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Influence of TOC and clay minerals on sedimentation process in Iraqi marine sediments

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ABSTRACT

The Studying marine sediments is an important aspect in the geological, environmental and economic. The Northwest of the Arabian Gulf region characterized especially the specific area between the port of Umm Qasir and Basrah oil port with natural hydrodynamic and depositional variety. In this paper, the effect of organic carbon on marine sediments and its relationship with clay minerals has been studied. Three marine cores (at depths between 15 and 30 cm) are collected for marine sites between Khor Shytianah (core 1), Khor Abdullah (core 2), and Basrah oil port (open sea, core 3) by using marine sediments core sampler device. Living fauna and present a good percentage of total organic carbon was presented in the low marine environment in the core 3. A linear relationship was obtained between the clay mineral accumulation and the organic carbon ratio, this may be attributed to the ability of organic sediments and clay minerals to preserve water. Total organic carbon is decreased with depth increase. The highest total organic carbon found in the open sea (core 3). Mixed layer clay minerals represented by Montmorillonite–Chlorite (M-Ch %) is prevalent in the study area followed by Illite – Palygroskite(P-I %), Chlorite, Montmorillonite, Kaolinite, Illite, and Palygroskite respectively.

1. Introduction

In the soils and sediments, total organic carbon is vastly distributed over the earth's surface occurring in almost all aquatic and terrestrial environments [19]. The composition and aggregation of clay minerals depends largely on the petrography and weathering pattern of the mother rocks in the source region [25]. The burial of organic matter in marine sediments represents between active surface pools of carbon in the oceans, atmosphere, on land, and in marine sediments [6].

There are many of previous reports discussed the organic matter and clay minerals of Arabian Gulf. Such as study of Al-Ghadban et al [3], concluded that there are several factors that might contribute in the concentration and distribution of TOC such as the water circulation, total petroleum hydrocarbons, inorganic carbon, sediment grain size and biological productivity. Study of Abaychi et al [1], showed the total organic carbon in surficial sediments of northwest of the Arabian Gulf was found to vary between 0.14% and 0.96%. Al-Jaberi et al [4], found that chlorite was the dominate clay minerals in the northwest of the Arabian Gulf. The purpose of this investigation is to determine the organic matter content in the Iraqi marine environment and the relationship with sediments texture.

2. Materials and methods

The study area is located in the northwest Arabian Gulf between (N 30°01′44.7″ Latitude, E 48°06′41.9″ Longitude) and (N 29°43′56.5″ Latitude, E 48°37′02.4″ Longitude). The depths of the samples differ in the study area as shown in Table 1 and Fig. 1.

Three marine core sediments were taken from three sites in the Iraqi marine environment, northwest of the Arabian Gulf. Every core was divided into several parts depending on the core length, the length of each part is 5 cm as shown in Fig. 2.

Samples were subjected to many analyses in the laboratory, these testes contained grain size analyses, estimated by using the device of Master Sizer (Model UM 2000). The sediments texture was determined according to the Folk Triangle [13]. Total organic carbon (TOC %) detected according to [10]. Clay minerals were

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Table 1
Coordinate number of the samples in the study area.

Sites	Cores	Depths of water(m)	Latitude	Longitude
Khor Shytianah	Core 1	10	N 30°01′44.7″	E 48°06′41.9″
Khor Abdullah 3	Core 2	12	N 29°53′44.8″	E 48°20′52.8″
Basrah oil port(open sea)	Core 3	15	N 29°43′56.5″	E 48°37′02.4″

