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# Geomorphology and Sedimentology of Gane Ṭal

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## Introduction

The Gane Ṭal site (see Arbel and 'Ad, this volume) is located in the southeastern part of the Israeli coastal plain at an elevation of c. 80 m asl, where the topography is flat to slightly undulating. Two major soil groups are found in this region: (1) red sandy soils, which are either calcareous (*ḥusmas*) or non-calcareous (*ḥamra*), overlying diverse types of sandy sediments of the Reḥovot formation (Gvirtzman et al. 1984); and (2) brown grumusols (vertisols) composed of alluvial/aeolian sediments (Singer 2007). In some cases, the *ḥamra* is the exposed topsoil, but in many cases, it is overlain by the dark brown grumusol (Dan et al. 1976; Dan, Fine and Lavee 2007; Singer 2007).

The occurrence of two soil types in a sequence is evidence of changes in environmental conditions. The sandy *ḥamra* soils developed above a stable sand dune as a result of a low rate of dust accumulation, a complete leaching of the carbonates and a long period of stable environmental conditions (Gvirtzman et al. 1999). The grumusol developed following a short period of unstable conditions and a very high rate of dust accumulation, allowing for soil pedogenesis (Wieder and Gvirtzman 1999). It is yet unclear whether the climatic conditions which prevailed during the development of each of these soil types were humid or arid.

The present-day climate in the region is Mediterranean semi-arid, in which the summers are hot and dry, and the winters are cool and rainy (Kafle and Bruins 2009). The mean annual temperature is 16–18°C, and the mean monthly temperatures are 12–14°C in January and 26–28°C in August (Shahar 2007). The rainy season lasts from October to May; the mean annual rainfall is 500–600 mm (*Israel Meteorological Service* 2000). The region is characterized by Mediterranean vegetation, today dominated by cultivated plants and flora.

This study aimed at examining the sedimentological environment of the site both before and during the period of ancient occupation, to assess the possibility that environmental conditions changed during that time span.

## Materials and Methods

Several sections were examined in the field: (1) the eastern sections of two excavation squares in Area D1, one in the center of the area, associated with W1069 (Fig. 1), and the other, in the eastern part of the area, associated with W1111 (Fig. 2; L1024); (2) the northern section of a square in Area E1, associated with W1659, near Floor 1680 (Fig. 3); and (3) the western section of a square in Area E3, where the only remains exposed were dated to the Mamluk period (Fig. 4; see Arbel and ʻAd, this volume). The sediments were described in detail according to their structure, texture, pedological characteristics, unit boundaries and color. In the laboratory,[1] soil texture was further examined using the hydrometer method for particle size distribution analysis (Klute 1986).[2] The results of this analysis are presented in Fig. 5.

The dates of the sedimentary units in the analyzed sections are primarily based on ceramic finds from the archaeological deposits. Optically Stimulated Luminescence (OSL), measuring the length of time since the last exposure of soil minerals such as quartz or feldspar—quartz in the present case—to sunlight, was also conducted to date the sedimentary units of the section on the eastern edge of Area D1 (for additional details on the OSL method and laboratory procedure, see, e.g., Porat 2007).

## RESULTS

### FIELD OBSERVATIONS

*Area D1, W1069*

Four primary sediment units were identified in this section (Fig. 1; Table 1). They are described from top to bottom:

*Unit 1*.— Topsoil of brown grumusol, 20–30 cm deep. This unit was mostly removed prior to excavation.

*Unit 2*.— An architectural feature, the foundation course of Byzantine W1069, comprising part of the archaeological layer in this part of the site.

*Unit 3a*.— Brown grumusol, 60 cm in depth, exposed in the section adjacent to W1069. It appears to comprise the natural soil, which underlies the base of the archaeological layer.

*Unit 3b*.— A gray fill, 5–20 cm in depth, underlying W1069. It seems to form the base of the wall and the archaeological layer.

*Unit 4*.— A red sandy loam *ḥusmas* soil, forming the bottom part of the natural sedimentological sequence of the site.

