Egyptian Geophysical Society
EGS Journal, Vol. 17, No. 1, 101-113 (2019)

STRUCTURAL MAPPING USING SEISMIC COHERENCE ATTRIBUTE ANALYSIS: AN EXAMPLE FROM SOUTHERN GULF OF SUEZ, EGYPT

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التخريط التركيبي في الجزء الجنوبي من خليج السويس (مصر) باستخدام تحليل السمات السيزمية المترابطة

الخلاصة: يعد حقل صدقي واحدا من حقول B-Trend الذي يقع في وسط الجزء الجنوبي من خليج السويس، مصر، والذي يقع أيضا بداخل منطقة إمتياز جي إس ٣٨١ كما يبعد ١٢ كم من شاطئ البحر وأيضا ٨,٧٥ كم شمال غرب حقل الزيت الشرقى. وجود المصادر البترولية في خليج السويس أعطته أهمية كبيرة وهو يوصف بأنه منخفض طولي كبير (٤٠٠كم) يفصل شبه جزيرة سيناء عن قارة أفريقيا. ويعد خليج السويس من أكثر المناطق المتصدعة في مصر وهو يحتوي علي صدوع عادية رئيسية تتجه شمال غرب– جنوب شرق وتفصل كتل صدعيه مائله تتكون من صخور رسوبيه يصل سمكها إلي ٦كم . وجود سمك كبير من متبخرات عصر الميوسين في جنوب خليج السويس أدي إلى ضعف جودة التسجيلات السيزمية ولذلك سيكون إستخدام طرق المعطيات السيزمية أكثر كفاءة في إظهار الصدوع عن التسجيلات السيزمية التقليدية. الهدف الرئيسي من الدراسة هو التعرف الدقيق علي التراكيب الجيولوجية التحت سطحية المؤثرة في منطقة الدراسة وذلك عن طريق التفسير التقليدي للبيانات السيزمية ثلاثية الأبعاد وأيضا عن طريق تفسير المعطيات السيزمية. تتأثر منطقة الدراسة بالعديد من الصدوع العادية بإتجاه شمال غرب – جنوب شرق حيث أظهر التفسير التقليدي للبيانات السيزمية ثلاثية الأبعاد أربعة صدوع عادية تتجه شمال غرب– جنوب شرق، بينما أظهرت المعطيات السيزمية ثلاثة صدوع أخري تتجه شمال غرب– جنوب شرق لم تظهر علي البيانات السيزمية التقليدية.

ABSTRACT: *Sidki field is one of the B-trend oil fields located in the central southern part of the Gulf of Suez, Egypt. The Gulf of Suez acquired its importance from having hydrocarbon resources. It is described as an elongated depression (400 km long) separating central Sinai Peninsula from Africa. It also represents one of the most intensively faulted areas of Egypt, which is dominated by major normal faults trending NW-SE and tilted fault blocks with sedimentary fill up to 6 km thick. The quality of the seismic records in the southern part of the Gulf of Suez is generally poor due to the presence of thick evaporitic sequence in the upper Miocene. Hence, the using of coherence seismic attribute will be an effective tool in visualizing the trends of faults, which are not visible in seismic amplitude information. The main objective of this study is to identify and delineate the possible subsurface structures of the area. The methodology combined conventional interpretation of 3D seismic data of the study area and then analyzing the coherence seismic attributes of the same 3D seismic dataset to enhance the fault interpretation. The conventional interpretation of the 3D seismic data reveals four normal faults having NW-SE trend, and other three new faults interpreted after applying the technique of coherence attribute analysis. These faults are also trending NW-SE and dipping to NE.*

INTRODUCTION

The Gulf of Suez is a late Oligocene rifted basin running in a NW-SE direction from 27°30'N to 30°00'N (Fig.1). The Gulf of Suez rift, together with the Red Sea and the Aqaba–Dead Sea transform systems comprise the Sinai triple junction, which resulted from the Northeasterly movement of Arabia away from Africa during the Neogene time.

In the Gulf basin the majority of normal faults show curved traces, oriented N140˚ and dipping between 60˚ and 80˚ toward the center of the basin and bounded tilted blocks with a tilt angle reaches 30˚.

A subsidence study proved that the tilted blocks were initially very large, and then divided into smaller ones when the tilt angle increased with increasing extension (Moretti and Colletta, 1987).The new faults that appear at this time are parallel to the previous ones and therefore enhance the apparent asymmetry of the Gulf.

In general, the Gulf of Suez rift is characterized by a zigzag fault pattern (Fig. 2) composed of N-S to NNE-SSW, E-W and NW-SE striking tensional fault systems (Garfunkel and Bartov, 1977, and Moustafa, 1993).

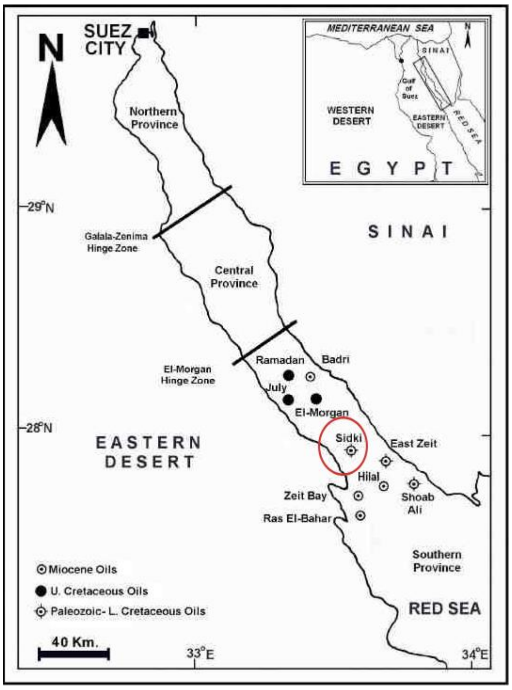


Fig. 1: Location map and regional geometry of the Gulf of Suez, showing Sidki field location.

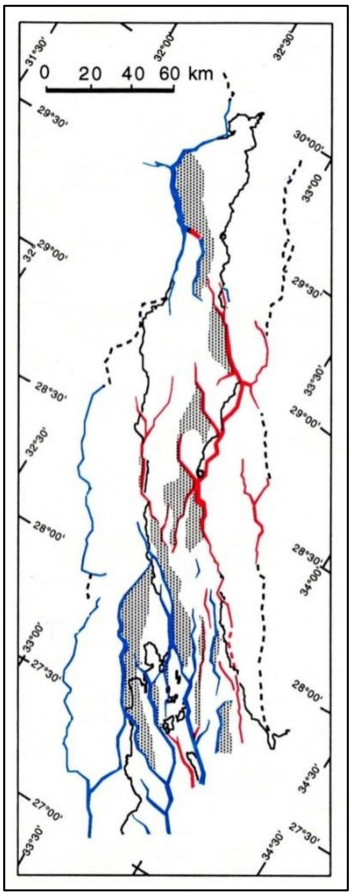


Fig. 2: Simplified fault map of the Gulf of Suez showing faults possessing in excess of 1 km (0.6 mi) of throw; blue faults are downthrown to the northeast and red faults are downthrown to the southwest. Stippled areas represent the pre-Miocene surface below 4 km (2.5 mi). The thin dashed line represents the locations of the rift-bounding faults. The map is grossly simplified after 1:50,000 scale structure maps constructed by H.M. Proctor and T.L. Patton.

