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Origin and Forming of Hacham Island in Khor Al-Zubair Channel, Southern Iraq

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Abstract

The marine geophysical survey was conducted using Sub Bottom Profiler and Side Scan Sonar techniques, integrated by petrographic analyses including grain size distribution, mineralogical and fauna analyses of the Hacham island and surrounding area. The island is located in the south part of the Khor Al Zubair channel southwest of the Basrah, Southern Iraq. The study aims to determine the origin and stages of the island formation. This study concluded that there is more than one factor that contributes forming this island represented by tectonic, morphological and sedimentological factors. The results of marine geophysical surveys revealed that the island and its surroundings were affected by the neotectonic activity that exposed the lower part of the Mesopotamian Basin, which in turn caused the lower part of the Khor Al-Zubair channel to meander eastward because of its impact by the fault that separated Warbah island from the Iraqi coast, forming Khor Shaitanah. The meandering of the Khor Al-Zubair course was accompanied by a decrease in flow velocity and thus a decrease in the channel’s ability to carry more sediments, therefore the Khor has to take another course, this waterway separated the island from the main east Iraqi coast. The results of the grain size distribution, mineral identification and fauna analyses indicated a variety of sediment supplying sources of the island, represented by the floods deposits of rivers and side drifts of the surrounding area, in addition to the aeolian deposits transported from the west and northwest Dibdibba Formation. The present study also concluded that the central East shore part of the island is exposed to erosion as a result of a submerged wreck in the waterway that separates the island from the coast.

Keywords: Hacham Island; Khor Al-Zubair; Marine geophysics; Grain size; Mineral and fauna analysis

1. Introduction

Iraq has many and wide water systems distributed in its mainland, consisting of small and large rivers, lakes, marshes, Khors (lagoons), or marine tongues. The streams of rivers in southern Iraqi plain areas were subjected to change from one place to another in the deltaic plains, due to river courses flow in a flat land with a slight slope and low river banks. Then the large quantities of transported sediments carried by the flooded water and left in their bottoms obstruct the water flow, then the flooded water spreads on low lands where it runs and break new streams or drift towards one side of the stream itself at the expense of the other side. On the other hand, the low current velocity, river width increasing and

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the low gradient will change the shape of the river course into many stages which appears straight on one site and meandering on another.

Therefore, the river energy has no sufficient capacity to transport large quantities of sediments away towards the Arabian Gulf (AG), so they are deposited on the sides of rivers or on the bottom of their courses as natural dams that are not visible (underwater submerged) or as extended islands, as spreading of many islands in the course of Shatt Al-Arab River (east of the Basrah). Al-Mahdi and Al-Saadi (2006) showed that the most of Shatt Al-Arab islands have a sedimentary origin. In the southwest of Basrah, specifically at the course of Khor Al-Zubair (KZ) (lagoon) channel, there are some small rocky islands in the northern part of the Khor, which its origin has been interpreted as a rocky beach formed as a result of complex hydrodynamic conditions in the area, furnished with large quantities of sand from the surrounding areas (Wasel and Albadran, 2003). But the largest island in the Khor channel which is called Hacham Island located in the Southern part of KZ which is the main focus of the present study.

The Hacham Island is located in the southern part of KZ, southwest of the Basrah (northwest of the AG), it is bordered easterly by the Iraqi coast which is separated from the island by a narrow stream with 182 m width branching from the Khor. To the west, the island is bordered by the main channel of the Khor with 605-1017 m in width. and from the northwest of the island lies the navigational channel of the Um Qasr, in the south-western part it is bordered by the international border between Iraq and Kuwait (Fig.1). It represents a barren land that almost lack any human, biological, or plant activity due to the high salinity of the water on both sides. The island has a maximum length of 4.3 km with a maximum width at its northern part of 718 m.

Fig.1. The Hacham Island and surrounding area

Geologically, the island is considered as a part of the KZ lagoon. Lagoon can be defined as a marine water body penetrate the land and considered one of the complex hydrological regions. The KZ extends to the flat area with sandy and muddy flat surfaces features, these features are formed due to the marine erosion as a result of the tides impacts (ebb and flood). The study area is located at the southern part of Iraq, which is geologically and tectonically associated with the Arabian Plate and AG, the study area is located within the unstable shelf (Jassim and Goff, 2006).

There are many studies have been conducted for the Shatt Al-Arab islands (Al-Mahdi and Al-Saadi, 2006; Usama, 2014) but there are no detailed geological studies that have been conducted for the Hacham island.The island has a distinctive location that can be suitable as a tourist site in an area (The Southern Region of Iraq) that lacks marine tourist sites, especially the islands sites as well as the location of this island may be suitable as an industrial facility for the port activities as it is close to the ports of Um Qasr and Khor Al-Zubair. So, the present study aims to explain the reason for the forming and development of this island based on marine geophysical surveys (Sub Bottom Profiler (SBP) and Side Scan Sonar(SSS)) with sedimentological, mineralogical and recent fauna analyses.

