Quaternary Stratigraphy Architecture and Sedimentology of Gaza and Middle- to Khan Younis Governorates (The Gaza Strip, Palestine)

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Abstract- This study aims to examine the stratigraphy architecture and sedimentology of the Gaza Strip, from the Pleistocene to the Holocene age. The study area is restricted to the Gaza and Middle-to Khan Younis Governorates of the Gaza Strip. The Gaza Strip is a southwestern part of the Coastal Plain of Palestine. To accomplish these aims, data collected from field observations of outcropping rocks, boreholes, and hydrogeological wells has been used. The logging of selected sections paid attention to genetic facies associations. A generalized stratigraphic cross section has been established. It shows that the Kurkar Group (Gaza Formation) in the study area consists of five informal, descriptive lithostratigraphic units (Unit-A through Unit-E). These units are mainly made of calcareous sandstones (Kurkar) and separated by mudstone (Hamra) subunits. These mudstone subunits are lense-like, and their lateral extensions and thicknesses decrease upwards of the succession. Sedimentologically, four facies associations have been described and interpreted, namely, Kurkar, Hamra, swamp, and alluvial, plus dune sands and recent soils. The Kurkar facies association represented fossil dunes of aeolian origin pushed forward by the sea, whereas, Hamra palaeosols are polygenetic and originated in humid environments.

***Index Terms*-** The Gaza Strip, Quaternary, Kurkar, Hamra, Gaza Formation.

I. Introduction

Over the last few years, knowledge of the geology of the Gaza Strip has increased considerably especially in detailed terms of sedimentology and a few in stratigraphy [1; 2; 3;4 ; 5]. There are, however, in the last decades relatively general studies related, both directly and indirectly to the stratigraphy of the Gaza Strip [6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 16]. This study presents a new generalized stratigraphic cross-section for the Gaza Strip and discusses and interprets its facies associations, which are based on wells, boreholes, and field observations.

The aims of this study are the identification of outcropping and subsurface stratigraphic units of the Kurkar Group (Gaza Formation) in the middle part of the Gaza Strip, which includes the southern part of the Gaza Governorate, the Middle Governorate, and the northern part of the Khan Younis Governorate. It also includes the study of the facies association in groups or genetically related beds based on data collection from wells, boreholes, and field observations.

II. Study of the Area

The study area is located in the center of the Gaza Strip, and it includes the southern part of the Gaza Governorate, the Middle Governorate, and the northern part of the Khan Younis Governorate (Fig. 1). The Gaza Strip is a southwestern part of the Coastal Plain of Palestine between longitudes 34^{o} 2`` and 34$^{o}$ 25`` east and latitudes 31^{o} 16`` and 31$^{o}$ 45`` north. The width of the strip ranges between 6 km in the middle to 8 km in the north and 12 km in the south. Its length is about 45 km along the coastline and its area is about 365 km^{2}.

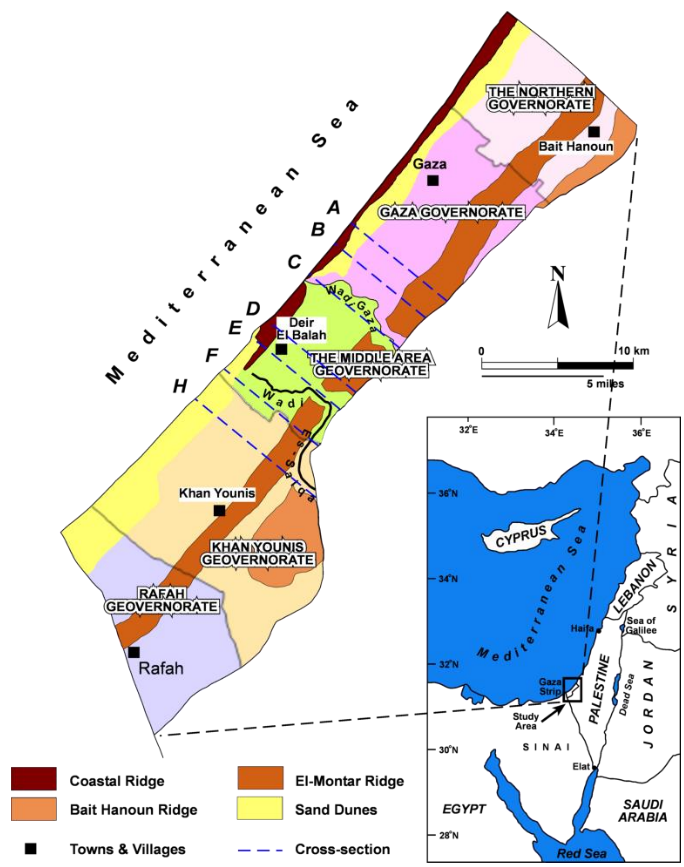

Figure 1: Location map of the Gaza Strip, shows the location of selected stratigraphic cross section (A to H) in the Gaza and middle to Khan Younis Governorates.

Three elongated ridges characterize Gaza's topography. These are known as the Kurkar ridges due to their hard sandstone that has been used extensively for construction purposes since earlier times [14]. The age of these ridges increases from the coastline eastwards. The ridges are built of several sedimentary cycles [17; 13], which are intercalated by red sandy loam soils locally termed Hamra (Arabic word for red) [7]. The ridges are separated by deep depressions (20-40 m above mean sea level) with alluvial deposits. The ridges and depressions generally extend in a NNE-SSW direction, parallel to the Mediterranean coastline. The first ridge is called the Coastal Ridge. It is up to 50 m above mean sea level [1], and it extends up to the current coastline in the west. In the middle lies the Al-Montar Ridge which is up to 80 m above mean sea level. The third ridge is the Bit Hanoun Ridge which partially runs along the armistice line in the east, and is up to 110 m above mean sea level [18].

