

GEOCHEMISTRY OF THE RED SEA SHELF SEDIMENTS AT AL - GHARDAQA.

II - GEOCHEMISTRY OF THE MAJOR ELEMENTS.

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ABSTRACT

The geochemical characteristics of marine sediments from Al-Ghardaqa region were investigated. This investigation dealt with the collected sediments in two steps; as a beach sediments representing the tidal zone and as a bottom sediments representing the shelf zone.

The concentrations of carbonates, calcium, magnesium, strontium, sodium, potassium, chloride and sulphate were determined. Relationships between elements were illustrated and the effect of both the detrital and biogenic contributions was revealed.

INTRODUCTION

The distribution and mechanism by which various elements are incorporated into marine sediments have been studied extensively for the last 25 years or more (see for ex. Wedepohl, 1960; Turekian and Wedepohl, 1961; Chester and Messiha - Hanna, 1970; Jones, 1972 and Beltagy, 1973 and 1981). However, the ecological importance of determining the concentration levels of major elements in marine environments has been more emphasized in recent years (Goldberg et al., 1971; Brown, 1971; Turekian, 1971 and Ali and West, 1983).

According to Goldschmidt (1954) the mineral composition of a sedimentary rock may be calculated from the chemical composition of the rock. This method, however, can only be successful if the factors affecting the distribution of elements are established. This can only be done through the study of the geochemistry of elements in recent depositional environments.

The abundances and concentrations of various elements in the recent sediments of Al-Ghardaqa, have been discussed (Beltagy et al, 1986). The mineral composition of these sediments was also studied (Lotfi, 1986).

In the present contribution the geochemistry of the major elements will be discussed in order to establish the geochemical association of the elements and to illustrate the effect of the environment on the distribution and the chemistry of the sediments.

MATERIAL AND METHODS

Samples were collected from the area of Al Ghardaqa using a grab sample. Description of the area and location of sample stations are given in earlier paper, (Beltagy et al., 1986). Detailed description of the area and the samples are given in Lotfi, (1986). Figure (1) gives the location of sampling stations.

Elemental analyses were performed on the samples using standard methods described in the literature, (Lotfi, 1986).

RESULTS

Results of the chemical analyses for the elements Ca, Mg, Sr, Cl and S as sulphates are given in Table (1) together with the carbonate content, mean particle size, depth of water, and distance from the shore. Except for a very few number of samples, sediments contain over 50% carbonates.

DISCUSSION

In the following discussion, the ratio between the elements will be taken as criteria for the degree of association of a certain mineral phase. Possible origin and processes involved in the deposition of these sediments will be discussed in order to understand these processes in the light of the arid climatic conditions prevailing in this area. Table (2) shows the element ratios and mole ratios of Ca^{+2} and Mg^{+2} .

1- Carbonate, Calcium and Magnesium:

The carbonates show a significant correlation with the mean size suggesting that carbonates increase with increasing mean size.

The carbonate phases which seem to host calcium, magnesium and strontium show a distinct trend with depth, they correlate positively with depth ($r = 0.41$). All these elements, however, do not correlate in the same manner (Ca^{+2} $r = 0.4$, Mg^{+2} $r = 0.2$ and Sr^{+2} $r = 0.3$). This may reflect the effect of the presence of different sources for carbonate for the different parts of the area.

Since, we assume that Mg^{+2} and Sr^{+2} are mainly confined to the carbonate phases, then we expect that the relation between the elements will show similar patterns.

