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Morphotectonics of Shaitanah Coastal Lagoon, Northwest of the Arabian Gulf

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Abstract - Several lagoons (khors) are found in the northwestern Arabian Gulf, including Khor Al-Zubair, Shaitanah, Abdullah, and Subiya. Determining whether these lagoons formed through tectonic or sedimentary processes is essential for understanding their development and the region's geological stability. While most prior research has focused on hydrological and sedimentological aspects, comprehensive field studies of lagoon genesis remain limited. Ongoing debate centers on the relative roles of tectonic and sedimentary influences. This study aims to clarify the causes responsible for the creation of the Shaitanah lagoon, which links Khor Al-Zubair and Khor Abdullah to the Arabian Gulf.To address this gap, marine geophysical surveys were conducted using a Sub Bottom Profiler (SBP) and an Acoustic Doppler Current Profiler (ADCP), in addition to a geomorphic index of Transverse River Profiles (TRPs), which quantitatively assesses the topographic features of the seabed. The cross-sections indicate asymmetry in the seabed topography of the selected sections and discontinuity in the extent of the seabed layers. The cross sections also identify a steep slope and a sudden increase in depth to 15 m, representing the navigation channel of the khor, which shifts position across all cross sections. The results obtained from the geophysical surveys and TRPs analysis, in addition to the khor's channel meandering at an angle of more than 90 degrees and flowing from west to east, unlike all other khor in the region, indicate a direct link between tectonic influence and related fault systems, specifically the Jal Az-Zor fault, on the creation of the khor. This is consistent with previous studies on neotectonic effects across the entire northwestern Arabian Gulf region and on regional faults.

مورفوتكتونية خور شيطانة الساحلي، شمال غرب الخليج العربي

ولاء مجيد الموسوي، زينب عادل المطوري، داود سلمان المياحي ، زينب عبد الرضا الحميدان ، حلا علي شبار
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المستخلص - يتميز شمال الخليج العربي بوجود العديد من البحيرات الساحلية والخيران خصوصاً في الجزء العراقي، منها خور الزبير، وخور شيطانة، وخور عبد الله، وخور الصبية. ويُعدّ تحديد ما إذا كانت هذه البحيرات قد تشكلت بفعل عمليات تكتونية أم رسوبية أمرًا بالغ الأهمية لفهم تطورها والاستقرار الجيولوجي للمنطقة. وبينما ركزت معظم الأبحاث السابقة على الجوانب الهيدرولوجية والرسوبية. لا تزال الدراسات الميدانية الشاملة لنشأة هذه الخيران محدودة. ويدور نقاش مستمر حول الأدوار النسبية للتأثيرات التكتونية والرسوبية. هدفت هذه الدراسة إلى توضيح العمليات الجيولوجية المسؤولة عن تكوين أحد هذه الخيران وهو خور شيطانة، الذي يربط خور الزبير وخور عبد الله بالخليج العربي. أُجريت مسوحات جيوفيزيائية بحرية باستخدام تقنية المقاطع العرضية للقيعان SBP وتقنية قياس سرعة التيار الصوتي دوبلر ADCP، بالإضافة إلى مؤشر جيومورفولوجي لمقاطع عرضية للأنهار TRPs، والذي يُقيّم كميًا السمات الطبوغرافية لقاع البحر. اشارت المقاطع العرضية للخور إلى عدم تناظر في تضاريس قاع البحر في المقاطع المختارة، وانقطاع في امتداد طبقات قاع البحر، كما

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حددت انحدارًا حادًا وزيادة مفاجئة في العمق إلى 15 م وهي ظواهر غير مألوفة في خيران المنطقة، بالإضافة إلى تعرج قناة الخور بزاوية تزيد عن 90 درجة وتغير مجراها من الغرب إلى الشرق، على عكس جميع الخيران الأخرى في المنطقة. هذه الدلائل ترجح وجود صلة مباشرة بين التأثير التكتوني وأنظمة الصدوع ذات الصلة، وتحديدًا صدع جل الزور، في تكوين هذا الخور. يتوافق هذا الاستنتاج مع الدراسات السابقة حول التأثيرات التكتونية الحديثة في منطقة شمال غرب الخليج العربي.
الكلمات المفتاحية: خور شيطانة، شمال غرب الخليج العربي، المسوحات الجيوفيزيائية البحرية، المقاطع العرضية للأنهار، النشاط التكتوني الحديث

Introduction

Coastal lagoons and estuaries characterize coastal water bodies, which formed during sea-level rise in the early Holocene (about 12,000-8,000 years ago) and with waters receding about 6,000 years ago (Kjerfve, 1994). The Quaternary period witnessed numerous geological events, most notably fluctuations in sea level and the accompanying advance and retreat of the head of the Arabian Gulf, which played a major role in shaping the region's natural features, including the creation of these lagoons. The Arabian Gulf, in general, and its northern and northwestern parts in particular, are characterized by numerous lagoons (also called khors) along the coasts of Iran, Iraq, and Kuwait. The Iraqi coast has three khors, including Al-Zubair, Shaitanah, and Abdullah, in addition to the khors within the sea, such as submerged bottom channels like Al-Khafqa and Al-Amya, which differ in depth and sediment from coastal khors (Darmoian and Lindqvist, 1988).

