Geofísica Internacional (2024) **63-3**: 959 - 975

Using Integrated Seismic Interpretation Methodology in the (Abo-Rabah) Hydrocarbon Structure Field

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Abstract

The purpose of this study is to identify the characteristics of Kurachine Dolomite reservoir rocks (KD), and the Kurachine Anhydrite cover rocks (KA) in the (Abo-Rabah) hydrocarbon field in the Ad-Daw Basin (central Syria). The reservoir and covering rocks, being the most important elements necessary for the presence of hydrocarbon traps. The study focuses on the reservoir Kurachine Dolomite rocks (KD), and the covering Kurachine Anhydrite rocks (KA) in the Abo-Rabah area in the Ad-Daw Basin (central Syria). The mentioned Kurachine formations consider to be favorite traps for hydrocarbon accumulation in the (Abo Rabah) and adjacent area. A litho-stratigraphic model has been proposed for the study field, through analytical integration and interpretation processing. This model reveals differences between litho-stratigraphic relations in the concerned field. Most of significant reflectors in the district were investigated by transmitting the integrated seismic data into geological formations. Two Way Time (TWT) map of the reservoir formation (KD) has been originated. The comparison results of this study are with the previous results. It has been found that, the current prepared time map (TWT) is different from the previous maps, where the current (TWT) seems to be more realistic, because it is based on a larger number of boreholes, that are recently drilled in the study area. So, the reliability of the present results enabled to suggest three new promised hydrocarbon borehole locations favorable for drilling. Also, the current study exposed the relation between the clarity of the seismic signal and the thickness of kurachine anhydrite (KA) cover rocks.

Key words: Abo-Rabah field, Hydrocarbon, Ad-Daw basin, Two-Way Time map (TWT), Anticline, Strato-seismic model, Litho-stratigraphic model, Syria.

Resumen

El propósito de este estudio es identificar las características de las rocas de yacimiento de Kuraquina Dolomita (KD) y las rocas cubiertas de Anhidrita Kuraquina (KA) en el campo de hidrocarburos (Abo-Rabah) en la cuenca de Ad-Daw (Siria central). El yacimiento y las rocas cubiertas son los esenciales para la presencia de trampas de hidrocarburos. El estudio se centra en el reservorio de rocas de Dolomita de Kuraquino (KD) y las rocas de anhidrita de Kuraquino (KA) que cubren el área de Abo-Rabah en la cuenca de Ad-Daw (Siria central). Las formaciones de Kuraquinos mencionadas se consideran trampas favoritas para la acumulación de hidrocarburos en el (Abo-Rabah) y área adyacente. Se ha desarrollados un modelo litoestratigráfico para el campo de estudio, a través de la integración analítica y el procesamiento de la interpretación. Este modelo revela diferencias entre las relaciones litoestratigráficas en el campo en cuestión. La mayoría de los reflectores importantes del distrito se investigaron mediante la transmisión de los datos sísmicos integrados a las formaciones geológicas. Se ha originado el mapa de tiempo bidireccional (TWT) de la formación del yacimiento (KD). Los resultados comparativos de este estudio son con los resultados previos. Se ha encontrado que, el actual mapa de tiempo preparado (TWT) es diferente de los mapas anteriores, donde el actual (TWT) parece ser más realista, debido a que se basa en un mayor número de pozos, que se perforan recientemente en el área de estudio. Por lo tanto, la confiabilidad de los resultados actuales permitió sugerir tres nuevas ubicaciones de pozos de hidrocarburos favorables para la perforación. TA Además, el presente estudio expuso la relación entre la claridad de la señal sísmica y el espesor de las cobertura de rocas de Anhidrita Kuracina (KA).

Palabras clave: Campo Abo-Rabah, Hidrocarburos, Cuenca Ad-Daw, Mapa temporal bidireccional (TWT), Anticlinal, Modelo estratosísmico, Modelo litoestratigráfico, Siria.

Received: January 13, 2024; Accepted: April 26, 2024; Published on-line: July 1, 2024.

Editorial responsibility: Dr. Rafael Ávila

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https://doi.org/10.22201/igeof.2954436xe.2024.63.3.1775

1. Introduction

(Abo-Rabah) Structure is located in the S. Western part of the Ad- Daw Basin, central Syria (Figure 1-a, b). Regarding to (Abo-Rabah) is the largest hydrocarbon field in Ad-Daw basin, where 28 boreholes were drilled in it (Syrian Petroleum Co. 2010).

Seismic interpretations were done in this study to characterize the hydrocarbon (Abo Rabah) field. Many advanced software programs were used to achieve the objects of this study.

Similar studies have been carried out in several districts of the world, by using the same interpretation techniques, that applied in this study, as [GEOFRAME and PETRAL] programs to achieve the seismic sections and originate (TWT) maps. A stratigraphic and structural studies was done in: Khashim Al-Hamer, gas field (Iraq), using seismic reflection data for detecting the sub-surface structures (Khorshid & Owiad 2015). The same interpretation approach was used in Dujaila oil field (s. Iraq), where (TWT) maps of top and bottom reflectors were originated for getting the structural image. Two dome features were localized in mentioned oil field (Abd Al-Reda & Al- Khafajy 2015). Also, in Warka- Zakura (s. Iraq), using (2D) seismic data, (TWT) map has been drawn, depending on the seismic interpretation of the significant reflectors. The study revealed the existence of stratigraphic features in the studied formation favorable for hydrocarbon accumulation (Abd Al-Ridah *et al.*, 2016). A study of Naher Umar and Zubair in oil field (Central Iraq) where seismic interpretations have been done using (3D) seismic data. The structural interpretations of significant reflectors showed a structural anticline (Abd Al-Reidah etal., 2017). Another stratigraphic seismic study was carried out in the E. Razzaza, (central Iraq) to interpret the structural concept of E. Razazza district, by using the (TWT) map of the studied area (Ali *et al.*, 2017). A (3D) seismic interpretation study was done in (T.M) field, W. Niger delta, two horizons were verified by using (TWT) maps, enhanced by using velocity modeling and well- logging data, integrated with the seismic interpretation, in order to increase the choosing reliability of new borehole digging depths (Duru *et al.*, 2018).

In Addition, a Seismic study done in (Portugal) through the geological and geophysical interpretation of (2D) and (3D) seismic data processing of two sub-basins, in anticline structure. The study showed that, the anticline has convenient conditions be possessed of hydrocarbon accumulation traps (Rodrigues, 2018).

A study carried out in (Indonesia) for sub- surface structures and thickness mapping, to identify top and base (Parigi) formation, in (Java) basin, through (TWT) map origination, by the use seismic data interpretation. The study enabled boreholes to be located in the favorable places for hydrocarbon accumulation in the studied basin (Rafiandi *et al.*, 2021). According to the upper mentioned information the main objective of the current study is to overcome the technical difficulties of weak (blur) seismic signals at deep reflectors under the thick burden rock cover and originate a new seismic map with resent available geologic and well- logging data. This new originated seismic map allows to propose favorable locations for hydrocarbon prospecting and borehole drilling.

A similar seismic interpretation methodology was used in Pakistan, to identify hydrocarbon-bearing zones of Rajian area. Time maps of top Paleocene (Eocene) formations indicated the presence of positive structures in the study area (Ahmad *et al.*, 2021).

a. Inset Map of tectonic units in Syria (Syrian Petroleum Company, 2010).
b. The distribution of the structures of the Ad- Daw Basin, shows the location of the (Abo-Rabah) anticline structure (Syrian Petroleum Company, 2010).
c. Inset map shows the Geological outcrops in the (Abo-Rabah) anticline (Ponikarov, 1964).
d. Columnar litho- sequence, shows the geological formations of the (Abo-Rabah) anticline structure (Syrian Petroleum Company, 1997).

2. Regional setting

2.1. Geology

The study area characterized mainly by carbonate Cretaceous rocks, which cropped out in the central part of the (Abo-Rabah) anticline structure, where they are completely surrounded by belts of high ridges of Paleogene formations, which consists of chalky limestone alternating with marls and clay beds. (Figure 1-c) (Ponikarov, 1958- 1964).

These formations are covered by the Neogene rocks that are basically formed of conglomerates, sandstones and siltstones. The southern and western sides of the structure are formed intermountain sub-basins filled with thick erosional deposits (alluvium, clay, loam and sandy loam) of Quaternary age.

The subsurface geology litho- facies of the (Abo Rabah) district classified by (Syrian Petroleum Co., 1997 as follow table (top- down):

2.2. Structure

(Abo Rabah) is an elliptical dome- shaped anticline. This anticline is considered as one of the most significant and largest structure in the Ad-Daw basin. It extends longitudinally in line with the Palmyride folding zone. This kind of structures gave a belt form of high ridges separated by intermountain sub-basins, filled with thick erosional deposits. (Abo Rabah) anticline

