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Geomorphology of the Mesopotamian Plain: A Critical Review

Varoujan K. Sissakian[1,2], Nadhir Al-Ansari[3], Nasrat Adamo[4] , Mohammed Kh. Al-Azzawi[5], Mukhalad Abdullah[6] and Jan Laue[7]

Abstract

The Mesopotamian Plain is part of the large Mesopotamia which extends in Iraq and surrounding countries. The plain is almost flat and vast lowland, which has clearly defined physiographic boundaries with the other surrounding physiographic provinces. From the north and east, it is limited by the Low Amplitude Mountainous Province. From the west, the upper part is limited by Al-Jazira Plain, whereas in the lower part by the Western Desert Province. From the south it is limited by the Southern Desert Province. The plain is a huge accumulational geomorphologic unit, where the fluvial, lacustrine, and Aeolian landforms prevail; the fluvial units being the abundant among others. However, estuarine and marine forms also are developed, but restricted to the extreme south-eastern reaches of the plain. Moreover, some erosional landforms are developed in different places, but are not well expressed. In the central eastern part, large alluvial fans are developed with five stages covering vast areas along the Iraqi – Iranian international borders. The geomorphic units are classified according to origin, geomorphic position, and lithology. Some of the significant features are described with some details.

Keywords: Mesopotamian plain, fluvial units, Alluvial fans, Marshes, Aeolian forms.

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[1] Lecturer, University of Kurdistan Hewler
[2] Private Consultant Geologist, Erbil
[3] Professor, Lulea University of Technology, Sweden
[4] Consultant Dam Engineer, Sweden
[5] Chief Geologist, Iraq Geological Survey, Baghdad
[6] Private Engineer, Baghdad, Iraq
[7] Professor, Lulea University of Technology, Sweden

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1. Introduction

Mesopotamia is a historical region in West Asia 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 ancient Greek. The oldest known occurrence of the name Mesopotamia dates to the 4th century BCE, 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, also known as the Jazira, 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 et al., 2011). In modern scientific usage, the term Mesopotamia often also has a chronological connotation. 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, 2013)

The Mesopotamian Plain; however, is different 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 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 (Figure 2).

2. Geomorphology of the Mesopotamian plain

2.1 Topography

The Mesopotamian Plain is almost a flat and vast lowland, which has clearly defined physiographic boundaries with the other surrounding physiographic provinces. From the north and east, it is limited by the Low Amplitude Mountainous Province. From the west, the upper part is limited by the Al-Jazira Plain, whereas in the lower part by the Western Desert Province. From the south it is limited by the Southern Desert Province, see Figure 3 (Sissakian and Fouad, 2012).

The Mesopotamian Plain is a huge accumulational geomorphologic unit, where the fluvial, lacustrine, and Aeolian landforms prevail. However, estuarine and marine forms also are developed, but restricted to the extreme south-eastern reaches of the plain. Moreover, some erosional landforms are developed in different places, but are not well expressed. The geomorphic units are classified according to origin, geomorphic position, and lithology. Some of the units involve different geomorphic features, which are described with some details taking in consideration their order and importance.

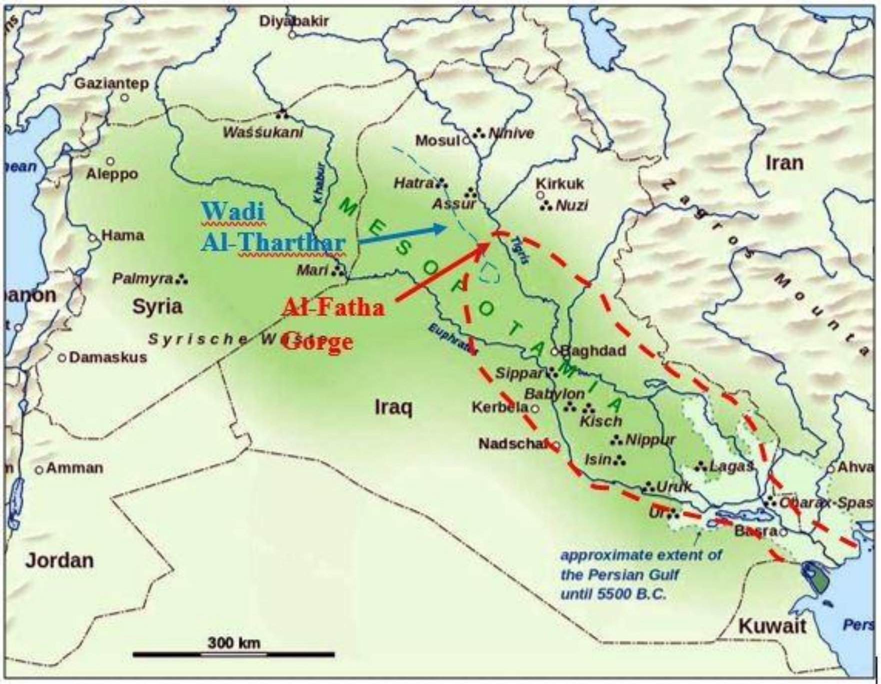

Figure 2: Tentative limits of the Mesopotamian Plain within the Mesopotamia (Limited by the authors using dashed red line).

The surface of the Mesopotamia Plain is almost flat with local depressions which are not more than one meter in depth, but are very large; attaining few square kilometres. The surface has an imperceptible gradient from northwest to the southeast. Its elevation drops southwards with an average of 1m/1Km, in its northern sector from Baiji to Balad towns. From Balad to Baghdad it drops 1m each 3km, and it decreases to 1m/20Km south of Baghdad to the head of the Arabian Gulf. However, the plain is sloping down gradually, but more steeply than the slopes southwards from the foothills of Himreen Mountain. Along the eastern borders of the plain; it slopes towards the flood plain of the Tigris River. In its western borders, the plain slopes down from the desert plateaus to the Euphrates River's flood plain.

2.2 Geomorphological Units

The landforms of fluvial origin; mainly flood plains are the most common accumulation forms in the Mesopotamia Plain. They are related to the activity of the Tigris and Euphrates Rivers, beside the foothill rivers (wadis) of Himreen Mountain.

2.2.1 Units of Alluvial Origin

Seven units are developed in the Mesopotamian Plain of alluvial origin. They are described hereinafter.

2.2.1.1 Fluvial Terraces

The most extensive terraces recorded within the Mesopotamia Plain are the fluvial terraces of the Euphrates River, near Falluja town. They are developed in two separate levels. The relics of the higher terrace level are about 23m above the recent water level of the river and along its right bank. The lower terrace level is recorded east of Falluja and near Iskandariyah town, farther towards the south. The top of this terrace level is about 10m above the water level of the Euphrates River near Falluja and reaches a maximum of 14 m above the surrounding flood plain, around Iskandariyah town (Yacoub, 2011).

