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2D seismic reservoir characterization of the Lower Goru Formation, Miano gas field, Lower Indus Basin, Pakistan

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Abstract

Miano gas field is one of the prominent gas-producing fields of the Middle Indus Basin, SW Pakistan. The Lower Goru is the distinct reservoir that is producing hydrocarbons for the last two decades. This study attempts to characterize the Goru reservoir using preliminary seismic interpretation to the 2D seismic profiles of the Miano gas field Pakistan. The velocity models confirm the presence of possible hydrocarbon bearing sands within the reservoir interval of interest. The Iso-pach map of the Lower Goru coincides with the identified low velocity zones. The massive clean sands are identified on the NE and the SE flanks within the reservoir zone. The well correlation show the maximum sand thickness near the well 02, suggesting the possible locations for the future oil and gas explorations.

Keywords: Miano gas field; Reservoir characterization; Clastic sediments.

1. Introduction

Identification of the prospective structural design within the heterogeneous structural and stratigraphic reservoir systems is one of the exploration concerns in the Miano gas field, Middle Indus Basin, SW Pakistan. These reservoirs systems are composed of varied architectural elements such as the Horst and Graben geometries. The implication for the reservoir characterization is that the productive sands are accumulated in the up thrown fault blocks such as Horst favorable for hydrocarbon exploration. To identify these structural features, we have characterized the Goru reservoir in terms of the its geometries. This study attempts to characterize the clastics sediments of the Goru reservoir using preliminary seismic interpretation to the 2D seismic profiles of the Miano gas field, Middle Indus Platform, SW Pakistan. Seismic structural interpretation reveals two leads at the Lower Goru Formation (20m) and the B-Sands (25m) levels. The velocity models confirm the presence of possible hydrocarbon bearing sands within the reservoir interval of interest. The Iso-pach map of the Lower Goru coincides with the identified lead. The massive clean sands are identified on the NE and the SE flanks of the study area. The well correlation show the maximum sand thickness near the well 02, suggesting the possible locations for the future oil and gas explorations.

The aim of the present study is to characterize the Lower Goru reservoir for the possible hydrocarbon bearing association detection by executing the preliminary seismic interpretation of the 2D seismic profiles of the Miano region, Indus Platform, SW Pakistan.

Previously, in the area, seismic inversion and seismic attributes analyses have been performed for detecting the stratigraphic reservoir configurations (Shazia et al., 2016, Naseer et al., 2014; 2015). This is study focuses on the regional structural style and the possible reservoir sands detection.

2. Geology of the study area

The study area Miano located at latitude 27.15º to 27.45º N and longitude 69.00º to 69.45º E near Sukhar-Khairpur in Sindh province (Fig. 1). Sulaiman Fold Belt, Indian Shield, Kirther Fold Belt and Sindh platform respectively (Kazmi and Jan, 1997), bound it in north, east, west and south. Large varieties of structures have been produced by oblique subduction in the west along the Chaman transform fault zone (Lawrence et al., 1979). The Sulaiman range shows blind thrust front, which suggests that all frontal folds of the fold belt are cored by the blind thrusts. The trend of structures is east west roughly, which are perpendicular to the tectonic transport direction, which has gentle dips (Kemal, 1992).

