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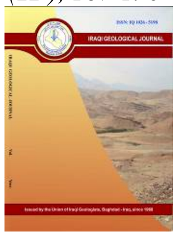

Unveiling Preliminary Study of the Holocene Sedimentary Environments and Biofacies in Wester of Al-Hammar Marsh, Southern Part of Iraq

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Abstract

Biofacies and sedimentary environment analyses were conducted across three sites west of Al-Hammar Marsh. Excavations were undertaken at different depths for a comprehensive study. The initial site was probed at 9 m depth, followed by the second site at 5 m, and the third site at 9 m. Subsequent examination of these samples aimed to unveil insights into grain size, fossil contents, and their respective ecological settings. The grain size analysis revealed three distinct sediment types: silt, sandy silt, and muddy sand. Additionally, fossil assemblages hinted at three primary biofacies. The first facies represented a fresh marsh-fluvial environment identified across all three sites at different depths. Specifically, this biofacies manifested from the surface to about 200 cm in site one, 50-150 cm in site two, and 50-250 cm in site three. The second biofacies indicated a shallow marine environment at depths ranging from 250 to 550 cm in site one, 200-300 cm in site two, and 300-650 cm in site three. Lastly, the third biofacies denoted a lagoon or tidal flat environment observed at 600-900 cm depths in site one, 300-500 cm in site two, and 700-900 cm in site three. Notably, the third biofacies in site three exhibited signs of influence from alkaline freshwater, particularly in the third location at a depth of 700-800 cm. This influence was attributed to a mixture of marine and freshwater species, including; *Quinqueloculina candeiana*, *Quinqueloculina angulta*, *Cubicula fluminalis*, and *Melanoides tuberculate*. Abundant occurrences of these species were noted in the silty clay lithology of this layer.

Keywords: Biofacies; Environment; Holocene; Mesopotamia; Iraq

1. Introduction

The Quaternary Period is the most recent geological period, from 2.58 million years ago to the present day. The Quaternary sediments in Iraq are mainly composed of alluvial deposits, resulting from the erosion of the surrounding mountains and sediment deposition in the Tigris and Euphrates River valleys (Sissakian and Saeed, 2012). The Holocene Epoch is the current geological epoch, from 11,700 years ago to the present (Al-Asadi, 2007). The Holocene sediments cover most of the Mesopotamia Plain in the middle and southern parts of Iraq. The Recent alluvium is composed of sand, silt, and clay and is found along the banks of rivers and streams (Al-Sheikhly et al., 2017).

Quaternary sediments constitute more than a third of the surface sediments of Iraq. The research area is situated in the western part of the lower Mesopotamian Plain. It extends south of the Euphrates River from the Al-Qurna town and Shatt Al-Arab River in the east to Al-Nasiriya City in the west,

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exactly west of Al-Hammar Marsh. Al-Hammar Marsh covers an area of around 2800 km² and can be extended up to 120 km. This region is ambiguous regarding terminology from sedimentary layers, and many theories for interpreting the Quaternary period exist. Because several glacial periods occurred during this time; many sedimentary layers formed in different environments: floodplain, alluvial fan, aeolian sediment, and marsh (Ahwar) sediment. Shallow depressions formed due to geological processes filled with water during the floods of the Tigris and Euphrates rivers, and sea aggression or rebound. These depressions are called marshes (Ahwar in Arabic). These are considered one of the world's essential water bodies due to their Biodiversity and environmental characteristics.

Numerous authors have conducted studies on recent sediments in Mesopotamia; however, these studies share commonalities (Al-Sakini, 1986; Aqrawi, 1993; Aqrawi and Evans, 1994; Aqrawi, 1995; 1997; and 2001; Yacoub, 2011; Sissakian and Saeed, 2012; Al–Sheikhly et al., 2017; Abdalrazak et al., 2017; Al-Jaberi and Mahdi, 2020; Al-Kaaby and Albadran, 2020; Albadran, 2021).

The current study aims to identify Holocene sediments' biofacies and sedimentary environments.

