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Sea Level Changes in the Mesopotamian Plain and Limits of the Arabian Gulf: A Critical Review

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Abstract

The Mesopotamian Plain is a vast almost flat plain which descends in elevation towards southeast until it reaches the sea level along the Gulf shore. The plain covers the central part of Iraq; it is covered totally by different type of Quaternary sediments. Among those sediments, the fluvial flood plain sediments of the Tigris and Euphrates rivers with their distributaries are the most prevailing. The two river merge together to form the Shatt (River) Al-Arab which drains into the Gulf. The extensions of the Gulf are a matter of debit, especially between two groups of researchers: geologists and archeologists and even within the same group. We have presented different opinions which have dealt with the Gulf extensions, since the beginning of the last century and until most recent studies. From the presented and discussed data, it is clear that there is no clear and sound data which confirms the actual extensions of the Gulf during Holocene and even Late Pleistocene.

Keywords: Arabian (Persian) Gulf; Pleistocene; Holocene; Sea level changes.

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1. Introduction

Mesopotamia is a historical region located in West Asia and situated within the Tigris– Euphrates river system. In modern days, roughly corresponding to most of Iraq, Kuwait, parts of Northern Saudi Arabia, the eastern parts of Syria, south-eastern Turkey, and regions along the Turkish–Syrian and Iran – Iraq borders (Collon, 2011), see Figure 1.

Mesopotamia means "(Land) between two rivers" in the ancient Greek. The oldest known occurrence of the name Mesopotamia dates to the 4th century BC, when it was used to designate the land east of the Euphrates in north Syria (Finkelstien, 1962). In modern times, it has been more generally applied to all the lands between the Euphrates and the Tigris, thereby incorporating not only parts of Syria but also almost all of Iraq and south-eastern Turkey (Foster and Polinger Foster, 2009). The neighbouring steppes to the west of the Euphrates and the western part of the Zagros Mountains are also often included under the wider term Mesopotamia (Canard, 2011, Wilkinson, 2000 and Mathews, 2000). A further distinction is usually made between Upper or Northern Mesopotamia and Lower or Southern Mesopotamia (Miquel et al., 2011). Upper Mesopotamia, is also known as the Jazira, which is the area between the Euphrates and the Tigris from their sources down to Baghdad (Canard, 2011). Lower Mesopotamia is the area from Baghdad to the Persian Gulf (Miquel, 2011). In modern scientific usage, the term Mesopotamia often has a chronological connotation also. In modern Western historiography of the region, the term "Mesopotamia" is usually used to designate the area from the beginning of time, until the Muslim conquest in the 630s, with the Arabic names Iraq and Jazira being used to describe the region after that event (Foster and Polinger Foster, 2009 and Bahrani, 1998).

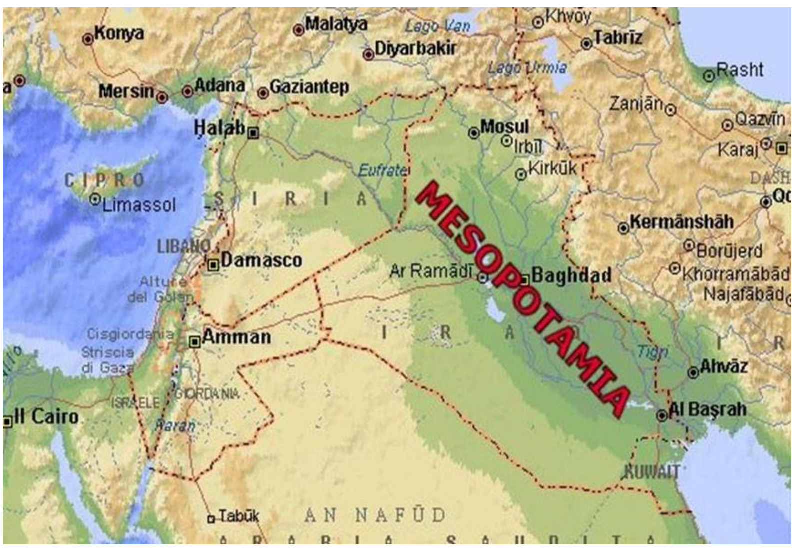

Figure 1: Geographical extension of Mesopotamia (Internet data, Wikipedia, 2019).

The Mesopotamian Plain; however, is differentiated, geographically, geologically and historically from Mesopotamia. The Mesopotamian Plain represents part of Mesopotamia, and nowadays it represents the existing plain between the Tigris and Euphrates rivers, which is limited to south of Al-Fatha gorge in the north. The alluvial plains along the Iraqi – Iranian borders in the east. From the west, it is limited by wadi Al-Tharthar and the eastern limits of the Western Desert; then extending with the northern limits of the Southern Desert (almost parallel to the Euphrates River); forming the southern limits of the plain. From the southeast, it is limited by the upper reaches of the Arabian Gulf (see Figure 2).
The majority of the published data about Mesopotamia is related to and concerned with the historical data about different civilizations; since it was the cradle of these civilizations. Therefore, the available published data is related to the late Holocene Period (less than 10,000 years). The majority of the available data is related to irrigation canals, changing of the river courses, dams' construction and flood controls.
The age of the Mesopotamian Plain backs to the Pleistocene (2.558 Ma), and because the alluvial sediments of the plain are not concerned in oil explorations; therefore, very limited data is available from the drilled oil wells, as well from the water wells; since the water wells very rarely encounter the Pleistocene sediments. Moreover, there is a large similarity between the alluvial sediments of the plain and the underlying Pre-Quaternary sediments (Yacoub, 20117 a and b); especially, when the Bai Hassan Formation underlies the Mesopotamian Plain sediments.

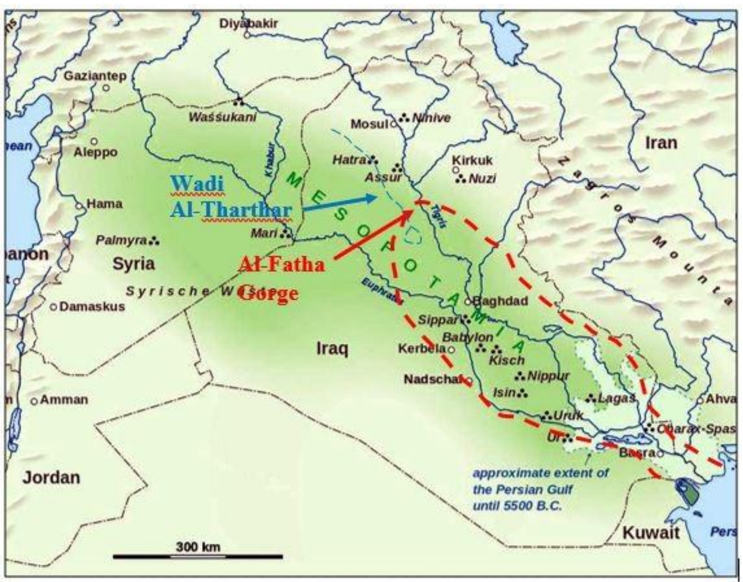

Figure 2: Tentative limits of the Mesopotamian Plain within the Mesopotamia. (Limited by the red line).

2. Sea level changes

One of the most significant and obscure subjects in the Mesopotamian Plain is the changes of the sea level and the geographical location of the shore line of the Arabian Gulf during the past history, especially during Pleistocene and Holocene. Almost the majority of the available data about the sea level and the geographical location of the shore line of the Arabian Gulf are restricted to the Holocene rather than the Pleistocene. This is attributed to the presence of enormous archaeological data as far as the Mesopotamian Plain is concerned. Because the Mesopotamian Plain was the cradle of civilizations; therefore, a lot of archaeological studies are available, not like the Pleistocene Period where archaeological data is very scarce. Accordingly, the data is related to the indications of Neotectonic activities. These data in turn are not clear and accurate as those of the archaeological data during the Holocene.

We will introduce some significant data mentioned by different authors concerning the sea level changes in the Mesopotamian Plain and the reconstructed shorelines together with our comments.

─ **de Morgan (1900):** He mentioned that in 696 B.C. the head of the Arabian Gulf was south – southwest of Shush, with the Tigris and Euphrates Rivers flowing into it separately about 70 km apart. Moreover, he mentioned that in 325 B.C. the sediments carried down by the Karun River were debouching at Ahwaz, assuming to have formed a chain of islands stretching southwest from Ahwaz right across the gulf, thus isolating a lake into which flowed the still separate Tigris and Euphrates Rivers. He was the first to reconstruct the shore line of the Gulf, by assuming its extension from Hit (along the Euphrates River) to Samarra (along the Tigris River) during the last phases of the Stone Age (about 8,000 – 5,000 years ago).

