Geomorphology 101 (2008) 416–428

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Geoarchaeology and aggradation around Kinet Höyük, an archaeological mound in the Eastern Mediterranean, Turkey

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ARTICLE INFO

Article history:
Received 1 September 2005
Accepted 1 April 2007
Available online 6 March 2008

Keywords:
Aggradation
Turkey
Geoarchaeology

ABSTRACT

We examined the alluvial history of the plain near Kinet Höyük, an archaeological mound (or Tell) with a sequence of six millennia of occupation on the southeast Mediterranean coast of Turkey, through 17 excavations over a 1000 m transect near the Mound. Excavations ranged from 2 to 6 m deep and up to 20 m across. This low gradient, alluvial plain shows significantly different rates and processes of near-Mound sedimentation, with one unit having nearly 4 m of Late Bronze Age habitation and flood deposits and another having 4 m of Hellenistic channel and floodplain deposition. This flat, alluvial surface turns out to be a rich geoarchaeological landscape that shrouds Early and Late Bronze Age settlements, Hellenistic walls, and two epochs of Roman Roads. One widespread phenomenon was a Hellenistic or earlier paleosol and occupation level covered by channel gravels and overbank deposits mostly from the Hellenistic to the Late Roman period. These channel and floodplain deposits filled in and flattened out the off-Mound settlements, blanketing the Pre-Hellenistic topography and silting in a long active port. This glut of alluvium correlates in time with drier conditions and the most intensive land uses in the watershed, where Roman and Hellenistic sites today are severely eroded.

1. Introduction

Geomorphologists have investigated alluvial histories in many different settings around the world to understand the causes and mechanisms of landscape change. Ideally, the focus in such studies would be on the watershed, linking alluvial history with sediment supplies and rates and timing of sediment sinks and transport (Beach, 1994). Such a sediment budget approach provides a fuller picture, but in many parts of the world data are not available and geomorphologists must focus on one part of a system. For example, in the eastern Mediterranean several factors limit access to whole watersheds, including the permit area held by a research group often in a radius around an archaeological mound (sometimes called a “Tell”) and for security concerns, especially in upper watersheds.

Both of these factors constrained this study to the alluvial plain near Kinet Höyük (tell) and to the history of aggradation rather than erosion and aggradation. Many mechanisms can cause alluviation, and these include increased watershed erosion and sediment loads, increased ratios of load to flow volumes, and rising base levels (Mackin, 1948). These proximate factors can in turn be the result of ultimate factors such as geology, land use, and changes in climate and channel gradient. Examples of alluviating systems in the geomorphology literature are numerous: watersheds in Australia (Wasson, 2006), the Upper Mississippi Basin (Knox, 1972, 2001; Trimble, 1983; Magilligan, 1992; Beach, 1994), the Southeastern United States (Trimble, 1974; Costa, 1975), the river valleys, upland karst depressions, and perennial wetlands of the Maya Lowlands (Beach et al., 2003, 2006; Luzzadder-Beach and Beach, in press), and California Gold Rush valleys from hydraulic mining (James, 1999; Gilbert, 1917). Another area of significant aggradation and progradation has been the eastern Mediterranean, where scores of studies have analyzed erosion and valley and coastal sedimentation for decades (Vita-Finzi, 1969; Brückner, 1997; Van Andel, 1998; Kayan, 1999; Bal et al., 2003; Cordova et al., 2005; Wilkinson, 2005; Casana, 2003). These studies have shown variable quantities of erosion and sedimentation, and have suggested different chronologies and causes of erosion and fill, though changing land use and climate are the key factors.

This article focuses on the alluvial history of the plain around Kinet Höyük, studying its sedimentary record in the context of the broader environmental and archaeological records. Kinet Höyük lies 525 m east of the Bay of Iskenderun on the extreme northeastern shoreline of the Mediterranean Sea (Fig. 1). This east-west running, oval-shaped mound formed through successive occupations over five millennia, which accreted the mound upward to 20 m above the plain. As the mound grew, artifacts eroded into the strata of the surrounding plain and, thus, help date and characterize sedimentation. The surrounding plain has aggraded and prograded through migrations of the Deli River (Çayı) and adjacent streams interacting with both post-glacial sea-level rise and a long-term human presence (Ozaner, 1994). Our goal is to understand the timing and causes of this aggradation in this little-studied region by integrating geomorphic, soils, ecological, and

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doi:10.1016/j.geomorph.2007.04.025

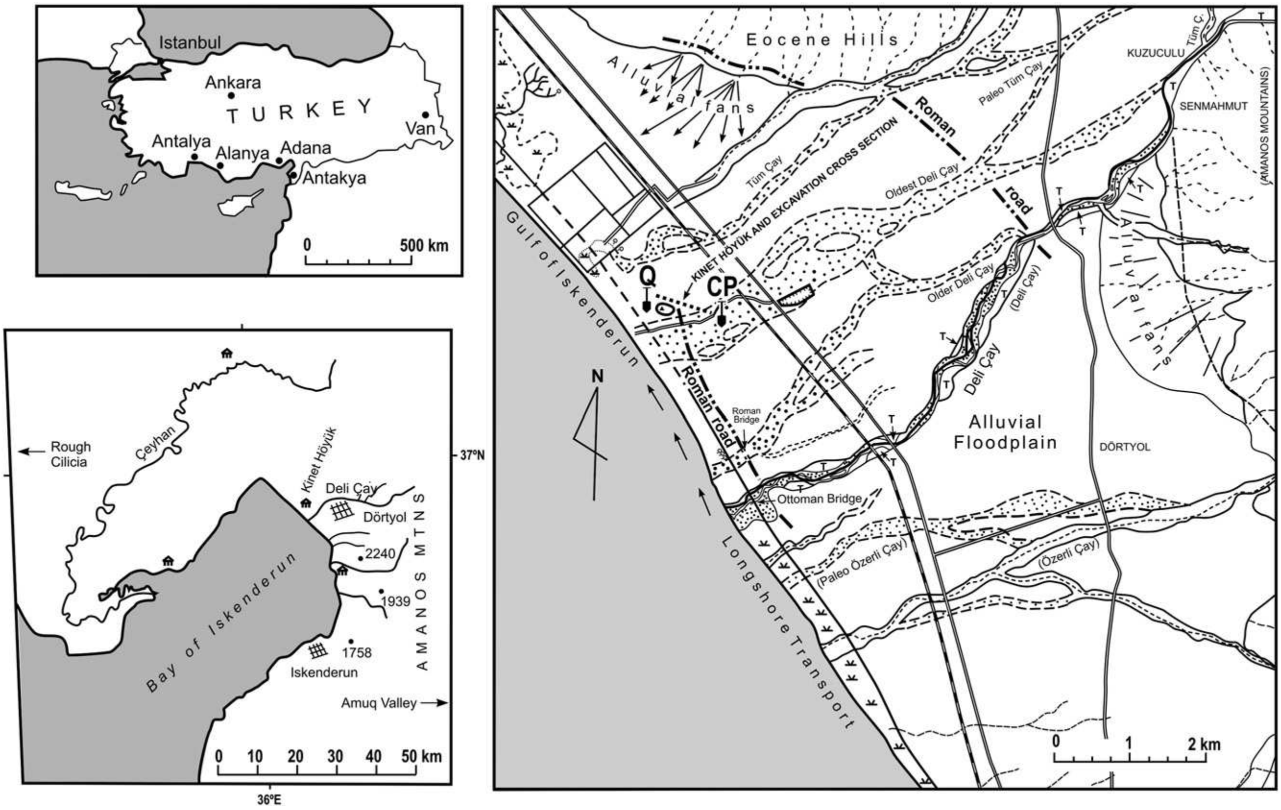

Fig. 1. Location map with regional geomorphology map showing excavation transect from Q to CP (after Ozaner, 1994).

archaeological lines of evidence (Butzer, 2005). Toward this end, we focus on a transect of 17 geoarchaeological soundings that cross 1000 m of the alluvial plain to describe and analyze sediments and artifacts to determine when and how they formed.

Most publications, thus far from the Kinet Archaeology Project, have focused on excavations of the Mound, and these have revealed a long, illustrious settlement history. The mound dates from the Late Neolithic (6th Millennium BC), through the Chalcolithic, Bronze Ages, Iron Age, Hellenistic (to about 50 BC), and for about a century in the Medieval Period 12th to 14th C. AD. Kinet was the port of Issos in Greek times and possibly Al Tinat in the Early Medieval (9th C AD), Sissu in Iron Age Phoenician (1200–330 BC), and Zise in Hittite times (1700–700 BC). The Hellenistic abandonment of this site around 50 BC may be the result of an earthquake or the siltation of the harbor (Gates, 2000, 2001, 2002, 2003, 2004; Redford et al., 2001). Overall, the human history of this region is episodic for these 6000 years of habitation, with archaeological evidence for habitation, destruction, and hiatuses (Gates, 2004). The broader region of ancient Cilicia, centered on Antakya, had the highest populations and most intensive land uses in the Hellenistic through Roman Period with a built up infrastructure of roads, towns, and farmsteads (Casana, 2003, 2007; Wilkinson, 2005). For adjacent Rough Cilicia, Blanton (2000, p. 60) found that population and settlement increased rapidly through the Early and Late Roman periods (65 BCE–AD 700) and declined in the Byzantine (AD 700–1071). The specific occupations at the mound of Kinet had only a waxing and waning Hellenistic and no Roman occupation (Gates, 2000, 2001, 2002, 2003, 2004).

