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GEOMORPHOLOGY OF THE MESOPOTAMIA PLAIN

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ABSTRACT

The present study is a review of the geomorphology of the Mesopotamia Plain. It depends on the data obtained from the regional geological survey project of the plain, which has been carried out during the years 1977 through 1981 by GEOSURV's geological staff.

The Mesopotamia Plain is vast lowland, which has clearly defined physiographic boundaries with the Low Folded Zone, in the northern and eastern sides and the Western Desert and Al-Jazira Area, in the western side.

The Mesopotamia Plain is considered as a huge aggradational (accumulational) geomorphologic unit, where the fluvial, lacustrine, and Aeolian landforms prevail. Estuarine and marine forms also exist, but these are restricted to the extreme southeastern reaches of the plain. However, the degradational (erosional) landforms are developed, but these 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.

The main geomorphologic units of the aggradational fluvial origin are: Terraces, alluvial fans, sheet run-off plain, flood plains of major rivers and their distributaries, shallow depressions, marshes and lakes, and sabkhas. The tidal flat is the only marine aggradation form. The Aeolian forms are: Nabkhas, sand sheets and sand dunes, in addition to anthropogenic forms. The degradation geomorphic features are: Erosional cliffs, margins of flood stages and bad land, which are developed due to the lateral erosion and vertical incision of rivers and streams, wind deflation and tidal channels (creeks), which are resulted due to marine tides action.

جيومـورفولوجيـة السـهل الرسـوبي

صباح يوسف يعقوب

المستخلص

تمثل هذه الدراسة مراجعة لجيومورفولوجية السهل الرسوبي التي اعتمدت بالأساس على المعلومات المستقاة من نتائج مشروع المسح الجيولوجي الإقليمي للسهل الرسوبي الذي تم تنفيذه خلال الفترة من 1977 إلى 1981 من قبل الشركة العامة للمسح الجيولوجي والتعدين العراقية.

السهل الرسوبي هو منطقة منخفضة واسعة لها حدود فيزيوغرافية واضحة من الجهة الشمالية والشرقية مع منطقة الطيات الواطئة ومن الجهة الغربية مع البادية الغربية ومنطقة الجزيرة. من الناحية الجيومورفولوجية يعتبر السهل الرسوبي بشكل عام وحدة إرسابية واسعة، حيث تسود فيه الأشكال الجيومورفولوجية ذات الأصل النهري والبحيري والريحي. أما الأشكال ذات الأصل البحري ومنطقة مصبات الأنهار فهي تنحصر في أجزائه الجنوبية الشرقية. مع ذلك فإن الأشكال ذات الأصل التعروي تظهر أيضا ولكنها محدودة الانتشار. تم تصنيف الوحدات الجيومورفولوجية بناءا على أصل النشوء، الموضع الجيومورفولوجي والطبيعة الصخارية. حيث تشمل كل وحدة مختلف الظواهر

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الأرضية والتي تم وصفها نوعا ما بشكل دقيق اخذين بنظر الاعتبار أهميتها ووصفها من الناحية الجيومورفولوجية. وتتمثل الوحدات ذات الطبيعة الإرسابية النهرية بـالوحدات التالية: المسطبات النهرية، المراوح الغرينية، سهل السيول الصفائحية، السهول الفيضية للأنهار الرئيسية وتفرعاتها، المنخفضات الضحلة، الأهوار والبحيرات، السباخ والمسطحات المدية هي الشكل الوحيد ذات الأصل البحري ألإرسابي. أما الأشكال ذات الأصل الريحي هي: النبخة الصفائح والكثبان الرملية، إضافة إلى ذلك الأشكال التي لها علاقة بالنشاط البشري. أما الظواهر التعروية فهي: الجروف الحادة، حافات المساطب الفيضية والأراضي المحززة التي تكونت بفعل التعرية الجانبية والعمودية لمجاري الأنهار والجداول، النحت الريحي، الأخوار والقنوات المدية الناتجة عن فعل الأمواج البحرية.

INTRODUCTION

The present article is a review of the geomorphology of the Mesopotamia Plain. The review depends on the data obtained from the regional geological survey project of the plain that has been curried out during the years 1977 through 1981 by GEOSURV. Therefore, only further details concerning the geomorphologic units may be found in the original geological reports of the Mesopotamia Plain, such as Hamza and Domas (1980); Hamza and Yacoub (1982); Yacoub (1983); Domas (1983) and Yacoub *et al*. (1985). In addition to many research studies and published data such as: Yacoub *et al*. (1981), Aqrawi (1993), Hamza (1997), Sissakian (2000), Barwari *et al*. (2002), Yacoub and Barwary (2002) and Benni (2009).

Interpretation of the space images and aerial photographs together with field observations are the basic methods, which have been followed in differentiating the geomorphic and geological units; both were found to be almost the same. The geomorphologic characters are basic features used for the delineation of the geological units in mapping the Quaternary Sediments of the Mesopotamia Plain. These data were used in the compilation of the basic geological maps at scale of 1: 100 000, which were reduced in order to compile the final geological maps at scale of 1: 250 000.

GENERAL TOPOGRAPHY

The Mesopotamia Plain is a vast lowland (116 000 Km^2), which has clearly defined physiographic as well as structural boundaries with the adjacent foothills, particularly Makhoul and Himreen Mountains, in the north and east, respectively, and with the Western and Southern Deserts, in the west and southwest, respectively. Wadi Al-Tharthar and Al-Tharthar Lake form its northwestern boundaries (Fig.1). Its surface is generally flat with broad undulation at the northern sector between Baiji and Balad and along its eastern margins. These undulations are either due to presence of subsurface structures such as the case in Samarra and Tikrit anticlines (west of Tigris River) or due to development of Bajada along the foothill slopes. The surface is smoothened south wards of Balad, where flood plain sediments are well developed. However, micro-relief could be found on such flat landscape due to local erosion, irrigation canals, hillocks of ancient settlements, or Aeolian sand dune accumulations. The highest point of the plain is 140 m (a.s.l.), in Fatha vicinity, whereas the lowest point is about 1 m (a.s.l.), in the extreme southeastern margin along the Arabian Gulf (Fig.2).

The surface of the Mesopotamia Plain has an imperceptible gradient from northwest to the southeast. Its elevation drops down with an average of 1 m/ 1 Km, in its northern sector from Baiji to Balad, and 1 m/ each 3 Km in the area from Balad to Baghdad, and it decreases to 1 m/ 20 Km south of Baghdad to the head of the Arabian Gulf. The plain is also sloping down gradually from the foothills of Himreen Mountain towards the Tigris River is flood plain, as well as from the desert plateaus to the Euphrates River's flood plain (Fig.2).

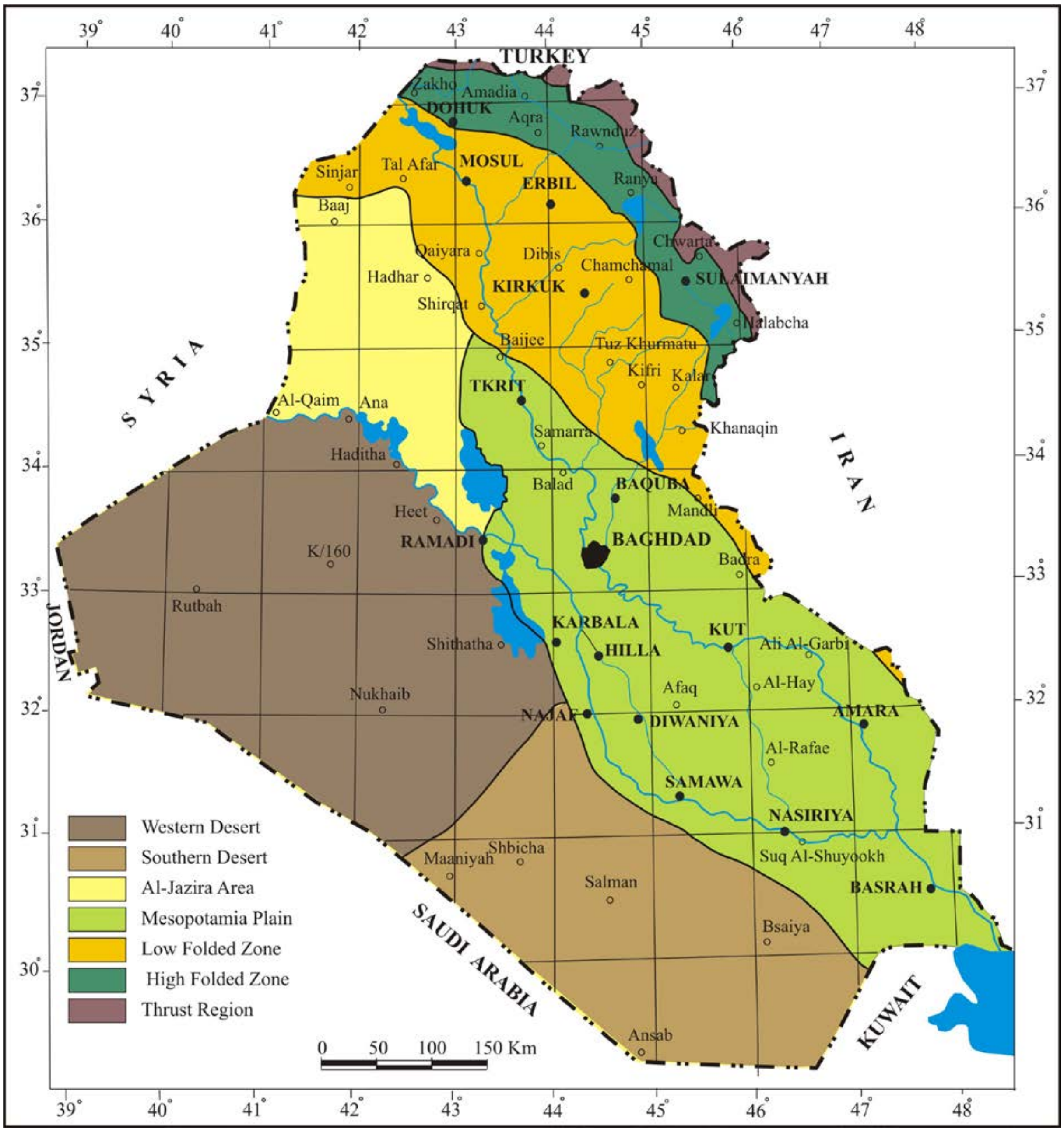

Fig.1: Location map of the Mesopotamia Plain

CLIMATE

The climate in the Mesopotamia Plain is arid to semiarid. It is characterized by extremely hot summer, mild winter and short transition seasons of spring and autumn. The climatic factors, which are obtained from the Meteorological Atlas of Iraq for the period (1961 – 1990) (Abdulla, 2000) are summarized in Table (1). These data are based on the measurements recorded by 11 meteorological stations distributed over the plain. The given climatic data of Table (1) represent the extreme ranges of different climatic factors, which lie between two stations: Baiji and Basrah.

