CHAPTER 3

GEOLOGY AND PALAEOENVIRONMENT OF NASIRIYAH AREA/SOUTHERN MESOPOTAMIA

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Salvatore Milli
Department of Earth Science,
Sapienza - Università di Roma
salvatore.milli@uniroma1.it

Luca Forti
Department of Earth Science,
Sapienza - Università di Roma
lucaforti93@gmail.com

3.1 Geomorphology

The Mesopotamian Plain constitutes the central and southern sector of the Iraqi territory having a length and width of about 720 km and 200 km respectively. It is a relatively flat terrain extending from Baiji in the north-west to the Arabian Gulf in the south-east; it is bordered to the north-east by the Zagros mountains belt and to the west by the Arabian Desert (Fig. 3.1). The Tigris and Euphrates rivers and their tributaries are the main waterways of the region, flowing through the plain for almost all of its extension. The two rivers, in fact, run separately onto a wide, flat, hot, and poorly drained floodplain for several hundred kilometres and merge to form the Shatt Al-Arab river in the south-eastern sector of the Mesopotamian Plain. Here the Shatt Al-Arab river flows for about 180 km before it enters in the Arabian Gulf where it forms, together with the Karun river, the Shatt Al-Arab estuary. In this last sector intermittent lakes, and marshy environments fed by the rivers in flood, are also present. Although much of the Marshland has been drained or has diminished as a result of drought, there are still large areas of permanent marsh, with additional areas becoming marshland only in years of great flooding.

The actual deposits of the plain are essentially fluvial and are represented by floodplain and channel deposits.[1] In particular the most prominent feature is a complex system of natural levees following the courses of the Euphrates and Tigris rivers, up to 3-4 m high, which laterally passes into a flood plain basin.[2] Such deposits are also associated to aeolian deposits and alluvial fans along the margins of the plain and to lacustrine and marshy deposits in the south-eastern sector of the plain.

Fig. 3.1 Geographic map showing the location of the Mesopotamian Plain.

Southern Mesopotamia, which is the investigated sector in this study, shows a present landscape characterized by a wide floodplain including active fluvial channels, natural levees, crevasse splays, flood basins that are inundated by the water of the Tigris and Euphrates during the Spring floods (Fig. 3.2); this sector displays also desert environments with dune fields and deflation areas that are

[1] Pournelle 2003; Pirasteh *et al.* 2009; Yacoub 2011b; Hritz *et al.* 2012.

[2] Verhoeven 1998.

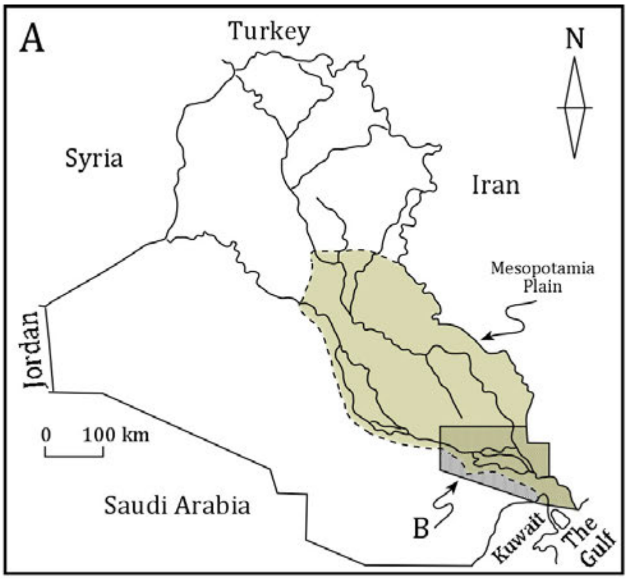
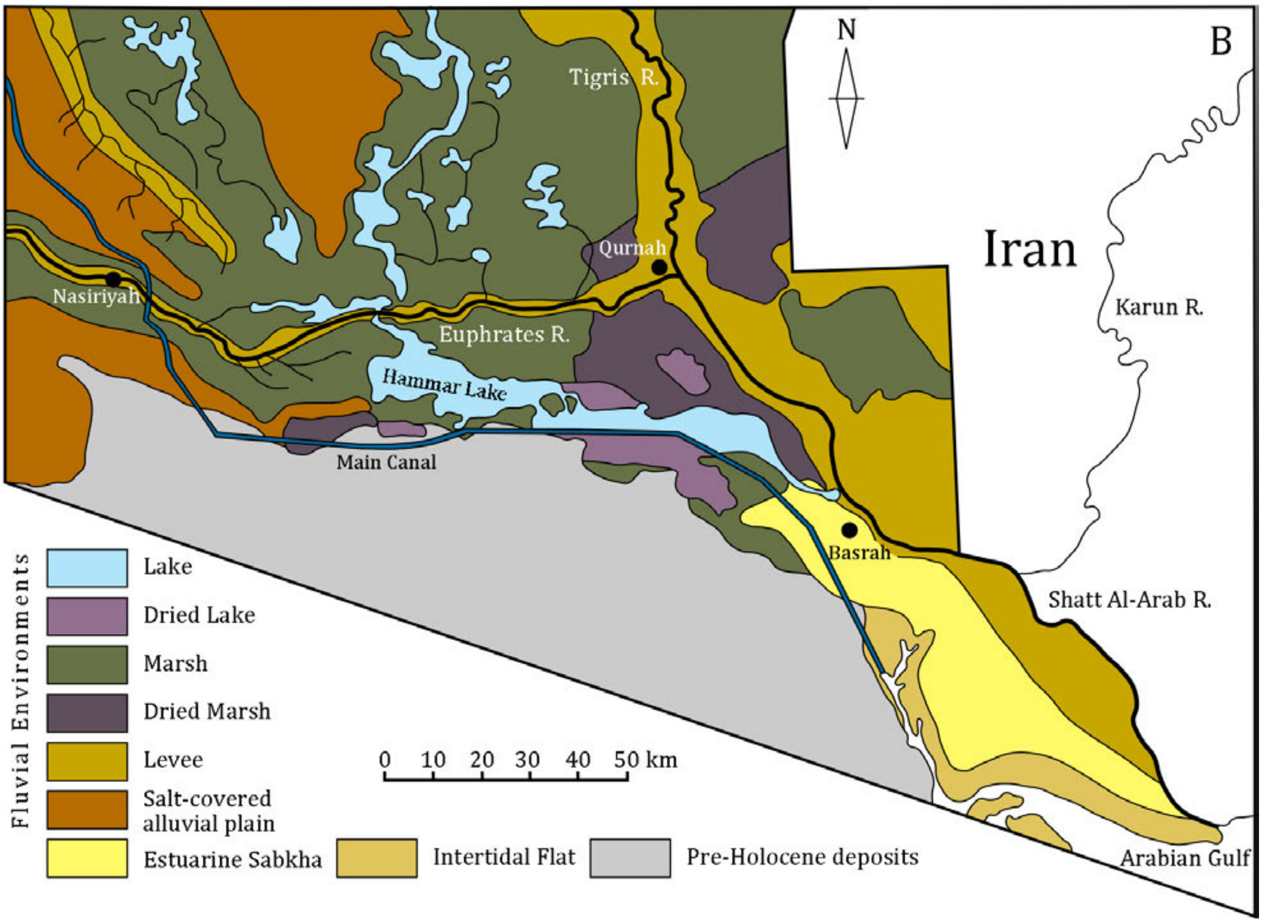