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[1] Field Service Laboratory at the Regional Agriculture Research Center at Ẓemaḥ in the Jordan Valley.

[2] Texture is the relative percentage of fine material particles <2 mm in size. These particles are classified according to their diameter: clay (<0.002 mm), silt (0.002 to 0.05 mm) and sand (>0.05 to <2 mm).

**Table 1. Area D1, W1069**

| Unit | Depth (cm) | Sediment Type | Color[i] | Texture | Structure | Consistency | Boundary | Date of the Sherds | OSL Calibrated Date (years BP) | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0–20/30 | Brown grumusol | Grayish brown, 10YR 5/2 | Sandy clay loam | Prismatic to angular blocky | Slightly hard to hard | Clear and wavy | | | Remains of the present surface; absolute height of section top: 73.30 m asl |
| 2 | 20/30–29/35 | Archaeological structure/ anthropogenic fill | Pale brown, 10YR 6/3 | Clay loam | Angular blocky to granular | Soft to slightly hard | Abrupt and wavy | Byzantine | | Wall base, W1069 |
| 3a | 29/35–90 | Brown grumusol | Brown, 7.5YR 5/3 | Clay loam | Prismatic | Slightly hard to hard | Not exposed | | 30 ± 9 ka | Prismatic structure inclined about 45º with well-developed slickensides; at 80 cm depth, sub-rounded rock fragments of 0.5 cm comprise 15–25% of the sediment matrix |
| 3b | 70/85–90 | Gray fill | Light brownish gray, 10YR 6/2 | Clay loam | Angular to crumb | Slightly hard | Clear to abrupt and wavy | | | Similar to Unit 3a except for sign of secondary carbonate sedimentation |
| 4 | 90–130/135 | Red calcified sandy loam *ḥusmas* soil | Yellowish red, 5YR 5/6, with dark brown, 7.5YR 5/6 | Sandy loam | Sub-angular blocky | Hard | Not exposed | | 92 ± 22 ka<br>123 ± 37 ka | Carbonate nodules up to 5 cm in diameter; a few manganese mottles |

[i] According to Munsell Soil Color Chart. Sample color was checked in dry conditions, unless otherwise stated.