Table 1: Climatic factors of the Mesopotamia Plain for the period (1961 – 1990)
(after Abdullah, 1990)

Station	Mean Annual Rainfall (mm)	Mean Annual Air Temp. (˚C)	Mean Annual Temperature (˚C)		Mean Annual Relative Humidity (%)	Average Yearly Evaporation (mm)	Mean Annual Wind	
			Max.	Min.			Speed (m/ sec)	Direction
Baiji (NW)	200	23	30	15	48*	2600	2.5	NW
Basrah (SE)	125	24	32	17	48*	3250	3.5	NW

* Decreases to 42% westwards in Najaf, Karbala and Samawa vicinities

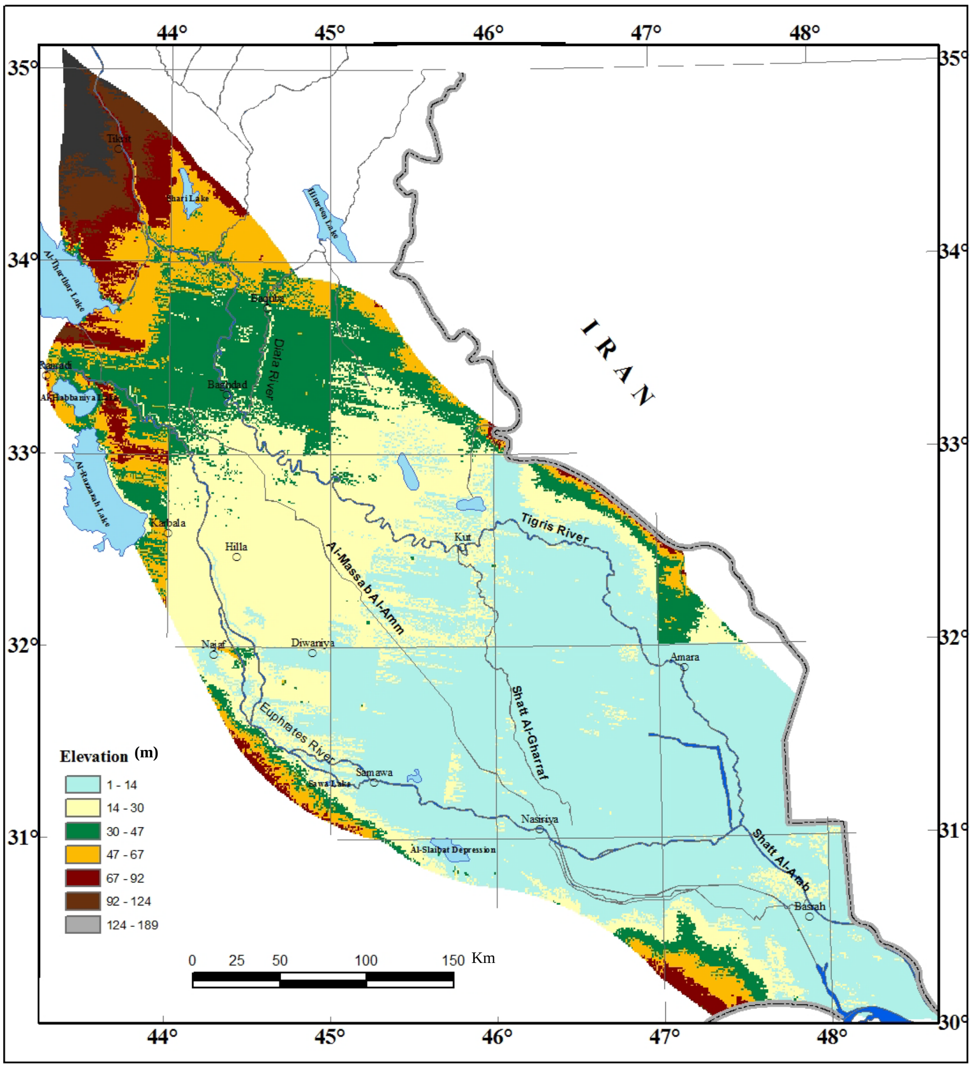

Fig.2: Digital Elevation Model (DEM, SRTM data, 2000) of the Mesopotamia Plain classified according to natural brakes, using GIS

GEOMORPHOLOGIC UNITS

The Mesopotamia Plain is considered as a huge aggradational (accumulational) geomorphologic unit, where the fluvial, lacustrine, and Aeolian landforms prevail. Estuarine and marine forms also exist, but these are restricted to the extreme southeastern reaches of the plain. However, the degradational (erosional) landforms are also developed, but they are not well expressed. They are restricted to the banks of the main rivers and their distributaries, to the foothill streams, and to very low intensity of sheet and rill erosion on the piedmont plains, down the foothill slopes. The geomorphic units of the Mesopotamia Plain are classified according to their geomorphic position, origin and lithology. They are described hereinafter.

1. Units of Structural – Denudational Origin

The Structural – Denudational units have not been found in the Mesopotamia Plain, but they are developed on the adjacent provinces close to its boundaries. Therefore, brief characteristics are given hereinafter.

The eastern and northeastern boundary of the Mesopotamia Plain is built up of a system of low folds, such as those of Himreen and Makhoul. Their marginal parts are preserved in form of cuestas and hogbacks. The inner parts of these structures are deeply eroded, particularly in the crestal part of Himreen Range. The products of erosional processes from the structural units are deposited on the foothills, in different accumulation landforms. The western boundary of the Mesopotamia Plain is represented by the contact of the flood plain with the Western and Southern Deserts. The desert plateau is also of structural origin, and is built up of semi-horizontal to very gently dipping strata. The contact is partly controlled by fault scarp (Abu Jir – Euphrates Fault Zone) (Ma'ala, 2009).

2. Units of Fluvial Origin

The landforms of fluvial origin 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 of Himreen Mountain (Jabal). These landforms are described hereinafter.

2.1. Fluvial Terraces

The fluvial terraces of the Euphrates River, near Falluja town are the most extensive terraces recorded within the Mesopotamia Plain. They are developed in two separate levels. The relics of the higher terrace level is built up on the strata of Injana Formation, at about 23 m 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, farther towards the south. The top of this terrace level is about 10 m above the water level of the Euphrates River, near Falluja and reaches a maximum of 14 m, above the surrounding flood plain, around Iskandariyah. The latter (Iskandariyah mesa) is considered as cut-off spar (Domas, 1983). Fluvial terraces of limited extent are developed alongside the courses of the foothill rivers. 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, Nafut, Galal Har'ran, Galal Badra, Chab'bab, Al-Teeb, and Khar Khar. Two levels were recorded, the surface of the higher level is around (7 – 8) m, above the recent river bed, and may reaches 18 m, as in the case of the Diyala River, and 12 m in Nafut River. The lower level occurs few to 6 m above the recent water courses. These terraces often pass gradually into the alluvial fan sediments, some of them are developed with more than two levels, farther up-stream area inside Himreen Range.

2.2. Alluvial Fans

Three alluvial fan systems are developed on the peripheral parts of the Mesopotamia Plain, these are:

2.2.1. Al-Fatha Alluvial Fan

It is a huge fan occupying the northern part of the Mesopotamia Plain. This fan has been a matter of discussion since 1956, when many authors have considered the gravel and conglomerate accumulations to be of different units. They were considered to belong to the Upper Bakhtiari Formation (Bolton, 1956 and Bellen *et al*.1959), and as terraces of 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) and Yacoub *et al*. (1990).Yacoub *et al*. (1990) added further evidences to confirm the alluvial fan origin, these are summarized as follows:

- Generally, the alluvial fan is developed when a stream emerges from mountains into relatively subsiding area, which is the case at the outlet of Al-Fatha, between Makhoul and Himreen Ranges
- The surface extension of the gravely body has fan-like form, as evidenced by satellite images.
- The presence of very gentle gradient off the axis of the fan.
- The fan extends from Shari Lake westwards to Al-Tharthar Lake without any remarkable surface feature for other geomorphologic forms, like terraces.

The surface of Al-Fatha Alluvial Fan is characterized by slight and broad undulations with shallow and wide valleys, and depressions of deranged pattern, which reflect high porosity of the fan sediments. It is covered by gypiferous soil and gypcrete with residual gravels. The gravels are scattered on the surface in variable densities, often concentrated on the slopes due to rain wash and wind erosion. The slight undulations of the surface reflect either the effects of the erosion processes or the uneven original surface of the alluvial fan. However, both assumptions also could be possible (Yacoub *et al*., 1991). The eastern boundary of the fan with the foothill slope is often clear and marked by smooth brake in the slopes, while 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, the boundary is sharp with the younger flood plain sediments of the Tigris River, represented by a break in the slope. Jassim and Goff (2006), however, deduced that the fan disappears bellow the flood plain sediments south of Balad.

2.2.2. Alluvial Fans System of the Eastern Mesopotamia Plain

It is a distinctive geomorphic unit developed on the margin of the Mesopotamia Plain alongside the foothill slopes (piedmont plain), extending particularly from north of Mandali, in the northwest, to north of Amara, in the southwest. The alluvial fans are of coalescent type, forming continuous belt of Bajada, with irregular width, exceeding 15 Km. The variation in the width is due to different sizes and extensions of the individual alluvial fans, which varies from few kilometers to more than hundred square kilometers. Actually, the size of the alluvial fan depends on the size of the catchment area and the gradient of the corresponding stream. The surface of the fans is generally flat, and gently slopping from the apex towards the flanks, usually coinciding with the drainage pattern. The geological survey (Domas, 1983 and Yacoub, 1983) revealed that the alluvial fans were developed in different stages, maximally five stages were recorded. These stages can be recognized including recent and sub-recent valley fill as the last stage, among them, the fourth stage is well preserved. These stages are separated by distinctive breaks in slopes (Fig.3). The apical parts of the oldest stage are eroded by the younger cycles; the younger alluvial fans are well preserved.