2. Environment

Kinet is in a region of sharp environmental gradients at 36E 51′ 26.5″ N Latitude and 36E 09′50.2″ E Longitude. In a 50 km transect from the west side of the Bay of Iskenderun to Kinet and rising up to the Amanos Mountains, the climate ranges from semi-arid, induced by rainshadow of the Taurus and Misis Mountains, to near per-humid conditions (with a mean precipitation of 2300 mm) induced by the orographic effect of the high Amanos. The city of Dörtyol lies in the middle of this transect, and has a mean temperature of 19.7 °C, a mean precipitation of 1080 mm, significant moisture surpluses in the winter and spring (400 mm), and significant moisture deficits in summer and early fall (350 mm). Indeed, annual evaporation is approximately as high (1025 mm) as precipitation, and the highest in Turkey (Erinç, 1955). Rainfall and evaporation, however, vary highly from year-to-year. In contrast, temperature variability is low, moderated by the Mediterranean Sea and protected from continental air masses by mountain ranges (Kehl, 1998).

No paleoecological studies around Kinet indicate past climatic and vegetation trends and possible human impacts. Our own cores have produced no pollen thus far. Roberts and Wright (1993) reviewed the paleoecology record for the broader region, but the closest pollen studies are in quite different environments c. 200 km northwest across the Taurus and more than 100 km south across the Amanos Mountains. In southern Turkey, *Pinus*, *Quercus*, *Cedrus*, and *Juniperus* increased by 7000 BC, but *Pinus* came to dominate after 4000 BC and forest clearance and cultivation of *Olea*, *Juglans*, *Vitus*, and cereals increased from 3500 to 50 BC. Many studies cite the Beyşehir Occupation Phase (BOP) as the most important in the record (Vermoere et al., 2002). The BOP ranges from approximately 1500 BC until at least AD 600 at several sites based on the agricultural (*Juglans*, *Olea*, and *Pistacia*) and disturbance indicators in the pollen record and decline of *Pinus*, *Cedrus*, and *Juniperus*. From most information sources, Hellenistic through Roman periods often show up as the most intensive occupations, though not all lake core records correlate well with the historical and archaeological records (Roberts, 1991).

Kinet lies approximately 600 km west of Lake Van and north of Soreq Cave, which are the two most cited paleoclimate records for the region. Wilkinson (2005) has argued that Lemcke and Sturm's (1997) oxygen isotope ratio and trace element study of Lake Van cores is the best climate proxy for this region. This record shows sporadic drying during the 3000 to 2000 BC period (Early Bronze Age) and again in the Hellenistic and Roman periods when populations and land-use intensities were also increasing. Bar-Mathews et al. (1998) cave study uses speleothem oxygen isotope ratios and analogs of modern precipitation, which provides a cross cutting line of evidence. The Soreq cave record shows high rainfall variability from about 3000 to 2000 BC period, steady but lower rainfall from 2000 BC to AD 1000, and greater variability again in the last millennium.

Histories that relate to environmental change begin with Bronze Age (3500–1200 BC) cuneiform records, including mention of the Amanos as a source of Cedar (*Cedrus libani*), Boxwood (*Buxuus longfolia*), and Cypress (*Cupressus sempervirens*) (Rowton, 1967). Early timber was likely floated down rivers on the east side of the Amanos to the Aksu and the Euphrates. Some timber was also floated down western Amanos rivers and into the Mediterranean (Rowton, 1967). Later Medieval Arabic sources mention the site called Hisn al Tinat (possibly Kinet) as a timber-exporting site, which implies timber extraction and floating the trees down the Deli Çayı during the high flows of winter and spring (Redford et al., 2001). Rowton (1967) quoting 19th C. sources notes that the Amanos Mountains had well preserved forests, but Seton-Williams (1954, p.126) notes 19th C. forest exhaustion near an Amanos port.

The study region includes the drainage basins and foothills of the Amanos Mountains and alluvial piedmont plain (Figs. 1 and 2). This Mediterranean coastal zone climbs from its narrow plain to a steep mountainous region with more than 2200 m of regional relief within 40 km of the study site (Erol, 1991). Mülazımoğlu (1979) described the initial formation here of coalescing alluvial fans, forming a piedmont along the sinking front. The alluvial plain has aggraded for at least 5 million years since the Pliocene (Ozaner, 1994), and Quaternary deposits are about 10–20 m deep in the study region (Doyuran, 1982, p. 151). Similar fans occur on the drier (600–700 mm of annual precipitation) eastern side of the Amanos along the Amuq Valley (Yener et al., 2000; Wilkinson, 2005). Here, 2.5 m or more of high energy, post Hellenistic gravels overlie a Hellenistic/Roman paleosol, which in turn mantles high energy Pleistocene gravels.

The Amanos geology near Kinet is part of an ophiolite sequence, mainly composed of Upper Cretaceous serpentines and Cretaceous to Tertiary dolimitic limestones, unconformably lying beneath Late Miocene and Plio-Pleistocene flysch deposits and ophiolites. This region occurs in a tectonic triple junction, where the leading edge of the African Plate, connected through Cyprus, is wedged between the Arabian Plate to the east and the Anatolian Plate to the west. Hence, these Mountains have formed by collision-induced crustal shortening between the three Plates. This massif was uplifted by a post Miocene, NE-SW trending anticline (Lyberis et al., 1992). Bridgland et al. (2003) estimate the long-term rate of Amanos uplift at 0.12 mm per year, or about 1 m in the Holocene. Other evidence of active tectonism includes several powerful, regional earthquakes in about 500 BC and 50 AD (Ozaner, 1994), and one in 551 AD (Pirazzoli et al., 1991) related to the “Early Byzantine Tectonic Paroxysm” (Nur and Cline, 2000). Geomorphic evidence near the study area includes a 1 m fault scarp that parallels the coast. Earthquake-induced landslides are an important agent of slope erosion in the watershed study area and throughout this seismically active region (Keefer, 1994).

3. Background: erosion and sedimentation in the Eastern Mediterranean

A vast literature exists on human impacts on soil erosion in the Eastern Mediterranean (Butzer, 2005). The first commentators about

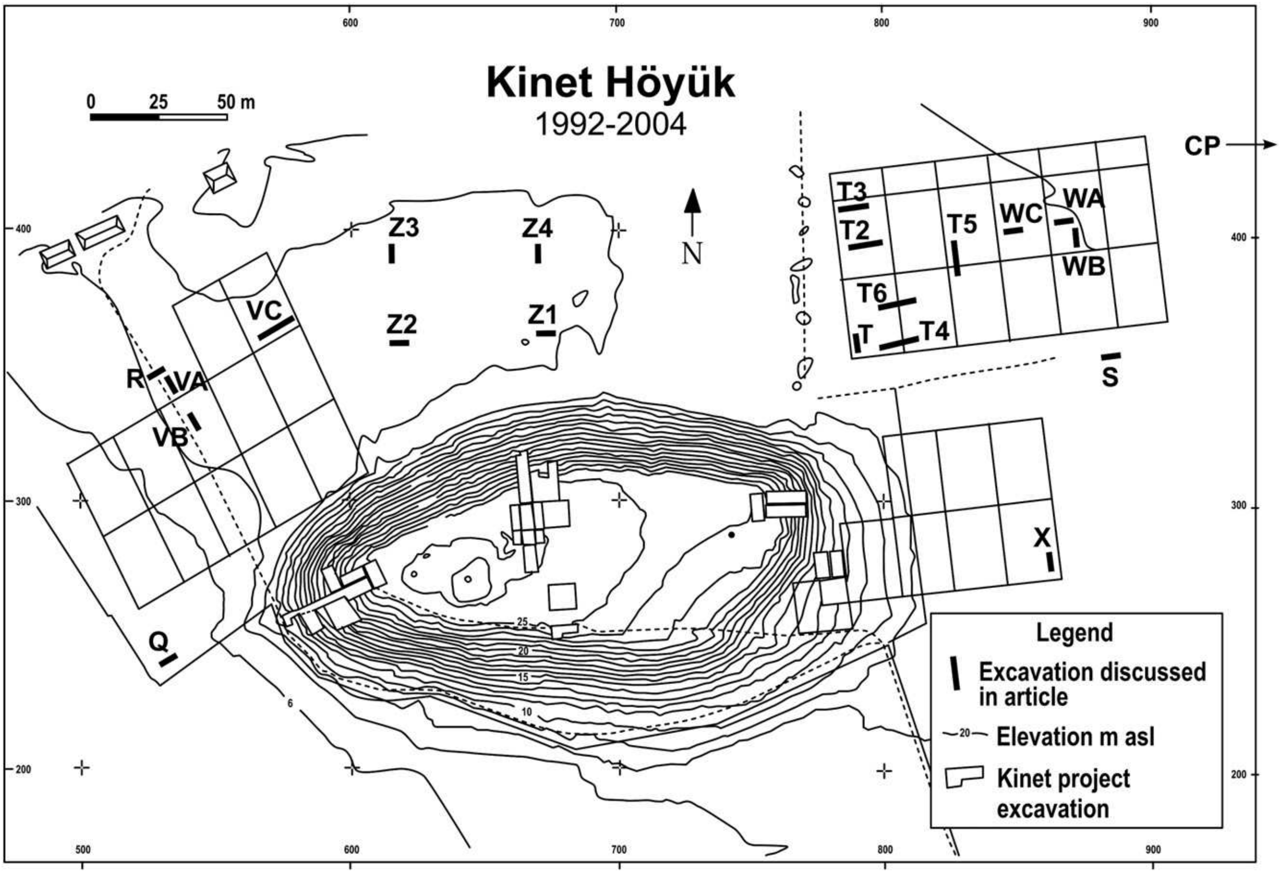

Fig. 2. Topographic map of the study area with excavation units.