Four offshore Kurkar ridges have also been mapped on the continental shelf [19; 9; 10; 14]. This system extends from the littoral zone in the east to the upper continental slope in the west [14].

III. GEOLOGICAL SETTING

The common overall lithostratigraphic of the coastal plain of Palestine is shown in Figure 2. The stratigraphy of the Gaza Strip is a part of the coastal plain of Palestine which belongs to the Tertiary and Quaternary age. The lithostratigraphic units recognized in this region are the Mt. Scopus, Avedat, Saqiye and Kurkar Groups. The Mt. Scopus Group is composed of Senonian to Paleocene Formations. It is made up of En Zetim, Ghareb, and Taqiye Formations and is represented by limy chalk, chalk, and marly chalk. The Avedat Group of the Lower and Middle Eocene age is composed of the Adulam and Maresha Formations. The members are represented by alternations of chalk and chalky limestones [11; 12]. The Saqiye Group overlies the Mt. Scopus and Avedat Groups unconformably and is overlain by the Kurkar Group. The Saqiye Group is composed of two major units: the lower and upper Saqiye, which are separated by Mavqi'im and Shiqma Formations. The lower Saiye Group mainly consists of marly chalks, marls, reefal, and bioclastic limestones. The upper Saqiye Group contains evaporates, sandstones and conglomerates. It also contains variegated shales, siltstones, and marls [20].

The Kurkar Group (Quaternary) sharply overlays the Saqiye Group. In contrast to the pelagic nature of the Yafo Formation, the Kurkar Group is mainly clastic, containing a variety of sediments: calcareous sandstones (locally termed Kurkar) (some strongly cemented and some loose), red fine grain deposits (locally termed Hamra), marine and continental clays, conglomerates, and sand dunes. It is worth noting that in the western coastal plain the Kurkar Group is generally more variable, with sharp lateral and vertical changes (the Hefer Formation), whereas to the east it becomes more regular, with two sandy Formations (Pleshet and Gaza) separated by the Ahuzam conglomerate [17; 13; 21].

The Gaza Formation mainly consists of alternations of Kurkar and Hamra with either gradational or sharp contacts. Lithologically, the Hamra consists of reddish-brown palaeosols that occasionally grade into blackish, clay-rich marsh deposits. Geometrically, it forms lenses several meters thick that extend for some hundreds of meters. The loess deposits form the Ruhama Member [11; 22; 1; 2; 4].

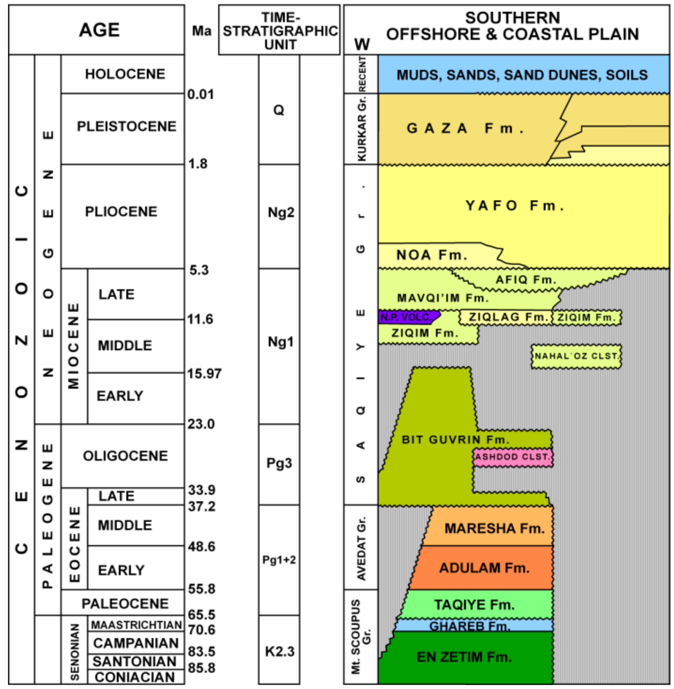

Figure 2: Stratigraphic scheme of outcrops and subcrops for Senonian to Recent sequence in the offshore southern and coastal plain of Palestine. It shows the time-stratigraphic units and ages given in millions of years (after Grivtzman et al., 2005 [21]).

Ubeid (2011) [2] categorized the palaeosols that occur in the Gaza Strip into two main groups based on the sand-sized versus clay-to-silt sized grains. The first group contains the sandy Hamra palaeosols, which are further subdivided into two types: (a) light brown Hamra palaeosols, which mainly consist of fine-to-very-fine grained sand with a calcium carbonate content of up to 13%, and (b) dark brown Hamra palaeosols, which mainly consist of fine-grained sands to clay, with a calcium-carbonate content of up to 12%. The second group contains the loess and loess-derived palaeosols.

IV. METHODOLOGY

This study was based on the field observations of outcropping rocks, data collection from boreholes, and hydrogeological wells that was done by the Palestinian Water Authority (PWA). Around 36 geological columns were constructed in different locations in the Gaza Strip (Table, 1). The lithofacies data was observed directly from rock samples either from boreholes, hydrogeological wells, the field works, and others from the lab analysis. The third type were collected according to the well owners and drilling during the well inventory carried out by the Water Resources Action Program.

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The geological columns were prepared by FreeHand version11. The correlation between the columns was done by using FreeHand version11 in order to construct the geological cross section. Seven geological cross-sections were prepared in the study area, in addition to the generalized stratigraphic cross-section of the study. The direction of these sections is WW to SE.

Table 1: Coordinates of geological logs of cross sections (A to H). For their locations see Figure 1.

