydrocarbon accumulations in the area are generally confined to the horst and tilted fault block structures. The upper Goru, which drapes over these structures, forms the top and lateral seals for the

Table 1. Stratigraphy of the study area (modified after *Kazmi and Jan, 1997*).

ERA	PERIOD	EPOCH	FORMATION	DESCRIPTION
CENOZOIC	QUARTERNARY	HOLOCENE	ALLUVIUM	Sandstone, clay, shale and conglomerate
	TERTIARY	PLIOCENE-PLEISTOCENE	SIWALIK GROUP	Sandstone, Shale and conglomerate
		MIOCENE	GAJ	Shale, sandstone and limestone
		OLIGOCENE	NARI	Shale, limestone and sandstone
		EOCENE – LATE		
		EOCENE – MIDDLE	KIRTHAR	Shale and limestone
		EOCENE – EARLY	LAKI/GHAZIJ	Laki: Limestone and Shale Ghazij: Shale and sandstone
		PALEOCENE	BARA-LAKHRA	Limestone, shale and sandstone
			KHADRO	Sandstone, basalt and shale
MESOZOIC	CRETACEOUS	LATE	PAB	Sandstone and shale
			MUGHAL KOT	Limestone, shale and minor sand
			PARH	Limestone
		MIDDLE	GORU – UPPER	MAIN SEAL Shale and marl
		EARLY	GORU – LOWER	Sandstone and shale
			SEMBAR	MAIN SOURCE Sandstone and shale
	JURASSIC	LATE		
		MIDDLE	CHILTAN/ MAZARDRIK	Chiltan: Limestone MazarDrik: Shale and sandstone
		EARLY	SHIRINAB	Limestone, shale and sandstone
	TRIASSIC	EARLY-LATE	WULGAI	Sandstone and shale

upper sand units of lower Goru formation and also acts as cross-fault seals. The interbedded shale units within the lower Goru formation provide seals for the deeper reservoirs. In general, the transgressive shales of the Cretaceous (Sember Formation) and Tertiary (Bara-Lakhra, Laki-Ghazij, and Kirthar Formations) provide seals to Jurassic and Tertiary reservoirs respectively. The oldest rocks encountered in the area are of Triassic age (Jhat pat and Nabisar wells). Central and Southern Indus basins were undivided until Lower/Middle Cretaceous when Khairpur-Jacobabad High became a prominent positive feature. This is indicated by homogenous lithologies of Chiltan Limestone (Jurassic) and Sembar Formation (Lower Cretaceous) across the High (*Kadri, 1995*).

2. Materials and Methods

Two main approaches for the interpretation of seismic data are adopted; first one is stratigraphic analysis while the other is structural analysis. Stratigraphic analysis involves the subdivision of seismic sections into sequence of reflections that are interpreted as seismic expression of genetically related sedimentary sequences. Application of structural analysis is the search for different structural styles within the subsurface. Seismic stratigraphic analysis is the delineation of individual seismic facies units (*Al-Sadi, 1980; Badley, 1985; Lines and Newrick, 2004*).

Seismic reflection data consist of four lines along with two wells (as shown in Fig. 2) acquired with the special permission from Directorate General of Petroleum Concession (DGPC) and are used for the interpretation of subsurface structures, stratigraphy and depth of basement.

A) seismic data:
- 972-SGR-529 (Strike line)
- 872-SGR-527 (Dip line)
- 872-SGR-532 (Dip line)
- 872-SGR-531 (Dip line)

B) well data:
- Buzdar-01
- Buzdar North-1.

