Egyptian Journal of Geology, v. 64, 2020, p. 1-11

VISUALIZATION AND EXTRACTION OF SAND RESERVOIR UNITS IN MIT GHAMR FORMATION USING SEISMIC FREQUENCY BASED ATTRIBUTES, TAURT FIELD, EAST NILE DELTA, EGYPT

El-Rawy, A. M. A.

Department of geophysics, Faculty of Science, Ain Shams University, Egypt.

ABSTRACT

Visualization and extraction of 3D sand units from seismic data are critical for improving reservoir understanding, detecting anomalies, and defining facies. Stratigraphic features of the reservoir can be identified using seismic frequency based attributes; spectral decomposition, RGB blending and geobody extraction. A geologic feature can then be better delineated and extracted as a geobody. Once extracted, the further 3D static reservoir model can be constructed for any future reservoir characterization and development.

The present study is an attempt to show at what extent the frequency based attributes success to define the lateral and vertical distributions of the sand bodies and its internal units without any conventional seismic interpretation. The study was performed on the sand reservoir units within Mit Ghamr Formation, Taurt Field.

The application of these frequency attributes was successfully revealed the geometrical distribution of the sand units; S10, S20 and S30 in different directions.

Keywords: Spectral decomposition attribute, RGB blending and geobody extraction.

INTRODUCTION

The Nile Delta is one of the most promising areas for gas exploration and production in Egypt and the Middle East. The delta body consists mainly of sand and clays that resulted from the activities of Nile River in the Pliocene-Quaternary time (Said, 1981). Proven reservoirs vary in age from Oligocene/Early Miocene through Pleistocene. Delineation and extraction of the sand reservoirs that found the delta formations is critical for improving reservoir understanding, detecting anomalies, and defining facies.

Combinations between different seismic attributes considered as a successful tool to define the sand reservoirs. Among them, spectral decomposition (SD) is a quick and effective method that gives better definition to determine stratigraphic architecture and structural features. It converts the seismic data originally in time or depth domain, to the frequency domain using the Discrete Fourier Transform method (DFT) for imaging and mapping temporal bed thickness and geological discontinuities over large 3D seismic surveys (Partyka and Gridley, 1999).

Usually conventional seismic interpretation and their attributes are used to study the geology, but sometimes a wide range of frequencies could hide a particular event that is trying to be detected. With this technique it is possible to analyze independently each frequency revealing features that were hidden before and also proved to be a robust approach for thickness and fault definition. By transforming the seismic data in time domain into the frequency domain via the DFT, the amplitude spectra delineate temporal bed thickness variability while the phase spectra indicate lateral geologic discontinuities. This signal analysis technology has been used successfully in 3D seismic data to delineate stratigraphic settings such as sand bars and structural settings involving complex fault systems (Brown, 2011).

The seismic volume rendering process is a display of all data within a seismic volume at the same time. By volume rendering a seismic volume and working with the opacity to make it partially opaque (high amplitudes) and partially transparent (crossover amplitudes), it is possible to identify hidden structural or depositional features. The RGB method is the best option in that situation because it allows the blending of different seismic attributes and its opacity scales using the primary colors (red, green and blue) which enable a better visualization of geological features. After visualizing the 3D object through seismic volume rendering or RGB blending, the body can be extracted. Once extracted, volumetric can be calculated or it can be directly sampled into a geological model as a discrete object to condition the petrophysical modeling.

Many studies were used frequency based attributes to define, visualize and model the structure and stratigraphic features in different areas among them (Chaves et al., 2011; Li et al., 2013; Torrado et al., 2014; Cao et al., 2015; Haris et al., 2017 and Okiongbo and Ombu, 2019).

GEOLOGIC SETTING

Taurt Field is located in the Mediterranean Sea approximately 72 km from offshore in the East Nile Delta area at a fault block to the northeast of Ha'py Field and northwest of the Denise Field in 108 m water depth (Fig. 1). Taurt is the first subsea-to-shore gas field development in BP's portfolio and the first subsea well production for BP Egypt. Taurt consists of six sand Pleistocene reservoir units. Down holes fluid samples have been collected from the exploration and the appraisal wells, which indicate that the reservoir fluids are considered dry gas.

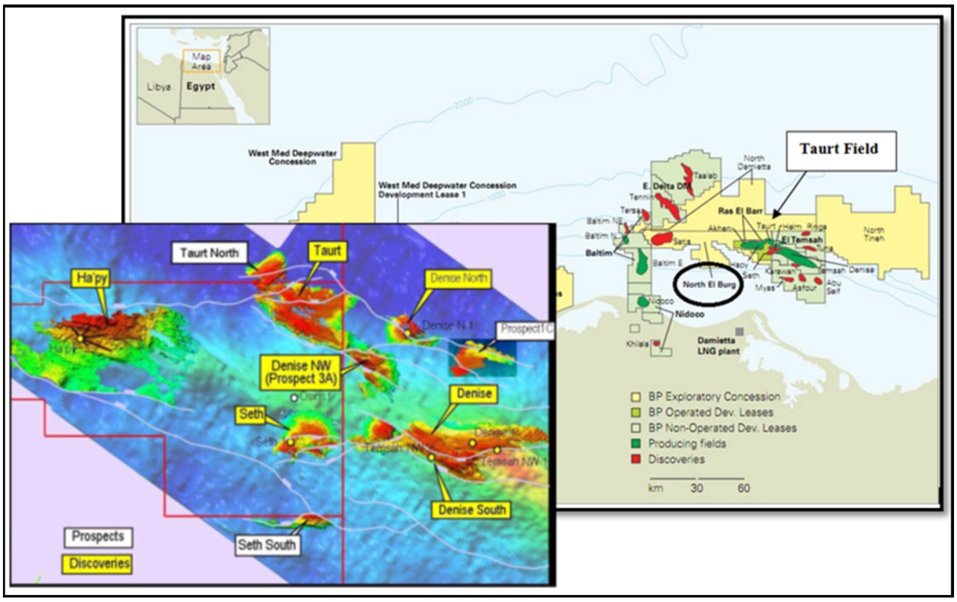


Fig. 1: Location map of the study area (Taurt Field).

