Marine Lithifacies and Depositional Zones Analysis along Coastal Ridge in Gaza Strip, Palestine

Khalid F. Ubeid

Department of Geology, Faculty of Science, Al Azhar University – Gaza

P.O. Box 1277, Gaza, Palestine

Tel: 9725-9971-2092 E-mail: k.ubeid@alazhar-gaza.edu

Abstract

The coastal plain of Gaza Strip is composed of an alternated kurkar and hamra deposits of Pleistocene to Holocene age. The hamra deposits consists of reddish brown sandy loam soils. The kurkar is mainly made of calcareous sandstones of marine and continental origin. Five marine lithofacies were identified along the coastal ridge within Gaza Strip which extends up to the current coastline of the Mediterranean Sea. These lithofacies are: (1) laminated medium- to very coarse-grained sandstones; (2) medium- to very coarse-grained cross-bedded sandstones; (3) graded coarse-grained sandstones; (4) massive coarse-grained sandstones; (5) bioclastic sandstones (calcarenite). The marine lithofacies identified in the study area belong to one of the two sedimentation zones: (1) the upper shoreface, represented by biogenic activities and marine fauna contents in sandy cross-stratification, and (2) the upper and lower foreshore, characterized by laminated with low-angle cross-stratification and channel deposits with low contents of marine fauna.

Keywords: Sandstones, Foreshore, Shoreface, Kurkar, Hamra, Gaza

1. Introduction

The Gaza Strip is located at the southwestern part of Palestine, at the southeastern coast plain of the Mediterranean Sea (Fig. 1). Its area is about 365 km^2, it has a length of 45 km from Beit Hanon in the north to Rafah in the south, and its width range from 5 – 7 km in the north to a maximum of 12 km in the south.

The Gaza Strip forms part of the coastal foreshore plain bordering the El-Khalil mountains (part of the West Bank) in the northeast, the northern Negev desert in the southeast, and the northern Sinai desert in the south. The coastal plain is dissected by three valleys (locally termed Wadis). The Wadi Gaza in the central part, with a large catchment area stretching far beyond Bear Esabaa. Since several decades, it rarely flows due to numerous water diversion and storage projects upstream in Israel. The Wadi Halib draining the depression of Beit Hanon, a tributary of Nahal Shiqma (Israeli terminology) flowing near Eres in the north. The third valley is Wadi Silka near Khan Younes, now a dry wash only flowing after torrential rains and no longer reaching the sea.

Three elongated ridges characterized the Gaza topography, these are known as kurkar ridges for their hard sandstone that has been used extensively for construction purposes since earlier times (Neev *et al*., 1987). The age of these ridges increase from the coastline eastwards. The ridges are built of several sedimentary cycles (Ronen, 1975; Gvirtzman *et al*., 1984), which are intercalated by red sandy loam soils locally termed hamra (Arabic word for red)(Yaalon & Dan, 1967). The ridges are separated by deep depressions (20-40 m above main sea level) with alluvial deposits. The ridges and depressions generally extend in a NNE-SSW direction, parallel to the Mediterranean coastline. The coastal ridge or Shiekh Ejlin ridge in sense of Anan and Zaineldeen (2008) is up to 50 m above main sea level, it extends up to the current coastline in the west. At the middle lay the Al-Montar ridge which is up to 80 m above main sea level (Gaza Environmental Profile (GEP, 1994)). The third ridge is Bit Hanoun ridge partially running along the armistice line in the east (GEP, 1994).

Four offshore kurkar ridges also have been mapped on the continental shelf (Emery and Bentor 1960; Neev *et al*., 1976; Almagor 1979; and Neev *et al*., 1987). This system extends from the littoral zone in the east to the upper continental slope in the west (Neev *et al*., 1987).

The stratigraphy of Gaza Strip is a part of coastal plain of Palestine which belong to Terriary and Quarenary age. It consists of three main groups; Avedat, Saqia, and Kurkar Group (Bartov & Arkin, 1980) (Fig. 2).

The kurkar Group has Pliocene-Pleistocene age. It consists of marine and continental deposits (Bartov & Arkin, 1980; Frechen *et al*., 2004; Al-Agha & El-Nakhal, 2004; Galili *et al*., 2007).

