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Sedimentological and paleontological study of the tidal flat recent sediments of Khor Al-Zubair and Khor Abdullah, Northwest Arabian Gulf

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Abstract The present study deals with sedimentological and paleontological aspects of the tidal flats recent sediments of Khor Al-Zubair and Khor Abdullah. The sediments of these tidal flats are mainly composed of silt and mud. Carbonate content was 7.83 – 26.58 % and 23.38 - 45.54 % in the sediments of the tidal flats of Khor Al-Zubair and Khor Abdullah, respectively and the percentage of organic carbon was 0.025-0.9 % in the sediments of Khor Al-Zubair tidal flats while the percentage in Khor Abdullah tidal flats sediments was 0.44-0.87 %. The main constituents of non –clay minerals were calcite, quartz and feldspar in the two tidal flats. Foraminifera, Ostracoda, Gastropoda and Pelecypoda were identified to determine the biofacies of these tidal flats. Four biofacies were identified in the sediments of Khor Al-Zubair tidal flats; BZ1 is a marine environment facies with estuarine condition, BZ2 is a mangrove swamp environment, BZ3 is a lagoonal environment of high salinity, and BZ4 is a brackish – marine environment. The biofacies of Khor Abdullah tidal flat sediments were BA1 and BA2 of marine and nearly marine environments, respectively, whereas, the biofacies of Khor Abdullah channel were BC1 and BC2 which represent the ends of delta and the biofacies BC3 and BC4 show a lagoonal environment.

Introduction

Khor Al-Zubair and Khor Abdullah tidal flats represent an interesting area to investigate the nature of sedimentological and paleontological aspects of northwestern coast of the Arabian Gulf, particularly, those tidal flats which are affected by daily variation in salinity of marine and freshwater. Freshwater comes from the Shatt Al-Arab River in the southeast of the study area and fresh to brackish water comes from Shatt Al-Basrah canal in the northwest of the study area.

Darmoian and Lindqvist (1988) studied the sediment of the estuarine environment of Shatt Al-Arab River and related the sediments to terrigenous and biogenic origin. Al-Abdul Razzaq *et al.* (1980) reported on the benthic microfauna of the tidal flats of Kuwait. The recent Foraminifera of southern Iraq were investigated by Elewi and Safawe (1989). The benthic Foraminifera of Khor Abdullah were studied by Darmoian and Al-Rubaee (1989). Recent work of Al-Jabbery (2005) focused on by the sedimentology and mineralogy of this area and interpreted that the sedimentary environment is of quite and low energy. Al-Ali (2007) studied the faunal assemblages within the surface and subsurface Quaternary sediments of the northwestern Arabian Gulf and Lower Mesopotamia.

The aim of the present study is to identify the biofacies of Khor Al-Zubair and Khor Abdullah tidal flats as well as their environments.

Materials and Methods

Twenty seven samples were collected from three locations. Two locations were in Khor Al-Zubair and the other in Khor Abdullah (Fig. 1). The depth of samples varied from the surface to a depth of 1.1 m. Two additional samples were taken from the rocky part of the Khor Al-Zubair tidal flat. Sampling was carried out during 5 May-2005 by using a hand auger. In the laboratory, the grain size distribution was obtained by wet sieving using a sieve of 230 mesh to separate the sand from silt and clay fraction, then the silt and clay percentage were measured by a SediGraph. The non-clay minerals were identified by using X-ray diffraction technique in the X-ray laboratory of Physics Department, Science College, University of Basrah. Carbonate percentage was measured by a calcimeter (Vatan, 1976) and total organic carbon was calculated by using the method of EL-Wakeel and Riley (1957). In the preparation for examination under light microscope, the Foraminifera and other fauna samples were washed on ASTM 230 mesh sieve to remove the finer (silt and clay) particles. The residue, which included sand and fauna were collected and dried, then picked, using 0.001 mm hairbrush. The Foraminifera and other fauna were spread carefully on a 60-chambered sorting tray and observed under a binocular microscope and identified to species level. In the present investigation the widely employed classification proposed by Loeblich and Tappan (1988) has been followed for foraminifera, Moore and Bitrat (1961 in Peiris, 1969) for Ostracoda, Keen and Coan (1974) for Gastropoda and Moore (1969) for Pelecypoda.