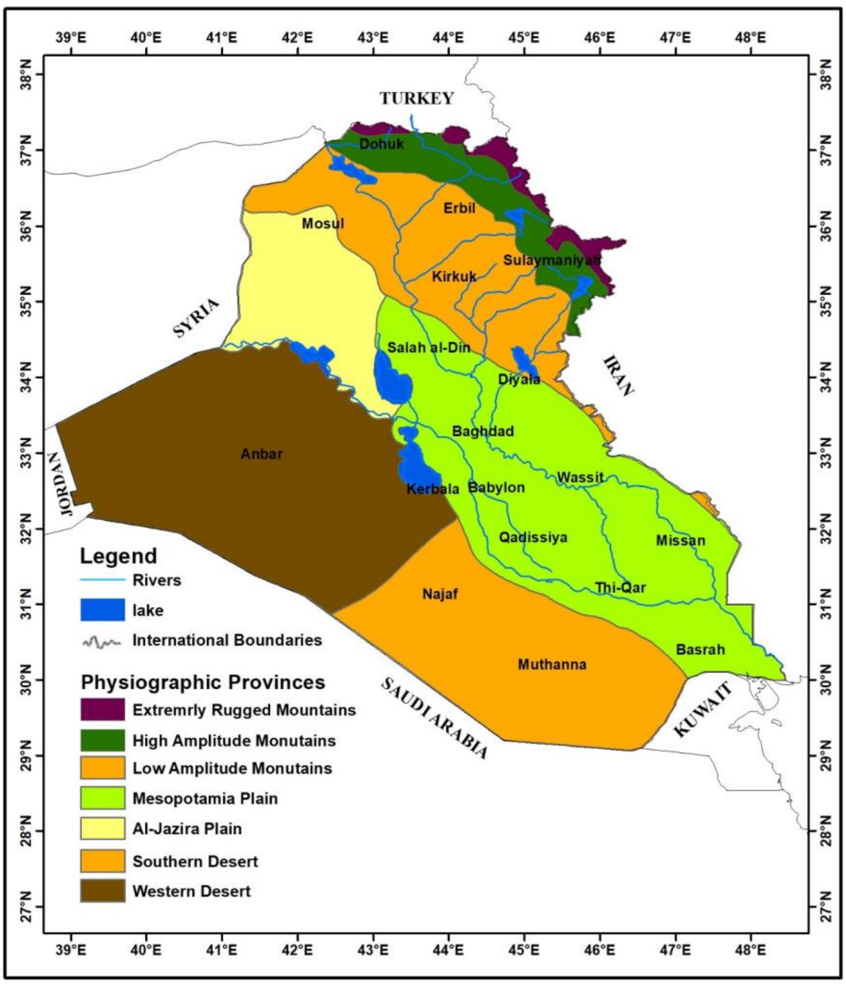

Figure 3: Physiographic Provinces in Iraq (After Sissakian and Fouad, 2012).

Alongside the courses of the foothill rivers (wadis), fluvial terraces of limited extent are also developed. These terraces are restricted to the outlets of the rivers where they merge into the Mesopotamia Plain. They are well preserved on the banks of ephemeral rivers: Diyala, Galal AlNafut, Galal Har'ran, Galal Badra, Chab'bab, and Al-Teeb. It is worth to mention that “Galal” means “wadi”. Usually, two levels were recorded, the surface of the higher level is around (7 – 18) m, above the recent river bed. The lower level occurs few to 6 m above the recent water courses. These terraces often pass gradually into the alluvial fan sediments, which are very well developed alongside the eastern limits of the Mesopotamian Plain (Figure 4). The pebbles of the terraces are composed mainly of carbonates and silicates, with rare igneous and metamorphic rocks. They are mainly rounded with average size that ranges from (3 – 10) cm. However, larger sizes and other pebble shapes are present too.

2.2.1.2 Alluvial Fans

Three alluvial fan systems occur on the peripheral parts of the Mesopotamian Plain; these are:

1-Al-Fatha Alluvial Fan: The origin of this huge gravel accumulation was a matter of debate since early fifties of the last century. The gravel body was considered to belong to the Upper Bakhtiari Formation (Bolton, 1956 and Bellen et al.1959), and as terraces of the Tigris River (Ibrahim and Sissakian, 1975; Hassan and Al-Jawadi, 1976, and Salim, 1978). However, Jassim (1981) considered it as a fan-like, which was proved by Hamza et al. (1990); Yacoub et al. (1990) and Yacoub, 2011). Actually, it is a huge fan occupying the northern part of the Mesopotamia Plain.

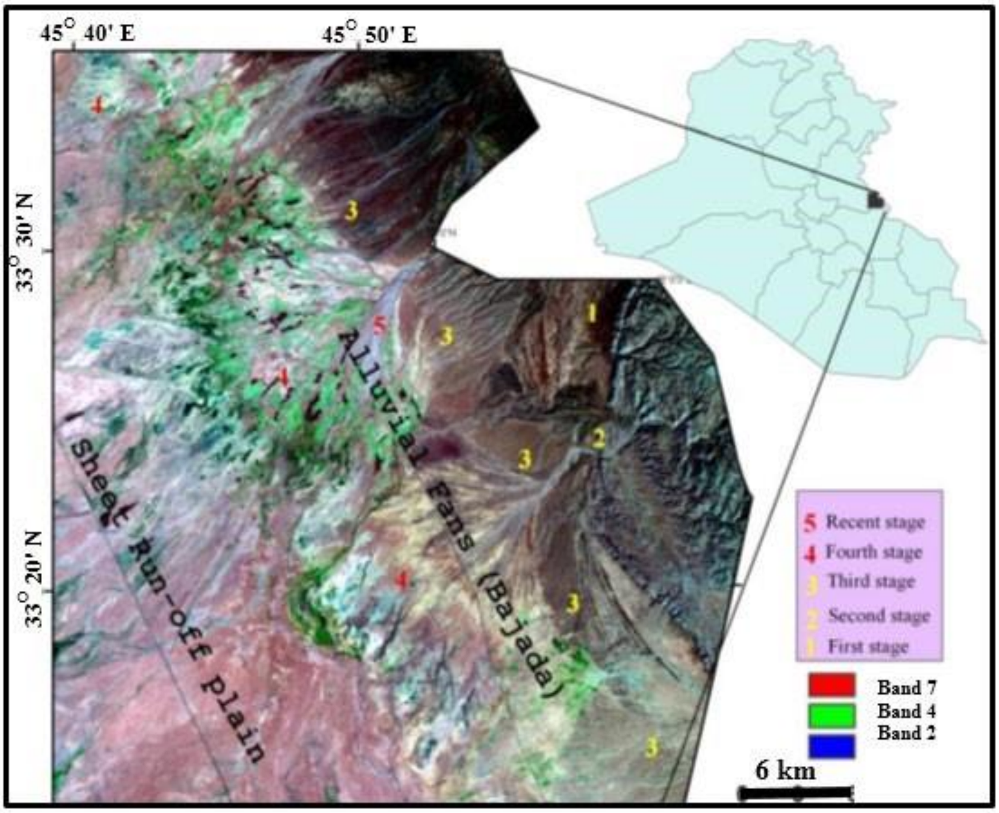

Figure 4: Satellite image (ETM) shows different stages of alluvial fans in the eastern part of the Mesopotamian Plain (After Yacoub, 2011).

The surface of Al-Fatha Alluvial Fan is characterized by slight and broad undulations with shallow and wide valleys, and depressions, which reflect high porosity of the fan sediments. It is covered by gypsiferous soil and gypcrete (a highly gypsiferous and compacted hard soil) with residual gravels scattered on the surface and locally in the uppermost soil horizon.