2. Materials and Methods

The present study is used more than one technique in order to integrate the information that has been collected from fieldwork, these methods include; Sub Bottom Profiler (SBP); the SBP is an acoustic survey to map the bottom beds (river and sea) with a single beam by ascribing the transducer or source to the water by a boat. The acoustic signal is sent to the water and then penetrates the bottom. The SBP section is produced by the reflection of the acoustic signal from seabed or river bottom. The reflection of acoustic energy takes place at beds which have different acoustic impedance, the Strata Box™ device with 3.5 kHz is used in the SBP survey. Six SBP profilers have been performed with lengths 182m, 232m, 226m, 2km, 695m, and 870m for 1,2,3,4,5 and 6 SBP lines respectability (Fig. 2). The lesser distances of these profilers were completed in the waterway that separates the island from the coast, but the large profilers were completed in the khor stream north and south of the island in addition to longitudinal profilers of the mentioned waterway. Side Scan Sonar (SSS); is an active technique involving a long acoustic array provided that a beam by a wide vertical to the array and narrow parallel for the array long axis, the technique is professionally used to make a view and visual information of broad areas to understand the bottoms for seafloor and river then understanding of the changes in materials types of these bottoms. The SSS creates acoustic images or sonar sections called" sonograph" which delineate the seafloor or river-sub bottom morphology and texture, the sonograph interpretation depend on the acoustic reflectivity and detailed acoustic criteria, (Blondel, 1999). The SSS interpretation allows for the identification of obstacles, sonar targets, and the main lithological features of the KZ bed in the area, SSS survey is performed by the Imagenex Model 872. One SSS profiler is performed with about 4 km length from North to South of the study area, (Fig. 2). In addition to SBP and SSS, Grain size analysis of sediments, mineral, and fauna identification has been carried out in this study on three sites. For the island, the bottom of the waterway separat the island from the coast and in the coast (Fig. 2), in order to describe and compare the sedimentary and conditions processes as well as sediment supply sources.

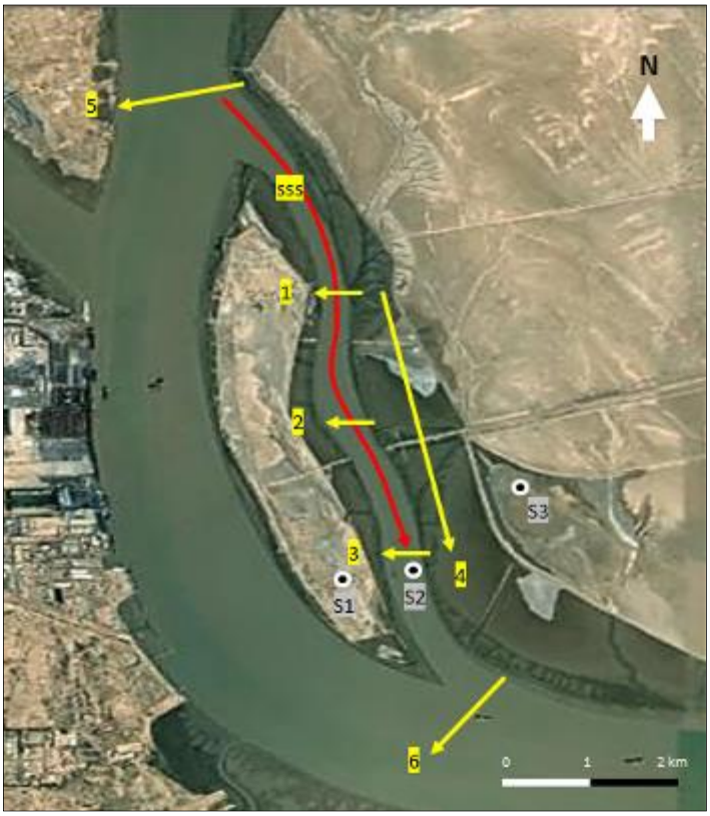

Fig. 2. The SBP (yellow) and SSS (red) track lines as well as the sampler sites

3. Results

3.1. The SBP

The SBP results revealed that there is a variation and irregularity in the bottom depths, both in KZ main channel and the branch that separates the island from the east Iraqi coast. The highest depths (16.4 m) were recorded in section 5 (Fig. 3), which represents the navigational channel of KZ, this depth is influenced by the human activity due to continuous dredging of the navigational channel, in addition to erosion processes that are still active on the right side of the channel adjacent to the port of Um Qasr. The lowest depth was recorded in a section1 in the north of the island separated branch. Also, the results revealed that the island submerged bar at the northern part (section 5) has a large area and size that occupied almost half of the width of the KZ channel. There are sedimentary processes and complex hydrodynamic conditions that left their impact on this site, this was inferred by the layers under the bottom are irregular and non-horizontal, and part of the bottom is rocky and irregular, also there is high deposition that occurred in the bar of the north island that is distinguished by the identification of the ancient bottom of the KZ. From this section, it is possible to distinguish the deposition that occurred in the separated branch, where many stages of stream development can be differentiated by buried ancient channels beneath the sea bottom. The increasing sedimentation rates in the northern part of the island, as well as the accumulation of sediments at the entrance of the branch that separats the island from the coast is due to the hydrodynamic conditions in the region and the erosion of the islands shore, beside the sediments resulting from the continuous dredging of the navigation channel. The decreasing of the branch depth has a significant role in increasing sedimentation rate as a result of the impact on flow velocity and consequently decreasing water-sediment mixture friction leading to activate filling processes.

