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Using Chaos and Ant Track Attributes to Recognize The Faulting Systems and Subtle Faults of a Jurassic - Cretaceous Sedimentary Packages in Merjan_West Kifl Oil Fields - Central Iraq

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Abstract

Study of three dimensional seismic data of Merjan area-central Iraq has shown that the Jurassic – Cretaceous succession is affected by faulting system. Seven major normal faults were identified and mapped. Synthetic traces have been calculated by using sonic and density log data of the well Me-1.Two exploration wells were drilled in the area Me-1 and Wkf-1 wells, the distance between them is 15.82 km. Discussion about the effect of this system on the sedimentary package has been presented. The tight faults that couldn't be distinguished it on seismic sections were determined using seismic attributes. They have different strike and limited in their vertical and horizontal extension. They are system facilitates the movement or migration of the fluid across the stratigraphic column in the study area. Faulting framework can be divided into two groups: the first affects the Jurassic and lower Cretaceous rocks and the second effect the upper Cretaceous and lower Tertiary rocks. The first group is associated with the post rift thermal sag, passive margin progradation and gravitational collapse (lower Jurassic – upper Cretaceous (Turonian) 200 – 93 Ma); approximately Sargelue – NahrUmr depositional time. The second group is few and is associated with the rifting creating the Euphrates graben (Late Turonian – Maastrichtian 90 – 70 Ma) approximately Tanuma shale / Sadi – Shiranish) depositional time.

Keywords: Merjan area central Iraq, Faulting framework, Subtle faults, Chaos and Ant-track attribute.

استخدام سمة الفوضى ومسار النمل لتعريف نظم التصدع والصدوع الدقيقة لمجموعة العصر الجوراسي – الطباشيري الرسوبية في حقول نفط مرجان – غرب الكفل – وسط العراق

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الخلاصة

دراسة بيانات المسح الزلزالي الثلاثي الابعاد لمنطقة المرجان – وسط العراق أظهرت بان التتابع الجوراسي – الطباشيري متأثر بنظام تصدع .تم تمييز سبعة صدوع اعتيادية رئيسية ورسم خرائط لها. تم حساب الآثار المصنعة باستخدام معلومات كل من المجس الصوتي والكثافة للبئر مرجان -1. يوجد بئرين استكشافيين محفورة في المنطقة هما مرجان-1 وغرب الكفل-1 ، وتبلغ المسافة بينهما 15.82 كم. وقد تم تقديم مناقشة حول تأثير هذا النظام على التتابع الرسوبي. تم تحديد الصدوع الدقيقة والتي لم يتم تحديدها في المقطع

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الزلزالي بأستخدام الملامح الزلزالية. نظام الصدوع الدقيقة له اتجاهات مختلفة ومحدود الامتداد الافقي والعامودي وهي تسهل من حركة وهجرة الموائع خلال العمود الرسوبي في منطقة الدراسة. الاطار العام للصدوع الرئيسية يمكن تقسيمه الى مجموعتين. الاولى تؤثر على تتابع صخور الجوراسي – الكريتاسي الاسفل والثانية تؤثر على تتابع صخور الكريتاسي الاعلى والثلاثي الاسفل. المجموعة الاولى ارتبط تكونها بالانخفاض الحراري بعد التصدع وتشكل الحافة الهادئة ذات السحنات التقدمية والتفلق الذي يحدث بسبب الجاذبية كنتيجة لثقل الرواسب خلال فترة (الجوراسي الاسفل – الكريتاسي الاعلى (التوروني) 200–93 مليون سنة وتقريبا ضمن عمر تكوين السركلو ونهر عمر. المجموعة الثانية والقليلة العدد تكونكت ضمن الانهيار الحاصل ضمن منخسف الفرات ضمن عمر (التيروني المتأخر – الماسترختيان 90–70 مليون سنة) وتقريبا ضمن عمر تكوين التنومة السجيلي / سعدي – شيرانش).

Introduction

The structural characteristics of continental basin influence the process of sedimentary filling and hydrocarbon accumulation [1, 2]. It is a more beneficial approach to integration of geomorphology and seismic data analysis. Within the last decade, the most logical workflow of using seismic data follows the transition from seismic stratigraphy, to sequence stratigraphy, to seismic geomorphology. Seismic geomorphology was defined by [3] as “the application of analytical techniques pertaining to the study of landforms and to the analysis ancient, buried geomorphic surface as imaged by three-dimensional (3D) seismic data.” Therefore, seismic geomorphology, when integrated with seismic and sequence stratigraphy, is a powerful and effective tool for analyzing the stratigraphy, understanding structural styles, processes and basin evolution, and predicting the spatial-temporal distribution of sedimentary facies under a sequence stratigraphic framework [4, 5].

The structural framework controls the sedimentary systems. An understanding of the relation between local deformation and deposition helps to infer the positions of subtle pinch-outs that may provide hydrocarbon traps and can yield a detailed history of structural development [6]. The accommodation space created by faulting and fault-related topography is the primary control on the large-scale sedimentary systems within rift basins. This topic has been addressed in many papers [7, 8, 9, 10]. Information’s from different seismic attributes are used to form fault geometry and can generally use to optimize well locations [11]. Some researchers have proposed that during rifting, the basins were relatively long, narrow, isolated, and asymmetric, bounded on one side by major faults, much as they are today [12]. Others have proposed that the basins were originally broad sag basins that were later tilted and faulted [13].

The case under consideration is for Merjan _West-Kifl Oil fields which are located in the middle of Iraq. Tectonically, the Merjan area lies in a critical position between the Mesopotamian Basin and the Stable Platform to the west. Pervious 2D seismic and well based investigations for oil field have been mainly focused on describing the structures in the area but didn’t point to the faulting system because of the limitation of 2D survey used in the interpretation [14- 17]. Petrel Resources plc. [18] deduced a study depends on elevation data, satellite images and later integrated with 2D seismic data to study the structures of the area. Only one main fault located close to the Merjan-1 well location is delineated by the study. This has a NW-SE orientation which coincides with the dominant fault trend in the region. On the other hand, satellite images were analyzed and showed several trends of lineaments.