Based on tilt direction of the fault blocks and the dip direction of main fault, the Gulf basin segmented into three main half grabens (or structure provinces) Darag basin (or Araba Dip province) at the north, Belayim province in the middle and Amal-El Zeit province at the south (Fig. 1). Each province has its own structural and stratigraphic history. Each province is asymmetric, bounded on one side by a major NW-trending fault system with large throws (4-6 km). The strike direction of major normal faults is constant however the dip direction reverses 180 degree between provinces.

The Northern Province where the main faults are tilted eastward and the block tilting is southwest, the central province where the main faults are tilted westward and the block tilting is southeast, the southern province where the main faults are again tilted eastward and the block tilting is southwest (Moustafa, 1976).

The study area lies within the southern province which is also characterized by the presence of salt tectonics which affected badly the seismic amplitude.

Fig. 3 is a structural cross section across the southern part of the Gulf of Suez includes the study area.

Structurally two accommodation zones shown in (Fig. 1), oblique to the rift trend, separate the three depocenters which are Galala- Zenima in the North and Morgan in the South (Moustafa, 1976). These accommodation zones are responsible for the change of asymmetry between each two provinces in the Gulf.

A number of unconformities interrupt the Gulf of Suez sedimentary record. These unconformities formed primarily due to the rift related tectonics.

The Stratigraphic succession of the Gulf of Suez can be subdivided into three mega sequences relative to the Miocene rifting, the Pre-rift sequence include Proterozoic basement rocks and Paleozoic to Upper Eocene sediments, the upper Oligocene and Miocene Syn-rift sequence and the Pliocene to Pleistocene Post-rift sequence.

Geologic setting of Sidki field

Sidki field is one of the B-trend oil fields which is situated in the central southernmost part of the Gulf of Suez, it is also lies within the GS 382 concession block, 12km from the shoreline and 8.75km NW of East Zeit field (Fig.1). The field is operated by the Gulf of Suez Petroleum company (GUPCO) which is a joint venture between the EGPC and BP Production Company.

Sidki field structural setting (Fig.4) is characterized by the presence of two fault trends, NW-SE and NE-SW trending faults and comprises a SW dipping faulted blocks (Helmy, 1990).

The stratigraphic succession of southern Gulf of Suez (Fig. 5) where situated the study area has been studied by many workers, it contains lithologies ranges from Paleozoic to recent, which is divided into:

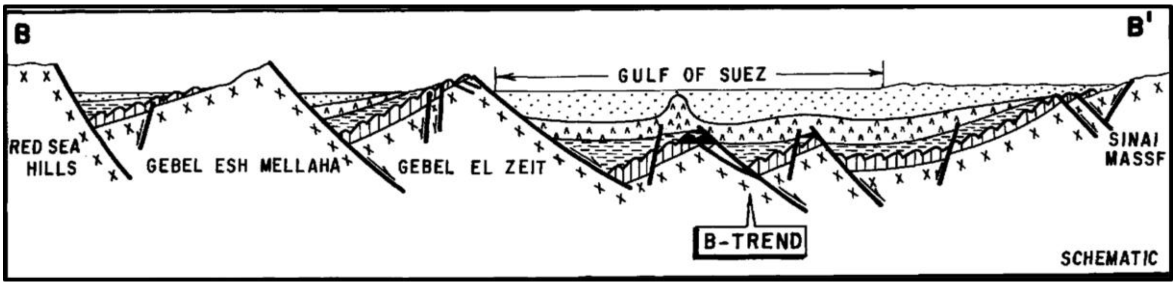
1- Pre-rift lithostratigraphic units (pre-Miocene units)

The pre-rift stratigraphic sequence is composed of strata ranging from Precambrian to upper Eocene and contains different facies that were deposited under terrestrial and marine-platform environments. This period of sedimentation was affected by major unconformities representing non-deposition or erosion at different geologic times.

2- Syn-rift lithostratigraphic units (Miocene units)

The syn-rift sequence starts with Oligocene units which unconformably overlies the Eocene rocks. It is composed of interbedded limestone, sandstones, and shales, also Red bed strata known as Tayiba red beds were deposited in the late Oligocene having accumulated during the early rifting stages.

The Miocene deposits are widely distributed over the Gulf of Suez and subdivided into two main groups, the Gharandal and Ras Malaab. The Gharandal Group contains Nukhul and Rudies formations while Ras Malaab group contains the Zeit, South Gharib, Belayim, and Kareem formations, in descending order. The presence of great Thick evaporitic sequence characterize the Miocene age.



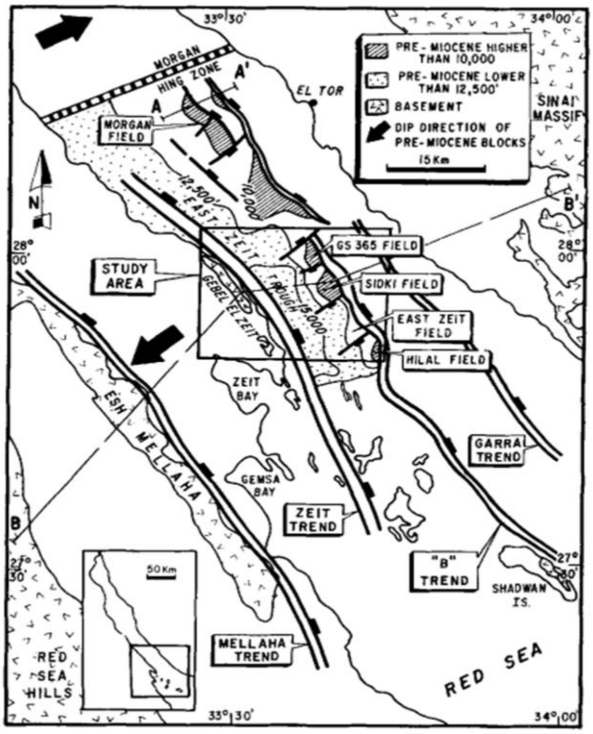


Fig. 3: Structural cross section across the southern part of the Gulf of Suez and the line of section is shown in the map below which shows also southern Gulf of Suez trends and pre-Miocene structures (after Helmy, 1990).

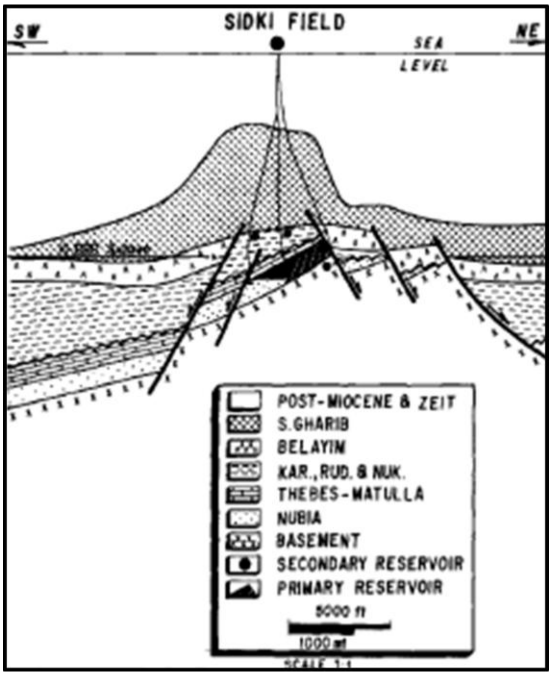


Fig. 4: Structural dip cross section across Sidki field (after Helmy, 1990).