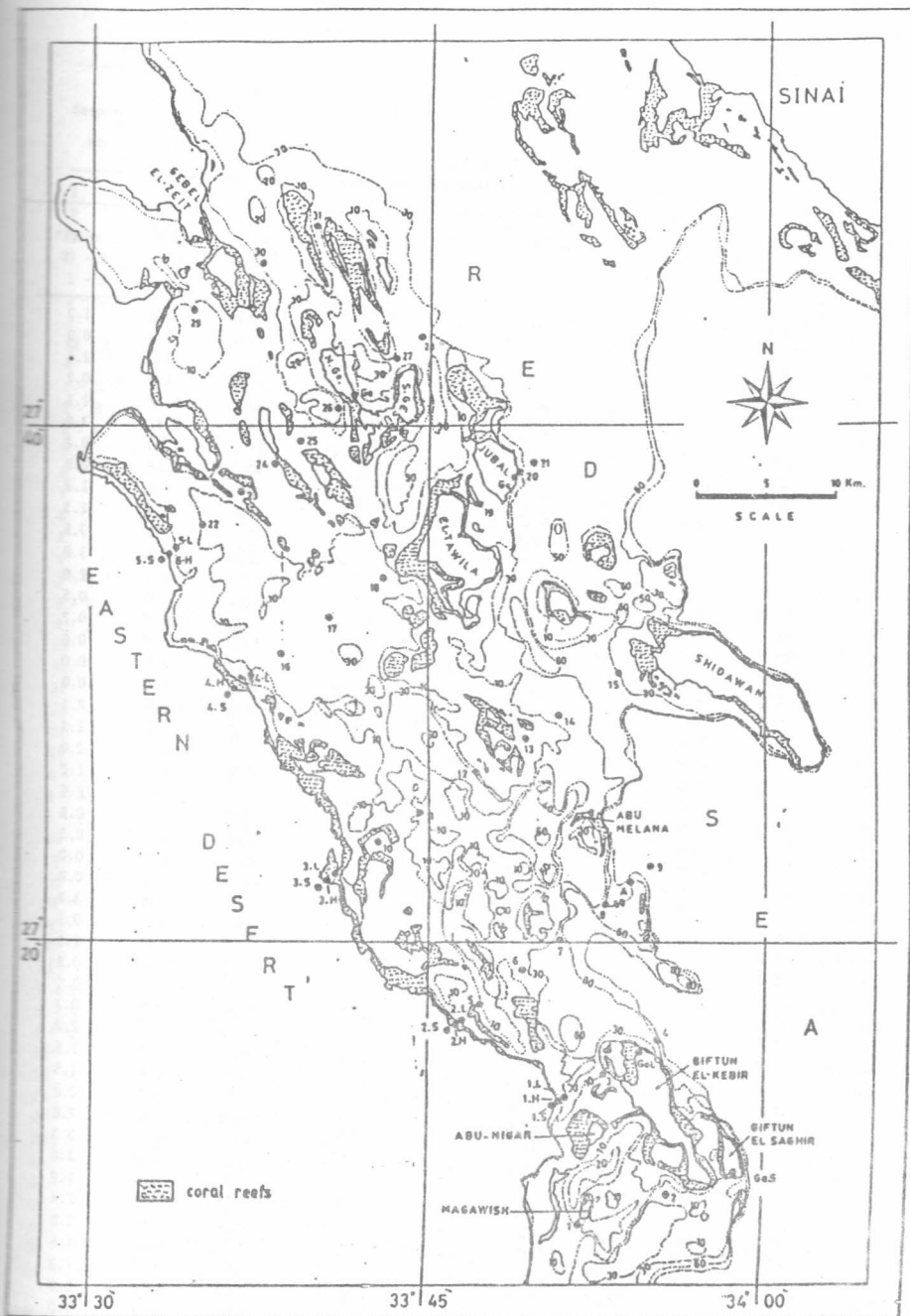


Fig. (1)
Map showing location and sampling stations,
the geomorphology of the Ghardaga region
and depth contours.

Table (1)
The parameters of geochemistry of Recent sediments near Ghardaqa, Red Sea.