Taurt Field accumulation is trapped in a tilted fault-block between two N-dipping listric growth faults which provide lateral seal to the north and south, converging at the western end of the field and opening out to the east, where sand reservoir units are dip-closed (Fig. 2). Top seals are shales of Bliqas Formation and their sealing capacity has been quantified as being very efficient. Two minor, west northwest-east southeast (WNW-ESE) faults are seen to splay from the North-bounding fault (Bb Internal report, 2007).

Mit Ghamr Formation contains thick layers of sands and pebbles which represent the filling of the basin by costal sands or by deposits from Nile flooding. The sands are medium to coarse grained size. The pebbles consist of quartzite, chert and dolomites. The sands can also contain shells of pelecypods (Rizzini et. al., 1978). The formation constitutes the filling up of the basin by coastal sands or by deposits from Nile flooding that reflects shallow marine to fluvial environments and ranges from Late Pliocene to Pleistocene.

METHODOLOGY

The dataset used in this study is multi-azimuth a post-stack time migrated seismic data volume (MAZ volume) (Fig. 3). The interested sand units are found in time interval (1100- 1500 msec). Seismic section

(Fig. 4) clarifies that tops of sand units S10, S20 and S30 have strong negative polarity (red color) due to gas effect but the base of them characterized by high positive polarity due to velocity change from gas sand to water sand. Also, the seismic section clarifies lateral and vertical extension of reservoir units, S20 reservoir unit represents maximum reservoir extension but S30 is minimum reservoir extension. S30 unit is not clearly appearing along the section. The resolution of seismic data is unable to clarify the internal elements within seismic units.

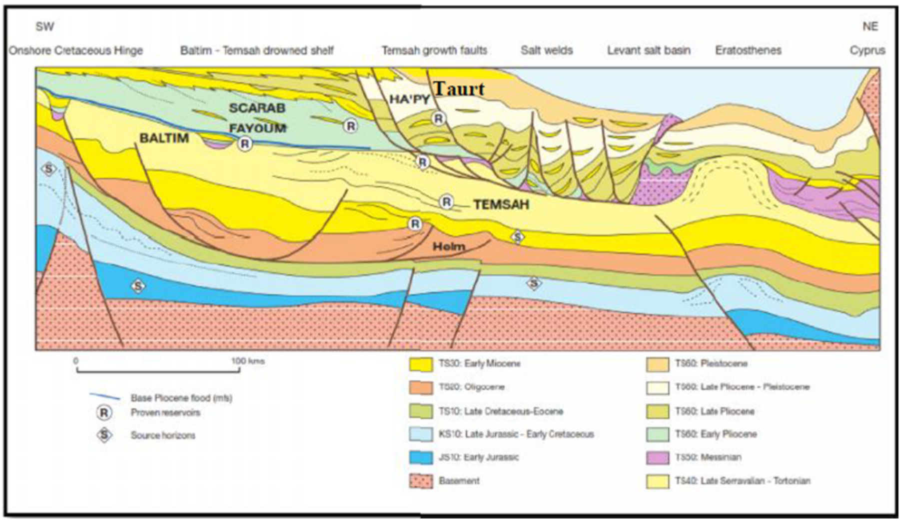
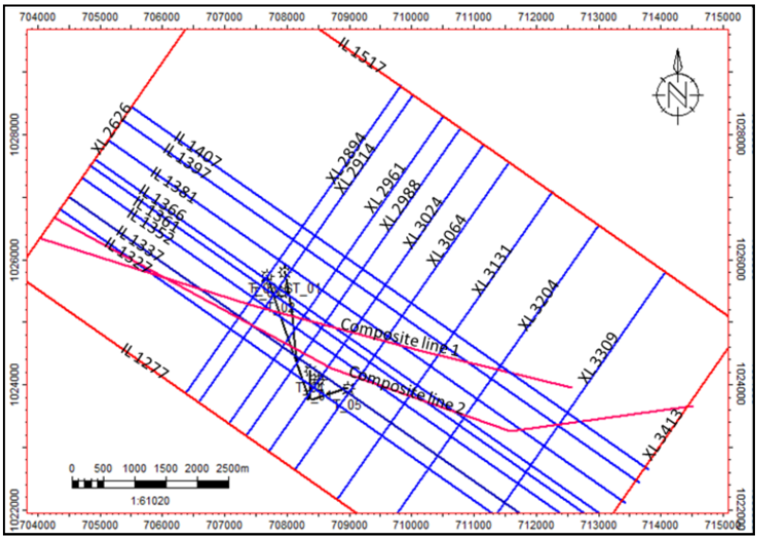


Fig. 2: Schematic cross-section through Nile Delta province shows regional and stratigraphic context of Taurt Field (Dolson et al., 2001).