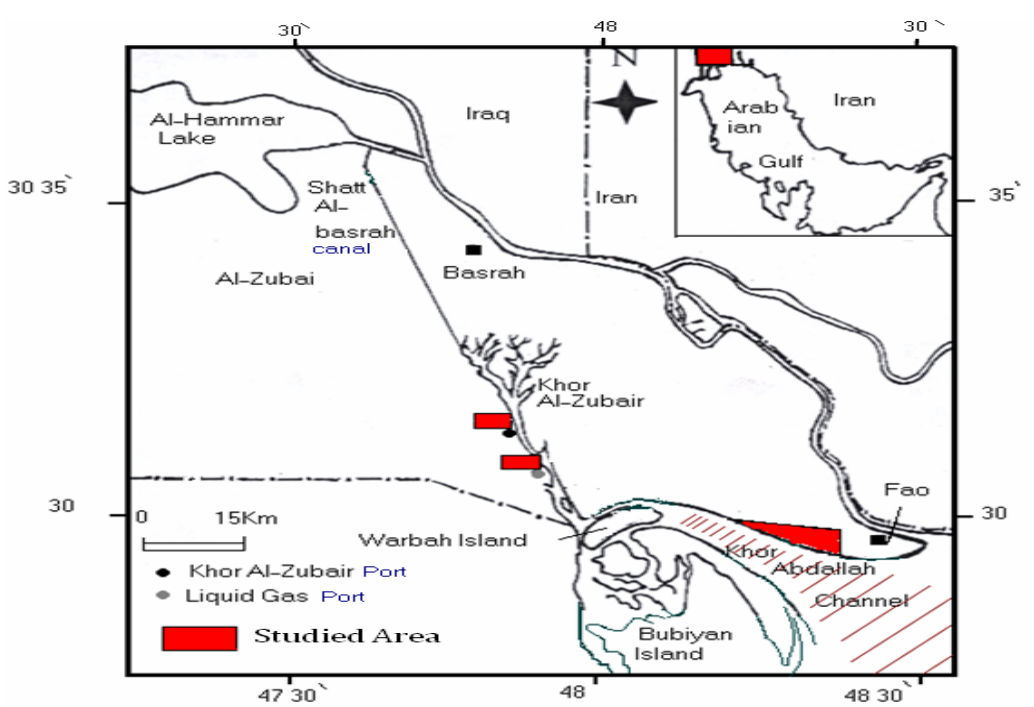

Figure 1. Map showing Khor Al-Zubair and Khor Abdullah tidal flats, and sampling sites.

Results and Discussion

Sedimentological study:

According to the texture classification of Folk (1974), the grain size analysis indicates seven Sedimentological textures in the Khor Al-Zubair tidal flat (Fig. 2A); silt, mud, sandy silt, sand, clayey sand, muddy sand and sandy mud, three of them were dominant; silt, mud and sandy silt (Table 1).

The average of sand, silt and clay fractions content in silty tidal flat were 2.80 and 18 %, respectively, 4.48 and 48 % in the muddy tidal flat, and 31.56 and 13 % for the sandy silt tidal flats, respectively. In Khor Abdullah tidal flat (Fig. 2B), the sediments were mud and silt as a main constituent (Table 2). The average of fractions content in the muddy tidal flat of Khor Abdullah were <1 % sand, 56 % silt and 44 % clay, and those in the silty tidal flats were 1 % sand, 78 % silt and 21 % clay. Sand facies were found in a rocky island in the western side of Khor Al-Zubair, the sand fraction reached 91%.

Table 1. Grain-size texture of Khor Al-Zubair sediments.

Texture of sediments		Sand%	Silt%	Clay%	Mean/ϕ
Silt	Max.	5	95	32	7.33
	Min.	<1	66	5	6.93
	Average	2	80	18	7.12
Mud	Max.	8	48	51	7.8
	Min.	3	47	44	7.15
	Average	4	48	48	7.52
Sandy Silt	Max.	39	67	16	5.79
	Min.	23	45	9	5.42
	Average	31	56	13	5.61

Table 2. Grain-size texture of Khor Abdullah sediments.

Texture of sediments		Sand%	Silt%	Clay%	Mean/ϕ
Mud	Max.	1	67	60	8.93
	Min.	<1	42	33	7.43
	Average	<1	56	44	8.05
Silt	Max.	3	87	25	7.65
	Min.	<1	72	13	7.18
	Average	1	78	21	7.38

Paleontological study:

The Microscopic examination of the selected samples proved the wide biodiversity of these samples. The assemblages of fauna support the identification of many biofacies (Fig.2):

Biofacies of Khor Al-Zubair Tidal Flats:

1. Biofacies (BZ_1):

This facies was found in samples 1 and 3 at depths, 0.50 and 0.75 m, respectively in the first station (Fig. 2A). The main constituents of fauna in this facies were the Mollusca, Gastropoda assemblages which were represented by *Tachyrynchus sp.*, *Aclis* (*Graphis*) *sp.*, *Retusa canaliculata*, *Odostomia sp.*, *Littorina sp.* and *Turritella fultoni* (Plate 1, Figs. 1, 2, 3, 4, 5 and 6). The Pelecypoda assemblage is; *Arca foliata*, *Anadara sp.* and *Corbula subquadrata* (Plate 1, Figs. 7, 8 and 9). According to Keen and Coan (1974), all of these species indicate the intertidal flat zone of marine environment, except *Retusa canaliculata*, which inhabits sandy sediment in estuarine environment (Emerson and Jacobson, 1976). This could reflect the influence of a river during the deposition of this facies.