erosion in the Greek world were such Classical writers as Herodotus, Plato, Aristotle, Strabo, and Pausanias (Kraft et al., 1975), and Plato and Pausanias linked human induced soil erosion with coastal sedimentation (Eisma, 1978). Vita-Finzi (1969) pioneered modern research on the history of Mediterranean soil erosion using evidence from across the Mediterranean (Van Andel, 1998; Cordova et al., 2005). His work recognized a climate-driven sequence of two main valley fills: an earlier, Late Quaternary fill with Paleolithic artifacts often in distinctive red soils and a younger fill often brown or gray in color ranging from the 3rd C AD until the 20th C.

Subsequent studies have found greater chronological and regional variation in this environmentally and historically diverse region (e.g., Kraft et al., 1975; Eisma, 1978; Butzer, 1980; Davidson, 1980; Brückner, 1986; Van Andel et al., 1990; Van Andel, 1998; Cordova et al., 2005). Some recent studies, like Vita-Finzi's early model, have also found evidence for climatic impacts on erosion and sedimentation (Faust et al., 2004; Verschuren et al., 2000), but more studies in the eastern Mediterranean have focused on the importance of natural fluvial responses and coastal progradation to post Pleistocene sea-level rise (Kayan, 1999) and to human impacts in watersheds: Roman abandonment of terracing (Butzer, 1982: 131), agriculture and grazing, lumbering and ship building, and firewood cutting and charcoal production (Van Andel, 1998). Many coring transects across the alluvial and deltaic plains of the Eastern Mediterranean have shown much greater progradation than the 525 m at Kinet (Eisma, 1978). Brückner and colleagues (and Pausanias in antiquity) link much of the trends of Mediterranean progradation with human induced erosion, especially Hellenistic and Roman (e.g., Brückner, 1986, 1997, 2003; Müllenhoff et al., 2004).

Wilkinson and colleagues (Wilkinson, 1999, 2005; Casana and Wilkinson, 2005; Yener et al., 2000; Casana, 2003) have studied Holocene environmental change across the Amanos Mountains from Kinet in the Amuq Valley, the Orontes River, and Lake Antioch. Wilkinson (1999) synthesized a number of studies around this region, finding many examples for periods of aggradation and erosion, but especially the Hellenistic through Roman periods. Casana (2003) and Wilkinson (2005) correlate high rates of erosion and sedimentation in these watersheds with the first dispersal of population onto the uplands and with aridity. Likewise in the geoarchaeological literature, Bintliff (2002) and Butzer (2005) have argued that the intersection of climate and land use events often link with episodes of accelerated erosion. Moreover, in the geomorphology literature, Knox (2001) found that erosion and sedimentation in the Upper Mississippi Valley occurred after agricultural expansion corresponding to intensive precipitation events.

Ozaner (1994) produced the first studies of geomorphology around Kinet, developing the following scenario of alluvial history based on field surveys and repeat aerial photography. First, a branch of the Deli Çay or the Tüm Çay ran north of the Mound in the Mid Holocene. Second, sometime after and up through the Hellenistic Period, the Deli Çay ran just south of the Mound with a port on the sea. Third, in the Late Hellenistic or Early Roman Period the stream shifted into an older channel 2 km south. This relocation of the river coincided generally with a regional earthquake and the Hellenistic abandonment of Kinet until the 13th C AD. Fourth, the river again shifted further south to its present location in the last 200 to 400 years, dated broadly by the remnants of an Ottoman Bridge. Fifth, progradation occurred along the coastlines at Kinet (by c. 525 m) and two other old regional Mounds (Kara and Muttalip Höyük) since antiquity. Kinet had such a long occupation, though, because three factors minimized coastline progradation compared with the former coastal Aegean sites of Ephesus and Troy: the deep and subsiding Bay of Iskenderun with a faultline near the coast and shifting river channels dispersing sediments alone the coastline (Ozaner and Russell, 1994). Last, the Kinet coastline has experienced 30 m of erosion since 1974, probably tied to sediment depletion from gravel mining in many river floodplains on the southern Turkish coast (Beach and Luzzadder-Beach, 2000; Bal et al., 2003).

Erosion and alluviation have also been common since the Roman Period. Many localized and sporadic examples of human induced fluvial change and erosion in the Medieval and later periods in the eastern Mediterranean occurred (Rosen, 1997; Van Andel et al., 1990). Likewise, McNeill (1992: 349), in his environmental history of the Mediterranean, concludes that the evidence is compelling for

Fig. 3. Oblique Air Photograph of Kinet Höyük and surrounding alluvial plain with the Bay of Iskenderun 525 m to the West (Dr. M.-H. Gates, 2001).

Table 1
Soil color and textures of excavations of Q, R, T, and CP

[a]Horizon depth cm	Munsell color	Sand % (>50 µ)	Coarse silt % (50 µ–20 µ)	Medium silt % (20 µ–5 µ)	Fine silt % (5 µ–2 µ)	Clay % (2 µ–1 µ)	Fine clay % (<1 µ)	Texture
Unit Q								
Ap 10	10YR3/2	34.3	16.9	20.3	8.3	4.3	15.9	L
A2 30	10YR3/3	26.0	12.1	22.8	10.0	5.6	23.5	CL
C1 125	10YR4/1	65.6	11.2	9.6	1.6	2.9	9.1	fSL
C2 220	2.5Y5/2	22.9	12.7	27.1	9.8	5.0	22.5	L
Ab 235	10YR3/2	32.0	12.7	21.0	8.3	3.8	22.2	L
Ab 340	10YR3/2	37.2	13.5	19.9	8.1	4.2	17.1	L
Cg 385	2.5Y3/2	37.1	14.2	19.7	8.5	3.9	16.6	L
Unit R								
Ap 5	10YR3/1	42.4	16.7	19.6	8.9	3.2	9.2	L
AC 50	10YR4/1	33.4	13.4	22.7	10.4	2.1	18.0	L
C 75	10YR4/1	33.2	12.3	22.9	9.3	4.0	18.3	L
100.0	10YR4/2	38.1	14.7	21.2	8.0	3.6	14.4	L
120.0	10YR4/2	41.9	14.1	20.2	8.1	3.8	11.9	L
160.0	10YR5/2	44.4	10.1	22.2	9.6	4.0	9.7	L
200.0	10YR4/2	46.1	12.5	23.1	8.1	3.5	6.7	L
250.0	10YR4/1	43.2	12.6	24.7	8.5	3.8	7.2	L
300.0	10YR4/1	42.5	13.0	24.4	8.7	2.7	8.7	L
360.0	10YR4/1	44.9	9.7	20.8	8.6	2.0	14.0	L
370.0	10YR5/1	35.3	11.4	28.6	11.2	3.6	9.9	L
380.0	10YR5/2	33.3	12.2	29.4	8.5	5.3	11.3	L
400.0	10YR4/2	47.4	9.2	17.5	5.9	3.3	16.7	L
410.0	10YR5/3	30.4	12.2	31.6	9.4	4.7	11.7	SiL
450.0	10YR5/2	31.2	10.3	30.2	10.1	4.9	13.3	SiL
Unit T								
Ap 10	10YR3/1	35.5	13.8	20.9	6.7	4.0	19.1	L
AC 50	10YR4/2	37.8	18.7	19.9	6.3	3.2	14.1	L
C 80	10YR4/2	34.9	20.4	23.6	6.1	3.3	11.7	SiL
C 110	10YR5/2	30.4	22.7	26.3	6.0	3.3	11.3	SiL
C130	10YR4/2	27.1	22.3	27.2	6.5	2.9	14.0	SiL
C 160	10YR4/2	82.2	5.0	4.8	2.2	0.8	5.0	LS
C 210	10YR5/2	65.3	12.8	9.7	3.2	1.2	7.8	SL
C220	10YR4/1	54.0	12.3	15.6	5.1	2.1	10.9	SL
C240	10YR4/4	37.7	15.3	23.1	7.7	2.3	13.9	L
Ab 260	7.5YR3/3	34.5	11.7	22.7	8.4	2.6	20.1	L
Ab 340	10YR2/2	28.8	14.2	23.5	8.1	3.7	21.7	L
Unit CP								
Ap1 10	10YR3/2	38.5	14.6	20.7	6.4	3.3	16.5	L
A2 40	10YR 3/3	33.0	14.3	21.2	7.7	3.4	20.4	Gr L
C 90	10YR5/2	29.4	15.6	26.8	8.2	3.6	16.4	Gr SiL
Ab 125	10YR 3/3	37.3	15.1	20.0	7.1	3.1	17.4	L
Ab2 170	10YR 3/1	20.1	11.8	19.1	10.2	5.6	33.2	CL
2C 200	10YR 4/2	21.3	16.4	32.9	9.3	3.9	16.2	SiL

[a] Horizons defined in Soil Survey Staff (1998).

