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Seismic stratigraphy study of the East Razzaza in Jurassic- Cretaceous succession- Central Iraq

Layalen H. Ali *****, Salman Z. khorshid* , Ghazi H.AL.Sharaa**

*Department of Geology, College of Science, University of Baghdad, Iraq.
**Ministry of petroleum, Oil exploration company*

***Abstract*— *This study is deal with seismic structural and stratigraphic interpretation that applied on the East Razzaza (central of Iraq) area, by using 2D seismic data from Oil Exploration Company. Three main seismic reflectors were picked. These reflectors are Zubair, Yamama and Gotnia Formations, which were used to define petrophysical well logs and synthetic seismograms , that are calculated from sonic-logs of the wells of East Baghdad-1 (Eb-1) and West Kifl-1(Wk-1) by Geoframe program, to interpret the Yamama basin and the boundaries of the basin (Zubair and Gotnia Formations), and suggest a stratigraphic model for the study area. Structural maps are prepared for each reflector in addition to analyze stratigraphic features on the seismic sections to obtain the location and direction of the sedimentary basin and shoreline. It is concluded that the basin lies in the east and south east of the area. Seismic stratigraphic interpretation of the area approves the presence of some stratigraphic features in the studied formations. Some distributary buildup mound and carbonate platform are determined. Yamama Formation is interpreted to represent a carbonate platform, and it is divided into three sequences; they represent progradational seismic facies (sigmoid). Maximum flooding surface (MFS) is recognized on top of Yamama Formation and system tracts are determined on the basis of seismic and log data. Seismic attributes technique was used to predict the physical properties distribution of Yamama Formation succession.*
Keyword—Seismic stratigraphy-East Razzaza-Jurassic-Cretaceous succession.

I. INTRODUCTION

Seismic methods are widely applied to exploration problems involving the detection and mapping of subsurface boundaries, they also identify significant physical properties of each subsurface unit, and are therefore widely used in the search for oil and gas [1]. The effectiveness of the seismic method varies for different kinds of stratigraphic features. For example, many types of reefs can be located with consistent success on seismic record sections [2]. The studied area (East Razzaza) is located in the middle parts of Iraq, and belong to three governorates (Baghdad, Karbala and Anbar governorates) on the western side of Mesopotamian basin between Euphrates river and Razazza lake, figure (1). The aim of this study is to interpret a (2-D) seismic data available in Oil Exploration Company for surveys carried out in East Razzaza to determine the seismic stratigraphic architecture and facies changes for the Zubair, Yamama and Gotnia Formations in the area which are covered by two dimensional survey for locating the probable reservoir.

<u>The Geophysical Information of studied area</u>

Gravity Surveys

The Bouguer anomaly map shows increasing of gravity values in NE direction with presence of anomaly as a nose about (-46) milligal in the middle part of the study area, figure (2). Bouguer gravity values is ranged between (-40) to (-53) milligal. This anomaly may be due to difference in rock densities and topography of basement rocks.

The Magnetic Survey

The aeromagnetic map shows that depth of basement rocks in the area ranges between (7-8km). This depth increases towards the S and SW. It was noted the existence of magnetic anomalies with continuous increase in the intensity of the total magnetic field towards the S-SW figure (3).

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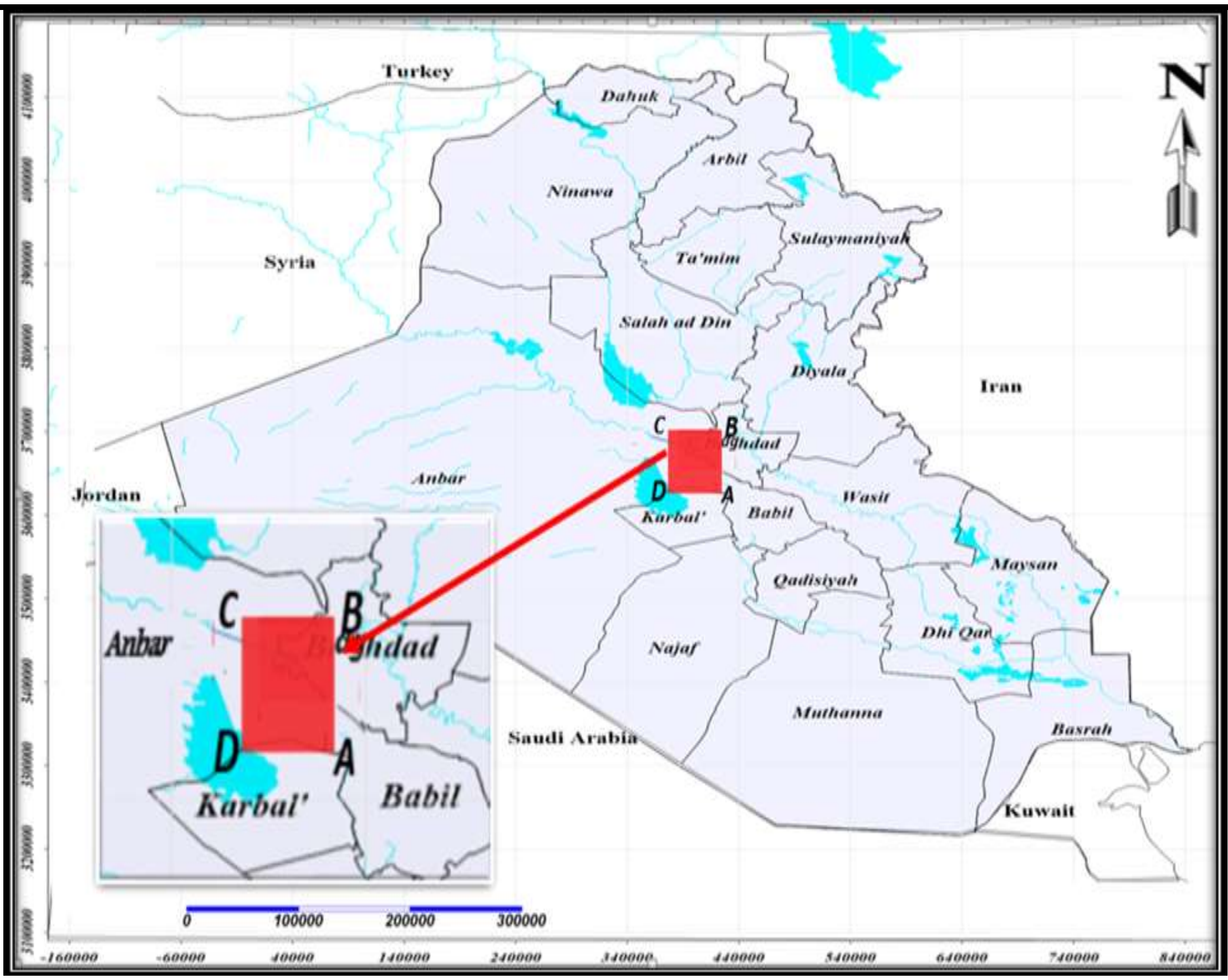

Fig.1: Iraqi map shows the study area.

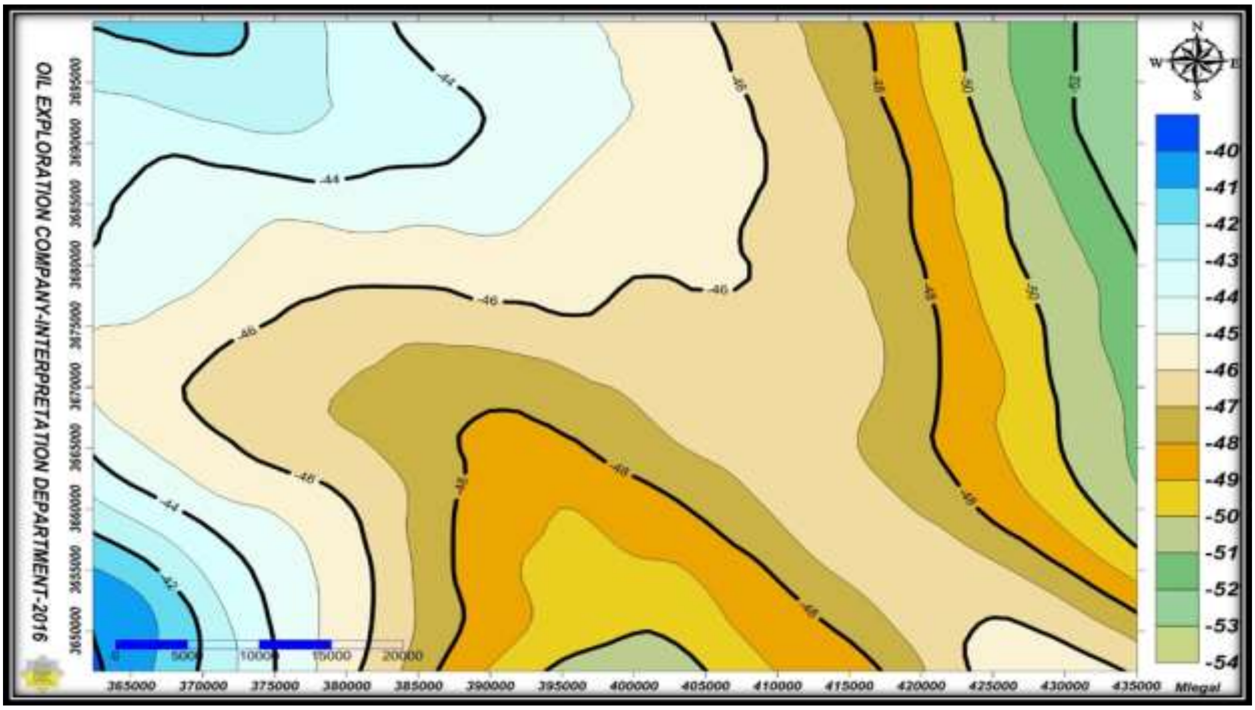

Fig.2: Bouguer anomaly map of the study area.

