ISSN: 0067-2904
GIF: 0.851

Submerged Shoal Imaging By Sub-Bottom Profiler Technique Southern Iraq/ Northwest of the Arabian Gulf

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Abstract

A marine geophysical survey using high-resolution Sub Bottom Profiler was carried out for Palinurus Shoal (PS) , one of the shallow sites within Iraqi marine borders, NW of the Arabian Gulf. Eight parallel transverses survey lines of (SBP) were performed at the study area from southwest to northeast. Six lines were about 2.5 km in length, the two more lines crossed about 4.6 km area extended up to Khawr Al Khafga. The distance separated the survey lines is about 0.6-0.8 km. In addition, one more profiler was acquired longitudinal to the north-south direction, 6.3 km length. Abrupt reflectors slope changes reflectors discontinuity and coherency were the main interpretation guides on the sub-bottom images. The behavior of the built-surface articulates that Palinurus Shoal feature was formed by structural activity of a deeper diapiric structure. The surface depth is fluctuated. It was 6-7 m at the center of the structure and deepen toward the east to be 13-14 m. And it becomes even deeper, up to 30 m, at the western end. The dimension of the observed structure surface are about 6 km along northwest-southeast direction and about 2-2.5 km along transvers direction. Toward the east of the observed diapiric, there is an evidence of another daipriric structure. These structural features, diapirics, suggest the evolution of salt plugs from a salt accumulations (e.g., salt domes or pillow structures). This postulate was proved by reflection disappearance through these bodies. It is characteristics of seismic waves behavior at salt compositions. Furthermore, tilt reflectors faults and distortions of the structure bottom may tie-in neotectonic activity in the region.

Keywords: Arabian Gulf (AG), Sub Bottom Profilers (SBP), salt diapiric.

الكشف عن أحد التراكيب الضحلة المغمورة باستخدام تقنية رسم المقاطع العرضية للقيعان جنوب العراق/ شمال غرب الخليج العربي

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الخلاصة

تضمنت الدراسة الحالية انجاز مسح جيوفيزيائي بحري باستخدام تقنية رسم المقاطع للقيعان البحرية (Sub Bottom Profilers) لأحد المواقع البحرية الضحلة (Palinurus Shoal) الواقعة ضمن المياه الاقليمية العراقية شمال غرب الخليج العربي. تضمن المسح البحري أنجاز 8 مسارات عرضية لمنطقة الدراسة باتجاه

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جنوب غرب– شمال شرق. ستة مسارات كانت بطول 2.5 كم، أما المساران المتبقيان فبلغ طول كل منهما 4.6 كم حيث كان الغرض منهما تغطية أكبر مسافة وصولاً الى خور الخفقة شرق منطقة الدراسة. ان المسافة الفاصلة بين المسارات تراوحت ما بين 0.6– 0.8 كم. فضلاً عن المسارات العرضية، أُجري مسار طولي عمودي عليها بلغ طوله 6.3 كم. تم معالجة وتفسير البيانات وأظهرت المقاطع ان العواكس (الطبقات تحت القاع) تمتلك ميلاً متغايراً، وان هذه العواكس تظهر في بعض المقاطع وتختفي في أخرى. بينت النتائج أن الموقع الضحل قد نتج بفعل اندفاع تركيبي اختراقي عميق. تراوحت أعماق المياه 6–7 م عند ألمنتصف وبحدود 13–14م شرق الموقع ، في حين وصل العمق الى 30 م غرب الموقع. تراوح مقدار المحور الطولي للتركيب 6 كم والمحور العرضي ما بين 2–2.5 كم. كما بينت النتائج أن هنالك تركيب اخر يقع في الجانب الشرقي من الموقع الأول بالقرب من خور الخفقة، وتقترح الدراسة ان هذه التراكيب تمثل سدادات ملحية (Salt plugs) نتجت عن تركيب عميق يمثل قبة ملحية ، وما يؤكد ذلك عدم ظهور العواكس في بعض المقاطع بسبب وجود هذه التراكيب، الامر الذي يميز سلوك الموجات الزلزالية عند مرورها خلال التراكيب الملحية. فضلاً عن ظهور العواكس المائلة وعدم انتظام القاع ووجود العديد من الفوالق، والذي بدوره يمكن أن يشير الى تعرض المنطقة لاعادة تنشيط تكتوني في المنطقة.

Introduction:

Marine geophysical studies are essential for imaging the crustal and structures of the sea bottom. Among the marine basins around the Arabian Peninsula (AP), the Arabian Gulf (AG), specifically at the study area, is the less studied location by geophysical techniques. Even though the available geophysical data in the region are very limited in comparison with the other basins around AP, they provide valuable information on the structure and tectonic framework of the region. Previous geophysical studies of AG region were based largely on earthquake seismicity and gravity data. They focused primarily on the continental collision and tectonic activities along Zagros belt [1-5]. Moreover, many studies described the upper crustal structure of the Gulf based on seismic reflection and gravity data [6-8].

The depth of the AG is shallow where many large and small islands is located near the shore lines or off them. Also, there are many other islands do not rise above the sea level. There are 20 islands in addition to a number of submarine highs or shoals. Most of the islands are piercement salt domes and many of the shoals are also clearly due to salt diapirism [9]. The origin of these islands are different, such as by depositional processes, coral growth, tidal embayment, sea sediments , folding actions. and by uplift of the salt structure from lower formations, [10-12].

