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The *Kurkar* and *Ḥamra* Genesis of the Northern Hill of Tel Mikhal (Tel Michal)

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The geological setting of Tel Mikhal has been extensively dealt with in the University of Tel Aviv’s report published fourteen years ago (Herzog, Rapp and Negbi 1989). This paper updates that work on the *kurkar* and *ḥamra* genesis of the northern hill.

Physiography

The physiography of the Sharon Plain can be described as a series of elongated sub-parallel ridges and depressions extending inland of the present shoreline. These *kurkar* ridges characterize the entire coastal plain of Israel. The westernmost *kurkar* ridge forms a discontinued sea cliff rising up to 40 m above sea level. Tel Mikhal is the highest point of that ridge (Katzav 1994).

The Quaternary *kurkar* group sediments forming these ridges and depressions are composed of mobile sand, *ḥamra, kurkar* and grumosols (swelling and cracking clay soils). The term *ḥamra* is used for both a very well-defined, reddish, sandy-clay loam soil, as well as a mixed soil in which *ḥamra* is dominant (Dan and Koyumdjiski 1979; Dan and Yaalon 1990).[1] *Kurkar* is the local name of eolianites, essentially calcareous sandstone. *Kurkar* ridges were originally formed by sand dunes that covered the Coastal Plain and, over time, transformed through consolidation and pedogenesis. Although these ridges are called *kurkar* ridges, they are composed not only of *kurkar* but also of *ḥamra* soil (see Table 1). Each ridge has several sedimentary layers, resulting from the interaction of several processes: sedimentation, soil formation and erosion.

The sand originates in Ethiopia, flows down the Nile River, and is carried by currents northward along the coastline. The dry sand is then blown inland, where some sand is eroded on the coast itself. The coastline evolves either by erosion, or by deposition of sand near river inlets. Strong erosion of the ridges, where sands accumulated during former periods, is typical of the central coastline of Israel. Penetration of sand inland is controlled by major wind directions, topography of the beach, and the water content of the uppermost sand layer (Tsoar 1990; Tsoar and Blumberg 1990).

Table 1. The Geological Units of Ḥefer Formation Exposed near Tel Mikhal with their Approximate Ages as Suggested by Netser (1994)

Name	Approximate Ages	Suggested Isotopic Stages
Ramat Gan *Kurkar* Member	52 ka	3.3
Naḥsholim *Ḥamra* Member	45 ka	3.2
Dor *Kurkar* Member	30 ka	3.1
Netanya *Ḥamra* Member	20 ka	2.0
Tel Aviv *Kurkar* Member	101–6 ka	1.1
Ta‘arukha Sand Member	5.5 ka and 4.5 ka (and 3.5 ka)	
Ḥadera Sand Member	Younger than 1.4 ka	

The sea ridge changes over time through several processes: sediment supply; tectonic movement; sand deposition along the coast; erosion of the ridge caused by waves; and mass movement due to the internal structure of the ridge. The lowest mean sea level (MSL) during the peak of the last glacial (c. 18,000 BP) was 1.3 m below present. About 6000–7000 years ago, MSL reached its present level (Morner 1969). Since then, MSL has hardly changed more than one meter during the last two thousand years (Pirazzoli 1989).

Waves deposit a sheet of sand on the beach during summer, and extract it during the winter. Owing to the low amplitude of the waves, this sand sheet protects the cliff face. Yet, once the sand is removed, the waves cut at the base of the cliff, causing structural damage. Rain and subsequent runoff deplete the Netanya *ḥamra* layer, causing the upper Tel Aviv *kurkar* to break and fall into the sea. Gvirtzman suggested that the sea cliff at Tel Mikhal was formed because *kurkar* blocks between fault lines are tilted toward the north, thus minimizing the rate of cliff erosion. Gifford's calculations show that the rate of cliff erosion is the lowest along the coastal cliff in Israel (Gifford 1989: Fig. 18.4; Nir 1982; Metser 1994; Gavish and Bakler 1990). Ḥadera sands are the present-day sedimentary unit of the coastal plain of Israel. The Rishon Le-Ẓiyyon formation sand dunes advanced inland and filled the depressions east of Tel Mikhal (Netser1994).

Geological Structure

The younger Quaternary *kurkar* group sediments that form the Sharon Plain covered the deeper neogenic paleogeography and created a new landscape (Gvirtzman et al. 1984). The Sharon and the continental shelf form a 30 km wide plateau tilting to the west (at a gradient of 0.8%). The difference in elevation between adjacent high and low points of the plateau is less than 40 m (Gvirtzman 1990).

