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The Delta of Shatt Al-Arab River, Framework and Evolution

iD WalaaM. Al-Mosawi* and Faioq Y. Al-Manssory
Marine Science Centre, University of Basrah, IRAQ
**Corresponding Author: e-mail walaa.almusawi@yahoo.com*

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Abstract - Shatt Al-Arab Delta was built at the northern end of the Arabian Gulf (AG) on the top of a longitudinal shallow marine basin shape. Today the hydrologic regime of Shatt Al-Arab River is suffering from many changes caused by anthropogenic activity impacts, led to a significant decrease in water feeding about 1000 m^3/sec in 1990 into less than 50m^3/sec in 2016. Many previous studies have been discussed as well as performing a marine geophysical surveys to assess the evolution of Shatt Al-Arab Delta during the history. Many phenomenon and progradational parts of the Delta: Prodelta, distributary channel, bay fill, and beach ridge have been identified from marine geophysical survey. The lower reflector is appear as irregular surface, which could indicate the presence of an ancient beach that appear as a terraces region due to fluctuation in the sea level. The second reflector appear as a layer have had variation depth, which may represent a beginning of the ancient delta creation after of the sea level stability (< 5000 years ago). The top layers have been deposited, which represent the present day delta. This present result suggests that there are three phases of delta evolution during history, the first phase represents the beginning of the modern origin of this delta during 1000-2000 yr. ago when the Tigris and Euphrates Rivers are connected together, at that time the delta was not so large and have been formed by the excess sediment that coming from the marshes after the two Rivers dumping most of their sedimentary load there. The second phase represents the activation of this delta with stabilized coastline, especially after the manmade connection between Karun and Shatt Al-Arab Rivers, which occurred before thousand years ago. The third phase represents the last half of the previous century when several factors contributed on the evolution of Shatt Al-Arab delta, including hydrological, climatological and anthropogenic factors.

دلتا شط العرب .. بنيتها وتطورها

ولاء مجيد الموسوي وفائق يونس المنصوري
مركز علوم البحار، جامعة البصرة، البصرة-العراق

المستخلص - تقع دلتا شط العرب في الطرف الشمالي من الخليج العربي في منطقة مصب شط العرب الذي يمثل المجرى النهائي لنهري دجلة والفرات، ممتدة بشكل متطاول نحو الحوض البحري الضحل. يعاني النظام الهيدرولوجي لشط العرب في الوقت الحالي من العديد من التغييرات الناجمة عن آثار السيطرة البشرية على تدفق المياه من اعالي حوض التصريف، والتي ادت لحدوث انخفاض شديد في تصريف المياه من حوالي 1000 م3/ثانية خلال تسعينيات القرن الماضي إلى أقل من 50 م3/ثانية في عام 2016. ونتيجة لنقصان التصريف وقطع مصادر التغذية بالمياه لشط العرب من انهار الكرخة (عبر السويب) والكارون فقد انخفض الحمل الرسوبي للنهر وتغيرت طبيعة ونمط توزيع الرواسب في القناة النهرية ومنطقة المصب، وبالتالي اثرت على نشوء الدلتا وتطورها. تتضمن الدراسة الحالية مناقشة العديد من الدراسات التي تناولت منشأ الدلتا عبر التاريخ مدعمة استنتاجاتها بنتائج التحريات الجيوفيزيائية البحرية الحديثة في المنطقة. تم تحديد العديد من العواكس Reflectors لطبقات تحت القاع والعديد من أجزاء الدلتا القديمة والقنوات (الفروع النهرية) القديمة المدفونة تحت القاع. يظهر العاكس السفلي (أو طبقة الرواسب العميقة) بشكل سطح غير منتظم يمكن أن يشير لوجود الساحل القديم للخليج وتظهر هذه الرواسب كمنطقة مصاطب بحرية نتيجة التقلبات في مستوى سطح البحر. ويمثل العاكس الثاني بداية نشوء الدلتا القديمة بعد استقرار مستوى سطح البحر قبل حوالي 5000 سنة من الوقت الحالي، بينما تمثل الطبقات العليا منطقة الدلتا في الوقت الحاضر .تؤكد الدراسة الحالية إلى أن هناك

ثلاث مراحل لتطور دلتا شط العرب عبر التاريخ، تمثل المرحلة الأولى بداية المنشأ الحديث لهذه الدلتا قبل 1000-2000 سنة من الوقت الحالي عندما كان نهري دجلة والفرات يلتقيان معاً، ولم تكن الدلتا في ذلك الوقت كبيرة جداً وكانت قد تشكلت من الرواسب الفائضة القادمة من مناطق الأهوار التي كانت تستقبل معظم رواسب النهرين. بينما تمثل المرحلة الثانية مراحل تنشيط هذه الدلتا بعد استقرار الخط الساحلي، خصوصا إثر ربط نهري الكارون وشط العرب معا قبل حوالي 800 سنة مضت. أما المرحلة الثالثة فتمتد زمنيا خلال النصف الأخير من القرن الماضي عندما ساهمت عوامل عديدة في تطور دلتا شط العرب، متمثلة بالعوامل الهيدرولوجية والمناخية فضلا عن التدخلات البشرية . تتوقع الدراسة نقصان حجم الدلتا وربما تلاشيها في المستقبل القريب اذا استمرت الظروف الهيدرولوجية الحالية لشط العرب على ما هي عليه في الوقت الحاضر.
الكلمات المفتاحية: دلتا، نهر شط العرب ،الخليج العربي ،الاستقصاء الجيوفيزيائي ،مستوى سطح البحر.

Introduction

A delta can be defined as a 'discrete shoreline protuberance formed at a point where a River enters the sea or other body of water' (Elliott, 1986) and as such it is formed where sediment brought down by the River builds out as a body into the lake or sea. On the other hand, an estuary is a River mouth where there is a mixture of fresh and seawater with accumulation of sediment within the confines of the estuary, but without any build-out into the sea (Nichols, 2009).

Delta is one of the most complex sedimentary environments of others, this may be due to physical and geological natural variables related to the occurrence of the delta, as well as its geographical situation (Nichols, 1999). Delta is characterized by high deposition rate, which makes the delta shape variable consistently. The delta is a product of natural balance forces interact with each other near the River mouth, such as sediment transport and deposition nearby the downstream area, while tidal
currents and waves redistribute these deposits which lead to change the shape and type of Delta (Albadran, 2004). Shatt Al-Arab Delta was built at the northern end of the Arabian Gulf (AG), on the top of a longitudinal shallow marine basin shape (Al-Mulla, 2005). With several geomorphological units including, some coastal and bottom lagoons with wide tidal flats, divided into upper tidal flat, sub tidal flat and lower tidal flat units.