"massive deforestation and soil erosion" from 1800 to 1950, but dating soil erosion is always complicated (Grove and Rackham, 2001, p. 270).

4. Methods

To understand coastal plain formation around Kinet, we excavated 17 soundings across the alluvial plain (Fig. 2). A petroleum processing facility to the southwest of the Mound restricted study along this critical zone and the presence of many valuable cultural antiquities limited coring to clearly natural strata (Fig. 3). We, thus, manually excavated all soundings along a 1000 m transect on the east, west, and north sides of the Mound. We planned these soundings to analyze the geomorphic history of the Mound surroundings, using careful excavations to minimize invasiveness and gather as much cultural and environmental proxy data. We studied natural and occupational stratigraphy through visual, physical, and chemical methods to establish the timing of landscape change in this dynamic coastal and alluvial environment.

Field soil analyses included color, texture, structure, HCl reaction, and other descriptive terms as outlined by the Soil Survey Staff (1998). Two labs (under one lab director) analyzed these samples, the Milwaukee Soils Lab and the University of Wisconsin-Milwaukee Physical Geography and Soils Lab (Tables 1 and 2). Analyses included the following: pH; exchangeable P, K, Ca, Mg, and Na; cation concentrations in Ca, Mg, Na, and K by atomic absorption (P and K used the Bray 2 method because of high carbonate); particle size by pipette method; organic carbon (LOI); and soluble salts (Soil Survey Staff, 1996). We used these analyses to help identify soil sequences, such as buried A horizons, and as evidence of human inputs, such as with elevated levels of P (Beach et al., in press).

Artifact and radiocarbon analyses were the basis of dating. Project archaeologists identified all artifacts, and Beta Analytic Inc. dated samples by radiometric and accelerated mass spectrometry techniques and measured carbon isotopes (Table 3). We used a combination of charcoal, wood, and soil humates for radiocarbon samples. Because the bulk humate samples can give mainly the mean residency time of the carbon in the paleosols, these samples can only represent minimal dates (Smith and McFaul, 1997). We attempted to sample to minimize the problem of humate dates (see Matthews, 1985, p. 282) by collecting samples from the top 5 cm of buried A horizons in these

Table 2
Soil chemistry of excavations Q, R, T, and CP

Horizon depth cm	LOI OM %	pH	Ex Ca mg kg^{-1}	Ex Mg mg kg^{-1}	Ex Na mg kg^{-1}	Ex K mg kg^{-1}	Total P mg kg^{-1}	Soluble salts mS cm^{-1}
Unit Q								
Ap 10	2.8	7.3	2722.2	573.9	59.5	193.9	–	0.2
A2 30	1.7	7.7	2413.9	673.9	21.3	65.3	–	0.4
C 125	0.5	7.9	3289.7	320.6	7.9	21.2	–	0.2
220.0	0.5	7.9	3240.6	707.1	22.6	54.7	–	0.2
235.0	0.6	7.9	3415.2	756.6	25.3	64.2	–	0.2
340.0	0.6	8.0	4296.4	685.4	31.1	61.8	–	0.2
385.0	0.5	8.0	3709.8	719.7	25.1	61.1	–	0.2
Unit R								
Ap 5	2.6	7.3	2480.3	552.1	42.6	208.3	1676.1	0.5
AC 50	1.1	7.6	2257.9	557.9	24.5	58.2	1225.3	0.2
C 75	0.7	7.8	4259.6	626.5	34.4	52.3	1590.3	0.2
100.0	0.6	7.9	4301.6	590.8	18.0	43.1	1865.9	0.2
120.0	0.6	8.0	4170.6	568.3	20.8	37.1	1866.6	0.2
160.0	0.5	7.9	4677.2	582.5	44.5	38.7	1991.6	0.3
200.0	0.5	7.9	4333.7	611.1	44.3	40.7	1861.4	0.3
250.0	0.5	7.9	4019.9	636.6	37.9	42.5	1885.7	0.3
300.0	0.6	7.9	3743.1	695.6	39.4	49.4	1644.4	0.2
360.0	0.3	7.9	3711.0	859.8	32.3	71.3	1208.4	0.3
370.0	0.4	8.0	3883.9	705.4	28.5	59.2	1470.9	0.2
380.0	0.1	8.1	3762.9	567.7	15.1	48.7	444.6	0.2
400.0	0.2	8.0	3928.4	793.4	28.3	73.7	903.7	0.2
410.0	0.1	8.1	3577.5	576.2	21.3	50.0	372.0	0.2
450.0	0.1	8.1	3525.6	615.4	19.0	53.0	339.1	0.2
Unit T								
Ap 10	1.2	7.6	1654.9	562.7	22.3	52.9	784.1	0.2
AC 50	0.7	7.8	2974.5	418.9	22.3	37.1	488.7	0.2
C 80	0.2	7.8	3755.4	388.8	18.9	28.5	246.1	0.3
110.0	0.2	7.9	3360.1	337.5	12.2	23.1	244.4	0.2
130.0	0.3	7.9	3654.1	449.3	12.3	32.4	281.1	0.2
160.0	0.1	8.0	2220.8	248.6	6.7	12.0	156.3	0.2
210.0	0.2	8.0	2606.3	328.4	10.3	21.9	196.4	0.2
220.0	0.2	7.9	2519.8	424.6	10.0	32.7	243.6	0.2
240.0	0.2	7.9	3384.8	525.1	11.7	42.3	253.8	0.2
Ab 260	0.4	7.9	2801.6	656.0	16.0	59.8	609.4	0.2
Ab 340	0.6	7.9	3854.3	1001.2	20.1	78.6	1327.6	0.3
CP Unit								
Ap1 10	2.57	7.9	3408	544	11	70	1443	–
A2 40	2.22	7.9	2138	507	15	46	1017	–
C 90	1.42	8.0	3853	446	29	38	484	–
Ab 125	1.79	8.1	3535	522	25	46	767	–
Ab2 170	1.80	7.7	2332	671	25	139	1170	–
2C 250	1.33	8.1	4028	428	37	36	–	

aggrading environments. Additionally, all the soils and sediments we sampled formed since the middle Holocene and most have some artifacts that provide another date for comparison. Indeed, we obtained fewer radiocarbon dates because dateable artifacts were so common.

5. Results: Geomorphic excavations

We present soil chemical and physical data in Tables 1 and 2. In general all the sediments and soils in this environment are middle to late Holocene in age and have at most moderate pedogenesis. They are generally low in organic matter, slightly to moderately alkaline, have high base status, and are rich in cations. The textures are generally loams and silt loams, and soil structures are moderately developed. In the near-Mound alluvial plain we encountered no older, well developed surface or buried soils (based on colors no redder than 7.5 YR Munsell Hue and low clay accumulation), though well developed Mediterranean Red Soils (Atalay, 1997) are common in the foothills and older terraces with both Munsell Hues of 2.5 YR and Bt horizon formation.