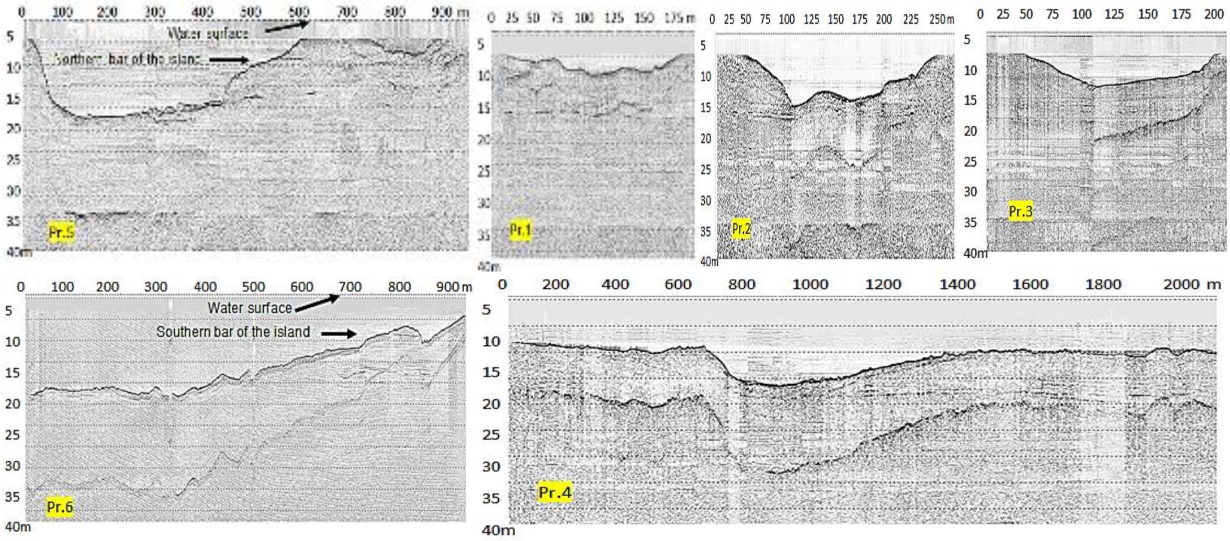

Fig.3. The SBP section results show that there is a variation in the depths of the bottom, with a rocky and irregular part of it (pr.5), the deposition occurred in the branch that separates the island from the land and buried ancient channels under the bottom (pr.1), south and north bars of the island (pr.5 and pr.6), the scouring in the bottom of the waterway that separates the island from the coast (pr.4)

Regarding the nature of the sea bottom and the layers below, the results were aligned with that reported by Toa Harbour Works (1975) and NCCL (2000), which used their borehole data to infer the type of the layers under the bottom. The SBP sections showed that the surface layer of bed sediments is generally soft clay which is a prominent feature of the KZ bottom sediments, due to their multi-source supply from bottom dredging, upstream KZ banks erosion, and dust storms. Section 5 (Fig. 4), shows that after the bed surface layer appears a clay layer with medium-hard sandy silt not exceeding 5 m depth with the presence of rocky bottom that is produced by the tidal processes and marine deposits coming from Khor Abdullah. After this layer, there is a soft silty clay layer deduced by the absence of any reflection or distinctive features in the SBP sections, which is extending to 20m depth below the bottom surface, most of these deposits are belong to Al-Hammar Formation followed by a layer of hard sand sediments represents a beginning of the sandy Dibdibba Formation.

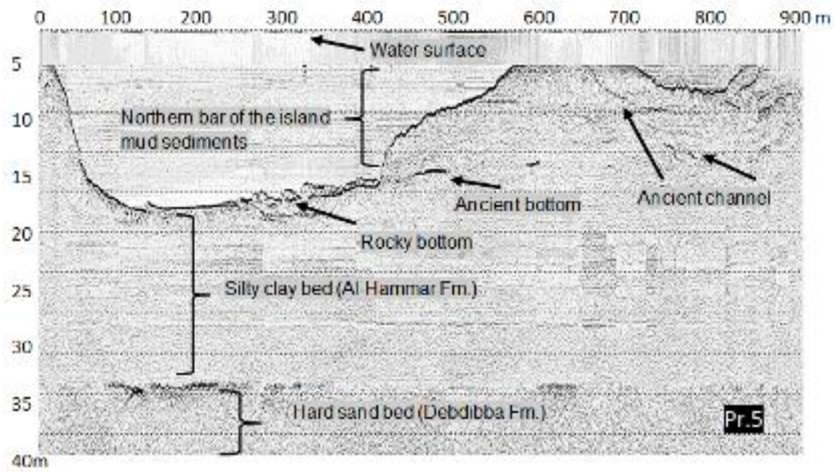

Fig.4. The SBP section of pr.5 shows the nature of the bottom and the layers below it

The section 6 revealed that the southern island bar has a much smaller size than the northern one, due to a filling activity at the north of the island, as divergent to the south, which shows an erosional characteristic due to the activity of ebb and flood currents with a prevailing of high-velocity flow during the ebb phase (low time period comparing with flood phase). Also this site is closer to the meander of KZ course adjacent to the island. The previous conclusions were indicated by the sounding depth recorded at the northern side of the separated branch at 6 m, while it is 9.8 m at the southern site (Fig. 3).

