# Stratigraphic analysis and structural development of Upper Ordovician Muminyat Formation in the El-Sharara oil field of block NC-115, Murzuq Basin, Libya, based on integration of seismic and well data

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## Abstract

This paper presents a structural and stratigraphic interpretation and correlation based on seismic and well data of the Upper Ordovician Muminyat Formation in the El-Sharara oil field of block NC-115 in the Murzuq Basin, southern Libya. The utilization of 3D surveys, which provide three-dimensional representations of structures and thickness, is essential for three-dimensional seismic interpretation. The ultimate goal of the seismic interpretation in this study is to explore the structure and thickness map for Mamuniyat Formation, which lies beneath the surface and study the nature of the rocks in this formation as well as the tectonics, that took place in this formation. In this regard information of detailed geological structure and thickness of the Mumuniyat formation, the relation of reservoir at the El-Sharara oil field to certain sedimentary facies zones is extremely important when developing predictive criteria for searching for hydrocarbons, as well as choosing methods to increase oil recovery.

**Keywords**: seismic interpretation, structure, stratigraphic analysis and petroleum elements

## INTRODUCTION

The general aim of three dimensional surveys is to achieve a higher degree of resolution of the subsurface geology that is achievable by two dimensional surveys. A proper understanding of seismic data is a necessary precursor to successful structural and stratigraphic interpretation. Before horizon tracking commences; the data must be qualified to understand what geologic information extraction is possible. The interpreter must consider data quality, frequency content, resolution, data phase, and data polarity. The interpreter must learn as much as possible about the data acquisition and processing and must determine whether the data are fit-for-purpose and not spend time conducting studies which have no chance of success. Also the interpreter must of course consider the background geology but should not be completely constrained by it; modern 3-D seismic data can under some circumstances dictate a new geologic model. Visualization is important today and always has been. Thinking in three dimensions is a critical ability of seismic interpreters (e.g. Telford, 1976; Khalifa et al., 2017; Khalifa and Mills, 2014, 2022). Three-dimensional seismic data match the dimensions of the data to the dimensions of the earth, and thus make visualization easier. But the greatest benefit of modern 3-D seismic data is their improved quality and resolution. There is typically an amazing amount of geologic detail in seismic data today, and the task of seismic interpretation is to extract it. Noise and spurious events are also present, so that the work of interpretation is to separate the desired geology from the unwanted noise. The better the data quality is understood, the better this separation can be accomplished (Bacon, 2000).

Computer-driven workstations and software are the tools of seismic interpretation, and modern workstations contain an amazing array of capabilities. The challenge of the workstation user is thus to be aware of the possibilities and to select the tool appropriate to the objective. We do not use workstation capabilities only because they are fashionable. So the modern interpreter must integrate not only geology and geophysics but computer-intensive workstation technology as well. Technological synergism reigns but creative pragmatism retains its place (Bacon, 2003).

The earth has always been three-dimensional, and the limitations of the old-fashioned 2-D seismic survey had long been recognized as the fundamental objective of a 3-D seismic survey is increased subsurface resolution. Resolution has both vertical and horizontal aspects and is significantly affected by the methods of data collection and processing (Bacon, 2003).

The resolving power of seismic data is determined by the wavelength, which is defined as the distance in meters or feet from the crest of one reflection to the crest of the next one of the same color (polarity). The wavelength is calculated as the quotient of formation velocity and predominant frequency seismic velocity increases with depth because the rocks are older and more compacted. The predominant frequency decreases with depth because the higher frequencies in the seismic signal are more quickly attenuated. The result is that the size of the wavelength increases significantly with depth, making resolution poorer. The interpreter of a 2-D vertical section normally assumes that the data were recorded in one vertical plane below the line traversed by the shots and receivers, the extent to which this is not depend on the complexity of the structure perpendicular to the line (Bacon, 2003). More recent publications have adopted a seismic reflection data and wireline logs approach in an attempt to develop a predictive understanding of the structural and stratigraphic architecture that has been described at different scales in the geologic record of sedimentary basins worldwide (e.g. Khalifa and Ward, 2009; Khalifa et al., 2017; Khalifa and Mills, 2014, 2022; Richards et al., 2013; Zhang et al., 2015).

