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Stratigraphy and Geographic Distribution of the Gaza Formation of the Kurkar Group, Gaza Strip, Palestine

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Abstract: This paper presents the citation and description of the outcropping Late Pleistocene Gaza Formation (alternating beds of Kurkar and Hamra) in the Gaza Strip of Palestine. The term Gaza Formation was originally applied to the 'kurkar' dune ridges and red 'hamra' paleosols in the eastern Mediterranean Coastal Plain, which represents the eolianites continental deposits of the upper Kurkar Group. This formation was early recognized only in boreholes in the Gaza area, which is never exposed in its entirety. Due to the problem of access of the type section of the Gaza Formation, the author designated an outcropping reference section, located at south Sheikh Ejlin (south of Gaza City), which is well known and easily accessible to the geologists and others in the area.

Key words: *Stratigraphy, Gaza Formation, Kurkar Group, Gaza Strip, Palestine.*

INTRODUCTION

The southeastern Levant coast narrows from approximately 50 km in the south (southern Mediterranean Sea coastal plain) to 20 km in the north near Jabal El Carmel at Haifa area (south Akka). It is characterized by longitudinal Kurkar ridges which trend subparallel to the coastline (Fig. 1). It is situated between the Mediterranean Sea in the west and the foothills of the Cretaceous-Eocene mountains in the east.

Gaza Strip is located at the southwestern coast plain of the Mediterranean Sea (Lat. 31° 12' - 31° 39' N, Long. 34° 11' - 34° 34' E). It is about 365 km² in area and 42 km long, while the width ranges between 6-12 km. Its surface as a whole is covered by Quaternary sediments, varying from the Pleistocene coastal area which has an alternating stratified calcareous (mainly cross-bedded) sandstones (locally termed Kurkar) and red sandy-clayey paleosols (locally termed Hamra = Arabic word for “red”) and also the Pleistocene loess and gravels outcrop in Wadi Ghazzah (Picard [(1)], El Khoudary & Anan [(2)]). The Holocene sediments are represented by coastal sand dunes and alluvial deposits.

PREVIOUS STUDIES AND STRATIGRAPHIC SETTING

The local name 'Hamra' was adopted by Reifenberg [(13)] for sandy-clayey loam, very common in the central Coastal Plain which is gradually replaced by loess and loess-loam toward the south. Loewengart [(4)] adapted another local name 'Kurkar' for cross-bedded calcareous sandstones, eolianites, bio-clastic limestone, beach-rocks deposited under continental or marine conditions and widely distributed in the Coastal Plain. Kurkar is the main component of several ridges of hills (originate from dunes) running parallel to the Mediterranean Coast line, showing by their steep landward slopes. The latter author also established the 'Kurkar Group' which consists of an alternating 'Kurkar' and 'Hamra', as well as conglomerates and non-consolidated dune sands. Picard [(1)] noted that the Quaternary Kurkar is mainly distributed in the western half of the Coastal Plain and forms 3-4 surface subdued ridges arranged more or less parallel to the coast, which can be grouped into two main complexes of continental kurkar: a lower one believed to be of the Lower-Middle Pleistocene age, and the upper one belonging to Upper Pleistocene. Still more to the south, at Wadi Ghazzah (W. Gaza) on the summit of the Kurkar ridges, bringing the Kurkar at least back to the Middle Pleistocene. Avnimelech [(5)] distinguished four kurkar complexes parallel to the coast .

Bentor *et al.* [(6)] noted that during the Pleistocene the subsidence of the coastal zone continued and let to the accumulation of more than 100 m. of clastic sediments (sand, sandstones and loams) in four times during the Pleistocene eustatic oscillations of the sea-level, modified by local tectonic movements, caused marine ingressions to submerge the western part of the Coastal Plain. Issar [(7)] recorded three sandstone ridges running parallel to the coast and longitudinal valleys filled with alluvial clays are found west of the ridges. Gvirtzman & Buchbinder [(8)] and Gvirtzman & Klang [(9)] figured the Pliocene-Pleistocene Kurkar Group unconformably overly the Eocene Saqiya Group/Hashephela Group. Neev *et al.* [(10)] tabled the Pleistocene-Holocene Kurkar Group (carbonate cemented eolianites interbedded with loams and swamp deposits in the coastal hinge-line) on the Upper Pliocene marly upper Yafo Formation, after Gvirtzman in Gvirtzman & Reiss [(11)].