3.2. The SSS

The SBP cross-sections were performed on the branch waterway that separates the island shore from the mainland coast. This profiler has been completed to find out the morphology of the bottom of branch waterway and the extent to which this affects the morphology of the island itself and the erosion in its center. It showed that the branch bottom subjected to a morphological change due to scoring activity which in turn affected the center of the island's east shore, while a filling activity was observed on the opposite facing side on the main land. The results show (cross-section 2) that the branch water depth increased to 12 m which is clearly appeared in the longitudinal section (section-4). This phenomenon occurs when there is an obstacle plugging the flow direction triggering a hydraulic jump causing differentiation of current flow velocity and energy, which in turn affects the occurrence of scoring at the bottom in the central part of the separated branch and the island coast. The results of SSS confirmed this conclusion because it revealed that there is a destroyed shipwreck that was completely submerged below the water surface in the middle of the separated branch, which was 45 lengths (Fig. 5). Al-Mosawi (2020) indicated that submerged wrecks cause sufficient changes in the river bed morphology and affect the river flow systems, which in turn affects the conditions of the score and fill as it has appeared in many cases phenomena in the SAR course. The occurrence of submerged and exposed shipwrecks in the course or banks of KZ is a frequently seen due to the region being a stage of the first and second Gulf War events, despite the recent extraction efforts of many of these wrecks. Yet the complete extraction submerged wrecks is very difficult because most of wrecks and its fragments are buried in sediment layers or lying for rusting on the shore of the island (Fig. 6). The SSS results also showed compatibility with the SBP results in terms of heterogeneity in the bottom deposits and the direction of the flow prevailing in the region (Fig. 5), SSS section displayed that the direction of the small wavelength dunes (bottom-waveforms) in the bottom towards the north, which confirms the control of tidal currents on the ebb currents.

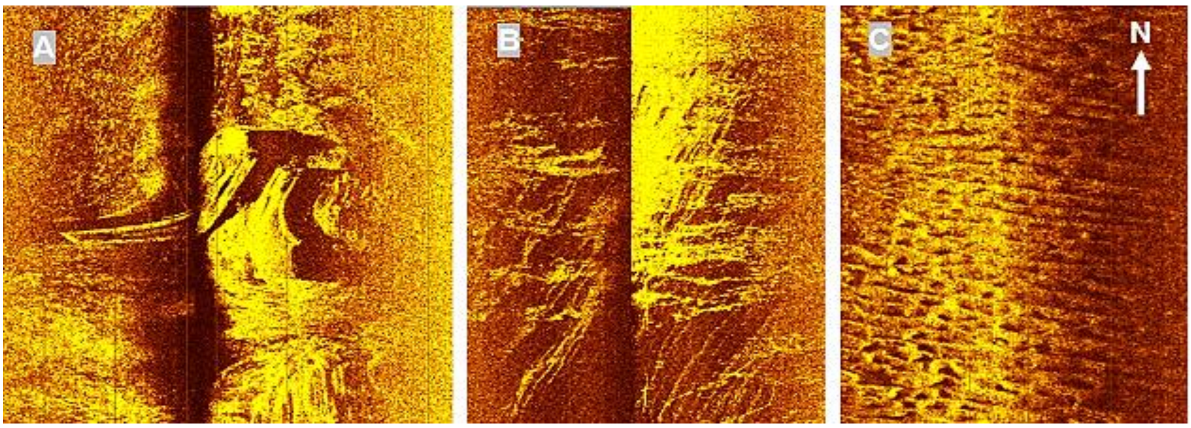

Fig. 5. Sonograph showing changes in Khor Al-Zubair bottom morphology. A) submerged wreck; B) the bottom with coarse sediment; C) small wavelength dunes

Fig.6. The shipwreck debris on the island's shore

3.3. Grain Size Analysis

The grain size analysis is of major importance in identifying ancient and modern sedimentary environments and also gives important information on transport, sedimentation rate, and flow conditions (Tucker, 1985). The results of the grain size distribution (GSD) (Table-1) revealed that the silt and clay are dominant in all the sampling sites, with a portion of sand between (1-13%). The slight increase in sand ratios at the first and second sites indicates that the area is affected by the hydrodynamic conditions that led to washing fine and very fine particles (silt and clay: mud) leaving the coarse particles(sand) to deposit on these sites. Because most of the accomplished studies to determine the quality of KZ deposits indicated that the muddy deposits account for the largest proportion of GSD, the region is subjected to a continuous impact of tidal processes and continuous dredging operations of the navigation channel, in addition to the impact of dust storms (Darmoian, 2000).

Table 1. Grain size analyses for the three sites

Sample	Sand %	Silt %	Clay %
S1(Hacham Island)	10	74	16
S2(Bed of separated branch)	13	56	31
S3(coast of main-land)	1	76	23

Sand deposits are increasing in restricted locations in rocky island sites north of the KZ channel (Abdullah and Omer, 2003). The source of sand deposits in these two sites is due to many reasons that the region is affected by transported sediments from the Debdibba Formation and transported sediments from the Khor Shaitanah south of KZ by the impact of tidal actions. Al-Jabri (2015) indicated that the sand percentage is increasing in the western part of the coast of Khor Shaitan compared with the whole region of the Iraqi coast, due to the impact of windblown sand transport from the Kuwaiti coastland into this site as the Kuwaiti coast strip is made up of a high percentage of sand deposits (Khalaf et al., 1984). In fact, this reason cannot be responsible for the increase in sand deposits on the coast of Khor Shaitanah since these deposits did not exist in the rest of the region (the Iraqi coast and KZ area) and concentrated at this certain site. The increase in sand deposits on the coast of Khor Shaitanah, was aligned with the increase in these deposits on the Kuwaiti coast on Warba Island opposite Khor Shaitanah, emphasizing the evidence and studies that indicated that the region was affected by many faults whose impact reached the surface and accompanied by new-tectonic activity in the region (Al-Mussawy,1993; Al-Mosawi et al., 2015; and Al- Muturi, 2021). One of these faults that separated Warba Island from the Iraqi coast, this was confirmed by the meandering of KZ course in the southern far part of its course with an angle of approximately 90˚ eastward. The convergence of the silt deposit ratios between the first and third sites indicates that they are affected by the same source, these deposits come from the recent flood deposits of rivers, which is the dominant feature of the deposits of the north-eastern part of AG, especially the area extending from KZ to the SAR as well as the Iraqi coast.