Sample No.	Depth (m)	Apart distance (Km)	H ₂ O	Ca CO ₃ %	Ca ⁺² %	Mg ⁺² %	Sr ⁺² ppm	SO ₄ ⁻² %	Cl ⁻ %
1	8.0	3.0	0.75	92.0	36.8	1.15	5000	0.0	1.2
2	12.0	9.0	2.37	84.0	34.6	1.90	4800	2.0	0.0
Ga - S	0.0	11.0	-0.07	93.0	37.2	0.65	4200	0.0	2.1
I - S	0.0	0.0	1.65	34.0	15.2	1.0	2400	4.0	0.2
I - H	0.5	2 m	0.87	45.0	18.7	1.80	9600	1.77	2.1
I - L	2.0	5 m	1.33	58.0	24.2	1.66	2400	2.47	3.0
3	15.0	3	1.27	88.0	35.6	2.1	2600	1.00	0.2
Ga - L	0.0	7	0.57	86	34.9	0.71	4000	1.15	2.0
4	40.0	10	2.37	88.0	35.2	2.50	2000	0.0	1.2
2 - S	0.0	0.0	1.40	69.0	28.6	0.80	1200	2.55	2.3
2 - H	0.5	10 m	2.90	49.0	20.6	1.80	1000	2.51	3.5
2 - L	2.0	0.2	2.53	52.0	21.6	1.20	1600	2.0	3.8
5	10.0	5.0	0.98	81.0	33.4	2.30	8700	2.3	2.0
6	12.0	8.5	1.33	87.0	34.8	2.10	9200	0.0	0.5
7	30.0	12.0	3.32	90.0	36	0.80	3800	0.0	0.2
8	35.0	15.0	3.43	89.0	35.6	1.60	6600	0.0	0.0
A	80.0	17.0	3.02	86.0	34.4	2.30	7800	0.0	0.0
9	100	19.0	4.97	63.0	25.2	2.80	4000	0.0	0.0
3 - S	0.0	0.0	1.63	36.0	15.9	0.50	1400	-3.58	2.1
3 - H	0.5	20 m	1.37	38.0	16.4	1.20	400	3.0	2.3
3 - L	1.0	50 m	1.80	45.0	19.0	1.66	1400	2.5	2.0
10	10.0	4.0	2.25	86.0	35.2	1.60	3500	2.0	1.2
11	15.0	7.0	3.07	89.0	36.3	0.80	7600	1.81	1.0
12	35.0	12.5	3.07	90.0	36.0	0.65	4000	0.0	0.6
13	8.0	18.0	1.62	88.0	35.2	2.10	9200	0.0	0.3
14	25.0	21.0	2.80	86.0	34.4	2.0	2600	0.0	0.0
15	45.0	25.0	4.56	82.5	33.0	2.2	4400	0.0	0.0
4 - S	0.0	0.0	0.73	31.0	14.6	0.7	3000	5.35	3.0
4 - H	0.5	0.1	1.87	47.5	20.7	1.9	1200	4.20	0.5
4 - L	2.0	0.5	1.37	62.5	26.0	2.1	9200	2.43	2.5
16	10.0	3.0	1.80	80.0	32.5	1.8	200	2.10	0.8
17	25.0	7.5	2.37	85.0	34.0	1.3	3800	0.0	0.5
18	30.0	13.0	2.10	80.0	32.0	2.4	8800	0.0	0.3
19	15.0	22.0	2.47	80.5	33.0	2.6	1600	2.0	2.0
Go	0.0	24.5	-0.90	84.5	34.5	1.3	4800	1.8	2.5
20	3.0	26.0	2.17	88.0	35.2	2.5	200	0.0	1.5
21	50.0	28.0	5.27	87.0	34.8	1.9	3200	0.0	0.0
5 - S	0.0	0.0	0.60	40.5	17.6	1.5	2800	3.37	2.0
5 - H	0.5	5 m	1.40	47.5	20.9	2.0	5000	4.50	3.3
5 - L	3.0	10 m	1.33	35.0	15.6	1.9	600	3.80	3.0
22	8.0	3.0	1.23	90.5	36.2	1.6	1600	0.0	1.2
23	10.0	6.0	2.80	84.0	34.4	2.4	2000	1.90	1.4
24	10.0	9.0	2.10	80.5	32.8	2.6	7000	1.50	1.8
25	10.0	12.0	2.47	63.0	25.2	2.1	6400	0.0	1.5
26	10.0	15.0	3.10	85.5	34.2	2.3	9500	0.0	1.3
Ge	0.0	17.5	0.23	72.0	29.5	0.65	2000	1.70	5.0
27	23.0	19.5	2.97	76.0	30.4	2.8	3200	0.0	3.0
28	45.0	23.0	3.30	88.0	35.2	2.9	4000	0.0	0.0
29	10.0	3.0	1.43	89.0	35.6	1.7	9200	0.0	0.8
30	12.0	9.0	1.23	82.0	33.6	1.9	3400	2.0	1.2
31	17.0	13.0	1.70	68.0	27.9	2.0	4000	1.8	1.5

Table (2)
 Mg^{+2} / Ca^{+2} mole ratio, Sr^{+2} / Ca^{+2} mole ratio, elemental ratio of
 Na^{+} / K^{+} , elemental ratio of Cl^{-} / SO_4^{-2} and mole ratio of
 Na^{+} / Cl^{-} in Recent sediment of Ghardaga.