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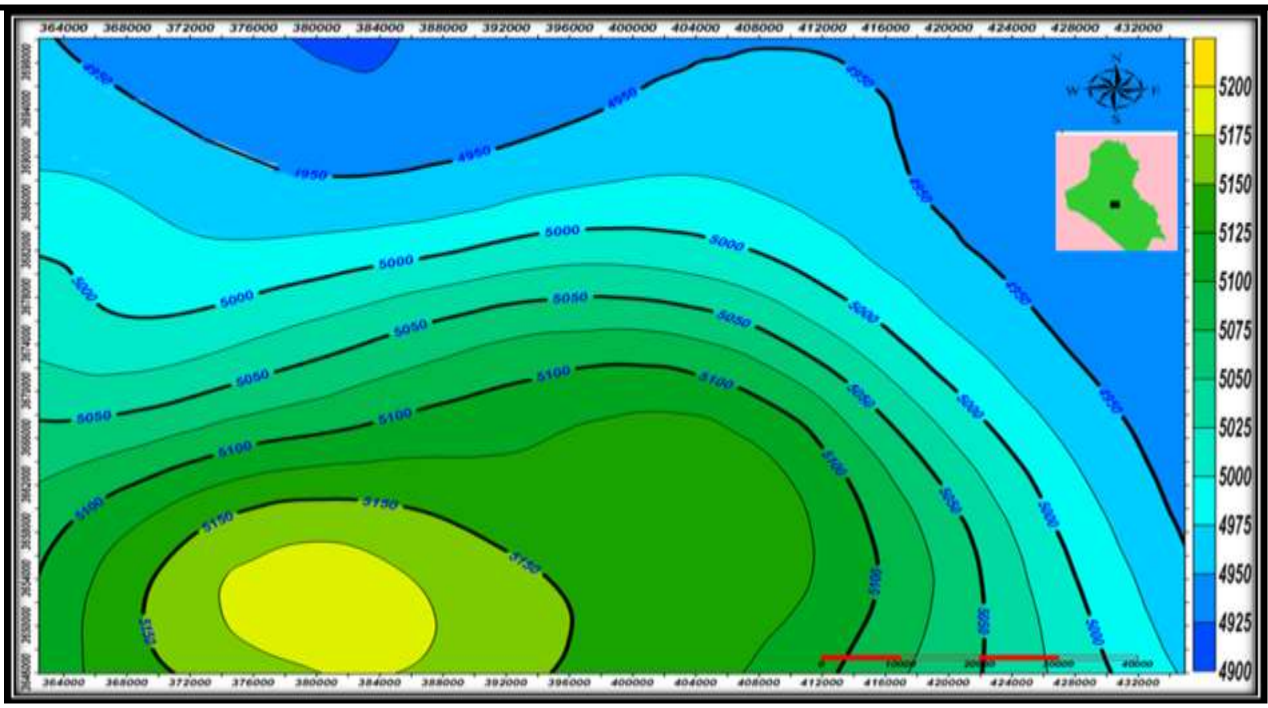

Fig.3: Aeromagnetic map of the study area.

Data Acquisition

Base map preparation

Processed seismic data are loaded in the interactive workstation of interpretation in SEG-Y format and before starting; special subprograms must be operated to define the required data for loading. This process is called (project creation) for achieving the interpretation process on an interactive workstation. After that, the base map of the study area is constructed. This process includes entering strike line and dip line numbers, the separated distance between bin sizes along strike line direction and dip line direction. Base map includes definition of the geographic coordinates in UTM coordinates system of study area, figure (4).

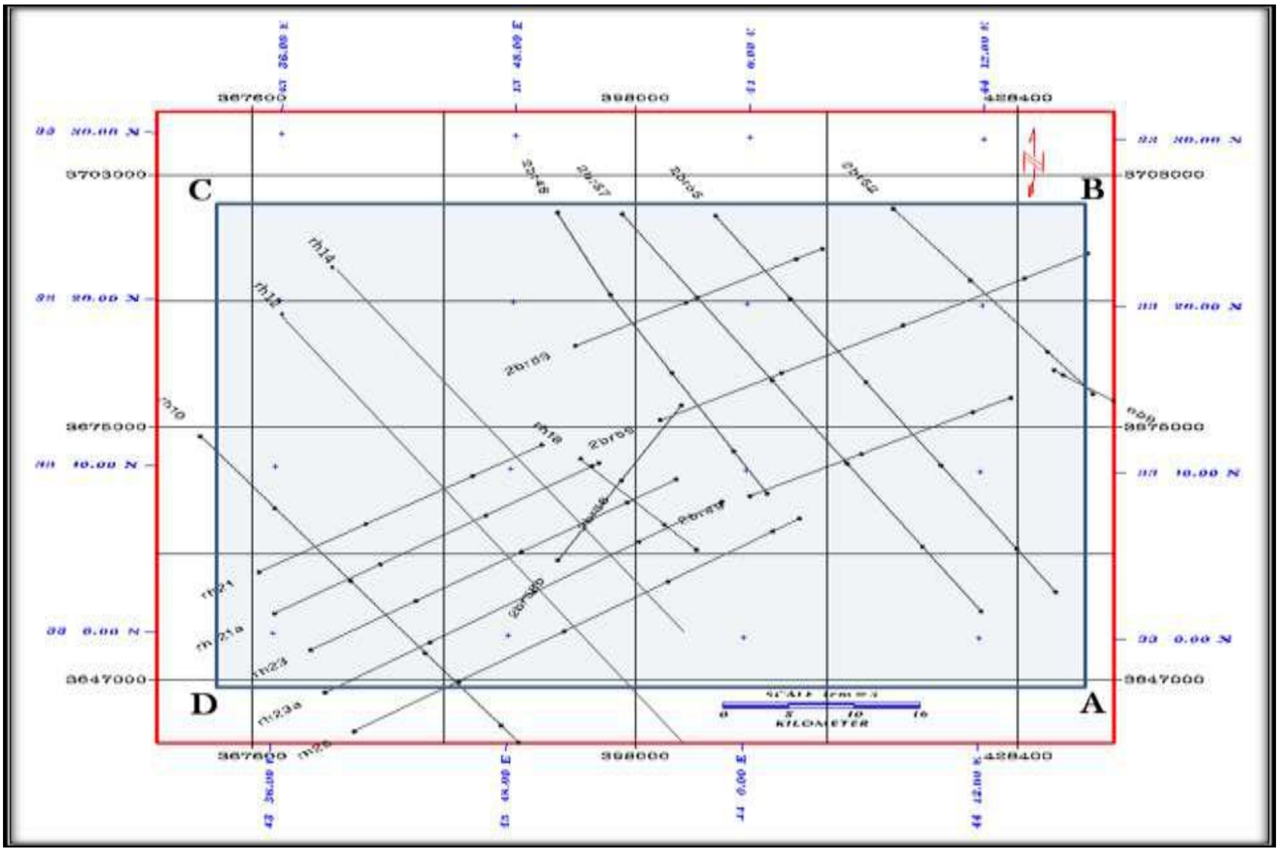

Fig.4: Illustrates a base map of study area (2D survey).

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Synthetic seismograms and reflectors definition

Synthetic seismograms that is, a theoretical seismic trace, can be made from one or two of the logs in a well [3]. Synthetic seismograms (figures 5,6) are artificial reflection records made from velocity logs by conversion of the velocity log in depth to a reflectivity function in time and by convolution of this function with a presumed appropriate wavelet or source pulse [4]. Synthetic seismograms were generated for Eb-1 and Wk-1 wells using GeoFrame software package. Basically, seismic well tie allows well data, measured in units of depth, to be compared to seismic data, measured in units of time. The sonic and density logs were transformed from depth to time domain. This conversion will permits correlation of horizon tops identified in well with reflections present in the seismic section. The picked reflectors wavelets appeared as peaks on synthetic trace (positive reflection) but in different intensity. The Zubair corresponds to a trough. This is very reasonable because the rocks in Zubair are shale as well as the sandstone was characterized by high porosity and lower density. For this reason, the reflection coefficient of sandstone in this interface is negative (trough). The Gotnia and Yamama corresponds to a (peak) because the rocks in Gotnia is anhydrite and Yamama is limestone which was characterized by low porosity and higher density. For this reason the reflection coefficient of this interface is positive (peak).

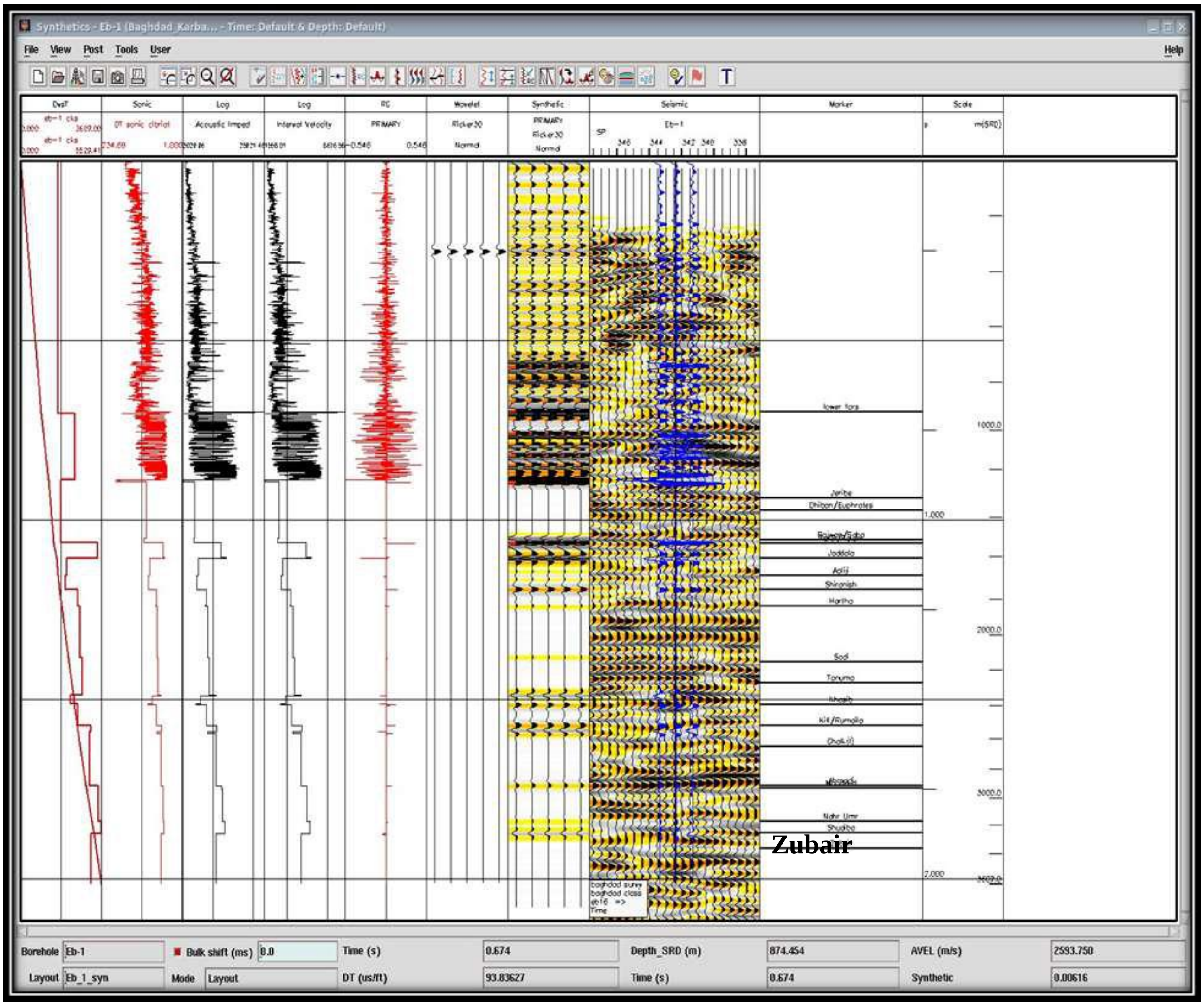

Fig.5: Illustrates the synthetic seismogram of Eb-1 well.

