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The origin, nature and stratigraphy of Pleistocene-Holocene palaeosols in Wadi Es-Salqa (Gaza Strip, Palestine)

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Abstract: *THE ORIGIN, NATURE AND STRATIGRAPHY OF PLEISTOCENE-HOLOCENE PALAEOSOLS IN WADI ES-SALQA (GAZA STRIP, PALESTINE).* The Gaza Strip is located in the southwestern part of Palestine. Its topography is defined by three ridges (locally termed "kurkar ridges") that are parallel to the Mediterranean coastline. The ridges consist of Pleistocene-Holocene calcareous sandstones (kurkar) and reddish fine-grained deposits (hamra). The ridges are intersected by three main wadis, from north to south: Wadi Beit Hanoun, Wadi Gaza, and Wadi Es-Salqa (Wadi Silka). During winter Wadi Es-Salqa collects water from a 40 km^2 catchment area.

The subcrop geological cross-section at Wadi Es-Salqa shows that the succession consists of kurkar and hamra of the Pleistocene-Holocene Gaza Formation, which belongs to the Pliocene-Holocene Kurkar Group and sharply overlies the Saqia Group. The outcrop successions in Wadi Es-Salqa consist of reddish-brown palaeosols of Gaza Formation. These palaeosols are loessial soils that developed in loam to sandy loam soils, as well as sandy soils. The model distribution of the loessial soil grains reflects atmospheric dust that accumulated from the Sinai and Saharan Deserts. The sandy soils are derived from sandy parent materials that generally cover the western part of the southern coastal plain of Palestine.

Resumen: *SOBRE EL ORIGEN, NATURALEZA Y ESTRATIGRAFÍA DE LOS PALEOSUELOS PLEISTOCENO-HOLOCENOS EN WADI ES-SALQA (FRANJA DE GAZA, PALESTINA).* La Franja de Gaza se encuentra en la parte suroeste de Palestina. Su topografía es definida por tres cordones (localmente llamado "cordones o crestas kurkar ") que son paralelas a la costa mediterránea. Las mismas se componen de areniscas calcáreas (kurkar) y depósitos de grano fino de color rojizo (Hamra) del Pleistoceno - Holoceno (kurkar). Las crestas son interceptadas por tres cauces principales, de norte a sur: Beit Hanoun, Gaza y Es- Salqa (Silka). Durante el invierno Es- Salqa recoge las aguas de una cuenca de 40 km^2.

La sección geológica de Es-Salqa muestra que la sucesión consiste en kurkar y Hamra de la Formación Gaza (Pleistoceno-Holoceno), que se incluye en el Grupo Kurkar del Plioceno-Holoceno y se superpone en contacto neto al Grupo Saqia. Las sucesiones aflorantes en Es-Salqa consisten en paleosuelos de color marrón rojizo asignados a la Formación Gaza. Estos paleosuelos están constituidos por material loésico desarrollados en suelos francos a franco-arenosos, y suelos arenosos. El modelo de distribución del suelo loésico lo vincula genéticamente al desierto del Sinaí y el sur del Sahara, mientras que los suelos arenosos son derivados de materiales parentales de arena que generalmente cubre la parte occidental de la llanura costera del sur de Palestina.

Key words: Gaza Strip. Wadi Es-Salqa. Wadi Silka. Pleistocene-Holocene. Kurkar. Hamra. Palaeosols. Gaza Formation.

Palabras clave: Franja de Gaza. Es-Salqa. Silka Pleistoceno-Holoceno. Hamra. Paleosuelos. Formacion Gaza.

Introduction

The Gaza Strip is located in the southwestern part of Palestine, at the southeastern coast plain of the Mediterranean (figure 1). The topography of the Gaza Strip is defined by three ridges. These ridges are locally known as "kurkar ridges", which extend from the northeast to the southwest (Issar, 1968; Neev *et al.*, 1987; Frechen, 2001, 2002, 2004; Ubeid, 2010a,

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2011). These ridges consist of Pleistocene-Holocene calcareous sandstones intercalated by red-brown palaeosols (locally termed kurkar and hamra, respectively). They are separated by deep depressions (20 - 40 m above mean sea level) with alluvial deposits. The Gaza Strip is dissected by three main wadis (figure 1).