The objective of this paper is aiming to give seismic studies of the stratigraphy of the Mumuniyat Formation, the main emphasis is to make on identifying the influence of the sediment formation conditions on the structure and thickness. Through the interpretation of the top and bottom of the Mamuniyat Formation.

## LOCATION OF STUDY AREA

The study area located in the El-Sharara oil field of NC-115 concession within the Murzuq Basin, as shown in Figure 1, it has an area approximately 25000 km$^2$ south of Tripoli, (NC-115) located on the Murzuq Basin, which is a regional intractonic basin in the south west of Libya, the basin lies between structural highs of the Gargaf region to the north, the Tibesti region to the east and the Tempoka Uplift to the west of the basin, is contiguous with the Jado Basin to the south (Elhag, 2016). The Third “Repsol” phase, where kept only the central part of the block with an area of 5000 km$^2$ for development stage, which started in 1993, has been characterized by development of three main fields discovered to date (Aziz, 2000).

Figure 2 show the grid of 3-D seismic section in the area of interest, the area covered by the 3D grid which must be larger than the subsurface area to be imaged, in order to acquire sufficient data for the area of interest. Generally, in order to acquire “full-fold data for an area, source and receiver points must be laid one-half to one mile beyond the boundary of the area of interest. The additional data acquired in this "halo" on the outer edge of a 3-D survey is sometimes called "tails.

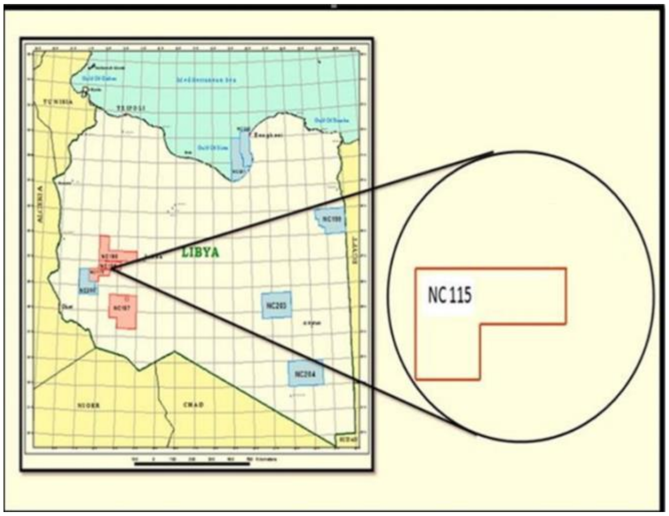

**Fig. 1:** The location of  study area within the El-Sharara oil field in Murzuq Basin

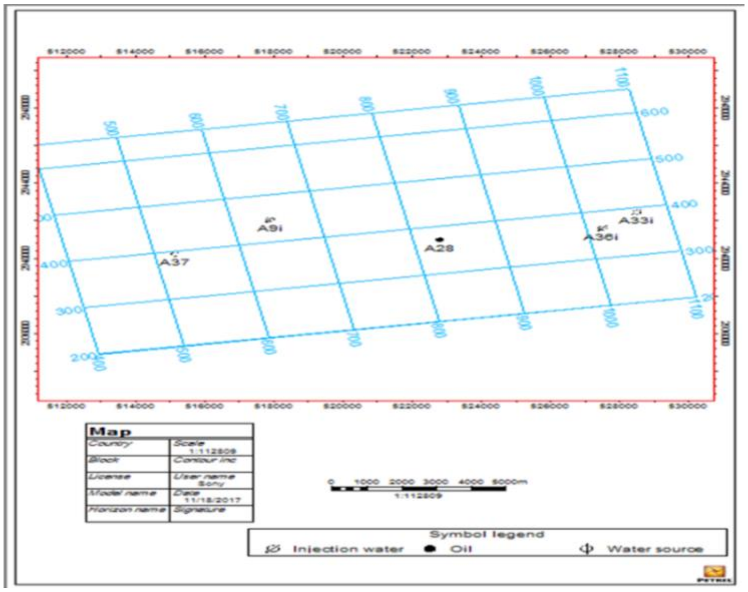

**Fig. 2:** The grid of three dimensional seismic section in the study area.

The quality of the subsurface data at the edge of the survey will not ordinarily be sufficient to map and evaluate the subsurface of these "tail" areas, 3D surveys must be conducted over a large area in order to provide sufficient data for accurate interpretation of the subsurface geology. 3D surveys commonly cover 50 to 100 square miles or more. 3D surveys conducted at different times and covering adjacent areas that later be combined into a single data set for processing and analysis.