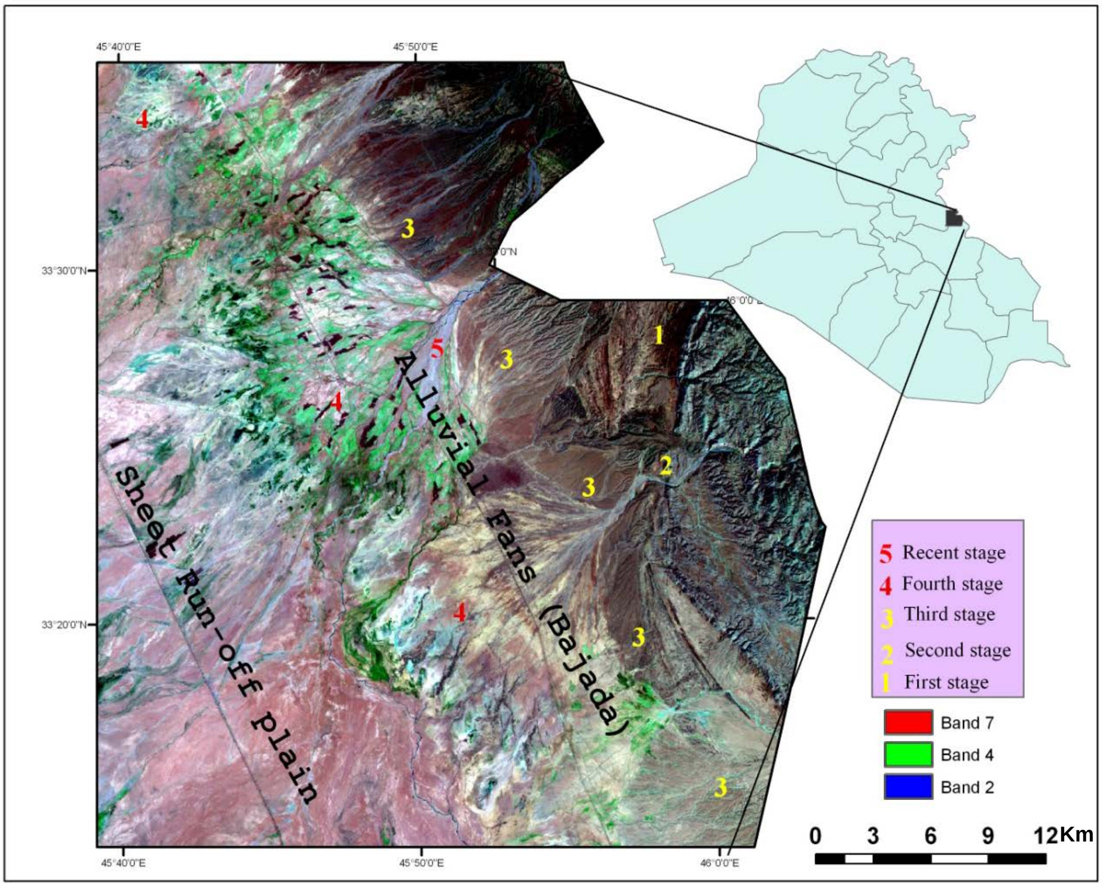

Fig.3: Satellite image (ETM) shows different stages of alluvial fans in the eastern part of the Mesopotamia Plain

The formation of these stages of alluvial fans is attributed to climatic oscillations during the Pleistocene and could be correlated with pluvial and inter-pluvial phases of the Quaternary Period. However, the affect of the neotectonic activity that is represented by the relative uplifting of Himreen structure versus the subsidence of the Mesopotamia Plain must not be excluded, too.

2.2.3. Alluvial Fans System of the Western Mesopotamia Plain

This system is developed at the outlets of the main valleys, which drain the Western and Southern Deserts. These alluvial fans terminate at the peripheral parts of the desert plateau. Their sediments are, in some places, buried beneath the Mesopotamian flood plain (Domas, 1983). 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 clearly visible on the satellite images, and well recorded by the geological survey. They are separated by wide distances; two of them are very extensive: The first fan covers the **Najaf – Karbala Plateau**, which was originated from Wadi Lisan (Hassan *et al*., 2002); the second fan covers the major part of **Dibdibba Plain**, SW of Basrah, whereas the third fan was originated from **Wadi Al-Batin**. 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's 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. Al-Sharbati and Ma'ala (1983) have recognized four stages of alluvial fans of Wadi Al-Batin.

The author believes that the four stages could be correlated with those stages of alluvial fans of the Eastern Mesopotamia Plain. The third alluvial fan, of the Western Mesopotamia Plain system is originated from **Wadi Al-Qusair**, south of Nasiriyah city; its spatial extension is much smaller than the aforementioned first and second fans. This fan was deposited in an elongated regional depression, which extends along the western side of the Mesopotamia Plain. The constituents of this fan are dominantly unconsolidated gravels; rich in carbonate rock fragments originated from the exposed rocks in the near surroundings. The author believes that the age of Al-Qusair fan is younger as compared with the aforementioned bigger fans; this assumption depends on its smaller size and lower geomorphic position. On the southeastern part of the fan, there is an elongated gravel body, it is considered as terrace sediments by Deikran (1995). The author believes that it could be originated as individual fan or small coalescent fans, which lost their cone shape after the deposition.

It is worth to mention that the fans of the Western Mesopotamia Plain system has been included within the Southern Desert Province, depending on the adopted physiographic divisions of Iraq, therefore it has been also elucidated in Ma'ala (2009).

2.3. Sheet Run-off Plain

The sheet run-off plain is the middle part of the piedmont plain. It is also considered as accumulational "glaci", which refers to the erosional slope developed on the accumulation unit. 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 (playas). The plain extends in NW – SE direction, parallel to the alluvial fans unit, its width reaches about 35 Km (Fig.3).

The sheet run-off plain is very flat and gently slopping towards the southwest, with average gradient of 1.1 m/ 1 Km (Yacoub, 1983). The very smooth flat character of the surface reflects the fine texture of the building up sediments, as well as the sheet wash and sheet flow activities, which are the prevailing processes on the surface of these plains. The flat surface is in some places scoured by narrow water courses inform of rills and anastomozing streams, which form a very intricate drainage pattern. This stream pattern usually starts as a single stream channel incised in the sheet run-off plain, 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, which are the characteristic feature of this plain.

Beside the fluvial processes, the Aeolian activity is also effective on the surface of the sheet-run off plain, particularly, during the dry seasons, which are more prevailing in the recent climatic conditions. The Aeolian activity is represented by both erosional features, such as wind abrasion, and accumulation forms such as sand sheet and small scattered sand dunes. The sheet run-of plain is generally barren land, except the moist parts alongside its boundary with the alluvial fans, as well as along the water courses where dense natural vegetations (often shrubs) are grown.

2.4. Flood Plains

The flood plains of Euphrates, Tigris, Shatt Al-Arab, Diyala, Adhaim Rivers, and foothill rivers are the major morphologic features of the Mesopotamia Plain system. They generally comprise of fine clastics (alternation of clay, silt and sand). Each individual flood plain of these rivers has rather similar minor morphologic features, such as meandering belt, natural levees, crevasse splays and flood basins. However, they differ in areal 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, so they are described separately hereinafter. It is worth to mention that the natural flood plain morphologies are clearly visible on the aerial photographs and satellite images, when they are well preserved on the surface. Whereas, in some cases these features may disappear and can not be distinguished, either due to natural reasons or they have been destroyed due to different man activities during both ancient and recent times.

2.4.1. Euphrates Flood Plain

The upper reaches of the flood plain of Euphrates River, near Al-Ramadi 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, in the concerned area is limited within the width of the meandering belt of the Euphrates River, which is about 10 Km. The river channel is strongly meandering due to very low gradient. The flood plain gradually widens down stream, starting from Falluja town. The Western and Southern Desert Plateau always limit its right bank, whereas the left bank is not remarked at all; since the sediments of Euphrates River pass gradually into the sediments of Tigris River. Further, down stream, the Euphrates River starts to build its natural levees following the main course, which attain few meters above the normal water level of the river. The width of the natural levees varies between (1 – 3) Km; their surfaces gradually slope away from the river towards the flood basins. The flood basins are flat floored depressions following the natural levees. A good example of such basins is east of Kifil town, where the flood basins are developed between the main river course of the Euphrates River and its distributaries. The most significant distributaries of the Euphrates River is Shatt Al-Hilla and its continuity Shatt Al-Diwaniya, beside several others between Al-Shamiyah town and Al-Samawa city. These main distributaries built their own system of natural levees and flood basins together with the related nets of irrigation canals resulting rather complicated flood plain system with micro relief morphology. The stages of the flood plain are another morphologic feature of the flood plain. Usually (4 – 5) stages are recognized along the main course of the Euphrates River and Shatt Al-Hilla, in vicinity of Al-Musayab town. The difference in their levels varies from one to very few meters (Domas, 1983). Further important micro-morphologic features of the Euphrates River flood plain are the relics of the abandoned river channels. One of the most expressive abandoned channels is the old course of Euphrates River, which is detected south of the recent river. It extends from Al-Samawa to Hor (marsh) Al-Hammar (Fig.4). This old river course has distinct meandering channel and locally well developed point bars, flood stages, natural levees and crevasses. The old flood plain surrounding the channel is dry and barren land and strongly influenced by Aeolian activity in the present time. The migration of the river channel from its old position to the recent one is quite normal phenomenon in such fluvial sedimentary environments. However, it is also deduced that there is an affect of continuous tectonic subsidence toward the center of the Mesopotamian basin. It is worth to mention that the relics of the old channel has been detected also along the southern margin of Hor Al-Hammar, which indicates that the old Euphrates River was crossing Hor Al-Hammar from this side and terminated at Garmat Ali town (out let of Hammar Lake, north of Basrah city). Consequently, the junction of Tigris and Euphrates River was at Garmat Ali town. The lowermost reaches of the Euphrates River flood plain is terminated inform of non-marine delta near Suq Al-Shiyoukh town (southeast of Nasiriya city), forming the western edge of Hor Al-Hammar. On the other hand, the Euphrates River continues crossing the marshes southeast wards to Al-Qurna town. Its natural levees were dominantly sub aquatic during high water conditions, before 1990. The levees appeared on surface, later on after drying processes of the marsh lands, during the early nineties of the last century.