2.Biofacies (BZ_2):
It is present in the samples 1 and 2 at the depths, 0.60 and 1.10 m, respectively, and extended to sample 5 at depths 0.30 and 0.70 m of station 1 (Fig. 2A). The sediment texture is silty. Foraminifera were the main constituent of this facies, represented by *Discorinospsis tropica, Trochammina inflata* and *Ammonia beccarii* (Plate 2, Fig. 2 and Plate 3, Figs. 5 and 8). The first two species characterize the marine marshes of shallow water (Phleger, 1960). According to Goldstein (1976), *Discorinospsis tropica* occurs exclusively in mangrove swamps and associated with *Trochammina inflata*, whereas *Ammonia beccarii* occurs in a wide range of sedimentary environments; mangroves, brackish water, lagoon and near shore (Javaux and Scott, 2003). Furthermore, some identified Foraminifera species (*Elphidium discoidel, Elphidium subarctium, Elphidium matagordenum, Quinqueloculina seminulum, Quinqueloculina ovula* and *Rosalina columbiensis* (Plate 2, Figs. 4, 10, 15 and 16 and Plate 3, Figs. 6 and 10) in this facies reveal a lagoonal environment.

3.Biofacies (BZ_3):
It is found at different depths of Khor Al-Zubair tidal flats (Fig. 2A). Sediment textures were mud, sandy mud, silt and sandy silt. The most common foraminifera was *Ammonia beccarii*. Other species such as *Elphidium advenum, Elphidium discoidal, Elphidium excavatum* form *clavata, Elphiduim incertum clavatum, Elphidium incertum mexcanum, Quinqueloculina laevigata, Quinqueloculina poyana, Quinqueloculina seminulum, Quinqueloculina sp.* and *Ammonia tepida* (Plate 2, Figs. 5, 8, 9 and 11 and Plate 3, Figs. 6, 12, 13 and 14) were less common.

Assemblage of *Ammonia beccarii* with the above species and the presence of the most calcareous hyaline tests and porcelaneous tests of Foraminifera species give a solid evidence of a lagoonal environment.

4.Biofacies (BZ_4):
It is located at a depth of 0.25 m in Khor Al-Zubair tidal flats (Fig. 2A). Nine species of foraminifera were present; *Ammonia beccarii, Elphidium advenum, Elphidium discoidal, Elphidium excavatum* forma *clavata, Elphidium incertum mexicanum, Quinqueloculina poeyana, Quinqueloculina ovula, Quinqueloculina seminulum* and *Rosalina columbiensis. Ammonia beccarii* was the most common among the other species in this facies. The occurrence of the other species means that the facies has an attendance to be more brackish-marine environment (Rao and Rao, 1974). The second assemblage found in this biofacies was Ostracoda assemblage, such as *Cyperideis torosa var. torosa, Haplocytheridea bradyi, Haplocytheridea keyseri, Loxoconcha sp., Loxoconcha gymeryi* and *Cushmanidea sp*. (Plate 4, Figs. 1, 3, 4, 5, 7 and 8). The first species was the most abundant. The environment of the first species could be brackish-marine (Besonen, 1997).

Biofacies of Khor Abdallah Tidal Flats:
1. Biofacies (BA_1):
The texture of this facies was silt and mud, it was found at depths 0.30-0.60 m (Fig. 2B). The facies represented by two main species of foraminifera; *Elphidium discoidal* and *Ammonia beccarii*, but the first species was more common than the second, which could mean that, according to Closs and Medeir (1967 in Boltovskoy and Wright, 1976), the environment is marine with low salinity. Other associated species in this facies were *Elphidium incertium mexicanam, Elphidium excavatum,*

Fissurina serrata, Fissurina marginata, Bulimina marginuta, Bolivina spathulata (Plate 2, Figs. 16, 17 and 19 and Plate 3, Figs. 2 and 11).

