

Palaeowind estimation of cross-bedding within the aeolian Kurkar layers of the Gaza Formation, Gaza Strip, Palestine



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ABSTRACT

Coastal plain deposits of the Gaza Strip have been distinguished in the Gaza Formation (Pleistocene) of the Kurkar Group. The Kurkar layers (medium to coarse-grained calcareous sandstone) are characterized by abundant cross-bedding that has two sets of cross-beds. These Kurkar layers form the ridges along the Mediterranean coast. The dip, and dip direction of the cross-beds, were measured at five sites to determine the palaeowind direction. The palaeowind directions were measured for the first time in the study area. The Kurkar layers are interpreted as having been deposited in an aeolian environment. Results at Sheikh Ejlin Ridge show that the lower set is dipping eastward (19/099), while the upper set dips northeast (23/051). At the Al Montar Ridge however, the lower set dips southeast (18/146), while the upper set dips north (19/001). These ridges are not coeval, but the precise age relationship between them is as yet unknown. However, the results indicate that there was a change in the palaeowind direction during deposition of the Kurkar layers, from westerly to southwesterly at the Sheikh Ejlin Ridge and from northwesterly to southerly at Al Montar Ridge.

Keywords: Gaza, Kurkar, aeolian deposits, cross-bedding, palaeowind, Sheikh Ejlin, Al Montar, Quaternary

1. INTRODUCTION

The Gaza Strip is located on the southeastern coastal plain of the Mediterranean Sea (Fig. 1). The coastal zone of the Gaza strip is 42 km long, and varies between 6 and 12 km wide, covering an area of 365 km². It is overlain by Pleistocene–Holocene sediments that have alternating stratified calcareous sandstone (locally named as Kurkar) and red brown layers (locally named as Hamra). The coastline of the Gaza Strip forms only a small section of a larger concave system that extends from Alexandria at the west side of the Nile Delta, via Port Said, the Bardawil Lagoon, El Arish, Gaza, up to the Bay of Haifa (INMAN & JENKINS, 1984).

The topography of the coastal plain is determined by the exposure of two aeolian Kurkar ridges presumably of different ages (SIVAN & PORAT, 2004). The ridges are separated by a deep depression (20–40m above sea level) containing alluvial deposits. These ridges have been studied by several authors. PICARD (1943) noted that the Kurkar is mainly distributed in the western half of the coastal plain and forms ridges parallel to the coast. NEEV et al. (1987) recorded three onshore Kurkar ridges along coastal line, while GAZA ENVIRONMENTAL PROFILE (GEP, 1994) mapped five scattered ridges on the Gaza Strip. ANAN & ZAINELDEEN (2008) mapped just two ridges within the Gaza Strip running

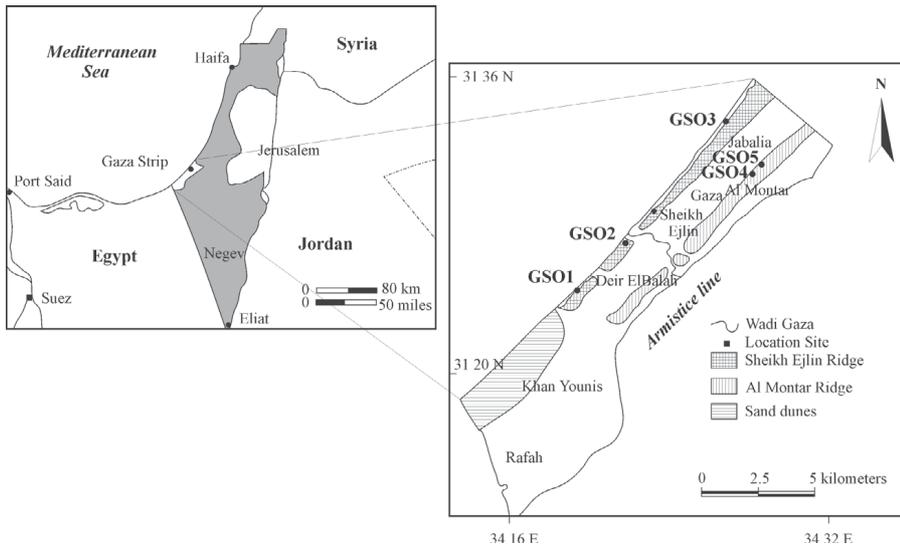


Figure 1: A Simplified map of the Gaza Strip showing the distribution of sites within the study area (after ANAN & ZAINELDEEN, 2008).

NE–SW, parallel to the Mediterranean coastline. They named the two ridges as: Sheikh Ejlin Ridge, which extends up to the current coastline in the west, and the Al Montar Ridge running near the armistice line in the east. HASSAN et al. (1986) recorded a series of eight limestone ridges that run parallel to the coast, west of Alexandria, Egypt. STANLEY (2005) also traced eight Kurkar ridges to the west of Alexandria.

The aim of the present work was to 1) study the cross-bedding within the Kurkar layers at the two ridges in order to determine the type of cross beds occurring at each ridge, 2) measure the dip and dip direction of the cross beds to estimate the palaeowind direction during deposition, and 3) compare the palaeowind directions of the two ridges with each other to give a better view of the circumstances during their respective formation.

2. OBJECT OF STUDY

The study area is located within the Gaza Strip of Palestine. Five sites (GS01, GS02, GS03, GS04 and GS05), as shown in Fig. 1, were examined over many field campaigns. Sites were located on the best exposures of the Kurkar layers in the Gaza Strip. Three of these sites (GS01, GS02 and GS03) are located on the Sheikh Ejlin Ridge, and the other two (GS04 and GS05) are on the Al Montar Ridge. The coordinates of these five sites are shown Table 1. All observation sites were located using a portable GPS.

Table 1: Coordinates of the observation sites.

Site	Location	Coordinates	Ridge
GS01	Deir ElBalah	31° 25.07' N, 34° 19.75' E	Sheikh Ejlin
GS02	South Sheikh Ejlin	31° 27.47' N, 34° 22.19' E	
GS03	AnNawras	31° 33.48' N, 34° 24.80' E	
GS04	Tal ErRayyes	31° 30.78' N, 34° 29.52' E	Al Montar
GS05	Tal ElKashef (Tal Zommo)	31° 31.35' N, 34° 30.09' E	

The exposures at the two ridges, are composed of alternating of Kurkar and Hamra layers, in the Gaza Formation of the Kurkar group (Fig. 2). The Kurkar Group describes coastal sediments from the Pliocene through to the Recent periods.