The coastline of Iraq is about 58 km long. In comparison to the other Gulf coasts, the Iraqi shore line can be considered short. However, it is very important to the area because it is the only part of the Gulf coasts join permanent water inlets from the Shatt al-Arab and Khawr Abdullah. In the Iraqi regional waters, there are many shoal features (i.e., under water islands) which lack any marine geophysical surveys. The present study focaused on image one of these structure and described the morphological features pertaining the Palinurus Shoal (PS) that is located in the southern most Iraq, nearby the Khawr Al- Khafka within Iraqi marine border.

Study area and Geological Setting:

The study area lies in the extreme southern part of Iraq at the vicinity of Khawr Al- Khafka within Iraqi marine border about 42 km southwest of Shatt Al-Arab creek and 40.3 km south Khawr Abdullah entrance. It bounded by latitudes (29° 38′ 22.4″N- 29 ° 35′ 22.3″N) and longitudes (48 ° 47′ 7.5″E- 48 ° 48′ 52.8″E), as shown in Figure-1. The study area represents northern part of the AG.

The AG is an elongated basin located in the south of the Zagros fold belt between the Tigris-Euphrates Delta and the Strait of Hormuz. It is the second smallest marine body, and lies in the Arabian plate [8].

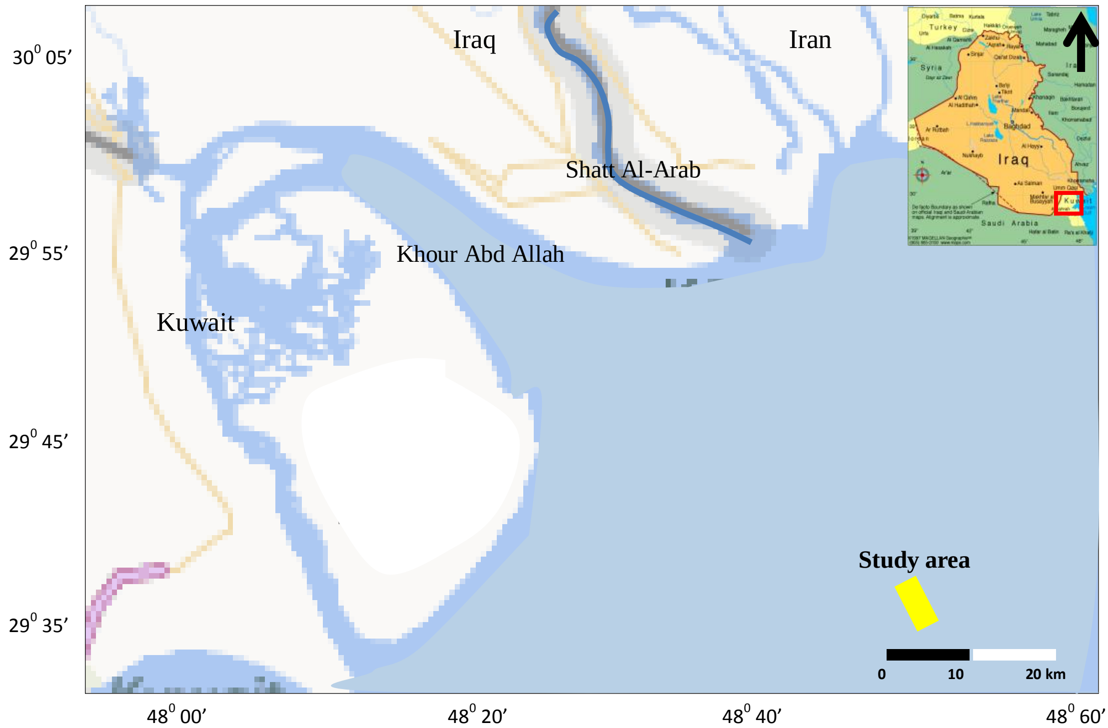

Figure 1- Location map of the study area

The evolution of AG agreed to be commenced at Late Tertiary and has been directly influenced by the continental collision along the Zagros fold belt. The first continental collision of Arabian and Central Iran took place during the Late Cretaceous. By early Miocene a Proto – AG was evolved from the closure of the Neo-Tethys [13]. The basin of the Gulf is asymmetrical where the slope of the Arabian flank being much gentler than that of the Iranian side and the deepest water lies close to the Iranian shore, [9]. A north-trending bathymetric high, centered around 52° E longitude, divides the Gulf into two major parts. The relief is rather small, but this subdivision may be tectonically controlled [8]. The basement beneath the Gulf dips towards the northeast and extends to the main Zagros thrust.

Two deformation events have been documented in the NW of AG that occurred during the Late Cretaceous and the Late Cenozoic. This part of the Gulf was reactivated through the Late Cretaceous, NNE-SSW Arabian trending folds. Then, it was affected by NE-SW shortening during the Late Cenozoic Zagros Orogeny [14].

The coastal region in the Arabian side of the Gulf is tectonically stable with only gentle movements [9]. The main morphologic features have been formed by tectonic activity. Climate and rock type play secondary roles. A flat deltaic surface, formed by the flood plains of the Tigris, Euphrates, and Karun rivers. The Iranian coast is irregular generally and backed by the northwest-southeast trending Zagros Mountains. The relief is composed of huge folds which are the product of the Miocene to Plio-Pleistocene Zagros Orogeny [2]. According to [15] and [16], the submarine topography of the Gulf is divided into seven bathymetric provinces namely: (1) The Mesopotamian Shallow Shelf; (2) The Arabian Shallow Shelf; (3) The Western Basins ; (4) The Central Swell; (5) The Eastern Basin; (6) The Eastern Swell; and (7) Hormuz Straits, figure 2. The study area is located in the Mesopotamian shallow shelf province. The depth of the study area ranged from 7 to10 m, while it ranged from 14 to 20m around the study area [17].