Inman & Jenkins [(12)] noted that coastline of southeastern Mediterranean forms a large system that extends from Alexandria of Egypt at the west side of the Nile Delta, via Bardawil Lagoon, El Arish, Gaza, up to the bay of Akka. Hassan *et al.* [(13)]

noted that an evidence of previous sea levels on the Mediterranean coast of Egypt consists of a series of eight linear limestone ridges that run parallel to the coast (west of Alexandria, Egypt), and are separated by troughs filled with colluviums and form sea cliffs with wave-cut platforms. Neev *et al*. [14] recorded three onshore and four offshore kurkar ridges along the Palestinian coastal plain, while GEP (Gaza Environmental Profile [15]) mapped five scattered ridges on land of the Gaza Strip. Stanley [16] also traced eight kurkar ridges at west of Alexandria which extended from the shore line in the west, to about 40 km in land to the east. Hirsch *et al*. [17] noted that the Kurkar Group includes the various sandy formations overlying the Saqiye Group in the Coastal Plain and Hashephela, and interfingers laterally with the uppermost Saqiye Group.

Recently, Anan & Zaineldeen [18] observed, in a preliminary study on the safty areas of the Gaza Strip (far enough from the armistice line), two Kurkar ridges and named by them as: (1) 'Sheikh Ejlin Ridge' which extends up to the current coastline in the vicinity of the Mediterranean coast in the west in four outcrops (GS01-04 - Fig. 1), and (2) 'Al Montar Ridge' near the armistice line in the east in five outcrops (GS05-09 - Fig. 1). These both ridges running NE-SW parallel to the coast line of the Mediterranean Sea and separated by deep depression with about 20 to 40 m above mean sea level (msl), covered with alluvial deposits and dissected by running water (Wadi channels) coming from the Palestinian mountains (Al Khalil = Habron, and Beer EsSabaa' = Beer Sheba) in the east to the coastal plain in the west. The latter authors noted that a third ridge (as noted by Neev *et al.* [10] and Neev *et al.* [14]) most probably may be located eastward, out side of Gaza Strip or just around the armistice line (the movement at that area in that time was fatal).

In this study (after the withdrawal of Israeli forces from that border area, at the end of the Israeli war on Gaza 2008/2009), besides 'Sheikh Ejlin Ridge' and 'Al Montar Ridge', the third ridge "Beit Hanoun Ridge" is added (GS10-Fig. 1), which is located in the northeast corner of the Gaza Strip, just beside the armistice border line between the Gaza Strip and Israel.

The Kurkar Group consists of many nearly synchronous formations due to different facies in the different localities in the Coastal Plain, and this is summerized as follows:

1) Pleshet Formation (Issar [19]) (Late Pliocene-Early Pleistocene). It consists of Calcareous Sandstone of Philistaea in the Mediterranean shelf and western coastal plain (Hull [20]) (Pleshet is the Hebrew name of Philistaea = land of Palestine). The type-section was studied in Majdal (Asqalan=Ashqelon, to the north of Gaza Strip), well no. 5a, and its maximum thickness about 160 m. Pleshet Formation also known as 'Lithothamniumkalk' (Blanckenhorn [21]), 'Shelly Oolitic Limestone' by Blake [22] and 'Abu Hareira' (Picard & Solomonica [23]). Pleshet Formation includes all calcareous sandstone and sandy limestone of the Coastal Plain, and conglomeratic sandstone is more abundant at the bottom.

2) Ahuzam Conglomerate (Issar [19], Early Pleistocene). The type-section was described near Ahuzam Village (about 20 km outside the northeast Gaza Strip), with 0-20 m. thick of the gravel beds found in the eastern parts of the Coastal Plain. It is synonyms to 'Les Terrasses de Ouadi Sarar' by Avnimelech [24], 'Upper and Lower Gravel Horizons' of Picard [1], 'Ancient River Terrace of Quaternary-Neogene' of Picard [25]. Ahuzam Conglomerate is intercalated and overlies the Pleshet Formation as well as the Hashephela and Saqiye Groups.