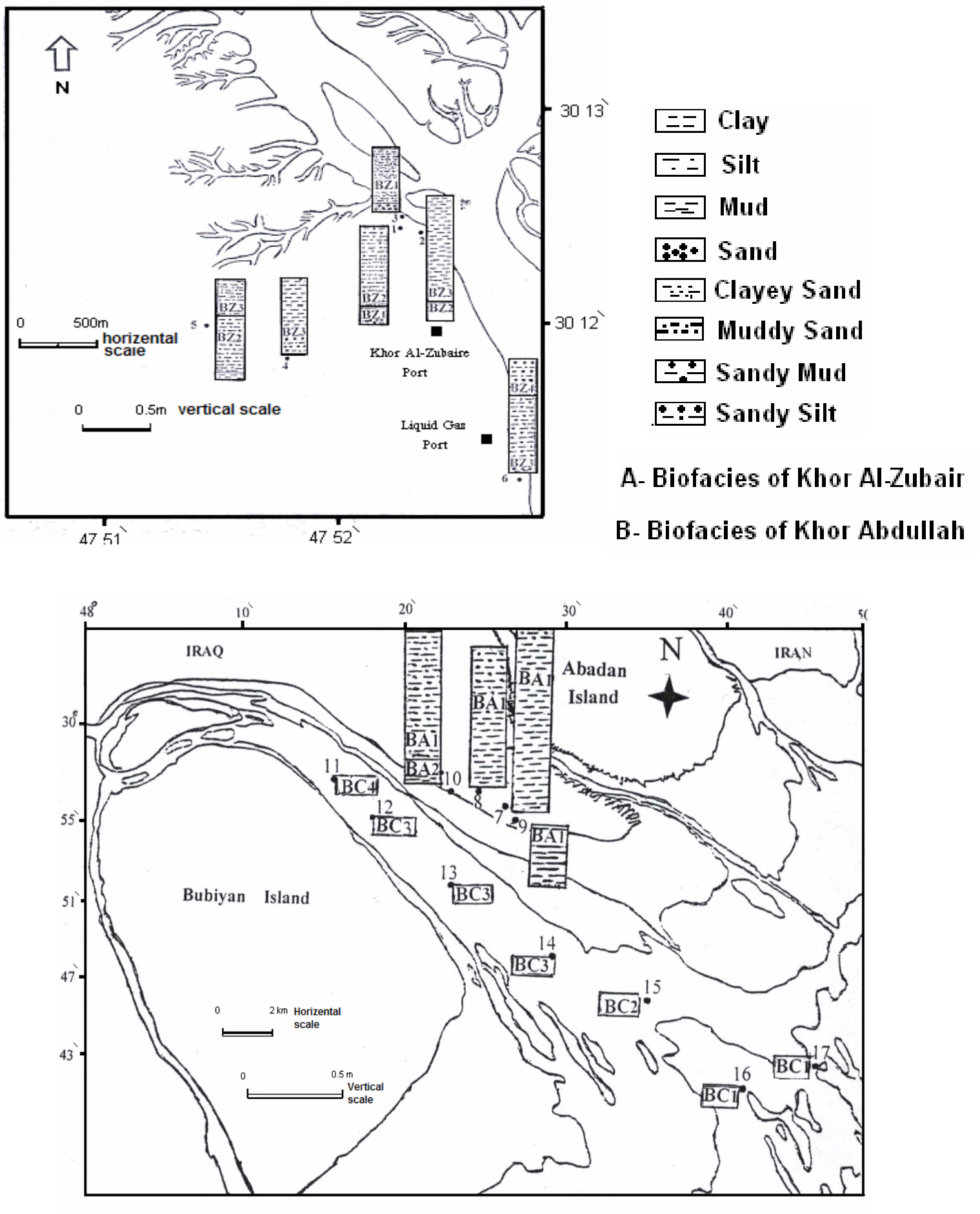

Figure 2. Map showing the distribution of sediment facies and biofacies in the study area of Khor Al-Zubair and Khor Abdullah tidal flats.

2. Biofacies (BA_2):
The facies found at a depth 0.75 m (Fig. 2B). It is represented by six species of foraminifera; *Ammonia beccarii, Elphidium excavatum, Elphidium discoidal, Elphidium incertium mexicanum, Quinqueloculina poeyana* and *Quinqueloculina seminulum*. All of these species are characterized by a high abundance. Other species of foraminifera were less abundant such as *Fissurina marginate, Bolivina striatula* and *Bolivina nitida* (Plate 2, Fig. 18 and Plate 3, Fig.1). The foraminifera assemblages of this facies were similar to BA1 facies, but the abundance of *Quiqueloculina seminulum* and *Quinqueloculina poeyana* and their porcelineous test composition reflect a marine environment without any attenuation to water salinity (Greiner, 1969 in Hill *et al*., 2003).

Biofacies of Khor Abdullah Channel:

Khor Abdullah channel was sampled for comparison between the biofacies of the tidal flats and the channel. The sediments of this channel are mainly composed of mud, sandy mud and clay. The biofacies were:
1. Biofacies (BC_1):
It is found in the muddy sediments (Fig. 2B). The species of Foraminifera were *Ammonia beccarri, Fissurina marginata, Quiqueloculina sp., Quiqueloculina seminula* and *Bolivina striatula* (Plate 2, fig.9). These species were dominant in comparison with *Quinqueloculina lamarckiana, Massilina sp., Triloculina earlandi, Elphidium subaretium, Elphidium advenum, Elphidium excavatum* forma *clavata, Elphidium discoidal, Cribrostomoides crassimargo, Bulimina marginata, Virgulina fusiformis, Buccella frigida, Asterorotalia dentate* and *Dentalina communis* (Plate 2, Figs. 1, 7, 12, 13 and 14 and Plate 3, Figs. 7 and 17). The dominance of *Ammonia beccarii* and *Fissurina marginata* in this biofacies in addition to the dominant species could lead to conclude that the environment is a deltaic - marine (Murray, 1976). Other species of ostracoda also present such as *Haplocytheridea keyseri, Haplocytheridea subovata, Neomenoceretina delicate, Cushmanidea sp. Loxoconcha gumeryi* and *Cyprideis torosa var. torosa* (Plate 4, Figs. 2 and 6).