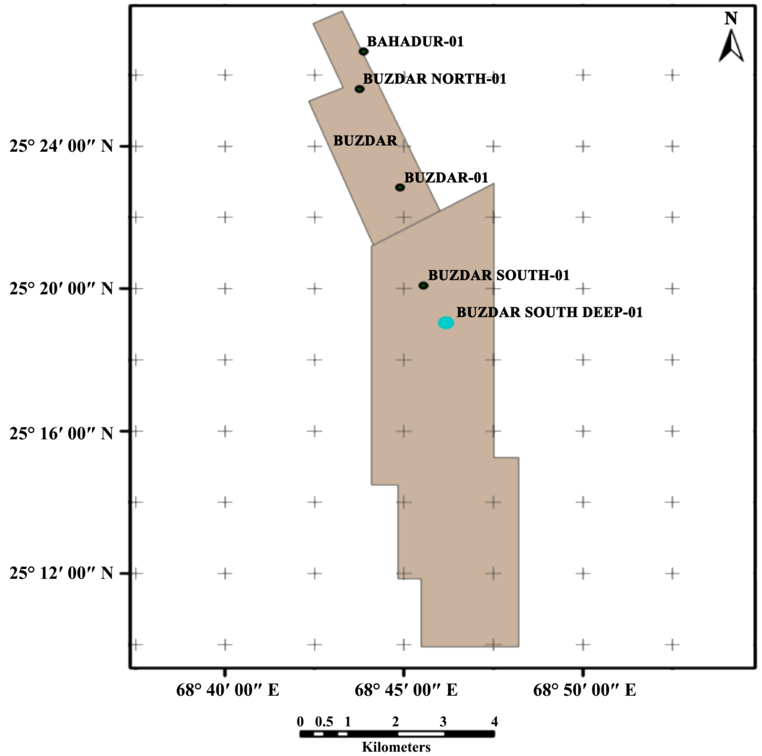

Fig. 2. Block diagram showing the location of wells (Buzdar Block).

Seismic data Interpretation:

One of the initial important things for an interpreter of seismic data is the picking or interpretation of reflectors of horizons. Base map was prepared which typically includes locations of lease or concession boundaries, wells and seismic survey points with geographic references such as latitude and longitude or Universal Transverse Mercator (UTM) grid information.

The Seismic data lines 972-SGR-529 (Strike line), 872-SGR-527 (Dip line), 872-SGR-532 (Dip line), 872-SGR-531 (Dip line) are interpreted by solving velocity windows panels to obtain the average velocity (Figs. 3–6). The LAS files of wells Buzdar-01, Buzdar North-1 and seismic lines were manipulated for calculating the corresponding depth, interval velocity, one way travel time (OWT), two ways travel time (TWT) and average velocity.

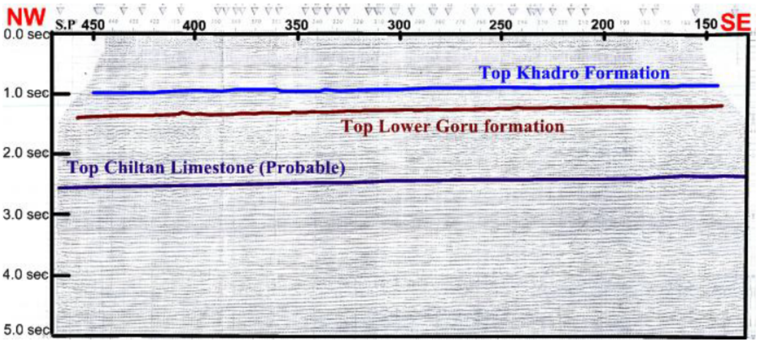

Fig. 3. Interpreted seismic section of seismic line 872-SGR–527.

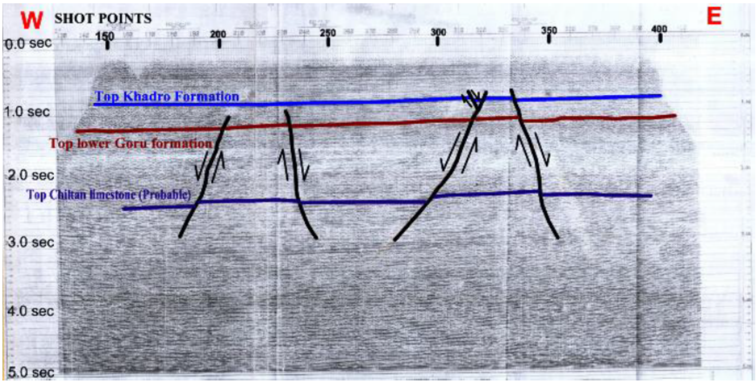

Fig. 4. Interpreted seismic section of seismic line 872-SGR–529.

