Sedimentary, Mineralogy and Biofacies of Holocene deposits of Al-Hammar and Al-Hewaiza marshes near Qurna

Abdalrazak A., Albadran B., Pournelle J.

***Abstract*— The southern part of Mesopotamia is an important area, it is considered as an ambiguous environment during the Quaternary period. Two sites were chosen for boreholes in the southern part of Mesopotamia on both sides of the Tigris River before its confluence with the Euphrates River north Qurna. Site one is on the east side of Al-Hammar marsh, site two is on the west side of Al-Hewaiza marsh. The sampling was carried out during October 2014 and February 2015. Sedimentology, mineralogy and fauna analyses were done to a depth about 3 – 3.5m in order to distinguish the paleoenvironments during the Holocene period. Results of grain size analysis indicate five textures; Silt, Silty sand, Sandy silt, Mud, and Clay. Silt percentage is dominant in the sediments of all the sites. Mineral analysis shows that the minerals are; Calcite, Quartz, Dolomite, Feldspar and Gypsum, Calcite is a dominant mineral in the area of the study. The clay minerals in the area of the study are; Kaolinite, Illite, Montmorillonite, Chlorite, Palygorskite and mixed layers of Montmorillonite – Chlorite, and Illite – palygorskite. According to fauna assemblages, three Biofacies were identified on every site. In site one, a light gray layer of 5cm in thickness at depth 252 – 257cm contains a lot and diversity of fauna assemblage, clay percentage is 97% and calcite percentage is 75%, considered this layer belongs to marine transgression during 6000 yrs. B.P based on fauna assemblages. Few numbers of fauna assemblages indicate a freshwater environment and large numbers indicate brackish, Tidal flat, Lagoonal and shallow marine environments. The sea – level of the Arabian Gulf was 3m above present level according to Lambeck (1996), when 2m added to 3m because the ground level of the area was 2m below the actual level due to the tectonic or depositional reasons, the sea – level of the Arabian Gulf, after adding 5m to the actual level, covers the area of study and go much further than that.**

***Index Terms*— Sedimentology, mineralogy, biofacies, Holocene, Hammar, Hewaiza, marshes.**

I. INTRODUCTION

The southern part of the Mesopotamian plain is characterized by an ambiguity in terms of Sedimentary layers, there are a lot of theories about it, due to the glacial periods which occurred during Quaternary age and led to a fluctuation in Sea level, in addition to flooding of the Tigris and the Euphrates Rivers. The Ancient Climate in the study area is semi- wet and Arid [1], The Tigris and the Euphrates Rivers, Al-Hammar and Al-Hwaiza marshes are the most important water bodies in the study area. The tectonic setting of the study area is located in the Zubair subzone within Mesopotamia zone, which lies within the unstable shelf [2], bordered on the north by Takhdid – Qurna transversal fault, in the south by the Al-Batin fault, Ramadi- Musayib longitudinal fault near the area of study [3]. Al-Jibouri [4]studied the paleoclimate of the area by using the palynology, and concluded that the area was a subject to a marine transgression period which produced marine sediments in the begging of the Holocene, Aqrawi [1] also, indicates that there was a marine invasion during the mid-Holocene covering the area, whereas Heyvaert and Baetman[5] mentioned that the Lower Khuzestan, to the east of the studied area, during the early and middle Holocene was a tidal embayment of low energy influenced by estuarine conditions. Marine transgression is controlled by the tectonic activity of the underneath salt domes, Al-Whaily [6] stated that some of the Islands of the Shatt Al-Arab River were originated by tectonic movements due to the uplift of salt domes. Al-Hawi [7] also by using the carbon dating and tracing the ancient courses of the Euphrates River, mentioned that the area was flooded by a transgression period 6000 yrs BP. Al-Sudani [8] studied the Hareer' Tell north of Basrah by using C 14 and indicated that the area was influenced by marine water.

The study area is covered by Holocene sediments that divided to Hammar Formation and Ahwar sediments. The aim of the current study is to identify the sedimentary environments of the area and the transgression border in the Mid- Holocene.

II. METHODS

The study area is located in the southern part of Mesopotamia plain. Two sites were chosen (Fig. 1). The first Site is to the west of Tigris River near Al- Eaz River, represents the eastern part of Al- Hammar marsh. The second Site is located to the east of the Tigris River in the western extremity of Al-Hewiza Marsh. Two boreholes in site one and one in site two were drilled to a depth about 3.5m below the ground surface of the area by using a galvanized metal tube pushed in the sediment one meter by one meter by a mechanical vibrator (Fig. 2). In the laboratory, the tubes were cut longitudinally from both sides and visual description was carried before sampling. The percentages of sand, silt and clay fractions were measured for 21 samples by using the Master Sizer instrument (Model UM 2000), in the Department of Geology, University of Basrah. Clay and non-clay minerals were identified by X

Abdalrazak A., Department of Geology/ College of Science, Basrah University
Albadran B., Department of Geology/ College of Science, Basrah University
Pournelle J., Department of Natural Science, South Carolina University.

–ray diffraction instrument of the type (Philips type PW 1352) in Physics Department University of Basrah. A semi-quantitative of the minerals was calculated from the area under the curve of the first reflection of each mineral and the minerals were identified by the method of Chao [9]. 50 g from each sample was taken and exposed to air dry, then washed through a sieve of opening 63 µm. The remains above the sieve placed in a backer and washed several times to remove any suspended matters and plant remains in the sediment, and the sediments were left to dry. Seventeen samples were identified for fauna under a binocular microscope and picked by a small brush and put it in the tray of fossils portfolio. The classification proposed by Loeblich and Tappan [10] for Foraminifera, Peiris [11] for Ostracoda, Keen and Coan [12], Moore [13] for Gastropods and Pelecypoda were applied.