Sample No.	Mg^{+2} / Ca^{+2} mole ratio	Sr^{+2} / Ca^{+2} mole ratio	Na^{+} / K^{+} elemental ratio	Cl^{-} / SO_4^{-2} elemental ratio	Na^{+} / Cl^{-} mole ratio
1	5.2	0.60	5.0	-	1.9
2	8.0	0.61	0.001	-	-
Ga-s	1.6	0.51	5.0	-	1.1
1 - S	10.0	0.70	0.25	0.05	1.5
1 - H	15.0	0.22	1.11	1.19	1.5
1 - L	10.0	0.45	0.24	1.20	1.65
3	10.0	0.23	1.25	0.20	1.5
Ga - L	3.0	0.51	12.10	1.70	2.6
4	10.0	0.25	0.45	-	1.2
2 - S	5.0	0.18	2.10	0.80	0.97
2 - H	14.0	0.21	1.40	1.40	1.1
2 - L	9.0	0.33	1.12	1.90	1.11
5	10.0	1.15	1.63	0.41	1.95
6	10.0	1.16	5.50	-	0.9
7	3.0	0.46	11.70	-	-
8	8.0	0.81	3.60	-	-
A	10.0	1.0	7.50	-	-
9	18.0	0.70	4.50	-	-
3 - S	4.0	0.39	2.55	0.59	1.9
3 - H	10.0	0.10	2.64	0.77	2.5
3 - L	14.0	0.32	3.64	0.80	2.4
10	8.0	0.44	1.61	0.60	2.3
11	3.0	0.16	1.90	0.60	1.8
12	1.4	0.49	0.93	-	4.0
13	8.0	1.15	4.60	-	-
14	9.0	0.33	1.40	-	-
15	10.0	0.57	0.81	-	-
4 - S	8.0	0.9	3.01	0.60	2.4
4 - H	14.0	0.26	0.42	0.12	1.5
4 - L	12.0	1.56	2.24	1.04	2.3
16	9.0	0.03	4.80	0.48	4.3
17	7.0	0.49	1.60	-	2.4
18	10.0	1.21	4.80	-	-
19	12.0	0.22	6.40	1.0	2.6
60	7.0	0.61	5.50	1.40	1.44
20	10.0	0.02	1.88	-	1.5
21	8.0	0.38	-	-	0.0
5 - S	12.0	0.7	2.8	0.60	1.95
5 - H	14.0	1.04	2.6	0.73	2.5
5 - L	19.0	0.17	2.6	0.79	2.3
22	8.0	0.19	0.7	-	1.2
23	10.0	0.25	0.36	0.74	1.3
24	12.0	0.93	5.0	1.20	1.9
25	13.0	1.11	8.3	-	2.0
26	10.0	1.22	0.38	-	1.2
Ge	3.0	0.29	2.7	2.94	1.1
27	14.0	0.46	4.0	-	1.0
28	12.0	0.50	1.25	-	-
29	8.0	1.0	3.8	-	1.5
30	8.0	0.44	13.3	0.60	3.0
30	10.0	0.63	1.7	0.70	2.8
Average					
Tide D Sediments		0.5	1.9	0.84	1.8
Shelf Sediments		0.61	3.4	0.24	0.95

Figure (2 a) shows the relation between Ca^{+2} and Mg^{+2} in beach sediments and shelf sediments and Fig. (2 b) shows the relation between Ca^{+2} and Sr^{+2} . As can be seen, there are large scattering. The beach sediments show better correlation between Ca^{+2} and both Mg^{+2} and Sr^{+2} than the shelf sediments do.