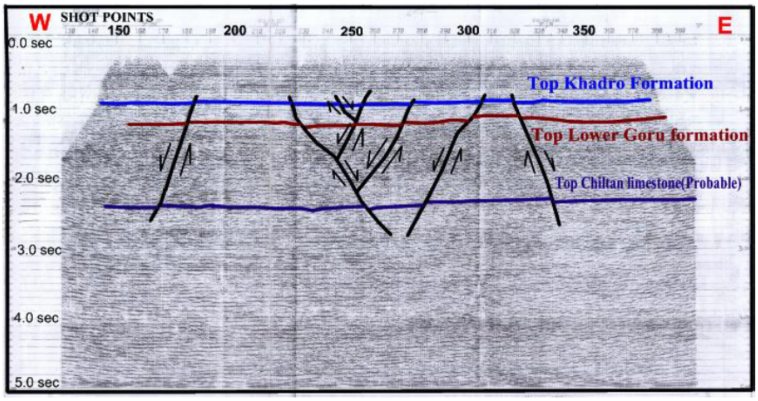

Fig. 5. Interpreted seismic section of seismic line 872-SGR–531.

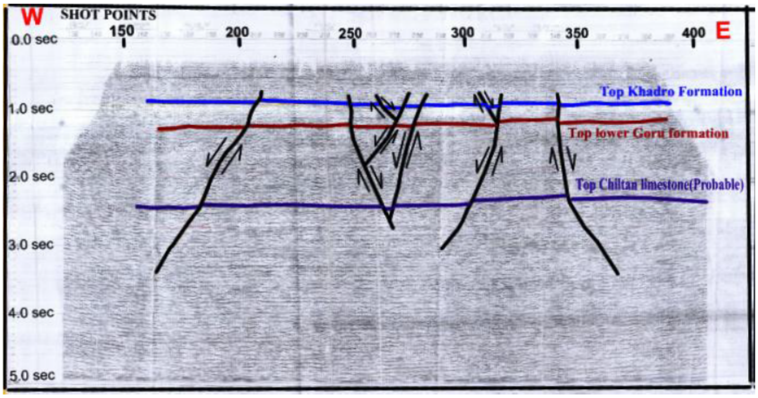

Fig. 6. Interpreted seismic section of seismic line 872-SGR–532.

Velocity windows were solved given on the seismic section to find the average velocity by using the Dix Equation as shown by *Cameron et al. (2008).*

$$V_{\mathrm{ave},n} = \frac{[(V_{\mathrm{int},n} \cdot (T_n - T_{n-1})) + (V_{\mathrm{ave},n-1} \cdot T_{n-1})]}{T_n}\,, \tag{1}$$

where V_{ave} is the average velocity, T is the two way travel time, and V_{int} is the interval velocity.

On strike line 872-SGR-527 all the three velocities i.e. root mean square velocity, interval velocity and average velocity were given so there was no need to solve the velocity windows to find average velocity.

On the dip lines 872-SGR-529, 872-SGR-531 and 872-SGR-532 only root mean square velocity and interval velocity were given which were transferred into MS Excel worksheet where we utilized them for further working to find out the average velocities (V_{ave}) by using the formula.

Regression analysis is a statistical technique which was used to find the RMS velocity at the times on which we picked our reflector. Regression analysis was used which utilizes the Root Mean Square (rms) velocity and the two way travel time from the velocity windows of the seismic section. In regression analysis we used the velocity windows of the seismic section saved in the MS Excel worksheets to generate a two way travel time vs. RMS velocity graph. Then a best fit line is passed through the graph, which gave us the equation of straight line:

$$y = mx + c\,, \tag{2}$$

where y = RMS velocity, m = slope, x = two way travel time, c = intercept (constant).

Time to depth conversion is necessary because we need to make the depth contour map of the horizon which shows the place of the horizon in subsurface depth wise. These maps are vital to seismic interpretation, as they tell us the physical place of the horizons.

