Egyptian Geophysical Society
EGS Journal, Vol. 15, No. 1, 107-117 (2017)

PROSPECT IDENTIFICATION USING INTEGRATED GEOPHYSICAL METHODS AT OCTOBER FIELD, CENTRAL PART OF THE GULF OF SUEZ, EGYPT

E. Abdel-Khalek[1], H. Ahmed[1], A. Said[1] and I. Rasha[2]

1- Ain Shams University, Faculty of Science, Geophysics Department
2- North Bahariya Petroleum Company.

تحديد أماكن آبار حفر جديدة باستخدام الطرق الجيوفيزيائية المتكاملة في حقل أكتوبرللبترول، في الجزء الأوسط من خليج السويس، مصر

الخلاصـــة: تم تفسير البيانات باستخدام الطرق الجيوفيزيائية المتكاملة في حقل أكتوبر للبترول، الجزء الأوسط من خليج السويس، مصر وذلك بهدف تحديد التراكيب الجيولوجية تحت السطحية، وتحديد اتجاهاتها التكتونية، وتقييم الخصائص البتروفيزيائية للخزان المدروس، ومن ثم اقتراح أفضل الأماكن لحفر الآبار الواعدة للأنشطة الاستكشافية فى المستقبل. ولتحقيق هذ ا الهدف، استخدمت طرق الجهد الحقلية (المغناطيسية والتثاقلية)، وتفسـير البيانات السيزمية الانعكاسية وتحليل تسجيلات الآبار. واكتشف وجود فالق رئيسي محيط بالكتل الصدعية المائلة في حقل أكتوبر في اتجاه البحر الأحمر الشمالي الغربي بالإضافة إلى تواجد فالق آخر عمودي عليه في اتجاه القوس السوري الشمالي الشرقي. وأيضا تم تقييم التواجدات الهيدروكربونية باستخدام تحليل بيانات تسجيل الآبار لعدد خمس آبار، أربعة منهم منتجين للبترول، في حين أن الخامس كان بئرا جافا. وتم أيضا اقتراح أفضل الأماكن لحفر الآبار الجديدة للتنقيب والاستكشاف عن البترول في المستقبل.

ABSTRACT: *Interpretation of the integrated geophysical methods has been carried out at October Oil field, central part of the Gulf of Suez, Egypt aiming at outlining the subsurface geological structures, delineating their tectonic trends, evaluating the petrophysical properties of the studied reservoir and finally, suggesting the best locations of promising new prospects for future exploration. Potential field methods (magnetic and gravity), seismic reflection interpretation and well logging analysis were used to achieve our target. One major fault bounding the tilted fault-blocks in October Field trending NW of the Red Sea System, in addition to, a one NE-trending cross-fault of the Syrian Arc System were found. Hydrocarbon potential is also evaluated using the available five wells clarifying that four of them are producing wells, while the fifth one is a dry well. New prospects for future exploration were also proposed.*

INTRODUCTION

October Oil Field is found in the central part of the Gulf of Suez, Egypt. It is located between longitudes 33° 00' & 33° 12' E and latitudes 28° 45' & 28° 52' N as shown in the study areas location map (Fig. 1).

The October Field is situated in the central part of the Gulf of Suez It was discovered and began producing in 1977. In 1977, the GS 195-1 well (later renamed October A-1) was drilled to test a large, NW-trending, fault bounded structure that had been identified from a 1976 regional seismic survey in the October area. The field comprises several tilted fault-blocks. Most of the reserves occur in a thick sequence of massive, predominantly fluvial sandstones in the Paleozoic Cretaceous Nubia Formation (Lelek et al., 1992). The Nubia in the largest fault-block contains a considerable oil column (435.5 ft) in October-C4 well.

The main purpose of this study is to delineate the tectonic framework of the studied area and analyses the different tectonic events that affected the distribution and accumulation of hydrocarbon in the area.

Moreover, imaging the subsurface geological structural features, evaluating the petrophysical properties of the main reservoir in the study area for evaluation of the hydrocarbon potentiality and proposing new locations for prospects, that can help in the future exploration activities in the central part of the Gulf of Suez, were also done.

METHODOLOGY

To achieve our target the following integrated geophysical methods: potential field data, (i.e. magnetic and gravity), seismic interpretation and well logging analysis were utilized.

1- POTENTIAL FIELD METHODS

Interpretation of the RTP magnetic map and Bouguer gravity anomaly map has been done to delineate the tectonic regime using a wider area within and around the October Field study area as shown in Fig. 2. Structural interpretation of these two maps shows that there are three major faults in the NW direction dissected by other three cross elements in the NE direction. Furthermore, two structural highs faulted blocks (H: horst structures) are found in the northwestern and southeastern parts of the study area separated by another structural low (L) in the central part. One of these major faults labeled (F1) on that Figure is matched very well with the seismic structural interpretation on the top of Nubia Formation given in the next section.

