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Quaternary Beach Dunes in Daryanah Area NW of Al Jabal al Akhdar, NE Libya.

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Highlights

- **Four distinctive lithofacies characterized the Quaternary beach dunes of Daryanah area**
- **The Quaternary wind direction in north Cyrenaica as depicted was from NW to the SE concordant with the location of the present shoreline**
- **The age of marine wave-cut terraces in Al Jabal al Akhdar, which occur between 140 to 200 m.a.s.l., is Early Pleistocene (Calabrian).**

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ABSTRACT

The present study has shown that the Quaternary beach dunes of Daryanah area are composed of four distinctive lithological facies, these are the planer cross bed calcarenite facies, lenticular calcarenite facies, massive calcarenite, and alluvial deposits facies. The planer cross-bedding and the lenticular bedding are interpreted to reflect aeolian deposits. The massive calcarenite is thought to have been accumulated in shallow marine. The interbedded calcarenites and alluvial deposits interpreted to represent cycles of prograding alluvial system associated with Eustatic sea-level changes.

The paleo-winds in the area were mostly unimodal blowing between 290°and 330°, which were influenced by the escarpment position and orientation. The age of these deposits has been attributed to Early Pleistocene (Calabrian) based on its occurrence above the sea level and correlation with previous studies.

1. Introduction

Carbonate dune sands line the coasts in areas of carbonate sedimentation in many parts of the world. Although they form a common and conspicuous facies in Holocene and Pleistocene carbonate sediments, few aeolian limestones are reported from ancient rocks. This is either because dune deposits are scarce in older carbonate rocks, or because few geologists have recognized wind-laid limestone. The latter may be the more likely case, inasmuch as recognition of carbonate eolianite is difficult, particularly in the subsurface, because of its similarity to clastic limestone deposited in high-energy, shallow marine environments. The conditions for Eolianite development are: (1) a warm climate favorable for a source of $CaCo_3$ sediment and (2) on-shore winds required to deliver coastal carbonate sand inland to areas of deposition McKee and Ward (1983).

Quaternary eolianite is lined almost parallel to the Libyan coast in many localities from the east to the west borders. The well-known formations are the Gargaresh Formation described by El Hinnawy and Cheshitev (1975) near Tripoli and the Ajdabiya Formation described by Francis and Issawi (1977) in the Ajdabiya area. Similar rock units were described as marine and aeolian calcarenite by Klen, (1974), Rohlich, (1974) and Zert, (1974) along the coast from Benghazi to Tobruk in eastern Libya.

Many studies dealing with description and subdivision of these deposits published throughout the years followed, for examples Minas (2003) and Minas and El-Bakush (2007), but the most recent, is the one by Shaltami *et al.* (2017), the later study described, named and radiometrically age dated the calcarenite deposits in three localities; the Tansulukh, the Al Hamamah and the Al Haniyah areas in the Al Jabal al Akhdar region. Shaltami *et al.* (2017) upgraded those sections into formations and named them after the localities in which they occur. They also assigned them to to Early-Late Calabrian, Middle Ionian, and Middle-Late Tarantian respectively.

2. The Aims of the Study

1. *Determine paleo-wind direction as manifested by calcarenite beach dunes.*
2. *Interpret the significance of its position at the current altitudes*
3. *Establish a depositional environment and history.*

3. Location of the Study Area

The area is situated about 45 km to the NE of Benghazi, (Fig. 1) and marked by the top-right intersection point of (32° 28' 9.45'' N & 20° 37' 32.48''E) and bottom left point (32° 17' 39.34'' N & 20° 17' 26.28'' E). The area is accessible through the Benghazi – Tukrah dual carriageway and then through the Tansulukh-Alwattyat blacktop (Fig.1). Three sections have been selected to study the Quaternary calcarenite beach dunes in Daryanah area, these are; (1) the Wadi Alkuf Section, (2) Alwattyat Section, and (3) the Bersas Section, (Fig. 2).

4. Stratigraphy of the studied sections

4.1. Wadi Alkuf section

The Wadi Alkuf is located about 2 km south of Alwattayat village; the studied section is located on the northern flanks of the

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wadi. The section is defined by the following UTM coordinates, longitude (445850 E) and Latitude (3572620 N), and it extends from elevation 143 m to 172 m a.m.s.l. The section is 29m thick and composed of two distinctive units, the lower planer cross-bedded is calcarenitic facies and the upper is lenticular calcarenite facies, (Fig. 3).