Spectral Decomposition Attribute

Spectral decomposition (SD) is a technique that breaks down seismic signal into narrow frequency sub-bands. When these sub-bands are examined in a spatial context (i.e., plan view of a 3D survey) they reveal interference that is occurring across the available bandwidth of signal so that it makes use of much lower seismic frequencies to image the reflective nature of the subsurface rock mass. Such decomposition provides greater resolution and detection of the layer stacking heterogeneity, boundaries, and thickness variability than are possible with traditional broad band seismic attributes. The interference that observed in seismic data is controlled by the interaction of a band-limited signal with local distribution of impedance contrasts. This interaction causes geologic features to tune in at some frequencies and tune-out at other frequencies. Finding frequencies at which the geologic features standout (i.e., either tune-in or tune-out) from the background amplitude is the key to the successful application of spectral decomposition (Brown, 2011). It has been used for a variety of applications including layer thickness determination (Partyka et al., 1999), stratigraphic visualization (Marfurt and Kirlin, 2001), and direct hydrocarbon detection (Castagna et al., 2003).

Fig. 3: Location map of seismic lines and available wells of the study area.



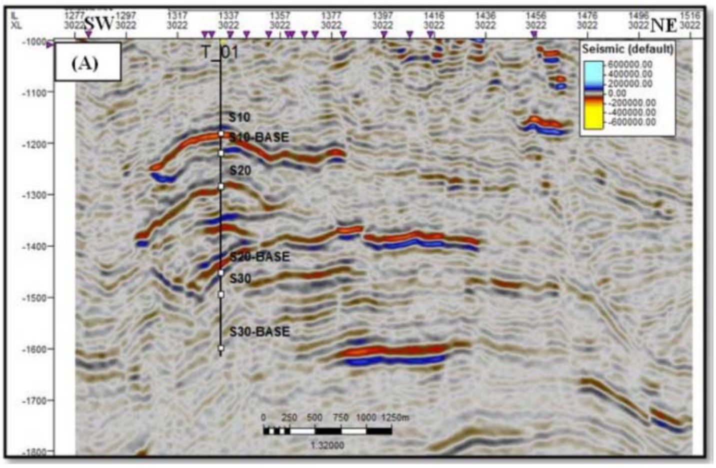
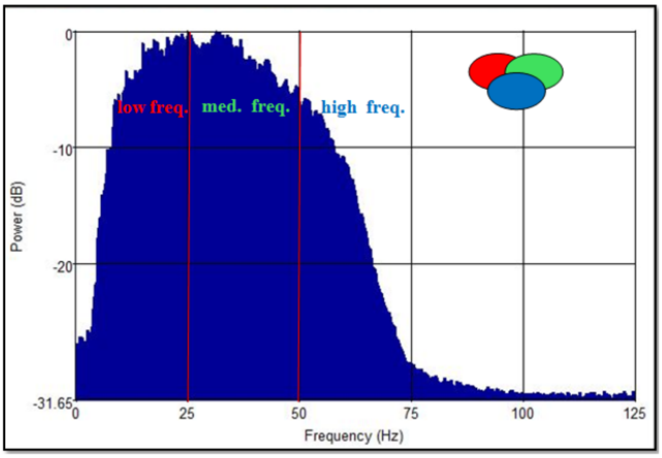


Fig. 4: X.-line 3022 seismic section with Top and Base S10, S20 and S30 reservoir units cross T-01 well.

The input to spectral decomposition is a seismic volume. The output is several volumes, each one representing a different frequency band. Creating spectral decomposition attributes enables to illuminate the structures with different frequency bands to see if any of them gives better resolution. When doing interpretation it is a common practice to look at instantaneous attributes such as envelope or phase volumes. Spectral decomposition gives several such volumes. At a specific frequency band certain size structures are more visible due to tuning effects, etc.

The spectral decomposition analysis has been done in this paper based on Discrete Fourier Transform (DFT). The workflow consisted of creating tuning cube for S10, S20 and S30 reservoir units by using SD-tuning cube of Opend Tect software. The frequency ranges that were used in tuning cube calculations were set to 5-65 Hz according to amplitude spectrum of the seismic data (Fig. 5). The software extracts and flats this slab of data then discrete Fourier transform was applied to this slab of data in order to produce the tuning cube. By analysis the tuning cube in z-direction (time slice), name the frequency slices, then choose the best frequency slices that better image the subsurface stratigraphic features.

Fig. 5: Amplitude Spectrum of the seismic bandwidth



From the amplitude spectrum window analysis (Fig. 5) the seismic could be split into different frequency ranges; low frequency range (5 – 25Hz), medium frequency range (25 – 50Hz) and high frequency range (50 – 65Hz). Amplitude maps have been taken at each frequency starting with frequency 5 Hz with 15 Hz increments (Figs. 6 to 10). From observations of these maps, the most representative maps for the reservoir geometry definition are at frequencies 5, 35 and 65 Hz.

RGB Blending Attribute

For the purposes of seismic data interpretation, the spectral decomposition method is very useful in the point of view of geological changes due to the frequency changes that is generally only carried out on a single frequency. The RGB is a new seismic attribute, which is proposed to increase the visualization of seismic data (Partyka et al., 1999). As an enhancement attributes, the RGB display is generated by combining the decomposed spectral into an RGB volume (Guo et al., 2009). The decomposed spectral is pointed out into color axis that represents the red, green and blue element into the 3D color volume.