2. Study Area

The research area is situated south of Iraq in the southern portion of the lower Mesopotamian Plain. Specifically, situated between longitudes 47 ° 45′ 33. 76″ - 46° 37′ 27. 27″ E and latitudes 30° 43′ 49. 34″ -30° 46′ 44. 18″ N (Fig. 1). The Hammar Marshes, located in Iraq form a wetland complex, within the Tigris Euphrates River system. The marsh is situated in the Dhi Qar and Basra governorates. Al-Qurnah Town borders it to the north, the Euphrates River to the northeast, Basra City to the southeast, saline lakes and the Arabian Desert to the south, and Nasiriyah and Al-Chibayish centers to the west and northwest, respectively.

The fluvial plains of the lower Mesopotamia Plain are intersected by the Tigris and Euphrates rivers and feature freshwater to brackish water lakes, and vast reed marshes. The influx of allochthonous sediments primarily originates from the seasonal floodwaters of the Tigris and Euphrates rivers.

3. Methodology

Three sites located west of Al-Hammar Marsh were chosen for the current study (Fig. 1). The three selected boreholes were drilled to a depth of 5 meters using a galvanized metal tube that was driven in the sediment one meter at a time by a mechanical vibrator. The other two boreholes were drilled at a depth of 9 meters (Fig. 1). Before sampling, the tubes were visually described and sliced lengthwise on both sides in the lab. In the Department of Geology at the University of Basrah, the pipette method, as described by Folk (1956), was employed to analyze 46 samples to determine the percentages of sand, silt, and clay fractions. A 100-gram portion of the samples' cutting was collected and mixed with 400 milliliters of distilled water.

The mixture was then placed on a hot plate, and 5 grams of sodium hydroxide was added to facilitate dispersion. Afterward, the sample was washed and sieved using a 63-micron sieve; once the sample was dry. Following this process, the fauna was carefully packed using a fine brush (000) under a standard microscope and transferred to a slide container for preservation. (Al-Ali et al., 2019; Al-Shawi et al., 2019). The classification projected by Loeblich and Tappan (1988) for Foraminifera, while the Ostracoda was classified according to Peiris (1969). Then, gastropods and pelecypods were classified according to Keen and Coan (1974) and Moore (1969).