The factors that led to the creation of these lagoons are linked to the development of the head of the Arabian Gulf and the evolution of its associated geological features during the Holocene epoch, which has been a subject of debate among researchers, this debate has even extended to include the location of the southern part of the Mesopotamian Plain, and to date, there is no conclusive opinion. Many theories suggested that the head of the Gulf moved far north of its current location, followed by a gradual retreat of the Gulf due to the advance of the delta during prehistoric times (Aqrawi, 2001; Tanoli, 2013; Pournelle, 2013; Al-Sheikhly *et al.,* 2017).

During the Pleistocene, the sea level decrease by as much as 120 m , emptying the Gulf and river valleys were eroded down the slopes, then the sea cut a series of platforms (Kassler, 1973), at its level of maximum retreat and at times of relative standstill during the post-glacial . The history evolution of the upper parts of the Arabian Gulf is occurred at the end of the last glacial period (Würm Glaciation) and the post-glacial Flandrian transgression, a major marine transgression inundated the head of the Arabian Gulf to a position as much many hundred kilometers inland from the present shoreline. Many researchers challenged and disputed the first opinion, they claim that the coastline is stable in its current location after the last glacial period and has not progressed as a result of large-scale marine flooding, as indicated by the first opinion. (Lees and Falcon, 1952; Hudson *et al.,* 1957; Hansman, 1978; Karim, 1989; Al-Mousawi, 1993; Al-Mousawi and Al-Mansouri, 2019).. (Lees and Falcon,1952; Hudson *et al.,*1957; Hansman, 1978; Karim,1989; Al-Mussawy,1993; Al-Mosawi and Al-Manssory, 2019).

Khor Shaitanah is considered part of the northwestern Arabian Gulf region, and its formation is closely linked to the development of the head of the Gulf throughout geological history. Many studies have been conducted in Abdullah and Al-Zubair Khors, but most previous research has focused on hydrological and sedimentological aspects. Comprehensive field studies on Khor Shaitanah origin are limited, due to the lagoon's challenging marine conditions and its sensitive location as a shared territorial boundary with Kuwait. Understanding the origin of this khor is of considerable importance, as it could resolve discrepancies among theories on the development of the head of the Arabian Gulf. This is due to Khor's unique location, its distinctive morphology, and the unique meander of its channel, in addition to its connection to the Abdullah and Al-

Zubair khors; therefore, the current study aims to determine the origin of this khor using marine geophysical surveys and morphological evidence, aided by sedimentary and tectonic evidence.

The Study Area:

The Khor is located northwest of the Arabian Gulf, within Iraqi territory, about 33.350 km from the Gulf head. It connects Khor Al Zubair to the north and Khor Abdullah to the south. It is approximately 16 km long and has a width ranging from 1100 to 1950 m (Figure 1). It is common among many researchers, when describing Khor Al-Zubair, not to distinguish its lower part (the mouth), represented by Khor Shaitanah, and they describe them as one Khor. Khor Al-Zubair and its lower estuary form a marine arm influenced by tides originating from the Arabian Gulf, where the dominant tidal system is mixed semi-diurnal. Based on the average tidal range, which can reach approximately 5 meters in Khor Al-Zubair, it is classified as a tidal meso estuary (Lafta *et al.,* 2019; Al-Ramadhan, 1986). The estuary can be classified as a lagoon estuary characterized by strong tidal flow. The tidal wave is symmetrical at the lower part of Khor Shaitanah and becomes asymmetrical as it progresses northward at the upper approaches.

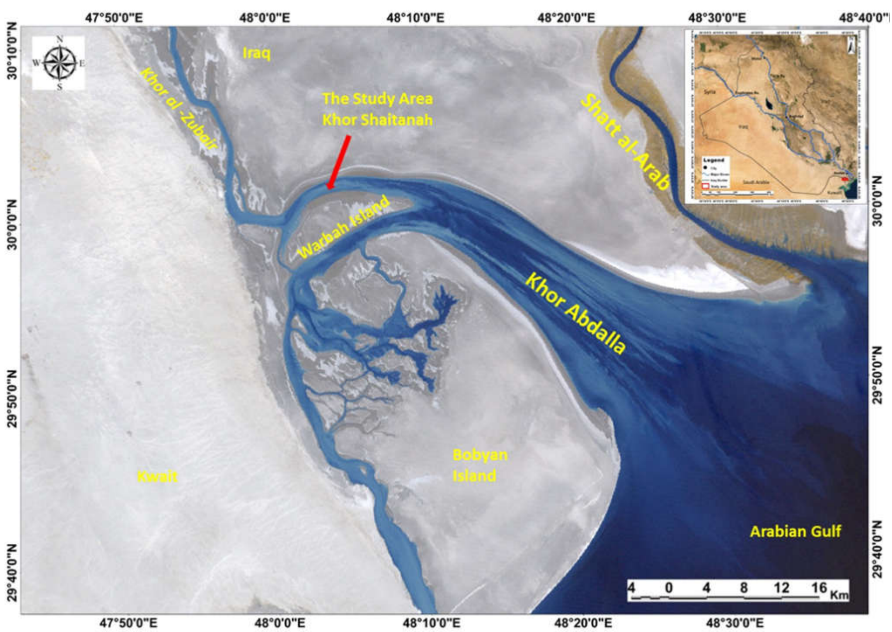

Figure 1. The study area

Geological Setting:

The study area (Khor Shaitanah) is considered a part of Khor Al-Zubair in the far southern part of Iraq, northwest of the Arabian Gulf. Geologically and tectonically the study area is associated with the Arabian Plate and Arabian Gulf, it is located within the unstable shelf (Jassim and Goff, 2006). According to Fouad and Sissakian (2011), the khor is located within the Mesopotamian Plain of the Outer Platform. The khor is located northwest of the Arabian Gulf, which in turn is considered part of the remnants of the oceanic basin of the ancient Tethys Sea (Buday and Jassim, 1987), which was closed in the late Eocene as a result of the collision of the Iranian and Arabian plates (Jassim and Goff, 2006). The study area and its surroundings are located in the Zubair subzone, which forms the southernmost part of the Mesopotamian Zone. The khor and surrounding are covered by Quaternary deposits consisting of fluvial/Aeolian deposits and marsh/lacustrine sediments deposits from Euphrates and Tigris rivers, as well as the khor extends to the sandy and muddy flat area with flat surface features and due to marine erosion, these features are formed by the tides impact (Figure 2). The Mesopotamian zone is characterized by the presence of several gently plunging subsurface structures with different sizes, these structures represent salt structures surface and subsurface faults (Karim, 1989).

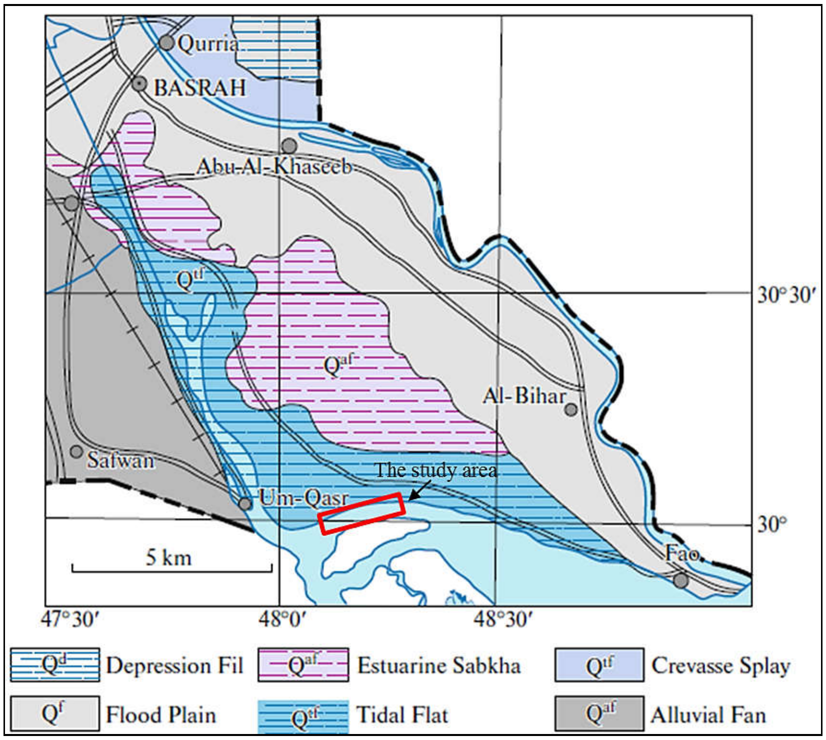

Figure 2. Geological map of the study area and its surroundings (after Sissakian, *et al.,* 2018

Methodology:

In the present study, three techniques were employed: field techniques, including Marine Geophysical Surveys using the Sub Bottom Profiler (SBP) and Acoustic Doppler Current Profiler (ADCP), as well as a geomorphic index of Transverse River Profiles (TRPs).

The SBP is a marine geophysical technique, an acoustic exploration technique that maps the sub-bottom river or seabed by reflecting an acoustic pulse from the seabed and sub-seabed materials (McGee, 1995). The reflection of acoustic energy occurs at boundaries with differing acoustic impedances; the reflection strength depends on the degree of impedance contrast. The technique is used to perform cross-sections and to identify the characteristics of river bottoms and sea beds. The accuracy of the information obtained, including the depth of penetration and the subsoil boundaries obtained from these pulses, depends on the frequency used and the nature of the sediments and rocks on the seabed (Stoker *et al.,* 1997).

As in seismic refraction surveys, acoustic SBP is used to map the shallow geological structure beneath the seabed or under river-bottom. The accuracy of measurements in the SBP is dependent on several factors, the depth and density measurements of sub bottom sediment obtained from these surveys may show a deviation of ±10% compared to actual sediment samples. In the shallow sedimentary layer of the seabed (30 cm), factors such as complex marine conditions and aquatic environments, vessel noise, and echo scattering introduce uncertainty into the obtained data. Therefore, careful selection of calm marine conditions during measurement, as well as precise selection of the survey vessel and control of its speed, are essential. The frequency used is a critical factor, as the accuracy of the measurements depends heavily on the frequency. Lower-frequency transducers (2–4 kHz) provide deeper penetration of the seabed but have lower vertical resolution (often 20–36 cm). High frequencies (10-45 kHz) provide a vertical accuracy of up to 5-11 cm, but have shallow bottom penetration. In the current study, a Strata-box device was used with a frequency of 10 kHz.