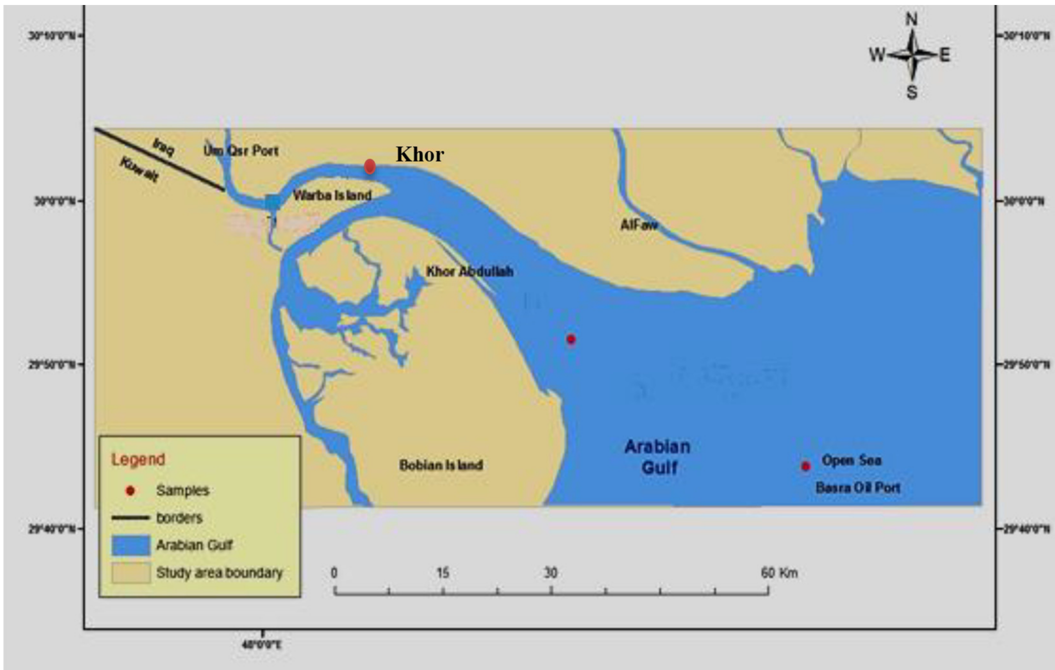

Fig. 1. Map of study area.

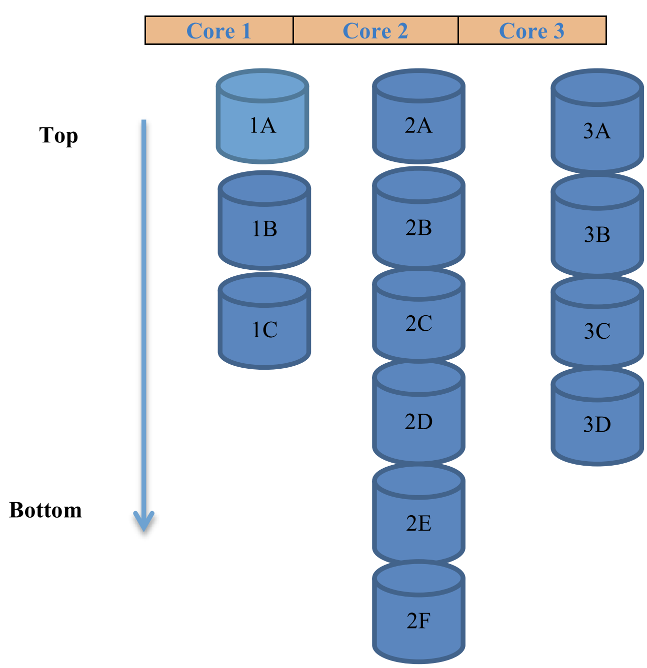

Fig. 2. Division the cores into parts.

prepared by taking a certain weight from the sample and sieve as a wet sieving with0.063 mm sieve. The clay part was treated with 17% acetic acid to remove the carbonate after washing with distilled water until the reaction was over and then rewashing with distilled water until the solution was suspended. A specific volume of clay is pulled after shake the sample into cylinder 1000 ml at a depth (5 cm) after (4 h: 6 m).

