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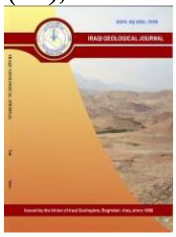

Assessment the Subbottom Sedimentary Situation for Khor Abdullah, NW Arabian Gulf Using Sedimentary Coring Analysis and Sub-Bottom Profile Technique

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Abstract

The Coring Analysis and Sub-Bottom Profile technique are effective tools for assessing the sedimentary development of the bottoms, in this study these methods were used to assess the Sub bottom Sedimentary Situation for Khor Abdullah, NW Arabian Gulf. Two marine core sediments were studied at a depth of 40 m. Detailed grain-size analysis was carried out on 86 samples from cores. In addition, many sedimentary structures were diagnosed, such as load structures, wavy bedding, interfingered, peat layers, sole marks, and others. The environments and the transgression and regression of the sea were detected and interpreted on the basis of these analyzes, which were also attributed to the presence of the fauna in some beds.

The integration of the SBP and sedimentary analysis results revealed the presence of many sedimentary facies (silt, sandy silt, silty sand, sand, muddy sand and mud). The sedimentary situations and reflection configurations include, SB1: Parallel reflection -Tidal sediments; SB2: Wavy reflection- Shallow transgression; SB3 and SB4: Oblique and Hummocky reflection regression), which indicate the different depositional environments as a result of changes in environmental factors, climatic conditions and the sedimentation energy. The study revealed there is a beds of peat at depth 12-18 m under the bottom, which is refer to lagoon or marsh environments where fresh and brackish water with high TOC%, the source of peat deposits belongs to one or a many of ancient river courses buried under the bottom and which is detected by the SBP section.

Keywords: Khor Abdullah, Sedimentary structures, Sedimentary coring analysis, Marine transgression and regression and Sub-Bottom Profiler technique.

1. Introduction

Many geological, environmental and economic studies have been conducted in the NW Arabian Gulf (AG) region due to its economic importance, as it is considered the primary trade waterway for Iraq. On the other hand, Khor Abdullah (that is located in NW the AG) is considered as a common maritime borders' corridor with Kuwaiti site, so there are political problems dividing the maritime borders. Many tidal flat sediments of Khor-Abdullah coast near an Al-Faw Grand Port (FGP) in southern Basrah city, these sediments have low to medium bearing capacity, which can be handled by strengthening with classic means like piles (Muttashar et al., 2010). Al-Sheikhly et al., 2017 also studied the paleoenvironment of southern Mesopotamia, where nine paleoenvironmental maps were drawn age intervals for ages between 22000 and 1000 B.P. explained the distribution of ancient river courses and

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the ancient coast line, based on the assemblages of Ostracoda and Foraminifera as environmental indicators. Al Humaidan, et al. (2019) conducted a sedimentological and fauna study of the sediments of Khor Abdullah and confirmed that the sediment texture is sandy silt and silt and is characterized by the presence of mixed layers of clay minerals and a few fauna. Al-Jaberi and Mahdi (2020) referred that the marine transgression began at depth 35-30 m and marine regression began at depth 27-17 m. The tectonic activities are influencing on Khor Shatana and Khor Abdullah due to of subsurface major faults that are related to the basement rocks. In addition, the ancient paths, discontinued rivers, and paleochannels have been revealed using digital image processing of satellite images (Al-Muturi, 2019). From the aforementioned studies, a detailed geological study of sediment sub-bottom at a depth of 40 m was not conducted. The main objective of this study is to identify the paleodeposition environments in the region and determine the conditions of sedimentation depending on the transgression and regression of the sea through sedimentary investigations.

2. Study Area

The study area extends into the Iraqi marine waters in the middle of Khor Abdullah and up to the nearby regional marine waters of the open sea. In this area, two cores were studied in Fig. 1, at a depth of 40 m, at the site adjacent to the FGP. The coordinates of the well cores sites and the depth of water are shown in table1, and the map of the study area is shown in Fig. 2.

Table 1. Latitude, longitude and depths of water in the study area.

Core	Thickness m	Depths of water (m)	Latitude	Longitude
Core 4	40	5	29°52' 25.068"N	48°26' 49.412"E
Core 8	40	5.5	29°50' 39.44"N	48°30' 18.84"E

Fig 1. Boxes of core samples.

3. Geological and Stratigraphic Setting of the NW Arabian Gulf

A Khor is a depression or valley within the coast, extending longitudinally on the water axis. Khor Abdullah is a body of water in the NW of the AG that extends between the islands of Warba and Bubiyan on the Kuwaiti side and the Faw peninsula on the Iraqi side. The depth of the Khor Abdullah channel ranges between 7 and 14 m and the width of the channel ranges between 5 and 14 km. It extends inside Iraqi lands, forming Khor Al-Zubair (Fig. 3). At the end of the Jurassic period, the Arabian plate began to subduct under the Iranian plate. These movements continued until the Pliocene epoch, when recent geological phenomena emerged, such as the formation of the Zagros Mountains and the rise of Musandam Island during the Ice Age in the Quaternary (Al-Azzawi, 1996).

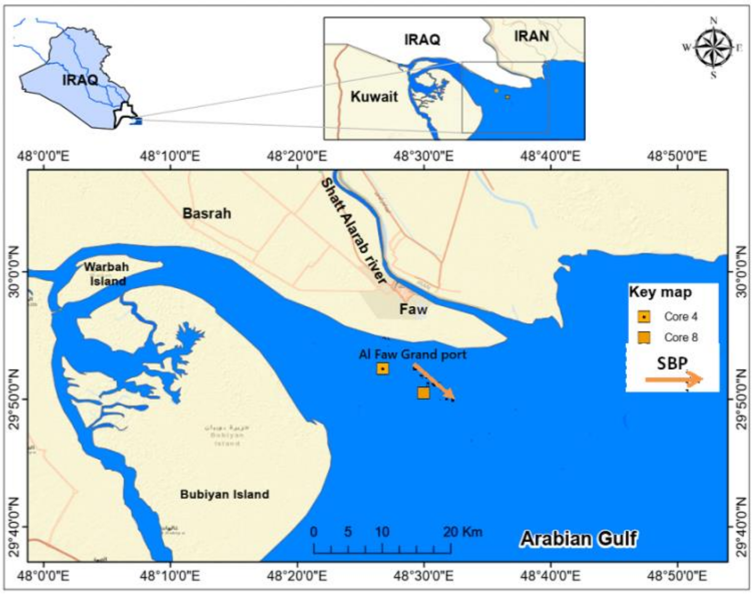

Fig. 2. The location map of the study area with cores and Sub-bottom profiler technique positions.