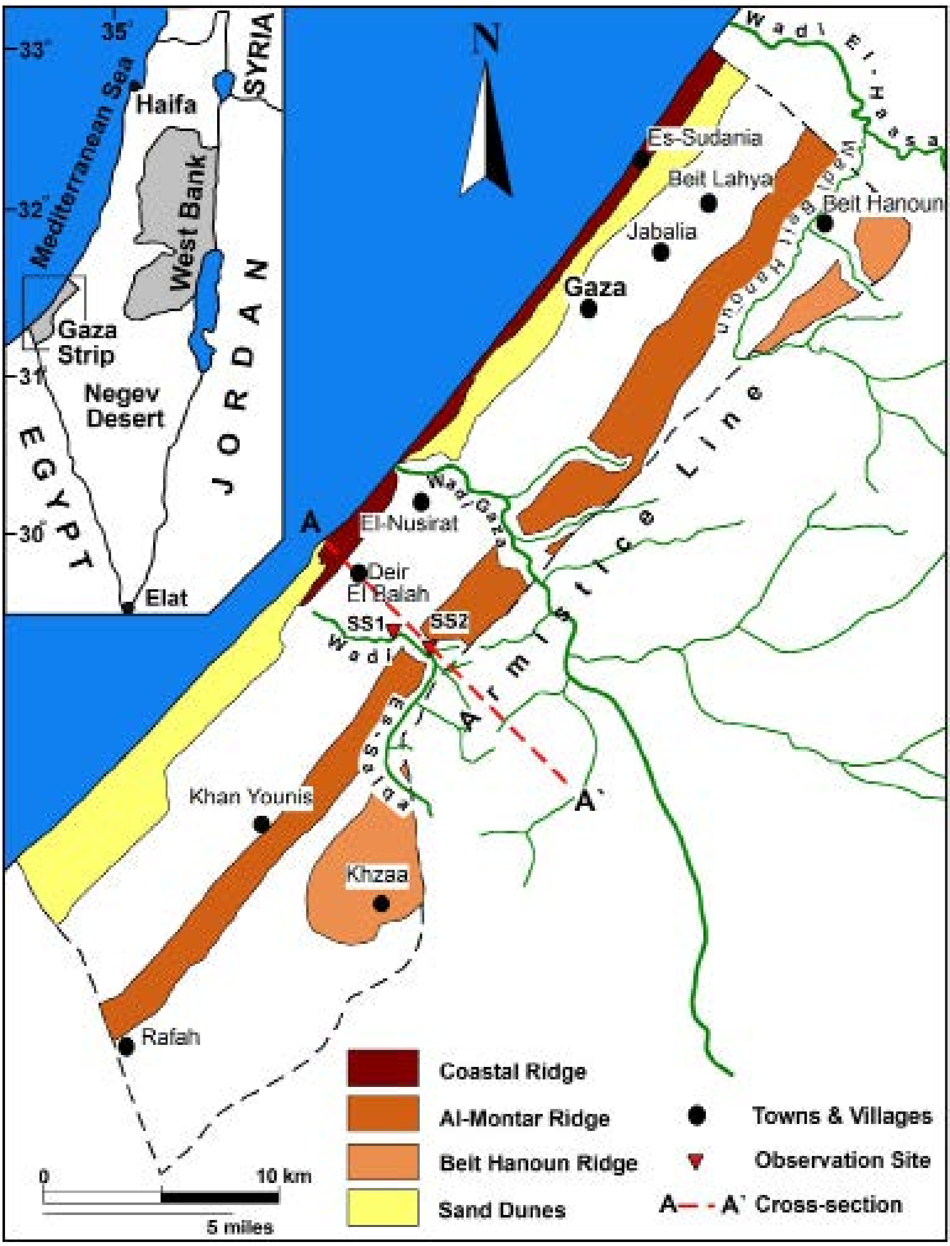

Figure 1. Location map shows the wadis in the Gaza Strip and the study sites in the Wadi Es-Salqa (after Ubeid, 2011)./***Figura 1.*** *Mapa ubicación mostrando los wadis en la Franja de Gaza y las áreas de estudio del Wadi de Es- Salqa (posterior a Ubeid, 2011).*

The first of the three wadis, Wadi Beit Hanoun, is located in the northern part of the Gaza Strip. It is considered a main tributary of Wadi El-Hassa which is located behind the armistice line (figure 1) (originating at Dora in Hebron (El-Khalil) Governorate and ending at the Mediterranean Sea between Beit Lahya and Asqalan). It collects water from a catchment area of 729 km^2 from Hebron (El-Khalil) Mountains; around 5.5% of the total catchment area is located in the Gaza Strip.

The second wadi is Wadi Gaza; it crosses the central part of the Gaza Strip from east to west. Its watershed is estimated to cover around 3600 km^2 of the northern Negeve Desert and Hebron Mountains as well as the small catchment in Gaza. The wadi's length from origin to mouth is about 105 km, and the last 9 km are located in the Gaza Strip. Wadi Beit Hanoun and Wadi Gaza have rarely flowed during the past several decades, due to numerous water diversion and storage projects upstream in Israel.

The third wadi, Wadi Es-Salqa (Wadi Silka), is in the southern region between Deir El Balah and Khan Younis (figures 1, 2). Its watershed is estimated to cover 40 km^2. The seasonal water runs from east to west and is collected in the Al-Berka (Al-Bassa), which forms the mouth of the wadi near the coastal zone of the Mediterranean Sea.