With an increasing demand on petroleum resources in Iraq, the Hartha Formation has become a significant hydrocarbon-bearing formation in the Merjan _West Kifl Oil fields. Although there has been some documentation of the tectonics, stratigraphy, sedimentology, and petroleum exploration and development of the area that helps for further sedimentary research and hydrocarbon exploration. However, traditional geological research based on logging data and 2D seismic reflector data is hard to well understand the complex characters and distributions of the Merjan _West Kifl Oil fields structure. The best way is to extend the good data to the entire investigation area and further study on the previously identified area using 3D seismic data.

In 2013, the 3D seismic survey has been achieved for the area. The data interpreted by Iraqi Oil Exploration Team. They showed that the general dip is toward east and that structurally cannot dependent because it interpreted the Hartha Formation only which is not adapted to delineate the geomorphology of subsurface structure, but they infer that the Hartha Formation is affected by normal fault strikes N-S which is well known as Tar fault [19].

Given this, the main objectives of this paper is to determine the detail geomorphological picture of the subsurface faulting framework by examine the 3D seismic data of Merjan area and provide a new case using seismic geomorphology to characterize structural styles over the sub basin including the slopes area and mapping the structural distribution of the Hartha Formation in details and discussing the controlling factors.

Location and Geological setting

The Merjan_West-Kifl- Oil fields are located in the middle of Iraq, west the Euphrates River within Al- Najaf – Karbala province approximately (60-70Km) to the south of Baghdad (Figure -1a). Tectonically, the Merjan area lies in a critical position between the Mesopotamian Basin and the Stable Platform to the west, (Figure -1b). The position is far from the center of activity, thus, simple structure attitudes in the area with NW-SE faults trend. Area represents part of northern eastern margin of Arabian Plate [20]. Stratigraphic succession is shown in Figure-(1c).

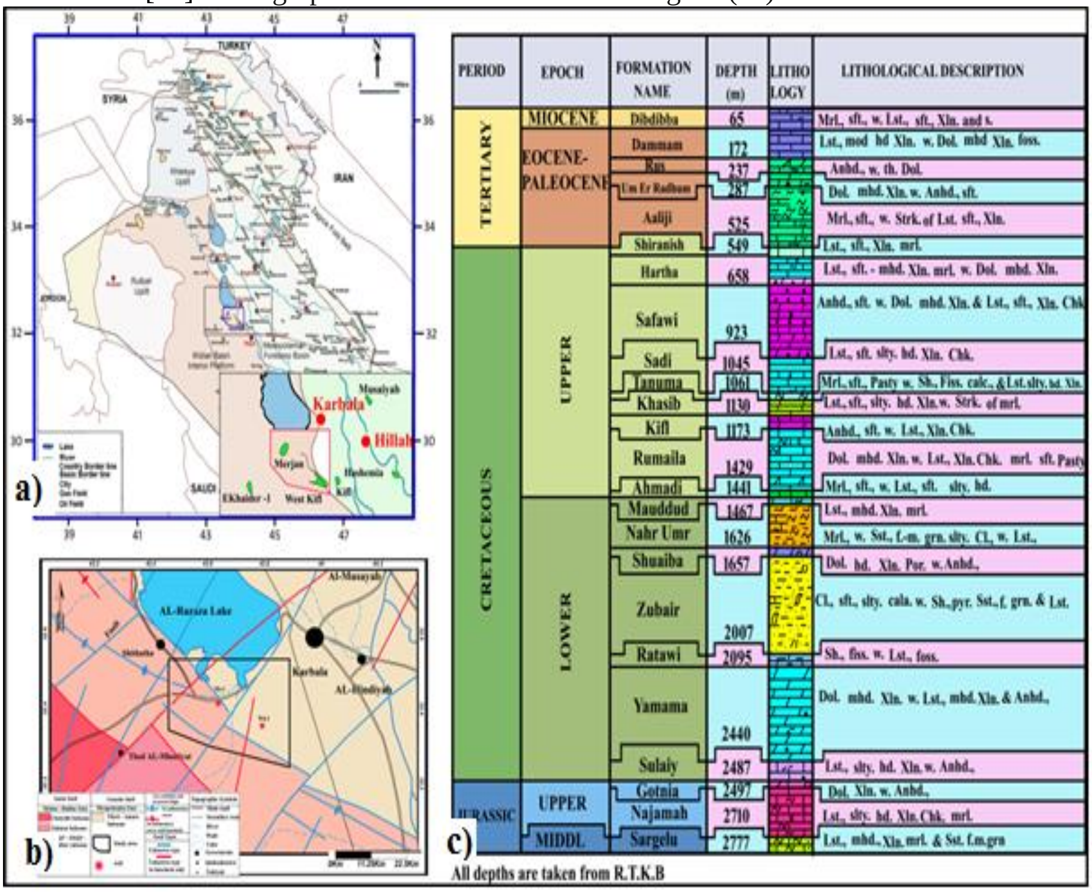

Figure 1 – a) Location map after [21]. b) Tectonic map of a study area, after [22] and c) Stratigraphic section of Me-1 well, after [17].

Available data, Synthetic Seismogram and Methodology

3D seismic data covering an area of 1026.17 km² of the Merjan_West-Kifl Oil fields have been acquired in 2013. Wire line log data which includes logging data of Me-1 well, and check shot of 2 wells (Me-1, Wkf-1). Depth of top Hartha Formation from sea level is 488m in Me-1 and 593m in Wkf-1.

The synthetic seismogram was generated using the Seismic to Well Tie module in GeoFrame Software. The sonic data was first edited for any spiky noise and calibrated to check shot and any gap in the sonic data was filled by interpolating the nearby data. The correlation of synthetic seismogram and 3D seismic data is very good and it was easy to identify well markers on seismic data (Figure -2). The methodology is summarized by the following workflow (Figure -3).

