Site Geology

by John A. Gifford, George Rapp, Jr., and Christopher L. Hill

Archaeological survey and excavation in the coastal plain of Israel depend to a great degree on understanding the recent geologic history of the region. Little bedrock crops out along the coastal plains, and even that is relatively friable. Microenvironments of erosion, deposition, and soil formation produce a complex mosaic of sedimentary units despite the generally subdued areal topography.

In this chapter we summarize our observations on the geologic aspects of Tel Michal and its immediate surroundings as an aid to understanding some of the natural and artificial phenomena that are recorded in the archaeological record of the site.

18.1. NATURAL ENVIRONMENT OF TEL MICHAL

The high tell is a promenade on the westernmost of a series of three to four subparallel rock ridges that extend along and inland of the present shore zone. Such elongated ridges (and their intervening swales) are physiographic elements characteristic of the entire coastal zone of Israel. In the central (Sharon) coastal plain, the westernmost ridge forms a discontinuous sea cliff rising to 40 m or more above present sea level. The Geologic Map of Israel (northern sheet, scale 1:250,000) identifies these as “kurkar ridges of the Upper Pleistocene Era.”

The kurkar ridges are fossil dune deposits (elolianites) cemented by the ubiquitous mineral calcium carbonate. Generally, the sediment of the ridges is a poorly consolidated, medium-to-fine sand, white to buff or gray in color. Filling the swales between these ridges (and, in the case of the westernmost ridge, interspersed therein) is the other basic sediment type of the coastal plains—a sandy loam of various shades of red, locally termed hamra (According to the U.S. Department of Agriculture Soil Taxonomy System, most hamras would be classified as calcic rhodo- Xeralfs.) In the historical and prehistorical past, both sediments represented major sources of building materials, as discussed below (Section 18.3).

The coast of Israel has been a transport route for Nile River sediments moving northward under the influence of predominant winds and currents (Emery and Neve 1960). The longest-period waves impinge upon the coastline out of the west (280 degrees), which is the greatest possible fetch direction, and longshore currents generally set to the northeast. Locally the current direction may be reversed close inshore, with sufficient velocity to transport fine sand. Along the Sharon coast, sand beaches are uniformly narrow (less than 100 m) and low angled, without well-defined berms and backbeach zones. Thus high-energy winter storm waves easily reach and undercut the friable kurkar foundations of the coastal ridge, producing vertical sea cliffs up to 10 m high. Such a cliff exists at the base of the highest prominence of the Tel Michal site. The modern beach sediment, as shown by Sample 7 (Table 18.1), consists of a poorly sorted medium sand.

Wind directions measured at Tel Aviv from 1940 to 1947 show that the predominant wind is out of the west (41.4 percent), with greater than 10 percent at force 6–7. The second most common winds come from the southwest (39.8 percent), with greater than 10 percent at force 4 (Yaalon and Laronne 1971). These strongest winds occur between January and April. Along the coast of Israel, the prevailing winds are also the dominant ones.