The SBP section is completed from the Iraqi coast (left bank) to the middle of the navigation channel with a distance of 1100 m (Figure 3). It should be noted that completing a full section or multiple cross-sections of the khor using this technique (in addition to the ADCP technique) is extremely difficult, as the area is sensitive due to its status as a shared maritime border between Iraq and Kuwait. Nevertheless, the SBP section achieved its intended goal of revealing the nature and extent of the sub-bottom layers.

Acoustic Doppler Current Profiler (ADCP): An instrument that measures the vertical paths of water velocity using an acoustic pulse. Like marine sonar and echo sounding, an ADCP pulse of energy is sent into the water column, but at much higher frequencies. This energy is reflected by particles suspended in the water, and some of it returns to the transmitter. The technique measures the change in frequency (Doppler shift) of the reflected energy and then calculates the water velocity relative to the acoustic Doppler (Bender & Di Marco, 2008). It also measures the current's velocity and direction across the khor. The ADCP is used to obtain a realistic cross-section of the khor to identify the bed's morphological nature and clarify the hydrological behavior of the currents at the site. The field section is completed with 1985 m, representing a Z-Z" section (which was also used in the TRPs analysis, Figure 3). It was not possible to cover the entire width of the canal because the waters near the Iraqi coast are shallow, with depths of up to 1m.

This technique allows for the measurement of several parameters, such as current velocity, depth, and cross-section of the channels; it also allows for the calculation of discharge (Velocity x width x depth). The velocity accuracy ADCP is defined as a percentage of the measured current velocity combined with a small fixed offset. For most standard of ADCP high-quality, the accuracy is rended ±0.25% to ±1% of the measured velocity, with a small constant like ±0.25cm/s. However, this accuracy depends heavily on environmental conditions, calibration, and operating settings. The Resolution of ADCP is Commonly 0.1 cm/s or better.

The TRPs are among the geomorphic indices suitable for assessing the level of tectonic activity and the characteristics of an area. The TRP application can provide important information on both geomorphic features and hydrodynamic factors of drainage basins (Sinha, 2001). The TRPs analysis represents a new method for tectonic activity analysis, using multiple quantifiable, comparable TRP parameters. The TRPs analysis includes several initial steps, including making slight alterations to cross-sections by adjusting values to the range 0 to 1, which represent the highest and lowest values in the TRPs curve. The method uses established measurements to evaluate tectonic activity in river basins. The parameters are interconnected. The total channel erosion factor (Ea) measures eroded riverbed material as the area between the riverbed's current shape and the original riverbank. Channel depth (Ch) is the greatest vertical distance from the water surface to the thalweg, which is the deepest point in the cross-section. Eh*Ln summarizes total erosion where Eh is the average vertical riverbed loss per cross-section, while Ln is the channel's total length. Channel symmetry (Bs) is the distance from the geometric center to the thalweg. A significant offset may indicate tectonic movement or tilting. Channel-side dip is the angle of the riverbank, measured from the channel. Valley symmetry measures the overall slope symmetry of the valley sides. The Differences between Vs and Va readings in a basin may suggest tectonic movement, though not always consistently.The parameters used with this indicator are shown in Figure 3.

In the present study, four TRPs sections across include W-W", X-X", and Y-Y" Khor Shaitanah that have been extracted from the Admiralty Chart (2004), and the Z-Z" section has been performed from the survey, as shown in Figure 4.

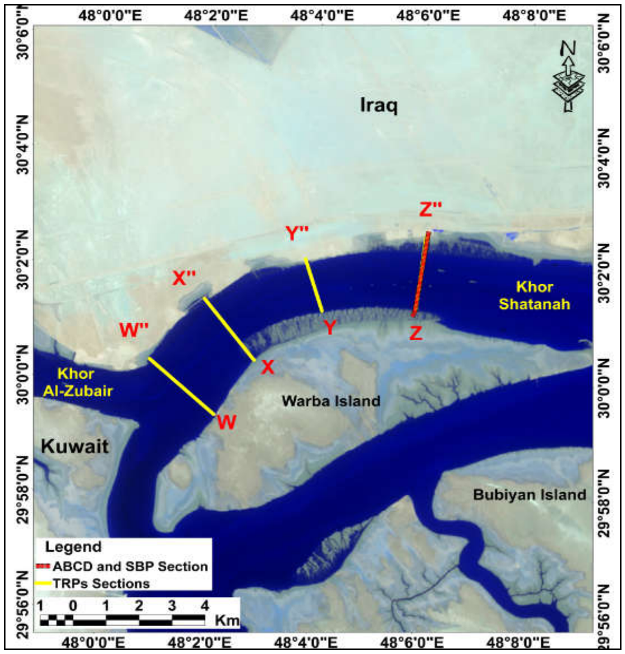

Figure 3. Khor Shaitanah, showing the four sections used in TPRs morphotectonics analysis, also the Z-Z" profile representing the location of the SBP and ADCP surveys section.