As velocity is required to convert the time into depths; so we got the velocity from well data of Buzdar-01 and Buzdar North-01 for lower Goru formation. While for Chiltan Limestone we used the average velocity calculated from the regression analysis because the wells were not drilled upto Chiltan Limestone. For depth conversion following formula was used:

$$S = V \cdot T/2\,, \tag{3}$$

where, S = depth of the reflector, V = well velocity or average velocity calculated by regression analysis, T = two-way time of the reflector read from the seismic section but here we have taken it as $T/2$ i.e. one way travel time in order to get the depth.

3. Results and Analysis

Following are the graphs got after regression analysis of the lines to get the equation of straight line for finding the RMS velocity. This equation was to find the RMS velocity against the two way time noted for Chiltan limestone and we also calculated the interval and average velocities against those times. This average velocity is required for time to depth conversion. We did not use this procedure to find RMS velocity and then average velocity for top lower Goru formation because we got the well velocity from the VSP data summary sheet of Buzdar-01 and Buzdar North-01 which was utilized in time to depth conversion. The results of regression analysis are shown in Fig. 7.

In order to calculate the depth for lower Goru formation we used the well velocity V = 2324.5 m/sec; while for the Chiltan Limestone we have used a mean average velocity calculated from average of four lines regression analysis, namely V = 3275.7 m/sec. The depth values of both the reflectors, i.e. lower Goru formation and Chiltan Limestone were used to generate the depth contour map of lower Goru formation and Chiltan Limestone.

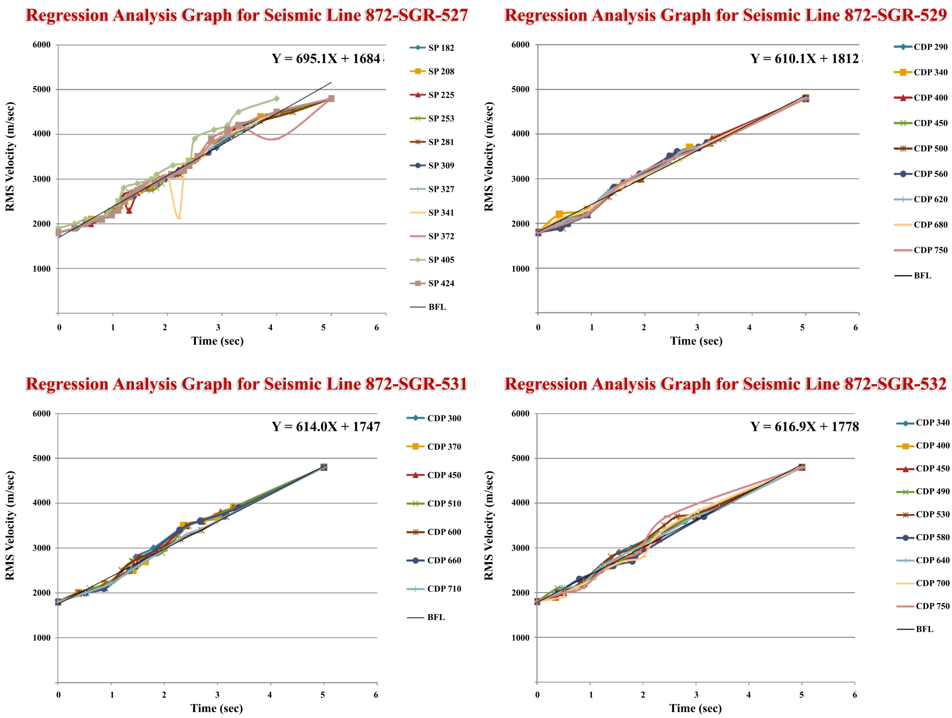

Fig. 7. Results of regression analysis.

Depth of Top lower Goru formation is varying from 1278 meters to 1592 meters while depth of Chiltan Limestone is varying from 3668 meters to 4353 meters. The depth of top lower Goru formation and Chiltan Limestone is decreasing as we move from south to north. Time & Depth contour maps show possible leads (highs) on top lower Goru formation near fault F4 on east side (due to which two wells Buzdar North-01 and Buzdar-01 had been drilled). Time & Depth contour maps also show possible leads (highs) on top lower Goru formation near fault F1 on west side. Time and depth contour maps of Chiltan Limestone also show possible lead (high) near fault F4 on eastern side. The traps have three ways dip closure bounded on one side by a fault. The vertical relief of the closure at top lower Goru formation is 50 milliseconds (40 meters) and Chiltan Limestone is 40 milliseconds (50 meters). As the data quality is poor so it is recommended that the data should be reprocessed. For more detailed study and to define potential sites in the area, more seismic lines are required. 3D survey may be performed in order to get a detailed subsurface picture of the Buzdar block.