Figure 2. Landscape view of Wadi Es-Salqa during the dry season in the southern part of the Gaza Strip./ ***Figura* 2.** *Vista del paisaje del Wadi Es-Salqa durante la estación de sequía en la parte sur de la Franja de Gaza.*

Floods generally occur in the wadis only once every two years. The peak discharge and thus flood volumes are directly related to catchment size (Amit *et al.*, 2007). Generally, water runs in the Gaza Strip wadis for a short time during the winter season; they remain dry for the rest of the year. Flooding in the Gaza Strip rarely occurs, and seems to take place only when the volumes of water in Israeli dams exceed their capacities. Table 1 summarizes the characteristics of the wadis in the Gaza Strip.

Information	Wadi Bait Hanoun	Wadi Gaza	Wadi Es-Salqa
Origin source	Hebron mountains	Hebron mountains and the northern Negeve	The northern Negeve
Mouth	Wadi El-Hassa	The Mediterranean Sea	Al-Berka / Al-Bassa
Total watershed area	729 km^2	3600 km^2	40 km^2
Length in Gaza Strip	11 km	9 km	10 km
Flow direction	From south to north	From east to west	From east to west

Table 1. Characteristics of the wadis in the Gaza Strip./***Tabla 1.*** *Características de los wadis en la Franja de Gaza.*

Brief stratigraphic overview

The common overall chronostratigraphic framework of the coastal plain of Palestine is shown in figure 3A. The stratigraphy of the Gaza Strip is part of the coastal plain of Palestine, which belongs to the Tertiary and Quaternary periods. It consists of three main groups: Avedat Group, Saqia Group and Kurkar Group (figure 3A). The Kurkar Group (Quaternary) is sharply overlays the Saqia Group. In contrast to the pelagic nature of the Yafo Formation, the Kurkar Group is mainly clastic, containing a variety of sediments: calcareous sandstones ("kurkar") (some strongly cemented and some loose), red fine grain deposits ("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 (Ronen, 1975; Bartov *et al.*, 1981; Gvirtzman *et al.*, 1984, 2005).

The Gaza Formation mainly consists of alternations of kurkar and hamra with either gradational or sharp contacts (Ubeid, 2010a, 2010b, 2011) (figures 3B-C). Lithologically, the hamra consists of reddish-brown palaeosols that occasionally grade into blackish, clay-rich marsh deposits (Ubeid, 2010b, 2011). Geometrically, it forms lenses several meters thick that extend for some hundreds of meters (figure 3C). The loess deposits form the Ruhama Member (Horowitz, 1975; Abed and Al Weshahy, 1999; Ubeid, 2011).

Ubeid (2011) categorized the palaeosols that occur in 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 calcium-carbonate content of up to 13%; and (b) dark brown hamra palaeosols, which mainly consist of fine-grained sands to clay, with calcium-carbonate content of up to 12%. The second group contains the loess and loess-derived palaeosols.

This paper describes the first geological study in Wadi Es-Salqa focusing on the stratigraphic units in the wadi, and recognizing the origin and the nature of the palaeosols in the studied area on the basis of field observations, sampling, and logging.

Field and laboratory methods

The field work was carried out within Wadi Es-Salqa. The study region begins west at the bridge that crosses the Salah E-Deen highway, and ends at the Deir El Balah landfill to the east. Two sites with well exposed stratigraphic units were selected, SS1 (N 310 23` 2``, E 340 22` 40``) and SS2 (N 310 23`, E 340 21` 47``) (figure 1). In the studied area only two columnar sections were observed and surveyed. Stratigraphic units and palaeosol horizons were described in the field. The stratigraphic units were described from bottom to top. The palaeosol profiles were described from the top to the bottom of the succession and were defined according to the American Soil Taxonomy (Soil Survey Staff, 1975). Samples for further sedimentological analysis were collected for each of the units.