Unit Q was 43 m west of the Mound toward the coastline and ranged from 5.5 to 1.5 m above average sea level (masl) (Figs. 2 and 4; Tables 1 and 2). The top 90 cm represents a cumulic suite of A horizons with the highest amounts of organic matter, melanization (10 YR 3/2

Table 3
Radiocarbon Dates

Sample	Technique	Site unit	Material	Depth M	$^{13}C/^{12}C$	Y intercept calibrated	Measured ^{14}C BP	Cal ^{14}C (2σ) 95% P
Beta 214241	AMS	T	Charcoal	.8	−24.1	AD 1250	790±40	AD 1180 to 1280
Beta 147490	AMS	T	Charcoal	3.4	−25.3	AD 50	1950±50	AD 130–50 BC
Beta 147491	Stand	R	Charcoal	3.15	*−25	1420 BC	3160±110	1130–1680 BC
Beta 146663	AMS	R	Org. Sed.	5.8	−22.4	5460 BC	6410±40	5330– 5480 BC
Beta 214242	AMS	Q	Org. Sed.	3.9	−24.5	1910 BC	3560±40	2020 to 1770 BC
Beta 120331	Stand	beach	Wood/peat	0.65	*−25	AD 1645	290±50	AD 1475–1950
Beta 183582	AMS	Wetland core	O. Sed	1.2	−28	Modern	Modern	Modern

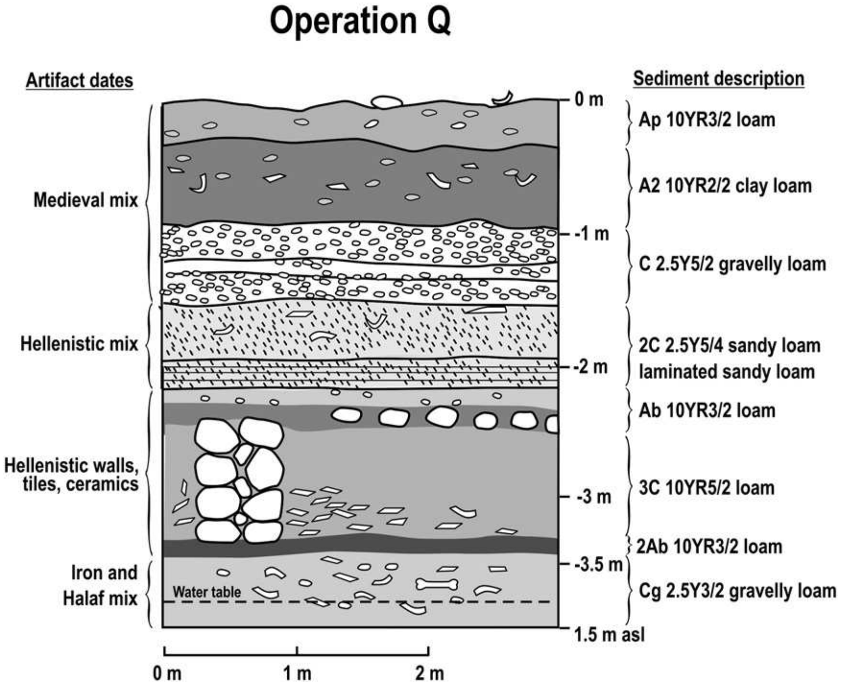

Fig. 4. Drawing of excavation Q showing soil and stratigraphic units.

and 3/3 colors), and loam and clay loam textures. Plowing, bioturbation, and pedogenesis have erased primary depositional units within these low energy flood and slope wash deposits. Artifacts were rounded and worn and represented a mixture of ages dominated by Medieval. Sediments from 0.9 m to 2.3 m are lighter in color (10 YR 4/1 and 2.5 Y 5/2), coarser in texture (gravelly, sandy loams), and laminated. These represent higher energy and faster alluviation because much of the flood stratigraphy is intact. The few artifacts here were rounded and worn and Hellenistic in style. Sediment from 2.3 to 3.5 m is sandwiched by paleosols that lie above and below a Hellenistic building wall, which is buried by ceramic, boulders, and tiles of the collapse of the house and flood sediments. We interpret the 2.3 to 2.5 m and 3.3 to 3.4 m areas as paleosols because of greater melanization (10 YR 3/2), gradual lower boundaries, and more granular structures (Birkland, 1999, pp. 24–28). Many roof and wall tiles and plaster and concrete litter the floor on the inside and on the lower paleosol on the outside of the house. The tile scatters near the base of the wall suggest a sequence of acute collapse followed by steady deposition around and over wall. Below the lower paleosol to a depth of 4 m (1.4 to 1.9 m asl), is a mixture of midden materials (weathered brick, iron slag, bone, ceramic, and shell) and flood gravels and sands in a gleyed (2.5 Y 5/1) loam matrix. This zone holds a mélange of pre-Hellenistic artifacts, including Iron Age (1200–330 BC) and Chalcolithic Halaf (c. 4000 BC) and organic sediment from 3.9 m has a calibrated 2 sigma date of 2020 to 1770 BC (Table 3). The sediments show little trend and variation in chemistry, except slight increases in organic matter and cations through the buried soils associated with the Hellenistic wall. The lowest layers were at the water table, moderately alkaline (pH 8), redoximorphic, and grayish brown and dark grayish brown loams. Excavations halted here because of the instability posed by rapidly infilling water.

Unit R was 100 m northwest of the Mound in area with no surface features except an abrupt 0.5 m slope rise (Figs. 2 and 5; Tables 1 and 2). We stepped this sounding down to 5 m and cored down another 1 m through non cultural sediments to within 1.4 to 1.9 m of modern asl. Again little variation occurred in soil texture and chemistry, except for total phosphorous, which is elevated by nearly an order of magnitude through the occupation sediments in the upper 3.8 m. The top 0.75 m had a mixture of Medieval artifacts and walls, and the layer from 0.75 to 1.5 m had a mixture of Iron Age (1200–330 BC) and Late Bronze Age (1600–1200 BC) artifacts. Late Bronze Age artifacts from *in situ* occupations and intervening flood deposits occur between 1.5 m and 4.8 m. Ceramics throughout this zone are angular and little rounded by stream abrasion. The excavation runs through sequences of floors and hearths with laid river stones and a midden filled with burned, cut, calcified bone from large fish and livestock, and shells from clams, oysters, and other shellfish. Two floors occur at depths of 2.5 to 2.7 m and of 3.3 to 3.5 m (Fig. 5) that have large amounts of burnt materials, a zone of elevated magnesium, potassium, and total phosphorous levels, and scattered lumps of yellowish clay, which may indicate a ceramic manufacturing area. At 3.15 m, just above the lower pottery unit, one radiocarbon date from charred plant material gives a calibrated 2 sigma date of 1680–1130 BC (Table 3), which parallels the Late Bronze ceramic dates through this zone. The units from 3.5 to 4.5 m are loam and silt loam-textured, laminated flood deposits with eroded Late Bronze artifacts and decreasing quantities of phosphorous and organic matter. This alluvium overlies a river cobble-boulder collapsed wall with abundant Late Bronze ceramic and burned bone from 4.5 to 5 m. Zone 3 represents the core from 5 to 6 m, which was mostly sterile, laminated, and shelly silt loam and one radiocarbon date from charcoal at 5.8 m (c. 1.4 m asl) yielded a calibrated 2 sigma date of 5480 to 5330 BC (Table 3), which is Neolithic in age and c. 4,000 years older than sediments 1 m above it.

The Kinet Project in 2001 and 2002 excavated three more trenches (VA, VB, VC) near Trench R to test the extent and chronology of settlement in this small region and a regional magnetometer survey conducted in 2000. VA was 5 m south of R, VB was 20 m south of VA, and VC was 30 m east (Figs. 2 and 9). Despite the nearly 4 m of Late Bronze sediments in R, VA showed mixed, disturbed sediments from 0 to 2 m, Middle Iron sediments to 2.3 m, and Early Bronze Age deposits (c. 2500 BC) to a sterile base at 3 m. Trench VB contained a mix of ceramics in the top 1 m and Middle Iron in the lowest 2 m (Gates, 2002). Trench VC produced 1.6 m of sediments dominated by Hellenistic artifacts and another 1 m of sediments dominated by