2. Biofacies (BC_2):
It is present in sandy mud (Fig. 2B). The foraminifera species were; *Cribrostomoides crassimargo, Dentostomina sp, Spiroloculina laevigata, Quinqueloculina seminula, Quinqueloculina sp., Massilina sp., Trilocilina earlandia, Ammonia beccarii, Asterortalia dentata, Elphidium advenum* and *Elphidium discoidal*. This assemblage represents a hetero-deltaic marine environment, and the abundance of *Ammonia beccarii* and *Quinqueloculina seminula* gives an impression of attenuation in the water salinity (Rao and Rao, 1974; Grossman and Benson, 1967). Ostracoda were present in this biofacies by an assemblage similar to that of the BC1 biofacies, but *Cyperideis torosa* var. *torosa* was most abundant than the rest, which support the conclusion of the attenuation in water salinity.

3. Biofacies (BC_3):
It is found in clay and sandy mud sediments (Fig. 2B). The most common species of foraminifera were *Ammonia beccarii, Triloculina earlandi, Elphidium discoidal* and *Quinqueloculina sp*. The rest of species were *Spiroloculina laevigata, Elphidium advenum, Elphidium subarcticum, Quinqueloculina seminula, Massilina sp*. and *Buccella frigid* (Plate 3, Fig. 3). The first assemblage favors lagoonal environment of normal marine salinity (Murray, 1976).

4. Biofacies (BC_4):
It is found in muddy sediments (Fig. 2B) and represented by *Ammonia beccarii* (dominant), *Fissurina marginata, Elphidium excavatum forma clavata, Elphidium discoidal, Elphidium advenum* and *Guttulina sp*. (Plate 2, Fig. 15). This assemblage was similar to that of biofacies BC3 but the abundance of *Ammonia beccarii* reflects the fluctuation in salinity (Rao and Rao, 1974).

Plate 1.

1. *Littorina sp.*
2. *Tachyrynchus sp.*
3. *Turritella fultoni* (Melvill).
4. *Aclis* (*Graphis*) *sp.* (13 X)
5. *Odostomia sp.*
6. *Retusa canaliculata* (Say).
7. *Arca foliate* (Forskal) (13 X)
8. *Anadara sp.*(13 X)
9. Corbula subquadrata (Melvill).

