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Nature and Composition of the Various Coastal Landforms, Tobruk city, NE Libya

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Abstract: The present work focuses on the mineralogical composition of the coastal landforms exposed along Tobruk shore zone. Nature and composition of these sub-environments help in recognizing the processes that shaped the present coast and supplied the sediments to the beach. Study such narrow and rugged coastal zone is characterized by a variety of landforms for shore, marine, aeolian, and wadi processes. Comparison of the bulk mineralogy between the different landforms proved great differences either by the dominance of the carbonate minerals (high Mg-calcite, low Mg-calcite, aragonite and dolomite) or the detrital constituents (quartz, feldspar and clay minerals) due to the sedimentary processes prevailed

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1.Introduction

Tobruk is a coastal city lies on the Mediterranean Sea in the North Eastern part of Libya, far from the Egyptian border by a distance of 150 Km. The coastal plain of Tobruk city is generally rugged, extends to more steeply rising ground that ultimately becomes an escarpment. Rugged rocky cliffs with different Wadis' mouths are the most common geomorphologic features characterized the coastal zone of Tobruk city. These rocky cliffs constitute what is called Al Dafna plateau forming the eastern border between Libya and Egypt (Fig. 1)

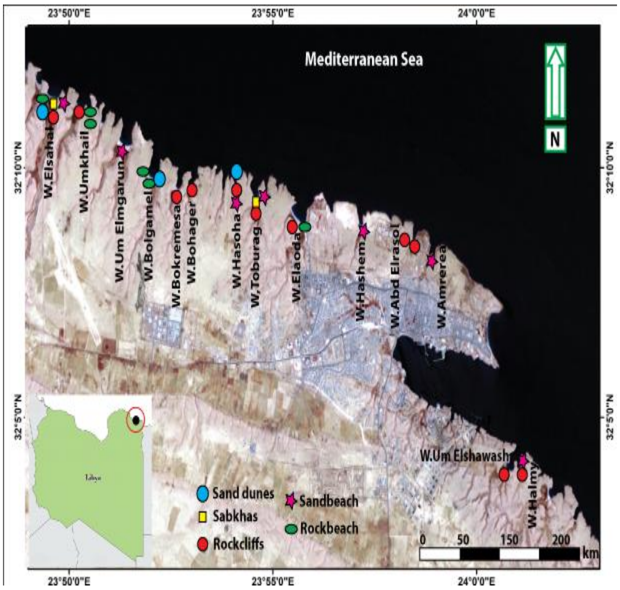

Fig. (1): Location and the coastal land forms of the study area of Tobruk.

Our background knowledge about the Mediterranean Sea coastal zone of Libya is not sufficient and there are many gaps that should be filled through this work.

The coastline stretches from Wadi Elsahal in the east to Wadi Toburag in the west. Sand beaches, sand dunes and sabkhas are developed in front of Wadi mouths in addition to Tobruk bay. The North Eastern coastal area of Libya is subdivided into two geomorphic units; the northern scarped terrain (Al Dafna plateau) is marked by the existence of many prominent scarps running in an ESE-WNW direction while the southern part of Al Bardia area is flat, monotonous plain [1-3]. Limited landforms including sabkhas, rock cliffs, beachrocks, sand beaches and sand dunes are the most characteristics geomorphologic unites studied in the present work.

2.Material and Methods

Thirty-seven samples were chosen from the different geomorphologic units along the shore zone of Tobruk including sabkhas, rock cliffs, beachrocks, and beach / coastal dunes. Sabkha sediments were sampled from the supratidal and intertidal flats at Wadis' mouths by inserting a small plastic tube into sabkha deposits and/or by dredging small trenches. Samples were dried and small portion of each sample was ground in an electrical mortar then the powder mounted in aluminium holders and analyzed by X-ray diffraction method for identification of the bulk minerology. Identification of minerals was based on the tables of key lines in X-ray powder diffraction patterns for minerals after Chen [4] and Chao [5].The height of the principal peak for each mineral present was measured and the relative percentages of each mineral were calculated according to Carver [6], Milliman [7] and Tucker [8], and then correlated with the data given automatically by the X-ray diffractometer. The clay fractions were separated from the sabkha sediments by sedimentation technique [9] to prepare oriented clay samples (untreated, glycolated and heated) according to Brown [10].

3 .Results and Discussion

1.1 Bulk mineralogy of sabkha deposits

Tobruk sabkha was studied in two sites; Wadi Elsahal and Wadi Toburag (Fig.1) where poorly developed intertidal and supratidal flat deposits occurred. In order to study the mineralogical composition of the sabkha sediments, ten trench and core samples were selected for analysis by XRD (Fig.2). Percentages of bulk minerals obtained are summarized in Table (1) and represented graphically in Fig. (3). It is found that the mineralogy of intertidal sediments is characterized by the dominance of terrigenous minerals; quartz, albite, microcline and kaolinite. While carbonate minerals included calcite and dolomite and occurred in moderate concentrations. Gypsum and halite were observed particularly in two samples with percentages varied from 2.85 to 12% for gypsum and 2.85% for halite. The bulk mineralogy of the intertidal sediments is consisted of mixed siliciclastic-carbonate minerals; quartz, calcite, feldspar, dolomite and gypsum, arranged in decreasing order of abundance. The bulk mineralogy detected in the supratidal sediments is composed mainly of prominent quartz with a subordinate amount of calcite, feldspar, gypsum and halite arranged in decreasing order of abundance. Role of eolian transportation is being relevant for transporting the weathered terrigenous materials from the nearby land.On the other hand, the supratidal sediments have composition dominated mainly by carbonate minerals; high Mg-calcite, calcite, aragonite and dolomite in addition to detrital quartz