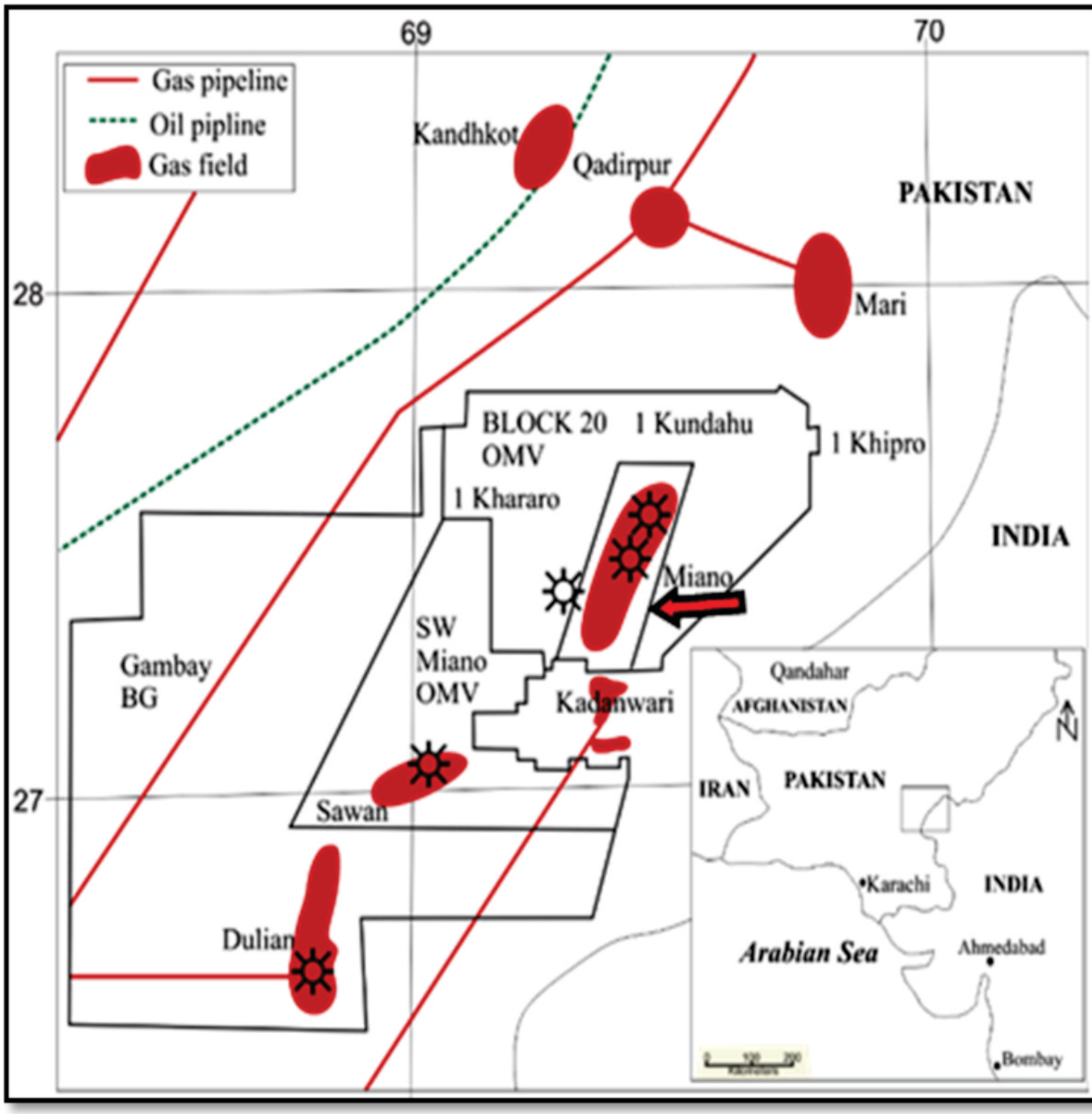


Fig. 1. Location map of the study area.

3. Reservoir potential and petroleum systems

Sember and Lower Goru Formations are the proven to be the potential reservoir rocks in Lower Cretaceous silici-clastics of the Lower Indus Basin. The best reservoir of the study area is Cretaceous age Lower Goru (sands) because of its high permeability and good porosity (Ahmed et al., 2007). All producing well in the study area are of type III-Kerogen that shows the good thermal maturity of source rocks (Lawrence et al., 1979).

Seal rocks in the Lower Indus Basin are composed of shales interconnected with sand. In the Lower Indus Basin, Ghazij shale and interbedded shale of Sui-Main Limestone are the seal rocks. Structural and stratigraphic traps have been observed in the study area (Kadri and Khan, 1992).

The structural traps are tilted fault blocks, normal faults, Horst Grabens and negative flower structures. These traps are the result of strike slip faulting, transtensional and extensional forces (Krois et al., 1998).

4. Data set

The data set utilized for the present study is composed of 10 2D seismic profiles. These seismic lines are divided into 8 dip lines and 2 strike lines (Fig. 2).The well data used for the current study are described in the (Table. 1).