## GEOLOGICAL SETTING OF MURZUQ BASIN

The North African platform has multiple intractonic basins, including the Murzuq Basin, which has a surface area of more than 350,000 $km^2$. The current basin geometry has little in common with the much larger North African sedimentary basin that existed during the early Paleozoic. Instead, the present-day boundaries of the basin are defined by tectonic uplifts, each of which was the result of multiple phases of production. Several generation of fault movement are recognized in the basin, but the resultant degree of deformation is relatively minor. The basin contains a sedimentary fill that reaches a maximum thickness of about 4000 m in the basin epi-center which comprises a predominantly marine Paleozoic section and a continental (Aziz, 2000).

The principle hydrocarbon play in the basin consists of a per-glacial sandstone reservoir of Ordovician age sourced and sealed by overlying Silurian shale Figure 3. This play has proved very successful and accounts for approximately 1500 million barrels of recoverable oil discovered to date. Oil generation may have taken place during the Cretaceous time, but further work is required to better define the timing of oil charge (Abdelmoula, 2017). Subsequent regional uplift and erosion have resulted in cooling of the source rocks. This is no longer generated oil over large parts of the basin to the present day (Davidson, 2000).

The Silurian source rock remains within the oil generation window only in a limited area of the basin center. The basin including the Tiririne High separating the Al Awaynat and Awbari troughs and the Traghan High The present-day Murzuq Basin did not develop until the Mesozoic. Prior to that, the Paleozoic basin comprised a series of NW-SE directed highs and lows (Goudarzi, 1967). In general, fault density and structural complexity increase from the southern, more stable parts of the basin, towards the north-eastern and north-western portions,. The most complicated and intensively faulted areas are generally located over the Tiririne and Traghan highs (Echikh and Sola, 2004 ).

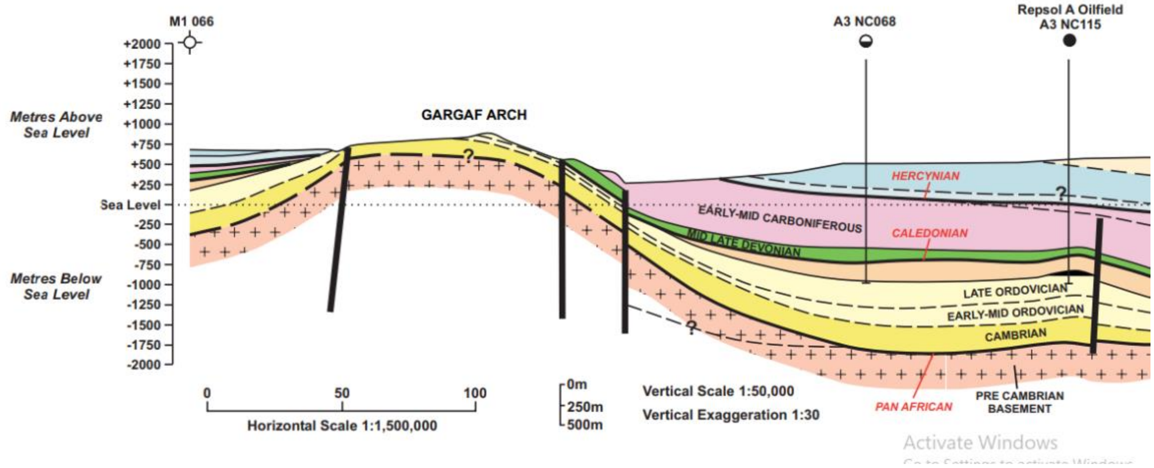

**Fig. 3:** North south geological cross-section of  Murzuq Basin.

## METHODOLOGY

Seismic surveys have become the primary tool of exploration companies in all expecting oil field, both onshore and offshore. 3-D seismic surveys have lowered finding costs and allowed exploration for reserves not locatable by other means, revolutionizing the industry. Below is a non-scientific explanation of how seismic surveys work.