TWT contour map at top lower Goru formation was generated with a contour interval of 10 milli seconds. Lower Goru was cut by faults at four locations. This cutting by faults made horst and graben structures along the formation. The contour map showed two highs in the formation shown in Fig. 8. TWT contour map at top Chiltan Limestone was generated with a contour interval of 10 milli seconds. Chiltan Limestone was cut by faults at four locations. This cutting by faults made horst and graben structures along the formation. The contour map shows one high in the formation (Fig. 9). Depth contour map at top lower Goru formation was generated with a contour interval of 10 meters.The formation shows two important highs which can be possible horst blocks and potential leads. One is located at the eastern side along the dip line 872-SGR-531 at a depth of 1270m. The second lead is located on the western side along the dip line 872-SGR-531 at a depth of 1370 m (Fig. 10). It is being proved by the depth contour map at lower Goru formation that the depth is increasing while we move from south to north as it is shown by the correlation of depths at top lower Goru formation in the 3 wells present in Buzdar block (Fig. 12). Depth contour map at top Chiltan Limestone was generated with a contour interval of 10 meters. The formation shows one important high located on the eastern side along the dip line 872-SGR-531 near fault F4 at a depth of 3730 m which can be possible horst block and potential lead (Fig. 11).

It is being proved by the depth contour map at lower Goru formation that the depth is increasing while we move from south to north as it is shown by the correlation of depths at top lower Goru formation in the 3 wells present in Buzdar block.

4. Conclusions and Recommendations

The area is an extensional regime, due to which there are normal faults and horst and grabenstructures.The trend of the faults is NW–SE. The throw of the faults at top lower Goru formation level is 25 to 30 milliseconds while at Chiltan Limestone level it is 30 to 35 milliseconds. The Average velocity of Chiltan Limestone calculated by regression analysis is 3275.7 m/sec.

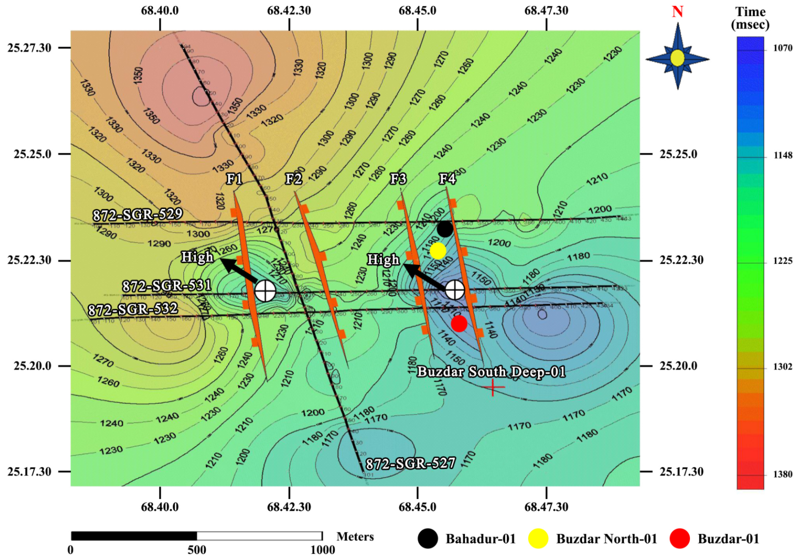

Fig. 8. Two way time contour map at Top lower Goru formation.