Log no.	E	N	Log no.	E	N
Section A			***Continuo:***		
BJ/2	97300	95800	**S/49**	91440	91090
Fi/2	96600	96700	**T/46**	92100	90300
G/3	96000	97000	**S/69**	91740	90720
Fi/8	95700	97200	**Section E**		
Fi/5	95150	97500	**DB/3**	87400	92400
Fi/4	94150	97850	**DB/2**	87700	92300
Section B			**Ji/13**	88460	91600
Fi/3	96000	94600	**J/10**	89260	91140
BJ/4	95700	95300	**?**	90770	89900
BJ/1	95200	96000	**J/85**	88940	91600
F/64	94470	96530	**Section F**		
G/51	92800	97700	**DB/6**	85100	91050
Section C			**DB/5**	85600	90600
S/72	93500	93300	**DB/8**	86700	89700
S/29	93190	93880	**K/19**	87640	89250
S/61	93050	94500	**T/44**	89250	87640
H/94	91700	95180	**SectionH**		
G/503	90380	96360	**DB/7**	87400	89200
SectionD			**Ki/2**	85550	87350
H/33	88210	93600	**Li/10**	85950	87000
DB/1	89500	92500	**M/1**	88500	84250

V. RESULTS AND DISCUSSION

The purely descriptive lithostratigraphic framework of the studied succession in this study will be described on the base of stratigraphic sections (Fig. 3 & 4), and compared with previous stratigraphic schemes (Fig. 2).

In this study, the succession of the Gaza Strip has been divided into two main groups: the Saqiye Group and the Kurkar Group. The succession in the area of study of the Kurkar Group from the Pliocene to the Holocene mainly consists of terrigenous deposits. It lies unconformably on the Saqiye Group from the Oligocene to the Miocene.

SAQIYE GROUP

Not being the subject of this work, this unit has been not studied, as most wells and boreholes do not reach its depth, so only general observations and descriptions can be given in this study. It is from the late Eocene to early Pleistocene age [23; 24; 16; 21]. Generally, this unit dips towards the west by about five degrees in the middle part, and nineteen degrees in the north and south parts. Its depth is about 135 m below sea level in the western direction, and about 75 m below sea level in the eastern direction. The Saqiye Group is developed within the subsurface in the western parts of the coastal plain where its maximum thickness reaches approximately 2,500 m beneath the coastline [20; 21]. In the central and eastern parts of the coastal plain and foothill area the Saqiye Group displays its marginal facies and only scattered outcrops occur. There, the thickness varies within a range of 0-150 m [24; 25].

The Saqiye Group is divided into two major units: the lower and upper Saqiye, separated by Mavqi'im and Shiqma Formations (Fig. 2).

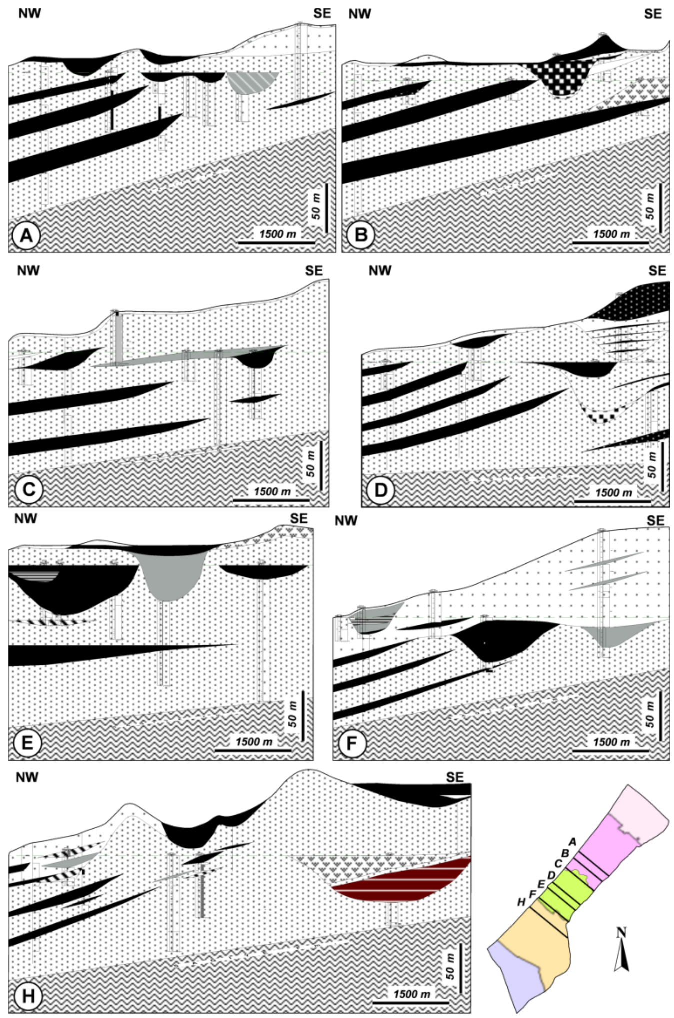

Figure 3: Shows the cross sections along the lines (A) through (H). The direction of these sections is NW to SE. The map on the bottom right shows the location of the section (see also Fig. 1), where the sections start from (A) in the north and ended at (H) in the south. For key to symbols see Figure 4.