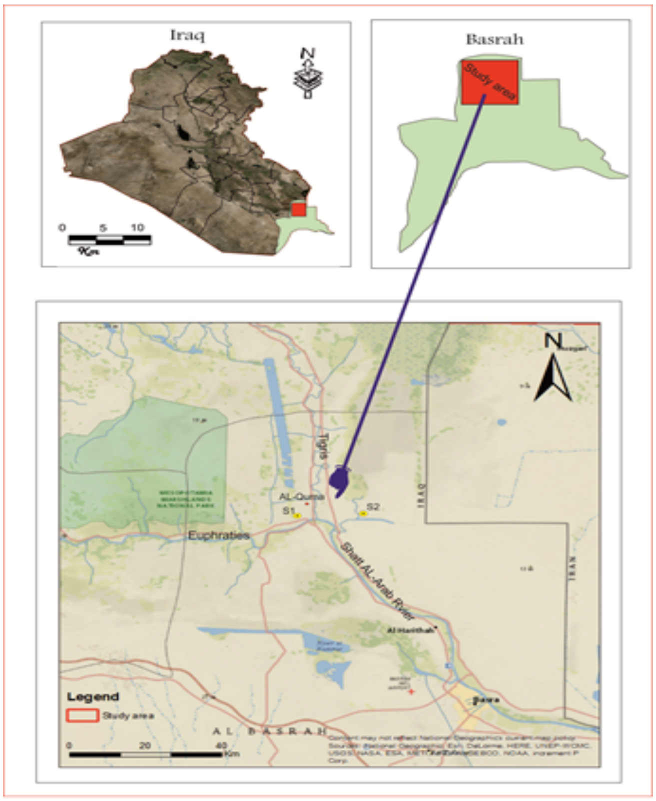


Figure 1: Location map of the study area

Figure 2: filed work.

III. RESULTS:

Grain size analyses were carried out to three boreholes of both sites, to knowing clay, silt and sand percentage (Table 1):

Table (1) Grain size analysis

Site No.	Sample	Depth (cm)	Clay %	Silt %	Sand %	Lithology
Site 1 Borehole No.1	1:00 AM	20 -33	23	75	2	Silt
	1 B	132 – 148	10	78	12	Sandy silt
	1 C	195 - 210	23	76	1	Silt
	1 D	255 -270	25	74	1	Silt
Site 1 Borehole No.2	2:00 AM	Jan-30	11	76	13	Sandy silt
	2 B	30 – 45	13	79	8	Silt
	2 C	75 – 90	17	78	5	Silt
	2 D	100 -110	4	69	27	Sandy silt
	2 E	140 -155	17	81	2	Silt
	2 F	187 -199	10	76	14	Sandy silt
	2 J	212 -227	23	76	1	Silt
	2 H	247 - 252	56	44	0	Mud
	2 I	252-257	97	3	0	Clay
	2 G	257 - 271	30	68	2	Mud
Site 2	3:00 AM	0 -10	30	69	1	Silt
	3 B	35 -50	28	66	6	Silt
	3 C	120 - 135	18	64	18	Sandy silt
	3 D	153 - 165	5	41	54	Silty sand
	3 E	230 - 245	4	41	55	Silty sand
	3 F	260 - 270	12	61	27	Sandy silt
	3 J	336 -350	18	80	2	Silt

The minerals were examined by X- Ray power diffraction (XRD) in Physics Department/ College of Science/University of Basrah, the percentage was calculated by semi-quantitative method by using area under curve of higher intensity of each minerals in the chart of XRD and the minerals was identified by Chao [9] method. The main non –clay minerals found in the area are; Calcite, Quartz, Dolomite, Feldspar and Gypsum (Table 2).

Table(2): Percentage of non-clay minerals

Site No.	Sample	Depth (cm)	Calcite %	Quartz %	Dolomite %	Feldspar %	Gypsum %
Site 1 Borehole No. 2	2:00 AM	1 – 30	54	35	11		4
	2 B	30 – 45	43	47	5	5	
	2 C	75 – 90	49	30	9	3	9
	2 D	100 - 110	47	39	9	5	---
	2 E	140 - 155	47	43	10	---	---
	2 F	187 - 199	49	45	6	---	---
	2 J	212 - 227	41	46	13	---	---
	2 H	247 - 252	51	39	10	---	----
	2 I	252 - 257	75	20	5	---	--
	2 G	257 - 271	52	44	6	---	---
Site3	3 B	35 – 50	64	31	5	---	---
	3 D	153 – 165	58	28	13	---	---
	3 J	336 -350	57	35	8	---	---

The clay minerals are Kaolinite, Montmorillonite, Chlorite, Palygorskite, and Illite and mixed layers, Palygorskite – Illite and Montmorillonite – Chlorite (Table 3). They are identified by preparing oriented samples of carbonate-free fine fraction

Table(3): Percentage of clay minerals.

Site No.	Sample	Depth (cm)	Ka %	I %	M %	Ch %	P %	M-Ch%	P-I%
Site 1 Borehole No.2	2:00 AM	Jan-30	25		54				21
	2 B	30 - 45	38	32				31	
	2 C	75 - 90	28		42		30		
	2 D	100 - 110	44					56	
	2 E	140 -155	17	14	52		17		
	2 F	187 - 199	28		24	15		33	
	2 J	212 - 227							
	2 H	247 - 252	28		28	44			
	2 I	252 - 257	24	19	20	15	22		
	2 G	257 -271	20	13	22		9	36	
Site 2	3:00 AM	35 – 50	22		42		15		21
	3 B	153 -165	13	13	28	28	18		
	3 C	336 - 350	31	17	11		13	28	

Ka= Kaolinite, I= Illite, M= Montmorillonite, Ch= Chlorite, P= Palygorskite,
M-Ch= Montmorillonite-chlorite mixed layers
P-I= Palygorskite-illite mixed layers

Samples were taken from different depths from each site (one and two) to identify the fauna. The groups of assemblages which are found in the area of study are: Foraminifera, Ostracoda and Mollusca in large numbers and variety. The following groups have been identified in the study area (Plate1, 2 and 3):

A)Foraminifra group
- Ammonia tepida(Cushman , 1926)
-Ammonia beccari(brunich , 1772)
-Elphidiumguntri(cole , 1931)
- Elphidiumadvenum(Cushman , 1921)
- Triloculinatrigounla(Lamarck , 1804)
- Quinqueloculinaimperssa
- Quinqueloculina sp.
- Rosalina sp.