Despite the previous studies such as Larson (1975); Hansman (1978); Evans (1979); Albadran (1995 and 2004) and Al-Hawi (2014) that focused on the evolution of the AG head, including the Delta region, yet there is no detailed survey about this region in particular, especially from the geological and geophysical marine survey viewpoint, as well as studying the stratigraphic setting (which can be done by drilling a testing bore holes in the sea bottom), most of these surveys are very difficult to accomplished due to the Delta region location as a combined borders between Iraq and Iran, so the current study considers as a unique by relying primarily on a geophysical surveys performed by the Marine Science Centre-Basrah (MSC-Basrah) as well as the accumulated experience and opinions about this area in order to shed some light and clearing many thoughts about Delta existence and development during the past and present history, in order to isolate the most important variables that might occur or under influence.

The Study Area:

Shatt Al-Arab Delta is located at the top of the AG head in the southeastern part of Iraq, it represents the northern part of the AG. Bounded Easterly by Khor Musa and Westerly by Khor Abdullah, while Shatt Al-Arab River stretches northwards, the gulf extends to the South of the Delta (Fig. 1).

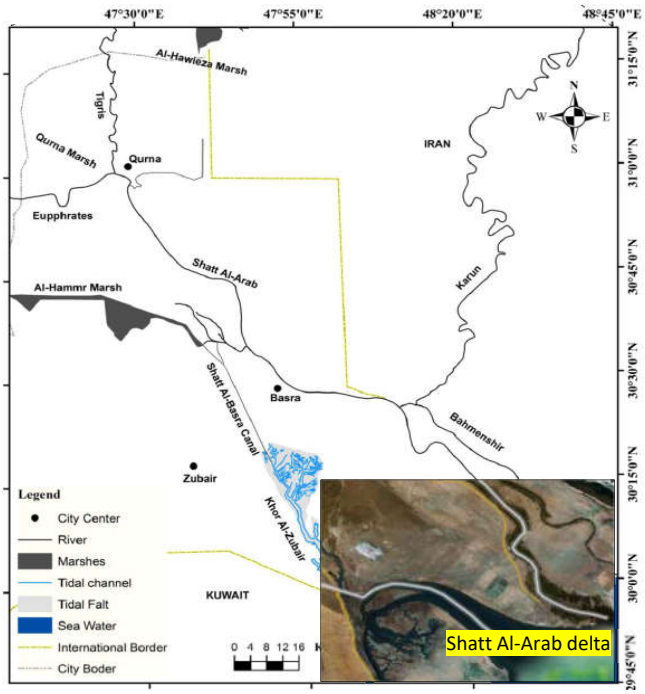

Figure 1. Location map of the study area.

The Tectonic Setting:

The study area is a part of the shallow basin of Mesopotamian zone, that is a part of foreland of the Arabian plate (Numan, 1997). Where the AG is a natural extension of the Mesopotamian basin, so we cannot study the tectonic setting of the study area apart from tectonic history of the Gulf region in special and the Middle East region in general (Al-Mussawy, 1993). The study area is located in the northwest of the Gulf, which is a part of the remnants of the Tethys sea, that is representing an old oceanic basin (Buday and Jassim, 1987). Tethys sea was closed at the Late Eocene as a result of the collision of the Arabian and Iranian plates (Jassim and Goff, 2006). The western and southern rifts have been separated the Arabian Peninsula from the Afro-Arabian mega-landmass collectively in conjunction with the eastern and northwestern mega-transform/trans-current faulting systems drifting towards northeast (Younes and McClay, 1998; Bosworth *et al.,* 2005), these actions caused an enormous compression forces all along the Zagros Thrust-Fold-Belt (ZTFB), as also evident from the NW-trending movement of the Arabian plate with an average velocity of about 5 cm/year (Nehlig *et al*., 2002).

The Tigris/Euphrates Basin, as well as its extension, the AG, occupies a zone of subsidence flanked by mountains and desert. This elongated depression was formed during an era of mountain building initiated early in the Tertiary which continues with the movement of the Arabian plate against the stable landmass of Asia.

Shatt Al-Arab and the surrounding area is located in Zubair subzone, formed the southernmost of Mesopotamian zone which is almost identical with Shatt Al-Arab River, which is covered by Quaternary deposits of marsh/lacustrine sediments and fluvial/Aeolian deposits from the Tigris and Euphrates Rivers (Fox and Ahlbrandt, 2002).

The Mesopotamian zone is characterized by the existence of many gently plunging subsurface structures of different sizes, these structures are surface and subsurface faults and salt structures (Karim, 1989), and the movement of the Mesopotamian zone is caused by deep faults from the

basement to surface, and the activity of alpine movement which is still effective to the present days, and existence of thick salt beds which is represented by Hormuz and Gotnia Formations (Al-Sakini, 1995).

The Historical Setting:

We cannot study the Delta and its development without addressing the evolution of the AG head during the geological history. The Holocene evolution in the region represents a controversy on the position of the delta of Mesopotamian plain and till now no decisive opinion is existed. Since the early of 19th century, historians and geomorphologists have debated the Holocene evolution of the Lower Mesopotamian plain, based on archaeological data, historical sources and surface observations. These early investigators were interested in the changes of the position of the AG shoreline and the paleo courses of Tigris, Euphrates and Karun River systems as a result of the post-glacial sea-level rise. The earliest theories suggested that the head of the Gulf shifted far north of its present position, followed by a gradual retreat of the Gulf caused by delta progradation during prehistoric and historic ages.

One of the leading studies in this field is that of De Morgan (1900) which reflect the 19th century concepts, when he considered that the Gulf was back down south-easterly towards the sea and construct the Delta of sediments which is carried by Tigris, Euphrates, and Karun Rivers.

Lees and Falcon (1952) challenged De Morgan concept, and claimed that there was no evidence for the occurrence of an extensive marine flooding followed by delta progradation since the early Holocene. They suggested a delicately balanced system between subsidence (neotectonic effects) and sedimentation processes instead of local marine inundations. Nevertheless, they reported to sediments containing marine and estuarine shells founded in the subsoil of the Mesopotamian plain as far inland as Missan city.