Boreholes were used to discover the Sharon area's geological structure. The data reveal complex anticlines and synclines having a common southwest to northeast axis, known as the Syrian Arc. The faults of the Sharon are characterized by a common east–west direction. Tel Mikhal is situated on the southern end of Ga'ash anticline, on the elevated flank of a fault oriented east–west (Gvirtzman 1990).

Kurkar *Lithogenesis*

The process whereby *kurkar* is formed from sand can take some 100,000 years. Along the Israeli coast, for example, blown sand accumulates as transverse dunes. Their slip face is 35 degrees off the north–south axis owing to the direction of the wind. The internal structure of eolianite ridges indicates that they are constructed as laminated dunes (Yaalon and Laronne 1971). Lamination in the dune is a result of particle-size differentiation during the formation stage. The calcareous fragments, being coarser grained than quartz, accumulate on the crest of the ripple (or dune), rather than at the trough (Yaalon 1967). One generation of dunes can reach 5–7 m in height.

The dune then advances over the previous generation of dunes, covering the accumulated topsoil. Next, quartz sand acquires calcium carbonate originating from seashells for cementation. When there is a large accumulation of these shells, cementation is rapid, forming a fairly hard beachrock, although homogeneous *kurkar* takes longer to develop. As shells erode to small wind-blown grains, they are pushed inland with quartz sand. Wetting and drying cycles cause cementation, which is the first stage of *kurkar* formation.

A clear relation exists between the degree of cementation and the amount of carbonate in the soil. A minimum of 8–10 percent calcium carbonate is needed to achieve lithification of a sand dune (Yaalon 1967). Hard *kurkar* rock has c. 30% calcium carbonate. The diagenesis of *kurkar* is a fairly slow process over geologic timescales to transform the original aragonite and magnesium calcite into calcite.

Ḥamra *Pedogenesis*

Pedogenesis is another kind of rock formation that starts when sand dunes are immobile. When sand is stabilized by vegetation, a process of reddening starts, which is the beginning of *ḥamra* pedogenesis. Reddening indicates that after calcium carbonate leaches out of the soil, magnetite and other iron oxides then coat grains of quartz and some dust infiltrates. Dust accumulation is important because it is the agent that drives clayey and silt-size grains into the soil.

Clay and silt accumulate mainly in B-horizon of soil profiles along the *ḥamra* association catena. As runoff water moves down the slopes, the lower parts of the slopes and the depressions receive much more water than the upper sections. Clay particles are shifted with the water down slope and leach at the lower parts of the catena. As a result, the clay content of these soils lower down the slope is higher than the soils higher up. A typical catena consists of a red sandy-clay-loam *ḥamra* on moderate slopes and sandy *ḥamra* on steep slopes. On the foot-slope, compaction by settling and embedding of clay impedes drainage, resulting in the development of *nazaz*, a dense mottled pseudogley.

Gray and black hydromorphic grumosols occur in the depressions, which exhibit a perched water table and marshy conditions during winter rains. Many of the depressions have no drainage (Yaalon 1964).

SUMMARY

Tel Mikhal is a high point of the sea cliff on the Sharon Coastal Plain (Katzav 1994). In terms of geological structure, the mound is situated on the southern end of the Ga‘ash anticline, on the elevated flank of an east–west fault (Gvirtzman 1990). It is classified as a steep slope (Netser 1994) and has the lowest rate of erosion along the coastal cliff in Israel (Nir 1982; Gavish and Bakler 1990; Netser 1994).

The geological environment of the site is composed of mobile sand, *kurkar*, *ḥamra* and grumosols (swelling and cracking clay soils) sediments of the Quaternary Ḥefer formation. The tell and the cliff near it can be classified as an island of Dor *kurkar* in the middle of much younger sediments (Gavish and Bekler 1990). Only the latest sand deposits (Ta‘arukha and Ḥadera sands) are mixed with archaeological sediments. All the *ḥamra*-like sediments within the archaeological strata of this excavation are human-driven deposits.

NOTE

[1] A second ridge is situated c. 1500 m west of the shoreline ridge, rising to a height of 40–50 m. The bottom trough between them is at 20–25 m above sea level. The third ridge is situated at a distance of about 4 km from the shore and the trough often only 10 m above sea level. Farther to the east, a fourth, less distinct ridge occurs. The ridges are an interference that should be breached by the hydrographic network draining the western national divide watersheds. Sometimes the waterways are closed resulting in the emerging of seasonal swampy areas and closed drainage basins. One of these channels is Naḥal Gelilot. A closed watershed was known near Gelilot (map ref. NIG 1823/6723; OIG 1323/1723). Another partly closed watershed might have been east of the tell, where Ḥadera Sand covered the lower part of the relief, resulting in the development of three alternative channels (see Gifford, Rapp and Hill 1989: Fig. 18.1).

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