Several Fms within the Kurkar Group have been distinguished (Fig. 2): Ahuzam Fm (0 to 15 m- thick), it consists of conglomerates made of limestone and chalk. Pleshet Fm (0 to 80 m- thick), it consists of calcareous sandstones with marine fauna indicating to marine origin. Gaza Fm, it mainly consists of an alternated kurkar and hamra deposits with gradational and sharp contacts, and attains some 50-60 m in thickness (Horowitz, 1975) (Fig. 3).

The aim of this work was to study the sedimentology of the coastal ridge along coastline in Gaza Strip. We will focus on the marine deposits that crop out in the ridge and analyse their depositional zones.

2. Methods

Field work was carried out along the coastal ridge in the Gaza Strip, it started from northwards at Es-Sudania locality and continued up to middle part of Gaza Strip at Dier El Balah locality where the ridge dies out. Three observation sites were selected where the facies are well cropped out; at the beach near the Es-Sudania; El-Nusirat; and Deir El Balah. These observation sites were located by GPS device (Table 1). In each site, the usual parameters of lithology, bedding, thickness, and sedimentary structures were noted down. Fresh samples were taken for their study in the laboratory.

The samples were studied under the binocular microscope to identify the marine fauna. Sieve analysis method was used to separate the grains for each facies (Table 2), then the resultant data were processed with WinSieve software to obtain the grain-size distribution. To find the percentage of calcium carbonate in the samples, insoluble residual analysis method was used.

The facies identification and interpretation will dealt in the lithofacies Chapter. The first step of facies identification was performed in the field, later with the additional data provided by study of the rock samples.

3. Lithofacies

Five marine lithofacies were identified in the outcrops along the coastal ridge which extends up to the current coastline of the Mediterranean Sea. These lithofacies are classified based on grain-size, sedimentary structures, carbonate contents, trace fossils, and fossil contents.

3.1 Lithofacies 1. Laminated medium- to very coarse-grained sandstones

This lithofacies crops out at the northern part of Gaza Strip to South of Es-Sudania locality (N 31.54344^o E 34.45124^o). It consists of medium- to very coarse-grained sandstones, with variable contents of calcium carbonates (from 10% up to 24%). The sand fraction of this lithofacies is mainly composed of moderately to well sort; rounded to subrounded quartz grains with subordinate amount of feldspares. The laminae range from horizontal to very low angle cross-stratification. The dipping of the laminae indicates to seaward. The thickness of the lamina is less 10 mm. They separated by few mm- thick of silt to very fine-grained sandstones, which are less hardness than the coarse-grained laminae due to low contents of calcium carbonates (Fig 4A). This lithofacies forms packages up to 15 cm-thick, and it forms unit up to 4 m- thick. It is gradationally overlain by brownish fine-grained sandstones (hamra deposits, out of scope of this work), and laterally to northwards it passes into massive coarse-grained sandstones rich with bioclasts (Lithofacies 4). The burrows in this lithfacies are weak.

3.2 Lithofacies 2. Medium- to very coarse-grained cross-bedded sandstones

This lithofacies consists of medium to very coarse-grained sandstones. Calcium carbonate content is up to 24%. The cross-bedding is high-angle planar, with tangential base (Fig. 4B). The dipping of the inclined laminae is about 13 degree. In some locations especially at Dier El Balah site the cross bedding is convoluted due to water escape (Fig, 4C). This lithofacies forms packages up to 4 m-thick, it commonly overlays brownish fine-grained sandstones (hamra deposits), with sharp contact (Fig. 3A). Foram shells e.g. Ammonia and very small size marine gastropods are found in Es-Sudania site (N 31.55798^o E 34.46333^o), and at Dier El Balah (N 31.41763^o E 34.32921^o). In addition to unidentified bioclasts of coarse- to very coarse-grained size are found in this lithofacies. These bioclasts are more than 30% at the northern parts especially at Al Nawras in Es-Sudania site, whereas decrease to less than 15% at the middle parts. The burrows in this lithofacies are moderate to intense. They are mostly vertical tube-like, their diameters are about some mm, whereas their length is about 10 cm. Horizontal or diagonal tubes are not common. These tubes are filled with similar sand surrounded with them. Mostly these tubes cut with top of the beds which also reach in thickness to several centimeters (Fig. 4B). The paleocurrents that have been measured at the Deir El Balah site in the middle of Gaza Strip indicate to NE direction; whereas, the paleocurrents at the Es-Sudania site in the north of Gaza Strip indicate to NEE.