Hudson *et al.* (1957) agreed with the opinions of Lees and Falcon (1952), contradicting their own identification of a landward extending Holocene marine unit (Hammar Formation) underlying the fluvial deposits of the Shatt Al-Arab region. Hansman, (1978), Karim (1989) and Al-Mussawy (1993) agreed with Lees and Falcon that the Shatt Al-Arab region has been influenced by recent tectonic movements led to the formation of several subsurface geological structures. Lees and Falcon cited the validity of their opinion by the archeologists views in this case, the archaeological expert Sir Woolley (1929) discovered some layers of flooding mud or flood between layers of post eras of history while his archaeological excavating on the Ur city remnants between 1926 and 1929. Buringh (1960) agreed with Lees and Falcon opinion, when he claimed that the current gulf coast is at the same as before 5000 years ago, and Ur city did not located on the bank of Euphrates River which had penetrated this area on its way southerly to the Gulf coast where it ends East of the current Al-Zubair city.

Raul Miguel (cited by Al-Katib, 1971) believes that the area around Baghdad also have been subside, with event of the convergence between Euphrates and Tigris Rivers in this area which draw the courses of these Rivers toward it, as well as Al-Udhiam and Diyala Rivers flow toward it. Georges Roux (also cited by Al-Katib, 1971) conducted some of his investigations in the Hammar marshland, he found traces of an ancient civilization in the area that stretched between Tell Al-Lahem south Ur and Basrah. These effects have shown that some dating back to the Babylonian era and others from the second half of the first millennium BC and others to Kashanian era (1530-1160 BC) or before, therefore, he agreed with the opinion of Lees and Falcon that this area was not flooded with sea water at those times. The tectonic scenario as claimed by Lees and Falcon (1952) has been strongly censured in the 1970s (Purser, 1973; Larsen, 1975; Evans, 1979). These authors suggested that the Shatt Al-Arab region has been more influenced by eustatic sea-

level changes and deltaic progradation rather than by tectonic events. Macfadyen and Vita-Finzi (1978) claimed that the basis of faunal evidence and the presence of sands and silts below the alluvium surface of the Mesopotamian Plains near Basrah (Hammar Formation) indicted a marine embayment extended inland as far as Missan city, followed by an overall delta progradation over a distance of about 150 to 180 km during the historical period.

Later research carried out in the area also supported the view that Holocene sea-level changes controlled the evolution of the Shatt Al-Arab region, rather than tectonics (Ya'acoub *et al.,* 1981; Purser *et al.,* 1982; Al-Azzawi, 1986; Aqrawi, 1993; Lambeck, 1996; Sanlaville and Dalongeville, 2005). Pournelle (2003) speculated that the cluster of early sites around Ur and Tell Al-Lahm (near Nasiriyah city, about 200 km. from AG shoreline) during Isin-Larsa historical period (2000-1763 BC.) demarcate a tidal inlet where salt marsh vegetation was harvested, shellfish were gathered, or fishing expeditions launched into the Gulf area, indicating that salt sea water percolated northwards through many tidal channel branches.

The Historical studies indicate that the Karun River was separated from Shatt Al-Arab, despite the possibility of small streams which connect them or their branches and each River have his own estuary into the AG. About 364 H (989 AD) the Buwaihi's ruler Adhud Al-Dawla created a canal joining Karun and Shatt Al-Arab Rivers (Al-Katib, 1971).

Studies which have been conducted during the last century showed that the Tigris and Euphrates Rivers did not transport more than 6 million m^3/y of mud and silt into the Gulf at the mouth of Shatt Al-Arab River, while the Karun River transports about 29 million m^3/y (Abdullah, 1990), about 82% of the clay deposited at the mouth of Shatt Al-Arab in the AG is transported by Karun River. So the quantities of mud that have been transported by Shatt Al-Arab has increased suddenly after the opening of the waterway connecting these two rivers, more than it was before the fourth Hijri century. It appears that the head of the AG was stable before this connection, indicating that the deposition of silt and clay in the mouth of Shatt Al-Arab River is compensated by the subsidence in the AG head, but this equilibrium had been disturbed after this connection. It must be noted here that the growth of the Delta was also accompanied with the subsidence of the floor of the Gulf, due to that the land began to grow and the AG subsidence subsided for about thousand years.

Marine Geophysical Field Survey:

In the present study, a marine geophysical survey has been applied with Sub Bottom Profiler (SBP) technique, which is an acoustic investigation technique graphing the marine sub-bottom. 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 the objects in or on the top of sea bed, and by carrying out a sequence of measurements along a measuring track line, we can obtain a detailed information concerning the shape and composition of the sub-bottom sediment.

One longitudinal survey line with 10 km length was performed in the open sea water from the north west to the south east direction parallel to the outflow of Shatt Al-Arab into the AG from its mouth towards the open sea (Fig. 2). The SBP survey was conducted by using the Strata Box™ marine geophysical Instrument, with a resolution of about 6 cm with 40 m of bottom penetration while the maximum depth ranges are 150 m with a frequency output of 10 kHz. Many reflectors (phenomena) have been identified from the SBP (Fig. 3), as well as progradational parts of the Delta: Prodelta, distributary channel, bay fill, and beach ridge. The lower reflector (red line) at a depth of 5-10 m under the bottom is appeared as an irregular surface, which could indicate the presence of an ancient beach that appear as a terraces region, when the sea level of the Gulf was

lower than that at the present indicating the existence of these submarine platforms and submerged River valleys at various levels (Kassler, 1973). There is no feature lower than or above of these layers that may indicate the existence of sandy sediments that could cause a signal scattering of SBP. Due to the fact that Shatt Al-Arab River carrying a coarse grained sediments load to the Gulf during the sea-regression period, the presence of these terraces surfaces at this depth could be attributed to the subsidence evidence due to Neotectonic activity as well as to a high rate of sedimentation, which is about 5 cm/yr. in the Shatt Al-Arab delta (Karim and Salman, 1987). The presence of this layer may occurred during the progression and regression of the sea level (> 5000 years), and at that period, the Delta was not existing yet.

The second reflector appeared as a layer with a variable depth, at the beginning point of the section, it appeared at a depth of 1.5 m under the bottom, and it was at a depth of 5 m under the bottom at 700 m distance from the beginning point, as well as, there is a sub shoal (1 m) at 370 m distance which may represent the beginning of an ancient delta creation after of the sea level stability (< 5000 years ago).

Under this surface, the sediments consist of sandy sediments that though to reflect a more agitated episode during the drifting of these sediments from the Shatt Al-Arab mouth to the sea, or may be that these sediments had been reworked from nearby sediments mixing with the mud of the Shatt Al-Arab sediments discharge. This surface represents an erosional surface that separated the top layer from the lower ones.