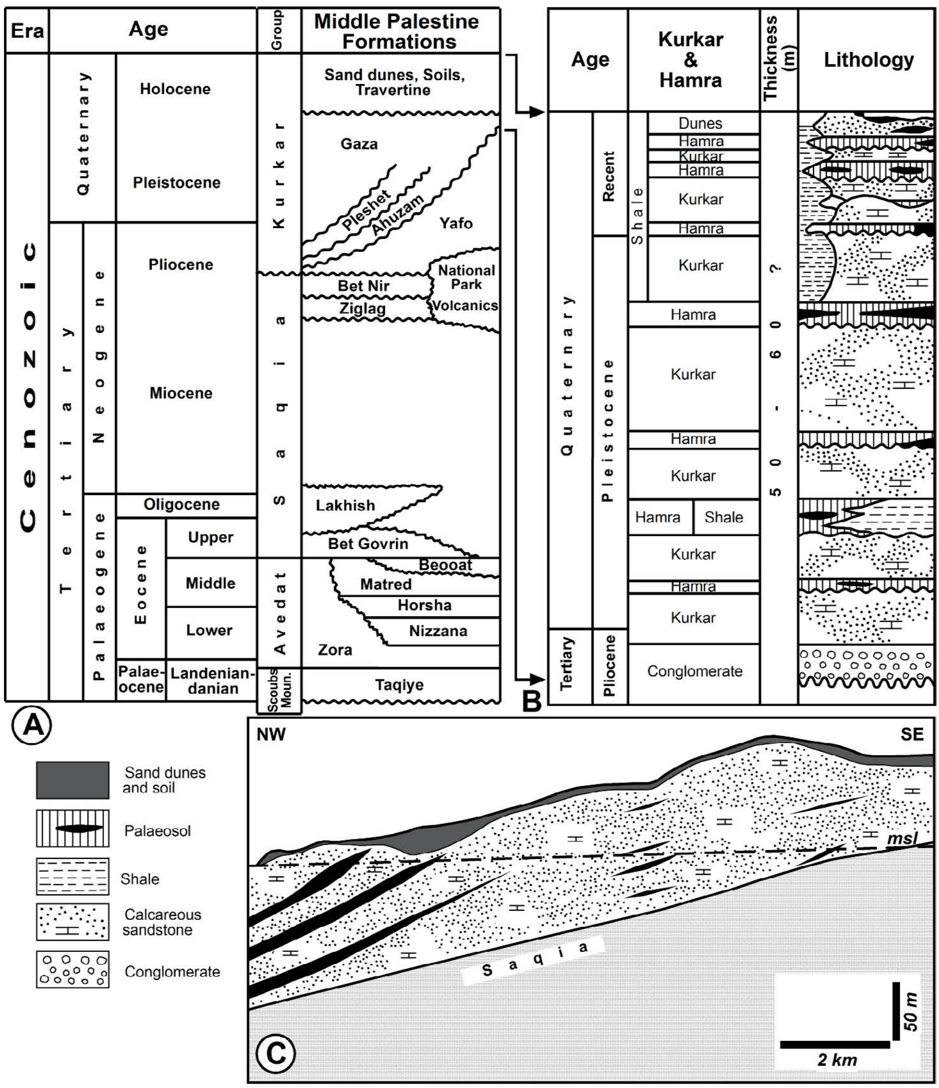

Figure 3. (A) Stratigraphic framework of outcrops and subcrops for Palaeocene to Recent sequence in the central coastal plain of Palestine (after Bartov *et al.,* 1981). (B) Kurkar and hamra alternations in the Plio- Pleistocene Gaza Formation (after Abed and Al Weshahy, 1999). (C) NW-SE subcrop geological cross-section (AA`) showing the stratigraphy and lithology at the study area; its location is shown in Figure 1./ ***Figura 3.*** *(A) Marco estratigráfico de los afloramientos y subsuelos desde el Paleoceno a las secuencias recientes en la planicie costera central de Palestina (después de Bartov* et al.*, 1981). B) Alternancias de Kurkar y de Hamra, en la Formación Gaza del Plio-Pleistoceno (después de Abed y Al Weshahy, 1999). C) Sección transversal geológica NO-SE de los subsuelos (AA `) mostrando la estratigrafía y litología en el área de estudio; su ubicación se muestra en la Figura 1.*

In order to clarify the field observations, we also used the laboratory methods of hydrometry and sieving for particle size distribution, and the calcimetry method to determine calcium carbonate contents. The particle size distribution data were processed using GRADISTAT software following Blott and Pye (2001).

Results

The studied area has two good outcrop successions; their locations are shown in figure 1. At the first site (SS1), there is a sequence of light brown fine-grained deposits. At the second site (SS2), the succession consists of light brown fine-grained deposits and light-colored soft sandy deposits. Stratigraphically, three units can be distinguished within the sequence at SS1 (Unit-1, Unit-2 and Unit-3, from bottom to top) (figure 4). Each unit within this sequence contains complex profiles with at least two amalgamated horizons. The succession at SS2 comprises four units. Two of the units are composed of fine-grained deposits (Unit-1 and Unit-4, from bottom to top) and represent palaeosols. The other units are composed of coarse-grained deposits (Unit-2 and Unit-3) (figure 5). The units within this succession are separated by sharp contacts. In addition to these, recent deposits at the top of each section were accumulated, but these are beyond the scope of this study.