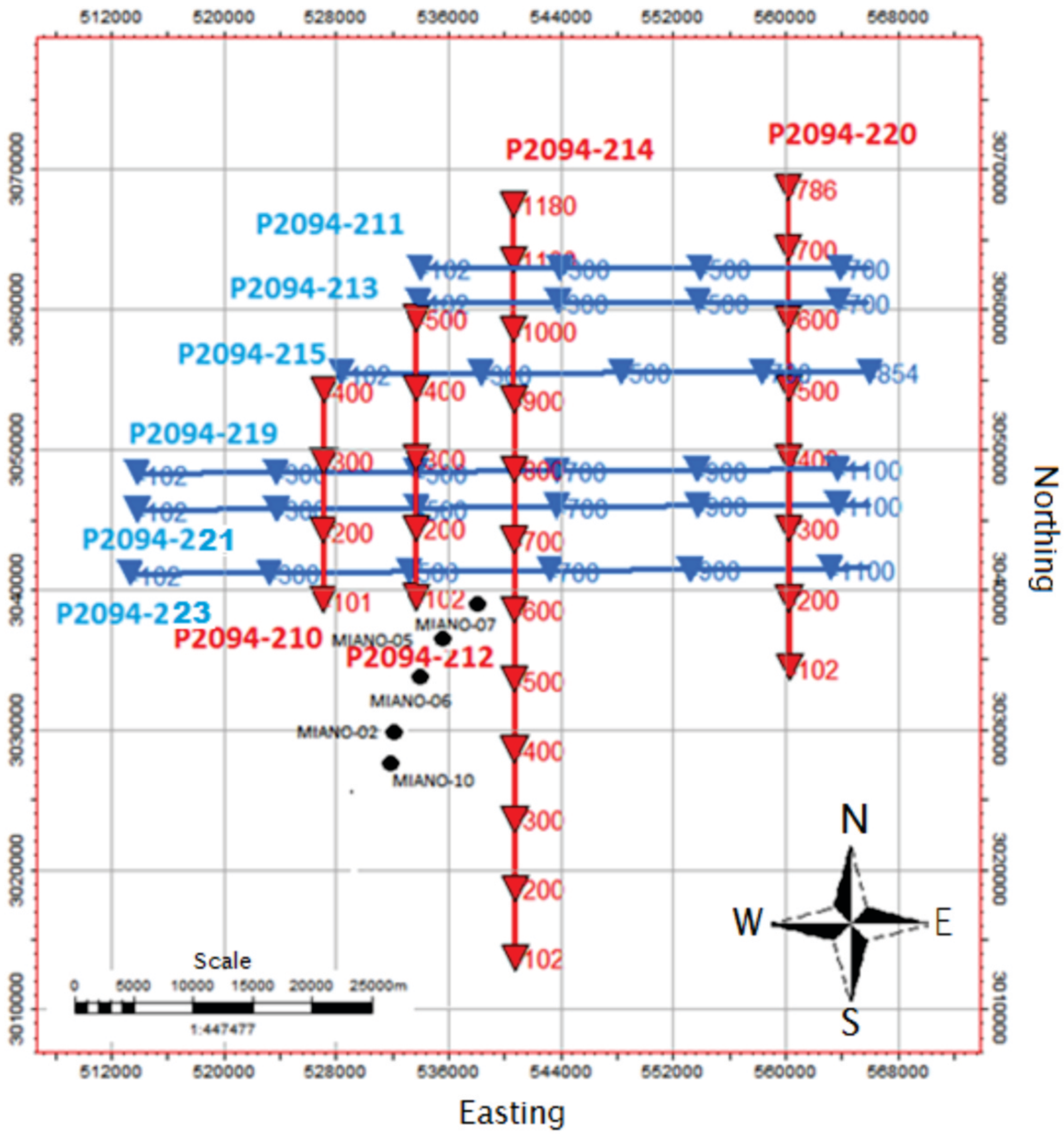


Fig. 2. Base map of the study area.

Table 1. Well data parameters.

Well	Depth (m)	Type	Production
MIANO-02	3484.9	Appraisal	GAS/SUS
MIANO-05	3334.2	Development	GAS
MIANO-06	3271.9	Development	SUS
MIANO-07	3364.3	Development	GAS
MIANO-10	3533.0	Development	GAS

5. Methodology

Seismic interpretation is the transformation of the 2D-seismic reflection data to a geological image by the application of corrections, migration and time to depth conversion (Badley, 1985). The zone of interest is defined is between the 0.800 sec to 3000 Sec that is composed of the fluvial-deltaic sediments of the early cretaceous age. Our focus of research remains on the zone shown by the red bars in the Figures 3a, b, c and d, respectively.

5.1. 1D forward modelling

The 1D forward modeling or synthetic seismogram is used to correlate well data and surface seismic data. We used MIANO-02 well to correlate well data to seismic time sections. The objective of 1D forward modeling is to observe whether the synthetic seismogram correlate with seismic data recorded at the study area and to conform interpretation (Peterson et al., 1997). For this purpose we computed a first-order Ricker wavelet as a digital filter with two millisecond increments of two-way travel time; using a frequency in (30 Hz and zero phase) (Fig. 4a) The correlation shows a good understanding between surface seismic recorded data and 1D forward modeling and give us clue of lithological interpretation (Fig. 4b). In the first step six prominent horizons Laki/Ghazij shales of Eocene age (Red), Sui-main Limestone of Paleocene age (Blue), Lower Goru Formation of Lower Cretaceous age (Yellow), C-interval of sand in Lower Goru Formation (Green), B-interval of sand in Lower Goru Formation (Brown), Chiltan Limestone of late Jurassic age (Orange) are marked on the seismic lines. The vertical seismic profile (VSP) data are used for naming the marked horizons. Numbers of normal faults with very small throw are marked on the seismic lines forming Horst and Graben structures. All the horizons and faults are marked in manual picking mode in Petrel software. The interpreted seismic lines of variance geological structures P2094-212, P2094-215, P2094-219, P2094-220, and P2094-223 are shown in (Fig. 4). The Jurassic Chiltan (Limestone) is prominent horizon in seismic sections. Many wells including MIANO-02 in Lower Indus Basin are not drilled until Jurassic Chilton (Limestone) horizon. It only goes up to Lower Cretaceous reservoir, Lower Goru. It is marked with the help of high acoustic impedance effect and surface geological record.

5.2. Time and depth contour map

Time contour maps of the Lower Goru and the B-Sands are prepared to analyze the trend of the regional structure and to observe the thinning and the thickening of the reservoir sands (Fig. 5a and 6a) along with their 3D views (Fig. 5b and 6b) respectively.

The depth contour maps of the Lower Goru and the B-Sands also prepared to observe the swallowing and the deepening effects of these two dominant formations (Fig. 5b and 6b).

5.3. Seismic velocity modeling and ISO velocity map

Seismic interval velocities with navigation data are uploaded into the Petrel software. After that, these interval velocities are converted into average velocities with the help of Dix equation which is automatically calculated in Petrel calculator (Dix, 1955). The seismic velocities are increasing with depth due to over burden pressure, increase in densities and acoustic impedance with depth. These velocities may be interval or average (Lillie, 1999). For this purpose, two-way travel time of subsurface horizons is plotted against the y-axis while shot points are plotted against x-axis (Fig. 7a and 7b).