B) Ostracoda group
-leguminocythereispapuensis(Brady)
- cypridestorosa var. torosa(Jones , 1858)
- Retusa(brown ,1827)

C)Molluscs group
1- Gastropoda
- Melanopsispraemorsum(Ferussac , 1822)
-Lymnaea(Muller)
- Littoina(Ferussac , 1822)
- Gyraulusconvexiusculus(Hutton , 1849)
-Gyrodes(Conrad , 1860)
2- pelecypoda
- Corbiculafluminalis(Muller , 1774)

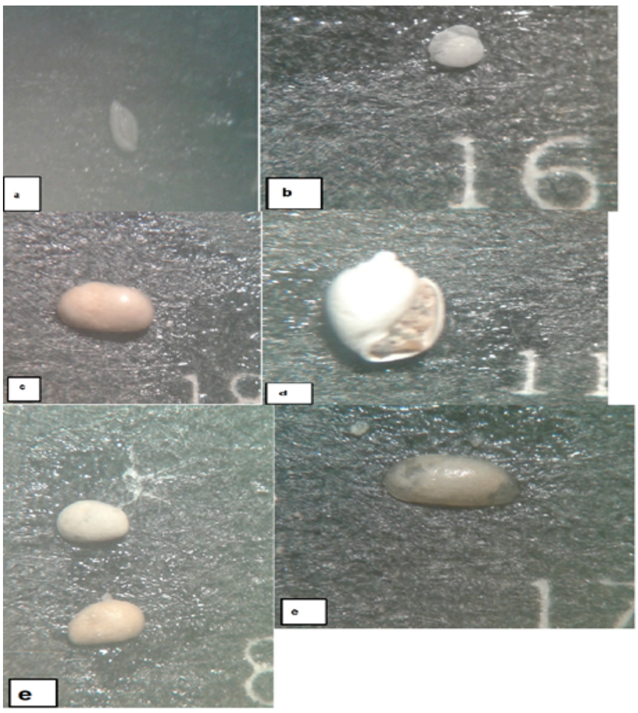


Plate (1)
a- Ammonia tepida
b- Ammonia beccari
c- Elphidiumguntri
d- Elphidiumadvenum
e- Triloculinatrigounla
f- Quinqueloculina sp.

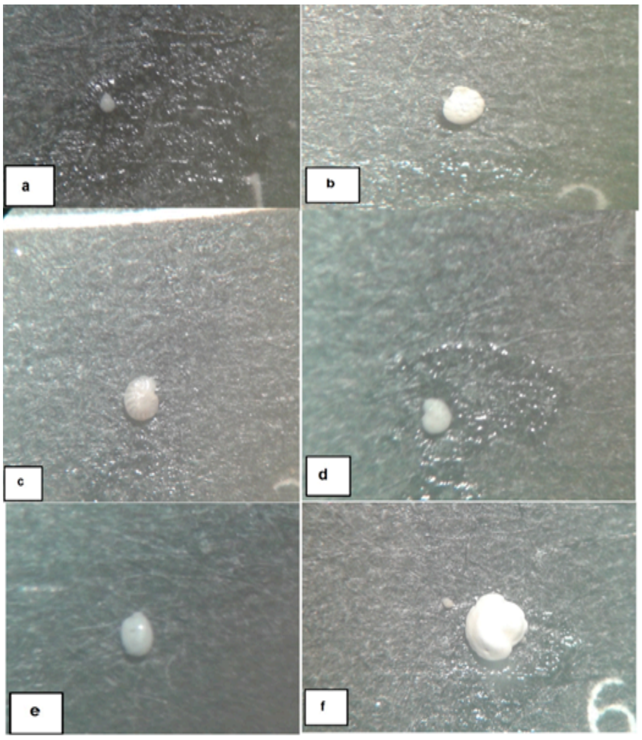


Plate (2)

a- Quinqueloculinaimperssa
b- Rosalina sp.
c- leguminocythereispapuensis
d- Retusa
e- cypridestorosavar.torosa

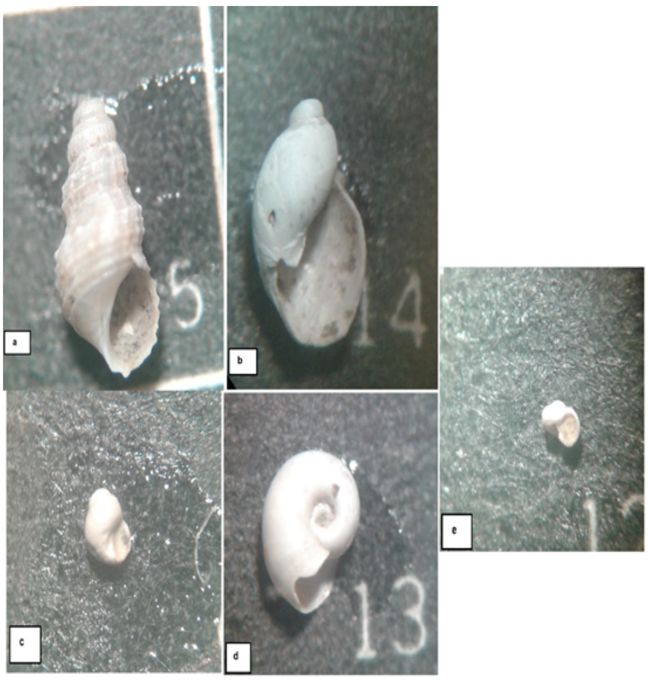


Plate (3)

a- Melanopsispraemorsum
b- Lymnaea
c- Littorina
d- Gyrauslusconvexiusculus
e- Gyrodes