Results and Discussion

Fault Interpretation

Examinations of the seismic sections show that the area is affected by extensional normal faults system which has picked and followed from line to line to track their strike and to determine the affected geological column. Both of the Jurassic and Cretaceous packages were faulted. Jurassic succession is characterized by more dense extensional faults from Cretaceous rocks. They were picked in all the area along each inline, many cross lines and arbitrary lines. The fault appears as zigzag line on the base map due to change of the strike trends, also there are differences in the dip of fault plane indicates an influence of horizontal stress on the structures which led to lateral displacement.

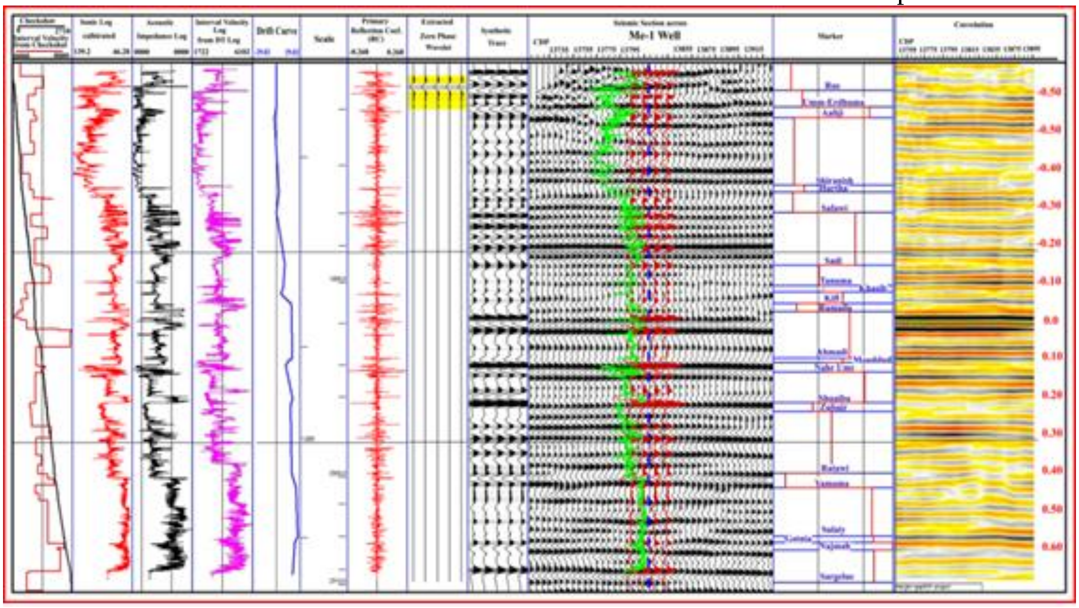

Figure 2 - Synthetics seismogram of Me-1 which shows a good tie with seismic data.

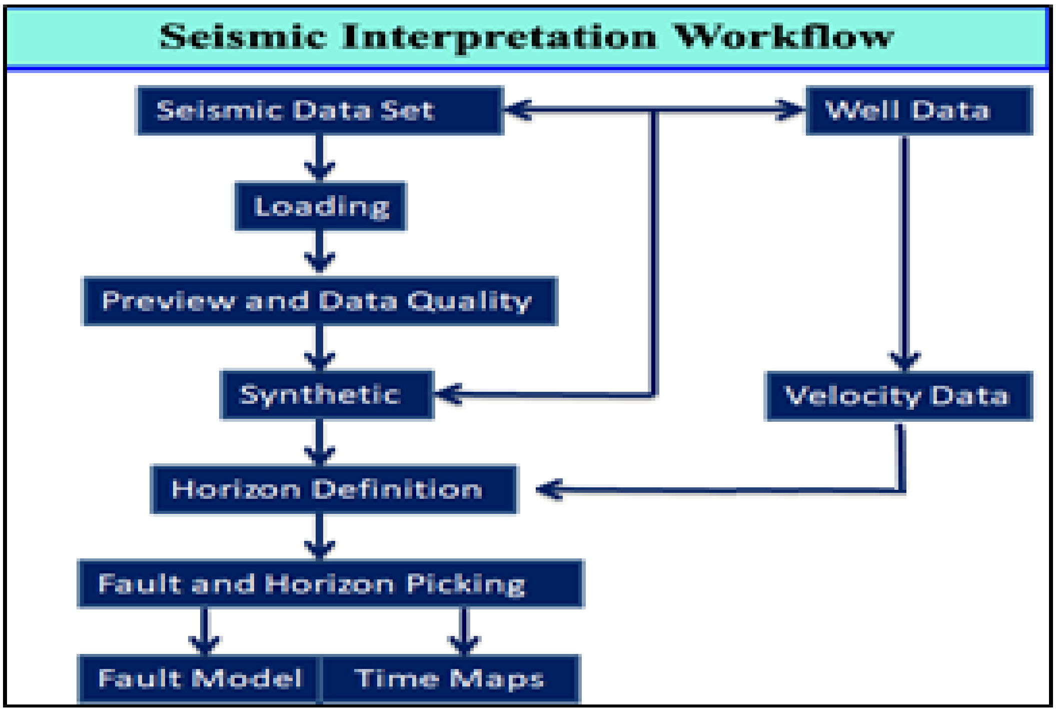

Figure 3 - Illustrates the seismic structural modeling workflow.

The seismic geomorphology of the observed faults can be divided into two groups: the first affects the Jurassic and lower Cretaceous rocks and the second effect the upper Cretaceous and lower Tertiary rocks, (Figure -4) and (Figure -5).

The first group is the most intensive and visible in the study area, especially those that formed the NW striking extensional graben structures in the area.