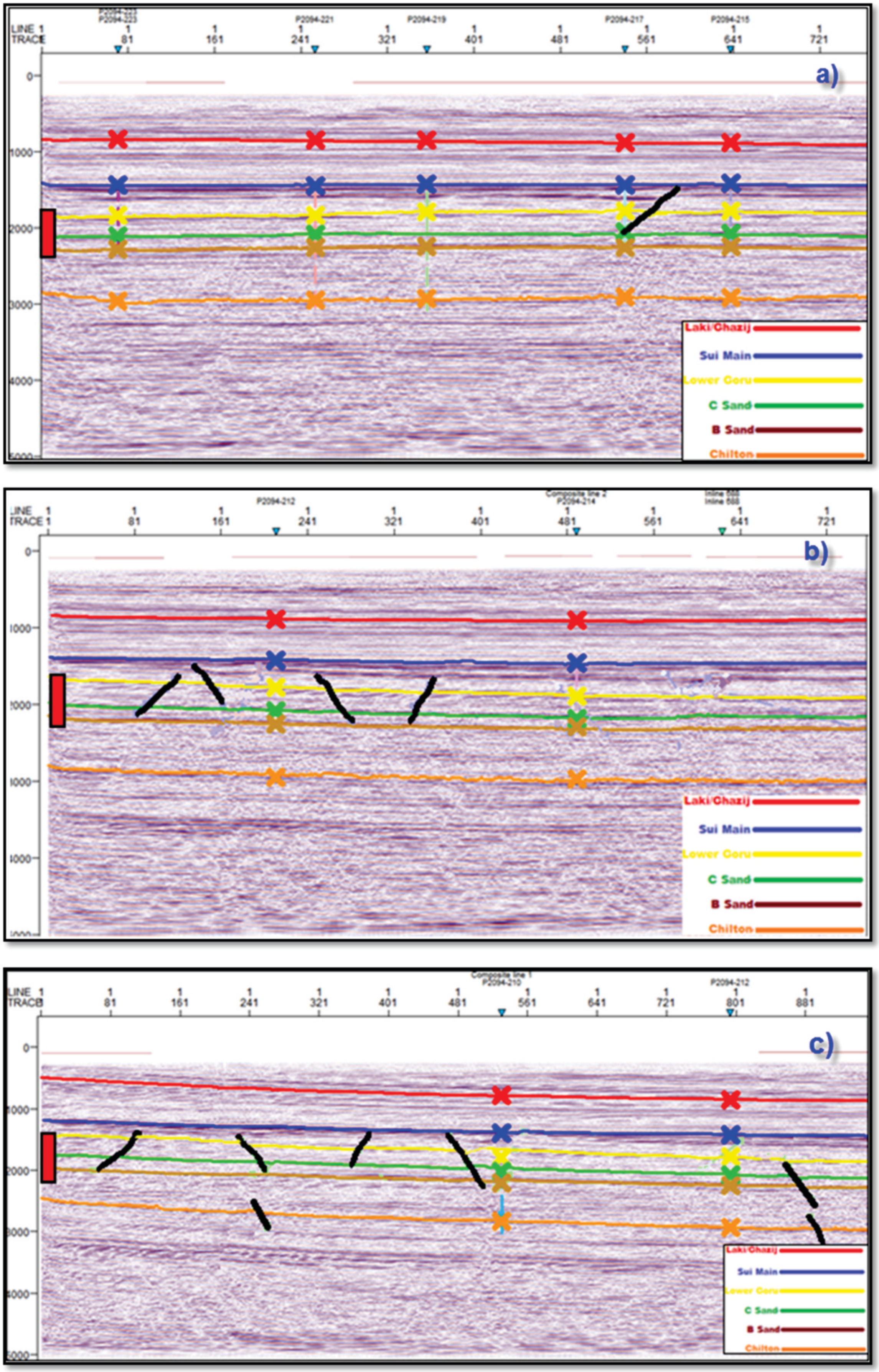
5.4. Iso-pach map

Iso-pach maps illustrate thickness variations of two subsurface horizons usually reservoir rocks. It measures perpendicular thickness and shows the true stratigraphic thickness (TST) (Lillie, 1999). Nothings and Easting's of the survey are plotted along the y-axis and x-axis respectively. The Iso-pach maps of reservoir, Lower Goru is shown in Figure 8.

6. Well log correlation

Well log correlations show the trend and well tops of subsurface horizons at their specific depth (Badley, 1995). The well tops can also be used for the correlation with the corresponding reflectors. For this purpose five different Miano wells, MIANO-02, MIANO-05, MIANO-06, MIANO-07 and MIANO-10 have been correlated together in order to evaluate the

7. Results and discussion



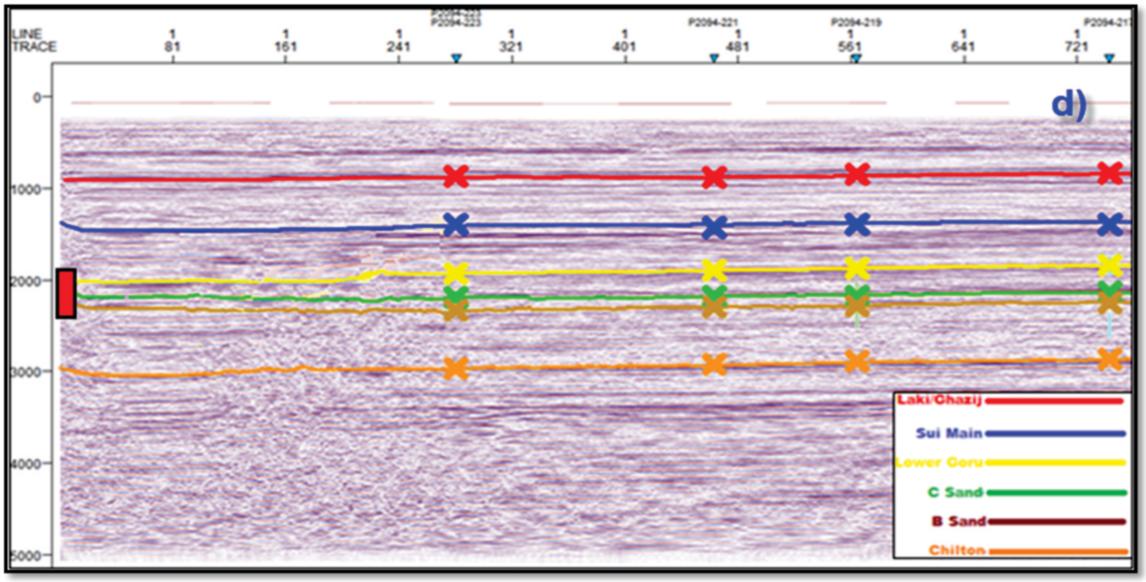


Fig. 3. Interpreted seismic time section (a) Strike line P2094-212 (b) Dip lineP2094-215 (c) Dip line P2094-219(d) Strike line P2094-220.The red bars are representing the zone of research.