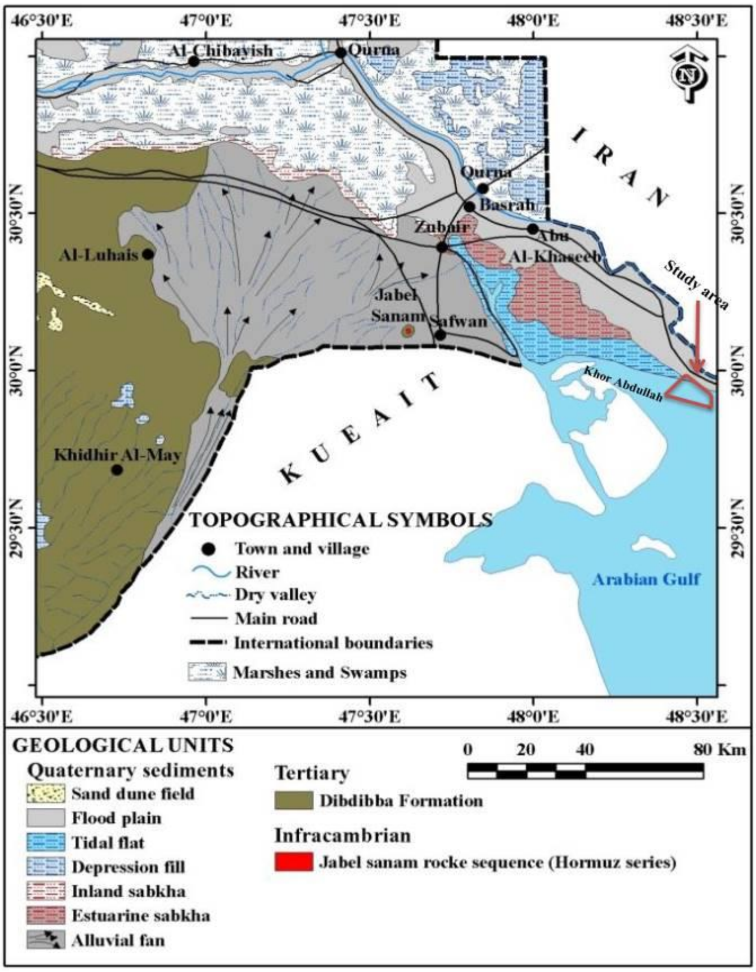

Fig. 3. Geological map of the study area south of Iraq after (Sissakian et al., 2014).

In addition, the ancient Tigris River stream was flowing inside the Arabian Gulf until the Hormuz Strait, while the Euphrates River was possible formed later after the faulting process that happened in the region along the Euphrates fault in the direction NW-SE, this led to the separation of Warba and Bubiyan regions from Kuwait due to the large fault resulting from tectonic activity that accompanied the regressive of marine waters (Al-Azzawi, 1996). The great fault was accompanied by lateral faults that formed the streams of the Al-Batin and Abu Al-Khaseeb rivers and the separation of Warba and Bubiyan from the coast of Mesopotamia, thus forming Khor Abdullah and Khor Shytianah (AlMoussawi, 1993).

Mesopotamian plain witnessed tectonic activity because of the structural depression in east of Zubair uplift and subsidence Northwest of Bubian Island which caused to separate from Warbah Island and emergence of Khor Bubiyan, and contacted the Khor AlZubair with Khor Abdullah (AlMoussawi, 1993). The stratigraphy and fold structures in the NW Arabian Gulf studied by using data from seven wells and 2760 km of seismic profiles Fig. (3) simplified l stratigraphic column of this area displays the superposition of three alternating ductile and three brittle layers (Soleimany and Sàbat, 2010) as shown in Fig. 4. The uppermost brittle layer consists of upper Miocene - Pliocene marine sandstone and siltstone. The upper part of the layer is coeval with the main deformation stage of the Zagros Orogeny (Homke et al., 2004).

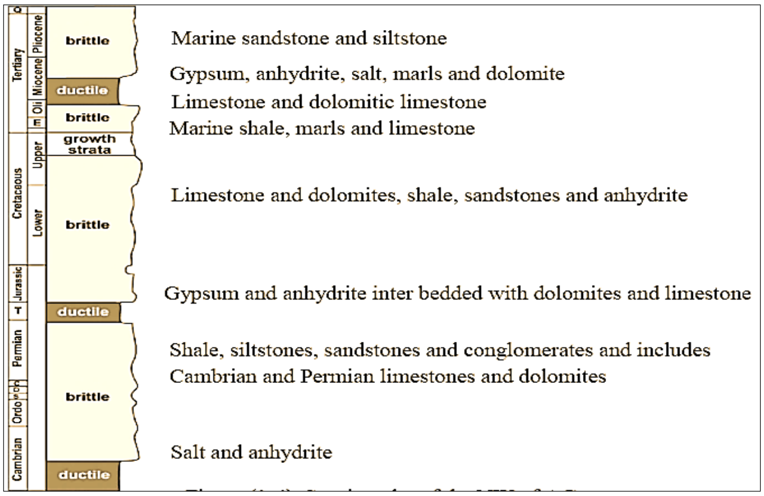

Fig. 4. Stratigraphy of the NW of Arabian Gulf (Soleimany and Sàbat, 2010).

4. Materials and Methods

4.1. Sedimentary Coring Analysis

Two marine core sediments with a depth of 40 m and a diameter of 10 cm were taken by the Iraqi Ports Company/ Marine Drilling Department. Core sediments have been studied in detail from a sedimentological point of view. In the laboratory, a visual description of the cores was carried out, represented by sediment colors, a diagnosis of sedimentary structures, and the identification of distinctive layers such as the presence of peat, gypsum crystals, salt layers, and the presence of large fauna. One of the key analyses performed on over 80 sediment samples was the determination of grain size using the pipette method at the Marine Sciences sedimentology laboratory, following the procedure outlined by Folk (1974). This involved calculating the percentage of sand, silt, and clay present in the samples, as well as determining the sediment texture. Additionally, the total organic carbon (TOC %) of the sediment was analyzed using a loss-on-ignition (LOI) method in the Marine Sciences Center sedimentology laboratory, in accordance with Bartels (1996) procedure.