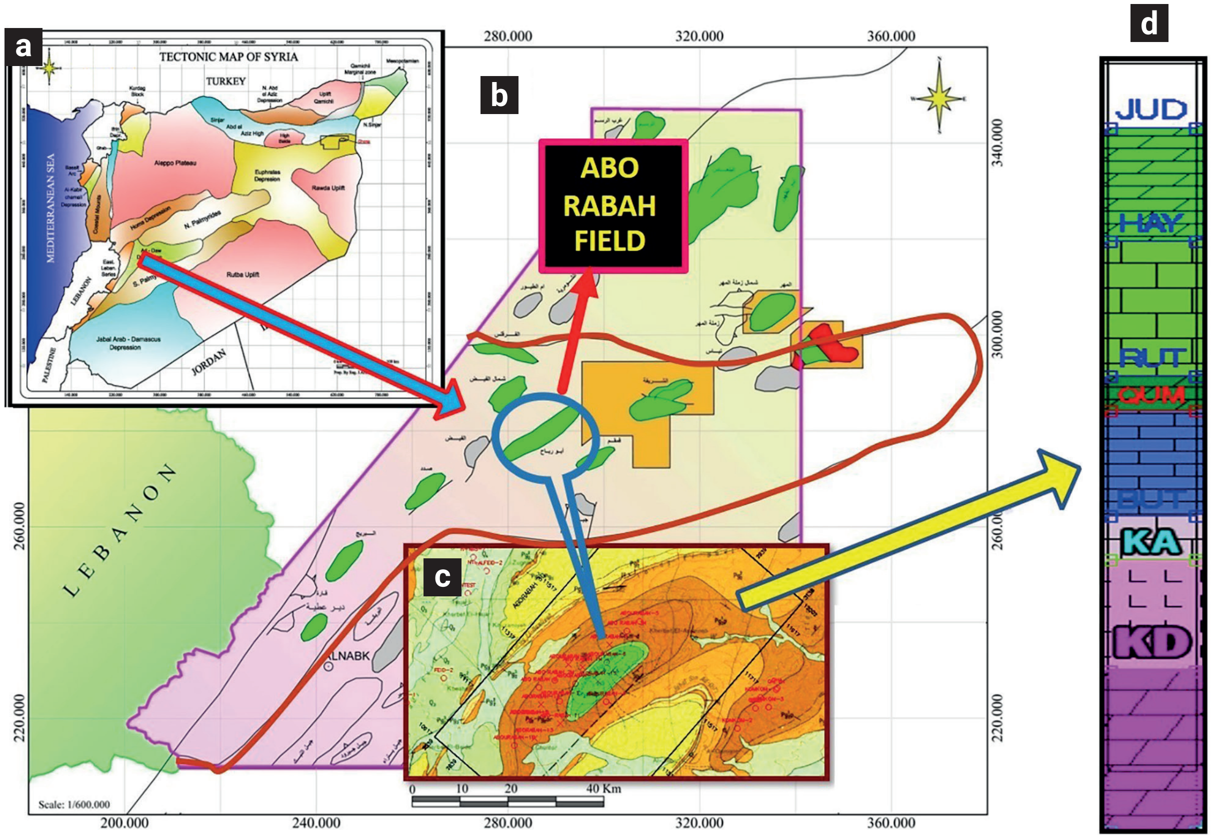


Figure 1. Explanation maps of Syria. a) Inset Map of tectonic units in Syria (Syrian Petroleum Company, 2010). b) The distribution of the structures of the Ad- Daw Basin, shows the location of the (Abo-Rabah) anticline structure (Syrian Petroleum Company, 2010). c) Inset map shows the Geological outcrops in the (Abo-Rabah) anticline (Ponikarov, 1964). d) Columnar litho-sequence, shows the geological formations of the (Abo-Rabah) anticline structure (Syrian Petroleum Company, 1997).

Table 1. Classification of litho-facies in the (Abo Rabah) structure (Syrian Petroleum Co., 1997).

Era	Period	Stage	Formation	Sym.	Litho- facies description
Mesozoic	Cretaceous	Up.	Judea	Jud	Dolomite with limestone intercalated streaks, flint bands.
			Hayan	Hay	Clayey limestone intercalated with thin dolomitic limestone streaks, thin bedded of anhydrite and flint.
		Lo.	Rutba	Rut	Intrusive of volcanic tuff, sandstone, sands with some limestone streaks.
Mesozoic	Jurassic				
		Up.	Quam	Qum	Limestone interbedded with dolomite and anhydrite.
			Shoka		
		Mid.			
		Lo.	Butmah	But	Dolomite, limestone intercalated with streaks of shale, clay and anhydrite.
Mesozoic	Triassic	Up.	Kurachine	KA	Anhydrite (thick beds), limestone, shale, salt sequences intercalated with gypsum streaks (cover rocks).
			Anhydrite.		
					D2 Impermeable limestone with dolomite streaks.
		Mid/Lo.	Kurachine	KD	Limestone separating layer in between D2/D1.
			Dolomite.		D1 Fractured limestone with dolomite streaks intercalations.
					C2 Limestone and dolomite i streaks with clay, shale and anhydrite intercalations (reservoir rocks).

structure began to take on the shape since the Paleozoic age (Barazangi *et al.*, 1990), which it influenced by pulling and pushing tectonic movements, where it is bounded with NE-SW and roughly E-W orientation trending faults (Ponikarov, 1964), (Technoexport, 1974). The Kurachine Dolomite (KD) and Kurachine Anhydrite (KA) formations are considered to be the reservoir and cover formations respectively in all rock formations of the Ad- Daw Basin, including (Abo-Rabah) anticline structure, (Figure 1).

3. Data and methodology

This study is original and subsequent to previous studies. As for the applied methodology, it is the same methodology that has been applied in previous studies. However, it is distinguished from them in two points:

1. More boreholes data is used in this study, as a result of the increase in the number of drilled boreholes in the study area, which increases the accuracy of the results.
2. This study has new interpretation model from the point of view of the interpreter.

Noting that collecting previous exploration data for the study area gives an important insight into the importance of the methods that are used in seismic interpretation processes, in addition to highlighting the development of results over time.

The seismic technique is one of the unique geophysical methods are used in geological sounding and exploration. This seismic technique is known as a physical mathematical tool means for geo- exploration (Nomokonov, 1990), which bases on studying the propagation of the artificially generated wave in the sub-surface rock sequence to identify the litho- characteristic. Waves propagate in the sub-surface rock in two ways: check shot and Vertical Seismic Profile (VSP) (Fayoumi, 2003). The check shot method is done by placing an energy source on the ground surface, as nearest to the borehole, and fixing the seismic geophones inside the borehole (Aldonia, 2002), this procedure done to measure the wave field velocity of the rock layers between the source and the geophones, by recording the arrival times of direct energy. The processing of generated waves and stacking the records must done repeatedly to improve the seismic signal and to attenuate the noise. After returning the measured times data to the vertical time, and attributing them to a comparison plane (Fayoumi, 2003). These recorded data are use in addition to measure the wave field velocity, for delineating the depth-time (T-Z) curves, to determine the top parts of formations (Aldonia, 2002).

The Vertical Seismic Profile (VSP) is a technical method, used for recording the direct and reflected waves. It is this the most useful technique for measuring seismic reflected waves. So, this technique has capability to distinguish between descended and ascended waves (Schlumberger, 1996). So, studying the transmitted and received wave vectors, allows to originate the changes of the seismic wave field related to the depth. Thus, the seismic waves of the rock characteristics can be directly connected with the sub-surface rock structures.

However, there are many ways enable to carry out these types of survey methods.

- One of them done by fixing the seismic source on the ground surface near the borehole and moving the geo-phones (it so called VSP with zero spacing method), which it provides a limit lateral information.
- The other one called (spaced vertical seismic planning method), where the seismic source is moved, while the geo-phones are fixed. This method provides a greater possibility of lateral coverage than the other one (Schlumberger, 1996).

The VSP results are used to:

= Distinguish and characterize the deep seismic reflectors.
= and to correlate the reflection planes of the seismic section on the ground surface, with the physical properties of the rock from that measured inside the borehole. These surveys allow also the follow-up of the structural and stratigraphic sequences for hundred meters distance around the borehole (Schlumberger, 1996).

The generated seismic waves, where propagate in the sub-surface rock sequences in all directions (spatially). So, when these waves reach the surfaces of different rock layers, they can be distinguished depending on their acoustic and/or velocity impedance, then they are reflected, refracted, and sometimes scattered. Part of this wave energy returns to the ground surface, where it is received (picked up) by special seismic geo-phones designed for this purpose. Then, delineate the rock- type sequences (limestone, salt, …), features, their placement depths and in special cases, from whose surface these waves were reflected. Also, identifying the period of time taken during their propagation in the adjacent rocks, by studying the nature of these waves, (Naser and Ahmad, 2003).

The seismic method, based on the double time taken by measuring waves transmission from source to the rock sequences and back again to the geo-phones. (Fayoumi, 2003). The seismic sections are therefore, interpreted as double time sections and drown as Two-Way Time (TWT) maps. It was widely applied in the Syrian territory through many geophysical companies, which allowed to attain a satisfied results s (Al-Bezreh, 2002).

The periods of seismic works obtained in Syrian districts are summarized in three stages (Al-Bezreh, 2002):

- 1st stage: Extends in period between [1935-1965]. The seismic studies covered the N. and N. E. districts of country, by using reflected waves methods, with normal single coverage.
- 2nd stage: Extends in 1980s, where the seismic field works have been carried out, by using the common reflecting point method with multiple coverage, processed by digital computers.
- 3rd stage: In 1990s, where the three-dimensional seismic sounding method (3D) used in the seismic surveys. Syrian has been divided in survey work into a group of sectors, some of them have been handed over under contracting by different foreign companies (French, American, etc...). So, lots of hydrocarbon fields were discovered. Where the Ad- Daw basin one of them, in which the (Abo-Rabah) hydrocarbon field is located.

Also, several two-dimensional (2D) surveys have been carried out in the (Abo-Rabah) hydrocarbon field during successive periods of time. Where a difference in field survey works and processing methods from each other. (Syrian Petroleum Company, 1997-2021). Then, the (Abo Rabah) field is already covered by a group of 43 interpreted survey lines, through different survey programs as, (CH-AR-QMS-QMW-QM) (Figure 2).

