Sedimentology and Mineralogy of the Sediments Beneath the Cyanobacteria and Marine Sabkha Area of Khor Al-Zubair, NW the Arabian Gulf

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Abstract

Twelve stations were chosen from the Intertidal flat and coastal sabkha of Khor Al-Zubair, northwest of the Arabian Gulf. The sampling was carried out from August to November in 2018, using plastic tubes for coring to a depth of 30 centimeters with 2 inches in diameter. The sediments are dominated by sandy silt texture in the area. Mineralogical analysis of sediments shows the Gypsum as the main constituents of minerals followed by Halite, Quartz, Calcite, and percentage of Clay minerals including Chlorite, Illite, palygorskite, and Kaolinite. As a result of the high evaporation rate in the area, in addition to the high salinity of the seawater which leads to the concentrate of gypsum crystals with the Microbial mats.

Key words: Minerals, sedimentology, Microbial, Khor Al-Zubair, Arabian Gulf.

1- Introduction

Khor Al- Zubair is one of the main tidal flats in the North-Western part of the Arabian Gulf and its main processes are generally affected by the entry of the river waters of the Tigris, and Euphrates [1 and 2]. Khor Al-Zubair was a semi-closed tongue of marine water forming part of the coast located in the North-Western part of the Arabian Gulf, currently, it is considered as an estuary after the connecting with the Shatt Al-Basrah Canal (Fig. 1). The tidal flats in Khor Al-Zubair are characterized by soft and fine sediments of clastic origin from the surrounding area, which is clayey and silty, this material is washed from the flood flats [3]. While the sediments of the Intertidal flat are to some extent composed of sand with a thin layer of a few centimeters of mud [4]. The study area is characterized by the accumulation of aeolian sediments, which are in the form of sand dunes located along the coast. The sea currents that run parallel to the coast distribute the marine sediments including sand and carbonate fragments and build marine barriers along the coast [5], these rocks could be a beach rock of regression period [6]. The modern sediments of Khor Al-Zubair are the product of various transport factors with multiple energies. Many studies have addressed the mineral distribution of the area, from these studies that concerned the region are the followings [6 and 7]. These studies have found that the minerals in the sediments can be confined to heavy minerals; opaque minerals, pyroxene, hornblende and epidote, and light minerals quartz, calcite and feldspar. Whereas, the clay minerals are Kaolinite, palygorskite, Illite, montmorillonite and Illite-montmorillonite mixed layers. Palygorskite could be an authigenic mineral where the climate, water, and sediment chemistry are suitable for the mineral formation of this mineral in the tidal flat [7]. These environmental conditions, the salinity of the water varies from 31-44.8 ‰ in February to 42.3 – 62.2 ‰ in Oct. and the conductivity is 52.2 – 271.6 mmohs/cm in autumn and 16.8 – 105 mmohs/cm in winter, and the pH measurements are between 8.04 and 8.12

which indicate that the water was alkaline, also helped the growth of cyanobacteria or the microbial induced sedimentary structures (MISS) at the shallow water depth of the intertidal flats of Khor Al-Zubair area, and many forms of microbial induced sedimentary structures are present [8].

The aim of this study is to highlight the nature of minerals formed under the microbial induced sedimentary structures (MISS) cover and comparing that with the other minerals in the other side of the coastal Sabkha.