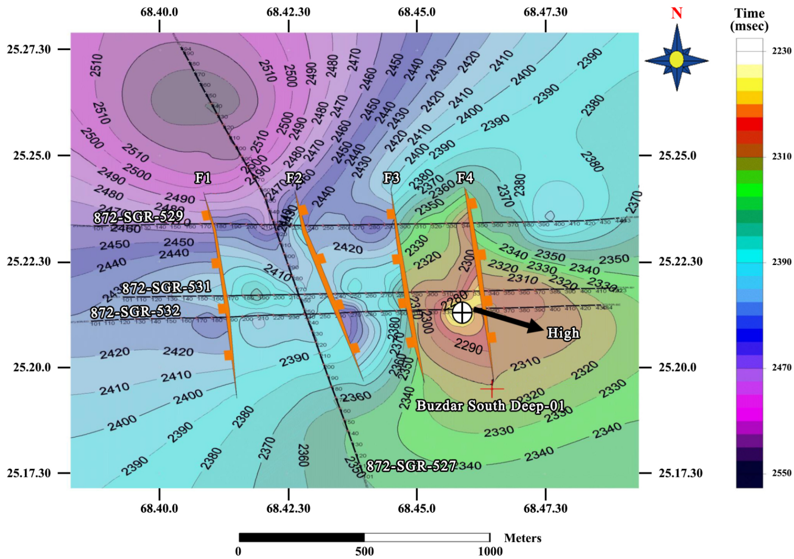

Fig. 9. Two way time contour map at top Chiltan Limestone (probable).

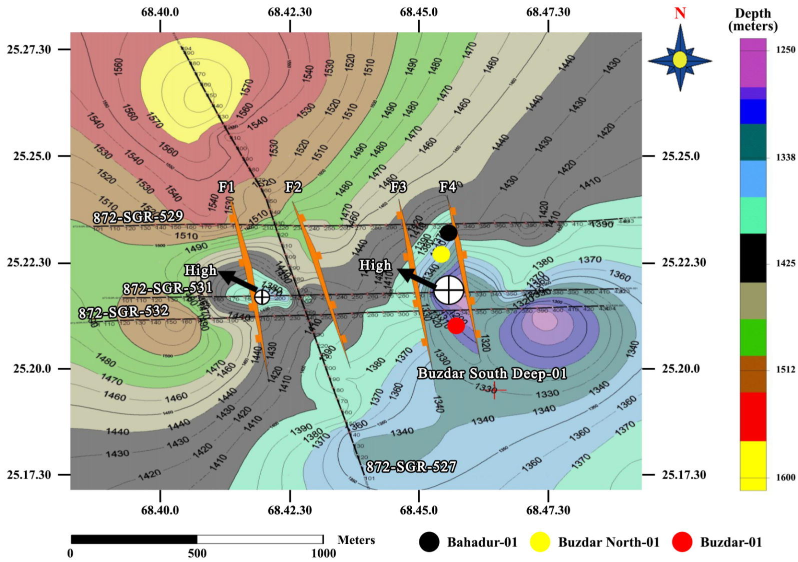

Fig. 10. Depth contour map at top lower Goru formation.

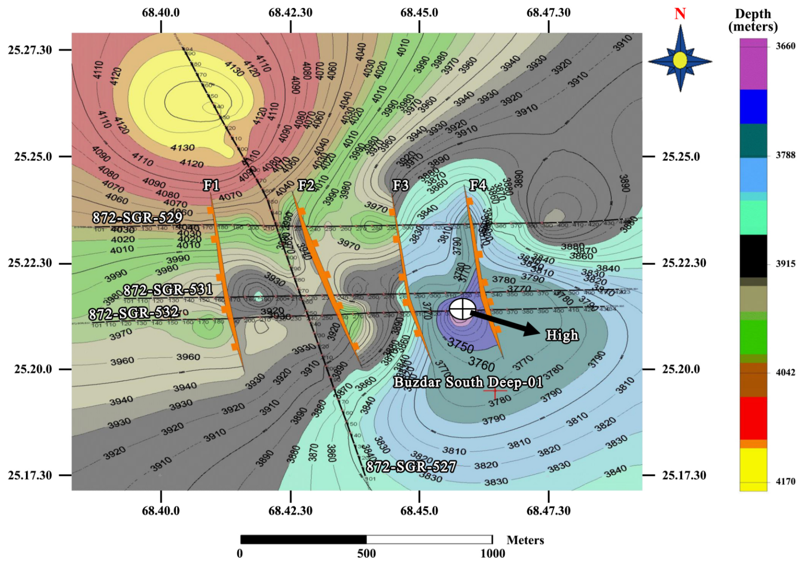

Fig. 11. Depth contour map at top Chiltan Limestone (probable).