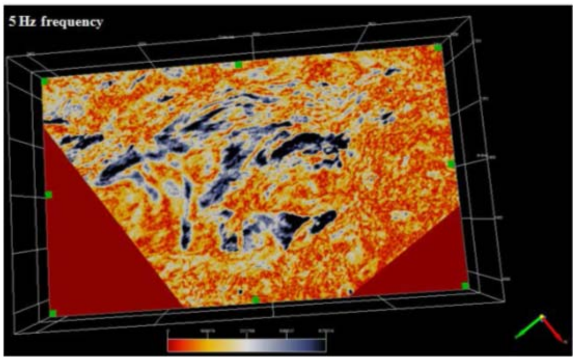


Fig. 6: 5 Hz amplitude map at 1500 msec time slice.

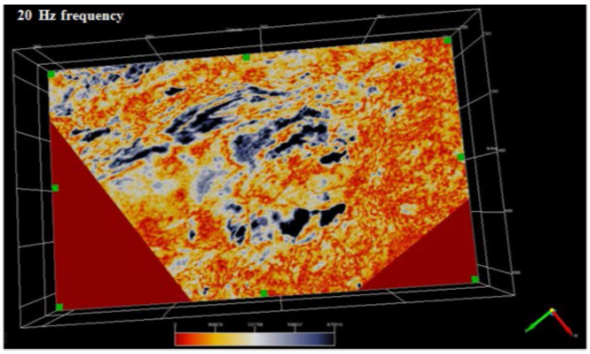


Fig. 7: 20 Hz amplitude map at 1500 msec time slice.

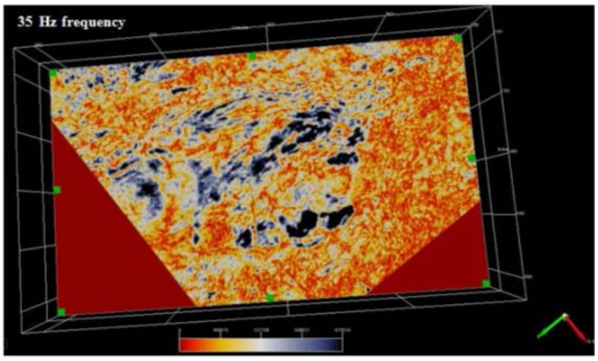


Fig. 8: 35 Hz amplitude map at 1500 msec time slice

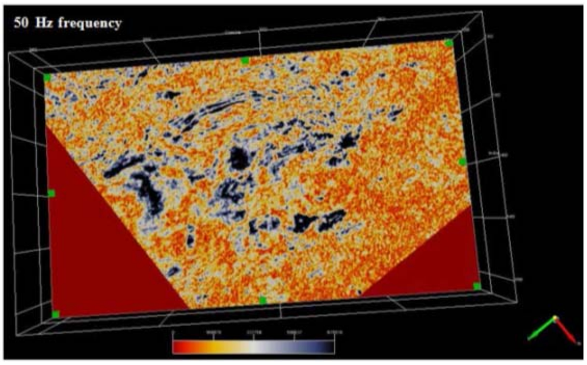


Fig. 9: 50 Hz amplitude map at 1500 msec time slice

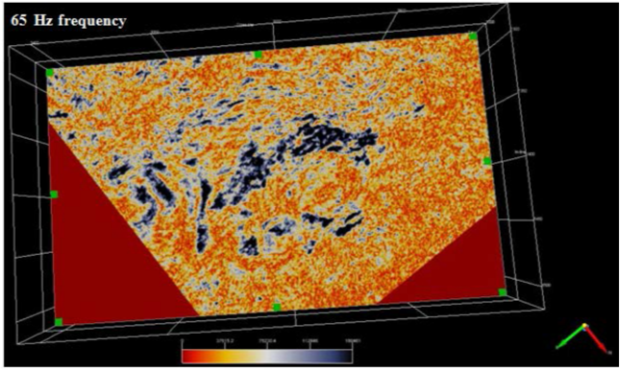
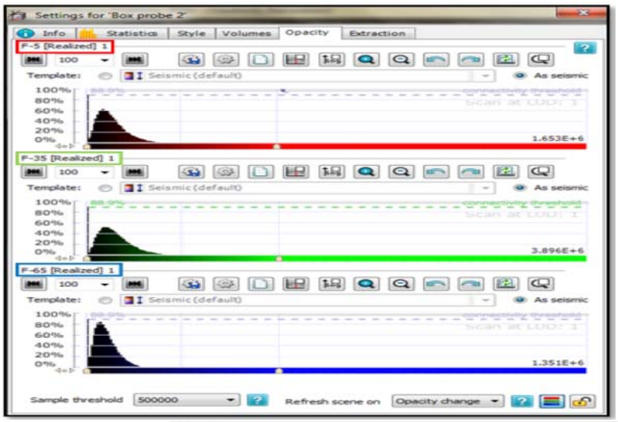


Fig. 10: 65 Hz amplitude map at 1500 msec time slice.

The amplitude spectrum of the data was analyzed then; three dominant frequencies from the amplitude spectrum were defined for RGB multi-color display. The three frequencies were chosen such that they represent the low (5 Hz), middle (35 Hz) and high (65 Hz) frequency of the seismic bandwidth. The three frequencies were then output as a single RGB blended full color image. This is important because mixing outputs of different frequencies enables to analyses results that depict different geological features related to different geometrical scales simultaneously i.e, higher frequencies reveal features of more detailed character, whereas lower frequencies those which are more coarse.