Coastal areas protected by islands and sand bars or coral reefs may form lagoons with recent evaporite formation. According to Bathrust (1971) there are several geochemical changes that occur in such environments. These changes lead to early diagenesis of the carbonates with subsequent increase in $\text{Mg}^{+2}/\text{Ca}^{+2}$ ratio in subsurface layer. Such subsurface layer is not the source of sediment to the beach. However, raised corals along the coast and several evaporite outcrops appear in the nearby areas and on the islands. The infiltration of sea water through sediments according to Kinsman (1966) hypothesis is confirmed by Beltagy (1983), who reports the presence of high saline waters in some isolated basins in the area and who believes that this water is most likely infiltrated through subsurface layers from coastal lagoons and tidal marches. Thus, if this is the case, it would be expected that tidal waters, which overflow into the tidal flats and into coastal lagoons will evaporate and high saline waters will permeate through subsurface strata again to the sea. Calcium in the carbonate is removed partially to be replaced by Mg^{+2} and high Mg-carbonates or even dolomite may appear latter transported to beach and near-shore sediments.

2 - Strontium

Strontium in the sediment of the area shows a low correlation with Ca^{+2} (Fig. 2c), while it correlates positively with Mg^{+2} . Beach sediments are low in Sr^{+2} and shelf sediments are rich in it. This may indicate the validity of the hypothesis which states that Mg^{+2} rich carbonates tend to develop in lagoons. Strontium may be incorporated into the crystal lattice structure of aragonite, calcite or dolomite. Thus, it is possible that strontium is leached away from beach sediments, as concentrated brine moves towards the sea, where waters are less concentrated. Thus, sediments became enriched in Mg^{+2} and depleted in Sr^{+2} . This is particularly true, if we look at Sr^{+2} as mainly included in the sediment due to biological processes rather than to chemical ones. Since the Sr^{+2} content of sea water does not allow precipitation of this element from sea water until almost the whole calcium carbonate is deposited. Thus, it is the bioenvironment which is responsible for the precipitation of Sr^{+2} with the calcium carbonate mineral phases.

However, the behaviour of strontium in sedimentary rocks is almost unpredictable, because of the many influences on strontium content in low temperature deposits. The ratio of Sr^{+2} to Ca^{+2} in carbonate shells and carbonate bearing sediments is a function of : i) $\text{Sr}^{+2}/\text{Ca}^{+2}$ ratios in the liquid phase (water), from which the solid phase is derived, ii) The vital effect of the organisms, iii) The particular solid phase in the case of formation of polymorph minerals, iv) The temperature, and v) The salinity of the liquid phase.