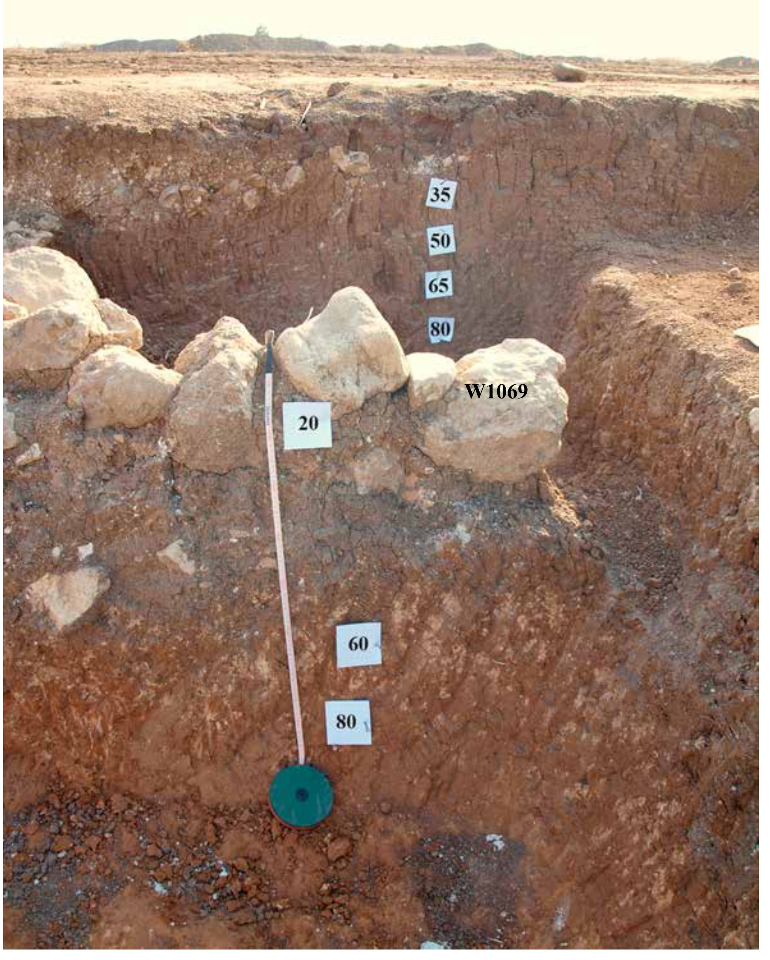


Fig. 1. Area D1, section showing the sedimentary units in the eastern edge of L1024 with OSL dates, looking east.

**Table 2. Area D1, W1111**

| Unit | Depth (cm) | Sediment Type | Color[i] | Structure | Consistency | Boundary | Notes |
|---|---|---|---|---|---|---|---|
| 1 | 0–30 | Brown grumusol | Brown, 10YR 5/3 | Prismatic | Slightly hard to hard | Not exposed | Carbonate nodules, clay skin |

[i] According to Munsell Soil Color Chart. Sample color was checked in dry conditions, unless otherwise stated.

*Area D1, W1111*

The Byzantine wall in this section, containing only two stratigraphic units, is located directly above a well-developed brown grumusol, at least 30 cm deep (Fig. 2; Table 2).


Fig. 2. Area D1, section showing W1111 situated atop a brown grumusol soil, looking east.

*Area E2, W1659 and Floor 1680*

Four primary sediment units were identified in this section (Fig. 3; Table 3). They are described from top to bottom:

*Unit 1*.— A grayish topsoil brown grumusol, c. 30 cm deep. As mentioned above, in most places it was removed before the excavations took place.

*Unit 2a*.— The foundation course of Byzantine W1659, comprising part of the archaeological layer.

*Unit 2b*.— A gray brown fill, 5–20 cm deep, underlying Floor 1680.

*Unit 3*.— *Ḥamra*, a yellowish red loamy sandy soil, the parent material in the area of Gane Ṭal.

**Table 3. Area E2, W1659 and Floor 1680**

| Unit | Depth (cm) | Sediment Type | Color[i] | Texture | Structure | Consistency | Boundary | Date of the Sherds | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0–30 | Brown grumusol | Brown, 10YR 4/3 | Sandy clay loam | Prismatic | Slightly hard | Clear and smooth | | Present surface, about 40–100 cm of the layer was removed mechanically before the excavation |
| 2 | 30–56 | Brown grumusol mixed with archaeological fill | Brown, 10YR 4/3 with mottles of dark brown, 7.5YR 5/6 | Sandy clay loam | Prismatic to subangular blocky | Soft to slightly hard | Abrupt and wavy | Byzantine | Archaeological layer |
| 2a | 0–5 | Archaeological floor | | | | | | Byzantine | W1659, Floor 1680 |
| 2b | 5–20 | Archaeological fill | Grayish brown, 10YR 5/2 | Sandy clay loam | Massive to subangular blocky | Slightly hard | Gradual and wavy | | The material is the foundation for an overlying floor; the layer pervades the underlying unit |
| 3 | 56–77 | *Ḥamra* | Yellowish red, 5YR 4/6 | Sandy loam | Prismatic to subangular, blocky to crumbly | Slightly hard | Not exposed | | Signs of secondary calcium deposition |
| 3a | 20–65 | *Ḥamra* | Yellowish red, 5YR 4/6 | Loamy sand | Massive, subangular blocky to granular | Loose | Not exposed | | |

[i] According to Munsell Soil Color Chart. Sample color was checked in dry conditions, unless otherwise stated.