Fig. 3.2 (A) Physiographic map of Iraq showing the location of the Mesopotamian Plain and the detail of the study area; (B) Enlarged map showing the lakes and marshes (Ahwar) occurring in the study area. Modified from Aqrawi and Evans 1994.



subject to intensive salinization.[3] This sector of the Mesopotamian Plain is also covered by shallow (generally less than 3 m deep), fresh-brackish water lakes, surrounded by reed beds and marshes, which together are locally called "Ahwar".[4] The two main freshwater lakes are the Zechri and Baghdadiyah Lakes, whereas the most extensive brackish water lake is the Hammar Lake (Fig. 3.2). Generally, the water of these lakes shows salinity and temperature fluctuations related to the seasonal variation of the air temperature, rainfall and evaporation, as well as the effect of varying river discharges during the year.[5] As evidenced by Aqrawi and Evans[6] during winter and spring the high river discharges raise

[3] Aqrawi - Evans 1994; Verhoeven 1998; Morozova 2005.
[4] Aqrawi - Evans 1994; Verhoeven 1998; Aqrawi 2001.
[5] Bozkurt - Sen 2011.
[6] Aqrawi - Evans 1994.

the water level in the Ahwar and lower the salinity of the water. By contrast, during the summer and early autumn, the low discharges coupled with the high air temperatures and evaporation result in an increase of salinity and water temperature.

The waters of the Tigris and Euphrates were extensively exploited for irrigation of the lower Mesopotamian Plain since the 6th mill. BC, consequently human impact played a leading role in modifying the ancient and the more recent landscape of this region through the construction of canals and settlements. Thus, the location of the ancient Tigris and Euphrates channels and the avulsion processes played an important role in the development of Mesopotamian civilization and in the settlement distribution of the urban centres, as well as their emergence and decline.[7] As highlighted by more recent studies, which investigated this area using a combination of geological, geomorphological, remote sensing, historical and archaeological approaches,[8] the present drainage pattern of the plain is rather different from that formed during the last 6000 years; in fact, several palaeochannels were identified and dated also evidencing a different age of the channels between the eastern sector (where the channels are older) and the western sector (where the channels are younger). Such changes reflect the effects of the autogenic and allogenic processes as well as the human influence,[9] so that most of the archaeological studies which were carried out in this area[10] have assumed that periods of active channels are closely linked to the age of archaeological settlements and most of the identified ancient settlements were established on the sectors where active channels occurred.[11] On this basis Jotheri and Allen[12] recognized in the Uruk area (just about 50-70 km north of Nasiriyah), more than 400 archaeological sites (period of time between 5950-2950 yr. BP) that are associated with palaeochannels having an anastomosing pattern that encloses flood basins. It is suggested here that a similar setting could probably have occurred in the Abu Tbeirah area about 4200 yr. BP, although this last area was nearest to the coast, occupying the internal plain of the Euphrates delta.

3.2 Geological Setting

From a geological point of view, the Mesopotamian Plain represents a portion of the larger Mesopotamian Foredeep,[13] a basin placed between the Arabian plate and the south-west-migrating Zagros fold-and-thrust belt, (ZFTB),[14] which extends from the north-east Syria to the Strait of Hormuz (Fig. 3.3). The Mesopotamia Foredeep consists of two main domains: 1) a terrestrial domain (the Mesopotamian Plain) that covers part of north-east Syria, Iraq, Kuwait and the coastal plain of Iran, and 2) a marine domain represented by the Arabian Gulf.[15]

The Mesopotamian Plain that occupies a large part of the Iraqi territory constitutes a subsiding basin,[16] with a thick Phanerozoic succession that was subdivided into three main tectono-stratigraphic units:[17] 1) the older Cambrian - Early Permian unit, 5 km thick, is dominated by siliciclastic sediments deposited in a shallow epicontinental sea;[18] 2) the Late Permian - Middle Cretaceous unit, also 5 km thick, consists of neritic and lagoonal evaporites, shales and carbonates at the base, passing upward to an alternation of shallow water carbonates and sandstones deposits; 3) the Late Cretaceous presents foreland deposits that show a highly variable thickness in different parts of the Iraqi territory; they consist of Palaeogene carbonate at the base passing upward to Neogene lagoonal and restricted marine evaporate facies, further replaced upwards by terrigenous continental and deltaic deposits.[19]

[7] Gibson 1972; Schumm 1977; Adams 1981; Diakonoff 1991.
[8] Hritz - Wilkinson 2006; Jotheri *et al.* 2014; 2016; 2018.
[9] Heyvaert - Baeteman 2008; Heyvaert *et al.* 2010; 2012; Wilkinson *et al.* 2015.
[10] See for example Adams 1981; Cole 1994; Cole - Gasche 1998; Morozova 2005.
[11] *E.g.* Adams 1981; Wilkinson - Jotheri 2015; Wilkinson *et al.* 2015; Jotheri *et al.* 2016; 2018.
[12] Jotheri - Allen 2017.
[13] Fouad 2010.
[14] Baltzer - Purser 1990; Alavi 1991; 1994; Allen - Talebian 2011; Carminati *et al.* 2013; Aldega *et al.* 2014; Garzanti *et al.* 2016.
[15] Berberian 1995; Alshrhan - Nairn 1997; Sharland *et al.* 2001; Alavi 2004; Fouad - Nasir 2009.
[16] Jassim - Goff 2006; Jassim - Al-Jiburi 2009.
[17] Fouad - Sissakian 2011; Sissakian 2013.
[18] Beydoun 1991; Alsharhan - Nairn 1997; Sharland *et al.* 2001.
[19] Fouad 2010.