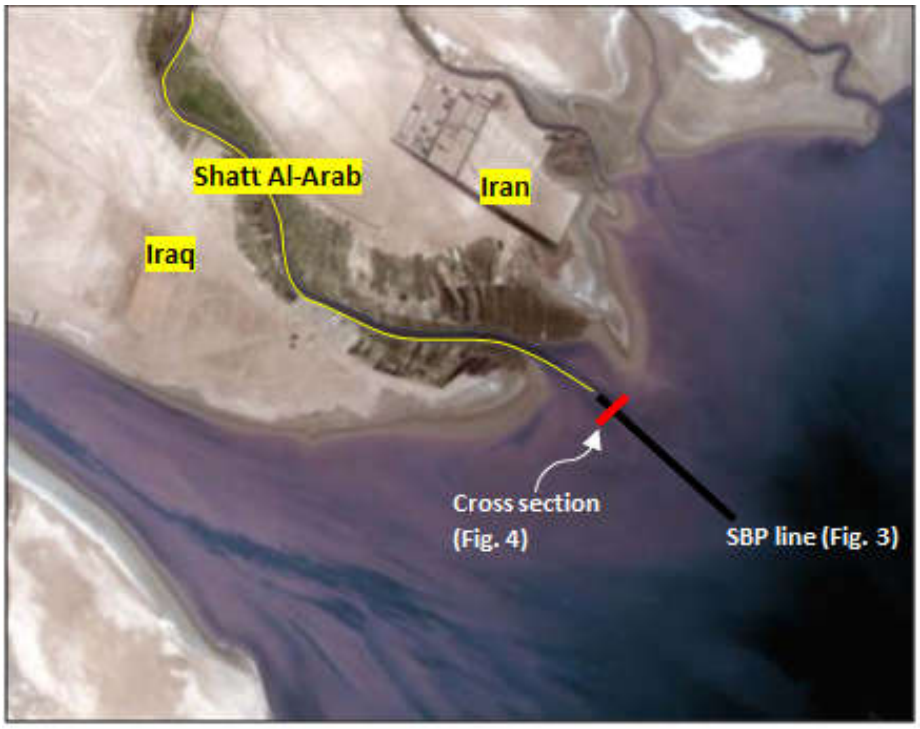

Figure 2. The locations of SBP line and Cross section.

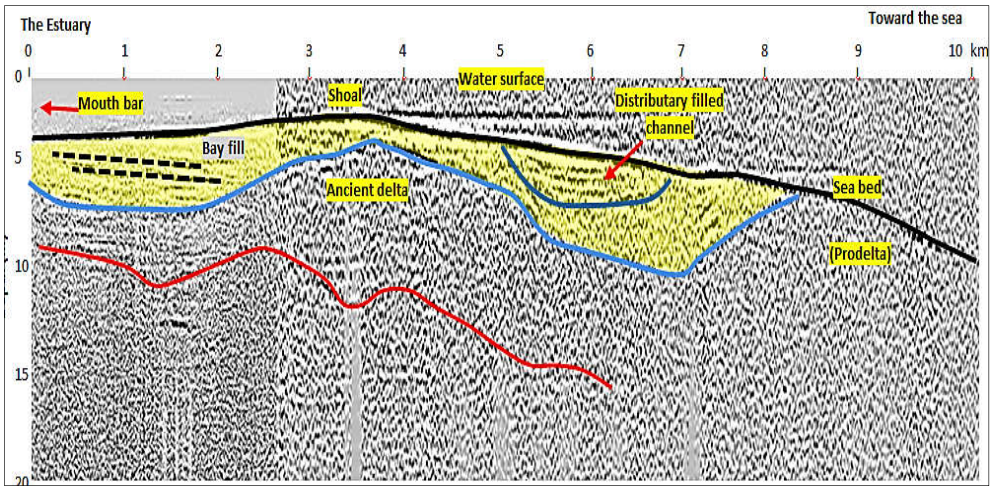

Figure 3. The SBP section.

The sea level reached its present level some 5000 years ago (Vita-Finzi, 1982), then, the top layers have been deposited (yellow area), which represent the present day delta. The Delta plain contains a homogeneous dark grey clay with organic debris and shell fragments (Albadran, 1995) with horizontally laminated clay. Bay fill contains fine-grained laminated mud and silt. The SBP section showed a distributary filled channel, these types of channels are formed due to longitudinal barriers parallel to the axis of the main channel, and these barriers were created due to the sediment discharge of Shatt Al-Arab River (Albadran, 2004). The prodelta lack any reflectors, this may be due to the presence of sand sediments towards Khor Al-Umia, the sandy sediments are probably subjected to continuous reworking, i.e., by fluvial currents of the Delta and waves (Albadran, 1995).

The reason of disappearance of the reflection of the sub-bottom layers after 5 m depth may be due to the suppressing of these waves from penetrating into greater depths because of the existence of the clayey sediments that composites the most part of the bottom deposits in this area, which leads to absorption and dispersion of sound waves. Therefore, it is necessary to perform a vibracores investigations integrated with the SBP results to get a more detailed descriptions of the studied area in order to map the sedimentary facies and linking that with the transgression and progression of the costal line.

Shatt Al-Arab cross section shape (Fig. 4) with a depths ranging from 2-5m, indicted that the River bottom shape is less sharp and inclined on the Iranian side compared with the Iraqi side, indicating that this side represents a fill area, on the contrary with the Iraqi side with a sharper and inclined perimeter which indicates a score process.

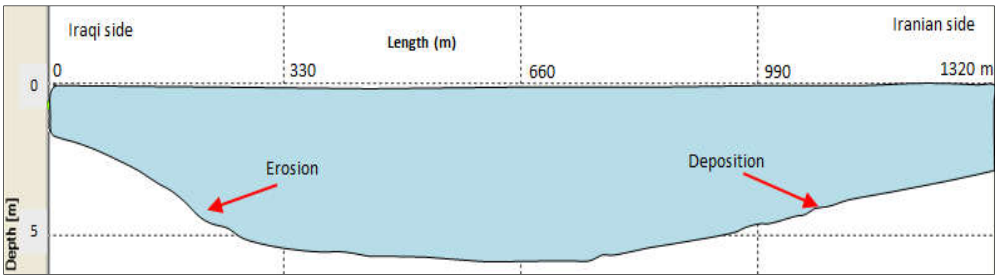

Figure 4. A Cross section of Shatt Al-Arab River in the estuary part.

Neotectonic Activity:

Because of the head of the AG and the surrounding area were subjected into a recent tectonic activity through the evidence of the occurrence of subsidence and uplifting processes distributed in and around the study area.

The clearest evidence of this neotectonic activity is that Al-Hammar marsh which was formed no less than 1300 years ago remained unchanged, despite the large amounts of sediments transported by the rivers during hundreds of years. It seems that the subsidence phenomenon is not prevalent in the marsh areas only, but in the tidal embayment areas (lagoons) in all of Al-Zubair, Musa and Bubiyan Khors, this conclusion is more acceptable due to the presence of sediments fan in these lagoons as well as confirmed by the shape of the drainage system of Bubiyan Island which is headed northwards.