**Table 4. Area E3**

| Unit | Depth (cm) | Sediment Type | Color[i] | Texture | Structure | Consistency | Date of the Sherds | Notes |
|---|---|---|---|---|---|---|---|---|
| 1 | 0–30 | Grayish brown grumusol | Grayish brown, 10YR 5/2 | Sandy loam | Massive | Abrupt and wavy | | |
| 2 | 30–106 | Archaeological/ anthropogenic fill | Light brownish gray, 10YR 6/2 | Sandy loam | Massive | Abrupt and wavy | Mamluk | Signs of laminae |
| 3 | 106–140 | *Ḥamra* | Yellowish red, 5YR 5/8 | Sand | Cross bedding, granular to subangular blocky | | | Sign of secondary carbonate sedimentation |

[i] According to Munsell Soil Color Chart. Sample color was checked in dry conditions, unless otherwise stated.

Fig. 3. Area E2, section showing the sedimentary units related to W1659, looking north.

*Area E3*

Three sediment units were identified in this section (Fig. 4; Table 4). They are described from top to bottom:

*Unit 1*.— Topsoil of grayish brown grumusol, c. 30 cm deep, which was removed in most places before the excavations took place.

*Unit 2*.— An archaeological fill, c. 80 cm deep, dated according to ceramic sherds to the Mamluk period (c. twelfth–fifteenth centuries CE).

*Unit 3*.— Natural *ḥamra*.

Fig. 4. Area E3, section, looking west.

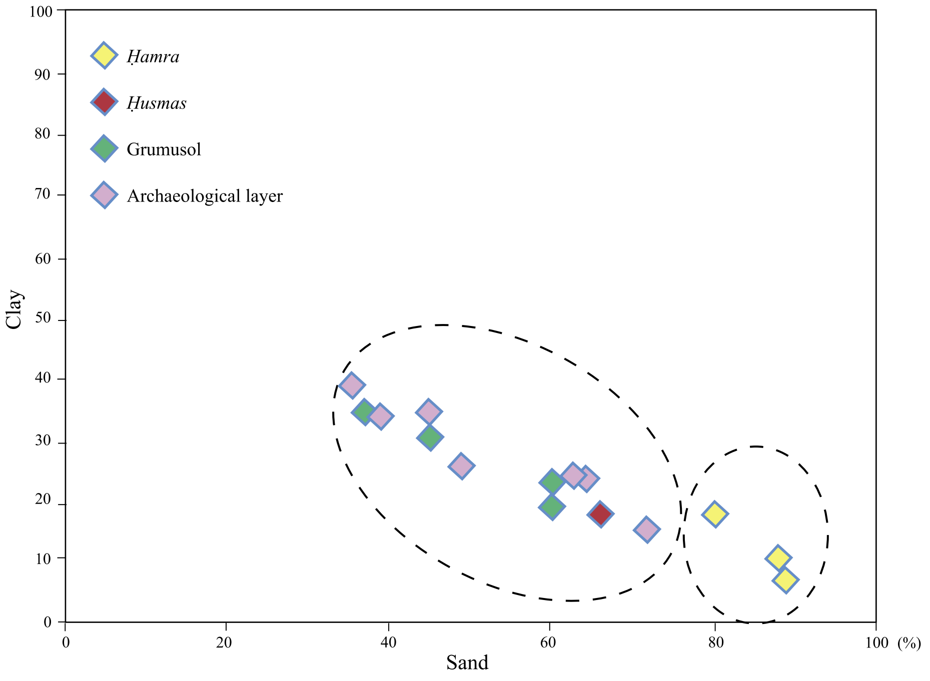


Fig. 5. Particle size distribution of the soils and archaeological sediments.

## Particle Size Distribution Analysis

Particle size distribution analysis allows for dividing the sediments sampled at the site into two main groups (Fig. 5): (1) *ḥamra:* and (2) grumusol, *ḥusmas* and the archaeological sediments. The *ḥamra* is sandy in nature and composed of 80–89% sand and 7–18% clay. The grumusol, the archaeological sediments and the *ḥusmas* are sandy clay in general, composed of 36–72% sand and 15–34% clay. There is close similarity in the particle size composition between the grumusol and the archaeological sediments.