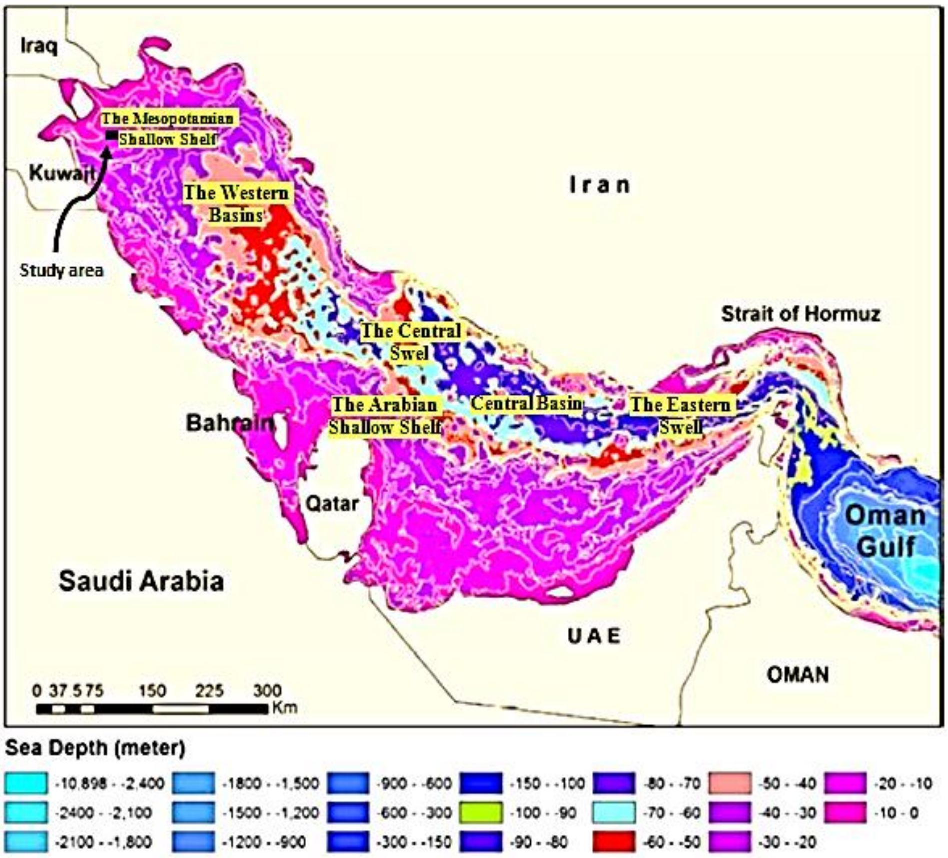

Figure 2- Location map of the study area and adjacent area showing principal bathymetric provinces and depth of water (in meters) of the Arabian Gulf (modified from [16] and [18])

Field Work:

The Sub Bottom Profiler (SBP) is an acoustic investigation technique that maps marine sub-bottom by attaching a probe to a boat and dragging it through the water. Depending on the desired accuracy (which is varying from a few meters to several tens of meters in depth) one can map the sub-bottom and trace objects in or on top of it.

The SBP uses acoustic waves that are sent into the sub-bottom by means of a transducer. The acoustic signals are reflected when they transmitted in the ground material and then registered by a receiver. It is dragged along by a boat on which positioning equipment is mounted. By carrying out a sequence of measurements along a measuring line, detailed information concerning the shape and composition of the sub-bottom and the internally present disturbances can be obtained.

The SBP field work was conducted during May – 2014 using the Strata Box™, a marine geophysical Instrument produced by SyQuest Inc, USA, Figure 3. This instrument was invented for inshore and coastal geophysical surveys [19] as a kind of low-power consuming portable underwater instrument. Specifications of the instrument are: strata resolution of 6 cm with 40 m of bottom penetration; maximum depth range of 150 m; frequency output of 10 kHz.

Eight transverses SBP survey lines were carried out over PS from southwest to northeast of length about 2.5 km for six lines (1, 2, 3, 5, 7, 9). The two remaining lines (4,8) are about 4.6 km extended to Khawr Al Khafga to cover larger area. The distance between survey lines is about 0.6-0.8 km. One longitudinal survey line also performed to the north south direction that is 6.3 km length, Figure-4.

The field data of SBP are converted into SEG-Y format (an industry standard seismic data format). The raw data were processed by an industry scale software VISTA V.12. The processed data were imported into the interpretation software Kingdom Suite V. 8.8 in order to highlight any structural features that is visible in the imagery. Figure-5 shows a longitudinal profiler-no.6 before and after processing.

Figure 3- Acquiring data of SBP survey.