4.2. Sub-Bottom Profiler Technique

Sub-bottom profiler technique (SBP) is a marine geophysical method that is specifically used to investigate and identify sediment or rock layers under the bottom. This technique provides continuous seismic reflection profiles in real time by sending acoustic waves to the bottoms and receiving the reflected energy by transducer, typically, it is used in marine geophysical and geological exploration surveys. The SBP basically works in a similar way to radar and sonar. Where a source of acoustic energy is used, to trigger a pressure wave that travels through the water column to the bottom, and by capturing the reflected sound waves, it is possible to build a picture of the geological and sedimentary structures of the bottoms (Stoker, et al., 1997).

There are many SBP systems available, some of these systems use high frequencies to identify small geological features in the shallow bottom, the other systems lower frequencies identify deeper geology and features. In the present study, Pinger systems have been used to identify small geological features in the shallow bottom with a high frequency system of 10 kHz using high resolution Strata Box equipment. Due to the shallow water depth, working in very shallow water is complicated, which is why SBP is operated mounted on the boat. The SBP section with a drill hole spacing of 6.5 km has been completed. The purpose of this section is to get the reflectors under the bottom.

5. Results

5.1. Grain Size Distribution

Grain size analysis of sediments is very important to distinguish between sedimentary processes and sediment flow conditions in sedimentary environments (Tucker, 1985). The grain size distribution gives information about the source of sediments, the mechanism and intensity of transport, and it is mainly related to sedimentary processes in addition to its relationship to the nature of the origin rocks, transport processes, weathering, erosion and friction (Boggs, 1995).

The current study focused on analyzing some characteristics, such as grain size distribution of sediments, colors and the texture variations of facies that were determined by Folk triangle as shown in Fig. 5. The calculated results averages were as follows: Sand 45.18%, silt 44.98% and clay 9.68% in core 4 and; Sand 36.42 % silt 49.42 % and clay15.95% for core 8. Fig. (6) explains the variations of percent the TOC, sand, silt and clay with depths. From a depth of 18m, the sand begins to increase to a depth of 32 m in Core 4, while in Core 8 the sand starts to increase at a depth of 29 m and decreases at a depth of 38 m.

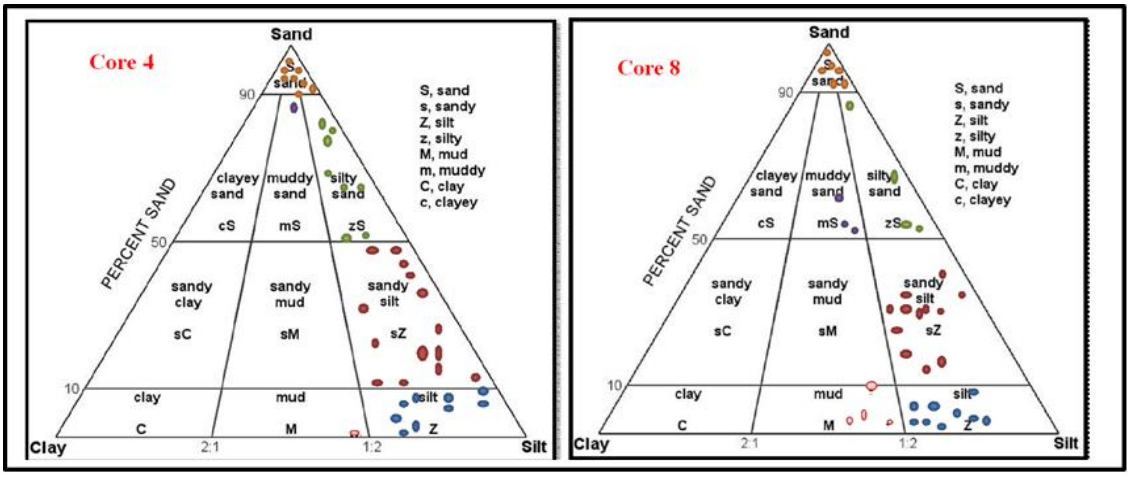

Fig. 5. Texture were was determined by Folk triangle 1974.