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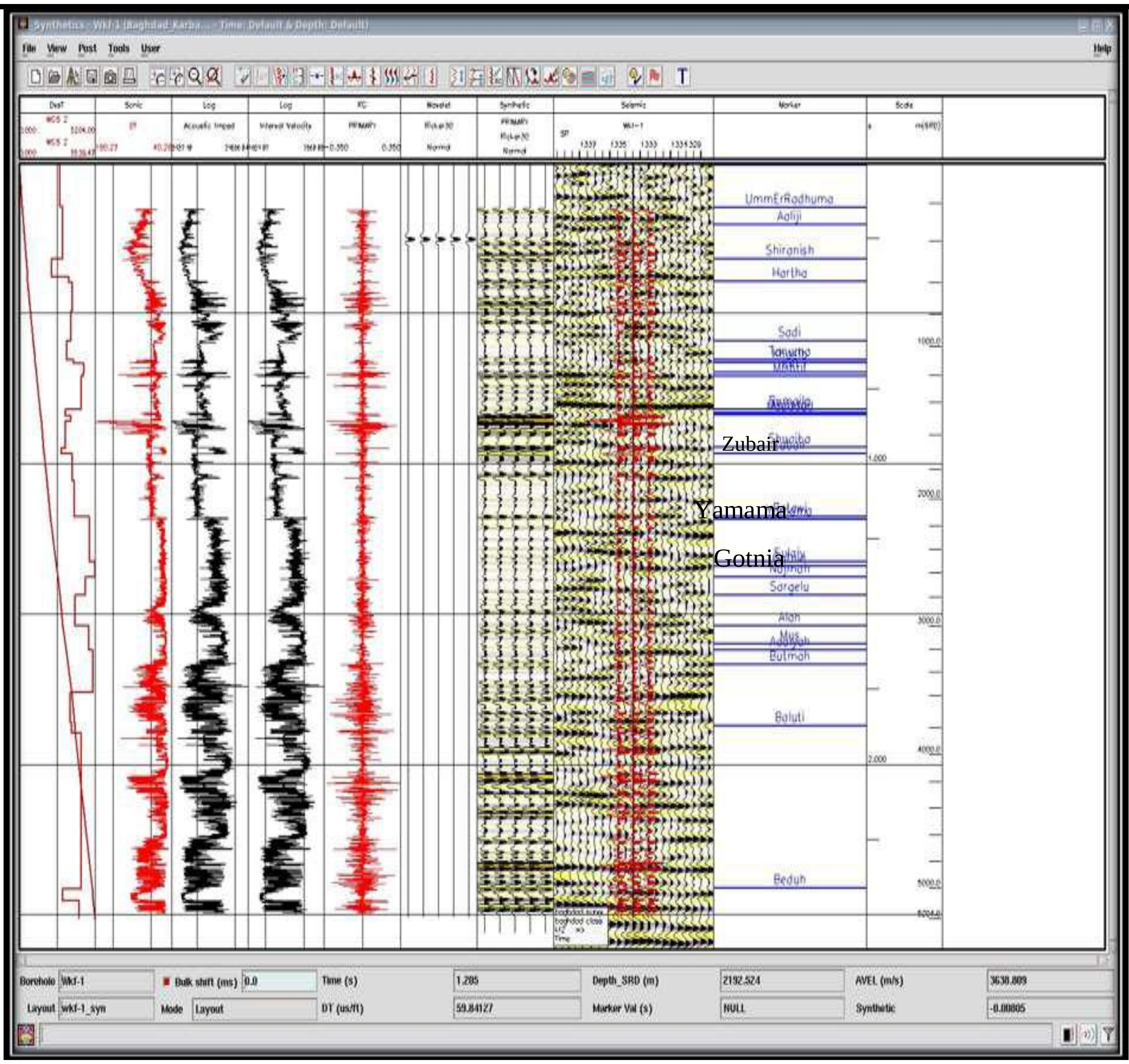

Fig.6: Illustrates the synthetic seismogram of Wk-1 well.

Interpretation of Seismic Data

After completion the process of creating synthetic seismogram and identification of reflection then picking the reflectors is represented by Zubair, Yamama and Gotnia Formations. As previously mentioned, the synthetic seismogram have been created for Eb-1 and Wk-1 wells, in order to identify the reflectors depending on:-

• The well records of sonic logs and integrated velocity survey.

• The well in adjacent area.

• The synthetic seismogram loaded on seismic section in order to matching the seismic signal and the result of matching are very good.

General Specifications of Seismic Reflectors

1- Continuity of reflectors

Continuity of the picked reflector can be described as follows, figure (7):

- Zubair reflector has good continuity.
- Yamama reflector has moderate continuity.
- Gotnia reflector has good continuity.

2- Concordance of reflectors

Concordance of reflectors is good especially at the Upper Jurassic –Lower Cretaceous, it is due to presence of the stratigraphic features.

3- Quality of the reflectors

In general, the quality of the reflectors on the seismic sections of the area is considered good. This is due to the high signal to noise (S/N) ratio of the recorded signal where the resolution is very good. Knowledge of the general specification of the reflector is important because it helps in determining how much and what quality of seismic section involved in achieving the interpretation before using the programs of automatic control. These programs are interpolation, auto picking and they are used to complete of the reflectors picking process.

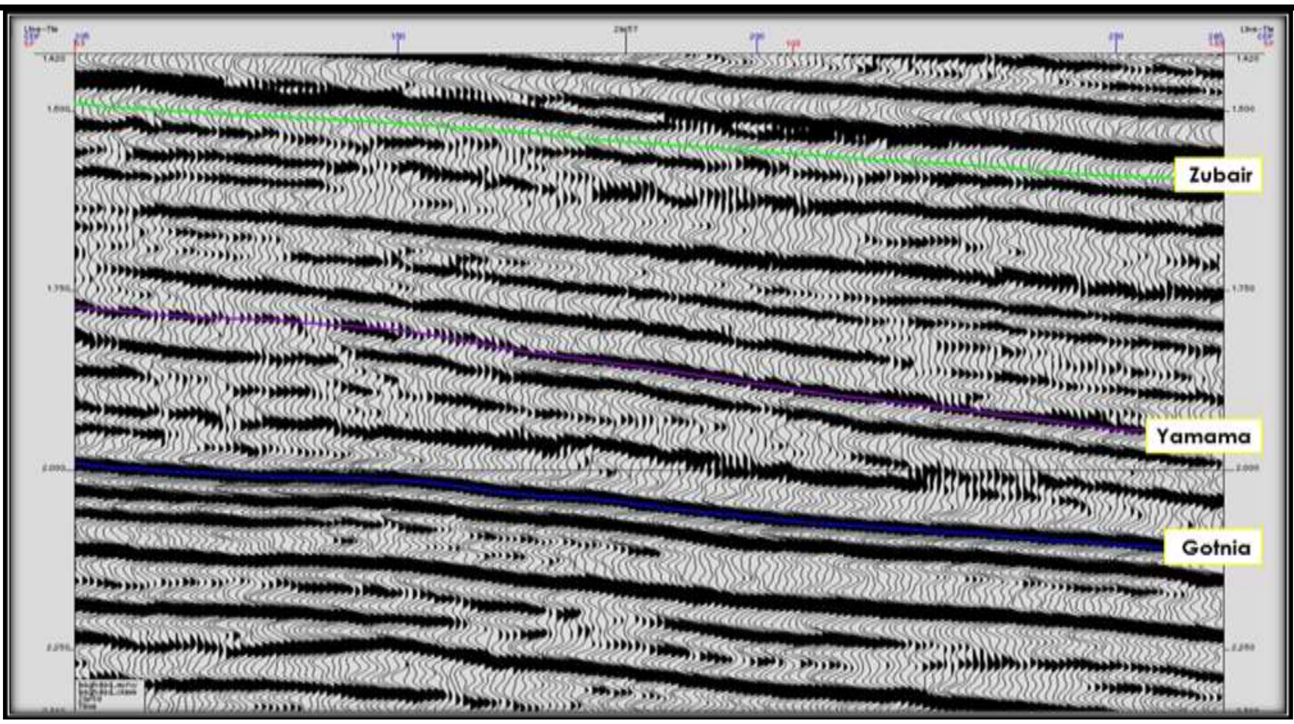

Fig.7: Shows continuity of the picked reflectors (Zubair, Yamama and Gotnia reflector).

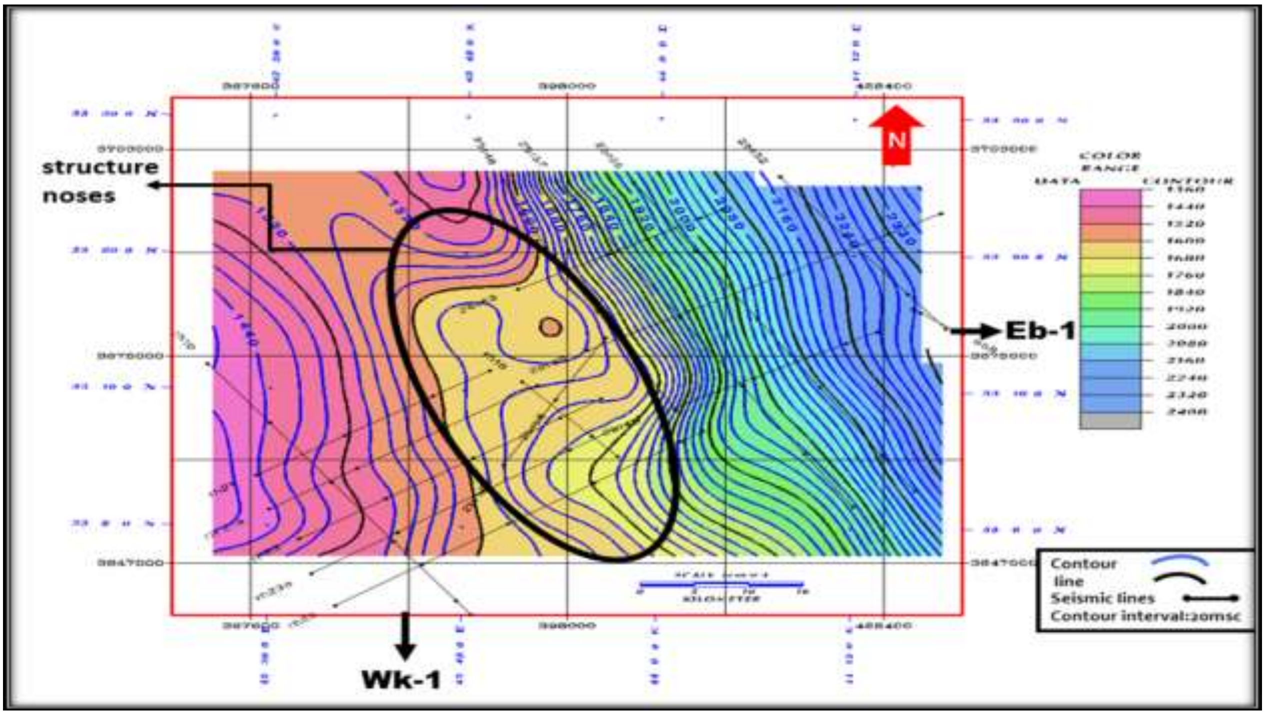

Fig.8: Two way time map of Yamama reflector.