Furthermore, many seismic research studies have been carried out in the (Abo Rabah) and adjacent area, where a time and depth maps are processed as a result of these researches, which that exposed the geological and tectonic characteristics of the KD formation. Depending on available resulted data of many seismic studies done by (Syrian Petroleum Co. 2011, 2016 and 2018) on (Abo Rabah) anticline structure. The following obtained and proceeded time maps presented the (Abo Rabah) anticline structure shape with NE-SW orientation which broken by two main faults and two secondary ones (Figure 3 and 4). The final time map done by (Syrian Petroleum Co. 2018) showed the (Abo Rabah) anticline shape and orientation, where cut by four main and five secondary faults. That dived the study area into a number of fault blocks (Figure 5). At that time about the (Abo Rabah) gas structure. Syrian Petroleum Company carried out in 2011, a seismic study in the (Abo Rabah) structure. Accordingly, the following time map representing the hydrocarbon-bearing (KD) reflector has been prepared for the study area (Syrian Petroleum

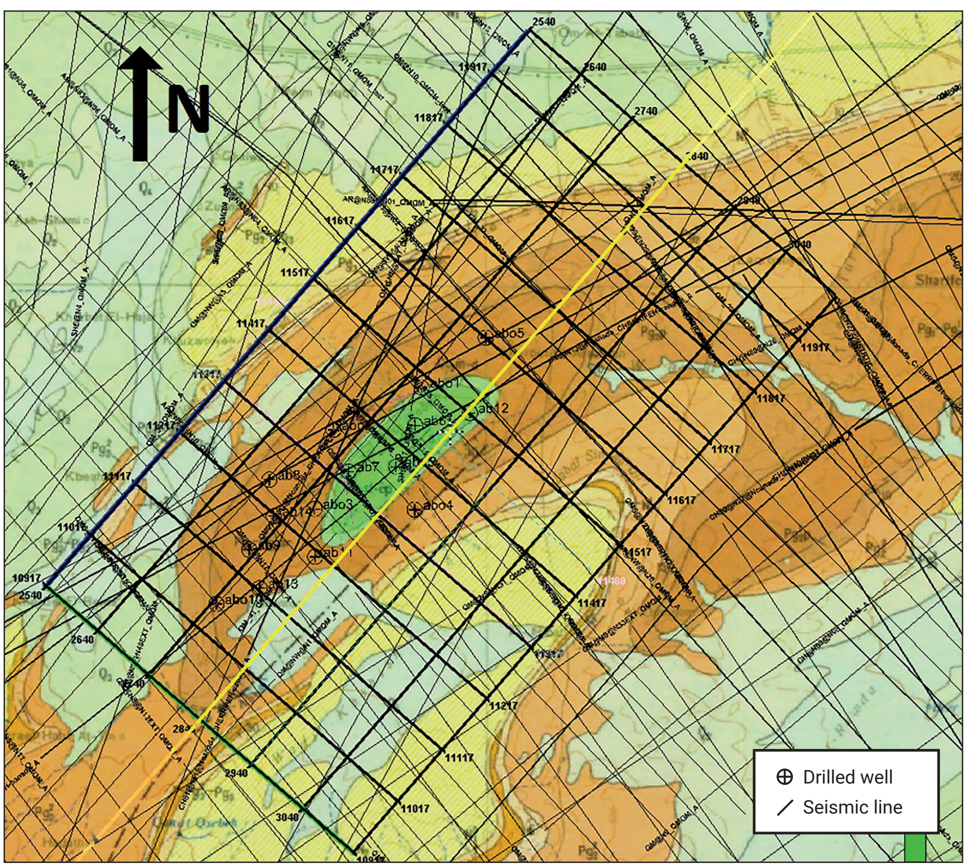


Figure 2. Well Locations and Seismic Survey Lines in Abo Rabah field (Ponikarov, 1964).

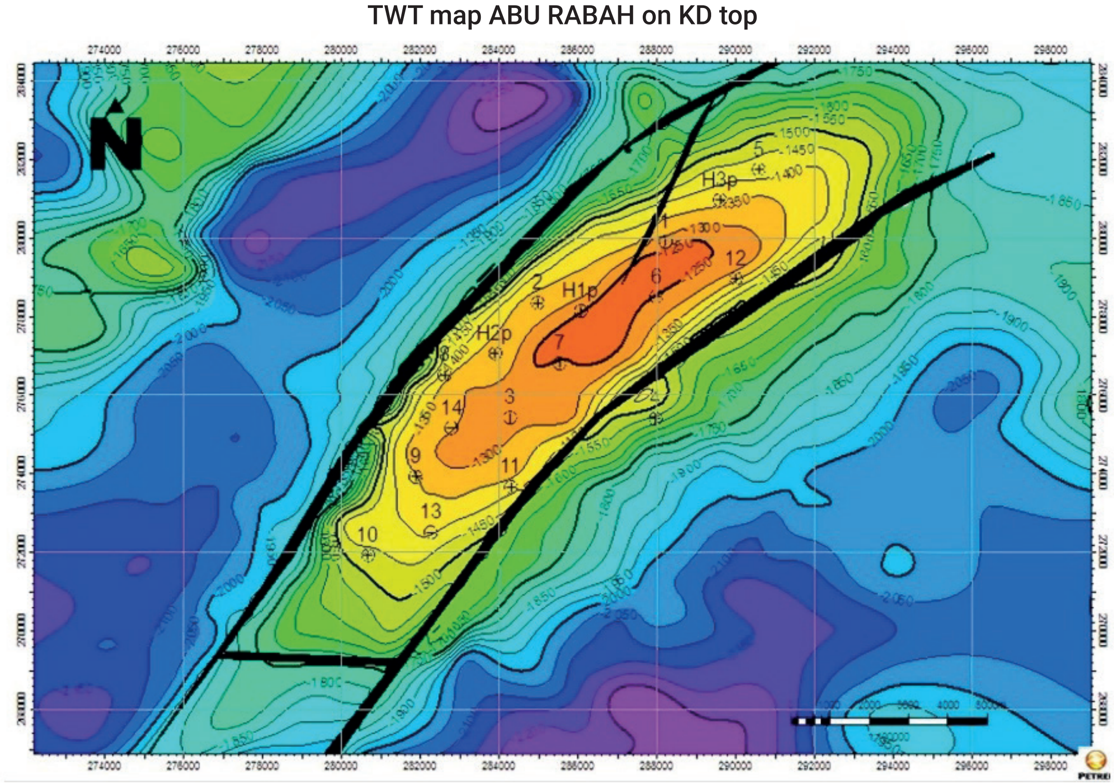


Figure 3. Time map of the (KD) formation in the Abo Rabah field (Syrian Petroleum Company, 2011).

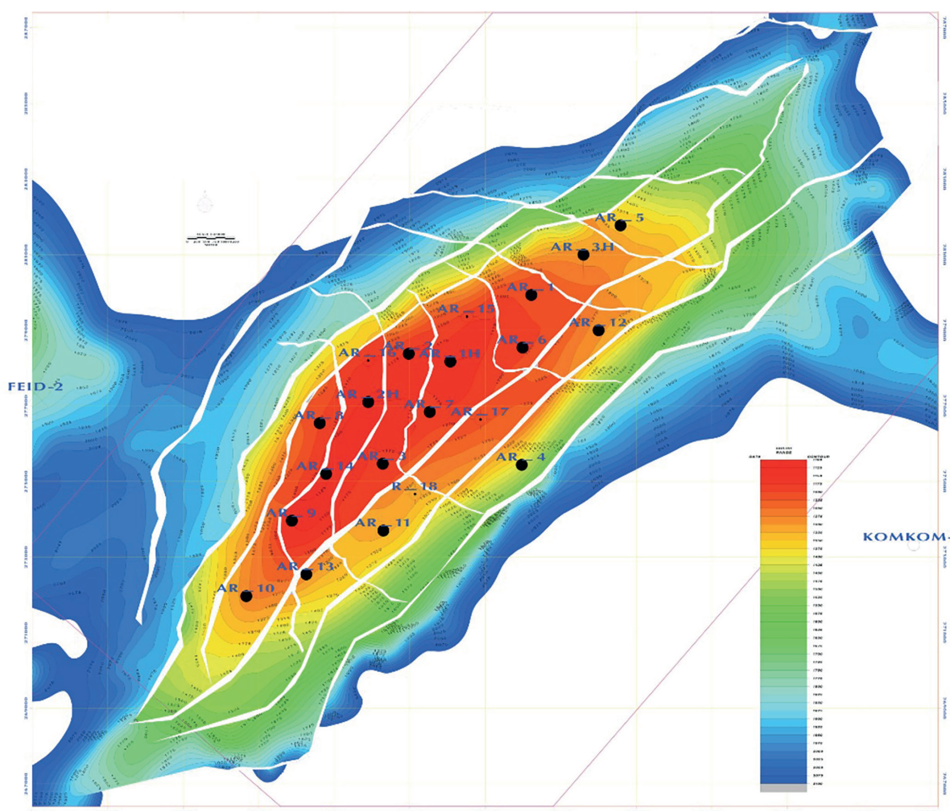


Figure 4. Time map of the (KD) formation in the Abo Rabah field (Syrian Petroleum Company, 2016).

Company, 2011) as shown in (Figure 3). The structure of (Abo Rabah) is represented in an elongated shape trending NE-SW, and bounded by two major faults and two secondary ones (Figure 3).

An implementation of a new study has been carried out in 2016, by which, a time map of the (KD) reflector in (Abo Rabah) has been also originated (Syrian Petroleum Company, 2016), as illustrated in (Figure 4). This map shows the structure of (Abo Rabah) in an elongated shape in the direction of NE-SW, and pounded by major and secondary faults, dividing the study area into a number of fault blocks (Figure 5).