Dominant west winds of force 6 and greater presently transport sand from the beaches over the coastal kurkar ridges and up to a kilometer inland (as at Ziqim and Hadera), forming a discontinuous sand blanket inland from the present shore. East of Tel Michal these dunes have an average relief (where undisturbed) of 3–4 m from crest to blowout floor; they are typically semistabilized by the Artemesia monosperma and Cyperus mucronatus plant association (Zohary 1962:117), a batha community of the coastal zone characterized by the dominance of phanerophytes (Fig. 18.1). On flatter areas of the coastal ridge with less sand cover, the vegetation is a Potentis spinosus and Thymelaea hirsuta association. Along the steep west slopes of the high tell and the ridgtops to the north and south, the association is Sporobolus and Lotus.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>(M_{z})</th>
<th>(\sigma_{1})</th>
<th>(Sk_{1})</th>
<th>(K_{G})</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
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<tr>
<td>1</td>
<td>From E slope of high tell</td>
<td>2.47</td>
<td>0.81</td>
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<td>3.26</td>
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<td>Sandpit 300 m E of high tell, top of section</td>
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<td>1.14</td>
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<td>Sandpit 300 m E of high tell, layer 1, “Upper Dunes”</td>
<td>2.10</td>
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<td>1.48</td>
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<td>Nahal Gelilot, S bank, Section 78/1</td>
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<td>1.93</td>
<td>0.22</td>
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<td>0.6</td>
<td>6.5</td>
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<td>2A</td>
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<td>0.15</td>
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<td>1.4</td>
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<td>High tell, Area A: thin stratum with MB IIB sherds</td>
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<td>5.8</td>
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<td>High tell, W slope: red-brown sand below MB IIB ash</td>
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<td>0.31</td>
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<td>2.00</td>
<td>96.9</td>
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<td>98.5</td>
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<td>0.3</td>
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<td>Bulldozed pit 400 m E of high tell, above Dor karkar</td>
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<td>2.28</td>
<td>0.69</td>
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<td>80.3</td>
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<td>Area D, bottom of deep test pit</td>
<td>5.37</td>
<td>3.83</td>
<td>0.86</td>
<td>1.05</td>
<td>64.9</td>
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<td>24.8</td>
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<td>3.75</td>
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<td>1.87</td>
<td>67.5</td>
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<tr>
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<td>56.1</td>
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<td>4.02</td>
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<td>0.89</td>
<td>1.23</td>
<td>65.0</td>
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<td>Hillock S of high tell, W slope, Section 79/1</td>
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<td>1.58</td>
<td>0.37</td>
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<td>87.1</td>
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<td>5A</td>
<td>Hillock S of high tell, W slope, Section 79/1</td>
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<td>85.1</td>
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<td>High tell, beach cliff, uncemented stratum</td>
<td>3.12</td>
<td>0.61</td>
<td>0.36</td>
<td>1.63</td>
<td>86.3</td>
<td>9.7</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>Swash zone W of high tell</td>
<td>2.40</td>
<td>1.58</td>
<td>0.37</td>
<td>7.49</td>
<td>90.7</td>
<td>0.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

* \(M_{z}\) = graphic mean, \(\sigma_{1}\) = graphic standard deviation, \(Sk_{1}\) = inclusive graphic skewness, and \(K_{G}\) = graphic kurtosis.
Figure 18.1. Combined geomorphologic-vegetation map of Tel Michal site area, based on 1948 air photography and field checking during excavation period (1977-80). Legend: (1) actively eroding coastal scarp slopes with little or no sediment cover, sparse vegetation cover of Sporobolus-Lotus association; (2) low angle slopes (less than 10 degrees) with Hadera dune sand cover of 0.2-0.5 m thickness and the Artemesia-Cyperus plant association; (3) flat ridge crest with sediment cover less than 0.2 m thick and a Potentilla-Thymelaea association; (4) inland Hadera dune field with sand thickness greater than 2 m, Artemesia-Cyperus plant association; (5) alluvial and colluvial sands of slope-wash channels and of Nahal Geitlor, transported to beach during winter rains; (6) low-angle beach; (7) nearshore (less than 2 m deep) medium sand cover; (8) rock substrate of fossil Vermetus reef protruding through sand cover; (9) excavation areas; and (10) transect and cross section locations: probe transect perpendicular to Nahal Geitlor (A-B), cross section on high tell (C-D) (see Fig. 18.3), and three transects perpendicular to cliff face of high tell (X-X', Y-Y', Z-Z').
Before extensive commercial development along the Israel coastal zone (beginning around 1948), a small wadi (el-Gharbi) drained the swale inland of Tel Michal (or Makmish); it emptied into the Mediterranean immediately north of the flat ridgtop containing excavation areas D and E (Fig. 18.1). Now the ephemeral winter discharge of this drainage (renamed Nahal Gelite) has been channeled in a subsurface culvert and the wadi bed itself has been graded and straightened to provide vehicular access to the beach. It appears that the premodern wadi bed followed an artificial channel cut in Roman (or earlier) times to drain both the swale east of the coastal ridge and the one east of the next kurkar ridge inland. In antiquity, low interridge areas were often either artificially drained for agriculture or dammed (as at Zikron Ya'akov) for matriculture or salt pans (Rim 1950).