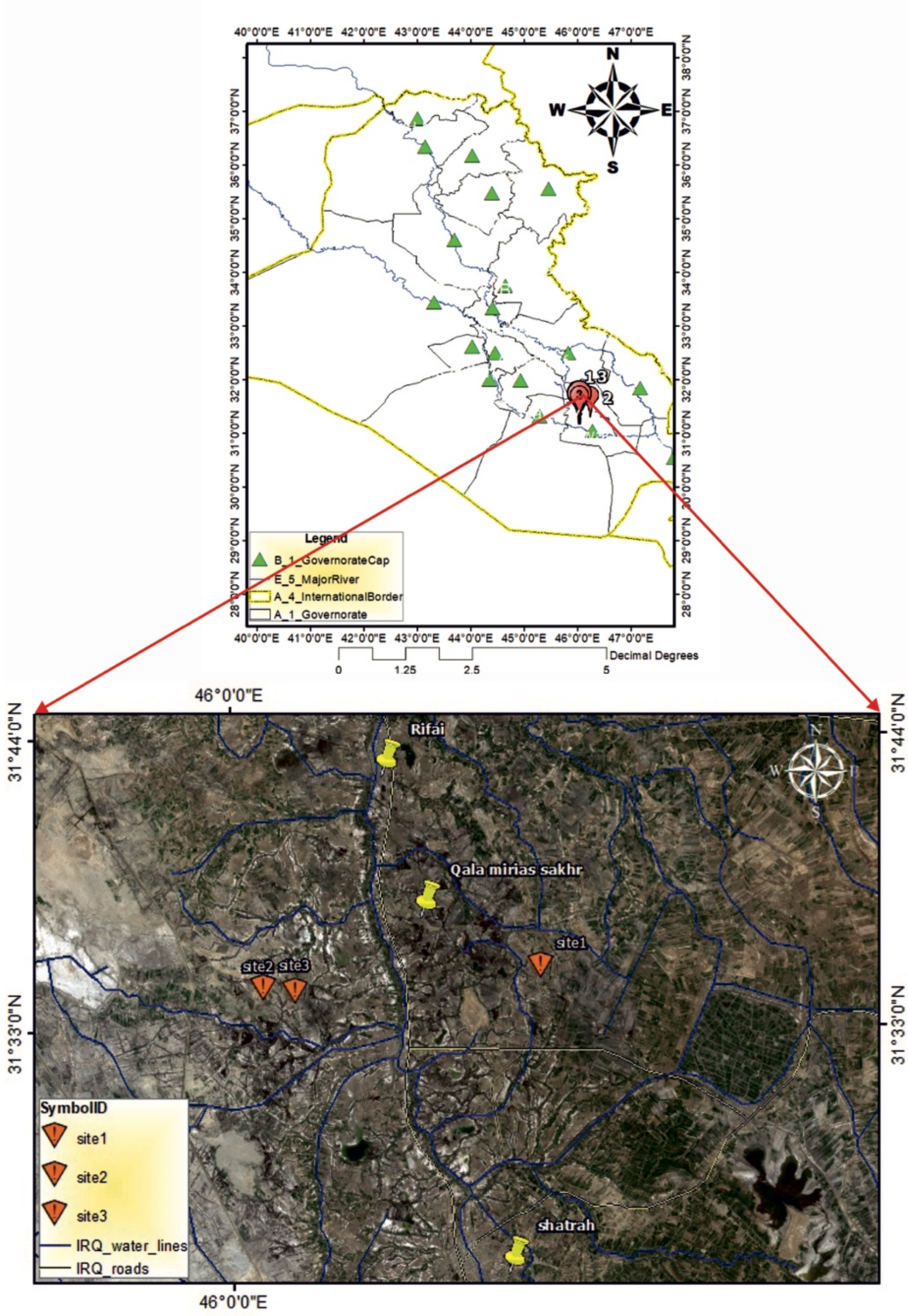

Fig.1. Google map of the study area, the three studied sites are presented in red triangles, South of Iraq

4. Results and Discussion

Grain size analysis was carried out on the samples collected from the three sites, to determine the clay, silt, and sand percentages (Tables 1, 2, and 3) and to indicate the lithofacies description (Figs. 2, and 3).

Three groups of fauna assemblages were identified in the study area (Plate1) (Tables 3, 4, and 5):

A) Foraminifera group

The identified fauna are: *Ammonia beccarii, Ammonia tepida, Ammonia hozanensis, Elphidium incetum, Quinqueloculina candeiana, Quinqueloculina angulta, Spiroculina exima,* and *Spiroloculina rotundata.*

B) Ostracoda group: Presented by *Cyprideis torosa* and *Cyprideis var torosa.*

C) Molluscs group: It comprises several types of species that follow Gastropoda and Pelecypoda, these are: *Cerithum pfeifferi, Lymnaea tenera euphratica, Monilea chiliarches, Theodoxus jordani, Melanoides tuberculate, Iymnaea* sp., *Gibbula* sp., as well as *Cubicula fluminalis* (Pelecypods).

Table 1. Grain size analysis of the samples of site one, west of Al-Hammar Marsh

Sample Site1	Depth (cm)	Sand%	Silt%	Clay%	Texture
1	0-50	9	87	4	Sandy silt
2	50-100	10	88	2	Sandy silt
3	100-150	8	91	1	Sandy silt
4	150-200	7	87	6	Silt
5	200-250	5	92	3	Silt
6	250-300	10	86	4	Sandy silt
7	300-350	2	92	6	Silt
8	350-400	10	89	1	Sandy silt
9	400-450	12	87	1	Sandy silt
10	450-500	1	96	3	Silt
11	500-550	1	95	4	Silt
12	550-600	1	94	5	Silt
13	600-650	2	94	4	Silt
14	650-700	10	87	3	Sandy silt
15	700-750	11	85	4	Sandy silt
16	750-800	1	93	6	Silt
17	800-850	3	92	5	Silt
18	850-900	2	95	3	Silt

Table 2. Grain size analysis of the samples of site two, west of Al-Hammar Marsh

Sample (site 2)	Depth (cm)	Sand%	Silt%	Clay%	Texture
1	0-50	20	78	2	Sandy silt
2	50-100	20	74	6	Sandy silt
3	100-150	11	88	1	Sandy silt
4	150-200	8	90	2	Silt
5	200-250	3	23	74	Silty clay
6	250-300	2	13	85	Silty clay
7	300-350	2	16	82	Silty clay
8	350-400	3	18	79	Silty clay
9	400-450	1	15	84	Silty clay
10	450-500	1	20	79	Silty clay