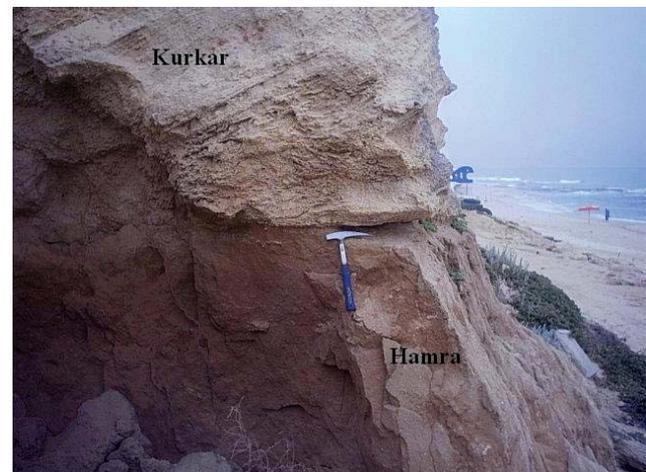


Figure 2: Kurkar and Hamra layers at site GS01 (hammer scale is 32 cm long).

These Kurkar ridges extend further to the north, parallel to the Mediterranean coast as observed by YAALON & DAN (1967).

The sands of the Kurkar layers are wind blown deposits originating from the Nile delta (HOROWITZ, 1979). Since the beginning of the Pleistocene sediments transported into the Mediterranean Sea by the Nile River, have been spread along the Sinai and Palestinian coasts by longshore currents (POMERANCBUM, 1966; GOLDSMITH & GOLIK, 1980; COLEMAN et al., 1981; INMAN & JENKINS, 1984; ROHRLICH & GOLDSMITH, 1984; CARMEL et al., 1985; STANLEY, 1989; FRIHY et al., 1991; FRIHY & LOTFY, 1997; PERLIN & KIT, 1999; ZVIELY et al., 2006; ZVIELY et al, 2007; ANAN & ZAINELDEEN, 2008).

3. PALAEOWIND AND PALAEOWIND INDICATORS

Palaeowind indicators are oriented sedimentary structures interpreted to have been deposited by grain flow. Grain flow strata are slightly coarser than grain fall sands that occupy the upper middle, and upper parts of Aeolian slipface dunes (HUNTER, 1977). Cross-bed slip faces are one of the palaeowind indicators, and can be used to determine the direction of the wind that actually deposited the sediments. This corresponds to the mean value of the down-dip direction shown by the foreset beds (PETTIJOHN, 1975; KOCUREK, 1981).

Palaeowind indicator analysis is important because it provides direct information about the orientation of the sedimentary system. In the current study, cross beds have been used to estimate the palaeowind direction of the current that deposited the sandstones.

Several studies in aeolian processes have been seen in published papers (e.g. YAALON & LARONNE 1971; KOCUREK, 1981, 1991). Studies dealing with sand dunes have also been published (e.g. YAALON & DAN, 1967; HUNTER, 1977; KOCUREK, 1981; CLEMMENSEN & ABRAHAMSEN 1983; GREELY & IVERSEN, 1985; PYE, 1987; MOUNTNEY & THOMPSON, 2002; RODRIGEZ-LOPEZ et al., 2008).

RODRIGEZ-LOPEZ et al. (2008) carried out a study of the aeolian sand at the mid-Cretaceous western Tethyan margin, Iberian Basin, Spain. They noted that sub-tropical climbing translent strata, grain flow and soft sediment deformation are among some of the small scale structures and components observed in the aeolian dune sandstones.

KOCUREK (1981) showed that surfaces and other manifestations of microtopography common in ancient aeolian strata are interpreted as representing damp or cemented surfaces.

4. DESCRIPTION OF THE EXPOSURES

The outcrops consist of alternating Kurkar and Hamra layers of Pleistocene age, (the Gaza Formation of the Kurkar Group). At each location, cross-bedding was recognized within the Kurkar layers (Fig. 3). The cross-bedded sediments were distinguished in the field by layers of foresets, (the series of layers that form on the lee side of the bed form). They are also recognized by truncations in sets of foresets. Two sets of cross-bedding have been identified within the Kurkar layer at the five sites.

Kurkar layers in the study area consist of coarse- to medium-grained sandstone cemented by calcium carbonate