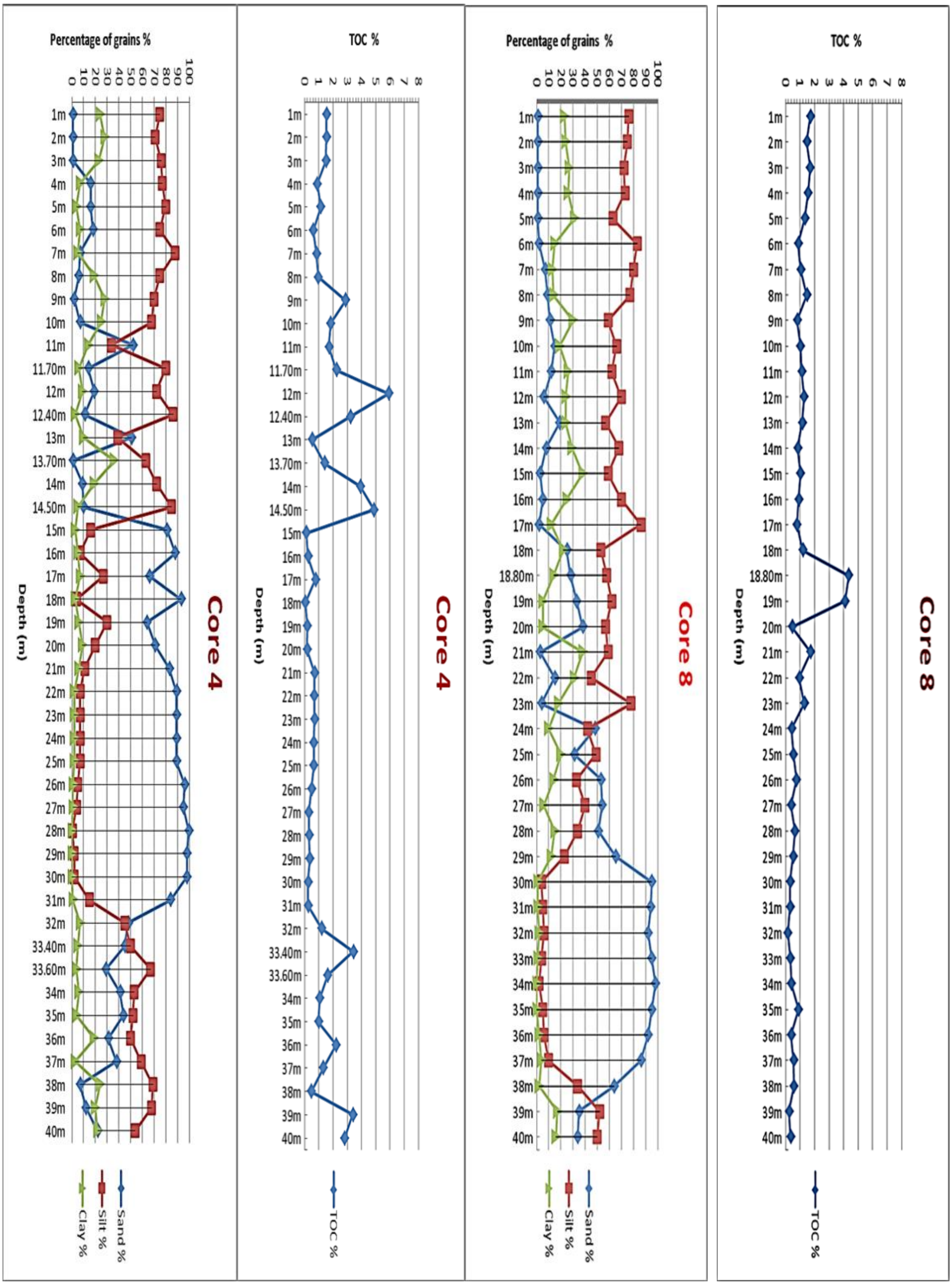

Fig. 6. The percentages of the sand, silt, clay and TOC with depths in core 4 and 8.

5.2. Total Organic Carbon (TOC %)

Organic matter is a good index of the environment in which the sediments have been deposited. The most important components of soils and sediments are total nitrogen (TN) and total organic carbon (TOC), they can be used to distinguish terrestrial and marine sources of environmental depositional conditions, organic matter, soil quality, productivity indexes, pollution indices and soil quality

(Avramidis et al., 2015). Furthermore, TOC and nitrogen content percentages have been utilized vastly as indicators for the reconstruction of depositional paleoenvironments and environmental conditions fluctuations (Dean, 1974, and 1999; Avramidis et al., 2013, and 2014). In the study area, the calculated average results for TOC% are 1.40% and 1.02% in core 4 and 8, respectively, as shown in Fig. 6.

5.3. Sedimentary structures

In the study area, many sedimentary structures were found in sediments at the sub- bottom in the cores, and this is an indication of the different environments in which they were formed, as well as the structures in the bottom Figs. (7 and 8). Sedimentary structures are described and classified based on their forms and formation times according to Selley (1976).

Fig. 7. Sedimentary structures in deposits of core 4;(1) splotchy (mottle) 3m, (2) Sand pockets (Wavy bedding) 10m (3) Load structures 35m (4) Iron oxides 38m (5) Dish, Load structures 33m(6) Spherical Concretions 36m (7) Salts 35m (8) Peat and lignite 14m (9) Interfingered layers 10m(10) uncosolidatede sand with large fauna 29m (11) splotchy and traces of roots 5m.

As a result of erosion, sedimentation, or post-depositional deformation of sediments, sedimentary structures commonly form in sediment layers and beds. Some of these structures are very useful in the interpretation of the paleocurrent, paleoenvironment reconstructions and depositional environment (Alderton and Elias, 2021). Eriksson et al., (2004) confirmed that there is invaluable evidence provided by sedimentary structures related to transport and sedimentation processes in rocks and ancient strata, as well as the physicochemical conditions after and during deposition.