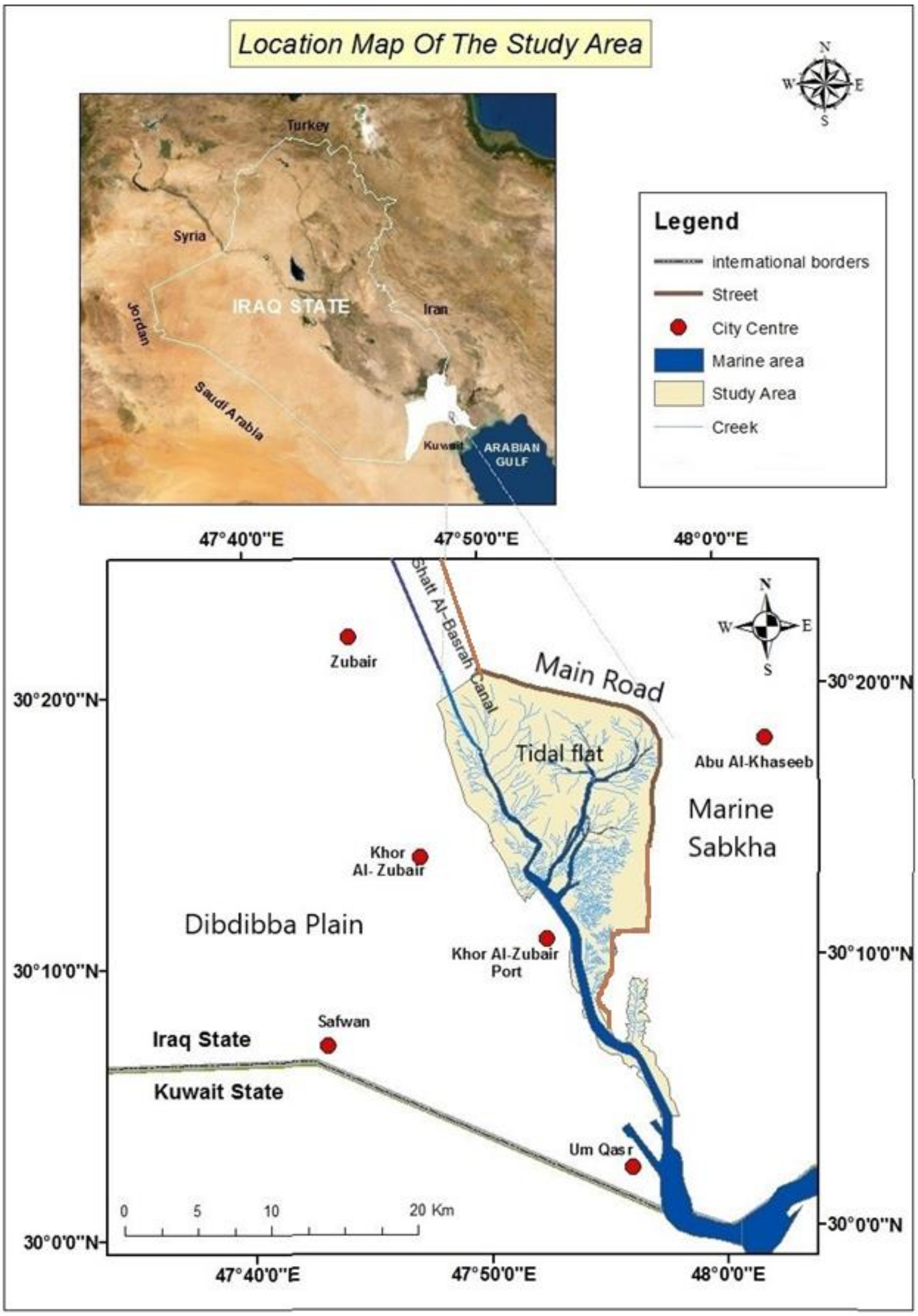

Fig (1) Location of the study area.

Location of the study area

The study area is located between longitudes 47˚ 54΄ 5″ and 47˚ 51΄ 6″ E, latitudes 30˚ 19΄ 0″ and 30˚ 20΄ 0″ N (Fig. 1). It represents a flat surface area of Khor Al-Zubair, which is located in the southern part of the Mesopotamian Plain, covered with very soft and soft recent sediments.

Geological settings

The Khor Al-Zubair region is part of the sedimentary plain in which the quaternary deposits are exposed, which are represented by the sediments of the Pleistocene and Holocene [9]. The deposits of Pleistocene and Holocene were represented by wind, river and marine deposits of the Dibdibba and Hammar Formations, respectively. According to [10] classification, the Mesopotamian Plain is located in the unstable shelf zone of the Arabian plate. It forms an external domain in Iraq [11]. [12] were changed the boundaries to a stable shelf by considering the Mesopotamian Plain as part of the stable shelf. [10] divided this zone into three subzones based on structural differences and partial developments, the first is Tigris Subzone located in the northeast, which is the most mobile unit and contains wide anticlines and synclines folds under the surface of the earth mostly trends to the Northwest - Southeast, accompanied by normal faults. The second is the Euphrates Subzone is located to the west of the Mesopotamia Plain, where it trends northeast with short anticlines folds that are less than 10 km and some long anticlines folds about (20-30) km near the Euphrates boundary fault, and the third one is Zubair subzone which forms most of southern Mesopotamia and has a unified structural pattern, controlled by the faults and uplifting of the basement rocks. The study area is located in the last one Zubair subzone. The formation of the Khor Al-Zubair is due to the fault caused by tectonic subsidence and this happened during the Furm glaciation period, which extends from 70 to 17 thousand years ago [13, 14, and 15]. The Arabian Gulf region, including the Khor Al-Zubair region, since its formation until now has been subjected to various changes during the various stages of development, which included the shape and structure of the region, the quality of its water and sediments, etc. and the influence of several factors, the most important of which are erosion, sedimentation, and tectonic activities in addition to climate changes that led to changes in the surface level [16].

2- Materials and Methods

Twelve cores were collected from different locations on both sides of the road separated the area to the east as the coastal sabkha and in the west as the tidal flats of Khor Al-Zubair of the study area (Fig. 1). The sampling was carried out during August (cores 1 to 7) and November (cores 8 to 12) 2018, the plastic cores are 30cm. in-depth and 2 inches in diameter were pushed vertically in the sediments and then digging around to pull them without distributing the sediments, figure 2 shows the location of these cores. The two ends of the core carefully closed to protect it from drying out. The cores were taken to the laboratory and placed in the refrigerator until it was cut. The cores were cut longitudinally and described visually in detail of the variation in color and texture. Grain-size analysis of the sediment and statistical parameters were performed according to [17 and 18]. Use in grain-size analysis in the laboratory of Geology Department, Science College, University of Basrah. Total Organic Carbon (TOC) of the investigated sediment was calculated by using the wet oxidation method as mentioned by [19]. The non- clay minerals were identified, there also appeared some clay minerals even the method was a powdered not oriented samples, using X-ray diffraction technique of powder sediments in the X-ray laboratory of Geology Department, Science

College, University of Baghdad and the remaining sand above the sieve 230 mesh were collected (dried and gold coated) for analysis under scanning electron microscopy (SEM) NOVA NANO SEM 450 and energy dispersive X-ray microanalysis system (EDAX) in the laboratory of Physics Department, Science College, University of Basrah.