Magnification 32 X unless otherwise indicated

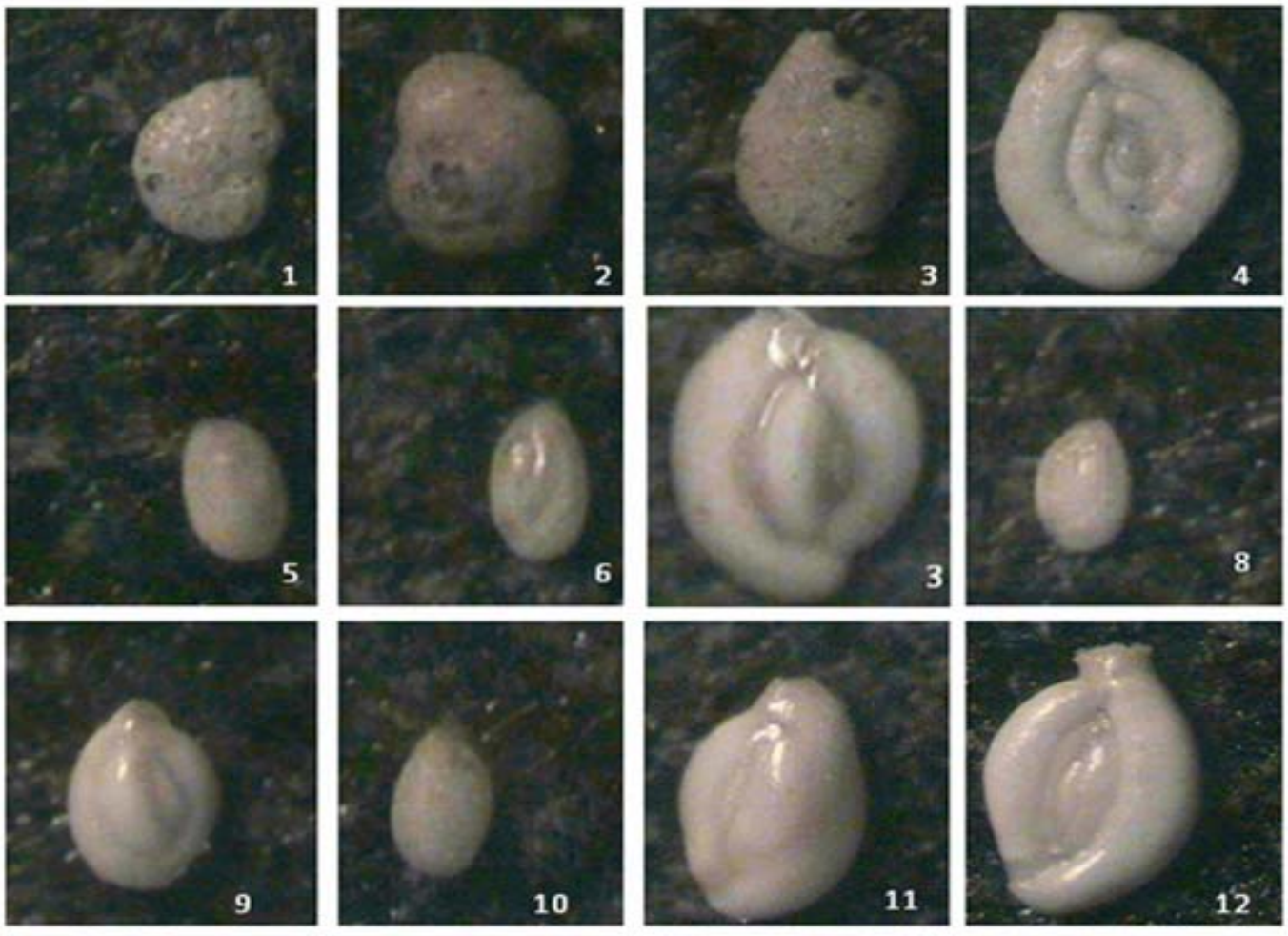

Plate 2.

1. *Cribrostomoides crassimargo* (Norman).
2. *Trochammina inflata* (Montagu).
3. *Dentostomina sp*.
4. *Spiroloculina laevigata* (Cushman and Todd).
5. *Quinqueloculina laevigata* (d´Orbigny).
6. *Quinqueloculina ovula* (Karrer).
7. *Quinqueloculina lamarckiana* (d´Orbigny).
8. *Quinqueloculina poeyana* (d´Orbigny).
9. *Quinqueloculina seminula* (Linné).
10 *Quinqueloculina seminulum* (Linné).
11 *Quinqueloculina sp*.
12 *Massilina sp*.
13 *Triloculina earlandia* (Cushman,Todd and Post),
13 a.Smooth form;13b.Striat form.
14 *Dentalina communis* (d´Orbigny).
15 *Guttulina sp*.
16 *Fissurina marginata* (Montagu).
17 *Fissurina serrata* (Schlumberger).
18 *Bolivina nitida* (Brady).
19 *Bolivina spathulata* (Williamson).