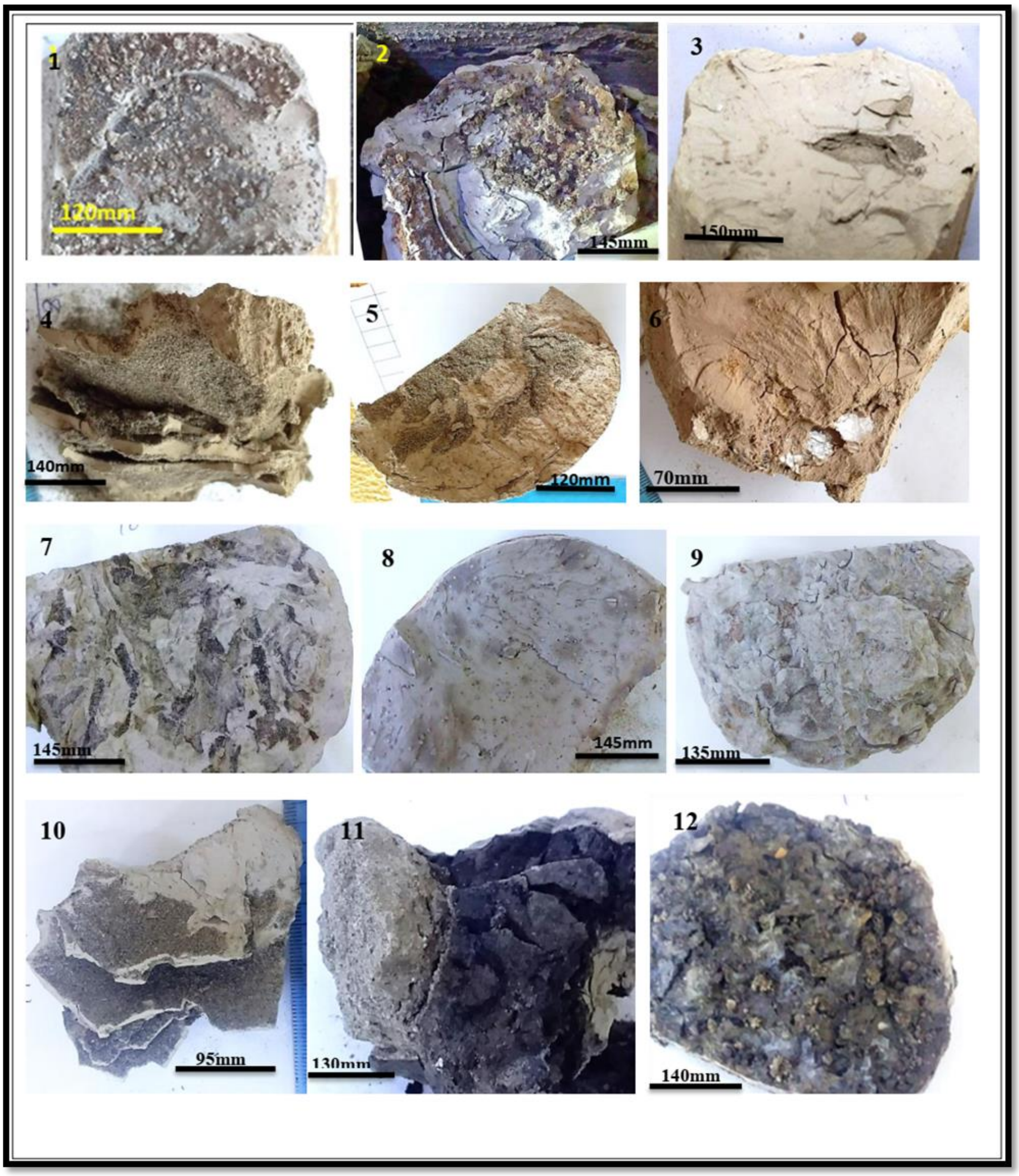

Fig. 8. Sedimentary structures in deposits of core 8. (1) Spherical Concretions 18m, (2) Concretions 19m, (3) Sand pockets (Wavy bedding) 16m, (4) Interfingered layers 18m, (5) Sand pockets 6m, (6) Gypsum crystals 39m, (7) Bioturbation (Sole marks)Wavy bedding 17m, (8) splotchy 5m, (9) Iron oxides 11m, (10) Interfingered layers 13m, (11)) Peat and lignite 19m, (12) Spherical Concretions 18m.

The main control over the difference in these structures are oceanographic processes, which include all of the dense bottom currents, tides, eddies, deep-sea storms, and fluvial processes, in addition to the factors of sediment supply and changes in sea level (Rebesco et al., 2014). Depending on the sedimentary structures, sediment texture, colors, fauna and TOC%. The depositional of paleoenvironment in which they formed was diagnosed with depths as illustrated in Tables (2 and 3).

Table 2. Sedimentary structures and their depositional environments with depths in core 4.

Depth (m)	Texture	Sedimentary Structures	Depositional environment
0- 3	Silt	Splotchy, mottle and Wavy bedding, Load structures	Marine - lagoon/ supratidal zone
4-7	Sandy Silt	Sand pockets, lenticular and Wavy bedding, Load structures	Marine – brackish- lower estuarine/intertidal zone
8 -9	Silt	Sand pockets, lenticular and Wavy bedding, Concretions	Shallow estuarine - brackish/sub-intertidal- Turbidities
10	Sandy Silt	ripple marks, Interfingered layers, Sand pockets, lenticular, sole marks	Shallow estuarine – brackish, inter-sub tidal sabkha, Turbidities
11	Silty sand	Small pockets of fine sand lenticular and Wavy bedding	Shallow estuarine – brackish, inter-sub tidal, Turbidities
11.7	Silt	Small pockets of fine sand lenticular and Wavy bedding	Fresh - brackish marsh/ Lagoon
12	Sandy Silt peat	Peaty or lignite bed	Fresh - brackish marsh/ Lagoon
12.4	Silt, Peat	Peaty or lignite bed	Fresh - brackish marsh/ Lagoon
13	Silty sand	Peaty or lignite bed-	Fresh - brackish marsh/ Lagoon
13.7	Mud	Peaty or lignite bed	Fresh - brackish marsh/ Lagoon
14	Silt Peat	Peaty or lignite bed, Interfingered layers	Fresh - brackish marsh/ Lagoon
14.50	Silt	Peaty or lignite bed,	Fresh - brackish marsh/ Lagoon
15	Silty sand	Peaty or lignite bed, unconsolidated fine interfingered sand	Fresh - brackish marsh/ Lagoon
16	Muddy sand	Unconsolidated fine interfingered sand	Lagoon, intertidal, subtidal Alluvial plain
17	Silty sand	Bioturbation and (Sole marks)	Lagoon, intertidal, subtidal Alluvial plain
18-21	Silty sand	Unconsolidated interfingered fine sand	Lagoon, intertidal, subtidal Alluvial plain
22 –27	Fine Sand	Unconsolidated interfingered fine sand	Lagoon, intertidal, subtidal Alluvial plain
28-30	Coarse sand	Unconsolidated coarse sand	Marine/ water high energy- coastal
31	Silty sand	Unconsolidated fine sand	Marine - brackish marsh
32 - 33.40	Sandy Silt	Small pockets of fine black sand and dish structure	fresh - brackish marsh fresh - brackish marsh
33.60	Silty sand	Ripple marks, Interfingered layers, Sand pockets, lenticular, sole marks	Alluvial plain with coastal and delta
34-37	Sandy Silt	Small pockets of fine sand and some calcite crystal in 35m and dish structure	Fluvial /Alluvial plain with coastal and delta
38	Silt	Iron oxides and interfingered layers	Coastal and Lagoon, intertidal
39 –40	Sandy Silt	Crystals of Gypsum & Halite	Supratidal / dry climate/evaporation/ Sabkha

Table 3. Sedimentary structures and their depositional environments with depths in core 8.