Geographically, the eastern boundary of the fan with the foothill slope of Himreen Range is clear and marked by smooth brake in the slopes. In the west; the fan is terminated by the eastern cliff of Al-Tharthar Lake. South of Al-Tharthar Lake, the boundary of the fan is diffused with the terrace sediments of the Euphrates River. South of Balad town, the boundary is sharp with the younger flood plain sediments of the Tigris River, represented by a break in the slope. However, Jassim and Goff (2006), deduced that the fan disappears bellow the flood plain sediments of the Tigris River south of Balad town.

2-Alluvial Fans System of the Eastern Mesopotamia Plain: This is a complex of alluvial fans system developed on the eastern margin of the Mesopotamian Plain alongside the foothill slopes. The fans extend particularly from the north of Mandali town, in the northwest, to north of Amara city, in the southwest. The alluvial fans form continuous belt of Bajada, with width exceeding 15 Km. Sizes and extensions of the individual alluvial fans varies from few kilometres to more than hundred square kilometres. The surface of the fans is flat and gently sloping from the apex towards the flanks, usually coinciding with the drainage pattern. The alluvial fans are developed in different stages, maximally five stages were recorded (Figure 4).
The formation of these five stages of alluvial fans is attributed to the climatic oscillations during the Pleistocene and could be correlated with pluvial and inter-pluvial phases of the Quaternary Period. However, the effect of the Neotectonic activity represented by the uplifting of Himreen structure versus the subsidence of the Mesopotamian Plain cannot be excluded.

3-Alluvial Fans Systems of the Western and Southern Mesopotamia Plains: This system of alluvial fans is developed at the outlets of the main valleys draining the Western and Southern Deserts. Their sediments are, in some places, buried beneath the Mesopotamian flood plain. Aqrawi *et al*. (2006) in Jassim and Goff (2006) have mentioned that these fans are located along the Euphrates Boundary Fault, where a sudden drop in gradient occurs. Among these alluvial fans, only three are very large: **1)** Najaf – Karbala Fan, which was originated from Wadi Lisan and covers the Najaf – Karbala Plateau, **2)** Dibdibba Fan, which covers the major part of
Dibdibba Plain, SW of Basra city, and **3)** Al-Batin Fan, which was originated from Wadi AlBatin. The sediments of the first and second fans are rich in quartz sands and silicate (igneous origin) gravels, with fewer amounts of carbonate gravels. The catchment area of the first fan lies mainly in the Western Desert and partly in Saudi Arabia, whereas that of the second fan lies mainly in Saudi Arabia. The catchment area of the third fan lies in Kuwait and Saudi Arabia; it consists of four stages (Yacoub, 2011). The length and the maximum width of the fan are 110.192 Km and 119.1 Km, respectively, whereas the slope along its length is 0.7˚ (Sissakian et al., 2014). Some other small fans are also developed by the valleys which drain the Western Desert (Sissakian and Abdul Jab'bar, 2014) and Southern Desert (Zaini and Abdul Jab'bar, 2015).

2.2.1.3 Sheet Run-off Plain

The sheet run-off plain is the middle part of the piedmont plain. It has close connection with the peripheral part of the alluvial fans and terminates in local erosional base level, which is represented by Hor Al-Shuwaicha shallow depression. The plain extends in NW – SE direction, parallel to the alluvial fans unit, its width reaches about 35 Km (Figure 4). The sheet run-off plain is very flat and gently sloping towards the southwest, with average gradient of 1.1m/1Km.

The flat surface, in some places is scoured by narrow water courses in the form of rills and streams with very intricate drainage pattern. This stream pattern starts usually as a single stream channel then downstream bifurcates into countless number of smaller branches and rills. These water courses are ephemeral and/ or periodical; during heavy rains they join each other forming the sheet floods. The sheet run-off plain is generally barren land, except the moist parts alongside its boundary with the alluvial fans, and the water courses where dense natural vegetation is grown (Yacoub, 2011).

2.2.1.4 Flood Plains

The flood plains of Euphrates, Tigris, Shatt Al-Arab, Diyala, Adhaim Rivers, and foothill rivers (wadis) are the major morphologic features of the Mesopotamian Plain system and cover the majority of the plain. They generally comprise of fine clastics (alternation of clay, silt and sand). Each individual flood plain has rather similar minor morphologic features, such as meandering belt, natural levees, crevasse splays and flood basins. However, they differ in aerial extension, surface relief, and nature of development. These differences occur from one flood plain to another, as well as, from place to another within the same river flood plain. This is attributed to the size of the river and the type of the exposed rocks in the catchment area.

1-Euphrates River Flood Plain: The upper reaches of the flood plain of the Euphrates River, near Al-Ramadi city is limited between two erosional cliffs of (6 – 10) m height, above the surface of the flood plain. These cliffs are built up of pre-Quaternary sediments at the bottom and terrace gravels at the top. The flood plain, is limited within the width of the strongly meandering belt due to the low gradient of the Euphrates River, which is about 10Km. The flood plain gradually widens downstream, starting from Falluja town. The right bank of the flood plain is always limited by the Western and Southern Desert Plateaus, whereas the left bank is not remarkable; since the sediments of Euphrates River pass gradually into the sediments of Tigris River. Further downstream, the Euphrates River starts to build its natural levees, which attain few meters above the normal water level of the river with variable width (1 – 3Km).

The flood basins are flat floored depressions following the natural levees, such as the basins east of Kifil town. They are developed between the course of the Euphrates River and its distributaries. The most significant distributaries of the Euphrates River are Shatt (River) Al-Hilla and its continuity Shatt Al-Diwaniya, beside several others between Al-Shamiyah town and Samawa city.

2-Tigris River Flood Plain: The flood plain of the Tigris River between Baiji town and Tikrit city is limited 3 km within its meandering belt, in the northern sector of the Mesopotamian Plain. South of Tikrit city becomes narrower and bounded by 10m high erosion cliffs. Two flood stages with height difference of

(1.5 – 2)m could be recognized within the meandering belt. Downstream of Balad town, the flood plain considerably widens, particularly the western bank, whereas its eastern bank is rimmed by the flood sediments of the Adhaim River, and farther southwards interfingers with the flood plain sediments of the Diyala River. In the central sector of the Mesopotamia Plain (south of Baghdad – north of Amara), the gradient of the Tigris River is less than 5 cm/Km. This very law gradient had caused extensive deposition as it is manifested by wide natural levees and extensive crevasse splays. The width of the natural levees reaches 5 Km between Suwairah town and Kut city, and their tops reach (3 – 4)m above the surrounding flood basins. The width of the levees decreases down Kut city, because the Shatt Al-Ghar'raf distributaries' and Old Dujalia River drain enormous amount of water from the Tigris River. The crevasse splay activity is very expressive and significant feature of the flood plain, between Azzizia and Kumait towns. The aerial extension of some crevasse splays reaches even few hundred square kilometers. Hor Al-Shuwaicha (north of Kut) and Hor Al-Sannaf (north of Amara), are the most expressive and active among the other marshes in the area. On the right bank of the Tigris River, NW – SE system of flood basins and depressions are connected with Hor Al-Dalmaj, which indicates the westernmost reach of the flood plain. Another extensive flood basin is Hor Al-Sa'diya between Tigris and Old Dujalia Rivers. The flood plains of Shatt Al-Ghar'raf and Old Dujalia River belong to the flood plain of the Tigris River. Both rivers formed less extensive natural levees, crevasses and many local flood basins. The crevassing of Shatt Al-Ghar'raf is still active and partly connected with irrigation canals, resulting in a wide flood plain, its width reaches more than 40 Km. The Old Dujalia River, is no more active, its flood plain is almost barren and highly affected by Aeolian activity. The most expressive morphological features in this plain are the abandoned river troughs, the relics of old irrigation canals and hillocks; locally called "Tells". The Tigris River in Amara vicinity bifurcates and loses its sedimentary charge in form of lacustrine delta forming the northern edge of the marshes. Two other deltas exist. The first is related to the discharge from Al-Ghar'raf River, whereas the second is inactive and related to the Old Dujalia River branches, both form the northwestern edge of the marshes. South of Amara city, when the Tigris River crosses the marshes, its flood plain becomes narrower and represented by natural levees, which are bounded by the marshes from both sides. One of the expressive morphologies features in this sector is the cut-off meandering loops, which had developed three distinct oxbow lakes separated completely from the main river channel. Similar oxbow lakes are also developed in the central part of the Tigris flood plain, near Azzizia and Suwairah towns. Flood plains along the course of the Tigris River show maximum of four stages in two main localities: 1) Near the junction of Adhaim River, 2) Between Azziziya town and Kut city. The height differences between the levels do not exceed few meters, their width varies from few hundred meters to three kilometers; their length may reach 10Km.