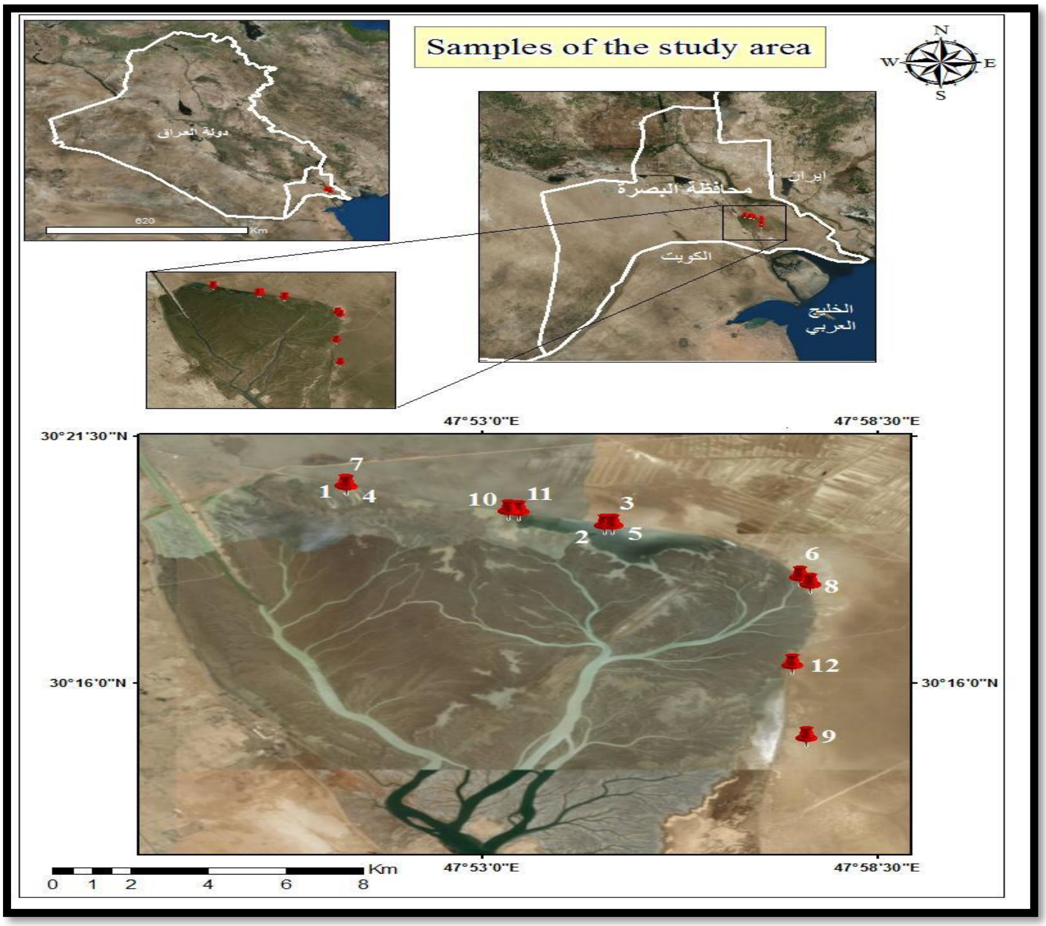

Fig (2) Location of cores.

3- Results and Discussion

The results based on the classification of [17] showed the presence of four types of sediments: sandy silt, silt, silty sand, and sandy mud (Table 1). In general, the amount of sand appears very low at the surface and increases when the increase in depth in the coastal sabkha (Fig. 3), which leads to reduced permeability and reduces the rising of the groundwater level due to capillary property. [20] pointed out that the wet tidal flats lead to the calm tidal currents creating a quiet environment that receives soft sediments to keep them away from waves and currents. The reason for the presence of coarse sediments, which includes (fine sand and silt) as a result of the wind source, which contributes to the transfer of sand to the region by continental sediments coming from the neighboring Dibdibba Formation [21], and the fact that the area is located in the coastal sabkha (Fig. 3) and the creeks of northern part of Khor Al-Zubair, which is characterized by the coarse grains observed through the deepening of the Shatt Al-Basrah Canal [22]. [23] confirmed that the sediments from Khor Al-Zubair to Khor Abdullah are soft and washed sediments during the ebb tides that were deposited during the period of stagnation. It was shown by statistical parameters that were applied to the sediments of the study area; the difference in the values of the average grain size can reflect the irregularity of the particle size of the sediments, which is related to the hydrodynamic conditions at the sedimentation sites. The sediment was characterized by a very poor to poor sorting because the sedimentation process could occur suddenly due to the nature of the movement of multi-directional water masses or may be the result of quiet currents in the region.

The results show that the total organic carbon (TOC) varies randomly in the sediments of the study area (Table 1), most of the percentages found in the sediments of Khor Al-Zubair flats could reflect the remaining organisms that existed during the sedimentation period. In general, the total organic carbon content is relatively low due to the prevailing conditions in the region (tidal flats and sabkha), where the high temperatures govern the abundance of organic matter in sediment [24]. According to [25], the relative decrease in total organic carbon values in the Arabian Gulf is due to the decrease in nutrients, the grain-size distribution of sediments and the dilution by continental sources. The area of tidal flats is an applied example of precedent factors, it is heavily influenced by tidal currents where it is variable in magnitude and direction as a result of many things, including the presence of khores, for [26] the grain-size of clay and silt in the areas of the sabkha are of inorganic origin and negatively affects the proportions of organic carbon.

A large variation in the mineral ratios recorded in the region between one mineral and another (Table 2), gypsum, which constitutes the main component of the region's minerals (Fig. 4 and 5), is highly variable in the surface of sabkha area during the summer (Fig. 4A) due to the impact of sulfate-rich groundwater and chlorides, the ground-water is ascended to the surface layer of the sabkha by the capillary property-carrying with it the basic components of the mineral. In addition to the prevalence of high drought conditions in the region, the high evaporation rates from the surfaces of the sabkhas encourage the deposition of these minerals in their surface layers [27]. The presence of halite in the region is also due to the evaporation of groundwater above saline. In winter, rainfalls reduce gypsum and halite minerals deposited on the surfaces [28]. Gypsum and halite minerals are high during summer in tidal flat surfaces (Fig. 5A), especially below microbial induced sedimentary structures (MISS) of domes and elephant skin forms (Fig. 6 and 7), because the area is continuously covered by water during the tide period, this water is characterized as being salty marine water of magnesium-sodium-chloride that lead to the concentration of salts in the surfaces in addition to the presence of large congruence between gypsum, halite and microbial mat, this is similar to what was found in both in the French coast of Santa Pola [29] and the coasts of Abu Dhabi, UAE [30]