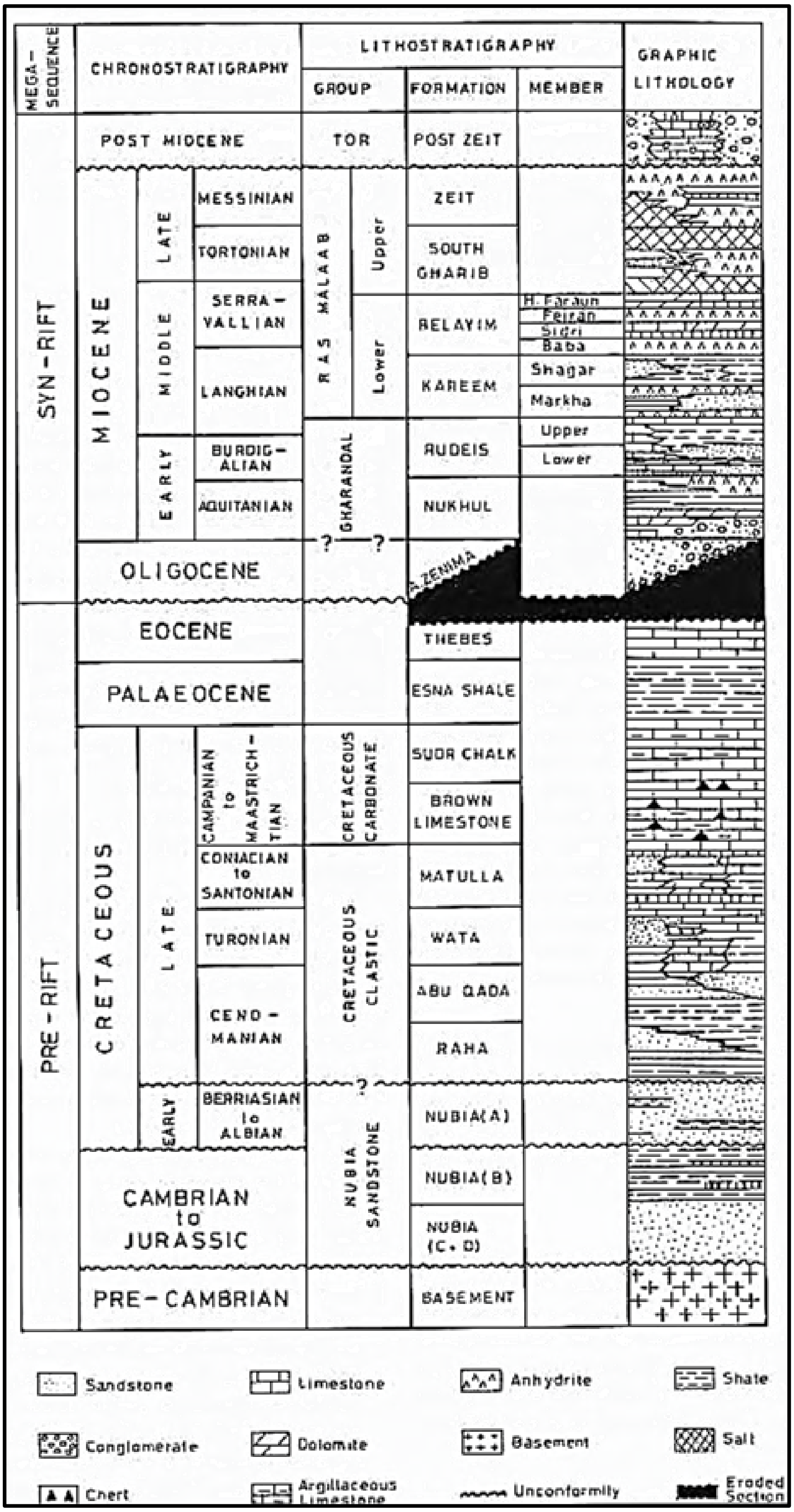


Fig. 5: Stratigraphic column of the southern Gulf of Suez (sources: Barakat, 1982; Khalil and Meshref, 1988; Salah, 1992; and Hammouda, 1992).

In the present study we focused mainly on the Kareem Formation, the secondary reservoir in syn-rift units. The Kareem Formation conformably overlies the Rudies Formation and consists mainly of interbedded sandstones, halite and carbonates with thin streaks of anhydrite in the lower part of the section. It is classified into Rahmi member (or Markha member) and overlying Shagar member and deposited in shallow, partly open marine, with localized lagoonal conditions with thickness reach 500m. It is langhian to serravalian in age.

3- Post-rift lithostratigraphic units (post-Miocene units)

The post-Miocene deposits are known as the post-Zeit Formation of Pliocene to Recent age. These sediments are widespread in the Gulf of Suez and show a marked variation from one place to another. Generally, they consist of sand and sandstone, shale and/or carbonate with thin streaks of anhydrite and unconformably overlying the Miocene sediments.

Field history

The discovery of Sidki field was in 1976 by well GS 382-1A and the production started in December 1977where the primary and secondary targets were Nubia sandstone and fractured basement respectively. In June, 1978 another well GS 382-3 began to produce, in December 1989, the Sidki platform “A” is considered a total loss and all wells have been plugged and abundant due to the collision of the platform with a Cargo ship. A new platform “B” was constructed and is located approximately 1150 feet NE of the old platform location and new nine wells were recommended to be drilled from the new platform “B”. The first seismic maps have been constructed on the top and the base of South Gharib salt and the quality of data was poor to fair.

Sidki field structural mapping

The regional structures of the study area are geophysically identified at Kareem level through workflow using seismic data interpretation. At First, conventional interpretation of 3D seismic data was carried out, and due to the poor quality of seismic data (caused by the presence of thick salt section), coherence attribute analysis of 3D seismic data of the same area was carried out later. Finally, comparing the results of the two different types of seismic interpretations by calibration of the borehole data of the area.

Conventional interpretation of seismic data

The 3D seismic depth volume was interpreted on an interactive workstation. Top Kareem reservoir was interpreted and mapped using adequate seismic to well correlation and their seismic continuity.

The main structure in this field is a structural high which is dissected into several parts by normal faults. Four faults trending NW-SE are obtained as shown in the inline seismic sections (10183 and 10108) (Figs.6 and 7). These faults are F1, F2, F3 and F4. The four faults are normal faults dipping toward the NE and have a direction of throw also toward the NE direction.

Dip- meter data show that the dip amount at Kareem level lies between 8 and 11 degrees and the dip direction is southwest. The seismic depth-structural map of top Kareem Formation (Fig. 8) illustrates the structural elements of Sidki field.