3.4. Petrography

From the mineralogical analyses aspect, its results can identify the source of sediments which is one of the most important elements or keys to any sedimentary model in the origin and distribution of sedimentary bodies (Morton and Grand, 1998). The study of minerals especially heavy minerals helps to determine the supply source and the direction of transport and shows the stability of the minerals present in sediments (Fuchtbauer, 1974). At the three selected sites in the current study, light minerals accounted for the largest proportion of deposits and were close at 98%, the largest value recorded in the island's deposits (Table 2).

The results of the light mineral analyses revealed the presence of six minerals shown in Table 3 and were distinguished under the polarized microscope as shown in Fig.7. The quartz mineral recorded the largest percentage in all locations with a range of 35% and its ratio is close to the first and third sites. Quartz is considered as one of the most abundant minerals, and consists of the main component of many rocks, also it is more stable than most other minerals. It is followed by feldspar and calcite minerals with a range of 19% and 21%, respectively which are closed to the first and third sites and the first and second sites, while the other minerals such as gypsum, dolomite, and rock fragments are recorded different ratios for all sites, dolomite recorded the lower ratios about 6% in average.

Table 2. The percentage of light and heavy minerals

No.	Sample	Light minerals	Heavy minerals
St1	S1	98.92	1.08
St2	S2	98.18	1.82
St3	S3	97.33	2.67

Table 3. The percentage of light minerals

Light minerals (%)	St1	St2	St3
Quartz	36	32	37
Feldspar	19	25	19
Calcite	21	21	24
Gypsum	9	7	5
Dolomite	5	6	7
Rock fragments	10	9	8

For the heavy minerals, which recorded low percentages compared with the light minerals ranging from 1.08% at the Hacham Island site to 2.67% at the coast site, five groups were identified in the area under study (Table 4). The results revealed that the minerals groups were different in percentages for the three sites, and it showed no high resemblance except in Muscovite mineral, the percentages of heavy minerals on the island did not resemble significantly the rest of the percentages for other sites. The heavy minerals are classified into opaque, mica, un-stable minerals, meta-stable, and ultra-stable group minerals according to the requirements of the investigation methods planned (by polarized light microscope and scanning electron microscope analysis) (Figs. 7 and 8), it is arranged according to their percentiles.

Table 4. The percentage of heavy minerals for the three sites

Heavy minerals (%)	Groups	St1	St2	St3
Opaque	Iron oxides	18	12	3
Biotite	Mica group	12	18	15
Chlorite		9	17	9
Muscovite		7	7	7
Garnet	Metastable group	5	5	10
Kyanite		8	1	1
Staurolite		1	2	2
Epidote		1	8	9
Zircon	Ultra-stable group	10	2	6
Tourmaline		7	3	3
Rutile		5	7	6
Pyroxene	Un-Stable group	2	5	8
Augite		6	7	7
Hornblende		9	6	4

Chlorite is concentrated in the fine sediments because of the flaky characteristics of this mineral that allowed it to float above the sediments (Aqrawi,1993). The Chlorite and biotite minerals are made from mafic igneous rocks. The origin of unstable and opaque group minerals are produced from mafic and ultramafic igneous rocks, whereas the opaque group minerals are moderately stable minerals (Folk, 1974) which consist mainly of iron oxides. The opaque group minerals, meta-stable group minerals included garnet minerals are mostly metamorphic rocks source. The epidote mineral is angular and sub-angular shapes with igneous rocks. Regarding the ultra-stable minerals, the rutile mineral is the most type of ultra-stable mineral, which occurs in metamorphic and plutonic rocks. The presence of pyroxene and hornblende minerals gives an indication of the participation of a nearby source of supply, and the presence of these two minerals is an evidence of rapid erosion and the dry climate of the region may have helped to occur mechanical weathering and the lack of chemical weathering. On the other hand, the increase in the proportions of Zircon and Tourmaline minerals (produced from the erosion of paleo-rocks (Sadik, 1977).

3.5. Fauna Species Analysis

Regarding the fauna, many species have been identified and included: seven species of Foraminifera, ten of Ostracoda, and eight of Mollusca (Table-5). Most of these species refer to marine and brackish environments, but some species indicated fresh environments as identified by many studies done in southern Iraq, for example, *Condona compressa* indicated fresh environments where this species was identified in Fao city (southern Iraq) by Al- Meshleb (2012), and Al-Jumaily (1994). Loxoconcha certinata lives in marine and freshwater, this species was identified in Um Qaser area by Shareef et al. (2015). Neomonoceratina iniqua indicated marine, brackish, and fresh environments, this species was found in the Um Qaser and Ras Al-Besha areas in southern Iraq by Shareef et al. (2015), and it is found in KZ north of the AG by Shareef and Mahdi (2015). Melanoides tuberculata is a freshwater species, this species was described as abundant in lacustrine environments.