Winds play the dominant role in controlling patterns of erosion (deflation) and deposition (dune formation) on the sand blanket inland from Tel Michal, but there is also localized erosion by running water on and around the coastal kurkar ridge, where base level is the Mediterranean. Light to moderate rains falling on the thicker sand deposits (greater than 20 cm or so) are probably washed with little or no erosive effect. Heavy or prolonged winter rains endanger sheet wash of sand, which is diverted around the north and south ends of the high tell to produce ephemeral shallow, braided channels. In this way, significant quantities of sand are transferred westward to the backbeach zone, though some of this redeposited sand is subsequently remobilized by the west wind and returned to the inland sand blanket, known as the Hadara dune bed. There is probably a net addition of sand, with constant reworking of the blanket to several meters in depth. Along the western slopes of the kurkar ridge (the high tell and ridgtops to the north and south), no permanent sand cover exists; unconsolidated to semiconsolidated archaeological and geologic strata there are subject to net erosion (by sheet flow and rill formation, as well as by wave undercutting of the basal kurkar unit) and mass movement (soil creep and microslumping) of the upper strata (discussed below). On the high tell, the western slope angle was measured as 40° above the kurkar cliff, somewhat steeper than average natural slopes in semiarid climates (Ritter 1978:165). Slope evolution may take place through parallel retreat if the unconsolidated sedimentary units are homogeneous throughout the interior of the high tell.

Some observations concerning the nature of mass movement on the west slope of the high tell were made possible by the stepped stratigraphic trench (Fig. 4.3; Pl. 5), of which the lowest locus (929, at 19.8 m above sea level or 10.2 m below datum) rests on natural undisturbed Dor kurkar overlying Ramat Gan kurkar. In the south face of the stepped trench (Plate 81), it appears that erosion begins within the strata—about 1.5 m in from the slope surface—by stepped microslumping along high-angle (70-90 degree) planar slip surfaces. This slumping initiates soil creep downslope to maintain equilibrium with the back-eroding, vertical kurkar cliff at the west base of the tell. A second erosional process operates simultaneously on the outermost 30-40 cm of slope sediments: this material is homogenized by root action, shrinkage/swelling, and slope wash to produce a characteristic mixed zone (Locus 906). Implications of all these long-term erosional phenomena for the evolution of the high tell will be considered below.

A series of three east-west probing transects (X-X', Y-Y', and Z-Z') across the width of the beach west of the high tell (see Fig. 18.1 for location) showed a maximum of 1.8-2.0 m of sand at the kurkar cliff foot, thinning to 0.5-1.0 m at the swash zone 40 m away. Allowing for the average beach slope of 1° 40', these transects indicate that a subhorizontal wave-cut platform exists on the Ramat Gan kurkar. The platform also underlies the mouth of the sand-filled gulley immediately south of the high tell, confirming that this feature has not eroded bedrock below the present base level and is therefore of recent origin.

Beneath the modern beach at the mouth of Nahal Geilit, however, a probing transect (A-B) revealed a buried channel cut to approximately 6 m below the beachface surface (for details of the subsurface stratigraphy of Nahal Geilit, see Fig. 17.1). This channel has no surface expression in the sandy nearshore zone.

Northwest of the high tell and the northern hill, a sinuous line curving out from the swash zone marks the eroded seaward trace of the kurkar ridge's bedrock foundation. Between this line and the beach, a discontinuous, irregular area of hard bottom projects through the sand cover. The hard bottom represents a dead vermetid gastropod (Dendropoma praetextum) reef, its surface now about 1.5 m below sea level. Since the upward growth of D. praetextum is limited by mean sea level (Safriel 1974), and radiocarbon analysis of a whole-rock sample of the reef surface shows it to be 495 ± 70 years old (UCR-11249), some local subsidence in this vicinity is indicated for the historical past. As demonstrated by underwater sampling of its core, the Dendropoma reef off Tel Michal developed on a hard substrate of Ramat Gan kurkar.

Roughly 500 m farther offshore, air photos show another kurkar ridge in 7 m of water (N. Bakler, personal communication). There probably exists an interridge swale (locally termed a marzew) between the present shoreline and this submerged ridge, as is the case off Tel Barukh, 2 km south of Tel Michal (Bakler 1976:24; Hall and Bakler 1975).