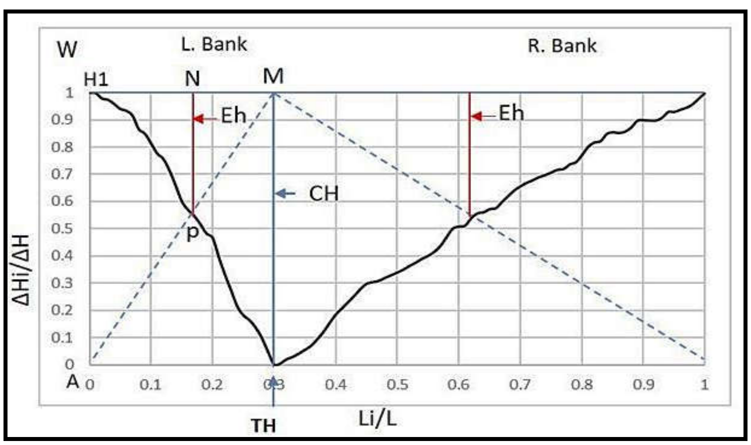

Figure 4. Parameters used with the TRPs index

Results:

The SBP section showed that there was a sudden increase in depths in the middle of the khor's channel, where the depths changed from 5 m to 15 m suddenly and at no more than 50 m (Figure 5). This condition is uncommon in the bottoms of the region's khors and occurs only in rocky bottoms. Since most of the bottoms of these khor consist of soft sediments, especially clay, silt, and sand, sedimentary activity is active in this location due to changes in the khor's course. Therefore, the accumulation of sediments does not leave any distinctive features of the bottom, contrary to what is observed in this section. Also, the section showed cuts and discontinuities in the layers beneath the bottom.

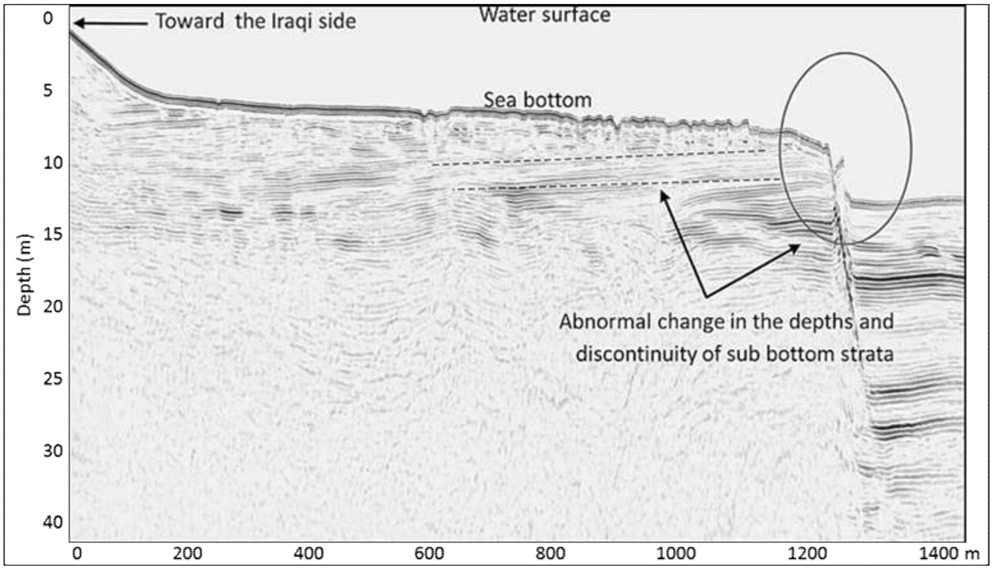

Figure 5. The SBP section, extending from the maritime territorial boundary line towards the Iraqi side, shows a discontinuity in the sub-bottom layers and a significant change in depth from 5 to 15 m.

The ADCP section revealed an irregular seabed, with shallower depths near the Iraqi coast compared to the Kuwaiti coast (Figure 6). High depths were recorded in the half channel closest to the Kuwaiti coast. Current velocity also varied with depth, with the lowest velocities recorded on the Iraqi side, not exceeding 0.9 m/s, while it exceeded 1.2 m/s in the middle of the channel. Overall, the current velocities were slightly higher on the Kuwaiti side.

The TRPs analysis is processed and evaluated for four sections across the Khor Shaitanah channel (Figure 7). Table 1 shows the parameters derived from the TRP analysis and calculations in the khor. The tectonic indicator (Ln*Eh parameter) is the highest magnitude in the cross-section Z-Z". The section X-X" has shown that the morphological parameter is low (Bs = 0.001) because of the abundance of sediments in this site.