IV. Discussion:

Through the results which appeared, the sedimentary facies are; silt, silty sand, sandy silt, mud and clay, the dominant facies is silt. The sediments of site one are finer than the sediments of site two (Table 1). This could be related to the alluvial fans in areas near site two. Calcite is abundant in fine grain sediments (Table 2). Quartz is found significantly in the deposits of sand (Table 2), which is a detrital mineral. A high percentage of quartz results from its high resistance to erosion, and that the study area is an estuaries environment. Sediments of rivers were considered the end travel from sources to their estuaries. Feldspar mineral found at a high percentage, reaches to 5%, a detrital mineral but can't resist weathering and erosion.

Dolomite mineral transformed from Calcite by dolomitization processes in water rich in magnesium ions (Darmoian and Lindqvist, 1988 in [14]). The high percentage of dolomite mineral in each site is 13%; the source of dolomite mineral in the area of study could from rivers present in area because the dolomitization process needs to long time and large depths. Gypsum mineral found in site one only (Table 2) and considered as evaporitic minerals, formed when evaporating saline water, exposure to several dry periods at a depth 2.5m above a marine layer at depth 2.5m. Gypsum is absent in site two, this could be related to the continuous leaching by Al-Sewaib River.

The clay minerals are in average of montmorillonite 35% and 27% in site one and two, respectively (Table 3), the mixed – layers montmorillonite – Chlorite is 39% and 28% in site one and two, respectively. The salinity and chlorinate of water increase the transformation of montmorillonite to Chlorite, and the favorable environments of montmorillonite minerals is lagoonal [15]. The favorable environment for chlorite mineral is saline water [16], therefore high percentage of chlorite is 44% at a depth 2.5 m in site one and 28% at depth 1.5m in site two, could indicates the presence of saline water in these depths of sites.

Montmorillonite, Chlorite and mixed layer Montmorillonite – Chlorite indicate a presence of saline water. Kaolinite minerals is in an average 28% and 22% in site one and two, respectively. The favorable environments are fluvial or near shore sediments [17], the percentage is low under depth 1.5m in site two and 2.5m in site one. Illite mineral formed in non – acidic conditions rich in potassium [16], and dominated in marine Shale and common in ancient sediments [15]. The presence of illite at a depth 1.5m in site one and 2.5m in site two and above there, could indicate presence of saline water in that depths. Kaolinite and montmorillonite minerals transformed to Illite and Chlorite minerals in marine environment [15]. Palygorskite mineral found in high percentage in 1.5m is 17% and 2.5m is 22% in site 1-No. 2, this mineral could be authigenic in alkaline saline water [18]-[19]. This supports the presence of saline or marine water in these depths. Albadran [20] related the formation of the mixed layers to diagenetic processes by Illitization and Chloritization. Palygorskite, Illite, Chlorite and Montmorillonite minerals could indicate to transgression in there depths because these minerals almost exist in saline water.

According to faunal assemblages, six biofacies appear in the two sites, in Site1;

1- Biofacies (B1), extended from the ground surface to a depth about 1m (Fig.4), the species found in this biofacies are Lymane, Gyraulus convexinsculus. These species could belong to the fresh water environment.

2- Biofacies (B2), the biofacies extends from 100 to 250cm in depth (Fig.4). The species found in this Biofacies are; Lymane, Gyraulusconvexinsculus and Ammonia tepid. This Biofacies could indicate a brackish – fresh water environment.

3- Biofacies (B3), extends from 250 to 270 cm in depth (Fig.4), dominant grain size in this biofacies is clay in percentage 97%. In this biofacies, there is 5 cm in thickness from 252 – 257 cm, the color is light grey and contains large amount of fauna; Ammonia tepida, Ammonia beccari, Rosalina SP., Cyprideistorosa, Leguminocytherespapuensis, Littorina SP. and Melanopsis SP. This biofacies could indicate a shallow marine environment.