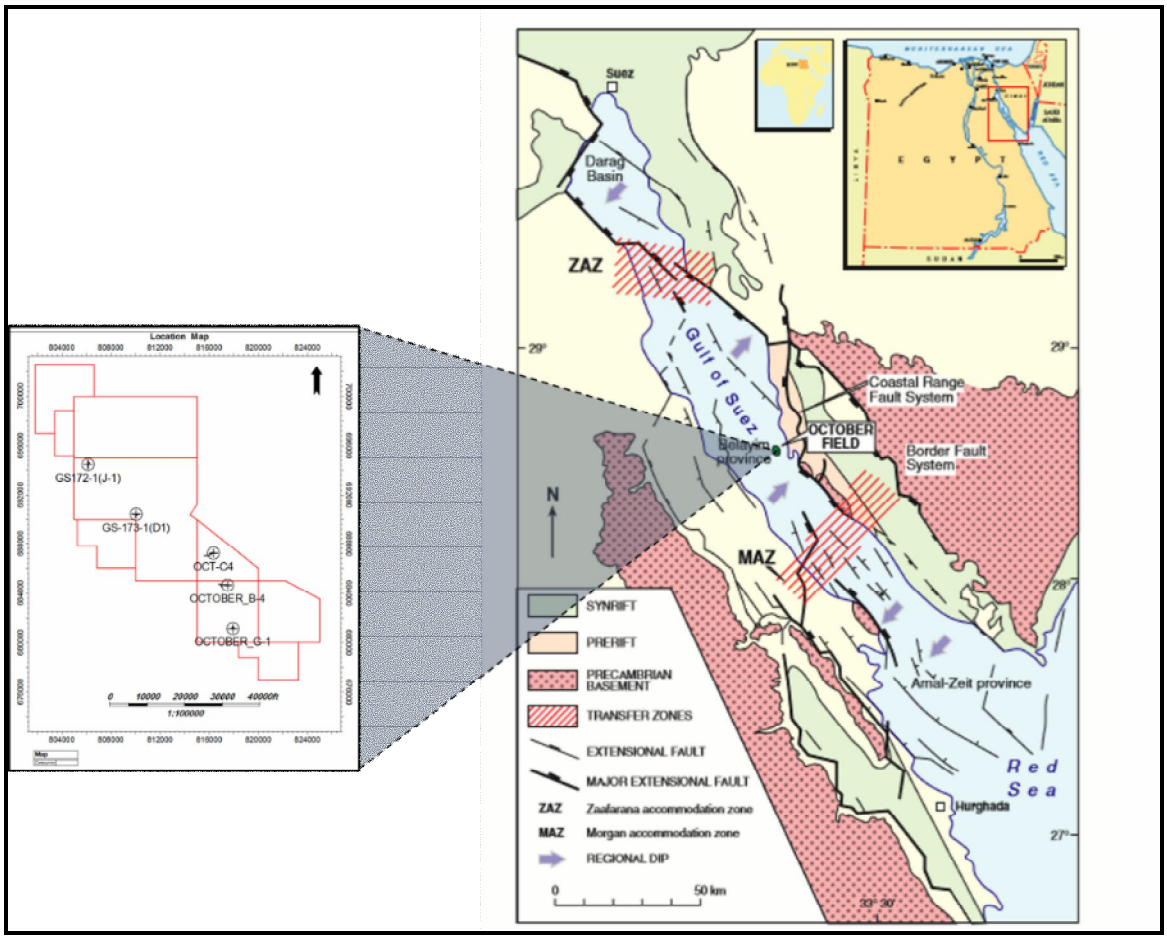

Fig. 1: Location map of the study area.

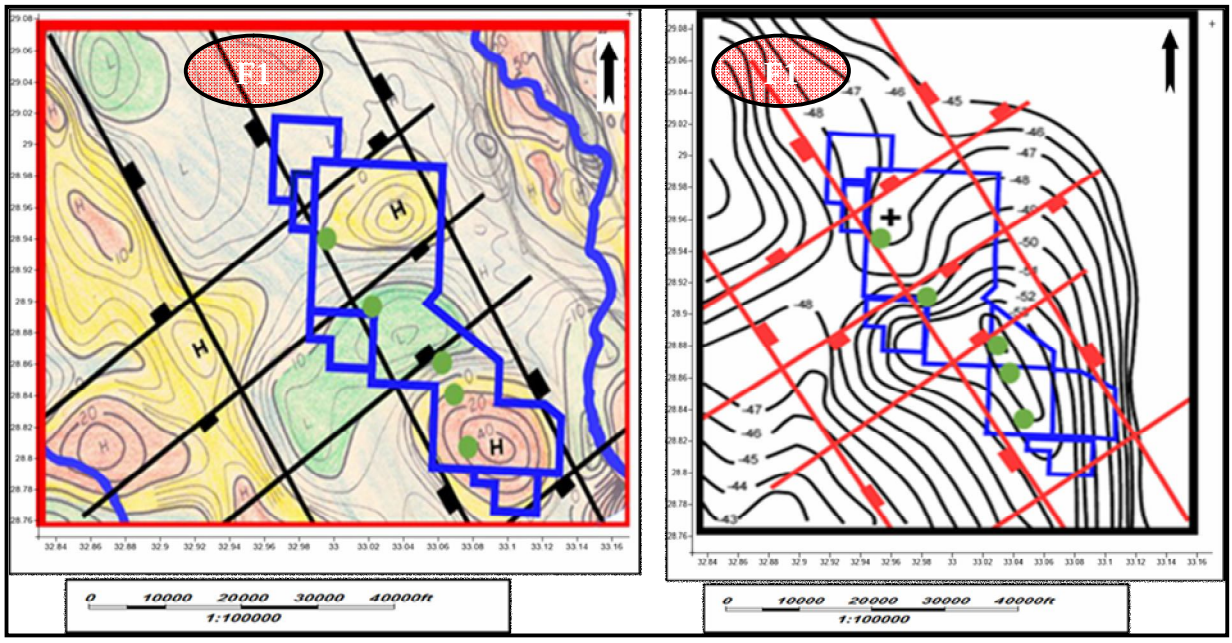

Fig. 2: RTP magnetic map (left) and Bougeur gravity map (right).

Second vertical derivative map is also shown in Fig. 3 with almost the same structural features of the two potential maps mentioned above.

2- SEISMIC DATA INTERPRETATION

Seismic structural interpretation has been carried out using thirty 2D seismic lines. In addition to, three vertical seismic profiling (October-G1, October-B4 and October-C4), were also used for identification of the geological formation tops and correlation of well-to-seismic tie. Three seismic reflection horizons arranged from old to young as follows: Top Nubia, Top Belayim and Top South Gharib Formations, were picked along all of these 30 seismic sections and tying loops using intersection points of these lines. Then, the two-way reflection time values were projected at each shot point on a shot point location map for each studied horizon using a computer software program (Petrel 2013) developed by Schlumberger Service Company.

Fig. 4 shows a 2D seismic line AR-10 in the dip direction (NE-SW) passing by October-G1 well. The 2D seismic data of the October Field of the Gulf of Suez has historically been plagued by strong multiples. Consequently, the structural resolution in this area has been poor (EGPC, 1994). This line shows four normal faults in the central part dissecting the interested formation tops.