Table 3. Grain size analysis of the samples of site three, west of Al-Hammar Marsh

Sample (site 3)	Depth (cm)	Sand%	Silt%	Clay%	Texture
1	0-50	20	78	2	Sandy silt
2	50-100	10	84	6	Sandy silt
3	100-150	28	69	3	Sandy silt
4	150-200	25	70	5	Sandy silt
5	200-250	16	82	2	Sandy silt
6	250-300	16	79	5	Sandy silt

7	300-350	2	90	8	Silt
8	350-400	3	90	7	Silt
9	400-450	2	93	5	Silt
10	450-500	10	87	3	Sandy silt
11	500-550	10	85	5	Sandy silt
12	550-600	2	92	6	Silt
13	600-650	3	90	7	Silt
14	650-700	5	89	6	Silt
15	700-750	4	40	56	Silty clay
16	750-800	2	39	59	Silty clay
17	800-850	19	74	7	Sandy silt
18	850-900	14	78	8	Sandy silt

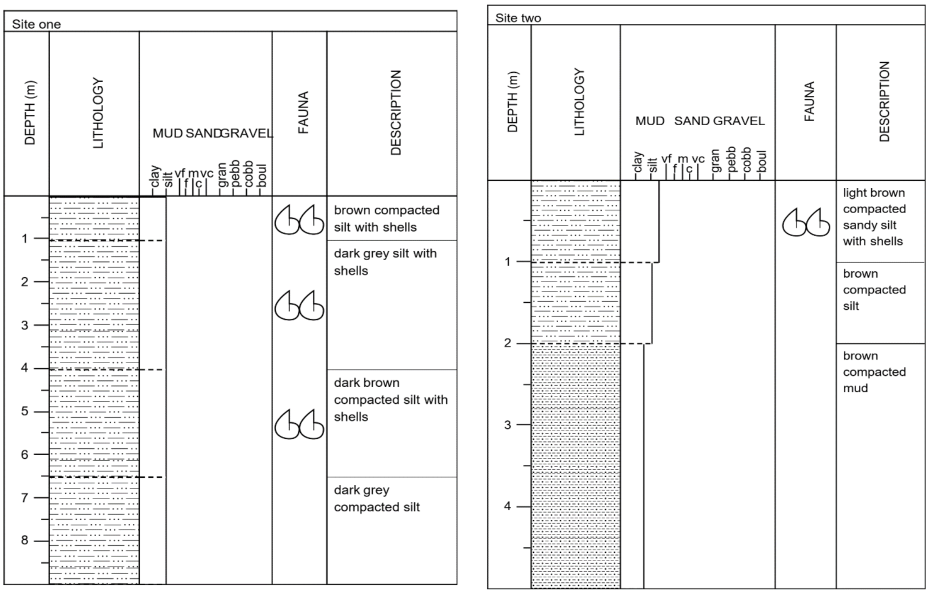

Fig. 2. Stratigraphic sections for the studied sites 1 and 2, west of Al-Hammar

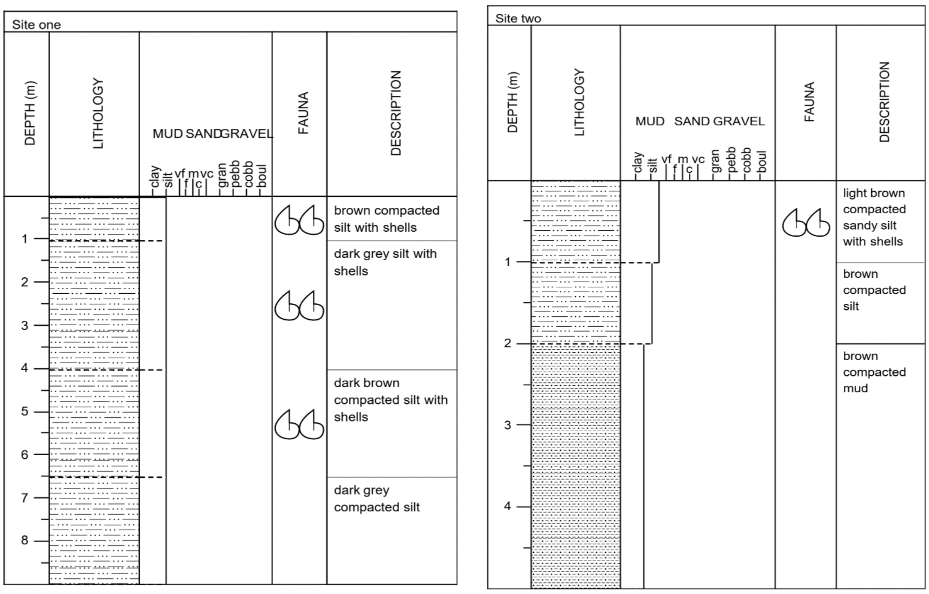

Fig. 2. Stratigraphic sections for the studied sites 1 and 2, west of Al-Hammar

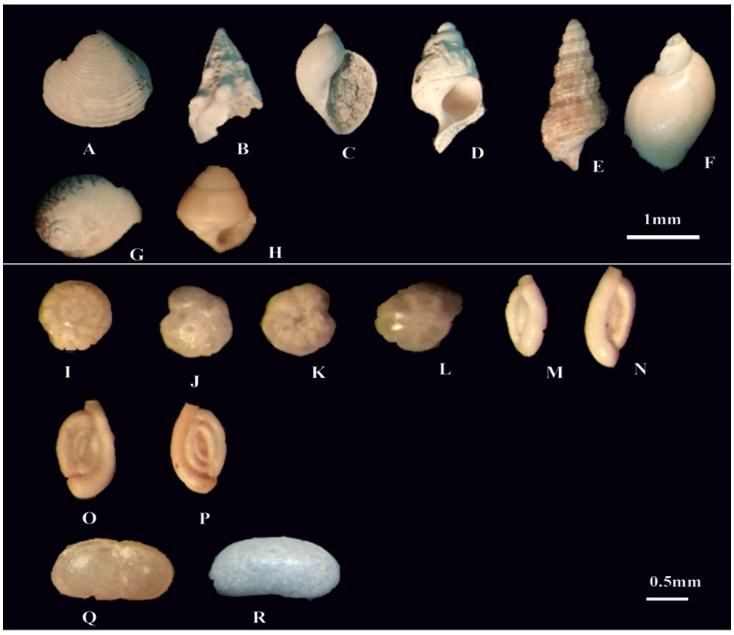

Plate 1. The identified fauna are: *A- Cubicula fluminalis, B- Cerithum pfeifferi, C- Lymnaea tenera, D- Iymnaea* sp.*, E-Monilea chiliarches, F- Melanoides tuberculate, G- Theodoxus jordani, H- Gibbula* sp.*, I- Ammonia beccarii J-Ammonia tepida, K-Ammonia hozanensis, L- Elphidium incetum M-Quinqueloculina candeiana, N- Quinqueloculina angulta, O- Spiroculina exima, P-Spiroloculina rotundata, Q-Cyprideis var torosa, R- Cyprideis torosa.*