Structural Picture of the picked Horizon

Depending on analysis of the seismic data, synthetic seismogram and well ties, it is easy to recognize and pick three reflectors: Zubair reflector, Yamama reflector and Gotnia reflector. After the definition of studied reflectors using synthetic seismograms in time domain for wells (Eb-1,Wk-1), we picked these reflectors in all area to prepare the time maps which are converted later to structural maps in depth domain by using velocity data of these reflectors, for describe the structural features of selected horizons from two way time(TWT) structure maps.

Time, velocity and depth maps

Time maps

The time maps may carry important information on the subsurface geo-logic features. Zubair, Yamama and Gotnia Formations two way time maps. Figure (8) shows Yamama TWT map as an example which is dominated by NE-SW trending high to the East and drops to the West. The structure rises sharply to the North East. In the middle area, the structure depicts ridges extending NW-SE on the surface, these ridges represent accumulation of sediments that may contain oil, and has nose structure shape (minor structure). Contour interval equals 20 ms.

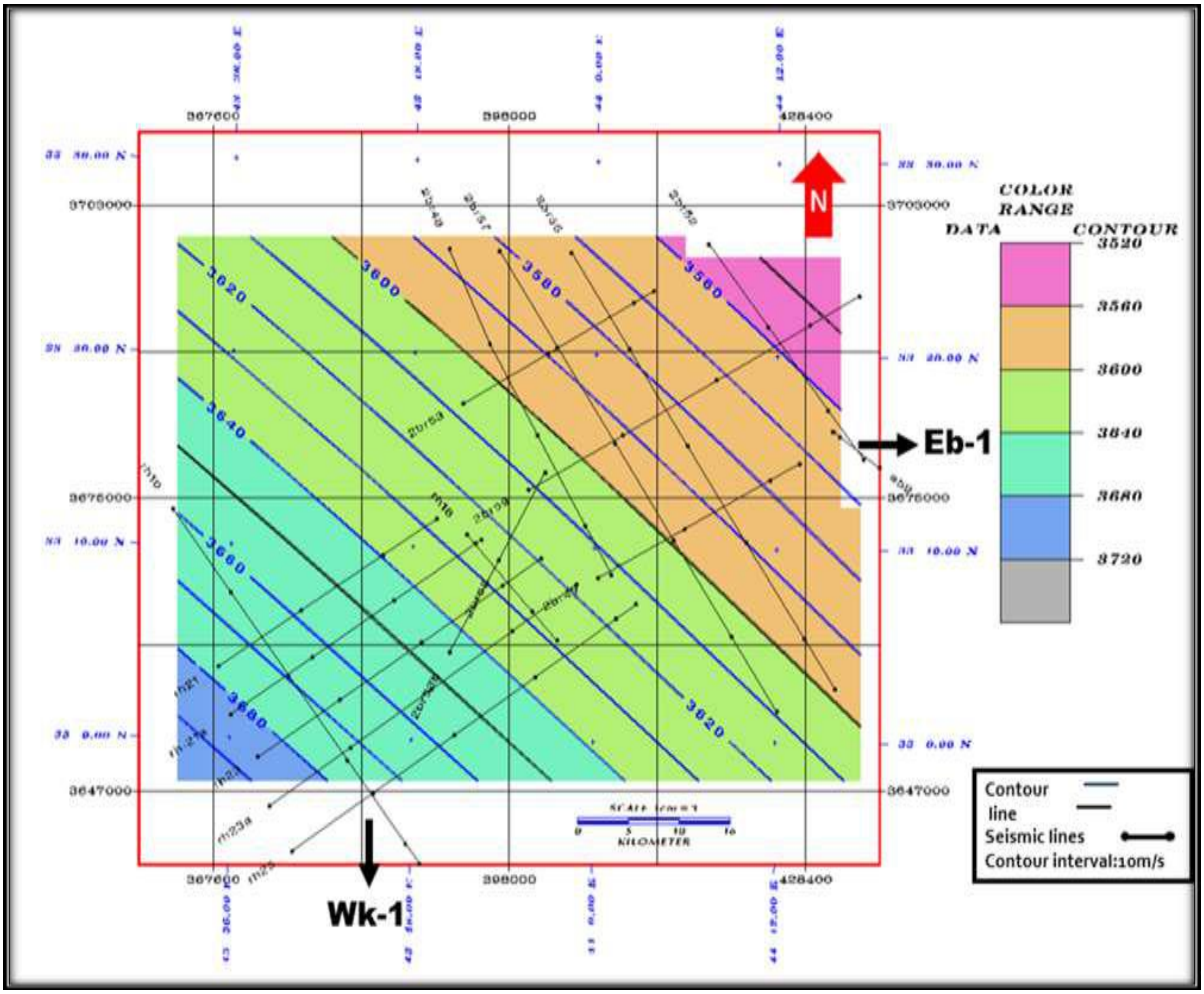

Fig.9: Velocity Map of Gotnia reflector.

Average Velocity maps

To obtain depth maps, the picked time data of any reflector is needed to the velocity data. The more accurate velocity to be used in time to depth conversion is the average velocity, which can be computed directly from well velocity survey (check shot) [5]. For the two wells the area (Eb-1 and Wk-1), check shot data are used to prepare the velocity maps. The velocity map of Gotnia shows the average of velocity increases in SW trend.The magnitude of velocity ranges from (3550-3690) m/s. Velocities in the Gotnia Formation variation and this is indication of variation in lithology and depth from NE to SW trend, figure (9).

Depth Maps

The time map of a given reflector is used with its average velocity map to extract the depth map, as follows:

Depth at any point = (velocity × TWT /2) at this point.

Zubair, Yamama and Gotnia depth maps reveal a structural feature having a general trend in the NW-SE direction. Yamama depth map showsthe minimum depth value of (3000) m is noticed at the W and gradually increase toward the E and NE, and reaches (4240) m towards the basin. Structural noses (minor structure) are observed in the middle part of the area and have NW-SE trend, which represents the direction of buildup carbonate shelf. Contour interval is 40m, figure (10).

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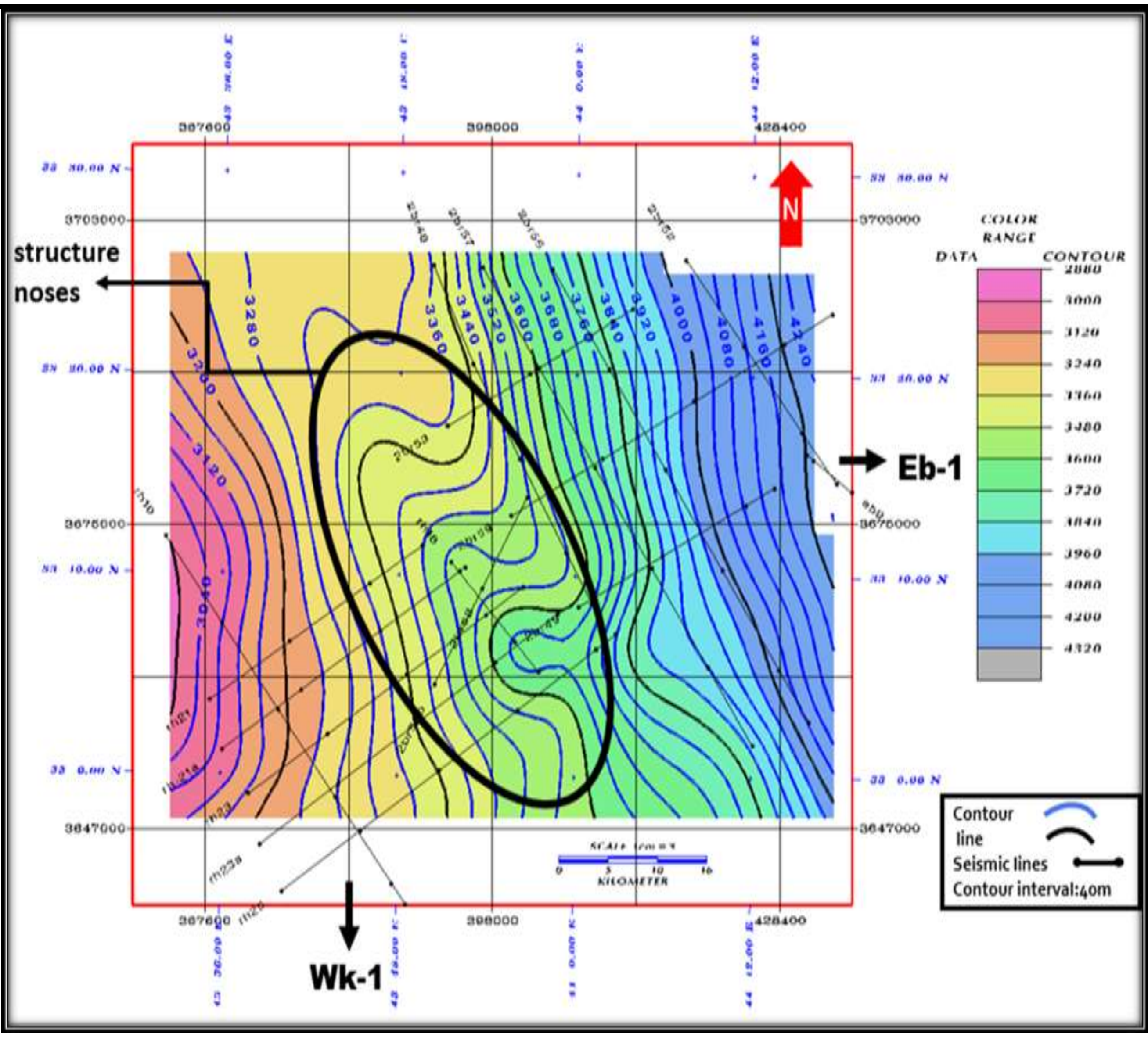

Fig.10: Depth structure map of Yamama Formation.

Stratigraphic Interpretation

Stratigraphic interpretation of seismic data may be simple if there is adequate well control, but in many cases the interpreter has to make inferences from the appearance of observed bodies, these may include both their external form and if the resolution is good enough for it to be visible [6]. Seismic stratigraphy can add important geological information and enhance the understanding of the depositional environments, which may help in the understanding the origin, accumulation, and trapping mechanisms of the hydrocarbon deposits. The seismic traces are trying to tell us the details of the subsurface [7]. The first phase in seismic stratigraphic studies of a basin fill is to delineate genetically related units, which are called depositional sequences [8]. These sequences are of regional importance and are further subdivided into individual system tracts [9]. The system tracts are delineated based on the presence of local unconformities and their laterally equivalent conformities. They contain a grouping of deposits from time-equivalent depositional systems [10]. Sequence stratigraphy analysis is increasingly viewed as an essential methodology for studying carbonate platforms [11].