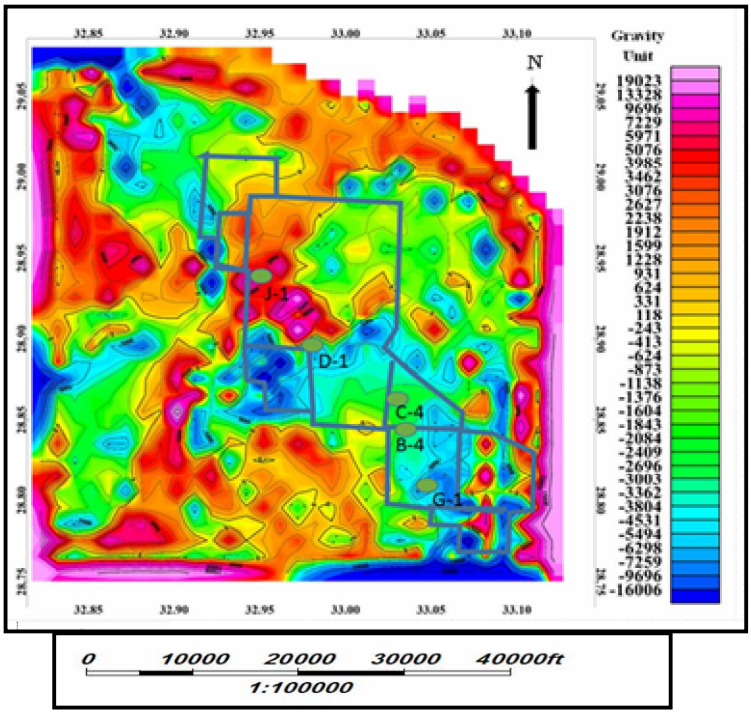

Fig. 3: Second vertical derivative map.

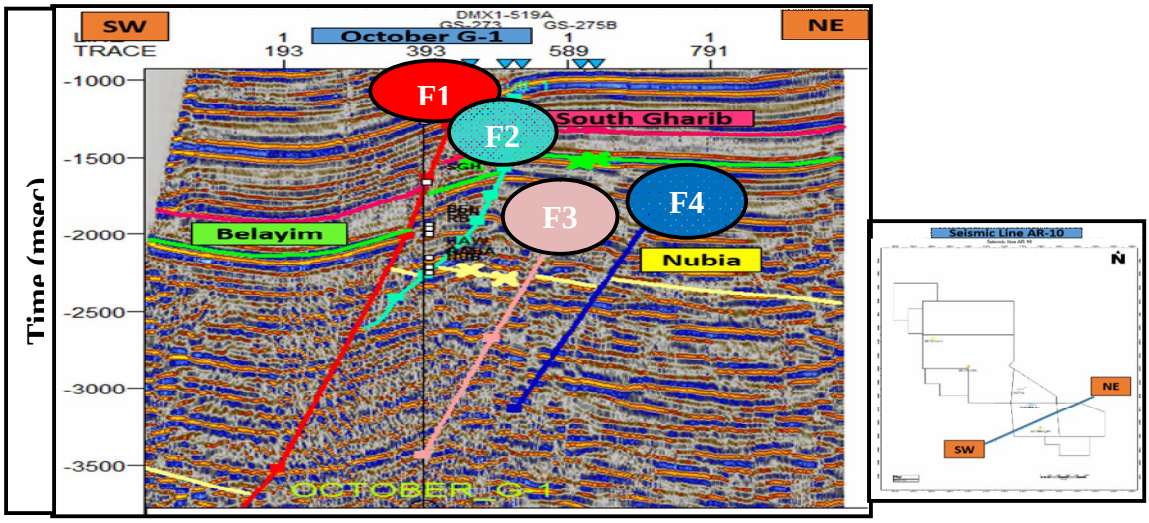

Fig. 4: Interpreted 2D seismic section (dip line) AR-10.

Two-way time maps in addition to average velocity maps were established on the tops of the interested reflection horizons, then they were used after depth conversion to contruct the depth structure maps on these tops.

Fig. 5 shows a depth structure map on the top of Nubia Formation. There are several NW-trending, NE-tilted fault-blocks bounded to the SW by a major normal fault that downthrows about 6000 ft to the SW. This major fault is oriented in the NW direction of the Red Sea System trend (Oligo-Miocene) parallel to the Gulf of Suez which labeled F1 and matched very well with the interpretation of the RTP magnetic and Bouguer gravity anomaly maps. The footwall upthrown side is cut by several faults that are typically sub-parallel the major bounding fault, with smaller heaves and throws dividing the area into smaller faulted blocks of several structural highs and lows. A cross-element fault is found in the northwestern part close to October J-1 well, trending NE of the Syrian Arc System (late Cretaceous). All these faults (major, minor and cross-element) accummodate separate suitable oil pools in October Field. The hangingwall downthrown side is a structural low elongated and found in the southwestern part of the study area.

3- WELL LOGGING ANALYSIS

Well logs analysis is used to evaluate the productive zones in terms of depths, thicknesses and petrophysical properties of these zones within the interested reservoir (Nubia Formation) for evaluation of the hydrocarbon potentiality using Interactive Petrophysics (IP) developed by LR Senergy Company.

Interactive Petrophysics (IP) helps to determine the amount of hydrocarbons in your reservoir. It does this by calculating porosity and water saturation using well logging data. This analysis was carried out for five wells (October J-1, October C4, October B4, October G1, and October D1) within Nubia Formation.

Fig. 6 shows shale volume within Nubia Formation with increasing value close to October D-1 well (9.5 %) and decreasing value close to October J-1 (3.5 %).

