WIND AND ITS IMPACT ON THE GEOMORPHOLOGICAL APPEARANCE ON MUSANDAM PENINSULA-SULTANATE OF OMAN

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Key words: coastal sand dunes, Rock Chimney, Musandam Peninsula, Arabian Gulf,

Abstract:

Musandam peninsula lies at the entrance of The Arabian Gulf. The area affected by the tilting subsidence that had happened in the Tertiary and are still happening now (Falcon, N.L., 1973). The climate impact on the area's surface. The old climate effect on the drainage networks. The current climate affecting the genesis of the geomorphological phenomena resulting from weathering with all its types.

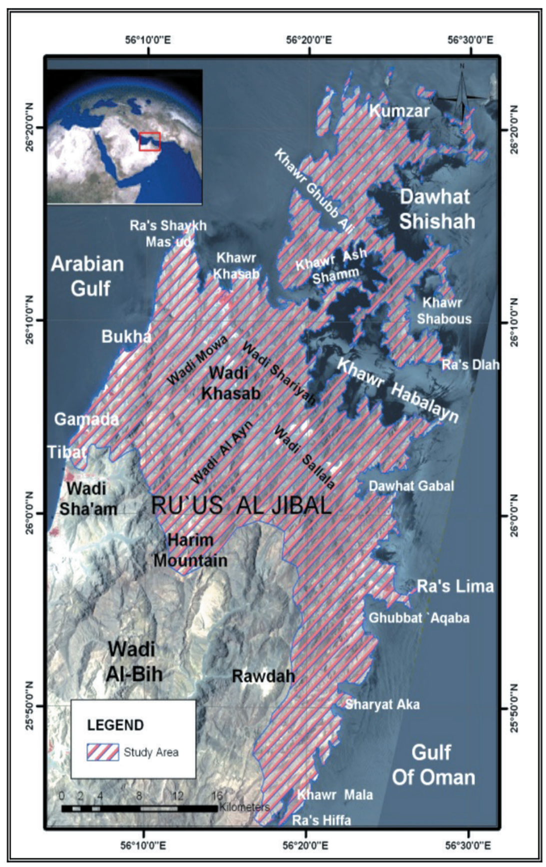
This study throwing light on Wind as one of the current climate elements formed the peninsula surface. Study the geomorphological phenomena resulting from wind. Especially rock chimney as wind erosion feature. Coastal sand dunes and nabkha . Study the size and mineral composition of sand deposit in an attempt to identify its sources.

Introduction:

Musandam Peninsula forms a marine head separating between The Gulf of Oman, eastward and The Arabian Gulf , westward, sloping from Harem Mountain, southward until reaching Khasab Inlet northward. In fact, Musandam Peninsula is regarded as a tectonically active area since it is subject to Tilting Subsidence Movement in the direction of Strait of Hormuz, and this movement is still active owing to the moving of Arab peninsula plate tectonic (Falcon, N.L., 1971-1972):, Its collision and subsidence below the Iranian Plate Tectonic, resulting in the marine submersion of some parts of the Arab peninsula surface This is besides forming the submerged coasts and a number of intents that formulate the area coast(Torab , M 2002).

Location:

Musandam peninsula lies at the entrance of The Arabian Gulf, extending between two latitudes of 25º 40′ and 26º 30′ to the north, and between two longitudes of 56º 05′ and 56º 30′ to the east. limited by The Gulf of Oman from the east and by The Arabian Gulf from the west. It overlooks Strait of Hormuz northerly, but the southern watershed separating between Basins of Wadi Tibet, Wadi Khasab, Wadi Al-Wahiya and Mala which slopes towards west, north and east, on one hand, and between Wadi Sha'am and Al-Bih, sloping towards south and west, on the other one this line is considered as a southern limit of the study area. Therefore, Musandam peninsula represents the maximum extension for Sultanate of Oman to the north, and its area is about 1000 square kilometers. Figure (1)



Source: - Topographic maps of scale 1:100000.
- Landsat, ETM+. Image with 14 m, resolution.

Fig. (1): The location of the study area

Goals and Objectives:

Clarification of the role played by the wind as one of current climate element formed the peninsula surface and study of coastal sand dunes as phenomenon resulting from the reaction between them. Investigate the sand deposit sources.

Methods:

This work uses some methods such as:

- The Cartographical and Quantitative Analysis.
- Land Sat ETM+, 9 Bands with a resolution of 14m (2005) were used and analyzed in order to take some spectral signature for sand dunes.
- Field work helps in measuring the cross sectors of the sand dunes and nabkha studied. All notes, field measurements a number of samples collected in order to be analyzed, knowing the results and drawing the necessary diagrams by computer.
- The laboratory Analyses were performed, dealing with the grain sizes of deposits and their Mineral properties, of the samples collected during the field study, from alluvial terraces and coastal sand dunes. So analysis was done at The Central Laboratory at The Desert Research Centre in Cairo.(2009)
- But the microscopic analysis of micro grain deposits was done, by using the Electronic Scanner at Faculty of Science, Alexandria University in order to examine the deposit granules and record any micro features on their surfaces. (2010)
- Wind shares in forming some parts of the study area as it blows in all directions, most of the year days. So we can observe the following facts, through studying table (1) and fig. (2):

Wind blows from all directions, as in Khasab, those directions are north, north east, and north west, especially in winter and this may be attributed to the location of the area, as part of the Arabian Gulf, exposed under the influence of the Siberian high in the east and the high stretching from the Atlantic Ocean from the West and created low secondary shallow over the Arabian Gulf as the source of the wind prevailing and affecting the area.