3-Adhaim River Flood Plain: The first tributary of the Tigris River within the Mesopotamian Plain is the Adhaim River. Its flood plain occupies the northeastern part of the main flood basin. The flood plain is characterized by barren flat terrain and convex form. This is attributed to very gently sloping downstream and outward of the river. Hamza (1997) considered it as an alluvial fan (Adhaim Fan). The natural levees are well developed; however, they are partly affected by badland erosion. Adhaim River had deposited four stages of flood plain; the highest (older) stage has only wide extensions, whereas the others are restricted inside the valley. Wadi Shta'it is one of the expressive micro-morphologic features in the flood plain. It is a shallow abandoned trough in form of ephemeral valley with a width that reaches 5 km with two stages of flood plain. The width and meandering characters of this trough deduce its natural origin, rather than artificial irrigation canal, and it might be the paleo-course of Adhaim River.

4-Diyala River Flood Plain: The second and largest tributary of the Tigris River within the Mesopotamia Plain is the Diyala River. Its flood plain is a flat terrain, very gently sloping towards south and southwest, with micro-relief caused by silted up irrigation canals (both ancient and active). The river flows towards the southwest to Ba'quba city and then it changes to the south and flows parallel to the Tigris River, following the main trend of the axis of the Mesopotamian Flood Basin. The natural levees are well developed along the right bank of the river and locally developed on the opposite side. This could be attributed to intensive lateral and bad land erosion, which had destroyed the levees in some places during successive strong flood conditions, during the last decades. The width of the natural levees ranges from few hundred meters to 2 km. Two stages of flood plains are developed, the surface of the higher one, which is the most extensive is around 5 m, whereas the second is around 3 m, above the present river level.

5-Foothill Rivers (Wadis) Flood Plains: Many foothill rivers (wadis) form distinct and elongated flood plains. They are generally narrow (1 – 2 Km) at their upper reaches, then widen downstream reaching about (5 – 7) Km, and even more than 10 Km. They are developed in two stages: The higher stage forms the majority of the flood plain system; its surface is (6 – 8) m above the river level. The natural levees laterally pass to the sheet-run off plains, and disappear at the lower reaches of the flood plains. The lower (younger) stage is restricted to the river channels. The flood plains are terminated in form of small fan shaped deltas at the ends of river courses in shallow depression, which are situated between the Tigris flood plain and sheet runoff plain. Among all those foothill rivers (wadis), only Al-Chab'bab River reaches and drops in the Tigris River course.

6-Shatt Al-Arab Flood Plain: Shat Al-Arab is formed from the joining of both Tigris and Euphrates Rivers after leaving the marshes at Al-Qurna town; it flows in smoothly meandered channel. Shat Al-Arab is also fed from Hor Al-Hammar by Garmat Ali channel (the outlet), just north of Basra city. It is rimmed by low natural levees of 1 m height above the water level. Their width reaches up to 2Km on both sides of the river. The flood plain between Al-Qurna and Basra is rimmed by marshes on the right side and by shallow flood basins on the left side. Downstream of Basra, the flood plain passes into estuarine sabkhas, on the right bank and the flood plain of Karun River on the other side.
Two abandoned river troughs west of Shatt Al-Arab flood plain are conspicuous morphologic features which most probably represent the former courses of Shatt Al-Arab. They are northwest of Al-Siba town and extend around 50 km southwards, almost parallel to the recent course and disappear within the estuarine sabkha. The width of these troughs is (200 – 400) m, which is nearly similar to the recent one. The width and alignments of both troughs are good indications for migration of the Shat Al-Arab due to neotectonic activity (Sissakian et al., 2018). The Shatt Al-Arab course widens at its lowermost stretch forming costal marshes, and then terminates by sub-aquatic marine delta at the margin of Arabian Gulf. The Shatt Al-Arab is affected by the input of Karun River; it is very clear at their conflux north of Al-Siba town (Yacoub, 2011).

2.2.1.5 Shallow Depressions

One of the common morphological features in the Mesopotamian Plain is the very flat and smooth shallow depressions. Their coverage areas vary from few hundred square meters to many hundreds square kilometres. The small and local depressions are essentially developed due to micro-relief within the flood plain. The more extensive shallow depressions are the flood basins of the main rivers and the playas, which are developed between the sheet run-off plain and the Tigris River flood plain. The more active basins are those located west of the Tigris River, between Kut and Amara cities, as well as the basins between the main branches of the Euphrates River, south of Shamiyah town. The more extensive shallow depressions are those situated near the contact between the Mesopotamian Plain and the Western Desert following Abu Jir – Euphrates Active Fault Zone. They extend from Bahir Al-Najaf to south of Nasiriya city; partly isolated by sand dunes with variable width; reaches in some places up to 20 Km. The largest one is Al-Slaibat Depression. These depressions are intensively affected by Aeolian activity and are characterized by buffy surface, resulted due to the presence of salt mantle (Yacoub, 2011).

2.2.1.6 Marshes (Ahwar) and Lakes

In the northern and central sectors of the Mesopotamian Plain, there are many individual marshes and lakes. The marshes can be developed in any shallow depression. The marshes and lakes system of the southeastern part of the Mesopotamian Plain are rather complicated, and might be developed and survived not only due to tectonically active subsiding land (Lees and Falcon, 1952), but also due to very low sedimentation rates that prevailed in the marshes region after total regression of the sea influence since about 2500 years (Aqrawi, 1993). Many authors such as Purser (1973); Larsen and Evans (1978) and Yacoub et al. (1981) have confirmed that the marshes region has been more influenced by eustatic sea level changes and deltaic progradation, rather than tectonic events. The marshes and lakes system underwent big changes during the last three decades due to oil exploration operations and drying them. The marshes were distributed on three main areas, named: Hor Al-Huwaizah (east of the Tigris River), Central Marshes (west of the Tigris River) and Hor Al-Hammar (south of the Euphrates River). The water depth varies from few decimeters to 2 m, exceptionally reaches (3 – 4) m, in Al-Hammar Lake. Many open lakes were in the marshes; they were free of vegetation; with dimensions varying from few to hundred square kilometers. Two main brackish-water lakes called: Khuraiz Al-Malih and Al-Luqait were also present in the marshes; formed due to cut off from Al-Hammar Lake by sand barriers. Inactive (dry) marshes are another variety of marshes, which are dried either due to natural reasons or man activity.