Sequence Stratigraphy of the Studied Formations

Zubair Formation

The Zubair Formation is interpreted by using the log data for the identification thickness and depositional sequence within Zubair in studied area. Both Eb-1and Wk-1 wells are essentially composed of alternating shales and sandstones with some siltstones. The variation in lithology displays some regularity, towards the shore, in the west the formation is composed mostly of sands only.

Yamama Formation

Yamama Formation is interpreted as three depositional sequence representing the base which is an initial lowstand systems tracts (LST), remaining to top as carbonate package; it represents the highstand systems tracts (HST) and transgressive systems tracts (TST) figure (11).Within

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the Yamama sequence, three reflection sequences that can be mapped across the entire platform top. The top Yamama was picked from wells parallel to the seismic surface approximately. The Yamama sequence appears to initially backstep and then progrades from SW-NE in the highstand. These latter seismic events can be interpreted as prograding clinoforms. Major environments of deposition are interpreted including three shelves margin, upper slope and inner shelf, and basin. Note that transgressive and highstand system tracts dominate, with transgressive system tracts being associated with major periods of shelves margin aggradations, as build-ups try to keep pace with rising sea level. During highstand, the basin margin progrades basin ward rapidly. Facies have also been interpreted for the individual sequences, figure (12). In terms of petroleum systems we are most likely to encounter source rocks in the deep water basinal settings. Reservoir distribution is harder to predict because of the effects of complex diagenesis associated with carbonate rocks.

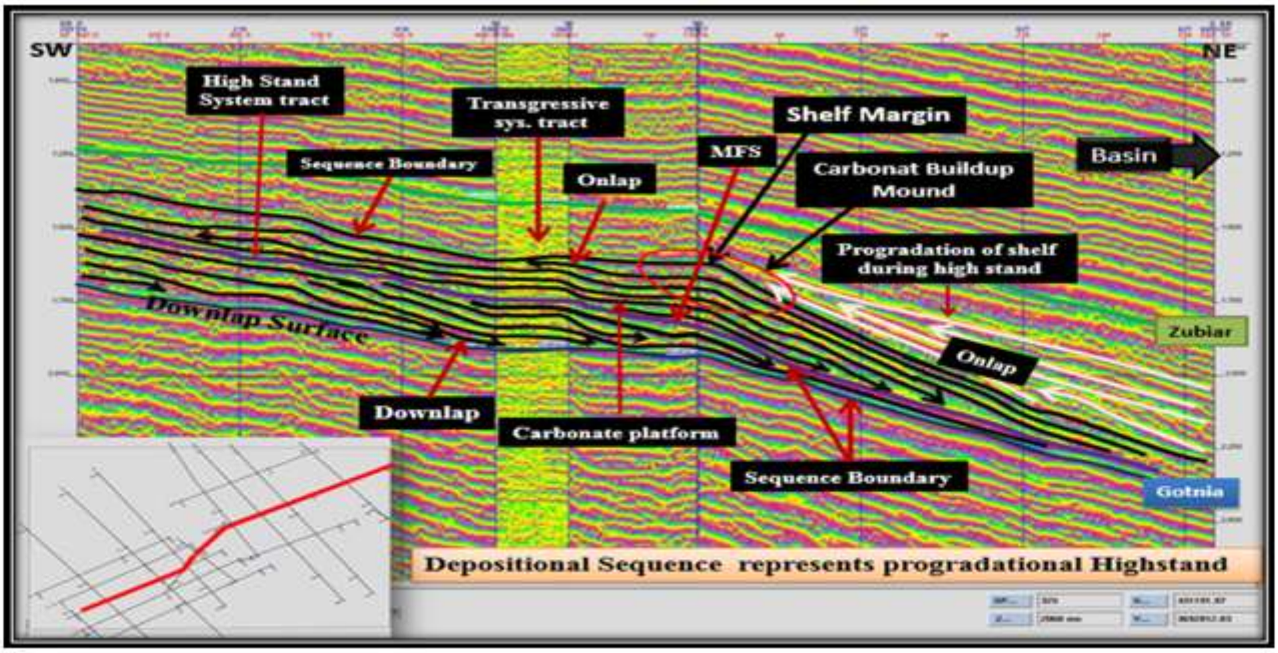

Fig.11: Illustrates architecture of basin ofYamama Formation.

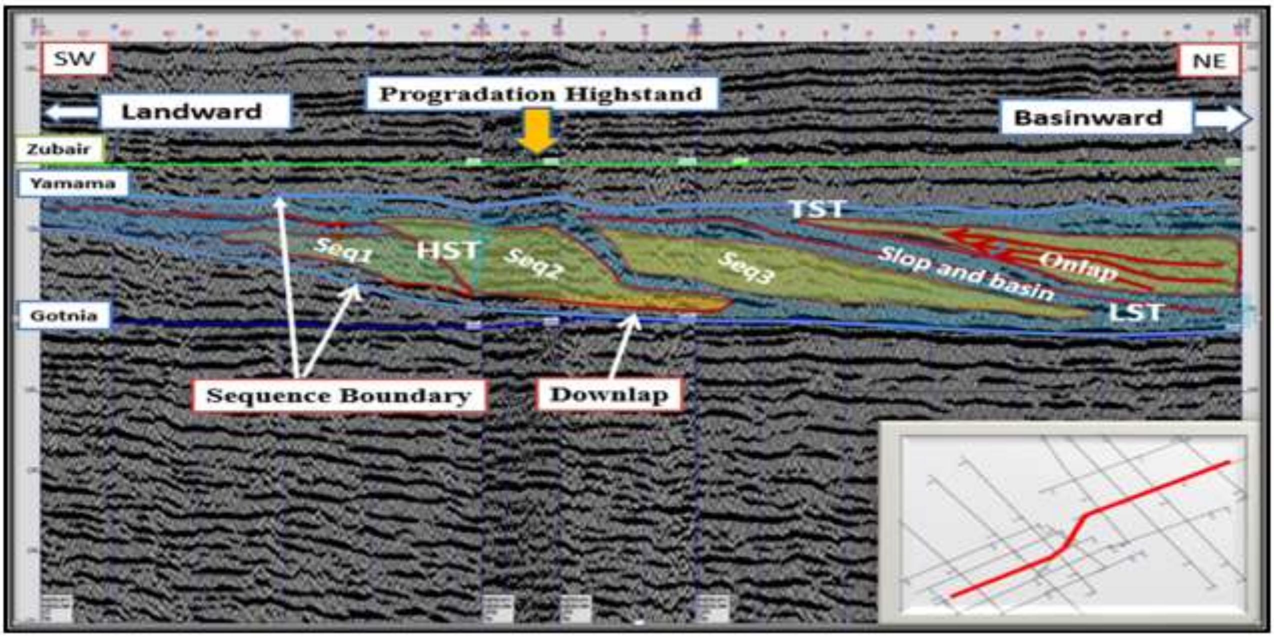

Fig.12: Illustrates sequence stratigraphy of the section.

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Gotnia Formation

The Gotnia sequence represents a complete evaporite sequence which was deposited on the basin center and continental slope. It is clear on seismic data and in Wk-1 well. The progradation of Gotnia Formation continued and caused a decrease in the extent of the basin, and therefore created an evaporitic. This interpretation implies that relative sea level needs not to fall, but rather continued progradation further away the basin off from marine circulation and creates an evaporitic basin. Seismic data clearly shows the top of Gotnia to be associated with a dipping event with dip to the north-east direction, and an updip thinning or pinchout onto a prominent shelf edge. The interpretation of deposition is thought to be related to a period of late highstand and associated basin starvation.

Seismic Reflection Configuration

A seismic facies unit is interpreted to express certain lithology, stratification, and depositional features of deposits that generate the reflections in the unit. Seismic facies analysis first involves recognition of distinctive (packages) of reflection within each sequences. Each reflection package exhibits a combination of physical characteristics that distinguish it from adjacent seismic facies [12].

In the studied interval Zubair- Gotnia, These are two main types of seismic reflection configuration are observed.

1- Zubair reflector displaying parallel configuration.

2- Yamama to Gotnia displaying the progradational configuration.

Zubair reflector characterize high to moderate amplitude and continuity. Reflection configurations of Zubair reflector indicate wide, relatively uniform lateral extent in sedimentary basin. The shelf facies consist of neritic shale and generally transgressive. While Zubair Formation represents delta platform facies consisting of shallow-water, high-energy marine (delta- front) sandstone.

The second type of reflection configuration in the studied package which includes Yamama and Gotnia reflectors is progradational, with two fundamentals types of configuration called oblique and sigmoid. The concluded sigmoid model is associated with progradation of shelf system. The depositional energy may be high, and the evidence on that is the reef limestone and predominance of oolites in Yamama, figure (13).

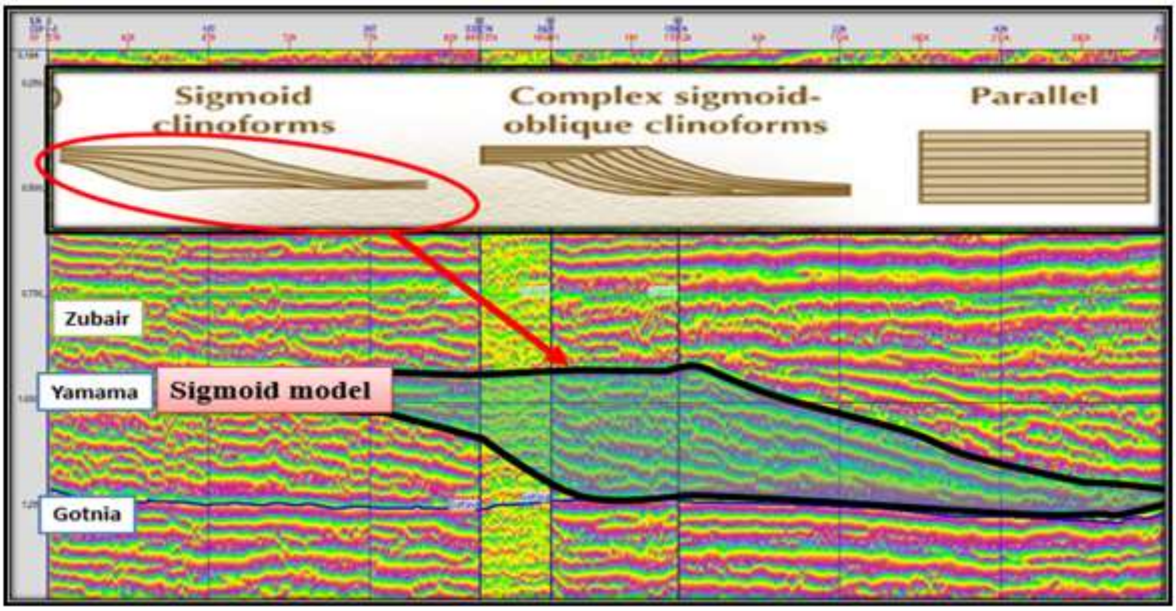

Fig.13: Shows sigmoid model in the study area.