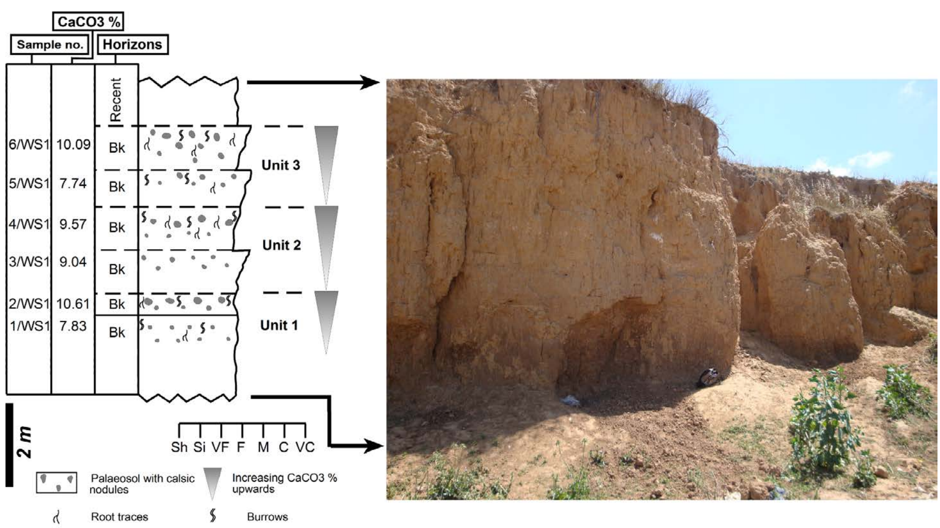

Figure 4. Columnar section of the palaeosols at Wadi Es-Salqa at site SS1./***Figura 4.*** *Perfil del paleosuelo del Wadi Es-Salqa en el sitio SS1.*

Description of the Units at SS1

Fine-grained Unit-1

The lowest unit in the succession represents palaeosols that developed in loamy soils: these are Bk horizons. The color of the soils in this unit is light brown. The thickness of this unit is about 2.5 m. It consists of fine-grained deposits (very fine to fine sand: 37%; silt: 34 - 36%; and clay: 27 - 29%) (table 2). The calcium carbonate contents as a matrix range from 8% in the lower parts to 11% in the upper parts (table 3). It contains elongated carbonate nodules up to 5 cm in diameter. The amount and the size of calcic nodules increase upward.

It also contains patches of carbonate in addition to small streaks of calcium carbonate. The Bk horizon is penetrated by rhyzolites and burrows, which are filled by younger sand. This unit contains organic matter that forms dark patches. It displays moderate hardness. The upper contact of this unit is sharp with a relief of few centimeters (figure 6).

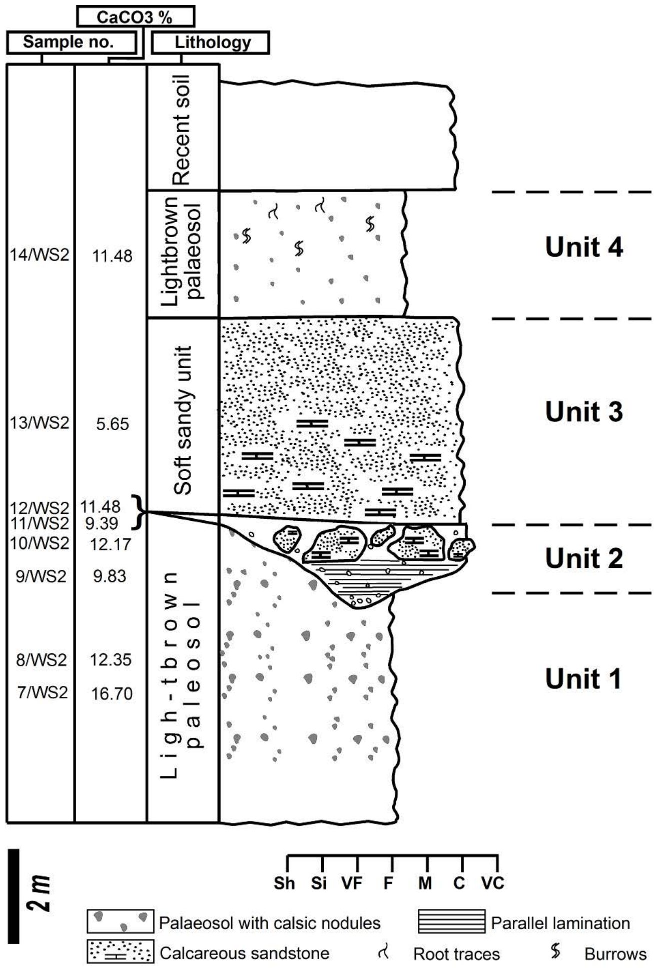

Figure 5. Columnar section of Wadi Es-Salqa at site SS2./***Figura 5.*** *Perfil del Wadi Es- Salqa en el sitio SS2.*

Fine-grained Unit-2

The middle unit in section SS1 (figure 4) developed in sandy loam soil and represents the Bk horizons. The thickness of this unit is about 2 m. The color of this unit is light brown. It consists of fine-grained deposits (very fine to fine sand: 51 - 53%; silt: 30%; and clay: 17 - 19%) and calcium carbonate contents as a matrix range from 9% at the lower parts to 10% at the upper parts (tables 2 and 3). The quantity and the size of the calcic nodules increase upwards within this unit. The soil structures in this unit are prismatic. It is also penetrated with burrows and root remains; these are dense in the upper parts. The degree of hardness is lower compared with that of the fine-grained Unit-1.