Depth (m)	Texture	Sedimentary Structures	Depositional environment
0-4	Silt	Splotchy, mottle and Wavy bedding	Marine - lagoon/ supratidal zone
5	Mud	Splotchy, mottle and Wavy bedding	Marine - lagoon/ supratidal zone
6	Silt	Interfingered layers, Sand pockets, lenticular, flaser structure	Lagoon/ supratidal, intertidal zone, Turbidities
7 -8	Silt	Splotchy, mottle beds	Lagoon/ supratidal, intertidal zone, Turbidities
9	Mud	Splotchy, mottle bed, fine sand pockets and Load structures	Lagoon/ supratidal, intertidal zone, Turbidities
10 - 11	Sandy silt	Fine sand pockets, Interfingered layers and Load structures	Lagoon intertidal and supratidal
12-15	Silt	some of flaser structure	Lagoon intertidal and supratidal, Turbidities
16-17	Silt	Bioturbation (Sole marks) ,Wavy bedding, sand pockets	Intertidal and supratidal subtidal, Turbidities
18	Sandy silt	Flaser and interlayers of fine sand pockets, Concretions	Fresh - brackish marsh/ Lagoon
18.8 -19	Sandy silt Peat	Peaty, fine sand pockets, Interfingered layers	Fresh - brackish marsh/ Lagoon
20	Sandy silt	Peaty, fine sand pockets, Interfingered layers sand	Fresh - brackish marsh/ Lagoon
21-23	Sandy mud	Fine sand pockets, Interfingered layers sand	Fluvial /Alluvial plain with coastal and delta
24	Silty sand	Fine sand pockets, Interfingered layers sand	Fluvial /Alluvial plain with coastal and delta
25-29	Muddy sand	Unconsolidated bed	Fluvial /Alluvial plain with coastal and delta
30 --32	Sand	Fine sand bed with few purple gravel	Marine / high energy water-coastal
33 --36	Sand	Fine sand bed	Fluvial /Alluvial plain coastal and delta
37 – 38	Silty sand	Unconsolidated bed	Fluvial /Alluvial plain coastal and delta
39-40	Sandy silt	Firm to stiff bed with gypsum crystals	Supratidal / dry climate/evaporation/ Sabkha

5.4. SBP Results

The SBP section revealed the presence of four acoustic reflection configurations (SB1, SB2, SB3, and SB4) which can refer to four sedimentary facies, each of which represents certain sedimentary conditions. The SBP section revealed that there is a pattern of reflection discontinuity below a depth of 10 m and the existence of many acoustic reflection configurations, so, the reflection discontinuity is a characteristic of sedimentary environments in which lateral facies change rapidly, such as delta and river environments. One of the acoustic reflection configurations observed at these depths is the lateral and gradual withdrawal of sedimentation processes such as the Hummocky reflection configuration that is observed at SB3, these configurations consist of segments of semi-parallel, discrete and irregularly shaped reflections forming a model of reflections of random plateau shape, these shapes indicate the forming of their lithological units in shallow water environments before and within delta sites.

The section showed the presence of an oblique reflection configuration at SB4, this pattern represents fairly high energy regression systems. At depths between 0.5 m to 10 m at SB2, the section showed wavy reflection configuration and parallel reflection configuration at SB1 at a depth of less than 1 m, which indicate similar sedimentation conditions for sedimentation materials or sequences located on descending layers in shallow water as shown in Fig. 9. In SBP section, any reflectors or features are not revealed under the bottom and the reason will be clear later. These reflection configurations can represent a variety of sedimentary environments, the assessment of the sedimentary situation and its evolution during the time in the region can be obtained in detail by comparing the results of the SBP section with the results of the cores as shown in Fig. 9.

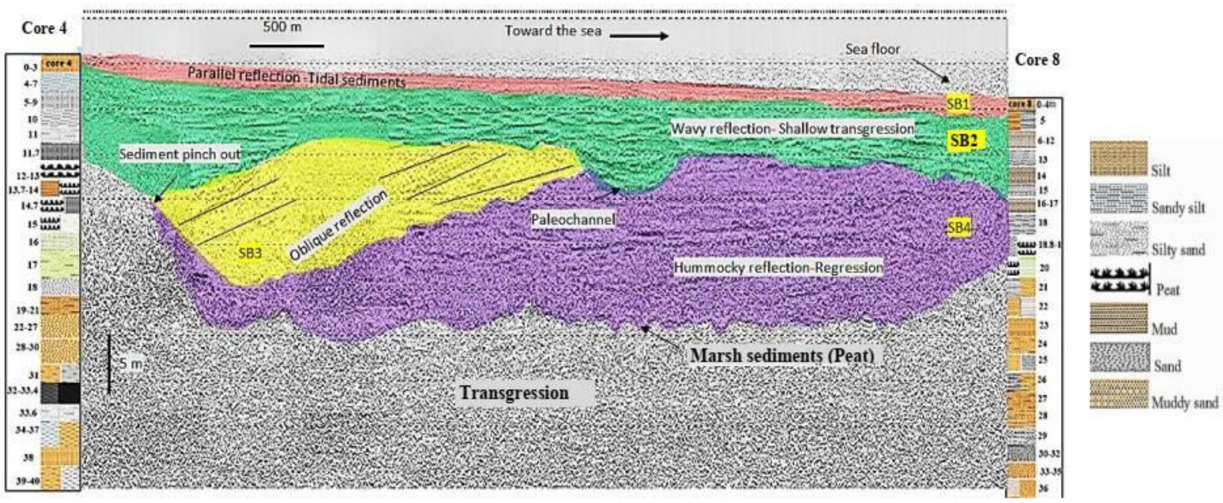

Fig. 9. Comparing the results of SBP section (that mentioned in Fig. 2)and sedimentary analysis, many sedimentary situations and reflection configurations have been identified, SB1: Parallel Hummocky reflection regression) as well as a buried channel had been detected under the bottom. SB2: Wavy reflection- Shallow transgression; SB3 and SB4: Oblique Hummocky reflection regression) as well as a buried channel had been detected under the bottom.

5. Discussion

The study area represents part of the Iraqi marine waters adjacent to the Iraqi coast; the area is characterized by shallow waters, which in turn represent the transitional zone between land and sea. In this zone, human activities are dominant, such as building infrastructure (Al-Fao Grand Port) and digging oil pipelines; therefore, there is a high interest in the sub-bottom layering in shallow waters. The integration of the SBP and sedimentary analysis results revealed the presence of many sedimentary facies (Silt, sandy silt, silty sand, sand, muddy sand and mud), which indicate the different depositional environments as a result of changes in environmental factors, climatic conditions and the sedimentation energy.