3) Gaza Formation (Horowitz [26], emended by the present author) (Middle-Late Pleistocene). It consists of 'kurkar' dune ridges and red 'hamra' paleosols in the Mediterranean Coastal Plain, which represents the continental deposits of the upper Kurkar Group. It is of terrestrial origin, influenced by sea level and pedogenetic processes, and recognized in boreholes in the Gaza area, which is never exposed in its entirety. Gaza Formation corresponds almost entirely to its junior synonym, the Hefer Formation, which was defined in the Jaffa-1 borehole and overlies the Jaffa (Yafo) Formation and also overlying the Ahuzam Conglomerate. It may overly many previous Mio-Pliocene or even Cenomanian rocks (Hirsch *et al.* [17]).

REFERENCE OUTCROP SECTION OF THE GAZA FORMATION IN GAZA STRIP

Author: Horowitz [26], emended by the present author.

Thickness of the outcrop reference section: The reference-type section of the Gaza Formation (of the Kurkar Group) is measured in south Sheikh Ejlin section (south of Gaza City) at the coastal line, which outcrops on the both sides of the Gaza-Deir El Balah main asphalted road (Long. 31º 27 43´ N, Lat. 34º 22 16´ E). The composite reference section consists of about 46 m (Fig. 2).

Description of outcrop reference section: The Gaza Formation in the outcrop reference composite section consists of successive alternating Pleistocene beds of Kurkar and Hamra (Fig. 3: 1-6). Two sets of cross-bedding have been identified within the Kurkar beds of the Gaza Formation (Zaineldeen, personal communication).

Age: Middle-Late Pleistocene.

Geographical distribution: The succession of the Gaza Formation is exposed at different locations in the three ridges of the Gaza Strip (see Fig. 1). The coordinates and elevations of some location sites are shown in Table (1).

DEPOSITIONAL ENVIRONMENT OF THE KURKAR RIDGES

Picard [1] noted that Kurkar is defined as calcareous sandstone derived from littoral as well as coastal dune-sand, and later diagenetically hardened by calcareous solutions. Part of the Kurkar ridges (formerly lay still more to the west), have since been eroded by strong action of surf-abrasion and the costal escarpments move a few centimeters per year inland on account of this 'soil erosion', from which we infer the existence of a broader coast plain in pre- and historic times. Wüst [27] (after Hamann *et al*. [28]) estimated the mean temperature of the Eastern Mediterranean surface water to be about 15-27° C, its salinity increased steadily during its eastward flow from 3.8 % to 3.9 % and this warm, saline and well-oxygenated water mass flows from 200 to 600 m depth. Issar [7] noted that the division of the stratigraphical column of the Central Coastal Plain into time stratigraphic units was based on the recognition of four main cycles of ingressions where the upper one includes two fluctuations. Each cycle left its mark by the change of the facies from deep sea facies to shallow and continental facies and vice versa. The three ridges in the coastal plain are not merely solidified sand dunes but ancient shore dunes representing ancient shore lines. The easternmost ridge seems to represent the shore ridge of the second or third ingression and the western ridge is that of the fourth ingression, while the ridge near the present shore seems to mark the most western extension of the last oscillation. Horowitz [26] noted that the sands of Kurkar are wind blown deposits originating from the Nile Delta. Inman & Jenkins [12] noted that the Mediterranean Sea receives annually very large volumes (~ 160 million tons/yr) of sediments discharged by the River Nile. Neev *et al.* [14] noted that the Kurkar seems to be deposited in continental environment from the eolian sands that accumulated during both high stands and regression of the sea level. Increased sand is related to increased tectonic activity that caused the uplift and disturbance of sediments within the Nile Delta province, thereby leading to increase erosion, and superimposed on direct tectonic destructions are sand ingression across the coastline. Hamra (buried soils) formed during low stands of sea level at low-energy. Those authors believed that these ridges have been much influenced by fault activity and the associated earthquakes and tension produced by westward arching of the slope which was concentrated mostly across the coastline, to be later released by reactivation of an old coast-parallel normal fault. Maximum post-Miocene displacements across the central segment of the coastline are about 300 m since Messinian (late Pliocene), 150 m since early Pleistocene and about 60 m since early to middle Holocene, and during the past 4000 years, much of the oscillatory movement may have had a creeping nature rather than catastrophic faulting. Bard *et al*. [29] noted that because the last Glacial Maximum sea level was 120 m lower than today the source area for dust expanded, and assumed that the global atmosphere dust load was up to 10 times higher during the last Glacial Maximum than during the Holocene. Stanley & Wingerath [30] noted that several dust-bearing winds are relevant for the Eastern Mediterranean region, and the Khamasin influences Egypt and the Near East blowing from south and southwest, which is associated particularly with intensive dust storms. They also noted that the Eastern Mediterranean Sea receives large quantities of sediments by the River Nile and the suspension load prior to the construction of the Aswan Dam in 1964 was some 120-160x10^6 t/yr, while the annual dust rates of approximately 30-60 g/m² have been reported from the southeastern Levantine Sea by Ganor & Foner [31].