Flattening Procedure

Flattening is transforms a seismic image to make the structural features in the image flat. A flattened seismic image is created by shifting sample in the original image up or down. This means that parts of the original image are stretched in some areas and squeezed in others to flatten the features in the image [13]. Look at a section below, figure (14) one with several good and continuous reflections across it, the up and downs of the reflections are mostly by geological processes that took place after the deposition beds. If we change the section so as to make a reflection flat, then the section more nearly represents the geological situation at the time that bed was deposited.

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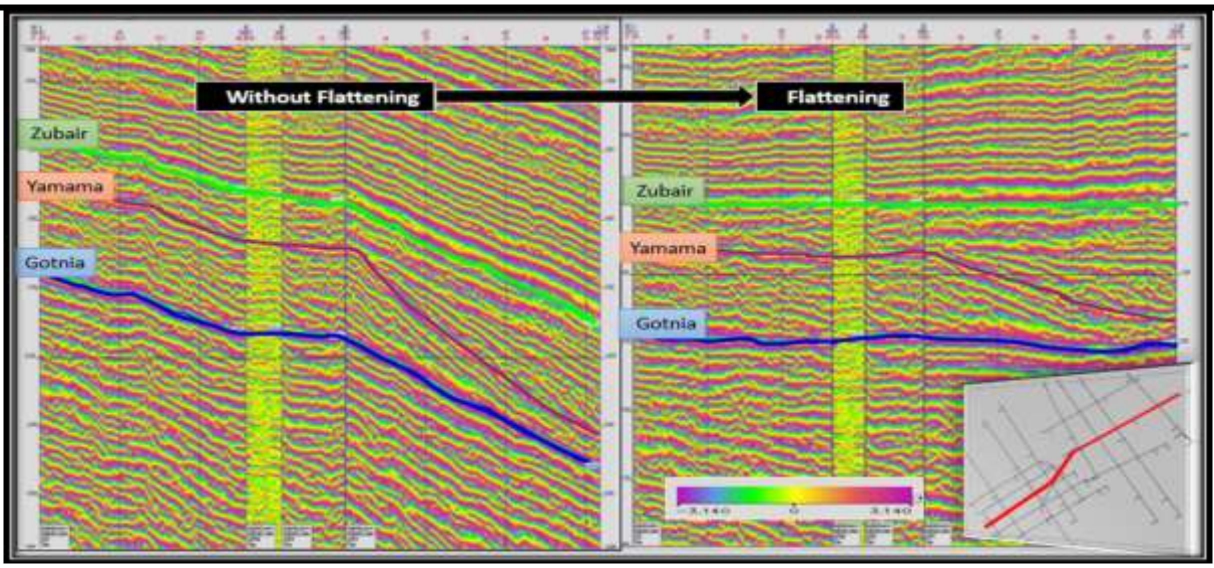

Fig.14: Illustrates Flattening technique applied on 2D section in the study area.

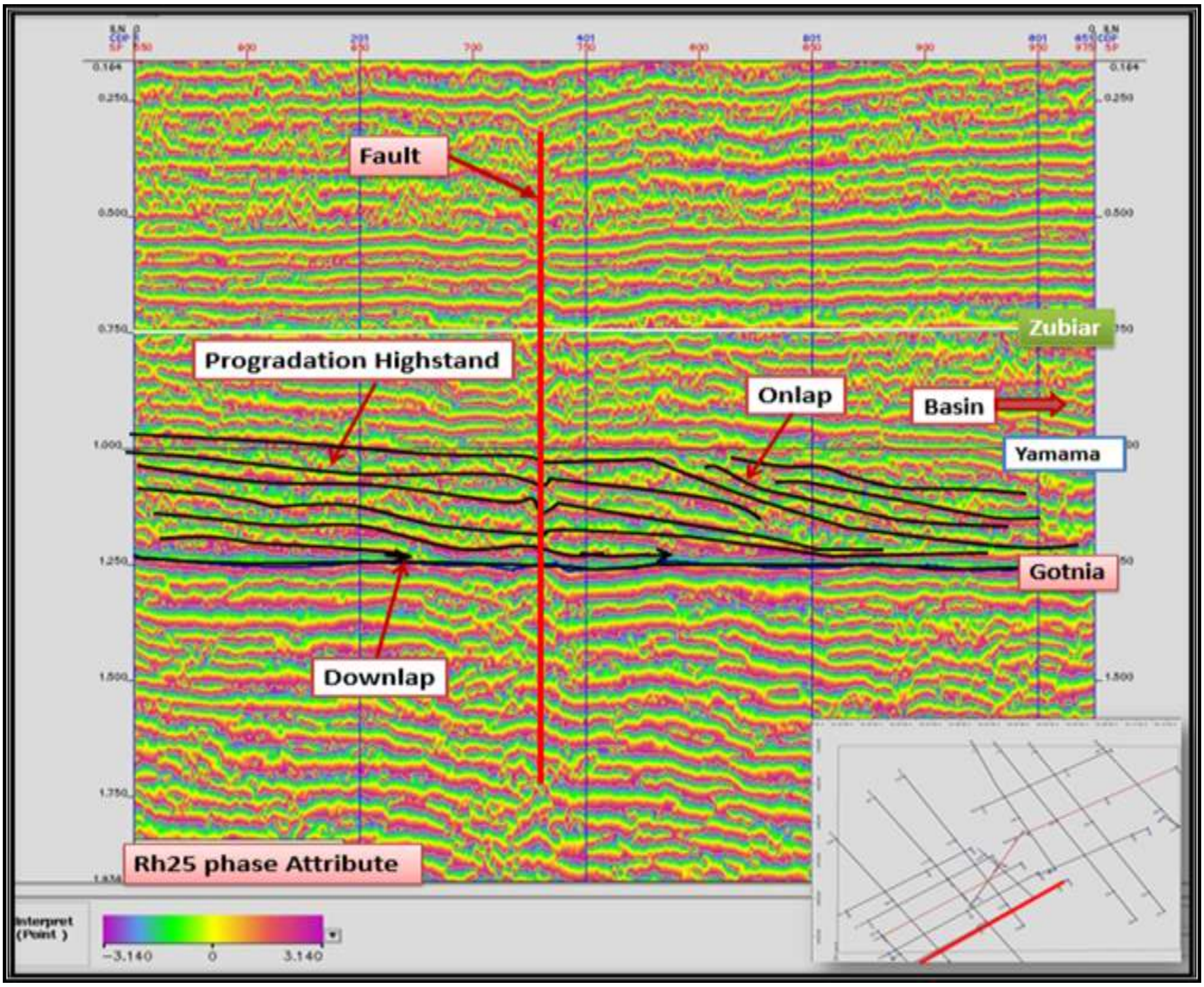

Fig.15: Explain instantaneous phase attribute on the 2D seismic section in the study area.

Seismic Attribute

Seismic attributes is any measure of seismic data that helps us visually enhance or quantify features of interpretation interest [14], and any mathematical transform of the seismic trace data, with or without other accompanying data requirements [15]. The seismic trace represents the variable function between the amplitude and time in the time domain. We can study other characteristics of seismic

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wave function by using the Fourier transform, where we get the amplitude change function with the frequency in the frequency domain. The seismic wave is not only a simple time function but, it is a complex function [16].

All instantaneous seismic attributes (amplitude, phase, frequency) can be used in interpretation. In practice, most interpreters use instantaneous amplitude, or some variations of an amplitude attribute, as their primary diagnostic tool. Amplitude is related to reflectivity, which in turn is related to subsurface impedance contrasts. Thus, amplitude attributes provide information about all the rock, fluid, and formation-pressure conditions. Instantaneous phase is useful for tracking reflection continuity and stratal surfaces across low-amplitude areas where it is difficult to see details of reflection waveform character. In general, instantaneous phase is the least used of the seismic attributes. Instantaneous frequency sometimes aids in recognizing changes in bed thickness and bed spacing [17].

Instantaneous phase

Instantaneous phase is measured in degree ($-\pi$, π) it is independent of amplitude and shows continuity and discontinuity of event, also it shows clear bedding, it is best indicator of lateral continuity and useful to show sequence boundaries. Figure (15) illustrates the application Instantaneous phase attribute at the 2D seismic section, where distinguished the end of the continuity of reflective surfaces, and showing the cases of layer termination (onlap, downlap) represented by progradation high stand, add to that the fault was identified at the seismic section.

Instantaneous Amplitude Sections

This attribute is measured in time and primarily used to recognize regional characteristics such as structure, sequence boundaries, thickness and lithology variations. In some cases, mound, bright and dim spots phenomena. Figure (16) illustrates the application Instantaneous phase attribute at the 2D seismic section, where distinguished three mounds with low amplitude coincided with the three shelves margin of Yamama sequences, which represents hydrocarbon content.

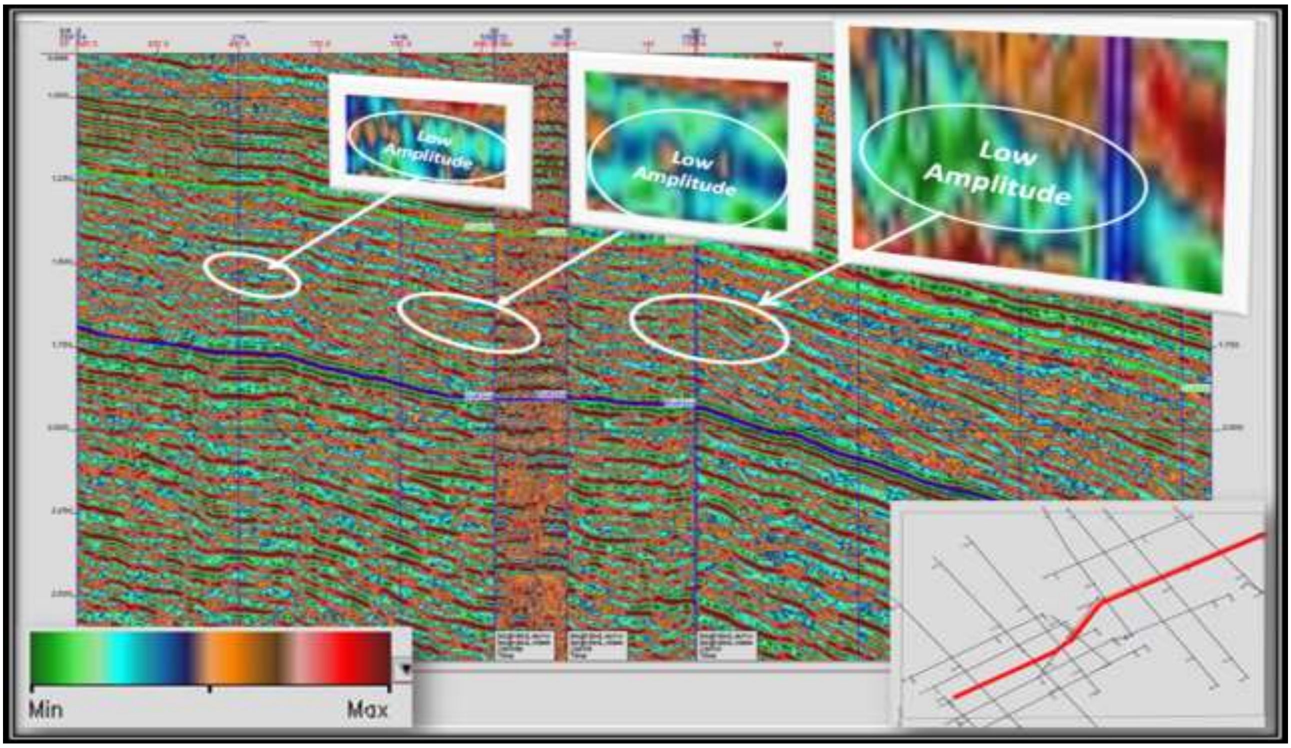

Fig.16: Shows Instantaneous amplitude attribute on the 2D seismic sections (composite).