As a matter of fact, the south east wind blows increasingly, from the direction (150 degrees) at Khasab, especially at the latest of autumn and the beginning of winter, it may be due

Table (1): Speed and direction of wind at both Meteorological stations of Khasab and Dibba during the period of (1993-2003).

Direction	Khasab		Dibba	
	Km / h	%	Km / h	%
0	8.1	10.2	4.6	6.4
30	8.5	7.8	7.2	17.9
60	10.1	8.4	10.5	30.6
90	14.3	7.2	7.3	3.4
120	16.5	8.3	5.2	1.5
150	9.7	19.0	5.2	1.4
180	8.7	4.3	13.2	4.6
210	13.2	7.5	11.4	21.4
240	12.3	5.2	13.0	7.6
270	12.8	5.9	16.8	2.8
300	8.6	6.6	6.9	1.1
330	8.6	9.7	3.9	1.3
Total	131.3	100.0	105.2	100.0
Calm		-		-
Variable		-		-
Prevailing Dir.	150		60	
Mean Speed (Knots)	10.9		8.8	
Gust Speed (Knots)	85.2		130.4	

Source: Climatic Data Form the Civil Aviation and Meteorology
Source : Table (1)

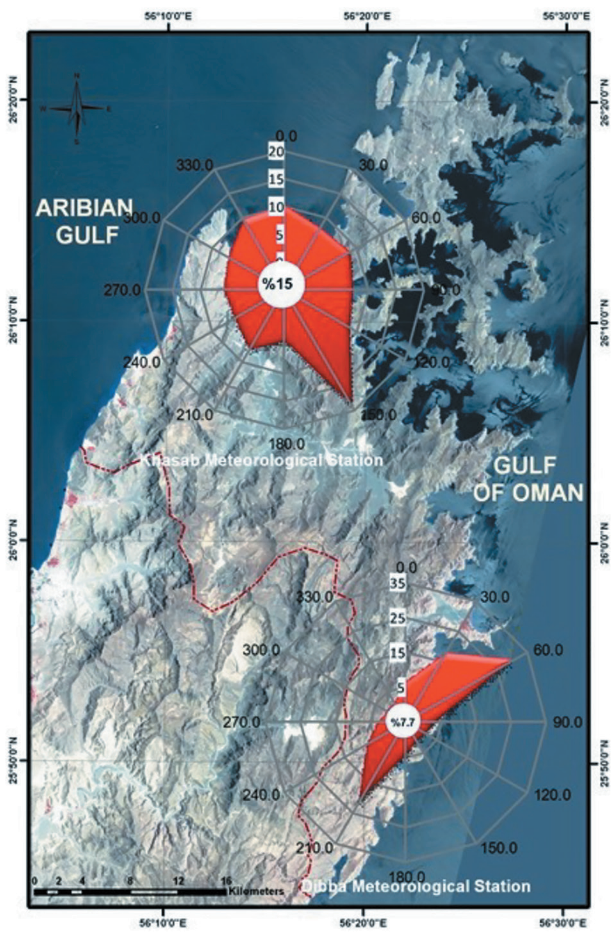


Fig. (2) – Directions of Wind at the Meteorological Station of both Khasab and Dibba, During the (1993-2003).

to the blowing of the cold marine polar air mass from the North Atlantic. But the south east active wind, creating some sandstorms. At the same time, wind blows increasingly at Dibba region from the north east direction (60 degrees) as wind blows at the arrival of spring and the beginning of summer but this may be due to the existence of seasonal Sudan low pressure, west south of the area, which unite with the seasonal Indian low pressure in Summer, forming an atmospheric low pressure that includes the study area, therefore, wind come from the northeast where the atmospheric high pressure, owing to the low temperature in Siberia

- The rate of calm days, reaches 11.5% at Khasab and 15.4% at Dibba.

- Wind blows at the study area at the speed that does not exceed 18.5 kilometers an hour while the area is listed according to Beaufort classification of wind comprising twelve classes between the first and the fourth class (Godah, 2002). That is, wind ranges between Light air and Moderate breezeو while the average of the wind speed is 10.8 kilometers an hour at Khasab and 9.2 kilometers an hour at Dibba. So it lies, according to Beaufort classification of wind, at the second class under the title of the Light breeze.

- The speed of wind at Khasab sometimes reach 85.2 kilometers an hour during the months of winter and wind is classified as of the tenth class and called Storm, and its strength can increase reaching the twelfth class, the top of Beaufort scale, known as hurricane as the speed of wind at Dibba reaches 130.4 kilometers an hour and this may be due to the fact that Dibba region faces The Gulf of Oman and the Indian Ocean in the domain of forming the violent hurricanes.

- Accordingly, the strength and importance of wind are clear regarding the formation of the study area surface whose effects were observed at the field study concerning forming a number of phenomena among which are:

Sand Dunes:

They are regarded as an obvious print of the wind action at the study area and characterized as follows:

- Coastal sand dunes extend from Ra's El-Jady in the north, to Wadi Tibat in the south, at the distance estimated of approximately 20 kilometers deepening in the direction of the dry vally for only one kilometers, owing to the existence of the coastal heights parallel to the coastal line. So these sand dunes overlook the Gulf water directly, forming part of its front and back shores and re-forming the foot margins of those dunes.