18.2. SEDIMENTARY UNITS OF TEL MICHAL

All of the geologic units underlying and surrounding Tel Michal date to the Late Quaternary (Pleistocene and Holocene) epoch and have been assigned most recently (Horowitz 1979:113) to the Ruhamah Loess member of the Gaza formation. Ronen (1983) presents a more detailed composite section of coastal ridge stratigraphy in the Sharon plain, comprising 10 sedimentary cycles of kurkar-hamra development that subsume the eight units identified by Horowitz and by Bakler (Bakler 1976:132). In the following subsec-
tions, descriptions and interpretations are presented of all units identified in exposures of the coastal cliffs, in the Nahal Gelilot channel, in commercial sand pits dug east and southeast of Tel Michal, and in the soundings of the excavation itself. The description proceeds in stratigraphic order from the lowest (oldest) unit upward.

18.2.1. Ramat Gan Kurkar

The basal eolianite of the coastal ridge, this friable, quartz-rich calcareous sandstone is well exposed in a 3- to 4-m-high vertical scarp at the western base of the high tell. The exposure reveals typical low-angled (0–30 degrees), undulating eolian cross-beding sets that represent vertical sand accretion beneath a vegetative cover (Yaalon and Laronne 1971). This unit is thickest under the northern hill, thinning out southward as it passes beneath the high tell; it probably continues below the present beach surface in front of the hillock immediately to the south.

Several theories have been proposed for the lithification of kurkar (e.g., Yaalon 1967), but none adequately explains the commonly observed rhythmic alteration of friably cemented strata with completely uncemented ones. Grain-size analysis of a pure sample of unconsolidated Ramat Gan sediment shows it to be a moderately sorted muddy fine sand with a graphic mean of 3.1 \( \phi \).

Most of the information that allows the granulometric characterization of sedimentary units from Tel Michal is contained in the weight percentages of the 1.5–2 \( \phi \), 2–2.5 \( \phi \), and 2.5–3 \( \phi \) size fractions relative to one another. A ternary plot of the percentages of these three size fractions for a number of samples (Fig. 18.2) separates them into well-defined fields. The Ramat Gan sediment (Sample 6) is the finest of all those plotted, and it acts as a fine-grained diluent to modern beach sand when cliff erosion introduces it into the shore zone (Fig. 18.2, Sample 7).
18.2.2. Nahsholim Hamra

This sandy loam crops out in the vicinity of Tel Michal only on the seaward slope of the hillock south of the high tell. The 1.5–3 μ size fractions of two samples of this unit are comparable in their mineralogy and proportions to the Ramarin Gan sediment, suggesting its derivation from the latter by addition of silt-clay size fractions. An eolian transport mechanism for these fine fractions in Israel's hamra is likely, since there are insufficient aluminosilicates in the kurkar sands to weather into an iron-rich fine fraction (Farrand and Ronen 1974). At issue is the source area for the fines — either the Negev (Karmeli et al. 1968) or the exposed Mediterranean continental shelf during the last pleniglacial (Ronen 1983). The latter seems more probable in light of the prevailing winds, and the similarity of coastal plain hamra clay mineralogy (Singer and Shachnov 1969) to that of the western Nile Delta sediments (Weir et al. 1975) supports this provenance.

18.2.3. Dor Kurkar

A section of this unit 3 m thick is exposed on the southwest downslope of the high tell and at the bottom of the deep test trench of Area D on the northern hill. It is a well-sorted, unconsolidated sand with a dry color of 7.5 YR 5/6 (strong brown), often showing rhizoconcretions. About 95 percent of the 1.5–3 μ size fraction consists of subrounded quartz grains (the more round are also polished), all slightly stained by iron oxide. Four percent of these size fractions comprises rounded and polished bioclastic carbonate grains, and the remaining 1 percent comprises rounded and polished, dark sedimentary rock fragments. The 1.5–3 μ size fractions of two Dor kurkar samples are plotted in Figure 18.2. They show a distribution very similar to that of the Hadera dune samples (Section 18.2.6).

18.2.4. Netanya Hamra

This is the best developed of the several rhodo-Xeralf units of the coastal ridge. Farrand and Ronen (1974), in their reconstruction of the geologic history of the Carmel coastal plain, state that the correlative Netanya unit there began to form during the maximum regression of the last glacial (ca. 18,000 years B.P.); Epipaleolithic (17,000–11,000 years B.P.) stone tools are often found within this unit all along the Israeli coast. Ronen (1983) identifies the source of the iron-rich silt-clay fraction of hamras in general as the fine-grained continental shelf sediments below 35 m.