4. Analysis and results

The aforementioned seismic survey lines are reinterpreted in this study. According to the clarity degree of the seismic signal. The quality of the processed seismic data is classified the clarity as [good, moderate, and weak (blur)]. During the seismic interpretation procedures, main technical difficulties encountered as the seismic signal attenuation at deep reflectors. Particularly in the Kurachine Dolomite (KD) reflector. Therefore, these difficulties being overcame by integrating the available seismic data

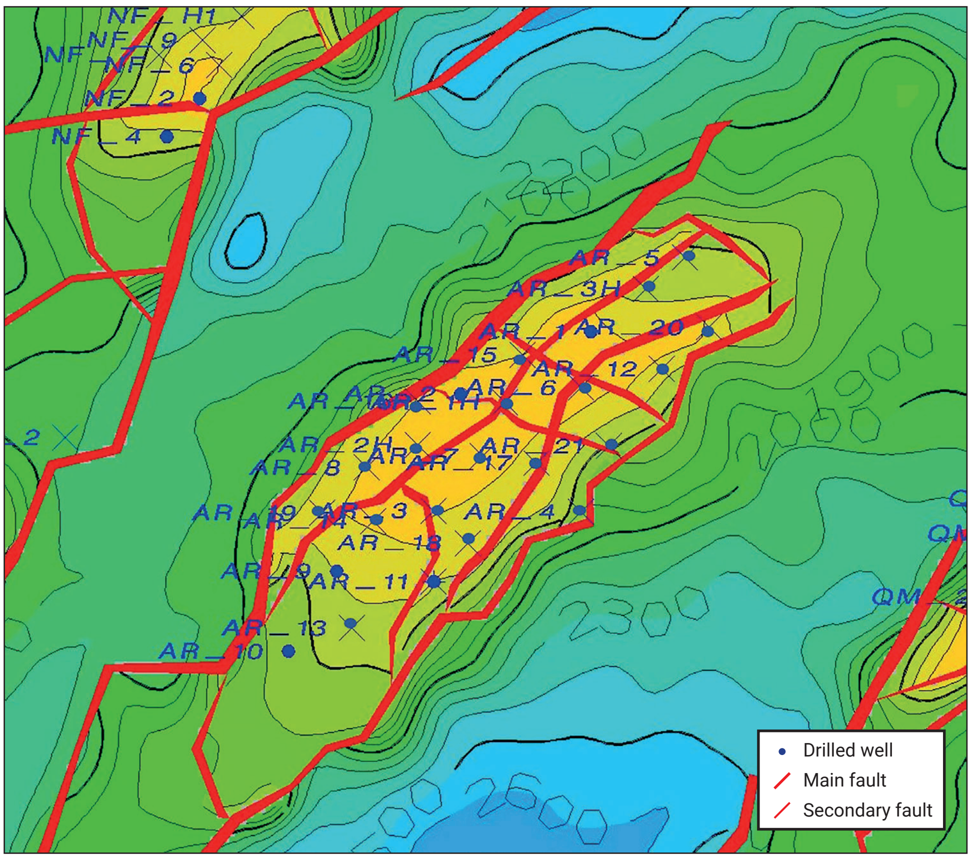


Figure 5. Time map of the KD formation in the Abo Rabah field (Syrian Petroleum Company, 2018).

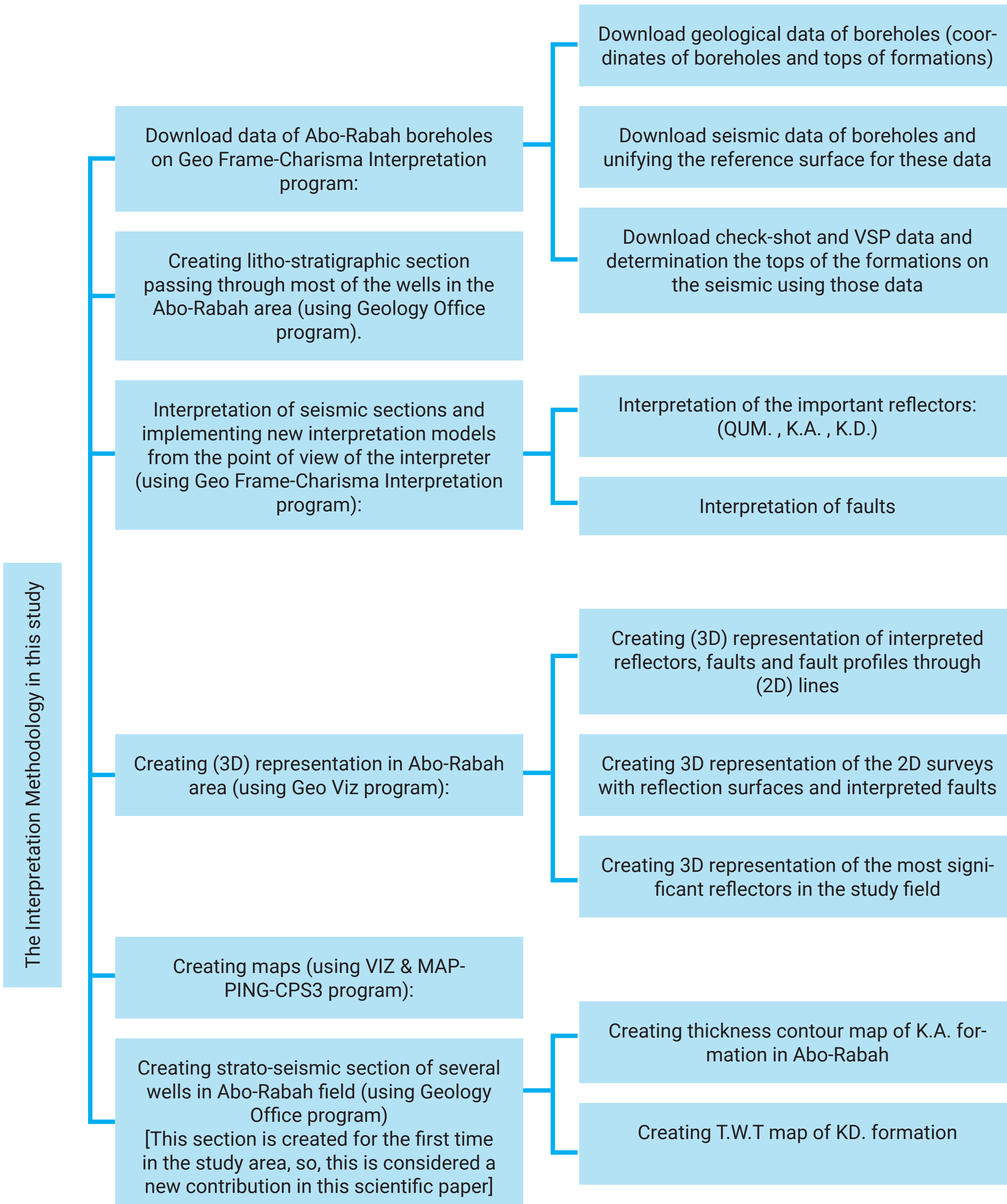
with geological information that taken from the drilled boreholes to prepare a modified concept of seismic methodology for (Abo Rabah) anticline hydrocarbon field. The use of methodology enables to make a comprehensive concept for geological and structural characteristics of Quamchouka (Qum), Kurachine Anhydrite (KA) and Kurachine dolomite (KD) formationsin of the study area by:

- Studying the extending and thickness variation of these formations.
- Analyzing the effect of thickness parameter of the clarity degree on the reflectors of formations.

The interpretation methodology, which is used in this study, can be clarified by the following flux diagram (in addition to highlighting the new contribution of this study):

Diagram 1: Flux diagram of the interpretation methodology, which is used in this study.

The proposed methodology basics in this approach are summarized as follow.


The Interpretation Methodology in this study
Download data of Abo-Rabah boreholes on Geo Frame-Charisma Interpretation program:
Download geological data of boreholes (coordinates of boreholes and tops of formations)
Download seismic data of boreholes and unifying the reference surface for these data
Download check-shot and VSP data and determination the tops of the formations on the seismic using those data
Creating litho-stratigraphic section passing through most of the wells in the Abo-Rabah area (using Geology Office program).
Interpretation of seismic sections and implementing new interpretation models from the point of view of the interpreter (using Geo Frame-Charisma Interpretation program):
Interpretation of the important reflectors: (QUM. , K.A. , K.D.)
Interpretation of faults
Creating (3D) representation in Abo-Rabah area (using Geo Viz program):
Creating (3D) representation of interpreted reflectors, faults and fault profiles through (2D) lines
Creating 3D representation of the 2D surveys with reflection surfaces and interpreted faults
Creating 3D representation of the most significant reflectors in the study field
Creating maps (using VIZ & MAPPING-CPS3 program):
Creating strato-seismic section of several wells in Abo-Rabah field (using Geology Office program)
[This section is created for the first time in the study area, so, this is considered a new contribution in this scientific paper]
Creating thickness contour map of K.A. formation in Abo-Rabah
Creating T.W.T map of KD. formation

4.1. Litho-stratigraphic analysis

25 vertically and 3 horizontally drilled boreholes, where located on (Abo Rabah) anticline structure by using [GEO- FRAME DATA MANAGER] program. All the upper mentioned boreholes passed through the following formations (Jud, Hay, Rut, Qum, But and KA) and penetrate the Kurachine dolomite (KD) formation. So, all data were loaded by the [GEO-FRAME- GEOLOGY OFFICE] program, making by that, a correlation between the most of litho- stratigraphic data of (Abo Rabah) boreholes. The processing correlation of litho- stratigraphic section revealed, there are slight changes in the thickness of formations. While, the (KA) formation thickness has large variations ranges between [90- 1000] m (Figure 6). Also, a [GEO-FRAME-SEISMIC-IMAIN] program was used to download and standardize all the former (2D) surveys data (Barragan, 1991) to a single seismic reference level of 600 m Datum planes.

4.2. Seismic attribute analysis

4.2.1. Determining the top parts of geological formations on seismic lines

The tops parts of the geological formations, that penetrated by the drilling boreholes. They were identified with available two-dimensional (2D) seismic survey lines in the study district (Syrian Petroleum Company, 2007). The [GEO-FRAME-SEISMIC-IMAIN] program is used for this purpose to deal with the digital check shot survey data, (table.2) (Syrian Joint Company for well services, 2011). The results of vertical seismic gridding measurements (VSP), already carried out in previous work in drilled well-2, (table.3) (Schlumberger, 1999).

Noting that V.S.P. and check-shot information was correlated with presented seismic sections because this information is used to determine the tops of the formations on the seismic. That determination is made whatever the frequency content and the seismic resolution.

In terms of frequency content:

Quamchouka formation is interpreted on the positive peak in seismic, whereas Kurachine Anhydrite and Kurachine dolomite are interpreted on the negative one. Knowing that the strongest seismic signal has been followed for the K.D. formation.