Al-Mussawy (1993) pointed out that the Arabian Gulf head area during the period from the end of the Pliocene-beginning of Pleistocene until the present time have been passed by many changes in shape and sedimentary structures until it acquired its recent form. Also, he stated that Khor Al-Zubair has resulted from a fault, extended to the end of Khor Al-Subbiya. This fault has accompanied with a tectonic subsidence occurred during the Wurm glaciation period, forming the Riverbed of the ancient Euphrates River. This opinion has been confirmed by recording of a new frequent seismic activity occurred in the northwest AG, induced by tectonic activity not only on land but even in the Iraqi territorial marine and the Shatt Al-Arab River. Al-Mosawi (2015) discovered a salt daipirc caused by an uplifting of vertical tectonic stresses of the deep structures, about 40 km south of the entrance to the Khor Abdullah. It seems that it is a delicately balanced system between subsidence and uplifting processes in the region. The subsidence is still active and this is the simplified explanation of the formation of the Southern Mesopotamian Marshes.

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, which latterly influencing upon changing and interruption of some ancient River courses (Al-Sakini, 1993).

The neotectonic movements also led to create the meander of Euphrates River near the Al-Medainah town north of Basrah (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-Hawi, 2014). The uplifting movements occurred at the subsurface structures which is called the Zubair anticline, caused to shift the Euphrates River eastwards and joining finally with Tigris River at Qurna (Al-Sakini, 1986).

Also, the Shatt Al-Arab River drainage basin have been affected by the neotectonic movements (uplifted and subsided of subsurface structures) (Al-Kubaisi and Hussein, 2014).

Through a review of many studies concern with the evolution of the delta and the AG head during time, we can deduce that the researcher opinions were divided into two categories, the first goes with the changing of the AG head position during the geological history, this category depends on the sedimentary and faunal evidences, and they thinks that the head of the Gulf was located in Nasiriyah City, before 5000 years ago then the coastline receded to its current location because of delta progressing which was formed by the sediments carried by Euphrates, Tigris and Karun Rivers. The second category goes to adopt that the head of the Gulf during the geological history is in it's current location during the last 5000 years.

This category depends on the tectonic evidence and the influence of the neotectonic activity in the area which left their marks on the subsurface structures, accordingly this area is in equilibrium condition between the Rivers deposition and the tectonic subsidence.

Struggle of Opinions:

Despite criticism and rejection made by each team to each other's, but we find that both teams have evidence to support their opinion, so we can gather some of these opinions to make a closer opinion to reality. According to the first team opinion, we can confirm the validity of their conclusions about the existence of marine faunal evidences dating to 5000 years ago to emphasize the extending of coastline to the marshlands by the possibility of coastline progredation to this site due to the fact of low differences in land level between the current coastline and marshland location which does not exceed 3m (Fig. 5).

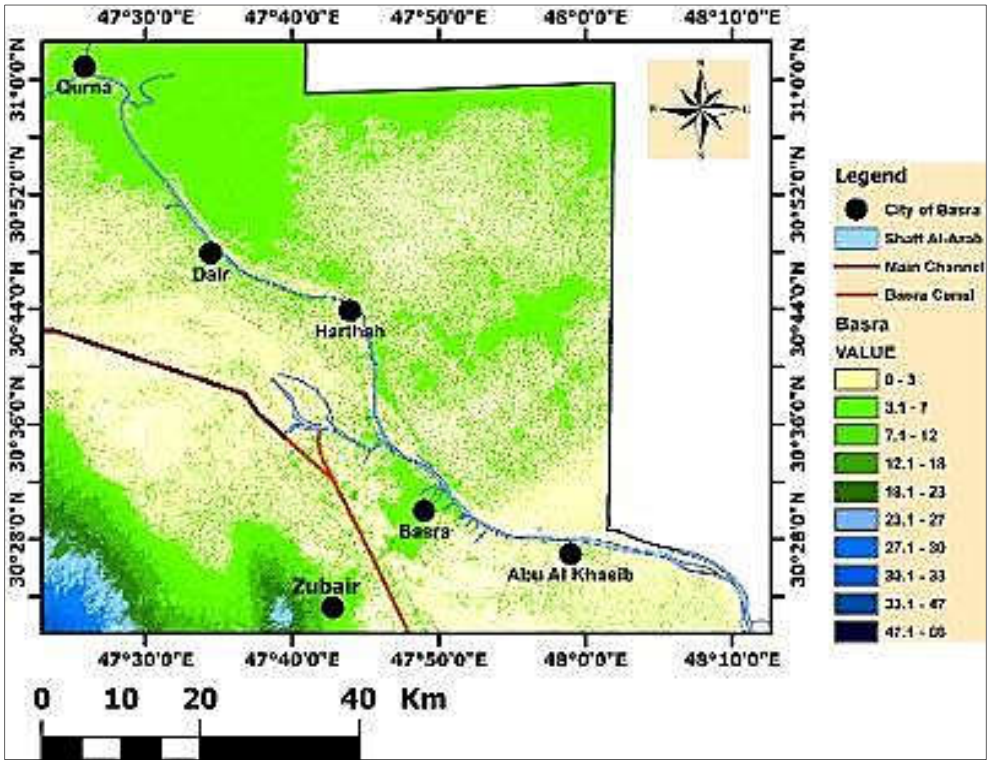

Figure 5. The ground level Elevation (m) of the Mesopotamian Delta plain.

So, any fluctuation in sea level during the Holocene, if less than 3m, will lead to progress or retreat the sea coastline for over hundreds of kilometers.

Vanessa and Cecile (2007) investigated the Holocene sequence of the Lower Khuzestan plain in southwest Iran in the context of coastal evolution and relative sea-level changes, by studying a vertical and spatial distribution of sedimentary facies during the ancient time by using radiocarbon dating to draw the chronological timeline.

They extinguished five different zones in the flood plain depending on the environmental interpretation with respect to the relationship of tide levels in the area, they suggested that a Holocene high stand sea level rising above the present-day sea level did not occurred and this is in

agreement with the previous studies. Apparently this result cann't be applied to the southern part of Iraq because of the difference in the ground level between Khuzestan plain which exceed 22 meters, while it did not exceed 4 meters in the Mesopotamian Delta plain and the marshland (Fig. 5).

Modern Time Delta existence:

According to the first category, the imputation of the receding of the shoreline from the marshland into the current location only as a result of transported sediment by Tigris and Euphrates Rivers. The delta progression is unreliable without the intervention of other factors, as the Tigris and Euphrates Rivers were flowing separately by different paths from their current courses until they meet at AG during 2000 years ago.