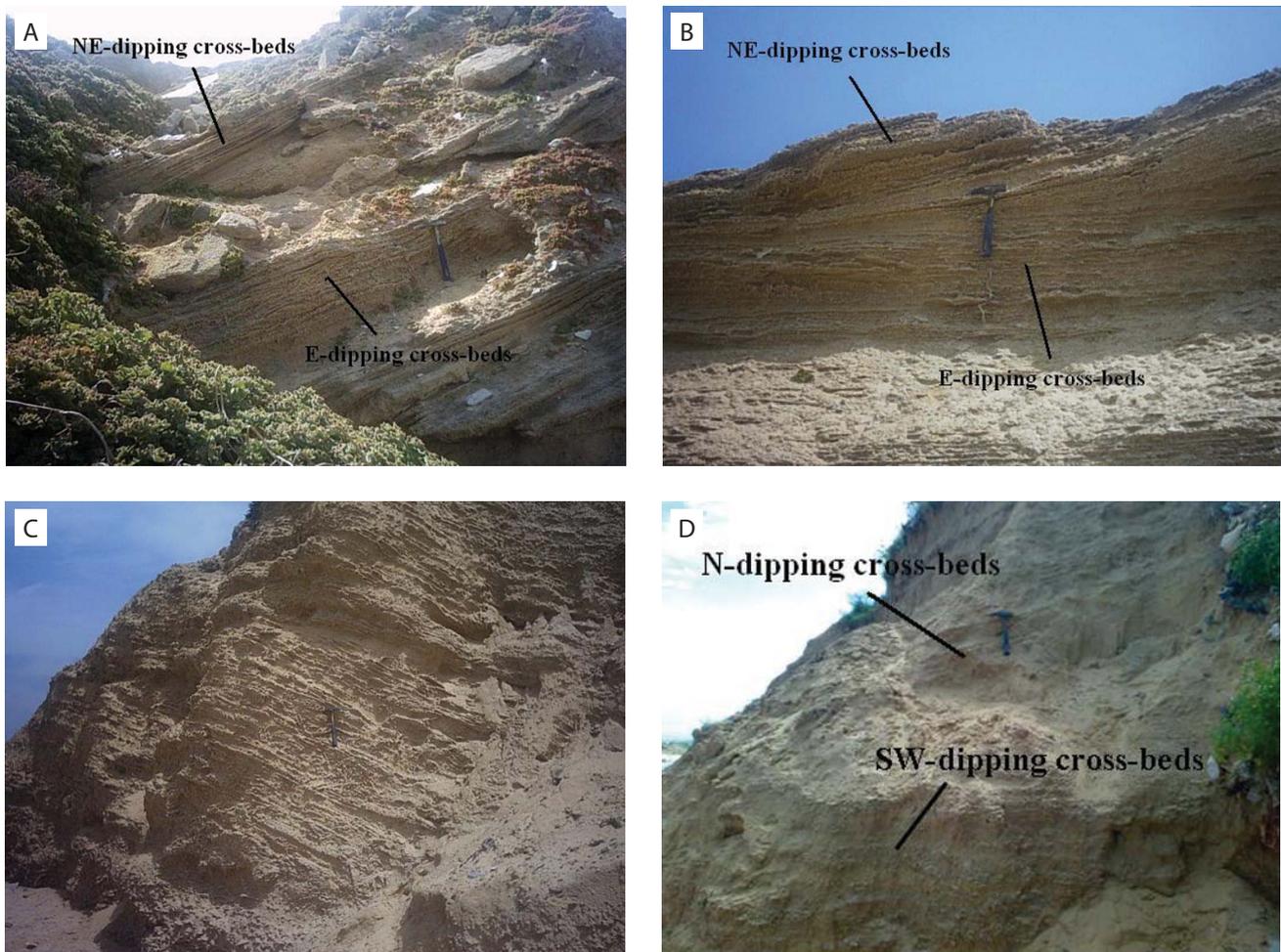


Figure 3: Lower and upper sets of cross-beds within the Kurkar layer. A) at Deir ElBalah, (GS01), B) at south Sheikh Ejlin (GS02), C) at AnNawras (GS03), D) at Tal ErRayyes (GS04). Hammer scale is 32 cm long.

(about 30%). Most of the Kurkar layers are cross-bedded, laminated and massive sandstone. Tabular types of cross-bedding have been observed in the study area. GVIRTZMAN et al. (1984, 1998) pointed out that Kurkar and Hamra sequences are very similar along the coastal plain.

The sand dunes occur along the shoreline especially near Deir ElBalah, and vary in thickness up to 15 m. The dunes

are oriented east-northeast to west-southwest. Further to the north, the dunes become irregular and the sand accumulations are scattered in a 2 to 3 km zone along the coast (GAZA ENVIRONMENTAL PROFILE, 1994). Aeolian deposits are dominant in the Gaza Strip. Those deposited especially in the southern Gaza Strip, have more loess and are mixed with windblown sands, but are much thinner.

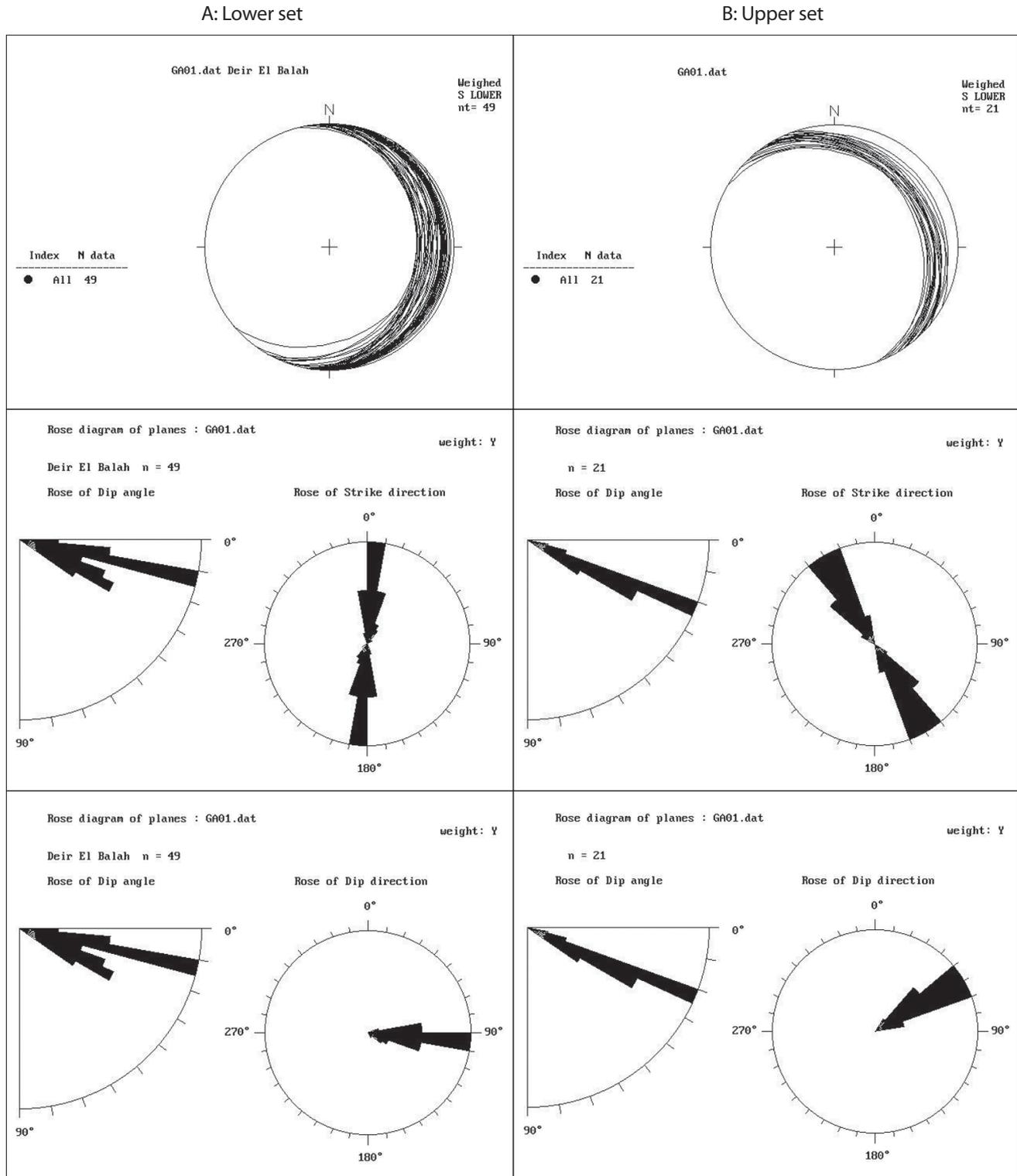


Figure 4: Rose diagram and stereographic projection for the cross-beds at the Deir ElBalah site (GS01). Column (A) for the lower set and (B) for the upper one.