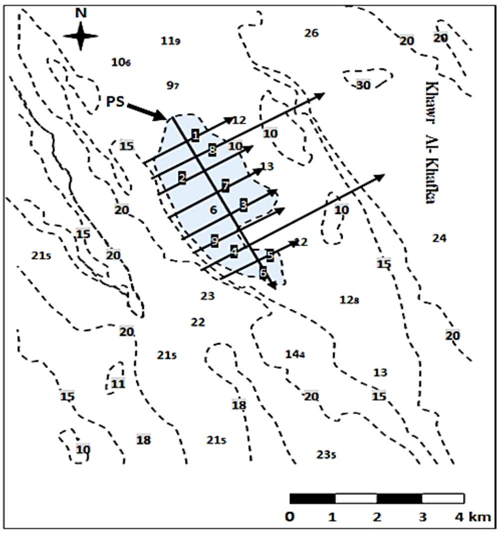

Figure 4-The SBP track lines (bathymetric of the study area modified from Admiralty map of Khawr Abdullah and Approaches to Shatt Al- Arab, [17]).

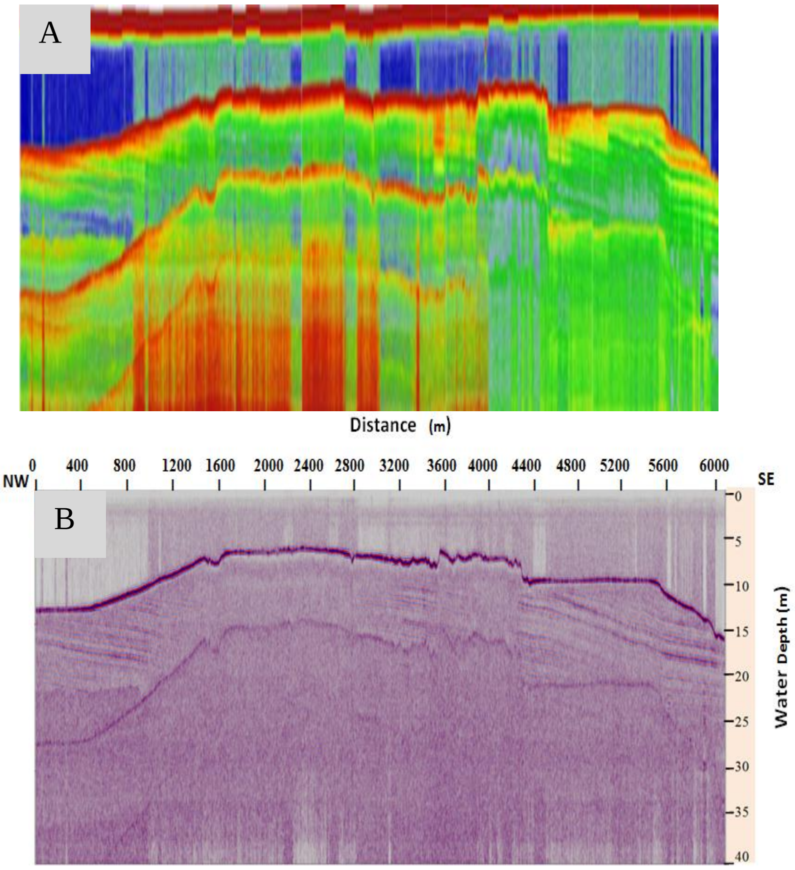

Figure 5 - The SBP section along longitudinal profile-no.6, A- before processing, B- after processing.

Results and Discussion:

The processed profiles are showed in Figure-6. Abrupt reflectors, slope changes, reflectors discontinuity, and coherency were the main interpretation guides on the sub-bottom images. Generally, the data qualities are good and interpretable except profilers 2 and 7. The reflectors do not continue all along the section. Particularly, the strong reflectors of flat areas and deeper sea bottom, but they are weakened at convex and shallower areas (e.g., cross section no. 4).

The signal survey depth depends primarily on the nature of the sea bottom material which controls the penetration depth. The maximum penetration depth of Sub Bottom data was 25 m. The profilers showed that the PS depth ranged between 6-7 m at the site center. At both ends of the profilers, specifically (3, 7, 9), PS depths were about (13 -14 m) and (15-29 m) to the east and west sides of the structure, respectively. The depth appears to be 15 m on sections (1, 2, and 8). In the far east of the study area, the direction of Khawr Al-Khafga and exactly at the end of sections of profilers the depth becomes 29 m.

It is worthwhile to be mentioned that the penetration depths of 15 and 20m underneath sea bottom at the study area are because of the presence of medium-coarse sand, and existence of hard materials that consist the sea bottom that may cause strong multiples as shown on Figure-6. It has been noticed two thin layers of approximately 10-30 cm thickness near the sea bottom. These layers have been distributed at a uniform pattern on all lines. In some locations, these layers (reflectors) are covered by a thin layer of sand that doesn’t exceed the 10 cm, as has been visually observed during survey time.

The sea bottom takes different layouts at different places. It was observed to be flat on profilers 3 and 9, and it is deepened towards South West. So that the noticed slope is about 10°. This slope changed even more (e.g., about 25°) towards the North West the study area, Figure-7.

Also, the SBP cross-sections evidenced an irregularity pattern of sea bottom and perhaps some of rubble rocky laid on top of it**,** particularly in the distance between sections- no.8 and no.4 that are cross middle part of the study area. Moreover, imaged some structural features in the area (e.g., faults). On profiler no 6, faults were imaged at the distances of 750 m, 1200 m and 2300 m of the section-no.9 (figure 9. On profiler no 3, faults were picked at the distances 600 m and 800 m. These faults are traced on section-no.6 (Figure-8. In addition, anomalous features represented by no reflection signal were noticed. Two of the anomalous features appeared on Figure-7. For a better manipulations, a 3D depth map was constructed and referenced to the profilers which showed the structures, figure 9. The anomalous features on the profilers may indicate a salt diapiric.