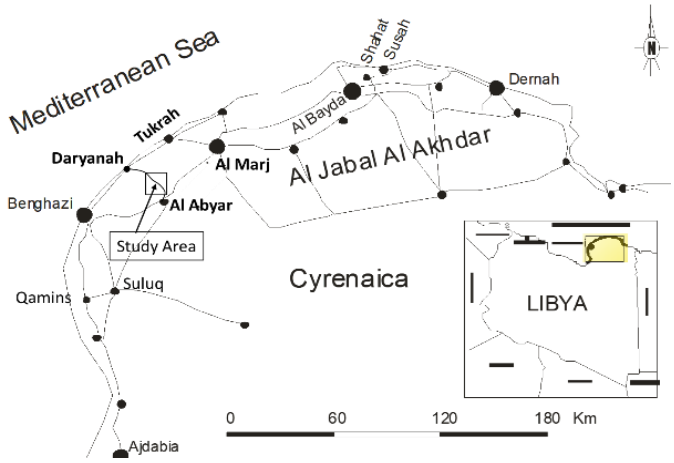

Fig. 1. Location map of Daryanah area

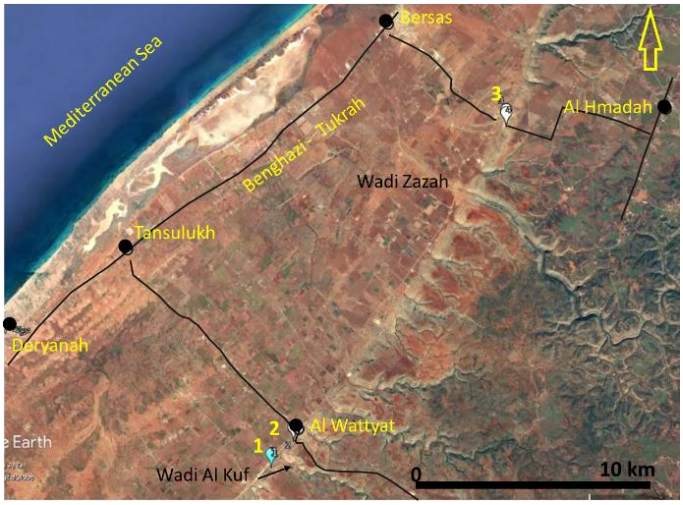

Fig. 2. Locations of the studied sections: 1) Wadi Alkuf Section, (2) Al Wattyat section, and (3) Bersas section.

a) Cross bedded calcarenite facies

It represents the lower part and it is a grainstone, white, medium-hard and well bedded. It is medium bedded 25 to 35 cm. thick with a total thickness of about 20 meters. It is composed of shell fragments and carbonate grains of sand size mostly fine to medium grains with well sorting and well roundness. Fossils include echinoid fragments, small rotalid (*Elphidium*), large rotalid and *Operculina*. This facies is characterized by large-scale high angle planer cross-bedded with dip angle ranges between 25° to 28° and dipping to the SE direction (Figs. 4 & 5).

In this lower facies total of 84 reading of dip, the direction has been measured and plotted on the rose diagram (Fig. 3). It shows that the wind blowing direction was between 304° and 327°, with an average direction 310°

b) Lenticular calcarenite facies

This upper facies is grainstone, yellow and medium-hard. The beds are medium to thickly bedded (15 to 25 cm) with a total thickness of about nine meters. The carbonate grains are mostly fine to medium sand size with well sorting and well roundness. This facies is characterized by lenticular shape bodies made of poorly developed low angle cross-bedding (Fig. 3) with dip angle ranges between 7° to 15° to the SE direction (Fig. 6).

In this upper facies total of 126 reading of dip, directions have been measured, analyzed and plotted (Fig. 6), it is showing that the wind direction was drifting between 281° and 304° and mostly between 304° and 327°, the average wind direction is 305°.