The sand forms the bulk of the coastal sediments, together with additional calcareous materials and aeolian and alluvial silty and clayey materials. The sand is composed of well sorted medium to coarse quartz grains, with less than 5% of feldspar and heavy minerals. The sand supply was reduced northwards and less but finer grained sandy material deposited along the coast to Haifa (GAZA ENVIRONMENTAL PROFILE, 1994). The mineralogy of the aeolianites in

the northern part of the coastal plain is dominated by quartz and a little feldspar (YAALON & LARONNE, 1971).

FRECHEN et al. (2002) pointed out that neither the Kurkar nor Hamra layers correlate with glacial and interglacial periods of the Northern Hemisphere.

SIVAN & PORAT (2004) showed that the Kurkar accumulated along the coastal plain at different time intervals throughout the Late Pleistocene, and that its deposition was

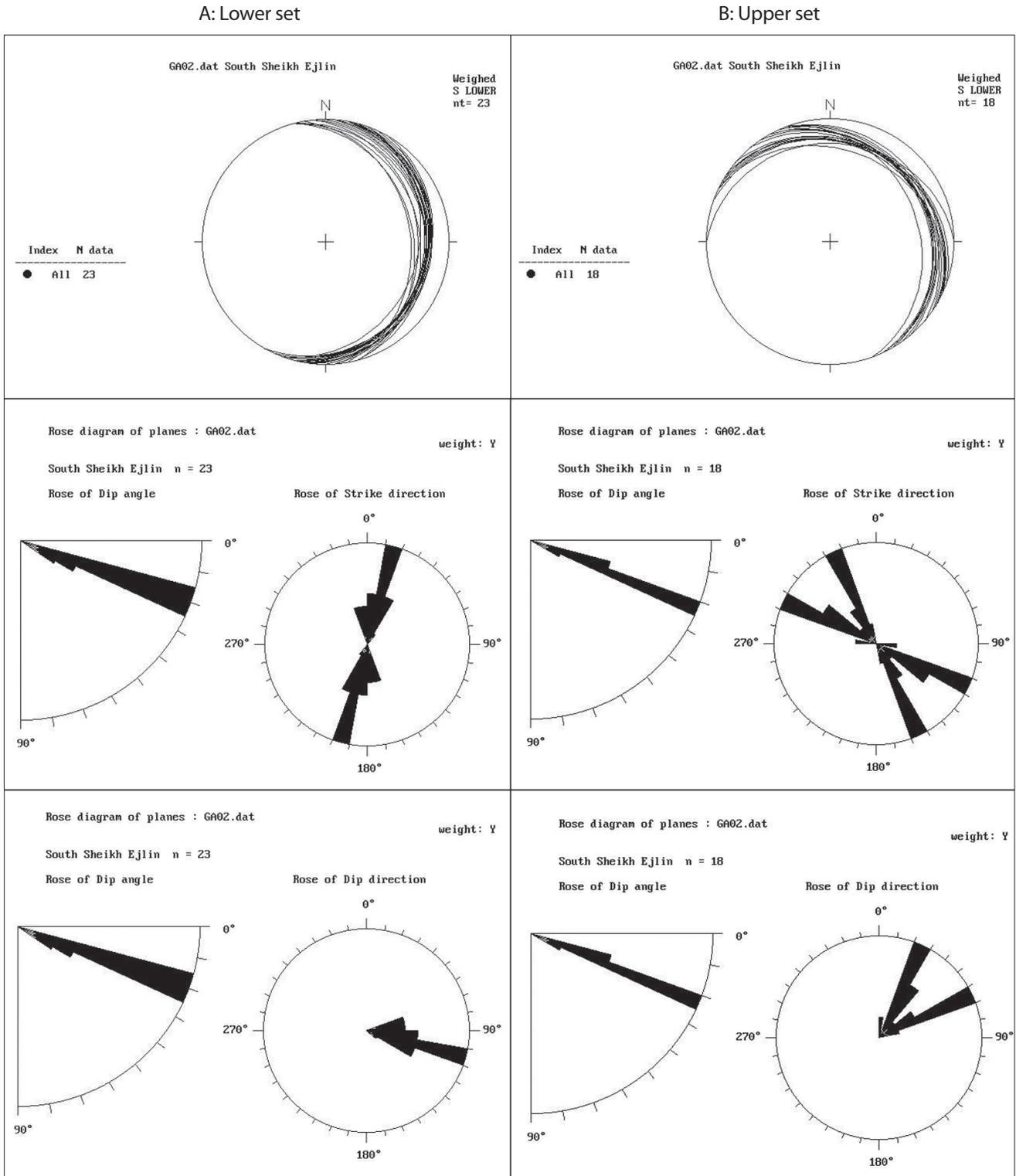


Figure 5: Rose diagram and stereographic projection for cross-beds at the south Sheikh Ejlin site (GS02). Columns A and B are same as for Figure 4.

not necessarily associated with high sea levels. They obtained detailed stratigraphy and luminescence ages for the Kurkar and Hamra layers that range from 35 to 101 ka, indicating coeval formation of these units during the Late Pleistocene.

At location GS01, at Deir ElBalah, a Kurkar layer overlies the Hamra layer. Tabular cross-bedding has been observed within the Kurkar layers at this site. Two sets of cross-beds have

been recognized (Fig. 3A). The lower set dips east, while the upper set is dips northeast. 70 measurements of dip and dip direction for the cross-beds of the lower and upper sets have been measured. The measurements plotted as rose diagram and as a stereographic projection (Fig. 4). The mean dip and dip direction have been calculated for the lower set as 16/098 (to the east) while it is 23/053 (to the northeast) for the upper set.