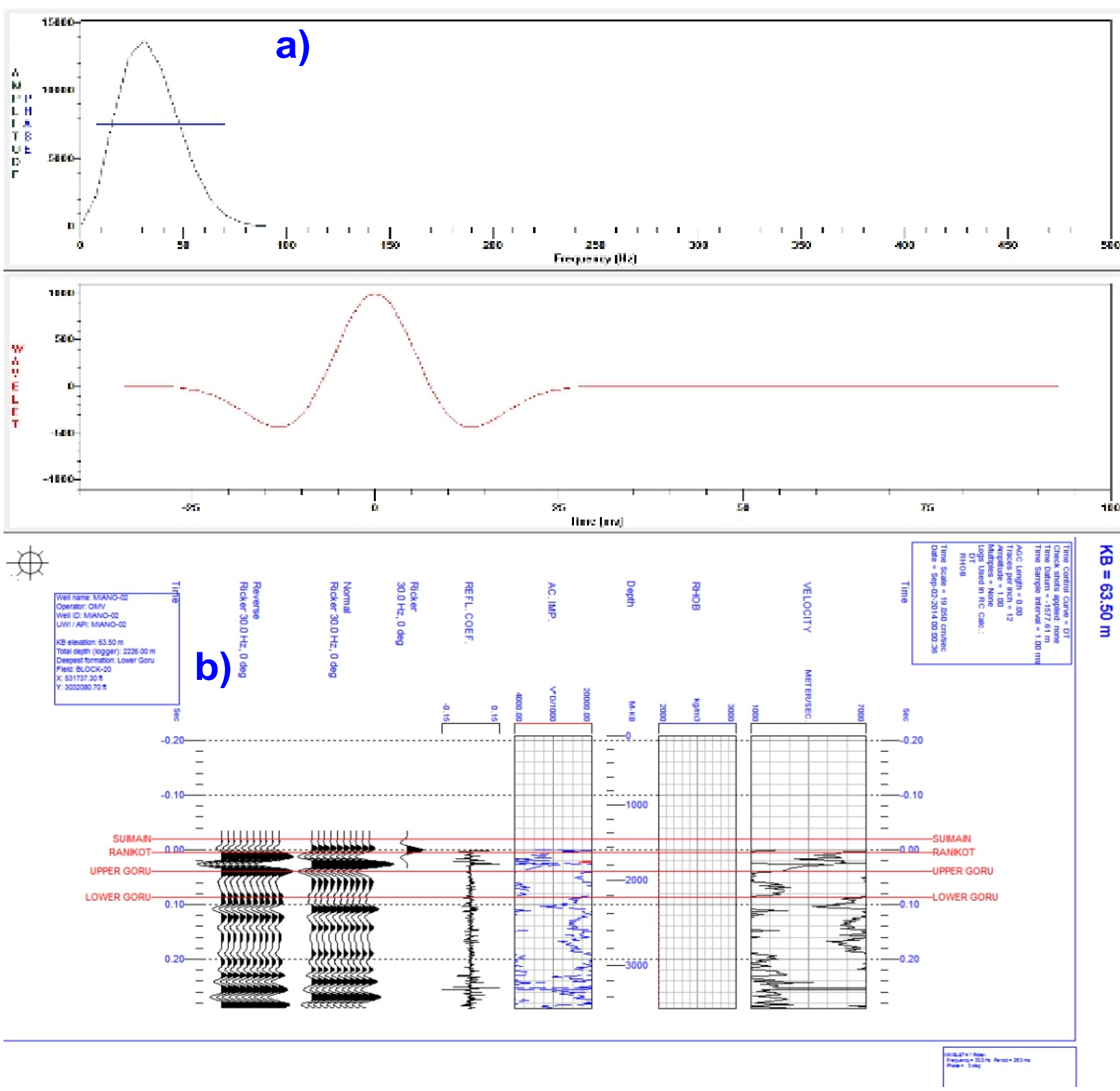
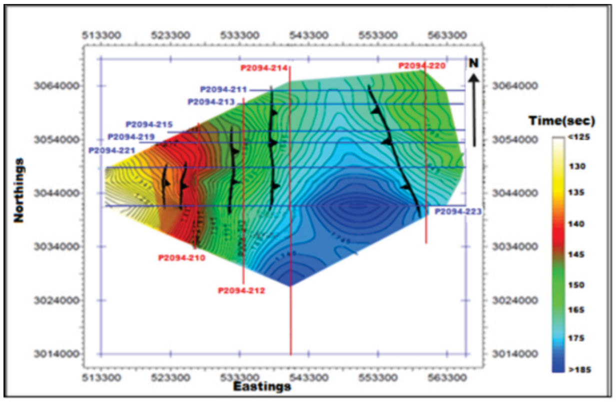


Fig. 4. Source Ricker wavelet and 1D forward modeling of MIANO-02.

different depths of reflectors across the area. The contours show that the normal faults with small throw is dipping at a steeper angle towards the higher values of the time i.e. from north to south. The contour of the Lower Goru Formation shows the formation is shallowing at the western side. In addition, the contour shows the deepest part of the area with time at large Graben in the western side, which is bounded by faults on both sides. The map forming two major Horst structure at eastern side together with the two Grabens (Fig. 5a) represents five major faults. The 3D view is shown in the (Fig. 5b).