It is appropriate to consider that, these faults in its regional context (in terms of structural style) are gross structural position through time and consistently demonstrates with interpretations from wells and seismic. The first group is associated with the post rift thermal sag, passive margin progradation and gravitational collapse (Lower Jurassic – Mid Turonian 190 – 92 ma); approximately Sargelue – Nahr Umr. The second group is few and is associated with the rifting creating the Euphrates graben as collision wanes (Late Turonian – Maastrichtian 90 – 70 Ma) approximately Tanuma shale / Sadi – Shiranish).

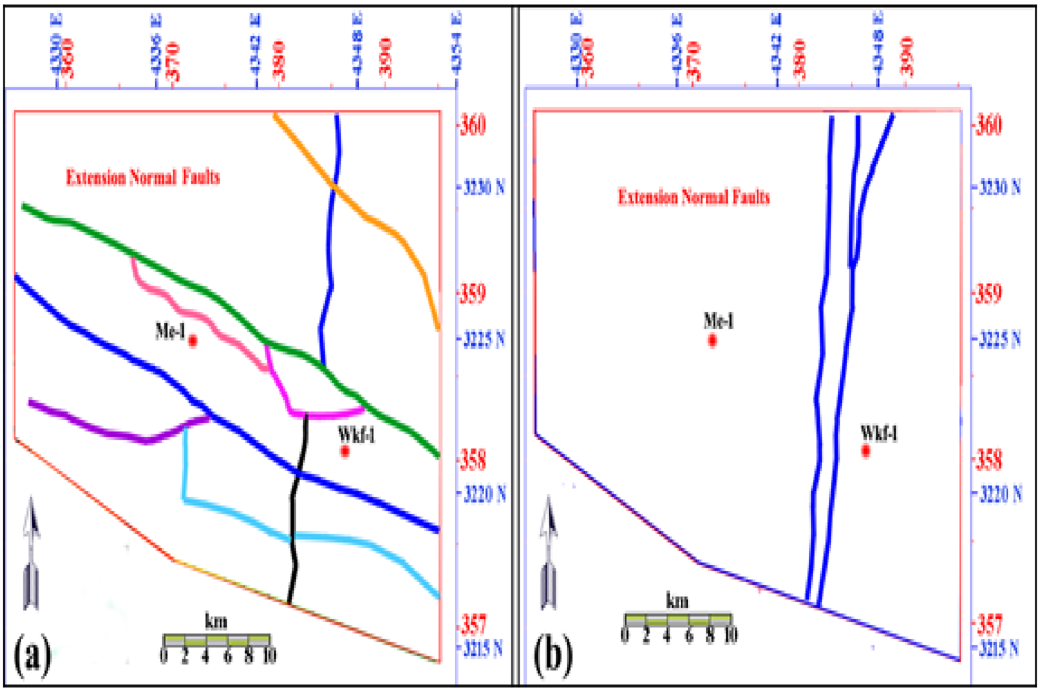

Figure 4 - (a) fault systems effect on Jurassic – lower Cretaceous rocks and (b) upper Cretaceous and Tertiary rocks.

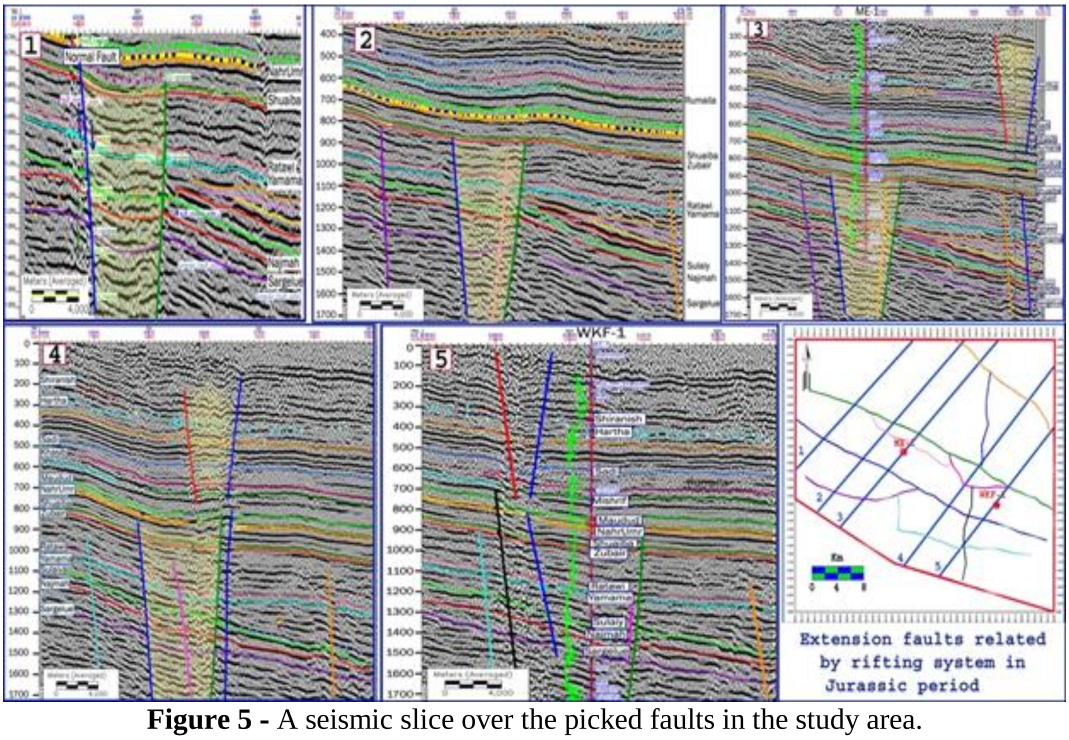

Figure 5 - A seismic slice over the picked faults in the study area.

Instantaneous Phase in Fault Recognition

Taner, et al., [23] has indicated that seismic attribute sections, especially the instantaneous phase section are very important for the distinction of reflector surfaces continuity termination because it does not depend on the reflection strength. For this reason, the instantaneous section (Figure -6) is used for distinguishing the reflector surface terminations and sharp discontinuities in the amplitude such as that caused by faults. Figure-7 illustrates the instantaneous phase slices which selected at a different level as shown in Table 1.