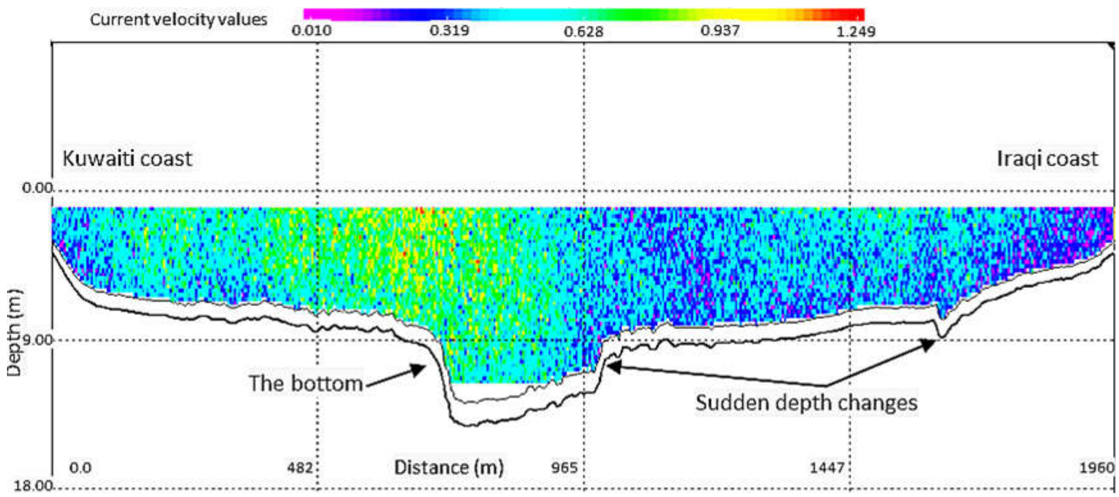

Figure 6. The ADCP section shows seabed irregularities and sudden depth changes at multiple locations, affecting current velocity variations, which are lower near the Iraqi coast than near the Kuwaiti coast. The waterway is also closer to the Kuwaiti coast, indicating that the Iraqi coast is characterized by sedimentation, whereas the Kuwaiti coast is characterized by erosion.

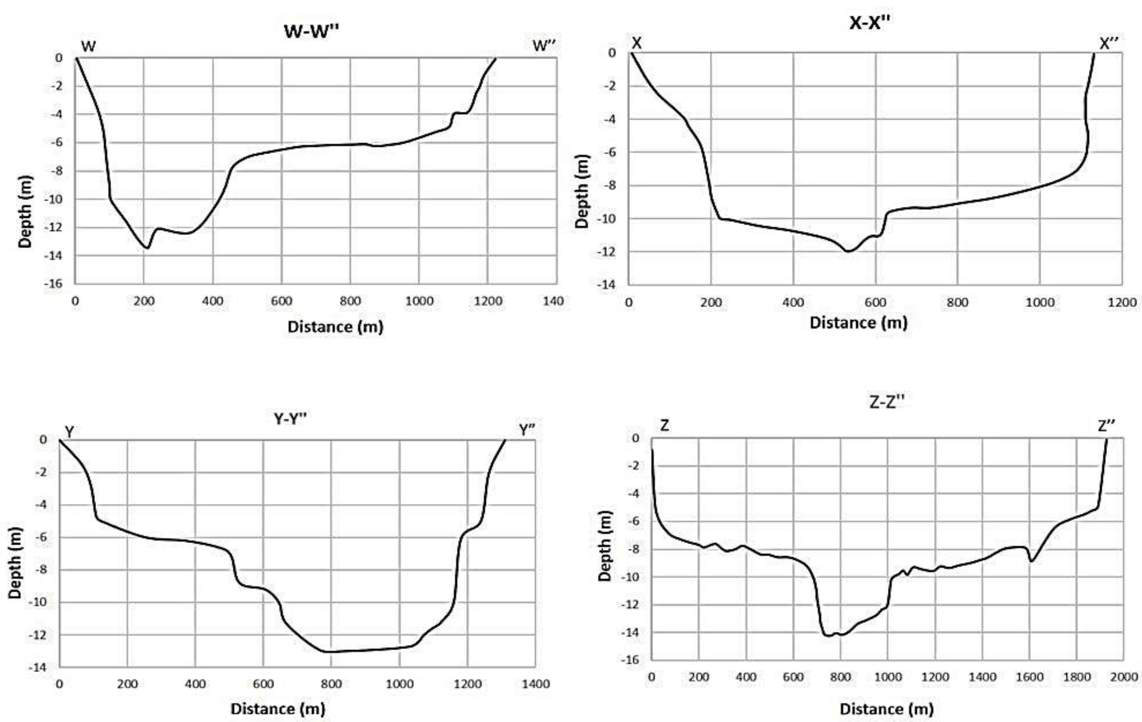

Figure 7. The completed TRP cross-sections in Khor Shaitanah show irregularities in depth both between sections and within each section. The completed sections represent the lowest tide state and record the highest depths in section Z-Z", which marks the end of the khor. The navigation channel is closer to the Kuwaiti side in the W-W" section. It creeps to the middle of the khor, in the X-X" and Z-Z" sections. Unlike the Y-Y" section, the navigation channel is closer to the Iraqi side.

Table 1. Computed parameters of the TRPs of Khor Shaitanah

Sec.	Eh (Lb)	Eh (Rb)	Eh (Lb) /Ch	Eh (Rb) /Ch	Eh*	Lp(m)	Lmax	Ln	Ln*Eh	Th	Bs=Th -0.5	Ea%
W-W’’	0.45	0.55	0.45	0.55	0.50	1225	1930	0.634	0.317	0.2	-0.3	42
X-X’’	0.35	0.30	0.35	0.30	0.33	1132	1930	0.586	0.193	0.501	0.001	47
Y-Y’’	0.52	0.34	0.52	0.34	0.43	1311	1930	0.679	0.292	0.53	0.33	58
Z-Z’’	0.6	0.5	0.6	0.5	0.55	1930	1930	1	0.55	٠,٤٨	-0.1	39

Discussion:

The Arabian Gulf, in general, and the coastline in its northwestern part, in particular, have undergone stages of development throughout geological history. At the end of the last Ice Age, a large ocean wave flooded the Arabian Gulf, and the coastline changed in conjunction with this flooding.