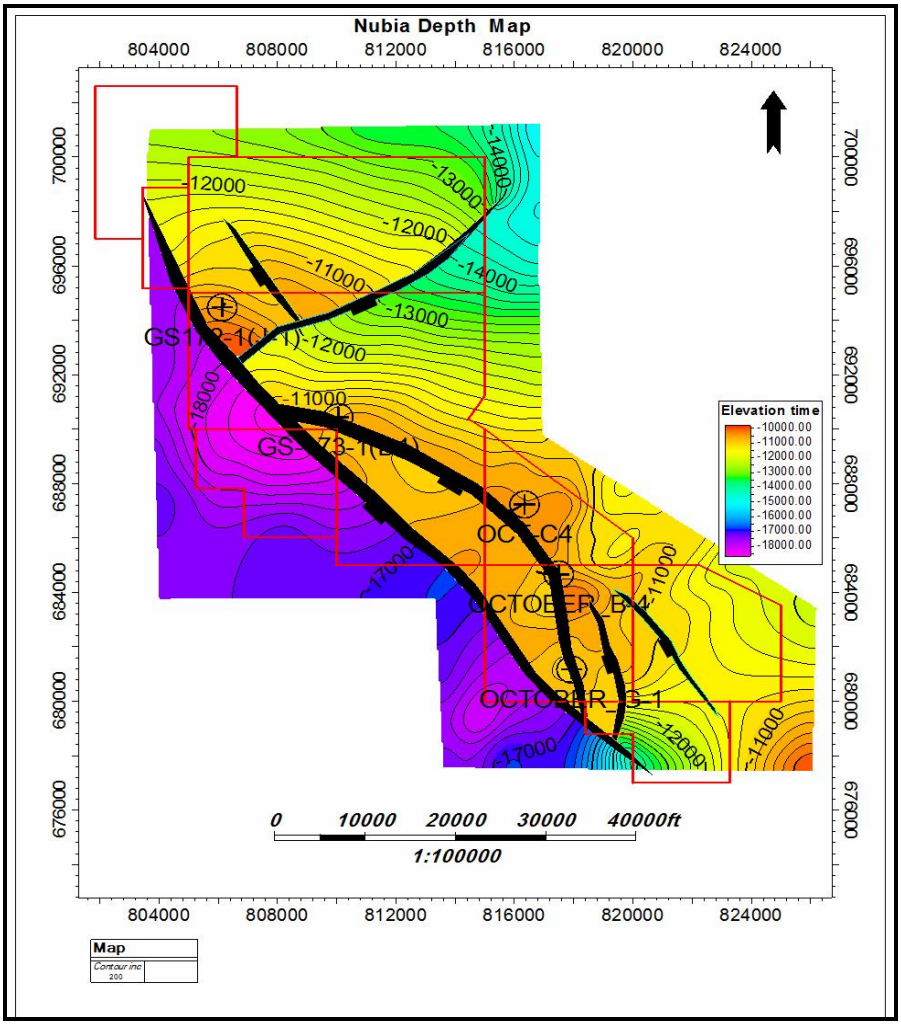

Fig. 5: Depth structure map on the top of Nubia Formation.

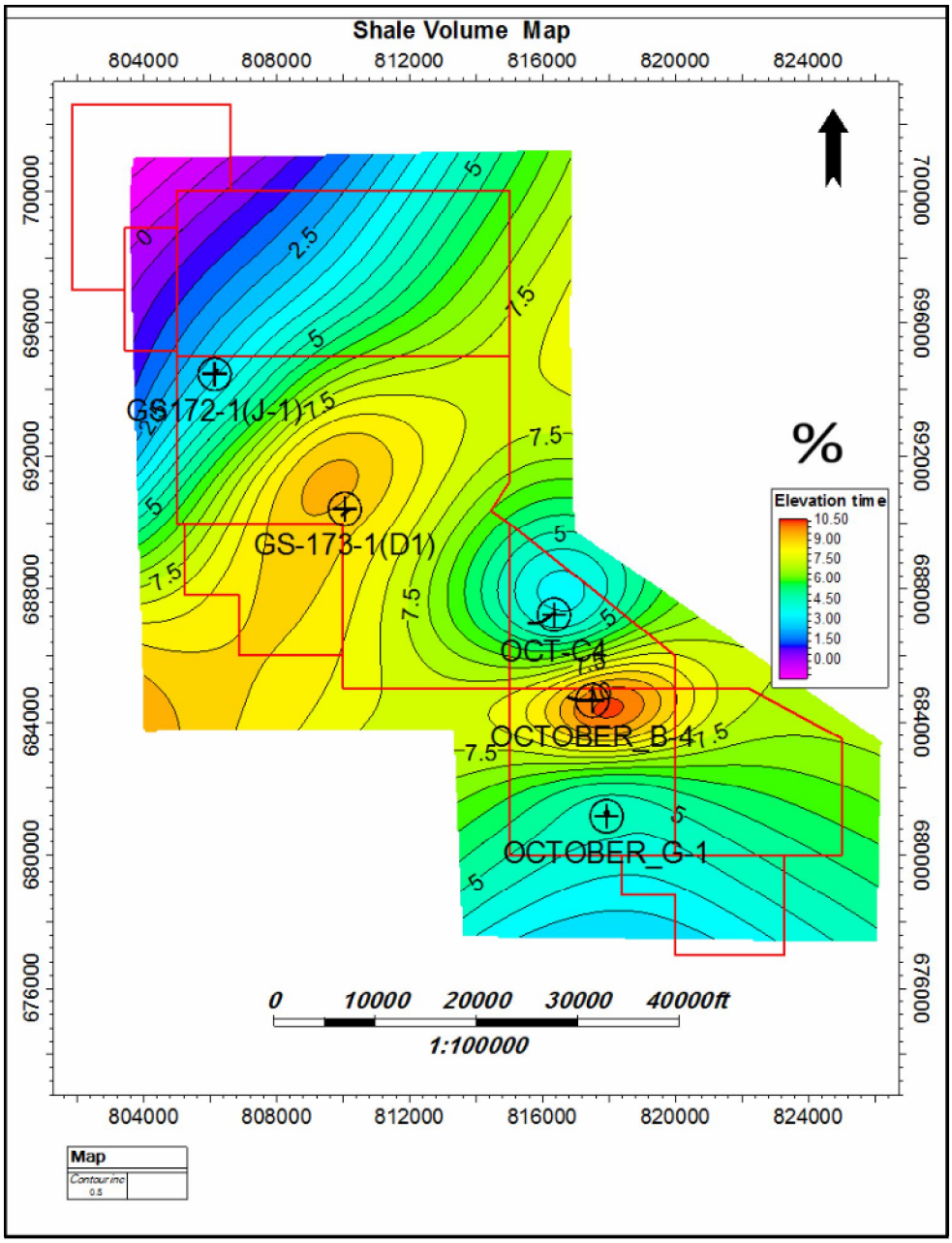

Fig. 6: Shale volume map within Nubia Formation.

Net pay thickness distribution map (Fig. 7) shows higher values in the SE and NW parts, while it shows lower values in the central part which is close to October D-1 well that is why it is a dry well. The effective porosity map of Nubia Formation reservoir at October Oil Field is shown in Fig. 8. It also shows higher values close to the producing wells and lower values at the central part of the dry well. Fig. 9 is a water saturation map at October field with increasing values at the central part of the dry well and decreasing outwards. Hydrocarbon saturation distribution map is shown in Fig. 10 which is opposite to the previous water saturation map.

PROSPECTS FOR FUTURE EXPLORATION ACTIVITIES

A seismic prospect is a local area having hydrocarbon in commercial quantities. It may or may not need more investigations or ready to be drilled.