Lower Saqiye Group

The lower Saqiye rock sequence is composed of the Ziqlag, Ziqim, and Bet Guvrin Formations (Fig. 2). It mainly consists of marly chalks, marls, reefal, and bioclastic limestones deposited during a sequence of sedimentary cycles representing transgressions and regressions [20]. During the Early Oligocene, a major westward regression occurred, which was accompanied by a deep incision of erosional non-conforming surfaces [8]. According to Druckman et al. (1995) [26], geological evidence indicates a drop in sea level of over 800 m, which resulted in the incision of large submarine channels into the lower shelf. This phase, known as the Messinian desiccation, is characterized by a massive deposition of evaporates on a strongly dissected topography, particularly within the incised submarine channels. These evaporates comprise part of the Mavqi'im Formation [8], which consists of anhydrite, gypsum, rock salt, and dark marly shales from the Late Miocene age. The maximum thickness this formation reaches in the basinal domain is more than 1,000 m, whereas in the erosional channels beneath the coastal plain the thickness is about 200 m [27]. In the erosional channels and within the anhydrite sequence, halite beds were encountered which reached thicknesses of several tens of meters. These beds were deposited in a sabkha environment [20]. Within the evaporate sequence, up to seven marine intercalations were identified [26]. In the subsurface the Mavqi'im evaporates from a characteristic continuous veneer, plastering the erosional surface of the Ziqlag Formation.

Upper Saqiye Group

The thick sequence of evaporates is covered by sandstones and conglomerates of the Afiq Formation. This formation also contains variegated shales, siltstones, and marls. It is restricted to the thalwegs of the erosional channels and was deposited in fluvial and lacustrine-marsh environments, in the river channels, and on flood plains. The Afiq Formation represents continuous fluvial deposition, which terminated the Ziqlag-Mavqi'im sedimentary cycle. The upper Saqiye rock sequence is composed of the Noa Formation and the Yafo Formation (Fig. 2). The Noa Formation consists of nearshore sandstones. The Yafo Formation which makes up the main part of the upper Saqiye Group lies on an erosional topography cut into the Mavqi'im and Afiq beds. The Age of the upper Saqiye Group is Pliocene to Early Pleistocene. It varies in thickness from a few meters on the eastern coastal plain to 1,500 m in the western offshore area, and represents a large-scale marine transgression that penetrated deeply inland to the foothills of the Judea Mountains.

The predominant lithology of the Yafo Formation consists of impermeable, plastic, blueish-gray shales. The beds of the Yafo Formation, underlying the Kurkar Group sequence, were regarded as a regional flat, continuous, uniform, and impermeable hydrological boundary. However, many wells drilled on the coastal plain encountered hydrocarbon gas and saline water in porous horizons within the Saqiye beds [28; 29].

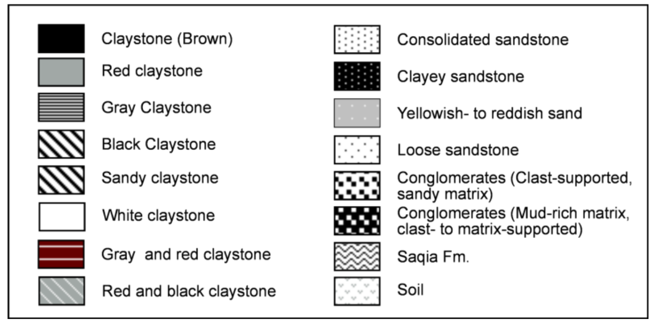

Figure 4: Key to symbols used in sections (Fig. 3 & 5).

KURKAR GROUP (GAZA FORMATION)

The Kurkar Group (the Quaternary sequence) unconformably overlies the Yafo Formation (Fig. 2). In the study area, the Kurkar Group (Gaza Formation) reaches an average thickness of 140 m. The Gaza Formation thins to the east and terminates towards the ascending slope of the coastal plain. In the west and

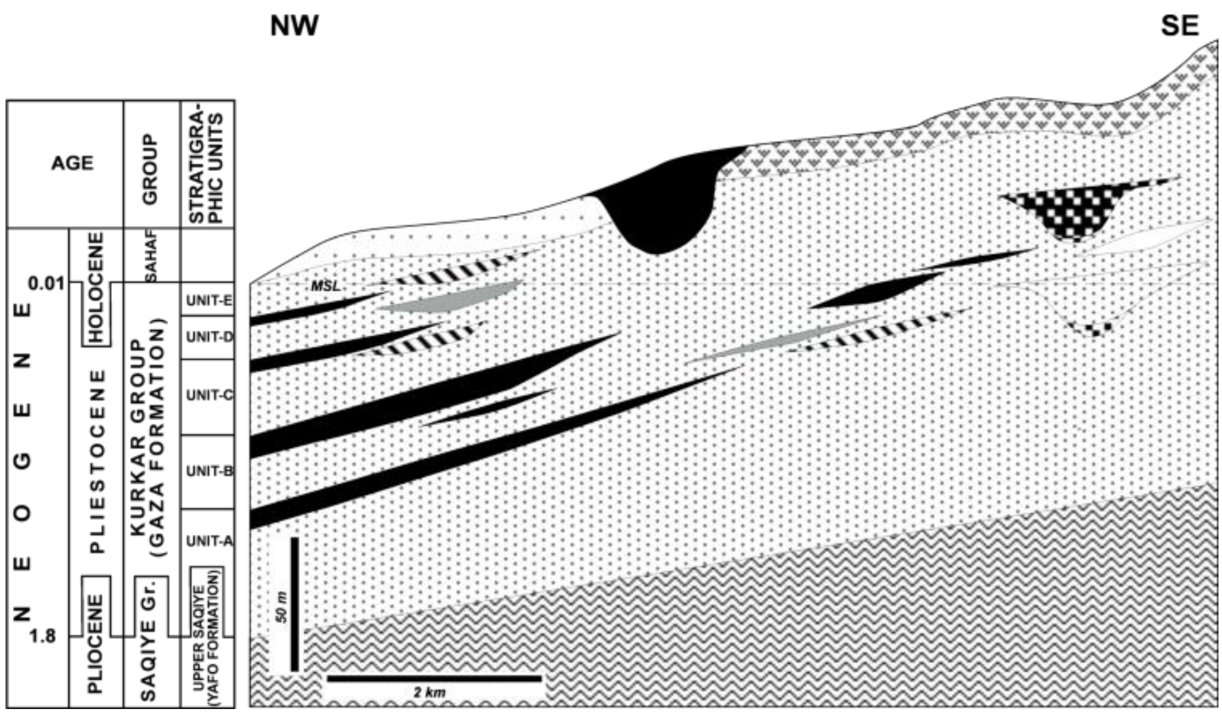

Figure 5: Generalized cross section in the study area. It shows the downdip in the stratigraphy of the studied sections, and the overall distribution of the facies association. It depicts the age of the Kurkar Formation in the Gaza Strip. The direction of the section is NW to SE. For key to symbols see Figure 5.