Saaroni *et al*. [32] described strong easterly wind (called Sharqiya), which develop over the Near East and bring dust storms to the eastern Levant Sea. Abed & Yaghan [33] noted that the region of the Eastern Mediterranean Sea with several marine and terrestrial records document an increase dust supply. Frechen *et al*. [34] noted that the kurkar ridges at the Levant are designated to represent typical longitudinal sand dunes formed synchronously parallel to the coastline by dominant wind direction perpendicular to the coast. The different facies are related to changes in the environmental setting. Five periods of sand accumulation and kurkar formation can be distinguished at about: 140 ka, 130 ka, 90 ka and between 60-50 ka. Hamra formation took place between 140-130 ka, around 80 ka, 65 ka, around 60 ka and between 20-12 ka. For that, the luminescence dating results indicate that neither kurkar nor hamra formation correlate with glacial and interglacial periods of the Northern Hemisphere. Garzanti & Abdel Megid [35] noted that after nearly 6700 km of northward fluvial transport along the outer flanks of the East Africa and Northern Red Sea rift shoulders, sediments reaching the Mediterranean Sea were either funneled down slope as turbidity currents or shifted eastward by alongshore currents for another 600 km along Sinai-Levant passive-margin as Northern Palestine. During the Quaternary, the Nile system has undergone repeated changes to climatic and eustatic fluctuations, and recently also to human activities. Wadi El Arish (north Sinai), draining the undissected outer flank of the Sinai shoulder, carries carbonaticlastic sands as far as 60 km from the coast, where it is choked by quartzose eolian sands. Similar abrupt variations from carbonaticlastic to quartzose compositions affect the Palestinian streams draining the outer flank of the Dead Sea shoulder, which extensively recycle Pleistocene eolianites (Kurkar ridges) across the coastal plain and Palestine beach sands as far as Akka are quartzofeldspathic, indicating ultimate origin mainly from Nile delta. Porat *et al*. [36] noted that the precise infrared-stimulated luminescence dating on alkali feldspar from both alternated Kurkar and Hamra sediments in the coastal plain confirms that all the units comprising the most westerly kurkar ridge were deposited during the last 65 ka, and calculated rates of accumulation for the kurkar (1-7 m/1000 years with thick beds being deposited over periods as short as 2000-3000 years), but about 0.1 m/1000 years for Hamra.

Laukhin *et al*. [37] introduced that the presence of archaeological sites corresponds with periods of regressions, during which Hamra formed and was subsequently reworked by slope processes. When Hamra was inundated by shallow lakes, people could settle on lake shores.

Galili *et al*. [38] noted that the Late Pleistocene sediments of the Eastern Levantine coastal zone consists mainly of alternating deposits of calcareous cemented aeolian sandstones (locally named kurkar) and reddish sandy-silty soil (locally named hamra) and three kurkar ridges are present on land, while one ridge is on land at the northern part. They also noted that the beach deposits were related to the Last Interglacial Maximum about 125 ka (i.e. the MIS 5e high sea stand) and during that time the maximum possible vertical displacement was less than 48 mm/ka. Enzel *et al*. [39] noted that when the north Sinai coast shifted 30-70 km northwest due to last glacial global sea level lowering, the newly exposed coastal areas supplied the sand and dust to these active eastern Mediterranean. Hamann *et al*. [40] noted that the main sediment influx to the Eastern Mediterranean Sea is through rivers. The composition of surface sediments in this area is mainly controlled by the characteristics of the source areas, the climatic conditions on the adjacent continents and the sediment distribution by the wind and current ocean. The sedimentation in southeastern Levant is dominated by the suspension load of River Nile and aeolian dust from the North African Sahara, and variation in grain size reflects the early to mid-Holocene climate transition from the African Humid Period to recent arid condition. The surface water of the Eastern Mediterranean Sea generally circulates in an anticlockwise gyre and flows parallel to the North African coast towards the east, then turns towards the north and flows along the coast of Israel, Lebanon, Syria to the southern coast of Turkey. The northern hemisphere climatic events obviously caused a major environmental changes in the Mediterranean Sea region. This implies a successive decrease in Nile river sediment supply due to a step-wise aridification of the headwaters. The grain-size data shows a humidity maximum at 5 kyr BP coincident with a regionally restricted wet phase in the Levant.