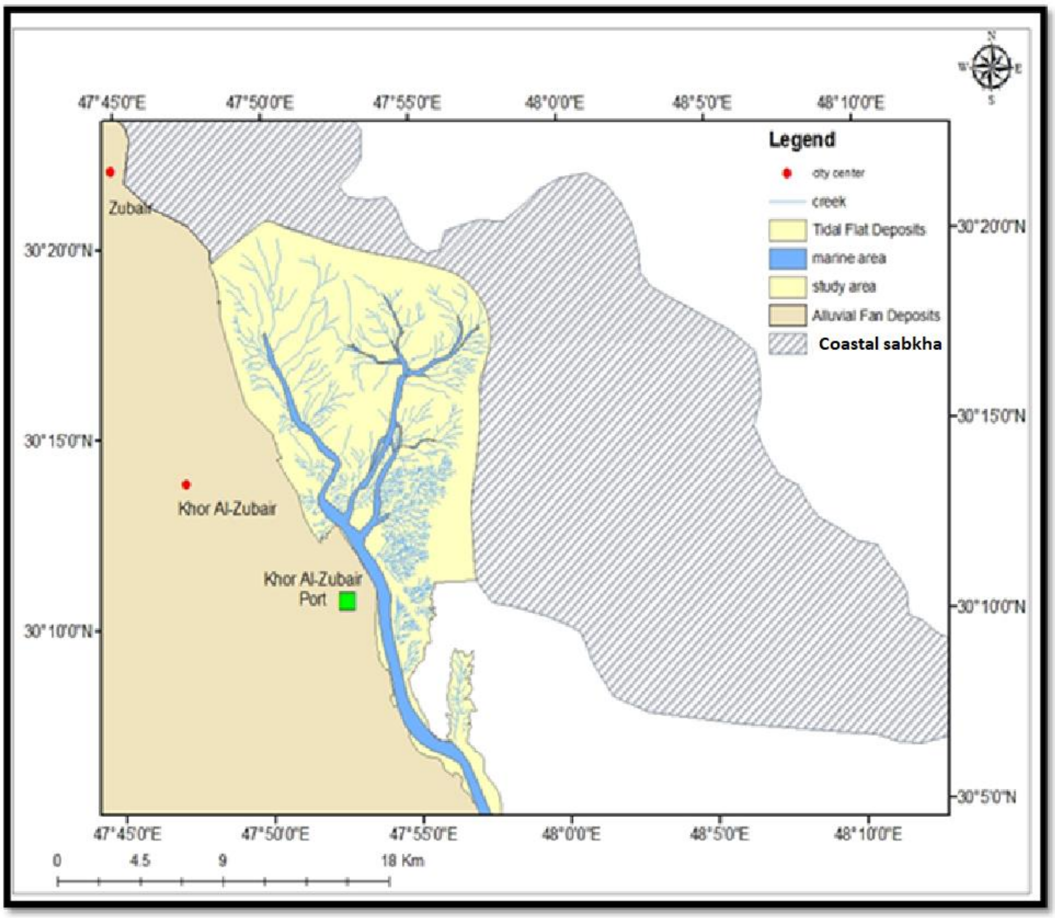

Fig (3) Distribution of Marine Sabkha in the study area.

In the winter, the presence of gypsum and halite minerals is reduced (Fig. 5B) as a result of rainfall, which leads to reduced salinity. These salts are deposited above the grains of calcite and quartz (Fig. 7). The Arabian Gulf is characterized by the deposition of carbonate of bio-origin, which is available in abundant quantities, as well as high temperatures and salinity as main factors in the deposition of carbonate materials [30].

The clay minerals are accompanying gypsum and halite minerals, which include minerals palygorskite, Illite, chlorite, and others in the area of wet tidal flats under the structures of MISS. Clay minerals in the sabkha could be also transported to the study area by rivers or by wind a dust falling on the area [31], which was transferred from the Shatt Al-Basrah canal to Khor Al-Zubair.

The emergence of high rates of calcite in the sediment of sabkha in summer (Fig. 4) as a result of flooding of seawater over the surfaces during periods of high tide and strong storms lead to the transport of large amounts of sand and mud towards the sabkha. The carbonate is precipitated as a plate form in the tidal flats (Fig. 5A and B), but most of the sediments dry up mostly due to the high evaporation that occurs in the region leading to the growth of evaporative minerals and this leads to the emergence of advanced polygons on the surface of the sabkha, as mentioned before by [32]. The presence of palygorskite mineral was recorded in some samples (core 6, 8, 10 and 11) mainly from sabkha of the study area, there is a possibility that the mineral forms in the area due to the appropriate environmental conditions, the temperature as well as the availability of magnesium ion after the withdrawal of calcium ion in the formation of gypsum mineral, this same conclusion he reached by [7]

Table (1) Grain-size analysis of the study sediments.