Coherence attributes analysis of 3D seismic data

Seismic attributes are essentially derivatives of the basic seismic measurements (i.e. time, amplitude, and frequency) and considered a powerful tool in the characterization of faults and fractures in 3D seismic data volumes (Brown, 1996).

Most of faults and fractures are usually not visibly imaged by the conventional seismic sections and time slices displays, this is because they have smaller throws relative to the resolution limit of the seismic survey. Seismic attributes often provide a quick way to visualize the trends of faults and fractures, which are not visible in seismic amplitude information (Santosh et al, 2013).

One of the most effective seismic attributes is Coherence attribute which measure the similarity or dissimilarity of a particular point to its neighbors and provide useful tool to identify the faults missed using conventional method of interpretation (chopra and Marfurt, 2007) and to study the discontinuities by similarity attribute a 3D seismic dataset of similarity is created.

By applying the coherence seismic attribute analysis, as shown from (Figs. 9 to 16), seismic sections, coherence sections and Coherence slices at different depths extracted to show the faults on different levels. Three New faults appeared which are F5, F6 and F7. The three faults have a NW trend, dipping NE and have a direction of throw toward the NE, and as shown in the coherence slices the faults are very clear and easily recognized.

Fig. 17 illustrates the resulting top Kareem depth-structural map that shows the structural elements of Sidki field, after applying coherence attributes analysis techniques.

RESULTS AND CONCLUSION

The present study deals with the interpretation and evaluation of the seismic data of Sidki field in the southern part of the Gulf of Suez, in terms of subsurface geologic structures characterizing the area. The 3D seismic data, integrated with the geologic data, are worked to define the structural configuration of the area, through the structural mapping of Kareem horizon.

The Kareem depth map of Sidki field reflects an asymmetrical NW trending anticlinal feature dissected by a set of NW-SE fault elements.F1, F2, F3 and F4 are four normal faults have northwest trend and dipping toward southwest are interpreted on conventional seismic, and clearly obtained on coherence seismic attribute.

Other three new normal faults, trending northwest - southeast and dipping toward southwest, are interpreted after using coherence seismic attribute analysis; these faults are F5, F6 and F7.

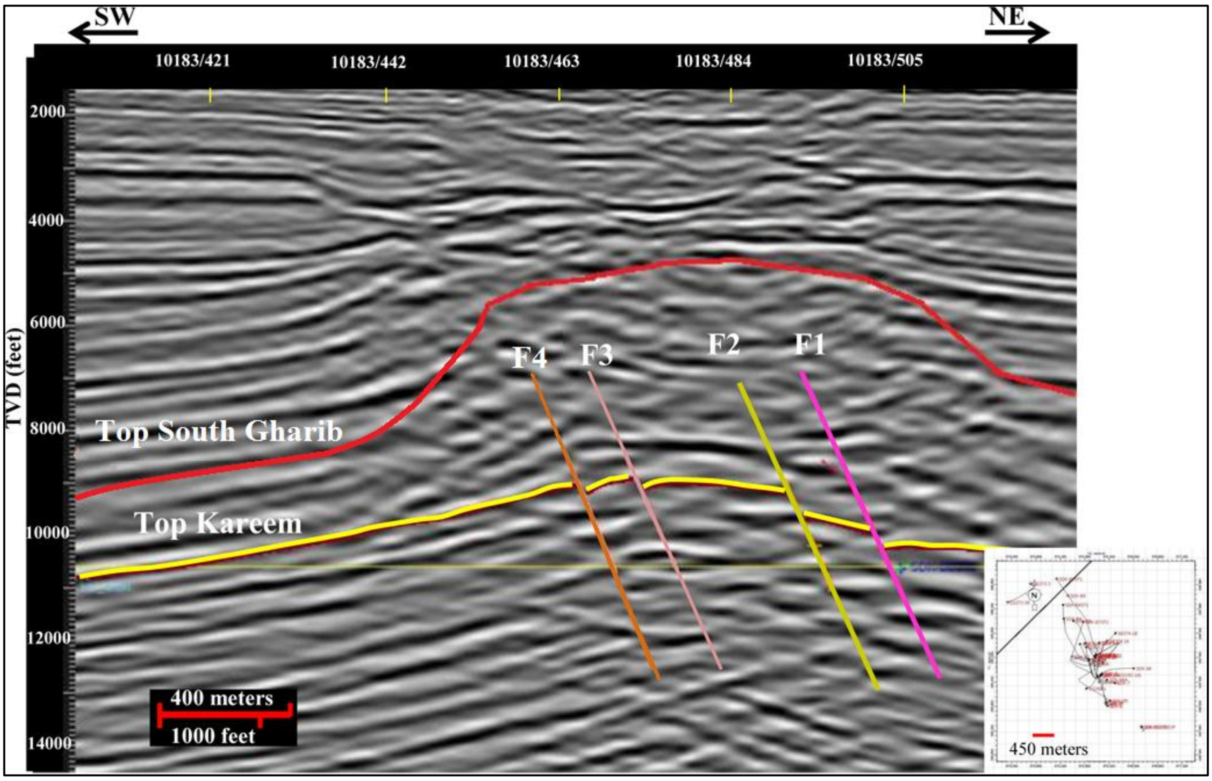


Fig. 6: Inline seismic section (10183) showing the faults F1, F2, F3and F4.