SUMMARY AND CONCLUSIONS

Gaza Strip is located at the southeastern corner of Palestine, at the southeastern Levant coast of the Mediterranean Sea. It is covered by three typical longitudinal Pleistocene kurkar ridges running parallel to the Mediterranean Coast line, from west to east (Sheikh Ejlin Ridge, Al Montar Ridge and Beit Hanoun Ridge), which consist of alternating cross-bedded calcareous sandstone (locally named Kurkar) and red brown sandy-silty sediments (locally named Hamra) belong to the Gaza Formation of upper Kurkar Group. This formation was early recognized in boreholes in the Gaza area, which never exposed in its entirety. Due to the problem of access of the type subsurface section, the author designated an outcropping reference section at south Sheikh Ejlin (south of Gaza city). It is well known and easily accessible to the geologists and other scientists in the area.

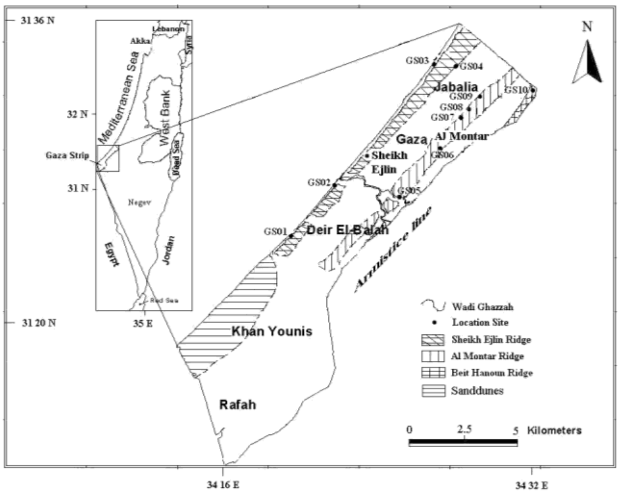

Fig. 1: Location map of the Gaza Strip at the southwest of Palestine, showing the geographic distribution of the three ridges (Sheikh Ejlin, Tal Al Montar and Beit Hanoun Ridges) and the ten location sites of these ridges, (including the site of the outcrop reference section of the Gaza Formation (GS02), at south of Gaza city.