3.3 Lithofacies 3. Graded coarse-grained sandstones

This lithofacies consists of coarse-grained sandstones graded to fine-grained. It cemented by calcium carbonates with variable contents (12% to 24%). Bedding surfaces cannot be distinguished due to weathering activities. Overall, it forms unit up to 3 m-thick, and shows fining upwards. It overlain by brownish fine-grained sandstones with gradational contact. This lithofacies can be easily observed in Dier El Balah and Es-Sudania sites. Scarcely bioclasts are found in this lithofacies, and rare burrows are observed.

3.4 Lithofacies 4. Massive coarse-grained sandstones

This lithofacies consists of well sorted and rounded- to subrounded coarse- to very coarse-grained sandstones. The grains are mainly made of quartz, and subordinate feldspars. This lithofacies contains variable contents of calcium carbonates as cement. It displays more hardness comparing with the other lithofacies of the ridge due to high contents of calcium carbonate which mostly reach up to 25%. Also, it contains small-size marine gastropods and bivalves especially in Dier El Balah site. Bioclasts of coarse-grained size are found in this lithofacies. The boiclasts content increases in northern part of Gaza Strip (Fig. 4D). Beds of this lithofacies are difficult to individualise de to amalgamation, but it forms packages up to one meter in thickness.

3.5 Lithofacies 5. Bioclastic sandstones (Calcarenite)

This lithofacies has been detected only at the beach of El-Nusirat locality (N31.45785^{o} E34.36985^{o}) (Fig. 1). It consists of very coarse-grained bioclasts carbonate cemented. Few amount of small-size marine gastropods and bivalves shells are found, also considerable amount of forams are found in this lithofacies. The boiclasts mainly made of partly broken and crushed bivalves and gastropods, and unidentified bioclasts (Fig. 4E). Coarse- to very coarse quartz grains form around 5% of this lithofacies. It forms beds up to 15 cm- thick with concave base and flat top embedded in laminated calcareous sandstones (Lithofacies 1) (Fig. 4D), forming package up to 1.5 m in thickness overlain and underlain by poorly cemented kurkar units of continental origin (out of scope of this work).

4. Depositional Environments

4.1 Lithofacies 1

The presence of horizontal- to gentle seaward dipping stratification in this lithofacies together with its comparatively better sorting fine grains, are indicative of deposition in foreshore zone which dominated by high-energy wave swash and related processes (Inden & Moore, 1983). Its vertical relationship with paleosoles (hamra deposits) is indicative of deposition on the upper foreshore (lower intertidal zone) (Fig. 5). The silt- to very fine-grained sandstone thin laminae high possibly would record deposition from slack-water periods (Rahmani, 1988; Darlymple, 1992). The variable contents of calcium carbonate high possibly referred to seasonal valleys and drainage which carried dissolved calcium carbonates from El-Khalil Mountains which mainly made of Cretaceous limestones.

4.2 Lithofacies 2

The characteristics of this facies e.g. grain-size, sedimentary structures, and fauna contents suggest to deposition in shallow marine environment. The cross-stratification found in this fcaies can be interpreted as product of deposition on the lower foreshore (subtidal) and upper shoreface zone (Oliveira *et al*., 1990). High possibly, these cross-stratification resulted from the migration of sinuous-crested bedforms with paleocurrent patterns similar to those observed on the present coastline and which are mainly influenced by longshore currents (Bezerra *et al*., 1998).

The presence of burrows on form parallel vertical tubes in this facies is characteristic of rapidly shifting substrates in shallow marine environments (Prothero and Schwab, 1996). It is typically encountered in clean, well sorted nearshore sand with a high level of wave and current energy, which prompt resistant organisms to dig vertical burrows for shelter. The prominent parallelism and vertically of these burrows are indicative of an environment with a high sedimentation rate inhabited by organisms capable of quick escape. Considering the high energy and frequent erosional processes that characterize the environment in which these tubes are most commonly found, the upper shoreface zone is the most suitable site (Fig. 5).

4.3 Lithofacies 3

The texture and scarce fauna suggest the deposition on the foreshore zone. The lateral and vertical relationship of this lithofacies with brownish fine-grained sandstones indicate that this facies deposited in upper foreshore (supratidal) environment (Fig. 5).