From the results that emerged, these sedimentary facies were present; sandy silt, silt, silty clay, and mud, the dominant facies is silt. The deposits of the second site are finer than the deposits of the first and third sites. Three distinct biofacies are evident across the three study sites, delineated by their faunal assemblages as depicted in Figs. 2 and 3 and presented in Tables 4, 5, and 6.

Table 4. Faunal distribution of Holocene deposits in site 1.

Site	Sample	Depth (cm)	*Lymnaea tenera*	*Cerithum pfeifferi*	*Cubicula fluminalis*	*Theodoxus jordani*	*Monilea chiliarches*	*Cyprideis torosa*	*Ammonia tepida*	*Quinq.candeiana*	*Ammonia beccarii*	*Quinq. angulta*	*Spiroculina exima*	*Spiroloculina*	*Ammonia hozanensis*	*Elphidium incetum*	*Melanoides*	*Iymnaea sp.*	*Gibbula sp.*
	1	0-50		***	***	***	***										***	***	***
	2	50-100	**	**	***	***	***										***	***	**
	3	100-150	**	**	***	**	**						*				**	**	**
	4	150-200	**	***	**	**	**						*				**	**	**
	5	200-250							***		***		***						
	6	250-300			***	*	***		***		**		***	**	**				
	7	300-350			**		**		***	***	**	***	***	**	**	***			
	8	350-400			**	*	***		***	***	***	**	***	**	**	***			
	9	400-450			**	*	**		***	**	**	***	**	**	***	**			
	10	450-500			***	*	***	***	**	***	***	***	***	***	***				
	11	500-550				*	**	***	**	***	***		**	***	**				
	12	600-650						***	**	***		**	**			**			
	13	650-700						***	**	***									
	14	700-750						**	**	**	**		**						
	15	750-800						**	**	***	**	**	**			***			
	16	800-850						**	**	***	**	**	**			***			
	17	850-900						**	**	***	**	**	**			**			

*** Abundance ** rich *few

Table 5. Faunal distribution of Holocene deposits in site 2.