In Hacham island, there are four species of Foraminifera have been identified (Ammonia beccarii, A.tepida, E.sp. Eilohedra rotunda,Globigerinoides trilobus), and four species of Ostracoda(Condona compres, Cyprideis torosa, Loxoconcha certinata, Hemicytheridea sp., and two species of Mollusca (Calyptraea sp., polyline mamilla) (Fig. 9). The species (Condona compressa, Loxoconcha certinata) are indicated fresh environments, while the species (Ammonia beccarii, A.tepida) are indicated marine and brackish environments, and (E.sp.) is indicated marine, brackish, and lagoon environments.

The results of the Fauna analysis revealed that the diversity of sedimentary environments of Hacham Island included marine, fresh, and brackish environments, this indicates that the variety of sources of sediment supply for the island, this situation is realistic and represents the current environment of the island's location, but the species which it was appear on the fresh and brackish water environments (with 30 cm depth from the island seface) indicate the existence of an ancient source of freshwater, this is another evidence of the fact that the ancient Euphrates River was passing through the area and carrying the sediments in addition to the flood deposits of ancient rivers, these results correspond with the results of grain size and mineral analysis.

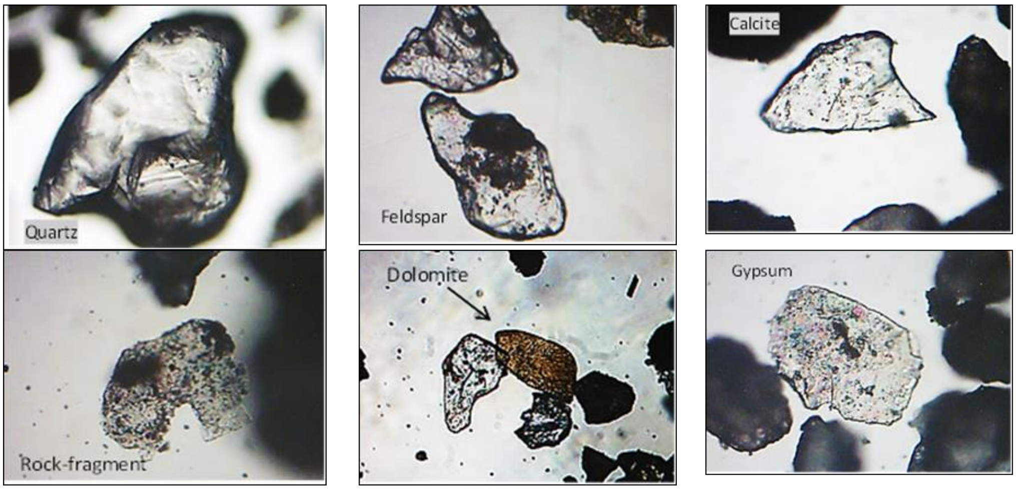

Fig.7.Images of light minerals slides which are identified in the island and its surrounding.

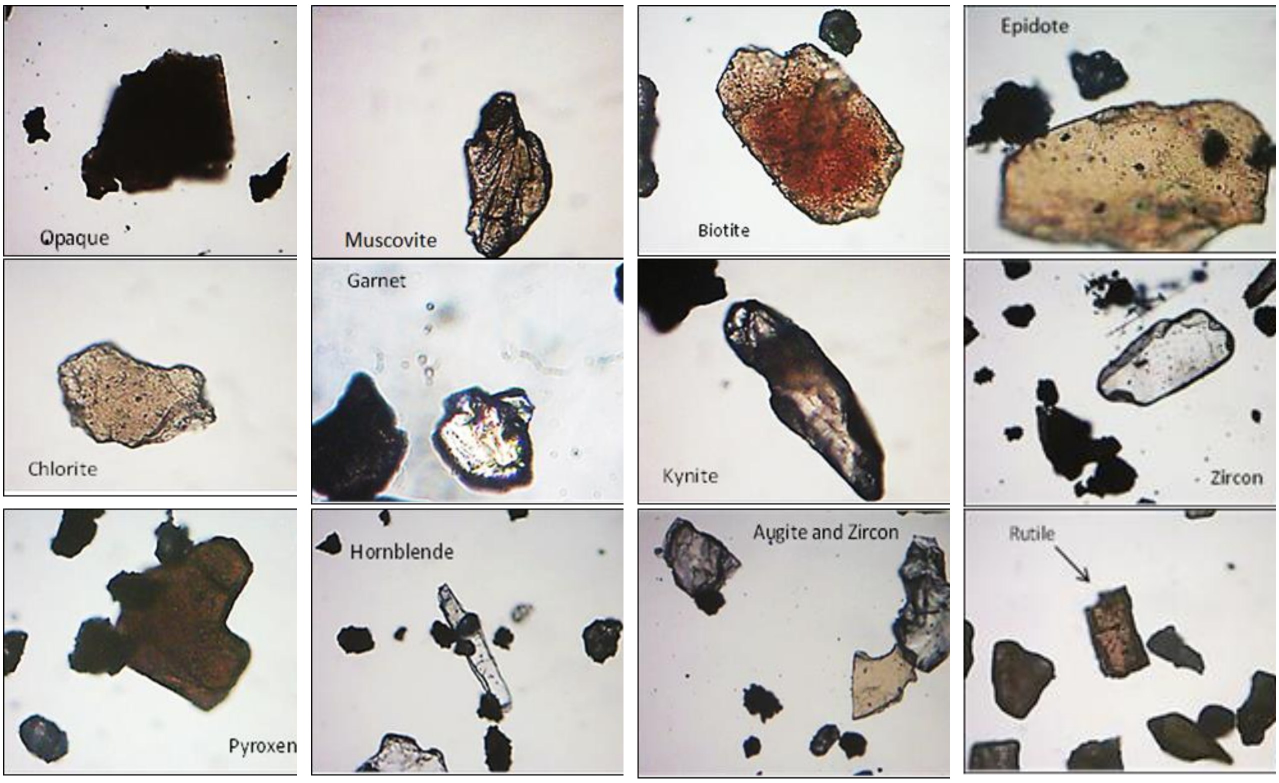

Fig.8. Images of heavy minerals slides which are identified in the island and its surrounding

Table.5. Types of Fauna and its Environments in the study area.