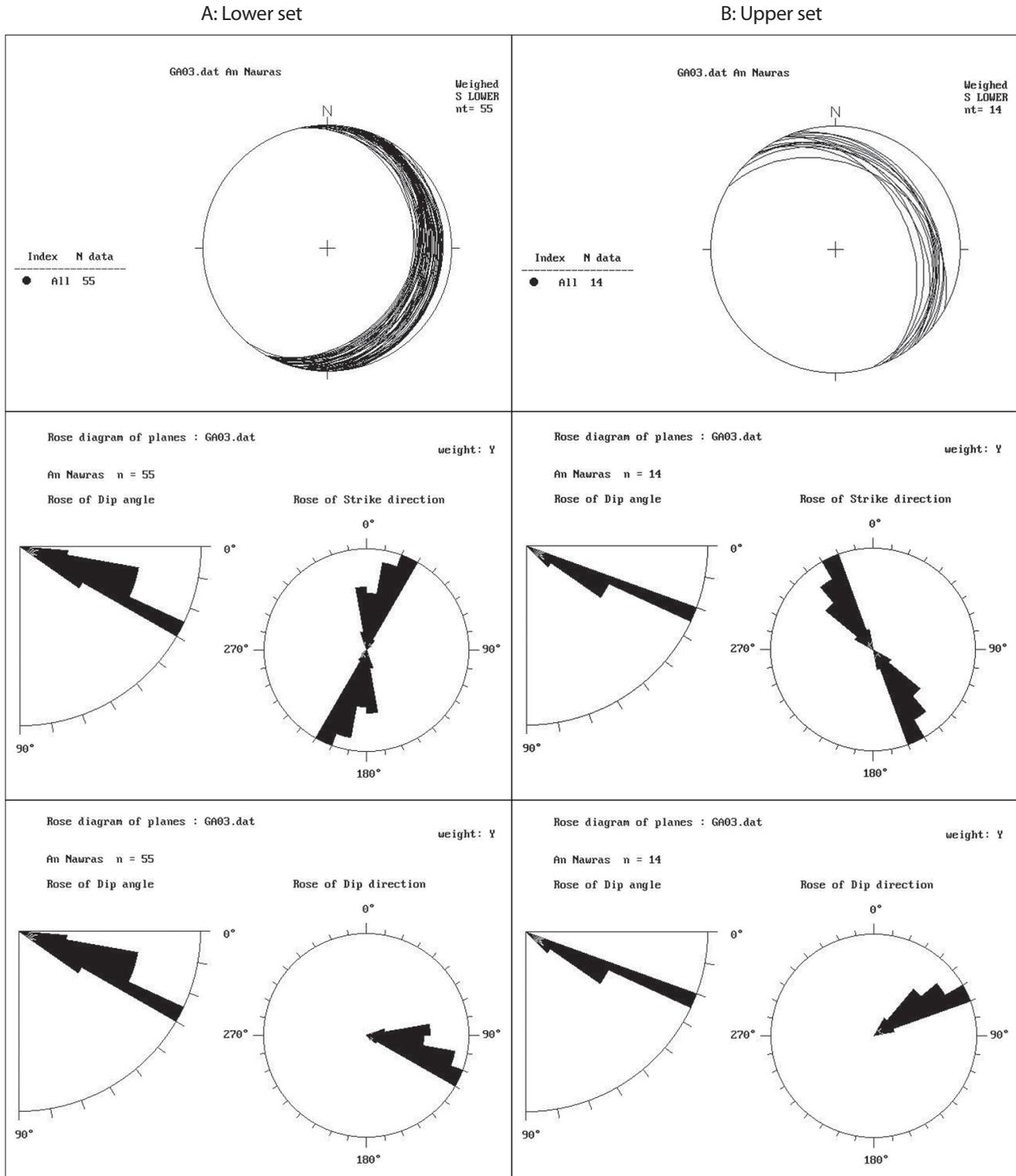


Figure 6: Rose diagram and stereographic projection for the cross-beds at the AnNawras site (GS03). Columns A and B as Figure 4.

At site GS02, south Sheikh Ejlin, the Kurkar layer also shows tabular cross-bedding (Fig. 3B) and overlies the Hamra layer. Fig. 5 shows the represented data collected at this location site. The mean dip and dip direction for the lower set of cross-beds is 20/096 (to the east) and for the upper set is 20/042 (to the north east). These mean values have been calculated from 41 measurements collected at this site.

At site GS03, at AnNawras, to the north of the Gaza Strip, only the Kurkar layer has been observed (Fig. 3C) and shows tabular cross-bedding with two sets of cross-beds. 69 measurements of dip and dip direction were collected for the two sets of cross-beds (Fig. 6). The mean dip and dip direction for the lower set is 20/104 (to the east) and for the upper set is 27/055 (to the northeast).

Convolute cross-bedding, as observed here (Fig. 7A), is a distinctive kind of internal deformation seen within many sandy beds that have been laid down very rapidly. It takes an irregular form within the bed itself, which is otherwise not affected by the deformation. Although its origin is somewhat uncertain, it appears to affect sediments in a state of partial liquefaction caused by its very rapid deposition, so

that this structure is most likely to be formed by the upwards escape of water during the very early stages of compaction (ROBERTS, 1996).

The three previous sites (GS01, GS02 and GS03) are located at Sheikh Ejlin Ridge where the lower set of cross-beds dips east and the upper one dips northeast.

At site GS04, Tal ErRayyes, two Kurkar layers, with Hamra layer in between, have been observed. Tal ErRayyes is located at the Al Montar Ridge where the dip directions of the two sets of the cross-beds are differ from those at the previous locations on the Sheikh Ejlin Ridge. Within each of Kurkar layer at this site (GS04), two sets of tabular cross-bedding have been identified (Fig. 3D). The lower set dips southeast while the upper one dips north. Fig 8 shows the results of 61 dip and dip direction measurements for the cross-beds, collected for the lower and upper sets within the two of Kurkar layers. The mean dip and dip direction for the lower set is 18/146 (to the southeast) and 21/359 (to the north) for the upper one. Convolute cross-bedding was again observed at Tal ErRayyes (Fig. 7B).

At site GS05, Tal ElKashef (Tal Zommo), a Kurkar layer with only one set of cross bedding was observed. The set dips north here (Fig. 9). Since sites GS04 and GS05 are located on the Al Montar Ridge, the set of cross-beds within the Kurkar layer observed at GS05, is the upper set of tabular cross-bedding that occur on the Al Montar Ridge. The mean dip and dip direction for this set is 18/003 (to the north).

5. DISCUSSION

The current study presents palaeowind directions obtained from the cross-bedding data from within the aeolian Kurkar layers of the Gaza Strip, Palestine.

Wind has much less competence than water to pick up particles. The aeolian environment is characterized by spectacular cross-beds at high angles of 20–30 degrees. Most of these beds are tabular (planar), as shown in the Kurkar layers in the study area. Moreover, sediments deposited by water are more consistent than those deposited by the wind. The Kurkar of the Gaza Strip is less consistent. Therefore, the Kurkar of the study area is interpreted as having been deposited in an aeolian environment. Kurkar layers are soft and reliable.