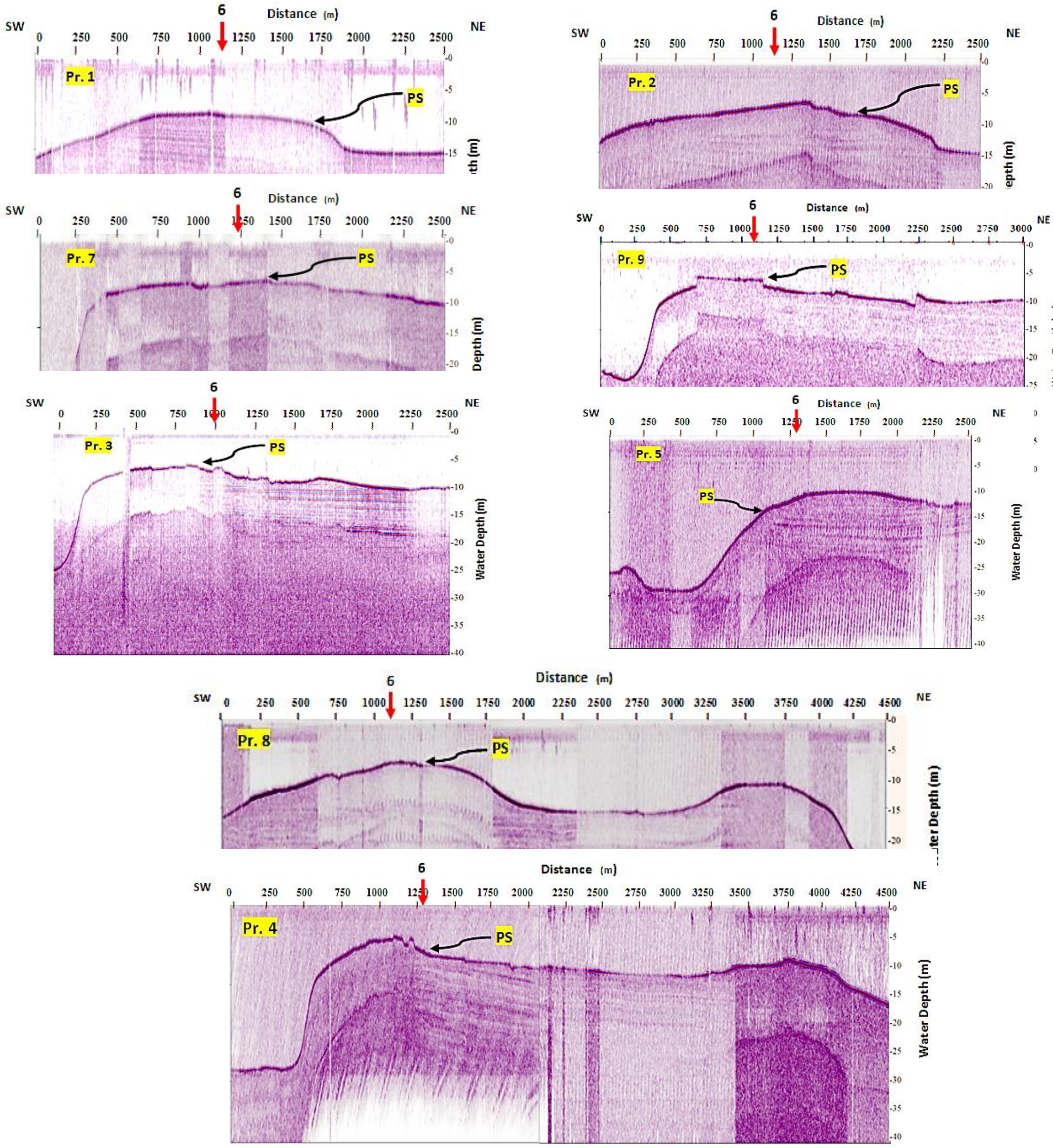

Figure 6- The SBP Profilers processed, shown the Abrupt reflectors, slope changes, reflectors discontinuity, and coherency were the main interpretation guides on the sub-bottom images., another diperic structure was detected east of the PS in the profilers 4,8.