In this study, RGB color blended maps were prepared by petrel software using mixing of three frequencies (5, 35 and 65 Hz) into 3D color volume. Figure (11) shows RGB color blending for each frequency. A set of RGB color blended maps for Mit Ghamr reservoir units have been created from this color volume by time slicing (Figs. 12 to 21). From these maps, it was observed that the geometry and lateral extension of the sand reservoir units are in NW-SE direction, S20 reservoir unit represent maximum extension with hydrocarbon saturation as in Figure (17), while S30 unit is smallest reservoir unit as in Figure (19).



Sample threshold 500000

Refresh scene on Opacity change

Fig. 11: RGB Color blending for the selected frequencies.

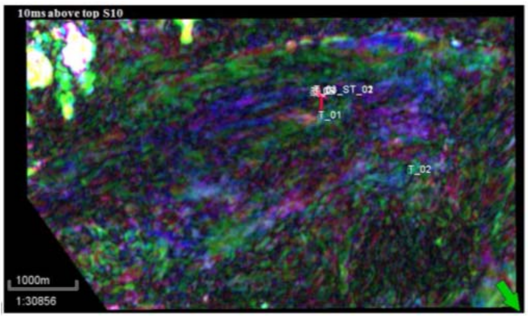


Fig. 12: RGB color blended map above top S10 with 10 m

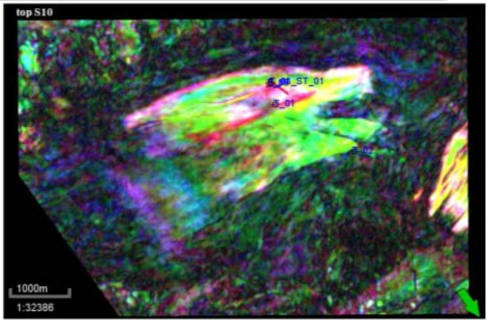


Fig. 13: RGB color blended map at time slice 1212 ms. Top S10

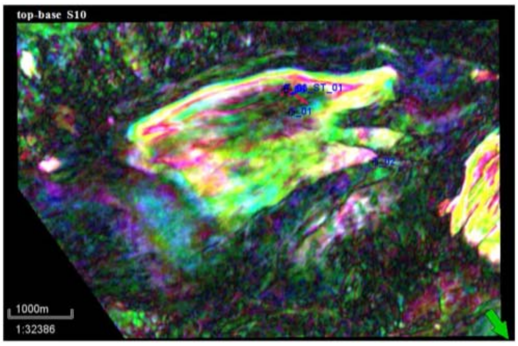


Fig. 14: RGB color blended map at time slice 1240 ms. between Top and Base S10

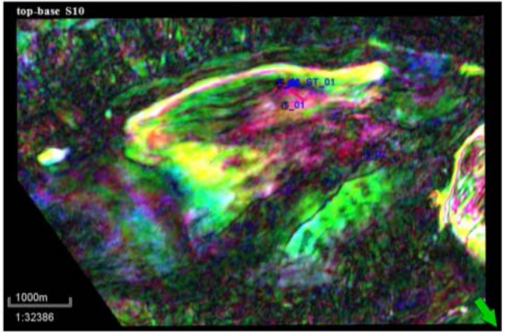


Fig. 15: RGB color blended map at time slice 1268 ms. between Top and Base S10.

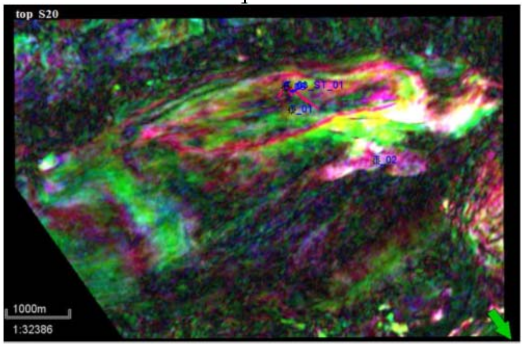


Fig. 16: RGB color blended map at time slice 1324 ms. (Top S20).

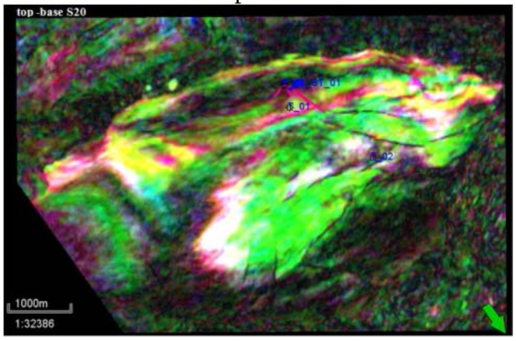


Fig. 17: RGB color blended map at time slice 1392 ms. between Top and Base S20.

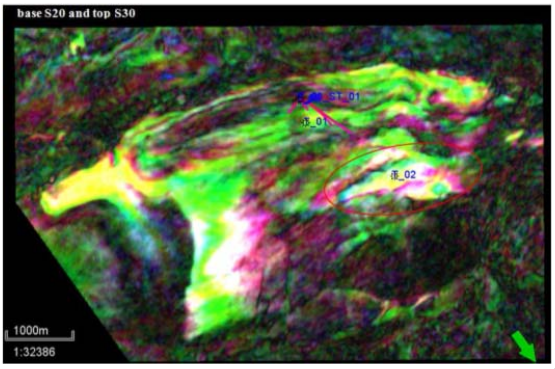


Fig. 18: RGB color blended map at time slice 1436 ms for Base S20 and Top S30 (red circle).