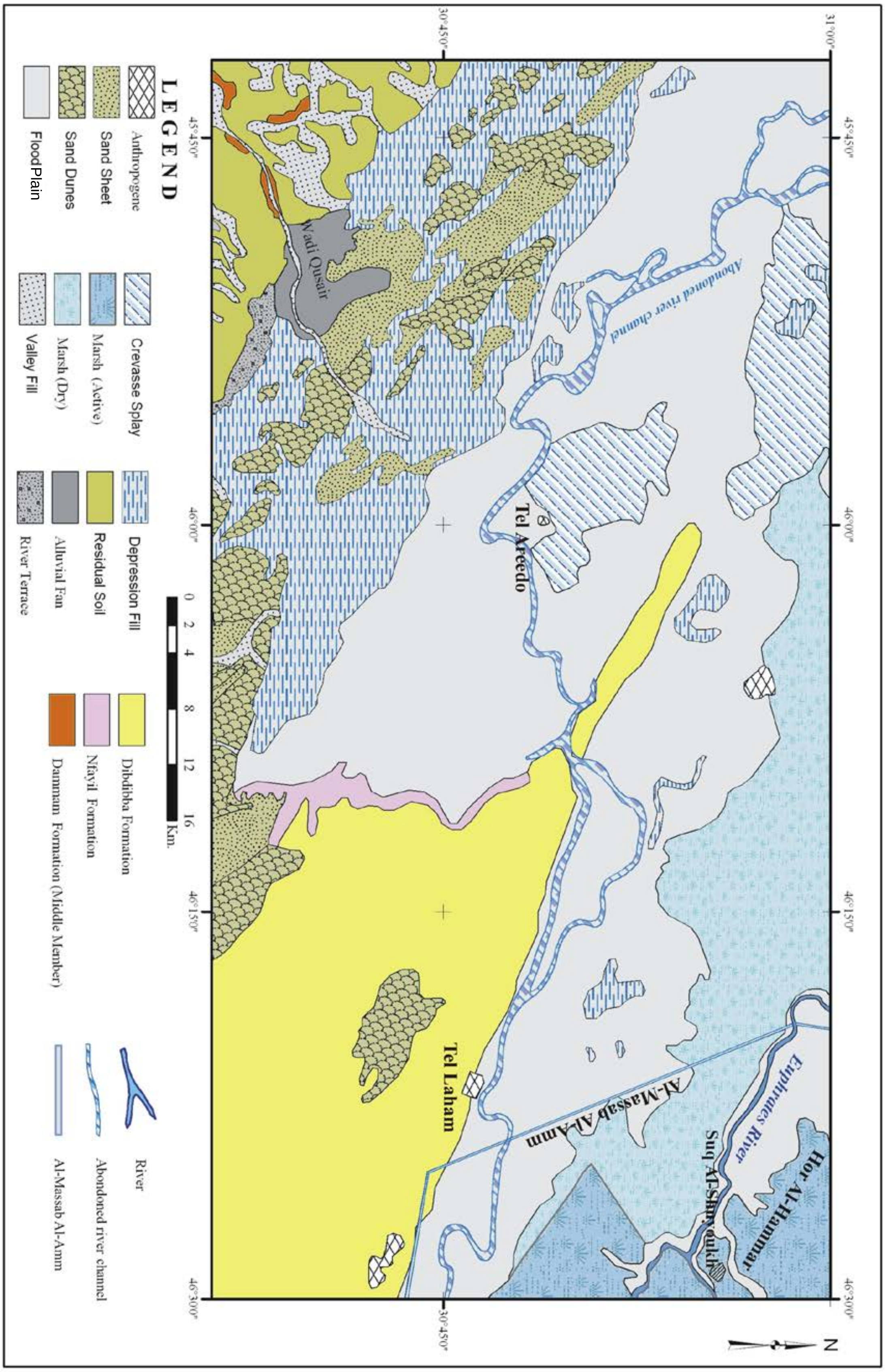

Fig.4: Geological map shows different geomorphic forms of Euphrates flood plain, southern part of Mesopotamia Plain, south of Nasiriyah (modified after Deikran, 1995)

2.4.2. Tigris River Flood Plain

The flood plain of the Tigris River is limited within its meandering belt, which is around 3 Km wide, in the northern sector of the Mesopotamia Plain, between Baiji town and Tikrit city; south of Tikrit becomes narrower. It is bounded by high erosion cliffs which attain more than 10 m in height. The recent river course form local braided channels, which are separated by islands and sand bars attaining 2 m in height, above the water level. Two flood stages could be recognized within the meandering belt, the difference in height between them is (1.5 – 2) m; the higher stage is densely cultivated. Downstream of Balad town, the flood plain considerably widens, particularly the western bank, whereas it's eastern bank is rimmed by the flood sediments of Adhaim River, and farther southwards interfingers with the flood plain sediments of 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, much greater than that of the Euphrates River, as it is manifested particularly, by wide natural levees and extensive crevasse splays (Domas, 1983). The width of the natural levees of the Tigris River reaches 5 Km on both sides of the river, between Suwairah town and Kut city, and their tops reach (3 – 4) m above the surrounding flood basins. The width of levees decreases down the Kut, because the Shatt Al-Ghar'raf distributary's and Old Dujailah River drain enormous amount of water from Tigris River. The crevasse splay activity is very expressive and significant feature of the Tigris River flood plain, between Azizziyah and Kumait towns. The areal extension of some crevasse splays reaches even few hundreds square kilometers (Fig.5).

The most prominent flood basins are on the left bank of the Tigris River flood plain, which are represented by a system of flood basins that extend throughout the area between the flood plain and the sheet run-off plain (Fig.6). Hor Al-Shuwaicha (north of Kut) and Hor Al-Sannaf (north of Amara), are the most expressive and active among the other marshes. On the right bank of the 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 Dujailah Rivers.

The flood plains of Shatt Al-Ghar'raf and Old Dujailah River (Fig.5) belong to the flood plain of the Tigris River, since both are its distributaries. Both rivers formed comparatively 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 a wide flood plain, its width reaches more than 40 Km. The Old Dujailah River, apparently is no longer active, its flood plain is almost barren and highly affected by Aeolian activity. The most expressive morphological features of this flood plain are the abandoned river troughs, the relics of old irrigation canals and hillocks (locally called Tells).

In the southern sector of the Mesopotamia Plain and at Amara vicinity, the Tigris River bifurcates and looses much of its sedimentary charge in form of lacustrine delta, forming the northern edge of the marshes. This active delta is clearly seen on the satellite images. Two additional deltas exist also: The first appears to be related to discharge from Al-Ghar'raf River, whereas the second (inactive) is related to the Old Dujailah River branches, both form the northwestern edge of the marshes. South of Amara the Tigris River crosses the marshes, its flood plain becomes narrower and being essentially represented by natural levees, which are bounded by the marshes from both sides. One of the expressive morphologies in this sector; of the Tigris channel 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 Tigris flood plain, near Azizziyah and Suwaira (Fig.6).

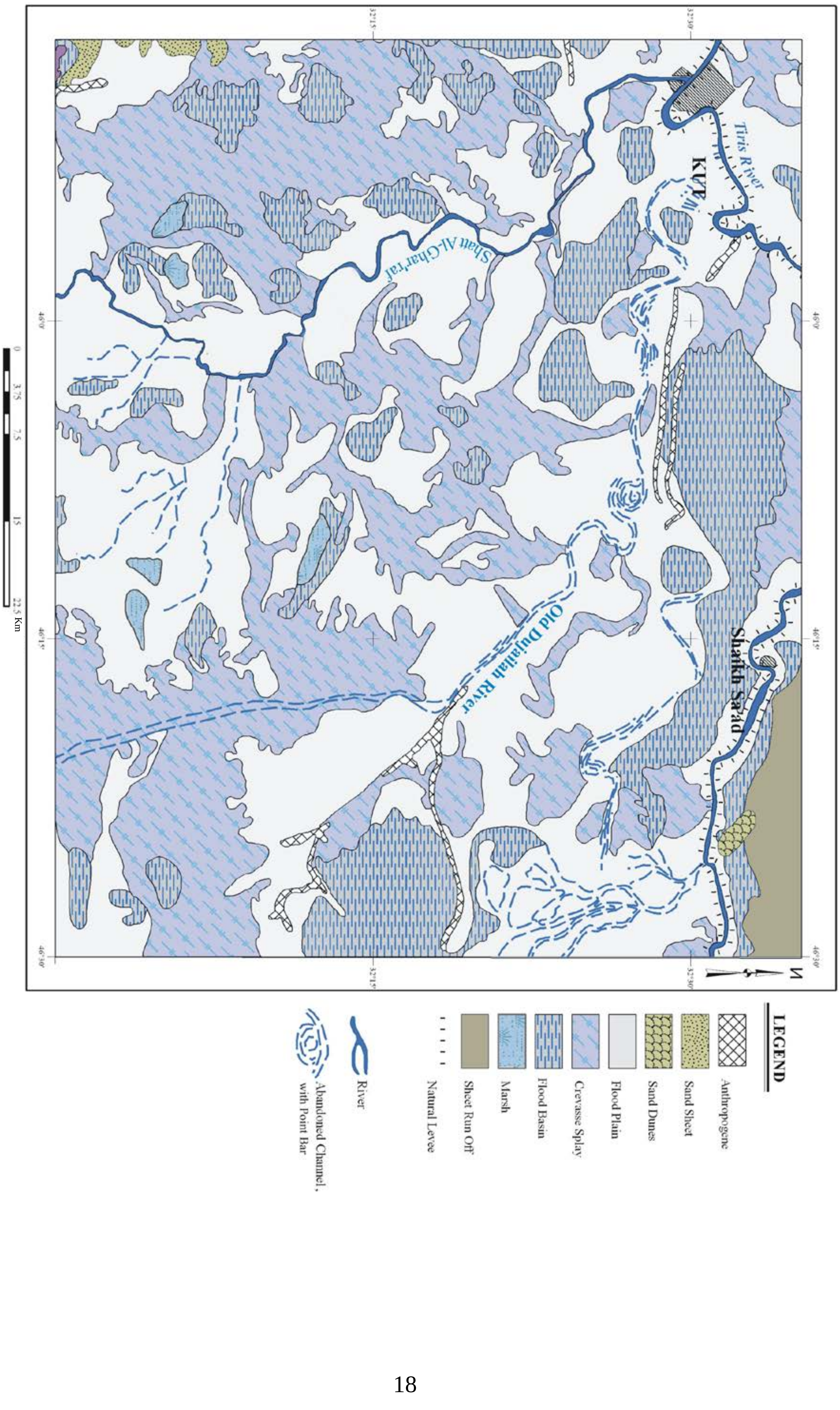

Fig. 5: Geological map of Kut area shows different geomorphic landforms of the Tigris River flood plain (Barwari *et al.*, 1994)