Cores	Season	Sample Location	Sample No.	Depth/ cm	Sand %	Silt %	Clay %	Mean ϕ	Sorting ϕ	Texture	TOC %
Core 1	Summer	Tidal Flat	1A	0-3	32	42	26	6.03	2.66	Sandy mud	0.19
			1B	3-6	14	70	16	5.76	2.07	Sandy silt	0.07
			1C	6-10	12	74	14	6.91	1.95	Sandy silt	0.17
			1D	10-14	50	43	7	4.83	1.66	Sandy silt	0.37
			1E	14-18	30	54	16	5.6	2.34	Sandy silt	0.36
			1F	18-23	30	60	10	5.36	1.829	Sandy silt	0.32
Core 2		Tidal Flat	2A	0-4	30	56	14	4.7	3.11	Sandy silt	0.06
			2B	4-8	50	46	4	4.4	1.72	Sandy silt	0.29
			2C	8-12	40	54	6	4.9	1.91	Sandy silt	0.51
			2D	12-16	36	54	10	3.83	2.72	Sandy silt	0.22
			2E	16-20	14	80	6	5.8	1.84	Sandy silt	0.27
			2F	20-23	40	53	7	4.53	2.59	Sandy silt	0.25
Core 3		Tidal Flat	3A	0-4	12	66	22	6.46	1.95	Sandy silt	0.32
			3B	4-8	40	55	5	4.1	2.70	Sandy silt	0.11
			3C	8-12	32	56	12	5.56	2.20	Sandy silt	0.16
			3D	12-18	30	62	8	5.13	1.76	Sandy silt	0.23
			3E	18-23	34	52	14	5.7	2.41	Sandy silt	0.25
Core 4		Tidal Flat	4A	0-4	42	46	12	4.5	2.04	Sandy silt	0.23
			4B	4-10	16	60	24	6.53	2.65	Sandy silt	0.32
			4C	10-14	8	68	24	6.83	1.96	Silt	0.30
			4D	14-18	6	68	26	6.6	1.84	Silt	0.10
Core 5		Tidal Flat	5A	0-4	34	57	9	5.03	1.67	Sandy silt	0.12
			5B	4-10	46	50	4	3.96	2.11	Sandy silt	0.18
			5C	10-15	20	56	24	6.2	2.63	Sandy silt	0.31
			5D	15-20	12	72	16	6.1	2.20	Sandy silt	0.22
Core 6		Sabkha	6A	0-8	14	68	18	6.3	2.15	Sandy silt	0.25
			6B	8-17	30	50	20	5.8	2.60	Sandy silt	0.23
Core 7		Tidal Flat	7A	0-6	14	72	14	5.93	1.74	Sandy silt	0.32
			7B	6-14	40	54	6	4.76	2.02	Sandy silt	0.31
Core 8	Winter	Sabkha	8A	0-3	17	77	6	5.9	1.70	Sandy silt	0.3
			8B	3-7	11	79	10	5.93	1.90	Sandy silt	0.42
			8C	7-10	10	80	10	6	1.66	Sandy silt	0.23
Core 9		Sabkha	9A	0-4	16	74	10	5.3	1.71	Sandy silt	0.15
			9B	4-7	35	60	5	4.63	1.86	Sandy silt	0.12
Core 10		Sabkha	10A	0-5	60	38	2	2.66	2.46	Silty sand	0.32
			10B	5-11	22	68	10	4.9	2.21	Sandy silt	0.3
			10C	11-18	20	72	8	5.43	1.76	Sandy silt	0.07
Core 11		Tidal Flat	11A	0-3	28	64	8	4.86	1.59	Sandy silt	0.21
			11B	3-12	10	75	15	5.66	1.61	Sandy silt	0.39
Core 12		Sabkha	12A	0-6	30	65	5	4.5	1.77	Sandy silt	0.17
			12B	6-12	45	53	2	4.96	2.55	Sandy silt	0.02
			12C	12-20	45	52	3	4.03	2.29	Sandy silt	0.2

Table (2) minerals percentages of study area sediments.

Cores	Season	Sample Location	Sample No.	Depth (cm)	Calcite %	Quartz %	Gypsum %	Halite %	Dolomite %	Bassanite %	Clay minerals %
Core 1	Summer	Tidal Flat	1B	3_6	22.7	13	38.7	6.4	0	0	19.2
Core 2		Tidal Flat	2A	0_4	10.4	0	62.8	7.8	0	19	0
			2B	4_8	12.3	0	79	6.2	0	2.5	0
Core 3		Tidal Flat	3B	4_8	12.6	0	42.9	17.9	0	9.2	17.4
Core 4		Tidal Flat	4D	14_18	45	18.4	2.8	11.2	7.3	0	15.3
			4B	4_10	19.7	12.2	26.3	23.7	0	0	18.1
Core 5		Tidal Flat	5C	10_15	32.8	7.7	10.6	19.3	0	0	29.6
			5A	0_4	10.8	4.9	65.2	11.3	0	0	7.8
Core 6		Sabkha	6A	0_8	31.7	11.9	30.8	7.1	5.1	0	13.4
Core 7		Tidal Flat	7A	0_6	18	8.4	56.5	5.7	0	0	11.4
Core 8	Winter	Sabkha	8A	0_3	40.4	15.1	6.9	9.2	8.8	0	19.6
			8B	3_7	49.2	12.4	3.9	7.3	8	0	19.2
Core 9		Sabkha	9A	0_4	25.5	0	38.5	0	0	0	36
			9B	4_7	32.2	5.2	29.2	8.8	0	0	24.6
Core 10		Sabkha	10A	0_5	3.2	0	95.9	0.9	0	0	0
			10B	5_11	34.2	8.7	23.8	6.8	9.2	0	17.3
Core 11		Tidal Flat	11A	0_3	67.8	0.6	0	0	7.5	0	24.1
			11B	3_12	53.3	8.7	8	0	7.7	0	22.3
Core 12		Sabkha	12A	0_6	6.7	8.5	50.5	6.7	0	0	27.6
Average					27.43	7.1	35.6	8.27	2.83	1.62	17.09