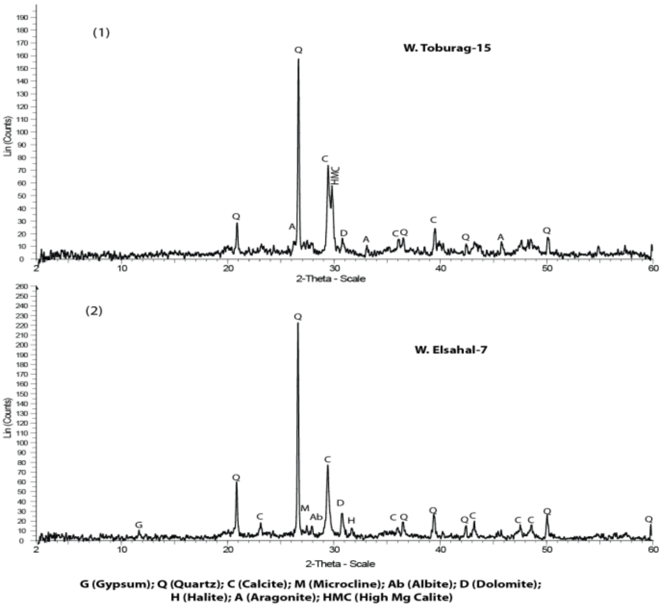

Fig. (2): Representative X-ray diffraction patterns for the bulk mineralogy of the intertidal (1) and supratidal (2) sabkha.

Table (1): Data of bulk mineralogy determined for Tobruk's sabkha deposits.

Sample No.	Depth (cm)	Location		Carbonate Minerals %				Evaporite Minerals %		Detrital Minerals %				
				l c i	c a	o m	g o	y p s	a l i t	a r	b i	o c	l i	r i
1	0-7	W. Elsahal	Intertidal Trench	20	-	5.7	-	2.85	2.85	62.8	2.85	2.85	-	-
3	10-16			22.3	-	5.2	-	-	-	34.8	11.6	20.3	-	5.8
6	28-35			19.4	-	5.8	-	12.0	-	42.6	12.1	8.1	-	-
7	0-11		Supratidal Core	23.6	27.4	8.5	12.5	-	-	28	-	-	-	-
9	22-35			21.8	20.7	8.5	25.1	-	-	23.9	-	-	-	-
10	0-4	W. Toburag	Intertidal Trench	24.3	-	5.4	-	8.1	-	54	5.4	2.7	-	-
13	14-18			33.3		6.6	-	2.2	-	48.8	2.2	4.4	2.2	-
15	22-25			13.8	-	3.4	-		-	75.8	3.4	3.4	-	-
16	0-15		Supratidal Core	19.35	-	-	-	3.22	3.22	64.5	3.22	6.45	-	-
18	30-40			8.1	-	-	-	-	2.4	81.3	4.1	4.1	-	-