A seismic survey is conducted by creating a shock seismic wave on the surface of the ground along a predetermined line, using an energy source. The seismic wave travels into the earth, is reflected by subsurface formations, and returns to the surface where it is recorded by receivers called geophones – similar to microphones. The seismic waves are created either by small explosive charges set off in shallow holes ("shot holes") or by large vehicles equipped with heave plates ("Vibroseis" trucks) that vibrate on the ground. By analyzing the time it takes for the seismic waves to reflect off of subsurface formations and return to the surface, a geophysicist can map subsurface formations and anomalies and predict where oil or gas may be trapped in sufficient quantities for exploration activities (Telford, 1976; Khalifa and Mills, 2014, 2022). Bearing in mind, the reading errors that can yield between interface because of anisotropic and correcting them for high resolution and proper interpretation (Anwar, 2022).

The area covered by the 3D grid must be larger than the subsurface area to be imaged, in order to acquire sufficient data for the area of interest. Generally, in order to acquire “full-fold data for an area, source and receiver points must be laid one-half to one mile beyond the boundary of the area of interest. The additional data acquired in this “halo” on the outer edge of a 3-D survey is sometimes called “tails.” If, therefore, a landowner’s property is on the outer edge of a 3D survey, the permitting of his land as part of the survey will not be for the purpose of exploring the subsurface of his property, but for the purpose of acquiring a “full-fold” image of the adjacent property nearer the center of the survey figure 4 show this techniques. The quality of the subsurface data at the edge of the survey will not ordinarily be sufficient to map and evaluate the subsurface of these “tail” areas, 3D surveys must be conducted over a large area in order to provide sufficient data for accurate interpretation of the subsurface geology. 3D surveys commonly cover 50 to 100 different but adjacent areas can later be combined into a single data set for processing and analysis, provided there is sufficient overlap of the areas covered by the two surveys (Bacon, 2003).square miles or more. Various 3D surveys spanning a succession of ongoing thoughts on the 3-D migrating portion were undertaken.

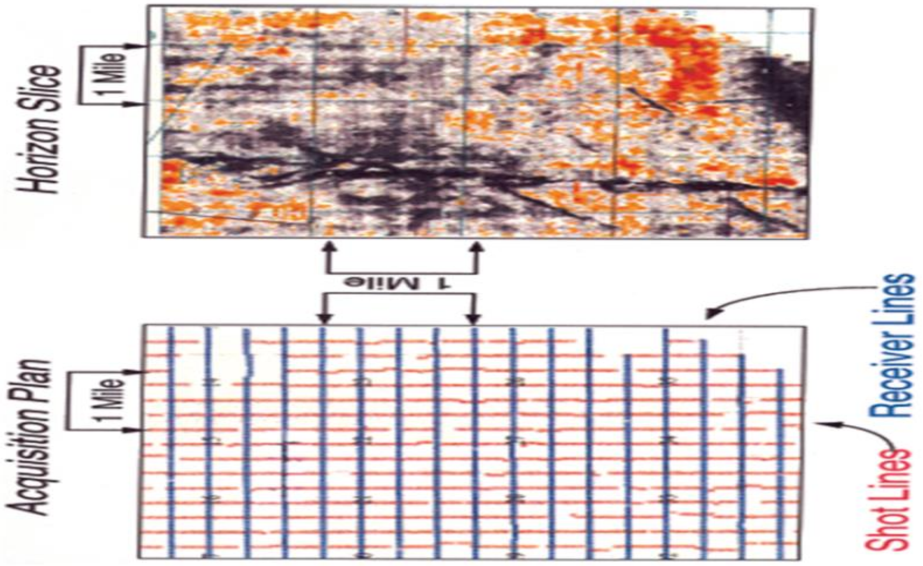

**Fig. 4:** The distribution of source and receivers and how the 3D signal recorded.

## SEISMIC DATA ANALYSIS

The seismic record contains two basic elements for the interpreter to study, the first is the time of arrival of any reflection (or refraction) from a geological surface. The actual depth to this surface is a function of the thickness and velocity of overlying rock layers. The second aspect is the pattern of reflection, which comprises the strength of the signal, the frequencies it contains, and how the frequencies are distributed over the pulse. This information can often be used to support conclusions about the lithology and fluid content of the seismic reflector being evaluated, The interpretation process can be subdivided into three interrelated categories: structural, stratigraphy and lithology. Structural seismic interpretation is directed toward the creation of structural maps of the subsurface from the observed three-dimensional configuration of arrival times.