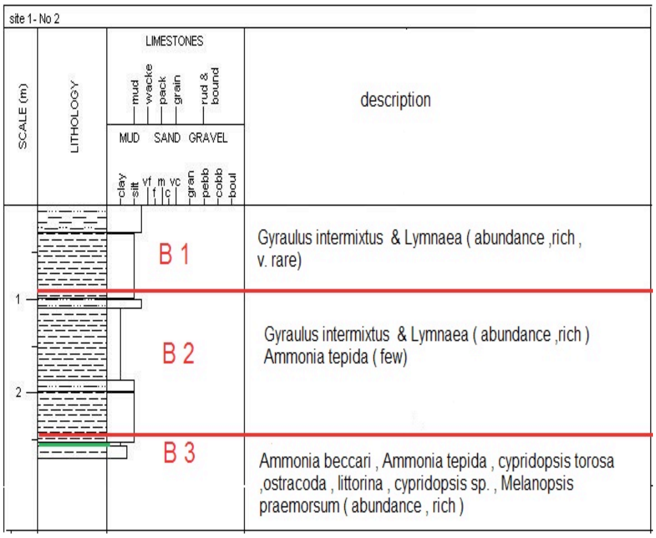


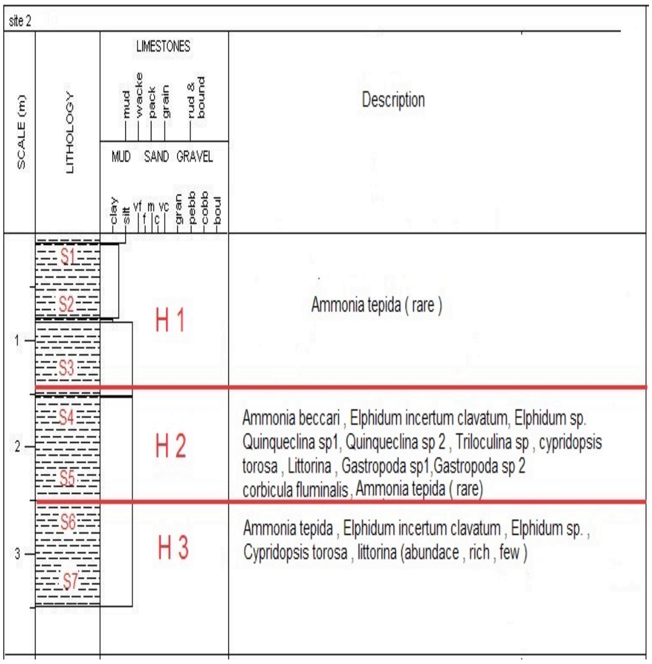
Figure 4: Biofacies succession in site 1.

In site 2, the biofacies which found are;

1- Biofacies (H1), extends from the ground surface to 150cm in depth (Fig.5), characterized by the rareness of the following genus; Ammonia tepida in particular depths. It could belong to brackish water environment.

2- Biofacies (H2) extending from 150 to 245cm in depth (Fig.5), the species found in this biofacies are; Ammonia beccari, Elphidumguntri, Elphidumadvenum, Quinqueloculina SP., Triloculinatrigonula, Cypridiestorosa, Quinqueloculina impressa, Littorina and Retusa with rareness of Corbicula flumind. At the bottom of this biofacies all the pervious species disappear only Ammonia tepida presents in rare abundance. The environment of this biofacies could belong to shallow marine, lagoon or tidal flat.

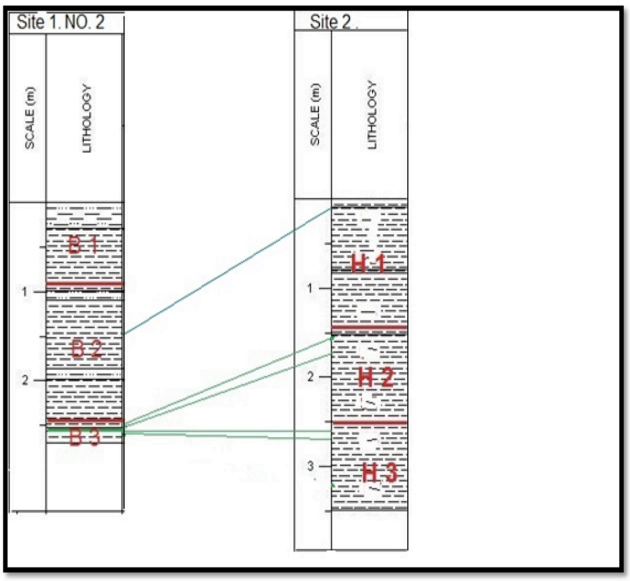
3- Biofacies (H3) extending from 260 to 350cm in depth (Fig.5). All species of fauna disappear except a thin bed from 260 to 270cm in depth, where there are a lot of the following species; Ammonia tepida, Elphidiumguntri, Elphidumadvenums, Cypridiestorosa and Littorina. This Biofacies could indicate brackish environment effected significantly by marine water.



Figures 5: Biofacies succession in Site2.

Biofacies Correlation

Through the comparison between the two sites, the biofacies one B1 in site one that indicates fresh water environment don't found in site two. The biofacies B2 in site one is similar to H1 in site two where the appearance of Ammonia tepida with disappearance of fresh water species that appeared in the biofacies B2. This could indicate that the first meter in site one was affected by fresh or river water but in site two was affected by brackish water. As for the biofacies B3 is similar to H2 and H3 biofacies in site two in terms of the species that appeared at both sites, which could indicate to a phase of transgression. The marine effect appeared in 1.5 m in site two but appeared in 2.5m in site one, this variation in depth could related to the difference in topography between the sites or to tectonic movement that led to lifting of the site two 1m more than the site one (fig.6).



Figures 6: Biofacies correlation between Site1 and Site 2 in the study area.

Correlation with previous studies in the area

Al-Hawi [7] suggested in her study about Al-Hammar marsh and surrounding areas that the Mesopotamia plain in period 9000 – 5000 yrs. BP was tidal flat (Fig.7). Aqrawi [1] studied Al-Hammar marsh, confirmed the period of transgression was 9000 – 5000 yrs. BP. To compare site one of the current study with section that charted by Aqrawi [1] study, found that MFS at 2.5 m matched with site one in the current study. The Biofacies B1 and B2 in current study are similar with unit 4 and unit 5 of Aqrawi [1], which belong to Ahwar, lacustrine and fluvial sediments with salt. Their age is < 3000 yrs. BP. also, biofacies B3 in this study is agreed with unit 3 of Aqrawi [1], unit 3 is characterized by the existence of Ammonia beccari and Ostracods Cypridisetorosa, rich in clay fraction deposited during the transgression before 9000 yrs. BP. Maximum flooding surface MFS (specified by Aqrawi [1]), overlaid the Biofacies B3, its age is 4000 – 4500 yrs. BP and confirms the last transgression (Fig. 8).