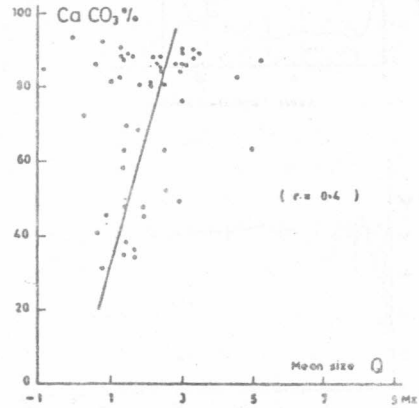
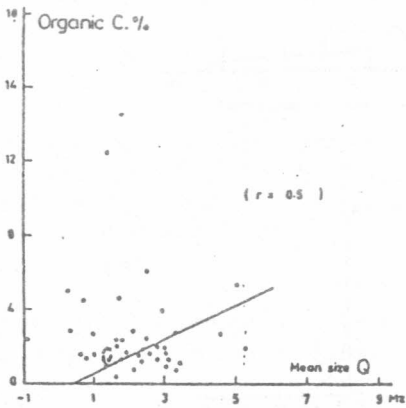
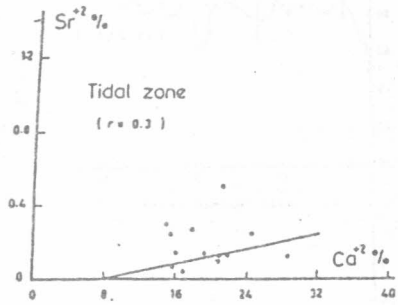
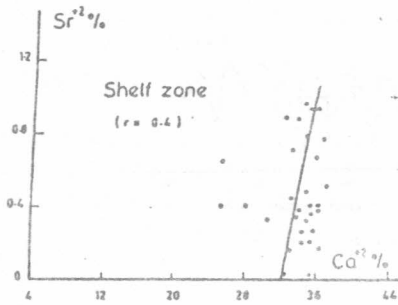
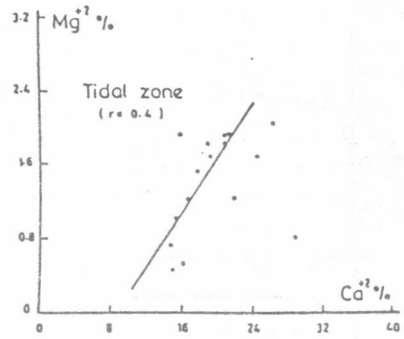
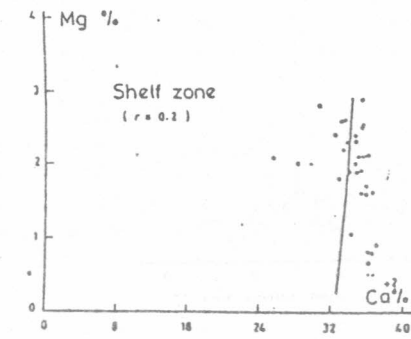
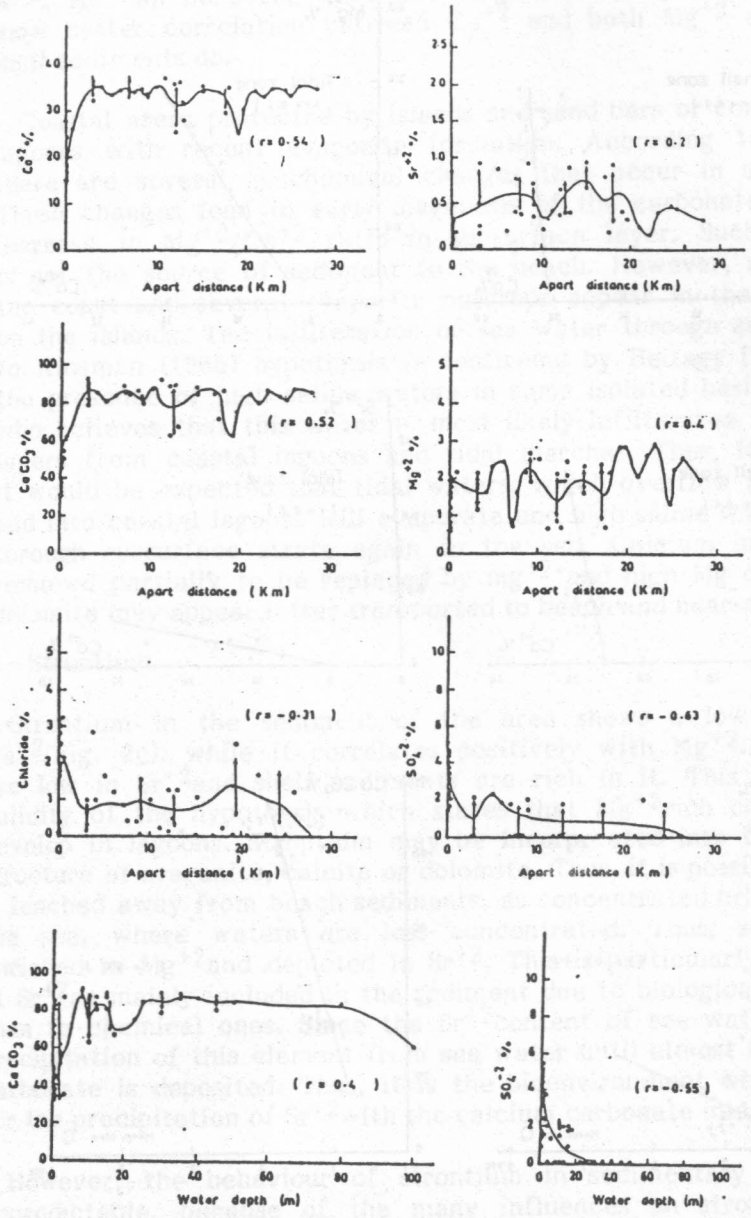


Fig. (2, a)
The relation between the geochemical parameters of
Recent sediments off Ghardaga area.