─ **Woolley (1938):** During his excavations at Ur from 1926 to 1929, discovered an 8-foot (2.42 m) bed of clean clay separating pottery and other remains of Sumerian age (About 2,000 years B.C.) from the relics of an older period. The bed of clay was correlated with the Sumerian history and legends, on which the story of Noah is based. This explains one of the great puzzles of South Mesopotamian archaeology, which was the sudden and complete disappearance of the painted pottery which at one time seems to have been universally distributed southern sites. The older people who made this painted pottery were wiped out by the flood and are thought to have lived-in low-lying villages. The early Sumerians who survived the flood are considered dwellers, living at a level to which the flood waters did not reach. After the flood, they were thought to have been able to develop uncontaminated lands, and to advance northwards and occupy lands depopulated by the flood. Thus, the Sumerians "who according to their traditions were originally settlers on the sea coast of the Arabian Gulf are found when history opens to be masters of the delta for a distance of 360 km from the sea. The authors believe that the finding of Wooley (1938) is good evidence about the location of Ur as far as the shoreline of the gulf is concerned.

─ Lloyd (1943): Showed that the head of the Gulf before 4,000 B.C. was about 108 km northwest of Baghdad, and in Sumerian times (about 2,500 – 2,000 years B.C.) it was in the neighbourhood of Ur, 415 km farther southeast. The authors would like to mention that the presented evidence indicates on the contrary that the head of the Gulf may, at the dawn of revealed history had even been more seaward of its present position.

─ Lees and Falcon (1952): They have presented geological evidence which conflicts with archaeological reconstructions and it seems certain that the real course of geographical history has been far more complex than the archaeologists have assumed. The most recent event has been, contrary to archaeological opinion an advance of the head of the Arabian (Persian) Gulf and it is probable that such advance has alternated with retreat throughout historic and prehistoric ages.

The archaeologists usually have assumed that there has been a gradual retreat of the sea to the southeast in the Mesopotamian Plain. This is attributed to normal processes of delta formation, where the vast amount of silt carried down by the Tigris, Euphrates and Karun rivers is supposed to have filled the Gulf gradually. The general rise of the sea-level resulting from the melting of the great ice sheets at the end of the Last Glacial Period (about 11.1 Ka, Walker et al., 2009) may have amounted to about 90 m (Holmes, 1944). He has stated that the bottom of the Arabian (Persian) Gulf must have been then a fertile plain, floored with alluvium from the united waters of the Tigris and Euphrates Rivers. This assumption coincides with historical evidence that the great Hor Al- Ham'mar marsh between Ur and Basra only came into existence in about 600 A.D.

The rejuvenation of the Karun system was caused by a renewed subsidence of the Mesopotamian Plain to the southwest, or by a tilting of the hill country (Inside Iran) to the northeast, or probably by a combination of both. Accordingly, the gradients of the rivers were increased causing them to trench into the alluvial deposits which had been accumulating during the still-stand period, and the alluvial plains on which the Sassanian settlements remains (about 200 A.D.) are found were incised to a depth of 5.15 m. The rejuvenation of the rivers; however, is not certain to be entirely post-Sassanian as these settlements may have been established after the rivers had commenced their downward cutting. But the main facts are that between about 3,000 B.C. and the present day there was first a build-up of the land surface by sedimentation to about 2.4 m, and that this was followed by an entrenchment of the rivers by 5.15 m. The southwestern extension of the earlier plain has been removed by erosion and the remains of any earlier habitations on its surface or entombed within its silts have been scattered and lost.

─ Lambeck (1996), predicted the sea-level change in the Arabian (Persian) Gulf since the time of the last maximum glaciation at about 18,000 years B.P. to exhibit considerable spatial variability, because of the response of the Earth to glacial unloading of the distant ice sheets and to the melt water loading of the Gulf itself and the adjacent ocean. He constructed models for the glacio-hydro-isostatic effects and compared them with observations of sea-level change and also reconstructed the paleo shoreline of the Gulf (see Figure 3). From the peak of the glaciation until

about 14,000 years B.P., the Gulf was free of marine influence out to the edge of the Biaban (Bubian) Shelf. By 14,000 years B.P., the Strait of Hormuz had opened up as a narrow waterway and by about 12500 years ago the marine incursion into the Central Basin had started. The Western Basin flooded about 1,000 years later. Momentary still stands may have occurred during the Gulf flooding phase at about 11,300 and 10,500 years B.P. The present shoreline was reached shortly before 6,000 years ago and exceeded as relative sea level rose (l – 2) m above its present level inundating the low-lying areas of lower Mesopotamia. These reconstructions have implications for models of the evolution of the Euphrates – Tigris – Karun delta, as well as for the movements of people and the timing of the earliest settlements in lower Mesopotamia. For example, the early Gulf floor would have provided a natural route for people moving westwards from regions from the east of Iran from the late Palaeolithic to early Neolithic.
Figure 3 illustrates the components for the Arctic ice sheet model whose eustatic contribution at the time of the last glacial maximum is 90m. The Antarctic eustatic contribution is about 37 m making up a total eustatic change of 127m since the last glacial maximum.

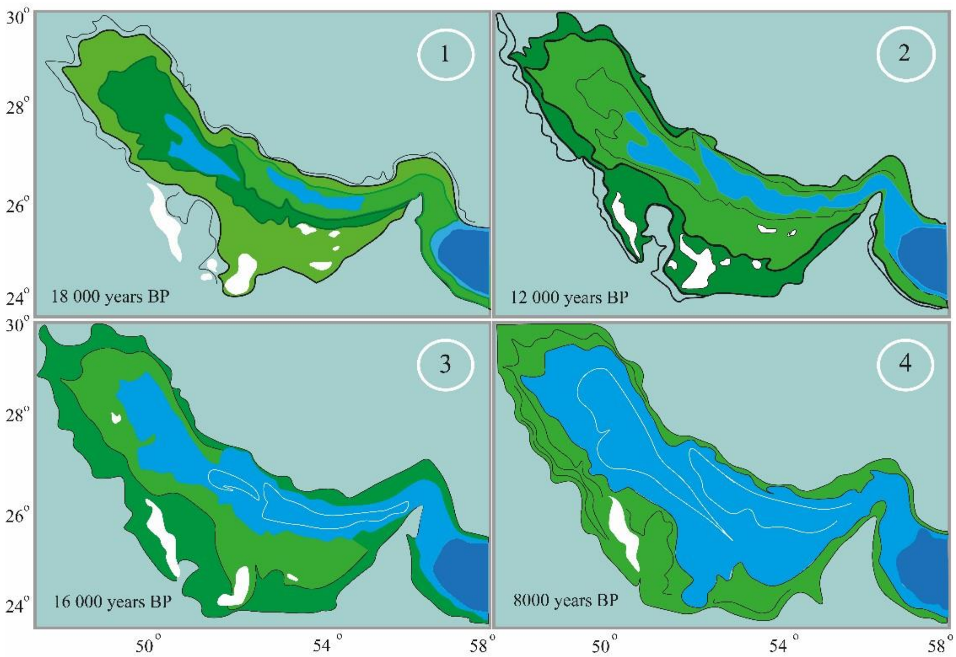

Figure 3: Reconstruction of the shore lines in the Arabian Gulf. 1 = 18,000 B.P., 2 = 12,000 B.P., 3 = 10,000 B.P., and 4 = 8,000 B.P. (After Lambeck, 1996). (The enclosed blue areas define the max. limits of the lakes that could form if filled to their sill levels. The blue – white areas define shallow topographic depressions).

–**Aqrawi (2001):** He studied the Tigris – Euphrates deltaic deposits, and concluded that wet climate conditions prevailed due to this transgression to around 6,000 years B.P., semi-arid during the regression between 6,000 – 4,000 years B.P., and arid conditions since around 3,000 years B.P. until present.

During early Holocene, arid climate dominated the Mesopotamian Plain after a long period of the wetter conditions of Pleistocene. Such a climatic change has resulted in the formation of gypcrete occurring within the fluvial-plain muds. However, the sediments were highly admixed with coarser sandy deposits of playa and aeolian sources in the margins of the Western Desert, and with older reworked sands of Zagros foothills to the Northeast of Lower Mesopotamia.