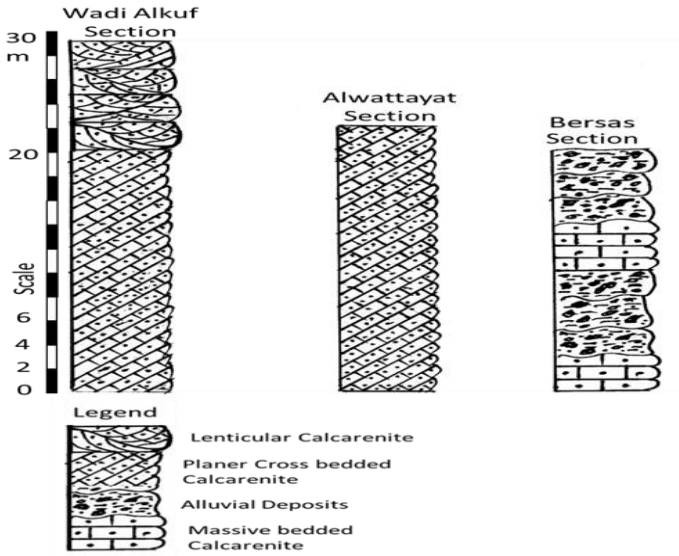

Fig. 3. Stratigraphy of the studied sections

Fig 4. Wadi Alkuf section showing the lower and upper facies

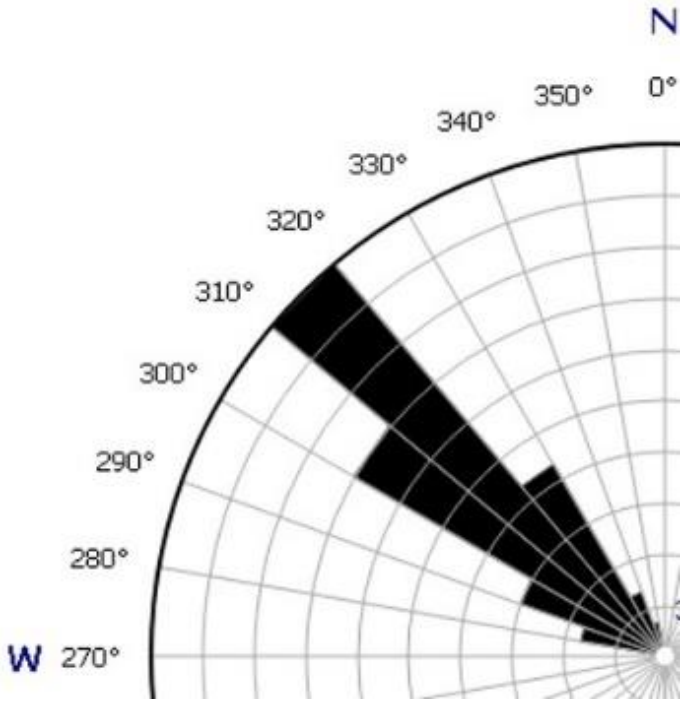

Fig 5. Wind paleocurrent directions in the upper facies, high angle planer cross-bedding, Wadi Alkuf section

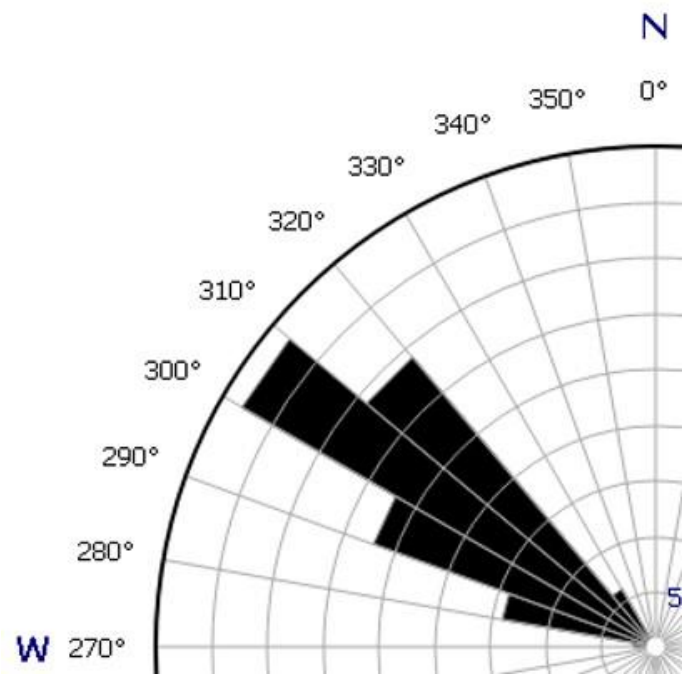

Fig. 6. Wind paleocurrent directions in the lower facies, low angle cross-bedded in lenticular facies, Wadi Alkuf section