central part of the study area the Kurkar Group (Gaza Formation) is subdivided by intercalated mudstone beds into five units: Unit-A through Unit-E (Fig. 5). The mudstone subunits are lense-like, and their lateral extensions and thicknesses decrease upwards of the succession.

Unit-A

This mainly consists of calcareous sandstones (FA-1), with a single subunit of facies association (FA-4), which consists of gray and red claystones, sandstones, conglomerates and soils (See chapter Facies Association), and a lense-like subunit of brownish mudstones (FA-2) or palaeosoles according to Ubeid (2011) [2]. Unit-A forms the lower part of the Kurkar Formation. It unconformably overlies the Yafo Formation (Fig. 5). In the northern part of Palestine this unit equivalent Kurdance Formation which consists of calcareous sandstones and sandy limestones. While in southern part of Palestine, it may equivalent Pleshet Formation [30; 31, 32; 21]. Unit-A is not exposed in the Gaza Strip, and only a few outcrops can presently be seen at Hirbet Harev Ridge in the northwestern Negev coastal plain [12].

Unit-B

This unit mainly consists of calcareous sandstones (FA-1) with predominantly lense-like subunits (Fig. 5). These lense subunits are composed of brownish mudstones (FA-2) and red shale (FA-3). In the west this unit is sharply separated from Unit-A by a subunit of brownish mudstones (FA-2) which extends up to 6 km towards the east. Whereas, east of the study area the mudstones pinch out, and the contacts become gradation and the two units are merged. This unit is not exposed in the study area, but it crops out at Nahal Gerar the northwest Negev coastal plain, behind the armistice line [12], It is located to the west of the Dier Al Balah locality in the Gaza Strip Fig. 1. Its equivalent Akko Member consists of sandy limestones in the Hefer Formation in the north of Palestine [31].

Unit-C

This mainly consists of calcareous sandstones (FA-1), with about three subunits of lense-like. The first is composed of channel-like deposits of claystone (FA-4), which were detected in the northern section of the Gaza Governorate in the study area. The second is composed of red shale (FA-4), which was observed in the section of the Middle Governorate in the study area (Fig, 3C). The third subunit is composed of black shale (FA-3), which was detected in the southernmost section of the Khan Younis Governorate (Fig. 3H). This unit is sharply separated from Unit-B by brownish mudstones (FA-2) of a lense-like subunit, which extends westward to eastward up to 3.5 km. To the east the mudstones pinch out and the two units B and C are merged together (Fig. 5). This unit crops out at Tel Fara on the bank of Nahal Besor on the northwestern Negev coastal plain [12]. Unit-C could be equivalent to the Regba Member in Hefer Formation [31]. The Regba Member consists of calcareous sandstones.

Unit-D

This unit mainly consists of well-cemented calcareous sandstones (FA-1) in sections from Gaza and the Middle Governorates. While in southern sections of the Khan Younis Governorate (Fig. 1), it mainly consists of dune sands (DS). Red shale (FA-3) in the sand dunes of the Khan Younis cross section is detected. This unit is sharply separated from Unit-C by a lense-like subunit which consists of brownish mudstones (FA-2). The brownish mudstones subunit extends from west to east up to 1.5 km, after that the mudstones subunit pinches out, and Unit-C is merged with Unit-D. This unit crops out at Deir El Balah and is associated with the Coastal Ridge (Fig. 1) [1]. In the north of Palestine, it crops out at El Khedera (Gedera) which is associated with Ziqim Ridge [12]. Unit-D could be equivalent to the Yasaf Member in the Hefer Formation [31]. The Yasaf Member consists of biocalcarenites.

Unit-E

This unit mainly consists of calcareous sandstones (FA-1) in sections of Gaza and the Middle Governorates (Fig. 1). It mainly consists of dune sands (DS) in sections of the Khan Younis Governorates in the study area. In the west direction, it is sharply separated by brownish mudstones (FA-2) in a lense-like subunit. The brownish mudstones subunit laterally extends up to 1 km from west to east, after that Unit-D is merged with Unit-E. This unit crops out at Tel Al-Montar which is associated with Al-Montar Ridges. Also, it crops out at Wadi Es-Salqa which is associated with Beid Hanoun Ridge (Fig. 1) [1; 2; 4]. In the north of Palestine, it crops out in Ramt Gan [12]. This unit could be equivalent to the Nahlieli Member in the Hefer Formation [31]. The Kurkar of Nahlieli Member consists of biocalcarenites. Unit-E is sharply overlain by the recent unit.

Recent Unit

This unit consists of brownish mudstones (FA-2), soils (RS), and dune sands (DS) (see chapters 5 & 6 below). The sand dunes of the present day are transgressive and cover a large area in the south and middle parts of the Gaza Strip. The sand dunes are still active in some locations in the Gaza Strip and can be seen covering historic settlements of different ages. In contrast to the other sandstone subunits, these sand dunes are not cemented, although they sometimes contain up to 5% carbonates. These sand dunes are studied in detail by Ubeid & Albatta (2014) [5]. They are equivalent to Hedera sand dunes [31; 12]. The recent unit grades in northwestern Negev into loess, and is defined as Ruhama Loess Member. This member continues to be deposited up to the present day [12].