During the mid-Holocene, marine invasion had occurred when the climate became wetter as well, brackish-water marine sediments were deposited, overlying the previous fluvial plain deposits. The deposition started with transitional sediments over the older early Holocene gypcrete deposits signalling the marine transgression. After about ,2000 years of maximum flooding there was the end of the marine brackish-water deposition and signalling another climatic change towards a more arid setting around 4,000 years ago. These climatic conditions are still continuous in the area and reflect the salt-covered fluvial plain deposits of these rivers. However, marsh – lacustrine deposits and environments remained, covering some vast lowland parts of the fluvial plains but further inland to the north of the present-day northern Gulf coasts (Figures 4 and 5).

Complex implications of neotectonic activities, sea-level fluctuations and differential sedimentation rates in addition to the climatic changes during Holocene have resulted in the formation and preservation of these unique marshlands, which are still covering most parts of the ancient Tigris–Euphrates–Karun delta. On the other hand, the high contribution of Aeolian deposits within the Holocene deltaic successions, particularly to the western parts occurred during the high aridity periods, which is still continuous. This contribution increased to form up to one third of the sediments accumulated in the region after the domination of more severe dry conditions and an arid climate from about 5,000–4,000 years B.P. It is worth mentioning that the highest Aeolian contribution occurred through the advance of sand dunes and storms (Aqrawi, 1995). Almost pure aeolian sands of a 0.5 m were found in the western side boreholes which referenced to about 5,000 –5,500 years B.P.

The decline in the rain precipitation had caused dramatic change in the climate, and has resulted in the reduction in sediment load and the discharge of the Tigris and Euphrates rivers, consequently, reducing the sedimentation rates to less than 0.5m/1,000 years during the last 3,000 years B.P. As a result, most of the sediments reaching the northern parts of the Gulf since then are believed to be transported by the Karun River; rather than the Shatt Al-Arab (i.e. Tigris and Euphrates Rivers). The Shatt Al-Arab was developed in very late Holocene, most probably during the Abbasid Era (Aqrawi, 1993), and followed the ancient channel of the Tigris River, at the confluence with the Euphrates River at Qurnah Town.

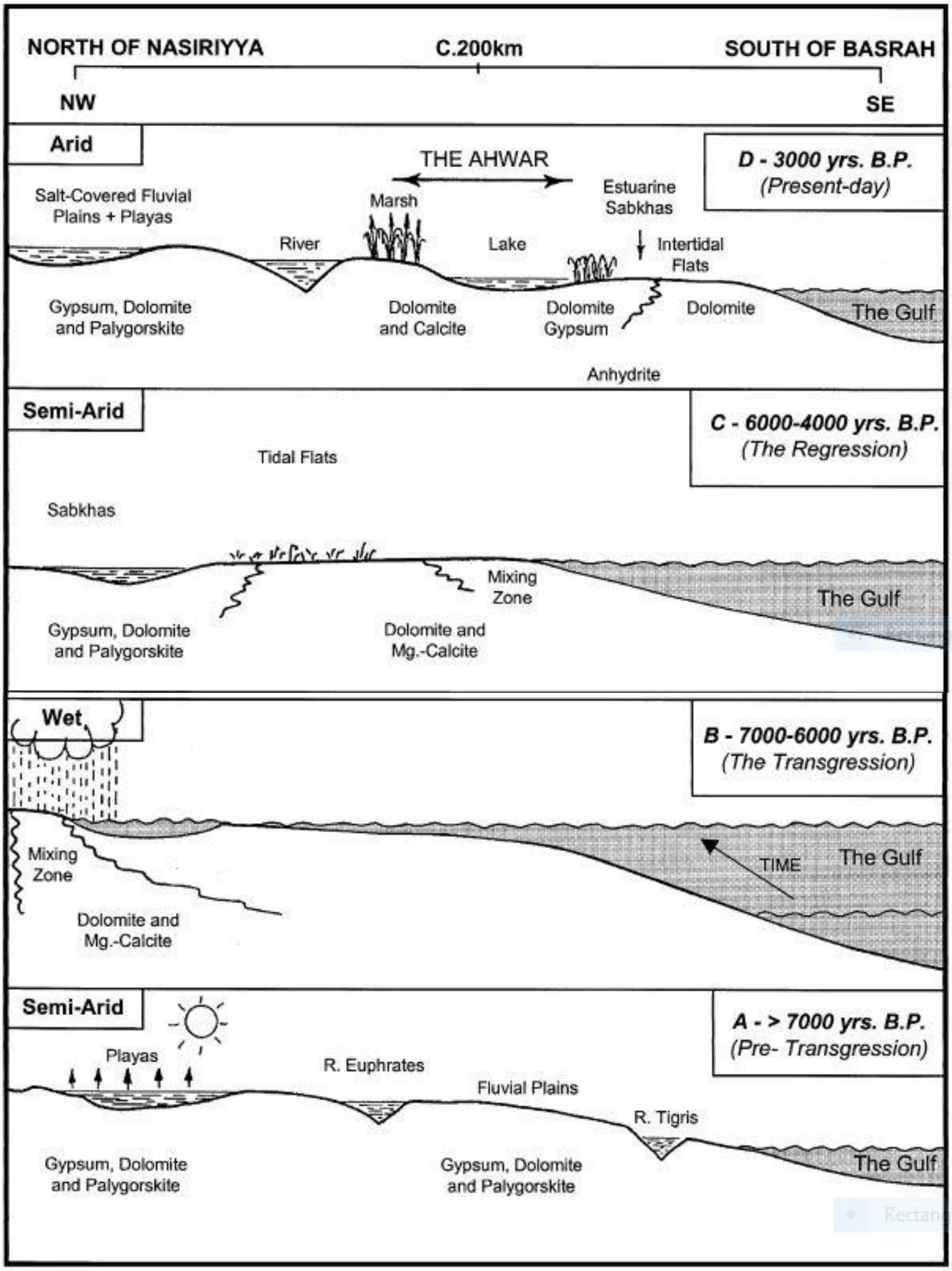

Figure 4: Schematic cross-sections showing various periods of the Holocene evolution of the Tigris–Euphrates delta when various climatic conditions were dominant (After Aqrawi, 2001).