4.4 Lithofacies 4

The features of this lithofacies and its relationship with the other lithofacies such as lithofacies 1, suggest the deposition from high concentrated flow. Where, the lateral variation from laminated sandstones (lithofacies 1) to massive sandstone (lithofacies 4); and high percentage of calcium carbonate in this lithofacies indicate to increase in the concentration of the sediments and rapid deposition. That sediments originate from the Nile delta (Horiwitz, 1979), and have been spread along the Sinai and Palestine coasts by longshore currents (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; Zviely *et al*., 2007; Zaineldeen, 2010)

4.5 Lithofacies 5

The characteristics of this facies suggest the deposition on intertidal zone (Neev *et al*., 1987). The bioclasts clear result from crushing and pulverization of mollusk shells by waves and currents generated by winds in the upper shoreface zone (Reineck & Singh, 1980). These bioclasts transported due to their low density and deposited in intertidal channels after intense winnowing that removed the fine-grained sediments (Fig. 5).

5. Conclusions

In this study, the marine lithofacies and the hamra lithofacies distributed along the coastal ridge in Gaza Strip have been observed in three locations: the first location is at Al Nawras in Es-Sudania locality in the north, the second is at El-Nusairat locality in the middle, the third location in the Dier El Balah locality in the middle to south of El-Nusirat. Five marine lithofacies were identified along the coastal ridge in Gaza Strip. They are (1) laminated medium- to very coarse-grained sandstones; (2) medium- to very coarse-grained cross-bedded sandstones; (3) graded coarse-grained sandstones; (4) massive coarse-grained sandstones; (5) bioclastic sandstones (calcarenite). The characteristics of these lithofacies indicate that they are formed in the shallow marine coastal environment. These lithofacies are deposited in one of the two sedimentation zones:

1- The upper shoreface, represented by biogenic activities (burrows) and marine fauna contents in sandy cross-stratification

2- The upper and lower foreshore, characterized by laminated with low-angle cross-stratification and channel deposits with low contents of marine fauna.

References

Al-Agha, M.R. & El-Nakhal, H.A. (2004). Hydrochemical facies of groundwater in Gaza Strip, Palestine. *Hydrrological Sciences-Journal-des Sciences Hydrologiques*, 43, 359-371.

Almagor, G. (1979). Relict sediments of Pliestocene age on the continental shelf of northern Sinai and southern Israel. *Israel Journal. Earth-Sciences*, 27, 128-132.

Anan, H.S. and Zaineldeen, U.F. (2008). Kurkar ridges in the Gaza Strip of Palestine. M.E.R.C. *Ain Shams University, Earth Science Series,* 22, 139-146.

Bartov, Y., & Arkin, Y. (1980). Regional Stratigraphy of Israel. A guide to geological mapping. *Geol. Surv. Israel, Current Research,* p. 38-41.

Bezerra, F.H.R., Lima-Filho, F.P., Amaral, R.F., Caldas, L.H.O., and Costa-Neto, L.X. (1998). Holocene coastal tectonics in NE Brazil. In: Stewart, I.S. and VITA-FINZI Vita-Finzi, C. (eds.), *Coastal Tec-tonics.* London: Geological Society of London, Special Publication, 146, 279–293.

Carmel, Z., Inman, D. & Golik, A. (1985). Directional wave measurements at Haifa, Israel, and sediment transport along the Nile littoral cell. *Coast. Eng.,* 9, 21-36.

Coleman, J.M., Roberts, H.H., Murray, S.P. & Salama, M. (1981). Morphology and dynamic sedimentology of the eastern Nile Delta shelf. *Mar. Geol.,* 42, 301–326.

Darlymple, R.W. (1992). Tidal depositional systems. In Walker, R.G., and James, N.P. (Eds.). *Facies models: Response to sea level change.* Geological Association of Canada, Geotext 1, p. 195-218.

Emery, K.O., & Bentor, Y.K. (1960). The continental shelf of Israel: *Geol. Surv. Israel. Bull.,* 26, 25-41.

Frechen, M., Neber, A., Tsatskin, A., Boenigk, W., & Ronen, A. (2004). Chronology of Pleistocene sedimentary cycles in the Carmel Coastal Plain of Israel. *Quaternary International,* 121, 41-52.

Frihy, O.E., & Lotfy, M.F. (1997). Shoreline changes and beach-sand sorting along the northern Sinai coast of Egypt. *Geo. Mar. Lett.,* 17, 140-146.