- The coastal sand dunes existence is due to the west south wind blowing from the

Arabian Peninsula, at the speed average of 13.9 kilometers an hour and which can reach 130 kilometers an hour during stormy days. This wind carries deposits from the near shores dried by the solar radiation action.

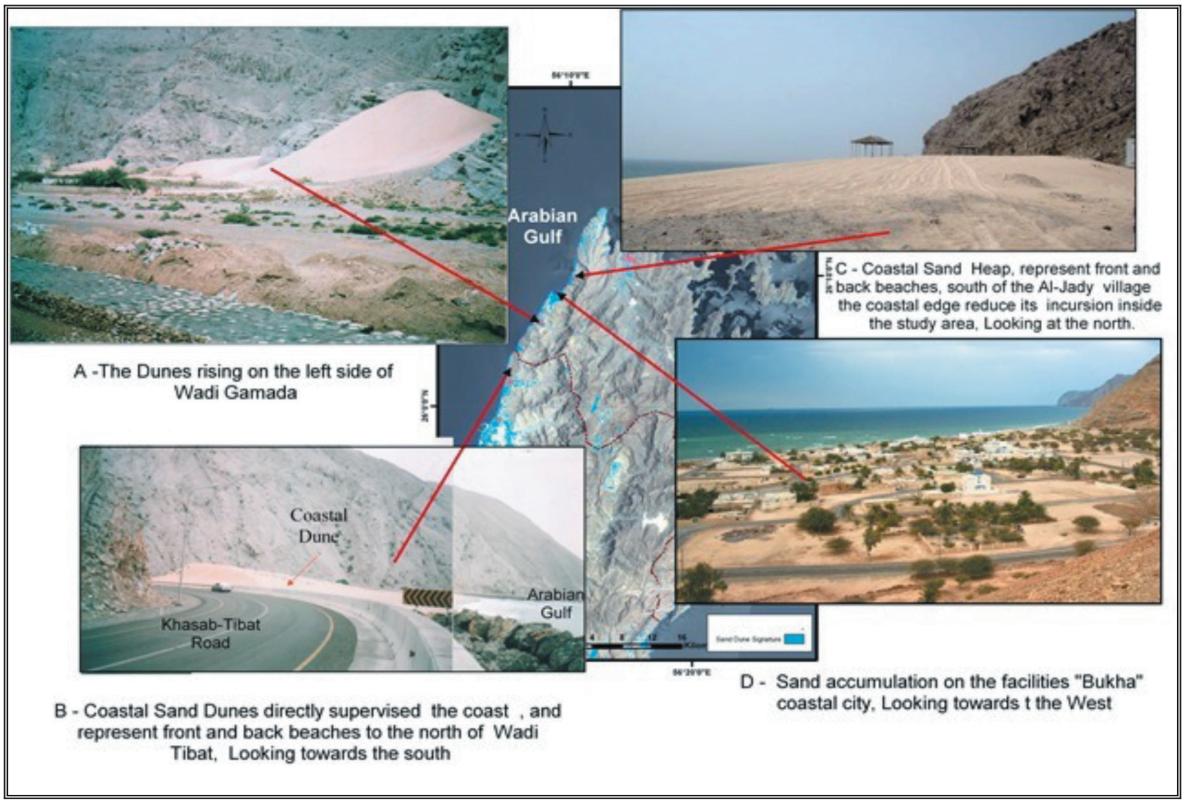
- Sand dunes take the shape of sand heaps having tops and extend from the south west to the north east where they are faced by the coastal edge between Ra's Al-Jady in the north and Bukha in the south, leading to the sand creeping on the coastal road and on the establishments near it. Some of those dunes accumulated on the coastal ridges , especially at the area between Gamada north ward and Tibat southward as wind lays its, then it serves to raise deposits from the dune foot to its top Fig.(3).

Table (2), shows some of the characteristics of the coastal sand dunes of the study area, we observe that the lengths of dunes, range between 69.2 meters in front of Al-Jady village and 125.7 meters. At Tibat, having the average of 108.2 meters while the width of dunes ranges between 155.6 meters at Gamada and 326.7 meters, south of Gamada' at the average of 256.6 meters. The increase of length, width and the sloping of dunes are noticed when going southward, but this may be due to the excess of deposits made by the southern and western wind, south of the study area and due to the weak depositing towards north, with the exception of Gamada dunes of the rising increase and the very sloping front at the expense of length and width. This may be ascribed to the dune depositing on the coastal edge, then wind helps to blow away the deposits existing at the feet of those dunes to be on then, leading to more sloping of the front surface reaching 42o besides the increase of their height average reaching 54 meters.

Table (2): Some characteristics of the coastal sand dunes at the study area.

Dimensions / Location	Length (M)	Width (M)	Average Height (M)	Average Interface Slope (Degrees)
Al-Jady	69.2	286.6	23	19
North Bukha	112.6	189.5	31	34
Gamada	117.4	155.6	54	42
South Gamada	116.2	326.7	33.6	35
Tibat	125.7	325.4	28.5	35
Total	541.1	1283.8	170.1	162
Average	108.2	256.8	34	32.4

Source: Field Work.



Source: Field Work.