The Tigris River was flowing in the current path of the Shatt Al-Arab River in isolation from the Euphrates River which was flowing westward towards the Zubair town near the current path of the Shatt Al-Basrah to conject with Khor Al-Zubair (Hansman, 1978; Al-Sakini, 1986; Mussawy, 1993). However, after the two Rivers meet in the upper marshland (at the triangle of Basrah-Amarah-Nasiriyah Cities) before forming the Shatt Al-Arab River since 1600 years ago to lay their sediments and composing a type of inland Delta in the marshland area they couldn't fill up that marshland area, so, how could they fill up the Shatt Al-Arab estuary to form a delta of such a size?

The Karun River is considered as the most influential factor in forming the delta of Shatt Al-Arab (noted that Karun and Shatt Al-Arab Rivers connected only before about one thousand years ago). The presence of the delta is associated closely with the effect of Karun River, and rather to manmade changes in the area of Karun and Shatt Al-Arab Rivers confluence (Abdullah, 1990), so the role of the Tigris and Euphrates Rivers in creating the delta is considered as a secondary factor due to fact that they lay most of their sediments in the marsh area. One of the evidence of this is that the most of the Shatt Al-Arab islands were located near and after the confluence of the Karun and Shatt Al-Arab Rivers.

Karim and Salman (1987) pointed that most of the sediments transported by Tigris and Euphrates Rivers have been deposited in the top of the delta front, Wilson (1925) mentioned that about 90% of the silt of these Rivers after Baghdad City does not reach the AG, but deposited their loads in the marshland Delta. Albadran (1995) showed that the sediment source of Shatt Al-Arab delta is from Karun River, as well as a part of continuing erosion of the River's banks and the bed of Shatt Al-Arab River, and most of the accumulated delta sediments at the West of Rass Al-Bisha is due to the ebb and flood currents of the Shatt Al-Arab River. Karun River is discharging about 30,000,000 tons/yr of sediments after its confluence with Shatt Al-Arab River, about 9,500,000 tons as suspended load and 85,000 tons as bed load annually were deposited in the River's course segment before the River meet with the AG. And discharging about 20,000,000 tons/yr into the gulf, although this amount of sediments reaching the delta is very low compared with other deltas, but it has been accumulated over the years to make a significant landmark (Al-Manssory, 1996).

The progressing and receding of the sea have been controlled by any factor that have the greater impact (sedimentation or subsidence factors) if the sediment amounts increased against subsidence, the sea is receding, but if the subsidence increased, the sea is progressing to the land, so, the Tigris, Euphrates and Karun Rivers didn't form a sort of delta that moving towards the sea because most of these Rivers deposits or unloaded their transported sediment in the lowlands of the alluvial plain which occupies the zone that has subsided and continues to subside, not because of the sediment gravity only, but because of subsiding and tectonic uplifting activity even in the head of the AG particularly the lagoon areas Northwest the Arabian Gulf (Karim, 1992).

Delta Phases Evolution:

Apparently, there are many phases of delta evolution during history. The present results suggest that the first phase represents the beginning of the modern origin of the present delta during 1000-2000 years. ago when the Tigris and Euphrates Rivers are connected together and formed Shatt Al-Arab River during 2000-1600 years before present at that time the delta was not so large and have been formed by the excess sediments that coming from the marshes after the two Rivers dumping most of their sediments load there. The second phase represents the activation of this delta with stabilize the coastline, especially after the manmade connection between Karun and Shatt Al-Arab Rivers, which occurred before thousand years ago, confirming that the presence of Shatt Al-Arab delta is associated with the presence of Karun River.

The third phase represents the last half of the previous century when several factors contributed on the evolution of the Shatt Al-Arab delta, including hydrological, climatological, and anthropogenic factors. The anthropogenic factor is considered as the most important one among these factors, without under estimating the natural factors, these interferences that led to change the hydrological system in the upper reach of Shatt Al-Arab drainage basin by constructing about 70 hydraulic structures which led to a substantial decrease in water discharge and sediment supply into Shatt Al-Arab, thus had a negative impact on the development of the delta. At this phase the River's energy cannot transport a large amounts of sediments, therefore it could not be able to reach the downstream.

Nowadays, after continuing anthropogenic changes that altered the hydrological system of the Shatt Al-Arab by continuously decreasing in water discharge, from 1300 m^3/s in the 1970's to about 250 m^3/s at the beginning of this century until the present days which does not exceed 50 m^3/s. However, this very low discharge was becoming lower because of the blocking off the Euphrates water from flowing into Shatt Al-Arab by constructing a submerged barrage upstream Al-Medainah town, so, the Tigris River is now consider as the main contributor to the Shatt Al-Arab with an amount of not exceeding 30 m^3/s of water discharge, with neglecting Sweeb River contribution into Shatt Al-Arab after blocking Huwazah River from reaching Huwazah marshes due to a major dam built at the Iranian territory. This amount of water discharge is very low compared with what was the River discharging during the old days.

Most importantly nowadays, the diversion of Karun River course that had contributed more than 70% of the total water and sediment discharge of Shatt Al-Arab by constructing a hydraulic structures to alter its water into Bahmanshir Canal in the Iranian land, this will have a great influence on decreasing the size and degradation of Shatt Al-Arab delta, and may declined in a very short time. Moreover, the decreasing of water discharge that supply the Shatt Al-Arab with water will lead to move the location of the Shatt Al-Arab estuary northwards into the Seebah town (60 km south of Basrah City), and thus will prevail the influence of tidal currents on the Delta growth process.

We can conclude that the emergence and development of the Delta through history involved several factors including modern tectonic activities (raising and falling), sedimentation processes, climatic changes, sea level fluctuations, effect of tidal currents, and anthropogenic induction on the River's course changing or interrupting or diverting, the riverbeds subsidence or uplifting and the decrease of the River's flowing into the AG through Shatt Al-Arab River.

From the cross section in the downstream area which shows that the edge of the Shatt Al-Arab River in the Iranian side representing a depositional area, while the River's edge in the Iraqi side exposed to erosion processes. Most of the sediments which were transported and discharged by Karun River after its diversion will accumulate at the confluence of Bahamnshir River with the AG at Khor Musa, and these deposits will move Westward due to the effect of tidal currents and

Coriolis force towards Shatt Al-Arab entrance into the AG and this lead to loss more of Iraqi territorial land and degradation of marine coastline. If the situation continues this will lead to loss more of Iraqi territorial land and degradation of marine coastline.