3. Results and discussion

The results of grain size analyses and total of organic carbon are shown in Table 2.The grain size of studied sediments is finer towards the southeast of the study area. Texture variations in the sediments may be due to the variation in marine currents energy relating to the hydrodynamic conditions, as confirmed by the study of Khalaf et al [17]. The sediments contained a number of broken shells that emphasize their deposition under the lagoonal beach environment as mention by Varghese [23]. There are three observable depositional environments in the study area. First, the high energy sedimentary environment in core 1, located between Umm Qasir port and Khor Shytainah where sand particles are common, reached to 95% as cleared in Table 2 and Fig. 3, caused by two reasons, the first may be influence by Kuwait marine current during the tide, and the second may back to bent shape of warbah Island caused to narrow navigation channel in this area as mentioned by Darmoian and Lindquvist [7].

The second depositional environment is the medium current environment represented in core 2, were affected by turbidity currents from the Shatt Al-Arab delta. Eventually, the low energy environment is the third, it dominated in the core 3, it is considered as a suitable environment for living fauna and present a good percentage of total organic carbon as presented in table

Table 2
Percentages of Sand, silt, clay and TOC % with depths.

TOC %	Texture	Clay %	Silt %	Sand %	Depth (cm)	Sample Name	Cores
0.32	Sand	1	4	95	0–5	1A	**core 1**
0.40	Silty sand	10	20	70	5–10	1B	
0.52	Silty sand	4	27	69	10–15	1C	
1.82	Silt	19	75	6	0–5	2A	**Core 2**
1.68	Silt	23	73	4	5–10	2B	
0.99	Silt	31	64	4	10–15	2C	
0.72	Silt	31	64	5	15–20	2D	
0.90	Silt	22	72	6	20–25	2E	
0.51	Silt	22	74	4	25–30	2F	
2.13	Silt	21	75	4	0–5	3A	**Core 3**
1.92	Silt	11	82	7	5–10	3B	
1.84	Sandy silt	13	56	31	10–15	3C	
1.52	Silty sand	6	31	63	15–20	3D	

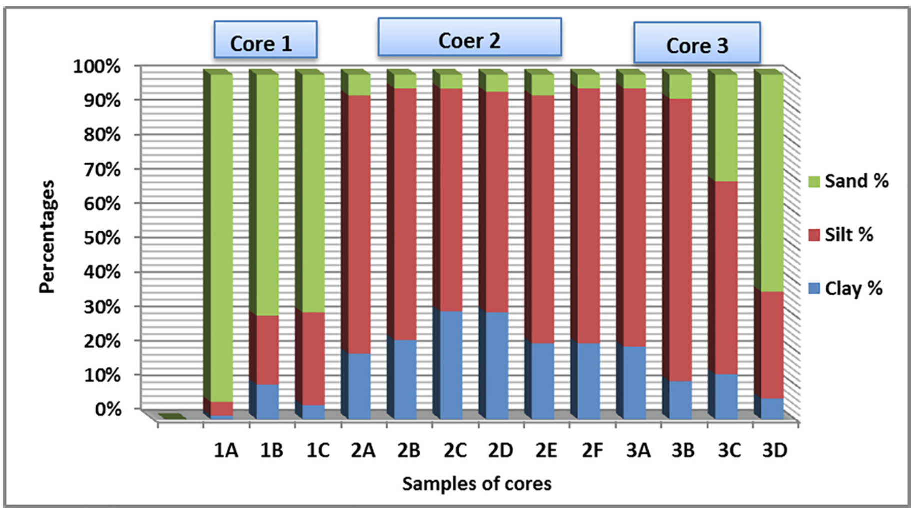

Fig. 3. Distribution of sand, silt and clay in cores 1, 2 and 3.

(2). In soils and sediments, total organic carbon is vastly widespread over the earth's surface occurring in almost all aquatic and terrestrial environments[19]. Total organic carbon values ranged between 0.32 and 2.13% as shown in table 2, these variations may attribute to a diverse grain size as well as the biologic, chemical, physical and hydrodynamic conditions. There is a reverse relationship of total organic carbon with an increase in grain size and depth (Figs. 4 and 5). (10) estimated that total organic carbon was an increase in the marine deposits of bays and estuaries. Fleming and Barnes [11] pointed the abundance of total organic carbon in the sediment controlled by the amount of organic carbon generated by marine organisms in the region or transported to the sea by local rivers. AlAbaychi [2] concluded that total organic carbon in general transported and deposited with fine-grained or silt and clay-sized particle, and it decreasing in coarse-grained sediment such as sand.