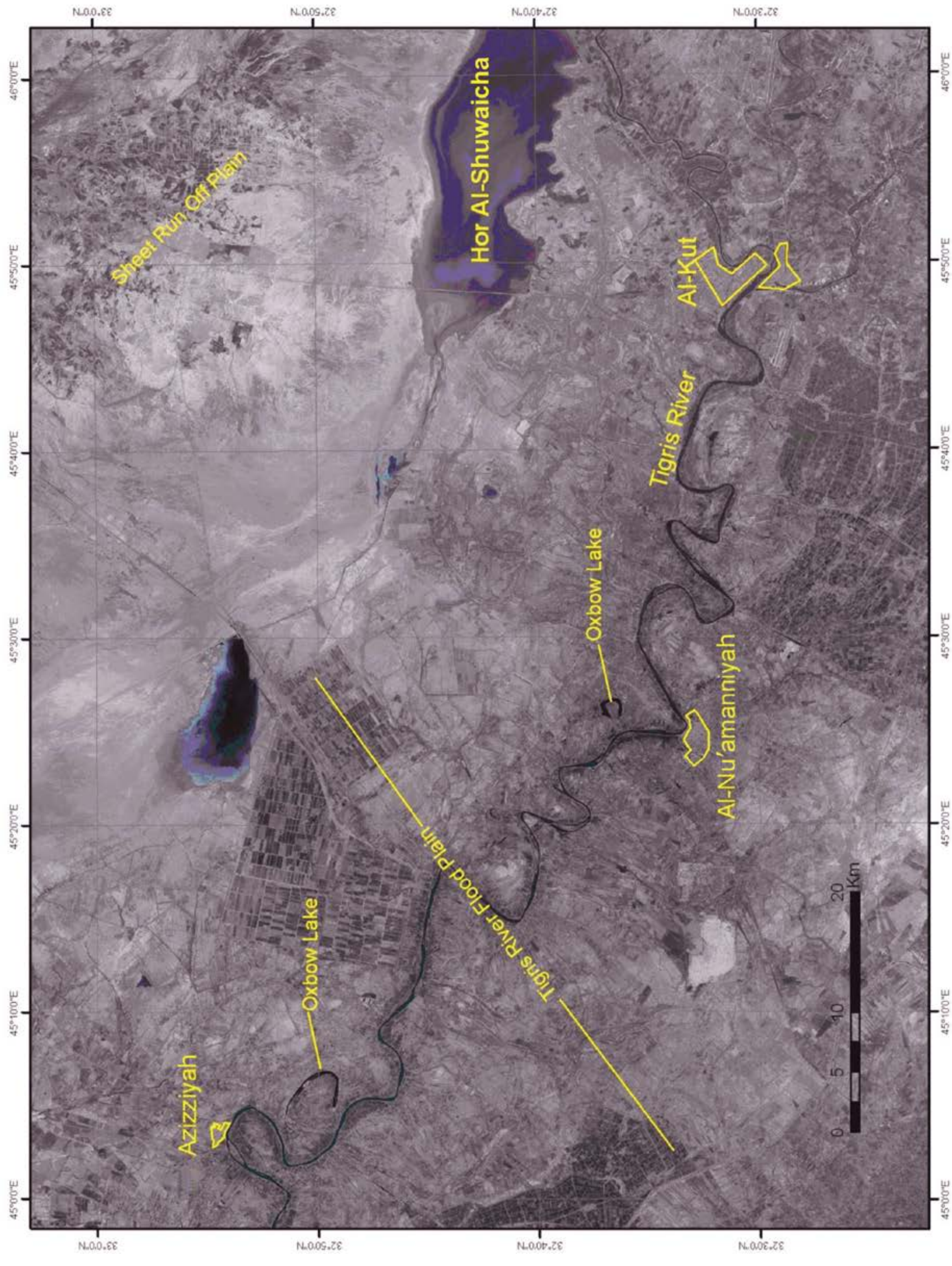

Fig. 6: Landsat image (ETM 2002) of the central part of the Mesopotamia Plain, shows different fluvial Geomorphic features

Maximally, four flood plain stages are well developed in two main localities of the Tigris River flood plain: The first is near the junction of Adhaim River, whereas the second is between Azizziyah and Kut. The vertical differences between levels of individual stage do not exceed few meters, their width varies from few hundred meters to three kilometers; their length may reach 10 Km (Domas, 1983).

2.4.3. Adhaim Flood Plain

Adhaim River is the first tributary of the Tigris River within the Mesopotamia Plain. Its flood plain occupies the northeastern part of the main flood basin. The flood plain is characterized by almost entirely barren flat terrain, very gently sloping downstream and outward of the river that gives to the surface convex form. This convex surface reflects a fan like shape of the flood plain. This shape can also be detected from the pattern of ancient irrigation canals and from land sat images (Hamza and Domas, 1980). However, Hamza (1997) considered it as an alluvial fan (Adhaim Fan). Moreover the natural levees are well developed, however they are partly affected by badland erosion. Adhaim River had deposited four stages of flood plain, their surfaces are 14 m, 6 m, 2.5 m, and 1.6 m (above the water level), respectively, the highest (older) stage has only wide extensions, whereas the others are restricted inside the valley. One of the expressive micro-morphologic features is the shallow abandoned trough called Wadi Shta'it, it is infilled ephemeral valley, and its width reaches 5 Km, at vicinity of Adhaim village. Its present valley floor is around 11 m above the water level in Adhaim River. It forms two stages of flood plain; the surface of the higher one is 3.5 m above the valley floor, whereas the lower one is only 0.5 m. 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.

It is worth to mention that the construction the of Adhaim Dam, slightly up stream from its outlet from Himreen Range, has decreased the influence of hazardous floods of Adhaim River, which could happened during heavy rains. Moreover, some barren lands are inhabited and vegetated, after the construction of the dam.

2.4.4. Diyala River Flood Plain

Diyala River is the second and the biggest tributary of the Tigris River within the Mesopotamia Plain. Its flood plain is generally flat terrain, very gently slopping towards south and southwest, from its outlet from Himreen Range, with micro-relief caused by silted up irrigation canals (both ancient and active). The river flows towards the southwest from its outlet to Ba'quba city, following the main foothills gradient, 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 between Mukdadiya and Ba'quba, at Ba'quba vicinity and further downstream, the levees are well 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. Such floods were frequently happened before the construction of Himreen Dam. However, in the last decades the natural levees have been reinforced, artificially to prevent areas behind the levees from intensive floods. The levees on both sides of Diyala River are densely covered by date-palm fields. The width of the natural levees range from few hundred meters to 2 Km. The floodplain is densely cultivated and vegetated; particularly those parts located near the river course and irrigation canals, whereas the distal parts are almost totally barren. Two stages of flood plains are developed by the Diyala River, 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.

2.4.5. Foothill Rivers Flood Plains

The main foothill rivers form distinct and elongated flood plains. They are generally narrow (1 – 2 Km) at their emergence from the corresponding alluvial fans, then gradually widen downstream reaching width of (5 – 7) Km, and in some cases more than 10 Km. These flood plains are generally developed in two stages: The higher stage forms the majority of the flood plain system, its surface is often (6 – 8) m above the river level, the height usually decreases downstream. This stage is characterized by well visible natural levees, particularly on the upper reaches of the flood plain and on both banks of the river. The natural levees laterally pass to the sheet-run off plain, and usually disappear at the lower reaches of the flood plains. The lower (younger) stage is restricted to the river channels, which include the recent and sub recent valley fill and point bars. These flood plains are terminated in form of small fan shaped deltas at the ends of river courses in the shallow depression (playas), which are situated between the Tigris flood plain and sheet run-off plain. Among them, only Al-Chab'bab River reaches and drops in the Tigris River course.

2.4.6. Shatt Al-Arab Flood Plain

Tigris and Euphrates Rivers join each other after leaving the marshes at Al-Qurna, forming Shatt Al-Arab (River), which flows in rather smoothly meandered channel. It is also fed from Hor Al-Hammar through Garmat Ali channel (the outlet), just north of Basrah. The river is rimmed by low natural levees. The height of the levees is around 1 m, above the water level and their width reaches up to 2 Km on both sides of the river. They were often covered by dense date-palm forests particularly downstream of Basrah; however, they are mostly deforested, recently. The flood plain is rimmed by marshes on the right side and by shallow flood basins on the left side, along the whole distance between Al-Qurna and Basrah. Downstream of Basrah, the flood plain passes into estuarine sabkhas, on the right bank and the flood plain of Karun River on the other side.

The conspicuous morphologic features of Shatt Al-Arab flood plain are the two abandoned river troughs, which most probably represent the former courses of Shatt Al-Arab (Fig.7). They are recognized northwest of Al-Sibah 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 Shatt Al-Arab course widens at its lowermost stretch forming costal marshes, and then it terminates by sub-aquatic marine delta at the margin of the Arabian Gulf. The Shatt Al-Arab is affected by the input of Karun River; this is clearly visible at their conflux north of Al-Sibah, where abrupt increase in the amount of suspended mud in the water of Shatt Al-Arab downstream of Al-Sibah occurs. It is worth to mention that the water level of Shatt Al-Arab is influenced by the tidal action of the head of the Arabian Gulf, especially down stream of Basrah. The water fluctuation ranges within (1 – 2) m, occasionally reaches 3 m.

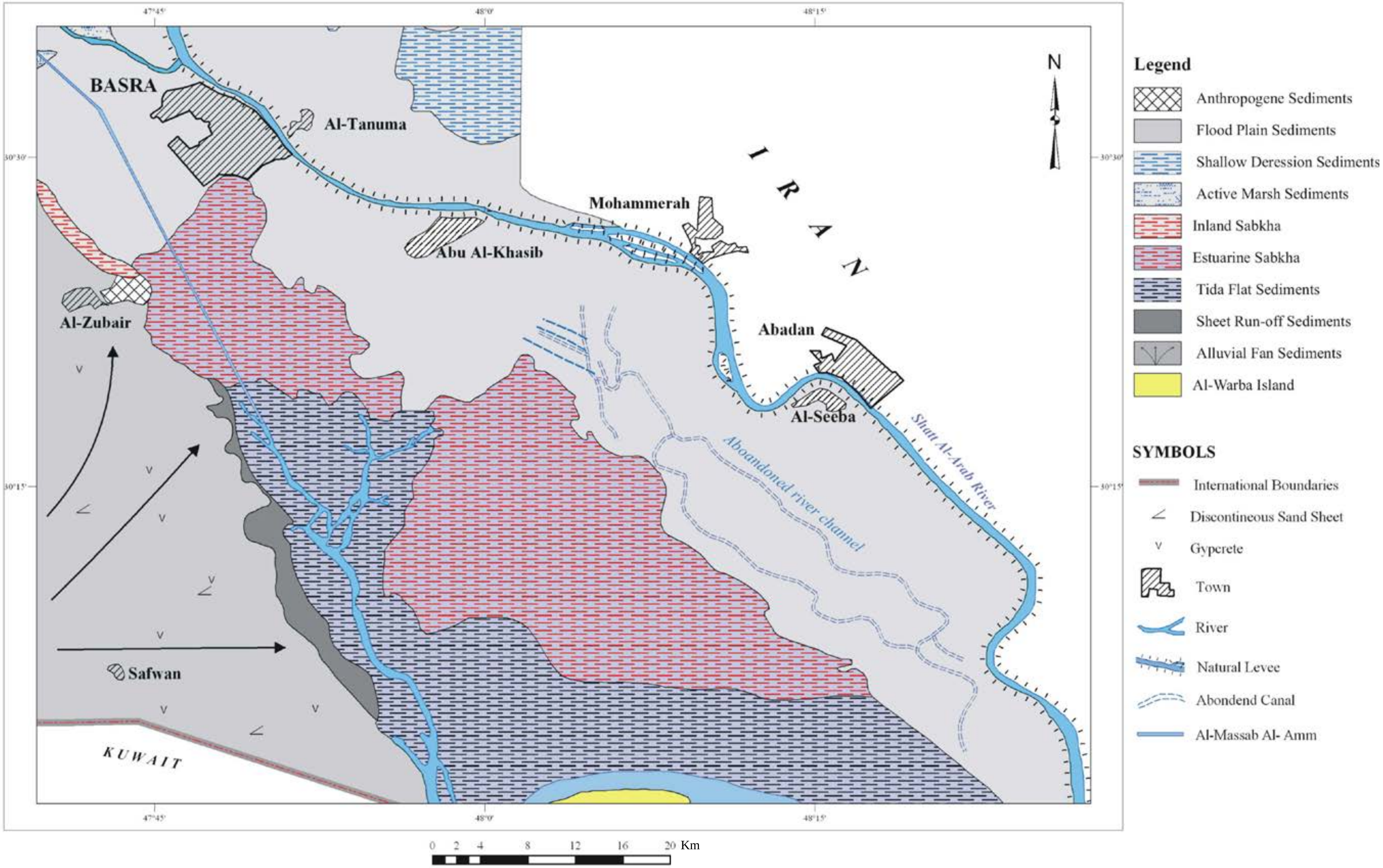

Fig. 7: Geological map shows geomorphic land form of Shatt Al-Arab flood plain and coastal region, extreme southeastern part of the Mesopotamia Plain (Yacoub, 1994)