Depths of 39 and 40 m in both cores 4 and 8 represent exposed surfaces, these depths are distinguished in firm light brown to gray to light brown bed with the crystals of gypsum because of excessive evaporation and dry climate and absent fauna as shown in Figs. 7 and 8. Depth 38m in core 4 was distinguished with iron oxides and interfingered layers in the end of the core from the terrigeneous material. This period referred to the supratidal – Sabkha environment. The deposits at these depths are due to the Al-Baten alluvial fan which belongs to the Pleistocene epoch and which formed most of the southwestern part of Iraq and most parts of Kuwait (Sissakian et al., 2014). This stage represents the period of the end of the receding sea that occurred during the period of the last Wurm glaciation in which the head of the Gulf reached the Strait of Hormuz (Kassler, 1973). During the Quaternary period, especially the Holocene, large fluctuations occurred in climates, and this led to a shift in deposition environments, and the differences in mineralogy and texture gave an indication of this change. (Geisler, 1982).

The depths of 31–38 m in Core 4 are characterized as stiff beds of light brown color with little fine sand from light brown to a gray color with the absence of fauna and small pockets of fine sand and some calcite crystal in 35m with load structure, the load structures may represent the deformation structures that created as a result of the weight of the sediments coming from the Shatt Al-Arab during the time when the river was in its young stage and was able to carry a lot of sediment. As per Owen (2003), these structures form due to partial deformation of soft, liquefied sediments that occur after deposition. These structures are commonly observed in fine sands and muddy sands, and most of them result from unstable density differences, such as density loading, or lateral changes in load, such as unequal loading.

This period referred to fluvial /alluvial plain with coastal and delta belongs to Pleistocene. In same depths in core 8 are characterized as light brown to gray fine sand beds. These depths are interpreted as a period of Pre- marine transgression. On the other hand, core 4 at the depths of 28-30 m were characterized by unconsolidated, coarse sandy sediments containing large fauna in dark colors. This fauna was diagnosed as marine species in Fig. 10A, these species represented in Molluscas such as *Crassostrea iridescens, Cardilia* sp. and *Carditella pallid*. Conversely, the depths of 30-32 m in core 8 were characterized by medium to fine sand beds, with existence of gravel in a dark pink to purple and white color, with a size of 2-6 mm Fig. 10B, these gravels describe with high - medium angle refers to limited strong currents or waves that were capable to move gravel and dunes in water. This has been confirmed by Martins and Barboza (2005) that the sand and gravel deposits are the result of a reworking of the terrigenous components due to the occurrence of marine transgression due to the rise in sea level to 110-120m and 20-30 m resulting from strong storms after the glacial period.

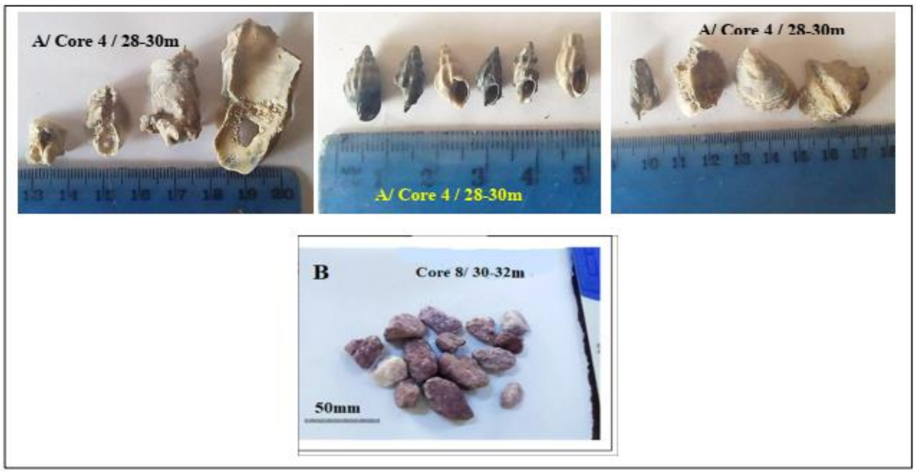

Fig. 10. A-Large fauna in core 4 and B-colorful gravel in core 8.

The presence of large fauna and pebbles in these depths indicates that the environment is shallow marine with high waves and represents beaches, spits or sand bars. This period is interpreted as the peak of the marine transgression, where the high energy of the waves. The sedimentary situation at these depths indicates the beginning of the transgression stage that occurred due to the melting of the ice after the end of the glacier Worn period before 18,000 years ago (Aksu, et al., 1987; Fairbanks, 1989; Flemming et al., 1998; Petit-Maire, 2004).

After this period, the sea begins to regression in depths 16-27 m in Core 4, and the environment changes, and the sediments shift into unconsolidated fine sand containing structures such as: fine sand pockets, interfingered layers sand, bioturbation and sole marks especially at depths 16-21 m. As well as in core 8 at depths of 21-29 m, the same situation of sedimentary structures as showed in Figs. 5 and 6, Tables 2 and 3. The origin of these deposits may be in one of the channels of the ancient Tigris River, where there are interfingered layers of fine sand and mud representing the deposits of the flooding alluvial plain. This conclusion can be confirmed by the study of Muturi (2021), which indicated that there are many parallel ancient river streams to the current course of the Shatt Al-Arab River, including the course of the ancient Tigris River and the ancient Euphrates River, which were run separately before they were connected and formed the current Shatt Al-Arab (Fig. 11).