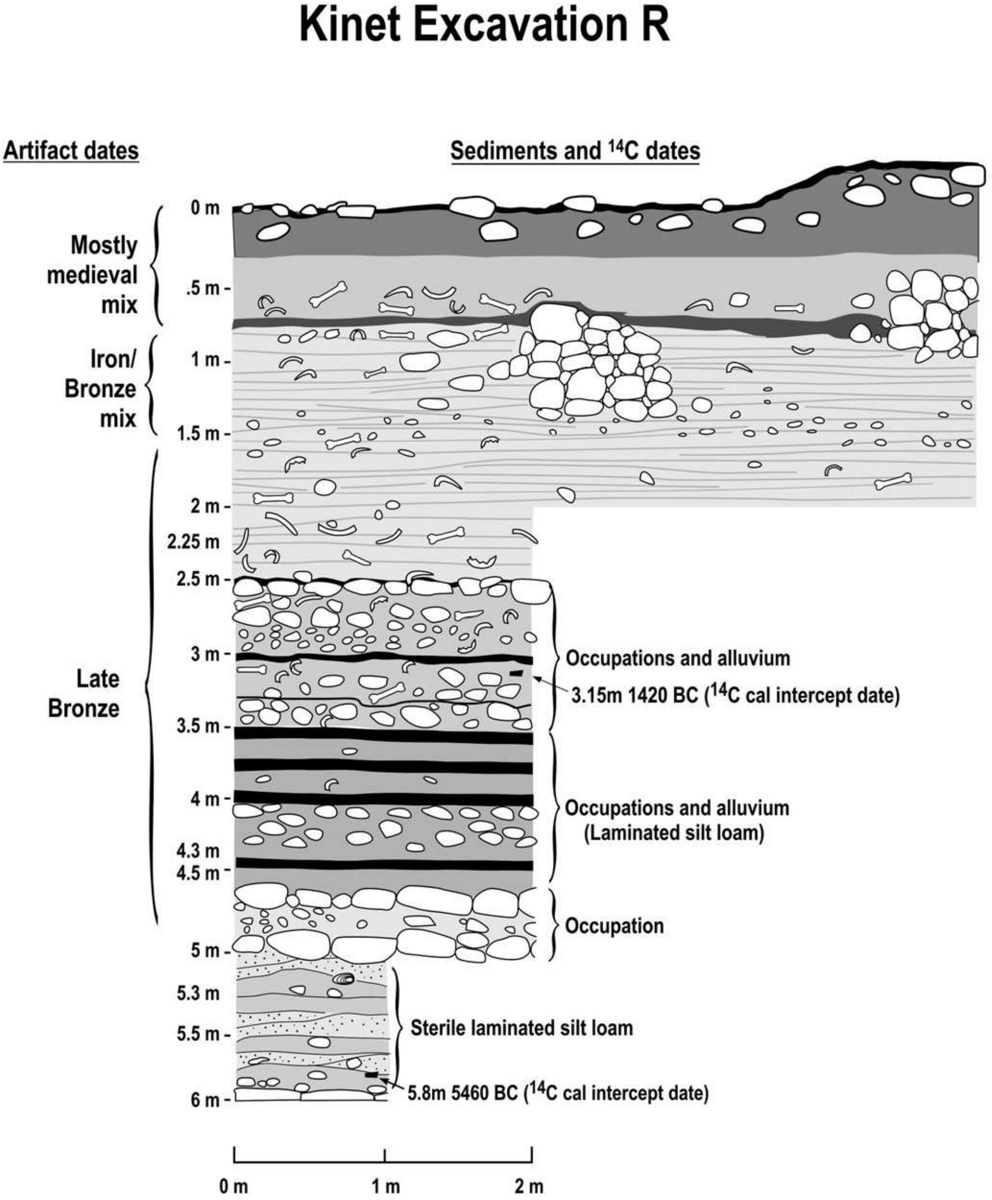

Fig. 5. Drawing of excavation R showing soil and stratigraphic units.

Iron Age artifacts. Together these show 1–2 m of natural sedimentation with mixed but dominantly Hellenistic artifacts over Iron Age habitations over an island of Early Bronze occupation.

North and downhill from the Iron Age fortress wall of the site at c. 7.8 m asl, the Kinet Project excavated units Z1–Z4 in an 1800 m^2 area that produced more consistent results, including common flood-deposited layers throughout occupational sediments (Figs. 2 and 9). Two units (Z1 and Z2) about 22 m from the Mound produced an upper 2.5 m unit of mixed Medieval through Hellenistic sediments over about 2.5 m of Iron Age and the top of Late Bronze Age occupational deposits at the water table about 5 m deep. Two units (Z3 and Z4) about 50 m from the Mound also showed consistent results: about 2 m of mixed Medieval through Hellenistic sediments over 1 m of Iron Age and 2 m of Bronze Age occupational deposits. Unit Z3 had a 5th Century BC Iron Age level overlying Late Bronze Age deposits that occurred to the bottom at 5 m. Unit Z4 had Early Bronze Age deposits in its lower 2 m (Gates, 2004).

Unit T was 20 m from the northeast flank of the Mound at an absolute elevation of 8.2 m asl (Figs. 2 and 6). This site was closest to the Mound and near to the Hellenistic and Roman channel of the Deli Çay. The excavation showed continuous Hellenistic artifacts in its lower 3 m down to a depth of 5 m from the surface. This site, like the others in this area, had a loam topsoil of moderate pedogenesis with very dark brown colors built on 2 m of silt and sandy loams, well drained soils with yellowish and grayish brown colors. These upper 2 m had few artifacts, even though near the Mound, and horizontally laminated strata, which indicate fast enough deposition to minimize surface alteration of primary stratigraphy. Moreover, a proxy for human input into these flood deposits was relatively low: total P from the top 200 cm below the topsoil to the first paleosol averages only 236 mg kg^{-1}, which is 14% of the average at unit R. From 250 to 270 cm and again from 310 to 340 cm are buried A horizons, with loam textures, very dark gray to dark brown colors and increasing artifacts and charcoal downward to the lower paleosol. Total P in the upper paleosol jumps to nearly as high as the fertilized top soil in these modern orange groves. The lower paleosol is built on a parent material of artifact-rich and loamy sediments, and is elevated in all cations and total P, which is 1327.6 mg $kg^{-1}$and nearly twice the fertilized topsoil (Table 2). One date from charcoal in this paleosol at 3.4 m yielded a 2 sigma calibrated date of 50 BC to AD 130. This paleosol contains a rich

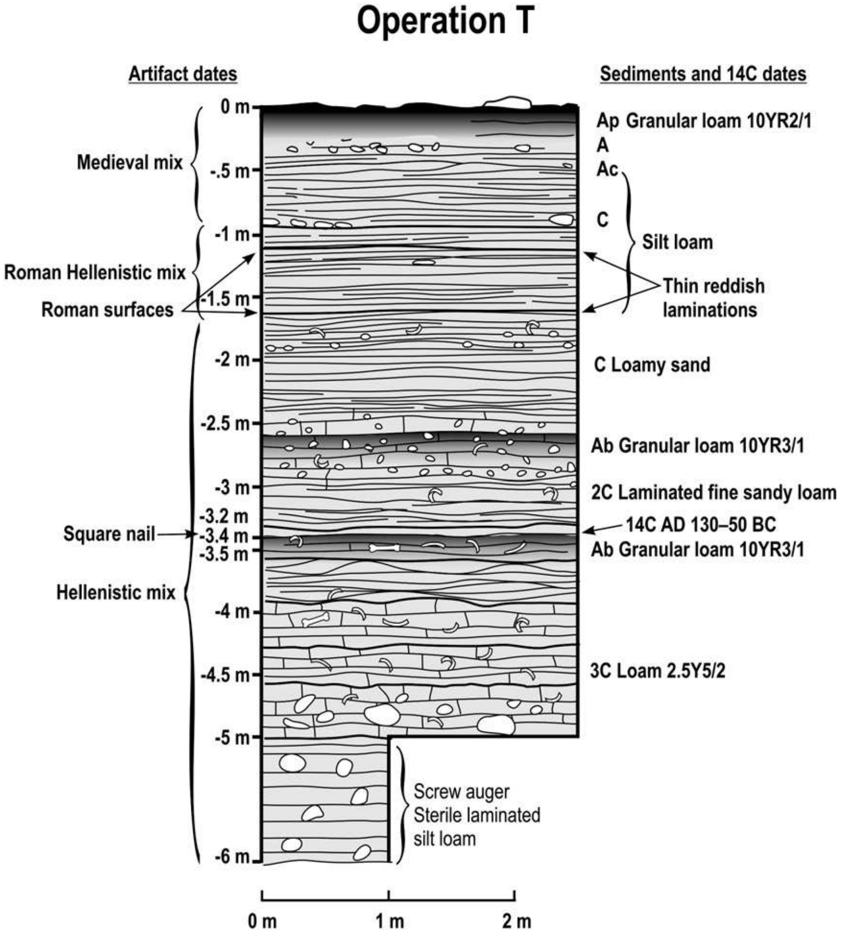

Fig. 6. Drawing of excavation T showing soil and stratigraphic units.

cultural deposit that diminishes downward to a cobbly loam soil at 5 m with 3rd and 4th C BC Hellenistic artifacts. From 310 cm to the bottom of the excavation, textures are loams that fine downward with increasing clay and redoximorphic, light to dark gray colors. This lowest excavation depth is about 2 m asl, and we encountered few artifacts and no water table in this July excavation. Overall, sediments were principally Medieval above 170 cm and Hellenistic or Roman from 170 to 500 cm (Gates, 2002). The radiocarbon date from the top of a paleosol at 3.4 m dates to Late Hellenistic or Roman, and the 170 cm of alluvium with Hellenistic artifacts above this is probably later Hellenistic through later Roman. The lowest 130 cm must be earlier Hellenistic deposition because of the upper bracket of the radiocarbon date and the preponderance of 3rd and 4th C BC Hellenistic ceramics.