Figure 6. The contact between the truncated Bk of Unit-1 and Unit-2 in SS1./***Figura 6.*** *Contacto entre el Bk truncado de la Unidad 1 y la Unidad 2 en SS1.*

Fine-grained Unit-3

Unit-3 is the upper unit in section SS1 (figure 4). This unit developed in sandy loam soil and represents the Bk horizon. The thickness of this unit is about 1.7 m. Its color is light brown. It consists of fine-grained sediments (very fine to fine sand: 53 - 57%; silt: 26 - 34%; and clay: 13 - 17%); the calcium carbonate content as a matrix ranges from 8% at the lower parts to 10% at the upper parts (tables 2 and 3). The quantity and the size of calcic nodules increase upwards. The structures are prismatic. It is penetrated with burrows and root remains. The hardness is less than that of with the two previous units.

Sample no.	Clay %	Silt %	Sand %
1/WS1	27	36	37
2/WS1	29	34	37
3/WS1	17	30	53
4/WS1	19	30	51
5/WS1	13	34	53
6/WS1	17	26	57
7/WS2	25	18	57
8/WS2	21	24	55
9/WS2	23	24	53
10/WS2	25	20	55

Table 2. Grain size distribution for fine-grained samples, using the hydrometer method./***Tabla 2.*** *Distribución del tamaño de grano para muestras de grano fino, usando el método hidrómetro.*

Sample no.	Lithology	$CaCO_3$ %
1/WS1	Hamra	7.83
2/WS1	Hamra	10.61
3/WS1	Hamra	9.04
4/WS1	Hamra	9.57
5/WS1	Hamra	7.74
6/WS1	Hamra	10.09
7/WS2	Hamra	16.7
8/WS2	Kurkar	12.35
9/WS2	Hamra	9.83
10/WS2	Hamra	12.17
11/WS2	Hamra	9.39
12/WS2	Kurkar	11.48
13/WS2	Kurkar	5.65
14/WS2	Hamra	10.48

Table 3. Calcium carbonate contents of different samples./ ***Tabla* 3.** *Contenido de carbonato de calcio en diferentes muestras.*

Description of the Units at SS2

Fine-grained Unit-1

This unit represents the lower palaeosols in section SS2, which developed in sandy clay loam. The thickness of this unit is about 6.5 m. It is interrupted by lenticular laminated sandstone of the Unit-2. The color of this palaeosol is light brown. It consists of fine-grained deposits (fine- to very fine-grained sand: 55 - 57%; silt: 18 - 24%; and clay: 21 - 25%; see table 2 and figure 5). The calcium carbonate contents as a matrix in this unit range from 10% to 17% (table 3). Dense pebble-sized carbonate nodules are found in the upper part and decrease in the middle and lower parts forming the Bk horizon. The number of nodules also changes laterally. The middle part of this unit also has a mottled appearance, and is accompanied by root traces in some cases (figure 7). There is no clear relationship between the organic matter and the carbonate nodules. Moreover, this unit shows prismatic structures. It is sharply overlain by soft sandy Unit-3.

Lenticular laminated sandstones Unit-2

This unit consists of meter-scale sandstone containing a basal conglomeratic division; it is diagnostically lenticular in shape (figures 5, 8A), with a concave base and flat top. The maximum thickness of this unit is about 2 m, and reaches widths of up to several meters. The basal conglomeratic is up to several centimeters thick. It consists of pebble-sized grains made of kurkar (calcareous sandstone). It has poorly graded, poorly sorted, grain-supported conglomerates with a sandy matrix (table 4). Upwards, the basal division is followed by parallel laminated fine- to medium-grained sandstone with low consistency. In addition to this, aggregations of pebbles with sandy matrices are found (figure 8B). In the uppermost part, large boulders 10s of cm in diameter are found.

Figure 7. Fine-grained Unit-1 in section SS2. Note the dense carbonate nodules in the middle and upper parts, the dark middle part due to organic materials, and the sharp contact with Unit-3./ ***Figura 7.*** *Unidad 1 de grano fino en la seccion SS2. Se destacan los densos nódulos carbonaticos en la parte media y superior, la oscura parte media es debido a material orgánico, y el marcado contacto con la Unidad 3.*

Figure 8. (A) Lenticular laminated sandstones Unit-2 in section SS2. Note the boulders that were carried by flooding through the tributary. (B) The parallel lamination and scattered pebbles which are made of kurkar. (C) Soft sandy Unit-3 which is sharply overlaying fine-grained deposits of Unit-1./ ***Figura 8.*** *(A) Areniscas lenticulares laminadas de la Unidad 2 en la sección SS2. Se destaca los cantos rodados que fueron acarreados por flotación a través del afluente. (B) Laminación paralela y guijarros distribuidos hechos de kurkar. (C) Unidad 3 de arena blanda la cual esta bruscamente superpuesta a los depósitos de grano fino de la Unidad 1.*

Soft sandy Unit-3

This unit consists of fine- to medium-grained sand, with up to 6% carbonates. The mean grain size is fine sand; the grains are moderately well sorted (tables 4 and 5). They also statistically display symmetric skewed and platykurtic distributions. This unit is about 4 m thick. Its color is yellowish-white, becoming lighter to about white downwards, indicating an increase of carbonate contents. It has very low consistency with land snails, and has concretions of pebble-size sandstones cemented by highly concentrated carbonates in lower parts. No internal sedimentary structures are observed within this unit. It is sharply underlain and overlain by light brown palaeosols (Unit-2 and Unit-4, respectively) (figures 5, 8C). Its lower base dips to the east at a 15 degree angle, reflecting the channel structures.