Both terrestrial (containing oxidized iron minerals) and paludal (with reduced iron) facies of the Netanya hamra crop out in natural and artificial exposures around Tel Michal. Several samples (4–41) from geologic and archaeological contexts are plotted in Figure 18.2. Their 1.5–3 μ size fractions are intermediate between the fine Ramarin Gan and Nahsholim sediments on the one hand and the coarser Dor sands on the other, suggesting that the Netanya sand fractions may be a mixture of these two sources through redeposition.

18.2.5. Tel Aviv Kurkar

This unit is of limited distribution around Tel Michal, with a maximum observed thickness of about 2 m along the course of the Nahal Galiot; it quickly thins and intermixes with the underlying Netanya hamra to the east and south of the tell.

Tel Aviv kurkar is unique in its high percentage of biogenic carbonate grains: 51 percent of the 1.5–2 μ fractions of samples from Nahal Galiot is composed of cemented fecal pellets, micromollusc shell fragments, worn echinoid spines, polished Halimeda plates, foraminifera tests, and bryozoan fragments, all indicating derivation from a hard-bottom community in nearby shallow marine water. The balance of these samples comprises subrounded to rounded and polished quartz grains lacking any iron oxide coating, which explains the relatively light color of this unit in exposures. Grain-size analysis shows the Tel Aviv kurkar to be a poorly sorted sand with a graphic mean of about 2.3 μ (Table 18.1). The more common large carbonate grains in the 1.5–2 μ fraction account for its coarseness relative to the sand fractions of the other units (Fig. 18.2).

Horowitz (1979) states that the Tel Aviv kurkar was deposited during a stillstand of the Verrallian Transgression that was 2–3 m higher than present sea level, and Bakker et al. (1972) also conclude that this unit represents a shallow marine deposit. But Ronen (1983) places it with all the other terrestrial (continental) deposits of the coastal plain, and we concur with this identification. The unit as exposed along Nahal Galiot (Plate 82) shows low-angle eolian cross-bedding, exhibits rhizoconcretions penetrating the underlying Netanya hamra, and also contains infilled insect burrows and snail shells, 90 percent of which are the land species Xeropus vespertillus (Heller and Tchernov 1978).

Ronen (1983) obtained six radiocarbon dates on this unit (his No. 4): they equal an average age of 6,135 ± 41 years B.P. (5368 half-life), or 5,290–4,915 calendar years B.P. using the correction tables of Klein et al. (1982).

To the east of Tel Michal, the Tel Aviv kurkar grades laterally into a calcarenitic hamra. Within this facies, a bulldozed area 400 m southeast of the high tell revealed an in situ deposit of worked stone and pottery fragments: flint scrapers, one coarsely denticulated sickle blade, one small winged arrowhead, retouched flint flakes and debitage, and friable fragments of a coarse-ware vessel. The arrowhead and pottery were dated to the Pottery Neolithic (PN) by E. Ayvalon (Museum Haaretz).

18.2.6. Hadera Dune Bed

Deposition of this unit has occurred from the cessation of the influx of carbonate-rich Tel Aviv sediment in post-Pottery Neolithic time up to the present, since it represents the constant eolian transport of Mediterranean beach sand eastward. Human activities of construction, agriculture, and herding during the occupation of Tel Michal modified this unstable sand surface on a small scale, but natural erosion and dune movement have more effectively homogenized the archaeological stratigraphy over the past
Figure 18.3. Schematic east-west cross section illustrating stratigraphic relationships of geologic and archaeosedimentary materials on west side of high tell (see Fig. 18.1, section C-D). Representative samples (see Table 18.1) of stratigraphic sequence are indicated in legend. Ramat Gan kurkar is oldest unit in the sequence. Sediments representative of Nahsholim hamra were observed only on western slope of hillock to south of high tell and are not shown in this diagrammatic stratigraphic section.