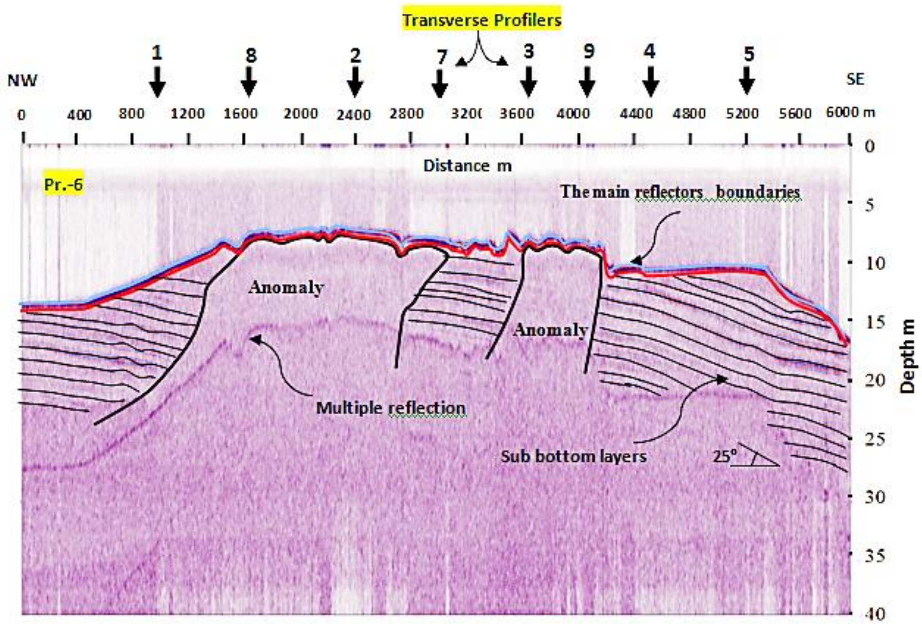

Figure 7- An interpreted profiler no. 6. It shows anomalous bodies, multiple-reflection, and a set of multi-bub bottom layers.

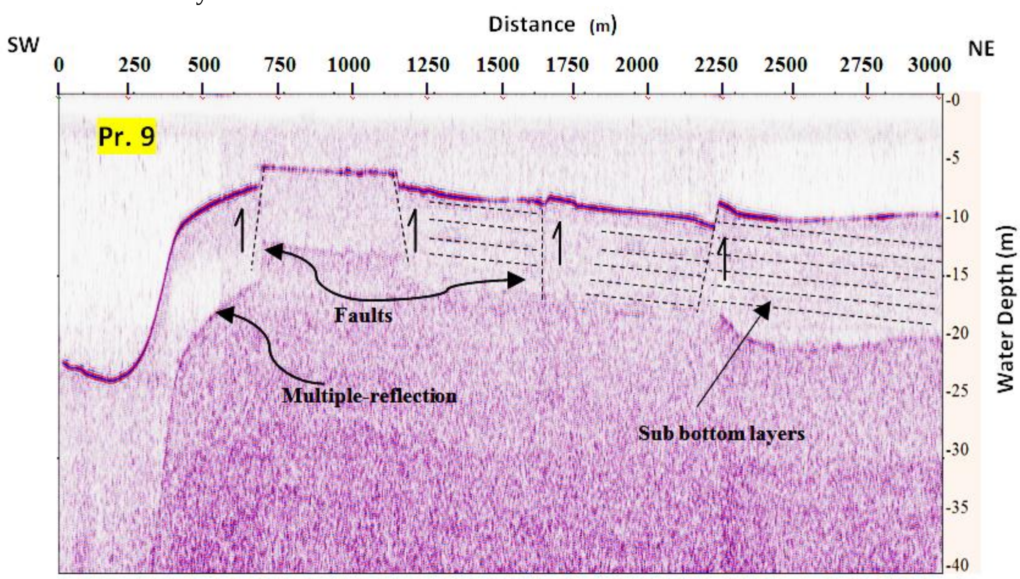

Figure 8- Section –no.9, Sample of sub bottom image showing the faults, sub bottom reflectors and multiple-reflection

There are a multi-lines of evidences, the presence of high variation in the depth of sea bottom, tilting of the sub bottom layers, faults, rock debris, and the existence of anomalous features of no sedimentary sequences beneath the rocky bottom which prove that study area has gone through uplift process stressed by deeper forces coincident with deeper structure movement driven by a salt diaper. This activity formed a graben-like structure of 6 km length and 2-2.5 km width. The structure trends to NW-SE direction. The structure is tilted about 25°. The sub bottom layers on both sides of the salt diapiric have the same slope because the axis of feature is not vertical and rather tilted to SE, Figure-9.

The salt diapiric is the mass of salt rocks that form the core of a salt dome. This salt rack core have been interpreted as a single uniform mass of salt rock that had moved upwards by buoyancy. Latter investigations revealed that salt was forced upward by regional and local compressive forces [20]. The salt sediments may have been supplied by different sources at several kilometers below surface or from shallower places driven by the lower specific gravity. They found point(s) where break through the seafloor may occur. Depressions and sometimes mounds may form according the furnished power. In some case, these features may be considered as a good hydrocarbon trap. Out postulation is supported by negative gravity anomalies on the other salt diapiric structures. The lower specific gravity of the salt bodies than adjacent rack mass helped [8] to investigate the part of AG between the Tigris-Euphrates Delta and Qatar Arch. More studies firmed the existence of diapirics and salt domes in AG and the surrounding areas [21-23]. These structures are existed in southwest Iran, south of Iraq, AG region and parts of the west coast. The Hormuz salts series are the main source most salt diapiric structures. The Hormuz evaporates have been risen to the surface piercing through overlying thick sedimentary rocks in the form of salt dome, plugs and other diapiric structures. It was inferred that the overburden, the salt buoyancy and basement faulting interestingly produced the salt-flowage anticlines and as such rows of anticlines were formed by compressional-folding in Late Pliocene [24]. The late Pre-Cambrian, highly plastic Hormuz salt layer acted as a decoupling layer, disconnecting the sedimentary cover structures from the crystalline basement structures, which allowed the crystalline basement to deform by faulting while the sedimentary cover deforms mainly by ductile folding [25].