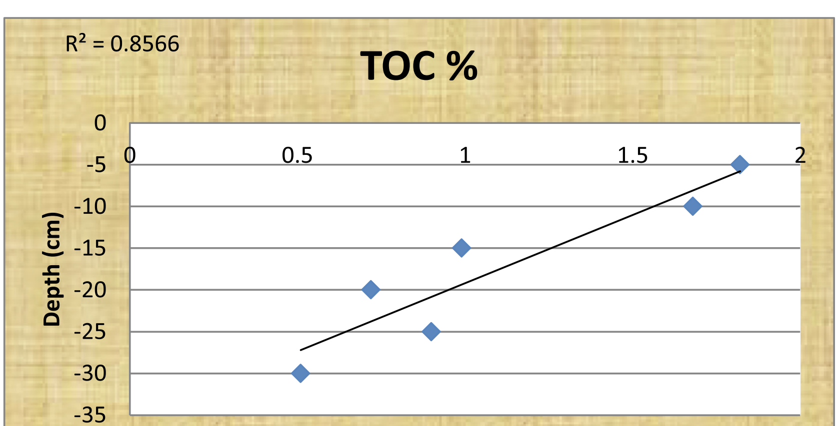

Fig. 4. Reverse relationship between Depths and TOC % in core 2.

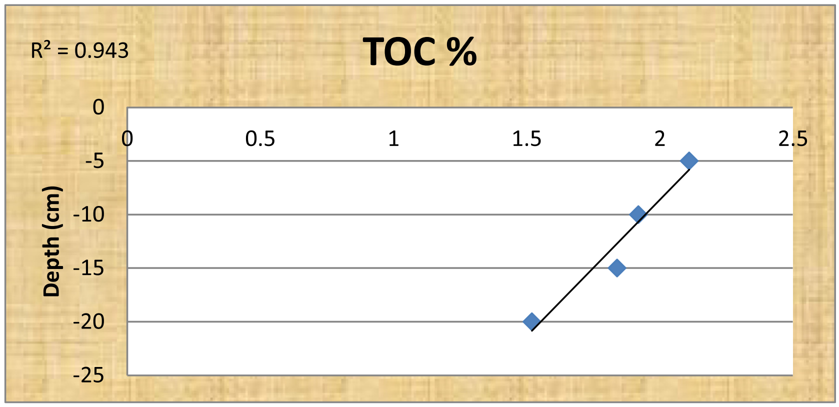

Fig. 5. Reverse relationship between Depths and TOC % in core 3.

4. Clay minerals

Kaolinite (K), Montmorillonite (M), Chlorite (Ch), Illite (I) , Palygroskite (P) and mixed layers of Montmorillonite – Chlorite (M-Ch) and Palygroskite- Illite (P-I) are the most clay minerals in studied area as shown in (Table 3).

There are variations in the proportions of clay minerals as shown in Figs. 6, 7, and 8.