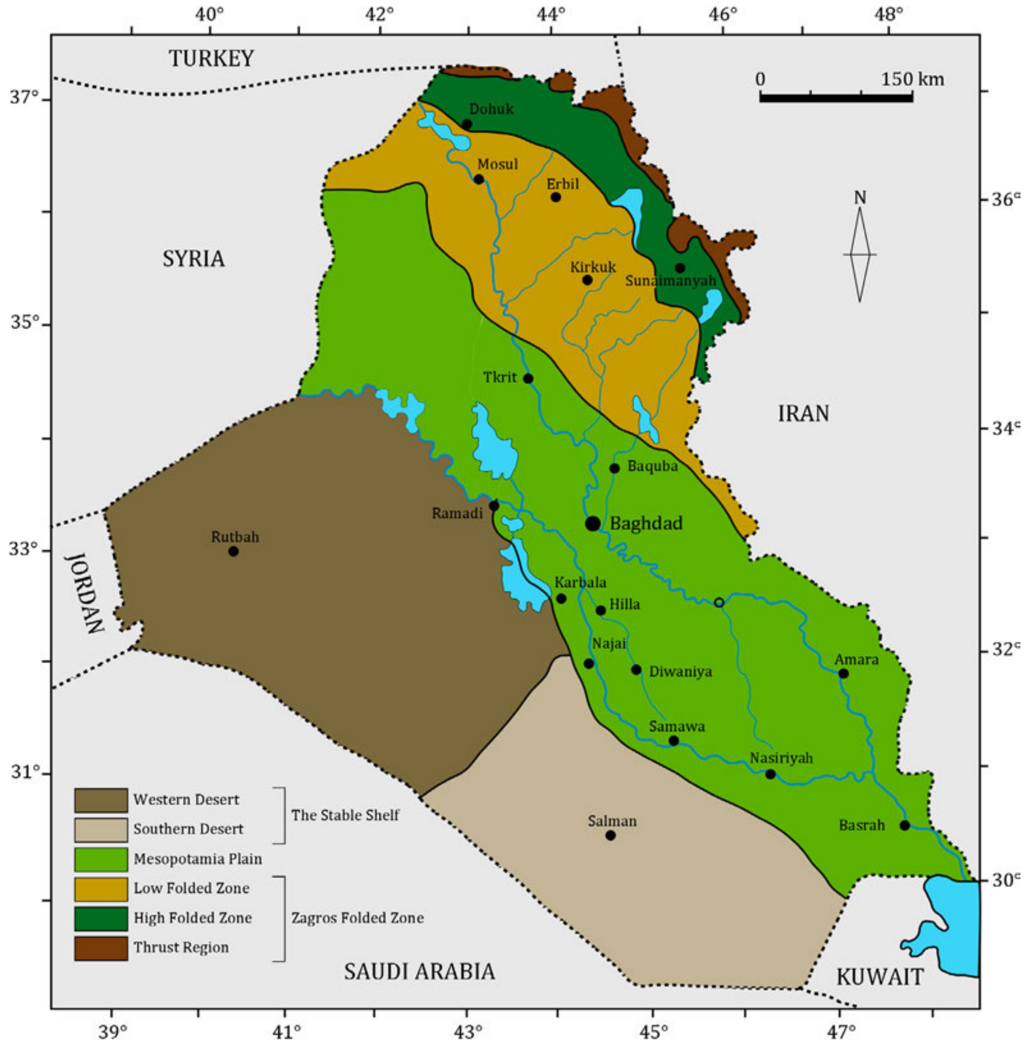


Fig. 3.3 Physiographic map of Iraq showing the location of the Mesopotamian Foredeep between the Arabian Plate and the Zagros fold-and-thrust belt. Modified from Sissakian 2013.

Subsurface investigations of the Mesopotamian Plain have revealed an asymmetric geometry of this basin with a wedge-shaped profile and a maximum sediment thickness in correspondence to the Zagros orogenic front that gradually decreases south-west towards the undeformed continental interior.[20] Such investigations have shown that a number of buried tectonic structures including folds, faults and diapiric structures occur. Many of these buried structures are still active, indicating neotectonic movements that can be observed through their effects on the Pleistocene-Holocene stratigraphy and coastline position, and through a modification of the Quaternary landforms; the latter is, in fact, characterized by abandoned river channels and shifting of river courses (both processes recognized for the Tigris and Euphrates rivers), and the different activities of the alluvial fans, mainly developed along the eastern margin of the Mesopotamian Plain.[21]

3.3 The Quaternary Deposits

The Quaternary deposits cover the totally of the Mesopotamian Plain and are mainly represented by gravels, sands, silts and clays that are essentially related to the cyclic fluvial sedimentation of Tigris and Euphrates rivers with their tributaries and distributaries. During the Pleistocene and Holocene, the basin, in fact, was supplied with

[20] Sissikian - Deikran 1998.

[21] Al-Sakini 1993; Fouad - Sissakian 2011.

sediments, derived by erosion of the Zagros fold-and-thrust belt and the Arabian Platform, through active fluvial systems. Thus, the infill sediments of the basin are essentially fluvial, deltaic, and lacustrine deposits although during the Holocene, estuarine, marine and aeolian sediments were also deposited (Fig. 3.4).[22] The Quaternary sediments of the Mesopotamian Plain, were investigated through a detailed geological survey either of the cropping out deposits, or of the subsurface deposits. The latter, in particular, were examined through several shallow and deep boreholes (from 20 to 200 m depth respectively),[23] which allowed to show a progressive thickening of the Quaternary deposits from north-west to south-east, with their maximum thickness, about 180 m, near Basrah city.[24]

On this basis and taking into account the climatic changes occurred during the Quaternary, three main stratigraphic units were recognized in these deposits on the basis of their age:[25] 1) a unit of Pleistocene age; 2) a unit of Late Pleistocene-Early Holocene; 3) a unit of Mid-Late Holocene age. For the chronostratigraphic subdivisions of the Quaternary we referred to the *International Chronostratigraphic Chart* (2018).