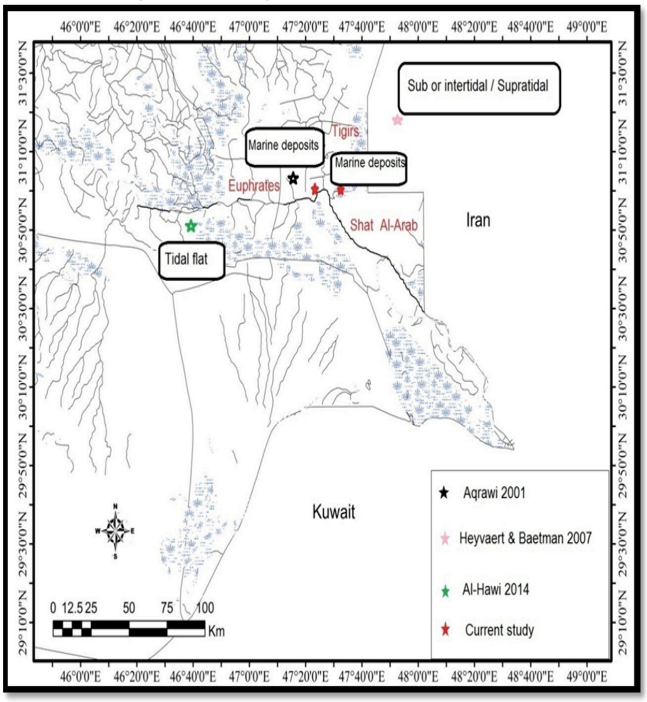


Figure (7): correlation between current study with previous studies.

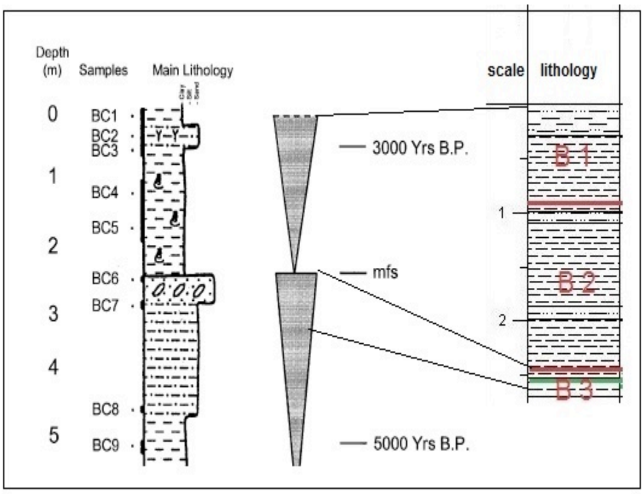


Figure (8): correlation between current study and Aqrawi [1].

Lambeck [21] studied the coast-line of the Arabian Gulf at 6000 yrs. BP, sea – level lied above the present level by 3m, so that the coastal line of the Gulf reached to between Basrah, Amarah and Nasiriyah at that time (Fig.9).

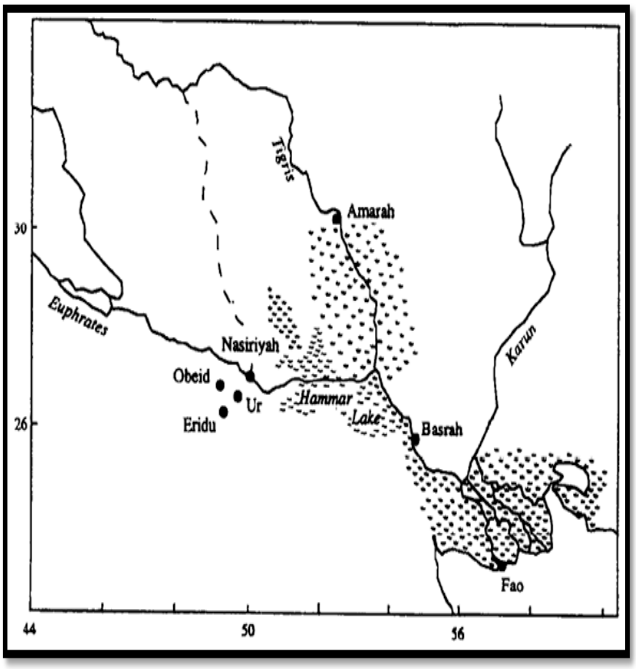


Figure (9): Sea- level (after lambeck [21]).

The study of Heavert and Baeteman [5] in Khuzestan plain, which is near from site two of this study, shows that the environments are sub or intertidal transform then to supratidal ended by marshes, that could explain the tidal flat environment of the area (Fig. 7).

4- Paleo-coastal line

The results of sedimentology, mineralogy and fauna show that there was a transgression during middle – last Holocene at (5000 – 6000 yrs BP) in Mesopotamia, found in site two at 1.5 m depth (Fig. 10), in site one at depth 2.5m (Fig.11). This difference could belong to topography or tectonic movement was lift Al-Hewaiza area.

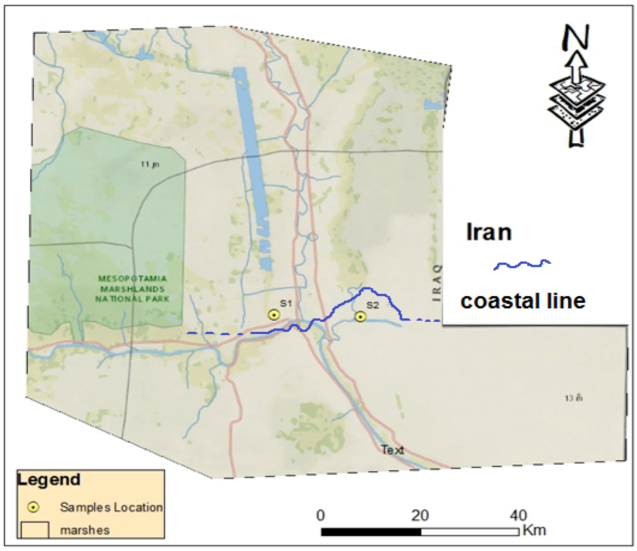


Figure (10): coastal line at depth 1.5m in the study area.