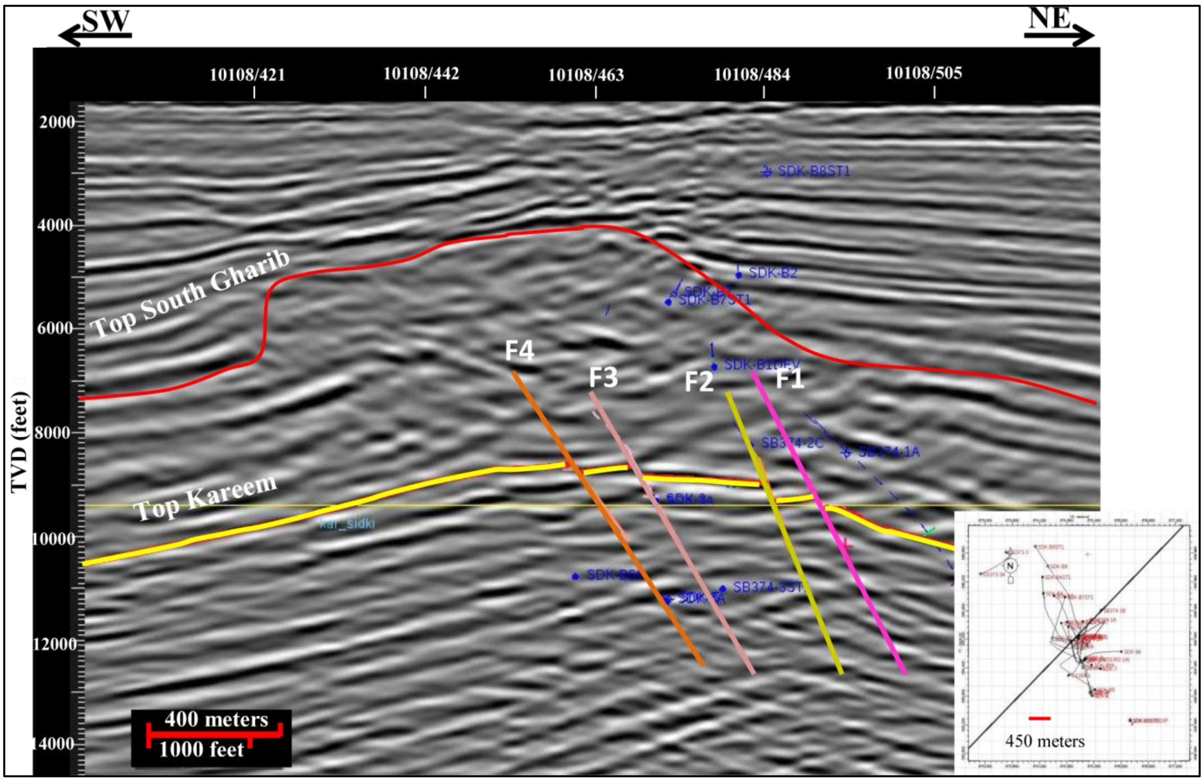


Fig. 7: Inline seismic section (10108) showing the faults F1, F2, F3and F4.

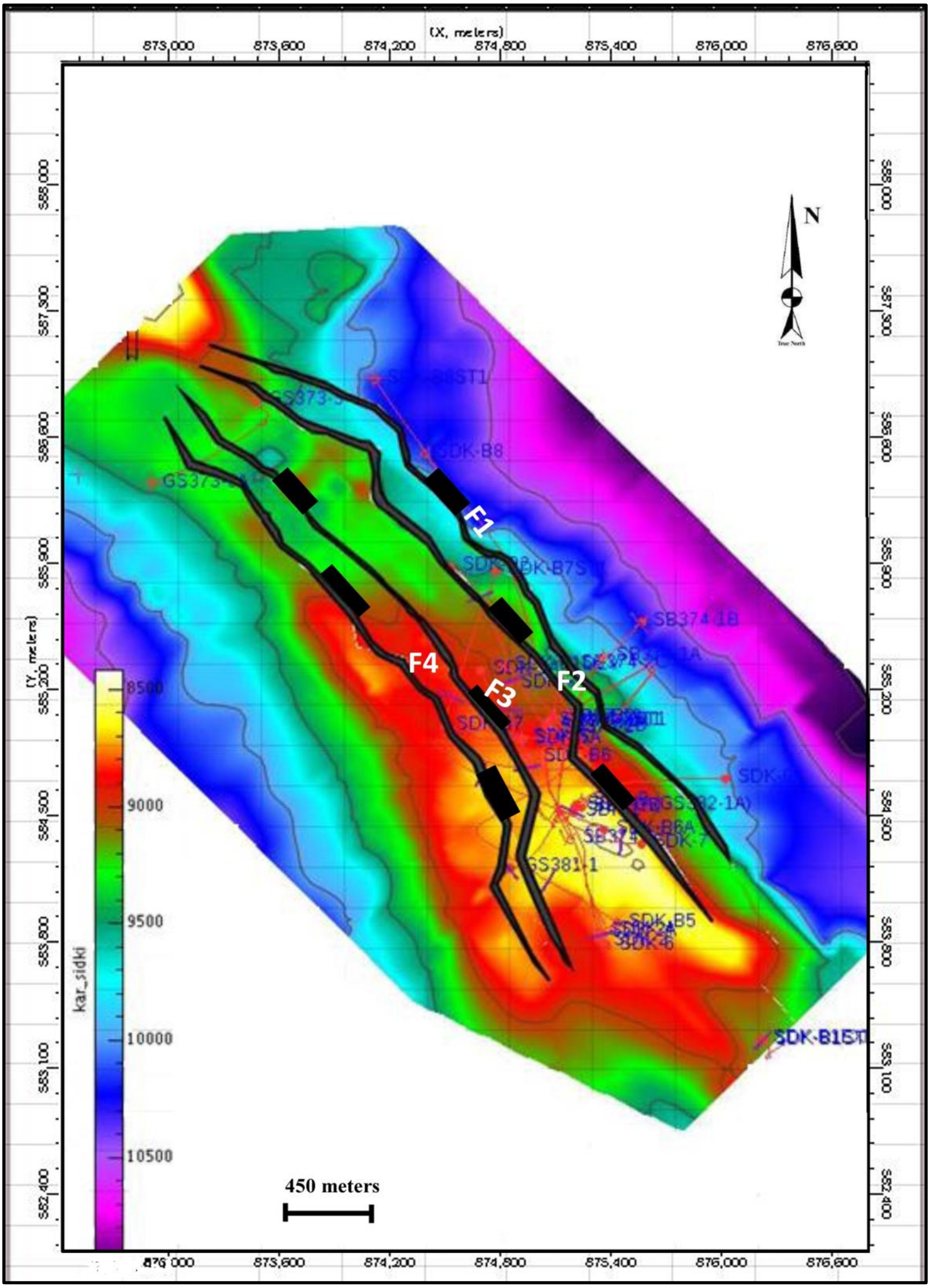


Fig. 8: Depth-structural map of top Kareem Formation, constructed by using conventional seismic interpretation techniques.

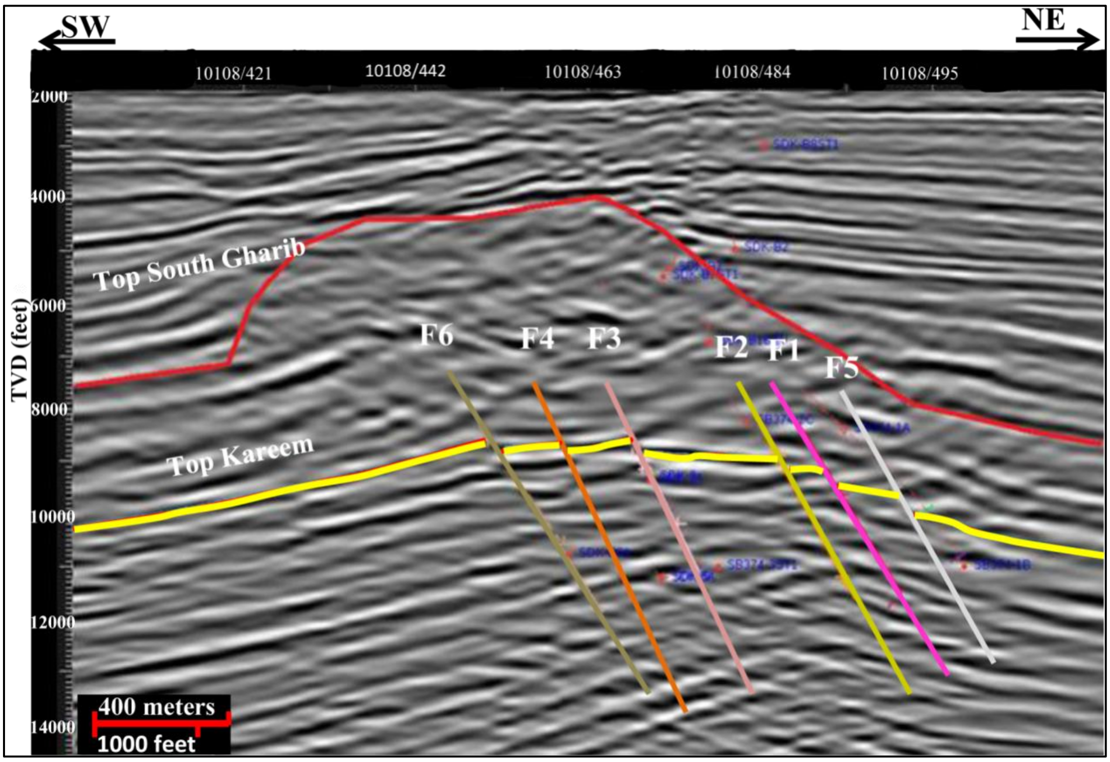


Fig. 9: Inline seismic section (10108) showing two new faults F5 andF6, see Fig. 10 for the location.