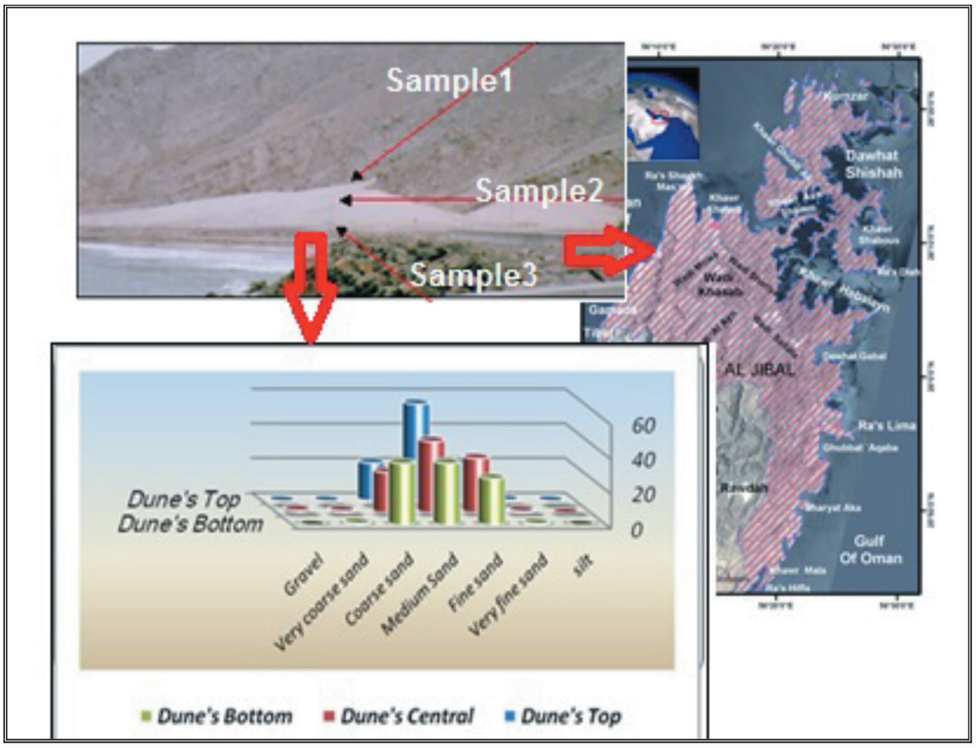
Fig. (3). Coastal Sand Dunes and Their Shapes at the Study Area.

- One of the coastal dunes was studied in detail, in order to know the size, source and surface texture of those dunes. Some samples were taken from the upper, low and middle parts of that dune and analyzed regarding their size, metals and by using microscope. Here are the most important results displayed. Table (3) and Fig.(4)

Table (3): Size of Sand Dune Deposits

Sample Location	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt
	> - 2Ø	-1:0	0:1	1:2	2:3	3:4	4:5
Dune's Top ((sample1	0.00	0.00	21.90	55.88	21.71	0.51	0.00
Dune's Central ((sample2	1.61	1.24	23.42	41.30	31.44	1.00	0.00
Dune's Bottom ((sample3	0.01	1.09	35.56	35.63	26.80	0.92	0.00
Total	1.62	2.33	80.88	132.81	79.95	2.43	0.00
Average	0.54	0.78	26.96	44.27	26.65	0.81	0.00

Source: Results of Size Analysis.



Source:- Field work - Results of Size Analysis.

Fig.(4): the location of sand dune Deposits samples, and its Sizes

1- Grain Sand Size:

Table (3) illustrates the Results of size Analysis of the sand dune deposits Fig. (4) Shows the percentage related to each size, according to the sample place; it is possible to deduct the following:

The sizes of granules range between small pebbles and the very smooth sand, noticing that the small pebbles having a size more than 2 ø, are of a little percentage not exceeding 0.54% as an average of the total sample size, though this category appears only at the samples taken from the middle and lower parts of the dune while the rough sand and very rough sand have the percentage of 27.74% of the total sample size. But the Mean sand granules represent 1-2 ø and this is the highest percentage reaching 44.27 of the total sample size. However, this percentage is more than the Mean sample of the upper parts of the dune than its middle and lower parts as it reaches 55.88% of the sample size, whereas the percentage of fine and very fine sand reaches 27.46% of the total sample size, indicating the strength and speed of the wind that had deposited the coastal dunes parallel to the coast.

Size factors had been calculated in table (4) using the mathematical equations developed by the scientists (Falk and Ward, 1957) are as follows:

Table (4) the Results of Statistical Analysis of Sand Dune's Samples of

Sample Location	Average	Sorting	Skewness	Kurtosis
Dune's Top	0.67	0.95	0.67	1.23
	Coarse Sand	Average Sorting	Very positive	sharpened
Dune's Central	1	0.95	0.67	1.23
	Coarse Sand	Average Sorting	Very positive	sharpened
Dune's Bottom	0.33	1.02	0.33	1.23
	Coarse San	Poor sorting	Very positive	sharpened

Source: Data from the researcher calculation

- **Mean size** = $\frac{\mathbf{84\Phi+50\Phi+16\Phi}}{\mathbf{3}}$

Deposit Mean size of the dune samples ranges between 0.33ø and 1ø and there upon, the sample is included in the coarse sand.

- Sorting Coefficient:

$$\text{Sorting Coefficient} = \frac{16\Phi-84\Phi}{4} + \frac{5\Phi-95\Phi}{66}$$

Then, sorting coefficient ranges between ø 0.95 and ø 1.02. This indicates that sorting samples ranges between mediocre and bad.