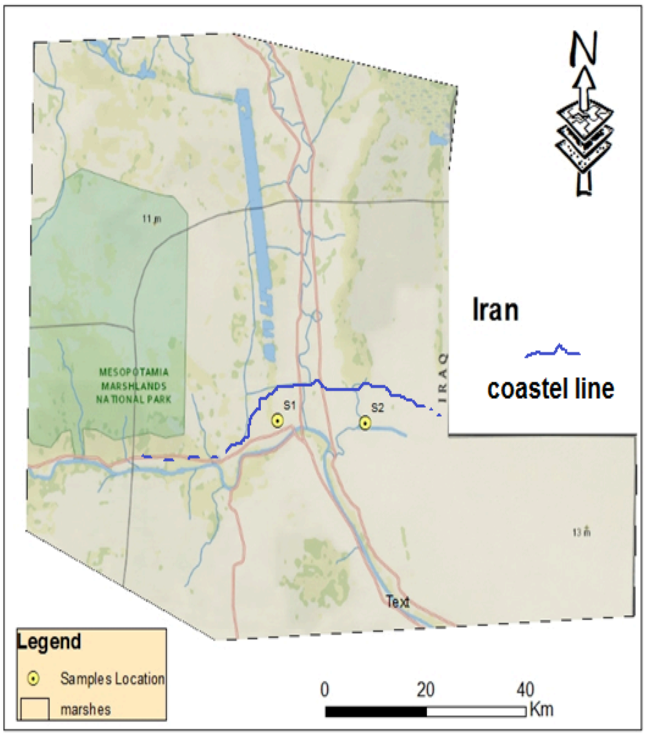


Figure (11): coastal line at depth 2.5 m in the study area.

For confirmation of the pervious conclusions, this study tends to apply the ArcGIS program by using DEM file and rise sea – level of the Arabian Gulf 3m above present level according to Lambeck [21], show sea – level rise 3m because of ocean water rise 1.5 – 2m, but marine water don't reach to study area (Fig.12).

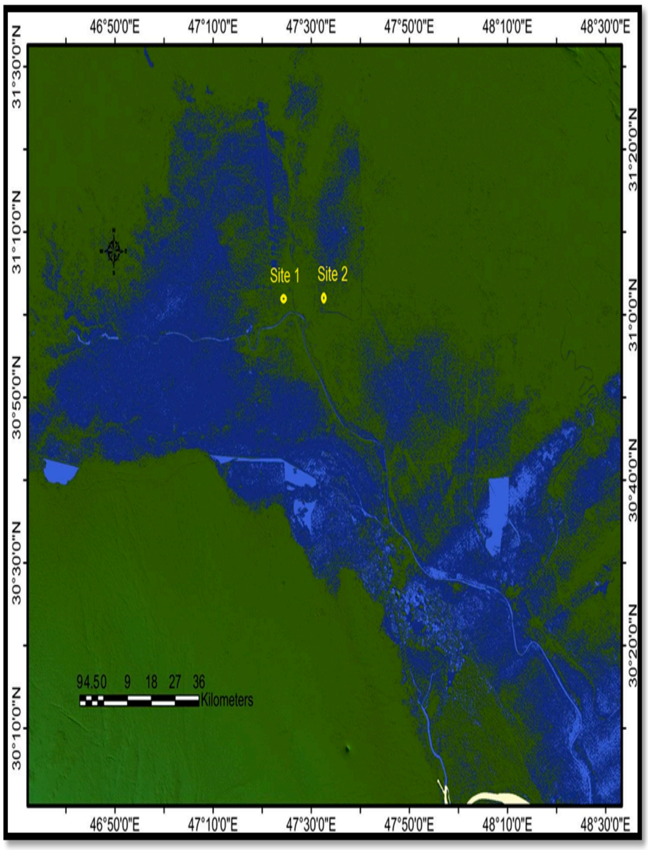


Figure (12): coastal line according to DEM (Sea – level above present day by 3m).

The ground- level of the area was 2m below the present due to the tectonic activity; to know the influence of transgression by 3meters it could add these 2 meters to the rising of the sea-level by 3m. of figure 12. The sea – level of the Arabian Gulf covers the area of study and goes much further than that (Fig. 13).

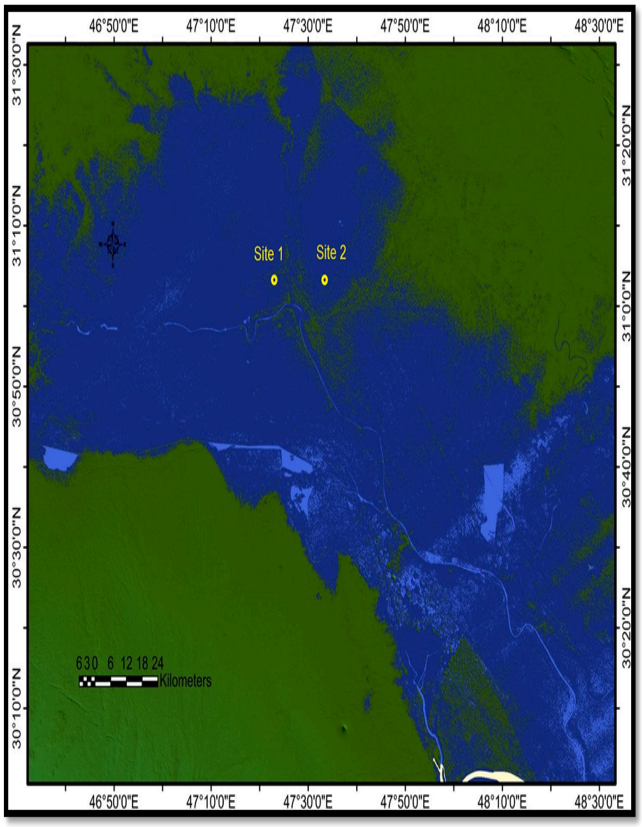


Figure (13): coastal line according to DEM (Sea-level above present day by 5m).