The diversity of clay minerals referred to the various source of rocks that come from. The origin of these minerals is in situ or detrital which transported to the study area by rivers, waves and dust storms. Montmorillonite – chlorite mixed layers (M-Ch) is dominant in the core sediments, these layers are the result of the transformation mineral to another by ion exchange due to water entry. The presence of mixed layer indicated the origin of the sedimentary deposits that could be coming from the Dibdibba Formation sediments or from re-depositing processes (Al- Manssory and Al Ali, [5]). Clay minerals are the most reactive soil particles. Consequently, the chemical and physical properties of soils are directly or indirectly subjected to clay minerals. Clay minerals supply both permanent and changeable surface charges and different specific surface areas that are crucial to determine the carbon protection capacity of soils. They form organic–mineral complexes, promote the total establishment and save soil organic carbon against microbial decomposition[18]). In this paper, the ratios of the Montmorillonite – chlorite mixed layers (M-Ch) estimated to be the highest in the range (33–50%) of other minerals (Table 3). This layer is concentrated in the upper core depths. Therefore, they are the most influential and interacting with organic carbon in the sediments. Sediments carbon and nutrient concentrations increased with decreasing grain size because organic matter adsorbs onto mineral surfaces and has a high affinity for fine-grained sediment; the adsorption process helps to preserve the organic carbon (Huon, [16]). This is consistent with the current study, as organic carbon increases with fine grains, especially in cores 2 and 3. Through the results of the study revealed the positive relationship between clay minerals and organic carbon as shown in Fig. 9.

Vogel et al [24] found that only some of the clay-sized surfaces can bind organic matter. Surprisingly, Vogel et al [24] noted that < 19% of visible clay mineral surfaces accumulated labelled organic carbon, and this organic carbon was found to be preferentially associated with organo-mineral clusters with rough surfaces. Organic carbon is unevenly distributed on clay surfaces and does not cover the mineral surface as a monolayer [15,14]. The total organic carbon content in marine sediment is controlled by numerous factors such as the grain size, productivity and oxygen content of the waters, water depth, intensity of monsoons, bacterial degradation, and sedimentation rates[22]. The linear relationship between clay minerals and total organic carbon rate is clearly noticed in the surface depths. This indicates the presence of microscopic plant and biological organisms on the surface.

Table 3
Clay minerals distribution in Cores with depths.

Cores	Name	Depth (cm)	M-Ch %	P-I %	Ch %	M %	K %	I %	p %
Core 1	**1A**	**0–5**	**45**	**24**	**5**	**9**	**17**	**–**	**–**
	1B	**5–10**	**40**	**19**	**20**	**7**	**14**	**–**	**–**
	1C	**10–15**	**40**	**18**	**15**	**10**	**13**	**–**	**4**
Average			**41.6**	**20.33**	**13.3**	**8.66**	**15**	**–**	**1.3**
Range			**40–45**	**18–24**	**5–15**	**7–10**	**13–17**	**–**	**0–4**
Core 2	**2A**	**0–5**	**48**	**23**	**2**	**4**	**17**	**5**	**1**
	2B	**5–10**	**46**	**21**	**5**	**5**	**16**	**7**	**–**
	2C	**10–15**	**45**	**22**	**5**	**5**	**15**	**8**	**–**
	2D	**15–20**	**48**	**–**	**4**	**7**	**20**	**20**	**1**
	2E	**20–25**	**–**	**26**	**49**	**8**	**17**	**–**	**–**
	2F	**25–30**	**–**	**22**	**44**	**14**	**18**	**2**	**–**
Average			**31.2**	**23**	**25.66**	**7.33**	**17.16**	**7**	**0.3**
Range			**45–48**	**21–26**	**2–49**	**4–15**	**15–20**	**2–20**	**0–1**
Core 3	**3A**	**0–5**	**50**	**–**	**6**	**5**	**14**	**21**	**4**
	3B	**5–10**	**33**	**15**	**22**	**16**	**11**	**–**	**3**
	3C	**10–15**	**–**	**18**	**61**	**4**	**15**	**–**	**2**
	3D	**15–20**	**–**	**–**	**43**	**27**	**10**	**18**	**2**
Average			**20.75**	**8.5**	**33**	**13**	**12.5**	**9.75**	**2.7**
Range			**0–50**	**0–18**	**6–61**	**4–27**	**10–15**	**0–21**	**2–4**