In terms of seismic resolution:

Vertical seismic resolution = the length of a seismic wave/4

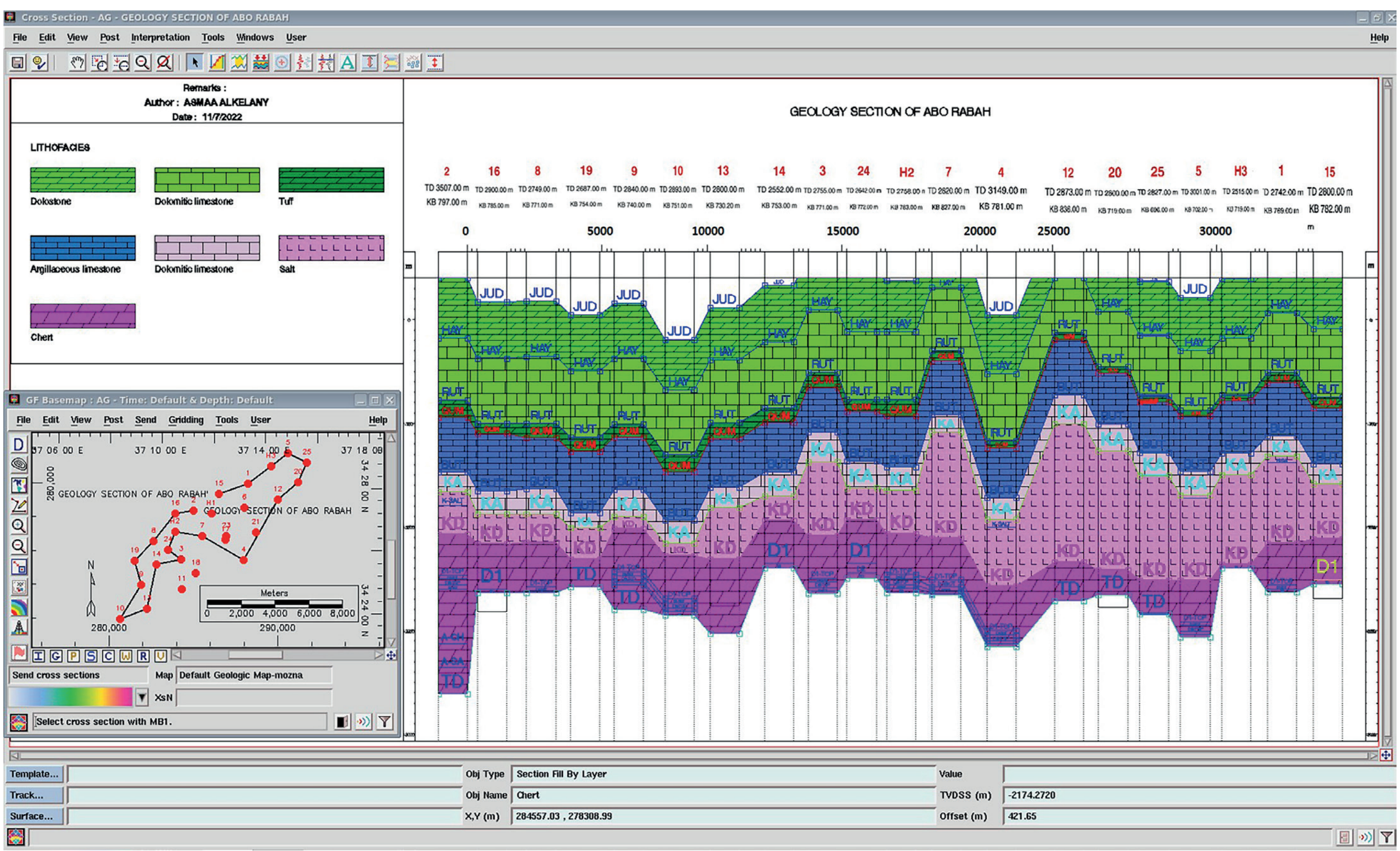


Figure 6. Correlation of litho-stratigraphic section passing through most of the wells in the Abo-Rabah area.

Table 2. Check-Shot information of Abo-Rabah-11 (Syrian Joint Company for well services, 2011)

Depth (m)	Two Way Time (ms)
0	0
1863	840
1954	880
2054	922
2154	974
2254	1020
2354	1076
2406	1096
2415	1100
2453	1114
2554	1154
2654	1200
2754	1234

Table 3. V.S.P. information of Abo-Rabah-2 (Schlumberger, 1999).

Depth (m)	Two Way Time (ms)
0	0
302	160
735	376
1183	548
1305	600
1711	736
1841	780
2135	916
2947	1240
3124	1308
3266	1364

The length of the seismic wave usually ranges between 30 – 35 m. Horizontal seismic resolution = seismic signal strength.

4.2.2. Interpretation of reflective seismic surfaces

Seismic interpretation works are carried out for the available seismic profiles data for the top parts of the geological formations. (KD) the reservoir rock, (KA) the cover rock and (Qum)] of (Abo Rabah) field. The main and secondary faults and fracture zones are proceeded by using the gridding of seismic two- dimensional (2D) survey lines, also three dimensional (3D) (Figure 7). The illustration shows the aforementioned interpreted reflection surfaces and faults in three dimensions.

The Geo Viz program displays seismic lines and seismic interpretation in a three-dimensional view (3D). So, the interpreted two-dimensional data (2D) was displayed in a three-dimensional view (3D) to clarify the geological shape of the reflectors, and highlight the thickness variations of K.A. formation in 3D view (not 3D data).

The schematic gridding interpretation that illustrated in (Figure 7), allows to represent the reflection of the top parts of formations (QUM, KA, and KD), also exhibited in (Figure 8).

It is noticed through the seismic interpretation, there are no difficulties in following the reflection surfaces through the survey lines of good quality seismic signal- data (such as the QM-W-19, W8 and W16), as shown in Figure 9.

While, there is difficulties arise to delineate the seismic reflection surfaces of moderate and weak (blur) quality of the seismic signal, because the increasing thickness of (KA) formation. Then, a resorting to VSP and CHECK SHOT data of the top parts of formations, that already loaded on the seismic sections, measured values of available drilled boreholes of (Abo Rabah) field are needed to make integration between top parts of formations, which already loaded on the seismic sections and geological information of the drilled boreholes (Figure 10). The illustration shows the boundaries of seismic section of (KA) and (KD) formations. This may be generalized in all over the investigation area, by using a three dimensions presentation. A thickness contour map is obtained, where denoted the greatest thicknesses of (KA) formation are situated in the N toward N. E of (Abo Rabah) hydrocarbon field (Figure 12).

The study of the geological data of the available boreholes in the investigated area shows a large variation in the thickness of the KA formation, as presented in (Figure 11), which indicates to the geological position of the upper (KA) and (KD) surfaces, and the thickness variation of the (KA) formation depending on the three dimensions representation (3D).

A three-dimensional section achieved map of Kurachine formation thicknesses, which shows the greatest thickness of (KA) formation in (Abo Rabah) field. (Figure 11).

Also, a contour map of Kurachine Anhydrite formation (KA), taken from boreholes data drilled in the (Abo Rabah) field. The map shows the greatest thickness of Kurachine Anhydrite (KA) situated in NW and SE of (Abo Rabah) area (Figure 12).

A strato-seismic section is obtained in this study, by using the [GEOLOGY OFFICE] program. This section confirms the

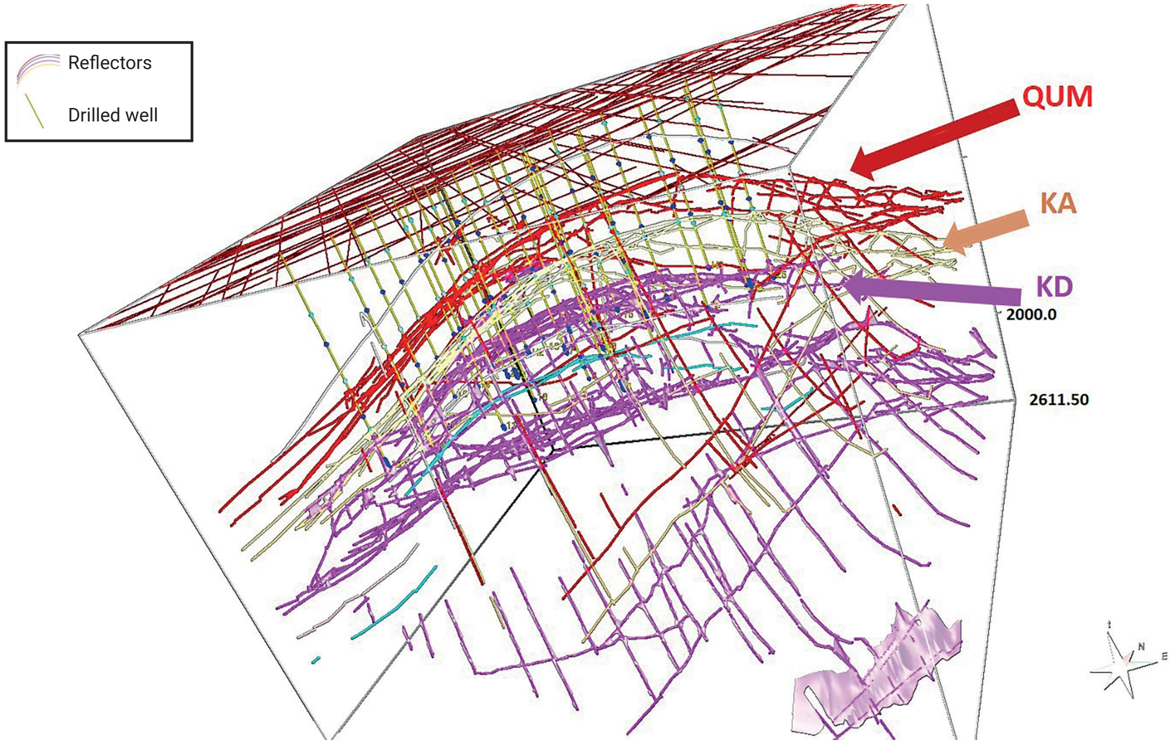


Figure 7. (3D) representation of interpreted reflectors, faults and fault profiles through (2D) lines in (Abo Rabah) area.