2.5. Shallow Depressions

The shallow depressions are common morphological feature in the Mesopotamia Plain. They are characterized by very flat and smooth floors. Their dimensions vary from few hundreds square meters to many hundreds square kilometers, depending mostly on their origin and geomorphic position. The small and local depressions are essentially developed due to micro-relief within the flood plain, often between the secondary distributaries of the rivers, or between the irrigation canals. 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 (Fig.6). They are filled by water perennially, periodically, or ephemerally. The more active basins are those located near the rivers, such as the flood basin west of the Tigris River, between Kut and Amara, as well as the basins between the main branches of the Euphrates River, south of Shamiyah. They are filled by water periodically and even partly perennially. The less active and ephemeral depressions are those situated far from water sources and within the abandoned flood plains, such depressions are often affected by wind actions. The more extensive shallow depressions are those situated near the contact between the Mesopotamia Plain and the Western Desert. They are a series of coalescent depressions that extend from Bahir Al-Najaf to south of Nasiriyah; partly isolated by sand dunes with variable width; reaches in some places up to 20 Km. These depression are intensively affected by Aeolian activity and are characterized by buffy surface, resulted due to the presence of salt mantle.

2.6. Marshes (Ahwar) and Lakes

There are many individual marshes and lakes developed in deferent parts of the Mesopotamia Plain, particularly in its northern and central sectors. The marshes may be developed in any shallow depression, if favorable conditions (stagnant water) are available for growth of dense marsh vegetations. Consequently, such marshes are considered as especial case of shallow depressions (Hamza and Yacoub, 1982, and Domas, 1983). The marshes and lakes system of the southeastern part of the Mesopotamia Plain are rather complicated, and might be developed and survived not only due to tectonically active subsiding land (Lees and Falcon, 1952). However, it is also due to very low sedimentation rates that prevailed in the marshes region after total regression of the sea influence (i.e. 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. Moreover, they have distinct geomorphic features and posses important sedimentary environment being predominant in the southeast of the Mesopotamia Plain.

The marshes and lakes system underwent big changes during the last three decades. The changes in geomorphic and environmental situation in the marshes are summarized hereinafter starting from early 1980's, onwards.

During early 1980's, when the geological mapping of the southern sector of the Mesopotamia Plain were conducted by GEOSURV (Yacoub et *al*., 1985), the active marshes were covering about 7000 Km^2 (Fig.8A). These 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). They were filled by fresh and limpid water and densely populated, with various marsh plants among which *Phragmites* and *Typha* were predominant. The water depth was varying from few decimeters to 2 m, exceptionally reaches (3 – 4) m, in Al-Hammar Lake. The attitude of water, within the marshes was not far from the sea level (around 2 m, a.s.l.). The marshes included many open lakes, which were free of vegetations; their dimensions were varying from few to hundred square kilometers. Besides, the fresh-water marshes, there were also two main brackish-water lakes called: Khuraiz Al-Malih and Al-Luqait. They were formed due to cut off from Al-Hammar Lake by sand barriers. The relatively high salinity of the water of these lakes was attributed to high rate of evaporation, low feed of water, and possibly the influence of underground water. Inactive (dry) marshes are another variety of marshes, which are dried either due to natural reasons or man activity.

During 1991 – 1993, the aforementioned situations of the marshes have been completely changed, after the drying operations. The drying operation continued and reached its optimum at the beginning of 2003 (Fig.8B). Consequently, the active marshes were limited only in two main localities; one as a strip of 2 Km wide running parallel to the Tigris River, on the western side, and the other restricted to the northern portion of Hor Al-Huwaizah. The majority of the marsh floors were exposed; therefore, new morphologic features appeared in the dried marsh areas. The new surface was flat covered by organic soil, grey colored mud rich with plant debris. In some places salt ponds appeared, perhaps they substitute the previously existing open lakes. The native vegetation cover was also changed and new species of plants substitute the reed and rushes of the marsh environment. However, after 2003 great efforts have been conducted for reactivation of the mashes; thus a new project for this purpose has been performed. Then after two years a considerable areas of the dried marshes were partly rejuvenated (Fig.8C).

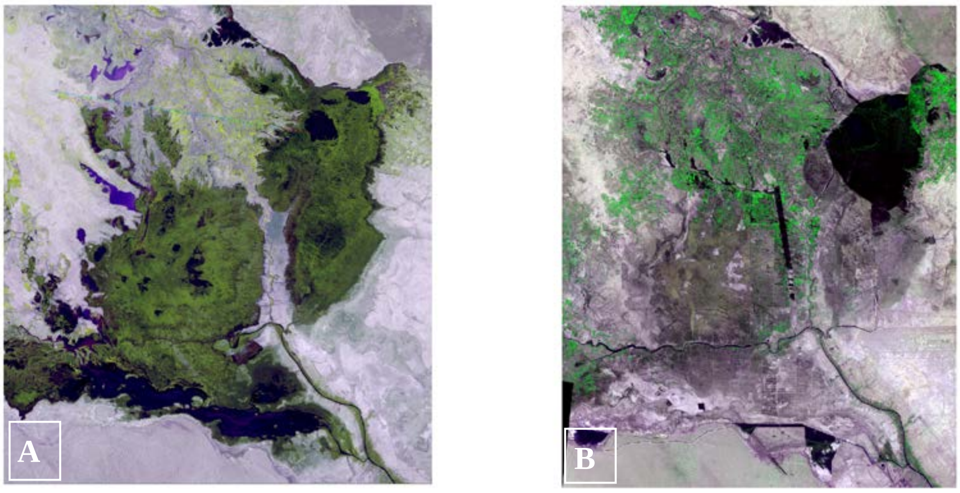

Fig.8: Satellite images illustrate the situations of the marsh areas during three stages
(A) MSS, 1973, before drying operations
(B) ETM+, 2002, after drying
(C) ETM, 2005, reactivation of marshes

Al-Ma'amar *et al*. (2008) and Abdul Jabbar (2008) have concluded that after the reactivation operation of the marshes in 2005, around 50% of the dried areas of Al-Hammar and Al-Huwaizah Marshes have been rejuvenated, whereas in the Central Marshes; the reactivated area represents 24% only. This conclusion was achieved from evaluation of remotely sensed data that represent deferent time intervals, TM 1973, ETM 2000 and 2005 (Fig.8).

2.7. Sabkhas

The main sabkhas are developed in shallow depressions, particularly those situated along the western and southern margins of the Mesopotamia Plain, in the dry marshes, playas and periodic lakes. They resulted after intensive evaporation of salty water accumulated on the surface, or rising of the shallow under ground water to the surface; in some depressions, like Hor Al-Sannaf. Extensive sabkhas are developed near Hor Al-Dalmaj, west of Kut because of evaporation of salty water collected by the drainage canal system.

The Estuarine sabkha characterizes the flat areas between Basrah and Khor Al-Zubair. Its surface is usually moist and mantled by thin salt crust. The origin of this sabkha 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 *et al*., 1981)

3. Units of Marine Origin

These geomorphic forms of marine origin represent the extremely southern part of the Mesopotamia Plain. They are either accumulational, represented by tidal flat (mud flat) or erosional, represented by tidal channels (Tidal creeks) (Fig.7). Both types are mentioned hereinafter.

3.1. Tidal Flat

The tidal flat is the coastal muddy shore of the head of the Arabian Gulf, occupying the intertidal zone between the high and low tides, which ranges between (1 – 1.5) m. The active tidal zone has an average width of (1 – 2) Km, extends along the coast from Al-Fao to Um Qasir. The super tides may reach a distance of 10 Km; land wards. However, the recent constructed embankment along the coast between Al-Fao and Khor Abdullah could suppress the super tidal action and limited its extension, landwards. The active tidal flat have wet muddy surface entrenched by narrow rills (Fig.7).

3.2. Tidal Channels (Creeks)

One of the expressive degradational geomorphic features of the marine origin is the tidal channel system of Khor Al-Zubair. This system resembles a river with meandering course and system of tributaries having dendritic pattern; branching inland-wards and they merge 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. The tidal channels are generally narrow; at their landward ends, and gradually widen towards the main channel, Khor Al-Zubair, which reaches 1 Km, in width (Fig.9).

4. Units of Aeolian Origin

The Aeolian activity could be found everywhere in the Mesopotamia Plain, in form of small accumulations superimposed the fluvial sediments, with variable intensities, particularly in the barren and dry lands. However, the most extensive and significant Aeolian sediments are concentrated in form of sand dune fields. The main sand dune fields cover large areas, which reach few hundreds square kilometers. They are distributed in deferent localities within the Mesopotamia Plain (Fig.10).