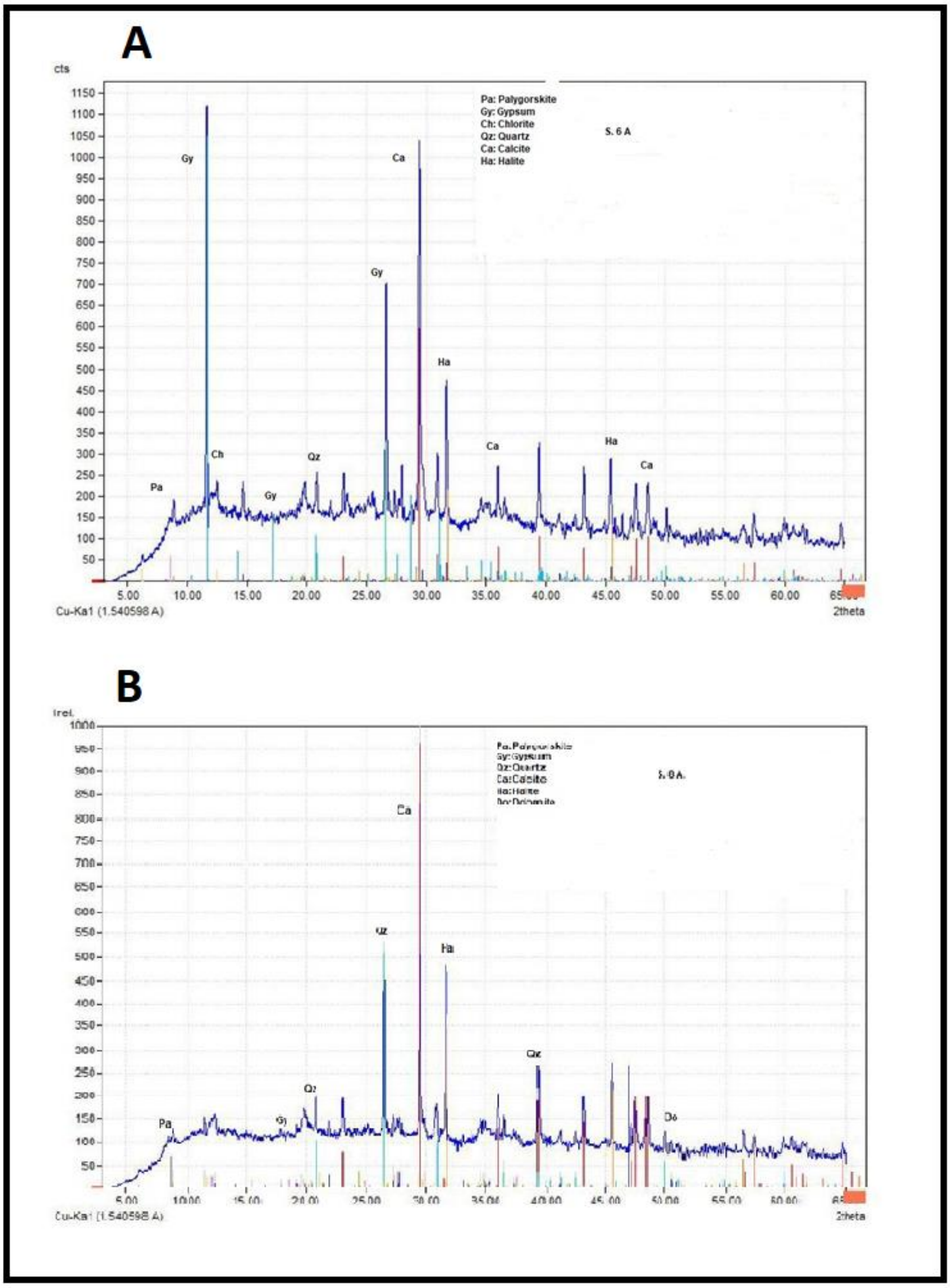

Fig (4) XRD patterns of bulk sample from sabkha.

(A. during summer, B. during winter).