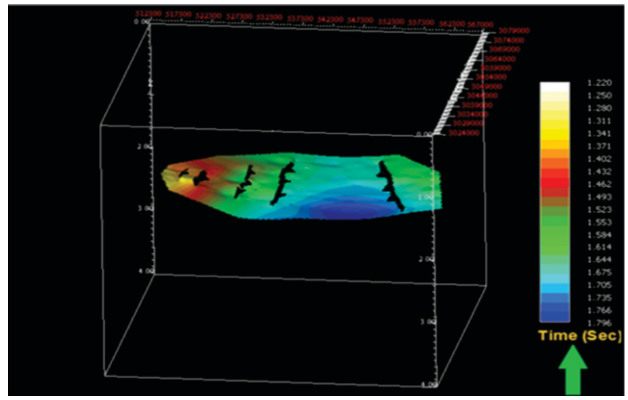
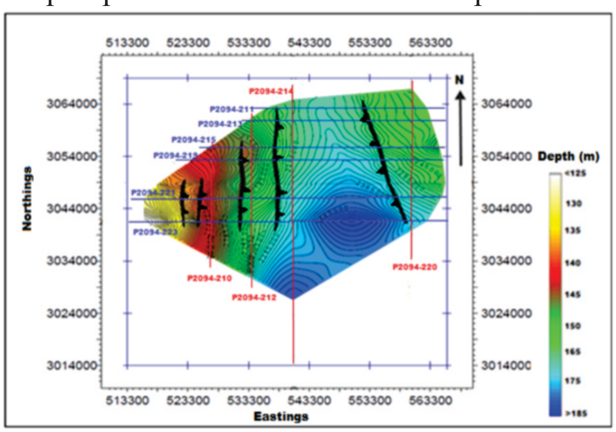
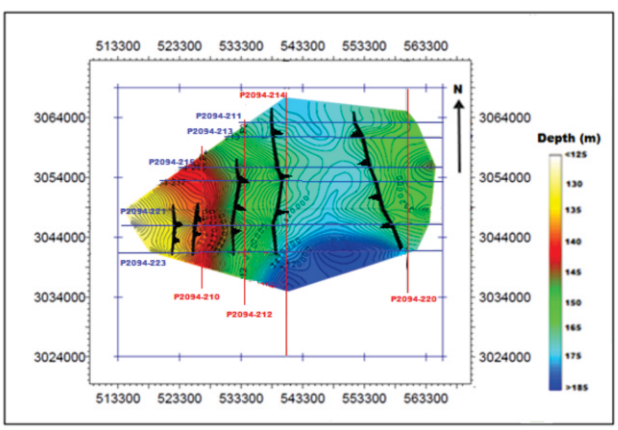


Fig. 5. 2D Time contour maps, of (a) Lower Cretaceous reservoir, Lower Goru (b) time surface model of all overlay layers.

The time contour of B-Sand interval shows the deepest part of the horizon with time up to 2.500 seconds is at large Graben in the eastern side while the shallowest part is towards the west.





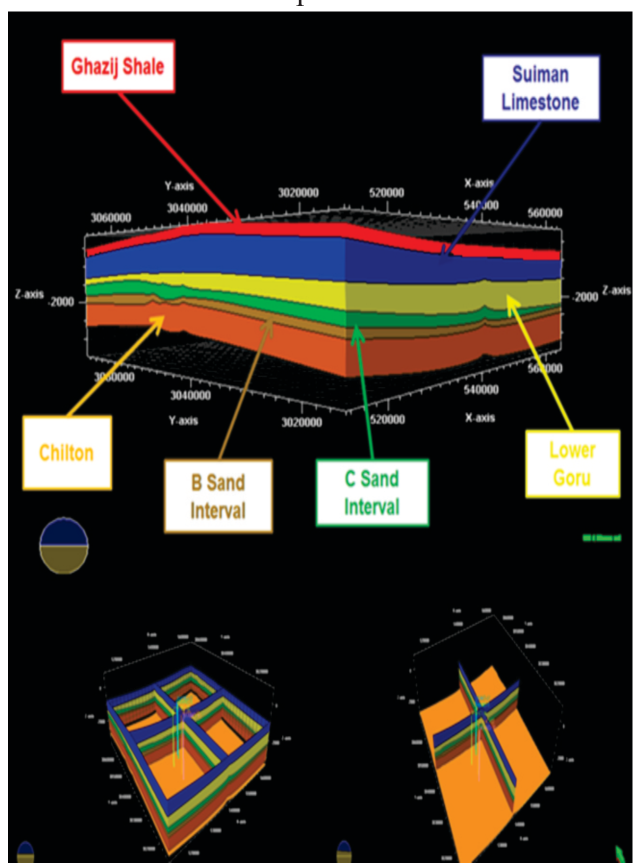


Fig. 6. Depth contour map of formations (a) reservoir Lower Goru (b) B-Sand interval (c) subsurface models of interpreted seismic horizons.

The iso-velocity map is showing the low velocity values shown by the blue rectangle (Fig. 6a). These low velocity zones are exactly in the zone of interest, where the time and depth contour maps of the Lower Goru and the B-Sands are interpreted (Fig. 5a and b), (Fig. 6a and b). These low velocities are depicting optimistic signs for the hydrocarbon accumulations.