				Mollusca			
Foraminifera	**Env.**	**Ostracod**	**Env.**	**Gastropoda**	**Env.**	**Pelecypoda**	**Env.**
Ammonia beccarii	Marine to brackish	*Agrenocythere pliocenica*	Marine	*Pyramidellidae* gen. sp.	Marine	*Arca holoserica*	Marine
A. tepida	Marine to brackish	*Carinocythereis indica*	Marine	*Thais carinifera*	Marine	*Calyptraea sp.*	Marine
Cibiciidoiides brady	Marine	*Cyprideis torosa*	Marine to brackish			*Codakia orbicularis*	Marine
C.pseudounqerianus	Marine	*Condona compressa*	Fresh			*Macrocallita umbonella*	Marine
Elphidium lessonii	Marine, brackish and lagoon	*Hemicytheridea sp.*	Marine			*Melanoides tuberculata*	Fresh
E. incertum	Marine, brackish and lagoon	*Flexus trifurcate*	marine and fresh			*polynice mamilla*	Marine
E.sp.	Marine, brackish and lagoon	*Loxoconcha certinata*	Marine and Fresh				
Eilohedra rotunda	Marine	*Neomonoceratina iniqua*	Marine, and fresh				
Globigerinoides trilobus	Marine	*Paijenborchallina (Eupaijenborchalla) iraqensis*	Marine				
Quinqueloculina angulta	Marine and lagoon	*Schneiderella vulgaris* sp.nov.	Marine				
Spiroloculina rotundata	Mrine and lagoon						

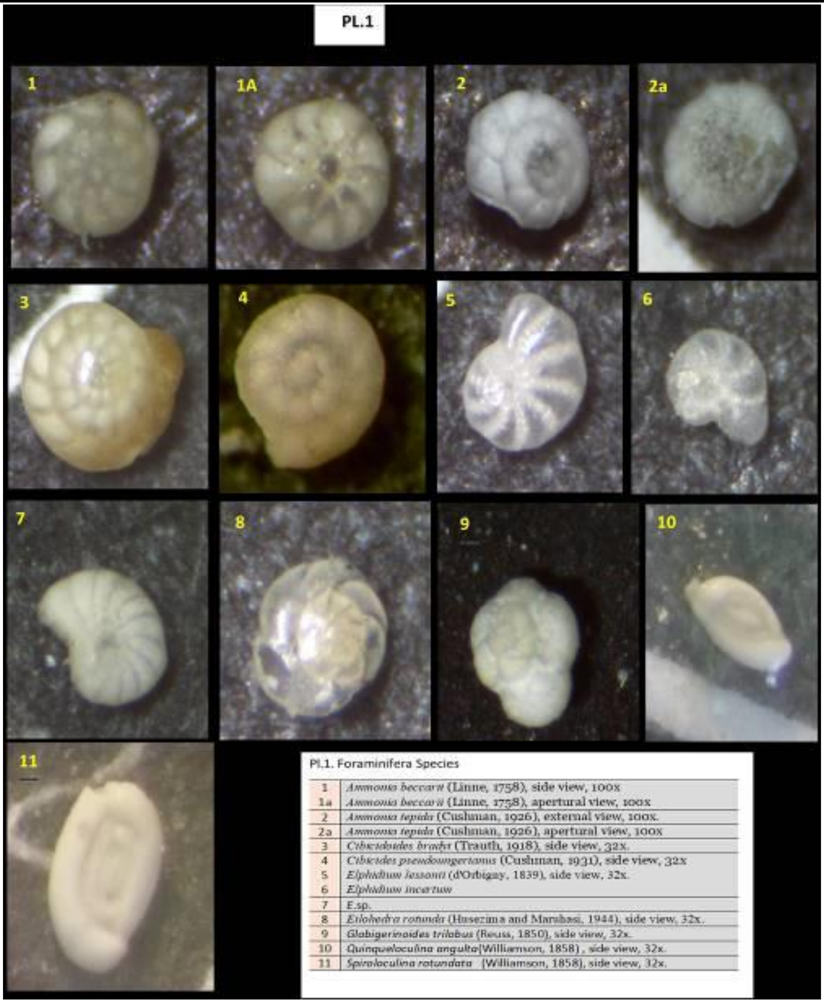

Fig.9. Images of fauna slides which is identified by the polarized microscope of the island

4. Discussion

The results showed the multi-supply of sediment sources for the island, consisting of modern sediments floods of rivers, and side drifting of the formations surrounding the area by aeolian transport of sediments from the west and northwest exposed Debdibba Formation, and the marine deposits transported from the Gulf through tidal currents. Although many sources of sediments, cannot form an island as size as Hacham Island, these sources can be a factor that has contributed to the evolution and development of the island, but it is not the main reason.