- Skewness Coefficient:

It is used to estimate the equality degree of the distribution two curves with the deviation of deposit Mean size and it is calculated according to the following equation.

$$\text{Skewness Coefficient} = \frac{(50\Phi)2-16\Phi+84\Phi}{(16\Phi - 84\Phi)2} + \frac{(50\Phi)2-5\Phi+95\Phi}{(5\Phi - 90\Phi)2}$$

Then, the skewness of the deposit distribution two curves ranges between ø 0.33 and ø 0.67, e.g., this skewness is a very positive one, indicating the coarse sizes increase in the samples studied.

– Kurtosis :

This criterion measures the curve kurtosis degree and this is done by finding the ratio between the spreading deposits at the curve middle, and their spreading at the extremes in accordance with the following equations:

$$\textbf{Kurtosis} = \frac{\mathbf{5\Phi-95\Phi}}{\mathbf{(5\Phi-75\Phi)\ 2.44}}$$

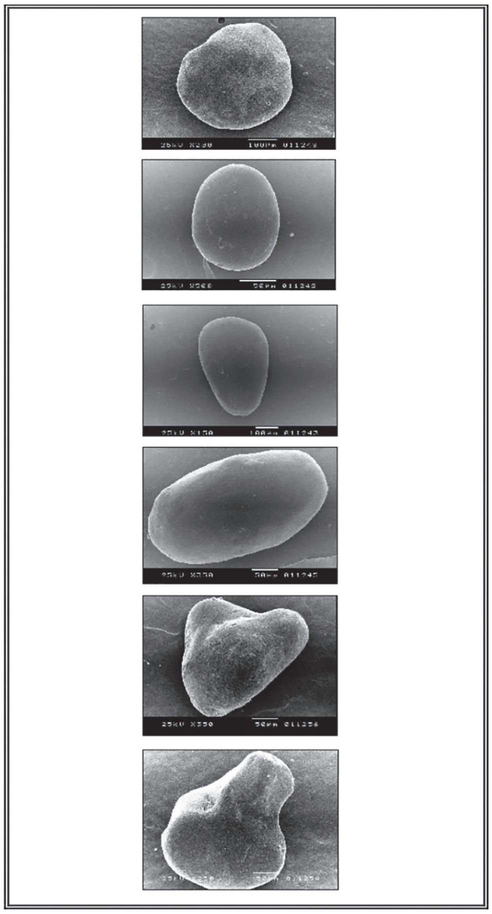
Then, the kurtosis coefficient value is equal between samples as it reaches 1.23 ø, and therefore, the curve is extremely pointed, meaning that most of the deposit samples focus at one size.

2-The shape of the sand grains and surface textures:

The shape of the sand grains concerning the three samples was studied through the Electronic Microscope. Fig. (5) Shows that sand of a good circulation and highly spherical has no acute angles. And this refers to the traveled distance by wind before depositing through its collision with the coastal edges. There are also some of grains of medium sand sizes observed, taking an oval and circular shape , resulting from rubbing between sand granules during being carried by wind through jumping of the fine sand or rolling of the medium and coarse sand together with separating parts of grains, taking irregular shapes.

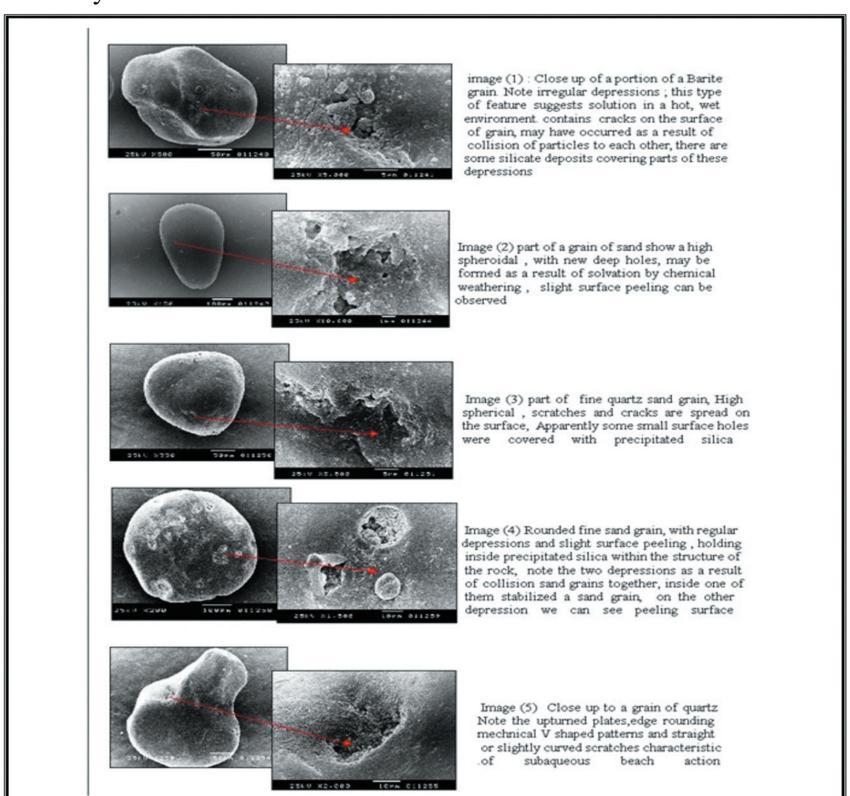
In this context, the microscopic study showed the existence of micro relief's on the surfaces of sand grains as there were the impacts of erosion processes, resulting from rubbing and colliding between sand grains having the shape of depressions and deep hole inside the sand grain.