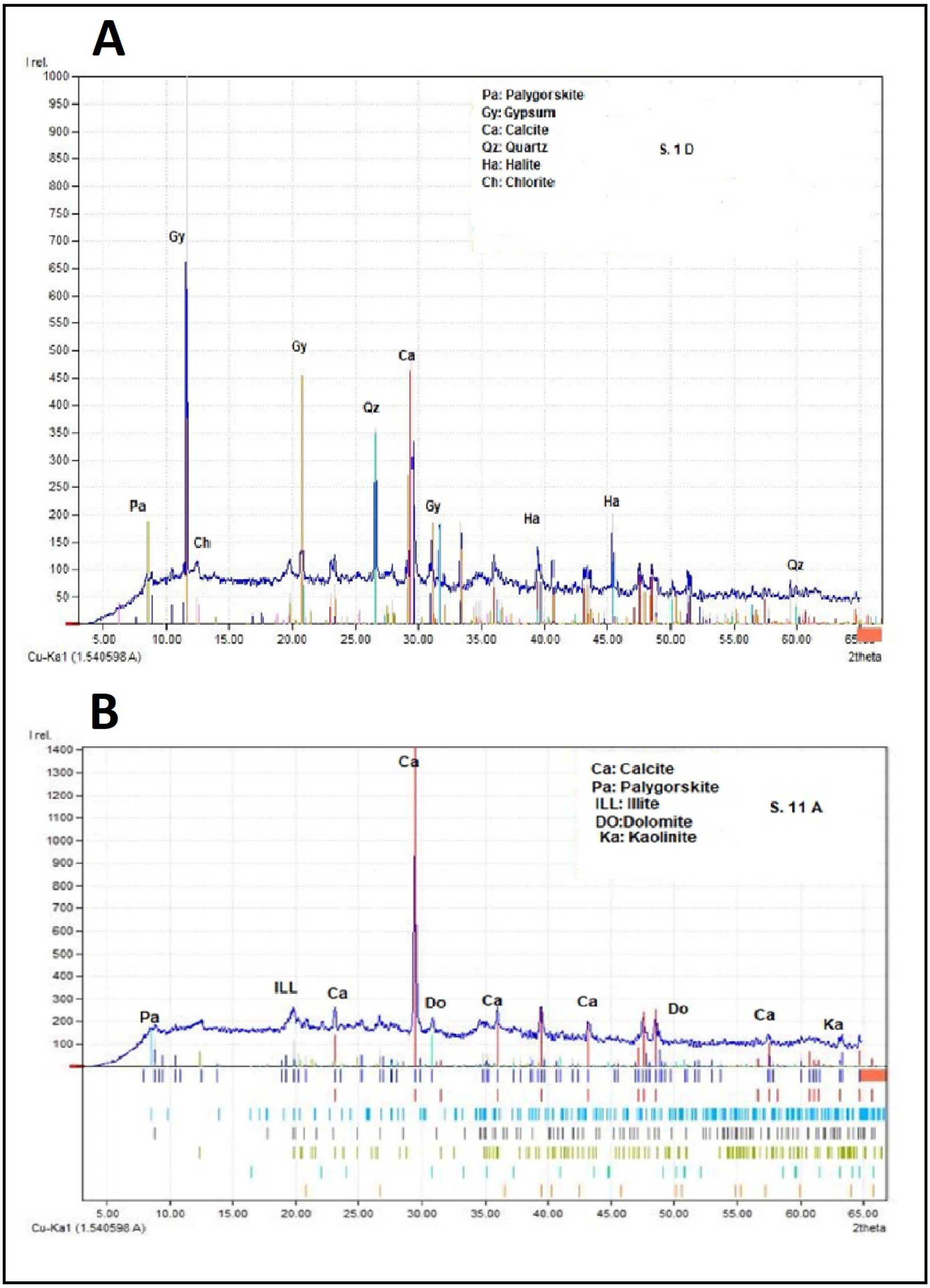

Fig (5) XRD patterns of bulk sample from tidal flats.

(A. during summer, B. during winter).

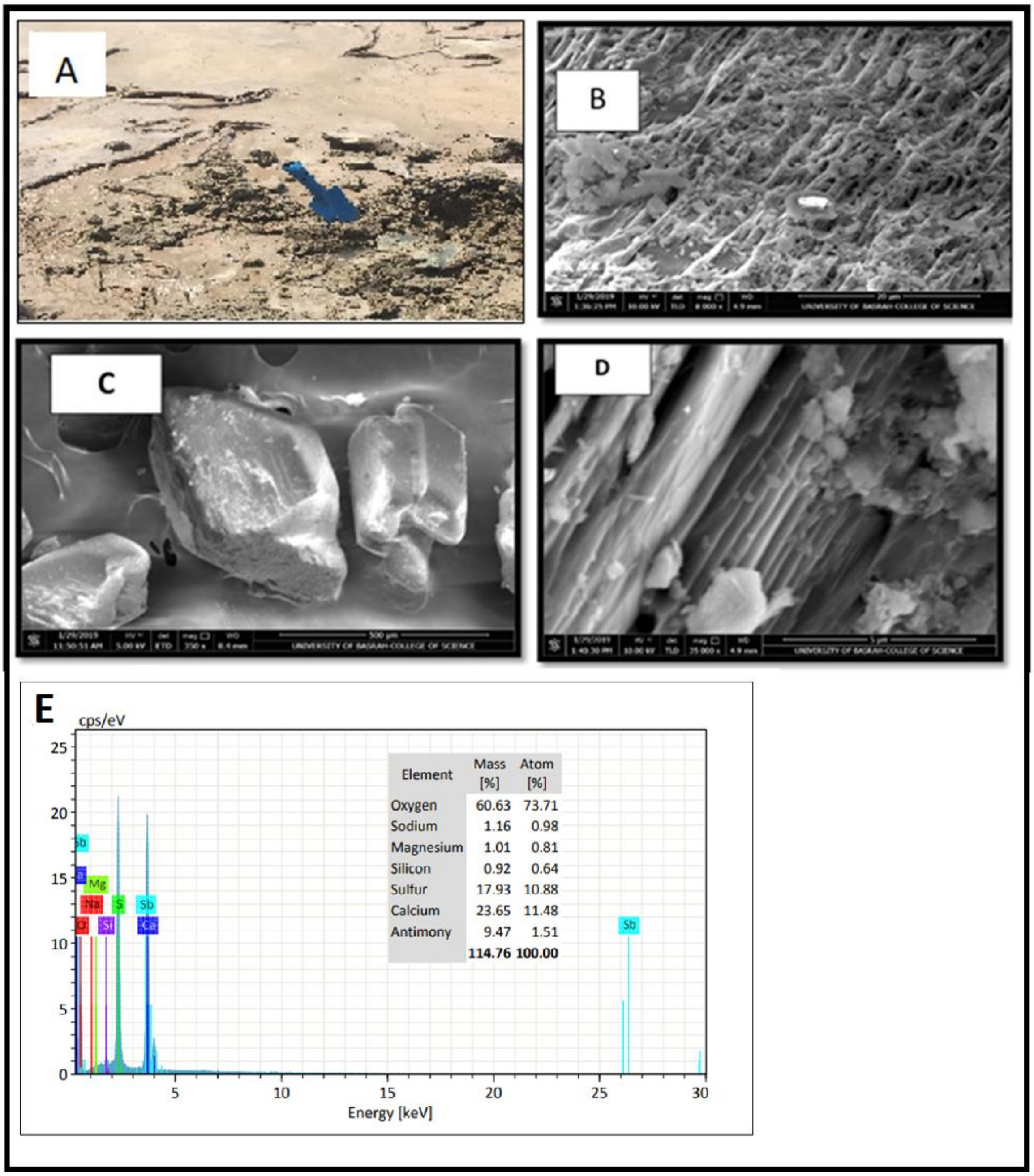

Fig (6) A – Elephant skin structure (MISS), 20 cm scale, in the intertidal flat, B – SEM of clay mineral deposited on the calcite grain of the sediment beneath microbial induced sedimentary structure (MISS), C- SEM of calcite grain of the sediment beneath (MISS), D- SEM of gypsum crystal on the calcite grain, E- SEM- EDAX analysis.