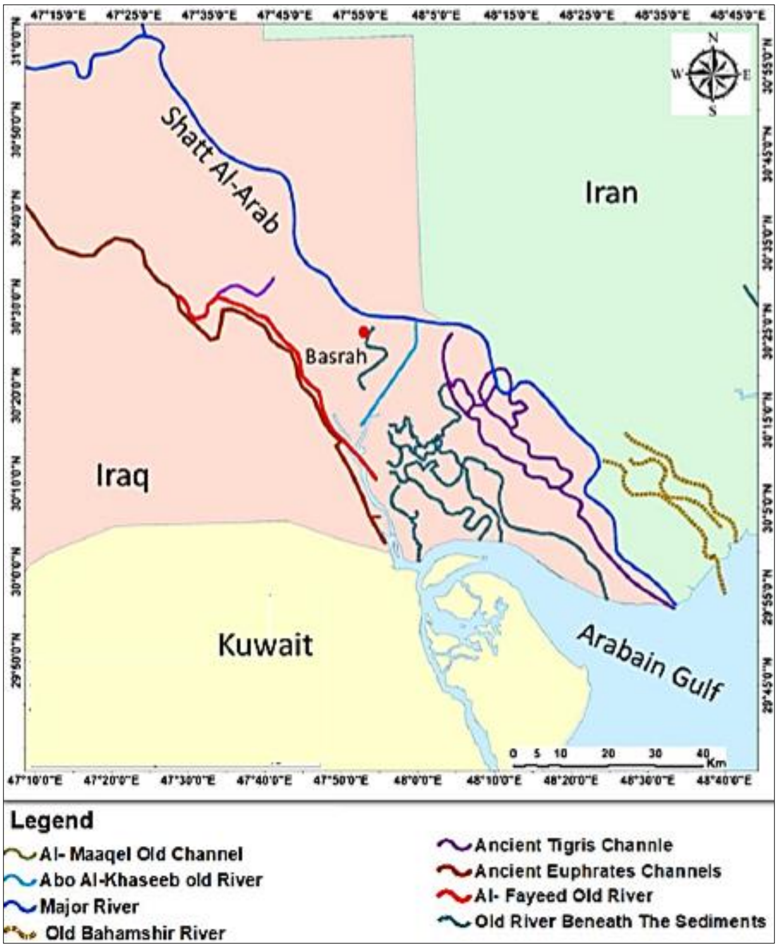

Fig. 11. The paleochannle in N and NW of the Arabian Gulf were extracted by satellite images integration with geophysical investigation (Al-Muturi et al., 2021).

The existence of ancient river courses is also clearly identified in the SBP section (Fig. 11), it was observed there was a paleochannel buried under the bottom at a depth of 12 m, most of these river courses were a source of fresh water transported to the sea, especially when it had a high discharge, and on the other hand the sea level did not reach its current state. The study area and surrounding area, including the Shatt Al-Arab Delta, were receiving large quantities of river sediments, and these sediments worked to maintain the equilibrium through the continuous subsidence in the bottom (Less and Falcon, 1952), this case led to the stability of the northern coast of the Gulf for thousands of years during the Holocene age, and this explains the presence of channels buried under the bottom.

In core 4 at a depth of 11m, the TOC% begins to increase until it reaches 5.9% at 12 m and continues to 14.5 m, while core 8 reaches 4.3% at 18.8 m. These beds represent peat or lignite, the beds rich in TOC are interpreted as being deposited in the lagoon, brackish- freshwater marsh environments. These have been confirmed by Aqrawi and Evans (1994) that the beds rich in organic matter are controlled by salinity, whereby the (TOC%) increases with the decrease in salinity and may reach up to 22%, even in the dried or reclaimed parts of the marshes, but it reaches to -1% in saline parts of the marshes. Suleiman et al. (2020) confirmed that peat deposits can be used as an indicator of sea level and the reconstruction of the ancient sea. The presence of peat or lignite beds indicates fresh or brackish/ lagoon water environments and often indicates marshes. The presence of peat deposits was also determined from the SBP section at depths 12 and 20 for core 4 and core 8 respectively, after this layer it was not possible to distinguish any features or reflectors in the SBP section because the peat deposits act as a filter for acoustic waves and absorb the signal and do not allow it to penetrate to deeper depths. The peat deposits represented the intervals between sea transgression and regression and they were usually represented by vegetation somewhat similar to swampy areas. According to Larsen and Evans (1978) and Yacoub et al. (1981), the marsh regions of the Mesopotamia Plain has been primarily affected by eustatic sea level changes and deltaic progradation, rather than tectonic events. These studies have also revealed that the region exhibits unique geomorphic features and significant sedimentary environments, particularly in the southeast of the Mesopotamia Plain.

Current evidence is useful for identifying static-environmental cycles during the last glacial phase, and may combine existing knowledge to establish a relationship between cycles recorded in continental sediments and marine successions sediments. From the SBP section, the presence of coarse sediments with increasing depth (which had previously been deposited in shallow waters) resulted in no further penetration of the acoustic signal. So, McGee (1995) revealed that the coarse sediments exhibit strong dispersion and reduce the penetration of the acoustic signal to the seafloor. Besides, the penetration was affected by the presence of peat deposits. Moreover, these results were confirmed by the study of Kouznetsov and Chun (1999) that sound waves are absorbed when they reach peat deposits because of the high attenuation coefficient of peat, which makes the signal not reach greater depths and the difficulty of detecting reflections at these depths.

The depths of 6-12 m were characterized by the existence of different structures, such as: Interfingered layer structures that include (Sand pockets, lenticular, sole marks, flaser, laminated sand and wavy bedding) also some of load structures, these sedimentary structures indicate several environments like shallow estuarine- brackish/ sub-intertidal, alluvial plain and turbidity. The sedimentation energy was low at depths of 0-13m, with very low sand ratios, and this indicates that these sediments were deposited in tidal environments (Supratidal and intertidal). This is indicated by Robert et al. (2003) that the supratidal environment is the area in which sediment was deposited above the natural high tide by tidal and spring: these environments reflect the characteristics of tidal flats that were deposited under arid or wet conditions. The presence of stiff beds of clay and silt in dark and light brown oxidation spots or mottled, especially at depths 0-5m as explained in Figs. (7 and 8), indicates that the sedimentation was above the groundwater level. These areas may be mainly low and characterized as wetlands due to the proximity of groundwater to the surface or exposure to inundation by river mouths and little evaporation (Heyvaert and Baeteman, 2007).

7. Conclusions

In the present study, integration of SBP survey and sedimentary coring analysis have been used in Khor Abdullah, NW the Arabian Gulf. New information for the evaluation sedimentary situation of this area was obtained, different phases of the last relative sea-level variations were recorded, as well as highlighting origin and fluvial drainage variations.

The marine transgression, which was at a depth of 28-30 m below the bottom; It results from the melting of ice in the early Holocene. The sea began to regression above the depth 28m that is dominated the lagoon or alluvial environment. The represent beds of peat or lignite, a reference to lagoon or marsh environments where fresh and brackish water and high TOC%, the source of peat deposits belongs to one or many of ancient river courses on the coast and parts of which are buried under the bottom. The depths above the peat strata were characterized by Interfingered and sole marks structures, which interpret the turbulent environment from the tides. At depths 5-0 m, the sub bottom is interpreted as layers that were deposited with low energy and sedimentation below the groundwater level. It is assumed that this environment is marine tidal, indicating the shallow marine transgression, and these conditions are still continuing until now.

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