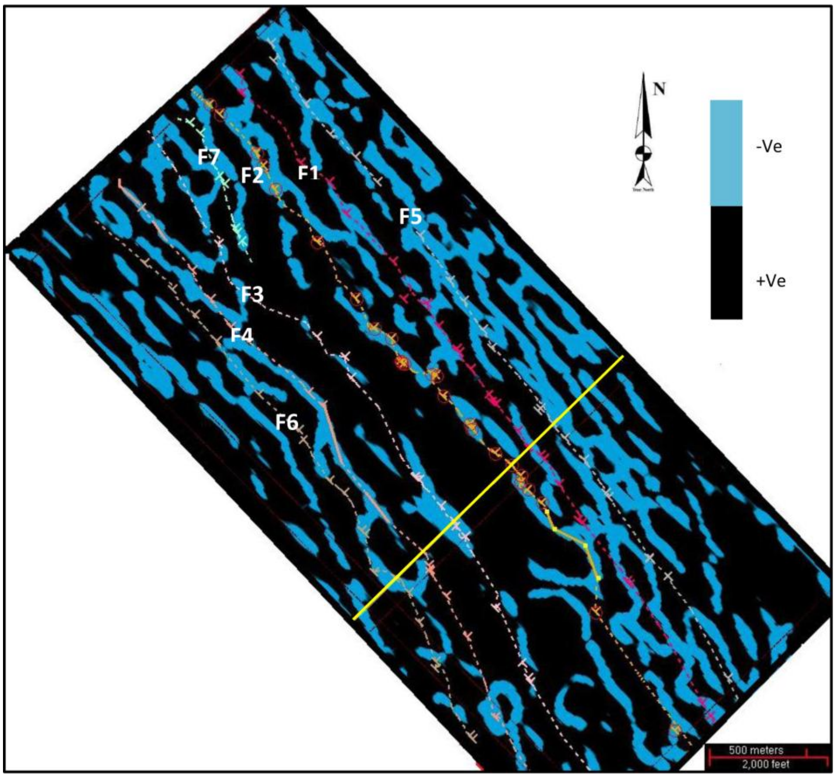


Fig. 10: Coherence slice at 9200ft. showing the trend of faults, the yellow line represents the location of the inline seismic section in Fig. 9.

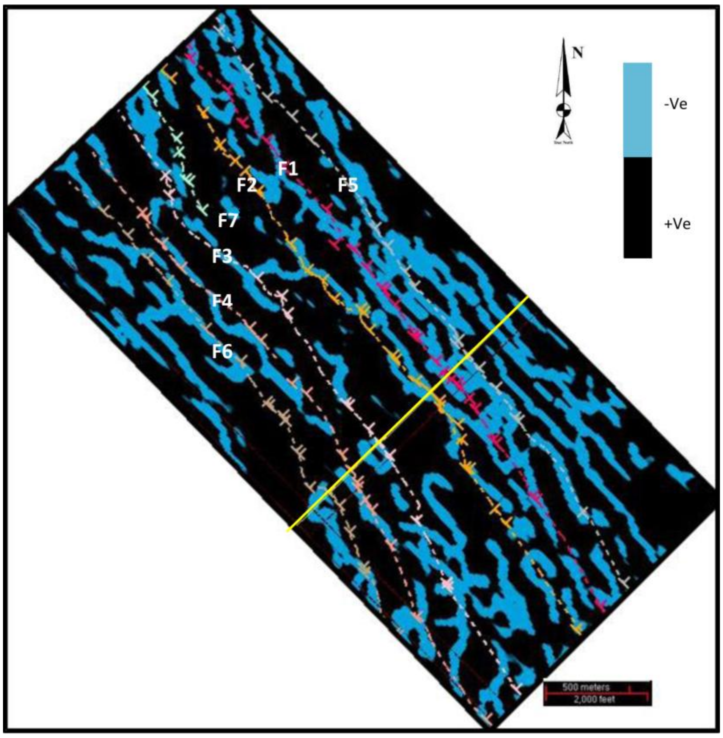


Fig. 11: Coherence slice at 9600ft. showing the trend of faults, the yellow line represent the location of the inline seismic section in Fig. 9.

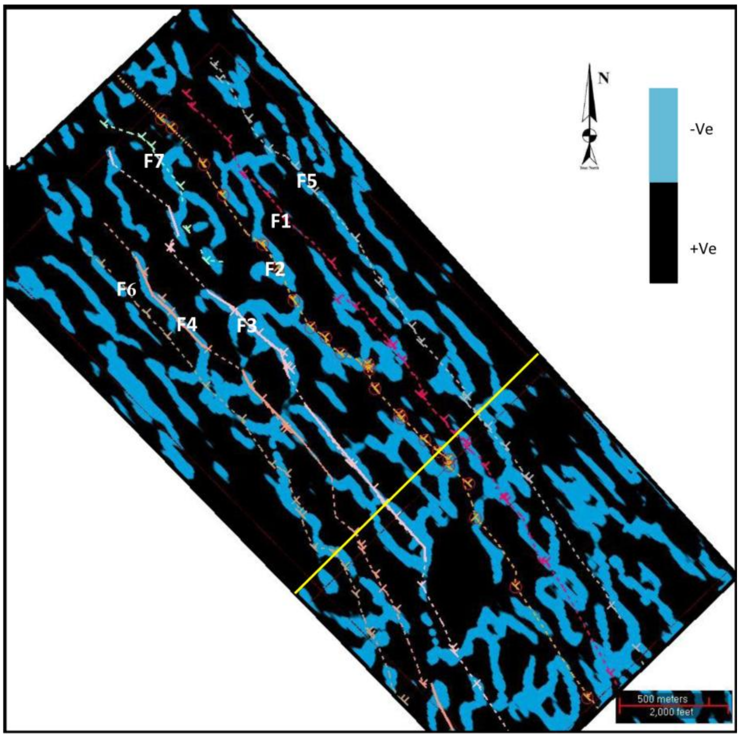


Fig. 12: Coherence slice at 10200ft. showing the trend of faults, the yellow line represents the location of the inline seismic section in Fig. 9.