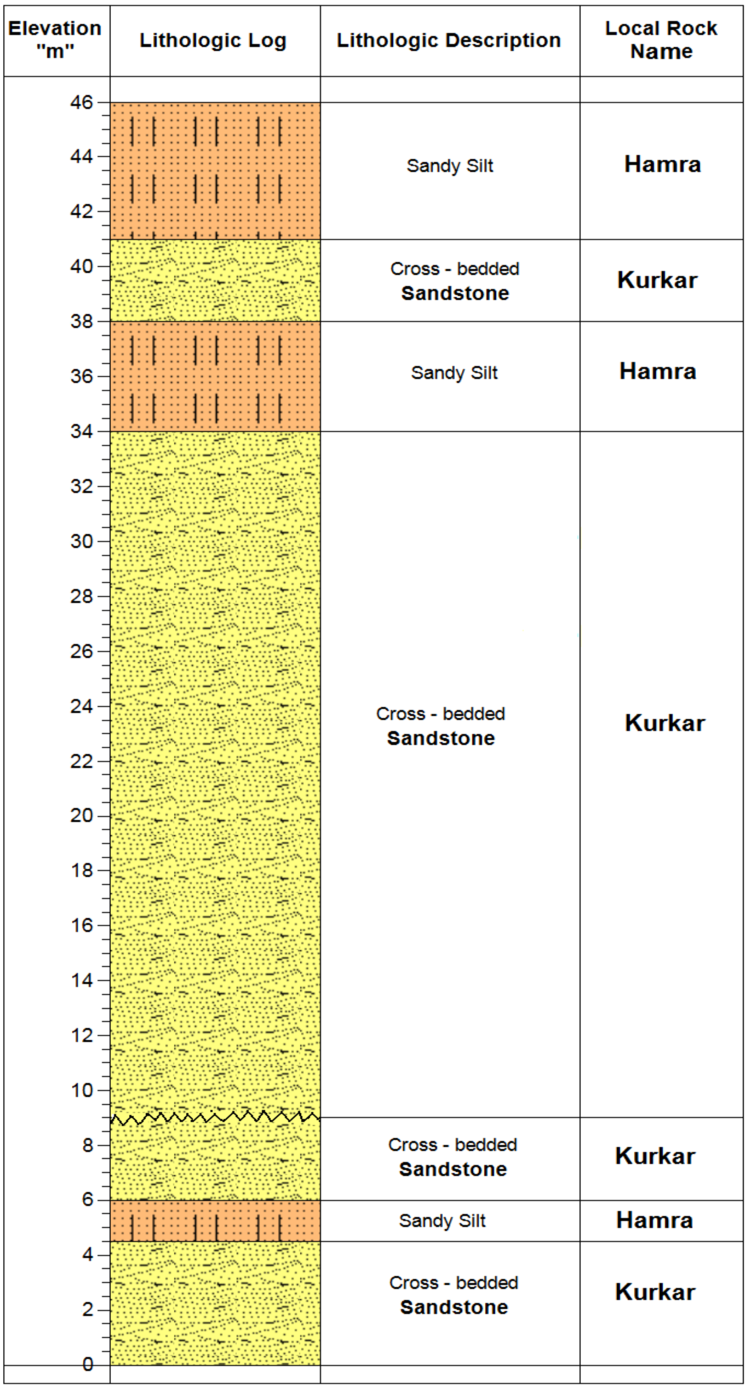

Fig. 2: Composite stratigraphic log of the Gaza Formation in the south Sheikh Ejlin section (south Gaza city), Sheikh Ejlin Ridge. Zigzag line represents the boundary between the lower part (tilted to the south) and the upper part of the composite section. A small local sedimentary gap may be existed in this contact area which covered by sands, from the eroded kurkar and beach sand.