Hence, a very small sand grain may settle into those depressions. There was also the mechanical weathering effect on some grains, represented in widening the cracks inside sand besides the exfoliation phenomenon appearing on the surfaces of some grains. But there was the chemical weathering effect on deep holes as a result of the dissolution action, Fig. (6)



Source: Results of Size Analysis

Fig. (5) Some Grains Forms of Coastal Sand Dunes in the Study Area



Source: Results of Size Analysis

Fig. (6) Micro- Features Formed on the Surfaces of the Sand Grains

Table (5) Results of the Mineral Analysis of Samples (%)

Sample Location	Calcite	Aragonite	Barite	Vaterite	Dolomite	Anhydrite	Jarosite	Other Elements
Dune's Top	17.4	33.7	7.5	3.2	2.3	3.9	2.7	29.3
Dune's Central	18.1	19.3	15.2	2.4	1.8	2.8	5.3	35.0
Dune's Bottom	24.4	30.8	12.7	1.3	1.0	3.2	2.6	24.0
Average	20.0	27.9	11.8	2.3	1.7	3.3	3.5	29.4

Source: Results of Mineral analysis

3- Sand Dunes Chemical Elements:

Sand samples were analyzed by X-Ray illustrates the similarity of the components forming those dunes, as shown by Fig. (7) .In fact, Dunes consist of seven main metals (Metals are defined by Dictionary of sedimentary rocks, Moshrif and Edris), as the following:

- *Calcite:* It is one of the most common metals in the world. It chiefly consists of calcium carbonate, having hexagonal crystal system, appearing in samples at the rate of 20% of average sample size.

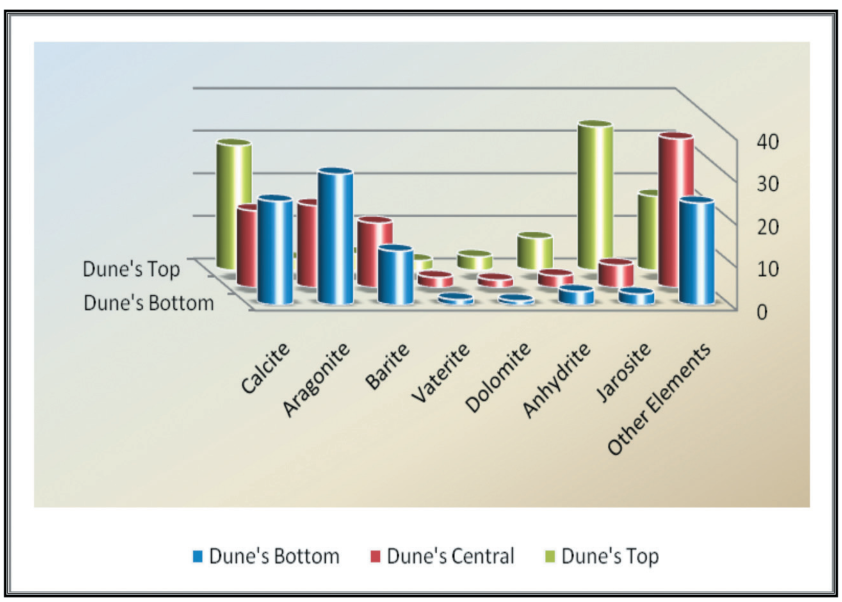
-*Aragonite:* It is equal to calcite in its chemical components, as it consists of calcium carbonate but differs from it in having a right form crystal system which is the most common in sand dune samples where its average percentage 27.9% of the sample sizes.

- *Vatrite:* It consists of calcium carbonate, dissolvable in water, changing into calcite when reacted with water, at low temperature. It can be also changed into Aragonite at rising temperature therefore; it represents 2.3% of the sample size.

- *Dolomite:* It consists of calcium carbonate and Magnesium, with a rate of more than 15% .Dolomite represents about 1.7% of the samples size.

- *Anhydrite:* It is sulphate metal formed by the action of water dissolutions and its rate does not exceed 3.3% of the sample size.

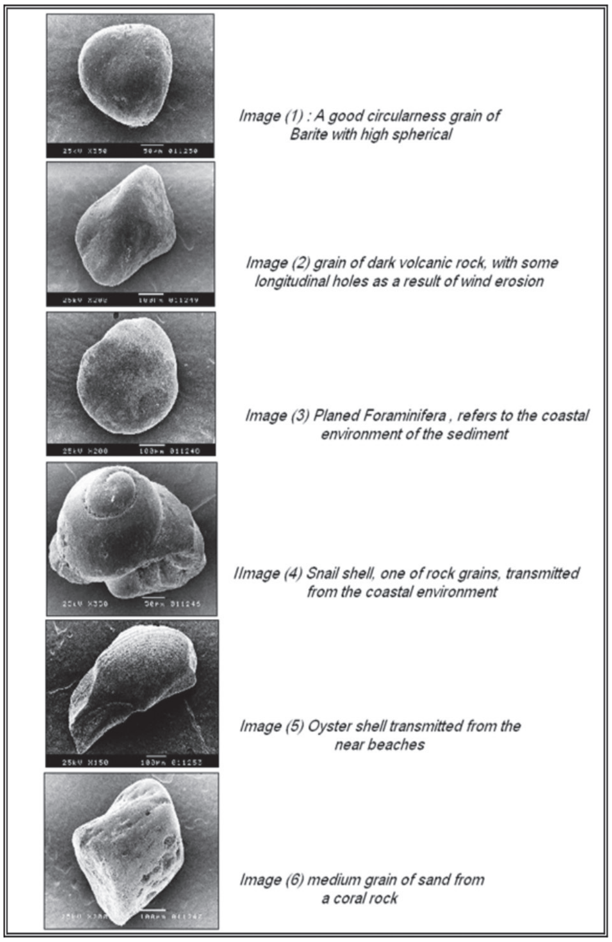
- *Jarosite:* It chiefly consist of water potassium sulphate, having a hexagonal crystal system and its color ranges between yellow and brown, representing a rate of 3.5% of the sample size.