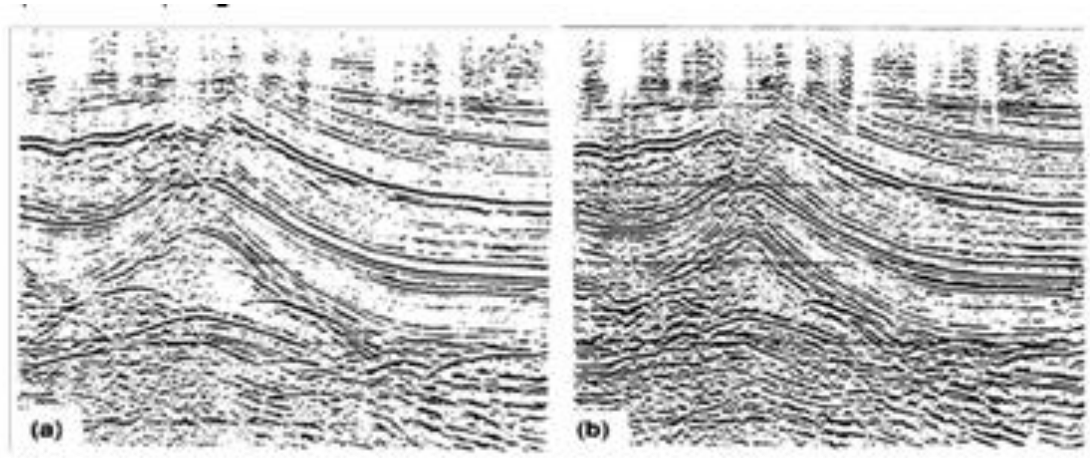

**Fig. 5:** (a) shows no reflection zone on the 2-D migrated section, (b) 2-D migrated section at the same zone .

Three-dimensional migration often produces surprisingly different sections from 2-D migrated sections. The example in Figure 5 (a) and (b) shows a no reflection zone on the 2-D migrated section, while the same zone contains a series of continuous reflections on the 3-D migrated section that are easily correlated with reflections outside that zone, from the field data example, we see that 3-D migration provides complete imaging of the 3-D subsurface geology. Specifically, 2-D migration cannot adequately image the subsurface and introduces mistiest between 2-D lines in the presence of dipping events. However, 3-D migration eliminates these mistiest by completing the imaging process. The difference between 2-D and 3-D seismic methods is the way in which migration is performed. Just having a dense coverage on top of a target zone, for example, a 25-m in-line trace spacing and a 25-m cross-line trace spacing will not necessarily provide adequate subsurface imaging unless migration is performed in a 3-D sense. But one does need the dense coverage to perform the 3-D migration accurately. Also, to be able to map small subsurface features, sufficiently close spatial sampling is needed.

The 3-D data volume is available as vertical sections in both the in-line and cross-line directions and as horizontal sections (time slices). The time slices allow us to generate contour maps for marker. The interactive environment provides an effective and efficient means for interpretation of the sheer volume of 3-D migrated seismic data, fault correlations horizon tracking, horizon flattening and some image processing techniques can be adapted to the interactive environment to help improve interpretation. Since the 3-D volume provides detailed constraints on interpretational decisions. The overall aim of seismic interpretation is to aid in constructing the most accurate earth model or reservoir description possible. This can be accomplished when the seismic data are merged with petro physical, geological, and engineering databases.

The first step in horizon picking is to review the sections of lines that have well intersecting it or runs near it, then integrating seismic sections with borehole data which leads to tying seismic sections to the well data as shown in figure 5, well-seismic ties allow well data measured in units of depth to be compared to seismic data measured in units of time. The subjective science of seismic interpretation within anticline structure we see some geological feature. The anticline crosses an almost horizontal line.