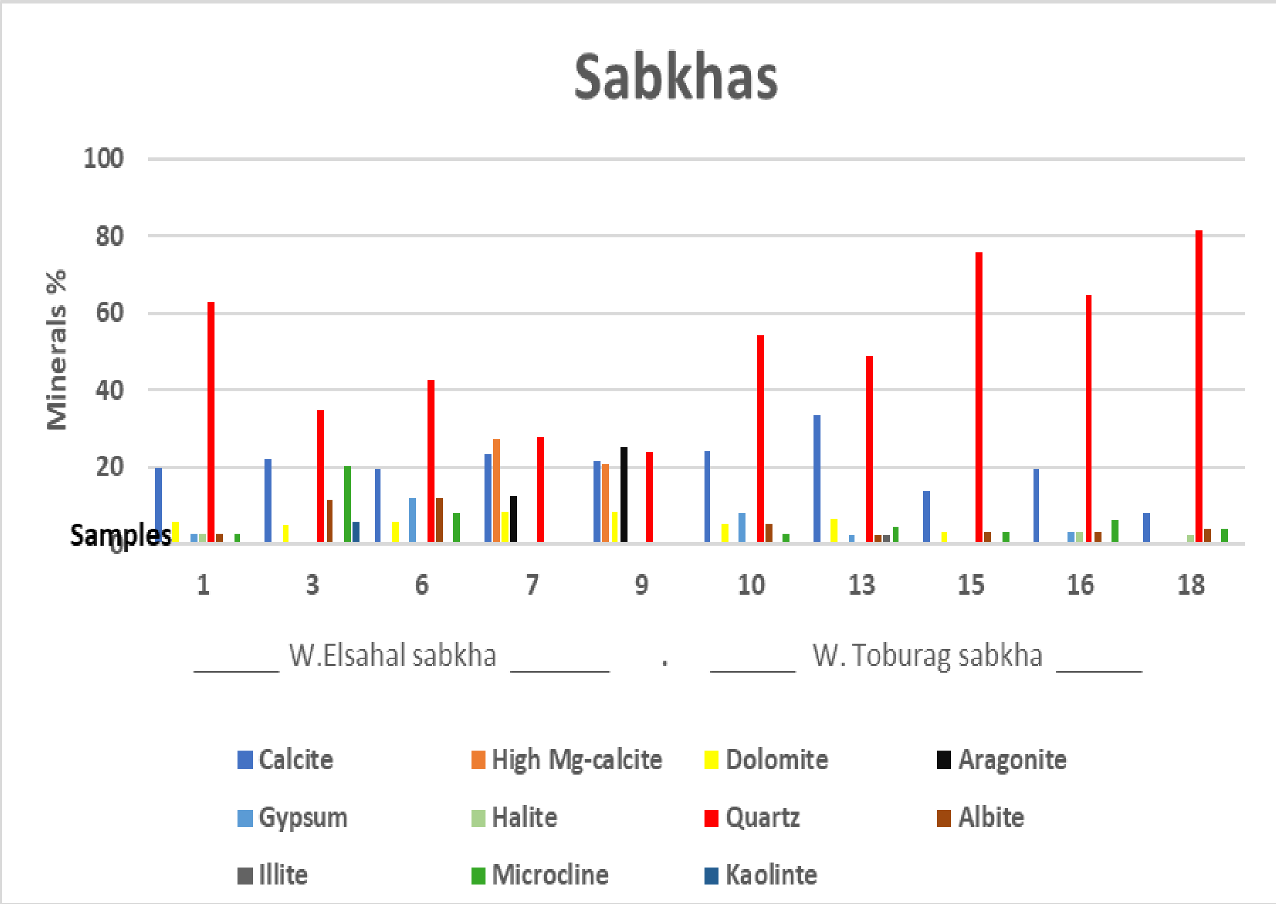

Fig. (3): Bar graph representation showing the relative percentages of the bulk minerals in the Wadi Elsahal and Wadi Toburag Sabkhas

Concerning the identified carbonate minerals of the studied sabkha deposits, it was noticed that calcite and dolomite are indicated in both intertidal and supratidal deposits, while high Mg-calcite and aragonite are dominated particularly in the supratidal deposits in Wadi Elsahal sabkha. The existence of these minerals is related to the invasion of seawater to the mouth of the Wadi during high tides. Dolomite is identified by the main peak (2Ө 30.9°) in low amounts fluctuated between 3.4 and 8.5%. Dolomitization was associated with lithification and took place at a depth similar to that present in Abu Dhabi, UAE [11-13].

Quartz predominates over feldspar (albite and microcline) and exists in high amounts in both studied sabkhas indicating the continuous influx of detrital components through weathering of the neighboring land mass.

Correlating the displayed mineral constituents in both studied sabkha from Tobruk coastal zone with those identified in Al-Dafna coastal area [14], indicates a distinct composition in the occurrence of carbonate minerals. High Mg-calcite and aragonite are noted in Tobruk sabkha in addition to the detrital quartz. Shaheen [15] examined the coastal sabkha in some localities at the north-western Mediterranean coast and found that gypsum and halite constitute the main evaporite minerals besides carbonate minerals; calcite, aragonite, quartz and feldspar.

3.1.1 XRD of clay minerals in sabkha deposits

In general, the detrital clay minerals indicate the kind of source rocks and are slightly modified by the diagenetic processes [16]. The weathering and alteration of silicate minerals generally produced neo-formed minerals while transported clay minerals resulted from weathering and alteration of pre-existing clay minerals [17]. Millot [18] related the existence of clay minerals in the sediments to the source materials, environments of deposition and deep burial diagenesis. In the studied sabkha deposits, the identified clay minerals are consisted of kaolinite and illite (Fig.4). Kaolinite mineral was detected in all analyzed samples based on its characteristic peaks at d-spacing of 7.03A° (001).

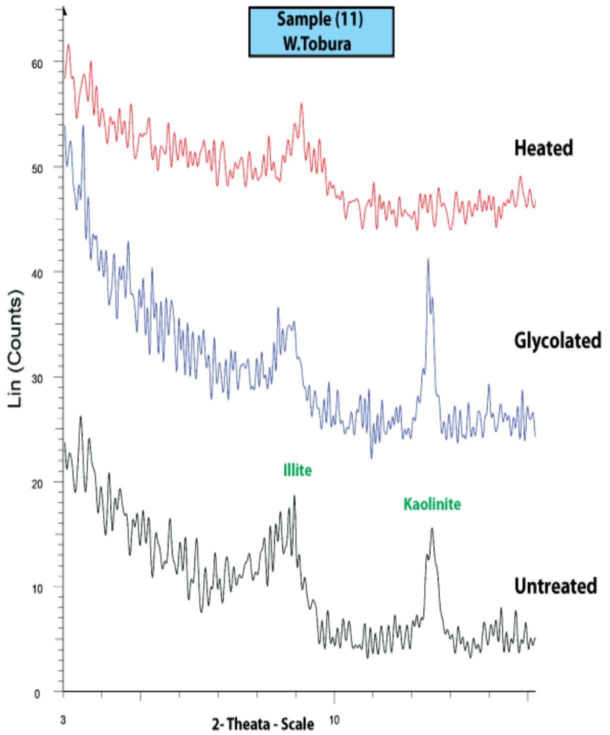

Fig. (4): Representative X-ray diffraction patterns of the clay minerals identified in the sabkha deposits. Table (٢) Relative percentages of clay minerals determined in sabkha deposits

S. No	Depth (cm)	Sabkha		Kaolinite	Illite
1	0-7	W. Elsahal	Intertidal	59	41
3	10-16			50	50
6	28-35			24	76
11	4-8	W. Toburag		41	59
13	14-18			60	40
15	22-25			37	63