Site	Sample	Depth (cm)	*Lymnaea tenera*	*Cerithum pfeifferi*	*Cubicula fluminalis*	*Theodoxus jordani*	*Monilea chiliarches*	*Cyprideis torosa*	*Ammonia tepida*	*Quinq. candeiana*	*Ammonia beccarii*	*Quinq. angulta*	*Spiroculina exima*	*Spiroloculina rotundata*	*Ammonia hozanensis*	*Elphidium incetum*	*Melanoides tuberculate*	*Iymnaea sp.*	γ
Site two	1	0-50																	
	2	50-100	***	**	**	***	***										***	***	***
	3	100-150	**	***	**	***	***						*				**	***	**
	4	150-200	**		*		*			**		***					**		
	5	200-250			***	***	**	**	***	**			**		**	**			
	6	250-300			***	***	**	**	***	**	***	**	***	**		***			
	7	300-350							**	***		***	***	**		**			
	8	350-400						***	**					**	***	***			
	9	400-450						***		***	***	**	***	***	***	***			
	10	450-500						***	***	***	***	***	***	**	***	***			

*** Abundance ** rich *few

Table 6. Faunal distribution of Holocene deposits in Site 3.

Site	Sample	Depth (cm)	*Lymnaea tenera*	*Cerithum pfeifferi*	*Cubicula fluminalis*	*Theodoxus jordani*	*Monilea chiliarches*	*Cyprideis torosa*	*Ammonia tepida*	*Quinq. candeiana*	*Ammonia beccarii*	*Quinq.angulta*	*Spiroculina exima*	*Spiroculina rotundata*	*Ammonia hozanensis*	*Elphidium incetum*	*Melanoides tuberculate*	*Iymnaea sp.*	*Gibbula sp.*
	1	0-50																	
	2	50-100	***				***										***	**	**
	3	100-150	**	**	**	**	***										**	*	**
	4	150-200	**	**	**												*	*	*
	5	200-250	***	***		**	**			**					***	***	**	**	
	6	250-300	***	***	***					***		***		***	***	***	**	**	**
	7	300-350						***						***		***			
	8	350-400						***	***	***		***			**				
	9	400-450						***	***	***	***	**	***	***	***				
	10	450-500							***		**	***	***			**			
	11	500-550						**	***	***	***		***	***	***				
	12	600-650						**	***	**		**				***			
	13	650-700						**		***	***			***	***	**			
	14	700-750			***					***	***	***	**	***	***	**	***		
	15	750-800			***			**	**	**	***	***					***		
	16	800-850						**	**	**	**	***	***	***	**	**	***		
	17	850-900						**	**	***	**	***	***	***	**	**			

*** Abundance ** rich * few

In site one, the first biofacies was found from the surface to around 200 cm of depth; in site two, it was found between 50 and 200 cm of depth; and in site three, it was found between 50 and 250 cm of depth. The presence of species like *Melanoides tuberculate, Lymnaea tenera euphratica, Cerithum* *pfeifferi, Cubicula fluminalis, Theodoxus jordani, Monilea chiliarches, Spiroculina exima,* and *Gibbula* sp. characterize this biofacies. These groups of fauna represent freshwater environments coming from rivers and fresh marshes and were recorded in the first meters of all sites. It was recorded at a depth of 250-550 cm in site 1, while was recorded at 200–300 cm in site 2, and at 300–650 cm in site 3.

Theodoxus jordani, Monilea chiliarches, Cyprideis torosa, Ammonia tepida, Quinqueloculina candeiana, Ammonia beccarii, Quinqueloculina angulta, Spiroculina exima, Spiroloculina rotundata, Ammonia hozanensis, and *Elphidium incetum* are among the indicative species that characterize this biofacies. These fauna groups represent mixed groups, which indicate a transitional zone between the riverine and marine environments, as confirmed by several studies, such as Issa et al. (2009), Shareef and Mahdi (2015), and Al-Jaberi and Mahdi (2020).