Source: Results of Mineral Analysis

Fig. (7): Mineral Elements for Samples of the Sandy Coastal Dune

- ***Other components:*** they are represented by remains of shells, corals and marine micro organisms, having a rate of 29.5% Fig. (8)



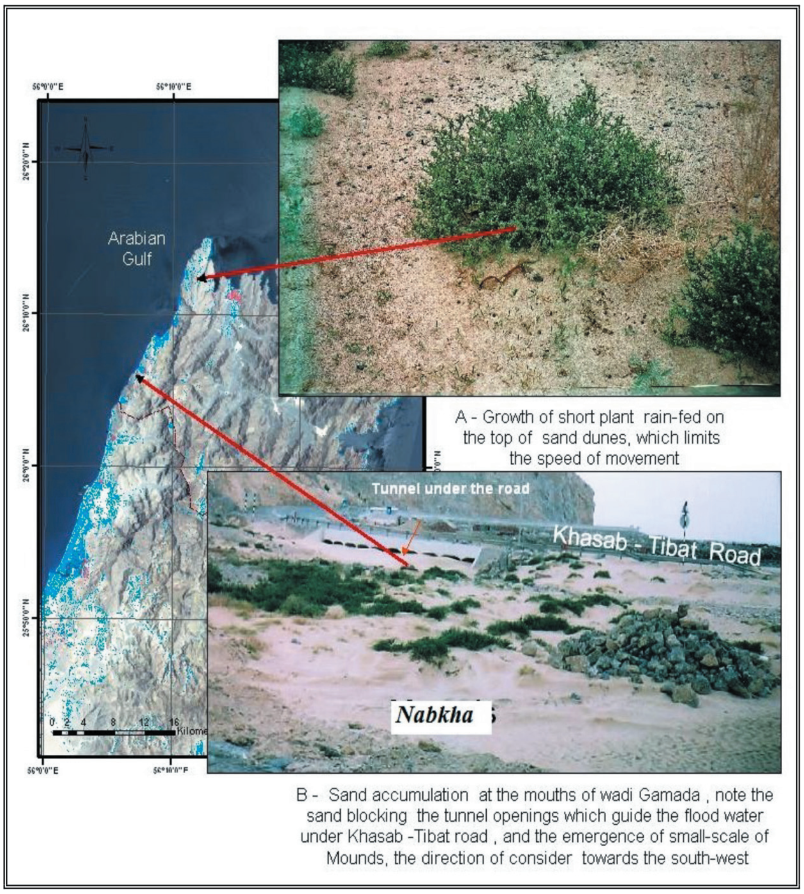
Source: Results of Mineral Analysis

Fig. (8) Some of the Elements Formed Coastal Sand Dunes

According to the above – mentioned facts, it is clear to say that there is the similarity of the chemical components forming the sand dunes spreading at the study area, and which consist, mostly, of the calcium carbonate metal, having a rate of 51.9% of the sample size and of sulphate at a rate of 18.6% of the sample size besides remains of shells and corals at a rate of 29.5% of the sample size, as well.

4- Sources of Sands:

The results of the size, metal and microscopic analysis of the dune samples, clearly indicate that the fine dune sands of a medium size, good circulation and being very spherical, are distinguished by the carbonic elements spreading in their metal some of marine organisms like shells and corals. This means that those dunes had existed owing to accumulated sands from the near shores lying in the south and south west of the study area. The microscopic sand analysis also indicates that those sands are well circulated and very spherical. So this means that the sands had passed more than one depositing stage, as it is believed that they had been swallowed from the middle of the Arabian peninsulas and deposited on the shores near the study area besides being mixed with the marine deposits. Moreover, the metal analysis of the sand dune, subject of the study, refers to the marine source of sands, and which is represented by the remains of shells and oysters. Then, wind carry those sands and deposit them once again at the study area, particularly, the rate of the wind blowing from south and west direction is about 45% of the total blowing wind direction.



Source: Field Work.