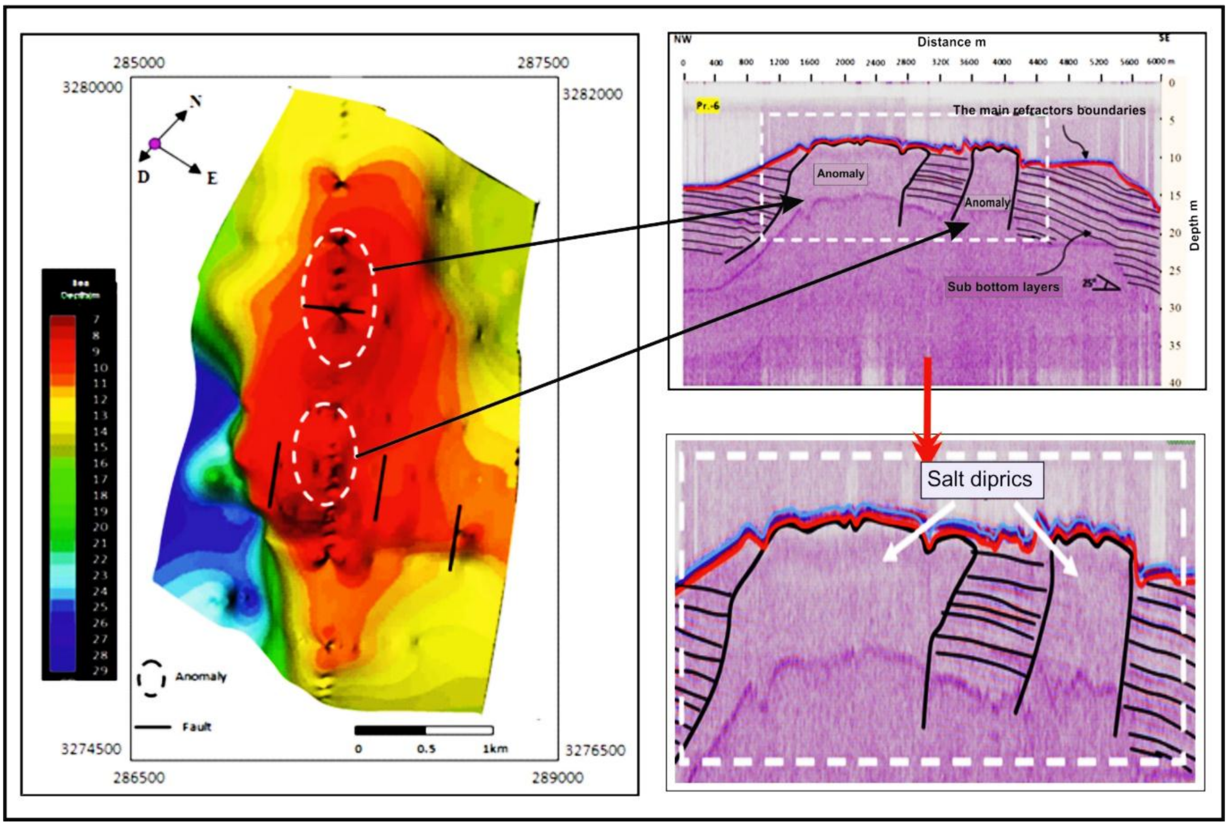

Figure 9- 3D bathymetry map with section no. 6 showing the anomalous features, faults and possible a salt diapiric.

More than 200 salt-plugs have been reported in Zagros-south region of Iran [26] and also in northeastern offshore area of AG across Strait of Hormuz in addition to one plug in southern Iraq is representing Sanam plug. More recently, [27] have reported more than 500 exposed and/or buried salt diapiric structures in Iran along the northern coastal areas of AG. Moreover, [26] reported a number of salt-diapiric stock-like structures that have been identified during the analyses of the customized bathymetry map. A randomly scattered pattern of these small diapiric salt-structures has been observed almost throughout the bottom of AG.

The SBP sections- no.4 and no.8 illustrate the existence of another diapiric structure east of the first diapiric. It suggests that these diapiric features represent salt plugs which have been evolved from a salt dome or pillow that supplied by Pre-Cambrian salts through basement faults. Folding the sedimentary layers cover the salt dome. It is believed that the stage of development of these domes happened at the end of the Tertiary that coincided with Plio-Pleistocene movement as explained by [9]. Such movements that led to the construction of the Zagros Mountain belts and the evolution of the many piercement salt domes in AG and southwest Iran.

Conclusion:

- The sub Bottom profilers were successful to image sub-bottom of the sea at the study sit. They showed depth fluctuations of the bottom. These depth changes are related to tectonic structures at the PS. The area is affected by a diapiric structures.
- The origin of PS can be related to a salt plug evolved from a salt dome or pillow that is affected by folding and faulting processes. The tectonic print is manifested by faults and irregularity of the seabed.
- Our results are consistent with many other studies that have been conducted in the Gulf region and surrounding areas which proved that the diapiric structures and salt domes are belong to the Infracambrian, possibly an equivalent of the Hormuz Salt Series of the Arabian Gulf region.