There are two points must be studied for the evaluation of the offshore October Oil Field from prospects point of view for future exploration activities:

1- Prospect Elements, and

2- Prospect Locations Identification.

1- PROSPECT ELEMENTS

There are five elements required for any prospect evaluation:

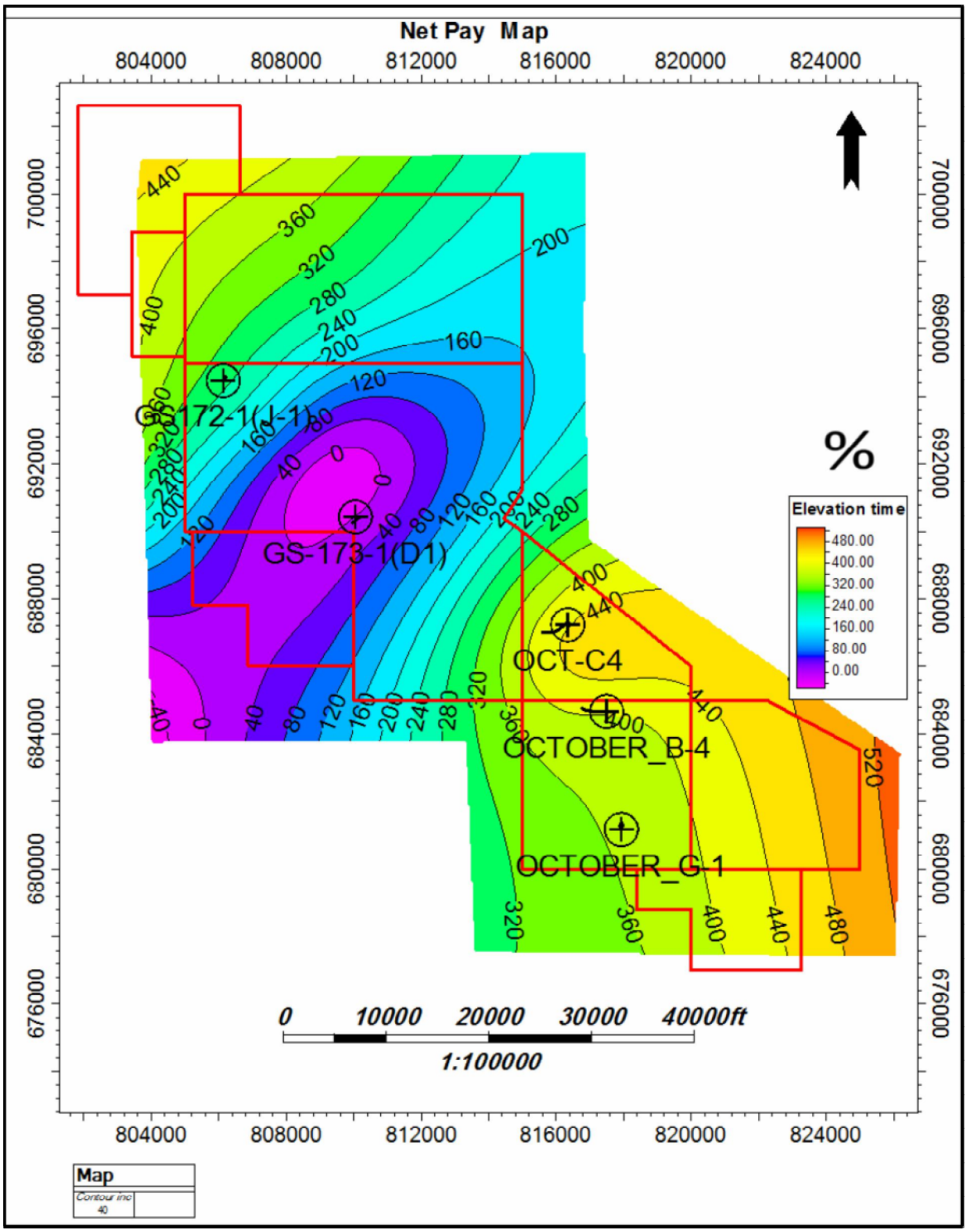

Fig. 7: Net pay thickness within Nubia Formation.