VI. SEDIMENTARY LITHOFACIES ASSOCIATION ANALYSIS

The facies associations introduced below are subdivided into those belonging to the Kurkar Group (Gaza Formation) in the Gaza Strip. The samples from the wells and those that cropped out revealed four sedimentary facies association: the Kurkar facies association (FA-1), the Hamra facies association (FA-2), the swamp facies association (FA-3), and the alluvial facies association (FA-4). These facies associations are differentiated by composition, color, grain size, and sedimentary structures. No quantitative methods, like the Markov chain analysis, have been performed to establish the facies associations. For the sake of clarity, these facies associations are named genetically. In addition to these facies associations, the dune sands and recent soils that are observed in recent unit are described below.

FA-1: Kurkar facies association

The Kurkar facies association (FA-1) contains some 10s m of calcareous sandstones with different sedimentary structures: cross-bedded, laminated, massive, and graded sandstones. The grains are medium-to-coarse, and they are moderately sorted. The Kurkar facies also contains marine bioclasts. It is cemented by calcium carbonate which reaches up to 40%. Whereas, in some locations the Kurkar is slightly cemented, in other places it is composed of sand dunes. The cemented sandstones have burrows in rocks that crop out at the coastal ridge, which is also documented by Ubeid (2010) [1]. Granules of small pebbles are observed in this FA, which are normally graded into medium sands. This facies association is underlain and overlain by brownish mudstones (FA-2) in most locations. It crops out in different locations in the Gaza Strip (Fig. 6A & B).

The environmental sedimentary conditions that have affected the Kurkar deposits are a matter of dispute among various authors. Environments of deposition for the Kurkar are accepted by most investigators [6; 7; 11; 12; 13; 33; 34], namely because the calcareous sandstones represent fossil dunes of aeolian origin pushed forward by the sea. In spite of this some facies are interpreted as a shallow marine environment [35; 1].

FA-2: Hamra facies association

This facies association is composed of fine-grained deposits. It mainly consists of brownish to reddish mudstones, and in some locations it contains fine-to-very-fine grained sandstone and siltstones (Fig. 6C & D). These types of deposits were studied in detail by Ubeid (2011) [2], and the author divided these deposits into two main groups: the sand-sized versus clay-to-silt sized grains, (1) the Hamra paleosols, and (2) the loess and loess-derived paleosols. The Hamra paleosols are classified into two main types according to their color and grain-size composition: (1) light brown Hamra paleosols, and (2) dark brown Hamra paleosols. The light brown Hamra are loamy sand to sand, whereas the dark brown Hamra are sandy clay soils. In some cases this facies association graded laterally into gray palaeosols. This facies association forms four main lense-like bodies in the successions, and is interbedded in the Kurkar deposits. These main lense bodies divided the succession into four main stratigraphic units. The maximum thickness of these lense bodies is up to 20 m in lower parts of the succession and is up to 8 m in the upper parts. They extend laterally up to few kilometers. In addition to these main bodies there are several minor lense-like bodies with a few meters of thickness which extend laterally to a few hundreds of meters.

Overall, the features of this facies association suggest the deposition under the influence of the subaerial environment. In the view of Ubeid (2011) [2] these Hamra palaeosols are polygenetic and originated in humid environments. Their brownish and reddish color results from iron-oxide segregation and/or coatings, reflecting oxidising conditions, but also by illuviation. The palaeosol units and their gradual boundaries formed during a relative short time-span with a high accumulation rate and a long phase of pedogenesis with a lower rate of dust accumulation.

FA-3: Swamp facies association

This facies association is composed of massive gray to black shale, showing burrows and horizontal lamination and containing thin intercalations of silt-to-fine sandstones. This FA is lense-like and its maximum thickness is up to ten meters thick. It extends laterally to hundreds of meters. It is mostly found in the area of the middle to southern parts of the study area and interbedded in the Kurkar (FA-1) or mudstones (FA-2).

The features of this association suggest deposition in swamp environments, where at the beginning of Paleocene, the Gaza Strip is affected by earth movements caused by the regression of the Mediterranean Sea and formation of swamps. At the beginning of the Pleistocene the swamps were dry and filled with continental sediments. The presence of organic matter in this facies association reflects the prevalence of low-energy and weak reduction conditions.

FA-4 Alluvial facies association

This facies association comprises some 10-15 m of conglomerates, sandstones (Fig. 6E), and gray and red mudstones, forming coarse-grained bodies and mud-rich stretches.

The sandstone bodies are mainly formed of conglomerates and sandstones and have erosional concave-down to flat tops and a lenticular shape with a high width/thickness ratio. They display a fine upwards trend and can be ideally described as formed of three parts. The lower part consists of clast-supported conglomerates or of sandy matrix-supported conglomerates. The middle part consists of medium-to-coarse grained cross-bedded sandstones. Finally, the upper part consists of sandstones and mudstones.

The mode of occurrence of the sandstone bodies and mudstone-rich stretches link to sub-associations, the channel-fill sub-association and the flood plain sub-association.

The channel-fill sub-association is mainly found in the east of middle and northern parts of the study area. It consists of composite conglomerate and sandstone packages, up to several meters in thickness. To the top and laterally, each composite package commonly passes into the mud-rich stretches of the flood plain sub-association. Weak and moderate bioturbation and root traces are present in the upper part of the composite packages and sandstone bodies of this sub-association.

The flood plain sub-association consists of mudstone stretches alternated with sandstone bodies (small-scale tabular sandstone bodies) by means of gradational contacts. In these units, the barren gray mudstones commonly occur in the lower part, and the yellowish and reddish mudstones in the upper part.