## The General Sedimentary Sequence of the Site

The general sedimentary sequence of the site contains the following units, from top to bottom (Fig. 6): (1) upper (brown) grumusol, (2) archaeological layer, (3) lower grumusol/ gray fill and (4) *ḥamra*, *ḥusmas*.

The sedimentological formation process of the site, encompassing both the natural soils and the archaeological layer, is reconstructed as follows, employing the dates which are based on either ceramics or OSL measurements:

*Phase 1*: Sand accumulation and dune formation, sometime between 150,000 and 70,000 years BP.

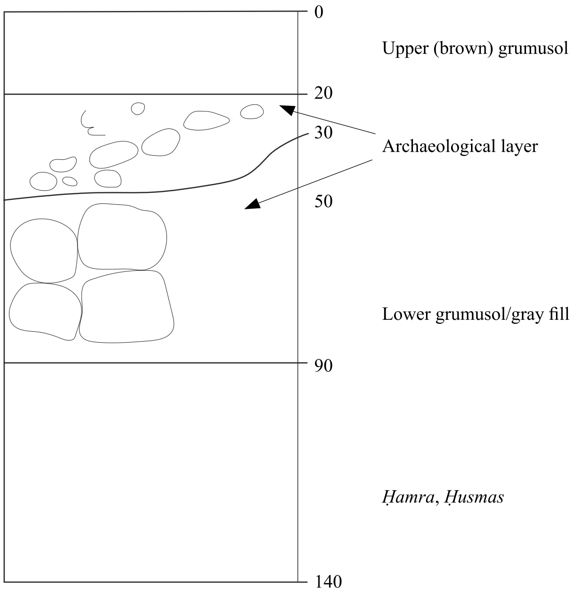


Fig. 6. General sedimentary sequence of the site.

*Phase 2*: Surface stabilization and *ḥamra* soil formation above the stabilized sand dunes, probably from 150,000–70,000 up to c. 40,000 years BP.
*Phase 3*: Dust accumulation, probably for a relatively short period of time.
*Phase 4*: Surface stabilization and formation of the lower grumusol/gray fill.
*Phase 5*: Establishment of Byzantine site, c. 1500 years BP, above lower grumusol/gray fill.
*Phase 6*: Renewal of dust accumulation and burial of the site, at the end of the Byzantine period or shortly thereafter.
*Phase 7*: Surface stabilization and formation of the upper grumusol.

## CONCLUSIONS

The sedimentary sequence uncovered at Gane Ṭal indicates several phases of sediment accumulation, each of them followed by long periods of stabilization and soil formation, which is in concurence with previous findings (Gvirtzman et al. 1999).

The settlement at Gane Ṭal appears to have been established above a thin grumusol/gray fill during a period of stabilization and soil formation (Phase 5). This conclusion is supported by field observations, as well as on the analysis of particle size distribution, which shows a similarity between the grumusol and the archaeological sediment. The sedimentary sequence in Area E3, encompassing a Mamluk structure, is an exception to this pattern, as it was established directly above *ḥamra*. It seems that during the establishment of this structure, the gray fill was removed.

The relationship between formation processes of different soil types and varying climatic conditions has been long debated. According to Gvirtzman et al. (1999) and Wieder and Gvirtzman (1999), the formation of *ḥamra* relates to humid conditions, while that of grumusol relates to drier, semi-arid conditions. A reverse relationship was detected by Marder et al. (2011) at Revadim, a prehistoric site located about 2 km south of Gane Ṭal, where the soil carbon isotopic composition of the *ḥamra* indicated drier conditions for the development of the Mediterranean vegetation, and that of the grumusol indicated wetter conditions for its development. At Gane Ṭal, only few OSL dates were obtained from the *ḥamra* horizon, providing a broad age range of c. 70,000 years. Hence, it is unclear which climatic conditions prevailed during the formation of this soil horizon, requiring further research on this topic.

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