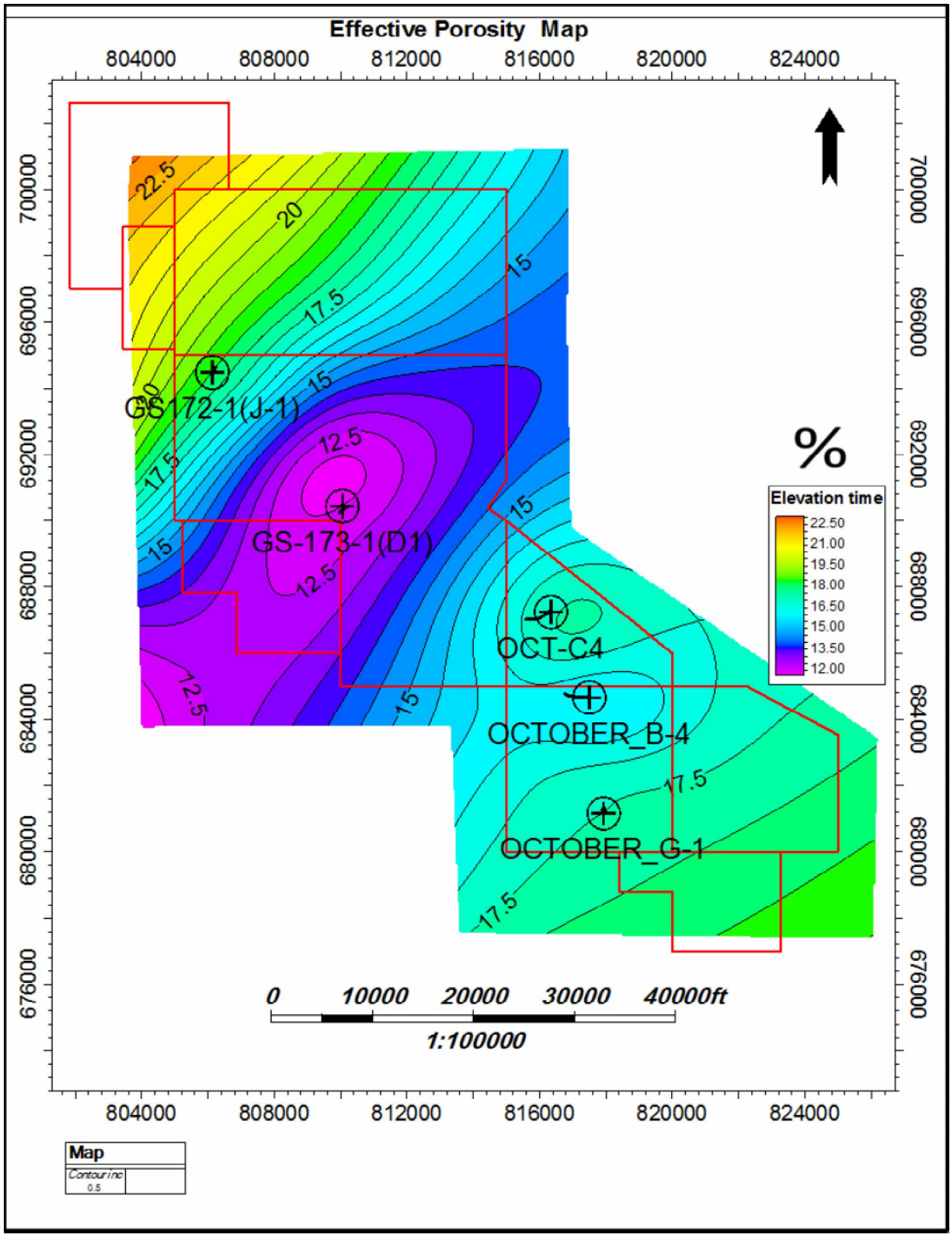

Fig. 8: Effective porosity map of Nubia Formation reservoir at October Field.

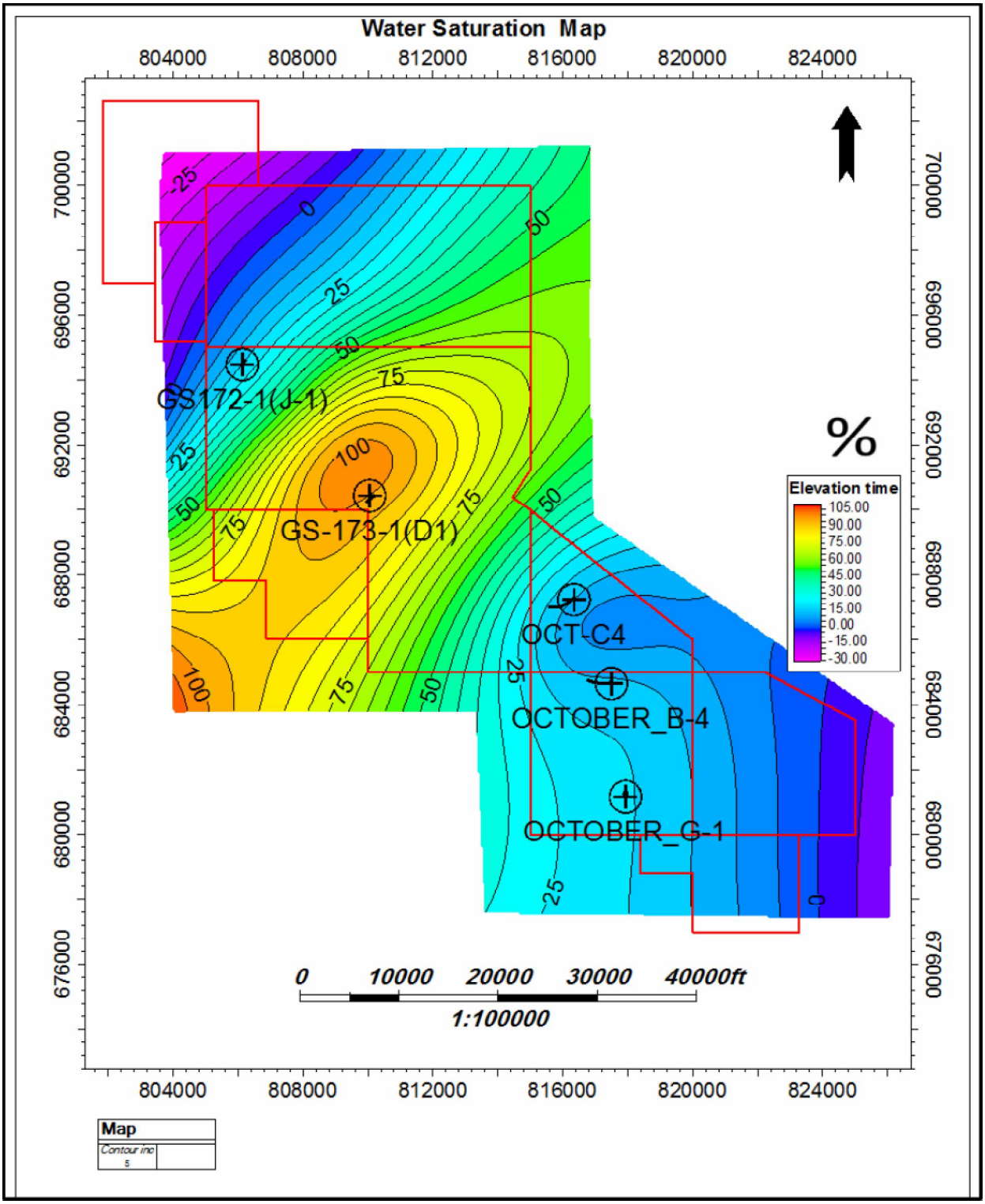

Fig. 9: Water saturation map at October Field.