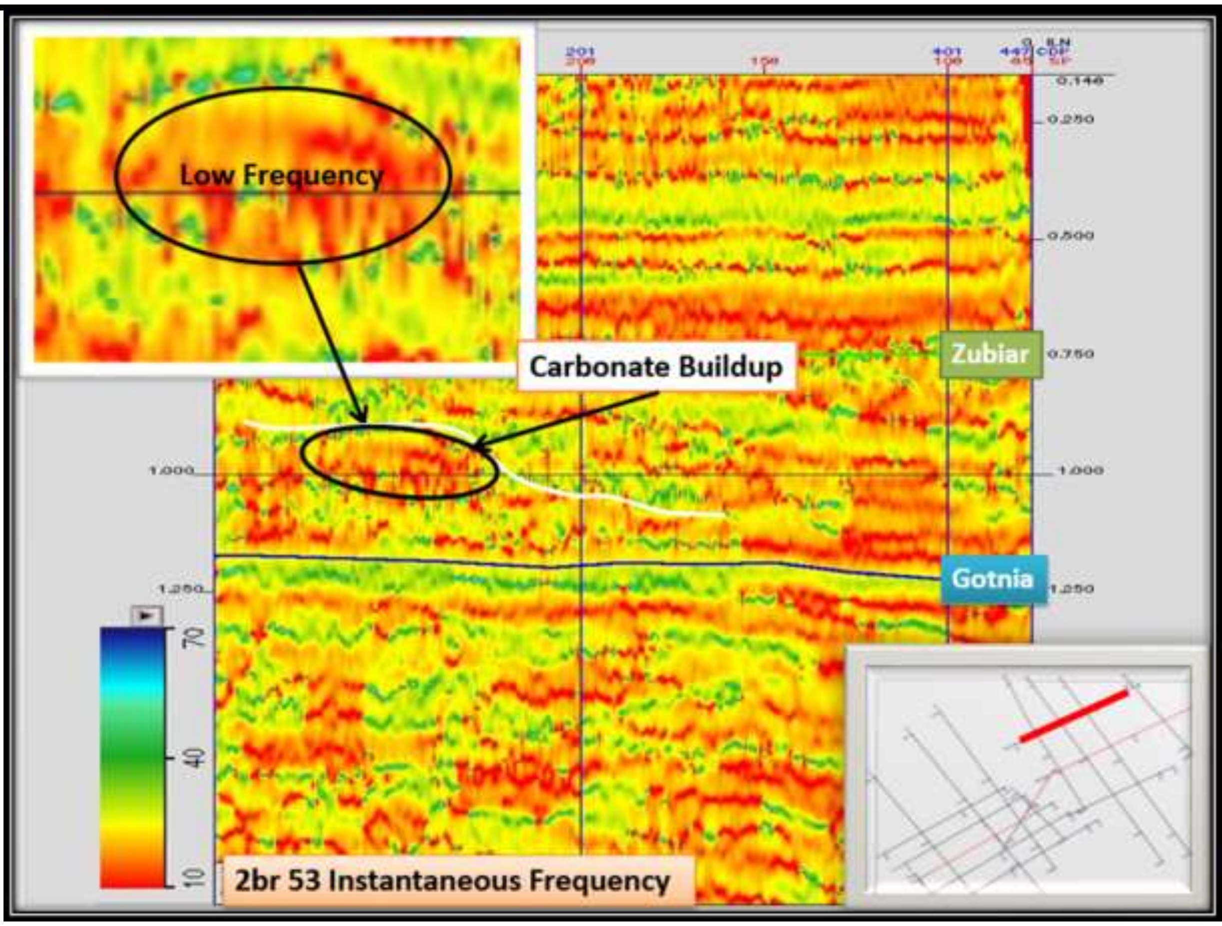

Fig.17: Shows Instantaneous frequency attribute on 2D seismic section of the study area.

Instantaneous Frequency Sections

It is used for visualizing regional depositional patterns. Frequency tuning can indicate changes in bed thickness. The results of the application of attribute assist to determine sites changes Instantaneous frequency and their relationship to changes in petrophysical qualities, is linked frequencies of low-lying areas to zones communities of hydrocarbon.Figure(17) shows a progradation pattern, also a matching is noted between area of low frequency and carbonate buildup which represent the accumulation of hydrocarbon.

Mound

Mound is a seismic reflection configuration interpreted as strata forming an elevation or prominence rising above the general level of the surrounding [8]. They indicate higher energy environments in the basin.

It was Displayed many seismic attributes to explore the stratigraphic phenomena in the area like channel, mound, and unconformity. Figure (18) explains the mound by applied phase attribute photo gray on 2D seismic section. Note that the domes formed through transgressive system tract (TST), where it is deposit during some part of a relative sea level rise cycle can occur progradation and seismic reflection terminate of downlap toward basin. This leads to the accumulation of carbonate material in the shelf margin and be mound.

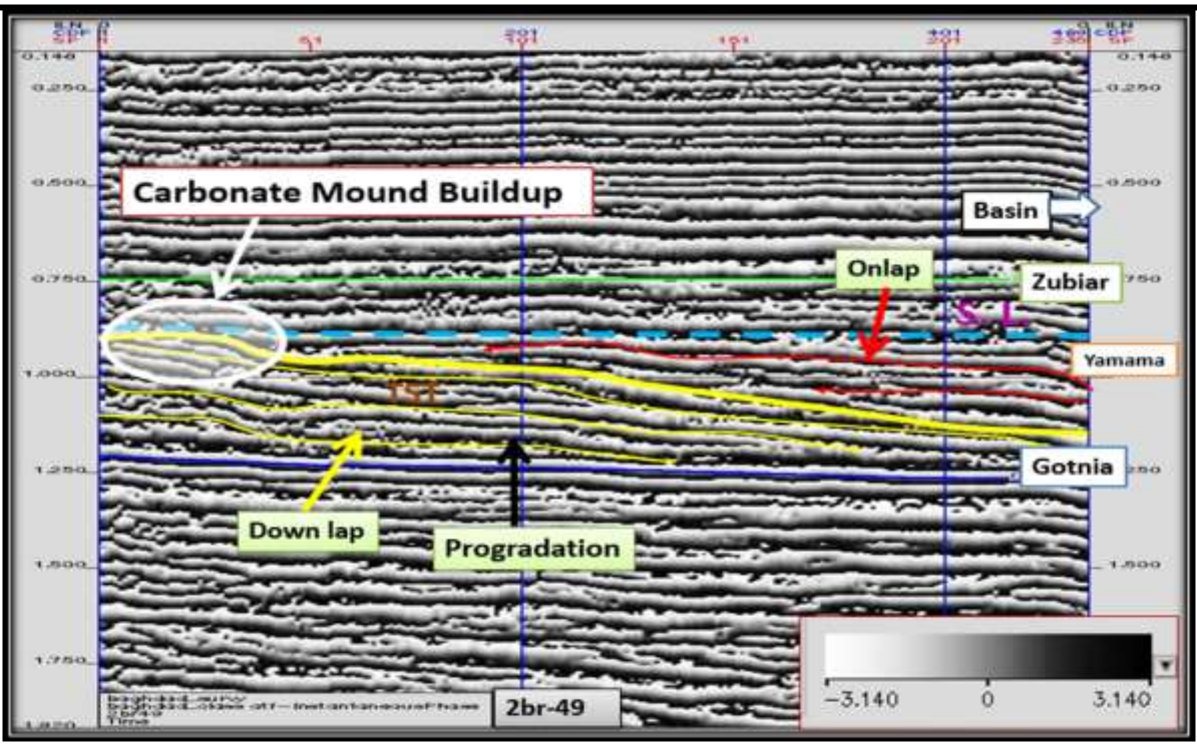

Fig.18: Shows mound on 2D seismic section applied by phase attribute photo Gray in the study area.