Fault Description

A total of **7** major normal faults were identified which can be summarized in Table-2.

a- Trend: NW-SE faults along the basin margin. Except the NE–SW faults. The principal, northwest trending coincides with faults controlling the southwest margin of the Mesopotamian Basin. The WNW trending fault zone forms graben system. It is an important structure at the basin margin that has controlled sedimentation and thickness of stratigraphic units, particularly during the Late Jurassic and Early Cretaceous.

b- Type of fault: These faults are extensional faults.

c- Throw and heave: Throw is calculated from depth map, and heave is calculated according to equation: Tan (dip angle) = vertical throw / heave

d- Angle: It is calculated from seismic section.

e- Vertical effects of faults: The faults affect mainly on the Jurassic early Cretaceous formation. But they have secondary act on the upper Cretaceous formation.

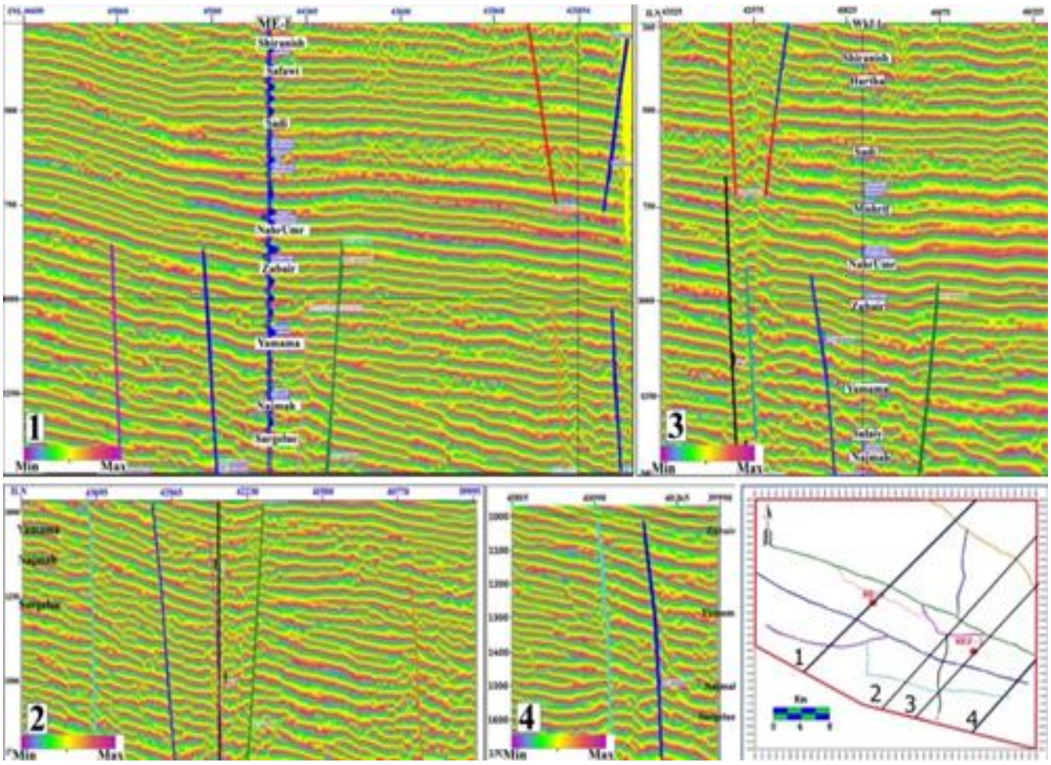

Figure 6 - Shows an instantaneous phase sections over the picked faults in the study area.

Subtle Faults

Study area containing tight fault that couldn't be distinguished it on seismic sections. They have different strike and limited in their vertical and horizontal extensions. They are non-insulated as far as the system facilitates the movement or migration of the fluid across the stratigraphic column in the study area. Lots of fractures and dissolution features are developed through these faults net. Seismic attributes were used as a tool to discriminate the subtle fault and karst features in the area. Both of them plays an important role in the oil migration from the source into the reservoirs. Several attribute slices were used to emphasis the sharp discontinuity in the reflectors caused by these faults.

Chaos Attribute

Chaos attribute is defined as a measure of the “lack of organization” in the dip and azimuth estimation method. In another word, chaos attribute can detect chaotic textures within seismic data, which can highlight directly positions of reflector geomorphological disruption. Due to the discontinuous character of coarse grained sediments within the channel in fills, this can give the chaotic signal pattern contained within seismic data [24, 25]. Hence, chaos attribute is applied to delineate the geomorphological shapes of subtle faults in the area (Figure -8). Chaos slices images were processed in the image processing program to extract extra information about the shapes of subtle faults. Filtering has been applied on the edge property of the image to highlight fault edges in the image slices. The following is description of these attribute results.