Kaolinite content varied between 24 and 60%. Illite mineral was identified by its characteristic 10 Å peak and it occurs in content ranging from 40 to 76%. Kaolinite can be produced by weathering and soil formations of all rocks, where its formation requires an environment of strong leaching. Such conditions are generally encountered in marsh environment. Thus, kaolinite is a typical mineral of continental weathering [18]. It was not affected by transportation so that when it enters the basin of deposition, its composition and amount remain the same [19]. While illite was considered the direct product of chemical weathering under arid, semi-arid and alkaline soil conditions [20] .When correlating the clay minerals in Tobruk sabkha with other studies, it was found that kaolinite and illite are the essential clay minerals detected at Melfa and Ein Zohra in north-western frontier of Egypt [21]. Also, illite and kaolinite are the main clay minerals found in the pink limestone rocks at north western coastal zone of Egypt [22].

3.2 Bulk mineralogy of the exposed rock cliffs

Calcite is the most prevalent and prominent carbonate mineral in all analyzed coastal cliffs (Fig.5). However, high Mg-calcite and aragonite are dominated in the coastal cliff of Wadi El aoda ((Fig.5). Dolomite occurred with amount ranging from 3.5 to 22.2% (Fig. 6). In general, calcite is the stable carbonate mineral appears in various environments, while aragonite and high-magnesium calcite usually exist in the temperate, shallow marine environments by direct precipitation from seawater or from skeletons of different organisms [23, 24 and 25]. It is obvious that sedimentation of the Tobruk coastal area is marked by marine transgression with deposition in shallow marine shelf basin controlled by calcite. The maximum content of quartz was 8.3% in Wadi Abd El rasol.

3.3 Bulk mineralogy of beachrocks

Beachrocks occur on Tobruk beach in the intertidal zone as bars lie scattered here and there on the beach. It exists in the form of segments

inclined toward the sea with a slope approximately equal to that of the foreshore. It is located beside the raised carbonate cliffs near the coastline with thickness approximately 20 to 30 cm. In general, the beachrock in the area is patchy and occasionally distributed. Textural characteristics of the beachrocks are like those of the beach sediments of the neighboring foreshore where beach sediments undergone marine processes of cementation and have been developed into beachrocks.

The beachrocks are illustrated by Krauss and Galloway [26], Russell [27] and Alexandersson [28]. They are mainly carbonate but may have considerable or even dominant siliciclastic components. Also, they can develop as is evidenced by the inclusion of man-made substances such as cans and World War II debris [29]. The grains in beachrocks are identical to those of adjacent, unlithified beach sediments, consisting of foraminifera, bivalve, gastropods, red algae and coral fragments.

Moreover, the grain size varies from fine to very coarse sand [30].

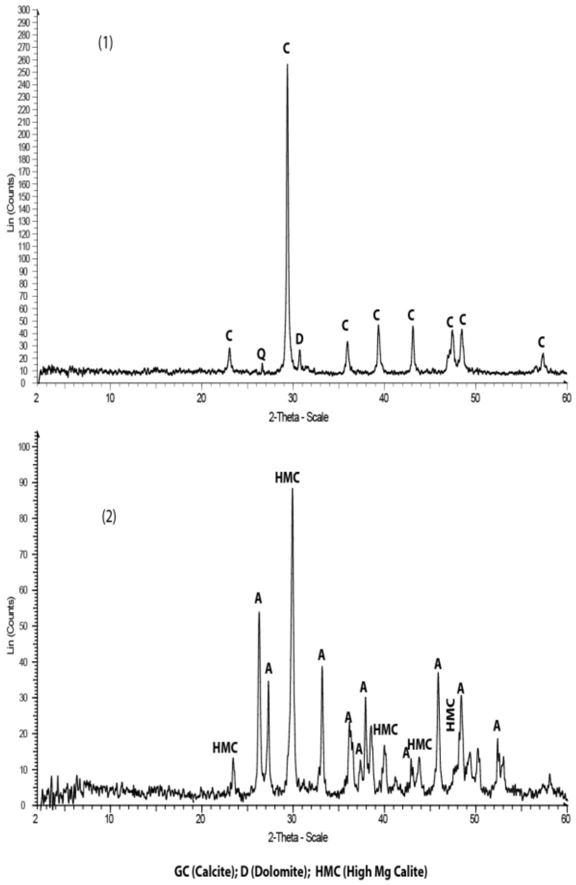

Fig. (5): Representative X-ray diffraction patterns showing the bulk mineral components identified in rock cliffs at Wadi Elsahal (1) and Wadi El aoda (2)

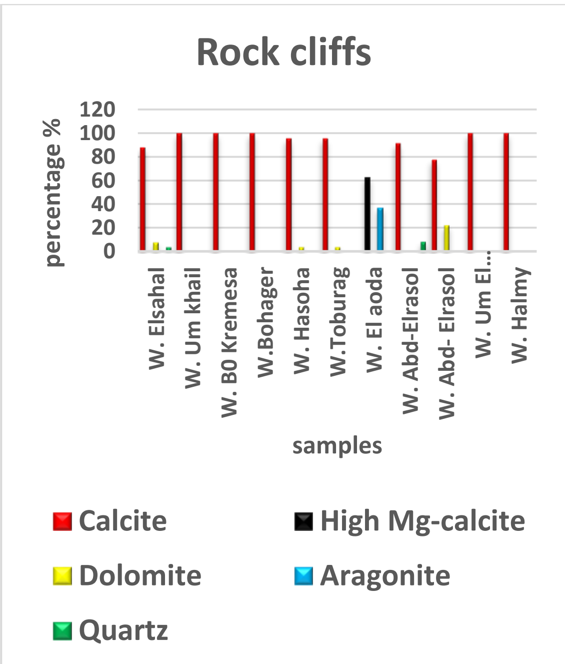

Fig. (6): Bar graph representation showing the relative percentages of the bulk minerals in the different rock cliffs