The shallow depressions, especially those situated along the western and southern margins of the Mesopotamian Plain, in the dry marshes, playas and periodic lakes are filled with sabkhas. They are resulted either due to intensive evaporation of salty water, or rising of the shallow groundwater to the surface like Hor Al-Sannaf. Near Hor Al-Dalmaj, west of Kut extensive sabkhas are developed due to the presence of drainage canal system. Between Basra and Khor Al-Zubair, the estuarine sabkha covers the flat areas. It is considered as estuarine, because it is resulted by combined action of seawards progradation of the coast line and flood plain of Shatt Al-Arab (Yacoub, 2011).

2.2.2 Units of Marine Origin

Only two units of marine origin are developed in the extreme southern parts of the Mesopotamian Plain. They are described hereinafter.

2.2.2.1 Tidal Flat

The coastal muddy shore of the head of the Arabian Gulf is the tidal flat, which occupies the intertidal zone between the high and low tides, which ranges between (1 – 1.5) m. The active tidal zone extends along the coast from Al-Fao to Um Qasir.

2.2.2.2 Tidal Channels (Creeks)

These are one of the expressive degradational geomorphic features is the tidal channel system of Khor Al-Zubair. This system resembles a course of meandering river and system of dendritic tributaries merging with the adjacent sabkha. The tidal channels are the result of both lateral and vertical marine water erosion effect into unconsolidated sediments, mainly due to tidal action. However, Neotectonic activity cannot be disregarded (Sissakian et al., 2018) as can be seen from many indications (Fog. 5). The tidal channels are narrow and gradually widen towards the main channel, Khor Al-Zubair, which reaches 1Km, in width (Figure 5).

Figure 5: Left, aerial photograph (General Directorate of Survey, 1962); right, satellite image, 2006. The tidal channels system of Khor Al-Zubair. Note the differences due to Neotectonic activity.

2.2.3 Units of Aeolian Origin

Only three units of Aeolian origin are developed in different parts of the Mesopotamian Plain, especially in dry and barren lands. They are described hereinafter.

2.2.3.1 Sand Dunes

These are the most expressive morphologic form of the Aeolian origin. The most prevailing type is the Barchan; other types like Transverse, Elongated, Climbing and Falling are rare. The height of a Barchan dune is about (4 – 5) m, exceptionally reaches more than 10 m south of Nasiriya city. The Barchans are either active or fixed by thin muddy soil mantle. The fixed Barchans are subjected to wind deflation activity, whereas, the active Barchans are creeping towards the main wind direction; influencing the adjacent areas, which are locally cultivated, as west of Bahir Al-Najaf. The creeping of the sand dunes is progressively increasing during the last decades, which led to increase of the desertification phenomenon, particularly in the Mesopotamia Plain.

2.2.3.2 Sand Sheets

These are usually associated with the sand dune. The drifting sand sheets have usually developed ripple marks on the surface. They are partly fixed either by vegetation or by thin soil mantel, such as in Baiji and Mukdadiya vicinities, they are subjected to wind deflation.

2.2.3.3 Nabkhas

These are the simplest Aeolian forms, commonly developed on the leeward side of shrubs and other forms of scattered vegetation. They are found either within the sand fields or as scattered patches in the barren lands, or depressions. Their lengths vary within a meter or locally few meters and their heights may reach 1 m and very rarely more.

2.2.4 Units of Degradational Origin

The units are result of fluvial or Aeolian deflation; only two units are developed in the Mesopotamian Plain. They are described hereinafter.

2.2.4.1 Fluvial Degradational Forms

The lateral erosion and vertical incision are the most common degradational (denudational) features of the main rivers, which lead to the development of flood plain stages. Among these features are ox-bow lakes, along the channels of the main rivers. Good examples are developed in the Tigris River flood plain downstream of Azziziya and north of Nu'amaniyah towns. The same kinds are visible within the Euphrates and Diyala Rivers meandering belts. The fluvial erosion form, of the foothill rivers (wadis) appear as entrenchment of the rivers into their alluvial fans, or to the sheet run-off plain in form of rills and gullies. Bad land is developed in different locations within the Mesopotamia Plain. Good examples could be seen along the banks of the Tigris River between Baiji and Samarra towns, and along the banks of Adhaim River.

2.2.4.2 Aeolian Deflation Forms

Wind erosion is affecting during thunder storms on surface of barren flood plains, and the surface of the sheet run-off plain. They commonly affect the fixed sand dunes in different Aeolian fields.

2.2.5 Unit of Anthropogenic Origin

The Mesopotamian Plain was the cradle of civilization. Therefore, a lot of anthropogenic forms are present because of human's activities, which have been living in the Mesopotamia Plain. These geomorphic forms are: irrigation canals, ancient settlements and artificial tells (hillocks). The irrigation canals often form elongated earth dykes with variable lengths, range from few to several tens of kilometers, some of them reach more than 100 Km. Their average height is about 2.5 m. An exceptional long and historical irrigation canal is Al-Nahrawan Canal. It is considered as the longest, deepest, and largest irrigation canal ever built in the history (Buringh, 1960 and Yacoub, 2011). Its length reaches about 300 km, it extends from north of Samarra to HorAl-Shuwaicha north of Kut city. Many isolated "tells" (hills) or group of tells are distributed in the Mesopotamian Plain. The average height of the "tells" does not exceed 5m; their diameter reaches few hundreds of meters. However, some of the prominent tells reach the height of 10 m and cover an area of few square kilometers. Such tells are concentrated in groups, corresponding to main archeological sites, like Babylon, Nippur and Al-Warka (Yacoub, 2011) (Figure 6).

3. Discussion

The main topics which are discussed in the current work are: 1) the alluvial fans, 2) marshes and 3) river courses; since the other geomorphic subjects are well discussed by different researchers.

Changing of river course: Large changes of the river courses have occurred during the Pleistocene and Holocene periods. There is a big difference between the considered reasons between the archaeological and geological studies. The archaeological studied assume that all happened changes in the river courses are related to major floods and/ or constructed irrigation channels (Elison, 1978). Whereas, the geological studies assume that the main reason for changing of the river courses is the Neotectonic activities 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 and is still shifting the river course more northeast ward. Some large alluvial fans also have shifted the river courses during their growth, especially during Late Pleistocene and Holocene. 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 hydraulic, especially during large floods are also considered in majority of geological studies.