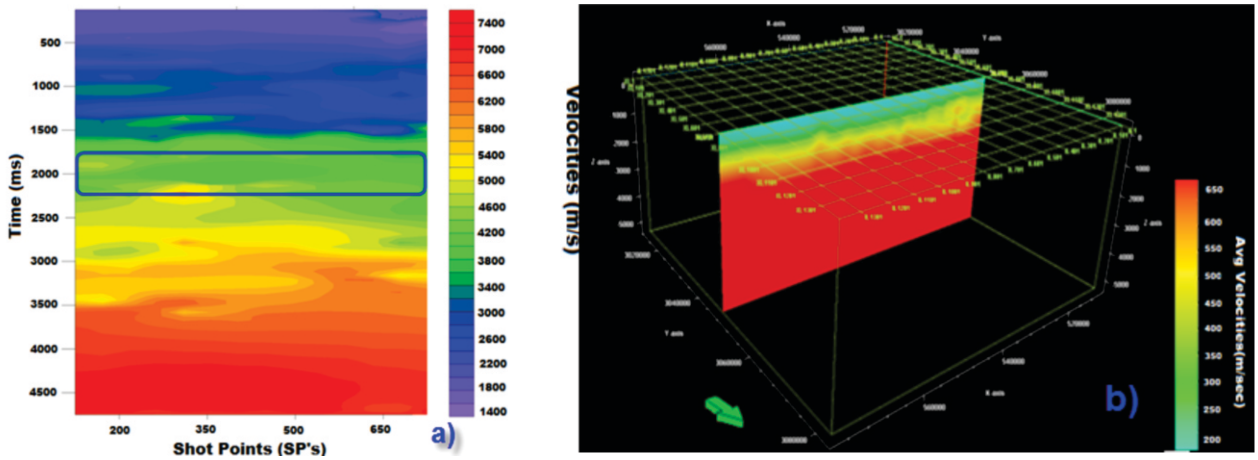


Fig. 7. (a). ISO velocity map of given seismic lines (b). Velocity model of seismic velocities.

The iso-pach map is showing the Lower Goru formation is getting thicker on the SE regions. There is also small patch on the NW regions. These thick zones are depicted by the red squares (Fig. 8).

If we compare the SE and the NE regions, it is evident that the SE flanks are found to be more promising for future exploration (Fig. 8). These observations are also in agreement with the well correlation (Fig. 9).

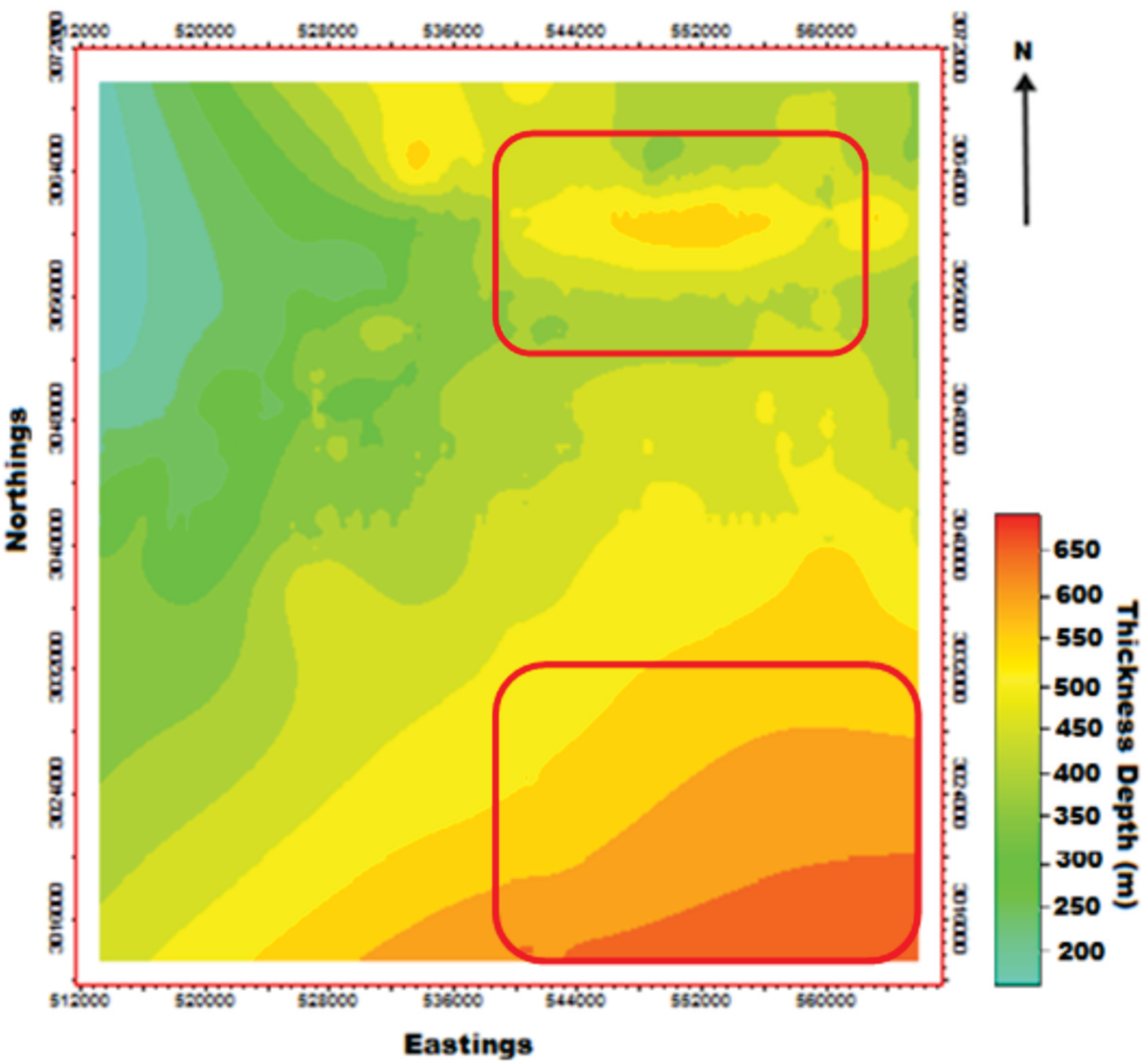


Fig. 8. Iso-pach map of the Lower Goru.