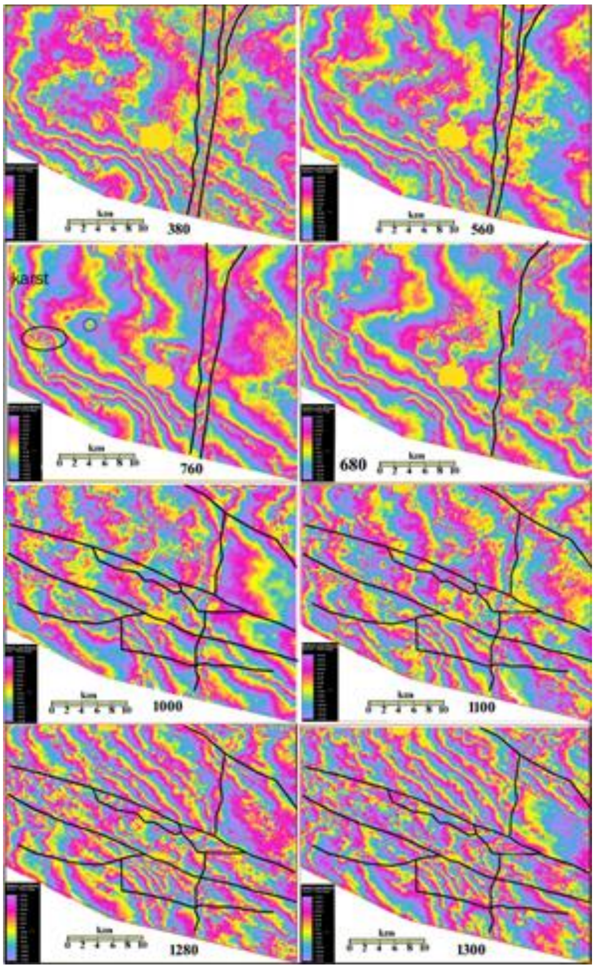

Figure 7 - Instantaneous phase slices at different levels sampling the Cretaceous –Jurassic interval.

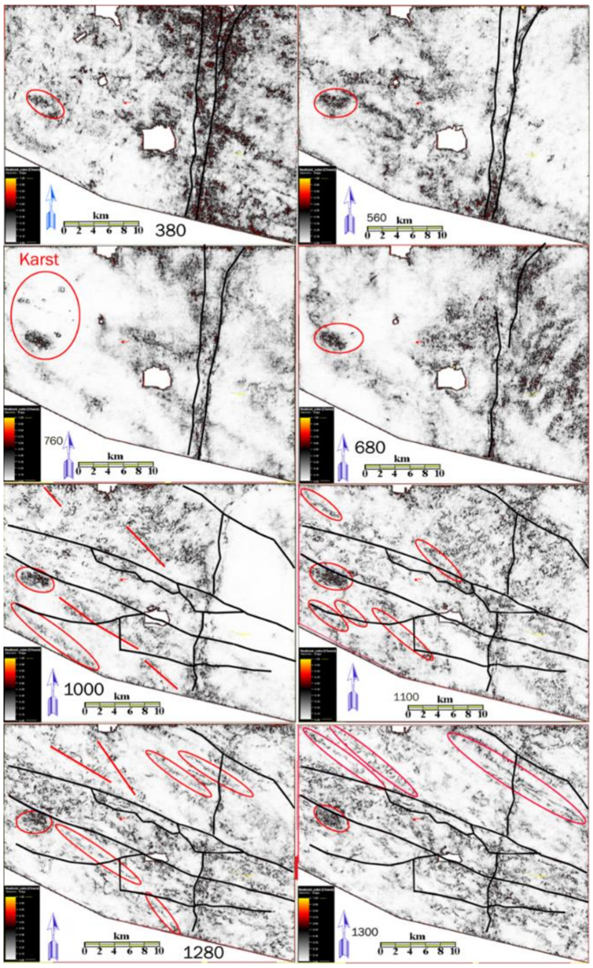

Figure 8 - Chaos slices at different level across Jurassic – Cretaceous packages illustrate the geomorphological shapes of subtle faults in the area.

Find Edge

Identifying the areas of an image with significant transitions is emphasizes the edges. Finding Edges outlines of an image with dark lines against a white background are useful for creating a border around examined features (Figure -9).

Glowing Edge

Identifies the edges of color and adds a neon-like glow to them (Figure -10).

Table 1 - Illustrate the time slices levels relative to their equivalent formations.

Time Slice (ms)	Me-1 (Formation)	Wkf-1 (Formation)
380	Hartha	
560	Sadi	Hartha
680	Rumaila	Sadi
760	≅ Bottom Rumaila	≅ Top Mishrif
1000	Zubair	Within Shuaiba
1100	Ratawi	Zubair
1280	Najmah	Within Yamama
1300	Najmah	Within Yamama

Table 2 - Interpreted faults system parameters calculated from seismic data.

Fault no./color on a map	Trend	Throw (m)	Heave (m)	Dip angle (θ)
1 (Turquoise)	WNW-ESE	10	1.4	82
2 (Purple)	WNW-ESE	10	1.76	80
3 (Blue)	NW-SE	20	3.5	80
4 (Green)	NW-SE	10	1.76	80
5 (Black)	NE-SW	10	0.87	85
6 (Blue also called Tar fault)	NE-SW	12	1.26	84
7 (Orange)	NW-SE	10	1.4	82
8 (Red)	SURFACE 1	8	0.84	84
9 (Blue)	SURFACE 2	8	1.26	81

Ant – Track Attribute

Ant attribute was developed based on the concept of ant colony systems to determine discontinuities such as faults in 3D seismic data. This attribute uses the principles of swarm intelligence, which explain the collective behavior of social insects in finding the shortest path between the nest and a food by communicating via a chemical substance known as Pheromone. When searching for foods ants use these pheromone trails to direct other colony members to the food they have found. Through this process, the ants find the most efficient path from the nest to the food [26, 27]. The shortest path is marked with more pheromones in the algorithm; ants are more likely to choose the shortest route, and so on. In the ant attribute algorithm, large numbers of electronic ants are distributed in the seismic volume allowing them to move along faults and emitting pheromones. Surfaces that are strongly marked with pheromones are likely to fault [28- 30]. Ant track cube has been constructed according to the workflow (Figure -11). Ant track attribute is an effective tool suitable to enhance fault interpretation in 3D seismic data set and to draw the boundary path of geomorphological features from seismic data (Figure -12). The effective implementation of ant attribute can be achieved when other fault sensitive attributes are used as input data in the application of ant attribute.

Chaos and variance attribute are sensitive to faults, so these attributes were used as our input data to run the ant attribute separately so as to see faults clearly that where difficult to display on the dataset. The seismic data used was carefully conditioned using structural smoothing attribute to remove the background.