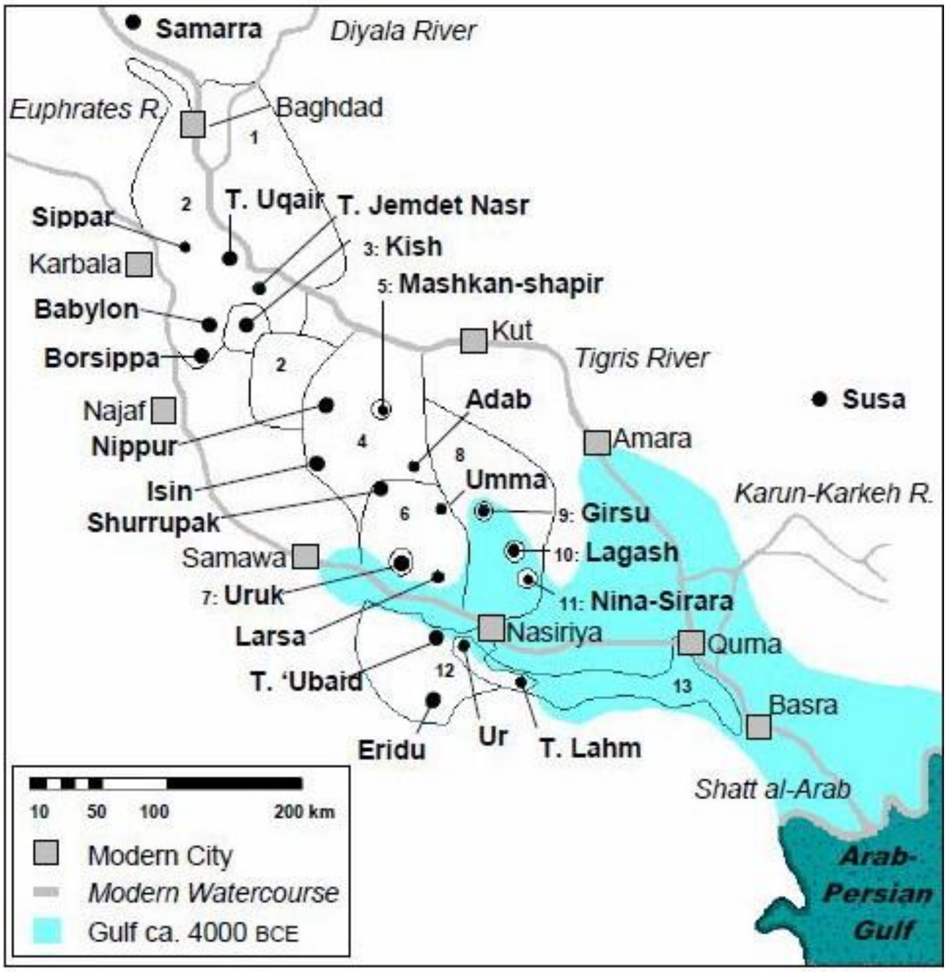

Figure 6: Major archaeological sites of Mesopotamian Plain with surveyed areas (serial numbers) and hypothetical extent of the Arabian Gulf ca. 4000 B.C. 1) Diyala, 2) Akkad, 3) Kish, 4) Nippur, 5) Mashkan-Shapir, 6) Warka (Uruk), 7) Uruk), 8) East Ghrraf, 9) Tello Region, 10) Lagash, 11) Zurghal (Nina-Sirara), 12) UR-Eridy, 13) Hammar Lake. (After Pournelle, 2013).

As well as, the presence of main irrigation channels which were constructed during early civilizations are considered too in geological studies a 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 have contributed in changing the river courses. This is attributed to the erosional forces and the power of the carried sediments in entrenching the courses of the rivers into more straight courses, especially when acute meanders were existing in the river courses and/or the irrigation channels were constructed perpendicularly along large meanders. This is called rapidly varied flow (Kindsvater, 1958).

Marshes: The marshes (Ahwar) and lakes have distinct geomorphic features and possess important sedimentary environment, being predominant in the southeast of the Mesopotamia Plain. They are rather complicated system, might be were developed and survived due to combined actions of slight tectonic subsidence, and low rates of sedimentation. Moreover, the marsh areas have been influenced by the eustatic sea level changes and deltaic progradation during the Holocene. The accurate procedure for the development of the Iraqi marshes is still a matter of debate. However, many archeological and geomorphological evidences still occur indicating that the marshes were covering vaster areas, especially southwards from the nowadays existing marshes. The location of the archaeological site; Ur (Figure 7) which is about 25 Km south of Nasiriya city along the Euphrates River is good indication that the Ur was located in wet land either marshes or the gulf. The presence of Al-Slaibat Depression which is located south of Samawa city (Figure 7) is another possible indication that the depression is a relic of ancient marsh. It was dried when the Euphrates River was shifted northwards. This also can explain the vanishing of Ur civilization. The marshes system underwent significant changes during the last three decades, which were mainly caused by human activities. The artificial drying operation of the marshes that have been conducted during the early 90's of the last century led to change the active wet marshes land to dry land with salty ponds. This dry situation continued and reached its optimum during beginning of 2003 (Figure 8). Then after, the marshes were partly rejuvenated. Nowadays, the marshes started covering more areas than the last two decades; however, not like before 90’s of the last century.

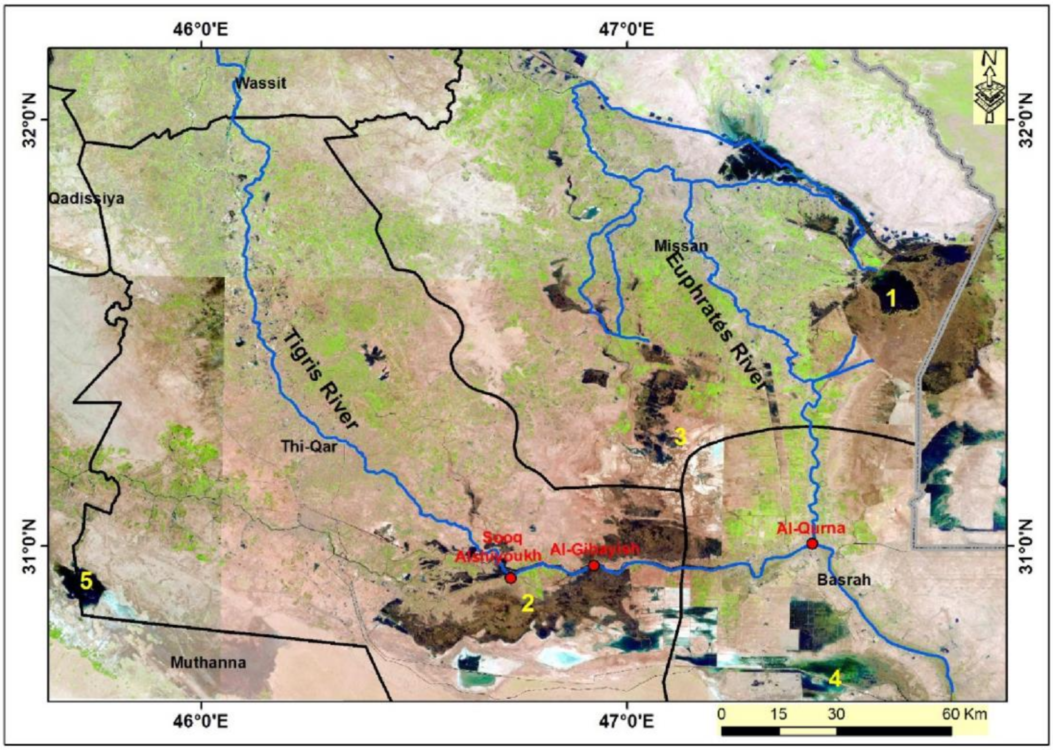

Figure 7: Satellite image of the marshes (2018). 1= Al-Huwaiza, 2= Al-Hammar, 3= northern marshes, 4= Southern marshes, 5= Al-Slaibat Depression.