The Pleistocene sediments are constituted by fluvial and alluvial fan deposits that occupy the central and marginal sectors of the Mesopotamian Plain respectively. Such deposits are essentially represented by an intricate interbedding of gravels, sandy gravels, sands, silt and silty clay, with a prevailing of sands and silt on large part of the plain and the coarser sediments along the margin. They record alternating pluvial and inter-pluvial phases, which correspond to the well-known glacial and inter-glacial phases that have characterized the Pleistocene and that have produced significant glacioeustatic sea-level changes. In our opinion, such Pleistocene fluvial deposits contain several subaerial unconformity surfaces, which represent the depositional sequence boundaries formed during the Pleistocene glacioeustatic sea-level oscillations. The most recent of these unconformity surfaces was formed during the sea-level fall that followed the last highstand phase correlated with the MIS 5.5. In our opinion, such unconformity occurs on top of the Pleistocene fluvial deposits, which show in the southern portion of the Mesopotamian Plain a distinctive and slightly weathered brown silt clay or clay layer, from 2 m to 5 m thick, which constitutes

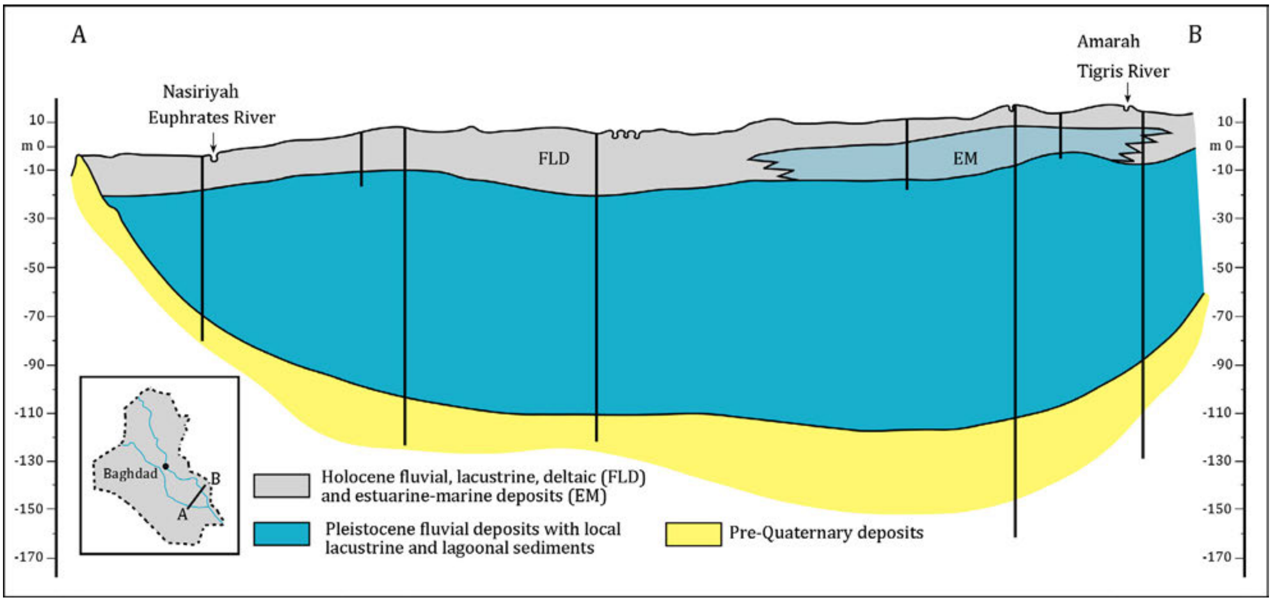


Fig. 3.4 Subsurface geological cross-section of the southern Mesopotamian fluvial basin between Nasiriyah and Amarah. Modified from Yacoub *et al.* 1985.

[22] Yacoub *et al.* 1985; Aqrawi - Evans 1994; Yacoub 2011b.
[23] Hamza - Domas 1980; Hamza - Yacoub 1982; Domas 1983; Yacoub 1983; Yacoub *et al.* 1985.
[24] Yacoub - Barwari 2002.
[25] Yacoub 2011b.

the expression of a mature palaeosoil, indicating a long subaerial exposure.

Based on what was stated previously, both units 2 and 3 are here considered to be the product of deposition during the last glacial-interglacial cycle of post-Tyrrhenian age. The unit 2 (Late Pleistocene-Early Holocene age), consisting of i) alternating layers of sand, silt and silty clay forming the distal portions of alluvial fan, ii) coarse-grained subaerial gravity flows sediments mixed with gypsiferous sands, and iii) gypsum-indurated layers (Gypcrete), was deposited in a hot, arid or semiarid climate condition and in a basin that had internal drainage; it is considered to be formed during the falling, stillstand and the rise of relative sea-level. The unit 3 (Mid-Late Holocene age) which includes sediments of different origins, such as fluvial, lacustrine, marine, estuarine, aeolian, anthropogenic and all the deposits of the modern sedimentary environments of the Mesopotamian Plain is, instead, considered to be formed under rising and highstand sea-level conditions that determined a landward (transgression) and a subsequent depositional regression of the coastline respectively. Data from MacFadyen and Vita-Finzi and Purser *et al.*[26] suggest also a tectonic deformation of these recent deposits with an elevation of +2 m at Amarah and a subsidence from Nasiriyah to Qurnah. This suggests that the highstand progradation was probably also favoured by a slight drop of sea level.

3.4 The Holocene Stratigraphy and Sedimentology of the Southern Mesopotamian Plain

The presence of Holocene marine sediments (*e.g.*, Hammar Formation) was particularly recognised in the southern Mesopotamian Plain where different locations for the point of maximum marine transgression, *e.g.* the maximum landward migration of the shoreline at 6000 yr. BP, were proposed on the base of stratigraphic, sedimentological and archaeological data. Cooke [27] suggested the sea reached the locations of Diwaniya and Kut, whereas Sanlaville, Aqrawi and Kennett and Kennett suggested the alignment between Nasiriyah and Amarah as coastline position at 6000 yr. BP (about 270 and 260 km north of the present day northern Arabian Gulf respectively).[28] As suggested in these notes, based on the recent acquisition of stratigraphic-sedimentological data and through various remote sensing techniques, it is possible to confirm this last coastline position as the most probable. This is also confirmed by the spectacular remote sensing images that show the plan geometries of the coeval Euphrates and Tigris deltas, geometries that resemble the river-dominated deltas.

More in detail the subsurface Holocene deposits of the southern part of the Mesopotamia Basin are well preserved in Amarah, Nasiriyah and Basrah areas; they are about 15-20 m thick and can be subdivided into three stratigraphic units (from bottom to top): 1) a lower fluvial sandy unit, rich in gypcretes often associated to ancient plays deposits; 2) an estuarine brackish/marine unit, and, 3) an upper fluvial/lacustrine unit.[29] Both the unit 1 and 2 are transgressive and were deposited during the Holocene sea-level rise (Early-Mid Holocene), whereas the unit 3 was formed during the Holocene highstand phase (Late Holocene) and shows a progradational character.

1) The lower fluvial unit consists of floodplain silty sand sediments rich in gypcretes; it prevalently occurs on the eastern side of the basin and grades laterally into marsh/lacustrine silty sand deposits rich in organic matter along the axis of the Mesopotamia depression. Playa evaporitic clayey sandy silt occurs towards the western desertic margin.[30] Such unit was formed during the Early Holocene, and shows a thickness that increases toward south, from Qurna to Basrah.