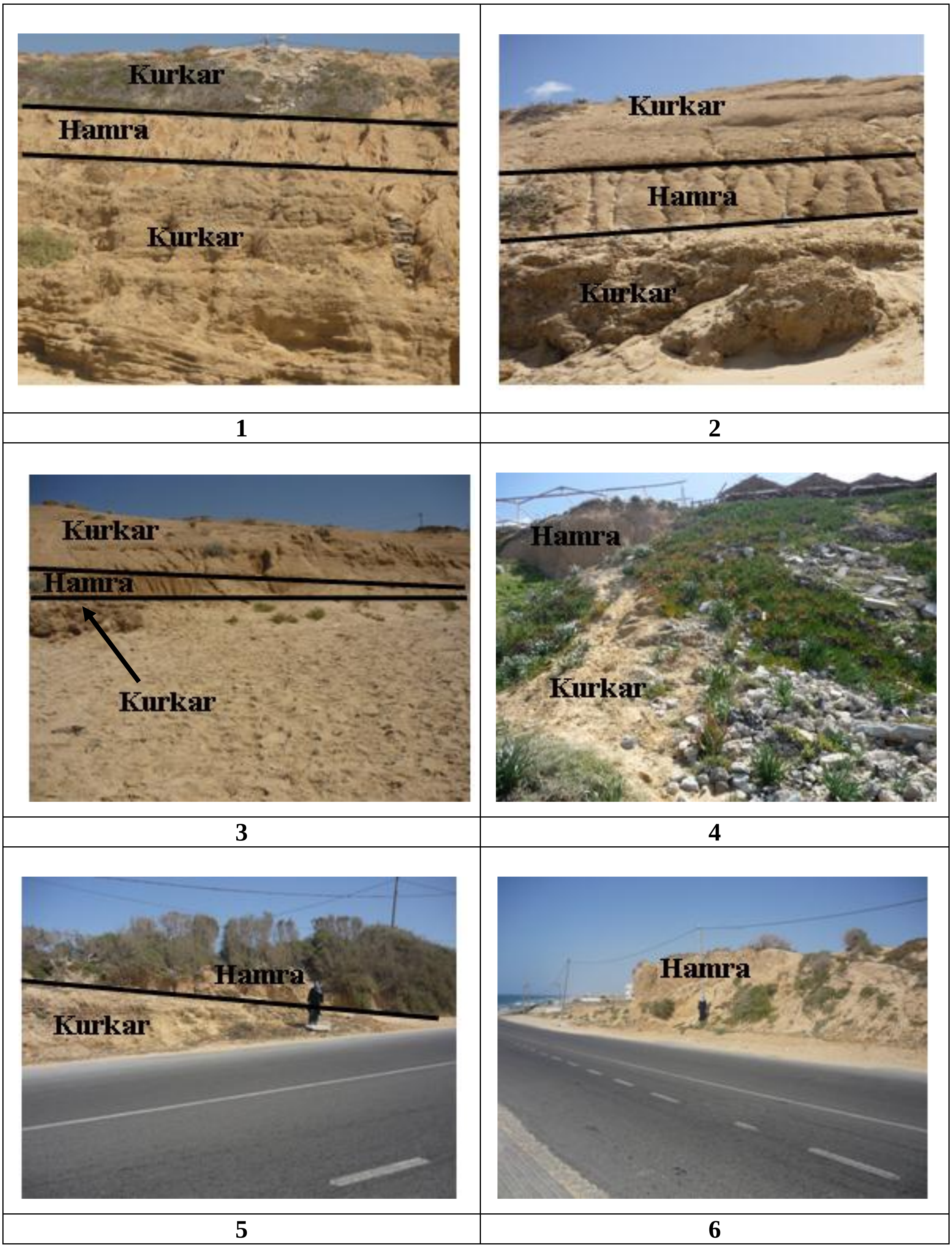

Fig. 3: After the beach area, the base of the section starts with 4. 5 m. of Kurkar, followed by 1.5 m. of Hamra, which also followed by another 3 m of Kurkar (Fig. 3. 1). The lower Kurkar bed gradually died out (disappeared) to the southern direction of the section (Fig. 3. 2, 3). It is followed by a thick bed of Kurkar (about 25 m.) in a gentle slope outcrop (Fig. 3. 4), and a prominent cliff of Hamra (with about 4 m.) is capped this succession. On this cliff, the Gaza-Deir El Balah asphalted road is build. At the eastern side of the asphalted road, a marked outcrop of Kurkar bed appears with about 3 m. thick (Fig. 3. 5), and it is followed by 5 m. of Hamra (Fig. 3. 6), which consists another prominent cliff in the section.