The zone below the reservoir Lower Goru top shows the minimum and maximum value of GR which indicates different sand and shale intervals and packages in which include B-Sand interval. The well log correlation is shown in Figure 9.

It is also evident that the the iso-velocity maps (Fig. 7) and iso-pach map (Fig. 8) are showing the zones favorable for hydrocarbon accumulations. These zones are near the wells Miano 06 and Miano 02 respectively, are diligently calibrated from the well correlations (Fig. 9). It is transparent that the central to SE regions, the iso-pach map is showing a very thickness of the Lower Goru reservoir is ~620m thick interval in the zone of interest.

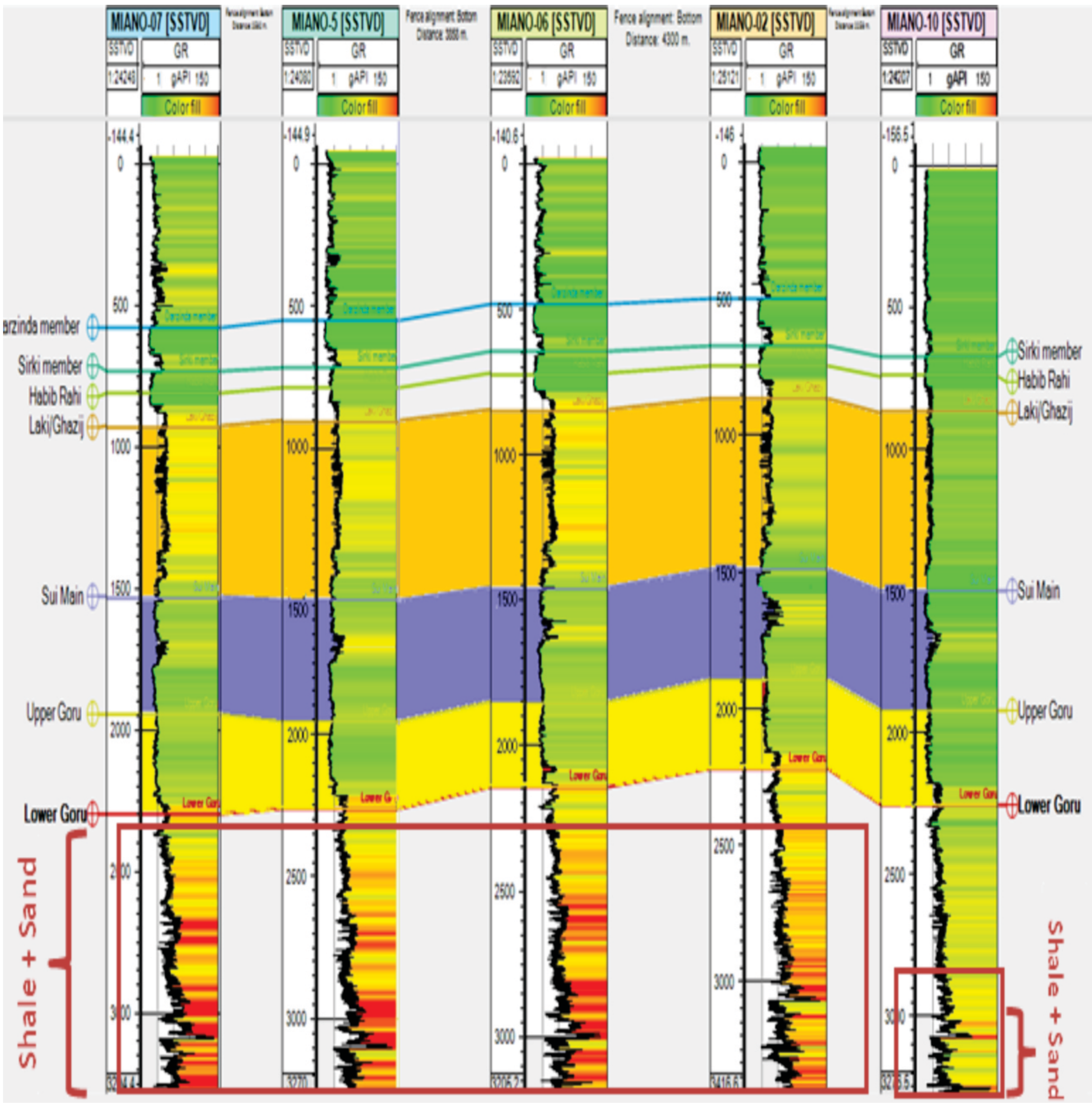


Fig. 9. Wells Correlation of various wells with panels (left to right) –Miano-02, Miano-05, Miano-06, Miano-07 and Miano-10.

As a summary, based on the time and depth contour maps (Fig. 5 and 6), Iso-velocity map (Fig. 7), Iso-pach map (Fig. 8) and the well correlations (Fig. 9). The SE is the most favorable zone declared from the current study for future exploration activities.

Conclusions

We have characterized the Goru reservoir and its producing interval using the preliminary seismic interpretation .The main outcomes of the present study is concluded as follows;

- The Lower Goru and the Basal sands are getting thicker on the SE part of the study area.
- The velocity models confirm the presence of possible hydrocarbon bearing sands within the reservoir interval of interest.
- The Iso-pach map of the Lower Goru coincides with the identified lead. The massive clean sands are identified on the NE and the SE flanks within the reservoir zone.
- The well correlation show the maximum sand thickness near the well 02, which is present on the SE regions suggesting the possible locations for the future oil and gas explorations.

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