The island site compared to other sites is affected by the transported deposits that are influenced by human activityfactors, including a military site during the Gulf Wars, windblown from the vicinity of the region (the Debdibba Formation), or the outcrop of the formations in the southwestern desert.

The results of light minerals analyses indicate that there are many supply sources of sediment in the area, consisting of the river load of modern deposits of Tigris and Euphrates Rivers and the side drifts of the sedimentary formations surrounding the area.The wind brings exposed sediments from the west and northwest from Debdibba Formation, as well as it transports rich carbonates marine sediment from the AG through tidal currents. The island location recorded the lowest percentile presence of heavy minerals, which can be attributed to the human activities interaction impact.

As aforemetioned, the results of the current study (mineral and fauna) confirmed that there are indications that the region is affected by an ancient source of freshwater of the ancient Euphrates River course when it flowed separately toward Khor Al-Sabia (that separated Boubyan Island from Kuwaiti shoreline). These results are supported from a severalstudies (Hansman,1978; Al-Sakini,1986; Al-Mussawy,1993). In spite of these results, the transported sediments by the river cannot be considered the main factor in the creation of the island. The river had flowed with large energy in the past. In this event,carries large amounts of sediments carried by the river should be deposited further from the current location from the island to the point of contact with the AG, perhaps to Boubyan Island or further of that, while Wilson (1925) indicated that large quantities of sedimentary load transported through the Euphrates River were clustered in the marshes as a result of the low level of its lands. So, the island is formed after the decrease of the ancient flow energy of the Euphrates River, which occurred because the lower part of the Mesopotamian Basin was affected by new tectonic and structural activity. This has been referred to by many studies (Hansman, 1978; Karim ,1988; Al-Mussawy,1993; Al-Mosawi et al., 2015), where it caused many structural uplifting on the west side (the highest level) and which in turn caused meandering of the ancient river courses of the region in general, and specially Euphrates River to the east (the lowest level) this accompanied by the impact of the area with many of faults which influence reached to the surface, such as the fault, which separated Warba Island from the Iraqi coast and formed Khor Shaitanah (Al-Mussawy,1993; Al-Muturi et al., 2021).

The meandering of the ancient Euphrates stream (currently KZ) at an angle of about 90˚ at the site of Khor Shaitanah was the other reason for the creation of this island. It is because usually at the beginning of the meandering of any waterway the flow velocity speed is decreased and weakens the river's energy to carry sediment for further sites. Therefore the river stream is forced either to collect its deposits at this site forming an island, or make another course for it. According to the results of the current study, the ancient Euphrates River has been made into a secondary stream, which separated the island from the Iraqi coast is represented the first phase of the forming of this island. The island then began to grow up by the nourishment of the transported deposits from this river after its weakening energy and drifting the river course completely to the east to connect with the Tigris River and consisting of SAR.In addition to the quantities of transported sediments by the marine tidal current was being the second reason of the Island growth. This view is supported by the fact that there are no river streams in the area causes the forming of this island can be attributed until Shatt Al-Basra canal connected to KZ in 1983. This canal has no more than 150 m wide and it is unreasonable to be the reason for the forming of this island during this period of time, this phenomenon occurred in several locations in the course of SAR. So there are many islands are formed in SAR meanders sites such as Mahila and Um Al-Resas islands. The island was originally part of the Iraqi coast and was cut off from it and grew during the time according to the reasons referred, this fact is confirmed by:

- The island's land level is close to the ground level of the post-coast land area (4-5 m) above sea level, this level is considered high for the island if compared with the levels of the SAR Islands, which do not exceed 2 m.
- The pattern of flow of the old streams on the island from west to east is accompanied by the pattern of flow of the old streams flow.
- Corresponding the shape of the coast with the edge of the eastern island, especially on the northern side.
- The shallow depths of the course of the separated branch between the island and the mainland coast, especially in the northern part are not affected by the strong tidal currents or hydraulic jump.
- Extending the northern island bar upward for a large distance.

5. Conclusions

The present study concluded that there is more than one factor that contributed to the forming of the island represented by tectonic, morphological, and sedimentary factors. The first factor that contributed to the island forming is the impact of the lower part of the Mesopotamian Basin on new-tectonic activity, which caused the KZ course to bend (the ancient Euphrates River) 90° eastward at the current Iraqi-Kuwaiti border influenced by the fault separated Warba Island from Iraqi coast and forming Khor Shaitanah at the present time.

The meandering of the KZ course (the ancient Euphrates River) is accompanied by flow velocity decreasing, and thus a reduction in the river's capacity to carry sediment loads for further sites. Therefore the course of the Khor had to be cut off another course, which separated the island from the Iraqi coast. This stage represents the effect of the morphological factor that contributed to the forming of the island. The island began to grow through the deposits transferred from the ancient Euphrates River after its weak capacity and before its course was completely diverted to the east to connect with Tigris River consisting of SAR, in addition to the multiplicity of sources of sediment processing for the island, represented by the modern flood deposits of rivers and side drift of the sites surrounding the area. Also, by aeolian transport of sediments from the west and northwest exposed the Debdibba formation as well as marine deposits transported from the Gulf by tidal currents, this represents the effect of the sedimentary factor. The current study also concluded that the east coast of the island is exposed to erosion in its central part as a result of the presence of a submerged wreck in the waterway that separates the island from the mainland coast. This wreck has caused the scouring and increase of the bottom depths.

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