V. Conclusions

The study area is covered by silt, mud, silty sand, sandy silt and clay sediments. The main minerals presence in high percentage is calcite followed by Quartz, Dolomite, Feldspar and Gypsum. And clay minerals are; Kaolinite, Illite, Montmorillonite, chlorite, palygorskite and the mixed layer palygorskite – Illite and Montmorillonite – chlorite. Most of clay mineral composed in an acidic neutral – Alkaline and saline water environments. The presence of Palygorskite mineral at high rate in the depths 2.5 and 1.5 m indicates that there is saline water refers to transgression. The fauna in the area of study are; Ammonia tepida , Ammonia beccari , Elphidumgunteri , Elphidum advenum , Triloculina trigonula , Quinqueloculina sp. , Quinqueloculina impressa , cypridiestorosa , Littorina , corbiculafluminalis , Retusa , Gyrodes , Gyraulusconve xinsculus ,lymnae , Melanopisis sp. , Rosalina sp. And leguminocythereis papuensis. The faunal assemblages indicate little fresh water, brackish water, Lagoon, tidal flat and shallow marine environments. The results show the southern part of Mesopotamia plain was affected by transgression during 6000 – 3000 yrs. BP.

Acknowledgments

We would like to express our appreciation to the University of Basrah/ College of Science College to support this work.

REFERENCES

[1] A. A. M. Aqrawi, 2001, Stratigraphic signature of climate change during the Holocene evolution of the Tigris and Euphrates delta, lower Mesopotamia. Global and planetary Change, 28, PP. 267-283.

[2] S. Z. Jassim and T. Buday, 1987, The regional geology of Iraq Tectonics (magmatism and metamorphism). GEOSURV publishing Baghdad, 322 P.

[3] S. Z. Jassim and J. C. Goff, 2006, Geology of Iraq. Dolin, Prague and Moravian museum, Brno. 341 p.

[4] B. S. Al-Jibouri, 1997, Palynological evidences of the climatic and environmental changes during the Quaternary period in the Mesopotamian plain southern Iraq. Unpublished M.Sc. University of Baghdad, (In Arabic), 90 p.

[5] V. M. A. Heyvaert, and C. Baeteman, 2007, Holocene sedimentary evolution and paleocoastlines of the lower Khuzestan plain (Southwest Iran). Marine geology, 242(1-3),pp. 83-108.

[6] U. K. K. Al-Whaily, 2014, Origin and Evolution of the Islands of the Shatt Al-Arab River southern Iraq. Ph. D. thesis College of Science, University of Basrah, 130p, (In Arabic).

[7] Sharma, R. K., Mittal, A., & Agrawal, V. (2012). A design of hybrid elliptical air hole ring chalcogenide As2Se3 glass PCF: application to lower zero dispersion. International Journal of Engineering Research and Technology, 1(3).

[8] K. J. M. Al-Sudani, 2015, Geological study of Hareer's Tells, Southern Iraq. Unpub. MSc. Thesis, University of Basrah, 129pp.

[9] G.Y. Chao, 1969, 2θ (Cu) Table for common minerals, Ottawa, Canada, 34 P.

[10] A. R. Loeblich and H. Tappan, 1988, Foraminifer's genera and their classification, Von Nostrand Reinhold, New York, 970 p.

[11] N. I. Peiris, 1969, Recent foraminifera and ostracoda from the Persian Gulf. M.Sc. thesis, University College of Wales, Aberystwyth, 168 p.

[12] A. M. Keen and E. Coan, 1974, Marine molluscan genera of western North America. Stanford University Press. Stanford, California, 208 p.

[13] R. C. Moore, 1969, Treatise on invertebrate paleontology, part N: Mollusca Geol. Soc. Am. And University of Kansas press. 6, (Bivalvia), 2: 952p.

[14] B. M. Issa, 2006, Sedimentalogical and palaeontological study of tidal flat- Northwest of the Arabian Gulf. Unpublished M.Sc. thesis , collage of science , University of Basrah, 149 P. (In Arabic).

[15] F. J. Pettijohn, 1969, Sedimentary Rocks. Oxford & IBH Publishing CO. Calcutta: Bombay: New Delhi. 716 P.

[16] A. A. Saadallah and A. J. Ali, 1987, Sedimentary Petrology. University of Baghdad. 284 p.(In Arabic).

[17] R. E. Grim, 1968, Clay mineralogy, 2nd edition, McGraw-Hill Book Co. New York, 596 p.

[18] D. Carroll, 1970, Clay mineral: A guide to their X- Ray Identification. Geo, Soc. America, 80 P.

[19] B. N. Albadran, and W. F. Hassen, 2003, Clay mineral distribution of supratidal area, South of Iraq. Marina Mesopotamia, Vol. 18. No. 1, pp. 25-33.

[20] B. N. Albadran , 2000. Clay mineral distribution in selected locations along the Tigris and Shatt Al-Arab Rivers, south Iraq. Marina Mesopotamica, V. 15 , No.2 , PP. 439 – 452.

[21] K. Lambeck, 1996, Shoreline reconstructions for the Persian gulf since the last glacial maximum. Earth and planetary science letters, 142, pp. 43-57