Conclusions

1. The decreasing of water discharge of Shatt Al-Arab will lead to move the location of Shatt Al-Arab estuary northward into Seebah town (60 km south of Basrah city), and thus will prevail the influence of the tidal currents on the Delta growth process.
2. Many phenomena and progradational parts of the Delta: prodelta, distributary channel, bay fill, and beach ridge have been identified from marine geophysical survey. The lower reflector is appear as irregular surface, which indicates the presence of an ancient beach that appear as a terraces region due to fluctuation in the sea level. The second reflector appear as a layer with variable depth, which may represent a beginning of the ancient delta creation after of the sea level stability (< 5000 years) ago had occurred. The Delta plain contains a homogeneous dark grey clay with organic debris, and a horizontally laminated clay. Bay fill contains fine-grained laminated mud and silt. The SBP section showed a distributary filled channel. The prodelta lack any reflectors, this may be due to the presence of sands sediments towards Khor Al-Umia.
3. There are three phases of delta evolution the during history of the region; the first phase represents the beginning of the modern origin of the delta during 1000-2000 yrs. ago when the Tigris and Euphrates Rivers are connected together, the second phase represents the activation of this delta by stabilizing the coastline especially after the manmade connection between Karun and Shatt Al-Arab Rivers before 1000 yrs. ago, and the third phase represents the last half of the previous century when several factors contributed on the evolution of Shatt Al-Arab delta, especially the anthropogenic factor.
4. The diversion of Karun River course by constructing a hydraulic structures and water diversions to Bahmanshir River in the Iranian land had a great influence on decreasing the size and degradation of Shatt Al-Arab delta, and may leads to a deterioration in the region soon.

5. Most of the sediments that were transported and discharged by Karun River will accumulate at the confluence of Bahamnshir River with the AG at Khor Musa, and these deposits will move westward towards Shatt Al-Arab entrance into AG due to effect of the tidal currents and Coriolis force and this lead to loss more of Iraqi territorial land and degradation of marine coastline.

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References

Al-Azzawi, M., 1986. La sédimentation actuelle sur la plaine de la basse Mésopotamie, Iraq. Unpublished PhD Thesis, University of Paris, Orsay.

Albadran, B. 1995. Lightfaces of Recent Sediments of Khor Abdullah and Shatt Al-Arab Delta, N.W. Arabian Gulf. Iraq Jour. Sic., 36(4): 113-117. https://scholar.google.com/scholar?cluster=7022804747277295867&hl=ar&as_sdt=2005&sciodt=0,5.

Albadran, B. 2004. Shatt Al-Arab Delta, Southern Iraq, sedimentlogical study. Marine Mesopotamia, 19(2): 311-322. https://scholar.google.com/scholar?cluster=14992843803916241920&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Hawi, N.A. 2014. Geoarchaeological and Morphotectonic study of Al-Hammar marsh area and surrounding. Unpubl. M.Sc. Thesis, Univ. of Basrah, 135 p. https://scholar.google.com/scholar?cluster=4970495781068958268&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Hamad S.S., Albadran, B.N. and Pournelle, J.R. 2017. Geological History of Shatt Al-Arab River, South of Iraq. International J. of Science and Research (IJSR), 6(1): 2029-2039. https://doi.org/10.21275/ART20164492.

Al-Katib, M.T. 1971. Shatt Al-Arab and Shatt Al-Basrah and the history. Iraqi ports company printing House-Basrah, 190 p. (in Arabic).

Al-Kubaisi, M. and Hussein, M. 2014. Morphotectonic of Shatt Al-Arab River Southern Iraq. Iraqi Journal of Science, 55(3A): 1051-1060. https://www.iasj.net/iasj/pdf/5fcd6913dd76f237.

Al-Manssory, F.Y. 1996. Sediment transport in the lower reach of Shatt Al-Arab. Unpubl. M.Sc. Thesis, University of Basrah (In Arabic).

Al-Mosawi, W., Al-Rawi, F. and Almayahi, A. 2015. Submerged Shoal Imaging by Sub-Bottom Profiler Technique Southern Iraq/Northwest of the Arabian Gulf. Iraqi Journal of Science, 56(4C): 3463-3473. http://un.uobasrah.edu.iq/papers/1767.pdf.

Al-Mulla, S.T. 2005. Geomorphology of Shatt Al-Arab valley by remote sensing techniques. Unpublished Ph.D. Thesis, College of Art, University of Basrah, 200 p. (in Arabic). https://scholar.google.com/scholar?cluster=17176679775811247847&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Mussawy, S.N. 1993. Evolution of Khor Al-Zubair and the surrounding areas throughout the recent geologic history. Journal Geologic Society of Iraq, 26(3): 1-17 (in Arabic). https://scholar.google.com/scholar?cluster=10067939841917321066&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Sakini, J. 1986. Neotectonic activity in Basrahh vicinity and the dryness of western canals of Shatt Al-Arab. Proceedings of the first symposium on Khor Al-Zubair. Marine Science Center, Basrah University, PP: 415-416 (in Arabic). https://scholar.google.com/scholar?cluster=8798220097627576122&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Sakini, J. 1993. New window on the Mesopotamian history in the light of geological evidences and archaeology. Dar Al-Shuaon Al-Thakafiya Al-Aamah, Baghdad (in Arabic). https://scholar.google.com/scholar?cluster=9415359684315297648&hl=ar&as_sdt=2005&sciodt=0,5.

Al-Sakini, J.A. 1995. Neo-tectonic events as indicator to determine the oil structures in the Mesopotamian fields. Third Geological Conference, Jordan, PP: 130-142. https://scholar.google.com/scholar?cluster=4808793112413207586&hl=ar&as_sdt=2005&sciodt=0,5.

Abdulla, S.S. 1990. An investigation to River load of Shatt Al-Arab in Basrah. Unpublished, M.Sc. Thesis, Marine Science Center, University of Basrah, 98 p. (in Arabic). https://scholar.google.com/scholar?cluster=3387212814349008967&hl=ar&as_sdt=2005&sciodt=0,5.

Aqrawi, A.A.M. 1993. Correction of Holocene sedimentation rates for mechanical compaction: The Tigris-Euphrates delta, lower Mesopotamia. Mar. Petrol. Geol., 12: 409-416. https://doi.org/10.1016/0264-8172(95)96903-4.

Bosworth, W., Huchon, P. and McClay, K. 2005. The Red Sea and Gulf of Aden Basins. J. African Earth Sci., 43(1-3): 334-378. https://doi.org/10.1016/j.jafrearsci.2005.07.020.

Buday, T and Jassim, S.Z. 1987. The Regional Geology of Iraq. Volume 2, Tectonism, Magmatis and Metamorphism. Geological Survey and Mineral Investigation, Baghdad.