The surfaces of beachrocks grade from yellow in the lower intertidal zone to black in the upper intertidal zone, a color zonation that has been applied to the types of algae that colony the beachrocks [31]. The surfaces of beachrocks are also pitted owing to the grazing of chitons and gastropods that fed upon algae. Larger pits are probably solution features. They are commonly filled with younger sediments.

Several theories have been applied to demonstrate the origin of beachrocks cement, including precipitation at the water table, precipitation from mixed meteoric water and marine waters, and precipitation directly from seawater [30]. Also, there are three processes of beachrock formation have been proposed [32]: a) a purely physico-chemical precipitation through evaporation of seawater and CO_2 loss, especially at times of low tide, b) a biochemical precipitation through decomposition of organic matter, chiefly algae and c) precipitation from fresh ground water or seawater mixing with fresh water. Beachrocks are even composed in groundwater seeps along the top of beach zones in lake environments [32].

Nature and composition of the beachrocks have been assessed from analysis of six samples chosen to represent the carbonate beachrocks exposed on the Tobruk beach near the mouths of four Wadis; Elsahal, Um khail, Bolgamel and El aoda. X-ray diffraction patterns of beachrocks are shown in Figure (7). While results of X-ray diffraction analysis are summarized in Figure (8).

Distribution of mineral components in the analyzed beachrocks proved that the stable calcite is the dominant mineral in most samples with content ranging between 11.6 and 100%. While high Mg-calcite is the second abundant carbonate mineral existed in values varying between 25.21 and 71.1%. Dolomite is less common and occurred particularly in two samples with maximum content of 28.6% in Wadi Um khail. Aragonite is the second recent carbonate mineral occurred with content reaches up to 25.5%.

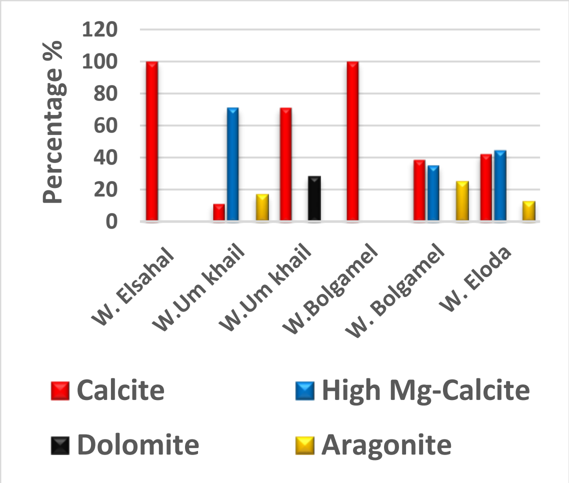

Fig. (7): Bar graph representation showing the relative percentages of the bulk minerals in the different beachrocks.

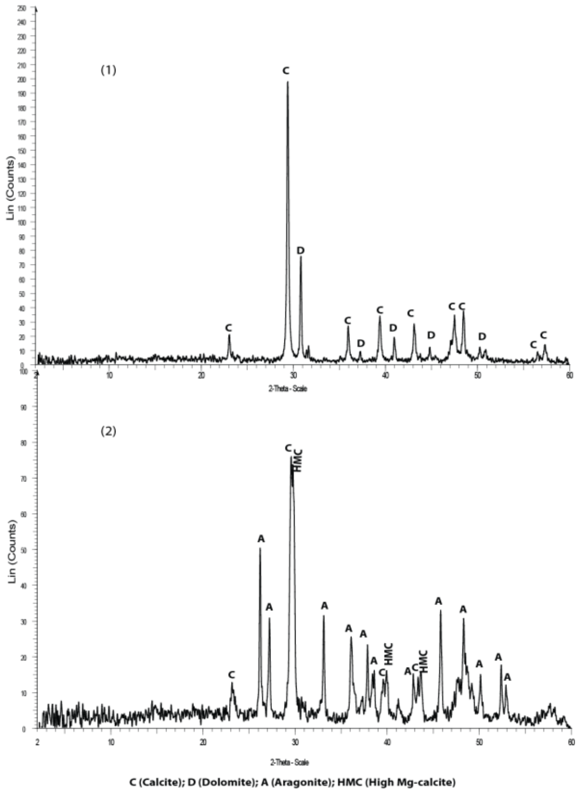

Fig. (8): Representative X-ray diffraction patterns showing the bulk mineral components

identified in beachrocks in Wadi Um khail (1) and Wadi Bolgamel (2)

3.4 Bulk mineralogy of the sand beach sands

Seven beach samples were collected at the mouths of the different wads. Their powdered samples are subjected to X-ray diffraction analysis. Results obtained revealed that Mg-calcite, calcite, and aragonite are the most common carbonate minerals while dolomite is uncommon and occurred in minor amounts (Table 3, Figs. 9&10). The detrital quartz mineral was identified from the X-ray charts at d-spacing of 4.27 Å and 3.343 Å. Quartz occurred with minor contents in most samples except at W. Um Elmgarun, W. Elhwauat and W. Toburag.