Northeast and east of the Mound, the Kinet Project excavated 7 other soundings in the same field as T (Figs. 2 and 9). We abandoned excavation S at 75 cm from the surface because it landed on top of a Medieval burial. Trench X, 60 m east of the Mound, began on a trench that had been started by looters and uncovered a Medieval well, buried under 60–80 cm of sediment, and extended downward more than 1 m through Hellenistic deposits (Gates, 2002). Three soundings (WA-C) northeast of the Mound produced consistent artifacts down to

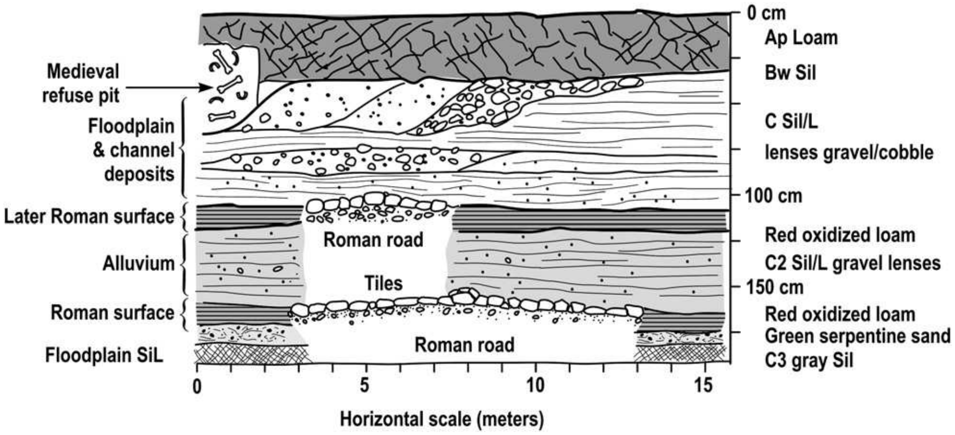

Fig. 7. Drawing of excavation T2 showing soil, Roman Road, and stratigraphic units.

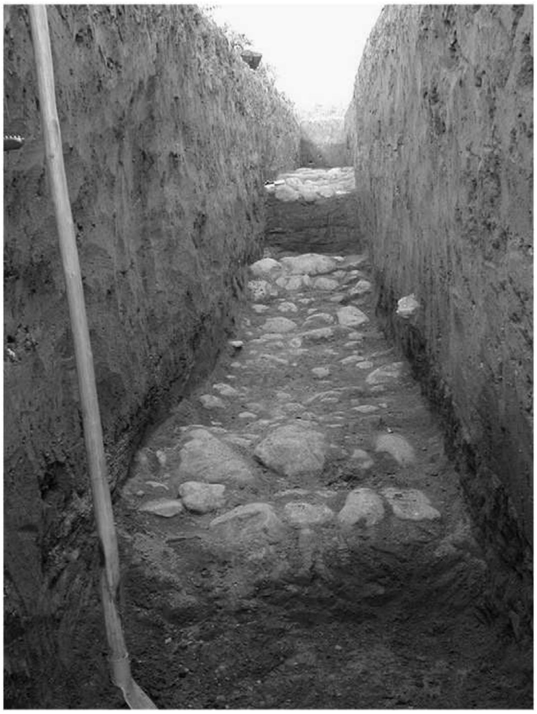

Fig. 8. Photograph of the Roman Roads in Excavation Unit T2.

2.5 m. Eroded Medieval artifacts dominate the top 1 m, and from 1 m to c. 2 m a gravel deposit exists as testament to high energy channel flows north of the Mound from Hellenistic through Roman times. Hellenistic artifact-laden, loamy paleosols continue below the gravels (Gates, 2001).

A very similar pattern occurred in units T2 through T6, where high-energy channel gravels and cobbles interspersed with flood loams cover the top 1 m above a Roman Road and another 0.6 m of coarse, sandy loam channel deposits bury an earlier Roman Road (Figs. 2, 7 and 8; Table 2). These units have few artifacts: a 1 m Medieval and Late Roman veneer over the Late Roman road and 0.6 m over Roman sediments of an earlier Roman Road (Fig. 8). Along and spreading out from the Roman Roads are the wavy, layered, densely packed, and oxidized layers of a surface of intensive traffic. Charcoal from one of these layers at 80 cm, 20 cm above the road, yielded a 2 sigma calibrated date of AD 1180 to 1280 (Table 3). Medieval artifacts near the road surface also suggest the road was in use or near the surface until the Medieval period. Paradoxically in a broader region with such dense Roman occupation, the T units along with the Z units exhibit the first Roman evidence at Kinet Höyük (Gates, 2003).

We excavated trench CP about 500 m southeast of the Mound into an area mapped as the oldest channel of the Deli Çayı (Figs. 2 and 9) (Ozaner, 1994). The topsoil here formed in 1.2 m of high energy, channel gravels and cobbles. Beneath this lies a sequence of two cumulic Ab horizons that range from 1.2 to 2.3 m, one Ab from 1.2 to 1.5 m separated by 0.2 m of loamy C horizon from the lower and thicker Ab horizon that stretched for 0.6 m to another C horizon. These paleosols were dark and very dark brown (highly melanized) loams with little gravel and laced with ceramic sherds, identifiable to the 1st to 2nd centuries BC. The grayish brown, clay loam C horizons reach down to the bottom of the excavation with no more datable materials. Within the surrounding fields lie Hellenistic or Roman column fragments, probably associated with paleosol surfaces. These paleosols are probably the Hellenistic or earlier surface and are the base of more than 2.3 m of sedimentation since Hellenistic times. Hellenistic aggradation through the buried soils represented loam and clay loam overbank deposits, but sometime during or after the Hellenistic, the Deli Çayı (Fig. 1) channel aggraded by at least 1.2 m of gravels and cobble. This channel is what Ozaner (1994) mapped as the "oldest Deli Çayı" and was active between the Hellenistic and late antiquity because a channel Ozaner (1994) mapped as younger with a surviving Late Roman bridge runs about 1.5 km south of this channel.

Taken together, the gross rates of aggradation for this landscape in the Hellenistic to Late Roman period is c. 0.23 cm yr^{-1} (2.3 m 1000 yr^{-1})

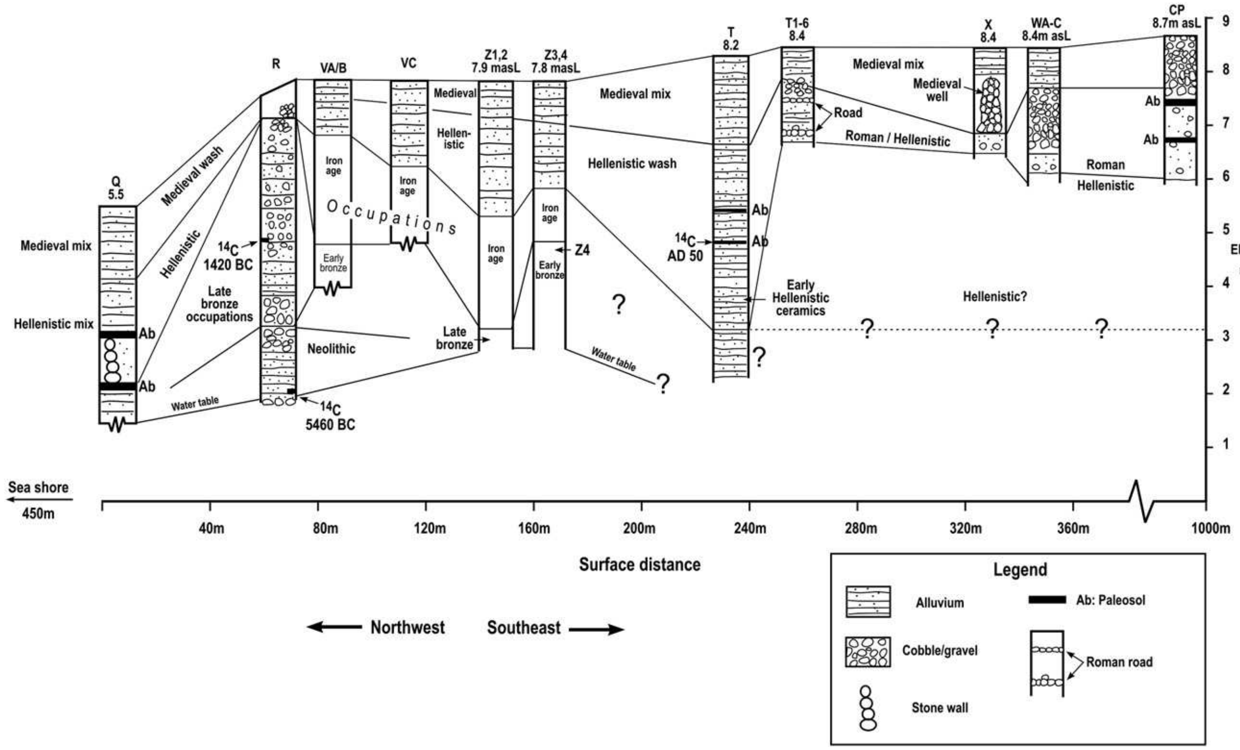

Fig. 9. Comparative sketch of all excavation units.

and about 0.09 cm yr^{-1} (0.9 m 1000 yr^{-1}) since the Medieval period (approximately the last 1000 years) and in the Pre-Hellenistic Periods. These are comparable, but 1.9 and 1.3 times higher, than the evidence from the Amuq Plain of 0.48 m yr^{-1} for the Medieval to Present and 1.75 m 1000 yr^{-1} for Hellenistic to Late Roman aggradation (Yener et al., 2000, p. 178). We should expect higher rates of geomorphic change in the watersheds that flow toward Kinet because they are at least as steep and have 1.5 times more precipitation than leeward Amuq watersheds. Pre-Hellenistic aggradation occurs only at a 200 m long island of occupation with intervening flood layers from trench Q to Z4. The record is limited but aggregating the units together produces a gross rate of aggradation of 0.9 m 1000 yr^{-1}, virtually identical to the Post-Roman rate.