4.2. Alwattayat section

The section is located in the vicinity of the Alwattayat village along with the Tansulukh-Al Abyar road cut. The base of the section is located at the intersection of the UTM longitude (446850 E) and the latitude (3573730 N). It occurs between elevation 143 to 165 m. a.m.s.l., (Figs. 2 and 3). It consists of high angle planer cross-bedded calcarenite facies. This section named Tansulukh Formation by Sheltami *et. al.* (2017)

a) Planer cross-bedded calcarenite facies

The section is grainstone, white and medium-hard. It is well and medium bedded 5 to15 cm thick with a total thickness of about 22m. Carbonate grains that made up the section are mostly sand size with well sorting and well roundness. Undifferentiated shell fragments are the most common with some echinoid fragments and peloids that may be recognized. This section is characterized by well-defined large-scale planar cross-bedding with 15° dip inclined towards the SE direction, Fig. (7).

One hundred fifteen readings of dip direction have been measured, analyzed and plotted on a rose diagram (Fig 8). Two wind directions have been recognized, the main direction occurs between 310° and 320°, it represents 90% of the total readings. The average wind direction is 318°. The second direction occurs between 56° and 79° azimuth, with 70°average wind direction.

Fig 7. Calcarenite beach dunes in Alwattyat section showing large scale planer cross-bedding

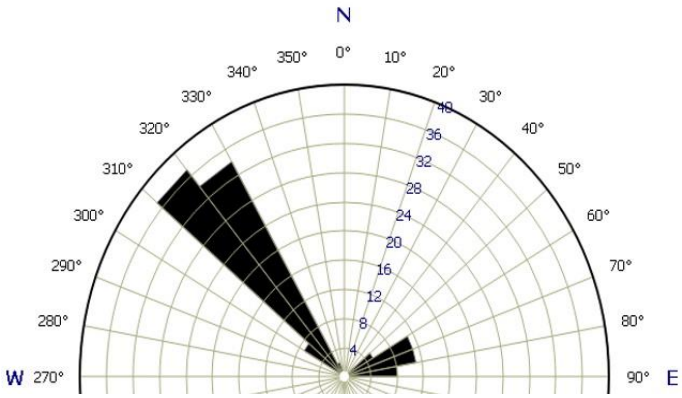

Fig 8. Rose diagram of paleocurrent wind directions measured in calcarenite beach dunes in Alwattayat section

4.3. Bersas section

This section located along with the road cut that connects the Bersas coastal village and the village of the Al Hamada on the plateau. It occurs between the elevations 143 m to 148 m a.m.s.l. The base of the section is denoted by the point of intersection of the UTM longitude (456388 E) and the latitude (3586955 N). This section composed of three units, the lower and the upper units are massive calcarenite facies, and the middle is a fluvial deposits unit, Fig (3).

a) Massive calcarenite facies

The lower and the upper units are grainstone, white, moderately hard; they are 1 and 2 meters thick respectively. The carbonate grains are mostly fine to medium sand-size grains, well sorting and well rounded. The shells fragments are mostly undetermined, however, some echinoid spine, *Discorbis* sp., *Rotalia* sp. and peloid may be recognized. No evidence of sedimentary structures can be seen in this section, (Fig. 9).

b) Alluvial deposit

This middle unit is alluvial deposits made of a mixture of mud to cobble size materials (intra-formational) with variable angularity, it is about 2 meters thick, (Fig. 9).

Fig. 9. Calcarenite beach deposits and alluvial deposits in Bersas Section

5. Discussion and Conclusion

Four distinctive lithological facies can be recognized in the studied area, these are the planer cross bed calcarenite facies, lenticular calcarenite facies, massive calcarenite facies, and alluvial deposits facies.

The studies of Dunbar and Rodgers (1957), Reading (1978), Ahlbrandt and Fryberger (1982), Blatt (1982) and Selley (1985) mentioned that large scale planer cross-bedded indicates aeolian dunes, so that the current study considered that large scale planer cross-bedded facies as shoreline calcarenite dunes formed by winds that were blowing from NW to the SE, this direction coin-

cides with current shoreline position. The Alwattyah section showing bimodal current direction, the minor trend suggesting that the wind was blowing from NE to the SW, however, the trend coincides with the current shoreline position.