References:

1. Nowroozi, A.A. **1971.** Siesmotectonic of the Persian plateau, eastern Turkey, Caucasns and Hindu- Kush region. *Bulletin of the seismological of the America*, 61, pp: 317-341.
2. Bird, P. **1978**. Finite element modeling of lithosphere deformation: the Zagros collision orogeny, *Tectonophysics,* 50, pp: 307-336.
3. Dahghani, G.A. and Makris, J. **1984**. The gravity field and crustal structure of Iran, *Neues Jahrbuch für geologie and Paläontologie Abhandlugen*, 168, 215-229.
4. Snyder, D.B. and Barazangi, M. **1986.** Deep crustal structure and flexture of the Arabian Plate beneath of the Zagros collision Mountain belt as inferred from gravity observation. *Tectonics*, 5, pp: 361-373.
5. Ni, J. and Barazangi, M. **1986**. Seismotectonics of the Zagros continental collision zone and a comparison with the Himalayas, *Journal .of Geophysical Research*, 91, pp: 8205-8218.
6. Ross, D. **1978.** General data of the geophysical nature of the Persian Gulf and Gulf of Oman, Woods Hole oceanographic Institution technical report, *WHOI-78-39 Report D,74-107,* Woods. Hole, Massachusetts, USA.
7. White, R.S. and Ross, D.A. **1979**. Tectonics of the western Gulf of Oman, Journal of Geophysical Research 84, pp: 3479-3489.
8. Warsi, E.K. **1989.** Geophysics of the Arabian Gulf, *Journal of University of Kuwait Science,* 16, pp: 183-192.
9. Kassler, P. **1973**. The Structural and Geomorphic Evolution of the Arabian Gulf. In: The Arabian Gulf- Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea, Purse B.H.,(Ed.), *Springer Verlag, New York, Heidelberg*, Berlin, pp:11-32.
10. Metwali, M. **1975.** *The Arabian Gulf basin*. part 1, library of Englo Eagebt. 360p. (InArabic).
11. Karim, H.H., and Salman, H.H. **1988**. *Geology of the Arabian Gulf.*University of Basra. Marin science center publication, p: 330.(In Arabic).
12. Al-Ghadban, A.N. **2002.** *The Gulf Ecosystem: Health and Sustainability.* Geological oceanography of the Arabian Gulf, Backhuys Publishers, Leiden, The Netherlands, pp: 23-39.
13. Koop, W.J. and stonely, R. **1982.** *Subsidence history of the Middle East Zagros Basin.* Permian Recent. Philosophical Transaction of the Royal Society, London, A 305, pp: 149-168.
14. Soleimany, B. and Sàbat, F. **2010.** Style and age of deformation in the Northwest Persian Gulf. *Petroleum Geosciences*. 15, pp: 1-10.
15. Seibold, E., Vollbrecht, K. **1969.** *Die bondengestalt des Persischen Golfs*. (Structural aspects of the Persian Gulf. In German), meteor, For schungsergennisse, Reihe (Meteor for research result) 2(C), pp: 29-56.
16. Seibold, E., Diester, L., Futterer, D., Lange, H., Muller, P., and Werner, F. **1973.** *Holocene Sediment and Sedimentary Processes in the Iranian Part of the Persian Gulf.* . In: Purser, B.H. (Ed.), The Persian Gulf- Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. . Springer-Verlag, Berlin, pp: 57-80.
17. United Kingdom Hydrographical Office (UKHO). **2004.** *Admiralty map of Khawr Abdullah and Approaches to Shatt Al- Arab*. Related Admiralty Publications. No-9.
18. Nayyar, A., Z., Omar, S., A., Zeeshan, A., N., Gohar, A., M., and Azhar, S. **2013.** Salt-tectonic plays major role in contribution high seawater salinity in Arabian/Persian Gulf: A constant constrain on seawater desalination, *Journal of Water Resources & Arid Environment.* 2(4), pp:187-194**.**

19. Sindhu B, Suresh, I., Unnikrishnan, A. S. **2007**. Improved bathymetric datasets for the shallow water regions in the Indian Ocean. *Journal of Earth System Science*.116, pp:261–274.

20. Looff, K.M., and Rautman, C.A. **2010.** Salt spines, boundary shear zones and anomalous salts: their characteristics, detection and influence on salt dome storage caverns. Spring 2010 Meeting, Grand Junction, Colo., Solution Mining Research Institute, Clarks Summit, Penn., 26p.

21. Karim, H.H. **1989.** Qualitative Interpretation of Basrah Aeromagnetic Map, SE Iraq. Jour.Geol.Soc.Iraq, 22(2), pp:1-8**.**

22. Karim, H.H. **1993.** General Properties and Patterns of the Gravity Field of Basrah Area. *Iraqi Geological Journal*. 26(1), pp:154-167.

23. Al-Muttory, W.G. **2002.** Structure and tectonic of Jabal Sanam southern Iraq, M.Sc, Thesis, Department of Geology, College of Science, University of Basra.Iraq, 93p. (In Arabic).

24. Hariri, M.M. **2011**. Regional geology; GEOL- 318-Part II-Sedimentary Strata. KFUPM, <http:// fauculty.kfupm.edu.sa/ ES/ mmhariri/ Material/ REGIONAL-GEOLOGY.ppt> (Jun. 16, 2011).

25. Berberian, M. **1981.** Active faulting and tectonics of Iran, in H.K. Gupta, F.M.D., ed., Zagros-Hindu Kush-Himalaya Geodynamic Evolution: Washington D.C., American Geophysical Union, pp: 33-69.

26. Liaghat, C. and Jouanne, F. **2002.** Ground surface deformation induced by salt diapirism in oil field zones: some examples in SE Zagros (Iran). Proc., 2002 AAPG Annual Meeting, AAPG, Houston, TX, pp: 1-9.

27. Amini, S.V., Faramarzi, N. and Sheikhi, F. **2010.** Tectonic activities effects on mineralization in Hormuz island, Persian Gulf, southern Iran. Proc., GSA Conference on Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia, GSA, Ankara, Turkey, pp: 35-39.