2) The estuarine brackish/marine unit, from 5 to 12 m thick, is known in literature as the Hammar Formation[31] and is attributed to the Mid Holocene.[32] It is constituted by fine to medium grey sand, alternating with brownish and greenish grey silty clay and clayey silt. Clayey silts and silty clays are more abundant from Amarah to Qurnah, whereas south of Qurnah the fine

[26] MacFadyen - Vita-Finzi 1978; Purser *et al.* 1982.
[27] Cooke 1987.
[28] Sarnthein 1972; Sanlaville 1989; Aqrawi 1995a; 2001; Kennett - Kennett 2006.
[29] Yacoub *et al.* 1985; Aqrawi 1995a; 1995b; Yacoub 2011b.
[30] Aqrawi 2001.
[31] Hudson *et al.* 1957.
[32] Aqrawi 1995a; 1995b; 2001.

sands are the dominant sediment. This unit is subdivided into four subunits, from bottom to top: i) a basal shelly layer with authigenic brackish-water dolomite; ii) a thick, grey marine clayey silt with abundant marine fauna; iii) a coastal marsh/intertidal silty clay; and iv) a sabkha gypsum evaporite, particularly developed in the western margins of the plain.[33] The mixture of fresh water and marine fauna, essentially represented by mollusks, and numerous foraminifera, crab and echinoid fragments,[34] suggests that the southern part of the Mesopotamian Plain was flooded during the Mid Holocene. In fact, as evidenced by Sanlaville, Lambeck, Kennett and Kennett,[35] from the peak of the glaciation until about 14000 yr. BP, the Arabian Gulf was totally in subaerial conditions. Starting from 14000 yr. BP with the post-glacial sea-level rise, the Gulf was flooded. The rise of sea-level was rapid until ~ 9000 yr. BP (estimated value ~10-11 mm per year) allowing a landward migration of the coastline that probably exceeded 1000 m per year.[36] Such flooding of the Arabian Gulf coincided with a major humid conditions associated with an increased seasonal rainfall between 10000 and 6000 yr. BP, which is witnessed by several indicators including geochemical evidences,[37] sedimentological and geomorphological evidences,[38] pollen evidences,[39] and palaeoceanographic and climatic evidences from oxygen isotopic values.[40] Successively the rate of sea-level rise slowed reaching a value of ~3 mm per year in the last 7000 years. This sea-level rise trend is similar to that documented in the Mediterranean basin in correspondence of the main deltaic apparatus.[41]

In the Arabian Gulf the present shoreline was reached probably about 7000-8000 yr. BP (Fig. 3.5) and was surpassed as sea level rose above its present level by about 2-2.5 m. The sea-level rise reached its maximum about 6000 yr. BP; this allowed to flood much of the Mesopotamian Plain giving rise to an estuarine shallow-marine-lagoon environment, which stretched along the axis of the valley developed in the most depressed sector of the Mesopotamian Plain (Fig. 3.6).[42] What was the real northern extension of this estuary is not known precisely, although Cooke[43] indicated about 400 km inland from the present shoreline. With the stabilization of the sea-level and the strongly reduced accommodation space, fluvial aggradation was at the minimal; the Tigris and Euphrates rivers moved rapidly towards south-east, forming a shoreline along the alignment between Amarah and Nasiriyah with well-developed river-dominated deltas.

3) The upper fluvial/lacustrine unit developed essentially during the Late Holocene and includes also the modern sedimentary environments of the plain.[44] This unit, some meters thick, was deposited in connection to a seaward coastline migration related to the highstand progradation of the Tigris and Euphrates deltas. Deltaic progradation was particularly rapid between 6000 and 4000 yr. BP[45] due to the well-developed multiple fluvial channel networks (Fig. 3.6). Such environmental setting increases avulsions processes, and this consequently brought an increase in irrigated floodplain areas, agricultural productivity, and human settlements;[46] these processes could not have been developed without a near-stable (stillstand) position of sea-level.[47]

Deltaic progradation slowed significantly between 4000 and 3000 yr. BP (sedimentation rate of about 1.0 mm/yr) due to the increase of aridity, a process that had already begun between 6000 and 5000 years ago, and which continued to increase through the Late Holocene. The consequence of this was the gradual abandonment of these channel networks and the transition to the present two-channel system.[48] This determined the

[33] Aqrawi 1995a; 1995b; 2001.
[34] MacFayden - Vita-Finzi 1978.
[35] Sanlaville 1989; Lambeck 1996; Sanlaville 2003; Kennett - Kennett 2006.
[36] Teller *et al.* 2000.
[37] Sirocko *et al.* 1993.
[38] Diester-Haass 1973; Hötzl *et al.* 1984; Dabbagh *et al.* 1998.
[39] Wright 1993; Yan - Petit-Maire 1994.
[40] Rossignol-Strick 1987; Haynes *et al.* 1989; Street-Perrot - Perrott 1990; Almogi-Labin *et al.* 1991.
[41] See Warne - Stanley 1993; Amorosi - Milli 2001; Milli *et al.* 2013; 2016.

[42] See the proposed reconstruction reported in Cooke 1987, Aqrawi 1995a, 1995b, 2001, Kennett - Kennett 2006, and what we proposed on the basis of our considerations.
[43] Cooke 1987.
[44] Larsen - Evans 1978; Aqrawi 1995a; 1995b; 2001.
[45] Sedimentation rate of about 1.8 mm/yr; Aqrawi 1995a.
[46] Morozova 2005.
[47] Kennett - Kennett 2006.
[48] Sanlanville 1989; Aqrawi 2001; Sanlaville 2003.