Buringh, P. 1960. Soils and Soil Conditions in Iraq. Republic of Iraq, Ministry of Agriculture, Baghdad. https://edepot.wur.nl/480098.

De Morgan, J. 1900. Délégation en Perse, Mémoires, Tome 1, PP: 4-48.

Elliott, T. 1986. Deltas. In: Sedimentary Environments and Facies (Ed. Reading, H.G.). Black-Well Scientific Publications, Oxford, PP: 113-154.

Evans, G. 1979. The development of the Mesopotamian delta, comments. Geogr. J., 145: 529-531. https://scholar.google.com/scholar?cluster=14930768968256547002&hl=ar&as_sdt=2005&sciodt=0,5.

Fox, J.E. and Ahlbrandt, T.S. 2002. Petroleum geology and total petroleum systems of the Widyan Basin and interior platform of Saudi Arabia and Iraq. US geological Survey Bulletin, 2202-E, 26 p. https://pubs.usgs.gov/bul/b2202-e/B2202-E.pdf.

Hansman, J.F. 1978. The Mesopotamian Delta in the First Millennium B.C.. Geographical Journal, 144(1): 49-61. https://doi.org/10.2307/634649.

Hudson, R.G.S., Eames, F.E. and Wilkins, G.L. 1957. The fauna of some recent marine deposits near Basrah, Iraq. Geol. Mag., 94: 393-401 https://doi.org/10.1017/S0016756800069429.

Jassim, S.Z. and Goff, J.C. 2006. Geology of Iraq. Dolin, Prague, Czech Republic, 352 p. https://scholar.google.com/scholar?cluster=12524762156265431111&hl=ar&as_sdt=2005&sciodt=0,5.

Karim, H.H. 1989. Qualitative Interpretation of Basrah Aeromagnetic Map, SE Iraq. J. Geol. Soc. Iraq, 22(2): 1-8. https://scholar.google.com/scholar?cluster=10794580849242467179&hl=ar&as_sdt=2005&sciodt=0,5.

Karim, H.H. 1992. Structural Nature of Lower Mesopotamian Region from Geophysical Observations. University of Basrah. Marine Science Center, PP: 14-26. https://scholar.google.com/scholar?cluster=18026468788093212 96&hl=ar&as_sdt=2005&sciodt=0,5.

Karim, H.H. and Salman, H. 1987. Estimation of sediment discharge, sedimentation rate and the fate of hydrocarbon residues of Shalt AI-Arab River sediments, northwest Arabian Gulf. Marina Mesopotamica, 2: 103-115. URL.

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, edited by B.H. Purser, Springer Verlag, New York, Heidelberg, Berlin, 471 p.

Lambeck, K. 1996. Shoreline reconstructions for the Persian Gulf since the last glacial maximum. Earth Planet. Sci. Lett., 142: 43-57. https://doi.org/10.1016/0012-821X(96)00069-6.

Larsen, C.E. 1975. The Mesopotamian delta region: A reconsideration of Lees and Falcon. J. Am. Orient. Soc., 95: 43-57. https://www.jstor.org/stable/599157.

Lees, G.M. and Falcon, N.L. 1952. The geographical history of the Mesopotamian plains. The Geographical Journal, 118: 24-39. https://www.jstor.org/stable/1791234.

Nehlig, P., Genna, A., Asfirane, F., Dubreuil, N., Guerrot, C., Eberlé, J.M., Kluyver, H.M., Lasserre, J.L., Le Goff, E., Nicol, N., Salpeteur, N., Shanti, M., Thiéblemont, D. and Truffert, C. 2002. A review of the Pan-African evolution of the Arabian Shield. Geo. Arabia, 7(1): 103-124.

Nichols, G. 2009. Sedimentology and stratigraphy. Willy Black-Well, Second edition, West Sussex, UK. https://www.wiley.com/go/nicholssedimentology.

Numan, N.M.S. 1995. A Plate Tectonic Scenario for the Phanerozoic Succession in Iraq. J. Geol. Soc. Iraq, 30(2): 85-110. https://igj-iraq.org/igj/index.php/igj/article/download/122/65.

Pournelle, J.R. 2003. Deltaic Landscapes and the Evolution of Early Mesopotamian Civilization. Marshland of Cities, Ph.D. Thesis, University of California, San Diego, 314 p. URL.

Purser, B.H. 1973. The Persian Gulf, Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Springer Verlag, Berlin. https://library.wur.nl/WebQuery/titel/180967.

Purser, B.H., Ya'acoub, S.Y., Al-Hassni, N.H., Al-Azzawi, M., Orzag-Sperber, F., Hassan, K.M., Plaziat, J.C. and Younis, W.R. 1982. Charactères et évolution du complexe deltaique Tigre-Euphrate. Mém. Soc. Géol. Fr., 144: 207-216. https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCALGEODEBRGM8320041609.

Sanlaville, P. and Dalongeville, R. 2005. L'évolution des espaces littoraux du Golfe Persique et du Golfe d'Oman depuis la Phase finale de la transgression post-glaciaire. Paléorient, 31: 9-26. https://www.persee.fr/doc/paleo_0153-9345_2005_num_31_1_4780.

Vanessa, M. and Cecile, B. 2007. Holocene sedimentary evolution and palaeocoastlines of the Lower Khuzestan plain (southwest Iran). Marine Geology, 242: 83-108. http://dx.doi.org/10.1016/j.margeo.2007.01.008.

Vita-Finzi, C. 1982. Recent coastal deformation near the Strait of Hormuz. Proc. R. Sot. London Ser. A., 382: 441-457. https://doi.org/10.1098/rspa.1982.0111

Woolley, C.L. 1929. Ur of the Chaldees. London: Penguin. https://www.abebooks.com/first-edition/Ur-Chaldees-C-Leonard-Woolley-Ernest/31067911838/bd.

Ya'acoub, S.Y., Purser, B.H., Al-Hassni, N.H., Al-Azzawi, M., Orzag-Sperber, F., Hassan, K.M., Plaziat, J.C. and Younis, W.R. 1981. Preliminary study of the Quaternary sediments of SE Iraq. Joint-project between the Geological Survey of Iraq and University of Paris XI, Orsay, Unpublished Report.

Younes, A.I. and McClay, K.R. 1998. Role of basement fabric on Miocene rifting in the Gulf of Suez, -Red Sea. Proc., 14th Petroleum Conf., Egyptian General Petroleum Corporation, Cairo, Egypt, PP:35-50. https://scholar.google.com/scholar?cluster=16679622884642777872&hl=en&as_sdt=2005&sciodt=0,5