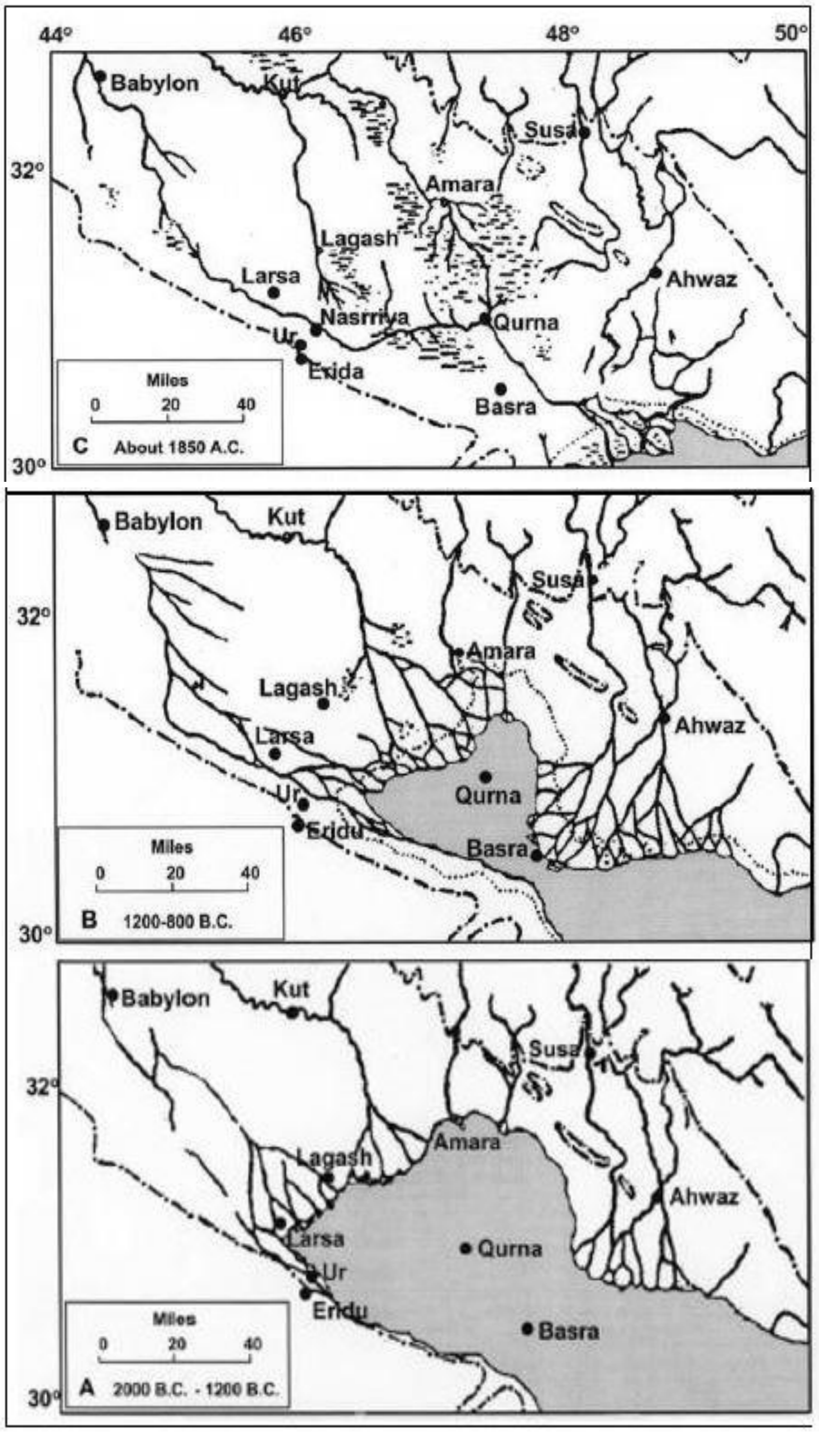

Figure 5: Selected archaeological maps of southern Mesopotamia (adapted from Geographical Handbook of Iraq and Persian Gulf, 1944) showing the historical changes in the northern shorelines of the Gulf. (From Aqrawi, 2001).

─ **Tanoli (2013):** Variations in sea level are caused by a combination of eustatic, isostatic, and tectonic factors (Anzidei et al. 2011; Lambeck et al. 2011) and the relation between rate of base level change and the sedimentation rate (Catuneanu et al. 2009). Melting of ice after the last ice age of Late Pleistocene has contributed to additional land-locked water to the sea, resulting in an overall sea level rise during the Holocene. The removal of large ice sheets has readjusted the Earth's crust due to change in gravitational potential in higher latitudes (Lambeck 1996).

Since the last glacial maximum around 18,000 years ago, as a consequence of melting of the ice sheets, unlocked water resulted in sea level rise. Generally, this sea level rise was initially fast, slowing to very slow rate afterward from around 7,000 years B.P. Prior to this global sea level rise, it is widely recognized that the Arabian Gulf was a dry valley (Lambeck, 1996) through which the Euphrates – Tigris Rivers flowed (McIntosh, 2005) and their deltas might have emptied into the Gulf of Oman (Biot report #422, 2007, from Nutzel, 1979) (Figure 6).

The present average depth of the Gulf is around 46 m, with maximum depth around 82m (Biot report #422, 2007, from Nutzel, 1979). From the glaciation peak until 14,000 years B.P., the Gulf was free of marine influence (Lambeck, 1996). Around 14,000 years B.P., the Strait of Hormuz opened as a narrow waterway, and by 12,500 years B.P., the central basin had started experiencing marine incursion (Lambeck, 1996). The sea transgressed at an average rate of (100 – 120)m per year across the floor of the Arabian Gulf (Sarnthein, 1972), based on estimates of the distance covered by the transgressed waters from the Strait of Hormuz to the mouth of the Euphrates –Tigris. Transgression over this distance, about 1,000 km, took approximately 7,000 years, between 13,000 and 6,000 years B.P. Kassler (1973) has suggested fluctuating sea level rise in the gulf floor with relatively rapid rises occurring between 12,000 and 11,000 years B.P., 9,500 – 8,500 years B.P., and around 7,000 years B.P.

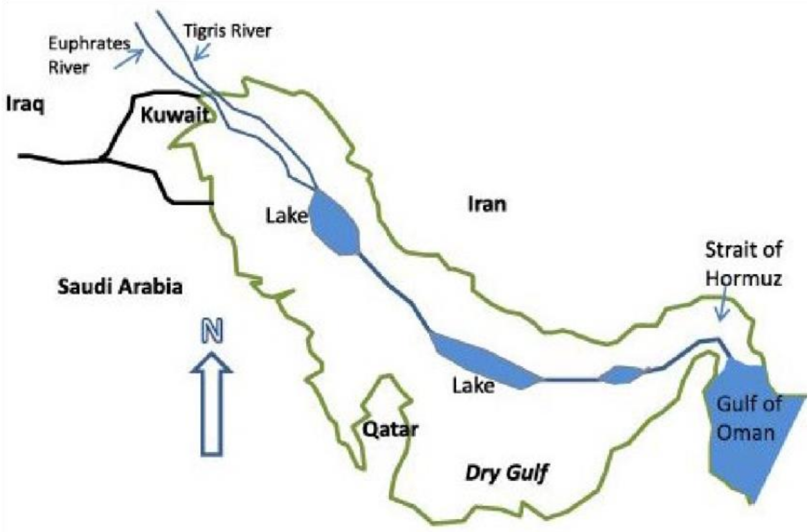

Figure 6: Arabian Gulf Portrayal circa 14,000 years B.P. The lower part of the Gulf is first flooded at about 13,000 years B.P., but large freshwater lakes could have developed in several locations within the valley floor. Large shallow depressions also occur on the southern margin of the present gulf (After Tanoli, 2013).

The Holocene sea level peaked at around 5,500 years ago and stood about (1–2) m higher than the present level in the southern Arabian Gulf (Williams and Walkden, 2002). However, Evans et al. (2002) from their study in coastal Abu Dhabi put the peak transgression time around 4,500 years B.P., and similarly Evans (2011), put it around 5,000 – 4,000 years B.P. The sea level stood about 3 m higher than the present-day level in the northern Gulf (SEMP, Biot report 422 2007), resulting in sea incursion within the hinterland of southern Iraq up to Amara and Nasiriya cities, some 200 km north of the current shorelines of Iraq and Kuwait (Aqrawi, 1995). In eastern Saudi Arabia, Holocene deposits close to the shoreline are 3 m higher than the present-day highwater mark (McClure and Vita-Finzi, 1982). Carbon-14 isotope age dating of the mollusk shells has yielded an age of 3,700 – 6,000 years B.P. for these deposits, confirming this sea level high.

– **Al-Sheikhly et al. (2013):** They reconstructed the shore line of the Arabian Gulf depending on the ostracoda and foraminifera assemblages as ecological indicators and concluded that the Southern Mesopotamia effected by three distinguished sea transgressions; the first was during the time interval 22,000 – 20,000 years B.P. (Figure 7), represented by deltaic environment which coincides with the marine transgression and is correlated with a period of humidity and sea level rise during Late Pleistocene (37,000 – 20,000 years B.P.). The second transgression registered during the time interval 16,000 – 14,000 years B.P., it is distinguished by deltaic environment and marine environment. The closure of Würm Glacial Cycle at 16,000 years B.P., which was distinguished by global climatic changes toward warmer conditions, and was registered by the distribution of fresh water- fluvial and back swamps environments in Southern Mesopotamia during the time interval 13,000 – 11,000 years B.P (Figure 7). So, by the end of Pleistocene (11,800 years B.P.) the third sea transgression was recorded by the presence of deltaic and shoal back swamps environments. This transgression continued during 9,000 years B.P. and represented by the deltaic environment, in addition to the back swamps and fluvial environments where the climate was wet with low temperature. The influence of the third transgression continued during the time interval 8,000 -7,000 years B.P. in addition to the distribution of back swamps and fresh water – fluvial environments.

During the interval 7,000 – 6,000 years B.P., the fresh water fluvial environment prevailed indicating an ancient river which coincides with the assumption of Adams and Nissen (1975) about the presence of a river during Ubaid Period (7,000 – 6,000 years B.P.). This also coincides with the presence of the Ancient Cities of Sipper, Kutha and Kish (Figure 8) which were lying on this river (Sousa, 1983). This ancient river might be a branch of the Euphrates River, called by the archaeologists as Arahtu River (Sousa, 1963).

During 6,000 – 5,000 years B.P. (Figure 7), the Post-Glacial Climatic Optimum occurred, where the sea level and humidity were changed worldwide. So, the Back Swamps environment was prevailed over the Southern Mesopotamia during 5,500 – 4,500 years B.P.

By the end of 5,000 years B.P., the Climate was cold and wet (Weiss et al., 1993), and that is recorded in Southern Mesopotamia by increasing rain fall and widening of rivers during 4,000 – 3,000 years B.P. Nützel (1975) mentioned that that there was a decrease in temperature (2 – 3 degrees) in Southern Mesopotamia during 3,500 years B.P., causing colder climate and rising of sea level (3 meters above nowadays level).