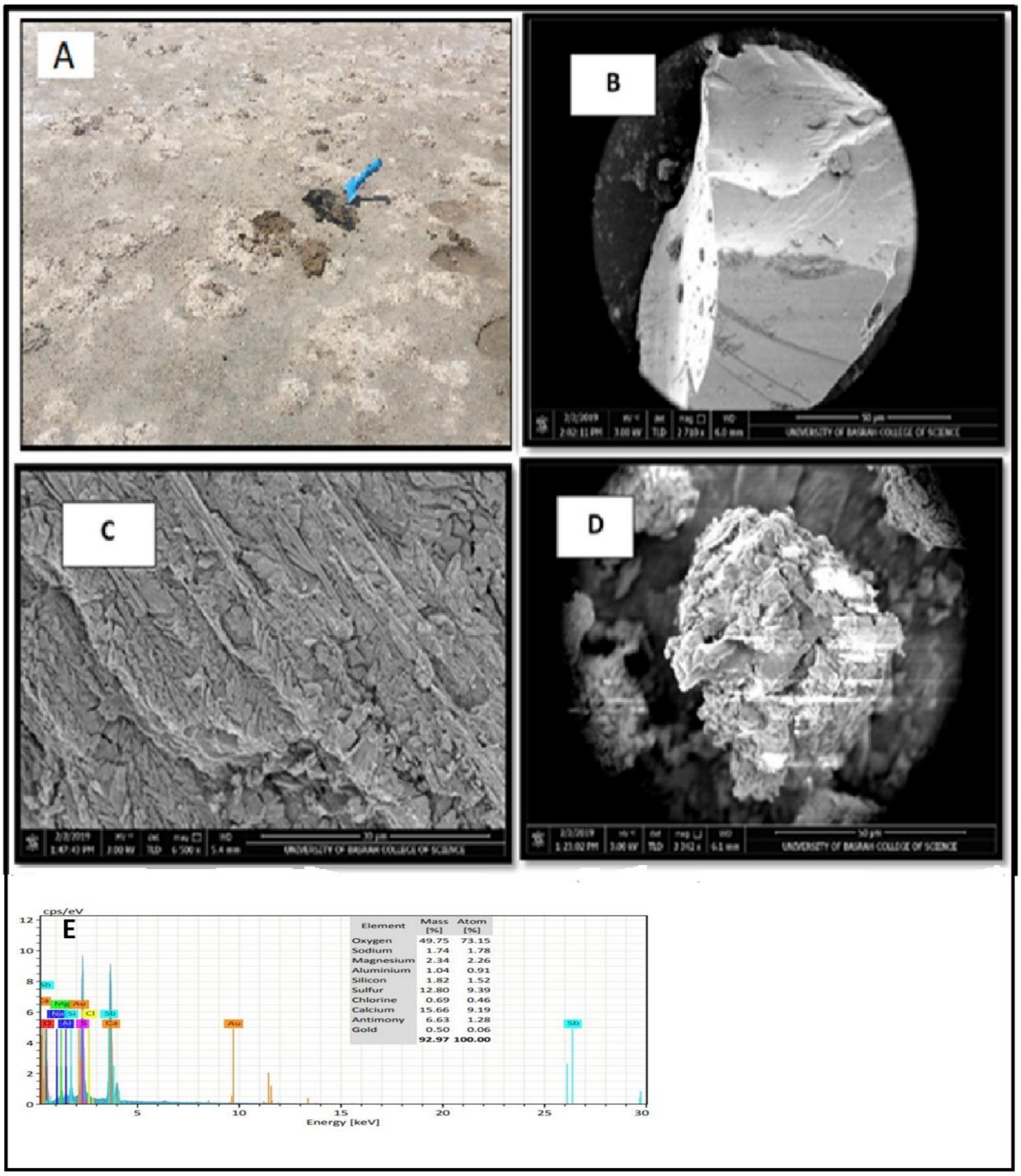

Fig (7) A- Domes structure (MISS), 3 cm scale in the intertidal flat, B- SEM of quartz grain deposited on the sediment beneath (MISS), C- SEM of clay mineral deposit on the quartz grain, D- SEM of gypsum crystal on the quartz grain in the sediment, E- SEM- EDAX analysis.

Conclusions

The sediments reflect the variation in the hydrodynamic conditions in the region. Grain- size of the sediments increase in depth in the sabkha and reduce in the tidal flats, this gives a good impression of the multiplicity of supplied sources for river and dust deposits, as well as the neighboring formations of the region. The mineralogical study also showed an increase in gypsum and halite minerals deposited under the microbial induced sedimentary structures, in larger quantities during the summer compared to the sabkha areas which gives evidence of the high salinity of marine water that leads to the concentration of gypsum and halite crystals in sediments due to high evaporation in the region. The clay minerals deposited below the structures indicate the increase of palygorskite minerals due to high alkalinity and salinity and magnesium ion enrichment in the sediments, which reflects the effect of chemical weathering in the region, whereas in the sabkha area there is a high concentration of chlorite and kaolinite, reflecting the effect of high physical weathering in the region and the lack of chemical weathering.

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رسوبية ومعدنية الرواسب تحت السيانوبكتريا و منطقة السباخ البحرية لخور الزبير

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المستخلص

أختير 12 موقعا من المسطحات مابين المد Intertidal والسباخ الساحلية Coastal Sabkha من منطقة خور الزبير، شمال غرب الخليج العربي. أجريت عملية جمع النماذج للفترة من أب والى تشرين الثاني من عام 2018، وبأستخدام انابيب بلاستيكية لعمق 30 سم وبقطر2 انج. اظهرت نتائج التحليل الحجمي بسيادة الغرين الرملي في المنطقة. بينت نتائج التحليل المعدني ان معدن الجبس المكون الرئيسيي للمعادن بالإضافة الى الهالايت والكوارتز و الكالسايت ونسب من المعادن الطينية والتي تشمل الكلورايت والالايت والباليجورسكايت والكاؤولينايت، نتيجة لمعدلات التبخر العالية في المنطقة فضلا عن الملوحة العالية لمياه البحر والتي تؤدي الى تركيز بلورات الجبس مع الحصيرة الميكروبية.