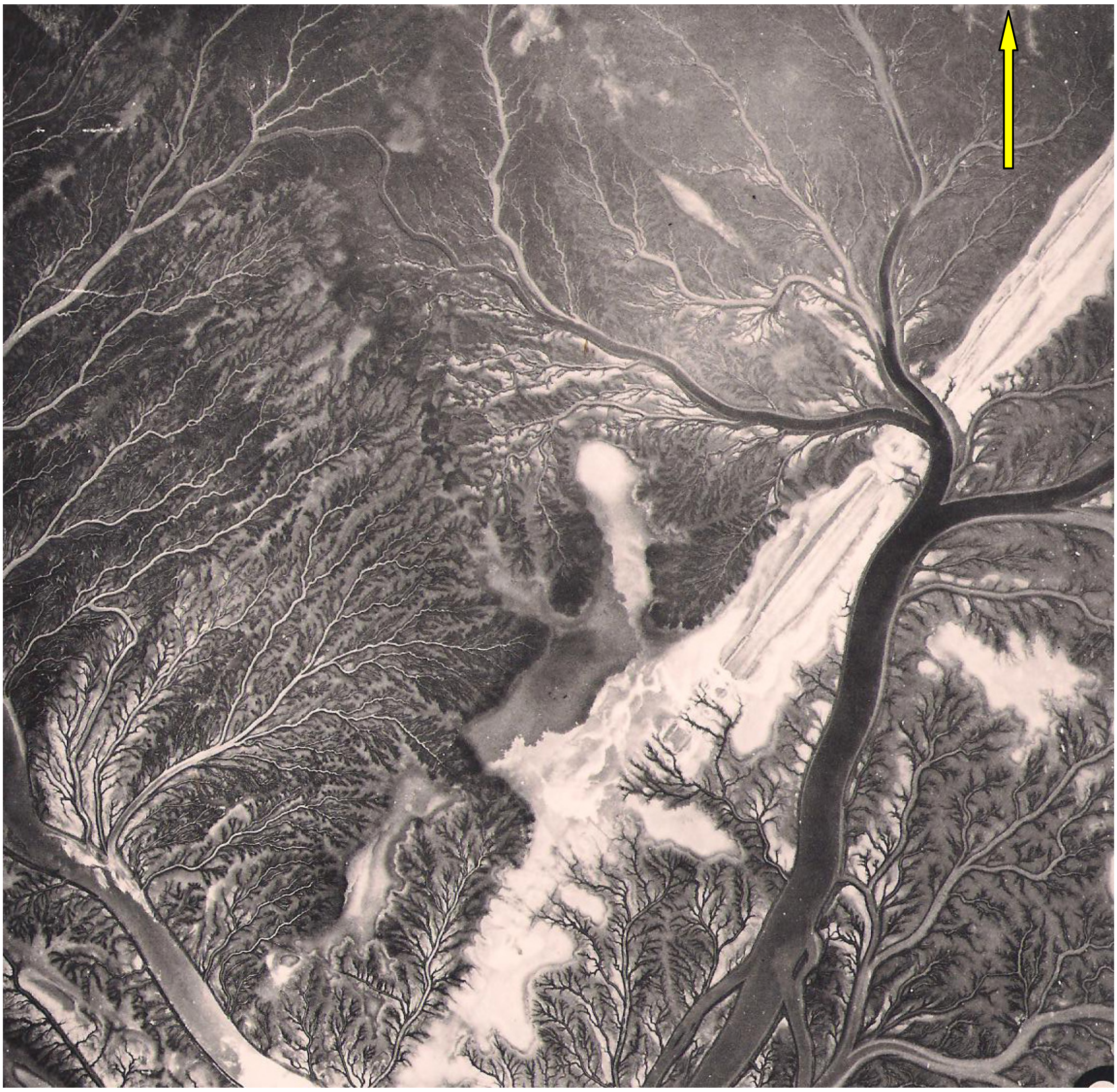

Fig.9: Aerial photograph shows the tidal channels system of Khor Al-Zubair,
Head of Arabian Gulf (scale ≈ 1:60 000, General Directorate of Survey, 1962)

There are many factors, which control the process and forms of the Aeolian sand accumulations, among them are the direction and speed of the wind, and the source and supply of sand are the most important (Munir, 1984 in Jassim *et al*., 1984). The wind-laden (Aeolian) sand is the northwestern winds, which are the most prevailing in Iraq. Generally, the Aeolian sediments are accumulated in form of Nabkhas, sand sheets and sand dunes, which are the classic land forms of Aeolian origin. The three types are described hereinafter.

4.1. Nabkhas

Are the simplest forms, commonly developed on the leeward side of shrubs and other forms of scattered vegetations. Changing the winds direction, some times leads to deposition of Nabkhas on both sides of shrubs. 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.

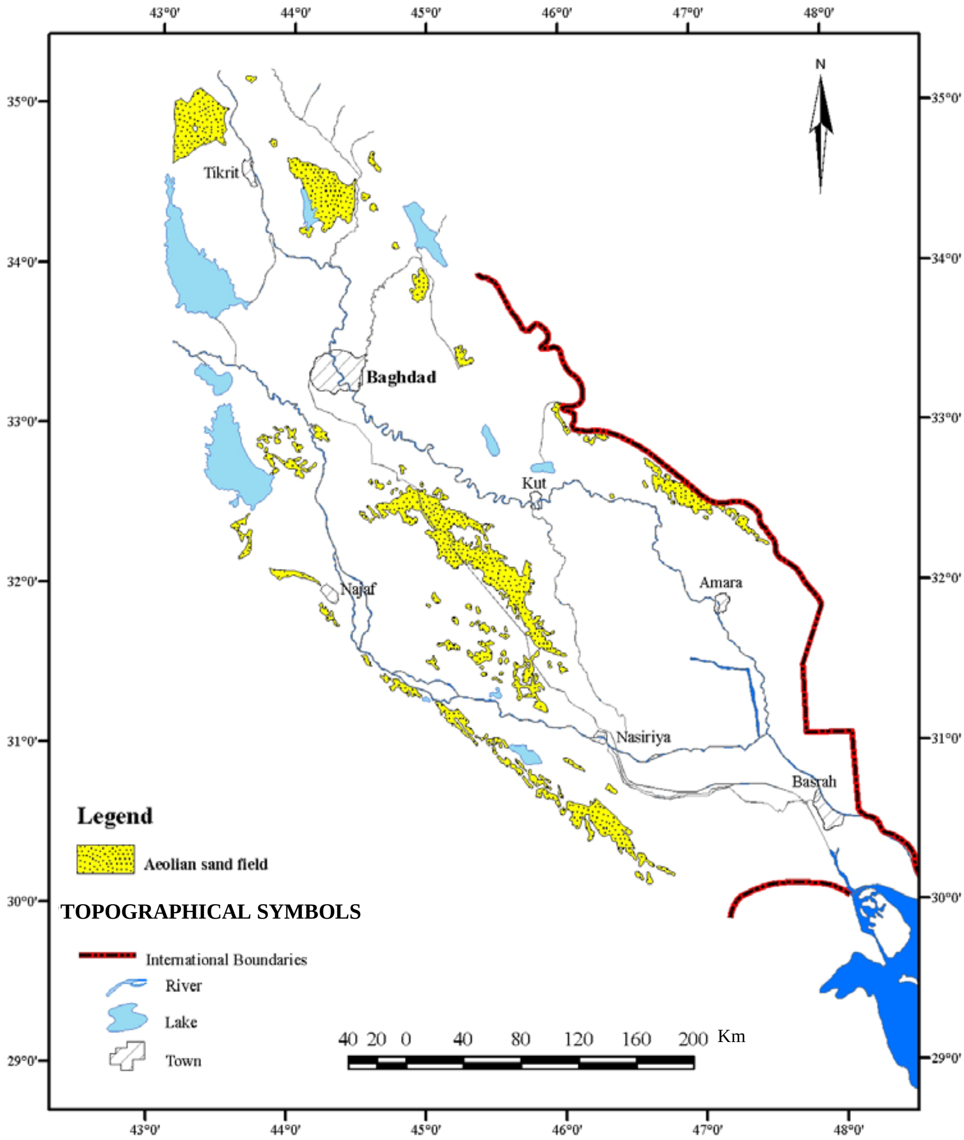

Fig.10: Spatial distribution of Aeolian sand fields within the Mesopotamia Plain (modified from Sissakian, 2000)

4.2. Sand Sheets

Sand sheets are usually associated with the sand dune fields covering the inter-dune areas and extending to the surrounding areas. They often cover large areas that reach hundreds square meters. The drifting sand sheets have usually well developed ripple marks on the surface. They are partly fixed either by vegetations or by thin soil mantel, such as in the sand dune fields of the central part of the Mesopotamia Plain, in Baiji and Mukdadiya vicinities. These sand sheets are subjected to wind deflation.

4.3. Sand Dunes

The sand dunes are the most expressive morphologic form of the Aeolian origin. They are well developed in all Aeolian fields of the Mesopotamia Plain; however, some variations in dimensions and compositions could be noticed in different localities. The most prevailing type of sand dunes is the Barchan type; other types like Transverse, Elongated, Climbing and Falling are rare. The average coverage of the surface area of an individual Barchan is about (300 – 400) m^2; the height is commonly (4 – 5) m, exceptionally reaches more than 10 m, in the Aeolian field of the western margin of the plain, south of Nasiriyah, the distance between the wings ranges between (10 – 20) m, in normal sized Barchans. The Barchans exhibit either isolated form, with the aforementioned dimensions, or they coalesce each other forming colonies covering large areas that reach few square kilometers forming a small scale example of "sand sea" (Domas, 1983). It is also noticed that the Barchans are either active or fixed by thin muddy soil mantle, as being observed in the fields of the Central Mesopotamia Plain. The fixed Barchans are subjected to wind deflation activity. The active Barchans are creeping towards the main wind direction; influencing the adjacent areas, locally these areas are cultivated, like the sand dunes 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.

5. Units of Degradational Origin

The degradational geomorphic land forms in the Mesopotamia Plain are result of fluvial or Aeolian deflation; only two units could be seen in the plain.

5.1. Fluvial Degradational Forms

The most common degradational (denudational) features of the main rivers are the lateral erosion and vertical incision, leading to the development of flood plain stages. The neck cut-off erosion activity, leads to the formation of ox-bow lakes, along the channels of the main rivers. Good examples of ox-bow lakes are developed in the Tigris River flood plain; such as the ox-bow lakes, downstream of Azizziyah, and north of Nu'amaniyah (Fig.6). The same kinds are visible within the Euphrates and Diyala Rivers meandering belts.

The fluvial erosion form, of the foothill rivers appear as entrenchment of the rivers into their alluvial fans, or to the sheet run-off plain. The entrenchment results in development of high cliffs bounding the river channels. The rills and gullies (1 – 2 m deep) cut into the sheet run-off plain are a kind of fluvial erosional phenomenon.

Bad land is developed in different locations within the Mesopotamia Plain. Like on the banks of the main rivers and the abandoned channels. Good examples could be seen along the banks of the Tigris River between Baiji and Samarra, within the alluvial fan sediments, another one is along the banks of Adhaim River.

5.2. 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.

6. Unit of Anthropogenic Origin

Because of human's activities, which have been living in the Mesopotamia Plain, since several thousand years ago, expressive morphological forms are developed on the flat-lying surface of the plain. These geomorphic forms are: irrigation canals (both ancient and recent), 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 historically well known irrigation canal is Al-Nahrawan Canal. It is considered as the longest, deepest, and largest irrigation canal ever built in the history (Buringh, 1960). Its length reaches about 300 Km, which extends from north of Samarra to Hor Al-Shuwaicha. However, it is not totally preserved now.

Many isolated "tells" (hills) or group of tells are distributed on the surrounding flood plain. The average height of the "tells" does not exceed 5 m; their diameter reaches few hundred 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 (or buried settlements), like Babylon, Nippur and Al-Warka.