Frihy, O.E., Fanos, A.M., Khafagy, A.A. & Komar, R.D. (1991). Patterns of sediment transport along the Nile Delta, Egypt. *Coast. Eng.,* 15, 409-429.

Galili, E., Zviely, D., Ronen, A., & Mienis, H.K. (2007). Beach deposits of MIS 5e high sea stand as indictors for tectonic stability of the Carmel coastal plain, Israel. *Quaternary Science Reviews,* 26, 2544-2557.

Gaza Environmental Profile (GEP) (1994). *Gaza Environmental Profile, Part one, Inventory of Resources,* Prepared for the Palestinian Environmental Protection Authority by Euroconsult and Iwaco, p. 60.

Goldsmith, V. & Golik, A. (1980). Sediment transport model of the southeastern Mediterranean coast. *Mar. Geol.,* 37, 147–175.

Gvirtzman, G., Shachnai, E., Bakler, N., & Ilani, S. (1984). Stratigraphy of the kurkar group (Quaternary) of the coastal plain of Israel. *Geol. Surv. Israel, Current Research1,* 983–84, p. 70–82.

Horowitz, A. (1975). The Quaternary Stratigraphy and Paleogeography of Israel. *Paléorient.,* 3, 47-100.

Horowitz, A. (1979). *The Quaternary of Israel.* Academic Press, New York, p. 85.

Inden, R.F. & Moore, C.H. (1983). Beach environment. In: Scholle, P.A.; Bebout, D.G., and Moore, C.H. (eds.), *Carbonate Depositional Environment.* American Association of Petroleum Geologists, Memoir, 33, 211–265.

Inman, D.L. & Jenkins, S.A. (1984). The Nile littoral cell and man's impact on the coastal zone of the southeastern Mediterranean. *Scripps Inst. Oceanogr. Ref., Ser.,* 31–84 (p.43).

Neev, D., Balker, N., & Emery, K.O. (1987). *Mediterranean coast of Israel and Sinai, Holocene tectonism from geology and geophysics and archaeology.* Taylor and Francis Publ., p.130.

Neev, D., Almagor, G., Arad, A., Ginzburg, A., & Hall, J.K. (1976). The geology of the southeastern Mediterranean. *Geol. Surv. Israel, Bull.,* 68, p. 51.

Oliveira, M.I.M., Bagnolli, E., Farias, C.C., Nogueeira, A.M.B., & Santiago, M. (1990). Consideracoes sobre a geometria, petrografia, sedimentologia, diagenese e idades dos beachrocks do Rio Grandedo Norte. *XXXIV Congresso Brasileiro de Geologia (Natal, RN, Brazil, Sociedade Brasileira de Geologia), Expanded Abstract 2,* 621–634.

Prothero, D.R. & Schwab, F. (1996). An Introduction to Sedimentary Rocks and Stratigraphy. *Sedimentary Geology.* New York: Freeman.

Rahmani, R.A. (1988). Estuarinetidal channeland nearshore sedimentation of the Late Cretaceous epicontinental sea, Drumheller, Alberta, Canada. In De Boer, P.l., Van Gelder, H., and Nio, S.D. (Eds.), *Tide-influenced Sedimentary Environments and Facies.* Reidal Publishing Company, Dordrecht, Holand, p. 417-432.

Reineck, H, E., & Singh, I. B. (1980). *Depositional sedimentary environments.* (2nd ed.). Springer-Verlag, Berlin, p. 549.

Rohrlich, V. & Goldsmith, V. (1984). Sediment transport along the southeast Mediteranean: a geological prespective*. Geo. Mar. Lett.,* 4, 99-103.

Ronen, A. (1975). The Palaeolithic archaeology and chronology of Israel. In: Wendorf, F., Marks, A.E. (Eds.), *Problems in Prehistory*: North Africa and the Levant, Southern Methodist University, Dallas, p. 229–248.

Zaineldee, U.F. (2010). Paleowind estimation of cross-bedding within the Aeolian kurkar layers of the Gaza Formation, Gaza Strip, Palestine. *Geological Croatia,* 63, 55-65.

Zviely, D., Kit, E. & Klein, M. (2007). Longshore sand transport estimates along the Mediterranean coast of Israel in the Holocene. *Mar. Geol.,* 238, 61–73.