Remaining units are archaeosediments or reworked (not in situ) geologic deposits. Netanya hamra is represented as fill. Tel Aviv kurkar was observed on high tell as thin, reworked stratum associated with MB materials. Other archaeosediments on high tell include MB II ashy fill, decomposed mudbrick, and mixed zone of colluvium on surface of tell. Inset diagram shows location of section C-D.
SITE GEOLOGY

two millennia. The net process here is considered to be one of deposition.

The 2-2.5 mm size fraction of a sample from the base of a 4-m-high sandpit scarp 300 m east of the high tell shows about 70 percent subangular to subrounded quartz grains (the rounded grains with more surface frosting), with the remaining 30 percent a biogenic carbonate composed of fecal pellets, *Halimeda* plates, foraminifera, and shell fragments. The biogenic fraction decreases upsection, reaching 5-10 percent at the modern surface.

Almost all the Iron Age, Persian, and Hellenistic features and artifacts at Tel Michal are buried under 0.5-2 m of Hadara dune sand. During the 1st millennium B.C.E., structures were built on (or in) this sediment and provisions were made to stabilize the sand surfaces around them by means of artificially laid *hamra* coatings. Postoccupation erosional and depositional processes have mixed the stratigraphy on the northern hill and eastern hillocks so that excavated artifacts of different periods often were found "floating" at the same level in the Hadara dune sand. There is probably almost no original stratigraphy in these areas, except perhaps beneath undisturbed features.

18.3. CONSTRUCTION MATERIALS (ARCHAEOSEDIMENTS)

The geologic materials at Tel Michal were used by occupants of the site for construction purposes and appear in the stratigraphic record as archaeosediments. On the high tell, leveling platforms composed of Netanya *hamra* and Tel Aviv *kurkar* sand were constructed during the Middle Bronze Age. On these *hamra* and sand fills, occupants erected walls of *hamra* or of Ramar Gan *kurkar* cobbles and small boulders collected from the beach. At the northern end of the high tell, a Middle Bronze Age *hamra* wall 3.4 m high was found to rest on alternating layers of *hamra* and sand fill. In the stratigraphic trench on the western slope, the leveling platforms were observed to lie directly on a thin, incipiently developed stratum of Netanya *hamra*, at an elevation 18 m above sea level (12 m below datum). Figure 18.3, which illustrates the relationships of geologic and archaeosedimentary units on the high tell, represents Netanya *hamra* as a fill resting above the Ramar Gan *kurkar* and the Dor *kurkar*. Other archaeosedimentary deposits on the high tell include Tel Aviv *kurkar*, ash fill, decomposed mudbricks, and a mixed surface zone (Fig. 18.3). Occupation debris (mostly ash) and rebuilding in later phases contributed to net accretion on the high tell while these construction materials (particularly the *kurkar* building stones) were constantly reused. Tel Aviv *kurkar* sands appear to be confined to the Middle Bronze Age strata and are replaced by Hadara sands in the Late Bronze Age and subsequent layers; this suggests that the Tel Aviv sands were still common surface sediments until the mid-2nd millennium B.C.E. However, in the Persian period cemetery (Area E), tombs were cut into the Tel Aviv *kurkar* unit and were built up of Ramar Gan *kurkar* blocks and occasionally of Netanya *hamra* mudbricks; the whole area eventually was buried underneath the Hadara dune sand (Plate 83). There has doubtless been a continuous overturning of the unstable Hadara dune sand covering Area E and the other outlying areas during the past 2,500 years.

Sample 4H (Fig. 18.2) illustrates the correlation of mudbrick sediment from Persian period strata with outcrop samples of the Netanya *hamra* from immediately south of the high tell.

Besides consolidated and unconsolidated natural sediments, another common inorganic building material utilized at Tel Michal was artificial lime plaster. Microscopic examination of several Persian period lime-plaster samples often showed fragments of partly burned marine mollusc shells (*Glycymeris*), plus some bone fragments. Beach shells and large mammal bones were calcined and slaked to produce the plaster.