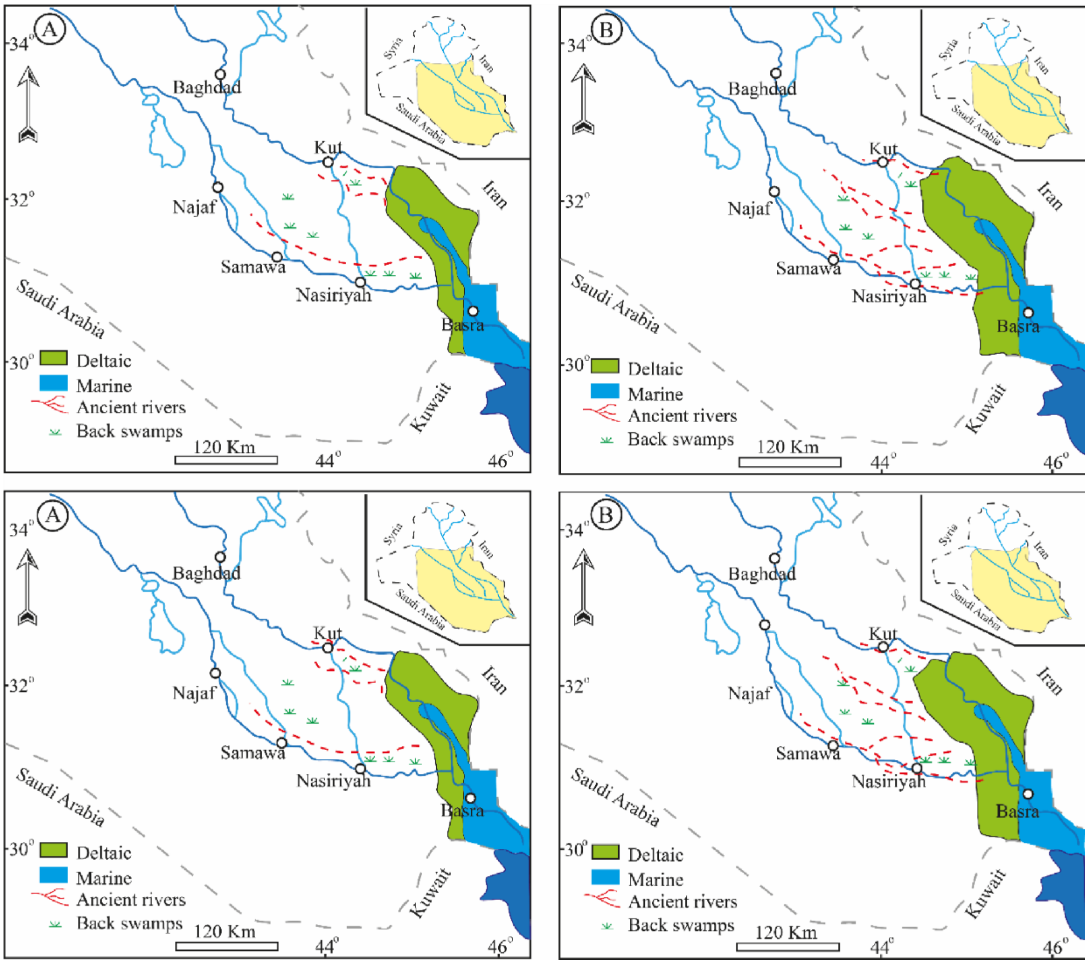

Figure 7: Four maps showing the extensions of deltas (in green), the shore line (in blue) and old traces of the rivers (in dashed red lines). A) 22,000 – 20,000 Years, B) 13,000 – 11,000 Years, C) 6,000 – 5,000 Years, and D)1,000 Years (Modified from Al-Sheikhly et al., 2017).

Throughout the time interval 3,500 – 3,000 years B.P., the fresh water fluvial environment was prevailing. The fresh water environment may indicate the changing of the Euphrates River to its present course during that time, or there was a bifurcation of the Euphrates River at that site. Sousa (1963) mentioned that the Ancient Euphrates River had changed its course westwards during the Babylonian Period from Kutha Ancient City towards Babylon river. This was due to a dam construction to raise the water levels which in turn led to prosperity of Babylon Civilization at that time. But the Euphrates River had changed its course tectonically because of the effect of Falluja Subsurface Structure (Al-Sakiny, 1993).

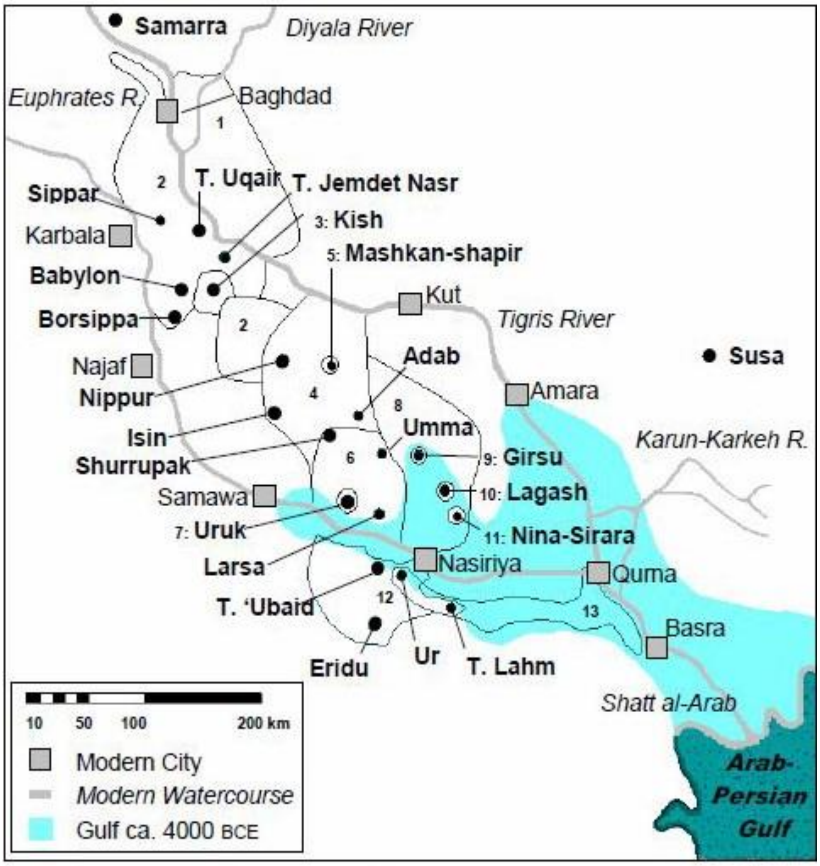

Figure 8: Major archaeological sites of Mesopotamian Plain with surveyed areas (serial numbers) and hypothetical extent of the Arabian Gulf ca. 4,000 B.C. 1) Diyala, 2) Akkad, 3) Kish, 4) Nippur, 5) Mashkan-Shapir, 6) Warka (Uruk), 7) Uruk), 8) East Ghrraf, 9) Tello Region, 10) Lagash, 11) Zurghal (Nina-Sirara), 12) UR-Eridy, 13) Hammar Lake. (After Pournelle, 2013).

3. Discussion

The main topic which needs discussion in the current work is the extensions of the Gulf coast during different times and the changes in the river courses. We have selected randomly few authors and summarized their results of the coast lines in Table 1. From reviewing the data presented in Table 1, it is clear that there is almost no any agreement between the selected authors as the extension of the coast line is concerned. It is very difficult to explain these extreme variations in the reconstructed coast lines. However, we believe that the main reason is the used data in their claims and how neat are the results. As the dating is the main significant item which plays the main role in reconstruction of the coast lines; therefore, the dating is still a main problem in considering its accuracy. This depends on many factors which are beyond the scope of the current study.

The dating procedure of the events is quite different between the assumptions of archeologists and geologists. The archeologists usually consider retreatment of the coast line of the Gulf due to continuous sedimentation and delta development by the Tigris and Euphrates rivers. Whereas, geologists adopt the melting of great ice sheets after the last glaciation period as their criterion (Lees and Falcon, 1952). Therefore, the assumptions of the selected authors are not in agreement with each other.