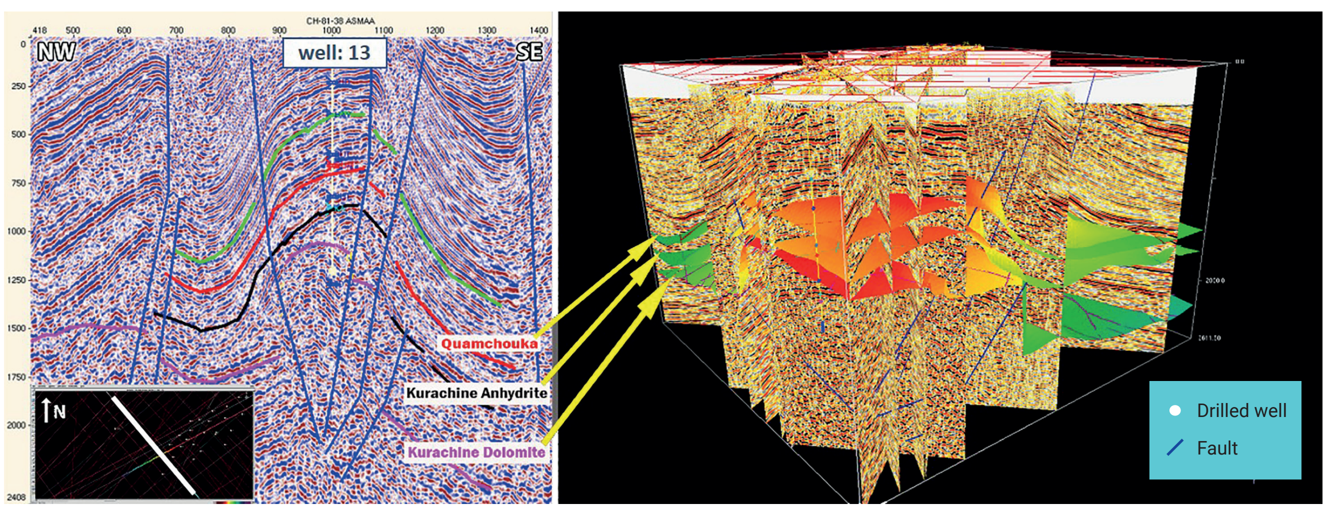


Figure 8. 3D representation of the 2D surveys with reflection surfaces and interpreted faults.

relationship between the absence of the seismic signal and large (KA) thicknesses, whereas the signal is clear at little and medium thicknesses as indicated in (Figure 13).

4.2.3. originating the time map of the Kurachine Dolomite (KD) formation

A different processed seismic data by using the [CPS3-VIZ] and mapping programs. These efforts led to construct the time map of the target reflector (KD) as shown in (Figure 14). The mentioned program requires the boundary of the study area, transferring the borehole locations and interpreted data (grid and faults boundaries) from the [GEO- FRAME- IMAIN CHARIZ-MA] program to the target reflector (KD"C").

The (Grid and Fault Boundary) data are converted into the surface, that enable to obtain the contour map of the equal time line- intervals (Figure 14).

The T.W.T. is validated by the shape of the interpreted re-

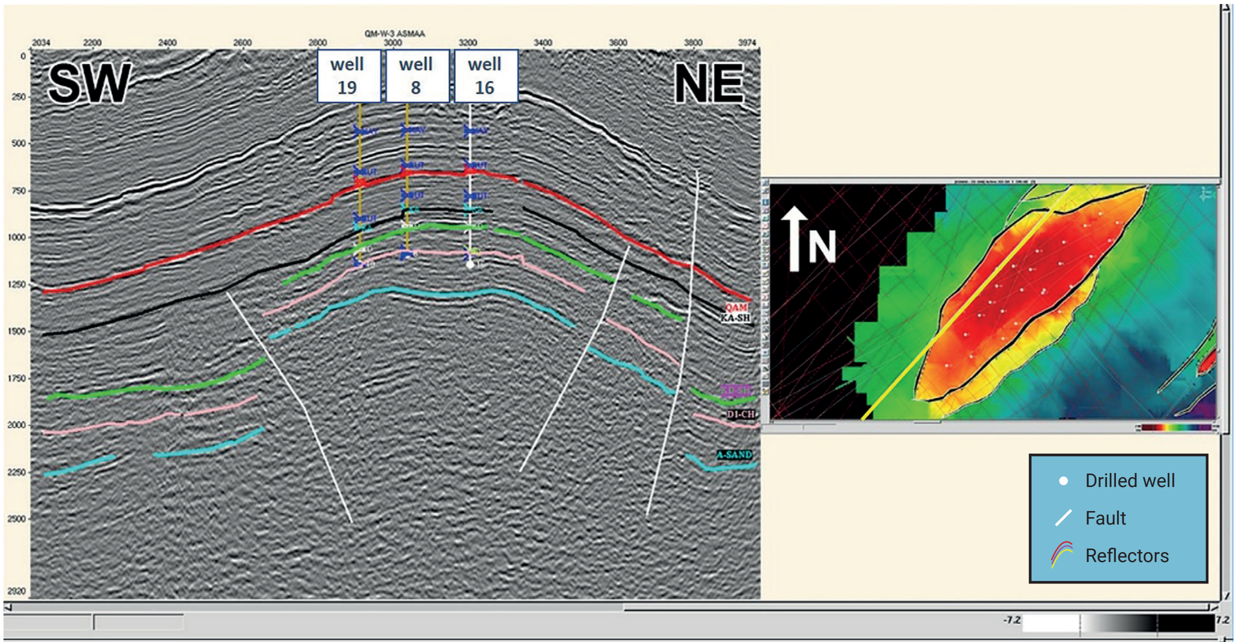


Figure 9. Seismic section prepared from processing data of QM survey lines in the study area.

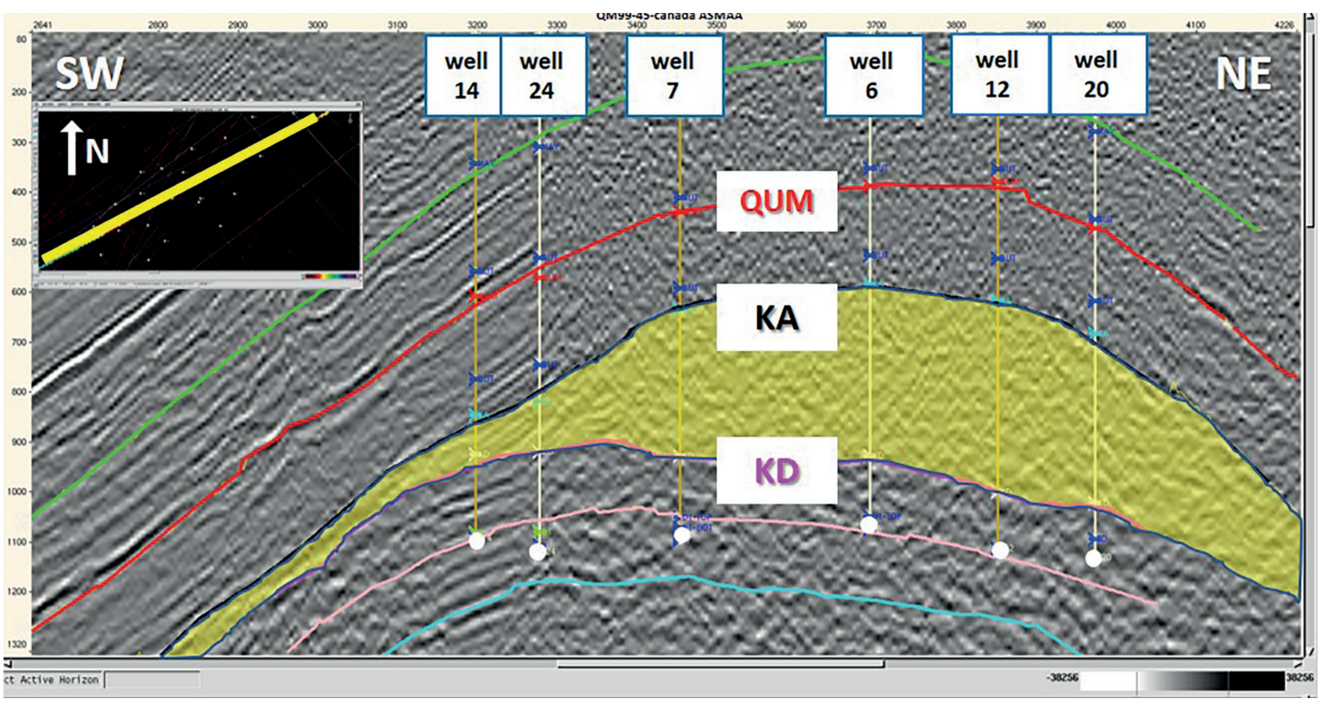


Figure 10. Seismic section shows the loss of seismic signal at large thicknesses of (KA) and the clarity degree of seismic signal at little thicknesses of (KA).