Table 1. Location of the marine lithofacies in Gaza Strip

Facies no.	Locality	Coordinates	
		N	E
Facies 1	Es-Sudania	34.45124°	34.45124°
Facies 2	Es-Sudania	31.55798°	34.46333°
	Dier El Balah	31.41763°	34.32921°
Facies 3	Es-Sudania	31.54344°	34.45122°
	Dier El Balah	31.41763°	34.32921°
Facies 4	Dier El Balah	31.41762°	34.32924°
Facies 5	El-Nusirat	31.45785°	34.36985°

Table 2. Grain size distribution of the marine lithofacies in the coastal ridge, Gaza Strip

Facies no.	Clay & silt (%)	Very fine sand (%)	Fine sand (%)	Medium sand (%)	Coarse sand (%)	Very coarse sand (%)	Fine gravel (%)
Facies 1	2.63	3.4	31	25	20	13	4.2
Facies 2	1.2	4.5	31	22	26	7.7	6.6
Facies 3							
(Upper part)	1.49	3.5	36	36	20	2.5	0
(Lower part)	1.57	2.6	9.4	30	51	5.8	0.14
Facies 4	1.2	1.1	13.2	23.6	27.4	28	5.9

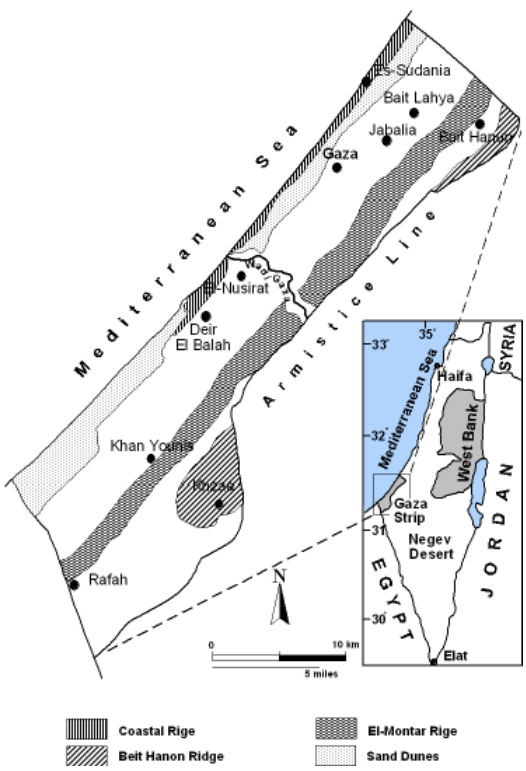

Figure 1. Location map shows the kurkar ridges within Gaza Strip (After GEP, 1994)

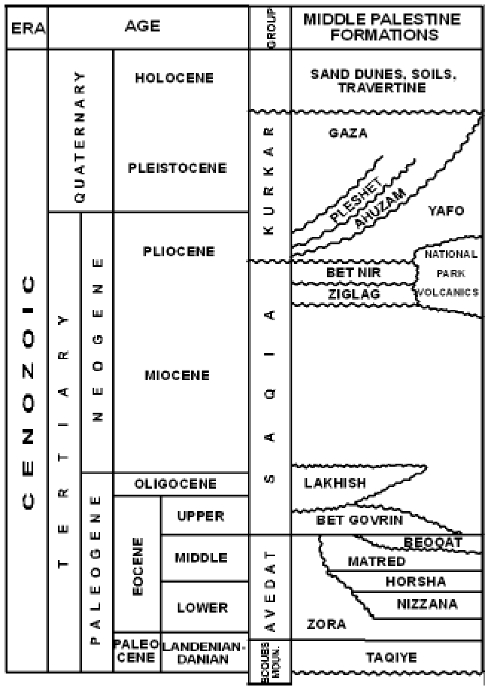

Figure 2. Stratigraphic succession of Tertiary and Quaternary age through the coastal plain of Palestine, showing the main formation defined in the area (After Bartov & Arkin, 1981)