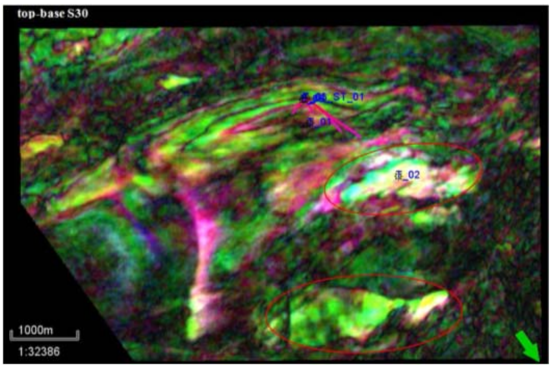


Fig. 19: RGB color blended map at time slice 1500 ms (red circle represents S30).

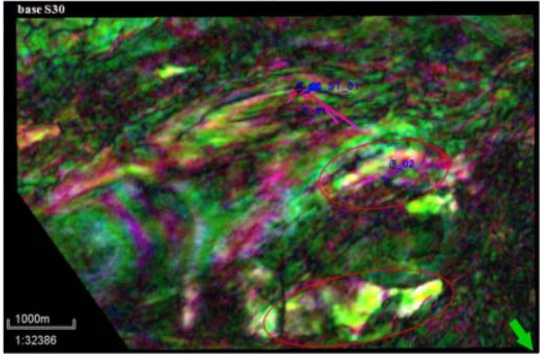


Fig. 20: RGB color blended map at time slice 1505 ms. (Base S30).

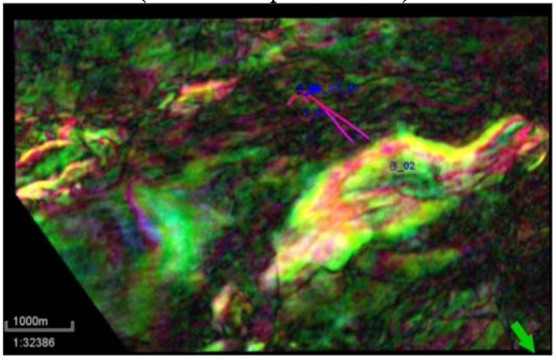


Fig. 21: RGB color blended map at time slice 1600 ms.

RGB color blended map at time slice 1600ms shows new sand body with lateral extension in E-W direction around red circle beneath Mit Ghamr sand reservoir units (Fig. 21) which be located around black circle in seismic sections with clear amplitudes as shown in Figure (22).

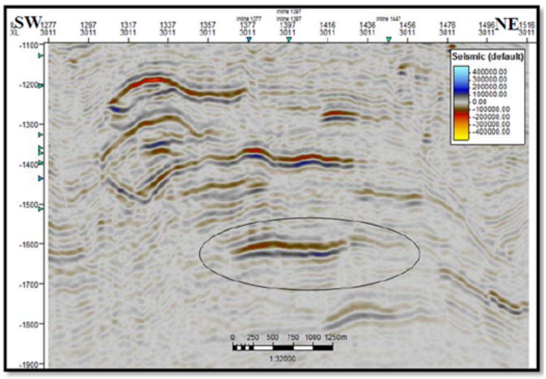


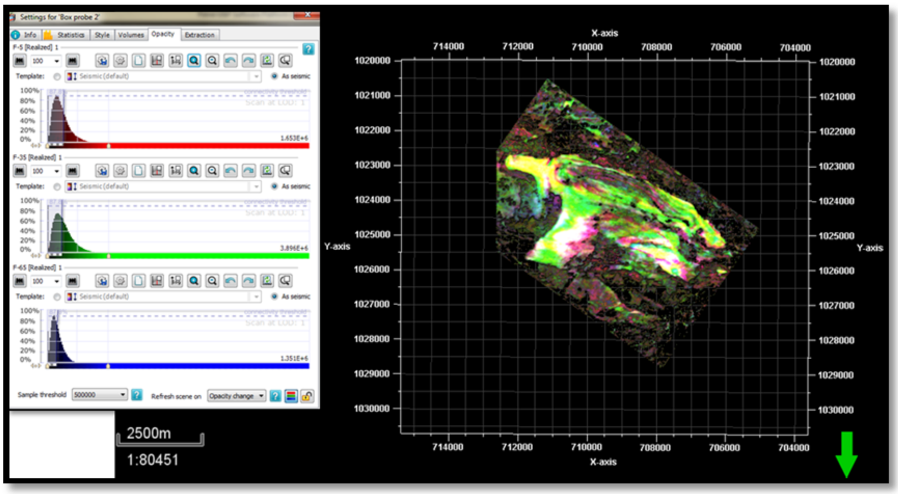
Fig. 22: X-line seismic section 3011 displays the amplitude for the new sand body.

Sand Reservoir Units Extraction (Geobody Extraction Attribute)

Visualization and distribution of the interested sand units were recognized from Spectral decomposition and RGB blending attributes. To extract these sand units Geobody Extraction attribute was utilized that

Extraction module in petrel soft enables quick and interactive blending and rendering of multiple seismic volumes with extreme clarity to detect anomalies, delineate structural and stratigraphic features, isolate areas of interest, and then instantly extract what is visualized into a 3D object called a geo-body (Michelle, et al, 2011).