YAALON (1967) proposed that the main factors controlling the transformation of the calcareous dune sand into either a consolidated aeolianite or a Hamra layer are the original content of CaCO_3 in the dune and the intensity of leaching as affected by the relief and micro-climatic conditions. He concluded that all the sedimentary deposits and associated soils could have formed under similar climatic conditions.

PICARD (1943) noted that Kurkar is defined as calcareous sandstone derived from littoral as well as coastal dune-sand and later diagenetically hardened by calcareous solutions. NEEV et al. (1987) noted that the Kurkar seems to have been deposited in a continental environment from aeolian sands that accumulated during both high stands and regressions of sea level. Increased sand is related to increased

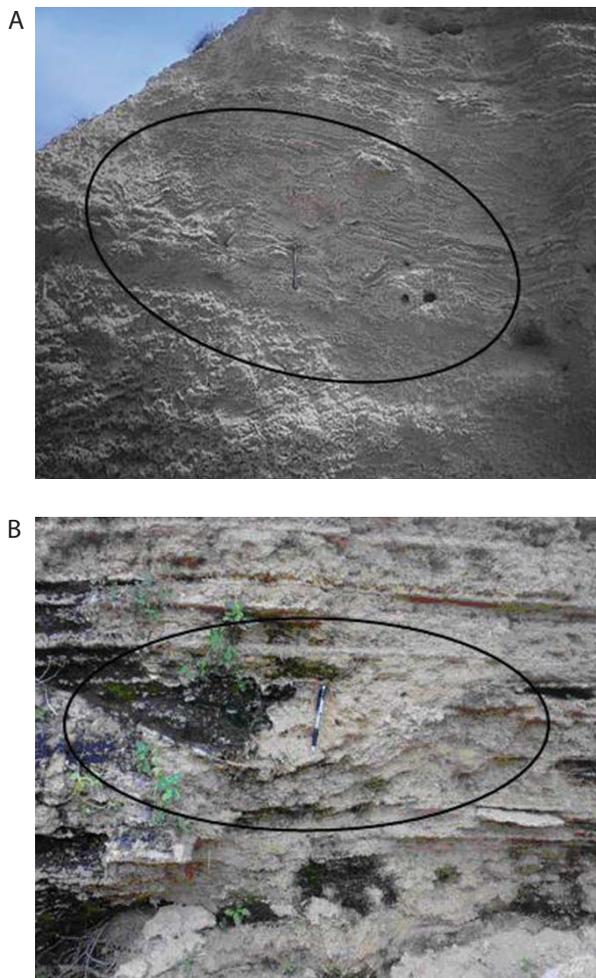


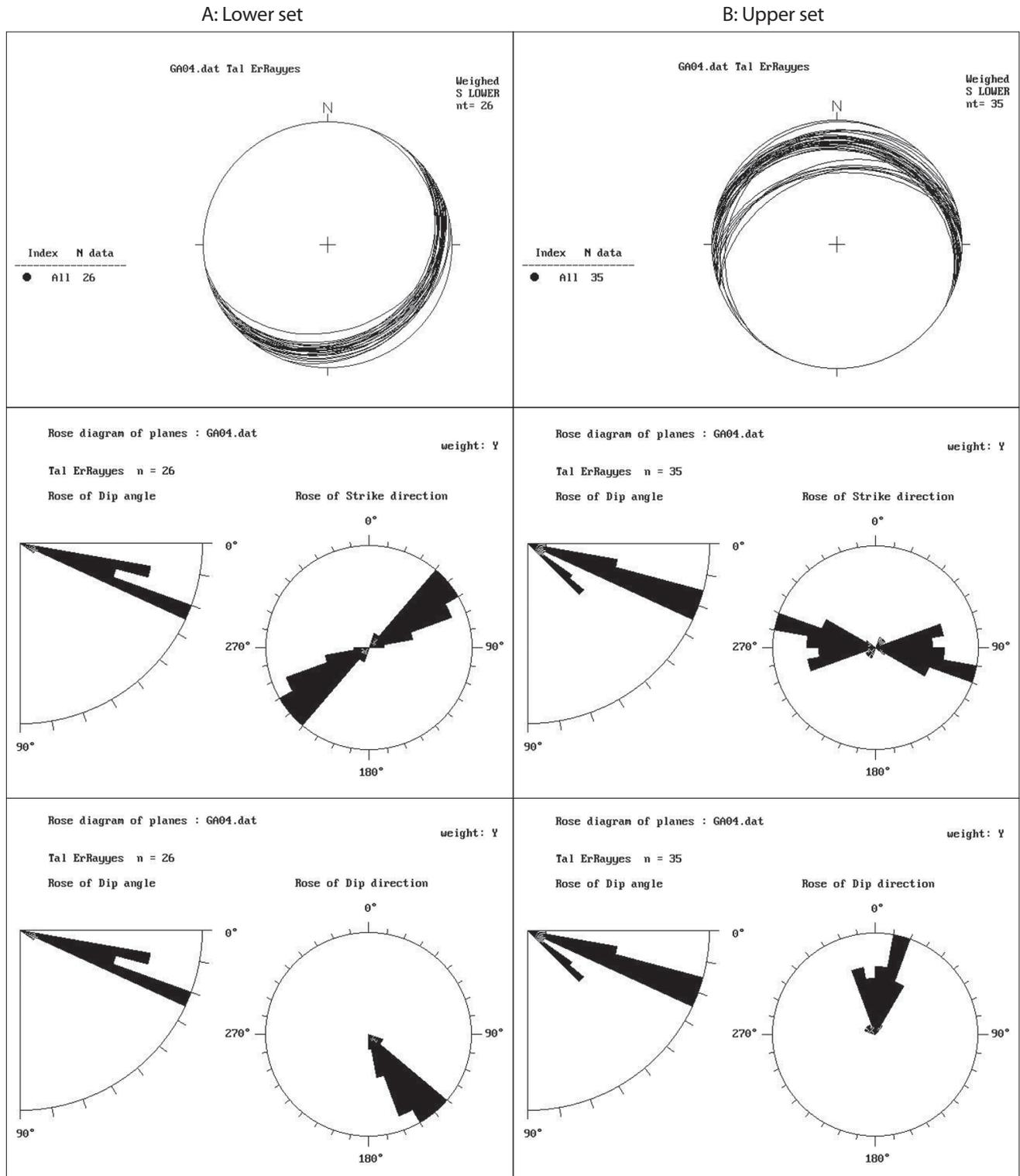
Figure 7: Convolute cross-bedding observed within the Kurkar layers. A) at AnNawras, B) at Tal ErRayyes. Hammer and pencil scale are 32 and 14 cm respectively.

tectonic activity that caused the uplift and disturbance of sediments within the Nile Delta province, thereby leading to increased erosion. The sand ingression across the coastline is superimposed on the tectonic destruction.