This allows us to relate horizon tops identified in a well with specific reflections on the seismic section, the synthetic trace compared to the seismic data collected on the well location while well velocity survey are used to define the one-way times on the formation tops. Consequently the two-way travel time are calculated and used to define the reflecting formation top on the seismic section. The top and bottom of Mamuniyat Formation is picked by well (A37) and integrated with seismic section of cross line 527 and in line 403 (Figure 6).

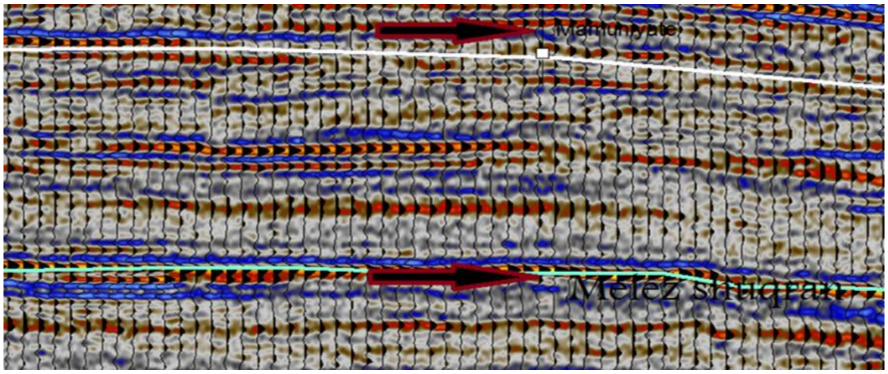

Fig. 6: Seismic section explains to well(A37) and inline (403) , Muminyat Formation.

Previous interpretations of 2D seismic data in NC-115 have concentrated on structural mapping, these data were seen to contain some geological information but this was not systematical interpretation. The resultant seismic coverage approximated to 4 by 4 km grid across much of block, although this becomes courser in places. The interpretation has been performed by using the Petrel- Software with all seismic data normalized with respect to amplitude.

## RESULTS AND DISCUSSION

After the completion of interpretation of all lines the Petrel- software has the ability to tie all section to well data and measure the two-way time for the top and bottom horizons of Mamuniyat Formation from reference surface.

In addition, through the data information of the wells and true depth of Mamuniyat Formation and (TWT) map and known the location of wells, we can calculate (AVR) using the following equation: $AVR = Depth \ X \ (2000 / TWT)$ .

The structure contour map in figure 8 above for the top horizon of Mamuniyat Formation show some closure in the middle with (-3120), However, the Figure 8 down for the bottom of Mamuniyat Formation show a closure with (-4500), which are consists of large diapric anticline ridges and rollover features developed downthrown to major growth faults. The structure contour map are lines of equal thickness in depth over an area, these maps are utilized in hydrographic survey, stratigraphy, sedimentology, structural geology, and petroleum geology.

**Table 1:** Average velocity calculation results for top of Mamuniyat Formation

| **Well Number** | **X Longitude** | **Y Latitude** | **SRD DEPTH (ft)** | **TRUE DEPTH (ft)** | **TWT** (m.sec) | **AVERAGE VELOCTY (ft/sec)** |
|---|---|---|---|---|---|---|
| A9 | 517898 | 2942116 | 5007 | 3537 | -997.65 | 7078.318 |
| A28 | 522796 | 2941028 | 4590 | 3120 | -966.43 | 6454.75 |
| A33 | 528500 | 2942500 | 4990 | 3520 | -1003.3 | 6971.747 |
| A36i | 527500 | 2941650 | 5033 | 3563 | -1015.22 | 7044.704 |
| A37i | 515150 | 2940270 | 5021 | 3551 | -1013.18 | 7028.691 |

**Table 2:** The average velocity calculation results for bottom of Mamuniyat Formation

| **NAME** | **X** | **Y** | **SRD DEPTH (ft)** | **TRUE DEPTH (ft)** | **TWT** (m. sec) | **AVERAGE VELOCTY (ft/sec)** |
|---|---|---|---|---|---|---|
| A9 | 517898 | 2942116 | 6574 | 5098 | -1290.94 | 7898.121 |
| A28 | 522796 | 2941028 | 6040 | 4564 | -1271.75 | 7177.511 |
| A33 | 528500 | 2942500 | 6575 | 5099 | -1321.47 | 7717.163 |
| A36i | 527500 | 2941650 | 6517 | 5041 | -1314.72 | 7668.553 |
| A37i | 515150 | 2940270 | 6470 | 4994 | -1304.94 | 7653.992 |