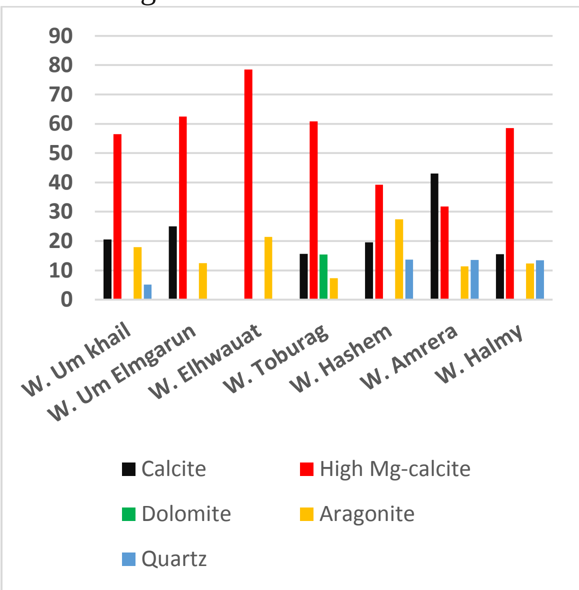

Fig. (9): Bar graph representation showing the relative percentages of the bulk minerals in the different beache sands.

Table (3): Data of bulk mineralogy for the beache sands

S.No	Location	Carbonate minerals				Detrital minerals
		Calcite (%)	**High Mg-calcite %**	**Dolomite (%)**	**Aragonite (%)**	**Quartz (%)**
2	W. Um khail	20.5	56.4	-	17.9	5.1
4	W. Um Elmgarun	25	62.5	-	12.5	-
10	W. Elhwauat	-	78.5	-	21.4	-
12	W. Toburag	15.6	60.8	15.4	7.3	-
14	W. Hashem	19.6	39.2	-	27.4	13.7
16	W. Amrera	43	31.8	-	11.4	13.6
18	W. Halmy	15.5	58.5	-	12.4	13.5

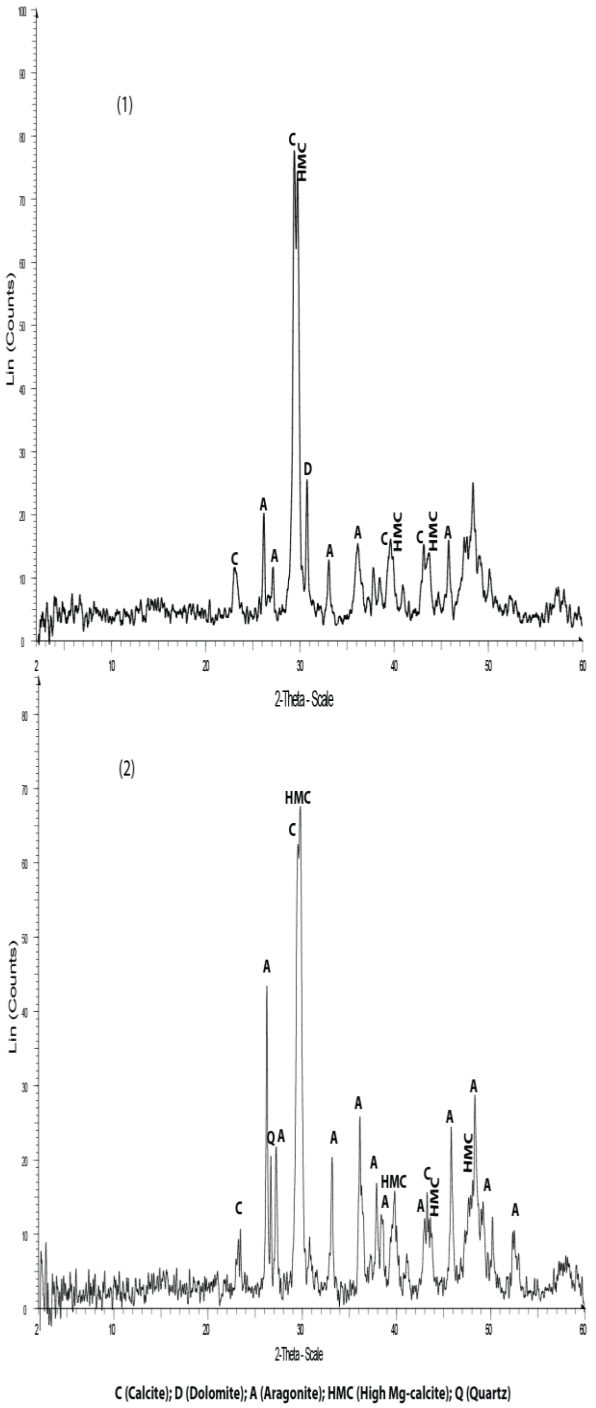

Fig. (10): Representative X-ray diffraction patterns showing the bulk mineral components identified in beache sands in Wadi Toburag (1) and Wadi Hashem (2)

3.5 Bulk mineralogy of sand dunes:

Sand dune deposits occur either near the mouth of Wadi Elsahal as small sand hummock or exist as fore - dune on the backshore zone parallel to the shoreline as Wadi Bolgamel. In some cases, small vegetated dunes occur as nabka formed in the course of Wadi Hasoha. Three samples were chosen from the various types of sand dunes. Their powder were analyzed by X-ray diffraction in order to determine the bulk mineral components.