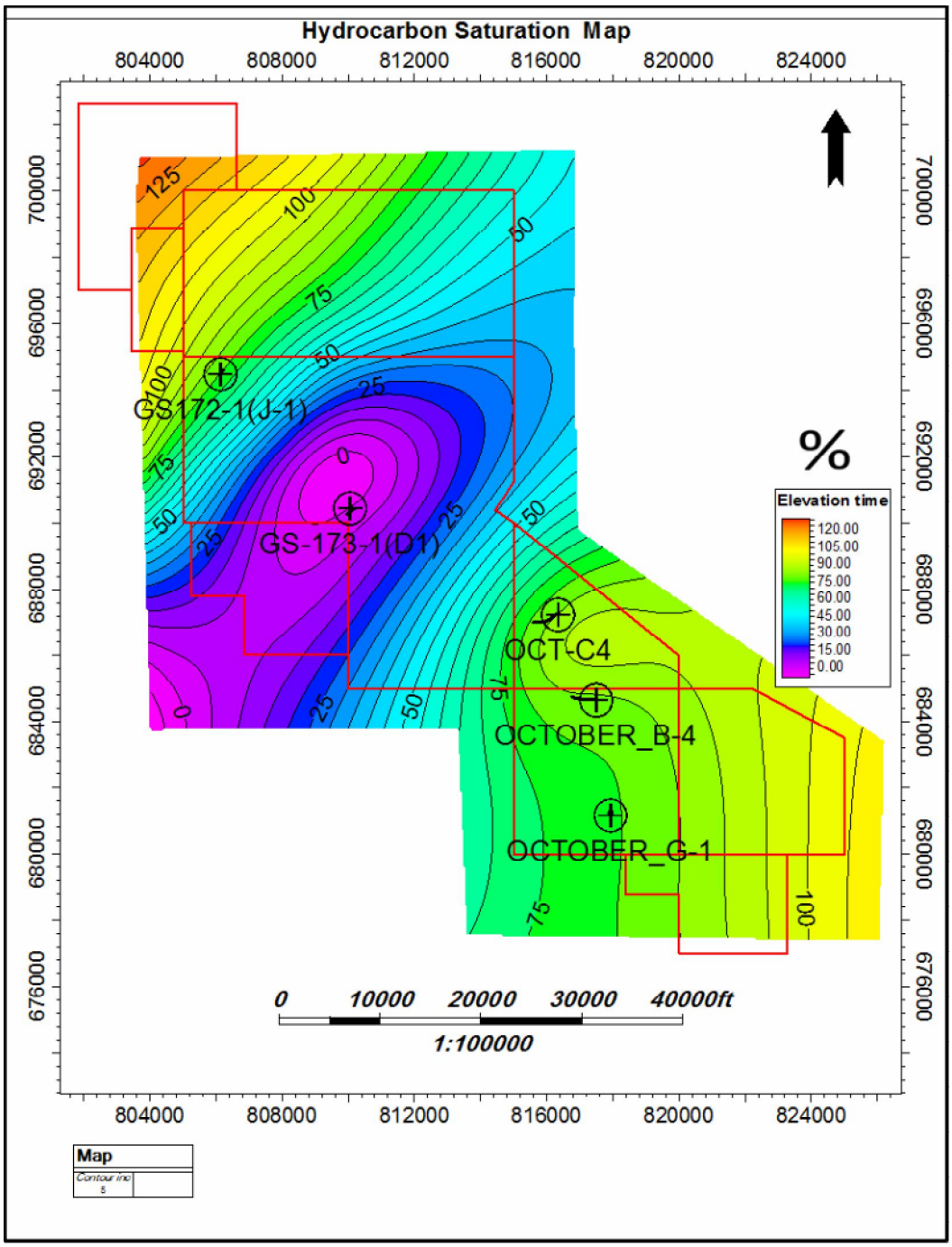

Fig. 10: Hydrocarbon saturation map at October Field.

1- Source rocks, 2- Reservoir rocks, 3- Cap rocks, 4- Traps.

1- Source Rocks:

The principal source rocks for the oil in the October Field are considered to be carbonates of the Upper Cretaceous Senonian Brown Limestone (lower unit of the Sudr Formation) (El-Ghamri et al., 2002).

2- Reservoir Rocks:

1- Nubia Formation (Paleozoic-Cretaceous);

2- Nezzazat Group (Cenomanian-Senonian); Raha, Abu Qada, Wata and Matulla Formations;

3- Nukhul Formation (Lower Miocene);

4- Asl Sandstone (Upper Rudeis Formation Lower Miocene

The Nubia Formation in the October Field has a layer-cake geometry, with the massive sands of fluvial depositional environment to marginal marine at its top and Nezzazat Group is marine/marginal marine. Most of the oil is produced from a subzone in the Wata Formation, known locally as the Wata Channel, and from the Matulla-2 and -3 subzones. The cross bedded sandstones of the Wata Channel are interpreted to be point bars deposited within an incised fluvial valley.