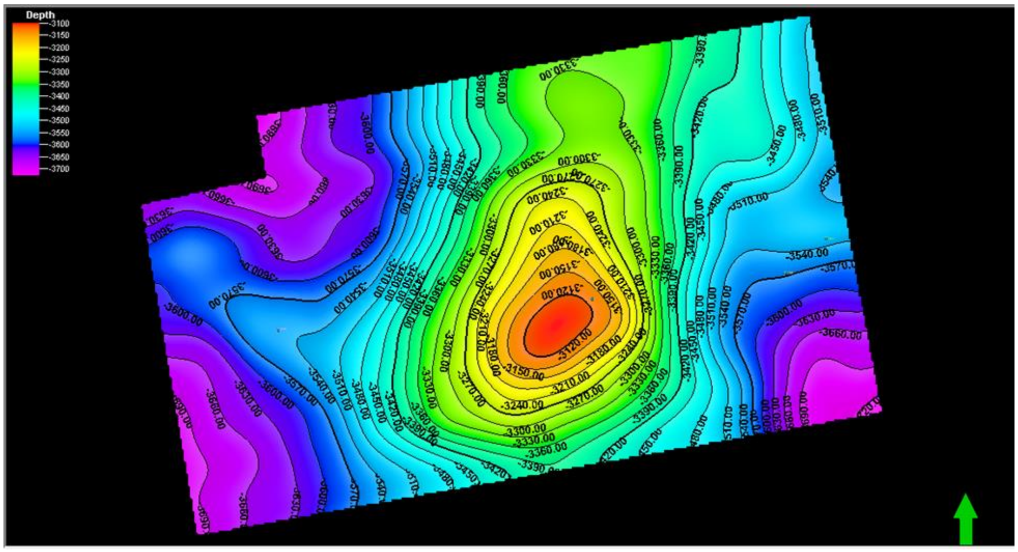

**Fig. 7:** The depth contour map for Top horizon of Mamuniyat Formation

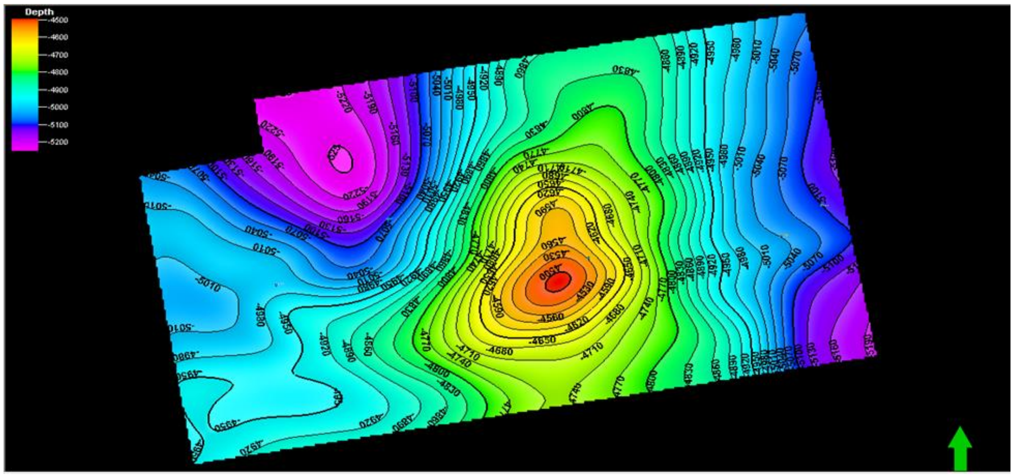

**Fig. 8:** The depth contour map for bottom horizon of Mamuniyat Formation

**Table 3:** Thickness Calculation results for Mamuniyat Formation

| NAME | X | Y | TRUE THICKNESS (ft) | CALCULATED THICKNESS (ft) | ERROR(ft) |
|---|---|---|---|---|---|
| A9 | 517898 | 2942116 | 1567 | 1561.357 | -5.643 |
| A28 | 522796 | 2941028 | 1450 | 1432.518 | -17.482 |
| A33 | 528500 | 2942500 | 1585 | 1562.985 | -22.015 |
| A36i | 527500 | 2941650 | 1484 | 1479.428 | -4.572 |
| A37i | 515150 | 2940270 | 1449 | 1443.825 | -5.175 |