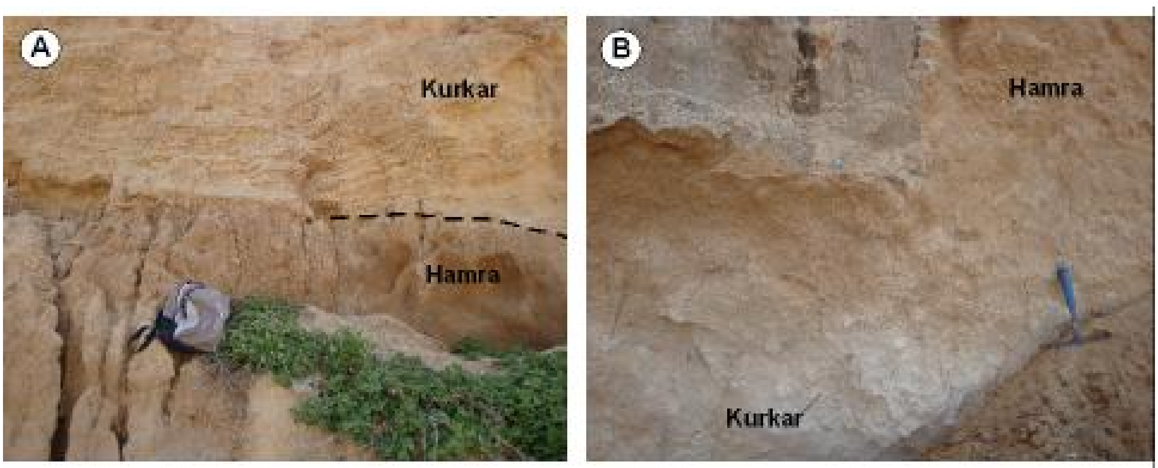

Figure 3. The contact between the kurkar and hamra deposits. (A) Graditional contact between massive sandstones. Northern part of Gaza Strip, at Es-Sudania locality. (B) Sharp contact between cross-bedded sandstones and hamra deposits. Middle of Gaza Strip, at beach of Deir El Balah locality. Bag and hammer scale are 45 and 32 cm respectively.