There are some discrepancies in the assumptions, even in the works of the same authors. For example, De Morgan (1900) assumes that the shoreline was near Hit; along the Euphrates River and at Samarra; along the Tigris River during 8,000 – 6,000 B.C., which are about 600 km northwest and north of the present shoreline. Moreover, he assumes that the Tigris and Euphrates rivers were flowing directly into the gulf without being merged together during 325 B.C. This means that the shoreline was more northwards than the present shoreline; otherwise, the two rivers couldn't flow separately into the Gulf. But, he didn't mention how far the shoreline was. It is worth to mention that before 8,000 years the Ubaid settlements were close to the location of Ur (Figure 8) which was very near from the shoreline (Carter and Philip, 2010).

The time of reaching the present shoreline location is again quite different from the mentioned assumptions by different authors (Table 1). For example, Lambeck (1996) claimed the present shoreline location was 6,000 B.C. Whereas, during 6,000 B.C. the shoreline was 360 km north of the present location according to Wolley (1939), and between Nasiriya and Amara (Tanoli, 2013, Al-Sheikhly et al., 2013, and Pournella, 2013). Moreover, Lambeck (1996) claimed that before reaching to the present shoreline, the whole Gulf was dry and the Tigris and Euphrates River were flowing into the Gulf directly. This assumption was confirmed only by Tanoli (2013). However, this agrees with the theory that the early Sumerians had crossed the Gulf which was dry at that time coming from a place in Baluchistan and they settled in Bahrain (Dilmun) before moving to Mesopotamia (Hamblin, 1987). Tanoli (2013) claimed that until 14,000 B.C., the whole Gulf area was a dry land. Later on, the sea started forward movement which is exactly the opposite of all other reconstructed scenarios of different authors (Table 1).

Al-Ameri et al. (2000) mentioned that the shoreline of the Gulf was 1440 km southeast of Baghdad before 10,500 B.C., and it was 250 km southeast of Baghdad along the Tigris River (near Amara city) and 60 km southwest of Baghdad along the Euphrates River (near Hilla city). Although they use palynological evidences like their colleagues (Al-Sheikhly et a., 2013) but they reached to very different results as the shoreline of the Gulf is concerned (Table 1).

Another abnormal assumption is presented by Al-Sheikhly et al. (2013). They constructed the shoreline during different time spans depending on the present ostracods and palynology. The abnormal presentation is that they extended the shoreline only along the Tigris River; not along the Euphrates River (Figure 7). This means the course of the Euphrates River was higher than that of the Tigris River, therefore, the gulf extended only towards the Tigris River. Moreover, this means that the ancient city of Ur was never been located along a shoreline, which is not in accordance with the majority of carried out archaeological and geological studies.

Another significant issue which needs discussion is the changing of the river courses during the Pleistocene and Holocene. There is a big difference between the considered reasons between the archaeological and geological studies. The archaeological studied assume that all the happened changes in the river courses are related to major floods and/ or constructed irrigation canals (Ellison, 1978). Whereas, geological studies assume that the main reason for changing of the river courses is the Neotectonic activities which are mainly related to the growth of the subsurface anticlines (Al-Sakiny, 1993, Fouad and Sissakian, 2012, Sissakian, 2013, Sissakian et al., 2017 and 2018). Moreover, the activity of the Abu Jir – Euphrates Active Fault Zone also has played role in shifting the course of the Euphrates River (Figure 9) and is still shifting the river course more towards northeast. Some large alluvial fans also have shifted the river courses during their growth, especially during Late Pleistocene and Holocene.

Table 1: Generalized dating of the Gulf's location based on the mentioned authors

No.	Authors	Sea level location during years B. C.					
		22,000-18,000	16,000-10,000	10,000-8,000	8,000-4,000	4,000-1,000	Notes
1	De Morgan (1900)				Hit (along the Euphrates River) to Samarra (along the Tigris River)		The Tigris and Euphrates Rivers were flowing to the gulf separately even in 325 B.C.
2	Woolley (1938)					360 km north of the current location	Based on a clay bed, 2.4 m thick
3	Lloyd (1943)					Near Ur (2,500-2,000 B.C) and 108 km NW Baghdad (4,000 B.C.)	
4	Lees and Falcon (1952)			The gulf area was a fertile plane			
5	Lambeck (1996)	The gulf was free from marine influence				The present shore line reached (6,000 years B.C.)	The Straight of Hurmuz was opened at 1250
6	Al-Ameri et al., 2,000	1,440 km southeast of Baghdad	350 km south of Baghdad along the Tigris River and 60 km southwest of Baghdad along the Euphrates River				

7	Aqrawi (2001)					North of Basra 110Km (2,000 – 1,200 B.C.), and 70 km (1,200-800B.C), 70km south of Basra (1850 (A.C.)	Shat Al-Arab was formed between 750 – 1260 A.D.
8	Tanoli (2013)					From Amara to Nasiriya	The Tigris and Euphrates River were merging south of Kuwait within the dry gulf area
9	Al-Sheikhly et al. (2013)	Near Amara along the Tigris River only				From Amara to Nasiriya	Near Basra before 1,000 years
10	Pournelle (2013)					From Amara to Samawa	

A good example is Al-Batin alluvial fan, which has shifted the course of the Euphrates River (Sissakian et al., 2014). However, the influence of major floods and the mechanism of river hydraulics, especially during large floods are also considered in majority of geological studies. The presence of main irrigation canals which were constructed during early civilizations are also considered too in geological studies as main factor which had contributed in shifting of the river courses (Williams, 2001, Ortega et al., 2014). The humid conditions associated with very heavy rain showers during wet stages of the Pleistocene and even early Holocene also had contributed in changing the river courses. This is attributed to the erosional forces and the weight of the carried sediments in entrenching the courses of the rivers into more straight courses, especially when acute meanders had existed in the river courses, where the irrigation canals were constructed perpendicularly on large meanders. This is called rapidly varied flow (Kindsvater, 1958).

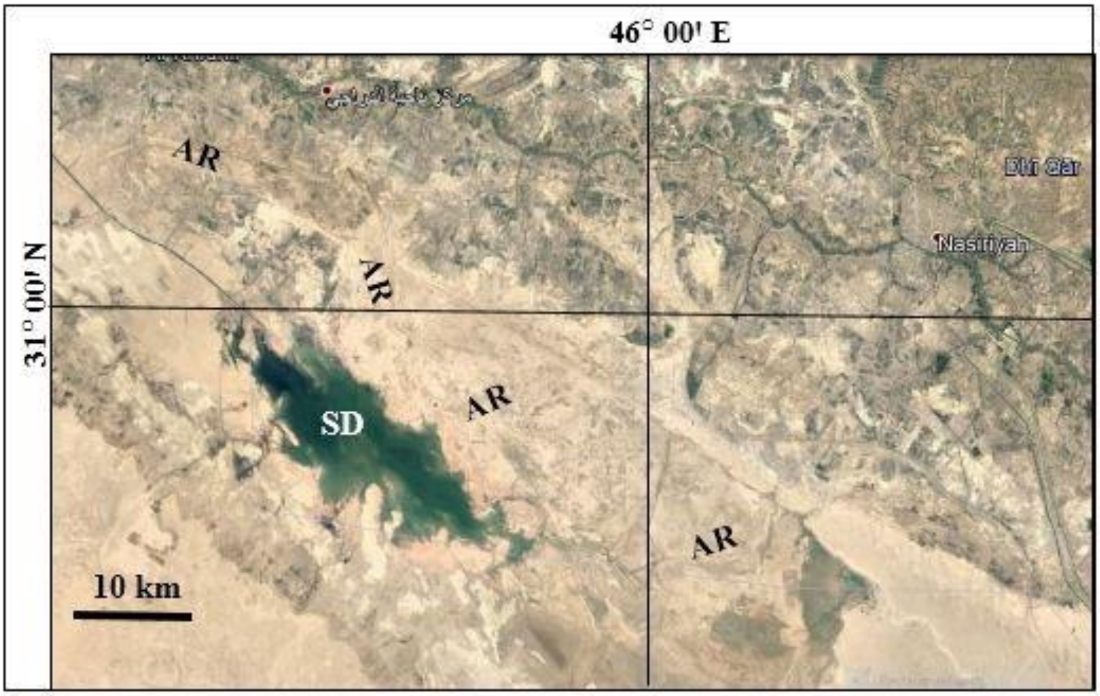

Figure 9: Satellite image showing abandoned river course (AR) of the Euphrates River. Note Al-Slaiabt Depression (SD) which was most probably an old marsh.

4. Conclusions

Our main conclusions deal with the extensions of the shoreline of the Gulf and the changes of the river courses. For the shoreline extensions, it is very clear from almost all the carried-out works including geological and archaeological ones that there is no agreement between the given extensions of the shorelines during different periods. However, geologists do believe that the Gulf was a dry area and was filled due to melting of huge amounts of ice; accordingly, the shoreline started progressing landwards. After that, due to climate change, the shoreline started retreating downwards due to the delta development of the Tigris, Euphrates and Karun rivers.