The last fauna group was concentrated in the last meters of the three sites under study, as follows: 600-900 cm at site one, 300-500 cm at site two, and 700-900 cm at site three. The indicated species include *Cyprideis torosa, Ammonia tepida, Quinqueloculina candeiana, Ammonia beccarii, Quinqueloculina angulta, Spiroculina exima, Spiroloculina rotundata, Ammonia hozanensis, Elphidium incetum, Cubicula fluminalis,* and *Melanoides tuberculate*.

These species' prevalence and abundance point to environmental circumstances indicating a typical lagoon or tidal flat habitats, which are typified by tidal current influence, changing salinity levels, and shallow water depths.

Comparing the three studied locations reveals unique patterns within each biofacies. From the surface to a depth of approximately 200 cm, the biofacies indicate a freshwater environment at all sites. The presence of both freshwater and brackish water species, on the other hand, is what bed sites one (250–550 cm depth) and two (200–300 cm depth) in biofacies two. The development of marine species including *Spiroculina exima, Cyprideis torosa, Ammonia tepida, and Spiroloculina rotundata* shows a transitional zone affected by salty water incursion.

The biofacies of site three demonstrate the clear influence of alkaline water, which is most noticeable at depths of 700–800 cm. A variety of freshwater and marine species, such as *Melanoides tuberculate, Quinqueloculina angulta, Cubicula fluminalis,* and *Quinqueloculina candeiana*, serve as proof of this finding. Moreover, the muddy sand that characterizes the lithology of this layer suggests that favorable depositional situations were present for the abundance and preservation of these species.

Through studying the quality of sediments and recorded fauna, it was revealed that several environments led to the complexity of these sediments and their mixing with others.

The Holocene sediments were divided into several units depending on their age by Aqrawi (2001), these are; Early Holocene has two units (1 and 2), Middle Holocene has one unit (Unit 3) and Late Holocene presents unit 4, the last unit also is divided into three distinctive beds that reflect lacustrine and brackish environments. Therefore, by comparing the results of the current study, it becomes clear that it falls within this age (Late Holocene), as the recorded fauna within the fresh environment were recorded in the first meters of the studied site sites.

Some of these fauna represent lagoon environment or water–close to the coast, especially the presence of groups of *Ammonia* and *Elphidum* species (Al-Jaberi and Mahdi, 2020).

Also, Al-Sudani et al. (2015) studied Hareer's Tells and determined that the environments in this area are (a) marsh to the fluvial environment; (b) shallow/upper estuary, brackish marsh environment at depth; and (c) lower estuary to the marine environment, indicating that the study area was most likely a marine environment during 8587-6495 Cal BP at depth of 3.5–5m.

Al-Sudani et al. (2015) found resembles between the first and second biofacies, which were found in the current investigation and cores they analyzed. These cores show a change in habitat from marsh to river at depths between the surface and one to one and a half meters. The ages of *Melanopsis praemorsum, Candona wanlessi, Umbonclla,* and *Ilyocypris bradyi*, which span from 536 Cal BP to 3334 Cal BP, define this transition.

Abdalrazak et al. (2016) suggested in their study about Quaternary sediments of Al-Hammar and Al-Hewaza marshes near Qurna areas that the identified fauna are; *Ammonia tepida, Ammonia beccarii, Elphidum gunteri, Elphidum advenum, Triloculina trigonula, Quinqueloculina* sp., *Quinqueloculina impressa, cypridies torosa, Littorina* sp., *Corbicula fluminalis, Retusa* sp., *Gyrodes* sp., *Gyraulus* sp., *lymnae* sp., *Melanopisis* sp., *Rosalina* sp.. These fauna indicate fresh, brackish water, lagoon, tidal flat, and shallow marine environments.

5. Conclusions

The study recorded a significant number of species of Foraminifera, Ostracods, and molluscs from three site, which are located in the west of Al-Hammar Marsh; extending to a depth of 9 m. Based on these species, their number, and distribution, the sedimentary column was divided into three distinct environments dating back to the last period of Quaternary. Fresh environments represent the surface environment and then mixed with marine and mixed environments, while the deepest part represents tidal flat environments.

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