The Lenticular calcarenite facies is characterized by lenticular shape bodies made of poorly developed low angle cross-bedding with dip ranges between 7° to 15° to the SE direction, Fig (6). Tangential cross lamination is thought to reflect aeolian deposition; Ahlbrandt and Fryberger (1982) mentioned that tangential cross lamination or wedge/planer cross lamination strongly indicates aeolian dune environment. The paleo-wind direction as depicted was from NW to the SE concordant with the location of the present shoreline.

It should be noted that the escarpment upon which these calcarenite sections are laid-on had played a significant role in deflecting wind directions, and so the orientation of the formed sedimentary structures. The escarpment runs in N40°E almost parallel to the coastline, with an average gradient of about (0.24), i.e. 240m/1 km (slop angle 13.5°). This orientation of escarpment forms a barrier upon which the winds that are blowing between 230° and 20° azimuths will dump its load. A modern example can be seen in Wadi Alkhabtah east of Darnah city. In this site the sand dune accumulated on the side of a barrier (wadi side) that bordering the sand beach, on this site, old solidified sand dunes and recent loss sand deposits are well-illustrated, Fig (10).

Fig. 10. Wadi Alkhabtah east of Darnah, a modern example showing how sand dune may accumulate on the side of a barrier (wadi side) that borders the sand beach, note the old solidified and the recent loss sand deposits (looking west)

The palaeocurrent direction measurements in the study area indicate landward wind direction during Late Pleistocene. The landward primary wind direction might reflect an aeolian origin, Minas (2003) and Minas and El-Bakush (2007).

The composition of the massive calcarenite facies with the occurrence of peloid and ooids and the massive nature, which may be due to bioturbation, may suggest deposition in a near-shore barrier environment.

The alluvial deposit is made of a mixture of mud to cobble size materials of intra-formational origin with variable angularity, the texture of these deposits and their occurrence at the mouth of the wadis may suggest they were formed as alluvial fans. The Interbedded of the alluvial deposits with marine massive calcarenite facies indicating prograding of the alluvial system due to drop of the sea level followed by the retreating of the alluvial system due to sea-level rise.

The Europe Quaternary glaciations periods were reflected as rainy periods on North Africa and on Libya as well. These rainy periods had a great role in the formation and development of many geomorphic features and deposits that we are seeing today. Gregory (1911), Hay and McBurney (1955), Hey (1956 & 1968) and Jawdah (1972, 1975) studied the Quaternary sediments/features in Cyrenaica and their relation to the climatic changes. The marine wave-cut terraces and the associated sediments, i.e. beach dunes, which are the core of this paper, they were formed and developed as a result of Eustatic sea-level changes.

Jawdah (1972) recognized five fluvial terraces along some wadies of Al Jabal Al Akhda and correlated them with knick points and marine terraces in Cyrenaica, Jawdah (1972) claimed that his findings are concordant with Knetsch (1942) who predicted a sequence of five rainy periods separated by dry times along the Libyan coast. MacBurny and Hey (1955) recognized two-wave terraces in Wadi Darnah and related them to the *Wurm* and *Riss* periods. Table (1) summarizes these wave terraces and compares them with European glaciation ages.

Table (1)

Correlation between glaciations ages and elevation of fluvial terraces, marine terraces, and beach dune calcarenites in Cyrenaica region, (modified after Jawdah (1972)).

Marin Terraces & age	Present study 2018	Hey & McBurny (1955)	Wadi Al Qattarha (Libya) Jawdah (1972)	
	Calcarenite beach dune Elevation (m)	Marine Terraces, Cyrenaica Elevation (m)	Alluvia Terraces Elevation (m)	Knick Point Elevation (m)
Monasterien 2 Pre glaciation		6	7	10
Monasterien 1 (Riss- Würm)		15-25	12-27	-
Tyrrhenian (Mindil - Riss)		30-40	35-45	40
Millazzo (Gunz-Mindel		44-55	50-60	60
Sicilian (pre-Gunz)		70-90	70-80	8
Calabrian Early Pleistocene	140-170 Daryanah	140-200 Two Sea Beaches	180-200 160-170	190 170
			205-215	210
			230-240	

The above discussion leads to the conclusion that the studied sections which occur between 140 and 170 m a.m.s.l. are comparable with marine cut terraces of McBurney and Hey (1955) and alluvial terraces and knick points of Jawdah (1972). They occur at levels correlatable with the Calabrian terraces of the Early Pleistocene age, this interpretation is also supported by radiometric age dating by Shaltami *et al.* (2017).

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