Fig. (9): Nabkha Shapes at the Area Study

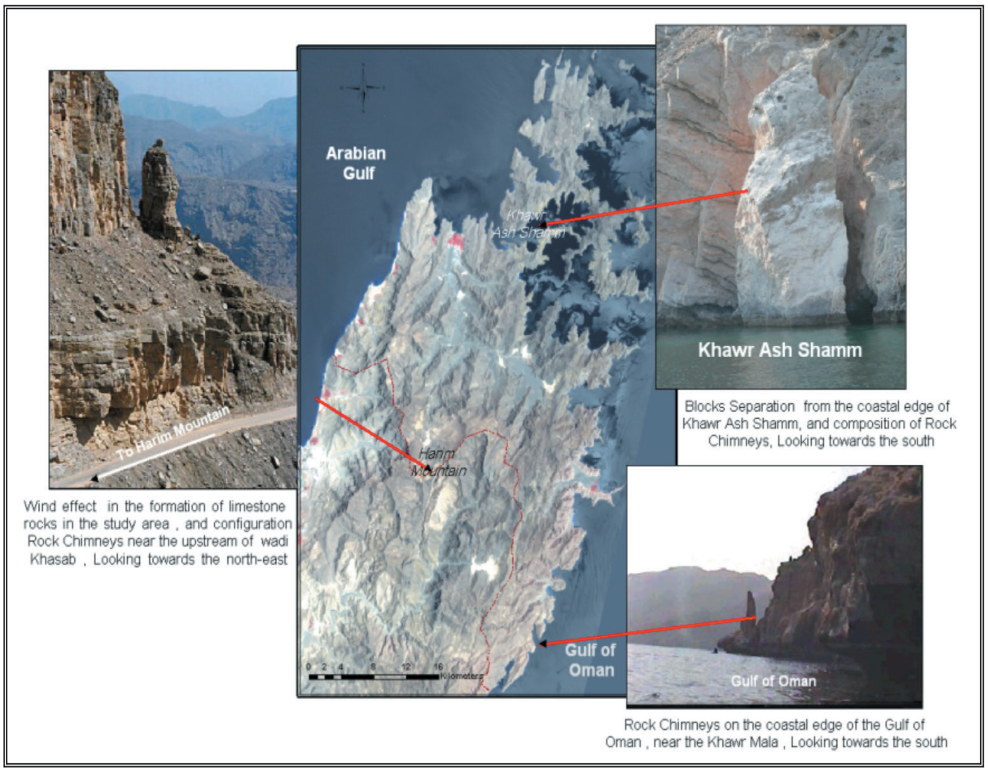
Nabkha:

There are kinds known of plants playing an important role based on fixing sand dunes and on their growth. Without those plants, the dune sands will be exposed to being swallowed. Accordingly, we may not see but sand sheets of no shape, furthermore, the plant growing at the dune sands, has two functions, fixing the dune sands through the plant roots branching deeply into those sands. Receiving new sands and trapping them. (Goda, 2002, in Arabic).

Noteworthy, Nabkha had served at the study area, as traps of Sands. They are of small sizes, existing like circular piles and the diameter of 1-3 meters, so Nabkha can be observed along the west coast of the study area between Ra's el-sheikh Mas'oud,. Fig. (9)

Rock Chimneys:

Those chimneys are formed by the continuous widening of cracks and vertical joints resulting from the thermal affecting factors, and solution due to water until some of vertical columns separate from the neighboring edge, after the sweeping of the substances mechanically weathered, by wind in order to make those chimneys stand steadily with a height reaching dozens of meters



Source: Field Work.

Fig. (10): Rock Chimney at the Study Area

Doubtless, the rock chimneys exist at study area near the upper sources of Wadi Khasab as wind had widened the distances between cracks inside calcareous rocks forming a rock chimney with a height of approximately 15 meters. This kind of the remaining forms at Ash Shamm Inlet and at Mala one overlooking the gulf of Oman as calcareous rocks strongly dissolve owing to the violence and speed of wind resulting in separating them from the original edges Fig. (10). They also appear inside Ash Shamm Inlet as a result of the dissolution action and its impact on both edges and headland and this serves to increasingly widen cracks and joints and create rock chimneys at the southern side of the Inlet referred to, (with a height of 34 meters over this Inlet surface level). Rock chimneys also appear on the coastal edge slopes on the gulf of Oman to the south of Mala Inlet as the wind parallel to the coast blows violently, and widens the cracks and joints cutting the coastal edge, serving to separate parts from it in order to form a rock chimney at the height of 12 meters above the Gulf surface level, extending to the height of 18 meters.

Results:

- Wind played a major role in the formation of the western part of the coastal range, resulting in sand sediments gathered on the edge of the coast and formed a number of sand dunes brought by the wind and deposited on the nearby beaches.
- It turned out through the mineral analysis of sand dunes samples, the similarity of the chemical elements of sand dunes in the study area. Consisting mostly of calcium carbonate, with 51.9% . Sulphate with 18.6% . Remains of shells and rags by 29.5% of sample size.
- The results of size, mineral and microscopic analysis of dune sediment samples show that the sand dunes are medium to smooth, well rounded and high-spherical. The dunes were created by carrying sand from nearby beaches to the south and southwest of the study area

Conclusion:

Wind is considered the most important factor of the climatic ones, because of having the high speed of 10.8 kilometers an hour as an average and this speed increases reaching 130 kilometers an hour during the stormy days, resulting in a number of phenomena among which are the coastal sand dunes which wind carries their deposits from the near shores. There are also the nabkha where plants serve as traps of sands and dust. This is besides the rock chimneys.

References:

1. Godah,H.G., 2002: Geography and biology with application to the climate of the continents of Europe, Asia and Africa and the climate and plants of the Arab world, Dar Al - Maarifa University, Alexandria (In Arabic)

2. Falcon, N.L., (1971-1972): expedition to unknown Musandam. Geographical Magazine

3. Falcon, N.L., (1973): The Musandam Northern Oman expedition, Geographical Journal.

4. Folk, R.L. and Ward, W.C. (1957): Parazos River Bar A study in the significance of Grain Size Parameters, J.Sed. Petrol. , Vol. 27, No.1.

5. Moshrif, M. and Edris, E.: Illustrated Dictionary Of sedimentologyical Terms. University Libraries, King Saud University

6. Torab , M ((2002): Musandam Peninsula - Sultanate of Oman, article on the book Changes in the Mediterranean Sea Level - Field Studies of the Change of the Fourth Time on the Arabian Gulf Coast and Gulf of Oman pp. 219-265. (In Arabic)