Magnification 80 X

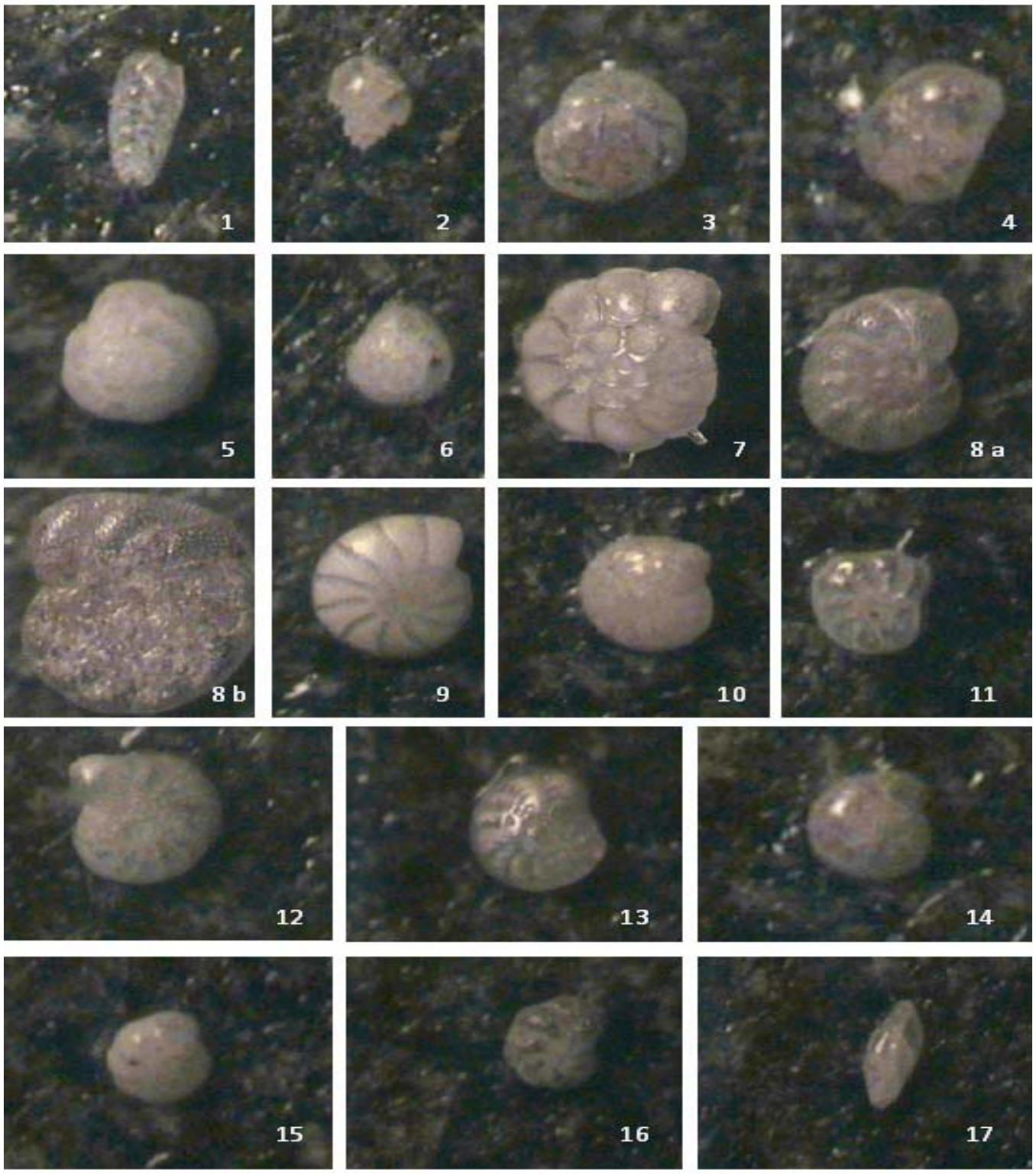

Plate 3.

1. *Bolivina striatula* (Cushman).
2. *Bulimina marginata* (d´Orbigny).
3. *Buccella frigida* (Cushman).
4. *Rosalina columbiensis* (Cushman).
5. *Ammonia beccarii* (Linné).
6. *Ammonia tepida* (Cushman).
7. *Asterorotalia dentata* (Parker and Jones).
8. *Disscorinopsis tropica* (Collins), 8a. Spiral side; 8b Umbilical side
9. *Elphidium advenum* (Cushman).
10. *Elphidium discoidal* (d´Orbigny).
11. *Elphidium excavatum* (Terquem).
12. *Elphidium excavatum* forma *clavata* (Cushman).
13. *Elphidium incertum clavatum* (Cushman).
14. *Elphidium incertum mexicanum* (Kornfeld).
15. *Elphidium matagordanum* (Kornfeld).
16. *Elphidium subarcticum* (Cushman).
17. *Virgulina fusiformis* (Williamson).