At the central coastal plain, to the north of the study area, FRECHEN et al. (2002) and PORAT et al. (2004) noted that the Kurkar ridges at the Levant are designated to represent typical longitudinal sand dunes formed synchronously par-

allel to the coastline by a dominant wind direction perpendicular to the coast. The different facies are related to changes in the environmental setting. They dated these sediments by luminescence methods as 65 ka to 5 ka.

Careful study of cross beds can often determine ancient wind directions as the dip direction of the cross-bedded sediments provides insight into wind direction. The field observations show that there are two sets of cross-beds within the



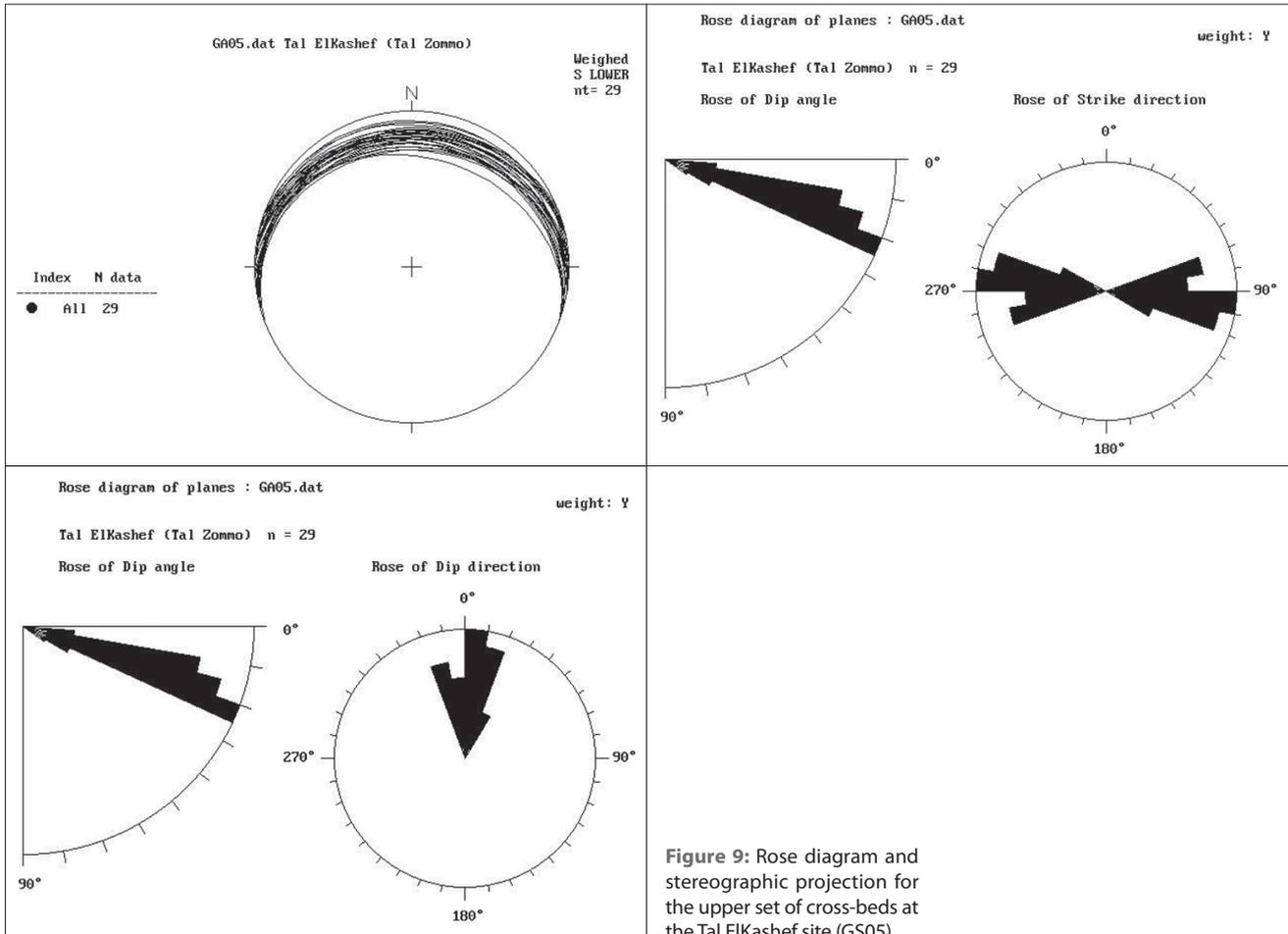


Figure 9: Rose diagram and stereographic projection for the upper set of cross-beds at the Tal ElKashef site (GS05).

Kurkar layers in the study area. As sites GS01, GS02 and GS03 are located on the same, Sheikh Ejlin Ridge, the mean values for dip and dip direction for each set were calculated for the three observation sites. The result shows that the mean dip and dip direction of the lower set at Sheikh Ejlin Ridge is 19/099 (to the east) while it is 23/051 (to the northeast) for the upper one (Table 2 and Fig. 10). Since the dip direction of the cross-bedded sediments provides insight into wind

direction, the palaeowind direction at the Sheikh Ejlin Ridge was westerly and southwesterly during deposition of the Kurkar layers. The same direction was obtained by YAALON & LARONNE (1971) at the aeolianite coastal ridge a few tens of kilometres north of the study area. They indicated that a westerly and southwesterly wind regime prevailed in the past. This ridge is the extension of Sheikh Ejlin Ridge of the study area.