The main steps in the geo-body extraction for Mit Ghamr Formation are **(1)** identification, **(2)** isolation and **(3)** extraction. In the identification step, there are numerous tools that let to better visualization of the target. These tools based on rendering techniques, such as box probe, surfaces probe or well probe. However, the use of different attributes can be applied to better understand the interested target; the best identification of Mit Ghamr Formation was done by RGB blending technique.



Sample threshold 500000

Refresh scene on Opacity change

Fig. 23: Isolation of sand bar reservoir body.

The second step, the sand reservoir units is isolated by applying different opacity values to different amplitudes (Fig. 23). Finally, the geo-body extraction is based on its opacity threshold value and amplitude window, threshold value is 87.8% for the interested reservoir, the geo-body extraction of Mit Ghamr units clarify reservoir distribution with lateral and vertical extension (Figs. 24 and 25).

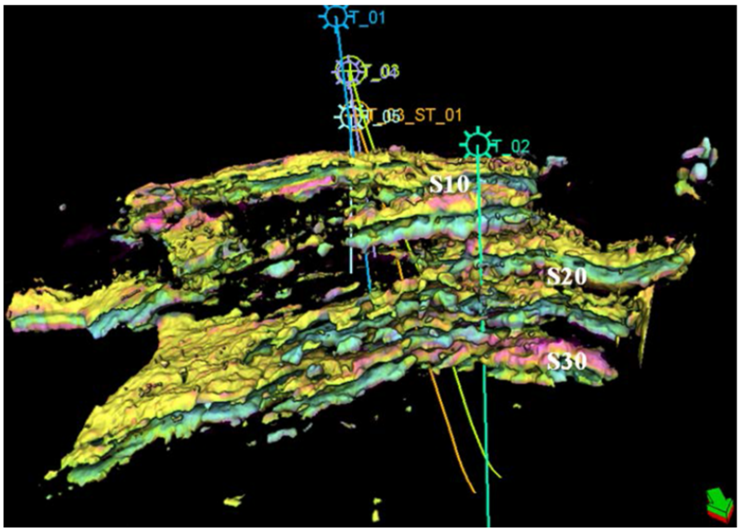


Fig. 24: 3D view of sand units extracted geo-body in E-W direction.

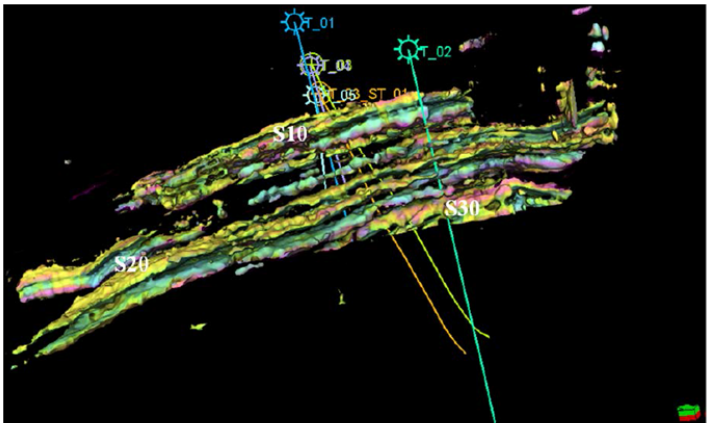


Fig. 25: 3D view of sand reservoir units extracted geo-body in N-S direction.

Visualization and extraction of sand reservoir units in Mit Ghamr formation

The maps reveal three sand units; S10, S20 and S30 in different directions. Also, it is obvious that S20 and S30 contain three sand elements within them. Figure (26) represents 3D view of sand extracted geo-body intersected with in-line and x-line seismic sections.

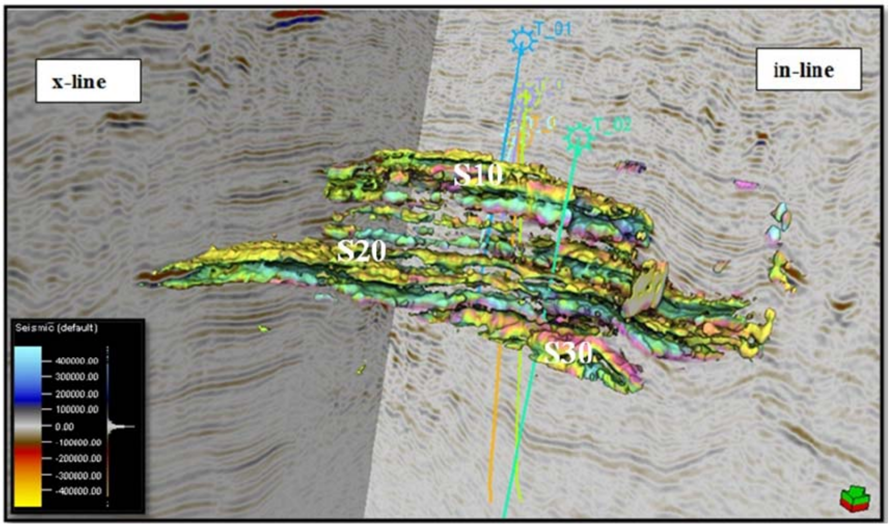


Fig. 26: 3D view of extracted sand reservoir units intersected with in-line and x-line seismic sections.

CONCLUSION

Frequency based attributes; spectral decomposition and RGB color blending have been successfully applied to represent the lateral and vertical distributions of the sand units within the Mit Ghamr Formation depending on the analysis of frequency band of the data. The better visualization of these sand units demonstrates that mapping of the sand reservoir can be track by quickly and accurately rather than conventional seismic interpretation. Using of geobody extraction attribute benefit in separating between the sand units and reveal their internal elements. These extracted sand bodies, which are documented as the sand reservoir units based on the internal reports, are useful for the advanced purposes particularly in reservoir modeling and characterization or in general to separate between different bodies.