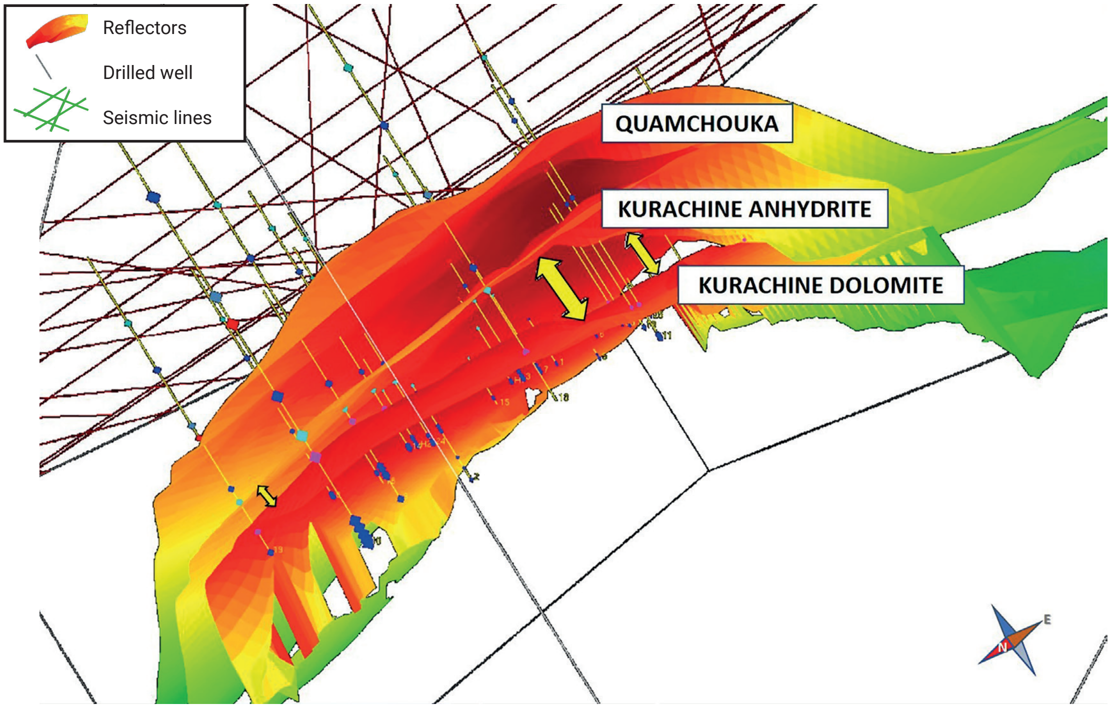


Figure 11. Three-dimensional section of the most significant reflectors in Abo-Rabah field.

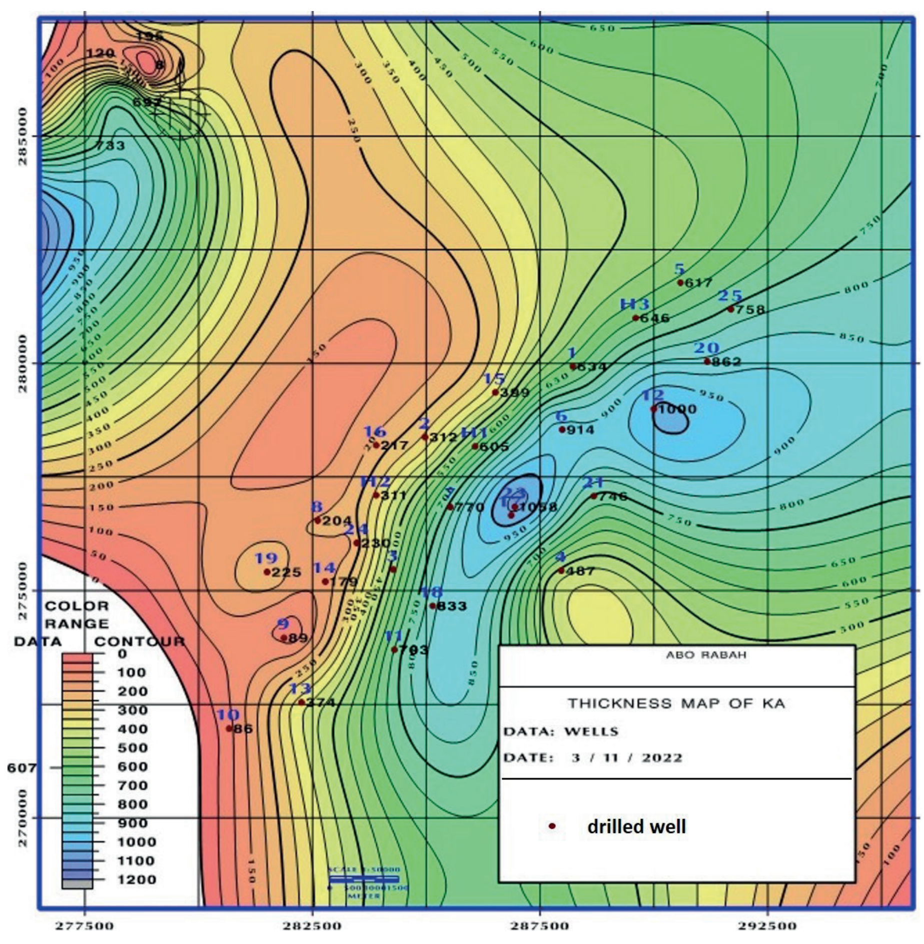


Figure 12. The thickness contour map of Kurachine Anhydrite (KA) formation in Abo-Rabah.

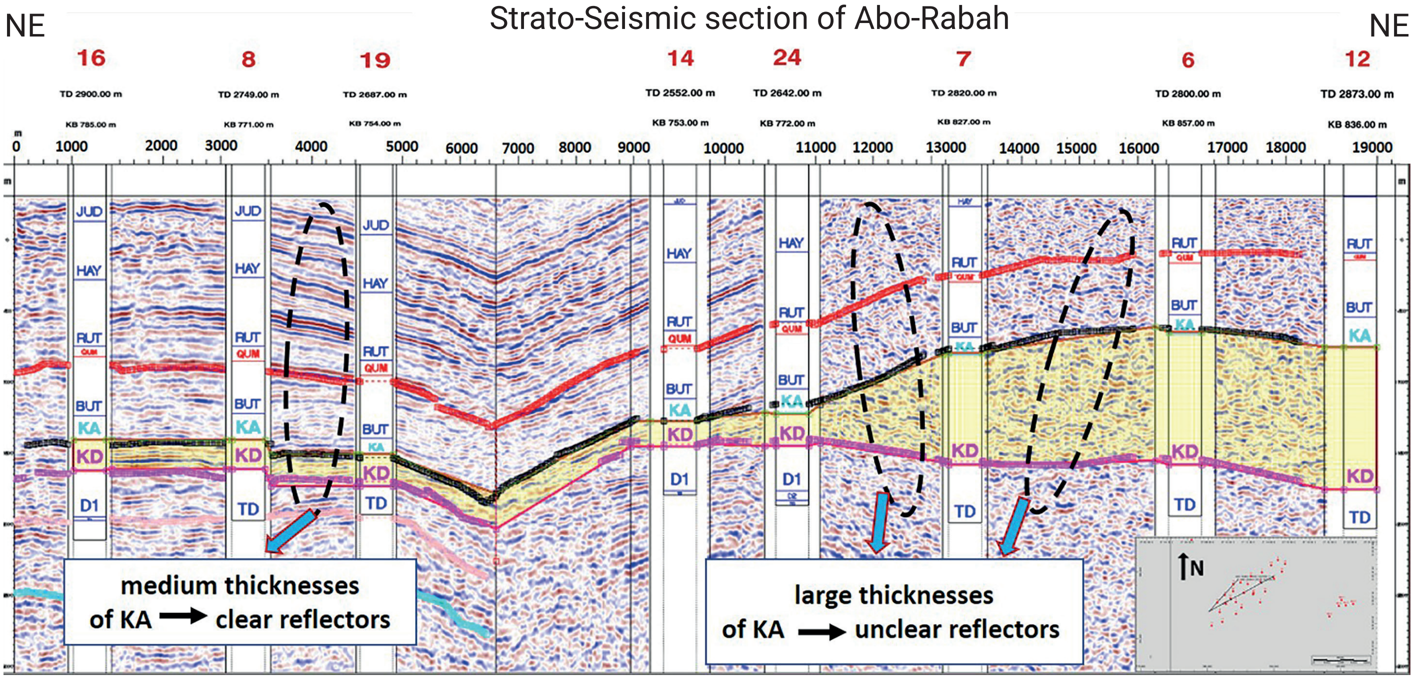


Figure 13. A strato-seismic section of the wells (16, 8, 19, 14, 24, 7, 6 and 12) in Abo-Rabah field, showing the blurring of the reflectors at the large thicknesses of the (KA), and their clarity when these thicknesses decrease.

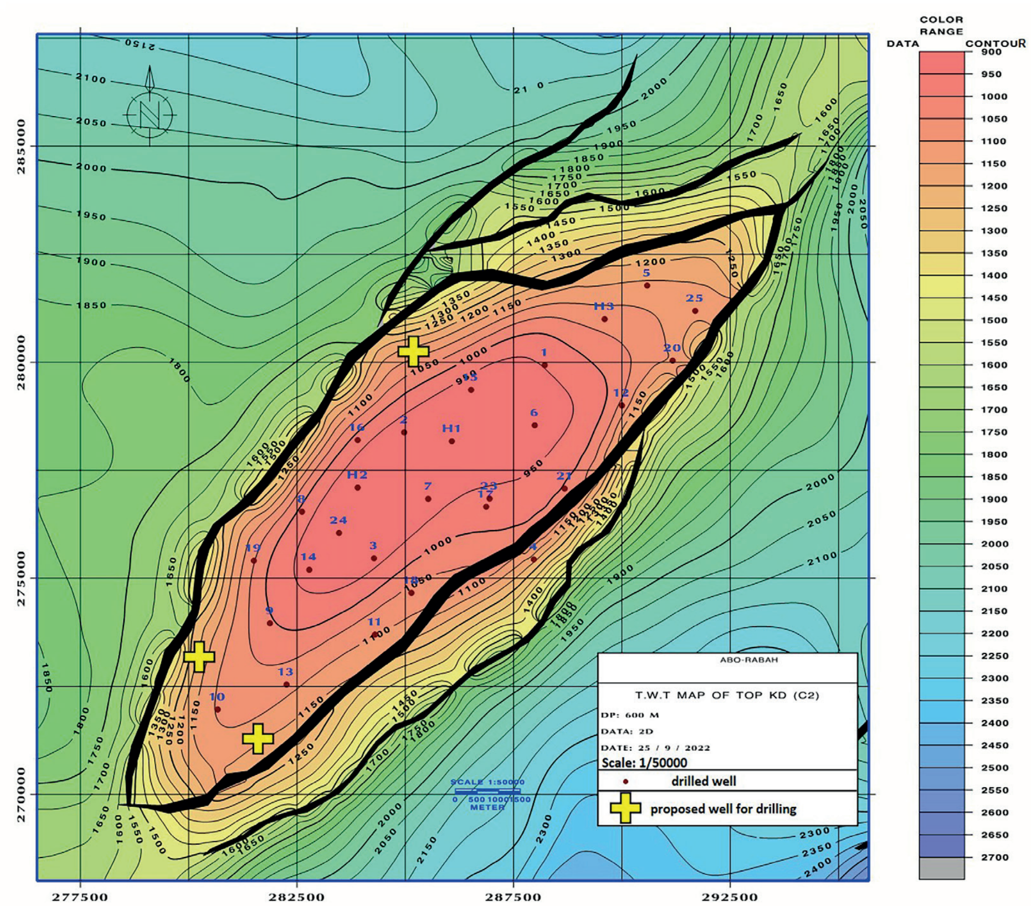


Figure 14. Time map (TWT) obtained for (KD) reflector in (Abo-Rabah) field and the chosen locations of boreholes proposed for drilling.