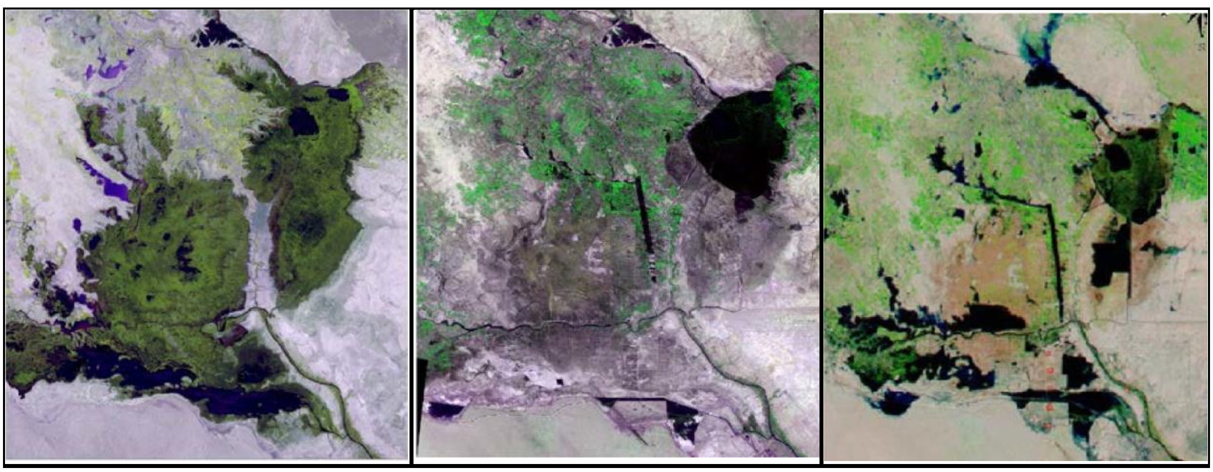

Figure 8: Satellite images illustrate the situations of the marsh areas during three stages. Left: Before drying operations. Middle: 2002, after drying. Right: 2005, reactivation of marshes (After Yacoub, 2011).

Alluvial fans: The Mesopotamian Plain includes many alluvial systems. However, careful interpretation of satellite images by the authors have revealed many alluvial fans (Figure 9) which were not described; previously. They are briefly described hereinafter.

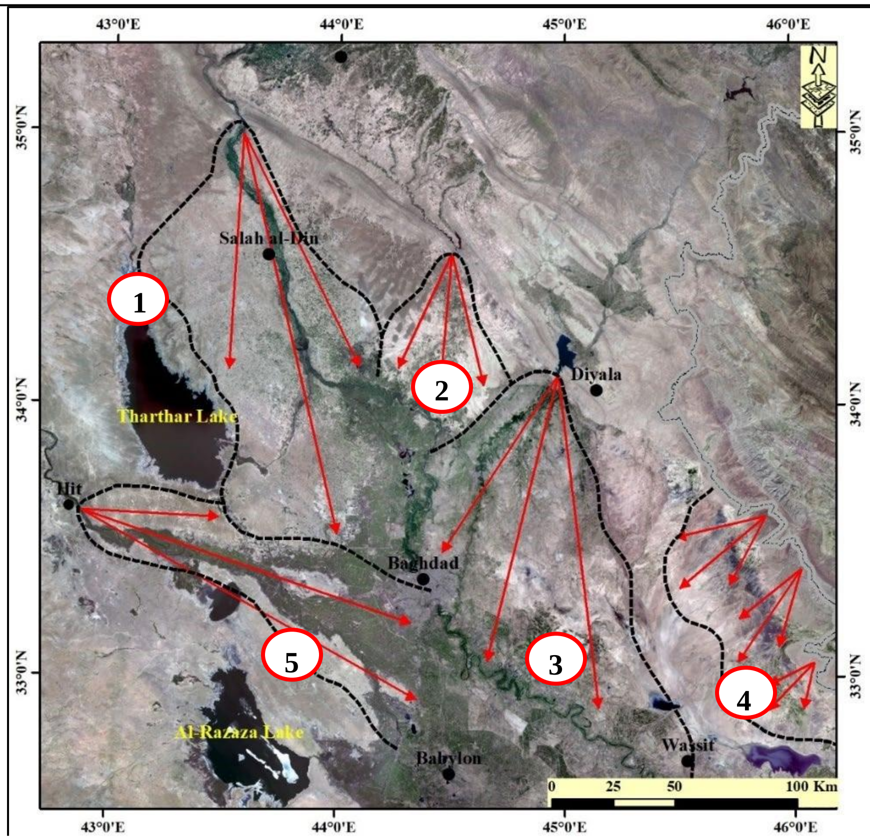

Figure 9: Satellite image of the northern part of the Mesopotamian Plain showing different alluvial fans. 1= Al-Fatha Fan, 2= Al-Adhaim Fan, 3= Diyala Fan, 4= Eastern Fans, 5= Ramadi Fan.

Al-Adhaim Alluvial Fan: It is developed by Al-Adhaim River when it enters the Mesopotamian Plain after living Himreen Mountain. The length and width of the fan is about 70 km and 50 km, respectively (Figure 9). The fans' sediments interfinger from east, west and south with Al-Fatha alluvial fan and Diyala alluvial fan sediments. The fan is of single stage type having typical fan shape (Sissakian and Abdul Jab'bar, 2014). It is worth mentioning that Hamza (1997) presented this fan but without any description.

Diyala Alluvial Fan: It is developed by the Diyala River when it enters the Mesopotamian Plain after living Himreen Mountain. The length and width of the fan is about 175 km and 85 km, respectively (Figure 9). The fans' sediments interfinger from the east and south with the flood plain sediments of perennial streams running from Iran towards Iraq and the Tigris River, respectively; whereas from the west they interfinger with the sediments of Al-Adhaim fan and towards the south with the flood plain of the Tigris River. The fan is of single stage type having typical fan shape (Sissakian and Abdul Jab'bar, 2014).

Ramadi Alluvial Fan: It is developed by the Euphrates River when it enters the Mesopotamian Plain after living the rocky terrain east of Hit town (Figure 9). The length and width of the fan is about 150 km and 50 km, respectively (Figure 9). The fans' sediments interfinger from the north with the sediments of Al-Fatha alluvial fan, whereas from the east and south with the flood plain sediments of the Tigris and Euphrates rivers; respectively. The fan is of single stage type having longitudinal fan shape (Sissakian and Abdul Jab'bar, 2014).

4. Conclusions

The main conclusions from the current work can be summarized as follows: The Mesopotamian Plain is a vast plain covered by Quaternary sediments; mainly fluvial origin with different types. The main fluvial types are the flood plain, terraces and alluvial fan sediments. The flood plain and alluvial fan sediments usually interfinger with each other. The eastern and southern (Al-Batin) alluvial fans are of malty stage fans; whereas those of the northern (Al-Fatha, Al-Adhaim and Diyala), western (Ramadi and Karbala – Najaf) fans are of single stage fans, all have typical fan shapes; except Ramadi fan which has longitudinal shape. This is attributed to the geomorphic nature of the surrounding areas of the fan which has limited the fan's shape; rather than the sediments size which plays big role in shaping of the fans. Moreover, there are some small alluvial fans with different shapes, sizes and stages usually formed by the valleys which drain the Iraqi Western and Southern deserts. In the extreme southern part, the tidal flat and sabkhas prevail covering large areas between Shat Al-Arab and the Arabian Gulf. The aeolian sediments also cover vast areas in forms of sand dunes, Nebkhas, and sand sheet cover; especially well developed between the Tigris and Euphrates rivers. Due to climatic changes, the coverage areas are extending forming desertification.