Fine-grained Unit-4

This unit contains palaeosols which developed in sandy soil, and represents the A and B horizons. It is about 2.5 m thick. It mainly consists of sand (very coarse to coarse sand: 29%; fine to medium sand: 60%; and very fine sand to clay: 11%. The mean size of the grains is medium sand and they are poorly sorted (tables 4 and 5). The grains also show symmetric skewed and leptokurtic distributions. In the lower parts the grains are finer. Its color is brown, passing downward into reddish-brown. The carbonate content as a matrix is about 11%. It displays massive structure. The calcic nodules are very small: pebble- to granule-sized. Root traces and burrows are observed in this unit. It sharply underlain by soft sandy Unit-3 and is overlain by a recent soil unit.

Sample no.	Mean	Sorting	Skewness	Kurtosis	Textural Group	Sediment name
11/WS2	Fine sand	Poorly sorted	Fine skewed	Leptokurtic	Sand	Poorly sorted medium sand
12/WS2	Very coarse sand	Poorly sorted	Very fine skewed	Platykurtic	Sandy gravel	Sandy very fine gravel
13/WS2	Fine sand	Moderately well sorted	Symmetrical skewed	Platykurtic	Sand	Moderately well sorted
14/WS2	Medium sand	Poorly sorted	Symmetrical skewed	Leptokurtic	Sand	Poorly sorted medium sand

Table 4. Description of coarse-grained samples./***Tabla 4.*** *Descripción de muestras de grano grueso.*

Sample no.	Clay %	Silt %	VF Sand %	F Sand %	M Sand %	C Sand %	VC Sand %	VF-F Gravl %
11/WS2	1.0	7.3	10.4	24.3	42.7	7.7	7.0	0
12/WS2	0.6	3.7	3.4	9.9	8.8	10.7	7.8	55.2
13/WS2	0.1	1.2	3.1	46.9	47.6	1.0	0.2	0
14/WS2	0.5	4	6.7	21.1	38.6	16	13.2	0

Table 5. Grain size distribution for coarse-grained samples, using the sieve analysis method./***Tabla 5.*** *Distribución del tamaño de grano para muestras de grano medio a grueso, usando el método de análisis sieve.*

Granulometry and identification of parent materials

The grain size analyses (tables 2 and 3) show that all of the units in SS1 contain clay (13 - 29%), silt (26 - 36%), and fine-grained sand (51 - 57%) (however, note that Unit-1 contains a lower proportion of fine-grained sand (37%). The grain size analyses of SS2 show that the fine-grained units contain clay (21 - 25%), silt (18 - 24%), and fine-grained sand (53 - 57%), except Unit-4 which contains approximately 5% clay and silt and 95% very fine- to very coarse-grained sand. The fine-grained size analyses in both sites reflect the contribution of dust to the pedogenesis processes. Overall, the fine-grained units in both sections show slight coarsening upwards. The brown color in the fine-grained units becomes lighter upwards, suggesting an increasing sand percentage.

The analyses indicate that the fine-grained units in the outcrop successions are identical in their grain-size contents and colors, except fine-grained Unit-4 in SS2. The grain-size of these palaeosols suggests that they are light brown loessial soil (Ubeid, 2011). This type of soil mainly covers the landscape of the eastern part of the southern coastal plain of Palestine. In the Gaza Strip, it appeared in two locations around Wadi Gaza (Ubeid, 2011) and Wadi Es-Salqa. In the mildly arid climate of the region with a mean annual rainfall of 220-320 mm, the loessial light brown soils (Haplargrids) are the zonal soils (Wieder and Gvirtzman, 1999; Ubeid, 2011). These soils are typically loam soil calcic horizons as observed in all fine-grained units except Unit-4 in SS2 which developed in sandy soil.