DISCUSSION AND CONCLUSIONS

- After the last phase of the Alpine orogenic movement, the outlines of the Mesopotamian fluvial basin were clearly defined. This tectonic movement caused relative subsidence of the Mesopotamian fluvial basin versus uplifting of the adjacent Foothills Province (Low Folded Zone) and Western Plateau.
- During the Quaternary Period, the tectonic activity decreased and the climatic factors and geomorphologic processes became relatively more effective on the bed rocks in the area and surrounding provinces. The aggradational processes were more prevailing in the Mesopotamia Plain, whereas the degradational processes were acting on the adjacent provinces. The latter produced huge amount of clastic sediments, which have been delivered, continuously to the Mesopotamian fluvial basin and deposited in form of successive fluvial cycles.
- The alluvial fans and river terraces represent the oldest Quaternary sedimentary cycles, which are preserved on the surface of the Mesopotamia Plain. They are built up of coarse clastics, where sandy gravels and conglomerate beds are dominating. They possess distinct geomorphic features, occupying the relative elevated peripheral parts of the plain. The type of the sediments, extensions and the geomorphic characters of the alluvial fans and river terraces reflect intensive fluvial activities, which characterize the pluvial phases of the Pleistocene Epoch. These pluvial phases were interrupted by inter-pluvial (arid to semiarid) phases, which led to the development of successive stages (maximally four) of alluvial fans and river terraces. These stages, morphologically are marked by brakes in slopes or sharp cliffs. The pluvial and inter-pluvial phases reflect the main climatic oscillations, which took place during the Pleistocene.
- The presence of gypcrete and highly gypsiferous clastic layer on the top of the alluvial fans and river terraces indicate arid to semiarid climatic conditions, started after the end of the last pluvial phase of Pleistocene. Consequently, the surface of the gypcrete is considered as an old surface that marks the end of the Pleistocene in the area.
- Despite of the considerable decrease in precipitation during the Holocene, the accumulation processes and fluvial activity have continued, but with decrease in rivers capacity and gradient. Consequently, new sedimentary cycles of fluvial and lacustrine origin were laid down, with local Aeolian and erosion activities, which led to the development of different geomorphic units. These units are preserved on the present surface of the Mesopotamia Plain, on relatively lower geomorphic level with respect to the alluvial fans.
- The sheet run-off plain is the middle part of the piedmont plain, and it has close connection with the peripheral part of the eastern alluvial fan system. It is characterized by flat surface, partly scoured due to sheet, rill and gully erosion.
- The flood plains of the Euphrates, Tigris, Shatt Al-Arab, Diyala, Adhaim, and foothill rivers are the major fluvial morphologic unit of the northern and central sectors of the Mesopotamia Plain. These flood plains are characterized by distinct morphologic features represented by; river channels bounded by natural levees, crevasse splays, flood basins, local oxbow lakes, and abandoned river channels. Commonly, two stages of flood plain are

developed; the older one is more extensive, whereas the younger is limited within the meandering belt of the corresponding river. However, (3 – 4) stages are locally developed. The flood stages phenomenon indicates, minor climatic oscillations during Holocene and also due to seasonal floods.

- The flood plains of the main rivers and their distributaries terminate in form of four non-marine (lacustrine) deltas forming the northern and western margins of the marshes, which extend from Amara to Suq Al-Shiyoukh.
- The shallow depressions are common morphological feature in the Mesopotamia Plain. They are characterized by very flat and smooth floors. Their dimensions vary from few hundreds square meters to many hundreds square kilometers. The most extensive shallow depressions are the flood basins of the main rivers and the playas, which are developed between the sheet run-off and the Tigris River flood plain. They often are filled by water perennially, periodically, or ephemeral.
- The marshes (Ahwar) and lakes have distinct geomorphic features and posses 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 marshes and lakes system underwent significant changes in geomorphic and environmental situation, 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 centaury 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. Then after, the marshes were partly rejuvenated and a new situation appeared. Therefore, the author recommends future studies to follow-up the changes in marshes environment, using remote sensing and GIS techniques.
- Two types of sabkhas are recognized: the inland sabkhas which are developed in shallow depressions, particularly on the southern and western margins of the Mesopotamia Plain; and the Estuarine sabkha, which is developed between Basrah and Khor Al-Zubair, as a result of combined actions of seawards progradation of coast line and the flood plain of Shatt Al-Arab.
- Two geomorphic forms of marine origin are restricted to coastal area. They are either of accumulation type, represented by tidal flat or of erosion type, represented by tidal channels. Both are still active phenomena.
- The Aeolian activities are highly effective in the Mesopotamia Plain, especially on the barren and dry lands. The most extensive Aeolian landforms are sand dune fields, which cover large areas that reach few hundreds kilometers. Other simple landforms, like Nabkhas and discontinuous sand sheets are scattered everywhere in plain, which superimposed the flood plain sediments. Three common Aeolian landforms are sand dunes, Nabkhas and sand sheets.
- The units of degradational origin are restricted to the stream and riverbanks, which are commonly represented by lateral erosion and vertical incision of the rivers. Badland erosion is locally developed on the banks of the main rivers and old channels. Another type of erosion is the wind deflation. Sheet erosion is mainly affecting the sheet run-off plains.
- The most common geomorphic forms of anthropogenic origin are: irrigation canals (both ancient and recent), ancient settlements and artificial tells (hillocks).

REFERENCES

Abdul Jabbar M.F., 2008. Application of Change Detection techniques in Marsh Areas, South Iraq. Iraqi Bull. Geo. Min., Vol.4, No.1. p. 105 – 115.

Abdulla, Sh.A.Z., 1990. Climatological Atlas of Iraq (1961 – 1990). Iraqi Meteorological Organization. GEOSURV, int. rep. no. 4154.

Al-Sharbati, F.A. and Ma'ala, K.A., 1983. Report on the regional geological mapping of west Zubair area. GEOSURV, int. rep. on. 1345.

Al-Ma'amar, A.F., Abd Al-Jabar, M.F. and Al-Rubaiay, A.T., 2008. Detection of surface changes in the Marshes Area southern Iraq, using remote sensing techniques and GIS. GEOSURV int. rep. no. 3135.

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

Aqrawi, A.A.M., 2001. Stratigraphic signatures of climatic changes during the Holocene evolution of Tigris – Euphrates delta, Lower Mesopotamia. In: Global and Planetary Change, Elsevier, 28, p. 267 – 283.

Barwari, A.M., Slewa, N.A., Domas, J. and Hamza, N.M., 1994. Geological Map of Kut Quadrangle, sheet NI-38-5, scale 1: 250 000. GEOSURV, Baghdad, Iraq.

Barwari, A.M., Yacoub, S.Y. and Benni, Th. J., 2002. Quaternary Sediments Map of Iraq, scale 1: 1000 000. GEOSURV, Baghdad, Iraq.

Benni, Th.J., 2009. Assessment of Desertification by Using Remote Sensing Data and GIS in the Western Part of Mesopotamian Plain, Iraq (Abstract of Ph.D. Thesis). Iraqi Bull. Geo. Min., Vol.5, No.2, p. 121 – 122.

Bolton, C.M.G., 1956. Geological Investigation of gravel area between Tel Ad'dair and Sumaika, near Baghdad. GEOSURV, int. rep. no. 268.

Deikran, D.B., 1995. The Geology of Suq Al-Shiyoukh Quadrangle, sheet NI-38-10, scale 1: 250 000. GEOSURV, Baghdad, Iraq.

Domas, J., 1983. The Geology of Karbala Kut and Ali Al-Gharbi Area. GEOSURV, int. rep. no. 1384.

General Directorate of Survey, 1962. Aerial Photographs, scale 1: 60 000, Baghdad, Iraq.

Hamza, N.M. and Domas, J., 1980. The Geology of the Adhaim Area. GEOSURV, int. rep. no. 1381.

Hamza, N.M. and Yacoub, S.Y., 1982. The Geology of Baghdad – Falluja Area. GEOSURV, int. rep. no. 1382.

Hamza, N.M., 1997. Geomorphological Map of Iraq, scale 1: 1000 000. GEOSURV, Baghdad, Iraq.

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. GEOSRUV, int. rep. no. 2023.

Hassan, A.M. and Al-Jawadi, B.H., 1976. Report on the geological mapping of Samarra – Baiji area. GEOSURV, int. rep. no. 719.

Hassan, K.M., Al-Khateeb, A.A.G., Khlaif, H.O., Kadhum, M.A. and Saeed, F.S., 2002. Detailed geological survey for mineral exploration in Karbala – Najaf area, part I, Geology. GEOSURV, int. rep. no. 2874.

Ibrahim, S.B. and Sissakian, V.K., 1975. Report on the Al-Jazira area (Rawa – Baiji – Tikrit – Al-Baghdadi). GEOSURV, int. rep. no. 675.

Jassim, S.Z., 1981. Early Pleistocene Gravel Fan of the Tigris River from Al-Fatha to Baghdad, Central Iraq. Jour. Geo. Soc. Iraq, Vol.14, p. 25 – 34.

Jassim, S.Z., and Goff, J.C., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno. 341pp.

Jassim, S.Z., Karim, S.A., Basi, M.A., Al-Mubarak, M.A., Munir, J., 1984. Final Report of the regional geological survey of Iraq, Vol. 3, Stratigraphy. GEOSURV int. rep. no. 1447.

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, p. 227 – 244.

Ma'ala, Kh. A., 2009. Geomorphology. In: Geology of Iraqi Southern Desert, Iraqi Bull. Geol. Min., Special Issue, No.2, p. 1 – 33.

Purser, B.H., 1973. The Persian Gulf, Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Springer Verlag, Berlin.

Sissakian, V.K., 2000. Geological Map of Iraq, 3rd edit., scale 1: 1000 000. GEOSUR, Baghdad, Iraq.

Salim, A.M., 1978. Report on the geological mapping of the Samarra – Falluja Area. GEOSURV, int. rep. no. 868.

Yacoub, S.Y., 1983. The Geology of Mandali Area. GEOSURV, int. rep. no. 1383.

Yacoub, S.Y., 1994. The Geology of Al-Basrah, Abadan and Bubyian Quadrangles, sheets: NH-38-8, NH-39-5 and NH-39-9, scale 1: 250 000. GEOSURV, Baghdad, Iraq.

Yacoub, S.Y. and Barwari, A.M., 2002. Quaternary Sediments Map of Iraq, scale 1: 1000 000, Explanatory Text. GEOSURV, Baghdad, Iraq.

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. GEOSURV, int. rep. no. 1078.
Yacoub, S.Y., Roffa, S.H., and Tawfiq, J.M., 1985. The Geology Al-Amara – Nasiriyah – Al-Basrah Area. GEOSURV, int. rep. no. 1386.
Yacoub, S.Y., Deikran, D.B. and Ubaid, A.Z., 1990. Local Geological Stage Report, Vol. 1, Project C.E.S.A. GEOSURV, int. rep. no. 2016.
Yacoub, S.Y., Sissakian, V.K. and Deikran, D.B., 1991. Final Geological Report, Project C.E.S.A. GEOSURV, int. rep. no. 2024.

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