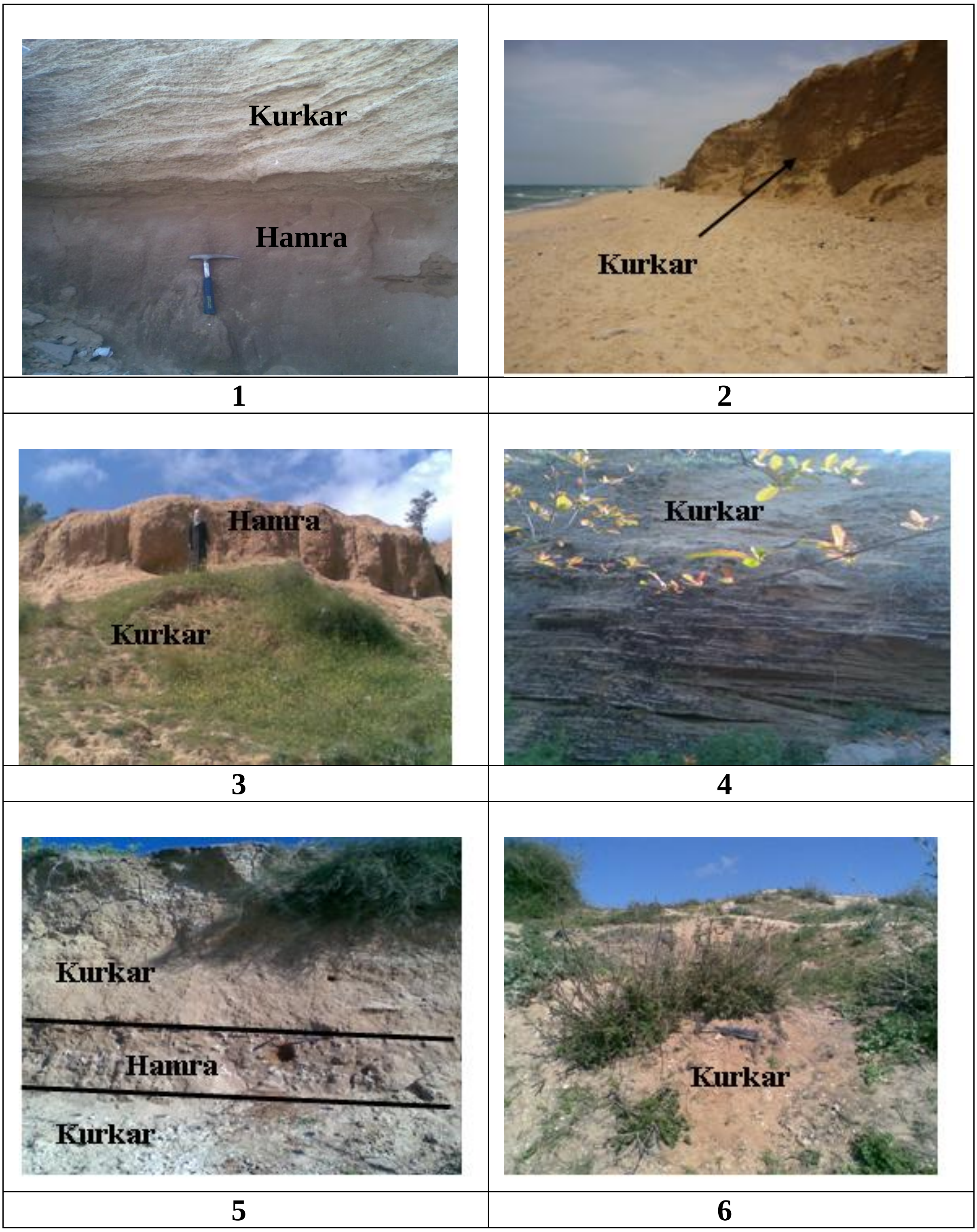

Fig. 4: Gaza Formation is illustrated at some localities in the Gaza Strip: Deir El Balah, Hamra followed by Kurkar in the lower part of the section (GS01, Fig. 4. 1), An Nawras, Kurkar in the lower part of the section (GS03, Fig. 4. 2), Tal Al Montar, Kurkar followed by Hamra (GS06, Fig. 4. 3), Tal Er Rayyes, Kurkar in the lower part of the section (GS07, Fig. 4. 4) and Beit Hanoun, altered beds of Kurkar and Hamra in the lower part (GS010, Fig. 4. 5), and in the upper part of the section (Fig. 4. 6).

Table 1. Coordinates and elevations of the location sites of the Sheikh Ejlin Ridge.

Site	Locations	Coordinates	Elevations (msl)
GS01	Deir El Balah	31^{0} 25.05' N, 34^{0} 19.74' E	09 m
GS02	South Sheikh Ejlin	31^{0} 27.43' N, 34^{0} 22.16' E	39 m
GS03	An Nawras	31^{0} 33.60' N, 34^{0} 27.95' E	12 m
GS04	Tal Es Salatein	31^{0} 33.51' N, 34^{0} 29.24' E	52 m

Table 2. Coordinates and elevation of the location sites of the Al Montar Ridge.

Site	Locations	Coordinates	Elevation
GS05	South Al Montar	31^{0} 26.95' N, 34^{0} 25.99' E	53 m
GS06	Tal Al Montar	31^{0} 29.40' N, 34^{0} 28.37' E	87 m
GS07	Tal Er Rayyes	31^{0} 30.78' N, 34^{0} 29.52' E	77 m
GS08	Tal Al Kashef	31^{0} 31.38' N, 34^{0} 30.03' E	62 m
GS09	Tal Ez Zaatar	31^{0} 32.02' N, 34^{0} 30.67' E	64 m

Table 3. Coordinate and elevation of the location site of the Beit Hanoun Ridge.

Site	Location	Coordinate	Elevation
GS010	Beit Hanoun	31^{o} 32.59' N, 34^{o} 32.49' E	56 m

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