Overall, the features of this facies association suggest deposition in an essentially subaerial environment, which is prone to plant colonization when sedimentation rate and coarse clastic input are low. The geometry and facies arrangement of sand-rich sub-association suggest the infill of shallow channels with a flood-dominated regime [see 36, 37; cf. 38].

Dune sands (DS)

This consists of fine-to-medium grained sand, which is mainly made up of of quartz with a minor amount of feldspars, heavy minerals, and bioclasts (less than 1%). It consists of barchans

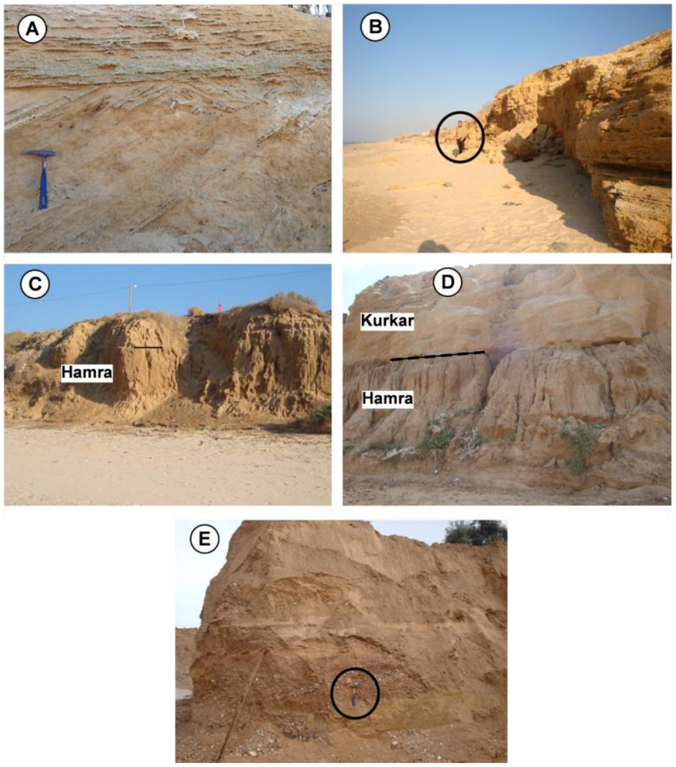

Figure 6: Shows field photographs from facies associations. (A) Cross-bedded calcareous sandstones (Kurkar), Coastal Ridge, Sudania locality, north the Gaza Strip. (B) Laminated Kurkar, middle part of the Gaza Strip (Coastal Ridge). (C) Hamra palaeosols crops out in the middle part of the Gaza Strip (Coastal Ridge). (D) Hamra palaeosols overlain by Kurkar with sharp contact, middle part of the Gaza Strip (Coastal Ridge). (E) Conglomerates and sandstones of alluvial facies association, Wadi Gaza, middle part of the Gaza Strip.

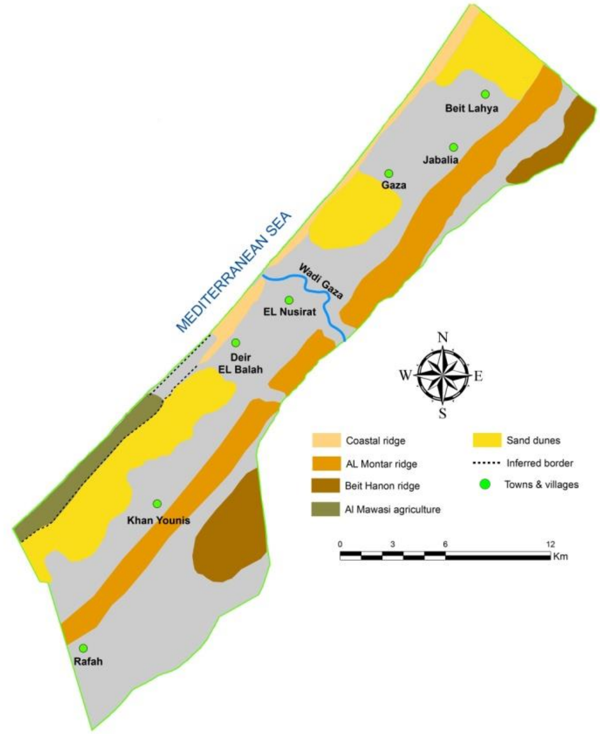

Figure 7: Shows the dune sands distribution in the Gaza Strip [5].

dunes that are asymmetrical to the northeast. The amplitudes and wavelengths of these sand dunes are up to 100 m. Their internal structures are dominated by complex cross-bedding. The thickness of these dune sands ranges from a few meters to more than 100 m, especially in southern sections. These dune sands cover a large area in the south and middle parts of the Gaza Strip (Fig. 7).

Overall, the dune sands are of aeolian origin and came from the Sinai and Negev Deserts [15; 39; 40; 41; 42; 43; 1; 3 5]. Another source of these sand dunes was the beach [5].

Recent soils (RS)

The recent soils of the Gaza Strip, according to their composition, can be divided into three categories: the sandy soils, the loess soils, and alluvial soils. The different types of soils in the Gaza Strip are depicted in Figure 8.

The sandy soils

In this category, the textures of the top meters are usually uniform and consist of medium- to-coarse quartz sand with a very low water-holding capacity. The soils are moderately calcareous (5-8% calcium carbonate), very low in organic matter, chemically poor, but physically suitable for intensive horticulture in greenhouses and tunnels. In the deeper subsurface (1-3 m below the surface), occasionally loam or clay loam layers of alluvial origin can be found. This type is dune accumulations which are regosols without a marked profile. Other sandy soils might be derived from material from the Kurkar ridges which can be seen from the presence of numerous carbonate nodules (0.5-1.0 cm) in the subsoil. Usually, the weathered layer on top of the Kurkar is thick enough for crops and vegetation to root, but occasionally the consolidated Kurkar beds are too shallow, inhibiting plant growth.