During the mid- to late Holocene, a relative drop in sea level led to the deposition of coastal facies along the northwestern Arabian Gulf. Neotectonic activity, resulting from the northeastward movement of the Arabian Plate beneath the Zagros Fold Belt, may have contributed to this sea retreat (Markovic *et al.,* 1996). Estuaries are formed by the interaction between geomorphological structures and dynamic processes, such as tides acting on unconsolidated sediments. Additionally, local influences resulting from climatic variations, relative sea-level changes, and human activities also contribute (Jackson *et al.,* 1995).

Alongside other factors, neotectonic activity can influence the formation of these estuaries by altering sedimentation rates, which in turn lead to the formation of new geomorphological features, in addition to its impact on sea-level fluctuations. Rodriguez *et al.,* (2012) stated that modern tectonic activity continues in river estuaries, as in geologically similar regions worldwide, and has contributed significantly to sedimentary deposition and the geomorphological formation of river basins during the Holocene epoch.

According to the results obtained from the current study, which include several factors such as the discontinuity and interruption of the sub-bed layers, the sudden changes in depth from 5m to 15m (while this case is not expected to occur and has not been recorded in the other channels of the region except in artificial channels such as the Umm Qasr Navigation Channel and rocky bottom such as Khor Al-Khafqa Channel (Al-Mousawi *et al.,* 2015), also, the high values of the morphological index Ln*Eh at the Z-Z section, this high value of TPRs indicates the occurrence of a tectonic influence (Sinha, 2001; Al-Mayahi, 2011). Furthermore, the irregularity of the bottom and the distribution of water current velocity of the Khor, in addition to the sudden change of the khor channel towards the east by more than 90° degrees. Therefore, these indicators constitute reliable evidence of the impact of recent tectonic activity in the studied area. Typically, river channels do not exhibit right-angle bends in areas characterized by soft, unconsolidated sediments, unless they are subject to tectonic influences (Sissakiana *et al.,* 2018). In that context, these indicators have also been confirmed by numerous researchers worldwide, for example, studies (Markovic, *et al.,* 1996; Koster, 2005; Kumanan, 2001) which indicated that some river courses and drainage patterns exhibit abnormal meanders and bends that suggest recent tectonic activity. This change in the drainage pattern of the khor is considered abnormal in such river estuaries and tidal flat areas, which are flat plains with a very slight northward slope.

The current study suggests that the creation of this khor resulted from tectonic activation that produced a transverse fault separating Warba Island from the Iraqi coast, thereby leading to its formation. This fault is linked to the Jal Az-Zor fault that separates Bubiyan Island from the Iraqi coast. The Jal Az-Zor fault was referred to by George (1986). Bird (2002) mentioned that the Arabian Plate was a coherent and potentially stable block since the end of the Precambrian, and throughout most of the Phanerozoicthe, entire Middle East region was an integral part of the African Plate, the separation between the African Plate and the Arabian Plate took place in the Cenozoic and since this time, the Arabian plate has rotated anticlockwise and drifted north currently with a rate of 2-3 cm/year (Figure 8), this view confirms that the region has been affected by recent and ongoing tectonic activity, from the Figure 7 it can be observed that the Khor Shaitanah site has been affected by the Al-Batin or Jal Az-Zor faults.

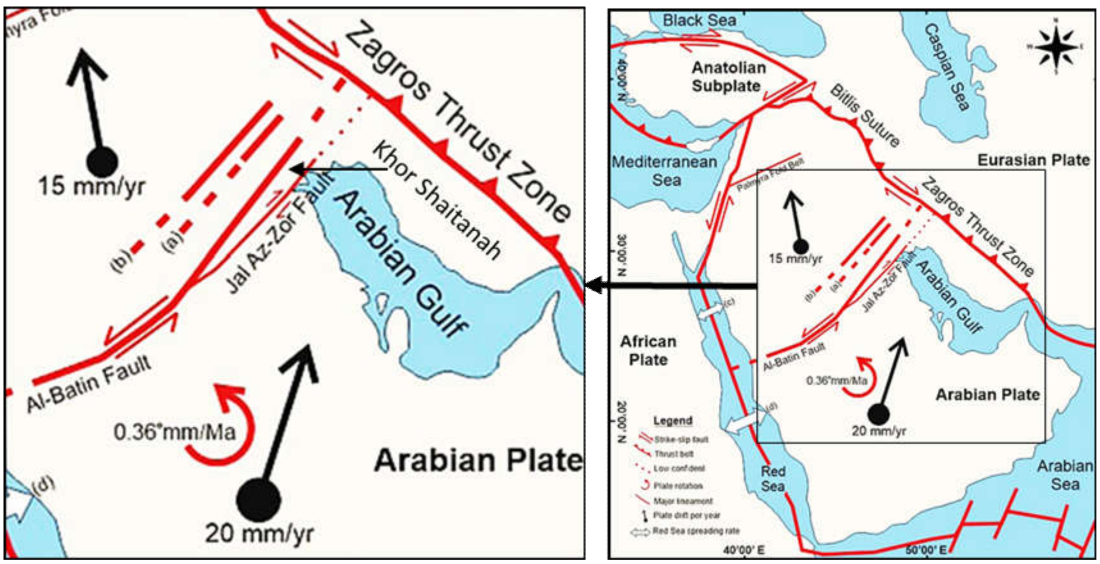

Figure 8. A map illustrating the continued movement of the Arabian Plate at a rate of 20-30 mm per year towards the Zagros Thrust zone, and the impact of the study area and its surroundings on the transverse fault system, such as the Al-Batin and Jal Al-Zour faults (after Amer and Al-Hajeri, 2020).