This scenario is not accepted by archeologists who believe that the shoreline was always retreating downwards due to delta development. The second main conclusion deals with the changes of the river courses. We do believe that the majority of the rivers have changed their courses due to the growth of subsurface anticlines in different parts of the Mesopotamian Plain, and the growth is still ongoing. However, the role of the major floods and the constructed irrigation canals have played a big role in changing the river courses as they contributed with the Neotectonic forces represented by the growth of the subsurface anticlines.

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References

[1] Adams, M. R. and Nissen, H. (1975). The Uruk Countryside. The Natural setting of Urban Societies, pp. 35 – 39, Figure 17. University of Chicago Press.
[2] Al-Ameri, T., Al-Joburi, B. and Al-Dulaimy, A. (2000). Palynological evidences for events of the historical Deluge on Mesopotamian peoples and the Future climate change. 5th Intern. Conf. on the Geology of the Arab World, Cairo University, pp. 1575 – 1584.
[3] Al-Badri, A., Ahmed, A. and Seryoka, S. (1984). Final report on the Samawa salt deposits, Muthana Governorate. Iraq Geological Survey Library Report No. 1510.
[4] Al-Jiburi, H.K. and Al-Basrawi, N. H. (2011). Hydrogeology of the Mesopotamian Plain. Iraqi Bulletin of Geology and Mining, Special Issue No. 4, pp. 83 – 103.
[5] Al-Mubarak, M.A. and Amin, R.M. (1983). The regional geological mapping of the western part of the Southern Desert and the eastern part of the Western Desert. Iraq Geological Survey Library Report No. 1380.
[6] Al-Kadhimi, J.M.A., Sissakian, V.K., Fattah, A.S. and Deikran, D.B. (1996). Tectonic Map of Iraq, scale 1:1,000,000, 2nd edit., Iraq Geological Survey Publication, Baghdad, Iraq. Journal of Science, 2017, Vol. 58, No. 4A, pp. 1856 – 1873.
[7] Al-Sakini, J.A. (1993). New look on the history of old Tigris and Euphrates Rivers, in the light of Geological Evidences, Recent Archaeological Discoveries and Historical Sources. Oil Exploration Co. Baghdad, Iraq, p. 93 (in Arabic).
[8] Alsharhan, A.S. and Nairn, A.E.M. (1997). Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier, Amsterdam, p. 811.
[9] Al-Sheikhly, S.S., Al-Jumaily, W.A., Al-Ka'abi, F.S., Al-Shehmany, Z.Kh. and Owen, M.O. (2017). Late Pleistocene – Holocene Paleoecology of Southern Mesopotamia, Iraq.
[10] Bahrani, Z. (1998). Conjuring Mesopotamia: Imaginative Geography a World Past. In: Meskell, L., Archaeology under Fire: Nationalism, Politics and Heritage in the Eastern Mediterranean and Middle East, London: Routledge, pp. 159–174. ISBN 978-0-41519655-0.
[11] Berberian, M. (1995). Master "blind" thrust faults hidden under the Zagros folds: active basement tectonics and surface morphotectonic. Tectonophysics, 241, pp. 193 – 224.

[12] Bhattacharya, S., Virdi, N.S. and Philip, G. (2005). Neotectonic activity in the outer Himalaya of Himacgal Pradesh and around Paonta Sahib: A morphotectonic approach. Wadia Institute of Himalayan Geology, Dehra Dun – 248 001, India.
[13] Buday, T. (1980). The Regional Geology of Iraq. Vol.1: Stratigraphy and Paleogeography. In: I.I., Kassab and S.Z., Jassim (Eds.). Iraq Geological Survey Publications, Baghdad, Iraq, p.445.
[14] Buday, T. and Jassim, S.Z. (1984). Tectonic Map of Iraq, scale 1:1,000,000. Iraq Geological Survey Publications, Baghdad Iraq.
[15] Buday, T. and Jassim, S.Z. (1987). The Regional Geology of Iraq. Vol. 2. Tectonism, Magmatism and Metamorphism. In: M.J., Abbas and I.I., Kassab (Eds.). Iraq Geological Survey Publications, Baghdad, p. 352.
[16] Canard, M. (2011). "Al-ḎJazīra, Ḏjazīrat Aḳūr or Iḳlīm Aḳūr". In: Bearman, P., Bianquis, Th., Bosworth, C.E., van Donzel, E. and Heinrichs, W.P. Encyclopaedia of Islam, 2nd edition. Leiden: Brill Online, OCLC 624382576.
[17] Carter, R.A. and Philip, G. (2010). Beyond the Ubaid: Transformation and Integration in the Late Prehistoric Societies of the Middle East (Studies in Ancient Oriental Civilization, Number 63) The Oriental Institute of the University of Chicago (2010) ISBN 978-1885923-66-0 p.
[18] Collon, D. (2011). Mesopotamia. BBC, Ancient History in Depth. http://www.bbc.co.uk/history/ancient/cultures/mesopotamia_gallery.shtml.
[19] De Morgan, J. (1900). Delegation en Perse, Memoires, Paris. Tome I, pp. 4 – 48.
[20] Ditmar, V. (1971). Geological conditions and hydrocarbon prospect of the Republic of Iraq (Northern and Central parts). Technoexport report, OEC Library, Baghdad, Iraq.
[21] Dunnington, H.V. (1958). Generation, migration, accumulation and dissipation of oil in Northern Iraq. In: G.L. Weeks (Ed.), Habitat of Oil, a Symposium. AAPG, Tulsa.
[22] Finkelstein, J.J. (1962). "Mesopotamia", Journal of Near Eastern Studies, 21 (2), pp. 73 – 92. doi:10.1086/371676, JSTOR 543884.
[23] Fouad, S.F. (2010). Tectonic evolution of the Mesopotamia Foredeep in Iraq. Iraqi Bulletin of Geology and Mining, Vol. 6, No. 2.
[24] Fouad, S.F. (2012). Tectonic Map of Iraq, scale 1:1,000,000, 3rd edition. Iraq Geological Survey Publications, Baghdad, Iraq.
[25] Fouad, S.F. and Sissakian, V.K. (2011). Tectonic and Structural Evolution of the Mesopotamia Plain. Iraqi Bulletin of Geology and Mining, Special Issue No. 4, pp. 33 – 46.
[26] Foster, B. R. and Polinger Foster, K. (2009). Civilizations of Ancient Iraq, Princeton: Princeton University Press. ISBN 978-0-691-13722-3.
[27] Hamblin, D.J. (1987). Has the Garden of Eden been located at last? Smithsonian Magazine, Volume 18. No. 2.

[28] Hessami, K., Koyi, H.A., Talbot, G.J., Tabasi, H. and Shalanian, E. (2001). Progressive unconformities within an evoluting foreland fold – thrust belt, Zagros Mountains. Jour. Geol. Soc., 158, pp. 969 – 981.
[29] Holmes, A. (1944). Principles of physical geology. Thomas Nelson and Sons Ltd. London, p. 638.
[30] ICS (International Commission on Stratigraphy) (2012). International Chronological Chart. Brisbane, Australia, IGC 34.
[31] Iraqi-Soviet Team (1979). Geological conditions and hydrocarbon prospects of the Republic of Iraq. INOC Library, Baghdad, Iraq.
[32] I.S.C.P. (1984). Iraqi standard specification No. 5/ 1984, Portland Cement. Baghdad, Iraq. www.sciepub.com/reference/124723.
[33] Jassim, S.Z. (1981). Early Pleistocene Gravel Fan of the Tigris River from Al-Fatha to Baghdad, Central Iraq. Journal of Geological Society of Iraq, Vol. 14, pp. 25 – 34.
[34] Jassim, R.Z. (1997). Mineralogy, Geochemistry and origin of Shari Saltern. Unpublished Ph.D. Thesis, University of Baghdad.
[35] Jassim, S.Z., Karim, S.A., Basi, M.A., Al-Mubarak, M. and Munir, J. (1984). Final report on the regional geological survey of Iraq, Vol. 3, Stratigraphy. Iraq Geological Survey Library Report No. 1447.
[36] Jassim, S.Z., Hagopian, D.H. and Al-Hashimi, H.A. (1986). Geological Map of Iraq, scale 1:1,000,000. Iraq Geological Survey Publications, Baghdad, Iraq.
[37] Jassim, S.Z., Hagopian, D.H. and Al-Hashimi, H.A. (1990). Geological Map of Iraq, scale 1:1,000,000, 2nd edition. Iraq Geological Survey Publications, Baghdad, Iraq.
[38] Jones, S.J. and Arzani, A. (2005). Alluvial fan response times to tectonic and climatic driven processes: Example from the Khrud mountain belt. Geophysical Research Abstracts, Vol. 7. European Geosciences Union.
[39] Judicial Watch (2002). Maps and charts of Iraqi Oil Fields. www.judicialwatch.org/maps-andcharts-of-iraqi.
[40] Lambeck, K. (1996). Shoreline reconstructions for the Persian Gulf since the last glacial maximum Earth and Planetary Science Letters, Vol. 142, pp. 43 – 57.
[41] Lees, G.M. and Falcon, N.L. (1952). The Geographical History of the Mesopotamian Plains. The Geographical Journal, Vol. 118, No. 1 (Mar., 1952), pp. 24 – 39.
[42] Lloyd, S. (1943). Twin rivers. A brief history of Iraq from the earliest time to the present day. Oxford University Press, p. 251. https://archive.org/details/in.ernet.dli.2015.61071.
[43] Kindsvater, C.E. (1958). River Hydraulics. Geological Survey Water-Supply Paper 1369-A. United States Government Printing Office, Washington.
[44] Koster, E.A. (2005). The Physical Geology of Western Europe, Chapter 2: Neotectonics. Oxford University Press, p. 472.