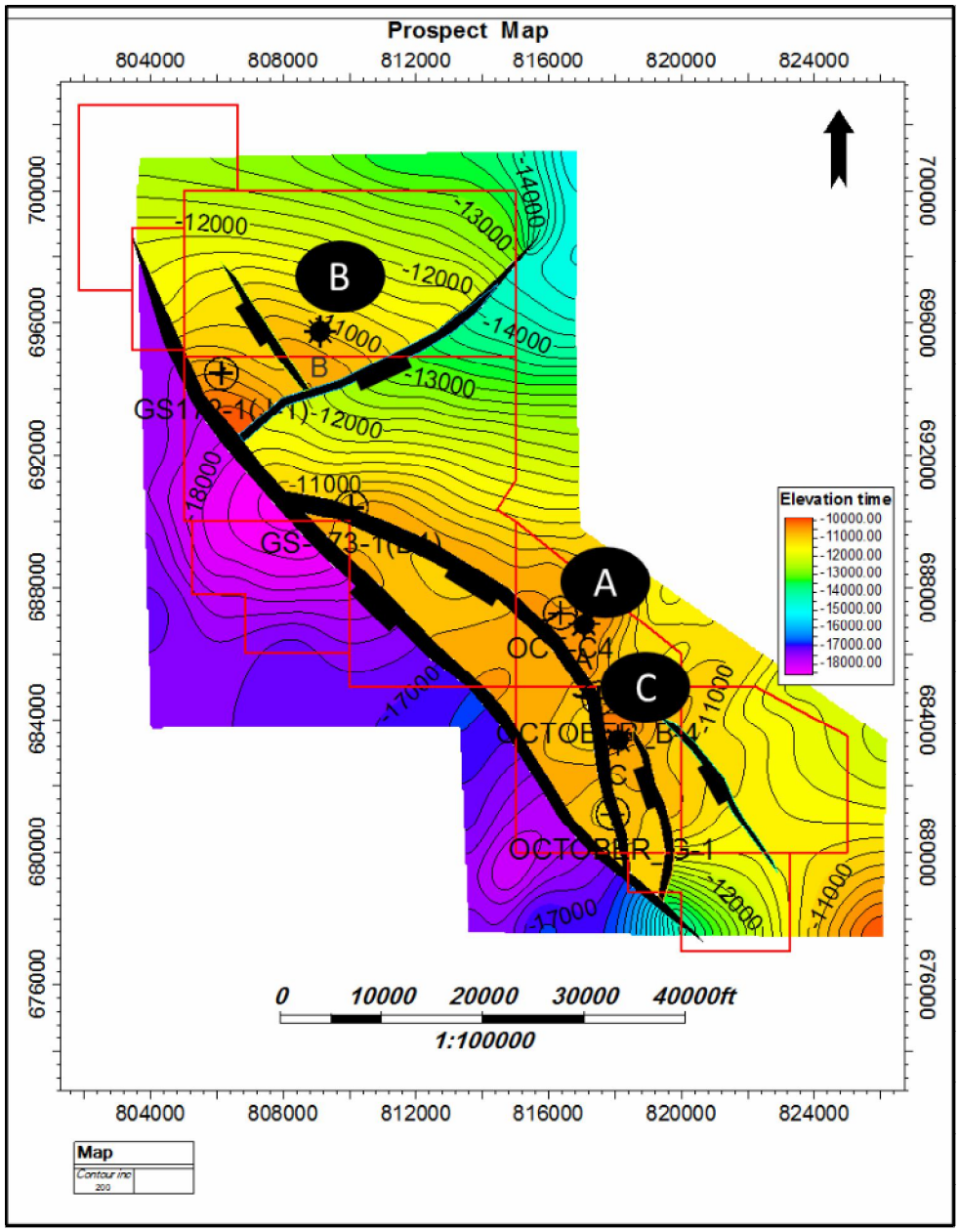

Fig. 11: Prospect identification on top Nubia Formation reservoir.

The Wata Channel has a maximum thickness of 76 ft and its meandering nature makes it difficult to delineate (Dolson et al., 1998).

The Lower Miocene Asl Formation consists of 230-320 ft of sandy limestone and sandstone within Upper Rudeis shales. Limestone and sandy limestone are usually found in the upper section, whereas calcareous sandstone and quartzose sandstone are found in the lower section. The Asl reservoir unit is absent on the upthrown sides of pre-existing pre-Miocene fault blocks in the October productive trend because of non-deposition (El Gendi et al., 1994).

3- Cap Rocks:

The reservoirs are top-sealed by overlying Cretaceous Shales of the Raha Formation and sealed laterally by downthrown Miocene Shales of the Lower Rudeis Formation. The ultimate seal is provided by the overlying Miocene evaporites of the South Gharib and Zeit Formations.

4- Traps :

The October Field is contained in several NW-trending, NE-tilted fault-blocks bounded to the SW by a major normal fault.

1- PROSPECT LOCATIONS IDENTIFICATION

There are three new locations (A, B and C) are proposed as prospects in October Field with respect to their seismic structural interpretation and petrophysical properties evaluation of the Nubia Formation reservoir as shown in Fig. 11.

Prospect A:

Prospect "A" is a three-way faulted dip closure located in the central part of study area close to October C4 well with expected depth of 10400 ft on the top of Nubia Formation with effective porosity of 17.5 %, hydrocarbon saturation of 90 % and a net pay thickness of about 460 ft.

Prospect B:

Prospect "B" is a three-way faulted dip closure located in the NW part of the study area close to October J1 well with expected depth of 10800 ft on the top of Nubia Formation, effective porosity of 17 %, hydrocarbon saturation of 65 % and a net pay thickness of about 240 ft.

Prospect C:

Prospect "C" is a two-way faulted dip closure located in the southern part of the study area with expected depth of 10200 ft, effective porosity of 16.5 %, hydrocarbon saturation of 82 % and a net pay thickness of about 380 ft.

CONCLUSIONS

October Oil Field is characterized by faulted blocks in the central part of the Gulf of Suez tilted towards the NE. There is a major fault trending NW in the direction of the Red Sea System (Oligo-Miocene) and dividing the area into two large fault blocks. The footwall upthrown side of this major fault is cut by several minor faults that typically sub-parallel the major bounding fault, with smaller throws dividing the area into smaller faulted blocks of several structural highs and lows that are accumodated as suitable separate oil pools. A cross-fault is found in the northwestern part close to October J-1 well, trending NE of the Syrian Arc System (late Cretaceous).

Hydrocarbon potential evaluation in the study area using the available five wells clarifies that four of them are producing wells, while the fifth one is a dry well. The results of interpretation calculated from the integrated geophysical methods propose new hydrocarbon potential locations as prospects for future exploration activities.

REFERENCES

Dolson, J., El-Sisi, Z., Ader, J., Leggett, B., Sercombe, B., and Smith, D., (1998): Use of cuttings, capillarypressure, oil shows and production data to successfully predict a deeper oil water contact, Wata and Matulla Formations, October Field, Gulf of Suez: Proceedings 14th Petroleum Conference, EGPC, Cairo, p. 298-307.

EGPC, (1994): Enhanced structural resolution in October Field: Egyptian General Petroleum Corporation, Cairo, 104 p. Zakaria, A., and Charmy, H.

El Gendi, O., Smith, D.R., and Leggett, B., (1994): Asl Sandstone (Miocene) downthrown traps and reservoirperformance, October Field, Northern Gulf of Suez: Proceedings 12th Petroleum Exploration Conference,EGPC, Cairo, Exploration v. 1, p. 307-319.

El-Ghamri, M.A., Warburton, I.C., and Burley, S.D., (2002): Hydrocarbon generation and charging in the October Field, Gulf of Suez, Egypt: Journal of Petroleum Geology, v. 25, no. 4, p. 433-464.

Khalil, S., and McClay, K., (1998): Structural architecture of the eastern margin of the Gulf of Suez: field studies and analogue modelling results: Proceedings 14th Exploration & Production Conference, Cairo, EGPC, Production v.1, p. 210-211.

Lelek, J.J., Shepherd, D.B., Stone, D.M., and Abdine, A.S. (1992): October Field - the latest giant under development in Egypt's Gulf of Suez, *in* Halbouty, M.T., ed., Giant Oil and Gas Fields of the Decade 1978-1988: AAPG Memoir, no. 54, p. 231-249.

Petrel Software 2013.1.0, developed by Schlumberger.