Importance of Faults

1- Vertical migration to up.
2- Enhancement of permeability system of a stratigraphic column in the study area.
3- These fault systems are the main controller on the:

- Shelf margin development (Najmah platform).
- Accommodation space.
- Creation of trapping mechanism by forming the second structure that can trap oil.
- Fault controls sedimentation and facies variation.

The results of seismic geomorphology faults from sub-seismic resolution data besides the compressional reactivation of graben faults related to regional inversion may have all played an important part in structural entrapment and the development of permeability facilitating vertical hydrocarbon migration. The combination of extension and later inversion would reduce the apparent displacement on the faults.

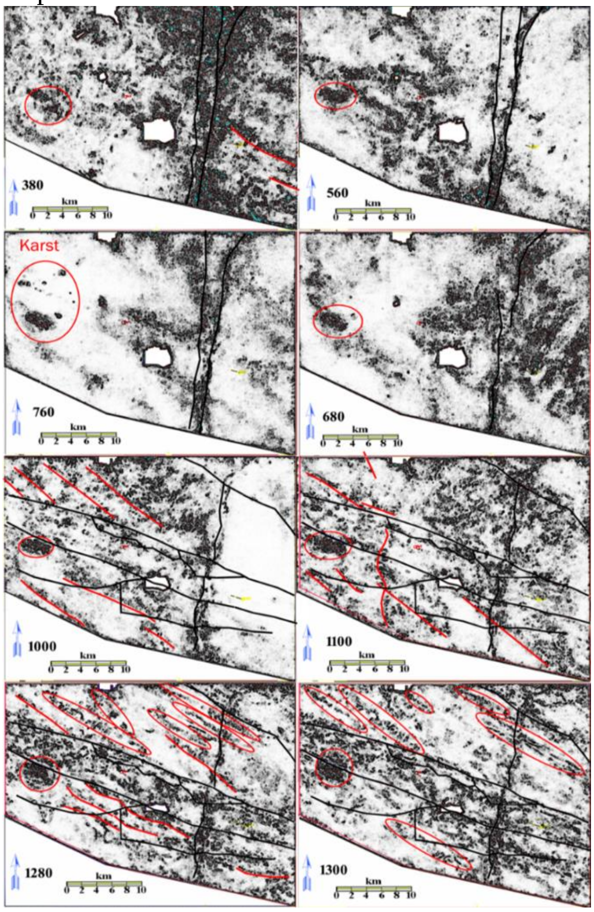

Figure 9- Chaos slices after find edge filter at different level across Jurassic – Cretaceous packages illustrate the geomorphological shapes of subtle faults in the area.

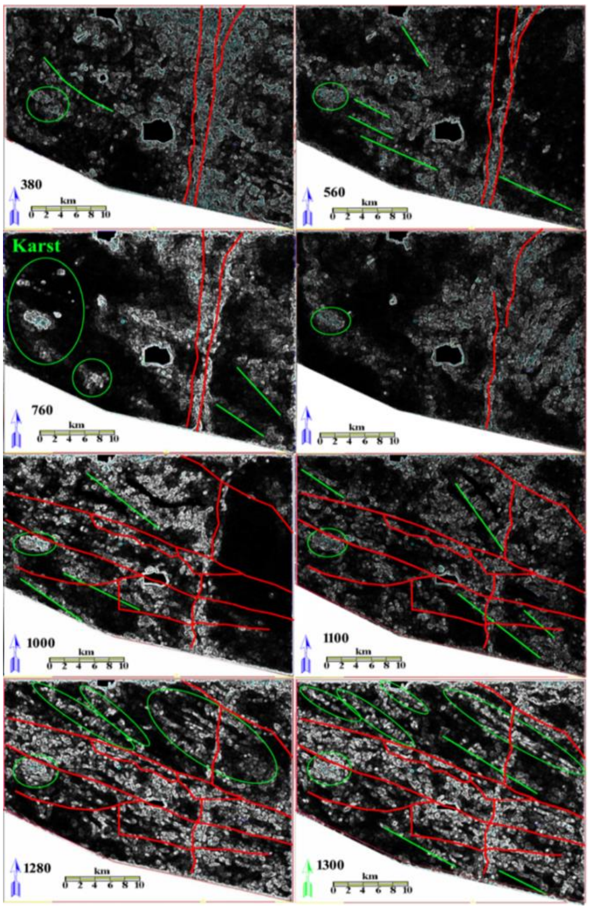

Figure 10 - Chaos slices after glowing edge filter at different level across Jurassic – Cretaceous packages illustrate the geomorphological shapes of the subtle faults in the area.

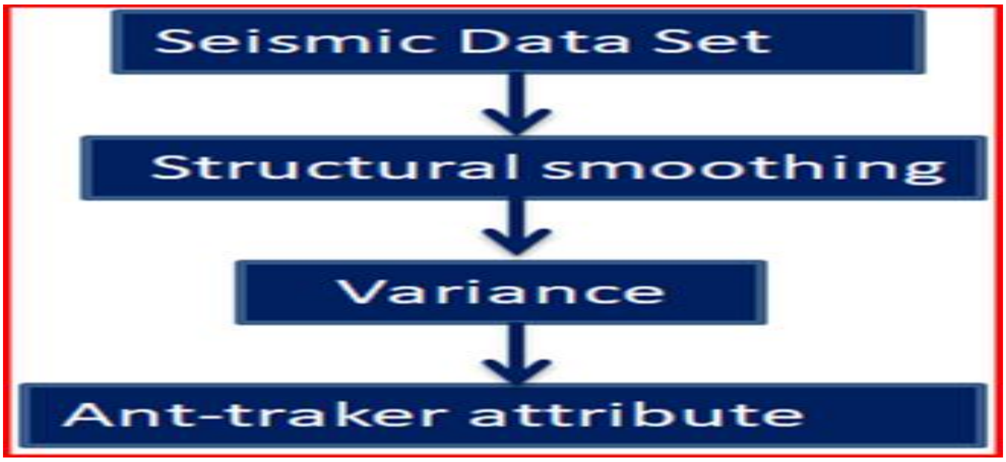

Figure 11- Work flow to calculate the Ant tracker attributes, modified after [31].