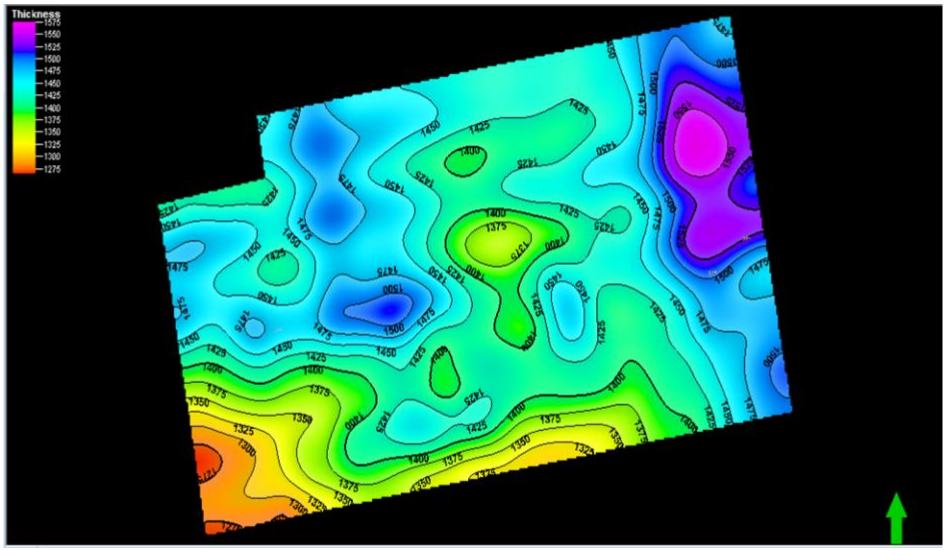

**Fig. 9:** The thickens contour map for Mamuniyat Formation

We have created a map of true thickness or calculated thickness as shown in the Table 3 above, by subtracted the bottom from the top of the Mamuniyat Formation. The thickness of the Mamuniyat Formation (Figure 8) above illustrates the thickness variations within a tabular unit by using the formation on the table 3. It is hold the reservoir system, which allows us the identification of the best regions on the figure 9 above, it shows the highest expression of good reservoir facies with thickness greater than 75ft and a large spread of moderate thickness between the wells A9, A28, A33, A36i and 37i. The reservoir thickness is particularly important because it has a pronounced effect the fraction of the introduced heat that remains in the reservoir, which known as the heat efficiency. For a given petroleum reservoir system illustrated on the structure contour maps above (Figures 7 and 8) specifically on the middle two red closure with 3120 and 4500 has a fixed thickness estimated constrained by seismic interpretation.

The most accurate interpretation for any specific oil or gas field can be prepared only after the field has been extensively drilled and most of the hydrocarbons have been depleted. However, accurate and reliable subsurface interpretations and mapping are required throughout all exploration and development activities.

## CONCLUSIONS

The thickness of the reservoir rock as well as the source rocks and the cap rocks, are very important elements of the petroleum system. The hydrocarbon deposits (Oil, condensate and gas) were accumulated in traps in subsurface reservoirs are usually of gaseous or oily or liquid deposits, under which the formation water of high salinities is helped accumulations. Existence or accumulation of oil or gas needs the presence of the following features which are the representing the hydrocarbon system, these are the source rocks, reservoir rocks, cap rocks and trapping mechanism. The influence of structure and thickness of the petroleum system in this study is quite clear, by analyzing the structure map of the Mamuniyat formation as well as the top and bottom map for the Mamuniyat formation. In this regard information of detailed geological structure and thickness of the Mamuniyat Formation, the reservoir of El-Sharara field, their relation to certain facies zones is extremely important when developing predictive criteria for search for hydrocarbons, as well as when choosing methods to increase oil recovery.

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