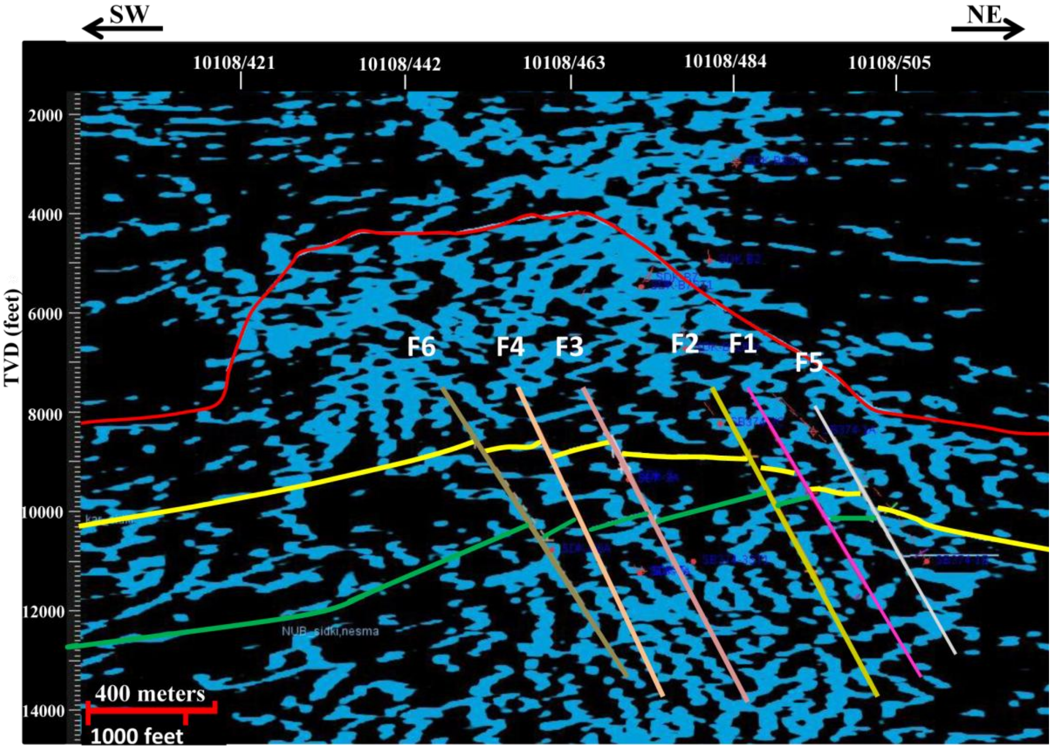


Fig. 13: Inline coherence seismic section (10108) showing two new faults F5 and F6, See Fig.10 for the inline section location.

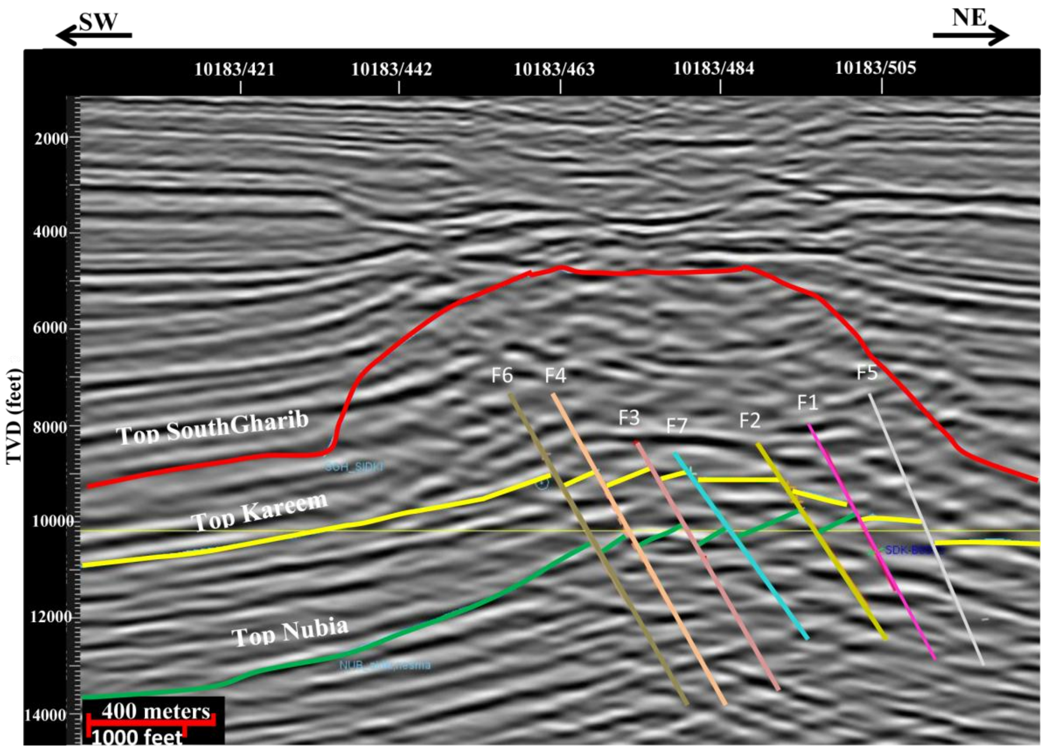


Fig. 14: Inline seismic section (10183) showing the three new faults F5, F6 and F7, See Fig. 16 for the location.

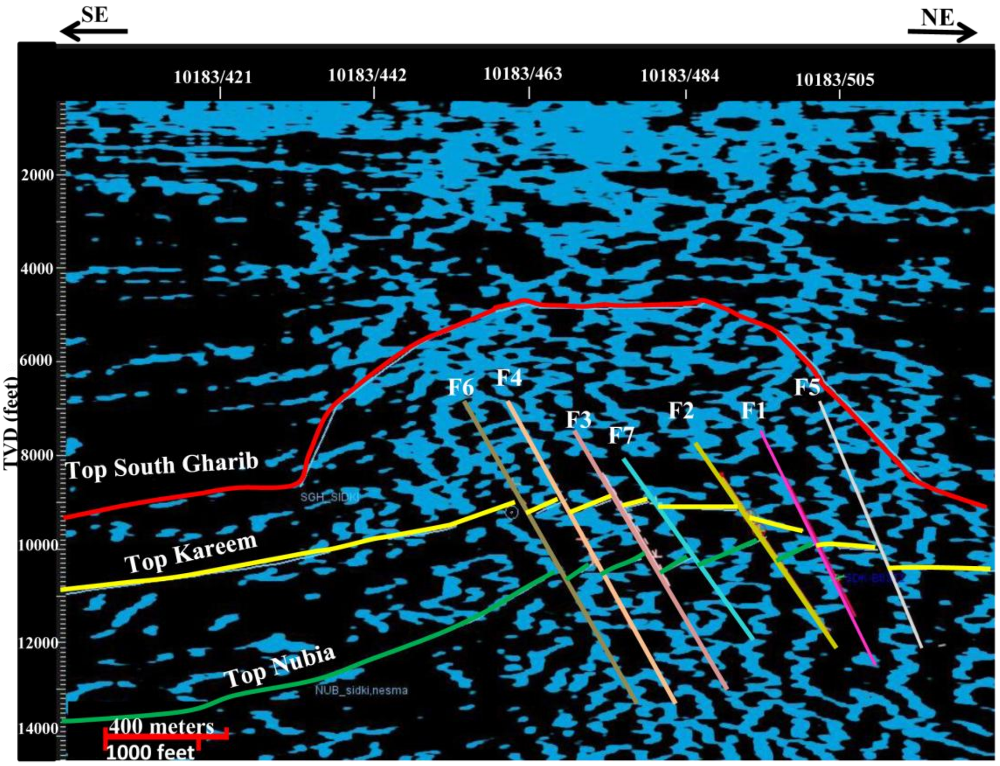


Fig. 15: Inline coherence seismic section (10183) showing the three new faults F5, F6 and F7, see Fig. 16 for location.