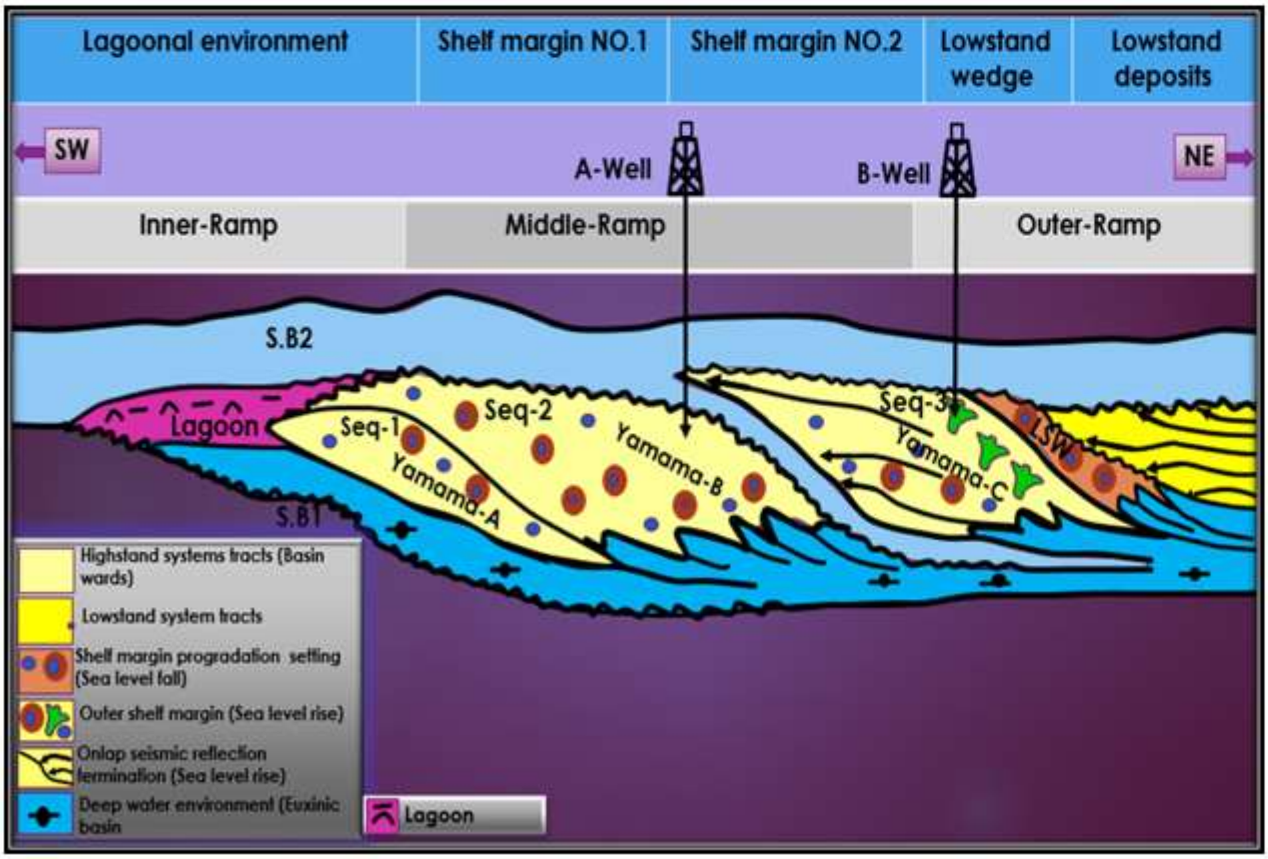

Fig.19: Show the stratigraphy traps and the proposed wells by geological model

Geological model

Geophysical data are best interpreted in tight integration with the geological data. It is combine the most practical and effective geophysical data. 2D geological models are relate with petrophysical properties and 2D seismic section to match the geophysical field data. The structural, formational, and facies modelling software tools ensure that 2D geological models in the context of consistent stratigraphic, and topological framework in addition to

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ensuring consistency between the geological models and geophysical data.

Working with an extensive set of 2D, exploratory data analysis to data security and enhance interpretational insight. Providing results in common 2D formats for the easy communication of ideas. All required link data that work on it to make the best image to the subsurface. Figure (19) shows the best image for geological model that is correspond with the interpreted seismic data in the previous figure (12). On the basis of the stratigraphic interpretation data we were able to identify two of the stratigraphic traps, which explain by A-Well in the sequence-2 of Yamama Formation and B-Well in the Sequence-3 of Yamama Formation. Which is considered promising hydrocarbon traps. Figure(20) shows the phenomena that have been identified and probable traps at the base map of 2D seismic line.

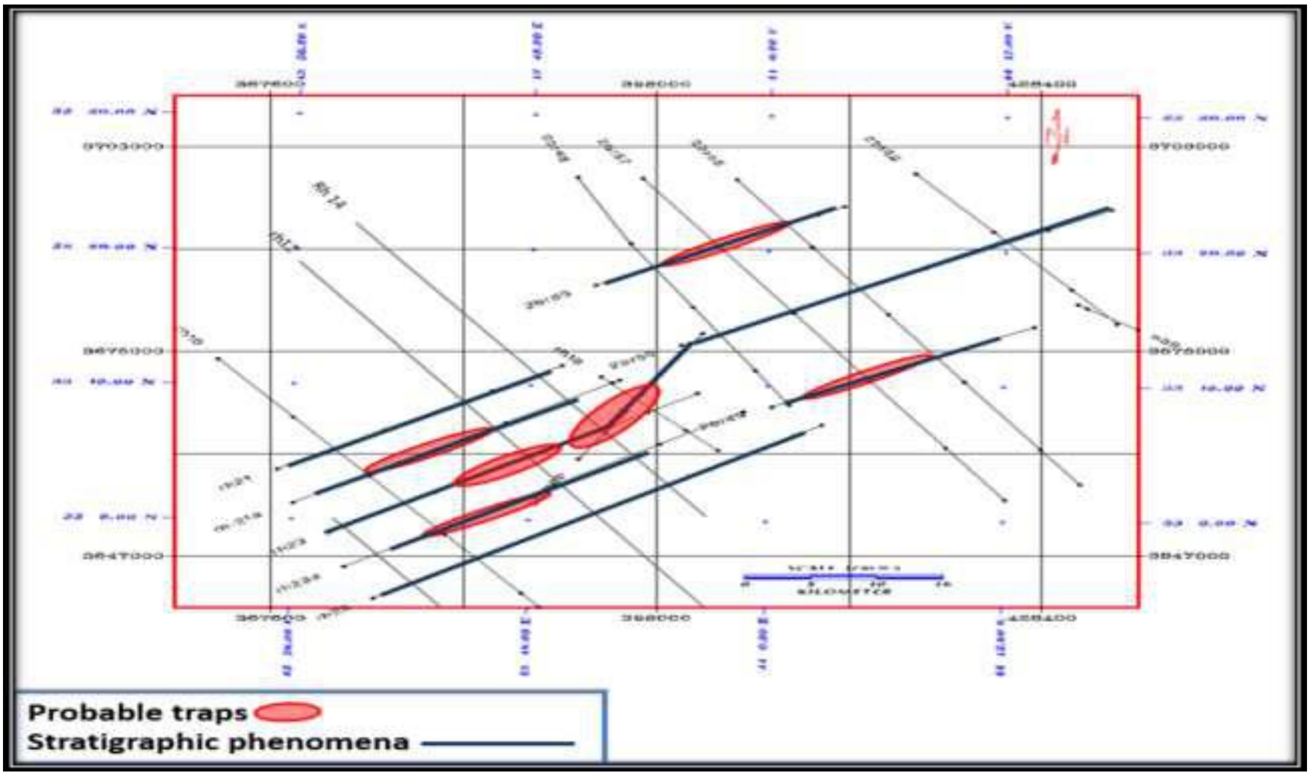

Fig.20: Shows the probable traps that determined from attribute and seismic reflection configuration.

II. CONCLUSIONS AND RECOMMENDATIONS

According to interpretation of 2D seismic data the following are major conclusions of this study:-

1- The TWT, average velocity, depth maps of the studied area interpret the structural picture of East Razazza. The trending of structural noses was toward NW-SE, these noses are compatible with carbonate build up feature, which was identified in the region. Depth maps reveal that the minimum depth values are noticed at the west and gradually increases toward the east and northeast till the middle part of the study area where structural anomalies are observed. The deepening increases from west to northeast, which reflects the transition from the continental slope towards the basin. This is confirmed by the behavior of the TWT and average velocity maps.

2- From studying the seismic section and applying the seismic attributes represented by instantaneous phase, Instantaneous amplitude and instantaneous frequency, discovered locations are considered as carbonate mound build up, which refers to hydrocarbon accumulation.

3- Yamama Formation was interpreted as three depositional sequences representing the base which is an initial lowstand system tracts, remaining to top as carbonate package; it represents the highstand and transgressive systems tracts.Three depositional sequences are identified, which indicate three shelf margin platform due to sea level fall, configured highstand system tracts and terminated by lowstand system tracts, they are regarded promising reservoir.

The geological model that was drawn is the final outcome of the research, where two stratigraphic traps are considered promising exploration targets figure (19).

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We recommend to use three-dimensional surveys to obtain high resolution power to confirm the stratigraphic features on the time sections, study more wells surrounding the studied area and correlate many wells probes, also drilling exploration well on top of shelf margin, is area requires large scale depositional environmental study in order to recognize depositional facies, reservoir facies and site of hydrocarbon kitchen.

REFERENCES

[1] Kearey, P., Brooks, M. and Lan H., **2002**. *An Introduction to Geophysical Exploration*, 3rd ed., Blackwell Science Ltd., 256p.

[2] Dobrin, M., **1976**, *Introduction to Geophysical Prospecting*, 3rd ed., McGraw Hill. Int. co., International Student Edition 386 p.

[3] Coffen, J.A., 1983, *Interpreting Seismic data, Tulsa, Oklanome, 260 P.*

[4] Dobrin, M.B. and Savit, C.H., **1988**, *Introduction to Geophysical Prospecting*, 4th ed. McGraw-Hill Co. 865*p.*

[5] McQuillin, r., Bacon, M, and Barclay, W., **1984**, *An Introduction to Seismic Interpretation*, Graham and Trotman, 287 p.

[6] Bacon, R.S., and Redshaw, T., 2003, *3D Seismic Interpretation, Printed in Unitrd Kingdom at the University press, Cambridge, 212p.*

[7] Gadallah, M.R., and Fisher, r., **2009**, *Exploration Geophysics* ,Verlag Berlin Heidberg, 292p.

[8] Mitchum Jr., R. M., (1977), *Seismic Stratigraphy and Global Changes of Sea Level: Part 11. Glossary of Terms used in Seismic Stratigraphy: Section 2. Application of Seismic Reflection Configuration to Stratigraphic Interpretation, Memoir 26 Pages 205 - 212.*

[9] Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Loutit, T.S., Hardenbol, J., 1988, *An overview of sequence stratigraphy and key definitions. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Sea Level Changes—An Integrated Approach, vol. 42. SEPM Special Publication, pp. 39–45.*

[10] Armentrout, J.M. and B.F. Perkins, 1991, *Sequence stratigraphy as an exploration tool, concepts and practices in the Gulf Coast. SEPM Foundation 11th annual research conference, 417 p.*

[11] Vail, P. R., R. M. Mitchum, Jr., R. G. Todd, J. M. Widmier, s. Thompson, III, J.B. Sangree, J.N. Bubb, W. G. Hatlelied, ,1977, *Seismic stratigraphy and global changes of sea level , in C. E. Payton, ed., Seismic Stratigraphy-Applications to Hydrocarbon Exploration: AAPG Memoir 26, pp.49-212.*

[12] Brown, l. and fisher W., 1984, *Seismic Stratigraphic Interpretation and Petroleum exploration, AAPG, Tulsa Oklahoma, 125 p.*

[13] Parks, D., 2010, *Seismic image flattening as a linear inverse problem, a thesis of master, Colorado school of Mines Golden ,Colorado, CWP-643.*

[14] Chopra, S. and V. Alexeev, 2004, *A new approach to enhancement of frequency bandwidth of surface seismic data. First Break 22 (8), 21–42.*

[15] Hampson, D., Schuelke, J., and Quirein, J. A., 2001, *Use of multiattribute transforms to predict log properties from seismic data: Geophysics ,**66**, 220–236.*

[16] Yilmaz,O., 1987, *seismic data processing, SEG series: Investigation Geophysics, V.2 526 p.*

[17] Hardage, B.A., 1985, *Vertical seismic profiling—a measurement that transfers geology to geophysics. In: O.R. Berg and D.G. Woolverton (Eds), 1985, Seismic Stratigraphy II: An Integrated Approach to Hydrocarbon Exploration,AAPG Memoir No. 39, AAPG, Tulsa, pp. 13–34.*