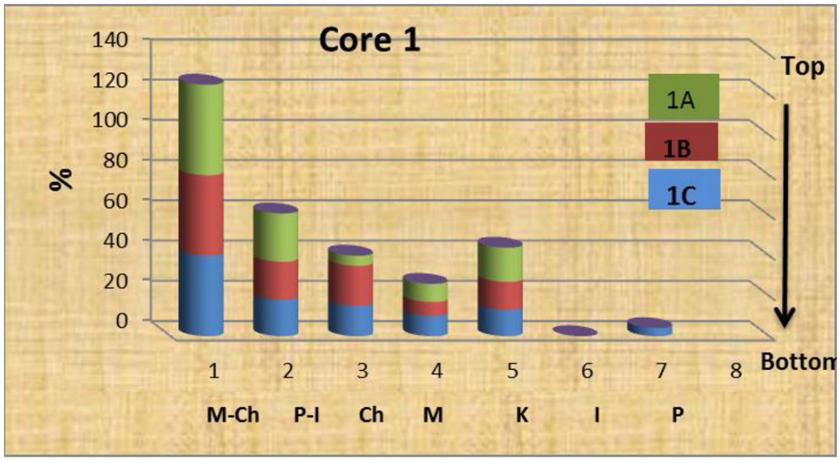

Fig. 6. Distribution of clay minerals in core 1.

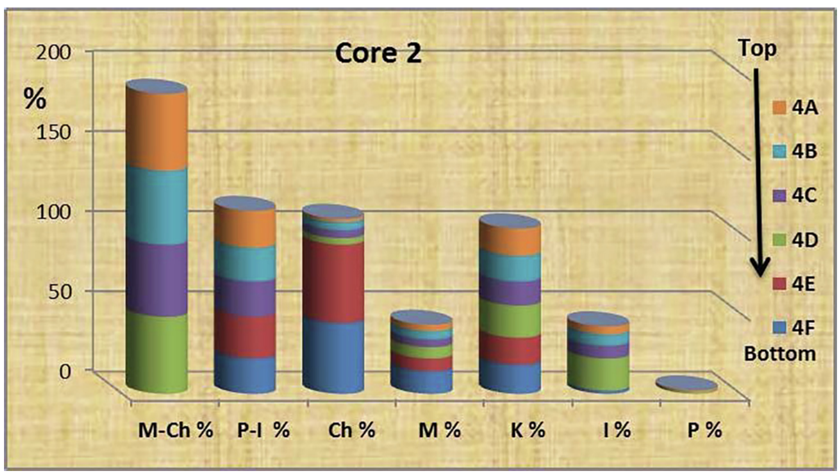

Fig. 7. Distribution of clay minerals in core 2.

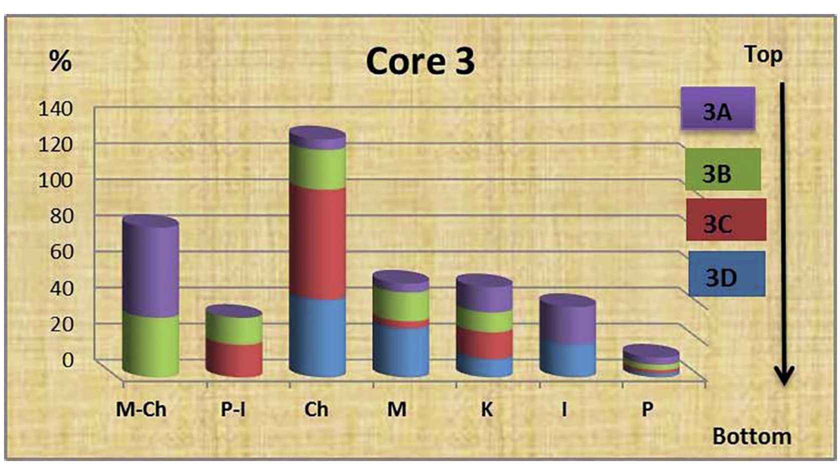

Fig. 8. Distribution of clay minerals in core 3.