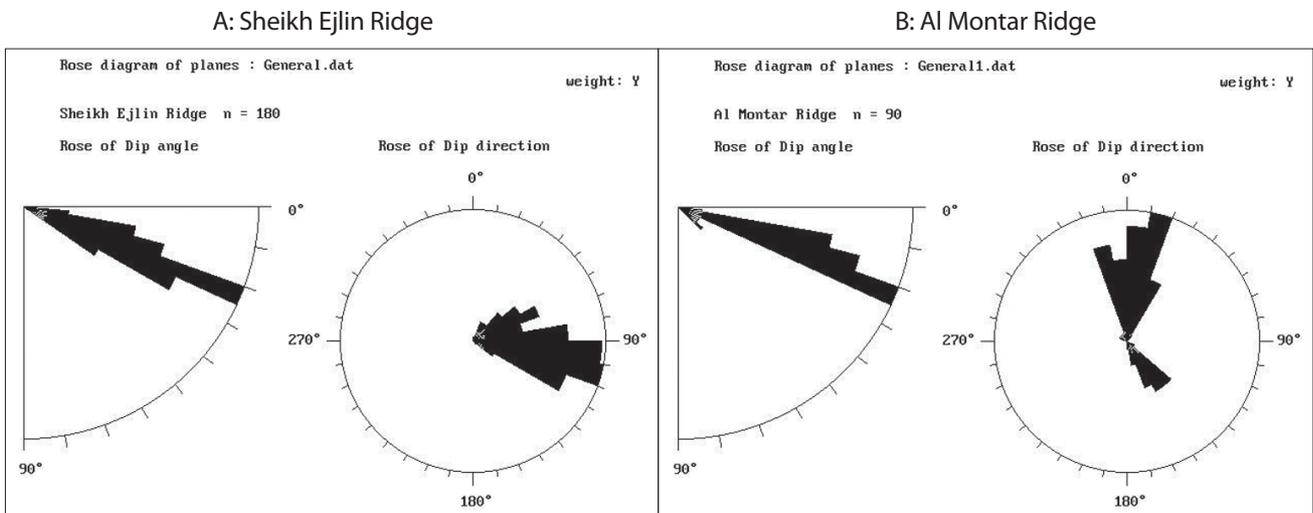


Figure 10: Rose of palaeowind directions of all data for both sets at the two ridges of Gaza Strip.

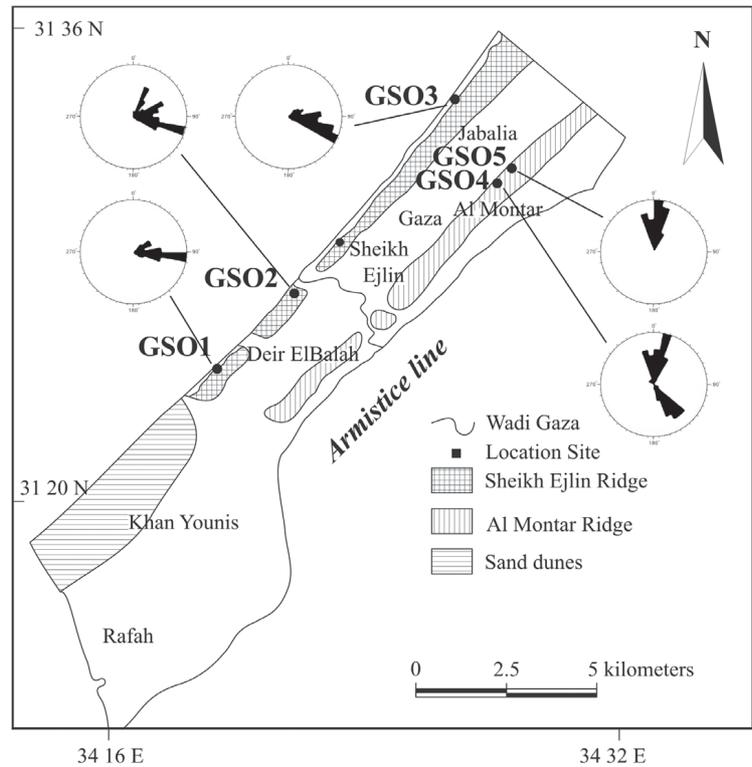


Figure 11: Rose of palaeowind directions at each site within the study area.

As sites GS04 and GS05 are located on the Al Montar Ridge, the mean values of the dip and dip direction of the two sets were calculated for the two observation sites. Since this ridge is presumably not age equivalent with Sheikh Ejlin, it is not surprising that the dip and dip directions are different. The mean dip and dip direction of the lower set of the cross-beds at GS04 site (the lower set observed just in this site) is 18/146 (to southeast). For the upper sets, the mean dip and dip direction at the two locations is 19/001 (to the north) as shown in Table 2 and Fig. 10. It can be inferred that the palaeowind direction was northwesterly and southerly at Al Montar Ridge. The mean direction of the palaeowind at each site was plotted at a map as shown in Fig. 11.

The results show that the direction of the palaeowind was westerly for the bottom (lower set) of the Kurkar layer and southwesterly for the upper set of the layer at Sheikh

Ejlin Ridge, while it was northwesterly at the bottom of the layer and southerly at the top of it at Al Montar Ridge. This result was clear for all five sites within the study area, suggesting that there was a change in wind direction during deposition of the Kurkar layers from a westerly to southwesterly direction at Sheikh Ejlin Ridge, and from a northwesterly to southerly direction at the Al Montar Ridge.

6. CONCLUSION

The study shows that the Kurkar layers are characterized by their tabular (planar) and convolute cross-bedding. Two sets of cross-beds observed within the Kurkar layers are documented. The dip direction of these sets indicates the direction of wind during deposition of the Kurkar layers. The lower set dips east at the Sheikh Ejlin Ridge and southeast at the Al Montar Ridge, while the upper set dips northeast at Sheikh Ejlin Ridge and north at the Al Montar Ridge.

It can be concluded that a change of palaeowind direction occurred during deposition of the Kurkar layers in the Gaza Strip in both analysed ridges. This appears to have been a change from a westerly to southwesterly wind at Sheikh Ejlin Ridge, as already reported by YAALON & LARONNE (1971), and from a northwesterly to southerly wind at the Al Montar Ridge.

Table 2: Summary of the mean dip and dip direction of the cross-beds within the Kurkar layer of the study area.

Site	Lat.	Long.	Location	Lower set	Upper set
Sheikh Ejlin Ridge:					
GS01	31° 25.07'	34° 19.75'	Deir ElBalah	16/098	23/053
GS02	31° 27.47'	34° 22.19'	South Sheikh Ejlin	20/096	20/042
GS03	31° 33.48'	34° 24.80'	AnNawras	20/104	27/055
Mean				19/099	23/051
Al Montar Ridge:					
GS04	31° 30.78'	34° 29.52'	Tal ErRayyes	18/146	21/359
GS05	31° 31.35'	34° 30.09'	Tal ElKashef	–	18/003
Mean				18/146	19/001

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