[45] Kumanan, C.J. (2001). Remote sensing revealed morphotectonic anomalies as a tool to neotectonic mapping, experience from south India. Centre for Remote Imaging, Sensing and Processing, Singapore.

[46] Markovic, M., Pavlovic, R., Cupkovic, T. and Zivkovic, P. (1996). Structural Pattern and Neotectonic activity in the wider Majdanpek area, NE Serbia, Yugoslavia. Acta Montanistica Slovaca, Rocnik 1, pp. 151 – 158.

[47] Matthews, R. (2003). The Archaeology of Mesopotamia. Theories and Approaches, Approaching the past, Milton Square: Routledge, ISBN 0-415-25317-9.

[48] Mello, C.L., Metelo, C.M.S., Suguio, K. and Kohler, C.H. (1999). Quaternary sedimentation, neotectonics and evolution of the Doce river middle valley lake system (SE Brazil). Revista do Instituto Geologico, IG Sao Paulo, Vol. 20, No. 1/2, pp. 29 – 36.

[49] Miquel, A., Brice, W.C., Sourdel, D., Aubin, J., Holt, P.M., Kelidar, A., Blanc, H., MacKenzie, D.N. and Pellat, Ch. (2011). "ʿIrāḳ". In: Bearman, P., Bianquis, Th., Bosworth, C.E., van Donzel, E., Heinrichs, W.P., Encyclopaedia of Islam, 2nd edit. Leiden: Brill Online, OCLC 624382576.

[50] Nutzel, W. (1979). On the geographical position of as yet unexplored early Mesopotamian cultures: contribution to the theoretical archaeology. Journal American Orient. Soc., Vol. 99, No. 2, pp. 288 – 296.

[51] Ortega, J.A., Razola, L. and Garzón, G. (2014). Recent human impacts and change in dynamics and morphology of ephemeral rivers. National Hazards Earth Syst, Vol.14, Issue 3, pp. 713 – 730. https://doi.org/10.5194/nhess-14-713-2014, 2014.

[52] Philip, G. and Virdi, N.S. (2007). Active faults and neotectonic activity in the Pinjaur Dun, NW Frontal Himalaya. Wadia Institute of Himalayan Geology, 33, Gen., Dehra Dun – 248 001, India.

[53] Pournelle, J.R. (2013). Marshland of Cities: Deltaic Landscapes and the Evolution of Civilization.

[54] Sissakian, V.K. (2013). Geological evolution of the Iraqi Mesopotamia Foredeep and Inner Platform, and near surrounding areas of the Arabian Plate. Journal of Asian Earth Sciences, 72 (2013) pp. 152–163, Elsevier Publication, Journal homepage: www.elsevier.com/locate/jeseas.

[55] Sissakian, V.K. and Deikran, D.B. (1998). Neotectonic Map of Iraq, scale 1:1,000,000. Iraq Geological Survey Publications, Baghdad, Iraq.

[56] Sissakian, V.K. and Fouad, S.F. (2012). Geological Map of Iraq, scale 1:1,000,000, 4th edition. Iraq Geological Survey Publications, Baghdad, Iraq. www.iasj.net/iasj?func=fulltext&aId=99666

[57] Sissakian, V.K. and Abdul Jab'bar, M.F. (2013). Alluvial Fans of the Hab'bariyah Depression, Iraqi Western Desert. Iraqi Bulletin of Geology and Mining 9, No. 2, pp. 27 – 45.

[58] Sissakian, V.K., Al-Ansari, N. and Knutson, S. (2013). Sand and dust storm events in Iraq. Natural Science, Vol.5, No. 10, pp. 1084–1094. http://dx.doi.org/10.4236/ns.2013.510133

[59] Sissakian, V.K. Shihab, A.T., Al-Ansari, N. and Knutsson, S. (2014). Al-Batin Alluvial Fan, Southern Iraq. Engineering, 2014, Vol. 6, p. 699 – 711. Published online, October, 28, 2014 in SciRes. http://www.scirp.org/journal/ eng. http://dx.doi.org/10.4236/3ng.2014.61 1069. DOI: 10.4236/eng.2014.611069.
[60] Sissakian, V.K., Shehab, A.T., Al-Ansari, N. and Knutson, S. (2017). New Tectonic Findings and its Implication on Locating Oil Fields in Parts of Gulf Region. Journal of Earth Sciences and Geotechnical Engineering, Vol. 7, No. 3, 2017, pp. 51 – 75. ISSN: 1792-9040 (print version), 1792-9660 (online), Scienpress Ltd.
[61] Sissakian, V.K., Abdul Ahadb, A.D., Al-Ansari, N. and S. Knutsson, S. (2018). Neotectonic Activity from the Upper Reaches of the Arabian Gulf and Possibilities of New Oil Fields. Geotectonics, Vol. 52, No. 2, pp. 240–250.
[62] Sousa, A. (1963). The Floods of Baghdad in History, Dar Al-Adib Press, Baghdad (in Arabic).
[63] Sousa, A. (1983). History of Mesopotamian civilization in the light of irrigation agricultural projects: Recent archaeological discoveries and historical sources. Al-Huriya Printing House, Baghdad, Iraq.
[64] Tanoli, S.K. (2014). Sedimentological evidence for the Late Holocene sea level change at the Enjefa Beach exposures of Kuwait, NW Arabian Gulf. Arabian Journal of Geosciences, Vol. 8, No.8, pp. 1 – 14.
[65] Walker, M., Johnsen, S., Rasmussen, S.O., Popp, T., Steffensen, J.P., Gibbard, P., Hoek, W., Lowe, J., Andrews, J., Bjorck, S., Cwynar, L. C., Hughen, K., Kershaw, P., Kromer, B., Litt, T., Lowe, D. J., Nakagawa, T., Newnham, R., and Schwander, J. (2009). Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records. Journal Quaternary Science, Vol. 24, pp. 3 – 17. ISSN 0267-8179.
[66] Wilkinson, T. J. (2000). Regional Approaches to Mesopotamian Archaeology: The Contribution of Archaeological Surveys. Journal of Archaeological Research, 8 (3): 219 – 267, doi:10.1023/A:1009487620969, ISSN 1573-7756.
[67] Woldai, T. and Dorjsuren, J. (2008). Application of remotely sensed data for neotectonic study in Western Mongolia. Commission VI, Working Group V. Conference: ISPRS 2004: Proceedings of the XXth ISPRS Congress: Geo-imagery bridging continents, Volume: Comm. VI WG VI/V. pp. 1192-1196.
[68] Williams, P.B. (2001). River Engineering Versus River Restoration. ASCE Wetlands Engineering & River Restoration Conference, Reno, Nevada.
[69] Woolley, L. (1938). Ur of the Chaldees. Pelican Books, pp. 18 – 21.
[70] Yacoub, S.Y. (2011a). Geomorphology of the Mesopotamia Plain. Iraqi Bulletin of Geology and Mining, Special Issue No. 4, pp. 7 – 32.
[71] Yacoub, S.Y. (2011b). Stratigraphy of the Mesopotamia Plain. Iraqi Bulletin of Geology and Mining, Special Issue No. 4, pp. 47 – 82.