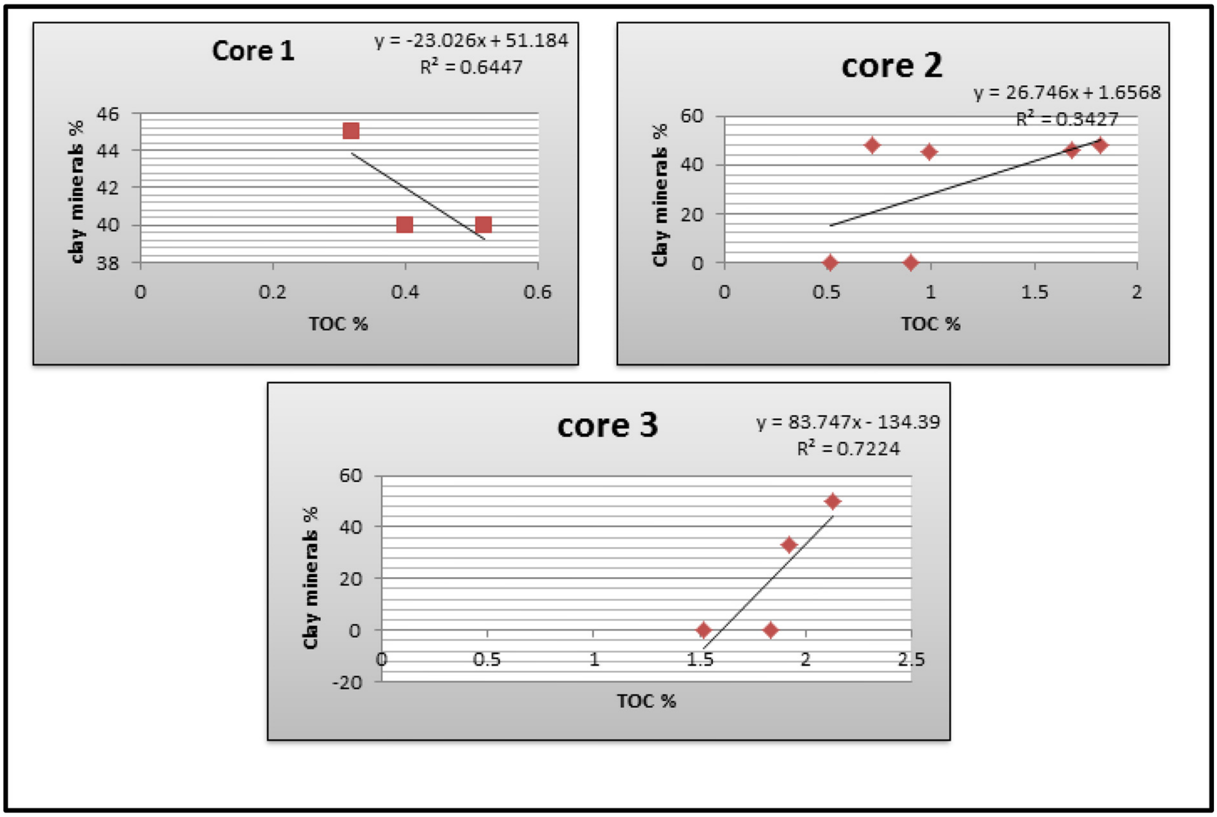

Fig. 9. Positive relationship between clay minerals % and TOC %.

5. Conclusions

Overall, the present study concluded the following:

1-. The variation of the sediment texture is due to their influence by water currents, tidal waves, and the geological nature due to the multiple islands.

2-. TOC values various in the sediments, this due to difference of grain size particles as well as due to the biologic, chemical, physical and hydrodynamic conditions.

3-. TOC increases in the fine grains, especially in the Khor Abdullah (Core 2) and Open Sea (Core 3).

4-. There is a positive relationship between clay minerals and TOC.

CRediT authorship contribution statement

Zainab A. Al-Humaidan: Conceptualization, Methodology, Software. **Mohanad H. Al-Jaberi:** Data curation, Writing - original draft, Visualization, Investigation. **Rasha A. Al-Ali:** Supervision, Software, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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