flector, which matches the characteristic geological shape of that reflector. Noting that the reflectors shown on the T.W.T. lines are located in the correct place (migration is applied to them).

4.3. Structural framework

The (TWT) map shown in Figure 14 denoted that, the (Abo Rabah) structure is an elongated anticline of NE-SW orientation. Its measured time amplitude is 550 milli- second and the time values of the map are approximately ranged from [950 to 1500] milli-second. It is clear that (Abo Rabah) structure is a faulty anticline, which it broken by two major faults of NE- SW orientation, and two secondary faults having the same direction as the two main faults. These faults are coinciding the general inclination and orientation of the structure. The (TWT) map also pointed out, where the drilled boreholes are located along the apex of (Abo Rabah) anticline structure, except (W-4), which is situated in the eastern flank of the mentioned anticline.

5. Results and Discussions

Analyzing of the time map (TWT) which constructed for the (KD) reflector, allows to identify a new three borehole gas locations. The locality of the suggested boreholes should be chosen in a height structural of the reservoir layer, considering of the distances between determined borehole and the other adjacent former drilled boreholes.

The comparison between the current time map (TWT), that obtained in this study, with the other former maps, already prepared according to the previous studies, indicate that all the former established maps are similar in the general orientation, structural shape and even in the main faults trending. The difference between the current time map (TWT) and the other formers, can be summarized as follows:

1. Comparing the current time map (TWT) with the first previous study done in 2011 (Syrian Petroleum Company, 2011), reveals the apex of (Abo Rabah) anticline was located in the N.E. of the studied area, which is not coincides with the (KD) formation depth. While in the current study, the anticline structure seems to be situated to the N.W direction of the (Abo Rabah) structure, which that coincides with the (KD) formation depth. Noting that the depth of the (KD) formation in all boreholes of Abo-Rabah field ranges between (1450 – 1881) m. The cause of the no-match in meters versus the reported by the Syrian company in 2011 is that the previous study relied on a smaller number of boreholes than the current study relied on. Emphasizing that the reliability of the results increases with the increase in the number of drilled boreholes in the study area.
2. Comparison between the time map of the second former

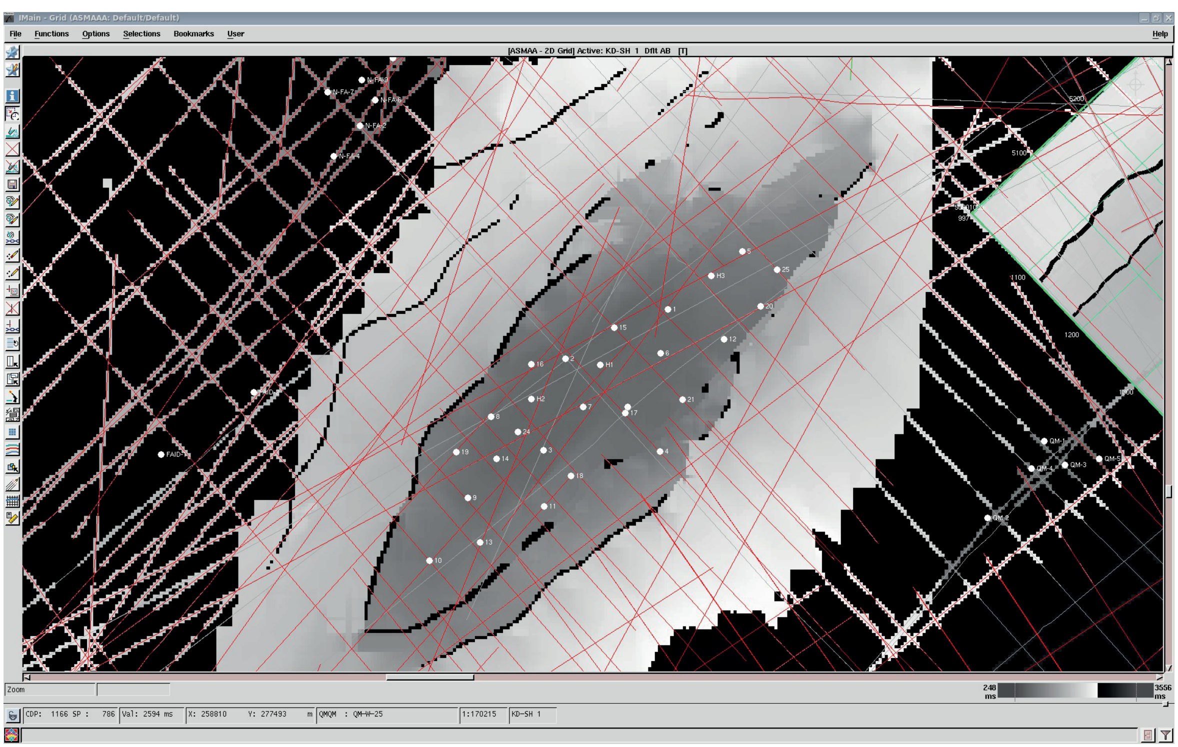


Figure 15. Dip map of (Abo-Rabah) field.

study, which done in 2016 (Syrian Petroleum Company, 2016), with the current study, reveals a difference in a secondary- fault numbers and their orientation, which orients (N.E- S.W) in the current study, while the former study exhibits a greater number of secondary faults, also difference in general orientation (NW-SE).

There is a similarity in the general form of the fault interpretation between this study and previous studies. The interpretation of the main faults is compatible with all studies, but the interpretation of the other faults differs according to the interpreter's point of view.

To verify the fault interpretation, several of attribute maps were created, such as the following dip map, (Figure 15).

3. Comparison with the former time map of the third study prepared in 2018 (Syrian Petroleum Company, 2018) and the time map of current study, reveals significant differences in the locality of structure apex and general orientation of secondary faults. Where the structure anticline apex situates in the NW and the secondary faults take NE-SW orientation, which that coincides with the (KD) layers formation depth in the current study.

It can be concluded that the time map which prepared in this study, being more realistic than the other former studies, because it is based on and integrated with a large number of boreholes, not all of them were drilled when former studies were carried out. The integration with a high number of boreholes in this study enhance and verify the reliability of the results.

6. Conclusions

The following results are attained the main objects of this study by:

1. Originating a litho-stratigraphic information of the study field, according to a correlation section passed through 20 drilled boreholes in the mentioned field.
2. The advantage of using of VSP´s data is determining the top formations on the seismic.
3. Overcoming the seismic interpretation of the medium to poorly accurate (blur) seismic lines, that suffer from loss of the seismic signals, caused by the large thicknesses of Kurachine Anhydrite (KA) formation. This has been obtained by integrating data of the top parts of formations loaded on the established seismic sections of available drilled boreholes in the studied area.
4. The reliability of seismic interpretation increases as the number of boreholes in the study area increases, and the interpreter relies on them in his study through his seismic interpretation model, even if the seismic is the same.
5. Originating the time map (TWT) for the Kurachine Dolomite (KD) formation in the (Abo-Rabah) field.
6. Implementing the stratigraphic relation integrated with the interpreted seismic results, through the strato-seismic section which is created for the first time in Abo-Rabah field, and that is a very important contribution in this study.
7. Propose new suitable locations promise for drilling boreholes, depending on the time map (TWT), which is obtained in the (Abo Rabah) area.

Finally, the results obtained according to this study enable to apply in similar districts for:

- Studying the possibility of the presence of hydrocarbon occurrences in the proposed borehole locations favorable for drilling.
- Using the strato- seismic sections concept for seismic data interpretation.
- Utilizing the results of the study methodology, to determine the anhydrite- layer of the Kurachine Anhydrite (KA) in the Ad-Daw basin and/ or other districts in the world.

7. Acknowledgment

The authors extend their sincere thanks and appreciation to Prof. Muhammad Usama Aljabban, the head of Damascus University, for supporting the academic process in Syria.

We present our respect and reverence to Prof. Goreous Shaheen, the head of Geology Department- Damascus University, for his cooperation and the administrative facilities he provided.

Acknowledgment is also due to Prof. Ramez Naser and Prof. Kayed Maalouleh for their great assistance.

Great thanksgiving and gratitude are given to the engineer Anwar Aldurra, the geophysicists: Mayssoun Harastani, Ahmad Al-Shihabi and Muzna Al-Fayoumi, in addition to the geologist Ahmad Abu Shouk.

The corresponding author thanks everyone who contributed to this research.

8. Funding

No funding received for this paper.

9. Data availability

The datasets related to this research are available with the first author, however accessing to these data or making them available to others requires special permission.

10. Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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