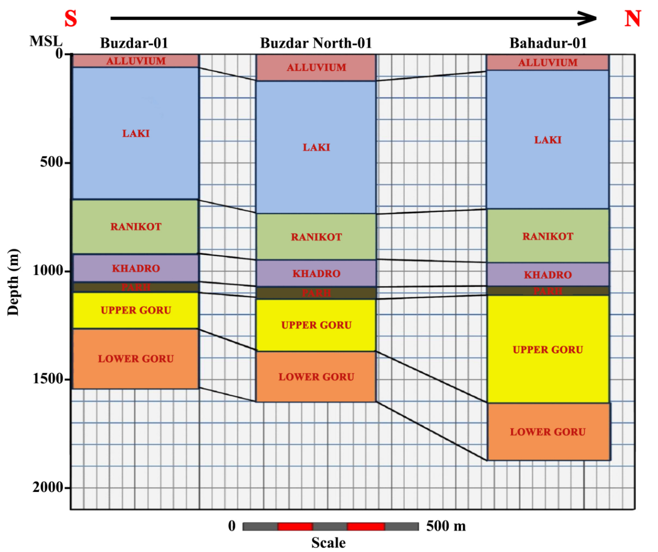

Fig. 12. Depth correlation at top lower Goru formation in 3 wells of Buzdar block.

Well may be drilled at Lower Goru formation near fault F1 on western side at a depth of 1370 meters and at 1290 meters near fault F4 on eastern side.

Detailed studies of petrophysical properties of Chiltan Limestone may be performed in the surrounding concessions located in Thar platform, if the results show reservoir potential of Chiltan Limestone then Buzdar North-01 and Buzdar-01 well may be drilled deeper upto Chiltan Limestone.

Acknowledgements. This study is supported by the NSFC (No. 41174021, No. 41474093) and China's International Education Funding for Chinese-Pakistani students.

References

Al-Sadi H. N., 1980: Seismic Exploration: Technique and Processing. Birkhäuser-Verlag, Boston, 211 p.

Badley M., 1985: Practical Seismic Interpretation. IHRDC publishers Boston, 266 p.

Cameron M., Fomell S., Sethian J., 2008: Time-to-depth conversion and seismic velocity estimation using time migration velocity. Geophysics, **73**, 5, VE205–VE210, `doi: 10.1190/1.2967501`.

Hussain M., Getz S. L., Oliver R., 1991: Hydrocarbon accumulation parameters in the central portion of the lower Indus of Pakistan. In: Ahmed G., Kamal A., Zaman A. S. H., Humayon M., (Eds.): Proceedings of international petroleum seminar on new directions and strategies for accelerating petroleum exploration and production in Pakistan, Islamabad Nov. 22-24, 13 p.

Kadri I. B., 1995: Petroleum geology of Pakistan. Pakistan Petroleum Ltd., Karachi, 275 p.

Kazmi A. H., Jan Q. M., 1997: Stratigraphic setting. In: Geology and Tectonics of Pakistan, Graphic Publishers Karachi, Pakistan.

Kazmi A. H., Rana R. A., 1982: Tectonic map of Pakistan, scale of 1:2,000,000. Geological Survey of Pakistan, 1 sheet.

Lines L. R., Newrick R. T., 2004: Fundamentals of Geophysical Interpretation. Society of Exploration Geophysicists, 289 p.

Wandrey C. J., Law B. E., Shah H. A., 2004: Sembar Goru/Ghazij Composite Total Petroleum System, Indus and Sulaiman-Kirthar Geologic Provinces, Pakistan and India. U.S. Geological Survey Bulletin 2208-C, available online: `https://pubs.usgs.gov/bul/2208/C/b2208-c.pdf`.

Zaigham N. A., Mallick K. A., 2000: Prospect of hydrocarbon associated with fossil-rift structures of the southern Indus basin, Pakistan. Am. Assoc. Pet. Geol. Bull., **84**, 11, 1833–1848, `doi:10.1306/8626C3A7-173B-11D7-8645000102C1865D`.