Loessial sandy soils can be found some 5 km inland in the central and southern part of the the Gaza Strip, in a zone from Khan Younis towards Rafah, parallel to the coast. This belt forms a transitional zone between the sandy soils and the loess soils, usually with a calcareous loamy sandy texture and a deep uniform pale brown soil profile. There might be some accumulation of calcium carbonate in the subsoil.

Loess soils

This category of soils are brownish yellow-colored, silty-to-sandy clay loams, often with an accumulation of clay and lime concretions in the subsoil and containing 8-12% calcium carbonate. Typical loess soils are found in the area between the city of Gaza and the Wadi Gaza. Most soils in the Gaza area are more or less influenced by the deposition situated at the flank of the main deposition zone in the northwestern Negev desert.

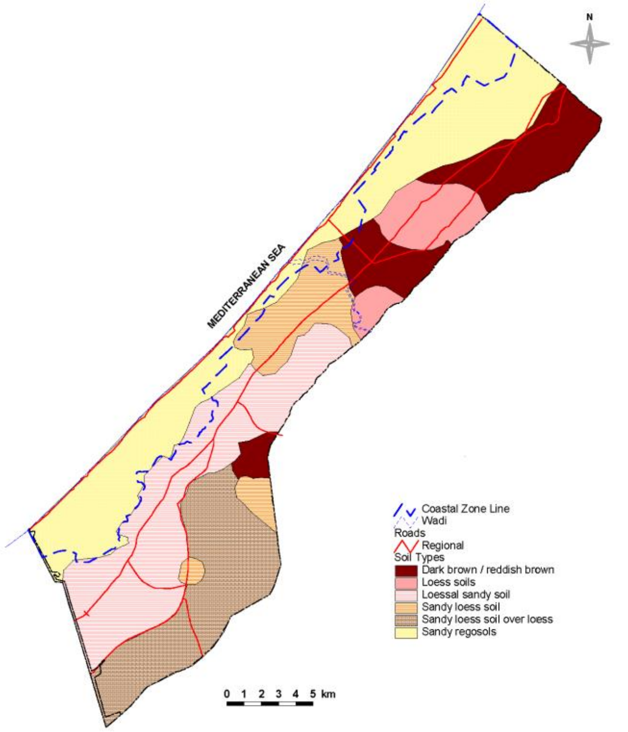

Figure 8: Shows the soil types distribution in the Gaza Strip [44].

A sandy loess soil is a transitional soil, characterized by a lighter texture. These soils can be found in the depression between the Kurkar ridges of Deir El-Balah. Apparently, windblown sands have been mixed with loessial deposits. Deposition of these two types of windblown materials originating from different sources has occurred over time and more or less simultaneously. These soils have a rather uniform texture.

Another transitional form is the sandy soil over loess. These are loess or loessial soils (sandy clay loam), which have been covered by a layer (0.2-00.5 m) of dune sand. These soils can be found east of Rafah and Khan Younis.

Alluvial soils

Usually this category is dark brown to reddish brown in color, with a well-developed structure. Alluvial and grumosolic soils, dominated by loamy clay textures are found on the slopes of the northern depressions between Erez and Wadi Gaza. Borings east of the Al-Montar Ridge have revealed that alluvial deposits of about 25 m in thickness occur.

At some depth, lime concertinos can be found. The calcium carbonate content can be around 15-20%. Some of the soils have been strongly eroded and the reddish brown subsoils may be exposed on top of ridges and along the slopes. The alluvial sediments are underlain by Kurkar.

VII. CONCLUSION

The stratigraphy of the Gaza Strip is a part of the coastal plain of Palestine. The lithostratigraphic units of the Late Eocene to Pleistocene recognized in this region are the Saqiye and Kurkar Groups.

The Saqiye Group is divided into two major units: the lower and upper Saqiye, separated by Mavqi'im and Shiqma Formations. The lower Saqiye rock sequence is composed of the Ziqlag, Ziqim, and Bet Guvrin Formations. It contains mainly of marly chalks, marls, reefal, and bioclastic limestones deposited during a sequence of sedimentary cycles representing transgressions and regressions. The upper Saqiye rock sequence is composed of the Noa Formation and the Yafo Formation. It contains sandstones and bluish-gray shales.

The Kurkar Group (the Quaternary sequence) unconformably overlies the Yafo Formation. In the study area, the Kurkar Group (Gaza Formation) reaches an average thickness of 140 m. The Gaza Formation thins to the east and terminates towards the ascending slope of the coastal plain.

The Kurkar Group (Gaza Formation) in this study is divided into five informal, descriptive lithostratigraphic units (Unit-A through Unit-E) by intercalated mudstone subunits. These units mainly consist of calcareous sandstones. Overall, towards the east these units merge together and contain separate small scale lense-like bodies of Hamra, swamps, and alluvial deposits. The mudstone subunits are lense-like, and their lateral extensions and thicknesses decrease upwards of the succession.

The succession has been studied from a genetic point of view, and four facies associations have been described and interpreted, namely, the Kurkar, Hamra, swamp, and alluvial facies associations, plus dune sands and recent soils.

The Kurkar facies association is interpreted to represent the fossil dunes of aeolian origin pushed forward by the sea, whereas, Hamra palaeosols are polygenetic and originated in humid environments. Their brownish and reddish color results from iron-oxide segregation and/or coatings, reflecting oxidizing conditions, and also by illuviation.

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