Many recent geological and/or morphological remarks of this region suggest the influence of neotectonic activation processes affected by the presence of subsurface geological structures (Hansman, 1978; Karim,1989; Karim, 1992; Al-Mussawy, 1993; Al-Kubaisi & Hussein, 2014; Al-Mosawi and Al-Manssory, 2019; Al- Mutori *et al.,* 2021), which latterly influence the changing and interruption of some ancient River courses (Al-Sakini, 1993).

The neotectonic activity has clearly changed the courses of many rivers in the lower Mesopotamian plain, for example: the neotectonic movements led to create the meander of Euphrates River near the Al-Medainah District north of Basrah City (Al-Sakini, 1993; Jassim and Guff, 2006), as well as the Euphrates have been affected by the subsurface structures which have been produced by the neotectonic activity, through the change of River patterns from meandering to straight in some location within the course and beyond of the study area which affected directly by the uplifting of subsurface anticline, especially Seebah, northern Rumila and Zubair anticlines (Al-Sakini, 1986 and 1993). The uplifting movements occurred at the subsurface structures, which are called the Zubair anticline, causing the Euphrates River to shift eastwards and finally join the Tigris River at Qurna (Al-Sakini, 1986). The Shatt Al-Arab River drainage basin has been affected by the neotectonic movements (uplift and subsidence of subsurface structures) (Al-Mayahi, 2011; Al-Kubaisi & Hussein, 2014). The migration of the Tigris River within the Mesopotamian Plain indicates clear Neotectonic activity (Fouad and Sissakian, 2011). Also, many ancient secondary river courses that have since disappeared lie north of the study area, near Khor Al-Zubair, including Al-Ma'aqel and Al-Faidh (Muturi et al., 2021).

The increase in the proportions of sandy sediments recorded at the study site on the left bank (Iraqi coast) and at the bottom, according to studies (Al-Jabri, 2013; Al-Humaidan *et al.,* 2019), is not observed in the rest coast parts and riverbeds of southern Iraqi (which are characterized by clayey sediments, unlike the sandy Kuwaiti coasts), except at the Khor Shaitanah site. Furthermore, the great depths, reaching 15 m at the bottom of the Khor, a situation considered uncommon for coastal Khors, reinforce and support the findings of the current study that the Iraqi and Kuwaiti coasts at the current study site were once a single entity and separated due to the impact of the Jal Az-Zor Fault, thus forming Warbah Island on the Kuwaiti side. Consequently, the course of the Khor shifted sharply northeast and then changed course again to the south and connected with Khor Abdullah, whereas its previous course before the shift was southward, which represents the current course of Khor Subiya, which separates Bubiyan Island from the Kuwaiti part (Figure 9). Although the potential impact of this fault cannot be ignored, the tectonic subsidence noted in previous studies cannot be ignored either, nor can the role of transported and accumulated sediments at the meander site, along with creeping sediments from the Dibdiba Formation.

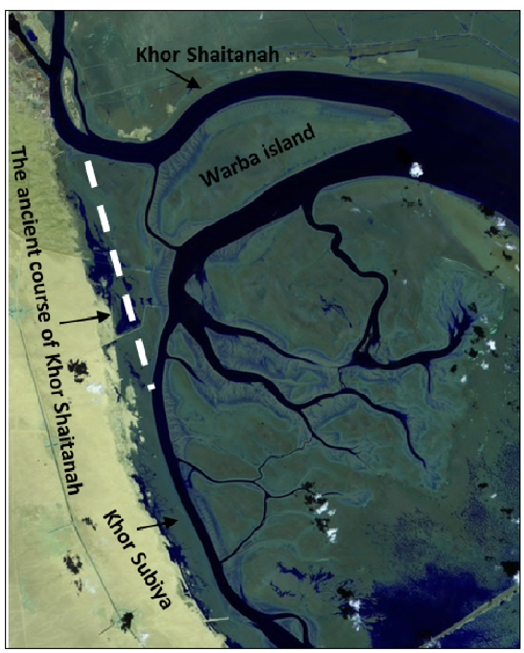

Figure 9. The current course of Khor Shaitanah and its old course towards Khor Subiya.

Conclusions:

In this study, marine geophysical surveys were conducted using SBP and ADCP techniques, along with a river cross-sectional geomorphological index o TRPs, to determine the origin and morphotectonics of Khor Shaitanah in the northwestern Arabian Gulf. By the results obtained from the current study included asymmetry in the seafloor topography of the selected sections, a discontinuity in the sub-bottom layers, a steep slope, and a sudden increase in depth to 15 m, additionally, the Khor's channel meanders at an angle exceeding 90° and flows from west to east, unlike all other Khors in the region, therefore, the study suggests that the creation of the khor resulted from tectonic activity, and there is a link between tectonic effects and relevant fault systems in the region, particularly the Jal Az-Zor fault, in the creation of the Khor. This conclusion is consistent with previous studies that indicated the northwestern Arabian Gulf region was affected by newtectonic activity.

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