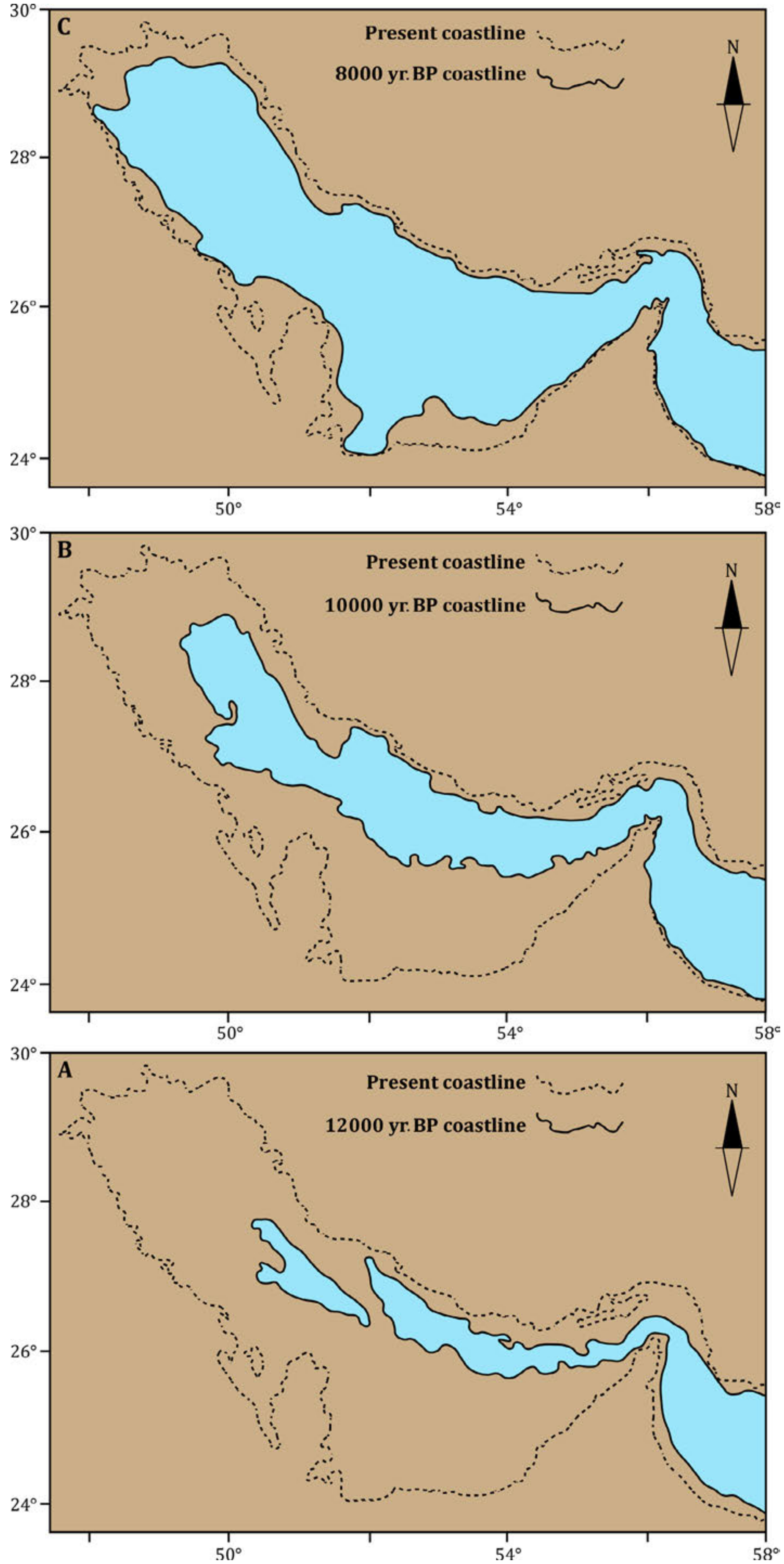


Fig. 3.5 Palaeoshoreline reconstructions of the Arabian Gulf at: (A) 12000 yr. BP; (B) 10000 yr. BP; (C) 8000 yr. BP. Modified from Lambeck 1996.

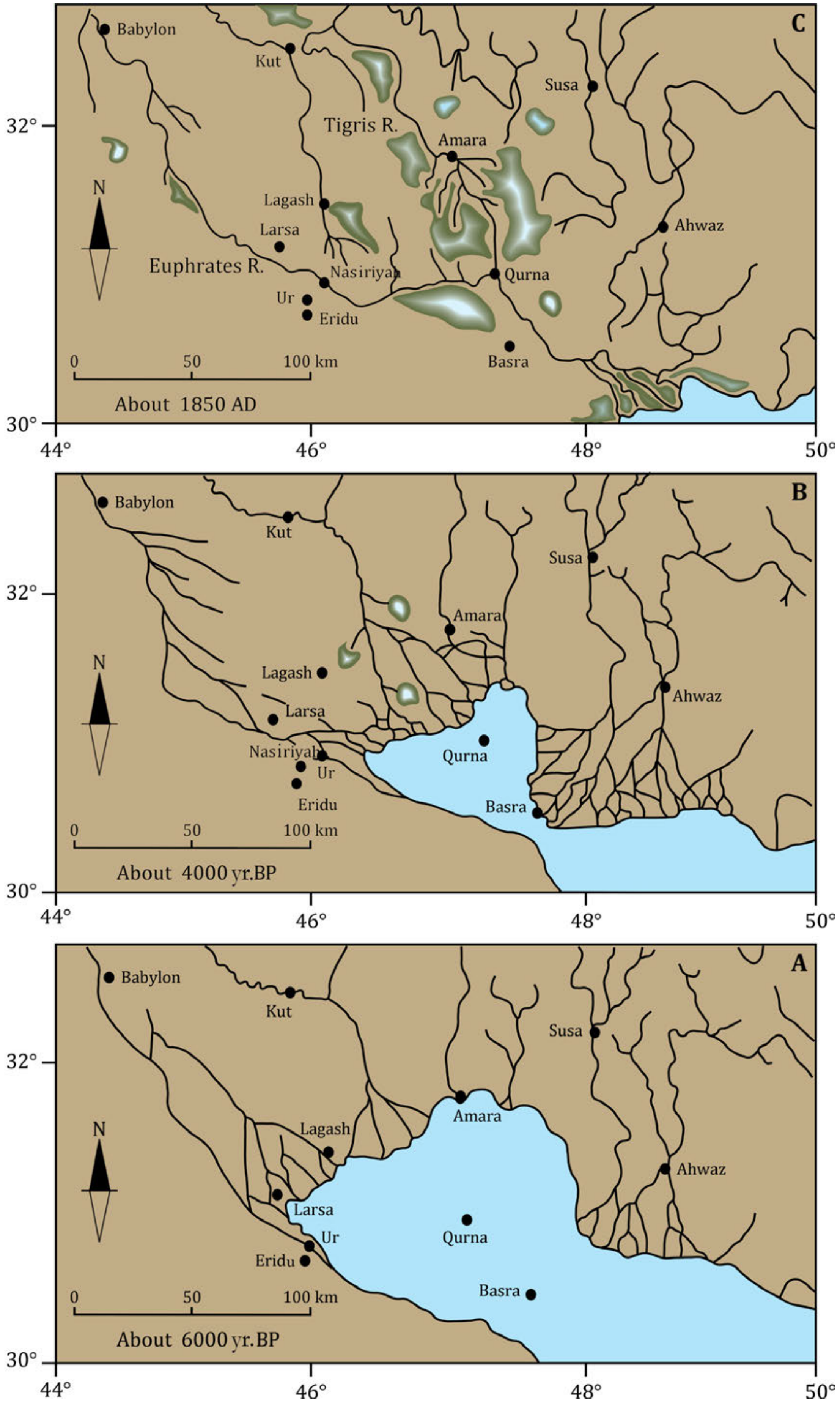


Fig. 3.6 Palaeogeographic maps of southern Mesopotamia showing the historical changes of the Gulf shorelines at: (A) 6000 yr. BP; (B) 4000 yr. BP; (C) 1850 AD. Green areas indicate marshlands. Modified from Aqrawi 2001.