High Mg- calcite is the dominant carbonate mineral, its values ranged between 34.8 and 76.9% (Figs. 11& 12). Calcite, the stable carbonate mineral, is the second prominent carbonate appears with a maximum value equals 46.5%, whereas aragonite varies from 9.3 to 23.1%. The detrital minerals identified in the studied sand dune deposits are represented only by quartz.

Comparison of average mineral constituents determined in the different sub-environments formed on the Tobruk coastal zone is demonstrated in Figure (13). Sigificant differences with some similarities in the bulk mineralogy between the studied different subenvironments have been achieved:

1- There is a big difference in bulk mineralogy between sabkha deposits of Wadi Toburag and Wadi Elsahal.

2- The beachrocks have high content of high-Mg calcite, aragonite and dolomite than the sea cliffs.

3- There is a similar composition between sand beaches and sand dunes where carbonate minerals predominated.

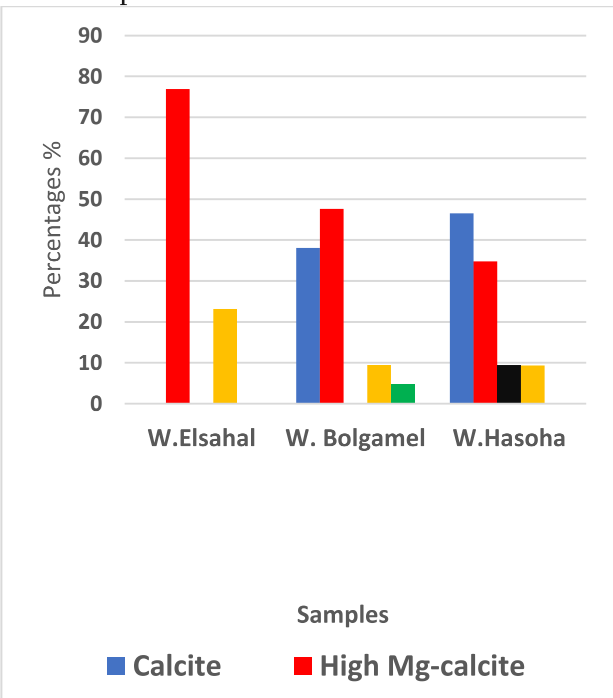

Fig. (11): Bar graph representation showing the relative percentages of the bulk minerals in the different sand dunes.

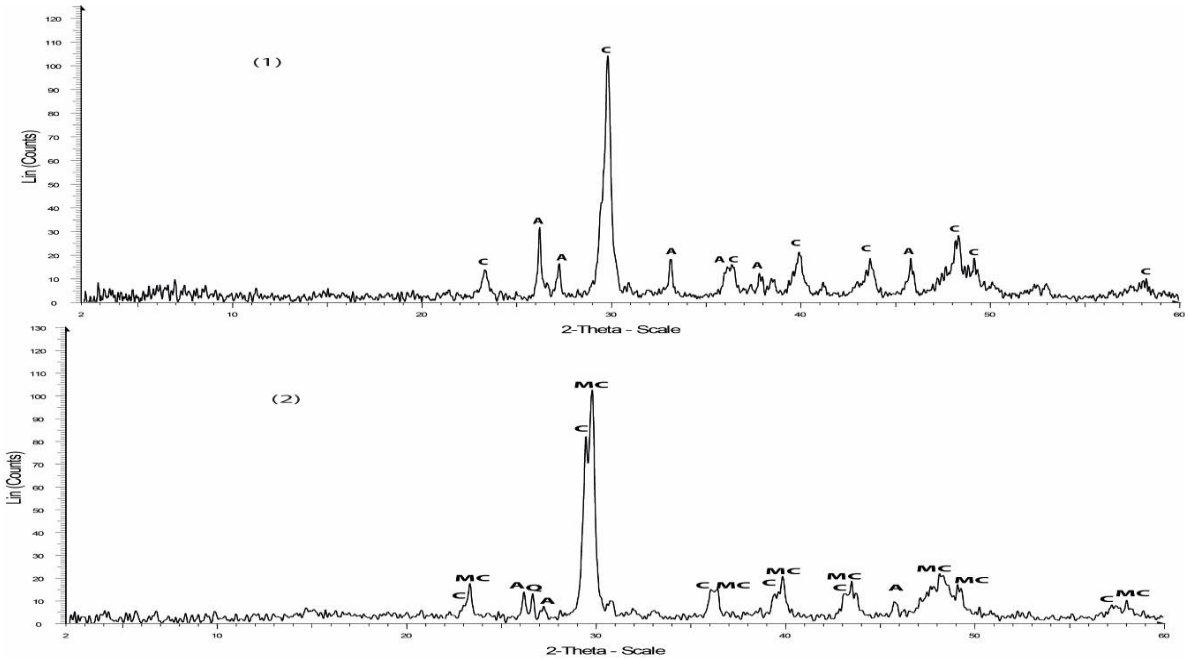

Fig. (12): Representative X-ray diffraction patterns showing the bulk mineral components identified in sand dunes in Elsahal (1) and Wadi Bolgamel (2)