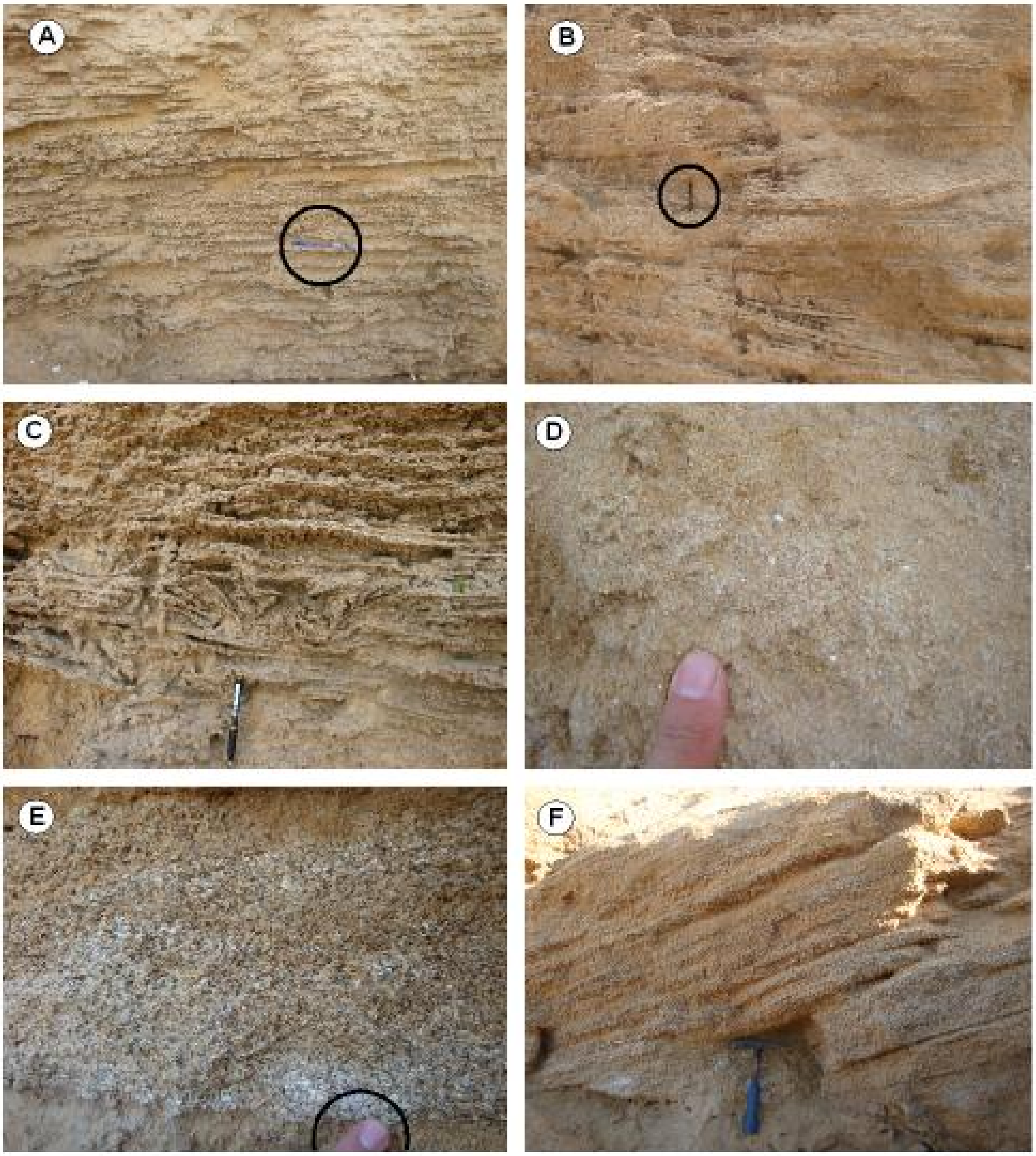

Figure 4. Field photographs of defined lithofacies. (A) Laminated medium- to very coarse-grained sandstones (lithofacies 1). Northern part of Gaza Strip at Es-Sudania locality. Pencil scale is 13 cm long. (B) Burrowed cross-bedded sandstones (lithifacies 2). Middle of Gaza Strip, at beach of Deir El Balah locality. Pencil scale is 13 cm long. (C) Convoluted structures of cross-bedded sandstones (lithofacies 2). Middle of Gaza Strip, at beach of Deir El Balah locality. Pencil scale is 13 cm long. (D) Massive coarse- to very coarse-grained sandstones rich with marine fossils and partly broken and crushed bivalves and gastropods (lithofacies 4). Nothern part of Gaza Strip, at Es-Sudania locality. Finger scale is 13 cm long. (E&F) Bioclastic sandstones (calcarenite) mainly made of marine fossils and partly broken and crushed bivalves and gastropods with subordinated of quartz grains (lithofacies 5). Middle part of Gaza Strip, at El-Nusirat locality. F shows the geometry of beds of lithofacies 5. Nail and hammer scale are 1.5 and 32 cm long respectively.

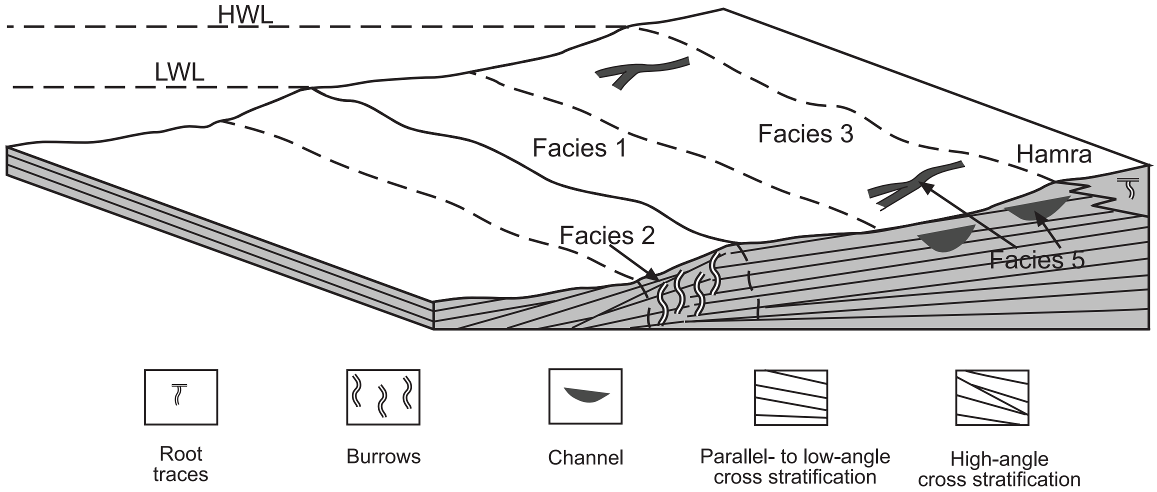

Figure 5. Depositional model showing the distribution of marine lithofcaies along the coastal ridge within Gaza Strip. HWL = high water level, LWL = low water level.