decline of many urban and rural settlements and the migration of population to other areas.[49] As evidenced by Aqrawi and Evans[50] in the Ahwar area, freshwater conditions have persisted since about 3000 yr. BP. During the later stages of the Holocene the sedimentation rate of about 0.4 mm/yr was not exceeded.

The Gulf probably attained its present configuration around 1000 AD as result of the construction, south of Basrah, of the Shatt Al-Arab delta. This latter is, at the present, mainly supplied by the Karun river, whose sediments are essentially derived from the northern Zagros mountains and from the small rivers draining the Arabian Platform.

During this last period several depositional environments (briefly described below) developed in this area, whose characters reflect the important climate changes that occurred during the last evolutionary phase of the Mesopotamian Plain.

The floodplain environments (mostly with fine and medium sand, clayey silt and silty clay) are the most extensive environments occupying the Mesopotamian Plain where interfingering sinuous channels, levees, crevasse splays and flood basins occured. Deposition of these sediments is strictly related to the Euphrates, Tigris, Shatt Al-Arab Rivers and their tributaries.

Extensive reed-marshes dominated by *Phragmites* sp., and *Typha* sp. and lakes with fresh and brackish water are strongly represented in the southern Mesopotamian Plain forming the marshland areas called Ahwar. The sediments occurring in these environments, generally silts with minor percentage of clay and fine sand, are supplied by the Tigris and Euphrates seasonal floodwaters, and by wind that transport aeolian dust and sand during the storms from the western deserts in summer.[51] Such deposits, about 1 m thick, consist of three separate layers (from bottom to top): 1) a basal brackish/marine silty clay or/and clay layer with foraminifera and ostracods; 2) a clayey silt with mollusc shells; and 3) an organic-rich sandy silt layer. Radiocarbon dates indicates that these deposits do not exceed the 2500 yr. BP and that the layer 3 began to develop about 400 year sago. All these data suggest that this sector of the Mesopotamian Plain was once brackish shallow water restricted environment, which became infilled by fluvial sediments carried by Euphrates, Tigris, and by aeolian sediments transported by wind.[52]

Sabkhas are typical arid and semiarid climatic environments, which develop due to the alternating wet and dry seasons and for intensive evaporation of salty water occurring on the surface or rising to the surface from shallow underground water. In the Mesopotamian Plain they occur in the inland and coastal sectors. The inland sabkhas are mainly developed along the western and southern margins of the Plain, between the Tigris floodplain and the eastern alluvial fans, and in the central sector of the Plain between the Tigris and Euphrates Rivers. In the coastal sector, well-developed sabkhas occur between the Shatt Al-Arab floodplain and Khor Al-Zubair. From a compositional point of view sabkha sediments are rich in sulfates, mainly gypsum and are less than 0.5 m thick. In the western and southern sabkhas due to the major influence of winds the sediments show a higher content of sand. Regarding the age of these deposits, sabkhas began to develop during the last phase of Holocene and continue to the present day.[53]

Moving towards the coastal sector, associated with Shatt Al-Arab floodplain and the sabkha environment a tidal flat occurs south of Basrah. Along the tidal flat, silt and clay are the predominant sediments, whereas sand occurs in minor percentage. These deposits that are about 2 m thick began to form starting around the Late Holocene and continued to recent time.[54]

Aeolian sediments were formed during the arid and semi-arid climatic conditions, which were active from the Late Holocene. Most of them form extensive sand dune fields with a north-west/south-east orientation that are located along the north-eastern and south-western margins and the central part of the Mesopotamian Plain. The

[49] Wright 1981; Nissen 1988; Weiss *et al.* 1993; Morozova 2005.

[50] Aqrawi - Evans 1994.

[51] Aqrawi - Evans 1994.

[52] Aqrawi - Evans 1994; Aqrawi 2001.

[53] Yacoub 2011a.

[54] Yacoub 2011a.

thickness of aeolian deposits range from one meter to five meters, although it attains 25-30 m in the south-west of Samawa.[55]

The most important human activitiy in the Mesopotamian Plain is represented by the artificial irrigation canals system that developed starting around 7000 years BP (see § 4). Such canals are generally concentrated near the ancient cities and along the main abandoned river courses. The modern irrigation network extends over the floodplain deposits and is able to transport and deposit even coarse sediments during river flood events.

3.5 Stratigraphy of the Nasiriyah Sector

The area of Nasiriyah where Abu Tbeirah is located is essentially occupied by fluvial floodplain environment where several sub-enviroments including marshes, levee, crevasse splay and salt-covered plain occur. These environments developed during the latest phase of the Holocene and are substituted downward by the brackish/ marine deposits of the Hammar Formation (Middle Holocene), which, in turn overlie playa and fluvial deposits rich in gypcretes of the Early Holocene. In terms of composition these Holocene deposits are on average constituted by quartz (20%), feldspar (10%), calcite (30%), dolomite (20%), Mg-calcite (< 5%), aragonite (< 5%), gypsum (15%). In particular detrital calcite and quartz mainly occur in the fluvial and aeolian sediment. These two minerals are usually followed in abundance by dolomite and feldspar. Dolomite, in particular, reaches its highest values in the playa and sabkha environments, as well as in the brackish marine unit of the Hammar Formation. Aragonite generally occurs as main component of the molluscan shells, while gypsum is restricted mainly to the upper near surface layers of the dried-out areas and to the evaporitic units as scattered crystals.[56] All these data suggest that brackish conditions mainly occurred in southern Mesopotamia from 6000 yr. BP to 3000 yr. BP, although locally the chemistry of the water changed related to sea-level fluctuations and fluvial input. Starting from 3000 yr. BP brackish conditions were replaced by freshwater conditions as a consequence of the further seaward progradation of the Tigris and Euphrates deltas.

A recent boring made with a hand auger that reached the depth of about 6 m, was realized in the middle of the area where a human structure interpreted as a harbour was identified (Fig. 3.7).