The model distribution of the grains for fine-grained deposits in the studied successions reflect cycles of aeolian activity, each starting with dust accumulation as a fine-grained sheet (Zilberman *et al.*, 2007) continuing with a period of stability by calcic soil formation and in some cases terminating with erosion of the upper part of the soil by deflation as in the lower unit of SS1 (figure 6). The origin of this loessial soil is dust storms from the Sinai and Saharan Deserts, which supplied detritus of desert weathering (Dan and Yaalon, 1971; Yaalon and Dan, 1974; Bruins and Yaalon, 1979; Yaalon and Ganor, 1979; Enzel *et al.*, 2008; Crouvi *et al.*, 2008, 2009, 2010); some of the dust also came from the eastern deserts (Yaalon and Ginzburg, 1966). A particle size of 100 μm is the upper threshold of atmospheric dust. The composition of the present aeolian dust is similar to that of the loessial arid brown soils, found in mildly arid climates (Dan *et al.*, 1976). This type of soil is identical to loessial soil in Wadi Gaza (Ubeid, 2011). This assemblage is found in the modern loessial arid brown soils throughout the northern Negeve. The secondary carbonate accumulation in these soils indicates that the dust comprising the original parent material was affected by a wetter climate, with higher precipitation (Wieder and Yaalon, 1985; Wieder and Gvirtzman, 1999; Gvirtzman and Wieder, 2001; Amit *et al.*, 2010).

The sandy soil of Unit-4 in SS2 is derived from sandy parent materials. This type of soil, which developed on sand or calcareous sand generally covers the western part of the southern coastal plain of Palestine (Ubeid, 2010a, 2010b, 2011). In the same way, the soft sandy Unit-3 in SS2 is representative of a new dune-sand accumulation, which can be considered a sediment with minimal pedogenesis formed above true palaeosols units.

Discussion

Despite the relatively long lateral distance between the two sections (i.e., SS1 and SS2), the lack of more outcropping rocks between them, the natural geometry of the hamra palaeosols which take the lens-like, the field observations and the altitudes of the two sections (28 m and 49 m above mean sea level, respectively) all suggest that SS2 is younger than SS1.

Lithostratigraphically, the outcrop successions in Wadi Es-Salqa consist of two types of palaeosol units, as shown in the analyses of SS1 and SS2. The successions of SS1 and SS2 belong to Pleistocene-Holocene periods (figure 3A-B) (Yaalon and Dan, 1974; Bartov *et al.*, 1981; Abed and Al Weshahy, 1999; Wieder and Gvirtzman, 1999; Crouvi *et al*, 2008; Ubeid, 2011). The subcrop geological cross-section in the studied sites indicates that the succession consists of alternations of calcareous sandstones (kurkar) and red fine-grained deposits (hamra) (figure 3C).

The deposits of the successions in Wadi Es-Salqa can be categorized into two types of soils based on their parent materials: loessial soils and red sandy soils (xeralefs). The yellowish-white soft sandy unit is a dune-sand accumulation with minimal pedogenesis, which is apparently similar to kurkar deposits.

Each unit of the successions is formed from aeolian dust accretions that took place at different intensities in the past. Two separate phases could be considered. The fine-grained unit palaeosols in the successions (except Unit-3 and Unit-4 in SS2) suggest the development of palaeosols in the phase of slow dust accretion during which the main pedogenesis took place. This would explain the gradual transition from one paleo-pedogenetic unit to the other. The catenary soil differentiation states that the intensity of soil differentiation is inversely proportional to the intensity of soil erosion and/or sedimentation. This would suggest that the pedogenetic phase was long and stable (Bulter, 1967; Wieder and Yaalon, 1985; Wieder and Gvirtzman, 1999; Ubeid, 2011).

On the other hand, Unit-3 and Unit-4 in SS2 suggest a formation phase of rapid sand grain accretion with slight pedogenesis, especially Unit-3. This would explain the occurrence of the contacts with these units (Wieder and Gvirtzman, 1999; Ubeid, 2011).

Ubeid (2011) noted that the loessial palaeosols developed during arid climate conditions, whereas the red sandy palaeosols (hamra) developed during humid and warm climate conditions. The author also suggested that the secondary carbonate accumulations in these soils were leached out completely in a humid climate.

The characteristics of Unit-2 in SS2 indicate that channel deposits interrupted the palaeosols of Unit-1 in SS2, and the characteristics of this unit suggest strong flooding during the winter season during which the flow was able to transport boulder-sized particles through the tributary of the main wadi.

Conclusions

Wadi Es-Salqa is one of three main wadis that intersect the kurkar ridge in the Gaza Strip. It located in southern part of Gaza Strip, and its watershed covers 40 km^2. The Pleistocene-Holocene Gaza Formation at Wadi Es-Salqa consists of alternations of calcareous sandstones and paleosols of fine-grained deposits, whereas the outcrop successions consist of palesosols. The palesosols at Wadi Es-Salqa can be placed in one of two categories based on their grain-size relationships and their parent materials. The first type is the loessial soils; these developed in loam to sandy loam soils and have a reddish-brown color. This type of soil consists of fine-grained deposits very fine to fine sand: 37 - 57%; silt: 18 - 36%; and clay: 13 - 29% and calcium carbonate contents as a matrix range from 8% to 17%. The model distribution of the grains for loessial soil reflects atmospheric dust that accumulated from the Sinai and Saharan Deserts. The second type is the sandy soils. Their color is reddish-brown (except for one soft sandy unit with minimal pedogenisis, which has a yellowish-white). This type of soil is derived from sandy parent material (mainly kurkar), and cover the western part of the southern coastal plain of Palestine.

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