The marshes are also special geomorphic forms being deposited in special environment within the southern parts of the Mesopotamian Plain. Their locations were changed periodically with the changes of the river courses and climatic fluctuations during Pleistocene and even Holocene.

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References

[1] 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).

[2] Aqrawi, A.A.M. (1993). Implications of Sea-level Fluctuations, sedimentation and Neotectonics for the Evolution of the Marshlands (Ahwar) of Southern Mesopotamia. In: Recent Advances. L.A. Owen, I. Steward and C. Vita-Finzi (Eds.), Quaternary proceedings No.3, Quaternary Research Association. Cambridge, pp. 21-31.

[3] Aqrawi, A.A.M., Domas, J. and Jassim, S.Z. (2006). Quaternary Deposits. In: S.Z., Jassim and J., Goff (Eds.) 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, p. 341.

[4] 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.

[5] Bellen, R.C., van, Dunnington, H.V., Wetzel, R., and Morton, D. (1959). Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris.

[6] Bolton, C.M.G. (1956). Geological investigation of gravel area between Tel Ad'dair and Sumaika, near Baghdad. Iraq Geological Survey Library Report No. 268.

[7] Buring, P. (1960). Soils and soil conditions in Iraq. Published in Baghdad, p.322.

[8] Canard, M. (2011). Aal-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.

[9] Collon, D. (2011). Mesopotamia. BBC, Ancient History in Depth. http://www.bbc.co.uk/history/ ancient/ cultures/mesopotamia_gallery.shtml.

[10] Elison, R. E. (1978). A study of Diet in Mesopotamia (c3000- 600BC) and associated Agricultural Techniques and Method of Food Preparation. Ph.D. Thesis submitted to the Archaeology Institute, College of Arts, London University May 1978 Vol. 1, pp. 15-28.

[11] Finkelstein, J.J. (1962). Mesopotamia, Journal of Near Eastern Studies, 21 (2), pp. 73-92. doi:10.1086/371676, JSTOR 543884.

[12] 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.

[13] Foster, B. R. and Polinger Foster, K. (2009). Civilizations of Ancient Iraq, Princeton: Princeton University Press. ISBN 978-0-691-13722-3.
[14] General Directorate of Survey (1962). Series of aerial photographs of Iraq, scale 1:42,000, Baghdad, Iraq.
[15] Hamza, N.M (1997). Geomorphological Map of Iraq, scale 1:1,000,000. Iraq Geological Publications, Baghdad, Iraq.
[16] Hamza, N.M., Lawa, F., Yacoub, S.Y., Mussa, A.Z. and Fouad, S.F. (1990). Regional Geological Stage Report, Project C.E.S.A., Geological Activity. Iraq Geological Survey Library Report No. 2023.
[17] Hassan, A.M. and Al-Jawadi, B.H. (1976). Report on the geological mapping of Samarra – Baiji area. Iraq Geological Survey Library Report No. 719.
[18] Ibrahim, S.B. and Sissakian, V.K. (1975). Report on the Al-Jazira area (Rawa – Baiji – Tikrit – Al-Baghdadi Iraq Geological Survey Library Report No. 675.
[19] Internet Data (2013). Mesopotamia Research Project/ WebQuest http://cybermesowebquest.blogspot.com /2013/10/ mesopotamia-researchprojectwebquest.html.
[20] 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.
[21] Jassim, S.Z. and Goff, J.C. (2006). Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, p.341.
[22] 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.
[23] Larsen, C.E. and Evans, G. (1978). The Holocene geological history of the Tigris – Euphrates – Karun delta. In: W.C., Price (Ed.). The Environmental History of the Near and Middle East. Academic Press, London, pp. 227-244.
[24] 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.
[25] Kindsvater, C.E. (1958). River Hydraulics. Geological Survey Water-Supply Paper 1369-A. United States Government Printing Office, Washington.
[26] Matthews, R. (2003). The Archaeology of Mesopotamia. Theories and Approaches, Approaching the past, Milton Square: Routledge. ISBN 0-415-25317-9.
[27] 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. Bearman, P., Bianquis, T., Bosworth, C.E., van Donzel, E. and Heinrichs, W.P. (2020). Encyclopaedia of Islam, 2nd edition. Leiden: Brill Online.
[28] 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.

[29] Pournelle, J.F. (2013). Marshland of Cities: Deltaic Landscapes and the Evolution of Civilization. DOI: 10.13140/RG.2.2.34918.11847.
[30] Purser, B.H. (1973). The Persian Gulf, Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Springer Verlag, Berlin.
[31] Salim, A.M. (1978). Report on the geological mapping of the Samarra – Falluja Area. Iraq Geological Survey Library Report No. 868.
[32] 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) 152–163, Elsevier Publication, Journal homepage: www.elsevier.com/locate/jeseas.
[33] Sissakian, V.K. and Fouad, S.F. (2012). Geological Map of Iraq, scale 1:1,000,000, 4th edition.
[34] Iraq Geological Survey Publications, Baghdad, Iraq. www.iasj.net/iasj?func=fulltext&aId=99666
[35] 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,Vol. 9, No. 2, pp. 27-45.
[36] Sissakian, V.K. and Abdul Jab'bar, M.F. (2014). Classification of Alluvial Fans in Iraq. Iraqi Bulletin of Geology and Mining, Vol. 10, No. 3, pp. 43-67.
[37] Sissakian, V.K. Shihab, A.T., Al-Ansari, N. and Knutsson, S. (2014). Al-Batin Alluvial Fan, Southern Iraq. Engineering, 2014, Vol. 6, pp. 699-711. Published online, October, 28, 2014 in SciRes. http://www.scirp.org/journal/ eng. http://dx.doi.org/10.4236/3ng.2014.611069. DOI: 10.4236/eng.2014.611069.
[38] 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.
[39] Sissakian, V.K., Abdul Ahadb, A.D., Al-Ansari, N. and 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.
[40] 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.
[41] Wilkinson, Tony J. (2000). Regional Approaches to Mesopotamian Archaeology: The Contribution of Archaeological Surveys. Journal of ArchaeologicalResearch,Vol.8,No.3,pp.219–267, doi:10.1023/A:1009487620969, ISSN 1573-7756.
[42] Yacoub, 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 research project by the Geological Survey of Iraq and University of Paris XI, Orsay. Iraq Geological Survey Library Report No. 1078.

[43] Yacoub, S.Y., Deikran, D.B. and Ubaid, A.Z. (1990). Local Geological Stage Report, Vol. 1, Project C.E.S.A. Iraq Geological Survey Library Report No. 2016.

[44] Zaini, M.T. and Abdul Jab'bar, M.F. (2015). Alluvial Fans of the Slabiat Depression, Iraqi Southern Desert. Iraqi Bulletin of Geology and Mining, Vol. 11, No. 1, pp. 79-93.