REFERENCES

Brown A. R., (2011): Interpretation of Three-Dimensional Seismic Data, 7th Ed., the American Association of Petroleum Geologists and the Society of Exploration Geophysics.

Cao J, Yue Y, Zhang K, Yang J, Zhang X (2015): Subsurface channel detection using color blending of seismic attribute volumes. Inter. J. Signal Process., Image Process. and Pattern Recognition 8: 157-170.

Castagna, J. P., Sun, S., and Siegfried, R. W., (2003): Instantaneous Spectral Analysis: Detection of low-frequency shadows associated with hydrocarbons. The Leading Edge 22(2): 120–127.

Chaves, M., Oliver, F., Kawakami, G. and Di Marco, L. (2011): Visualization of Geological Features Using Seismic Volume Rendering, RGB Blending, Geobody Extraction. 12th Inter. Cong. Brazilian Geophys. Soc..

Dolson, J. C., Shann, M. V., Matbouly, S., Harwood, C., Rashed, R., and Hammouda, H., (2001): The petroleum potential of Egypt. In: Downey, M. W., J. C. Threet and W.A. Morgan (Eds.). Petroleum Provinces of the Twenty-first Century, AAPG Memoir, 74, 453-482.

Guo, H., Marfurt, K. J., and Liu, J., (2009): 3D seismic volume visualization and interpretation: An integrated workflow with case studies: Geophysics, 74, 35-43.

Haris, T., Sari, W., Lisapaly, L., Isniarny, N., Riyanto, A., and Sujito, (2017): Delineating stratigraphic trap reservoir using RGB color blending of spectral decomposition method: Case study in the West Natuna Basin. AIP Conf. Proc.

Lei, L., Xianhua, R., Chunfeng, T., Zhonghong, W., and Shifan, Z. (2013): The Application of Semi-supervised Geobody Detection Technique using Multiple Seismic Attributes in Petroleum Exploration. AAPG Annual Convention and Exhibition.

Marfurt, K. J. and Kirlin, R. L., (2001): Narrow-band spectral analysis and thin bed tuning. Geophysics 66 (4), 1274-1283.

Okiongbo, K. S. and Ombu, R. (2019): Application of Spectral Decomposition and Seismic Attributes for Channel Geometry and Infill Lithology Determination: A Case Study from the Southern North Sea Basin. Int. J. Earth Sci. Geophys.

Partyka, G. A., Gridley, J., and Lopez, J. (1999): Interpretational applications of spectral decomposition in reservoir characterization, The Leading Edge, 18, 353–360.

Rizzini, A., Vezzani, F., Coccetta, V. and Milad, G., (1978): Stratigraphy and sedimentation of a Neogene – quaternary section in the Nile Delta area. Marine Geol. 27, 327-348.

Said, R. (1981): The Geology and Evolution of the River Nile Springer, New York, N.Y.

Torrado, L., Mann, P., and Bhattacharya, J. (2014): Application of seismic attributes and spectral decomposition for reservoir characterization of a complex fluvial system: Case study of the Carbonera Formation, Llanos foreland basin, Colombia, Geophysics, 79, 221-230.

Visualization and extraction of sand reservoir units in Mit Ghamr formation

تصوير واستخراج وحدات الخزانات الرملية في تكوين ميت غمر باستخدام السمات السيزميه القائمة علي الترددات حقل تورت ، دلتا النيل الشرقية ، مصر

عزه محمود عبداللطيف الراوى

قسم الجيوفيزياء – كليه العلوم– جامعه عين شمس– العباسيه – القاهره

الخــلاصة

يعتبر تصوير واستخراج الأجسام الرملية ثلاثية الأبعاد من البيانات السيزميه أمر بالغ الأهميه لتوضيح طبيعه الخزان ، وكشف و تحديد الأختلافات فيه . ويمكن تحديد الخصائص الجيولوجية للخزان باستخدام السمات القائمة علي الترددات السيزميه وهى التحليل الطيفى لتردد الموجات السيزميه ثم تحديد اعلى و اقل و متوسط التردد بناء على دراسه خرائط السعه عند الترددات المختلفه . ثم استخدام السمه الثانيه وهى مبنيه على استخدام الالوان الممثله لقيم التردد الثلاثه السابقه و دمجها مع بعضها البعض لتظهر البيانات السيزميه بشكل اخر يظهر خصائص لم تكن واضحه ثم الطريقه الثالثه و تعتمد على استخدام هذه الترددات لفصل و استخراج الأجسام الرمليه

ويمكن بعد ذلك بمجرد تحديد و استخراج الأجسام و توصيفها إنشاء المزيد من النمذجة الجيولوجية والبتروفيزيقيه لها.

وهذه الدراسة هي محاولة لإظهار مدي نجاح استخدام السمات القائمة علي التردد في تحديد التوزيعات الأفقيه والرأسية للأجسام الرملية ووحداتها الداخلية بدون إجراء التفسير السيزمى التقليدي . وقد أجريت هذه الدراسة علي وحدات الخزانات الرملية داخل تكوين ميت غمر حقل تورت . وقد كشف تطبيق هذه الخصائص بنجاح عن توزيع الوحدات الرملية في اتجهات مختلفه واستخراجها و فصلها عن بعضها البعض.