Magnification 80X

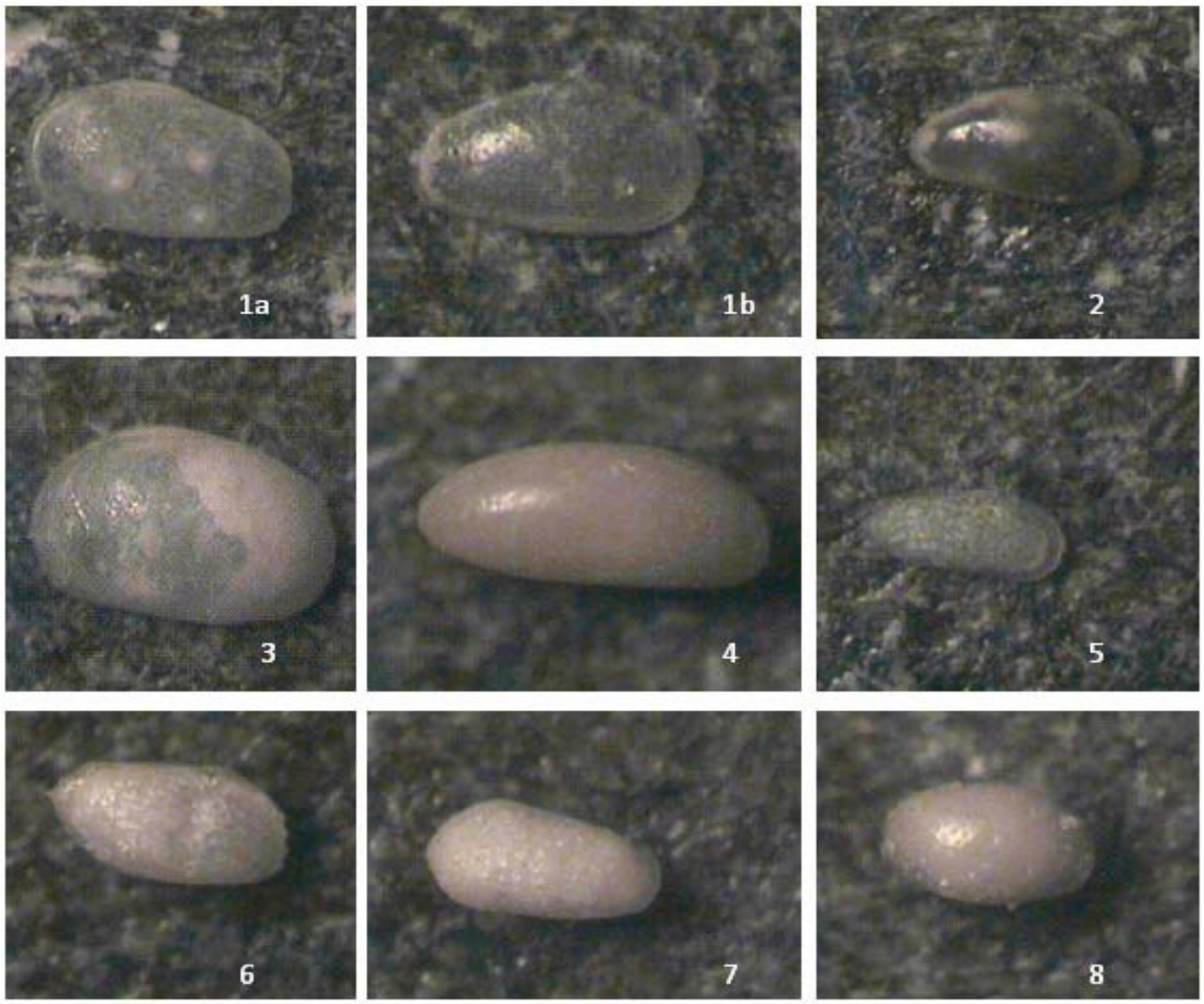

Plate 4

1. *Cyprideis torosa* var.*torosa* (Jones).
2. *Haplocytheridea subovata* (Ulrich and Bassler).
3. *Haplocytheridea bradyi* (Stephenson).
4. *Haplocytheridea keyseri* (Jain).
5. *Cushmanidea sp.*
6. *Neomenoceretina delicate* (Ischizaki and Kato).
7. *Loxoconcha* (*Loxoconcha*) *gumeryi* (Bata and Gurney).
8. *Loxoconcha sp.*

Magnification 80 X

Conclusions

It might be concluded that Khor Al-Zubair tidal flats area started as a lagoonal environment during the deposition of sediment at a depth 1-1.1 m followed by a shallow marine environment. After that period the environment might have been influenced by a river and ended as brackish-marine environment after the construction of the Shatt Al-Basrah canal. Biofacies of Khor Abdullah tidal flats might start as a marine environment without attenuation in water salinity and terminated by marine with low salinity.

Biofacies of Khor Abdullah channel indicates a notable variation in sedimentary environment; deltaic-marine, deltaic–marine with attenuation in water salinity, lagoon of normal salinity and lagoon with fluctuation in salinity. The two latter areas are highly affected by the fresh water of Shatt Al-Arab River.

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دراسة رسوبية ومستحاثية للرواسب الحديثة مسطحات المد والجزر لخور الزبير وخور عبد الله، شمال غرب الخليج العربي

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المستخلص تناولت الدراسة الحالية الخصائص الرسوبية والمستحاثية لرواسب المسطحات المدية لخور الزبير وخور عبد الله. تتكون رواسب المسطحات لكلا الخورين غالبا من الغرين والطين. يتراوح محتوى الكاربونيت بين 7.83 – 26.58 % و 23.38 – 45.54 % في رواسب مسطحات خور الزبير وخور عبد الله على التوالي، كذلك الكاربون العضوي كانت نسبته بين 0.025 – 0.90 % و 0.44 – 0.87 % للخورين على التوالي. المكونات الاساسية من المعادن غير طينية هي الكالسايت والكوارتز والفلدسبار. أستخدمت مجاميع المخرمات وأصداف الدرعيات وبطنية القدم والمحاريات لتعيين السحن الحياتية لمنطقة الدراسة. شخصت اربعة سحن حياتية لرواسب مسطحات خور الزبير: BZ1 والتي تمثل بيئة بحرية متأثرة بالظرف المصبي، و BZ2 تمثل بيئة مستنقع المانغروف، و BZ3 بيئة لاغونية عالية الملوحة و BZ4 بيئة مويلحة- بحرية. وظهرت سحنتان حياتيتان في رواسب مسطحات خور عبد الله: BA1 و BA2 الممثلتين لبيئة بحرية وبيئة قريبة من البحرية على التوالي. بينما أظهرت رواسب قناة خور عبد الله اربعة سحن حياتية: BC1 و BC2 يمثلان بيئة نهايات الدلتا و BC3 و BC4 ويمثلان بيئة اللاغون.