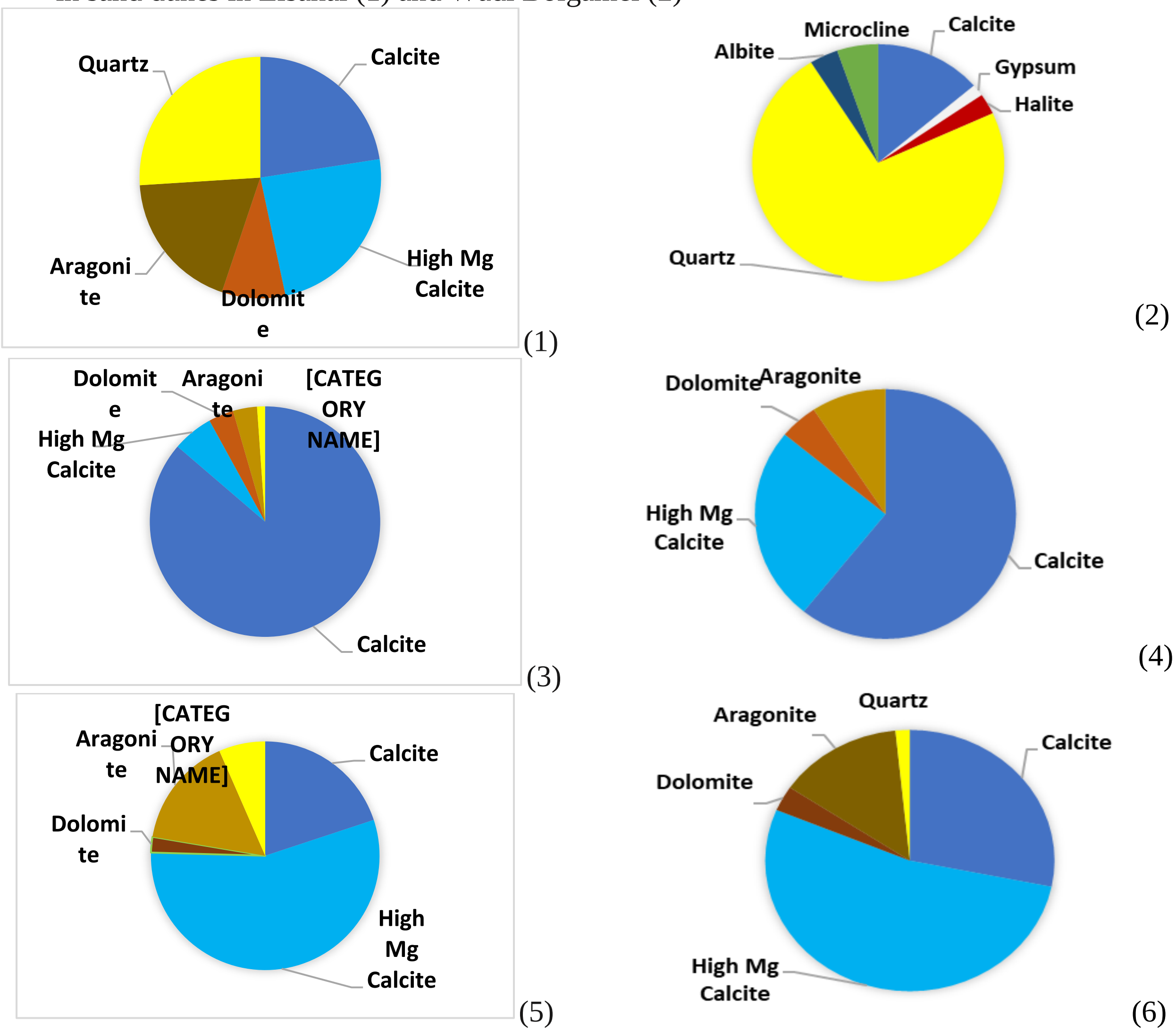

Fig. 13: Pie diagrams showing the average percentages of the bulk minerals in w. Elsahal supratidal sabkhas (1), w. Toburag supratidal sabkha (2), the rock cliffs (3), beachrocks (4), sand beaches (5), and sand dunes (6)

4. Conclusions

Nature and composition of sediments in the shore zone, source rocks, and transportation history are the fundamental tasks required in order to shed light on the conditions of sedimentation.

The coastal plain of Tobruk is bordered by an elevated coastal plain, which is an emergent part of the continental shelf. Beaches in these areas are narrow, poorly developed, and rocky; often lack lateral continuity and was deposited during a major transgression of the Mediterranean Sea. The following points can be concluded:

1. Calcite is the predominant carbonate mineral in sea rock cliffs indicating the ancient deposition in shelf area.
2. High Mg-calcite is dominated over aragonite and dolomite, distinguishing the sand beaches and indicating recent deposition from sea water.
3. The association of high Mg-calcite, aragonite and dolomite in beachrocks indicate that their origin is from beach sands.
4. Detrital quartz and feldspar are dominated in the supratidal sabkha of Wadi Toburag indicating transportation of sediments by wind action from the neighboring continental high land. Mixed carbonate and detrital minerals have distinguished Wadi Elsahal sabkha and pointed to the precipitation from sea water at high tide in addition to the wind transportation.
5. The mineralogical composition of the sand dunes is very significant and reflects the dominance of carbonate minerals, high Mg-calcite, calcite, aragonite and dolomite over the detrital minerals; indicating their transportation from the neighboring beach sands.

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