The gross rates of aggradation and geography of erosion suggests much of the alluvial Plain from 200 to 1000 m on the transect were high energy braided channels that aggraded and migrated with gravels and cobbles from Hellenistic to Late Roman times. Aggrading this plain and the channels here would also have aggraded any harbor facilities associated with Kinet or Issos at this time. The Roman roads here are buried by about 1 and 1.6 m of Late Roman sediments, but also lie over 3 m of early Roman and Hellenistic sediments. Hence, much of the alluviation and harbor siltation would have already occurred by Roman times and provided ample reason for abandonment about 50 BC.

6. Discussion: Mechanisms for lowland aggradation

Aggradation occurred by channel and overbank processes based on the different zones of low and high energy sediments. Overall, high rates of aggradation of this coastal plain reflect high natural rates of erosion in contributing watersheds because of high local relief, seismicity, and precipitation. But evidence from the trenches show that rates from the Hellenistic to the Late Roman period were 2.5 times higher than before or after this period. Several natural mechanisms could accelerate erosion in this region, especially natural floodplain adjustments to post Pleistocene sea level rise, seismic events, river propinquity, and climatic change. First, floodplains had to adjust to rising sea levels during the Holocene, but sea level rise was slow and approximately at present levels along the Levant coast by the Hellenistic period when the highest aggradation was occurring at Kinet (Sivan et al., 2001). Second, many earthquakes occurred in the Eastern Mediterranean over the Late Holocene that could have destabilized the landscape and instigated erosion and mass wasting, but the high aggradation period does not stand out as more seismically active period (Keefer, 1994). Third, although the river was near Kinet at this time providing a steady source of sediment, these channels filled and the river migrated during this time whereas the current channel is incised even with recent higher rates of watershed erosion.

The last mechanism is accelerated erosion, and numerous comments since antiquity have described Eastern Mediterranean landscapes as severely degraded. For example, Given et al. (1999) described much of their study region in the Troodos Mountains of Cyprus as “profoundly eroded”, though this is not universal (Bal et al., 2003) and quantifying, determining causes, and dating erosion are problematic (Butzer, 2005). In different areas of the Amanos foothills, several regions are heavily gullied from modern devegetation. To grapple with this problem of the timing of erosion, Wilkinson (1999, 2005) graphed population and aridity together to develop a generalized index of environmental stress east of the Amanos Mountains in the Amuq Valley. He showed a steady increase of stress to the Roman/Byzantine Period and to the present, and most of the sedimentation on the Amanos alluvial fans since the Hellenistic (Yener et al., 2000). Likewise in the same region, Casana (2003, 2007) showed the first large scale intensive uses of the uplands, high elevation settlements, and major valley sedimentation over paleosols only occurred from the Hellenistic onward, and especially from AD 150–700.

At Kinet we have only a few short erosion surveys in the western Amanos Mountains because security problems have limited access, but we have also observed large and extensive gullies, rills, soil profiles eroded to bedrock with 1.2 m remnant soil profiles in pedestals, and mass movement scars spread over the hillslope landscapes including Roman and Hellenistic sites and through ancient terraces. We can conclude only that this upland erosion had to occur after the Hellenistic-Roman construction, possibly during the latter part of this period of land use, and the current gullies probably reflect post abandonment erosion after Late Roman times. Linking the chronology of watershed erosion with plain alluviation will require more access to the upper watershed to build the sediment budget data base geographically and chronologically. Nonetheless, the western Amanos had its most intensive land uses, highest elevation settlements, and highest populations in the Hellenistic through Roman periods, which also correlates with the greatest rates of plain sedimentation.

7. Conclusions

We have considered the geomorphic and geoarchaeological evidence for sedimentation around Kinet Höyük and a synthesis of regional trends in soil erosion in the geoarchaeological record. Ozaner (1994) devised a model of timing of fluvial migration and coastal/floodplain formation by mapping the paleo stream channels and using historical evidence. The Deli Çayı flowed just south of the Mound in Hellenistic and earlier times; it shifted southward to an extant Roman Bridge in Roman times; and it shifted further southward to its present position by Ottoman times, based on the remnants of an Ottoman Bridge along its present bank. We can add further that the river shifted back toward the Mound in the Late Roman Period, burying the Roman road and adjacent trafficked surfaces with high-energy channel sands, gravels, and cobbles.

The second general finding is the gross rates of aggradation from the Hellenistic to the Medieval and from the Medieval to the present. From the Hellenistic to the Medieval, about 300 BC to AD 1000, deposition was at least 4 m at unit T, 2 m at Q, and 1–2+ m at the Ts, Vs, Ws, X, and Zs (long-term rate c. 0.23 cm yr^{-1}). Aggradation since the Medieval Period (approximately the last 1000 years) is from 0 to 170 cm and the long-term rate averages about 0.09 cm yr^{-1}. In total the quantity of aggradation in the Hellenistic through Roman Periods is 2.5 times higher than earlier and later periods (Fig. 9). Deposition sequences before the Hellenistic at most sites were mainly layers of structures, including walls and floors, with intervening natural deposition. These occur at excavations R, the V units, and the Z units and showed floors and collapsed walls with episodic abandonment and much thinner flood layers in the Iron and Bronze Ages. Aggregating these together gives an average of about 0.09 cm yr^{-1}, virtually the same as the Medieval to present rate of aggradation.

The third finding is that rates of aggradation vary greatly and erosion from the Mound and collapsing structures contributes to deposition over short distances. The area northeast of the Mound around Units R, VA, VB, and VC, varies strikingly over a few m in the chronology of deposition (Fig. 9). Unit R represents a Late Bronze occupation with intervening floods from a depth of 1–5 m, whereas the others showed Hellenistic, Iron, and Early Bronze from 1–3 m. Unit R appears to represent an arm of a Late Bronze settlement ridge extending through part of the Z units. The Iron and Bronze Age occupations in R, the Vs, and Zs were blanketed and flattened by Hellenistic and later sedimentation. Areas northeast of the Mound either lay in the Deli Çay or near to its floods, because all showed deep Roman to Hellenistic alluvium and Hellenistic paleosols from 1.6 to 3.4 m. Unit Q, west of the Mound and closer to R, also had a Hellenistic paleosol at 3.4 m with mostly Hellenistic, artifact-rich sediments above.

A fourth finding is the common Hellenistic soil surface and the deep aggradation of Hellenistic and Roman sediments in most of this region, especially in Q and the Ts and Ws. It is not surprising that aggradation through this period is the highest since land use intensity was greatest at this time and the river ran nearby, probably through the area northeast of the Mound and southward and then westward around the lowest elevation near the Mound today. Moreover, aggradation occurred during these periods and not just after them during the later Roman Period because at the Ts two Roman roads are buried by 1.6 and 1 m with Roman artifacts in between; at Q a Hellenistic house wall is buried from 3.3 m to 1.5 m by Hellenistic-laden sediments; at T Hellenistic artifacts are mixed with fluvial deposits from a depth of 5 m up to 1.7 m with a radiocarbon date of AD 50 at 3.4 m; and faint paleosols occur within and just below Hellenistic sherd scatters throughout the region (Fig. 9). These high rates of aggradation also correlate generally with the abandonment of this site in 50 BC, which had been a port and a coastal site for up to 5000 years.

The presence of a widespread surface covered by a major episode of sedimentation suggests some level of stability before the Hellenistic and much instability during and after until the Late Roman period. This paleosol shows up at T and Q at about 3.3 m, and at T dates to about AD 50 by radiocarbon and ceramic evidence. Of course, many natural mechanisms could accelerate erosion in this region, especially natural floodplain adjustments to post Pleistocene sea level rise, seismic events, river propinquity, and climatic change. But, the Hellenistic through Roman period with its highest rate of aggradation correlates with the most intense land uses and with climatic drying (Wilkinson, 1999). Thus, natural and anthropogenic explanations correlate with the timing of aggradation around Kinet. We are now studying additional lines of geomorphological and paleoecological evidence to understand better the geographic and chronological dimensions of erosion and sedimentation in the watershed.

Acknowledgements

This research is a part of the Kinet Archaeology Project, directed by Dr. Marie-Henriette Gates since 1992. We thank Georgetown and George Mason Universities for generous funding. Many people contributed to this research and deserve thanks, starting with Drs. Gates, Scott Redford, Nicholas Dunning, Charles Gates, Jennifer Tobin, Selima Ikram, and Franca Cole. Many students also helped with field study including Ezgi Akpinar, Aysegul Vural, S. Kaiser, S. al Saifi, J. Jacoby, M. Conrad, K. Fermoyle, D. Finnegan, J. Mitchell, K. Adair, and M. Coffman. Thanks also to Dr. Helmut Brückner, University of Marburg, and three outside reviewers for many useful comments.

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