18.4. ACCRETION AND EROSION OF THE HIGH TELL

At the midpoint of the west slope of the high tell, *kurkar* bedrock was reached at 18 m above mean sea level. On the downslope at the northern end, this same contact exists at about 15 m above mean sea level; on the downslope of the southern end, it exists about 16 m above mean sea level. Thus the MB II *hamra* platform was centered on a preexisting high point of the coastal ridge (Fig. 18.4). This core of Ramar Gan *kurkar* already had been significantly eroded on the west by sea-level transgression and wave abrasion. However, it is not unlikely that in the mid-2nd millennium B.C.E. the vertical backbeach cliff was still some 20 m west of its present position, or about half the width of the modern beach. Since then, far less erosion has occurred on the north and south flanks of the high tell, and least of all on the eastern slope.

Vertical and horizontal accretion of the original Middle Bronze Age platform on the high tell very likely proceeded in pulses of artificial sediment deposition from destruction and rebuilding events superimposed on a continuous addition of some beach sand by eolian transport. At the same time, erosion of the western slope probably always pressed later construction eastward, down the more gentle and weather-protected landward slope. Most of the coarsest stone building material—cobbles and small boulders of *kurkar*—would have remained near the high tell crest as recycled wall blocks, whereas sand and finer-size sediments would have been continually lost, necessitating frequent replacement. With the end of occupation on the high tell in the 8th century of this era, artificial addition of sediment ceased there, as did vertical and horizontal growth of the tell, so that erosion of the west slope by natural processes emerged as the dominant ongoing geologic process.2

Figure 18.4 is a schematic east-west cross section through the high tell that attempts to summarize the evolution of its deposits from the first habitation in the Middle Bronze Age up to the present.

216
Figure 18.4. East-West diagrammatic cross section through high tell at about position of stratigraphic trench on western slope. Three stages in evolution of high tell are schematically portrayed, based on geologic and archaeological data. In Middle Bronze IIB, artificial platforms were built on ridge crest of Ramat Gan kurkar bedrock covered by strata of Dor kurkar and Netanya hamma. West slope of tell extended some 20 m farther toward shore than at present. By (approximately) Late Persian period, continued Late Bronze Age, Iron Age, and Persian occupations had extended cultural strata upward and outward, while shore processes continued to erode west slope. Upper surface of high tell may have achieved its maximum areal extent at this time. Since abandonment of high tell, erosion has predominated and continues to undercut and bring down sediments of both natural and cultural strata. Modern-day outline profile of high tell is shown as dashed line.)
NOTES

1. The data obtained from grain-size analysis may be presented in several different ways. Here, the phi scale (φ) is used for diameters of sediment grains; it has significant computational advantages over a simple expression in micrometers of the diameter. Important size-class boundaries in this scale are from −1 to +4 φ (the sand size range), from +4 to +8 φ (the silt size range), and from +8 to +14 φ (the clay size range).

Descriptive statistical parameters (measures of average grain size, uniformity of grain size, symmetry, and peakedness of the grain-size distribution) here follow the formula of Folk (1974), which are standard for most American sedimentologic analyses. However, instead of presenting the usual graphics of histograms or cumulative distribution curves, Figure 18.2 only plots the relative percentages of three size fractions (1.5−2 φ, 2−2.5 φ, and 2.5−3 φ) in the medium- to fine-sand range that most characterize each of the different sedimentary units around Tel Michal. All of the grain-size statistics for each sample are presented in Table 18.1.

2. For a detailed stratigraphic description of construction and destruction processes during the Middle and Late Bronze Ages, see Chap. 4. Tectonic activities are considered by the author of Chap. 4 as one of the major forces that caused the drastic changes in the topography of the tell.

REFERENCES


Ronen, A. 1983. Late Quaternary Sea Levels Inferred from Coastal Stratigraphy in Israel. Pages 121−134 in: *Quaternary Coastal and Marine Archaeology*. P. M. Masters, and N. C. Flemming, eds. New York.


Plate 81. Microslumping exposed in south balk of stratigraphic trench A2 (west slope of high tell). Sediment of Locus 929 is Tel Aviv kurkar fill (unconsolidated), overlain by Netanya hamra fill.

Plate 82. Section along south side of Nahal Geililot, about 100 m inland from shore, showing nature of contact between Netanya hamra (paludal facies) and overlying friable Tel Aviv kurkar (calcarenite). The contact is transitional, with oxidized hamra sediment intermixed with calcarenite grains, as well as cobble-size clasts of semiconsolidated calcarenite lodged in hamra just below pure calcarenite.