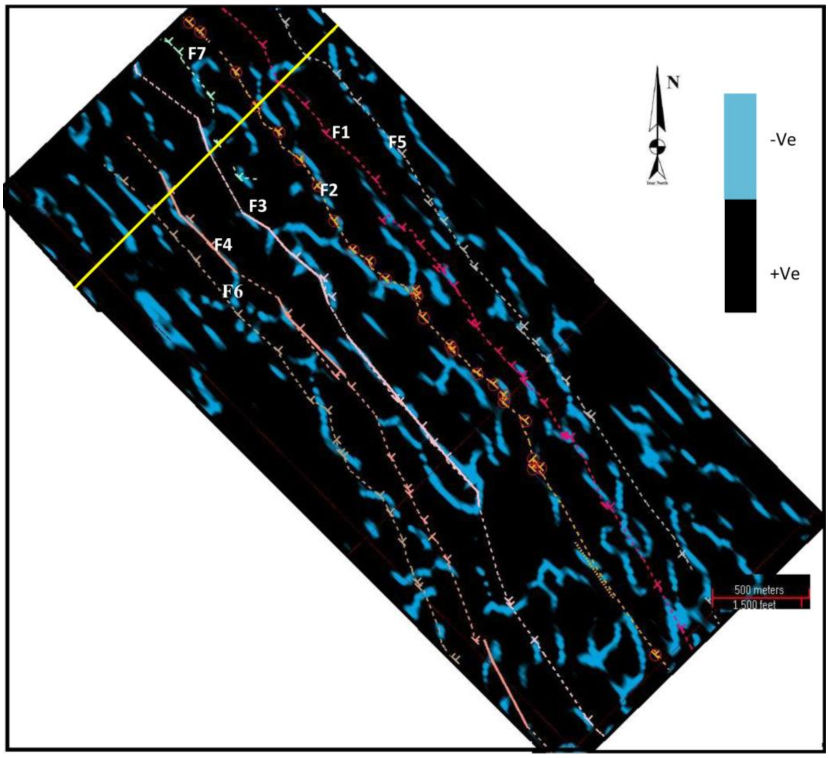


Fig. 16: Coherence slice at depth 10200 ft., the yellow line represents the inline sections in Figs. 14 and 15.

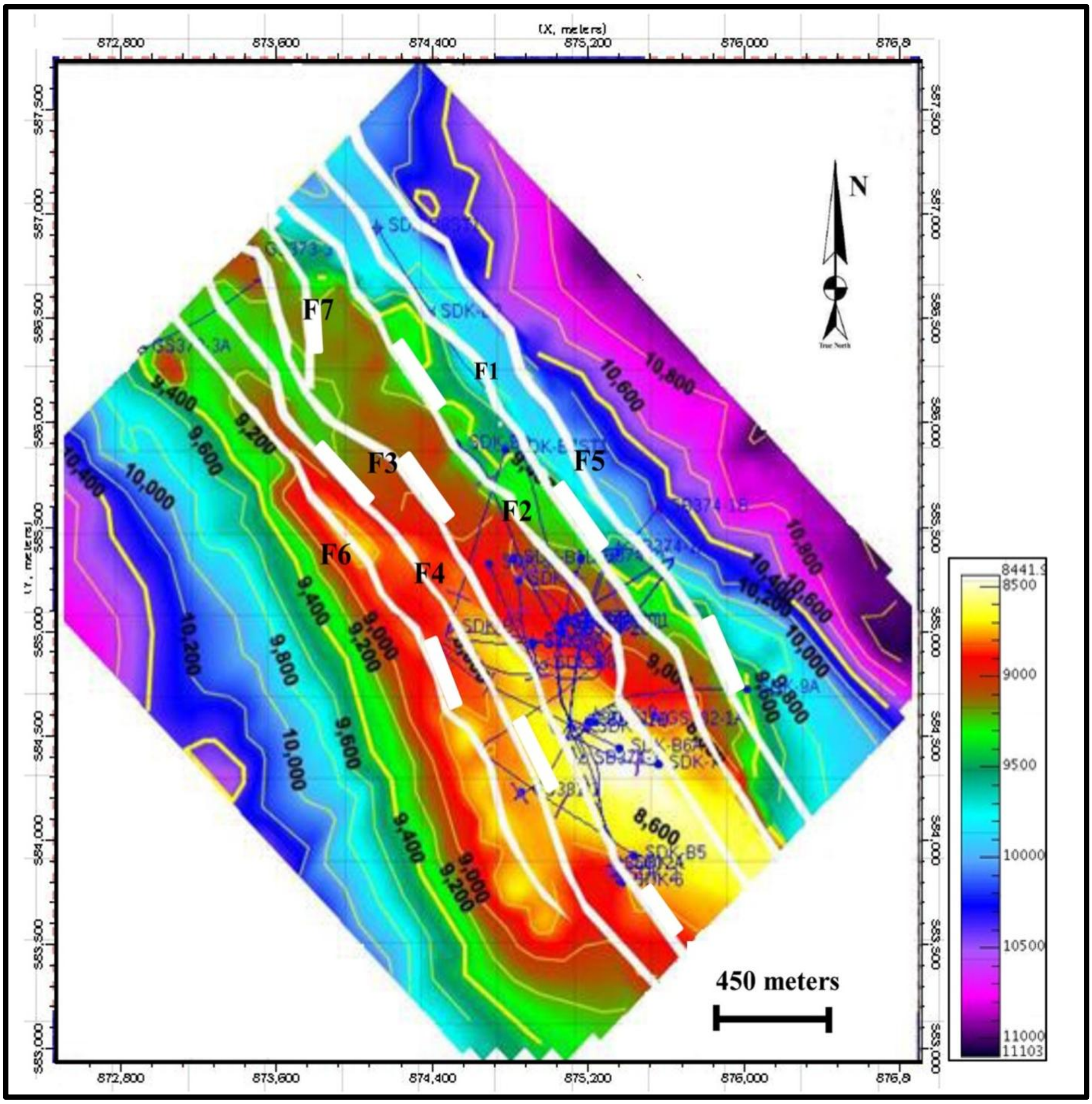


Fig. 17: Depth-structural map of top Kareem Formation, constructed using coherence attribute analysis techniques.

We can conclude that the interpretation of the 3D seismic data for outlining the structural elements will be more efficient using coherence seismic attribute analysis.

Acknowledgements

We would like to thank the Gulf of Suez Petroleum Company and the Egyptian General Petroleum Corporation for releasing the subsurface data used for this study.

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