Grain size and other textural attributes, as well as colour of the sediments were the main described features. Other aspects such as the presence of shelly debris, organic matter, wood fragments, peat and roots were also taken into consideration as useful features for environmental interpretation.

The extracted cores revealed a stratigraphy that can be attribute to the latest Middle and Upper Holocene fluvial floodplain deposits, which formed during the seaward progradation of the Tigris and Euphrates deltas in the last 6000 yr. BP. From top to bottom the following units can be recognized (Fig. 3.7):

1. a yellowish brow clay, silty clay and clayey silt unit (about 1.80 m thick) with a major organic matter concentration between 0.75 and 1.2 m depth. This unit was interpreted as a floodplain environment with local marsh;
2. a 1.2 m thick fining upward unit, with greyish brow sand at the base passing upward to light olive brown sand and light greyish olive clayey sand. The character of this unit suggests interpreting it as the filling of a small channel;
3. a 0.30 m thick unit of greyish brown clay alternating with sand layers. This unit was interpreted as a levee deposit;
4. a 2 m thick dark yellowish-brown clay and sandy clay unit, with small lens of sand, sparse organic matter and fragments of pottery, interpreted as a floodplain environment with local marsh;
5. a 0.70 m thick unit showing very dark greyish peat with fragments of shells at the base evolving upward to brow clay and silty clay with organic matter and fragments of shells. These features suggest deposition in a marsh environment;
6. a 0.7 m thick light olive brown sandy clay and clay unit that has been attribute to a floodplain environment.

[55] Yacoub 2011a.
[56] Aqrawi 1995b.

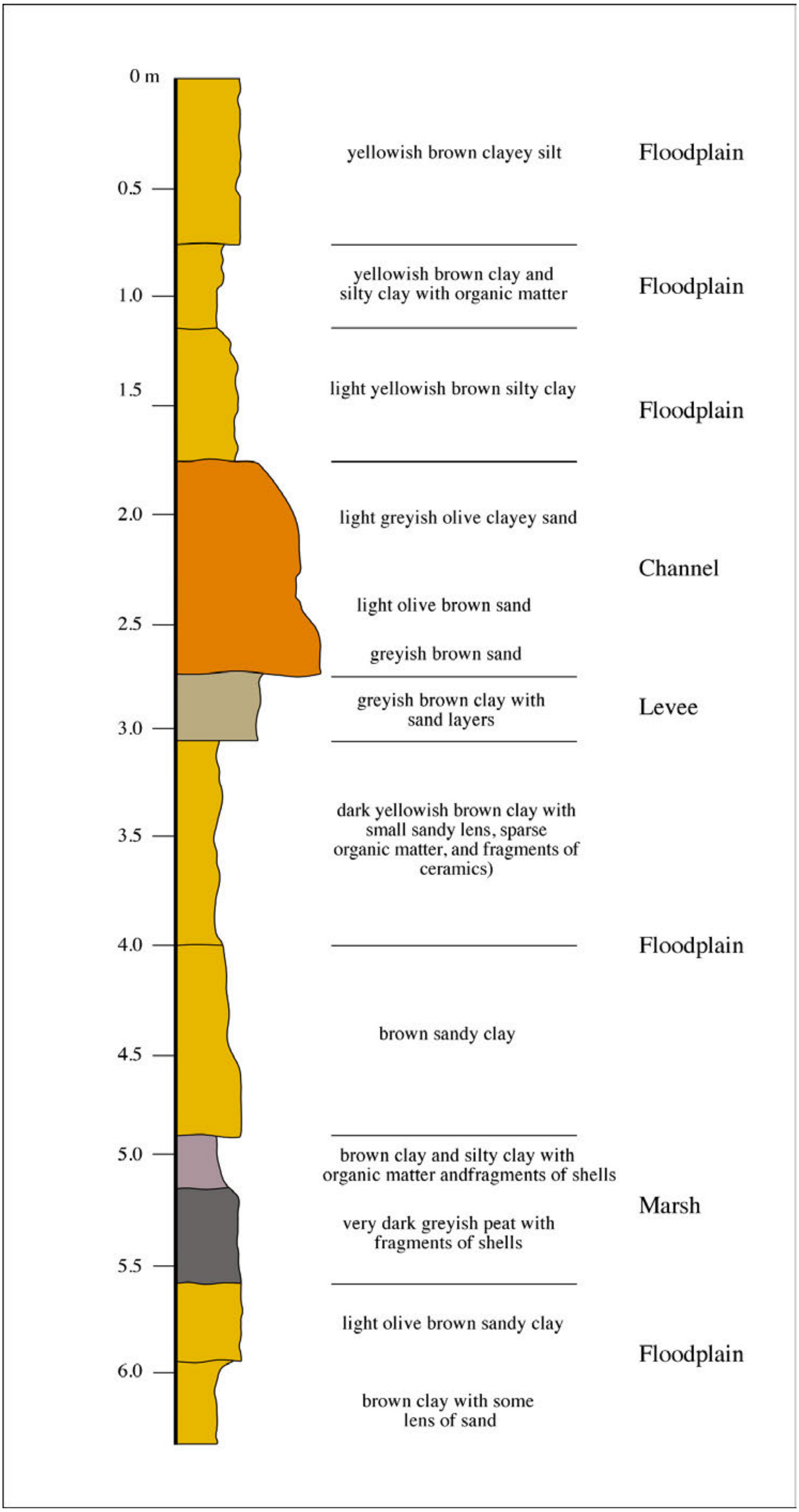


Fig. 3.7 Stratigraphic and environmental interpretations of the core recently made with a hand auger until the depth of about 6 m in the study area.

All the described features are consistent with a deposition of these sediments in a floodplain environment. It is not clear if the channel was artificial or natural; however, some elements seem to converge towards what was hypothesised through the archaeological studies: *e.g.* the presence of a fluvial dock, located on a secondary channel, which was connected with a main and large channel to the north (both placed south of Nasiriyah and Euphrates river), and probably with the sea to the south, through others secondary channels. This suggests that during the Sumerian period, and probably during the previous Ubaid, Uruk periods, the human communities also experimented with maritime activities, which helped to mobilize food surplus between settlements.[57] Such consideration highlights that during the Middle and Late Holocene the human cultural evolution in southern Mesopotamia was strongly influenced by important environmental changes in turn induced by global eustatic sea-level rise and climate changes (passage from humid to arid conditions). They modify the landscape and the environments, but most of all modify the lifestyle of the communities, favouring the emergence of highly centralized, urban-based states.

[57] See discussion in Kennett - Kennett 2006.

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