Ant track attribute images were processed. After several iteration of edge identification using image processing technique, the geomorphological path of subtle faults in the area were recognized. The linear behavior of edges is related with fault (Figure -13).

It is clear that the area is characterized by a net of fractures and subtle fault. The ant-tracker attributes have been expressed on these fracture net. It is powerful to delineate the related faults linear anomalies and related dissolution features random anomalies. The attribute is sensitive to irregularity in the sedimentation.

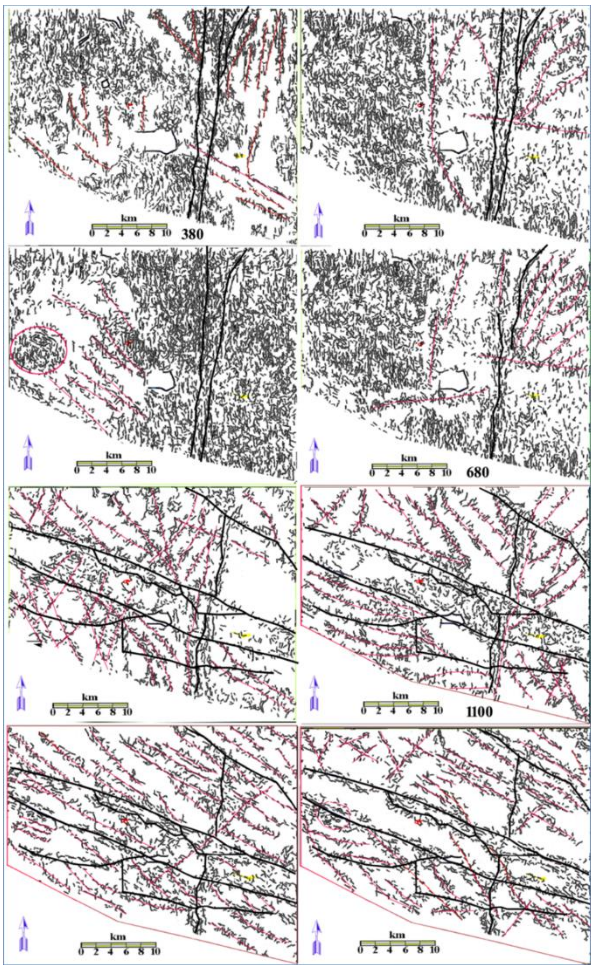

Figure 12 - Ant-track slices at different level across Jurassic – Cretaceous packages illustrate the geomorphological path of subtle faults in the area.

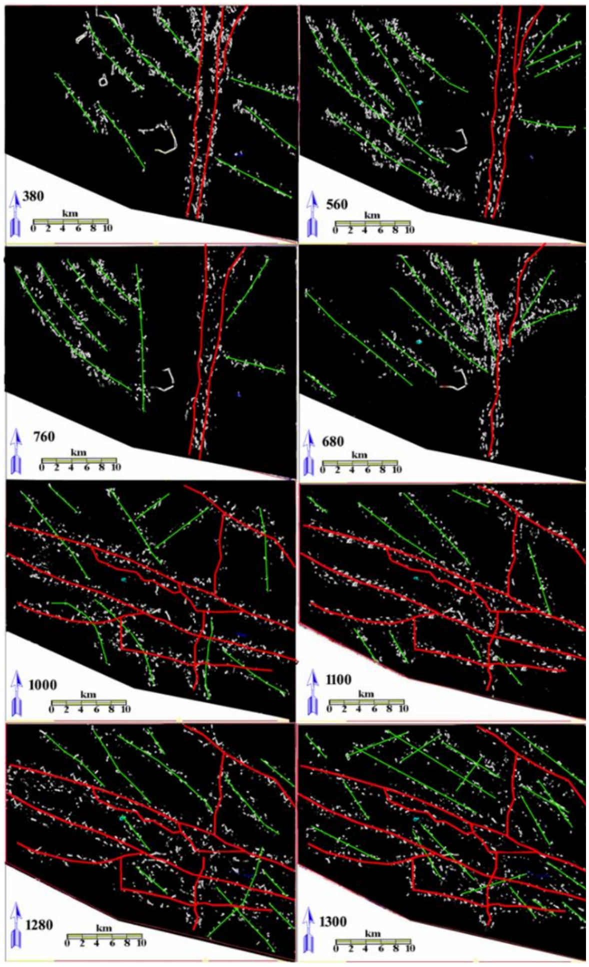

Figure 13 - Ant-track slices after find edge filter at different level across Jurassic – Cretaceous packages illustrate the geomorphological path of subtle faults in the area.

Conclusion

3D seismic data provide fantastic performance to make geomorphological faulting analysis in the Merjan_West-kifl oil fields. The study area has been affected by extensional normal faults which have divided into two groups: the first affects the Jurassic and lower Cretaceous rocks and the second effect the upper Cretaceous and lower Tertiary rocks. The first group is associated with the post rift thermal sag, passive margin progradation and gravitational collapse (lower Jurassic – mid Turonian 190 – 92 ma); approximately Sargelue – Nahr Umr Formations depositional period. The second group is few and is associated with the rifting creating the Euphrates graben as collision wanes (Late Turonian – Maastrichtian 90 – 70 Ma) approximately Tanuma shale / Sadi – Shiranish Formations depositional period). Subtle faults are very important where they facilitate the movement or migration of the fluid across the stratigraphic column in the study area. It plays an important role in the oil migration from source into the reservoirs. The ant-tracker attributes have been expressed on these fracture net. It is a powerful tool to delineate the related faults linear anomalies and related dissolution features random anomalies. Overall, the analysis of faulting framework and tectonic evolution provide deep understanding of our oil fields and rigid theoretical background to support for future prospecting whether it is in the study area and other similar rifted basins of the Mesopotamian.

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