(Fig. 2, b)

The relation between the geochemical parameters of Recent sediments off Ghardaga area.

In the sediments of Al-Ghardaqa, the average strontium content is 0.43%, which may be compared with that of reefal sediments of Al-Ghardaqa, which is (0.40%), as given by El-Sayed (1984). The sediments from the supratidal zone and the intertidal zone do not show strong correlation with calcium, while sediments from the shelf area show a relatively higher correlation, (Fig. 2a). This may be explained as due to the effect of the diversity of sources of calcium bearing carbonates to the shore zone. It may also be an indication of diagenetic processes acting on the sediment due to change in elemental composition of sea water, via high evaporation and concentration of salt content in the tidal flats and lagoons near the shore.

The Sr^{+2}/Ca^{+2} ratio for the sediments in the tidal zone ranges between 0.10 and 1.56 with an average 0.5; while the shelf sediments have a Sr^{+2}/Ca^{+2} ratio with an average 0.61. This may be compared to the Sr^{+2}/Ca^{+2} atomic ratio of 0.71 given by Turekian, (1960).

3 - Sodium and Potassium:

In the geochemical cycle, Na^{+} and K^{+} tend to become separated during weathering and deposition processes (Rankama and Sahama, 1950). Whereas, igneous rocks contain roughly comparable amounts of Na^{+} and K^{+} , marine sediments, particularly pelagic sediments, contain twice as much K_2O as Na_2O , (Chester, 1965).

In deep sea sediments Na^{+} and K^{+} are mainly located in clay, but may also be present in other mineral phases, such as K-feldspars and alkali-feldspars, (Hirst, 1962a). Because of the almost complete absence of such minerals in the sediment of the area, it is likely that Na^{+} and K^{+} are present as separate mineral phases or may be associated with the major mineral components (i.e. carbonate minerals).

The origin of K^{+} and Na^{+} in the investigated sediments is the sea water, from which the both elements are largely precipitated in areas where almost complete dryness occurs, in the spray zone. However, the Na^{+} / K^{+} ratio in the sediments shows values still much lower than the ratio of the two elements in sea water.

Potassium, on the other hand seems to be mainly concentrated in the nearshore areas that contain the highest amount of detrital materials.

During the evaporation of sea water, Na^{+} will start to precipitate, when the solution reaches 0.11 of its original weight, while K^{+} will precipitate when the solution reaches 0.016 of the original weight. Thus, it is expected that Na^{+} will be much more abundant than K^{+} .

According to Shearman (1963), halite occurs as ephemeral crusts on the surface of the sabkha. This surface crust of halite may be removed by high

winds, rain forces, tides or it may be infiltrated down and drained as brines into the sulphate sediments.

The gradual increase in the Na^+/K^+ ratios from 1.9 in the tidal zone to 3.4 in the shelf sediments, may indicate the effect of the transportation and the dissolution on K^+ -bearing mineralized sediments.

4 - Sulphate and Chloride:

Tidal sediments on the average have a $\text{Cl}^- / \text{SO}_4^{-2}$ ratio of 0.84, while shelf sediments have a ratio of 0.24. Both elements had no apparent origin other than precipitation from sea water. Gypsum was present in these samples. It is known that gypsum starts to separate from sea water when the solution is reduced to 25% of original volume, i.e., far before halite starts to precipitate (vide supra). Thus, although Cl^- is much more abundant than SO_4^{-2} in sea water, it is the stability of the mineral phase in sea water that determines the concentration of each element in the sediment. The $\text{Na}^+ / \text{Cl}^-$ mole ratio in the present sediment is 0.95, which is closer to the mole ratio of the same elements in sea water, which is 0.92 (Culkin, 1965). This may favour the idea that the area is a region of evaporite formation, particularly the peripheral and tidal lagoon. However, during transportation, several components are lost to sea water again.

Chloride does not correlate well with distance from shore, (Fig. 2b). The low correlation could be due to the effect of islands and coral formations, where new chloride-bearing components are added. On the contrary, sulphate correlates negatively with depth ($r = 0.63$), since sulphate-bearing minerals are mainly formed in shallow water and lagoon and constitute stable and sparingly soluble minerals, i.e. gypsum that will not be easily transported by water to new depths.

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